Executive Summary

Draft

Environmental Impact Statement/ Environmental Review and Management Programme

for the Proposed Gorgon Development

September 2005

GORGON
AUSTRALIAN GAS

Disclaimer

This Draft Environmental Impact Statement/Environmental Review and Management Programme (Draft EIS/ERMP) has been prepared by Chevron Australia Pty Ltd on behalf of the Gorgon Joint Venturers. In preparing the Draft EIS/ERMP, Chevron Australia has relied on information provided by specialist consultants, government agencies and other third parties who are identified in the Draft EIS/ERMP. Chevron Australia has not verified the accuracy or completeness of the findings, conclusions and observations of these consultants, government agencies and other third parties, except where expressly acknowledged in the Draft EIS/ERMP.

Note on Name Change

During the production of this Draft EIS/ERMP, ChevronTexaco Corporation changed its name to Chevron Corporation. As a consequence of this, ChevronTexaco Australia Pty Ltd changed its name to Chevron Australia Pty Ltd.

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Invitation to Comment

The Proposal

The Gorgon Joint Venturers propose to develop the Gorgon gas field that lies approximately 130 km off the north-west coast of Western Australia.

The proposed Gorgon Development is based on the installation of a subsea gathering system and a 70 km subsea pipeline to Barrow Island. The associated gas processing facility will be located at the central-east coast of the island. It is proposed to inject carbon dioxide, which occurs naturally in the reservoir, into deep formations below the island. Liquefied Natural Gas (LNG) will then be transported by ship to international markets. Domestic gas will be delivered to the Western Australian mainland through a subsea pipeline for use in industrial and domestic markets.

Assessment Process

Following referral of the Development in November 2003, the Commonwealth Department of the Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA) determined that the proposed Gorgon Development should be formally assessed at the Environmental Impact Statement (EIS) and Environmental Review and Management Programme (ERMP) levels, respectively.

The Commonwealth and Western Australian governments have agreed to a coordinated environmental assessment process. A single EIS/ERMP document that satisfies the requirements of each jurisdiction is required under this process. This Executive Summary is available as a separate document.

The Joint Venturers have prepared the Draft EIS/ERMP in accordance with the EPA and DEH requirements as set out in the environmental scoping document and guidelines (ChevronTexaco Australia 2004). This Draft EIS/ERMP is being placed on public exhibition for 10 weeks during which time public submissions will be sought. The DEH and EPA will assess the Draft EIS/ERMP following receipt of public submissions, and the Joint Venturers' response to those submissions, before reporting to relevant Ministers for a final decision on whether the Development should be approved and if so, under what conditions.

Availability of the Draft EIS/ERMP for Public Comment

This Draft EIS/ERMP is available for public comment from Monday 12 September 2005 until Monday 21 November 2005. It can be viewed at the Gorgon Australian Gas website (www.gorgon.com.au), or at the following locations:

Department of Environment Library
Level 8, Westralia Square Building
141 St Georges Terrace
Perth WA 6000

Department of Industry and Resources
1st Floor, 100 Plain St
East Perth WA 6000

Research and Information Centre
Department of Industry and Resources
1 Adelaide Terrace
East Perth WA 6000

Department of the Environment and Heritage Library
John Gorton Building
King Edward Terrace
Parkes ACT 2600

Ashburton Shire Council
Onslow Public Library
Second Avenue
Onslow WA 6710

Karratha Community Library
Millstream Road
Karratha WA 6714

Battye Library
Alexander Library Building
25 Francis Street
Perth WA 6000

This Executive Summary of the Draft EIS/ERMP is available free of charge. The Main Report (Volumes I and II) and the set of Technical Appendices are available at a cost of $10 each. These can be obtained from Chevron Australia by telephoning the Gorgon Health, Environment and Safety Administration Assistant on 08 9216 4000 or emailing your request to gorgon.info@chevron.com.

Submission Process

Individuals and organisations are invited by the EPA and DEH to submit comments on this Draft EIS/ERMP. A submission may include comments, provide information, and/or express opinions about the information presented in the document.

Reasons for conclusions stated in the submission should be stated clearly and supported by relevant data. The source of your information should also be included where applicable. Comments from the public will assist government in making their decision.

All submissions received by the agencies will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Commonwealth *Freedom of Information Act 1982* and the Western Australian *Freedom of Information Act 1992.* Submissions may be quoted in full or in part of the agencies' reports.

The closing date for public submissions on this Draft EIS/ERMP is **Monday 21 November 2005.**

Submissions should be addressed to:

Chairman, Environmental Protection Authority
PO Box K822
Perth WA 6842

AND/OR

First Assistant Secretary
Approvals and Wildlife Division
Department of the Environment and Heritage
GPO Box 787
Canberra ACT 2601

Why Write a Submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action – including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

Why Not Join a Group?

If you prefer not to write your own comments, it may be worthwhile joining with a group interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Submission Checklist

Comments should be in writing and:

- list points so that the issues raised are clear
- refer each point to the appropriate chapter and section in the Draft EIS/ERMP (e.g. Chapter 1, Section 1.1)
- keep the discussion of different sections of the Draft EIS/ERMP distinct and separate
- include relevant, factual and supportive information with details of the source.

Also remember to:

- identify the Development (i.e. the Gorgon Development)
- provide your name, address and date of submission
- identify any special interest you have in the Development (where relevant)
- indicate whether your submission is to be kept confidential.

Foreword

On behalf of the Gorgon Joint Venturers, (Chevron Australia, Texaco Australia, Shell Development Australia and Mobil Australia Resources Company), I am pleased to present this Draft Environmental Impact Statement/Environmental Review and Management Programme for the proposed Gorgon Development. As the Commonwealth and Western Australian governments have agreed to a coordinated environmental assessment process, this document is designed to meet the assessment requirements of both jurisdictions.

The gas fields discovered in the Greater Gorgon area represent Australia's largest undeveloped gas resource. As the custodian of the resource, the Joint Venturers accept responsibility for developing this important national and state asset in a sustainable manner. A successful Development will deliver substantial economic and social benefits to current and future generations of Australians, whilst also protecting the environmental values of the region and delivering net conservation benefits. This Development will be the key to unlocking the vast Greater Gorgon area resources, which are equivalent to 25% of Australia's total known gas resources.

Restricted use of Barrow Island is central to the commercial viability of the development of the Greater Gorgon area gas fields. Exhaustive studies show there are no commercially viable development alternatives to this location. Barrow Island is an internationally significant nature reserve and the site of Australia's largest onshore operating oilfield. The Joint Venturers recognise the importance of the conservation values of Barrow Island and selected this location only after thoroughly assessing the viability of alternative locations.

The environmental management strategies developed to avoid or mitigate the potential impacts of the Gorgon Development will protect conservation and biodiversity values and enhance Chevron Australia's successful stewardship of Barrow Island. The Gorgon Development will also deliver a clean fuel that will increase security of gas supply and provide price competition for consumers. The proposed Development will stimulate economic activity and create jobs that will have flow-on social benefits. The potential beneficiaries of the Gorgon Development range from communities in the Pilbara and the state of Western Australia to the whole of the Australian nation and our international customers.

Chevron Australia, operator of the Barrow Island oilfield, has been involved in existing oilfield operations on the island for over 40 years. The management of these operations is widely recognised as a demonstration of the successful co-existence of petroleum operations and the protection and maintenance of conservation values.

Our success in managing oil operations on Barrow Island, as well as our diligence in preparing this plan, demonstrates our commitment to meeting our environmental responsibilities, whilst also meeting national and international clean energy demands.

James W Johnson
Managing Director
Chevron Australia Pty Ltd

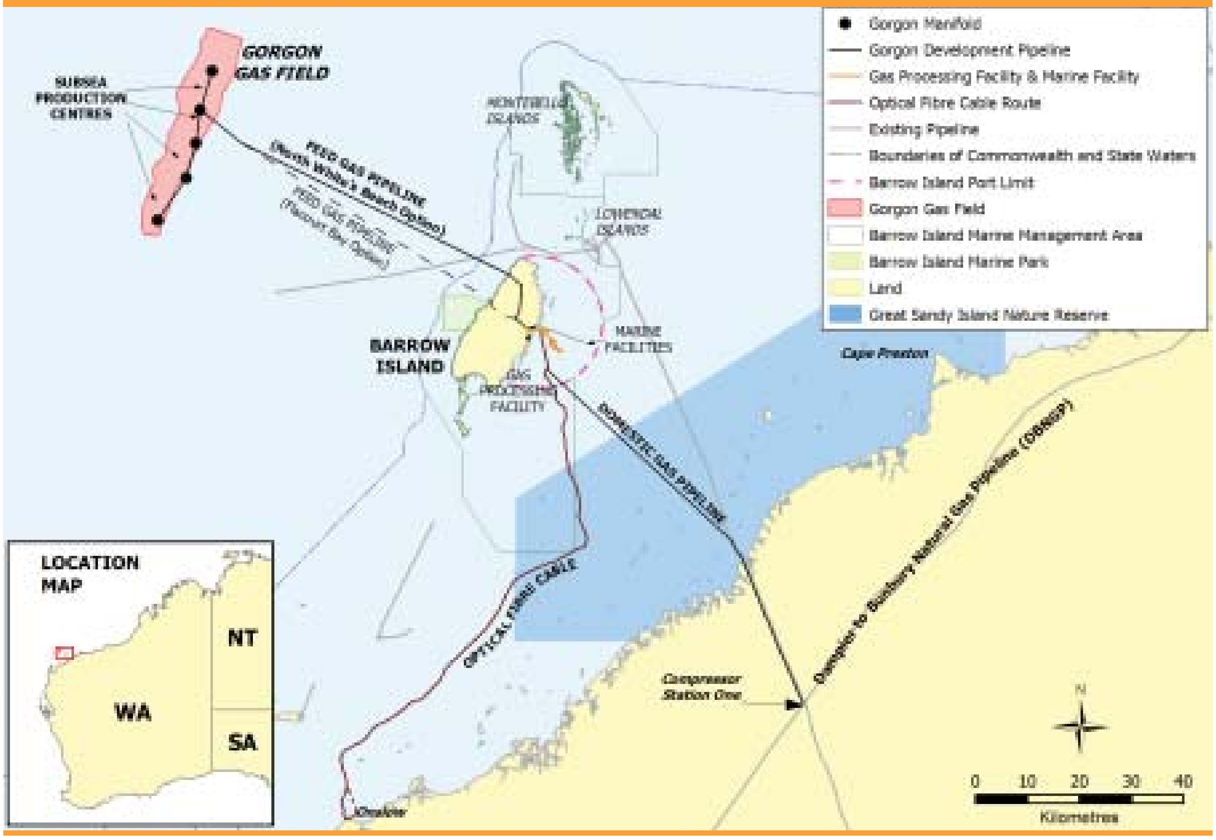
1 Introduction

1.1 Proposal Title

This document is the Executive Summary for the Draft Environmental Impact Statement and Environmental Review and Management Programme (Draft EIS/ERMP) for the proposed Gorgon Development. This Executive Summary was prepared by the Gorgon Joint Venturers in accordance with the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Western Australian *Environmental Protection Act 1986* (EP Act).

The title of this proposal is ‘the proposed Gorgon Development’, which comprises a range of offshore and onshore infrastructure components to recover gas

Figure 1-1:
Development Concept



from the Gorgon gas field (Figure 1-1), and to process this gas at, and ship it from a gas processing facility on Barrow Island. All construction, operation and decommissioning activities associated with this infrastructure are considered as part of the proposed Development.

1.2 Development Proponent

Chevron Australia is the operator and proponent for the proposed Gorgon Development (the key elements of which are outlined in Section 1.3.3) on behalf of the companies listed in Table 1-1. In this document, these companies are referred to together as 'the Gorgon Joint Venturers' (or the Joint Venturers).

The Gorgon Joint Venturers are subsidiaries of leading companies in the global oil and gas industry with proven technical and management skills for safe, efficient and environmentally responsible development. These companies have a wealth of international and domestic experience in oil and gas processing and LNG operations covering all aspects of the Development, ranging from drilling to subsea production systems, offshore operations, gas plant operations, and product shipping.

The Joint Venturers also have extensive experience in injection of carbon dioxide (CO_2) into subsurface formations associated with oil recovery operations. This is another key area for the Gorgon Development as discussed in Section 13. The Rangely operation in the United States is one such example. Chevron Australia has also been working closely with the Geodisc program, and its replacement the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC), to widen the knowledge base associated with CO_2 injection.

For over forty years Chevron Australia has been involved in the oilfield operation on Barrow Island and has produced some 300 million barrels of oil. Chevron Australia's management of oil production activities on Barrow Island is widely recognised as an industry benchmark for co-existence of petroleum development and the protection of conservation values (Box 1-1).

Implementation of conservation best practices underpins the success of the oilfield operations in managing quarantine and protecting the island from unauthorised visits. As a result, Barrow Island is Australia's largest landmass which has no introduced vertebrate pests such as rats, mice, cats, rabbits and foxes. Without Chevron Australia's environmental stewardship of the island, the same level of protection of the conservation values would have required a contribution of millions of dollars from the state of Western Australia. Chevron Australia's success in managing the conservation values of Barrow Island has been formally recognised by the receipt of a number of environmental awards (ChevronTexaco Australia 2003).

Table 1-1:
Addresses of the Gorgon Development Proponent and Joint Venturers

Company
Chevron Australia Pty Ltd Level 24, QV1 Building 250 St Georges Terrace Perth, Western Australia, 6000
Texaco Australia Pty Ltd Level 24, QV1 Building 250 St Georges Terrace Perth, Western Australia, 6000
Shell Development Australia Pty Ltd Level 28, QV1 Building 250 St Georges Terrace Perth, Western Australia, 6000
Mobil Australia Resources Company Pty Ltd 12 Riverside Quay, Southbank Melbourne, Victoria, 3000

Box 1-1:
Barrow Island – Oilfield and Nature Reserve

Barrow Island is the centre for Chevron Australia's oil operations in Western Australia. It has been operating as a producing oilfield since 1967. The conservation value of the island has long been recognised and a successful environmental management program has been in place for almost 40 years of the oilfield operation.

Barrow Island is a unique remnant of the natural ecology of the north-west with close affinities to the Cape Range area. In 1910, Barrow Island was proclaimed as a Class A Nature Reserve. The Class A status of the island reflects its importance as a refuge for wildlife species, some of which are endemic to Barrow Island and some of which are extinct, or near extinction, on the mainland.

Box 1-1: (continued)
Barrow Island – Oilfield and Nature Reserve

This island provides an indication of environmental conditions on the mainland prior to impacts such as weeds, feral animals and grazing following European settlement. The Reserve is vested in the Conservation Commission of Western Australia and managed by the Department of Conservation and Land Management (CALM) for the purpose of wildlife and landscape conservation, scientific study and preservation of features of archaeological, historic and scientific interest.

1.2.1 Environmental Commitment and Responsibility

Developing Gorgon gas in a sustainable manner is a major objective of the Gorgon Joint Venturers. Further, the Joint Venturers are committed to conducting activities associated with the proposed Gorgon Development in an environmentally responsible manner; and aim to implement best practice environmental management as part of a program of continuous improvement. This will be achieved by addressing issues systematically, consistent with internationally accepted standards and the Chevron Operational Excellence Management System which includes the values and goals of the Chevron Health, Environment and Safety Policy (Policy 530). To fulfil its commitment to ensuring the Gorgon gas resource is successfully developed in an environmentally responsible and sustainable manner, the Joint Venturers will draw on their collective experience and the most appropriate technologies available.

During the planning and design of the Gorgon Development, a range of mitigation measures to prevent or minimise adverse environmental impacts have been taken into consideration. For example, the location for the feed gas pipeline shore crossing was moved to avoid sensitive rock wallaby habitat. Further, a range of management measures for identified potential adverse environmental impacts are presented throughout this Draft EIS/ERMP. In many situations, where impacts cannot be avoided, the implementation of these measures will limit the degree or magnitude of the adverse impact; or rehabilitate any impacted sites. In addition, much of the assessment work and many of the proposed management strategies and monitoring programs will contribute significantly to the substantial body of scientific knowledge and understanding of the ecology of the Development area – thus providing benefit as environmental offsets.

The Joint Venturers are proud of their environmental record and, in accordance with the requirements of Schedule 4 of the EPBC Regulations, confirm that none of the Venturers are the subject of any proceedings under a Commonwealth, state or territory law for the protection of the environment or the conservation and sustainable use of natural resources.

1.3 Development Overview

1.3.1 Resource under Consideration for Development

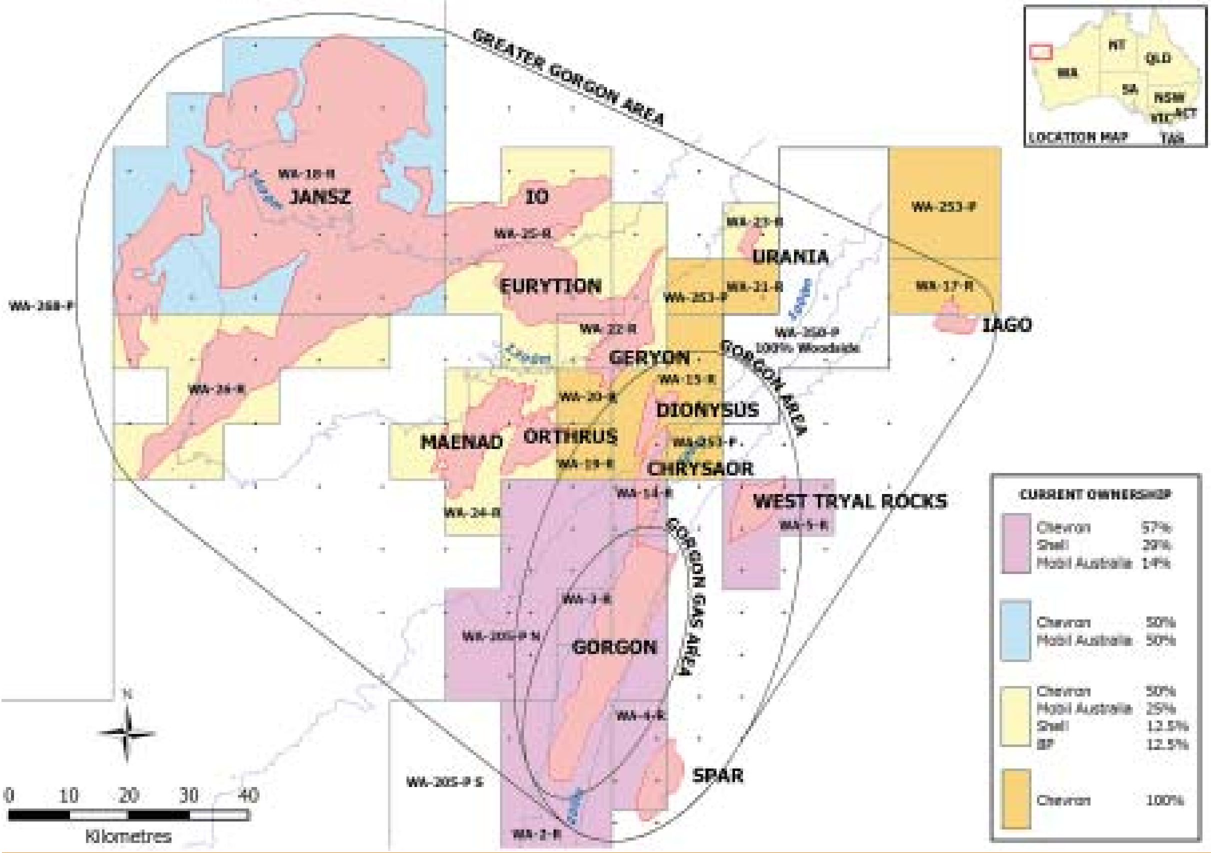
The Greater Gorgon area, situated 130 km off the north-west coast of Western Australia, comprises the largest gas resource discovered to date in Australia (Figure 1-2). The reservoirs of untapped natural gas contain in excess of 1.1 Tera cubic metres (Tm^3) (40 Trillion cubic feet (40 Tcf)) of gas which represents some 25% of Australia's known gas resources. Development of this substantial national asset would secure Australia's position as a leading gas producer and generate a new source of wealth for Western Australia and Australia.

The Gorgon Joint Venturers are considering developing the Gorgon field, which is located within the Greater Gorgon area (Box 1-2). The field retention lease is held by the Gorgon Joint Venturers and lies in Commonwealth waters approximately 70 km from Barrow Island. Due to development economics, the Jansz field, which is 80 km further north-west of the Gorgon field, will be developed in a similar timeframe. Gas from the Jansz field will also be processed at and shipped from Barrow Island. Mobil Exploration and Production Australia (MEPA) is the operator and proponent of the Jansz field. The Jansz deepwater development and pipeline will be subject to a separate approval process, coordinated by MEPA as operator of the field.

It is the intention of the Joint Venturers that the Gorgon and Jansz fields be developed first due to the economics of field development, which is driven by the following factors:

- resource size, internal structure, and reservoir properties of each field
- amount of information available on each field
- gas composition of each field, including the amount of hydrocarbon liquids (condensate) and inert gases
- distance of each field from land
- water depth at each field.

Figure 1-2:
The Greater Gorgon Area Gas Resource Base



NB: Ownership is subject to change pursuant to an agreement between Chevron Australia, Mobil Australia Resources Company and Shell Development Australia to align their interests on a 50/25/25 basis in certain permits. This change requires government approvals before it becomes effective.

Box 1-2:
Gorgon Gas Resource Base

The gas fields of the **Greater Gorgon area** contain an estimated gas resource in excess of 1.1 Tm^3 (40 Tcf) and include the Gorgon area gas fields in relatively shallow water; and the Jansz field, among others, in deeper water further offshore.

The gas fields of the **Gorgon area** contain a technically proven and certified recoverable gas resource of 0.37 Tm^3 (12.9 Tcf) and includes the Gorgon, West Tryal Rocks, Spar, Chrysaor and Dionysus fields.

The **Gorgon gas field** is the largest field in the Gorgon area, a technically proven and certified resource of 0.27 Tm^3 (9.6 Tcf), and one of the largest fields ever discovered in Australia.

1.3.2 Scope of the Proposed Development

The Gorgon Joint Venturers propose to develop a 10 million tonne per annum (MTPA) Liquefied Natural Gas (LNG) plant and, if deemed commercially viable, a 300 TJ/day domestic gas plant on Barrow Island that will be supplied from both the Gorgon and Jansz fields. Approximately 2000m^3/day (12 000 bbl/day) of hydrocarbon condensate will also be produced.

The scope of this Draft EIS/ERMP, as illustrated in Figure 1-1, covers:

- the Gorgon gas field wells and subsea installation
- a feed gas pipeline from the Gorgon gas field to the gas processing facility on Barrow Island
- an easement along the Gorgon gas field pipeline (onshore Barrow Island and traversing state waters) to accommodate additional feed gas pipelines
- a gas processing facility on Barrow Island (including two LNG trains, domestic gas and condensate facilities)

- port/marine facilities at Barrow Island
- water supply and disposal
- the construction village and associated facilities
- a proposal to dispose of reservoir CO_2 by injection into the Dupuy formation
- monitoring of CO_2 movement in the Dupuy formation
- an optical fibre cable connection to the mainland
- a domestic gas pipeline to the mainland.

For the purpose of cumulative impact assessment, this Draft EIS/ERMP addresses the impacts on, and near, Barrow Island associated with the installation of the Jansz feed gas pipeline to process gas from the Jansz field and other potential tieback opportunities associated with the Greater Gorgon area, or other nearby prospects. An easement along the Gorgon gas field pipeline corridor (onshore and traversing state waters) to accommodate the Jansz and additional feed gas pipelines is included in this environmental assessment and approval application with construction subject to conditions set for the Gorgon Development. Onshore and near shore construction of additional feed gas pipelines will be planned concurrently, where possible, to minimise the total environmental impact.

A proposal to dispose of reservoir CO_2 by injection into the Dupuy formation, to mitigate greenhouse gas emissions, is also included in this environmental approval application.

Under the provisions of the Western Australian *Barrow Island Act 2003,* no more than 300 ha of uncleared land are available for this and other future gas processing proposals on Barrow Island. This is comprised of 150 ha for gas processing purposes, 50 ha for petroleum pipelines and 100 ha for future developments. Future phases of the Development will be subject to separate approval. However, the cumulative impacts of land clearing and habitat modification for the full 300 ha are considered in this Draft EIS/ERMP.

The infrastructure and activities that are beyond the scope of this assessment and will be assessed under separate approval processes are:

- the Jansz field development and pipeline (operated by MEPA)
- subsea installations to develop additional gas fields in the Greater Gorgon area, or other nearby prospects
- feed gas pipelines from additional gas field developments in Commonwealth waters
- offshore seismic marine surveys
- shipping activities outside of the Barrow Island port facility.

1.3.3 Principal Elements of the Proposed Development

Development of the Gorgon field will require a range of infrastructure to extract the gas and transport it to Barrow Island for processing and delivery to market. The principal physical components of the proposed Development are provided in Table 1-2.

The initial Development will consist of subsea infrastructure for the production and transport of gas from the Gorgon gas field to Barrow Island, and a gas processing facility at Town Point. A subsea development concept circumvents the need for an offshore platform as part of the initial development.

Liquefied Natural Gas and condensate produced at the gas processing facility will be shipped from Barrow Island. If commercially viable, gas for domestic use will be exported by a pipeline from Barrow Island to the domestic gas collection and distribution network on the mainland. Associated infrastructure will be required on the island and in the adjacent marine area. This will include administration and accommodation facilities, a materials lay-down area, a materials offloading facility, a CO_2 injection facility and a conventional loading jetty.

Table 1-2:
Key Elements of the Proposed Gorgon Development

Element	Description
Market objective	First shipment of LNG in mid-2010
Construction start (site preparation)	Late-2006
Development life	60 years
Size of recoverable resource: • Gorgon field	0.27 Tm^3 (9.6 Tcf) (technically proven and certified)
Leases: • Gorgon field	WA-2-R; WA-3-R
Typical gas composition: • Gorgon field • Jansz field*	• CO_2 = 14–15%; N_2 = 2-3%; Hydrocarbon = remainder • CO_2 = < 1%; N_2 = 2%; Hydrocarbon = remainder
Wells (all subsea): • location • number	• Gorgon gas field • 18–25

Pipeline lengths:
• feed gas pipeline
  • Gorgon (offshore)
  • Gorgon (onshore, Barrow Island)
  • state-water easement**
• domestic gas
  • offshore (state waters)
  • onshore (mainland)
• CO_2 injection
	• ~ 70 km
	• ~ 14 km (~ 42 ha easement)
	• ~ 5.6 km
	• ~ 70 km
	• ~ 30 km (~90 ha easement)
	• < 5 km (< 6 ha easement)

Gas processing facility: • location • components	• Town Point, Barrow Island • 2 x 5 MTPA LNG trains • 300 TJ/day domestic gas plant • 2000 m^3/day hydrocarbon condensate
Port facility	• materials offloading facility (MOF) with an 800 m causeway • LNG load-out facility with a 3.1 km jetty
Other associated facilities	• mainland supply base • optical fibre cable • construction village • administration and maintenance facilities • offshore spoil ground (1500 ha) • widened roads • water supply, treatment and disposal facility • power generation and supply • extended airport
Air emissions: • greenhouse gases (with CO_2 injection) • total NO_x • total SO_x • total particulates (PM10)	• 4.0 million tonnes of CO_2 equivalents per annum • 4430 tonnes per annum • 0.15 tonnes per annum • 241 tonnes per annum
Dredging: • MOF channel and turning basin • shipping channel and turning basin	• 0.8 Mm^3 over ~ 21 weeks • 7.0 Mm^3 over ~ 45 weeks

Table 1-2: (continued)
Key Elements of the Proposed Gorgon Development

Shipping: • LNG export • condensate export	 • ~ 3 shipments per week • ~ 1 shipment per month
Element	**Description**

Total direct employment:
• construction (on Barrow Island at peak)
• operations:
  • on Barrow Island
  • on rotation (off the island)
  • in Perth office
	
	• ~ 3300 people
	• ~ 600 people:
	• 150–200
	• 150–200
	• 200–300

Development Investment	~ $11 billion

* *Composition of Jansz gas included here as the gas processing facility will receive gas from both Gorgon and Jansz fields and as such emissions calculations and modelling have been based on the total incoming gas stream.*

** *Potential impacts in the easement in state waters associated with construction and operation of the Jansz (or other) feed gas pipelines are considered for cumulative impact assessment purposes.*

The principal physical elements outlined in this table are described in greater detail in Section 6.

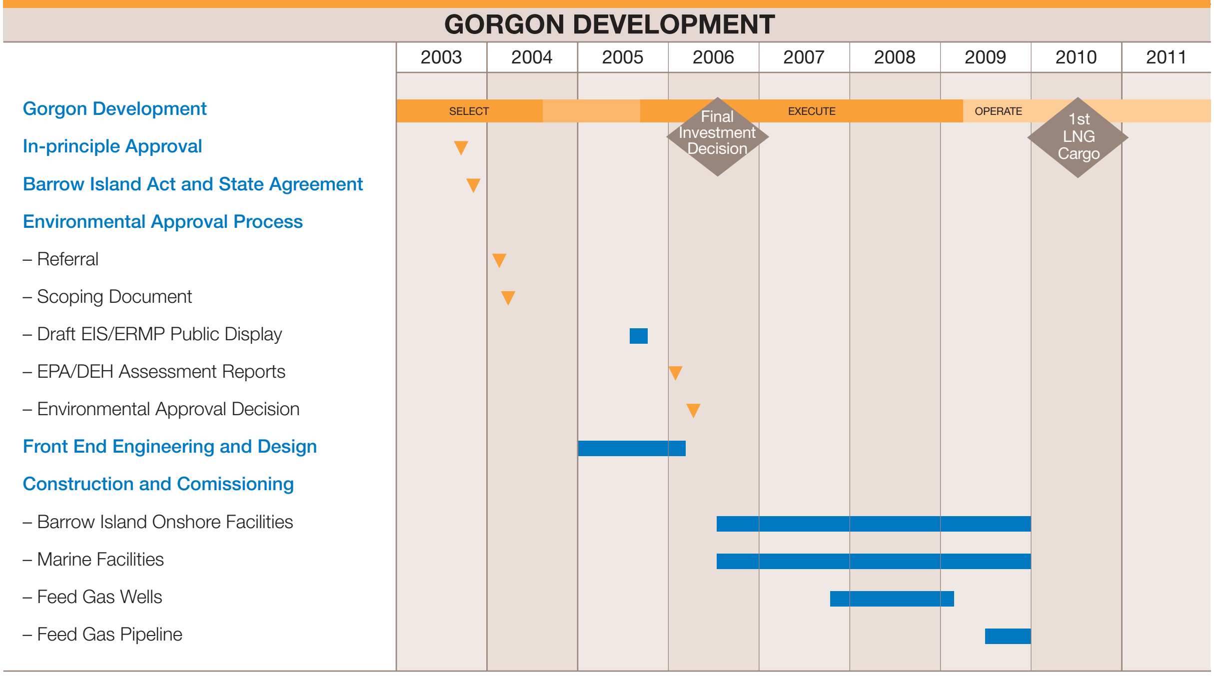
1.3.4 Development Timeline

An indicative schedule for the proposed Development is provided in Figure 1-3 with the first shipment of LNG expected in mid-2010. The production life of the proposed gas processing facility will fall within the lease period of 60 years that is allowed under the State Agreement scheduled to the *Barrow Island Act 2003.*

1.3.5 Development Area on Barrow Island

If environmental and State Agreement approval for construction of a gas processing facility on Barrow Island is granted, the area allowed for new disturbance will be limited to a total of 300 ha. Of that area, 50 ha have been set aside for petroleum pipeline easements and 150 ha reserved until 31 December 2009 for the Joint Venturers. The remaining 100 ha is reserved for other projects to process or use gas from the Title Areas or the Greater Gorgon area. A lease for gas processing

Figure 1-3:
Indicative Environmental Approval and Development Schedule



would be granted under the *Land Administration Act 1997* for a period of 60 years but this land would remain part of the Class A Nature Reserve. Lease rent and charges would be similar to those paid by other large gas processing projects in the Pilbara region. The lease would be subject to local government (Shire of Ashburton) rates.

1.4 Development Objectives

The primary objective of the Gorgon Joint Venturers is to commercialise the proven recoverable gas from the Greater Gorgon area in a sustainable manner. This includes continuing to protect the conservation values of Barrow Island, managing all environmental, health and safety requirements responsibly, and implementing best practices throughout all phases of the Development.

To meet this objective, the Joint Venturers established a set of sustainability principles and assessment criteria for the proposed Development on Barrow Island during the Environmental, Social and Economic (ESE) Review process (ChevronTexaco Australia 2003). These principles and criteria are based on widely accepted sustainability principles and address the key issues, particularly those concerning environmental protection, expressed by stakeholders consulted about the proposed Development. They are also considered to be consistent with the direction of the Western Australian Government. These principles will be applied to all phases of the Development, and provide a framework for the Joint Venturers to sustainably unlock the value of Greater Gorgon area.

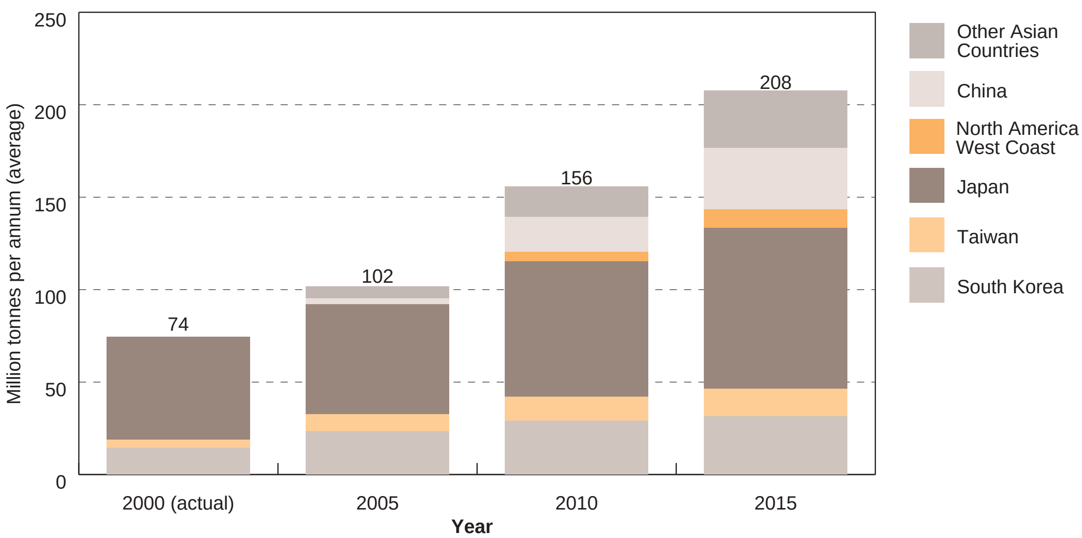
1.5 Development Rationale

The Western Australian and Commonwealth governments both identify the resource industry as a key to economic growth, so have enacted legislation and developed policy objectives designed to expedite development of Australia's resources. The retention licences issued to the Joint Venturers obligate them to actively seek development opportunities for these resources.

There is a growing demand for energy in the Asia–Pacific region (Figure 1-5) and the Australian domestic gas market. At the international market level, particularly in the Asia–Pacific region, the Development will supply LNG for the next generation of gas-based industries. At the Australian market level, the proposed Development will double the size of the gas industry in Western Australia at a time when there is a projected shortfall in energy supply. Further, the development of an additional strategic gas supply hub in Western Australia will significantly improve the availability of long-term, competitive supplies of gas to the state, and help build Australia's standing as a reliable gas supplier.

Development of the Gorgon gas field has the potential to secure Australia's position as a leading gas producer and provide a large source of additional wealth to Australia and Western Australia (ChevronTexaco Australia 2003).

Figure 1-4:
Asia–Pacific LNG Demand Forecast



1.5.1 Consequences of Missing the Current Development Opportunity

If the Development does not proceed, the economic, social and strategic benefits identified and described in the Draft EIS/ERMP will not be realised. Even a short delay to the Gorgon Development could trigger a long delay in capturing and transferring these benefits to Australia, Western Australia and the Pilbara. This is because the market opportunities currently available to the Joint Venturers could be easily won by competing countries such as Indonesia, Malaysia, Russia and Qatar. Future market opportunities may not become available for a considerable period if the current opportunity is lost.

Missing the current market opportunity or not developing the Gorgon gas field also risks not realising the national, state and regional economic benefits from the proposed Development that would increase general economic growth, sustain regional development, and increase competition in domestic gas markets.

A substantial increase in government revenues would also be at risk, both through the direct payment of taxes by the Joint Venturers and the workers and businesses associated with the Development. This would deny Australians and Western Australians the associated social benefits such as an increase in community services and highly skilled employment opportunities.

The Pilbara region of Western Australia, in particular, would be at risk of losing the benefits of growth in employment and business opportunities. The ecological values of the proposed Development area on Barrow Island would remain unaffected. Other opportunities to Western Australian businesses at risk from not proceeding with the Development include technology transfer and capacity building from the design, construction and maintenance of the gas processing facility and associated infrastructure – skills that could be applied to other resource and industrial projects in the state.

2 Legislative Background to this Proposal

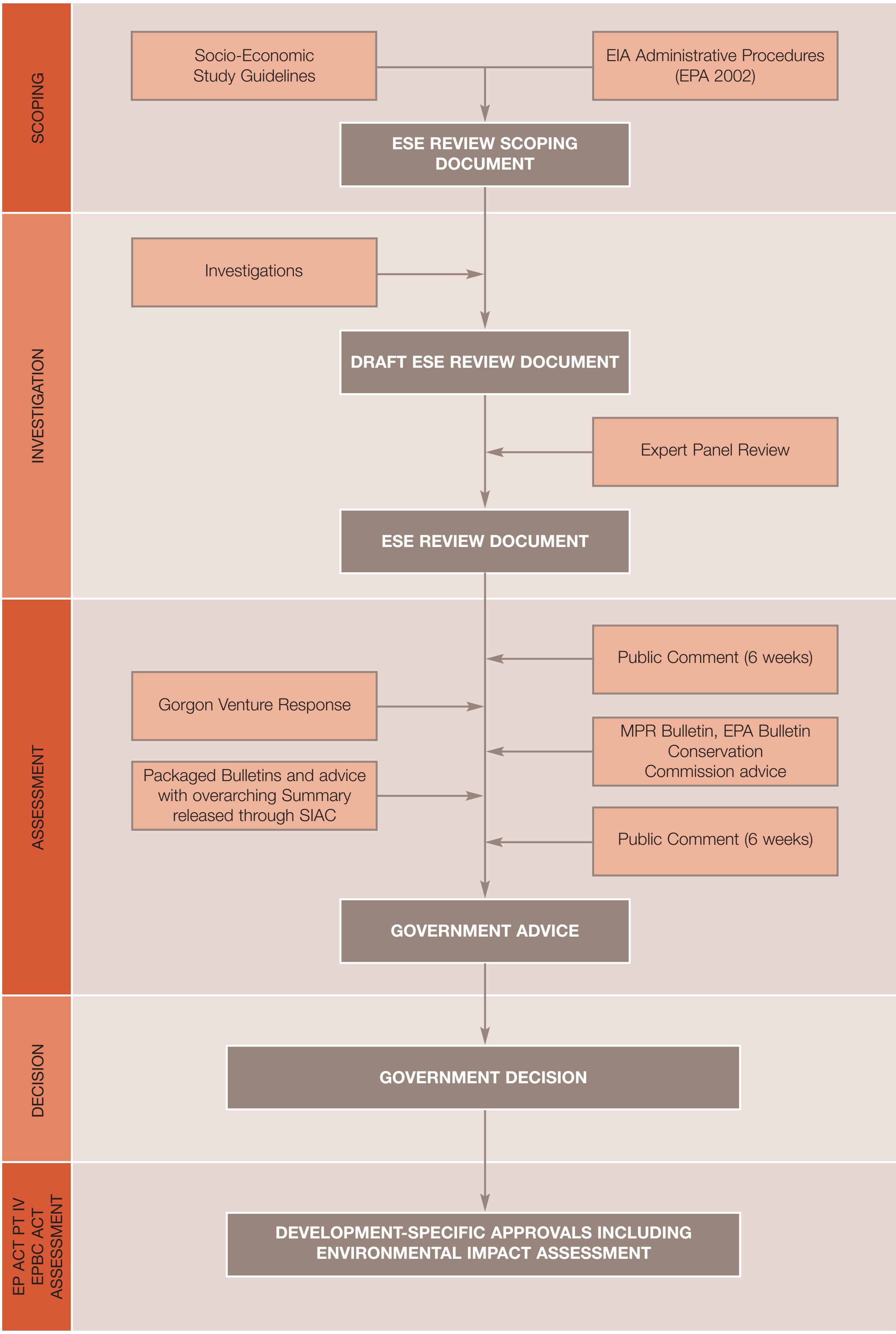
Before proceeding with the federal and state regulatory environmental approvals processes, the Gorgon Joint Venturers sought from the Government of Western Australia in-principle approval for restricted access to Barrow Island for a foundation development. In a progressive step towards formally assessing the sustainability of the proposed Development, the government in consultation with the Joint Venturers developed an environmental, social and economic review and assessment process (ESE Review process) (Figure 2-1).

The ESE Review process required the Joint Venturers to present a report to the government and public that examined relevant environmental, social, economic and strategic issues, and demonstrated the proposed Development would yield net conservation benefits to the state. The process was a first in Western Australia and one of the few sustainability assessment processes documented internationally for a specific development. A key feature of the ESE Review process was a high level of public consultation to encourage all interested stakeholders to contribute to the government's decision.

In-principle approval for restricted access to Barrow Island was granted in September 2003. If full federal and state regulatory environmental approval is granted for the proposed Development, the associated terms and conditions will be governed by the Western Australian *Barrow Island Act 2003* and the *Gorgon Gas Processing and Infrastructure Project Agreement* (the State Agreement) that has been signed by the State Government of Western Australia and the Joint Venturers (Plate 2-1).

Plate 2-1:
Signing of the State Agreement

Figure 2-1:
Summary of the ESE Review Process (source: ChevronTexaco Australia 2003)



3 Development Alternatives

3.1 Regional Development Locations

In the 10-year period before making the decision to seek in-principle approval for restricted access to Barrow Island for a foundation development, a number of alternative locations, within a 200 km radius of the Gorgon gas field, were investigated. Pursuing these concepts required the completion of many engineering, commercialisation, marketing and environmental studies at a cost of almost $1 billion.

A commercialisation attempt on the Burrup Peninsula was terminated in the late 1990s when it became clear that such a development would be internationally uncompetitive. Subsequently, a systematic and stepwise process was used to identify and assess alternative development locations. The alternative locations examined extend from the Burrup Peninsula in the north to Exmouth in the south; together with island locations (refer to Figure 3-1). Candidate locations were assessed against a suite of technical, commercial, social and environmental constraints and requirements.

The results of the assessment led the Joint Venturers to the conclusion that Barrow Island, the closest landfall to the gas field, was the only commercially viable location to develop this important resource. This finding was verified by an independent review (and cost audit) commissioned by the Western Australian Department of Industry and Resources (DoIR).

The naturally high levels of CO_2 in Gorgon gas must be removed in order to produce LNG and meet domestic gas specifications. Barrow Island provides the opportunity to dispose of reservoir carbon dioxide (CO_2) by injection into formations deep beneath the island. The proposed gas processing facility on Barrow Island provides the lowest cost option for CO_2 injection, due to the proximity to a suitable injection site. Injection of reservoir CO_2 would make the Gorgon Development one of the most greenhouse gas efficient LNG projects in the world. Development concepts that involve an alternative gas processing facility location would still require considerable construction activity, operating facilities and a substantial footprint on Barrow Island, associated with injection of CO_2.

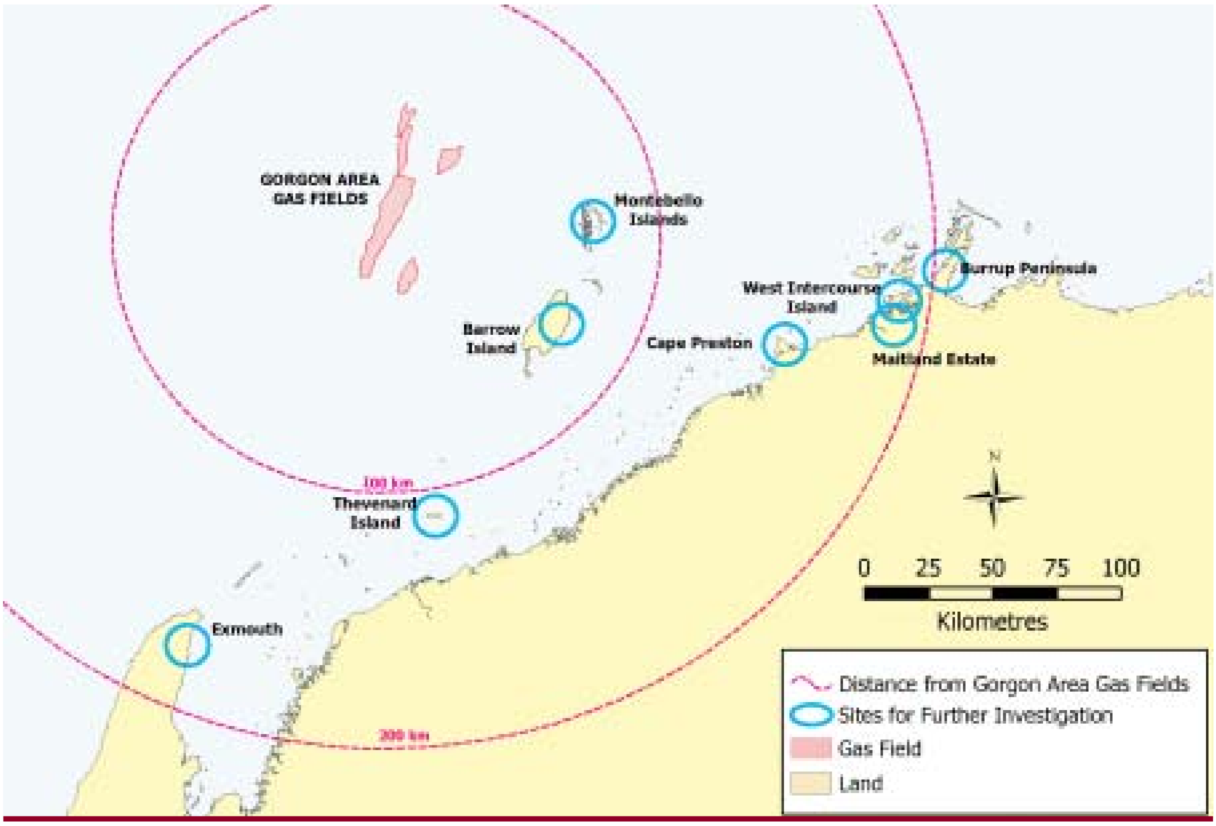
An assessment of the regional alternative locations against the controlling provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) showed that all the locations have similar potential for impacts on Commonwealth Marine Areas and only the Exmouth South location has the potential to impact a Commonwealth Marine Protected Area. Similarly, all locations have potential for impacts to species listed as threatened or migratory under the EPBC Act.

Key reasons for rejecting regional alternative locations are summarised below.

Montebello Islands

The Montebello island group was the location of nuclear weapon testing in 1952 and 1956 and elevated radiation levels are still found in some parts of the islands. The Gorgon Joint Venturers are not prepared to expose workers to such risks. The potential for radiation exposure would present serious industrial relations issues as well as create negative public and customer perceptions, adversely impacting the ability to attract and retain customers.

Figure 3-1:
Potential Locations for the Gorgon Gas Processing Facility



In addition, neither Trimouille nor Hermite Island has sufficient land available to safely accommodate the Gorgon Development; and both would present cost penalties over the Barrow Island development concept (i.e. $300 million for Hermite Island; and $70 million for Trimouille Island).

Thevenard Island

The Thevenard Island option is $500 million more expensive than the Barrow Island development concept, as a result of the required ground improvements, additional feed gas pipeline length, levees to protect against storm surge, connection to the CO_2 injection site, personnel transport and relocation of the existing airstrip.

Other disadvantages of Thevenard Island are the distance from the Greater Gorgon area reserves, the limited area available for development, and the lack of sufficiently sheltered waters for LNG carrier berthing and loading. It is also considered that operational safety would be compromised due to the need to evacuate personnel by helicopter in the event of a cyclone, and that a development at this location would result in impacts to recreational fishers, boat users and tourists (including the need to acquire the jetty location from Mackeral Islands Resort).

Maitland Estate/West Intercourse Island

The combined Maitland Estate/West Intercourse Island option is over $1 billion more costly than the Barrow Island development concept. These costs arise from the need for a remote hub platform, an additional 180 km of carbon steel gas pipeline, and additional pipeline and compression for CO_2 disposal.

The use of West Intercourse Island for LNG storage and load-out would require a 12 km long interconnecting causeway and a pipeline easement between the gas processing facility and load-out facility. Construction of the LNG storage tanks is likely to result in disturbance to mangroves and a significant number of aboriginal sites. An extensive dredging program would be required to reach the Hamersley Channel, or to create a new channel to avoid congestion or conflicts with shipping traffic.

Holden Point, Burrup Peninsula

The Burrup Peninsula option is over $1 billion more costly than the Barrow Island development concept. Additional costs are related to the need for a remote hub platform, an additional 160 km of carbon steel gas pipeline, and additional pipeline and compression for CO_2 disposal. Failure to secure a customer for a Burrup Peninsula-based development in 1998 supports the conclusion that such a development is not commercially viable.

Cape Preston

An existing mining tenement and proposed iron ore loading facility at Cape Preston are unlikely to be compatible with LNG loading activities, which require intrinsically safe operations to avoid ignition sources. Even if the Joint Venturers were to have exclusive use of Cape Preston, the site offers no significant cost advantage over a Burrup Peninsula location as development would cost $720 million more than a Barrow Island development concept.

3.2 Barrow Island Sites

An assessment of potential sites on Barrow Island led to the selection of Town Point as the preferred location for the gas processing facility (Figure 3-2). Overall, this site presents a low level of environmental impact (relative to the alternative sites) and offers safe and reliable marine operating conditions due to the sheltered nature of the adjacent waters. Other considerations included a range of technical, operational and cost-related issues.

Key reasons for rejecting alternative sites are summarised below.

Latitude Point

A Latitude Point site would require a larger dredging program, with associated impacts to adjacent coral communities, without any obvious technical or environmental benefit over the Town Point site.

Surf Point

Surf Point offers the greatest cost advantage of the alternative sites. Situated at the north-east corner of Barrow Island, it is located close to deep water, but is exposed to strong tidal currents which may adversely affect the safe operation of LNG carriers in the area. Potential development sites at this location are heavily restricted due to the presence of sensitive vegetation associations and sandy, unstable soils. The north of the island is also relatively undisturbed and is the furthest point on the island from the existing oil operations infrastructure. Stakeholder consultation has identified a strong preference for avoiding direct impacts to the less disturbed northern portion of the island.

Flacourt Bay and The Chair

Flacourt Bay and The Chair would provide access to deep water close to the shoreline, but marine terminal operations would be subjected to more severe swells that would adversely affect port availability for unprotected jetty sites. A jetty in either of these locations would require an extensive breakwater for protection; which would involve significant cost and result in considerable environmental impact associated with sourcing materials, smothering, silt movement, and impact on water flows. Both sites are also adjacent to sensitive rock wallaby habitat.

Bandicoot Bay

Bandicoot Bay is proposed as a Marine Conservation Area for benthic fauna and seabird protection (CALM 2004). It also provides very restricted access to deep water and would require a 3 km jetty connecting the loading platform to the site and a 9 km dredged approach channel. This exceptionally large amount of dredging would incur unacceptable construction and maintenance costs, pose safety hazards for shipping, and produce unacceptable impacts to areas important for marine benthic fauna and migratory birds.

Camp Point

Camp Point is located near the existing Chevron camp, and was raised by stakeholders as a potential site. The site offers some environmental benefits over other sites, such as proximity to the airport and existing accommodation, but would require the existing camp to be relocated and an extensive realignment of the airport runway. The need for a longer dredged channel for the materials offloading facility would result in additional seabed disturbance and increased risk to the coral communities off the south-east coast of Barrow Island. In addition, a Camp Point site would require a longer easement for the feed gas pipeline and the CO_2 injection line, resulting in an additional 10 ha of clearing. The south-east and south of the island also have the highest abundances of migratory shorebirds on Barrow Island.

3.3 Shore Crossing Locations

After investigating alternative shore crossing locations, and the associated onshore feed gas pipeline route, North White's Beach was selected as the preferred location, with the preferred construction technique being horizontal directional drilling (HDD) (refer to Figure 3-3). Flacourt Bay, to the south of North White's Beach, is being carried into the next design phase as a fall-back option, pending more detailed geological

Figure 3-2:
Potential Sites for a Gas Processing Facility on Barrow Island

investigations. An onshore pipeline route from North White's Beach will run along existing roads and other disturbed land as much as possible.

The North White's Beach/HDD option is preferred as it has a smaller footprint and presents lower risks to rock wallabies, turtle habitat and the Barrow Island Marine Park. It also requires less earthwork, involves a shorter construction period, and involves relatively simple stabilisation techniques. This option offers the lowest construction risk and provides cost-saving opportunities.

Conclusions regarding alternative shore crossing locations are as follows:

- **Flacourt Bay** is the preferred fall-back option as it provides a pipeline route which is adjacent to existing

Figure 3-3:
Potential Shore Crossing Locations

oil field operations and infrastructure and provides the shortest pipeline route across the island.

- The geology at **Obe's Beach** does not support the HDD technique due to the suspected presence of channelling, and therefore requires more environmentally intrusive and costly construction techniques.
- A **marine route to Town Point** was rejected as it would require a large dredging campaign (in addition to that required for the materials offloading facility and LNG load-out), and involve high cost and complexity associated with a longer offshore pipeline installation in shallow water.
- **Cape Dupuy** was ruled-out because of the greater footprint and technical challenges of operating installation vessels in the strong currents around the cape.

4 Legislative Framework for this Proposal

The Gorgon Development proposal was referred to the Commonwealth Department of the Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA) in November 2003. These agencies then determined that the Gorgon Development should be formally assessed at the Environmental Impact Statement (EIS) and Environmental Review and Management Programme (ERMP) levels, respectively. These are detailed levels of assessment that are generally applied to major projects which have significant environmental issues, many of which are complex or of a strategic nature.

The Commonwealth and Western Australian governments agreed to a parallel coordinated environmental assessment process. In accordance with this process, a Draft EIS and an ERMP that satisfies the requirements of each jurisdiction and consolidated as a single document (Draft EIS/ERMP) is required.

The Joint Venturers have prepared this Draft EIS/ERMP document in accordance with the requirements of the 'Guidelines for an Environmental Impact Statement and Environmental Scoping Document for an Environmental Review and Management Programme' (the Scoping Document) (ChevronTexaco 2004). The Draft EIS/ERMP is being placed on public exhibition for 10 weeks during which time public submissions will be sought. During this time, a package of additional information will be issued presenting the results of subterranean fauna species identification (refer to Section 10.4), the selected barriers for the three priority quarantine pathways (refer to Section 12.4), and the results of the field validation for the dredge plume modelling (refer to Section 7.8). The Additional Information Package will be available for comment for the last four weeks of the period of public exhibition.

The DEH and EPA will assess the Draft EIS/ERMP following receipt of public submissions, and the Joint Venturers' response to those submissions. Once the DEH and EPA have accepted that responses to public submissions are adequate, the document will become the Final EIS and ERMP (Final EIS/ERMP). The agencies will then report to relevant Ministers for a final decision on whether the Development should be approved and, if so, under what conditions.

5 Stakeholder Engagement

The Gorgon Joint Venturers are committed to open and accountable processes that encourage stakeholder engagement throughout all stages of the Development. The Venturers have established an extensive and ongoing stakeholder engagement program that builds on the pro-active approach to consultation that commenced in early 2002 during the ESE Review process. Stakeholders consulted include a broad range and diverse cross-section of government, industry and community representatives (Plate 5-1 and Plate 5-2).

Plate 5-1:
Media Conference on Barrow Island

Active participation in the carefully designed and implemented stakeholder engagement program has provided opportunities for stakeholders to obtain both technical and environmental information on potential issues and to express their views directly to the Development Team. Input from these stakeholders has provided the Venturers with valuable feedback and has contributed to guiding the assessment and management of the proposed Development. This input will continue to be valuable throughout the ensuing phases of the Development.

Plate 5-2:
EPA Visit to Barrow Island

6 Development Description

As noted in Section 1.3.3, development of the Gorgon field will require a range of infrastructure to extract the gas and transport it to Barrow Island for processing and delivery to market. The principal physical components of the proposed Development provided in Table 1-2 are described in the following sections.

6.1 Offshore Production Wells

The offshore production wells will be drilled using a vessel similar to that commonly used in north-west Australia at similar water depths. Drilling requires approval by the Western Australian Department of Industry and Resources under the Commonwealth *Petroleum (Submerged Lands) Act 1967* (P(SL)A). Detailed Environment Plans, Oil Spill Contingency Plans and drilling fluid management procedures will be produced as part of this process.

6.2 Feed Gas Pipeline

The pipeline between the gas field the onshore gas processing facility (the Gorgon feed gas pipeline) will be corrosion resistant alloy (CRA) clad carbon steel or carbon steel. To support the operation of the wells and manifolds it will be connected to the gas processing facility by an umbilical bundle. The umbilical bundle will include: electrical power and signal lines, control line (water-based control fluid), chemical injection lines and spare lines. Separate injection lines and utility lines and other essential service lines will also be required.

Corrosion inhibitors and other chemicals may also be injected into the wells and flowlines via the umbilical bundle which will follow the path of the main feed gas pipeline.

An electrohydraulic control system will be adopted to control the valves on the subsea trees. The control fluid will be a water-based fluid (with glycol), which has been designed and selected to be suitable for release to the environment.

To meet government regulations and safety requirements, corridors centred on the offshore pipelines and all subsea infrastructure, will be established in which anchoring by commercial vessels will be prohibited, and access restricted. The corridors, which will extend approximately 500 m on either side of the pipeline, and around subsea equipment, will be gazetted and marked on navigation charts.

6.3 Shore Crossing

The feed gas pipeline will be installed across the western shore of Barrow Island using HDD technology. This involves drilling a 1100 mm diameter hole from the rear of the beach to the 12 m water depth contour, approximately 1 km from shore. At the subsea exit point, a small amount of jetting or rock dumping will be required to create a gentle transition from the exit angle to the natural seabed contour to prevent a large unsupported pipeline span being generated. Approximately seven holes will be required for two complete feed gas pipeline systems.

6.4 Onshore Feed Gas Pipeline

The onshore section of the pipelines will be supported above ground with sufficient clearance to ensure that fauna can pass freely underneath the pipeline. The pipelines will be buried under roads, with appropriate culvert and right-of-way systems to enable installation of future pipelines. Seasonal water crossings may be traversed or trenched depending on their size, surrounding terrain, geology and other factors.

The feed gas pipeline construction activities will be located within a 30 m easement. As the design develops, endeavours will be made to improve on this to set a new industry benchmark. This width will provide adequate space for short-term stockpiling of vegetation and topsoil where it exists, as well as safe manoeuvrability for construction machinery and associated traffic. Vegetation along the easement will be slashed to prevent outbreak of fire associated with welding; and to promote successful regrowth. The easement will be graded, where necessary, to provide a safe and level working area and to reduce erosion and sediment transport. Easements for smaller lines will be much smaller.

6.5 Gas Processing Facility

A schematic representation of the gas treatment process is shown in Figure 6-1, while a likely layout for the proposed gas processing facility is presented in Figure 6-2.

The acid gas removal units will utilise accelerated-methyldiethanolamine (a-MDEA) in water as the solvent for CO_2 and H_2S removal.

Ethane and propane will be recovered from the gas for use as refrigerant in the liquefaction process for the LNG system. These hydrocarbons will be stored outside of the process area. Approximately 500 m^3 and 1800 m^3 of ethane and propane will be stored, respectively. It will be necessary to import ethane and propane to start the LNG process but after a period of time the system will be self-sufficient in these products.

The Joint Venturers will utilise a commercially available and proven liquefaction technology. Approximately 90% of current LNG plants around the world use a variation of the propane pre-cooled liquefaction technology from Air Products and Chemicals, Inc (APCI). This process is based on a mixed refrigerant process that utilises nitrogen, methane, ethane and

Figure 6-1:
Typical LNG Plant Process

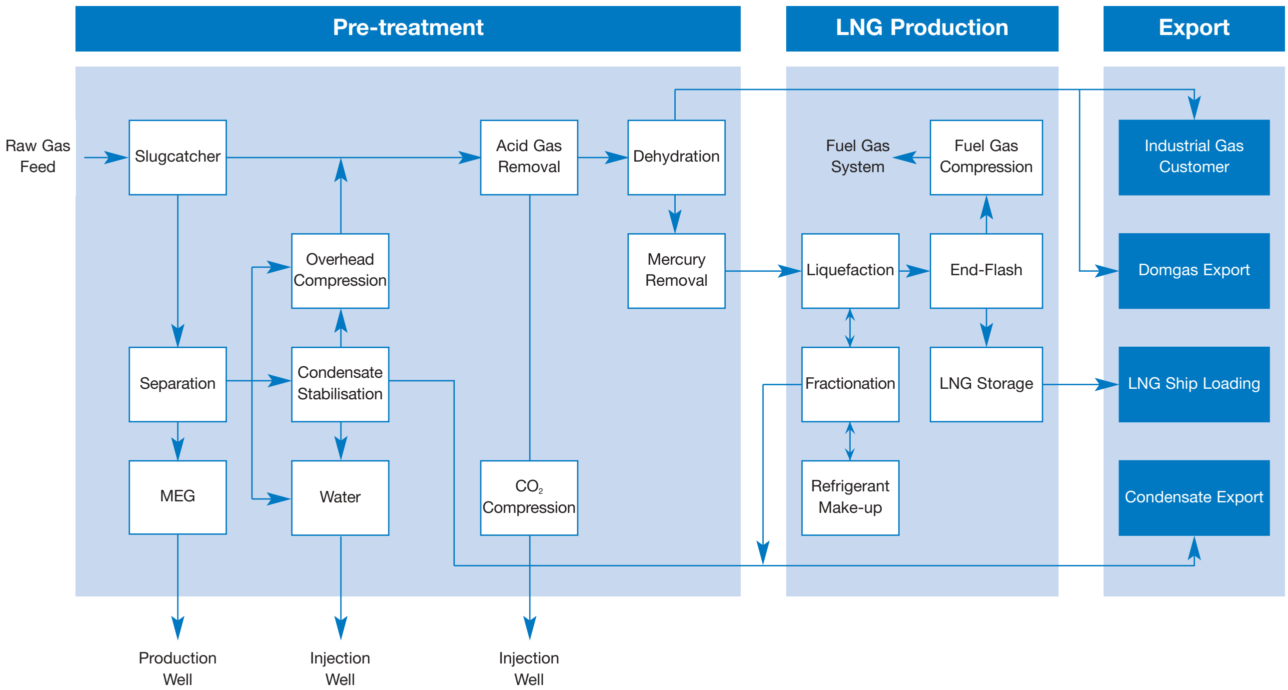
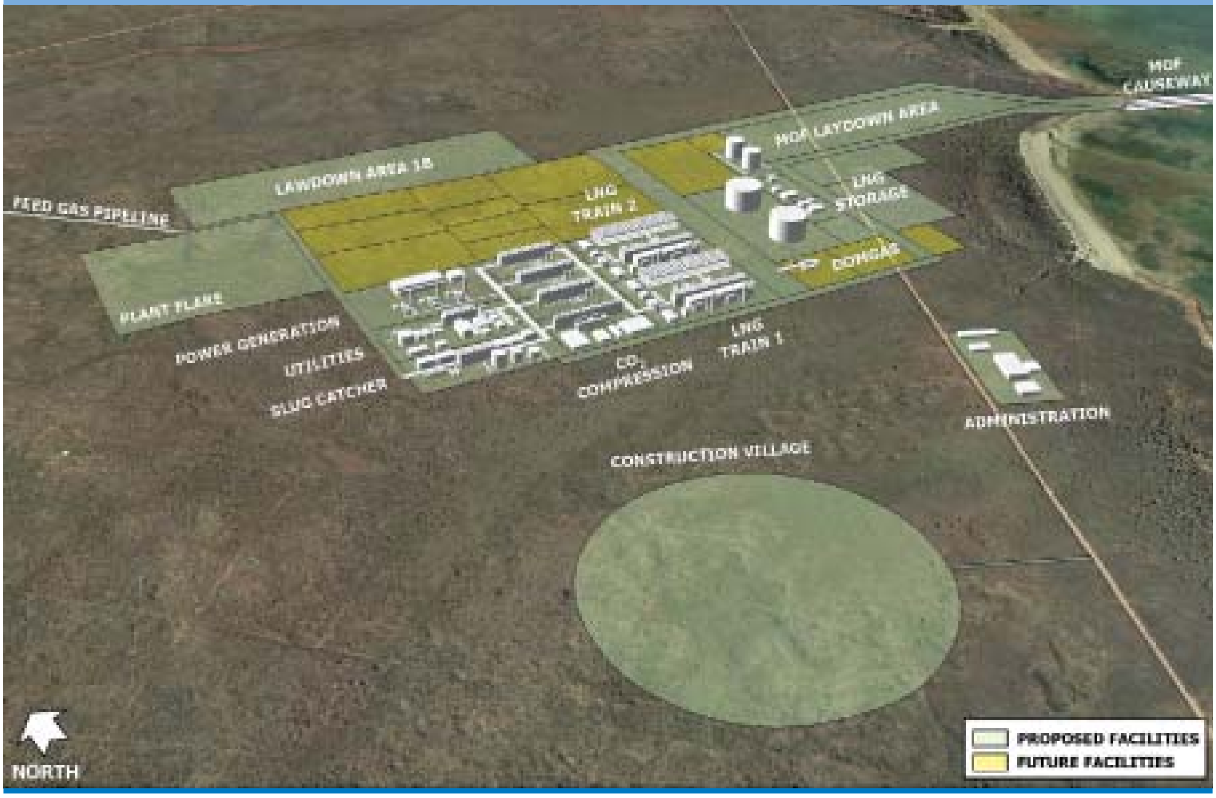


Figure 6-2:
Indicative Gas Processing Facility Layout



propane as refrigerants. This is the preferred technology and is the basis for assessment in this Draft EIS/ERMP.

For the purposes of this Draft EIS/ERMP, it is assumed that the refrigerant compressors on each LNG train will be driven by two large industrial gas turbines. These turbines will be assisted by electric motor starter/helper drivers that provide mechanical power for starting the turbines, and additional energy for production. Gas turbines will also be used for generation of electrical power. Gas turbine exhaust waste heat recovery units will provide the heat for the hot oil heating medium system and the dehydration regeneration gas.

As part of the 'flashing process', some LNG will be turned back to a vapour. This 'flash gas' will be relatively rich in nitrogen, allowing the remaining LNG product (mostly methane) to meet the nitrogen sales specification. The nitrogen-rich flash gas will be compressed and used as the main source of fuel gas for the gas processing facilities on Barrow Island.

LNG product from the liquefaction process will be stored in two full containment storage tanks of approximately 135 000 m^3–155 000 m^3 net each. The tanks are expected to be approximately 35–40 m high and 70–80 m in diameter. The design of LNG tanks is carefully controlled through British Standard EN1473 *'Installation and Equipment for LNG – Design of Onshore Installations'.* The tanks will be designed to withstand cyclonic wind forces and any impact from items caught by cyclonic winds.

The condensate tanks are expected to each have a net capacity of approximately 35 000 m^3. The condensate will be loaded onto ships either using the existing Barrow Island oil loading facilities, a subsea line from the LNG jetty, or directly from the LNG Jetty.

Condensate, diesel fuel, a-MDEA and other similar materials will be stored in tanks which are bunded to meet Australian Standards, as a minimum.

6.6 Domestic Gas

Following acid gas removal, the gas destined for the domestic gas market will be dehydrated and the hydrocarbon dew point controlled to meet the domestic gas specification.

It is proposed that the domestic gas pipeline will be routed directly from Town Point to the mainland. The final alignment will be modified to reduce impacts to sensitive habitat as the design develops.

This pipeline will approach the mainland immediately adjacent to the existing Apache Energy Gas Sales Pipelines to reduce environmental impact associated with development of a new shore crossing. The Barrow Island end will be in pre-disturbed land.

6.7 Plant Lighting

Minimising light spill is an important design criterion for the proposed Development due to potential impacts on turtle hatchlings. To minimise the potential impact, a hierarchical lighting strategy has been developed. In general, lighting levels will be reduced to those required for safe working and security.

In areas where colour definition is not required for safety or operational purposes, shielded red or mono-chromatic lights are proposed. This includes areas such as the MOF causeway, jetty, roads within the gas processing facility and general open areas. In areas where minimal colour definition is required, a reduced spectrum yellow/orange type of shielded light, such as sodium vapour, will be used. These lights will form the primary lighting for the facility.

Areas that require inspection during operator rounds and/or regular maintenance (e.g. filter change outs) will utilise fully shielded full spectrum white lights that are normally off. These lights will be switched on only as required. For an emergency situation, additional lights will be required for safety, including perimeter flood lights.

The lighting regime will continue to be reviewed during the design phase and is subject to confirmation that it is acceptable from a health and safety perspective.

6.8 Flare System

A 'no routine-flaring policy' will be adopted for the design of the gas processing facility. This means that during normal day-to-day operation, the flare will not be used for waste gas disposal.

A total of three flares will be required for the safe operation of the gas processing facility. The two main flares will either be located on a flare tower or at ground level. A flare tower may be in the order of 150 m high, located to the west of the facility. These flares would be used during plant emergencies, start-up, shut-down and short-duration upset conditions. Short-term (several hours) flaring can avoid the need for a full plant shut-down which would result in a greater volume of gas flaring.

Alternatives to reduce anticipated flaring loads, and possibly the size of the main flare stacks, will be reviewed during the design phase.

6.9 CO_2 Injection Facilities

Carbon dioxide will be compressed within the gas processing facility and transported via a 250–350 mm diameter above ground pipeline to the injection wellheads. The injection wells will be directionally drilled in clusters of three-four wells, from a small number of drill centres. Careful selection of the bottom-hole locations will be required to achieve the desired injection rates and distribution. This approach will reduce the land required for drilling and well operations.

The CO_2 injection pipeline will follow the most direct path practicable to the injection well locations while preferentially using previously disturbed land. The final alignment will be chosen to protect the safety of personnel in the unlikely event of CO_2 release from the pipeline.

6.10 Drainage and Waste Water System

The waste water system will be managed to maximise the re-use of water, and to protect soils, subterranean fauna, groundwater and the marine environment from contamination. To achieve this, a tiered waste water management approach will be adopted within the gas processing facility, which comprises the following:

- diverting water, which flows naturally onto clean areas of the site during rainfall events, to natural drainage areas
- allowing water from unpaved areas and paved non-process areas (e.g. roads and buildings), where no contamination is likely, to soak naturally into the ground, or directing this water to natural drainage
- directing water in areas that could be contaminated, but are usually considered to be relatively clean, to a holding basin for water quality testing before discharge or disposal. (Uncontaminated water will be discharged back to natural drainage, while contaminated water will be pumped to a treatment system.)
- directing water from areas that are expected to be contaminated (e.g. sumps and areas around pumps and turbines) to an oil recovery system.

The design of this tiered waste water facility will take into account the increased flows associated with severe storm events and potential firewater runoff (the latter of which may be contaminated with hydrocarbons, chemicals and salt).

All process water and potentially contaminated runoff will be treated in an oil recovery system. Recovered hydrocarbons will be recycled (by directing them back into the process, where appropriate), or will be returned to the mainland for recycling or appropriate treatment and disposal.

6.10.1 Sanitary Waste

Sanitary waste water systems will be required to support all phases of island-based work. Treated effluent will be disposed via one (or a combination) of the following systems/methods:

- re-use for construction, hydrotesting and/or land farming
- utilisation of the existing produced water disposal system
- injection to drilled deep wells.

The treated process water and the effluent from the demineralisation plant will be combined with the treated water from the sewerage plant and injected into subsurface formations below Barrow Island. It is anticipated that sludge will be removed from Barrow Island and disposed of on the mainland.

6.10.2 Fresh Water

The most significant single requirement for water will be associated with hydrotesting the feed gas pipelines, domestic gas pipeline and the LNG tanks. This is discussed in the relevant sections for these activities.

Horizontal directional drilling will be used for the pipeline shore crossings. This technique will also require a significant quantity of water (approximately 20 000 m^3) which would most likely be salt water, but may need to be fresh water depending upon the selection of drilling fluid.

Three options are currently being considered as the source of water to the water making facilities, namely groundwater, seawater or the Dupuy Formation.

6.11 Materials Offloading Facility (MOF)

Access to the MOF will be provided via an 800 m long causeway from Town Point. The MOF will extend a further 325 m from the offshore end of the causeway. This concept significantly reduces the volume of material to be dredged and associated blasting of the limestone platform that would otherwise be required to provide an access channel to a shore-based facility. Vessels will access the MOF via a dredged channel approximately 1.3 km long, 120 m wide and dredged to 6.5 m relative to chart datum. At this depth, the channel will be tidally restricted for the larger vessels required during construction. A deeper pocket will be dredged against the MOF to enable these larger vessels to be unloaded during all tidal conditions.

The MOF will also incorporate mooring facilities for tug boats and other vessels required to support the LNG carriers and refuelling capabilities for the smaller vessels (such as tugs). The details of the MOF specification will be reviewed with respect to module and equipment sizes determined as the design proceeds; however the basic concept will not change.

6.12 LNG Jetty

A jetty will be built with mooring facilities to receive LNG carriers and possibly condensate tankers. The jetty will be approximately 3.1 km long commencing from the offshore end of the causeway. The approach trestle and loading platform will be constructed with a steel open pile design and the height will be sufficient to avoid wave forces on the underside of the deck.

6.12.1 Jetty Approach Channel

The LNG carriers will require safe access via a shipping channel. The location of the proposed LNG loading berth has been developed in consultation with the Barrow Island shipping pilots, and will be located several kilometres from the existing crude oil loading mooring.

Dredging will be necessary to create a shipping channel and turning basin that is approximately 14 m deep relative to the chart datum to allow access/egress of LNG carriers in any tidal condition. The current estimate of the volume of dredge material produced is approximately 9 million m^3. It is proposed that the channel will be dredged by removing unconsolidated material by trailer suction hopper dredge, then using a cutter suction dredge to break the hard material and load into hopper barges moored alongside the vessel.

The approach route will have an alignment as straight as possible with any bends at least 1000 m radius, if bends cannot be avoided. The approach channel will require a minimum width of approximately 300 m. The channel will be equipped with appropriate navigation aids. An exclusion zone will be established around the LNG jetty and channel in accordance with industry guidelines. During the operations phase, the Barrow Island port will be controlled by a Loading Master/Harbour Master who will control all activities within the port limits. During construction, these duties will be assumed by a Marine Operations Manager, or similar role.

During severe adverse weather conditions, LNG ships and condensate ships will be diverted, delayed, or released to avoid being caught in shallow or confined waters. Tugs will also be released to avoid the weather. During severe adverse weather conditions, construction vessels will shelter in the Dampier archipelago, which is common practice in the region.

6.13 Administration and Maintenance Facilities

An administration building and maintenance facilities will be constructed either within the gas processing facility site, or in the vicinity. This area will contain offices and workshop facilities for the maintenance of the gas processing facility equipment. Some of these facilities may be shared with the existing oil operations on Barrow Island.

6.14 Roads

The construction of the gas processing facility will require the re-alignment and upgrading of several existing roads on Barrow Island. The upgrades will involve widening, grading and sealing to increase safety for both personnel and fauna due to increased visibility. Sealing the main roads will also reduce dust generation. Drivers will operate under strict procedures to reduce environmental impacts.

6.15 Interconnections with Existing Operations

There are likely to be a number of interconnections with existing facilities on Barrow Island, such as the condensate loadout, power supply, water injection systems, water supply, communications and gas supply. Where possible, these facilities will be installed along currently disturbed areas (e.g. power lines along existing roads), or along a common corridor, to reduce environmental impact.

6.16 Onshore CO_2 Injection Wells

The onshore CO_2 injection wells will require the following:

- access roads for personnel and equipment
- water and other materials required for the drilling fluid
- a level work site on which to place the drilling rig
- excavated and lined pits or tanks in which to store fluids
- facilities to remove cuttings from the drilling fluid
- systems to manage cuttings disposal
- facilities to enable each well to be cleaned up.

Carbon dioxide resistant cement will be the used to fix the casing in place. Use of this cement will also prevent the release of CO_2 via the wells.

6.17 Pioneer Camp

A pioneer camp will be constructed to accommodate personnel during the initial phase of construction, as the existing oil field operations camp does not have the necessary capacity. The initial phase of work will involve establishing the main construction village. The pioneer camp will accommodate 250 personnel and will require additional amenities such as water treatment, sewage treatment and waste management.

The pioneer camp does not form part of the proposal covered by this Draft EIS/ERMP as it will be constructed during the EIS/ERMP assessment period and will be subject to a separate approval process. The camp has been included here for completeness and to allow consideration of cumulative impacts.

6.18 Construction Village

The existing camp on Barrow Island and pioneer facilities will be too small to accommodate the expected number of people required to construct the gas processing facility and associated infrastructure, or to operate the facilities on a long-term basis. Therefore, a new construction village will need to be built. The construction village will cater for a peak workforce of approximately 3300 personnel. A section of the village will be designed as a permanent installation to support large-scale maintenance campaigns, or as an operational village.

The construction village will require a range of facilities and utilities including:

- power supply
- water supply
- waste water management
- sewage treatment (with connection to the water injection system)
- recreational facilities
- mess facilities
- laundry
- bus parking facilities
- waste management facilities, including an incinerator
- medical facilities
- fire station
- telecommunications (including internet and phone).

Various sites have been examined for the location of the construction village and four short-listed sites are currently under consideration. Preliminary assessments have not identified any significant difference in environmental sensitivity between the sites. Further work will be undertaken during the design phase to finalise site selection, such that potential environmental impacts are kept to acceptable levels.

6.19 Airport

Earthworks may be required associated with potential extensions to, and realignment of, the runway and any expansion of the terminal.

6.20 Telecommunications

A communications network will be installed on Barrow Island to support the construction and operational activities. The network will provide for radio, telephone and data links between most facilities on the island. An optical fibre cable will be installed between Barrow Island and the mainland to provide a reliable link to existing communication networks. Onslow and Peedamulla are currently under consideration as tie-in locations to the mainland optical fibre cable network (Figure 6-3). The latter provides a shorter subsea route but a significantly longer terrestrial route.

6.21 Waste Staging Area

Various wastes will be generated through all stages of the Development. The principles of 'avoid, reduce, re-use, and dispose in an environmentally responsible manner' will be followed. The focus will be on avoiding waste at source by working with the suppliers in the tendering and contracting processes. Appropriate waste segregation and storage facilities will be provided, such as for food wastes (e.g. covered where possible to keep out fauna), scrap steel (i.e. for recycling), and hazardous wastes (e.g. bunding for liquid wastes in line with relevant Australian Standards). These facilities will be designed in accordance with Australian Standards and incorporate best practice principles. No wastes will be disposed of on Barrow Island, other than those such as waste concrete, which can be utilised by existing oilfield operations.

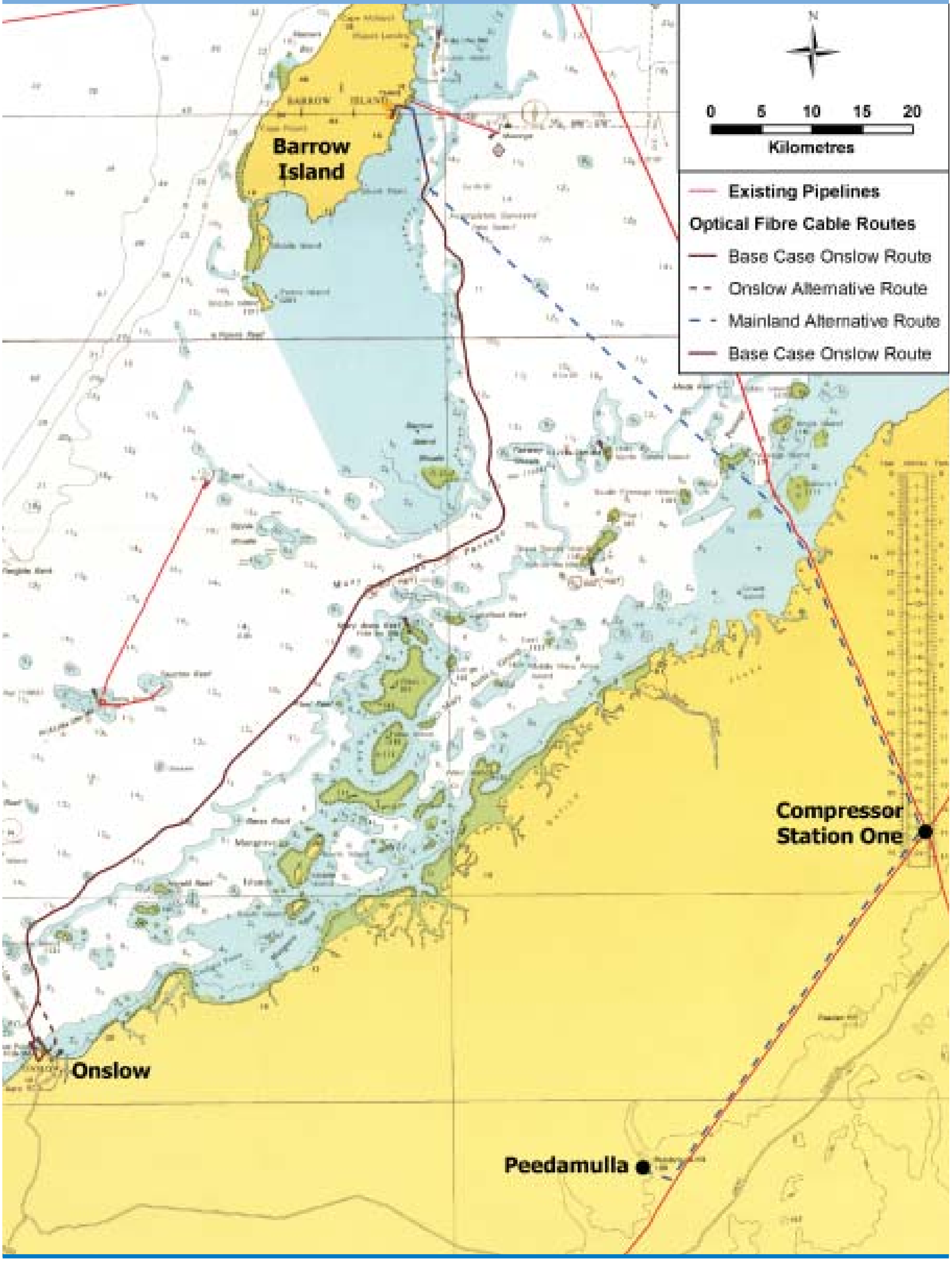
6.22 Mainland Supply Base(s)

Logistical support facilities will be required to support both offshore and Barrow Island operations. Mainland supply bases will allow for consignment, loading and refuelling of support vessels and subsea construction vessels, storage of construction materials, offloading of materials requiring transport and the return of waste. The preferred concept is to utilise existing facilities that either meet the construction requirements, or that can be upgraded readily. The exact location and nature of the facilities have yet to be decided; however, it is anticipated that existing infrastructure in the King Bay area near Dampier and at the Australian Marine Complex south of Perth may be utilised, with various locations in the Perth metropolitan area. The facilities will incorporate lay-down and storage areas, warehouses, quarantine facilities (such as a wash down bay, fumigation facility, inspection pit, etc), administration and wharf facilities (if adjacent), together with appropriate waste management systems and waste water collection and treatment systems. These facilities will also support the Development quarantine management system, and will have security surveillance.

6.23 Decommissioning

As the life of the proposed Development is expected to be in the order of 60 years, it is reasonable to assume that there will be changes to decommissioning procedures and regulatory requirements that incorporate advances in technology and information. In recognition of these potential changes, the Gorgon Joint Venturers commit to adopting best practices in environmental management at the time of decommissioning. However, the basic principle is that all surface equipment will be removed and the site rehabilitated.

Figure 6-3:
Possible Routes for Optical Fibre Communications Link



7 Emissions from the Development

Emissions will occur during the construction, commissioning, operation, maintenance and decommissioning phases of the proposed Gorgon Development.

The predicted emissions are based on current information. Opportunities to further reduce emission levels will be pursued during the detailed design phases of the proposed Development.

The main aspects considered are:

- atmospheric emissions
- light
- noise
- solid non-hazardous wastes
- liquid wastes
- dredging
- accidental releases (i.e. spills).

Greenhouse gas emissions are covered in Section 13.

Predicted emission levels have been compared to legislative standards and guidelines where they exist.

7.1 Atmospheric Dispersion Modelling Methodology

Two different atmospheric dispersion models were used to predict the impact of the proposed gas processing facility on air quality. These models were:

- DISPMOD, the Western Australian coastal model, which was employed to estimate local ground level concentrations of the emissions from various operating scenarios.
- TAPM, the CSIRO's prognostic meteorological and air pollution model, which was used to address regional air quality impacts and local deposition rates.

Emissions from the existing Barrow Island facilities were also included in order to address the potential cumulative levels.

7.2 Air Quality Criteria

Within Western Australia, the Environmental Protection Authority (EPA) assesses all new projects in terms of air emissions at the stack or vent outlet and the resultant ambient ground level concentrations. For emissions from industrial sources, the EPA requires that 'all reasonable and practicable means should be used to prevent and minimise the discharge of waste' (EPA 1999). For new projects, the EPA requires the assessment of best available technologies to reduce waste discharges, and justification for the adopted technology.

Best practice for NO_x reduction is generally considered to be Selective Catalytic Reduction (SCR), which involves the reaction of NO_x with ammonia to produce nitrogen and water. It requires the injection of a solution of ammonia (or a solution of urea) into a gas turbine exhaust, and the exhaust gases then passing over a catalyst. This process is not considered best practice for the Gorgon Development as transporting large quantities of ammonia or urea to Barrow Island, and using these materials, introduces additional safety, environmental and quarantine risks.

The EPA has developed a guidance statement for oxides of nitrogen emissions from gas turbines, with limits for emissions following the Australian Environmental Council/Natural Health and Medical Research Council (AEC/NHMRC) National Guidelines. These limits are 0.07 g/m^3 (Standard Temperature and Pressure, dry and 15% O_2) for gaseous fuels and 0.15 g/m^3 for other fuels. Modern natural gas-fired systems, employing NO_x control technology can be expected to achieve emissions lower than 0.07 g/m^3.

Current indications from gas turbines of a similar size are that NO_x emissions may be half to a third of this concentration; however the assessment conducted for this document is based on the more conservative figure of 0.07 g/m^3.

Other standards (such as National Environmental Protection Measure (NEPM), World Health Organisation (WHO) and the USEPA National Ambient Air Quality Standards) have been referenced where necessary.

A summary of the maximum predicted concentrations of the various emissions for normal (routine) operations as well as a range of emission levels during start-up and plant upset conditions are presented in Table 7-1. The results show that the proposed Gorgon Development will measure better than the relevant criteria. For example, the maximum 1-hour NO_2 concentration over the entire modelling grid is 0.06 parts per million (refer to Figure 7-1); this is half the NEPM value.

Figure 7-1:
Maximum 1-hour NO_2 Concentration (in ppm)

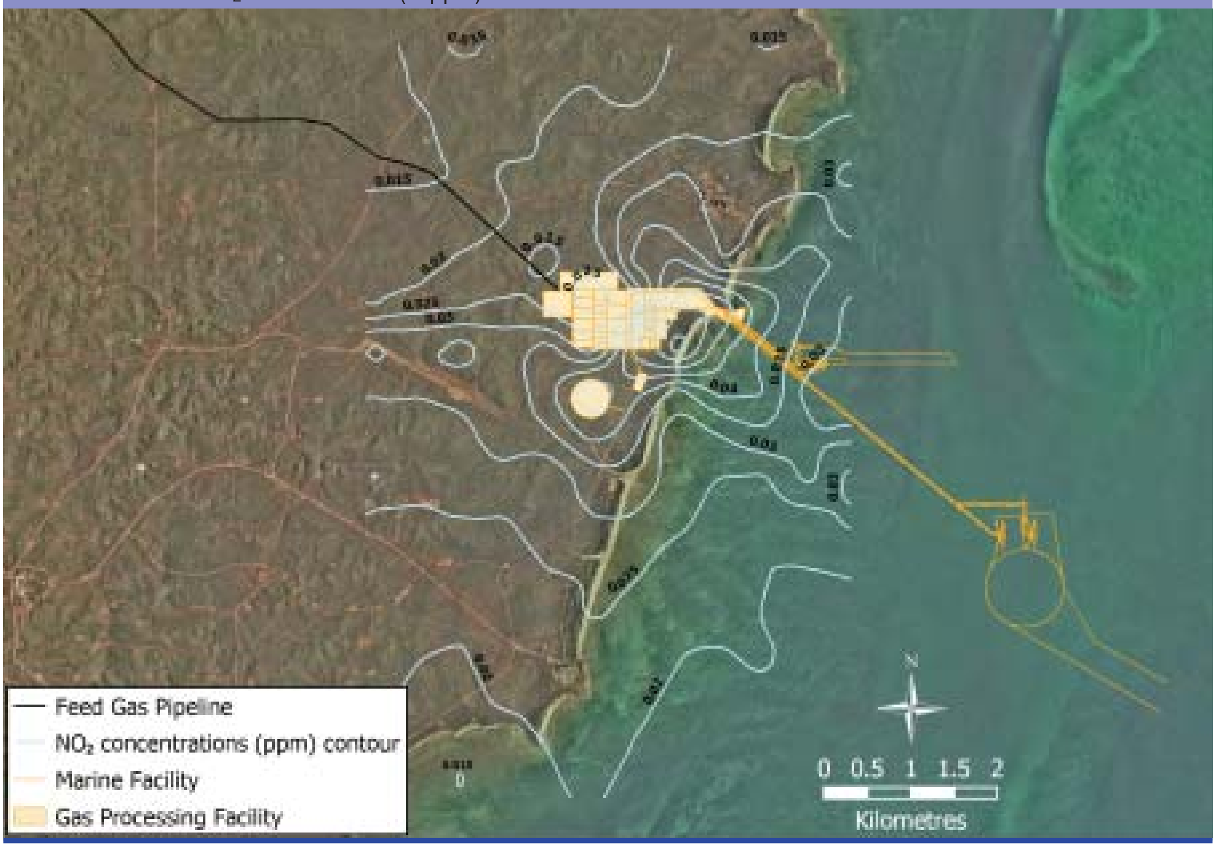


Table 7-1:
Comparison of NEPA, USEPA and WHO Ambient Air Quality Standards and Guidelines with Predicted Gorgon Development Emissions

Emission	NEPM		USEPA		WHO		Gorgon Development – Model Predictions	
	Averaging Period	**Maximum Concentration**	**Averaging Period**	**Maximum Concentration**	**Averaging Period**	**Maximum Concentration**	**Normal Operations (Max)**	**Non-Routine Conditions**
Nitrogen dioxide	1 hour	0.12 ppm (246 µg/m^3)					0.063 ppm (1 hr)	0.037–0.049 ppm (1 hr)
	1 year	0.03 ppm (62 µg/m^3)	Annual	0.053 ppm (100 µg/m^3)	NO_x – Annual	0.016 ppm (30 µg/m^3)	0.003 ppm (annual)	N/A
Photochemical oxidants (as ozone)	1 hour	0.10 ppm (214 µg/m^3)	1 hr	0.12 ppm		0.2–10 ppm	regional cumulative concentration (<0.1 ppm)	regional cumulative concentration (<0.1 ppm)
	4 hours	0.08 ppm (171 µg/m^3)	8 hr	0.08 ppm	5 days – 6 months			
Sulphur dioxide	1 hour	0.20 ppm	SO_x – 3 hr	0.5 ppm (1300 µg/m^3)			N/A (<0.001 ppm)	0.001 ppm (1 hr)
	1 day	0.08 ppm	SO_x – 24 hr	0.14 ppm (human)	24-hr	100 µg/m^3	N/A	N/A
	1 year	0.02 ppm	SO_x – Annual	0.03 ppm (human)	Annual	10–30 µg/m^3	N/A	N/A
Particles as PM10	1 day	50 µg/m^3	24 hr	150 µg/m^3 (human)			3 µg/m^3 (24 hr)	54–330 µg/m^3
			Annual mean	50 µg/m^3				
Nitrogen deposition					15–20 kg/ha/yr		0.06–0.55 kg/ha/yr	N/A

7.3 Light

Lighting associated with construction and operation of the Development has the potential to affect marine fauna, notably sea turtles and some seabirds (e.g. shearwaters and gulls). Because there is no single, measurable level of artificial brightness on nesting beaches that is known to be acceptable for sea turtle conservation, the most effective conservation strategy is simply to use 'best available technology' to reduce effects from lighting (Witherington and Martin 2000). Best available technology includes many light management options that have been used by lighting engineers for decades and others that are unique to protecting sea turtles. These include: reducing the number and wattage of lights; using longer wavelength (narrow spectrum) lights; positioning lights behind structures; and shielding, redirecting, lowering and/or recessing lights to prevent light spill to the beach.

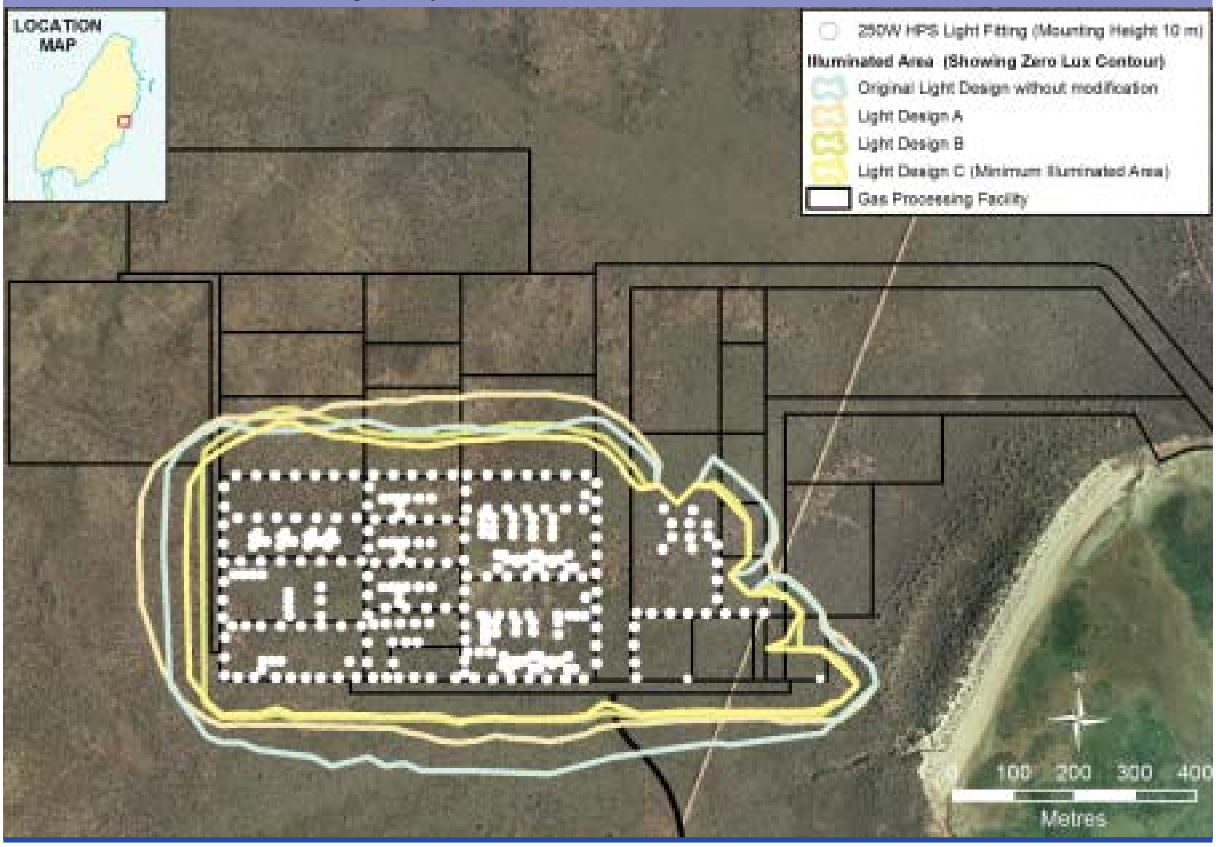
Preliminary modelling demonstrates that these types of measures will dramatically reduce lighting effects over a conventional lighting regime. For example, Figure 7-2 illustrates the reduction in light spill from a conventional lighting regime (250 watt high pressure sodium) as a result of redirecting lights away from beaches (Case A), reducing the height of lights (Case B), and reducing the wattage (Case C).

As the design progresses, the Gorgon Joint Venturers will continue to apply these principles and include more specific detail to minimise light spill from the onshore and offshore equipment.

7.4 Noise

A preliminary environmental noise assessment of the proposed gas processing facility on Barrow Island was undertaken. An acoustic model was developed using the Environmental Noise Model (ENM) developed by RTA technology. The ENM program calculates sound pressure levels at nominated receiver locations or produces noise contours over a defined area of interest around the noise sources. It was specifically used to generate noise contours for the area surrounding the gas processing facility, and to predict noise levels at the Chevron camp and the proposed Gorgon construction village site. In particular, the acoustic model was used to predict noise levels for normal gas processing facility operation, emergency blow-down of the facility, and the existing Barrow Island power station, respectively.

Figure 7-2:
Isolux Contours – Gas Processing Facility



Noise contours and noise levels were predicted for a range of meteorological conditions, including: calm conditions and worst-case wind conditions for sound propagation in the eight cardinal directions. The effects of temperature inversions on the modelling results were also reviewed.

Barrow Island is a Class A Nature Reserve and a producing oilfield, consequently public access to the island is limited and there are no noise sensitive premises. The Chevron camp site is located approximately 3.5 km to the south-south-east of the proposed gas processing facility site and the proposed Gorgon construction village will be located approximately 400 m south. These are the only facilities located on the island where noise could be considered to have any social impact.

Since these facilities are designed to service industry on the island, they have been classed as industrial premises according to Schedule 1, clauses 7 and 8, of the Environmental Protection (Noise) Regulations 1997. The assigned noise levels are, therefore, 65 dB(A), 80dB(A) and 90 dB(A) for the L_{A10}, L_{A1} and L_{Amax} descriptors respectively. The most significant of these descriptors for continuous plant noise is the L_{A10} assigned level of 65 dB(A).

The predicted noise levels for routine gas processing facility operation at the existing Chevron camp site for a range of meteorological conditions ranged from 23 dB(A) to 36 dB(A) with the highest noise levels predicted for northerly wind conditions. This is well below the assigned level of 65 dB(A) and it is likely that noise from the gas processing facility will be inaudible during normal operations. Under the same meteorological conditions, the noise levels at the Gorgon construction village during routine operations will range from 53 dB(A) to 65 dB(A), which is also within the assigned level of 65 dB(A).

7.5 Solid Non Hazardous Wastes

Solid non-hazardous wastes that will be generated by the Gorgon Development typically include plastic, packaging, scrap metal, general domestic waste, food waste, tyres, waste pipe, concrete and non-hazardous drums and containers.

Solid non-hazardous wastes will be generated in varying amounts throughout all phases of the Gorgon Development; however, it is expected that the majority of waste will be generated during the construction phase on Barrow Island. Wherever practical the following wastes will be re-used or recycled:

- vegetation, rock and soil overburden from site levelling, foundation preparation, pipe-laying, and drilling activity
- drilling fluids, cuttings and dredge spoil material
- scrap pipe, metal fabrication, insulation, concrete and general construction materials
- packaging.

Onshore construction and drilling wastes not re-used or recycled will be collected, stored or contained on location at designated collection sites. Wastes generated on Barrow Island will generally be removed from the island for disposal at an approved disposal facility.

Drill cuttings from offshore activity will be separated from drilling fluids and disposed to the marine environment, in accordance with legislative conditions and consistent with standard industry practice. Injection of cuttings into a suitable sub-surface formation is extremely unlikely in a subsea wellhead development program at the water depth (>190 m depth) and receiving environment in the Gorgon area. Drill cuttings and fluids from the onshore HDD associated with the shore approaches for the feed gas pipelines will initially be collected, separated and the fluid re-used in the drilling process. However, once the drill has broken through to the seafloor, some bentonite and drill cuttings will be discharged to the marine environment.

Development wastes will be identified, categorised, handled, stored and managed in accordance with a Development-specific Waste Management Plan to be approved prior to any construction activity. Wastes will be greatest during construction/installation of wells, shore crossings, shipping channel, MOF, gas processing facility, and associated pipelines. Waste volumes generated during operations and maintenance of the Gorgon Development will be substantially less.

7.6 Liquid Wastes

A range of liquid wastes will be associated with the proposed Development, including ballast water, drainage water, drilling fluids, produced formation water, hydrostatic test water and subsea control fluids. These are discussed below.

7.6.1 Ballast Water

Currently, all oil tankers visiting the Barrow Island and Thevenard marine terminals have been informed by Chevron (as operator) of the 'Australian Quarantine and Inspection Service (AQIS) Voluntary Guidelines for the Handling and Treatment of Ballast Water Carried in Ships Entering Australian Waters.' Since 1993, the source and volume of ballast water discharged from tankers visiting these terminals has been monitored. These requirements and monitoring activities will also be applied to the Gorgon Development.

7.6.2 Drainage

Clean deck drainage water on the drill rig, dredges, tankers and support vessels will be directed overboard. Where drainage contains traces of hydrocarbon, it will be directed to a sump and oil water separator. The discharge of surfactants, dispersants and detergents will be minimised. Detergents or dispersants used for wash-down will be biodegradable and phosphate free. All endeavours will be made to keep detergents out of oily water separation systems as they adversely affect the separation. Onshore, a wastewater system will be designed to protect soils, groundwater and the marine environment from contamination. In order to minimise the discharge of contaminants and nutrients, a multi-tiered waste water management approach has been adopted.

7.6.3 Drilling Fluids

Drilling fluids are likely to be a combination of water-based and non-aqueous drilling fluids. Non-aqueous drilling fluids, such as synthetic based fluids, will be low toxicity, and are commonly used in north-west Australia with regulatory approval. Full details of drilling fluids and alternatives considered will be provided in the Environment Plan, required under the Petroleum (Submerged Lands)(Management of Environment) Regulations.

7.6.4 Produced Formation Water

Produced formation water from the gas fields, along with additives such as monoethylene glycol (MEG) and corrosion inhibitor, will be separated from the incoming gas stream at the gas processing facility. The liquids will then be separated into a water phase and condensate. The water phase will be directed into deep injection wells on Barrow Island.

7.6.5 Hydrostatic Test Water

Where practicable, test water will be re-used to test other components. Following successful testing, the hydrostatic test water will be injected into dedicated disposal wells on Barrow Island. Alternatively, if it meets approved quality standards, it will be disposed of into the marine environment at an approved location and discharge rate. A Hydrostatic Testing Management Plan will be prepared for government approval.

7.6.6 Subsea Control Fluids

Subsea control fluids will be used to operate, protect and maintain the upstream manifolds and wellheads in the offshore field area. These fluids are specifically designed for this purpose and are commonly used in subsea exploration and development wells in north-west Australia, the Gulf of Mexico, North Sea and offshore Brazil. An open loop system for subsea control fluids is planned with small volumes of control fluid released from the valves on the seabed when they are operated. Control fluids will be selected for low toxicity and biodegradability while meeting operational requirements.

7.7 Hazardous Wastes

Hazardous wastes which will be generated include: sand, scales, filters, molecular sieves, and mercury removal adsorbent. All hazardous wastes associated with the Gorgon Development will be managed in accordance with a Development-specific Waste Management Plan. The Plan will include systems and details for tracking wastes from source to disposal to a licensed hazardous waste facility on the mainland.

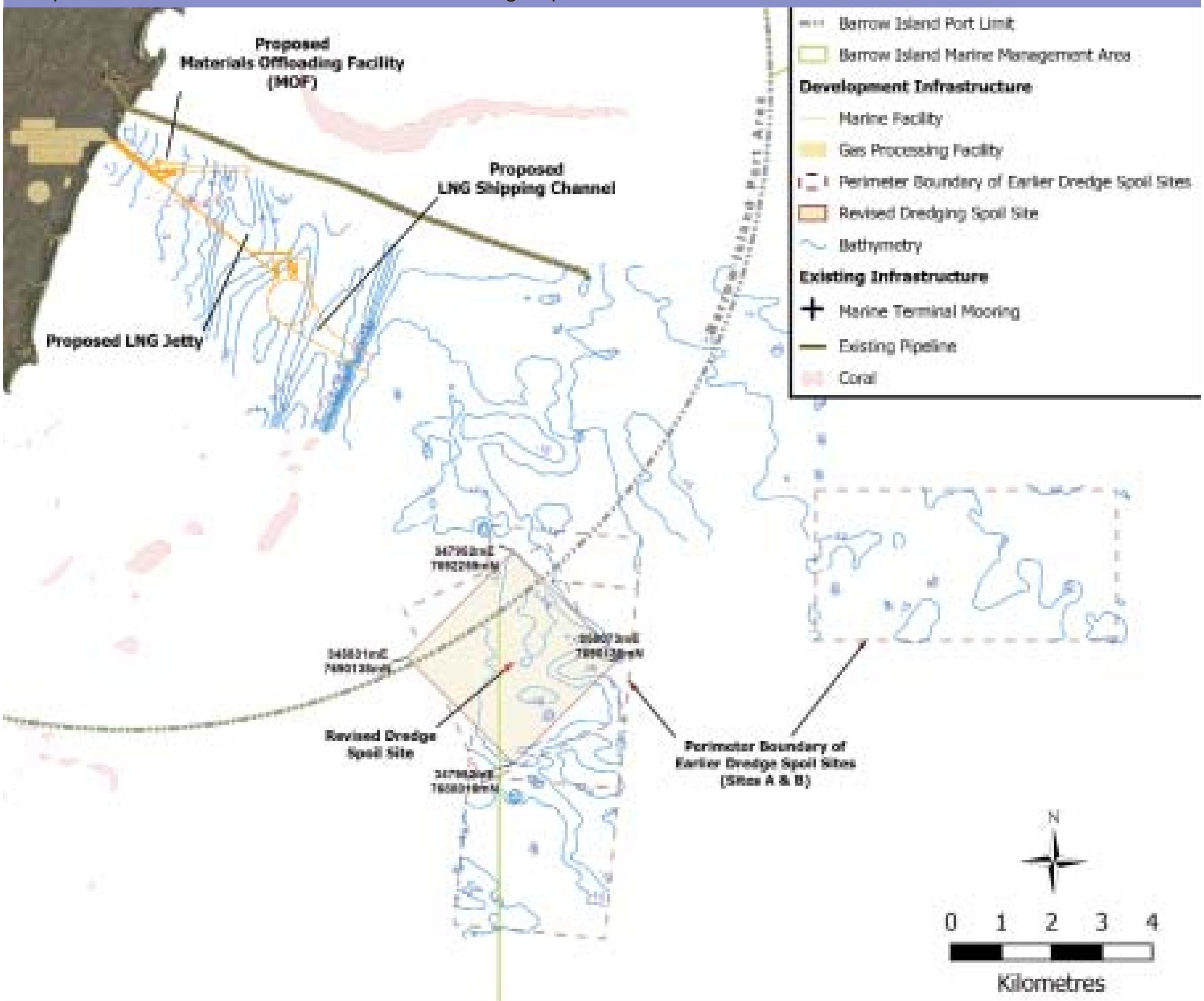
7.8 Dredging

Dredging on the east coast of Barrow Island is proposed within the existing Barrow Island port boundary and the proposed dredge spoil disposal site is located immediately to the south east (Figure 7-3). Dredge spoil from excavation at the MOF, access channels and turning basin will be disposed of in designated sites pursuant to the terms and conditions of the Commonwealth Sea Dumping Permit *(Environment Protection (Sea Dumping) Act 1981)* and National Ocean Disposal Guidelines for Dredged Material. Table 7-2 identifies the proposed locations, equipment, volumes and duration for the dredging program.

Table 7-2:
Location, Equipment and Estimated Volumes and Duration of Dredging Activity

Dredging Location/Activity	Dredger/Equipment Proposed	Volume (Mm^3)	Duration
MOF Channel and Basin to -6.5 m LAT	Cutter suction dredge Discharge pipeline to MOF causeway for fill	~0.80	~21 weeks
LNG channel and turning basin to –14 m LAT	Cutter suction dredge and trailer suction hopper dredge and self-propelled hopper barges with bottom dump	~8.0–9.0	~ 45 weeks
Disposal of dredged material to proposed 3 x 3 km spoil disposal site taking advantage of local bathymetry	Self propelled hopper barges with bottom dump	Capacity to handle 12.0	≥45 weeks

Figure 7-3:
Proposed Location of Marine Facilities and Dredge Spoil Site



The dredging required to create the access channels and berth areas for the Development will result in physical disruption to localised areas of the seabed and the generation of turbidity plumes at both the dredging and disposal sites. To predict and assess the potential impacts on corals and determine the monitoring that will be required, numerical modelling was undertaken using a particle tracking technique. The modelling was carried out in two steps. Firstly, the 3-dimensional ocean circulation of the region from south of Barrow Island to north of the Montebello Islands was predicted for 16 months using the GEMS coastal-ocean model GCOM3D. Then the total dredging program was simulated over 450 days using a sophisticated particle tracking model which simulates the daily behaviour of the dredge(s) based on an estimated dredge log.

Modelling predicted the daily distribution of Total Suspended Solids (TSS) and seabed coverage to be developed over the total dredge program (approximately 450 days). The daily output was analysed to derive periods of continuous exposure to turbidity and/or sedimentation above defined thresholds. The result of this analysis is summarised in maps of exposure zones showing regions affected by turbidity or sedimentation that result in high impact, moderate impact and the extent of sedimentation and the visible turbidity plume (Figure 11-1). Where there was uncertainty in model parameters, conservative values were chosen such that the model would tend to overestimate the extent and magnitude of impact. The model predictions were aligned to the current dredging schedule, which is throughout the year except for the period(s) of coral spawning.

Field validation of the dredge plume model is currently underway (at the time of publication). The results of the field validation work will be included in a package of additional information to the Draft EIS/ERMP (refer to Section 4).

7.9 Accidental Spills to the Marine Environment

The chance of a hydrocarbon release will be remote due to the high standards of design, material selection and construction and operation applied. Such standards are driven, not only by the environmental objective of the Gorgon Joint Venturers, but by the expectations of customers and external stakeholders that drive optimum supply reliability.

The potential hydrocarbon releases that were identified for the Gorgon Development include:

- an onshore release from the feed gas pipeline, condensate from the rupture or leak from a pipeline or tank within the gas processing facility
- a release of condensate and produced water (containing dissolved hydrocarbons and monoethylene glycol (MEG)) from the subsea production equipment, subsea flow lines or the feed gas line running from the supply fields to the western shore of Barrow Island
- a release of processed condensate from either of the subsea condensate off-loading pipelines (existing or new) on the eastern side of Barrow Island
- a release of diesel from shore facilities or small vessels operating around facilities on the east and west coasts of Barrow Island
- a release of condensate, crude oil (from other sources) and bunker fuel oil from tankers brought to the export terminal.

Tank and storage areas were excluded from assessment as they will be provided with appropriate bunding and drainage systems in line with Australian Standards, as a minimum.

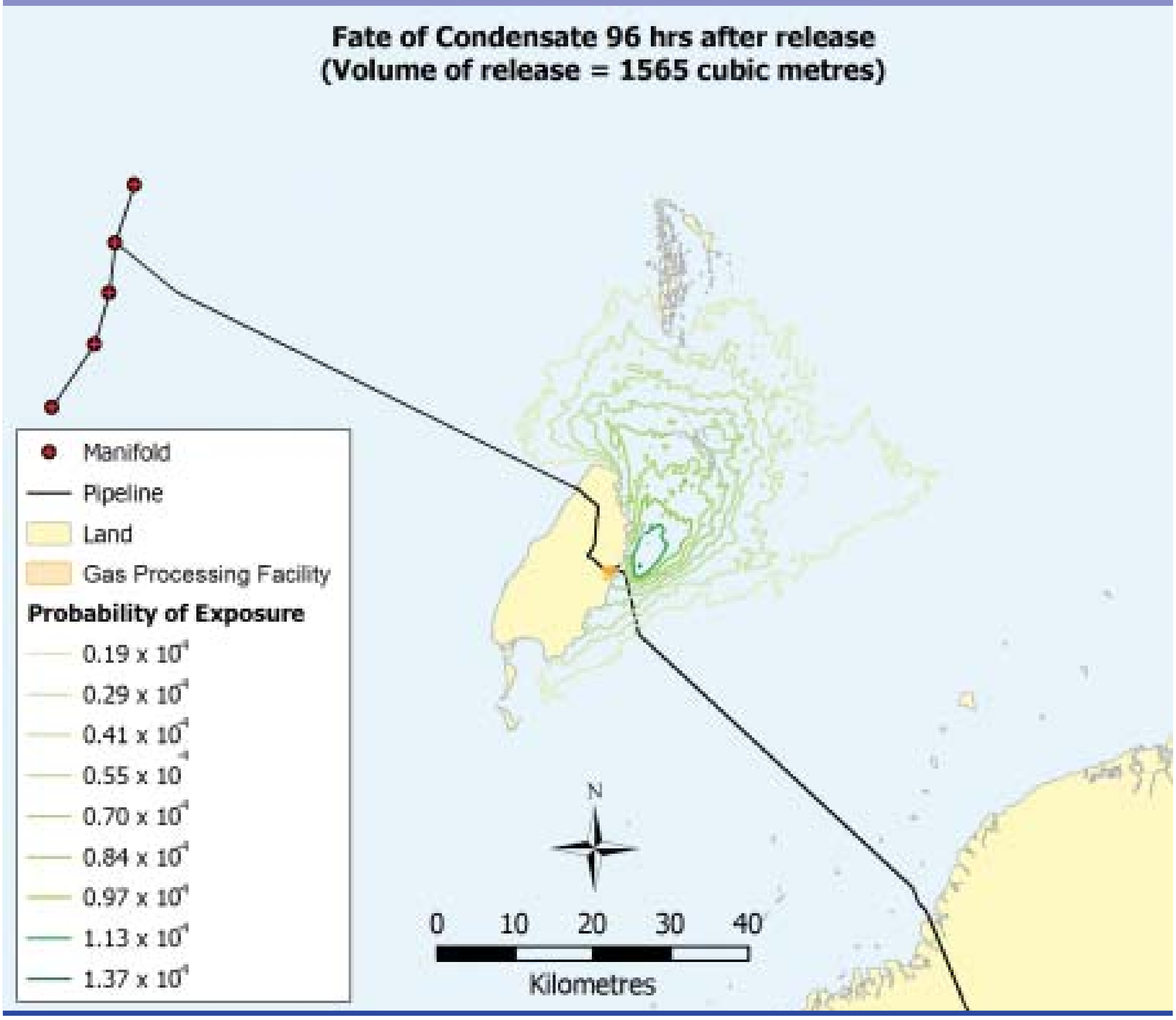
For each of the spill scenarios identified above, the risk of the event occurring was identified and trajectory modelling undertaken assuming the event occurred. It must be emphasised that the modelling assumed that there was no intervention, but the Gorgon Joint Venturers will have in place a comprehensive spill contingency plan, and therefore results are extremely conservative.

For example, a complete rupture of the existing condensate offloading pipeline, when pressurised and delivering condensate to a tanker, was identified as a worst-case spill scenario (Figure 7-4). Simulation of this spill scenario predicted that if such a release occurred (joint risk of 4.93×10^{-5}) a slick of floating condensate would most commonly drift along a north-south axis with the prevailing tidal currents. Depending on climate and metocean conditions, after 96 hours, parts of the slicks were predicted to have a high probability of washing onto shorelines throughout the adjacent islands. During winter, the probability of the Lowendal Island shorelines receiving floating condensate at the concentration of 0.8 g/m^2 was predicted to be 60% and those at the Montebello Islands was up to 30%.

Dissolved aromatic hydrocarbons within the intertidal and shallow sub-tidal areas along the east coast of Barrow Island were predicted to be in the order of 10–30 ppm, while the average predicted concentrations among simulations were 1–3 ppm.

Results of modelling and potential impact to the marine environment are further discussed in Section 11.2.

Figure 7-4:
Predicted Release of Condensate from Condensate Offloading Pipeline (2 km from Barrow Island)



8 Existing Environment

8.1 Baseline Studies

A range of environmental studies and field surveys were conducted as part of the preparation of this Draft EIS/ERMP. Field surveys in the terrestrial and marine environment were conducted from 2002 through to 2005 to establish the distribution and abundance of species and communities, both within and outside the Development area, and to assess potential impacts to environmental factors. Field surveys included:

- vegetation surveys covering over 1600 ha within and outside of the Development area
- a year of monthly terrestrial avifauna and shorebird counts
- extensive mammal, reptile and invertebrate trapping
- a comprehensive subterranean fauna sampling program including establishment of 43 subterranean sampling bores
- side-scan sonar, video transect and snorkel surveys of the marine environment
- surveys of marine turtle nesting activity on beaches around Barrow Island during the 2003–2004 and 2004–2005 breeding seasons.

Surveys were undertaken in accordance with EPA Guidance No. 51 (Terrestrial Flora and Vegetation Surveys), EPA Guidance Statement 54 (Subterranean Fauna) and EPA Guidance No. 56 (Terrestrial Fauna Surveys).

8.2 Physical Environment

The proposed Gorgon Development will be located in the tropical waters off Australia's north- west coast approximately 1200 km north of Perth and approximately 120 km west of Dampier and the Burrup Peninsula. This coastal environment is scattered with numerous small islands. Barrow Island is the largest island in the region, is a Class A Nature Reserve and supports an operating oilfield.

The region is characterised by an arid, sub-tropical climate. Summer is characterised by high temperatures (20–34ºC), high humidity and predominantly south-west winds. In contrast, winter is characterised by moderate temperatures (17–26ºC), fine weather and predominantly strong east to south-east winds. Tropical cyclone activity occurs from November to April with an average of two cyclones passing through the Barrow Island area per year.

The Gorgon gas field is located approximately 70 km west of Barrow Island in approximately 200 m water depth on the edge of the continental shelf. The majority of the seabed between the edge of the continental shelf and Barrow Island is level with areas of moderate relief comprising rock and reef outcrops. The seabed along the proposed domestic gas pipeline route is also relatively uniform with water depths of about 16 m along most of the route.

The western half of Barrow Island is characterised by steep valleys, escarpments and exposed limestone ridges. The topography along the west coast typically comprises weathered rocky cliffs and headlands interspersed with narrow sandy beaches. The eastern coastline is protected with a slight land gradient to the ocean. This coastline is characterised by vegetated sand dunes and expansive tidal flats.

There are no permanent creeks on Barrow Island. Freshwater seeps provide the only permanent source of surface water. There are two aquifers below Barrow Island: a deep, brackish aquifer and a shallow unconfined aquifer. These aquifers are currently used to supply the oilfield operations.

The mainland section of the domestic gas pipeline crosses the Onslow Coastal Plain which comprises coastal saline flats and extensive sandy plains and dunes.

8.3 Terrestrial Ecology

Flora and Vegetation Communities – The flora of Barrow Island is typical of the arid Pilbara region and has floral affinities with the Cape Range area.

A total of 68 families, 180 genera and 406 vascular plant taxa have been recorded on Barrow Island which constitutes approximately 23% of the flora records documented for the Pilbara region. Fourteen introduced vascular plant taxa have been recorded on the island, the majority of which have been recorded in or near previously disturbed sites.

No Declared Rare Flora species, as listed under the Western Australian Wildlife Conservation Act and as listed by CALM, occur on Barrow Island. Two Priority species occur on Barrow Island: *Helichrysum oligochaetum* (Priority 1); and *Corchorus interstans* (ms) (Priority 3). *Helichrysum oligochaetum* was not recorded within the proposed Development areas. *Corchorus interstans* was recorded within the proposed gas processing facility area and within the proposed North White's Beach pipeline corridor. *Corchorus interstans* is widely distributed on the island and occurs on the Pilbara mainland. It recovers well from disturbance and is not considered under threat on Barrow Island.

No vegetation communities listed under the EPBC Act, or Threatened Ecological Communities as listed on the Department of Conservation and Land Management Threatened Ecological Database, have been recorded or are known to occur on Barrow Island.

The mainland section of the proposed domestic gas pipeline corridor will traverse a pastoral lease that has been heavily affected by introduction of weed species and disturbance by domestic stock.

Avifauna – Fifty-one species of terrestrial avifauna have been recorded on Barrow Island; however only 16 of these species are residents or regular migrants to the island. Most species are considered to be vagrants from the adjacent mainland. The most common landbirds on Barrow Island are the spinifexbird, white-winged fairy wren, singing honeyeater, white-breasted wood swallow and the welcome swallow.

The Barrow Island white-winged fairy wren is an endemic subspecies that is abundant and widespread on Barrow Island (Plate 8-1). It is listed under Schedule 1 of the Wildlife Conservation Act and as a threatened species (Vulnerable) under the EPBC Act. The white-winged fairy wren is abundant on Barrow Island.

Table 8-1:
Plant Taxa and Families Recorded Within Proposed the Development area on Barrow Island

Proposed Development Area	No. Taxa	No. Families	Dominant Families
Proposed gas processing facility footprint	48	26	Euphorbiaceae (7 taxa), Papilionaceae (4 taxa), Poaceae (3 taxa), Asteraceae (3 taxa)
Proposed North White's Beach pipeline route	67	27	Chenopodiaceae (9 taxa), Poaceae (9 taxa) and Asteraceae (7 taxa)
Proposed alternative Flacourt Bay pipeline route	60	27	Poaceae (12 taxa), Asteraceae (5 taxa) and Papilionaceae (4 taxa)

Plate 8-1:
Pair of Nesting White-Winged Fairy Wrens on *Melaleuca* Shrub

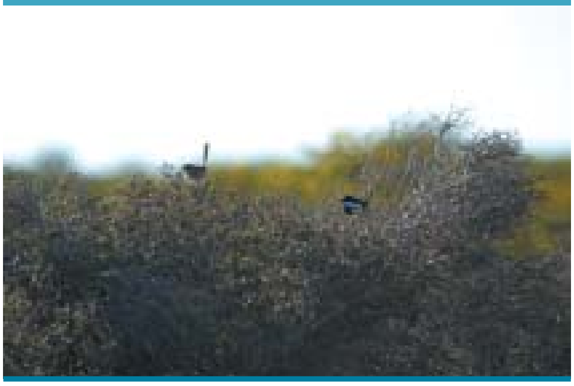


Plate 8-2:
Burrowing Bettong

Five EPBC Act-listed migratory species or their habitats may occur within the vicinity of the mainland domestic gas pipeline corridor. Due to the degraded state of the vegetation communities in this area and the narrow width of the proposed easement, it is unlikely that the domestic gas pipeline corridor contains critical habitat for any listed avifauna.

Mammals – Barrow Island is recognised as an important refuge for native mammal species that have either declined in numbers or become extinct on the mainland. The island supports 13 species of resident terrestrial mammals, with a further two species of bat recorded as vagrants to the island.

All of the terrestrial mammal species of Barrow Island, except bats, were either trapped or observed within the proposed Development area. Bats are likely to forage in the Development area, but have not been recorded. All of these species are widespread on the island, with the exception of the water-rat which is confined to coastal areas. There are no distinctive habitat features within the proposed Development area that are likely to support unusually high population densities of any mammal species.

The small black-flanked rock-wallaby population does not occur within the proposed Development area.

Reptiles and Amphibians – The reptile and amphibian assemblage on Barrow Island is depauperate in comparison with the herpetofauna of the adjacent mainland. Barrow Island is home to 43 species of reptiles comprising dragons, legless lizards, geckoes, skinks, blind snakes, monitors, snakes and one frog species.

Most of these species, or their habitats, are widely distributed on Barrow Island. Twenty-seven species, or more than half of the terrestrial reptiles known to occur on Barrow Island, have been recorded in the vicinity of the Development area.

The reptile assemblage along the proposed domestic gas pipeline route on the mainland is expected to be degraded by feral predators and habitat alteration through livestock grazing. The EPBC Act-listed Pilbara olive python is restricted to rocky habitats in the Pilbara and is not expected to occur in the sandy habitats along the domestic gas pipeline corridor.

Plate 8-3:
Endemic Skink *(Ctenotus pantherinus acripes)*

Short-range Endemics – The term 'short-range endemics' is used to describe invertebrate species such as trapdoor spiders, snails and millipedes, that are restricted in range by poor dispersal ability and are generally endemic to small areas.

Over 40 potential short-range endemic invertebrate taxa were collected on Barrow Island during field surveys. The collection comprised spiders, scorpions, pseudoscorpions, centipedes, millipedes and land snails.

The distribution of similar habitats to those represented with the Development area suggests that invertebrate taxa collected are widely distributed on Barrow Island. None of the invertebrate fauna known from the proposed Development area are listed under the Wildlife Conservation Act or as Priority fauna by CALM. A pseudoscorpion and a single specimen of a large, dark scorpion (*Urodacus* sp.), recently collected within the proposed Development area, appear to be new and undescribed species of conservation significance. Again, these species are expected to occur across Barrow Island in habitats similar to those within the Development area.

Subterranean Fauna – Subterranean fauna sampling program records to date confirm that the habitats under both the proposed gas processing facility and the adjacent parts of the island support stygofauna and troglofauna. However, these assemblages may not be as diverse as those recorded from caves and more developed karstic areas in other parts of Barrow Island.

Baseline surveys for subterranean fauna will continue on Barrow Island until construction of the proposed Development commences. The results of subsequent sampling, concluded prior to construction, will be published separately. This will provide a species level analysis of subterranean fauna distribution, along with a more complete analysis of the physical nature of the subterranean environment.

Plate 8-4:
Stygofaunal Blind Gudgeon *(Milyeringa veritas)*

Photo: Courtesy of Douglas Elford © Western Australian Museum

8.4 Marine Ecology

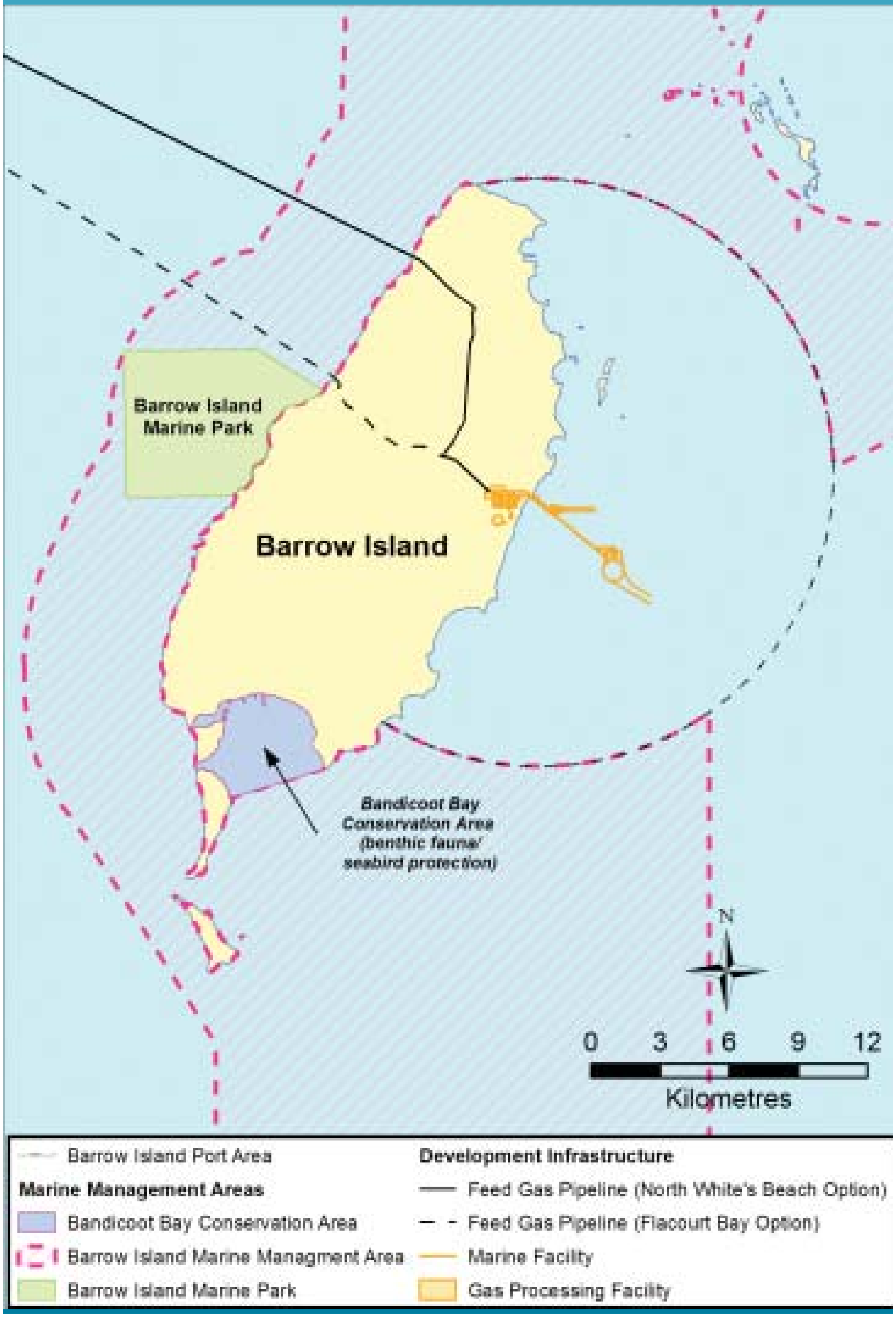
Marine Conservation Areas – The waters surrounding Barrow Island are part of the area covered by the Montebello–Barrow Island marine conservation reserves (Figure 8-1). The majority of the conservation area is zoned as a Marine Management Area, recognised for both commercial and conservation values. The Barrow Island Marine Park and Bandicoot Bay conservation area provide additional protection for Biggada Reef and Bandicoot Bay. A large area off the east coast of Barrow Island is currently a designated port.

Marine Macrophytes – The marine flora comprises vascular flowering plants such as mangroves and seagrasses and plants such as algae.

There are no mangroves in the proposed Development area on Barrow Island. However the proposed domestic gas pipeline will cross a dense and well-developed mangrove community. This community comprises large *Avicennia marina* trees at the seaward edge, backed by tall *Rhizophora stylosa* trees and more *Avicennia* further inland. In total 2.3 ha of mangrove community would be directly affected by the pipeline.

There are no significant seagrass meadows present in the proposed Development area around Barrow Island. All areas with exposed, or seasonally exposed, hard substrate in the shallow waters support macroalgae.

Figure 8-1:
Montebello–Barrow Islands Marine Conservation Reserves (Source: CALM 2004)



Marine Mammals – The Pilbara region supports migratory, transient and resident marine mammals such as whales, dolphins and dugongs.

Humpback whales are likely to be present off the west coast of Barrow Island during the June to October migration period. Most whale species are more abundant in deeper waters and are expected to be rare visitors to the offshore waters close to the western shore of Barrow Island and are unlikely to visit the shallow, turbid inshore waters in the vicinity of the proposed east coast port facilities, domestic gas pipeline or optical fibre cable shore crossings.

Dugongs occur throughout the shallow waters between the Pilbara offshore islands and the mainland. Ephemeral seagrass meadows along the mainland coast in the vicinity of the proposed domestic gas pipeline shore crossing are likely to be feeding areas; however seagrass habitats are very widespread along the Pilbara coast and the area in the vicinity of the mainland shore crossings is not expected to be significant habitat for dugongs.

Bottlenose dolphins, common dolphins and striped dolphins are likely to visit the offshore Development area on the west coast of Barrow Island. Bottlenose dolphins are also likely to be regular visitors to the east coast Development area.

Marine Avifauna – Barrow Island's marine avifauna comprises at least 67 species, including 25 species of migratory shorebirds and 20 resident shorebirds.

Barrow Island is both a staging site and an important non-breeding site for migratory shorebirds. The highest abundances of shorebirds on Barrow Island (over two-thirds of records for most species) are associated with the south-eastern and southern coasts of the island, from the existing Chevron camp to Bandicoot Bay. The Development area does not contain critical shorebird habitat. Despite the presence of broad intertidal reef platforms adjacent to Town Point, only 1% of shorebirds on Barrow Island were observed foraging near the proposed Development area in 2003 and 2004.

Plate 8-5:
Nesting Sooty Oystercatchers at Town Point

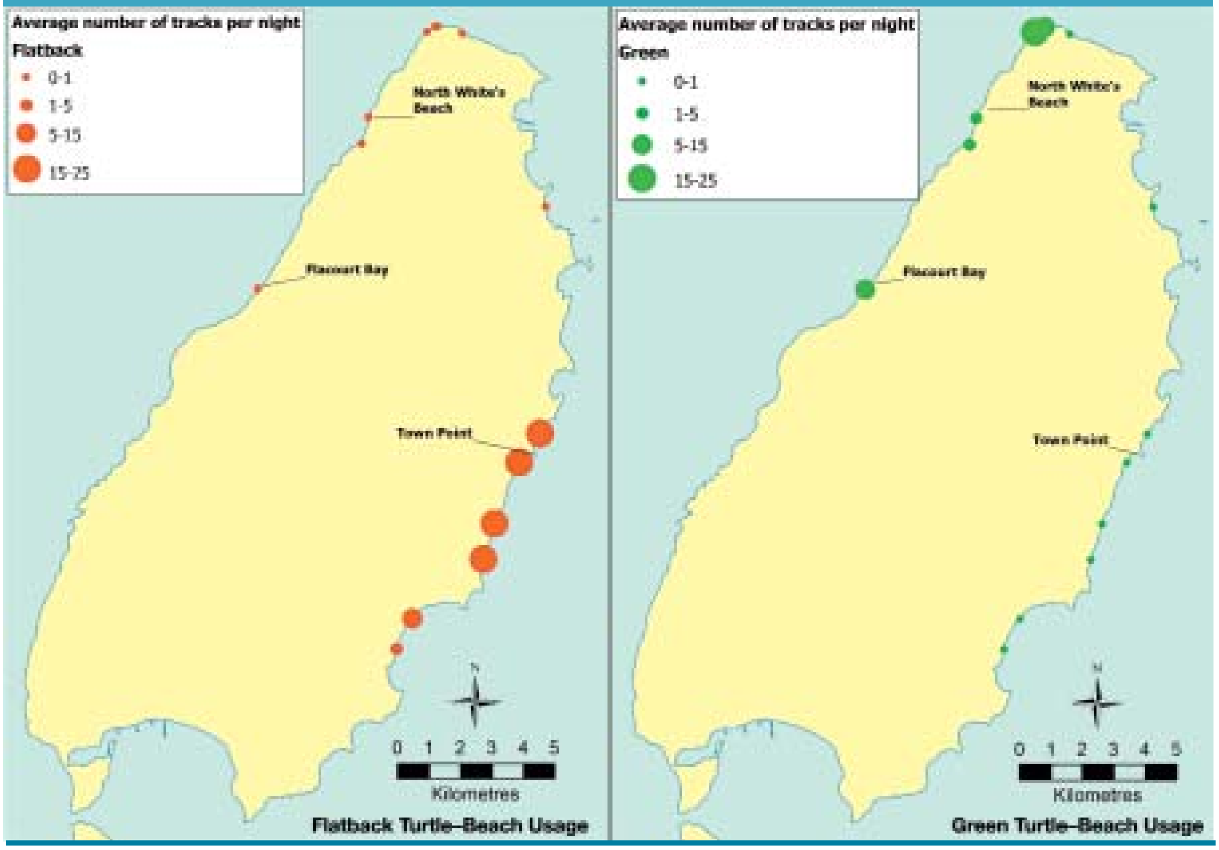
Marine Turtles – Barrow Island is a regionally important nesting area for green turtles and flatback turtles. Hawksbill turtles nest at low densities around the island and loggerheads have been only occasionally recorded from the island.

Green turtles nest predominantly on the sandy west coast beaches on Barrow Island in spring and summer. Hatchlings emerge from nests through summer and early autumn. While most green turtles migrate away from the area after breeding, some appear to be resident at Barrow Island, remaining near the island during the winter. The area of the proposed feed gas shore crossing at North White's Beach is not a locally important green turtle nesting site. Flacourt Bay, where the alternative pipeline shore crossing is proposed, is an important green turtle nesting habitat.

Nesting flatback turtles favour mid-east coast beaches on Barrow Island. The beaches either side of the proposed Development area at Town Point are important components of this regionally significant rookery. In the summers of 2003–2004 and 2004–2005, flatback turtle nesting densities were highest on the central east coast adjacent to Town Point (Figure 8-2).

The proposed shore crossing for the domestic gas pipeline is comprised of mangroves and mudflats and is unsuitable for turtle nesting. A flatback turtle rookery has recently been identified at Back Beach, Onslow.

Figure 8-2:
Distribution and Intensity of Sea Turtle Nesting Across Barrow Island



Fish – No areas of regional importance to fish species were identified during seabed surveys of the proposed Development area. Environment Protection and Biodiversity Conservation Act listed pipefish and seahorses are expected to be widespread throughout shallower benthic habitats of the area. Some of the protected species are expected to occur in the vicinity of the proposed pipeline routes and nearshore infrastructure on the east coast of the island and on the mainland coast. Other EPBC Act-listed species, such as the whale shark, grey nurse shark and great white shark, are occasional visitors to the Barrow Island area.

Marine Invertebrates – Invertebrate assemblages of the western and northern shores of Barrow Island are typical of the Pilbara offshore bioregion. Invertebrate assemblages of the eastern and southern shores are more similar to assemblages in the Pilbara nearshore bioregion along the mainland coast. All of the invertebrate assemblages in areas proposed for development are associated with habitats that are widely distributed regionally. None of the invertebrate assemblages are considered to be of high conservation significance.

8.5 Social Environment

The Pilbara resident population is approximately 40 000 people. The vast majority of Pilbara residents are located in the western third of the region, which includes the main townships of Karratha, Port Hedland and South Hedland. A small number of Indigenous communities occur in the eastern portion of the region.

The development of the Pilbara has coincided with the discovery of vast deposits of iron ore and oil and gas resources. Resource projects are the main economic and employment generators in the region and impact on the social profile and communities that support them.

8.6 Cultural Heritage

There are 13 registered archaeological sites on Barrow Island although none are close to the proposed Development area. There are no listed ethnographic sites on Barrow Island. There are two ethnographic sites located close to the proposed domestic gas pipeline route on the mainland and nine identified cultural heritage sites within the vicinity of the pipeline route.

8.7 Native Title

There are no lodged Native Title claims over the Gorgon gas field or Barrow Island. There are currently three registered Native Title claims that may overlap the proposed domestic gas pipeline route.

8.8 Economic Environment

The Pilbara region is one of the most important wealth producing regions in Western Australia. The region is responsible for the production of goods and services worth more than $16 billion per annum. The mining and petroleum industries are the main source of income for the region.

The Western Australian economy is dominated by the resources sector which also contributes largely to the Australian economy. Western Australia is now the major oil and gas producer in Australia, and has more than three-quarters of Australia's identified natural gas resource within its jurisdiction.

9 Risk Assessment Process

Environmental risk assessments for the proposed Gorgon Development, including definition of consequences and identification of stressors and receptors, were undertaken by technical specialists with recognised expertise in a broad range of environmental fields. This included specialists with a long-standing knowledge and experience of working on Barrow Island.

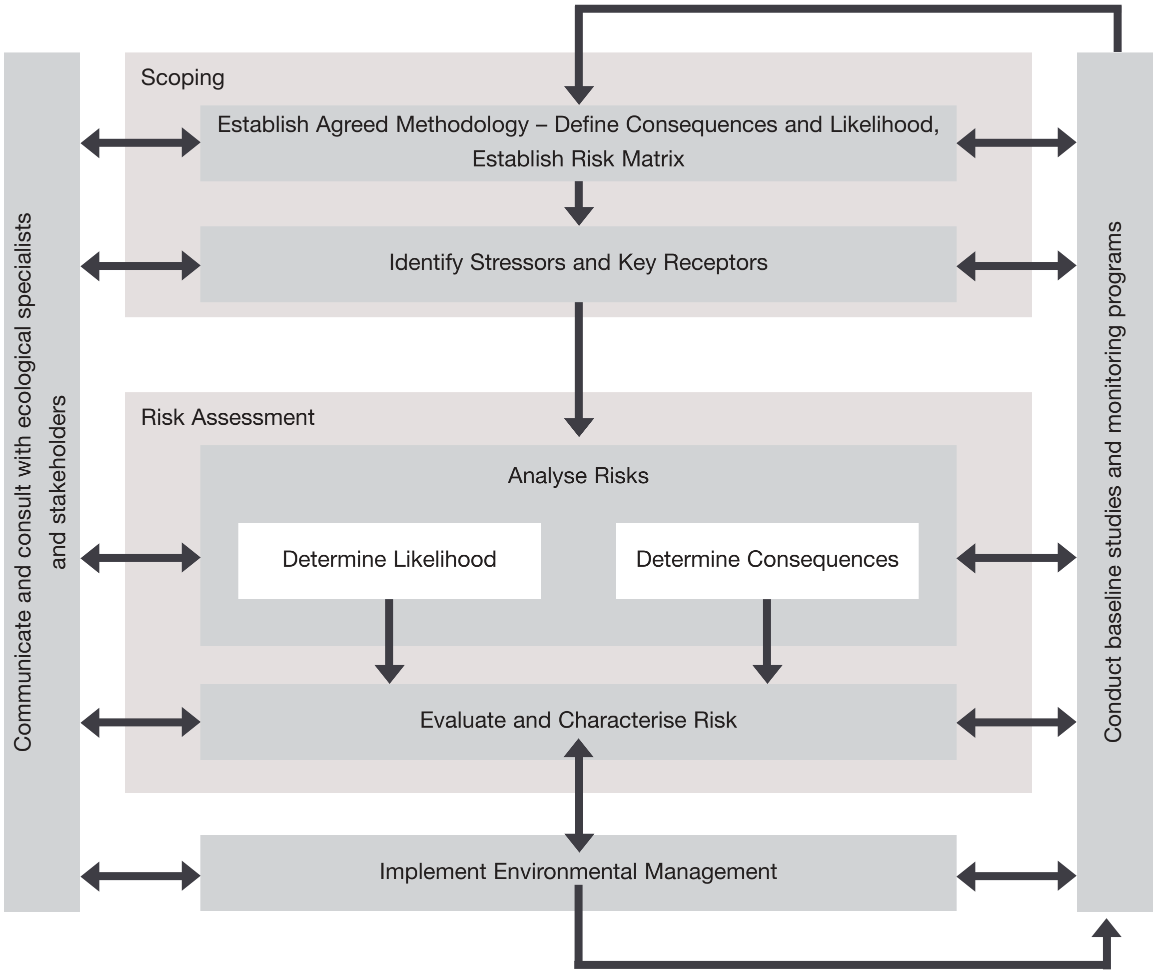
Environmental risk assessment is a process that evaluates the likelihood and consequence of adverse environmental impacts occurring as a result of exposure to one or more stressors. An advantage of this approach is that it allows potential environmental hazards or threats to be considered on the basis of the level of risk to the environment. This assisted in prioritising the development of management measures to determine whether an overall acceptable level of risk could be achieved.

The risk assessment methodology was developed by risk consultants and ecological specialists working together and in accordance with recognised standards for environmental risk analysis and management (Figure 9-1).

Risk assessments for the proposed Development initially involved identification of stressors (hazards or threats) through a series of hazard identification workshops. Examples of stressors include light, noise, and clearing and earthworks. This was followed by definition of consequence categories for groups of environmental factors (e.g. Table 9-1). The likelihood of a particular impact occurring from an interaction between a stressor and a receptor was also defined based on a nominal Development life of 60 years (Table 9-2).

Prior to risk characterisation, ecological specialists identified groups of receptors (species or communities) which were considered to be sensitive to stressors associated with the Development (e.g. protected fauna, restricted flora and vegetation communities). Within each group of receptors, key receptor species were identified which were considered to be particularly sensitive to stressors and hence protective of a wider biological group. Risk levels (low, medium, high) were then estimated for each stressor and associated key receptors through an assessment of consequences and likelihood (Figure 9-2).

Figure 9-1:
Outline of Risk-based Environmental Assessment Process (after AS/NZS 4360:2004)



By systematically identifying all of the hazards or threats to conservation values potentially associated with the proposed Development, and engaging ecological specialists to assist in the development of risk-based management strategies, potential impacts will be, or are being, reduced to meet acceptable risk standards. In some cases, potential impacts will be avoided altogether.

A risk is considered acceptable if it falls in the low category without any further mitigation measures, and 'tolerable' if it falls in the medium risk category and is managed to reduce the risk to a level 'as low as reasonably practicable' (SAA HB 436:2004). Risk reduction measures must be applied to reduce high risks to tolerable levels. Taken together, these risk levels and corresponding requirements for risk treatment are the standards for acceptable risk to flora and fauna.

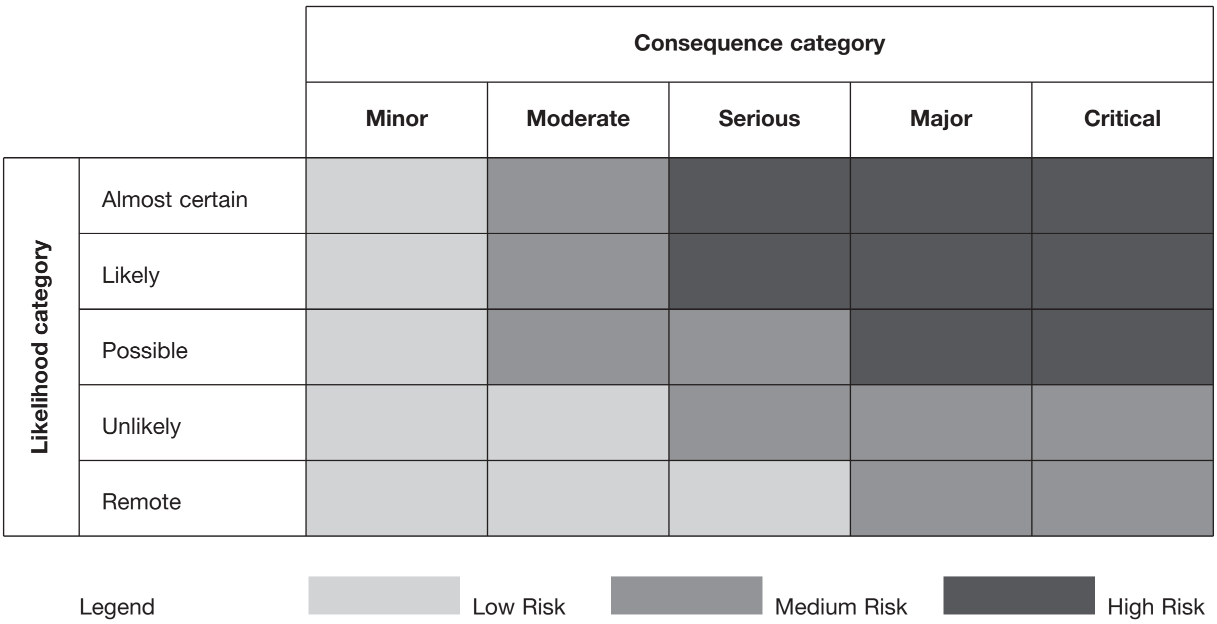
Table 9-1:
Consequence Definitions for Risk-based Environmental Assessment

Consequence Category	Minor	Moderate	Serious	Major	Critical
Protected fauna species (listed/ threatened)	*Individual level effects*				
	Local, short-term behavioural impact.	Local, long-term or widespread, short-term behavioural impact.	Widespread, long-term behavioural impact.		
	Population level effects				
	Local, short-term decrease in abundance. No lasting effects on local population.	Local, long-term or widespread, short-term decrease in abundance. Loss of small number of individuals without reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Loss of individuals leads to reduction in viability of local population. No reduction in viability of race on Barrow Island.	Local, long-term or widespread, short-term impact leads to loss of local population/s and reduced viability of the race on Barrow Island.	Widespread, long-term impact on population. Extinction of Barrow Island race.
General fauna communities and species (not listed/ threatened)	*Individual effects*				
	Local, long-term or widespread, short-term behavioural impact.	Widespread, long-term behavioural impact.			
	Population level effects				
	Local, long-term or widespread, short-term decrease in abundance. Loss of small number of individuals without reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Loss of individuals leads to reduction in viability of local population. No reduction in viability on Barrow Island.	Local, long-term or widespread, short-term impact leads to loss of local population/s and reduced viability on Barrow Island.	Widespread, long-term impact on population. Extinction on Barrow Island.	Loss from immediate region.

Table 9-2:
Likelihood Definitions for Risk-based Environmental Assessment

Likelihood category	Description
Almost certain	Very likely to occur on an annual basis. Includes planned activities. Socio-economic description includes the period during construction.
Likely	Likely to occur more than once during the life of the proposed Development.
Possible	May occur within the life of the proposed Development.
Unlikely	Not likely to occur within the life of the proposed Development.
Remote	Highly unlikely and unheard of in industry, but theoretically possible.

Figure 9-2:
Gorgon Development Environmental Risk Matrix



10 Terrestrial Environment – Risks and Management

For the purposes of risk assessment, the terrestrial environment was considered as four factors: the physical environment (i.e. soil and landform and water resources); flora and vegetation communities; terrestrial fauna; and subterranean fauna.

The potential stressors and assessed level of residual risk to terrestrial environmental factors are summarised in Table 10-2. The residual risks posed by stressors associated with each phase of the proposed Development were assessed as low to medium for all environmental factors except subterranean fauna. In each of these cases, the potential consequences to the terrestrial ecology of Barrow Island would be greatly reduced by implementing the proposed management measures, pose an overall acceptable level of residual risk to the conservation values of Barrow Island and meet the environmental management objectives for the Development.

The Joint Venturers are committed to adopting all management measures outlined in the Draft EIS/ERMP. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design of the proposed Development progresses, it may become necessary to modify proposed management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and targets will be developed.

10.1 Physical Environment

10.1.1 Soil and Landform

The main risks to soil and landform from the Development are associated with the following stressors:

- clearing and earthworks
- liquid and solid waste disposal
- leaks or spills.

Potential impacts to soil and landform associated with these stressors include erosion (wind and water) and soil contamination. Each of these stressors poses a medium level of residual risk to the environment during construction and a low level of residual risk during operations. The exception is leaks or spills which was assessed as a medium residual risk stressor during the operations phase.

Management measures have been developed to ensure that the risks of impacts from these stressors are minimised (Table 10-2). With respect to clearing and earthworks, management measures have been developed to ensure that impacts are limited to the specific disturbance required to construct and operate the proposed Development, and are restricted to the allowable footprint area (see Section 1.3.2).

10.1.2 Surface Water and Groundwater Quality

The main risks to surface water and groundwater quality from the Development are associated with the following stressors:

- clearing and earthworks
- physical presence
- liquid and solid waste disposal
- leaks or spills.

Potential impacts associated with these stressors include sedimentation, disturbance to natural drainage patterns, altered water infiltration and recharge rates and contamination. Stressors to surface water and groundwater present a medium level of residual risk during construction, with reduced low to medium risks during the operations phase of the Development.

Management measures have been developed to minimise potential risks associated with environmental stressors (Table 10-2). Erosion and sedimentation control measures will be applied to all clearing and earthworks. Impacts to groundwater recharge will be minimised by constructing a number of separate facilities on hardstand, interspersed with open and unsurfaced areas. The tiered drainage management system (refer to Section 6.10) will be based on hydrogeological data to maximise on-site infiltration of uncontaminated water. To mitigate potential risks associated with liquid and solid waste disposal, comprehensive waste management plans will be developed for all phases of the Gorgon Development. The primary focus of waste management will be minimisation of waste generation based on the principles of eliminate, reduce, reuse, recycle and environmentally responsible disposal.

10.1.3 Air Quality

The main risks to air quality are associated with atmospheric emissions and dust generated by clearing and earthworks. The potential impact of these stressors is a decrease in local and regional air quality. Both stressors present a low risk to local and regional air quality during construction, commissioning and operations (Table 10-2).

10.2 Flora and Vegetation Communities

No high risk stressors to terrestrial flora and vegetation communities were identified through the risk assessment process. Most stressors pose a low risk; however the following two stressors were assessed to present a medium risk:

- clearing and earthworks
- fire.

Clearing and earthworks poses the greatest risk during construction whereas fire is a risk associated with the Development during construction, commissioning and operations. Low risk stressors include atmospheric emissions, light/shading, heat/cold, dust, unpredicted CO_2 migration and leaks or spills. Potential impacts associated with all potential stressors include loss and/or disturbance to flora and vegetation and alteration of vegetation community composition.

Under the provisions of the *Barrow Island Act 2003,* no more than 300 ha of uncleared land is available for gas processing projects. Should 300 ha, or approximately 1.3% of the island, be cleared for the proposed or future gas developments, this would represent an increase in the area of cumulative disturbance from approximately 5.2% of the island (as currently disturbed) to approximately 6.5% of the island. The Joint Venturers are committed to limiting clearing to that available under the Barrow Island Act, and to avoiding restricted vegetation communities and priority flora.

Due to the presence of a high fuel load on Barrow Island, a fire originating from construction or operations activities could result in a substantial wildfire under certain climatic conditions (e.g. high temperatures, low humidity and strong wind). Examples of ignition sources during construction and operations include hot works (welding and grinding) and vehicle exhausts. The Joint Venturers' policy will be to control fires that are either caused by construction or operations activities or which pose a risk to Development facilities or personnel. The response to naturally occurring fires that do not pose a threat to Development facilities or personnel will be in accordance with policies and procedures agreed through the Barrow Island Coordination Council with CALM and the Conservation Commission of WA.

10.3 Terrestrial Fauna

No high risk stressors to terrestrial flora and vegetation communities were identified through the risk assessment process (Table 10-2). Medium risk stressors, which are associated primarily with the construction phase of the Development, include:

- clearing and earthworks
- physical interaction
- noise and vibration (operations)
- fire.

Risk assessments indicate that a number of stressors pose a low risk to terrestrial fauna during most phases of the Development, including:

- leaks or spills
- light or shade
- atmospheric emissions
- dust
- unpredicted CO_2 migration or release
- heat and/or cold
- noise and vibration.

The main potential impacts associated with these stressors include direct displacement or loss of fauna, habitat loss or modification, and increased competition between individuals and species.

The proposed location and layout of the gas processing facility and associated infrastructure was selected with reference to the distribution of significant terrestrial fauna species and their habitats. For example, the proposed location of the feed gas pipeline has been realigned to avoid black-flanked rock wallaby habitat. The result is that fauna habitats within all of the areas proposed to be cleared are well represented across Barrow Island and there is no indication that any habitats within the Development footprint are of critical importance to terrestrial fauna. Trapping and spotlighting data, from both CALM monitoring programs and field surveys for the Gorgon Development, indicate similar densities of most mammals across Barrow Island. It is estimated that clearing and earthworks will therefore affect approximately 1.3% of the terrestrial fauna on Barrow Island, should the total area available for the currently proposed and future gas processing developments be cleared (Table 10-1).

Unavoidable habitat loss and displacement of fauna will be mitigated by relocating selected fauna to suitable release sites. A translocation program will be designed in consultation with CALM and DEH to augment existing endangered species relocation programs.

The main impact associated with interaction between the Development and local fauna will be accidental road kill. Lesser impacts include injuries or fatalities in hazardous areas. Although some level of road kill is highly likely when vehicles are regularly travelling through fauna habitat, there are a number of management measures that can be implemented to reduce fatality rates. The Joint Venturers are committed to enforcing speed limits on all roads, reducing vehicle numbers and monitoring the number of road kills to ensure that management is successful and impacts are not greater than predicted.

10.4 Subterranean Fauna

Due to the limited data available on the distribution and diversity of subterranean fauna within the gas processing facility site, risks to subterranean fauna have conservatively been assessed as either medium

Table 10-1:
Estimated Abundance of Terrestrial Fauna Species within the Total Development Area on Barrow Island

Species	Estimated abundance (number of individuals) in total proposed Development area (300 ha)
Burrowing bettong	10–15* (one warren)
Euro	10*–20**
Golden bandicoot	780–1040**
Northern brushtail possum	20**
Spectacled hare wallaby	75*
White-winged fairy wren	315*

** based on direct estimate from surveys; ** based on 1.3% of estimated total island abundance* or high level. However, it is important to note that this level of risk primarily reflects uncertainty in the absence of final analysis of sampling data. Further information from the ongoing sampling program will provide a clearer model of the wider distribution of the subterranean taxa and is expected to result in a reduction in risk to medium or low levels.

High risk stressors based on the current assessment include:

- clearing and earthworks (construction and commissioning)
- physical presence of gas processing facility (operations).

Medium risk stressors include:

- wastewater discharge (construction and commissioning)
- noise and vibration (construction and commissioning)
- leaks and spills (operations)
- CO_2 leak (operations).

Bores established for subterranean fauna monitoring were first sampled in November 2004 and again in March 2005. This has comprised two rounds of stygofauna sampling and one completed round of troglofauna sampling (a second was underway at the time of printing). Final results, completed to species level, will be published in a package of additional information to the Draft EIS/ERMP (refer to Section 4).

Table 10-2:
Summary of Risk Assessment for Terrestrial Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Soil and Landform	• To maintain the integrity, ecological functions and environmental values of soil and landform.	• erosion and sedimentation • soil compaction • soil inversion • disturbance to significant geological features (e.g. caves) • changes in landform • soil contamination.	• limit clearing and earthworks (land use register) • reuse topsoil and vegetation • install use erosion and sediment control structures • suppress dust generation • develop a waste management plan • avoid disposal of solid wastes to landfill on Barrow Island • develop an emergency (spill) response plan • design equipment to include built-in safeguards • contain and remediate any contaminated soil • apply industry standards for storage and handling of fuels and chemicals • implement early leak detection and reporting systems.	• no solid waste disposed to landfill on Barrow Island • no contaminated soils outside of Development footprint • contaminated areas remediated • no long-term detectable impact at hydrostatic test disposal site/s • no measurable impact on groundwater • no contamination of surface water outside of Development area.	• Clearing and earthworks.	M	L	–
					• Liquid and solid waste disposal.	M	L	–
					• Leaks or spills.	M	M	–

Table 10-2: (continued)
Summary of Risk Assessment for Terrestrial Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Surface Water and Groundwater Quality	To maintain the quantity and quality of water so that existing and potential environmental values, including ecosystem function, are protected. To minimise the potential for erosion due to stormwater flow.	• sedimentation of natural drainage systems • disturbance to natural drainage patterns • change in water infiltration and recharge rates • increased runoff • change in groundwater level • surface water and groundwater contamination.	• avoid natural drainage lines • implement tiered stormwater drainage management system • install use erosion and sediment control structures • implement an approved waste management plan • avoid disposal of solid wastes to landfill on Barrow Island • design equipment to include built-in safeguards • apply industry standards for storage and handling of fuels and chemicals • develop an emergency (spill) response plan • contain and remediate any contaminated soil.	• no contamination of surface water outside of Development area • no measurable impact on groundwater regime (recharge and quality) • no solid waste disposed to landfill on Barrow Island.	• Clearing and earthworks.	M	L	–
					• Physical presence.	M	M	–
					• Liquid and solid waste disposal.	M	L	–
					• Leaks or spills.	M	M	–

Table 10-2: (continued)
Summary of Risk Assessment for Terrestrial Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Air Quality	To ensure that atmospheric emissions do not adversely affect environmental values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards. To minimise emissions of ozone depleting substances to levels as low as practicable on an ongoing basis.	• decrease in local and regional air quality.	• conduct regular inspection and maintenance of vehicles, plant and equipment • avoid ozone depleting substances • adopt energy efficient technology and design • comply with EPA licence conditions • implement greenhouse gas management plan • use dry gas seals on compressors • design and operate condensate storage tanks to reduce fugitive emissions • use high efficiency combustion in flare and fuel users • use a-MDEA in CO_2 removal process • inject CO_2 removed from feed gas into deep well • implement dust suppression measures.	• no breaches of environmental licence conditions • dust emissions limited to immediate vicinity of earthworks.	• Atmospheric emissions. • Clearing and earthworks.	L L	L L	L –

Table 10-2: (continued)
Summary of Risk Assessment for Terrestrial Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Terrestrial Flora and Vegetation Communities	To maintain the abundance, diversity, geographic distribution and productivity of flora through the avoidance or management of adverse impacts and improvement in knowledge. To protect EPBC Act-listed threatened and migratory species. To protect Declared Rare and Priority Flora, consistent with the provisions of the Wildlife Conservation Act.	• loss and/or disturbance to flora and vegetation communities • spread of weeds • alteration of community composition • reduced plant growth and productivity.	• develop flora and vegetation management plan • develop fire management program • avoid restricted vegetation communities • avoid priority flora • limit clearing and earthworks (land use register) • rehabilitate cleared areas that are no longer required for operations or future works • conduct surveys prior to clearing • prohibit off-road vehicle driving under normal circumstances • perform audit, inspection and maintenance of fire equipment and fire prevention mechanisms regularly • implement air emissions management procedures • suppress dust generation.	• Development footprint limited to that allowed under the Barrow Island Act • <10% estimated island-wide distribution of any community or taxa impacted • long-term viability of restricted communities and taxa maintained • no spread of introduced species • mainland mangroves rehabilitated • establishment of fire management program through BICC • no broad scale fires originating from Development • no breaches of environmental licence conditions • no loss of vegetation from emissions • no spills of stored chemicals contacting receptors outside bunded areas.	• Clearing and earthworks (restricted flora and vegetation communities).	M	L	–
					• Clearing and earthworks (general flora and vegetation communities).	L	L	–
					• Fire.	M	M	–
					• Atmospheric emissions.	L	L	L
					• Light/ shading/ heat/ cold.	L	L	–
					• Dust.	L	L	–
					• Unpredicted CO_2 migration.	–	-	L
					• Leaks or spills.	L	L	–

Table 10-2: (continued)
Summary of Risk Assessment for Terrestrial Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Terrestrial Fauna	To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge. To protect EPBC Act-listed threatened and migratory species. To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the Wildlife Conservation Act. To protect evolutionary significant units, including genetic races on Barrow Island.	• direct displacement or loss of individuals • increased competition • habitat loss or modification • direct behavioural disturbance • injury or fatality (i.e. road kill).	• avoid critical habitat • minimise clearing or modification of important fauna habitats • translocate selected fauna • identify hazardous areas/activities and prevent fauna mortality or injury • educate workforce and visitors and enforce rules on interaction/interference with fauna • restrict recreation in designated sensitive areas • establish workforce conservation programs • minimise lighting levels to that required for safe working • fence hazardous construction areas within gas processing facility.	• Development footprint limited to that allowed under the Barrow Island Act • <5% estimated island-wide population of any species impacted • long-term viability of listed fauna species maintained • critical/restricted fauna habitats avoided • translocation of listed fauna to suitable recipient sites • fauna prevented from entering spill sites • no contaminated soils outside of Development footprint • contaminated areas within Development area remediated • compliance with tiered lighting strategy • no listed fauna fatalities within the gas processing facility • adherence to 'no routine flaring policy'	• Clearing and earthworks. • Physical interaction. • Leaks or spills. • Light or shade. • Atmospheric emissions. • Dust. • Unpredicted CO_2 migration. • Heat and/or cold. • Noise and vibration. • Fire.	M M L L L L – L L M	L M L L L L – L M M	– – – – L – L – – –

Table 10-2: (continued)
Summary of Risk Assessment for Terrestrial Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Terrestrial Fauna (continued)				• no breaches of environmental licence requirements • workforce compliance with speed limits • no seismic source discharge within prescribed sensitivity buffers • no long-term behavioural impact from noise and vibration • all Development related fires successfully extinguished without long-term effects on local fauna or their habitats.				

Table 10-2: (continued)
Summary of Risk Assessment for Terrestrial Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Subterranean Fauna	To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge. To protect EPBC Act-listed threatened species. To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the Wildlife Conservation Act.	• direct loss of habitat • local loss of troglofauna and stygofauna • modification of subterranean habitats (e.g. changes to hydrology, sedimentation, contamination).	• ongoing subterranean fauna sampling and monitoring program • limit clearing and ground disturbance • install erosion control and flow diversion devices • prevent transport of contaminants to the subterranean habitat • use drill and blast techniques which reduce zone of effect • apply industry standards for storage and handling of fuels and chemicals • develop an emergency (spill) response plan • implement automatic emergency response engineered systems to reduce release volumes • design drainage strategy to maximise on-site infiltration of non-contaminated runoff.	• no loss of restricted subterranean fauna species • long-term viability of restricted subterranean fauna species maintained • no contamination of subterranean habitats • no breaches of environmental licence conditions • no CO_2 leak from subsurface formation • no measurable impact on groundwater regime (recharge and quality).	• Clearing and earthworks. • Physical presence. • Wastewater discharge. • Noise and vibration. • Leaks or spills. • Unpredicted CO_2 migration.	H* – H* H* M –	L H* – – M M	– – – – – –

** Although a worst case risk assessment, based on a precautionary approach, has found there to be some high risk stressors to subterranean fauna it is anticipated that further information from the proposed sampling strategy will provide a clearer model of the wider distribution of the subterranean taxa and result in a reduction in risk to medium to low levels.*

11 Marine Environment – Risks and Management

A risk-based assessment was undertaken on the stressors associated with each phase of the proposed Development that could impact on various species and communities (receptors) of the marine environment. For the purposes of risk assessment, the marine environment was considered as four factors: physical environment; benthic primary producers; benthic primary producer habitats; and marine fauna.

Table 11-3 provides a summary of potential stressors and assessed level of residual risk to marine environmental factors. The residual risks posed by stressors associated with each phase of the Development were assessed as low to medium for all factors. The potential environmental consequences of the Development are unlikely to have long-term implications for the marine environment surrounding Barrow Island or mainland components of the Development. The overall level of risk to marine conservation values is therefore considered to be acceptable and environmental management objectives for the Development achievable.

11.1 Physical Environment

11.1.1 Seabed Substrates

Risks from the Development to seabed substrates are associated with the following stressors:

- physical disturbance
- physical presence of infrastructure
- liquid and solid waste disposal
- leaks or spills.

All of these stressors, with the exception of physical disturbance, were assessed as low risk. Physical disturbance to the seabed is predicted to pose a low to medium risk to seabed substrates.

Potential impacts associated with seabed disturbance include:

- change in the seabed profile
- short-term increase in turbidity, elevated suspended sediment levels and sedimentation.

The areas of seabed likely to be disturbed by installing marine infrastructure are provided in Table 11-1.

Table 11-1:
Proposed Direct Disturbance to Seabed

Facility	Approximate Area of Disturbance (ha)
Temporary anchors for drilling and installation activities	Approx. 8–12 anchors, total area of 40 m^2
Subsea trees and manifolds	2.5 (25 wells)
Flowlines (intrafield flowlines)	15.5
Feed gas pipelines	200
Domestic gas pipeline	200
MOF and access channel (includes causeway)	42
Jetty	6
Optical fibre cable	123 (123 km x 10 m)
Turning basin and shipping channel	144
Dredge spoil grounds	900

The physical habitats potentially affected by the proposed Development are widely represented throughout the Montebello/Lowendal/Barrow Islands region. Impacted areas along the pipeline routes and optical fibre cable route will recover from physical disturbance. Seabed substrates impacted by dredging and installation of port facilities off the east coast of Barrow Island will be permanently impacted by the Development; however affected substrates are widely distributed and losses will be partially offset by creation of new habitat. Management of marine construction activities will be addressed in detailed Environment Plans.

11.1.2 Water Quality

The main risks to marine water quality are associated with discharges (e.g. drill cuttings and fluids) and leaks or spills. The potential impact of these stressors is short-term pollution of the water column. Both stressors present a low risk to marine water quality during construction, commissioning and operations.

11.1.3 Foreshore

The main risks to foreshore areas from the Development are associated with physical disturbance during construction and the ongoing physical presence of infrastructure over the life of the Development (Table 11-3).

Potential impacts to foreshore areas associated with these stressors include erosion, soil compaction, changes in longshore coastal processes and altered profile of coastal areas. Physical disturbance during construction poses a medium level of risk to foreshore areas. Both physical disturbance and the ongoing presence of infrastructure were assessed as a low risk during operations.

Management measures have been developed to ensure that the risks of impacts from these stressors are minimised (Table 11-3). Clearing and earthworks will be strictly controlled in foreshore areas (e.g. during construction of pipeline shore crossings) and erosion and sediment control measures will be installed where there is a risk of erosion. All pipeline shore crossings will be reinstated to a level consistent with surrounding terrain.

The construction of a causeway and MOF will impose a physical barrier on the site with a potential to impact on the dynamics of the existing foreshore environment. Field measurements and modelling indicate that beaches in the vicinity of Town Point are low energy zones with limited longshore drift. The alignment of beaches on either side of Town Point will be monitored following construction to confirm that longshore sediment drift will not be affected by the presence of the causeway.

11.2 Benthic Primary Producers (Marine Flora and Corals)

Benthic primary producers (BPP) are photosynthetic organisms that are attached to marine (intertidal and subtidal) substrates and contribute to the productivity of marine ecosystems. The marine macrophyte and coral assemblages in the marine environment surrounding Barrow Island are dominated by tropical species that are widely represented within the Montebello/Lowendal/Barrow Island region and across the Rowley Shelf. Mainland taxa are similarly widespread along the Pilbara coast.

Stressors which pose a potential risk to benthic primary producers include seabed disturbance, leaks and spills, physical presence of Development infrastructure and wastewater and other discharges. Both the physical presence of infrastructure and management of wastewater and other discharges have been assessed as low risk during both construction and operations. Seabed disturbance and leaks and spills are both stressors that pose a medium level of risk during the construction phase. Leaks and spills also present a medium risk during the operational phase of the Development.

The major, long-term impact of seabed disturbance on BPP is associated with direct removal of substrates with attached marine macrophytes and corals, such as excavation of vessel access channels by dredging, and installation of infrastructure on the seabed, such as by construction of the MOF. Construction activities in the marine environment, particularly dredging and drilling, will also temporarily affect benthic primary producers, most notably through increased levels of sedimentation and turbidity.

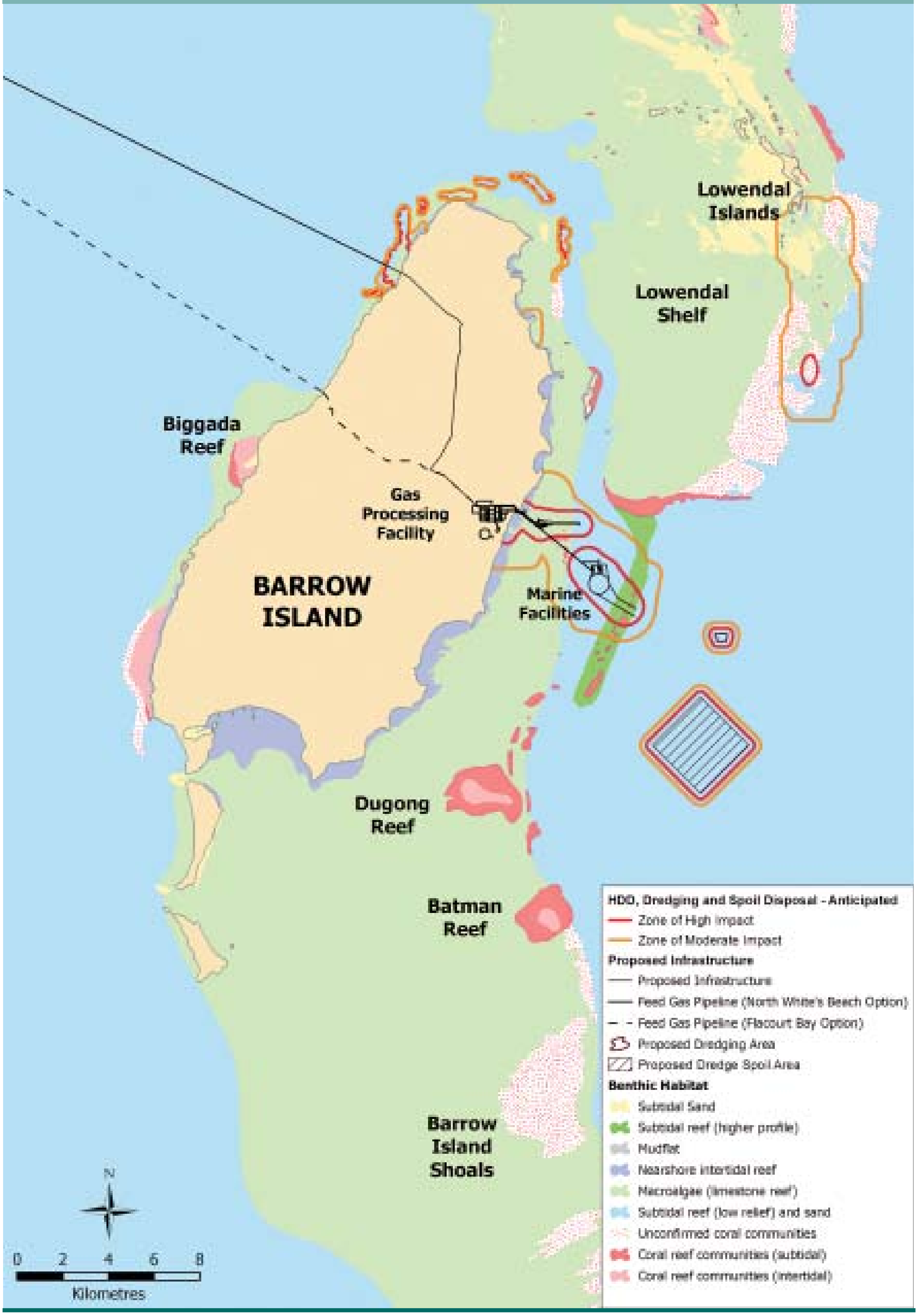
The likelihood of direct impacts to marine macrophytes (macroalgae and seagrasses) and corals from construction or operation of the feed gas pipeline, causeway, MOF, LNG jetty and access channels is almost certain, because the disturbance is an unavoidable element of the proposal. The consequence of the impacts is considered minor because potential impacts will be limited to a local, long-term impact on the communities and there will be no reduction in community or taxon viability in the local area.

Macroalgal beds and coral communities of the type that are likely to be impacted by the Development are widely distributed throughout the region and no regionally significant coral communities will be directly impacted. There will also be significant regrowth and recolonisation of hard substrates (e.g. jetty piles, spoil disposal ground) in the Development area.

The residual risk of significant adverse impacts to mangroves on the mainland from construction of the domestic gas pipeline is medium. The likelihood of impacts is categorised as almost certain because clearing is unavoidable for construction of the domestic gas pipeline to proceed. The consequence of impacts is considered moderate because the impacts are restricted to a small area of a regionally significant mangrove system that is well represented along the Pilbara coast. The absence of observable edge effects along the existing pipeline easement indicates that the integrity of the local mangrove habitat will not be reduced by the proposed Development.

The spatial extent of potential indirect impacts from sedimentation and turbidity associated with HDD for the feed gas pipeline shore crossing at North White's Beach and the dredging program off the east coast of Barrow Island was predicted using a 3D hydrodynamic model (GCOM3D) and a 3D dredge simulation model (DREDGETRAK). The implications to benthic primary producer communities of increased suspension and deposition of sediments resulting from construction operations will vary considerably depending on the extent and nature of impacts, including the taxa affected. It is anticipated that turbidity and sedimentation will result in a local long-term impact on benthic primary producers adjacent to the Development and short-term impacts in an areas which encompasses coral and macroalgae communities along the eastern edge of the Lowendal Shelf and northern coast of Barrow Island (Figure 11-1). The modelling results indicate that there will be no adverse impacts to regionally significant corals on the southern Lowendal Shelf, Dugong Reef or Batman Reef. The consequences of predicted impacts from turbidity and sedimentation will be minor, representing a short to long-term reduction in abundance but no reduction in community/taxon viability in the local area.

Figure 11-1:
The Anticipated Area of Impact During the Installation of the Feed Gas Pipelines and Construction of the Causeway, MOF, Jetty and Dredged Channels.



The Joint Venturers will develop and adopt a monitoring and management program designed to restrict the potential effects of HDD, dredging and dredge spoil disposal during the construction phase of the Development to predicted impact zones. The monitoring and management program will be developed in consultation with the Commonwealth and Western Australia state agencies. This will form part of the drilling, dredging and dredge spoil disposal monitoring and management plan for the Development.

The potential for significant impacts to marine benthic primary producers from a leak or spill incident associated with the Development relates primarily to a spill of condensate or liquid hydrocarbons from work vessels, LNG ships and work barges that will have bunkers of diesel and possibly other liquid fuels on board. Unlike other liquid hydrocarbons, LNG is not toxic and produces a buoyant vapour cloud when spilled on to water. As this cloud mixes with air, it warms up and disperses into the atmosphere. The potential for environmental impacts from a release of LNG are therefore considered negligible.

Spilled liquid hydrocarbons can adversely affect marine benthic primary producers if there is direct contact at low tide, through the dispersal of oil droplets into shallow subtidal areas or by dissolution of toxic hydrocarbons into the water column. The extent to which a spill will affect benthic primary producers in any area depends on a complex suite of interacting physical, chemical and biological factors. Within the area potentially at risk from a leak or spill, the intertidal coral communities at Biggada Reef on the west coast of Barrow Island are the most vulnerable benthic primary producer communities with high conservation significance. Significant coral communities on the east coast are mostly subtidal, as are the denser macroalgae and seagrass communities on both coasts. Modelling indicates that a small-volume spill from a refuelling incident on either the west or east coasts of Barrow Island would be unlikely (i.e. 2.43×10^{-2}/yr) to result in significant exposure of benthic primary producers to hydrocarbons. The probability of a large leak or spill is very low (2.76×10^{-5}/yr) and the likelihood of a large spill occurring and affecting benthic primary producers is categorised as remote.

Management of hydrocarbon spills within the offshore petroleum industry is focussed on prevention of incidents, combined with comprehensive contingency response planning, integrated at national, state and local levels. Equipment design, material selection and construction techniques and standards adopted for the Development are based upon proven, robust solutions used extensively in similar environments and applications worldwide.

The offshore Pilbara north-west shelf region is a major petroleum exploration and production province. Detailed contingency planning is in place to reduce the risk of a significant spill and substantial oil spill response capacity is currently maintained at the Port of Dampier and on the islands of the north-west shelf, including Barrow Island, to provide for rapid intervention if an incident occurs.

11.3 Benthic Primary Producer Habitats

Benthic primary producer habitats comprise both benthic primary producer communities and the substrates that support these communities.

The Joint Venturers have adopted the EPA’s risk-based approach, as outlined in Guidance Statement No. 29 (EPA 2004), to assess unavoidable cumulative impacts to benthic primary producer habitats within the proposed Development area. As specified by the Guidance Statement, management units were defined in consultation with the Western Australian Department of Environment (DoE) and existing and proposed disturbance to benthic primary producer habitats assessed against relevant cumulative loss thresholds. The recommended size for a management unit to represent an ecological unit is nominally 5 000 ha although larger and smaller units can be established (EPA 2004).

Fourteen management units have been defined to assess impacts to benthic primary producer habitats from the Development. This consists of eleven management units around Barrow Island and three on the mainland coast (Figure 11-2 and Figure 11-3). A summary of results from the assessment of cumulative impacts to benthic primary producer habitats within the proposed Development area using EPA guidelines is shown in Table 11-2.

Figure 11-2:
Barrow Island Management Units, Benthic Habitats and Predicted Area of Effects

Figure 11-3:
Mainland Management Units, Benthic Habitats and Proposed Infrastructure

Permanent loss of benthic primary producer habitats are predicted to exceed EPA cumulative loss threshold levels in three of the fourteen management units established in accordance with EPA Guidance Statement No. 29. The proposed dredge spoil area will permanently modify approximately 6% and 14% of the seabed in management units 10 and 11 respectively. While these losses exceed the benthic primary producer habitat cumulative loss threshold levels (2% and 10%), they do not represent a threat to the ecological integrity of the surrounding benthic primary producer habitat or to the conservation values of the Barrow Island Marine Conservation Area. The flat sandy seabed in both of these management units is very well represented in both the local area and the region. It is close to the depth limit for the seagrasses and is likely to be of marginal value in terms of seagrass productivity compared to shallower areas closer to Barrow Island. Similarly benthic primary producer habitats in management unit 8 within the port area are well represented throughout the Montebello/Lowendal/Barrow Islands region and permanent loss of some areas of benthic primary producer habitat (23%) is not predicted to affect ecosystem integrity in the port area or regionally.

Losses of unconfirmed coral habitat in the two Lowendal Islands management units (2 and 3) also exceed cumulative loss thresholds; however the majority of the assumed distribution of coral habitat in these management units, as identified by the CALM (2004) marine habitat mapping, has not been confirmed by field surveys. It is anticipated that only a small proportion of the areas affected by persistent turbid plumes represent coral habitat and that these coral communities would fully recover from sedimentation and turbidity impacts.

11.4 Marine Fauna

Physical interaction and light emissions were assessed as medium – high risk stressors to marine fauna (Table 11-3). Medium risk stressors, which are associated primarily with the construction phase of the Development, include:

- seabed disturbance
- noise and vibration
- leaks or spills (construction and operations).

Risk assessments indicate that physical presence of infrastructure and wastewater discharges pose a low risk to marine fauna during construction, commissioning and operations phases of the Development.

The main potential impacts associated with marine stressors include loss, injury, or disturbance to marine fauna, and loss or modification of habitat.

Sea turtles are one of the most sensitive receptors that will be affected by physical interaction with Development activities and by light emissions. There is potential for collisions between vessels (e.g. pipelay vessels and dredges) and sea turtles off the east and west coasts of Barrow Island. On the east coast, further surveys will be conducted, prior to construction, to establish the extent to which seabed habitats are utilised by resident and internesting flatback turtles. Results from surveys and satellite tracking studies will establish whether or not flatback turtles are using seabed areas off the east coast of Barrow Island as resting and internesting habitats and if management strategies such as relocation of turtles and modification of dredge specifications (i.e. turtle deflection devices) will be necessary. If dredge areas do not represent important flatback turtle habitat, then it is unlikely that significant numbers of flatback turtles (i.e. 10s) will be directly impacted by dredging.

Elevated light levels on nesting beaches can be detrimental to sea turtles because light may alter critical nocturnal behaviours, namely how sea turtles choose nesting sites, how adult females return to the sea after nesting, and how hatchlings find the sea after emerging from nests. Because there is no single, measurable level of artificial brightness on nesting beaches that is acceptable for sea turtle conservation, the most effective conservation strategy is simply to use 'best available technology' to reduce effects from lighting (Witherington and Martin 2000). Best available technology includes many light management options that have been used by lighting engineers for decades and others that are unique to protecting sea turtles.
To protect sea turtles, light sources can be minimised in number and wattage, repositioned behind structures, shielded, redirected, lowered, or recessed so that light does not reach the beach. To ensure that lights are on only when needed, timers and motion detector switches can be installed.

The Joint Venturers are committed to adopting a lighting strategy for the gas processing facility and associated infrastructure that will avoid or mitigate impacts to sea turtles caused by artificial light.
No permanent 24-hour lighting will be located within 500 m of turtle nesting beaches and light emission modelling and line-of-sight studies will be incorporated into lighting design to eliminate non-essential lighting and reduce essential lighting to lowest practicable levels. The implementation detail for these strategies will be developed, in consultation with CALM, the Department of Environment (DoE) and the Commonwealth Department of the Environment and Heritage (DEH), and submitted for approval as part of the EMP for the Development.

Table 11-2:
Summary of Benthic Primary Producer Habitat Assessment

Management Unit	% Benthic Primary Producer Habitat -Permanent Loss*	EPA Cumulative Loss Threshold (%)
North West Coast MU 1		
Macroalgae dominated intertidal limestone platform	<1	2 (category C)
Subtidal limestone reef platform with macroalgae and scattered corals	<1	
Lowendal Islands MU 2		
Macroalgae-dominated intertidal limestone platform	0	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	0	
Reef platform/sand with scattered seagrass	0	
Confirmed coral habitat	7	
Unconfirmed coral habitat	25	
Lowendal Islands MU 3		
Macroalgae-dominated intertidal limestone platform	0	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	0	
Reef platform/sand with scattered seagrass	0	
Confirmed coral habitat	<1	
Unconfirmed coral habitat	63	
Barrow Island Port Area MU4		
Macroalgae-dominated intertidal limestone platform	<1	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	2	

Table 11-2: (continued)
Summary of Benthic Primary Producer Habitat Assessment

Management Unit	% Benthic Primary Producer Habitat -Permanent Loss*	EPA Cumulative Loss Threshold (%)
Barrow Island Port Area MU4 (continued)		
Reef platform/sand with scattered seagrass	<1	10 (category E)
Coral habitats	<1	
Barrow Island Port Area MU5		
Subtidal limestone reef platform with macroalgae and scattered corals	0	10 (category E)
Reef platform/sand with scattered seagrass	0	
Coral habitats	8	
Barrow Island Port Area MU6		
Subtidal limestone reef platform with macroalgae and scattered corals	0	10 (category E)
Reef platform/sand with scattered seagrass	0	
Coral habitats	5	
Barrow Island Port Area MU7		
Macroalgae-dominated intertidal limestone platform	0	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	<1	
Reef platform/sand with scattered seagrass	<2	
Coral habitats	0	
Barrow Island Port Area MU8		
Subtidal limestone reef platform with macroalgae and scattered corals	0	10 (category E)
Reef platform/sand with scattered seagrass	0	
Coral habitats	23	
Barrow Island Port Area MU9		
Reef platform/sand with scattered seagrass	7	10 (category E)
Dredge Spoil Area MU10		
Reef platform/sand with scattered seagrass	6	2 (category C)
Dredge Spoil Area MU11		
Reef platform/sand with scattered seagrass	14	5 (category D)
Mainland MU1		
Mangrove habitat	<1	1 (category B)
Mainland MU2		
Seagrass habitat	0	5 (category D)
Onlsow MU		
Macroalgae and seagrass habitat	<1	5 (category D)

** Figures for benthic primary producer habitat loss are based on the anticipated impact scenario.*

Table 11-3:
Summary of Risk Assessment for Marine Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Seabed Substrates	To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones.	• change in seabed profile • sedimentation • damage to high profile reef structures • change in seabed type, e.g. sand to rock • smothering of seabed • localised change in longshore coastal sediment dynamics • localised contamination of marine sediments • alteration of sediment characteristics (sediment size and anoxic conditions).	• locate Development infrastructure to avoid sensitive areas • undertake dredge spoil disposal in accordance with licence conditions • locate and orientate Development infrastructure to minimise impacts to nearshore sediment transport • develop Environment Plans for marine activities • specify heavy metal limits in drilling chemicals (e.g. barite) if used • use HDD in favour of trenching at feed gas pipelines shore crossing • develop appropriate erosion control methods for domestic gas pipeline shore crossing • develop Waste Management Plan • comply with MARPOL 73/78 Annex IV requirements • develop an emergency (spill) response plan.	• compliance with EPA guidance statement for BPPH disturbance • no detectable long-term change in longshore coastal sediment dynamics • no long-term contamination outside of Development area.	• Physical disturbance.	L – M	L	–
					• Physical presence.	–	L	–
					• Liquid and solid waste disposal.	L	L	–
					• Leaks or spills (minor <10 m^3).	L	L	–
					• Leaks or spills (>10 m^3).	L	L	–

Table 11-3:
Summary of Risk Assessment for Marine Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Water Quality	To maintain the quality of water so that existing and potential environmental values, including ecosystem function, are protected.	• localised decline in marine water quality • increases in localised turbidity • localised copper or tributyltin (TBT) pollution from vessel anti-fouling leachate. • localised pollution of the water column from minor spill • more widespread pollution from spill >10 m^3.	• develop drilling Environment Plan • comply with MARPOL 73/78 Annex IV requirements • develop Waste Management Plan • design equipment to include built-in safeguards • develop protocols for transfer of fuel from support vessels • apply industry standards for storage and handling of fuels and chemicals (e.g. bunding) • develop and implement approved OSCP and emergency response and spill contingency planning.	• no long-term contamination outside of Development area.	• Discharges. • Leaks or spills (minor <10 m^3). • Leaks or spills (>10 m^3).	L L L	L L L	– – –

Table 11-3:
Summary of Risk Assessment for Marine Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Foreshore	To maintain the integrity and stability of beaches.	• soil compaction • erosion • changes in the foreshore profile • localised change in seabed profile • localised, minor change in longshore coastal sediment dynamics • localised surge in water level due to entrapment by causeway.	• limit clearing and earthworks • install erosion and sediment control structures • re-instate pipeline shore crossings to a level consistent with surrounding terrain • assess potential for acid sulphate soils on the mainland • implement revegetation/ rehabilitation plan for shore crossing sites • conduct numerical modelling of coastal processes and longshore coastal sediment transport dynamics adjacent to proposed causeway • orientate causeway to minimise impact on wave refraction patterns • monitoring of beach alignment either side of Town Point.	• foreshore profiles re-instated • no detectable long-term change in longshore coastal sediment dynamics.	• Physical disturbance.	M	L	–
					• Physical presence.	–	L	–

Table 11-3:
Summary of Risk Assessment for Marine Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Benthic Primary Producers (Marine Flora and Corals) and Habitats	To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.	• loss and/or disturbance to marine flora and coral communities • loss on mangroves along domestic pipeline route on mainland • enhanced growth of macroalgae and corals on causeway and jetty.	• identify regionally significant marine habitats and communities and avoid • reduce dredge requirements to minimum practicable • locate marine infrastructure to avoid sensitive habitats • conduct benthic primary producer habitat assessment in accordance with EPA guidance 29 • consult EPA Guidance Statement No.1 for arid zone mangrove protection for mangroves of special significance (EPA 2001) • use HDD or tunnelling in favour of trenching at feed gas pipelines shore crossing • design and operate of east coast dredging in accordance with requirements of the *Environment Protection (Sea Dumping) Act 1981* • develop and implement Dredging Management and Monitoring Plan • develop appropriate erosion control methods for the mainland section of the domestic gas pipeline.	• significant habitats and sensitive areas mapped and avoided. • heavy metal limits not exceeded • risks associated with trenching eliminated • requirements of *Environment Protection (Sea Dumping) Act 1981* recorded and met • alternative locations within the spoil sites and dredge areas used when trigger values exceeded • incidents reduced and/or avoided • fuels, chemicals and hazardous materials transported and stored safely • spill management efficient and effective • corrosion monitored and managed • longshore sediment transport processes maintained.	• Seabed disturbance. • Leaks or spills. • Physical presence. • Wastewater and other discharges.	L – M – L L	L - L L	– L – M – –

Table 11-3:
Summary of Risk Assessment for Marine Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Marine Fauna	To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect EPBC Act-listed threatened and migratory species. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act.	• loss of, or disturbance to (e.g. changes in behavioural patterns), marine fauna • vessel collision with listed marine fauna resulting in injury or mortality • loss of modification to habitats (e.g. turtle beaches) • creation of 'artificial' habitat associated with subsea facilities.	• develop Environment Plans for marine activities • schedule activities to reduce impacts to marine fauna • educate workforce and visitors and enforce rules on interaction/interference with fauna • control and restrict access to beaches and intertidal reefs • restrict vessel speed and access • use turtle deflection devices on the dredge barge, if required • relocation of turtles, if required • set gas processing facility and flare back from coast shielded by coastal dunes • design gas processing facility so that no permanent 24-hour lighting is located within 500 m of turtle nesting beaches • design lighting in accordance with tiered lighting strategy • establish a turtle tagging and monitoring program • presence of marine monitors during all relevant marine construction activities.	• no long-term impacts to significant marine communities • long-term viability of listed fauna species maintained • adherence to Environment Plan • no breach of environmental licence conditions • compliance with EPA guidance statement for BPPH disturbance • implementation of anchor management plan • adherence to workforce rules regarding interaction with flora and fauna • no contamination outside of immediate Development area • no light sources directly visible from nesting beaches • no permanent 24-hour gas processing facility lighting located within 500 m of nesting beaches	• Seabed disturbance. • Physical interaction. • Physical presence. • Wastewater discharges. • Light. • Noise and vibration. • Leaks or spills (minor <10 m^3). • Leaks or spills (>10 m^3).	M M – L M – H M M M	L M L L M – H M L M	 – – – – – – –

Table 11-3:
Summary of Risk Assessment for Marine Environmental Factors

Environmental Factor	Objective	Potential Environmental Impact/Consequences	Key Management Measures	Target	Residual Risk			
					Stressor	Const. and Comm.	Operations	Non-routine
Marine Fauna (continued)				• compliance with tiered lighting strategy • adherence to no routine flaring policy • no blasting outside of daylight hours.				

12 Quarantine – Risks and Management

12.1 Introduction

Quarantine management of Barrow Island has been instrumental in protecting the unique conservation values of the Barrow Island Class A Nature Reserve. It has formed a core component of the environmental management of Barrow Island since oilfield operations began in the 1960s, and has been effective in preventing the establishment of organisms which do not naturally occur on the island.

Quarantine management involves the application of barriers which are designed to prevent the introduction of non-indigenous species beyond a designated border. Such barriers may be applied in sequence over an entire transport pathway, and in the Barrow Island case extend from mainland supply depots, transport containers and vehicles, and ultimately upon arrival at Barrow Island. Quarantine activities also extend beyond the Barrow Island border to include monitoring and response to any non-indigenous species which may potentially breach quarantine barriers.

Quarantine will form a critical component of the environmental protection regime for the proposed Gorgon Development because the construction and operation of a gas processing facility on Barrow Island will result in a substantial increase in activity. Consequently, this will increase the potential for the introduction of non-indigenous species. Such an introduction could lead to irreversible and detrimental impacts to the ecological composition and function of the island's ecosystem through increased competition for resources, direct predation, or habitat modification.

To protect the conservation values of Barrow Island from the impacts of non-indigenous species, the Joint Venturers have developed a risk-based Quarantine Management System. The primary focus of this system is to prevent the introduction of non-indigenous species to Barrow Island and the surrounding marine environment. Further levels of protection will be provided through detection and response strategies which will prevent the establishment of any non-indigenous species in the native environment.

12.2 Quarantine Management Objectives

The quarantine management objective for the proposed Gorgon Development is to protect the conservation values of the Nature Reserve and simultaneously facilitate the construction and operation of a gas processing facility on Barrow Island. To support this objective, the Joint Venturers have developed a 'Barrow Island Quarantine Policy' (Box 12-1). This policy also forms a core element of the Quarantine Management System (QMS) which is discussed in Section 12.5).

To achieve the quarantine objective, the Joint Venturers have developed a risk-based approach to quarantine management based upon the advice of the Environmental Protection Authority (EPA 2003).

Box 12-1:
Barrow Island Quarantine Policy

Barrow Island Quarantine Policy

Chevron Australia Pty Ltd, the operator of the Barrow Island oilfield and the proposed Gorgon gas facility, is proud of its environmental reputation and performance on Barrow Island. As operator of both oil and gas ventures, Chevron will continue to hold overall management responsibility for operational activities on the island, and for operating in a manner that protects the conservation values of the Barrow Island Nature Reserve and the surrounding waters.

Central to this responsibility is our goal to prevent the establishment of introduced species on Barrow Island and in the surrounding waters. This will be achieved through the implementation of a Quarantine Management System that delivers world class performance and integrates quarantine management into business planning and operational processes.

Chevron will:

- Not compromise quarantine requirements;
- Identify and manage quarantine risks arising from our operation, with the objective of preventing the introduction and establishment of species to Barrow Island;
- Develop and maintain a positive quarantine culture in our staff, contractors and suppliers;
- Engage only contractors and suppliers who have demonstrated a willingness to meet or exceed our quarantine standards;
- Maintain a system of continuous improvement in our management of quarantine;
- Meet or exceed all legal requirements, be a responsible corporate citizen and demonstrate leadership in quarantine management;
- Provide the appropriate training to support the implementation and ongoing operation of the quarantine programmes;
- Set measurable quarantine targets and performance objectives;
- Ensure conformity with this policy by a comprehensive compliance program including audits;
- Have an open and transparent quarantine process that includes stakeholder engagement and reporting;
- Recognise and address government and community concerns on quarantine; and
- Respond quickly and effectively to any quarantine emergency with the potential to impact the biodiversity of the area.

Chevron will commit the necessary resources to ensure the effectiveness of this policy.

This policy, its intent and each person's responsibility will be communicated to employees, contractors, subcontractors and visitors. All are required to comply with the processes, procedures and systems of work developed in accordance with this policy.

This policy applies to all activities on Barrow Island and in the surrounding waters.

Signed

James W Johnson – Managing Director
Chevron Australia Pty Ltd
August 2005

12.3 Approach to Quarantine Management

The approach adopted by the Joint Venturers is consistent with the advice of the EPA, and specifically includes the establishment of a Quarantine Expert Panel, extensive community involvement, investigation of quarantine best practices, and the development of standards for acceptable risk.

12.3.1 Quarantine Expert Panel

The Joint Venturers established the Quarantine Expert Panel (QEP) to obtain the best possible advice to guide the development of quarantine management for the Gorgon Development. Experts invited to participate represented a broad cross-section of expertise including conservation, ecology, biosecurity and risk management. The QEP was chaired by Bernard Bowen, and its 10 members were affiliated with a range of government departments, scientific institutions, non-government organisations and private consultancies. Advice provided by the QEP guided the development of the Gorgon Risk-Based Method (Section 12.4), and the development of a set of standards for acceptable risk (Section 12.4.1).

12.3.2 Community Involvement

The Joint Venturers initiated extensive community involvement in the development of quarantine management options for Barrow Island. This specifically involved four Community Consultation Meetings and four technical workshops. The technical workshops specifically addressed the development of risk standards, the design of a Quarantine Management System, and the level of detail required in quarantine barrier design. Most importantly, community members were prominent in the development of risk standards. This is reflected in a formal report tabled at the Community Consultation Meeting of 16th June 2004, which was also forwarded to the EPA and the Joint Venturers. In this report the community expressed the view that the risk of establishment of introduced species would be acceptably low if it conforms to the risk standards developed at these workshops (Section 12.4.1).

12.3.3 Best Practice Benchmarking

The Joint Venturers commissioned a study to establish quarantine best practice for the protection of conservation values of nature reserves. The study revealed the existence of few such quarantine programs, and highlighted the relevance of current quarantine practices on Barrow Island which attend to a dual commercial and conservation imperative.

12.3.4 Baseline Data

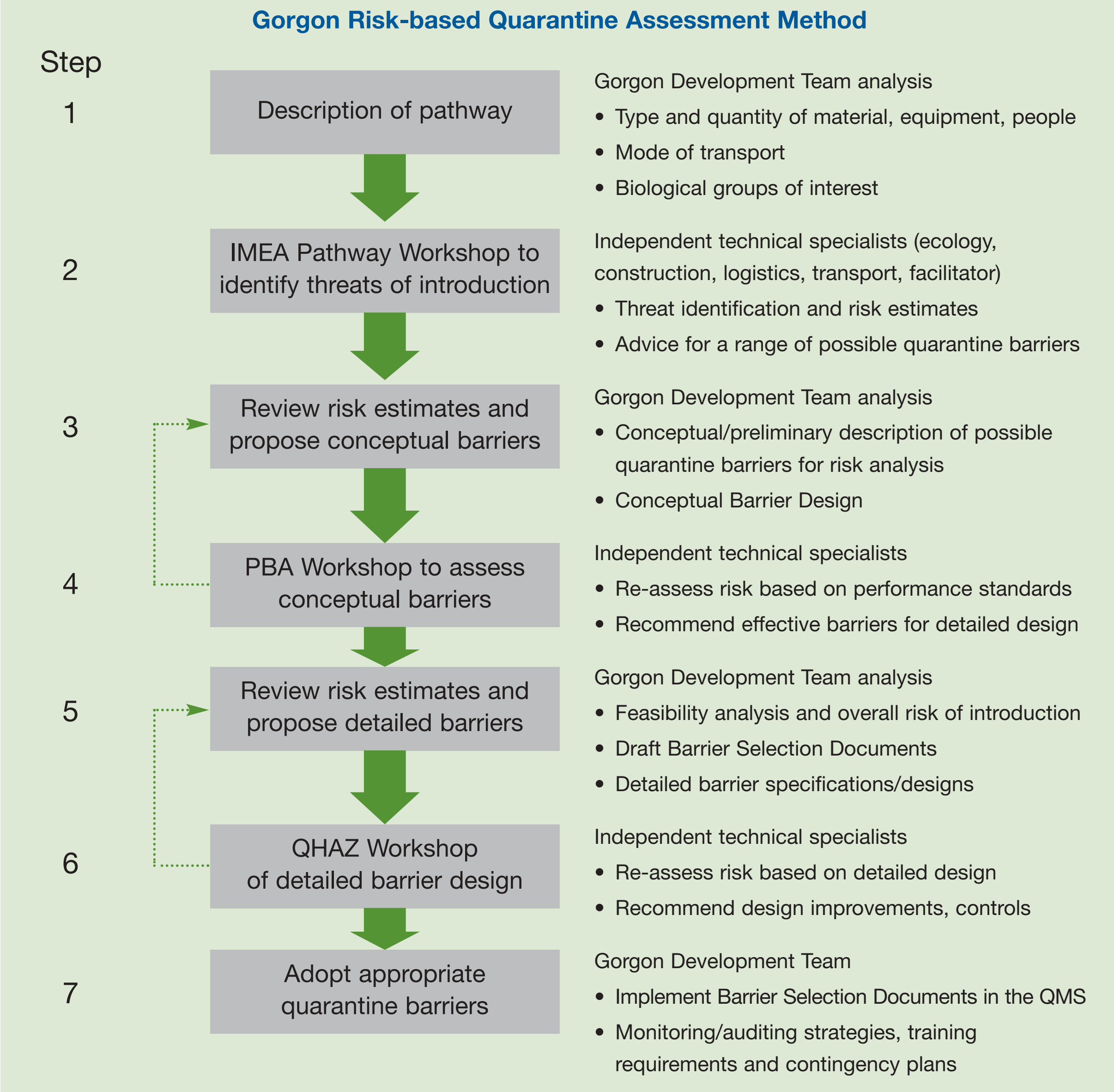
In order to determine a credible baseline dataset of species presence on Barrow Island, the Joint Venturers have engaged in a number of activities, including preparation of a report into baseline studies and data gaps. On the basis of expert advice, the Joint Venturers have initiated invertebrate baseline field surveys on Barrow Island, a preliminary marine monitoring and detection program, and have initiated further assessment of the extensive array of terrestrial flora and fauna data collected on Barrow Island to date. Baseline information collated as a result of these activities will provide a vital reference dataset which will be used to assess the effectiveness of quarantine efforts associated with the Gorgon Development.

12.4 Quarantine Risk Assessment Method

The centrepiece of the Joint Venturers' approach to quarantine management is the development of the Gorgon Risk-based Quarantine Assessment Method. This method has been adapted from accepted risk assessment approaches with critical input from the QEP, the community, and independent technical experts. The risk assessment method is a pathway-driven means that requires identification of quarantine threats, and the development of specific quarantine barriers to reduce the likelihood of introduction of non-indigenous species to Barrow Island.

In view of the difficulty of predicting the ecological outcomes of the introduction of any type of non-indigenous species, this risk assessment does not attempt to estimate the likelihood of ecological consequences of an introduction. To that end, the Joint Venturers have adopted a precautionary approach which focuses on the prevention of the introduction of any non-indigenous species in the first instance. Qualitative estimates of quarantine risk are therefore made on the basis of introduction, and to a lesser extent likelihood of survival, detection, and eradication for a range of biological groupings. This is an interactive process that involves input from independent ecological experts in risk assessment workshops. Seventeen such workshops have been conducted to date, and have focused on 3 pathways under priority consideration, those being: i) sand and aggregate, ii) food and perishables, and iii) personnel and accompanying luggage. Assessments of the remaining pathways will be undertaken as the necessary technical advice and design detail becomes available.

Figure 12-1:
Flow Chart of the Gorgon Risk-based Quarantine Assessment Method



12.4.1 Implementation of Risk Standards

The Joint Venturers propose to meet the standards for acceptable risk by implementing selected arrays of quarantine barriers along pathways of entry to Barrow Island. Three priority pathways were chosen to demonstrate the application of such barriers, those pathways being:

1. Sand and aggregate
2. Food and perishables
3. Personnel and accompanying luggage.

These priority pathways are considered to represent the greatest range of threats of introduction of non-indigenous species and are characteristic of early Development activities during site establishment and construction.

Selection of conceptual quarantine barriers for subsequent assessment in Quarantine Hazard (QHAZ) workshops involves consideration of proposed barriers in two phases: i) initial assessment of the feasibility of each barrier, and ii) consideration of

Health, Environment and Safety (HES) and Human Resource (HR) issues. The outcomes of this process provides detailed quarantine barrier specifications for each pathway which are subject to QHAZ assessment to ensure barrier function is satisfactory and that risk standards can be met. To date, information gathered in risk assessment workshops has enabled the Joint Venturers to demonstrate that the risk standards can be met with a very high level of confidence.

The Joint Venturers have established an ongoing process of analyses of the proposed quarantine barriers, and have committed to publishing the outcomes of QHAZ workshops for the three priority pathways. This will take the form of a package of additional information to this Draft EIS/ERMP (refer to Section 4). This report will provide more detailed information and justification on the barriers selected by the Joint Venturers to reduce the quarantine risks. The Joint Venturers will also conduct a further Barrow Island Quarantine Community Consultation Meeting subsequent to the release of the Additional Information Package.

Prior to completion of the QHAZ step, however, the Joint Venturers have committed to the implementation of a number of quarantine barriers common to all pathways, and some initial barriers specific to the three priority pathways. Additional barriers will be implemented subject to the outcomes of the QHAZ assessment workshops. An outline of barrier commitments to date is provided below.

12.4.2 Systematic Barriers

The Joint Venturers commit to the following systematic quarantine barriers that are common to all pathways:

- Inclusion of quarantine requirements in pre-qualification of suppliers and contractors.
- Inclusion of quarantine requirements in contracts for all contractors and suppliers providing goods and services for Barrow Island.
- Induction of all personnel (staff, contractors, and suppliers) in quarantine management requirements.
- Provision of specific quarantine training to personnel in the procurement and logistics supply chain.
- Inclusion of quarantine responsibilities in the position description for key personnel.
- Development and support of a strong culture of quarantine awareness in the workforce.
- Recording and tracking of quarantine compliance for all personnel and goods going to Barrow Island.
- Conduct of regular quarantine compliance audits and checks throughout the supply chain.

12.4.3 Sand and Aggregate Barriers

The Joint Venturers commit to the following key barriers for the sand and aggregate pathway:

- Implement a Quarry Environmental Management Plan.
- Clean and inspect quarry equipment.
- Cover material in segregated storage.
- Sample material to verify compliance.
- Cover during sea transport.

It can be demonstrated through the application of risk estimates for all barriers at each step in the sand and aggregate pathway that the residual quarantine risk may be reduced to ‘remote, unlikely’. Further development of quarantine measures at the Barrow Island border in the design phase, and post-border monitoring and eradication strategies, will provide additional levels of risk reduction and provide confidence that the standards for acceptable risk will be met.

12.4.4 Food and Perishables Barriers

The Joint Venturers commit to the following key barriers for the food and perishables pathway:

- Manage receipt, screening, consolidation, despatch from a central facility.
- Pre-process fresh food and vegetables prior to despatch.
- Select packaging to allow visual inspection; reduce organic packaging.
- Inspect, seal and tag shipping containers.
- Prohibit nominated food and perishable items from transport to Barrow Island.
- Design kitchen facility with internal quarantine zones and barriers to contain and eradicate non-indigenous species.
- Implement a dedicated food and packaging waste containment and removal program.

It can be demonstrated through the application of risk estimates for all barriers at each step in the food and perishables pathway that the residual quarantine risk may be reduced to ‘remote, unlikely’. Further development of pre-border quarantine barriers, and the design of Barrow Island border protection measures and post-border monitoring and eradication strategies will provide additional levels of risk reduction and provide confidence that the standards for acceptable risk will be met.

12.4.5 Personnel and Accompanying Luggage Barriers

The Joint Venturers commit to the following barriers for the personnel and accompanying luggage pathway:

- Establish pre-employment agreements, including awareness training and inductions to appreciate quarantine risks and barriers which carry personal responsibilities.
- Inspect all luggage via x-ray or visual by trained inspectors.
- Declaration of quarantine compliance for personal luggage.
- Cleaning of aircraft to meet quarantine standards.
- Shipment of toolboxes and work cargoes not accepted as checked luggage and processed through mainland logistics base.
- Confinement of transit passengers, luggage and freight to a secure area at Barrow Island airport.
- Implementation of a management plan for flights departing from locations other than Perth.
- Verification of personnel, luggage and freight on arrival.

It can be demonstrated through the application of risk estimates for all barriers at each step in the personnel and luggage pathway, that the residual quarantine risk may be reduced to 'extremely, remote, highly unlikely' which is consistent with the standards for acceptable risk.

An assessment of quarantine threats posed by rodents on marine vessels has also progressed to the pre-QHAZ stage of the risk-based method. Preliminary risk estimates suggest that the application of barriers such as inspection and fumigation of cargoes will reduce the risk of introduction to an acceptable level.

12.5 Quarantine Management System

Quarantine management will be implemented, updated, and monitored through a Quarantine Management System (QMS) which is currently under development. The QMS is modelled upon the principles of AS/NZS ISO 14001:1996, Environmental Management Systems – Specification with Guidance for Use (ISO 14001). The QMS is intended to embed quarantine practices in a consistent and integrated manner into all facets of operations.

The Joint Venturers are confident that implementation of quarantine barriers and practices through the Quarantine Management System will deliver new performance benchmarks for quarantine management, and provide an unprecedented level of quarantine protection for the conservation values of Barrow Island.

13 Greenhouse Gas Emissions – Risks and Management

The Gorgon Joint Venturers recognise and share the concern of the community, industry and government regarding the potential for global climate change. In response, the Joint Venturers have integrated these concerns into their business decisions. This commitment to responsible management of greenhouse gas emissions is reflected in the adoption of the Gorgon Gas Development Greenhouse Gas Management Strategy. The commitments contained in this Strategy have been used to guide planning for the proposed Development and will continue to provide a framework for future engineering decisions and the ongoing management of greenhouse gas emissions.

Integration of the Gorgon Development Greenhouse Gas Management Strategy into the gas processing facility design has resulted in the adoption of greenhouse gas efficient practices such as waste heat recovery and the proposal to inject the CO_2 contained in the reservoir gas stream. These actions represent a commitment to reduce emissions of greenhouse gases that exceed those of other LNG producers.

13.1 Alternative Greenhouse Gas Abatement Options

The Gorgon Joint Venturers have undertaken a range of studies into potential greenhouse gas reduction or offset opportunities that could be used to reduce the emissions from any proposed development of the Greater Gorgon gas fields. The options assessed include:

- investing in commercial forestry
- assisting in revegetation or land rehabilitation plantings
- facilitating reduced land clearing
- undertaking the disposal of reservoir CO_2 by injection into the subsurface
- assisting other industries to switch to alternative fuels (e.g. from coal to gas)
- facilitating the use of compressed natural gas (CNG) as vehicle fuel
- providing support for renewable energy technologies (wind, solar, biomass)
- promoting the sale of CO_2 as a feed stock to another company or industry
- market-based options.

Based on this analysis, the Gorgon Joint Venturers have elected to reduce the Development's greenhouse gas emission by the disposal of reservoir CO_2 by injection into the Dupuy Formation, 2000 m below Barrow Island.

13.2 Greenhouse Gas Emissions Efficiency Improvements

Early design concepts for the development of the Gorgon field included a gas processing platform located offshore in proximity to the gas field with an LNG processing facility on the Burrup Peninsula. Subsequent engineering decisions that have resulted in significant improvements in greenhouse gas emissions efficiency compared to this early design include:

- replacement of the offshore gas processing platform with an all subsea development
- changes in LNG process technology
- improved waste heat recovery on the gas turbines resulting in a significant reduction in the use of supplementary boilers and heaters
- significantly reduced greenhouse gas emissions resulting from the injection of reservoir CO_2 into the subsurface.

The contribution to improved greenhouse gas emissions efficiency from each of these areas expressed in tonnes of CO_2e per tonne LNG produced is shown graphically in Figure 13-1.

13.3 Emissions from Operations

The estimated annual greenhouse gas emissions from the proposed Development are 4.0 million tonnes of CO_2e (MTPA CO_2e). Table 13-1 documents the estimated emissions from the LNG and domestic gas components of the facility and the estimated emissions resulting in the provision of support infrastructure and logistics to Barrow Island.

Ongoing engineering and design work and the actions contained in the Greenhouse Gas Management Plan may reduce these estimated greenhouse gas emissions by a further 660 000 MTPA CO_2e.

Figure 13-1:
Greenhouse Emissions Efficiency Improvements

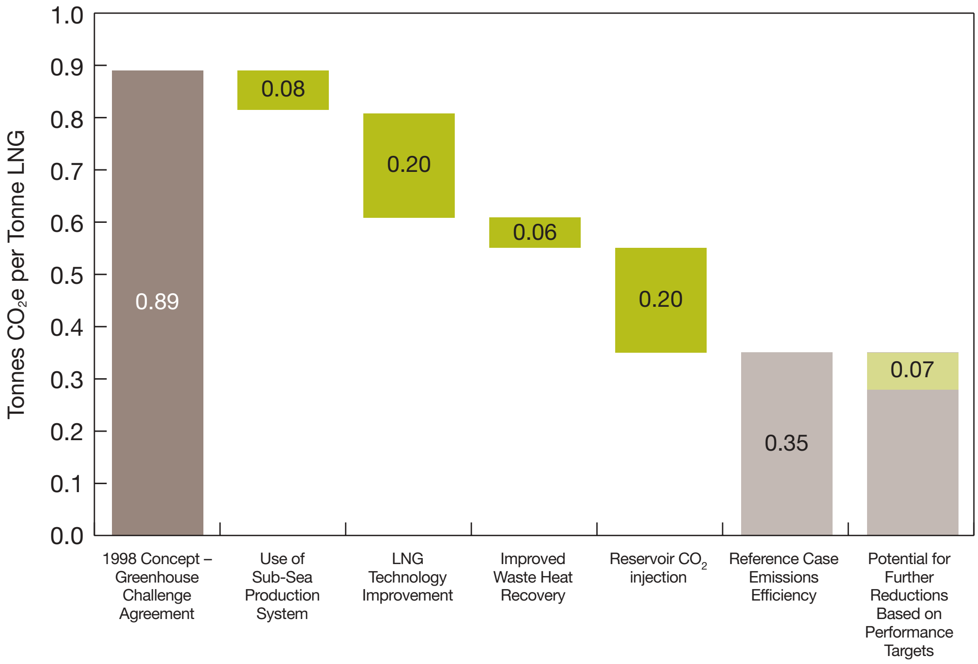


Table 13-1:
Predicted Annual Greenhouse Gas Emissions from the Gorgon Development

Emissions Source	LNG Processing	Domestic Gas Processing	Island Infrastructure Support
	TPA CO_2e	TPA CO_2e	TPA CO_2e
Gas Turbine – Gas Processing Drivers	1 612 000	Nil	Nil
Gas Turbine – Power Generation	1 287 000	200 000	60 000
Fired Heaters	71 000	28 000	Nil
Flare – Events	60 000	Minor	Nil
Flare – Pilots	2 000	Minor	Nil
Fugitive Emissions	Less than 1 000	Less than 1 000	Nil
Transport	Nil	Nil	10 000
Diesel Engines	Less than 300	Minor	Minor
Reservoir CO_2 Vented	500 000	180 000	Minor
Total	3 534 000	409 000	70 000

Reference Case Assumptions:

- LNG production is sourced equally from the Gorgon and Jansz fields.
- Domestic gas production is sourced from the Gorgon Field.
- Based on 8160 hours (340 days) plant operation per year.
- All power generation gas turbines (including spare) are operated at part load, resulting in an additional 65 000 tonnes per year of emissions over case where spare is on cold standby and online turbines are operated at maximum efficiency.
- 20% of reservoir CO_2 (0.68 MTPA) is vented rather than injected into the Dupuy Formation.
- Reservoir CO_2 vented is allocated between LNG and domestic gas production in proportion to throughput from the Gorgon gas field.
- Waste heat recovery is applied to LNG process drive gas turbines and hot oil used as the waste heat recovery medium.

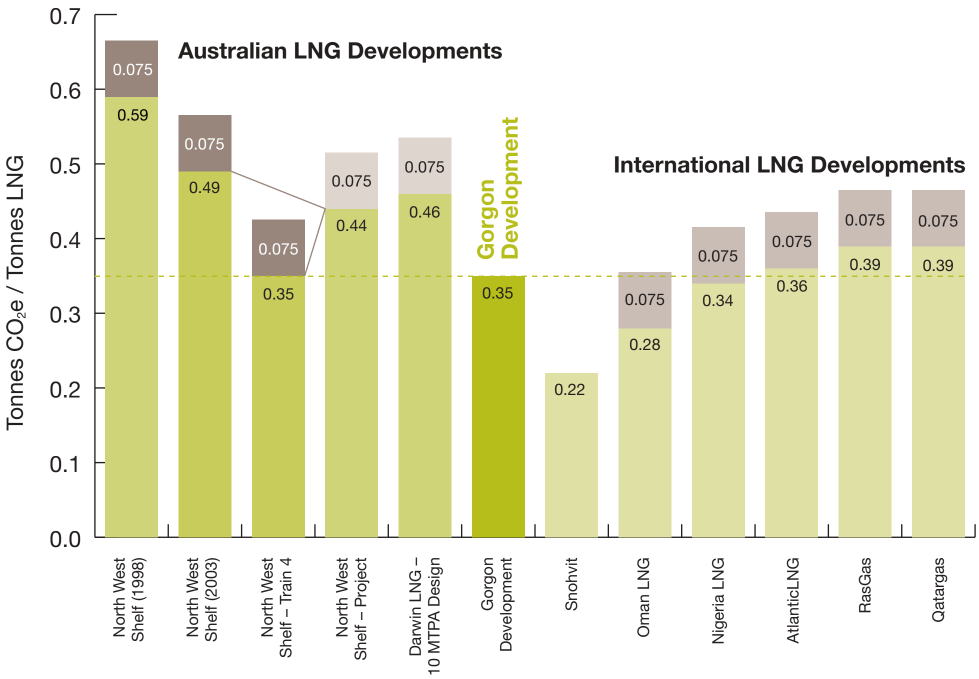
13.4 Benchmarked Greenhouse Gas Emissions Performance

Figure 13-2 shows the greenhouse efficiency of the Gorgon Development compared with data from the:

- North West Shelf Project
- Darwin LNG Project (under construction)
- Snohvit – Hammerfest, Norway (under construction)
- Oman LNG – Qalhat, Oman
- Nigeria LNG – Bonny Island, Nigeria
- RasGas – Ras Laffan, Qatar
- Qatargas – Ras Laffan, Qatar
- Atlantic LNG – Point Fortin, Trinidad and Tobago.

This benchmarking analysis shows that the Gorgon Development will be amongst the most greenhouse efficient LNG developments in the world, particularly when emissions related to the initial gas production are considered. Based on this data, only Oman LNG and Snohvit have appreciably better LNG greenhouse gas efficiency. If the data for the proposed Gorgon Development is normalised, taking into account the operating conditions under which Oman and Snohvit operate, the underlying gas processing facility efficiency is similar across the three projects.

Figure 13-2:
Benchmarked Greenhouse Gas Efficiency



13.5 Disposal of Reservoir Carbon Dioxide by Injection into the Dupuy Formation

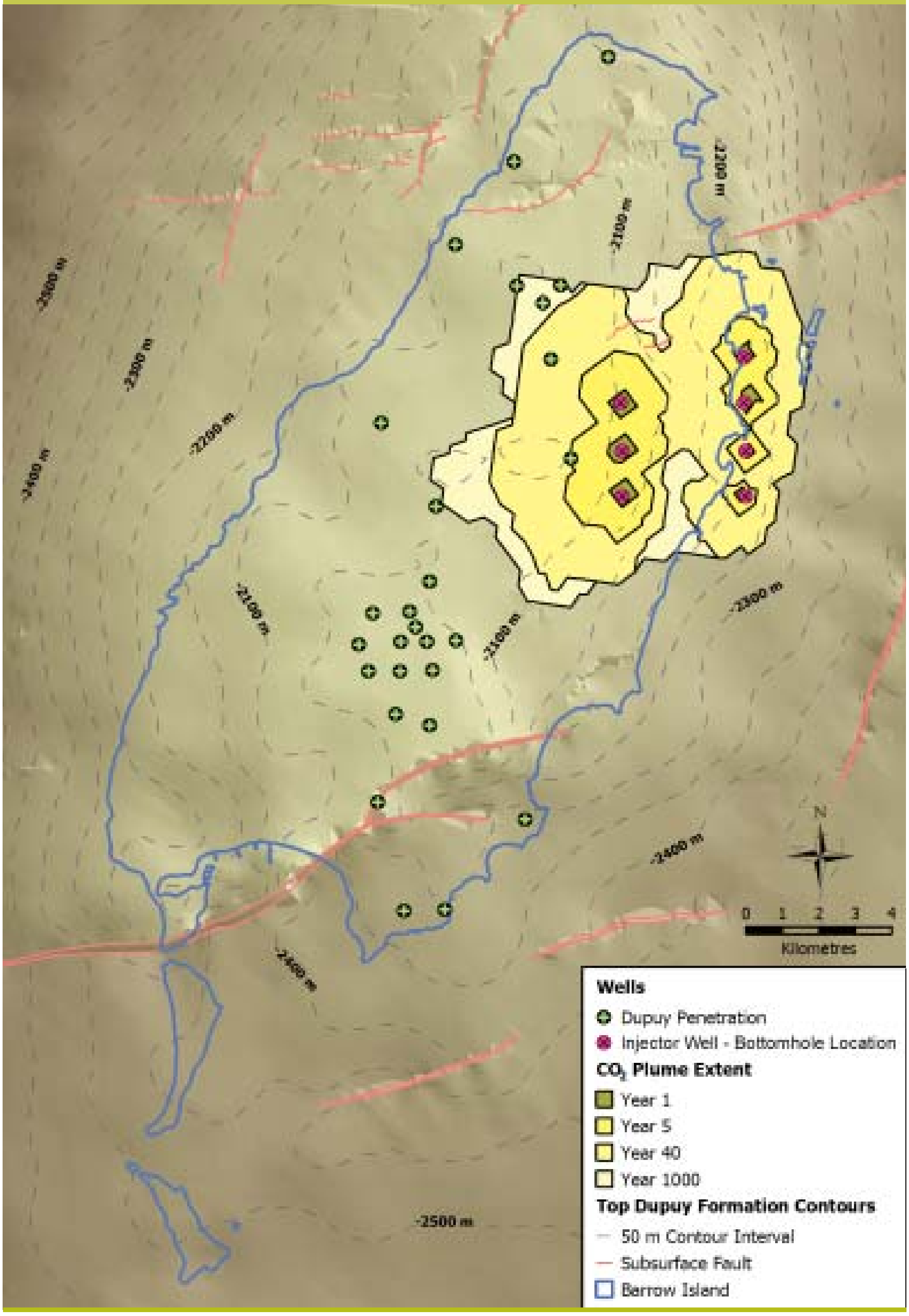
A thorough review of potential CO_2 injection locations has been conducted and has determined that the Dupuy Formation, accessed from the eastern side of Barrow Island, is the preferred location for this activity. Appropriate monitoring of the injected CO_2 is planned to assist with the ongoing management of the CO_2 injection operations. The proposed injection of the reservoir CO_2 will reduce greenhouse gas emissions attributable to the proposed Development (including domestic gas production) from 6.7 million tonnes per annum of CO_2 equivalent (MTPA CO_2e) to 4.0 MTPA CO_2e.

The opportunity to reduce greenhouse emissions by the subsurface injection of CO_2 is relatively new; however the technologies to be applied by the Gorgon Joint Venturers are well established in the oil and gas industry and are being used to inject CO_2 in other parts of the world.

Modelling by the Gorgon Joint Venturers shows that during the operational phase, the CO_2 will initially move out from the injection well bore as a discrete plume, driven by the injection pressure. As the plume moves further away from the injector well, the injection pressure will dissipate and the rate of migration will slow. At this point, the CO_2 plume will migrate under buoyancy forces where the migration path is determined by the dip and heterogeneity of the reservoir. As the CO_2 migrates during the injection phase, a portion of the injected CO_2 will become trapped in the formation by the solution and residual gas trapping mechanism.

Once injection ceases, the injection pressures will rapidly dissipate and the buoyancy contrast between the CO_2 and the formation water will be the driving force for migration of the remaining CO_2. As a result, the rate of lateral CO_2 migration will dramatically reduce and the CO_2 will tend to migrate upwards with vertical movement being restricted by the baffles and barriers in the system. The rate of migration will be determined by the tortuosity of the formation with a large proportion of the CO_2 plume anticipated to be trapped by residual gas trapping in the low permeability layers in the upper Dupuy Formation. Figure 13-3 shows the migration of the CO_2 plume through the Dupuy Formation over the injection period and for the next 1000 years.

Figure 13-3:
Reservoir Simulation Based on the Preferred Injection Scenario and Showing the Extent of the CO_2 Plume Over 1000 Years



The Gorgon Joint Venturers continue to study the most appropriate techniques to monitor the injected CO_2. It is likely that these activities will evolve as the behaviour of the CO_2 in the subsurface is verified and as existing technologies improve and new technologies become available. Monitoring activities are planned around:

- routine observation and recording of injection rates and surface pressures
- health, environment and safety oriented surveillance to detect surface leaks before they can pose a risk to personnel or the environment
- verification via seismic surveys and/or observation wells of the CO_2 plume migration in the subsurface.

13.5.1 Carbon Dioxide Injection Operations Management Plan

Oil and gas field operations are often managed through a Reservoir Management Plan or an Operations Management Plan, which outlines how a field will be developed. The Gorgon Joint Venturers propose to adopt this process to assist in the management of the CO_2 injection operations. The primary objective of the CO_2 Injection Operations Management Plan will be to maximise the volume of reservoir CO_2 injected whilst ensuring that injection does not pose a health or safety risk to people, an environmental risk to the conservation values of Barrow Island, or a risk to other assets such as oil or gas field operations around Barrow Island.

Responses to the unpredicted migration of CO_2, the avoidance of unacceptably high formation pressures, and ensuring that existing well penetrations are appropriately managed, are critical to the overall environmental and safety performance of the CO_2 injection operations. Management actions to ensure effective performance in these areas have been developed.

13.5.2 Potential Failure Modes Related to Carbon Dioxide Injection

The Gorgon Joint Venturers have undertaken a study to identify potential risks associated with the proposed injection of CO_2 into the Dupuy Formation. This study commenced with a Failure Mode and Effects Workshop conducted in accordance with the principles and guidelines contained in AS/NZS 4360 (2004) for risk management and AS/NZS 3931 (1998) for risk analysis of technological systems.

The objective of the workshop was to identify credible threats of failure of the proposed injection project, either through a failure in the injection facilities or a failure which might result in the loss of containment in the target reservoirs.

The probability of CO_2 migrating to the surface has been determined to be remote with potential environmental consequences limited to localised impacts on flora and possible detrimental impacts on subterranean fauna.

13.6 Greenhouse Gas Management Plan

The Gorgon Joint Venturers have developed a Greenhouse Gas Management Plan as a tool to further reduce greenhouse gas emissions from the proposed Gorgon Development. The Greenhouse Management Plan documents:

- the Gorgon Joint Venturers' participation in a range of government programs aimed at reducing greenhouse gas emissions, including the reporting of greenhouse gas emissions and reduction efforts under those programs
- performance indicators and the establishment of longer-term performance targets for those indicators
- planned actions to be taken by the Gorgon Joint Venturers to minimise greenhouse gas emissions from the Gorgon Development with the objective of meeting the set performance targets.

14 Social and Cultural Environment – Effects and Management

Both positive benefits and negative social risks will be created by the Gorgon Development. The Development will generally benefit the livelihoods and lifestyles for the Pilbara community through employment and local business opportunities. There is a strong linkage between the social and economic benefits of the proposed Development. Major benefits include increased employment and training initiatives and opportunities for increased participation by Indigenous people. Potential adverse social risks are mainly associated with cultural heritage, native title issues on the mainland, and workforce and family through implementation of a fly-in fly-out (FIFO) regime.

14.1 Government Policy and Plans

There are a wide range of social and economic plans designed to provide policy and guidance to local, regional, state and federal governments. The Gorgon Development will have implications for a number of these plans.

At the local level, Town Planning Schemes and Structure Plans provide guidance for development on the near and onshore areas of the Australian mainland. The applicability of the Shire of Ashburton Town Planning Scheme No. 7 to the Gorgon Development is currently being determined. The key regional plans for the Pilbara are the Pilbara Land Use Strategy and the Pilbara Regional Priority Plan. The former presents a strategic 25-year plan for the Pilbara and identifies broad objectives for the land use and development.

The key state legislation, policies and plans that have implications for the social impact issues are the *Barrow Island Act 2003* and State Agreement (see Section 2), the Western Australian Sustainability Strategy, and the State Planning Strategy and Regional Development Policy.

The potential socio-economic impacts (risks and benefits) of the Gorgon Development to the various federal government policy and plans include: perceived reduction in potential opportunities for industrial development in the Pilbara region as a consequence of development on Barrow Island; use of a FIFO workforce with potential loss of opportunities for local personnel; opportunities for increasing participation of local indigenous workforce by supplementing education and training; and the transfer of knowledge and technology.

14.2 Local Communities

The Gorgon Development will result in minor population changes in the Pilbara and Western Australia. The most significant changes would occur in Dampier/Karratha area should the Development require the construction of a supply base. The construction workforce of 130–140 workers for a potential new supply base may generate a short-term (40-month) demand for the services such as health, welfare, emergency response, transport and other services.

The significant majority of the Development workforce will be located on Barrow Island and will generate limited demand for social infrastructure in the Pilbara region or Perth. This situation would be substantially different if the Development were located on the mainland, as demand impacts on social infrastructure would be increased.

During operation, the population increase (if any) will be insignificant, and will have no major or serious impact on the local communities or social infrastructure. The residual risk for local communities is low.

14.3 Livelihoods and Lifestyle

Major resource projects have contributed significantly to the social, economic and cultural setting in the Pilbara region. It is unlikely that the Gorgon Development will change the way of life for a construction workforce which historically is engaged in FIFO employment in the resources sector. While there may be potential impacts, or specific Gorgon Development issues, it is expected that these differences will be managed through employee relations, employment sourcing and workforce health and safety systems. Some of these issues include: employment opportunities of the existing workforce; the staffing levels during construction and operations; the work schedules during construction and operation; recreation facilities and future access to Barrow Island.

A number of plans to identify and enhance the social opportunities are being developed. The Gorgon Development Australian Industry Participation Policy (AIPP) outlines the approach to local content and procurement. This Policy specifies a commitment to provide full, fair and reasonable opportunity for Australian industry to supply goods and services to the Development. In accordance with the Barrow Island Act, a Social Impact Management Plan (SIMP) is being developed in close consultation with Western Australian government agencies to enhance social opportunities. The SIMP is being prepared during the proposal stage of the Development and will be subject to Ministerial approval, but is separate from the EIS/ERMP process. At the local level, the Joint Venturers will continue to work through community groups in the region to ensure potential impacts are identified, managed and activities in the region are coordinated.

14.4 Land and Sea Use and Tenure

The Gorgon Development will not change the Class A Nature Reserve designation and tenure of Barrow Island which will remain with the state.

The water surrounding Barrow Island is part of the area covered by the Montebello–Barrow Islands marine conservation reserves (CALM 2004). The majority of the conservation area is zoned as a Marine Management Area, which is recognised for both commercial and conservation values. The Barrow Island Marine Park and Bandicoot Bay conservation area (benthic fauna/seabird protection) will provide additional protection for Biggada Reef and Bandicoot Bay. A large area off the east coast of Barrow Island is currently a designated port (refer to Figure 8-1).

The existing oil operations on Barrow Island will not be physically impacted by the Development in a substantial way as most of the infrastructure (pipelines) and gas processing is proposed to be located north and east of the existing oil field; and is not competing for similar hydrocarbon resources. It is expected that there will be synergies between the oil operations and the proposed Gorgon Development.

Should the domestic gas pipeline tie-in with the existing Bunbury to Dampier pipeline at Compressor Station 1, an easement over Crown lands located on the Australian mainland will be required. The pipeline will be located on Mardie Station, a rural pastoral lease area.

The waters off the Pilbara Coast are used extensively for oil and gas development with the entire proposed Development area covered by leases/licences granted under the *Petroleum (Submerged Lands) Act 1967.* The stretch of water between Barrow Island and the mainland contains management areas and leases for other purposes, such as: commercial fisheries zones, native title claim areas (near-shore) and a mangrove management zone.

The Gorgon Development will not change the boundaries or underlying designation of the management areas or zones and the potential impact is considered low.

14.5 Native Title

There are no native title claims over Barrow Island or to north-west of Barrow Island over the Gorgon or Greater Gorgon gas fields. There are currently three registered native title claims that may overlap the proposed domestic gas pipeline route option and associated shore crossing onshore seas approach to the mainland. The Joint Venturers intend to engage in appropriate, good-faith negotiations with the indigenous communities. Constructive and inclusive dialogue will maximise the potential for positive impacts and resolve any potential issues.

14.6 Cultural Heritage

No ethnographic surveys have been undertaken on Barrow Island or the onshore domestic gas pipeline alignment. However, from earlier work conducted by Apache Energy, and their predecessor Hadson Energy Resources Corporation, two ethnographic sites associated with Peters Creek are known to be located adjacent to the Apache Energy export pipeline on the mainland, in the general vicinity of the proposed domestic gas pipeline route. A further detailed survey prior to commencement of construction will confirm whether these sites, or other potential sites, may be affected by the Development.

Only two of the 13 registered indigenous sites on Barrow Island were identified as being close to the Development area. Both of these sites were artefact scatters. Prior to construction, all proposed ground disturbance areas (including the seabed) will be surveyed for indigenous, historical and maritime cultural heritage evidence. Emphasis will be on areas of high site potential such as clay pans, shore lines, freshwater and drainage areas.

A survey for indigenous sites was undertaken for the earlier Apache Energy/Hadson pipeline projects. Six archaeological sites were identified in the general area of these pipelines, but none were disturbed during the construction of these facilities. An archaeological survey of the proposed mainland domestic gas pipeline corridor will be undertaken. Any new sites identified will be avoided where practical. Where avoidance is not possible, the site will only be disturbed in accordance with clearance procedures specified in the Western Australian *Aboriginal Heritage Act 1972.*

A draft Cultural Heritage Management Plan (CHMP) has been developed to assist in avoiding or minimising potential impacts during the construction and operation of the Gorgon Development. This plan will be refined further in the current phase of Development planning. Consultation with Aboriginal groups will continue throughout the Development phases and good-faith negotiations will be undertaken should an easement for the domestic gas pipeline be required.

Overall residual risk for cultural heritage will be low during site selection and design, medium during construction, and low during operations and decommissioning.

14.7 Historical and Maritime Heritage – Terrestrial

One known historical site (a glass artefact scatter) has been located at the alternative feed gas pipeline shore crossing at Flacourt Bay. There is the potential for additional sites to be identified, particularly in the coastal zone of Barrow Island which may include subsurface cultural material buried by cyclone and dune aggradation.

There is one known mainland historical site in the vicinity of the domestic gas pipeline route (the remains of a reported shipwreck close to the Apache pipeline). Potential exists for other similar sites to be present in the vicinity of the domestic gas pipeline route.

Detailed surveys for historical sites will be undertaken following finalisation of the footprint well in advance of any surface disturbance or construction. The residual risk from the Development to historical heritage sites is low to medium with the greatest risk occurring during construction.

14.8 Maritime Heritage – Subsea

No shipwreck sites have been identified or recorded in the immediate area of the proposed Gorgon Development. Review of underwater video surveillance, side-scan sonar and bathymetry surveys of the general pipeline routes, the pipeline shore approaches, materials offloading facility and LNG shipping channel and turning basin has not produced any evidence of maritime heritage sites.

14.9 Landscape and Aesthetics

A visual assessment of the proposed Gorgon Development was undertaken to evaluate the degree to which its components (subsea wells, pipelines, gas processing facility and marine infrastructure) would change the 'seen' or visual amenity of the existing landscape (Figure 14-1).

The residual risks during construction are medium and during operation low. The medium risk is derived from the fact that landscape values will definitely be impacted by the proposed Development. Overall, however the number of receptors is very low and the impact is of low consequence. Following decommissioning the site at Barrow Island will be rehabilitated and some of the landscape values can be returned.

14.10 Workforce and Public Health and Safety

Protection of the workforce health and safety during both construction and operations is important to the Joint Venturers. Utilising expert personnel and the Chevron Operational Excellence Management System (OEMS), the potential health and safety hazards and risks to Development personnel will be identified and assessed, then the subject of substantial planning, organisation and procedural/facility development.

Hazard and Operability (HAZOP) studies will be conducted for Development components. Hazard and risk workshops will be held with a wide range of professionals in relation to the construction, commissioning and operation phases of the Development facilities to identify all hazards and risks, assess those hazards and risks identified and develop controls to manage these hazards and risks.

14.11 Public Risk Assessment

The level of risk to the public for the all of the Gorgon Development facilities was determined to be acceptable given the surrounding land use and the number of physical and procedural controls incorporated into the pipeline design, construction and operation complying or exceeding the controls criteria as provided by Australian standards.

Compliance with Australian standards requires that risk from each identified threat be as low as reasonably practicable through all stages of design, construction, operation and decommissioning.

Plate 14-1:
Viewing Simulation Looking North on Ridgeline from Camp (approximately 4 km from gas processing facility site)

15 Economic Environment – Effects and Benefits

The economic benefits resulting from the proposed Gorgon Development will have national, state and regional dimensions. The proposed Development will contribute substantial, positive economic benefits to Australia and Western Australia, derived from the combination of: export income; tax and royalty revenue paid by the Joint Venturers; increased supply and competition in the domestic gas market; businesses and individuals employed; and the amount of money spent in the local economy.

Using two independent economic models, AE-MACRO and MMRF-GREEN, a number of major benefits to Australia and Western Australia's economies were identified. At the national level some of the key benefits will include: approximately $17 billion in revenue from company tax and Petroleum Resources Rent Tax (PRRT); an increase in Gross Domestic Product (GDP) of approximately $3.6 billion by 2030 (depending on model and scenario used); and an increase of exports in excess of $2 billion per year (at today's prices) during operation. At the state level, Western Australia's economic welfare is expected to improve by approximately $4 billion, which is one-sixth of the total Australian economic welfare. Western Australia will also benefit from significant improvements to business investment and Gross State Product (GSP) (Figure 15-1).

In response to increased revenues and economic growth, governments may increase expenditures, and reduce the average personal income tax rate to keep the ratio of public debt to GDP from falling. In turn, such income tax reductions would stimulate further economic growth. This general growth will provide flow-on benefits for business, employment and government revenues. Western Australia and the Pilbara region will benefit from increased demand for goods and services that will further stimulate business development and employment opportunities.
The proposed Development is predicted to generate and sustain over 6000 jobs on average through the decades of operation, with 1700 generated in Western Australia (Figure 15-2).

Currently, the regional economy of the Pilbara is not large enough to provide all of the labour, goods and services that will be required by the Development. With increased labour and service demand, there is a risk that regional prices for goods and services will increase. This impact may be compounded by the influence of other large resource project activity scheduled for the area. Both economic models examined the potential for crowding-out investment opportunity and predicted that the proposed Development will have limited impact on this opportunity.

Figure 15-1:
Gorgon Development – Contribution to National GDP and Western Australian GSP (Net Present Value in 2002)

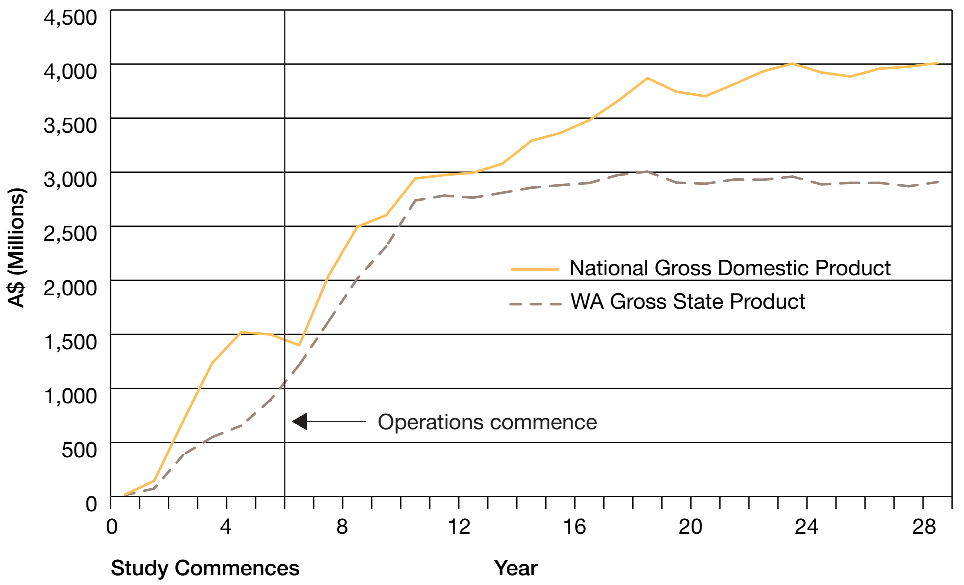
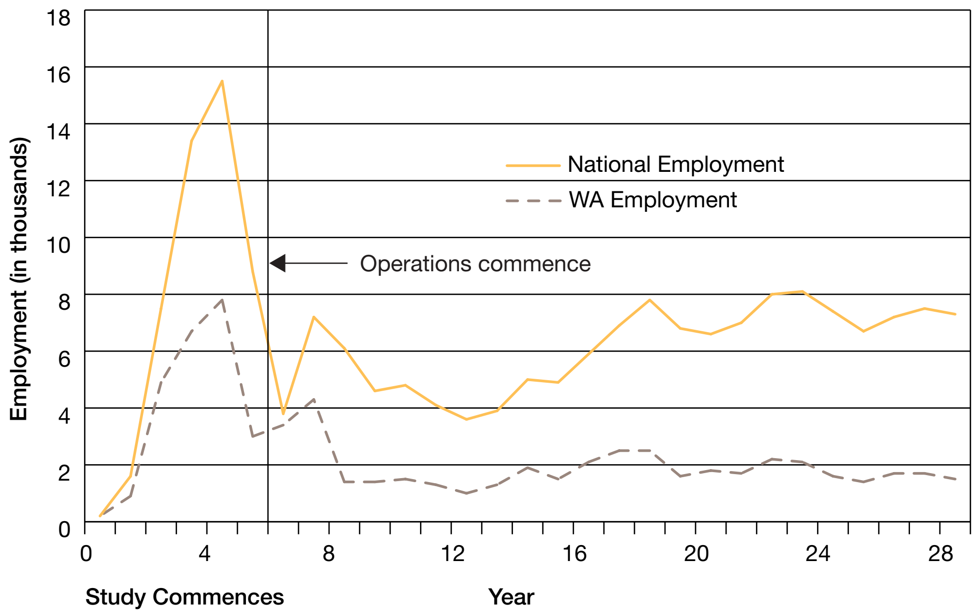


Figure 15-2:
Gorgon Development – Contribution to National and Western Australian Employment



16 Environmental Management Framework

The Joint Venturers are committed to conducting activities associated with the proposed Gorgon Development in an environmentally responsible manner; and will aim to implement best practice environmental management as part of a program of continuous improvement. To assist in meeting this commitment, a comprehensive Environmental Management System (EMS) will be developed that is consistent with recognised international standards and Chevron's Operational Excellence Management System. As part of this process an integrated series of Environmental Management Plans (EMPs) will be developed progressively though three related stages.

16.1 Environmental Management System

The Gorgon Joint Venturers will develop a project-specific EMS that is consistent with the recognised international standard AS/NZS ISO 14001:2004, Environmental Management Systems – Specification with Guidance for Use (ISO 14001). This standard has been selected because it is a proven method of establishing effective systems for environmental management generally, and contains all of the elements necessary to manage threats to the important conservation values of the Development area. The system will also be consistent with Chevron's established Operational Excellence Management System (refer to Box 16-1).

A key purpose of the EMS is to ensure that all environmental management measures presented in the Draft EIS/ERMP, and refined during further planning, design, construction and operation are captured and implemented in an effective manner.

The key elements of the proposed management system are outlined in Table 16-1.

Box 16-1:
Chevron Operational Management System

Operational Excellence is the systematic management of safety, health, environment, reliability and efficiency to achieve world-class performance. It is a common process applied to Chevron's operations around the globe in order to:

- achieve an injury-free work place
- eliminate spills and environmental incidents, and identify and mitigate key environmental risks
- promote a healthy workplace and mitigate significant health risks
- operate incident-free with industry leading asset reliability
- maximise the efficient use of resources and assets.

The Operational Excellence Management System consists of three parts:

- Leadership Accountability
- Management System Process
- Operational Excellence Expectations

Table 16-1:
EMS Elements

System Element	Detail
Policy	Chevron Policy 530 Protecting People and the Environment will be adopted.
Objectives and Targets	Environmental objectives listed in the draft EIS/ERMP and the Gorgon Development sustainability principles will be incorporated into the EMS.
Leadership and Commitment	The visible commitment of senior management will demonstrate the importance of sound environmental management.
Organisation Structure and Responsibility	The EMS will clearly define the organisation for the overall management of activities and operations. All personnel associated with the Gorgon Development will be responsible for delivering HES performance.
Operational Control	An integrated series of Environmental Management Plans (EMPs) will be developed progressively though three related stages: A Framework EMP; the detailed EMP series; and the Contractor EMIPs.
Documentation and Reporting	All elements of the EMS will be documented and managed through the existing Chevron Australia document control system. Internal and external reporting requirements will be clearly documented, and will include a public reporting process to inform stakeholders of the status and progress of key environmental issues.
Training, Awareness and Competence	The Joint Venturers will establish and maintain procedures for inducting and training all employees and contractors with regard to their environmental management responsibilities.
Monitoring	Detailed monitoring programs will be developed, in consultation with the Barrow Island Coordination Council, key regulatory agencies, and the Conservation Commission of Western Australia, to address construction and operational activities which have the potential to adversely impact the environment.
Auditing	A detailed environmental audit program will be developed in consultation with the Environmental Audit Branch of the Western Australian Department of Environment (DoE).
Non-Conformance and Corrective Action	Investigation and corrective action procedures will be established to determine the cause of non-conformance; identify and implement corrective action; initiate preventative actions; apply controls to ensure that preventative actions are effective; and record any changes in written procedure resulting from the corrective action.
Emergency Preparedness and Response	Emergency response procedures will address all credible risks associated with Development activities (such as hydrocarbon or chemical spill, fire, quarantine breach, and fauna injury). Procedures will be implemented through the Barrow Island Coordination Council.
Incident Reporting	Chevron Australia has a robust and proven incident management and investigation process. The Joint Venturers will revise this process where appropriate.
System Review	The Joint Venturers will assess the adequacy and effectiveness of the management system annually during construction and the first few years of operation, and address identified deficiencies.

16.2 Environmental Management Plans

Environmental Management Plans will form the cornerstone of the Gorgon Joint Venturers' EMS as they will document actions and responsibilities for protection of the conservation values of the Development area. The Plans will be developed in three related phases (Figure 16-1).

Framework EMP

The Framework EMP compliments the material presented in the main body of the Draft EIS/ERMP as it brings together activity-specific environmental management and protection measures currently under consideration. The document has been structured to address the major Development activities associated with construction and commissioning (e.g. drilling, pipe laying and earthworks) and the major Development components (e.g. offshore wells, feed gas pipeline and gas processing facility). The core of the Framework EMP is a set of environmental protection and management measures to avoid, reduce or mitigate environmental impacts.

The Framework EMP has a specific lifespan in its current form. Its purpose is to provide stakeholders with the opportunity to better understand the management measures proposed for construction and commissioning of the Gorgon Development. Following review of the Draft EIS/ERMP by the public and regulatory agencies, the Framework EMP will be used as a basis for, and be superseded by, the detailed EMP series.

The Detailed EMP Series

The detailed EMPs will guide the activities of specific workforce groups working on particular components of the Development (i.e. dredging and spoil disposal, construction of the construction village, onshore feed gas pipeline construction, etc.). They will address normal operations, unplanned incidents and emergency situations.

The Plans will be developed and documented through a systematic and consultative process to address environmental factors and risks identified during the environmental impact assessment phase. The documents will be prepared to the satisfaction of the Commonwealth Department of the Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA), upon advice from relevant regulatory agencies.

Detailed EMPs will be prepared progressively in the lead-up to the specific activity taking place. That is, some detailed EMPs, such as those for preparation of the Gas Processing Facility site, will need to be prepared in draft form prior to Ministerial approval of the Gorgon Development, as the activities will need to commence shortly after approval. Detailed EMPs for other activities, such as drilling or construction of the domestic gas pipeline, will not need to be prepared until after this time, as the activity may not occur for 12 months or more, and will be more meaningful when a greater level of engineering detail is available.

Operations EMPs will be developed during the late construction phase. Similarly, the Decommissioning EMPs will be prepared at an appropriate stage during the operation phase.

The detailed EMPs will build on the material contained in the Draft EIS/ERMP and include more detailed location-specific engineering and environmental information. In addition, the detailed EMPs will be prepared with input from government agencies and in consideration of public comment; and will incorporate conditions of approval and relevant legislative requirements and industry standards (Figure 16-2).

Figure 16-1:
Phases of EMP Development

Figure 16-2:
Inputs to Detailed EMPs

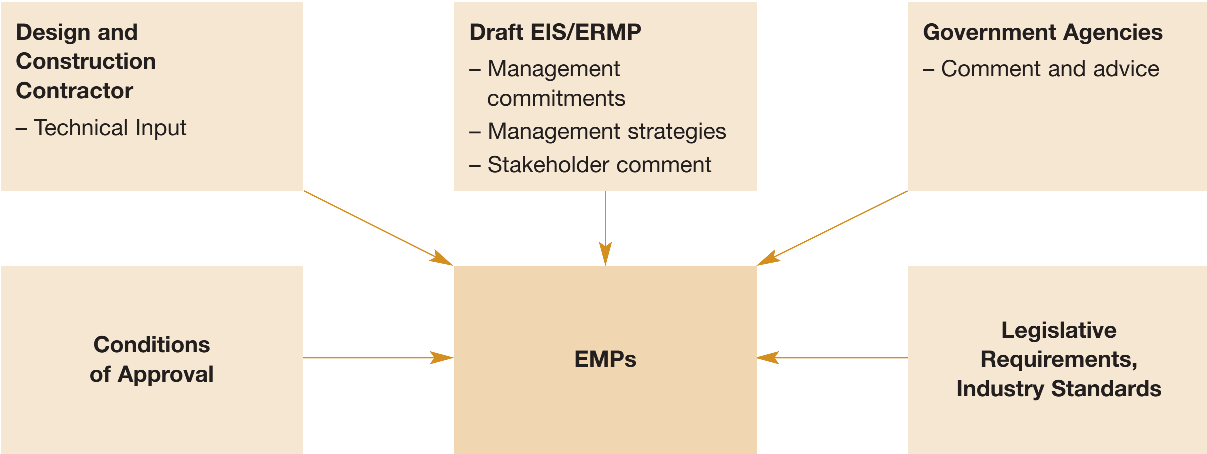


Table 16-2:
EMP Structure and Content

EMP Component	Content
Development Activity/Issue	The construction or operation activity to be managed (e.g. vegetation clearing at gas processing facility site).
Relevant Environmental Factor/s	Environmental factor/s that may potentially be affected by construction or operation activity to be managed (e.g. flora, fauna and cultural heritage).
Environmental Objective/s	The environmental management objective/s that relates to the environmental factor/s potentially affected by proposed construction or operation activity.
Performance Criteria	Measurable performance criteria for construction and operation activities.
Implementation Strategy	Detailed strategies and procedures to avoid, mitigate or minimise impacts of tasks or actions that will be implemented to achieve performance criteria.
Monitoring	Monitoring requirements to measure performance (i.e. specified indicators of change).
Auditing	Auditing requirements to demonstrate implementation of agreed construction and operation environmental management strategies and compliance with agreed performance criteria.
Reporting	Format, timing, and responsibility for reporting and auditing of monitoring results.
Corrective Action/s	Action required when performance requirements are not met and person(s) responsible for undertaking the corrective action.
Review	Process and timing for review and update of the EMPs.

Detailed EMPs will cover all Development components, with the final structure of construction EMPs determined during the detailed design phase in conjunction with the design and construction contractor, to the satisfaction of the EPA and DEH. Currently, the following EMPs are proposed, with the general structure for each plan as indicated in Table 16-2:

- Upstream Field Infrastructure (Manifolds and Flowlines).
- Offshore Feed Gas Pipeline.
- Onshore Feed Gas Pipeline.
- Gas Processing Facility, Camp and Associated Infrastructure.
- Port Facilities (materials offloading facility and LNG Jetty).
- Dredging and Dredge Spoil Disposal.
- Drilling (Offshore).
- CO_2 Injection System (Pipeline and Wells).
- Domestic Gas Pipeline and Associated Infrastructure.
- Greenhouse Gases.
- Optical Fibre Cable.
- Mainland Supply Base.
- Quarantine Management.
- Waste Management.
- Spill Contingency and Response.
- Cultural Heritage Management.

Contractor EMIPs

Environmental Management Implementation Procedures (EMIPs) will be prepared by the design and construction contractors. These internal project documents will build on the environmental protection measures contained in this Framework EMP and the detailed EMPs approved by agencies. The procedures will be finalised and approved by the Gorgon Joint Venturers prior to the construction activity being undertaken.

17 Conclusion

The Draft EIS/ERMP is the primary source of information for the public and regulatory decision-makers in their assessment of the potential environmental impacts of the proposed Gorgon Development.

During the course of preparing the Draft EIS/ERMP, the Gorgon Joint Venturers have addressed the environmental, social and economic issues associated with the proposed Gorgon Development using a rigorous risk-based assessment approach. These issues are relevant to the *Environmental Protection Act 1996* (WA), the *Environmental Protection and Biodiversity Conservation Act 1999* (Commonwealth) and the *Environmental Protection (Sea Dumping) Act 1981* (Commonwealth) and were identified in the Guidelines for an Environmental Impact Statement and Environmental Scoping Document for an Environmental Review and Management Programme (the Scoping Document) (ChevronTexaco Australia 2004).

The major ecological issues investigated during the environmental assessment process, using a risk-based approach, were:

- biodiversity and conservation values of Barrow Island and its surrounding waters
- quarantine management
- disposal of reservoir CO_2 by injection into the Dupuy Formation.

The Gorgon Joint Venturers are committed to adopting specific management measures that will protect the conservation values of Barrow Island and the Development area. The management measures, which are described throughout the Draft EIS/ERMP, particularly in Chapters 10–14, will reduce to acceptable levels the environmental risks associated with the Gorgon Development. To assist regulatory agencies, stakeholders and other interested readers, a consolidated list of commitments is provided (refer Attachment 1). In addition to these specific commitments, the design, construction and operation of the Gorgon Development will be guided by ten principles of conduct as outlined in Table 17-1.

If approval for the proposed Development is granted by the relevant ministers, the Gorgon Joint Venturers will be required to meet a range of commitments and obligations under the State Agreement of the *Barrow Island Act 2003*. Additional environmental assessment and management requirements would also apply to the Development under state and federal legislation.

The Gorgon Joint Venturers are committed to sustainable development and are committed to meeting each of the ten Gorgon Development sustainability principles by integrating them into its policies, practices and procedures (ChevronTexaco Australia 2003). The Gorgon Venturers' progress toward sustainability will be assessed through an annual sustainability reporting process which will utilise the sustainability criteria and measurement statements developed during the ESE Review process to measure performance against each of the sustainability principles.

Table 17-1:
Principles of Conduct for Sustainable Management of the Gorgon Development

Legislative Compliance	The Joint Venturers will design, construct and operate the Gorgon Development in a manner that complies with all relevant legislation.
Sustainable Development	The Joint Venturers will design, construct and operate the Gorgon Development in a manner that is consistent with its ten Sustainability Principles, which reflect those of the EPBC Act.
Footprint Compliance	The Joint Venturers will design, construct and operate the Gorgon Development in a manner that complies with the *Barrow Island Act 2003,* under which no more than 300 ha of uncleared land is available to this or any future gas processing developments on Barrow Island.
Biodiversity Protection	The Joint Venturers will design, construct and operate the Gorgon Development in a manner that maintains ecological structure and function, protects biological diversity and the integrity of populations of listed species.
Quarantine Management	The Gorgon Joint Venturers will adopt a comprehensive quarantine management system to reduce the risks to the conservation values of Barrow Island and surrounding waters to acceptable levels.
Greenhouse Gas Management	The Gorgon Joint Venturers will adopt currently applied best practice greenhouse efficiency measures in the design, construction and operation of the Gorgon Development and will inject reservoir CO_2 into the Dupuy Formation below Barrow Island unless it is technically infeasible or cost-prohibitive.
Cultural Heritage Management	The Gorgon Joint Venturers will design, construct and operate the Gorgon Development in a manner that recognises and manages sites of cultural importance.
Management System Implementation	The Gorgon Joint Ventures will implement an Environmental Management System that is consistent with internationally accepted standards and incorporates best practice environmental management as part of a program of continuous improvement. Specific environmental management procedures will be documented in an integrated series of Environmental Management Plans developed during the next phase of design in consultation with regulatory agencies.
Stakeholder Engagement	The Gorgon Joint Venturers will seek the views of stakeholders and give due consideration to their interests in the design, construction and operation of the Gorgon Development.
Transparency	The Gorgon Joint Venturers will make the results of environmental baseline surveys, environmental assessments and monitoring programs available to government agencies, scientific organisations, academic institutions, industry groups and the public to further the understanding of the ecology of the Development area.

A risk-based approach was applied to identify and assess the most significant risks to Barrow Island's conservation values, following the recommendation of the EPA to develop a set of standards for acceptable risks to the conservation values of Barrow Island and demonstrate that these standards could be met with a high level of confidence. This process was undertaken in accordance with Australian standards for risk management and widely accepted best practice in environmental risk assessment.

Established risk management practices have been adapted to address potential quarantine threats to the conservation values of Barrow Island. The approach taken is consistent with EPA advice as it has engaged independent technical experts to develop and undertake a risk-based quarantine management process, and has involved the community in a transparent manner in the development of acceptable risk standards. This approach involved establishing an independent Quarantine Expert Panel and a community consultation process.

The Gorgon Joint Venturers' commitment to the responsible management of greenhouse gas emissions is evidenced by the results of benchmarking the anticipated LNG emissions efficiency performance from the Gorgon Development with other LNG facilities. There is currently one operating LNG facility in Australia and another under construction. The expected performance of 0.35 tonnes of CO_2e per tonne LNG to be produced (based on the reference case assumptions) exceeds both these facilities when greenhouse emissions related to gas production are considered.

There is a strong linkage between the social and economic benefits of the proposed Development. The most significant benefits will be economic. In particular, the substantial input into the Australian economy through increased taxation revenues, direct spending, opportunity for local government rating, increased security of supply and availability of natural gas, employment and training initiatives, incremental improvement in the capacity of the economy and the labour force to absorb major oil and gas projects and opportunities for increased participation by indigenous people will be the major Development benefits. The Gorgon Joint Venturers aim to work with Australian companies who can assist in building and delivering a world-class competitive and safe Development.

The Gorgon Development will also provide the impetus for the expansion of existing services and industries and attract a number of new ones. It will help underpin the development of new technologies and skills, for example in disposal of CO_2 by injection and subsea technology, thereby creating regional capacity for future growth. The proposed Development will also underpin a second major gas supply to the mainland for domestic industry.

17.1 Stakeholder Engagement and Way Forward

Comprehensive and effective community consultation, engagement and participation have been, and remain, key elements of the proposed Gorgon Development. Community involvement will continue throughout all stages of the proposed Development and, where relevant, will be incorporated into the Social Impact Management Plan pursuant to the State Agreement.

The Gorgon Joint Venturers will continue to meet with stakeholders, answer questions and seek feedback throughout the EIS/ERMP process. The federal and state government review of the Draft EIS/ERMP document and the 10-week public comment period will provide stakeholders with further opportunity to provide formal input into the environmental approvals process.

As an integral component of their commitment to transparency, the Joint Venturers will make the results of environmental baseline surveys, environmental assessments and monitoring programs available to government agencies, scientific organisations, academic institutions, industry groups and the public to further the understanding of the ecology of the proposed Development area.

The Joint Venturers recognise that the proposed Development is of national significance and believe that, if the $11 billion proposed Development is granted environmental approval, implementation of the management measures proposed throughout this document will continue to protect the conservation values of Barrow Island and the Development area, whilst contributing $17 billion to government revenue, creating 6000 jobs across Australia and stimulating significant future regional Development.

18 References

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Key Commitments – Attachment 1

Key Commitments

General			
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
1.1	The Gorgon Joint Venturers will implement an Environmental Management System (EMS), which is consistent with the recognised international standard AS/NZS ISO 14001:2004, Environmental Management Systems – Specification with Guidance for Use (ISO 14001).	Ongoing	
1.2	A series of Environmental Management Plans (EMPs) will be developed and documented through a systematic and consultative process according to an agreed timetable with the EPA and DEH, taking into consideration comments on the Draft EIS/ERMP and recommendations from relevant agencies.	Prior to construction of the relevant Development component	Various DMAs
1.3	The Gorgon Joint Venturers will share the use of key infrastructure and services on Barrow Island, whether a part of the existing Barrow Island operation or developed as part of the Gorgon Development in accordance with the Barrow Island State Agreement.	Ongoing	
1.4	Further environmental surveys will be undertaken prior to the commencement of construction to finalise selection of alternatives or preferred routes and/or locations and the survey results provided to CALM. These environmental surveys will include: • the flora of the proposed optical fibre cable route • flora and fauna in the CO_2 injection seismic monitoring area • vegetation communities containing *Acacia synchronicia* to the north of the existing airstrip • avifauna along the proposed domestic gas pipeline route • the distribution of shorebird habitats near the mainland shore crossings • the inter-nesting or hibernating flatback turtles at Town Point.	Prior to construction of the relevant Development component	CALM
1.5	A detailed Decommissioning Assessment and Plan reflecting industry best practice, including completion criteria, will be prepared and submitted 6 months prior to decommissioning to identify the best overall outcome.	At least 6 months prior to decommissioning	Various DMAs
1.6	Once gas processing operations have ended, the facility will be decommissioned and the equipment removed from site; and the land rehabilitated to a condition which is consistent with the surrounding environment.	Decommissioning	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Clearing & Earthworks

Environmental Management Objective/s:

- To maintain the abundance, diversity, geographic distribution and productivity of flora and fauna through the avoidance or management of adverse impacts and improvement in knowledge.
- To protect EPBC Act listed threatened species, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*
- To protect evolutionary significant units, including genetic races on Barrow Island.

Commitment Number	Commitment (Action)	Timing	Advice From*
2.1	Gas processing facilities, associated infrastructure and the CO_2 monitoring grid and injection wells will be located to preferentially use previously disturbed areas and limit the disturbance to that required for safe construction and operation.	During design, construction and operations	CALM, DoIR
2.2	Further survey work during the detailed engineering phase will be undertaken to assist with final alignments of the CO_2 monitoring grid and preparation of Environmental Management Plans, which will be undertaken to the satisfaction of the EPA and DEH.	During design and prior to construction	
2.3	Disturbance to important fauna habitats, listed fauna species, restricted flora and vegetation communities will be avoided where practicable.	During design, construction and operations	CALM
2.4	Significant fauna, such as bettongs, will be translocated from the Development area to alternative locations on Barrow Island in consultation with CALM.	During construction	CALM
2.5	No new quarries or borrow pits outside of the construction site will be created to support the Development on Barrow Island.	Construction and operations	
2.6	Site specific rehabilitation procedures including completion criteria will be developed and implemented in consultation with the relevant authorities for areas that are no longer required for operations or future works.	Prior to rehabilitation	CALM, DoIR
2.7	Rehabilitation of works sites and access roads will be undertaken to a condition consistent with the surrounding landscape.	Ongoing	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Fire & Emergency Response

Environmental Management Objectives:

- To ensure that there is no adverse effect on environment values or the health, welfare and amenity of people and land uses.
- To maintain the abundance, diversity, geographic distribution and productivity of flora and fauna through the avoidance or management of adverse impacts and improvement in knowledge.
- To protect EPBC Act listed threatened species, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*
- To protect evolutionary significant units, including genetic races on Barrow Island.

Commitment Number	Commitment (Action)	Timing	Advice From*
3.1	An Emergency Management Plan that includes integrated safety and emergency response systems will be prepared and implemented in consultation with the relevant authorities and neighbouring industry participants.	Prior to construction of the relevant Development component and then ongoing	FESA, CALM and local Shire
3.2	In the event that a fire is started as a result of the Development, then immediate corrective action will be taken to extinguish or contain the fire and its occurrence will be reported to relevant authorities.	Ongoing	CALM
3.3	The Gorgon Joint Venturers will participate in a research program, managed by CALM, on the ecological effects of fire regimes on Barrow Island.	Ongoing	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

CO_2 Injection

Environmental Management Objective:

- To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.

Commitment Number	Commitment (Action)	Timing	Advice From*
4.1	The Gorgon Joint Venturers will significantly reduce Development CO_2 emissions by injecting the reservoir CO_2 removed during the gas processing operations into the Dupuy Formation, provided it is technically feasible and not cost prohibitive.	During operations	DoIR
4.2	In the unlikely event that it should prove technically infeasible or cost prohibitive to inject the proposed volume of CO_2, the Gorgon Joint Venturers will consult with government with the intent of maximising the injection of CO_2 within the commercial constraints of the Gorgon Development.	Ongoing	DoIR
4.3	A CO_2 Injection Operations Management Plan will be prepared with the objective of maximising the volume of reservoir CO_2 injected whilst ensuring that the injection does not pose an unacceptable health, safety or environmental risk.	Prior to commissioning	DoIR
4.4	If at any time the Gorgon Joint Venturers consider that the injection of reservoir CO_2 represents an unacceptable risk to the environmental values of Barrow Island, or a safety risk, then the CO_2 injection operation will be suspended until such time as all risks are addressed.	During operations	DoIR
4.5	Appropriate arrangements will be made with the Barrow Island Joint Venture to ensure that all wells in the path of the migrating CO_2 are assessed and if required, worked over such that they are fit for service in a CO_2 environment.	During operations	DoIR
4.6	A CO_2 Monitoring Program will be prepared, implemented and reviewed in consultation with the relevant authorities.	Prior to commissioning and then ongoing	DoIR

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Atmospheric & Greenhouse Gas Emissions

Environmental Management Objective:

- To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.

Commitment Number	Commitment (Action)	Timing	Advice From*
5.1	The Gorgon Joint Venturers undertake to report on and manage greenhouse gas emissions from the Gorgon Development in accordance with the Gorgon Development Greenhouse Gas Management Plan. This plan includes a series of longer term greenhouse gas emission performance targets to be used to guide the further reduction of greenhouse gas emissions.	During operations	
5.2	The Gorgon Joint Venturers will continue to participate in government programs aimed at the voluntary reduction of greenhouse gas emissions.	Ongoing	
5.3	Energy efficiency studies will be undertaken during the detailed engineering and design of the Development.	During design	
5.4	The Development will be designed based on a ‘no routine flaring’ policy and will incorporate a high efficiency flare to reduce the portion of uncombusted hydrocarbon and particulates to as low as reasonably practicable (ALARP). A small flare is required to be in continuous service for safety and maintenance purposes.	During design and operation	
5.6	The Development will be designed and operated to reduce venting of process hydrocarbons.	Operations	
5.7	A monitoring program of key emission sources and types will be developed and implemented in agreement with the DoE.	Prior to commissioning and during operations	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Liquid, Solid & Hazardous Waste

Environmental Management Objectives:

- To ensure that liquid and solid wastes do not adversely affect groundwater or surface water quality or lead to soil contamination.
- To ensure that hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.
- To ensure that there is no adverse effect on environment values or the health, welfare and amenity of people and land uses.

Commitment Number	Commitment (Action)	Timing	Advice From*
6.1	A Waste Management Plan will be prepared and implemented for hazardous and non-hazardous wastes in consultation with the DoE and will include systems and details for individual waste streams and their disposal.	Prior to construction of the relevant Development component and then ongoing	Local Shire, DoIR
6.2	The Waste Management Plan will be based on the principles of eliminate, reduce, re-use, recycle, treatment and environmentally responsible disposal.	During design, construction and operations	
6.3	Solid waste will not be disposed of on Barrow Island, with the exception of waste concrete where it may be used by the existing oilfield operation.	Ongoing	CALM
6.4	A Hydrotest Water Management Plan will be prepared and implemented.	During design and commissioning	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Leaks & Spills

Environmental Management Objectives:

- To ensure that hydrocarbons and hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.
- To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones.
- To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.
- To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated.
- To protect EPBC Act listed threatened, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*

Commitment Number	Commitment (Action)	Timing	Advice From*
7.1	Spills and leaks will be contained, recorded and affected sites remediated.	During construction and operation	CALM, DoIR & Dept of Transport
7.2	Copies of Material Safety Data Sheets (MSDS) for all chemicals will be held on site and all materials managed (handled, stored and disposed of) accordingly.	Ongoing	
7.3	An Oil & Chemical Spill Contingency Plan (OCSCP) including emergency response measures will be prepared, implemented and reviewed in consultation with the relevant authorities.	Prior to construction of the relevant Development component and then ongoing	CALM, DoIR & Dept of Transport
7.4	Spill recovery and cleanup equipment will be provided and maintained at key marine and terrestrial locations as identified in the agreed OCSCP.	Ongoing	
7.5	Navigational exclusion zones will be created around seabed infrastructure to prevent accidental damage to facilities and local pilots will be used to berth ships.	During construction and operations	AMSA, Dept of Transport
7.6	Installed equipment will be designed and operated to prevent spills and leaks through the provision of in-built safeguards such as relief valves, overflow protection, and automatic and manual shut-down systems.	During design, construction and operations	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Noise & Vibration

Environmental Management Objectives:

- To avoid adverse noise and vibration impacts to fauna.
- To ensure that noise impacts emanating from the proposed gas processing facility comply with statutory requirements specified in the *Environmental Protection (Noise) Regulations 1997.*

Commitment Number	Commitment (Action)	Timing	Advice From*
8.1	An Environmental Management Plan for CO_2 monitoring with seismic will be prepared to the satisfaction of the EPA and implemented.	Prior to commencing seismic surveys	CALM, DoIR
8.2	An Environmental Plan for offshore seismic activities will be prepared to the satisfaction of DoIR and implemented.	Prior to commencing offshore seismic surveys	DoIR
8.3	Blasting will be scheduled for daylight hours to avoid activity peaks of nocturnal mammals.	During construction	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Light & Temperature			
Environmental Management Objectives: • To avoid or manage potential impacts from light overspill and shade and comply with acceptable standards. • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened, migratory species and Threatened Ecological Communities (TECs). • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*			
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
9.1	The following key lighting strategies will be employed: • The main gas processing facility shall be designed such that no permanently on-lighting is located within 500 m of turtle nesting beaches. • Use red/yellow/orange type of reduced spectrum light, such as sodium vapour as the primary lighting for the facility. • Use shielded white type lights in areas that require inspection during operator rounds and/or regular maintenance. These lights will be switched off when not required.	During design, construction and operation	CALM
9.2	Lighting levels will be reduced to those required for safe working and security; and, in areas where colour definition is not critical for safety or operational purposes, shielded red or mono-chromatic lights will be utilised.	During design, construction and operation	
9.3	Areas where land fauna may come into contact with extreme or hazardous temperatures, will be fenced or selectively cleared in consultation with the CALM to provide a suitable buffer.	During construction and operation	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Physical Disturbance & Interaction (See also – Clearing & Earthworks)

Environmental Management Objectives:

- To protect EPBC Act listed threatened, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*
- To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities and ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated.
- To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge.
- To protect evolutionary significant units, including genetic races on Barrow Island.

Commitment Number	Commitment (Action)	Timing	Advice From*
10.1	A Dredging and Spoil Disposal Management Plan (DSDMP) will be prepared in consultation with the relevant authorities to the satisfaction of EPA and DEH, and implemented.	Prior to commencement of dredging and then ongoing	Marine and Harbours
10.2	To reduce dredge spoil disposal volumes, material will be assessed for use in the construction of the causeway and the MOF.	During construction	
10.3	Shore crossing activities will be managed to reduce impacts during the peak turtle nesting period.	During construction	CALM
10.4	Shore crossing disturbance areas will be rehabilitated to a condition consistent with the surrounding landscape.	During construction	CALM, DoIR
10.5	A Marine Anchoring Management Plan will be prepared and implemented in consultation with the relevant authorities.	Prior to construction of the relevant Development component and then ongoing	CALM, DoIR and Dept of Transport
10.6	Programs will be established to encourage and foster environmental awareness and conservation with the workforce.	Ongoing	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Quarantine

Environmental Management Objective:

- To prevent the introduction and establishment of non-indigenous species to Barrow Island and its surrounding waters.

Commitment Number	Commitment (Action)	Timing	Advice From*
11.1	The Gorgon Joint Venturers will develop the Quarantine Management System in consultation with the relevant authorities to the satisfaction of the EPA and DEH, and implement the system.	Prior to construction and then ongoing	CALM
11.2	The Gorgon Joint Venturers will prepare, implement and periodically review specific quarantine management procedures for all pathways.	Ongoing	
11.3	Monitoring and eradication including incident response and reporting will be undertaken in accordance with the agreed Quarantine Management System.	Ongoing	
11.4	An expert Quarantine Advisory Group will be established to provide advice on quarantine management.	Prior to construction	CALM
11.5	Ballast water management practices will be audited by the Gorgon Joint Venturers to verify conformance with domestic and international regulations.	Ongoing	Dept of Transport
11.6	Targeted flora and fauna surveys will be undertaken to determine baseline data that will be used to judge the effectiveness of quarantine barriers.	Prior to construction	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Cultural Heritage & Native Title

Management Objectives:

- To ensure the cultural and heritage values on and around Barrow Island are not compromised by the Development.
- To ensure that all works are performed in accordance with the *Aboriginal Heritage Act 1972, Heritage of Western Australia Act 1990 and Maritime Archaeology Act 1973.*

Commitment Number	Commitment (Action)	Timing	Advice From*
12.1	Undertake archaeological and ethnographic surveys within the Development area in consultation with the identified Indigenous communities.	Prior to construction of the relevant Development component	DIA
12.2	Prior to construction all proposed ground disturbance areas (including the seabed) will be reviewed for indigenous, historical and maritime cultural heritage evidence.	Prior to construction of the relevant Development component	DIA, WA Museum, Maritime Museum, Heritage Council
12.3	The Development will be managed in accordance with a Cultural Heritage Management Plan, which will be prepared in consultation with the relevant authorities.	Prior to construction of the relevant Development component and during operations	DIA, WA Museum, Maritime Museum, Heritage Council
12.4	The Joint Venturers will undertake consultation and negotiations with indigenous Native Title claimants in relation to mainland activities such as the domestic gas pipeline and optical fibre cable.	Prior to construction of the relevant Development component	DIA, DoIR and Office of NT
12.5	If cultural heritage sites cannot be avoided, the relevant authorities will be consulted and management measures agreed.	Prior to construction of the relevant Development component	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Commitment Number	Commitment (Action)	Timing	Advice From*
	Social		
	Management Objective: • To ensure that there is no adverse effect on the health, welfare and amenity of the workforce or public.		
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
13.1	A Social Impact Management Plan will be prepared in consultation with relevant stakeholders.	Prior to construction	Key stakeholders
13.2	Where necessary, Traffic Management Plans will be prepared in consultation with the relevant authorities prior to the movement of non-standard construction equipment, machinery or vehicles on public roads.	During construction	MRWA, Police and Local Shires
13.3	Significant navigational changes or constraints due to construction and operating conditions will be communicated to mariners and commercial fishing operators.	During construction and operations	Dept of Transport
	Health & Safety		
	Management Objective: • To ensure that there is no adverse effect on the health, welfare and amenity of the workforce or public.		
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
14.1	Comprehensive Safety Management Systems and Plans will be prepared in consultation with the relevant authorities.	Prior to construction of the relevant Development component	DoIR, WorkSafe, and NOPSA
14.2	Emergency evacuation procedures will be established in consultation with the relevant authorities to remove injured personnel off Barrow Island to suitable medical facility.	Prior to construction of the relevant Development component	FESA and local Shire
14.3	Medical personnel will be located on Barrow Island throughout construction and operations.	Ongoing	
14.4	Regular inspections of the Development by company safety professionals will be conducted throughout construction and operations.	Ongoing	DoIR, WorkSafe, and NOPSA
14.5	Appropriate recreational opportunities and facilities will be provided within the construction village.	During construction	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Auditing, Monitoring & Reporting			
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
15.1	A comprehensive Environmental Monitoring Program will be established, implemented and periodically reviewed in consultation with the relevant authorities and will be used to guide ongoing management and corrective action. Specific localised monitoring activities will be included within the EMPs.	Ongoing	CCWA, CALM, DoIR, WA Museum, DIA, Health WA
15.2	An Environmental Audit Program will be established and implemented in consultation with DoE and DEH to determine whether the Development meets environmental objectives, proponent commitments and requirements of the Development's EMS and EMPs. The program will be used to guide ongoing management and corrective action.	Prior to construction of the relevant Development component and then ongoing	
15.3	A Barrow Island land use register will be established and maintained to track all clearing and rehabilitation activities associated with the Development and included in the Annual Environmental Report to authorities.	Prior to construction and then ongoing	
15.4	The status and progress of key environmental issues with be included in the public Annual Environmental Report.	During construction and operations	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

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Main Report

Volume I

Draft

Environmental Impact Statement/ Environmental Review and Management Programme

for the Proposed Gorgon Development

September 2005

GORGON

AUSTRALIAN GAS

Disclaimer

This Draft Environmental Impact Statement/Environmental Review and Management Programme (Draft EIS/ERMP) has been prepared by Chevron Australia Pty Ltd on behalf of the Gorgon Joint Venturers. In preparing the Draft EIS/ERMP, Chevron Australia has relied on information provided by specialist consultants, government agencies and other third parties who are identified in the Draft EIS/ERMP. Chevron Australia has not verified the accuracy or completeness of the findings, conclusions and observations of these consultants, government agencies and other third parties, except where expressly acknowledged in the Draft EIS/ERMP.

Note on Name Change

During the production of this Draft EIS/ERMP, ChevronTexaco Corporation changed its name to Chevron Corporation. As a consequence of this, ChevronTexaco Australia Pty Ltd changed its name to Chevron Australia Pty Ltd.

Copyright Note

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Title: Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development: Main Report

Main Report

Draft

Environmental Impact Statement/ Environmental Review and Management Programme

for the Proposed Gorgon Development

September 2005

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250 St Georges Terrace

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WA 6001 Australia

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Invitation to Comment

The Proposal

The Gorgon Joint Venturers propose to develop the Gorgon gas field that lies approximately 130 km off the north-west coast of Western Australia.

The proposed Gorgon Development is based on the installation of a subsea gathering system and a 70 km subsea pipeline to Barrow Island. The associated gas processing facility will be located at the central-east coast of the island. It is proposed to inject carbon dioxide, which occurs naturally in the reservoir, into deep formations below the island. Liquefied Natural Gas (LNG) will then be transported by ship to international markets. Domestic gas will be delivered to the Western Australian mainland through a subsea pipeline for use in industrial and domestic markets.

Assessment Process

Following referral of the Development in November 2003, the Commonwealth Department of the Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA) determined that the proposed Gorgon Development should be formally assessed at the Environmental Impact Statement (EIS) and Environmental Review and Management Programme (ERMP) levels, respectively.

The Commonwealth and Western Australian governments have agreed to a coordinated environmental assessment process. A single EIS/ERMP document that satisfies the requirements of each jurisdiction is required under this process. An Executive Summary is available as a separate document.

The Joint Venturers have prepared this Draft EIS and ERMP (Draft EIS/ERMP) in accordance with the EPA and DEH requirements as set out in the environmental scoping document and guidelines (ChevronTexaco Australia 2004). This Draft EIS/ERMP is being placed on public exhibition for 10-weeks during which time public submissions will be sought. The DEH and EPA will assess the Draft EIS/ERMP following receipt of public submissions, and the Joint Venturers' response to those submissions, before reporting to relevant Ministers for a final decision on whether the Development should be approved and if so, under what conditions.

Availability of the Draft EIS/ERMP for Public Comment

This Draft EIS/ERMP is available for public comment from 12 September 2005 until 21 November 2005. It can be viewed at the Gorgon Australian Gas website (www.gorgon.com.au) and at the following locations:

Department of Environment Library
Level 8, Westralia Square Building
141 St Georges Terrace
Perth WA 6000

Department of Industry and Resources
1st Floor, 100 Plain St
East Perth WA 6000

Research and Information Centre
Department of Industry and Resources
1 Adelaide Terrace
East Perth WA 6000

Department of the Environment and Heritage Library
John Gorton Building
King Edward Terrace
Parkes ACT 2600

Ashburton Shire Council
Onslow Public Library
Second Avenue
Onslow WA 6710

Karratha Community Library
Millstream Road
Karratha WA 6714

Battye Library
Alexander Library Building
25 Francis Street
Perth WA 6000

The Executive Summary of the Draft EIS/ERMP is available free of charge. The Main Report (Volumes I and II) and the set of Technical Appendices are available at a cost of $10 each. These can be obtained from Chevron Australia by telephoning the Gorgon Australian Gas Health, Environment and Safety Administration Assistant on 08 9216 4000 or emailing your request to gorgon.info@chevron.com.

Submission Process

Individuals and organisations are invited by the EPA and DEH to submit comments on this Draft EIS/ERMP. A submission may include comments, provide information, and/or express opinions about the information presented in the document. It will be useful if you include any suggestions that you have to improve the proposal.

Reasons for conclusions stated in the submission should be stated clearly and supported by relevant data. The source of your information should also be included where applicable. Comments from the public will assist government in making their decision.

All submissions received by the agencies will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Commonwealth *Freedom of Information Act 1982* and the Western Australian *Freedom of Information Act 1992.* Submissions may be quoted in full or in part of the agencies' reports.

The closing date for public submissions on this Draft EIS/ERMP is **21 November 2005.**

Submissions should be addressed to:

Chairman, Environmental Protection Authority
PO Box K822
Perth WA 6842

AND/OR

First Assistant Secretary
Approvals and Wildlife Division
Department of the Environment and Heritage
GPO Box 787
Canberra, ACT 2601

Why Write a Submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action – including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

Why Not Join a Group?

If you prefer not to write your own comments, it may be worthwhile joining with a group interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a Submission

You may agree or disagree with, or comment on, the general issues discussed in the Draft EIS/ERMP or the specific proposal. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

Submission Checklist

Comments should be in writing and:

- list points so that the issues raised are clear
- refer each point to the appropriate chapter and section in the Draft EIS/ERMP (e.g. Chapter 1, section 1.1)
- keep the discussion of different sections of the Draft EIS/ERMP distinct and separate
- include relevant, factual and supportive information with details of the source.

Also remember to:

- identify the Development (i.e. the Gorgon Development)
- provide your name, address and date of submission
- identify any special interest you have in the Development (where relevant)
- indicate whether your submission is to be kept confidential.

Foreword

On behalf of the Gorgon Joint Venturers, (Chevron Australia, Texaco Australia, Shell Development Australia and Mobil Australia Resources Company), I am pleased to present this Draft Environmental Impact Statement/Environmental Review and Management Programme for the proposed Gorgon Development. As the Commonwealth and Western Australian governments have agreed to a coordinated environmental assessment process, this document is designed to meet the assessment requirements of both jurisdictions.

The gas fields discovered in the Greater Gorgon area represent Australia's largest undeveloped gas resource. As the custodian of the resource, the Joint Venturers accept responsibility for developing this important national and state asset in a sustainable manner. A successful development will deliver substantial economic and social benefits to current and future generations of Australians, whilst also protecting the environmental values of the region and delivering net conservation benefits. This development will be the key to unlocking the vast Greater Gorgon area resources, which are equivalent to 25% of Australia's total known gas resources.

Restricted use of Barrow Island is central to the commercial viability of the development of the Greater Gorgon area gas fields. Exhaustive studies show there are no commercially viable development alternatives to this location. Barrow Island is an internationally significant nature reserve and the site of Australia's largest onshore operating oilfield. The Joint Venturers recognise the importance of the conservation values of Barrow Island and selected this location only after thoroughly assessing the viability of alternative locations.

The environmental management strategies developed to avoid or mitigate the potential impacts of the Gorgon Development will protect conservation and biodiversity values and enhance Chevron Australia's successful stewardship of Barrow Island. The Gorgon Development will also deliver a clean fuel that will increase security of gas supply and provide price competition for consumers. The proposed Development will stimulate economic activity and create jobs that will have flow-on social benefits. The potential beneficiaries of the Gorgon Development range from communities in the Pilbara and the state of Western Australia to the whole of the Australian nation and our international customers.

Chevron Australia, operator of the Barrow Island oilfield, has been involved in existing oilfield operations on the island for over 40 years. The management of these operations is widely recognised as a demonstration of the successful co-existence of petroleum operations and the protection and maintenance of conservation values.

Our success in managing oil operations on Barrow Island, as well as our diligence in preparing this plan, demonstrates our commitment to meeting our environmental responsibilities, whilst also meeting national and international clean energy demands.

James W Johnson
Managing Director
Chevron Australia Pty Ltd

01: Introduction

Proposal Title

This document is a Draft Environmental Impact Statement and Environmental Review and Management Programme (Draft EIS/ERMP) for the proposed Gorgon Development. It was prepared by the Gorgon Joint Venturers in accordance with the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Western Australian *Environmental Protection Act 1986* (EP Act).

The title of this proposal is 'the proposed Gorgon Development', which comprises a range of offshore and onshore infrastructure components to recover gas from the Gorgon gas field (Figure 1-1), and to process this gas at, and ship it from, a gas processing facility on Barrow Island. All construction, operation and decommissioning activities associated with this infrastructure are considered as part of the proposed Development.

1.1 Development Proponent

Chevron Australia is the operator and proponent for the proposed Gorgon Development (the key elements of which are outlined in Section 1.2.4) on behalf of the companies listed in Table 1-1. In this document, these companies are referred to together as ‘the Gorgon Joint Venturers’ (or the Joint Venturers).

The Gorgon Joint Venturers are subsidiaries of leading companies in the global oil and gas industry with proven technical and management skills for safe, efficient and environmentally responsible development.

These companies have a wealth of international and domestic experience in oil and gas processing and LNG operations covering all aspects of the Development, ranging from drilling to subsea production systems, offshore operations, gas plant operations, and product shipping. Between them, the Joint Venturers are involved in eight other LNG projects that are currently operating or under construction. About three-quarters of the world production of LNG is produced by joint ventures involving the Gorgon Joint Venturers.

The Joint Venturers also have extensive experience in injection of carbon dioxide (CO_2) into subsurface formations associated with oil recovery operations. This is another key area for the Gorgon Development as discussed in Chapter 13. The Rangely operation in the United States is one such example. Chevron Australia has also been working closely with the Geodisc program, and its replacement the Cooperative Centre for Greenhouse Gas Technologies (CO2CRC), to widen the knowledge base associated with CO_2 injection.

Table 1-1:
Addresses of the Gorgon Development Proponent and Joint Venturers

Company
Chevron Australia Pty Ltd Level 24, QV1 Building 250 St Georges Terrace Perth, Western Australia, 6000
Texaco Australia Pty Ltd Level 24, QV1 Building 250 St Georges Terrace Perth, Western Australia, 6000
Shell Development Australia Pty Ltd Level 28, QV1 Building 250 St Georges Terrace Perth, Western Australia, 6000
Mobil Australia Resources Company Pty Ltd 12 Riverside Quay, Southbank Melbourne, Victoria, 3000

Chevron Australia has been involved in the oilfield operation on Barrow Island for over 40 years that has produced some 300 million barrels of oil. Chevron Australia’s management of oil production activities on

Barrow Island is widely recognised as an industry benchmark for co-existence of petroleum development and the protection of conservation values (Box 1-1).

Implementation of conservation best practices underpins the success of the oilfield operations in managing quarantine and protecting the island from unauthorised visits. As a result, Barrow Island is free from introduced vertebrate pests such as rats, mice, cats, rabbits and foxes. Without Chevron Australia's environmental stewardship of the island, the same level of protection of the conservation values would have required a contribution of millions of dollars from the state of Western Australia. Chevron Australia's success in managing the conservation values of Barrow Island has been formally recognised by the receipt of a number of environmental awards (ChevronTexaco Australia 2003).

Box 1-1:
Barrow Island – Oilfield and Nature Reserve

Barrow Island is the centre for Chevron Australia's oil operations in Western Australia. It has been operating as a producing oilfield since 1967. The conservation value of the island has long been recognised and a successful environmental management program has been in place for almost 40 years of the oilfield operation.

Barrow Island is a unique remnant of the natural ecology with close affinities to the Cape Range area. In 1910, Barrow Island was proclaimed as a Class A Nature Reserve. The Class A status of the island reflects its importance as a refuge for wildlife species, some of which are endemic to Barrow Island and some of which are extinct, or near extinction, on the mainland. This island provides an indication of environmental conditions on the mainland prior to impacts such as weeds, feral animals and grazing following European settlement. The Reserve is vested in the Conservation Commission of Western Australia and managed by the Department of Conservation and Land Management (CALM) for the purpose of wildlife and landscape conservation, scientific study and preservation of features of archaeological, historic and scientific interest.

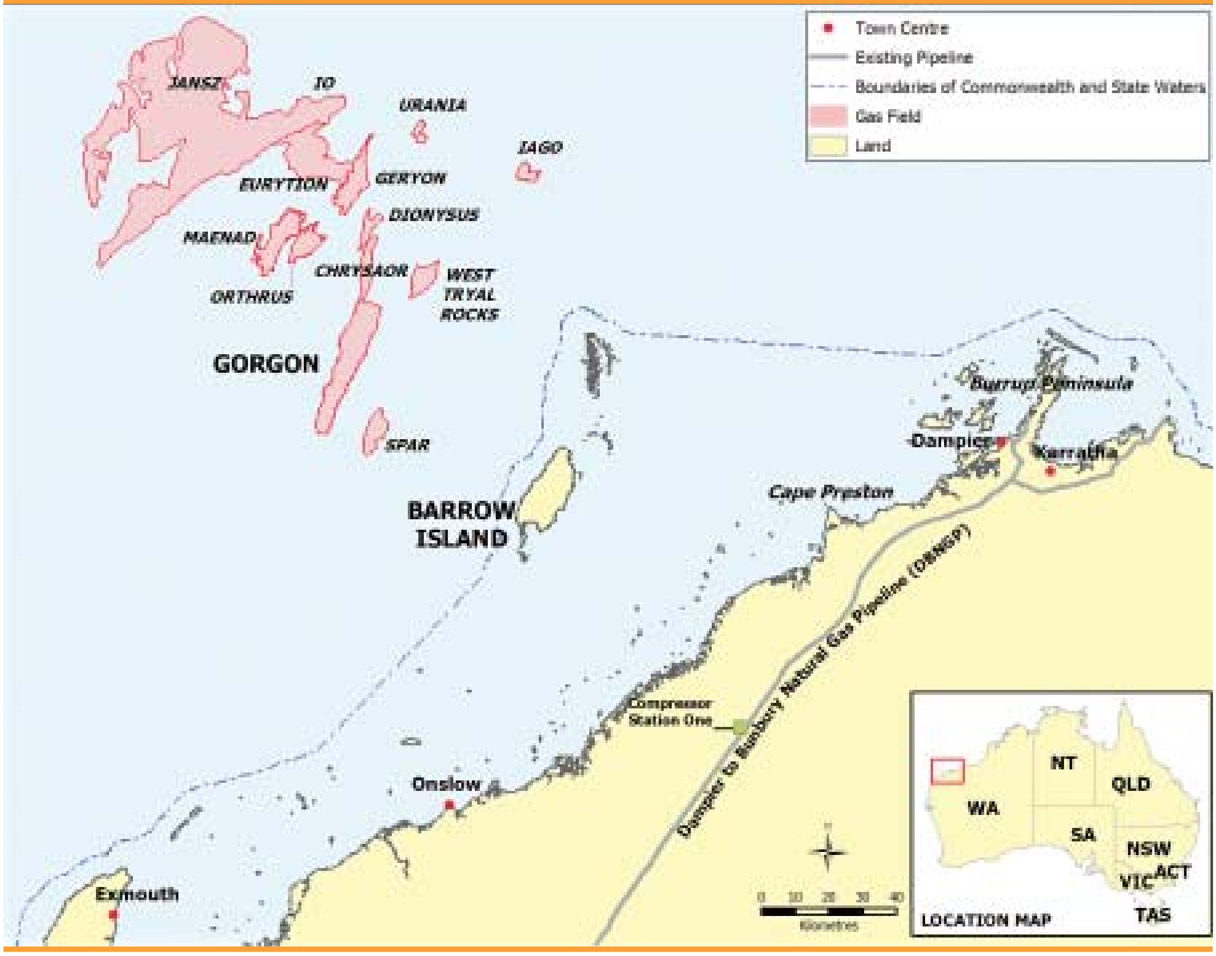
Barrow Island is the largest of a group of islands located off the Pilbara coast of Western Australia, 85 km north-north-east of the town of Onslow. Barrow Island is Western Australia's second largest island; it is some 25 km long and 10 km wide. The island has an arid climate with a highly variable rainfall (the average is about 320 mm per annum).

1.1.1 Environmental Commitment and Responsibility

Developing Gorgon gas in a sustainable manner is a major objective of the Gorgon Joint Venturers (Section 1.4). Further, the Joint Venturers are committed to conducting activities associated with the proposed Gorgon Development in an environmentally responsible manner; and aim to implement best practice environmental management as part of a program of continuous improvement. This will be achieved by addressing issues systematically, consistent with internationally accepted standards and the Chevron Operational Excellence Management System which includes the values and goals of the Chevron Health, Environment and Safety Policy (Policy 530) (Chapter 16). To fulfil its commitment to ensuring the Gorgon gas resource is successfully developed in an environmentally responsible and sustainable manner, the Joint Venturers will draw on their collective experience and the most appropriate technologies available.

During the planning and design of the Gorgon Development, a range of mitigation measures to prevent or minimise adverse environmental impacts have been taken into consideration. For example, the location for the feed gas pipeline shore crossing was moved to avoid sensitive rock wallaby habitat. Further, a range of management measures for identified adverse environmental impacts are presented throughout this Draft EIS/ERMP. In many situations, where impacts cannot be avoided, the implementation of these measures will: limit the degree or magnitude of the adverse impact; or rehabilitate any impacted sites. In addition, much of the assessment work and many of the proposed management strategies and monitoring programs have and will contribute significantly to the substantial body of scientific knowledge and understanding of the ecology of the Development Area – thus providing benefit as environmental offsets.

Figure 1-1:
The Gorgon Gas Field in Relation to North-West Australia



The Joint Venturers are proud of their environmental record and, in accordance with the requirements of Schedule 4 of the EPBC Regulations, confirm that none of the Venturers are the subject of any proceedings under a Commonwealth, state or territory law for the protection of the environment or the conservation and sustainable use of natural resources.

1.2 Development Overview

1.2.1 Resource under Consideration for Development

The Greater Gorgon area, situated over 130 km off the north-west coast of Western Australia, comprises the largest gas resource discovered to date in Australia (Figure 1-2). The reservoirs of untapped natural gas contain in excess of 1.1 Tera cubic metres (Tm^3) (40 Trillion cubic feet (40 Tcf)) of gas which represents some 25% of Australia's known gas resources. Development of this substantial national asset would secure Australia's position as a leading gas producer and generate a new source of wealth for Western Australia and Australia.

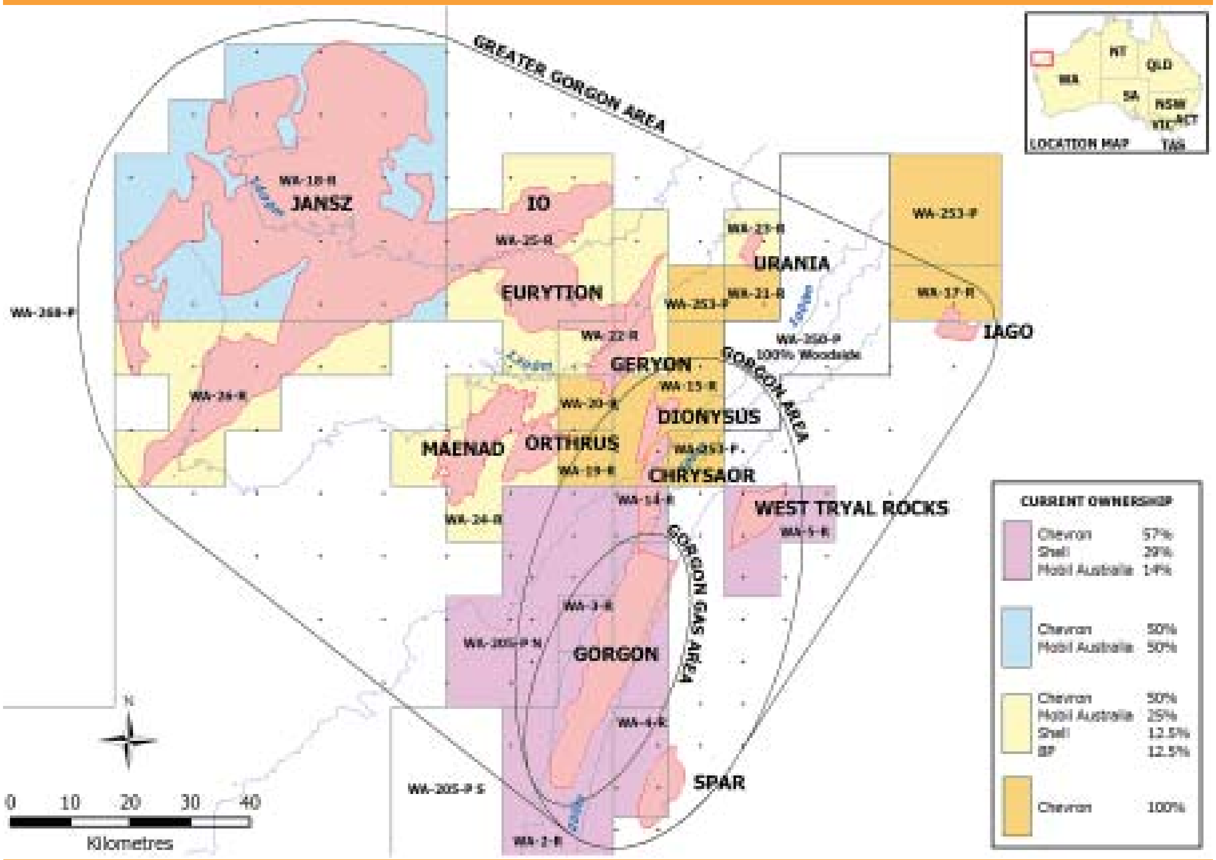
Box 1-2:
Gorgon Gas Resource Base

The gas fields of the **Greater Gorgon area** contain an estimated gas resource in excess of 1.1 Tm^3 (40 Tcf) and include the Gorgon area gas fields in relatively shallow water; and the Jansz field, among others, in deeper water further offshore.

The gas fields of the **Gorgon area** contain a technically proven and certified recoverable gas resource of 0.37 Tm^3 (12.9 Tcf) and includes the Gorgon, West Tryal Rocks, Spar, Chrysaor and Dionysus fields.

The **Gorgon gas field** is the largest field in the Gorgon area, a technically proven and certified resource of 0.27 Tm^3 (9.6 Tcf), and one of the largest fields ever discovered in Australia.

Figure 1-2:
The Greater Gorgon Area Gas Resource Base



NB: Ownership is subject to change pursuant to an agreement between Chevron Australia, Mobil Australia Resources Company and Shell Development Australia to align their interests on a 50/25/25 basis in certain permits. This change requires government approvals before it becomes effective.

The Gorgon Joint Venturers are considering developing the Gorgon field, which is located within the Greater Gorgon area (Figure 1-2 and Box 1-2). The Gorgon field contains approximately 0.27 Tm^3 (equivalent to 9.6 Tcf) of recoverable gas. The field retention lease is held by the Gorgon Joint Venturers and lies in Commonwealth waters approximately 70 km from Barrow Island.

The Gorgon and Jansz fields will be developed first due to the economics of field development, which is driven by the following factors:

- resource size, internal structure, and reservoir properties of each field
- amount of information available on each field
- gas composition of each field, including the amount of hydrocarbon liquids (condensate) and inert gases
- distance of each field from land
- water depth of each field.

The other fields of the Greater Gorgon area will be developed subsequently once production from the Gorgon and Jansz fields decline naturally; and/or as market demands dictate.

1.2.2 Background to this Development Proposal

Delivery of gas from the Greater Gorgon area gas fields will provide significant economic and social benefits to the state and nation, but developing the fields presents some challenges. Over the past 20 years, the Joint Venturers have spent approximately $1 billion on exploration, planning and marketing to prepare for the ultimate development of the Gorgon gas field. This preparation includes the evaluation of a number of development options and potential gas processing facility locations. In the 1990s, for example, customers were sought based on a processing facility on the Burrup Peninsula. However, the cost of transporting gas from the Gorgon gas field to this mainland site made the Development internationally uncompetitive.

Continued efforts to find a suitable location saw Barrow Island emerge as the only site that would enable the gas to be competitive in the current market.

Barrow Island is the nearest landfall to the Greater Gorgon fields with the Gorgon gas field being the closest field to the island. Establishment of a gas processing facility on Barrow Island will provide the catalyst for further development of the Greater Gorgon area fields.

Barrow Island also presents a unique opportunity to dispose of reservoir CO_2 from the Gorgon gas field into deep formations beneath the island (Chapter 13). The island is also Australia's largest operating onshore oilfield so provides the opportunity to utilise existing infrastructure (Box 1-3 and Figure 1-3). Despite the appeal of these drivers, the decision to apply for approval to base the onshore components of the proposed Development on Barrow Island was a difficult one for the Joint Venturers. The decision was made only after exhausting all other development alternatives (Chapter 3) because Barrow Island is a Class A Nature Reserve and home to a rich suite of wildlife, some of which are endemic to this island or listed as threatened on the mainland. This Draft EIS/ERMP demonstrates the Gorgon Venturers are committed to implementing the actions necessary to protect and maintain the conservation values of Barrow Island.

1.2.3 In-principle Approval for Restricted Access to Barrow Island

Before proceeding with the complex and expensive technical, commercial and environmental investigations necessary to advance the proposed Development, the Joint Venturers sought and received in-principle approval from the State Government of Western Australia for restricted access to Barrow Island.

The government's decision followed a strategic review by the Joint Venturers of the environmental, social and economic ramifications of the proposed Development on Barrow Island. This review (ESE Review), which included a wide range of public consultation, was subject to a six-week period of public comment. Responses by the Joint Venturers to those comments were also submitted to the government for consideration in the assessment of the proposed Development. Three government agencies also provided independent advice on the ESE Review in accordance with their areas of expertise and responsibility. This advice was also available for public comment for a six-week period (refer to Chapter 2 for further details on this process).

Box 1-3:
Infrastructure with Sharing Potential on Barrow Island

Under the *Barrow Island Act 2003* (Chapter 2), there is a requirement for the Joint Venturers during planning to take into account and make provision, as far as practicable, for use and sharing of services, facilities and infrastructure. Sharing will minimise environmental disturbance and impacts on the conservation values of Barrow Island.

Several components of the existing infrastructure on Barrow Island, which supports the Barrow Island Joint Venture operation on the island, could be shared with the Gorgon Development. These components include the:

- barge landing (until a new Materials Offloading Facility is built)
- airport
- roads
- old airstrip for materials lay-down
- oil offloading line
- water injection well
- accommodation (initially pioneer construction workforce and possibly longer term workforce)
- power
- water
- waste management (incineration)
- communications
- emergency response infrastructure.

The Joint Venturers are also required to enter into negotiations for the sharing and supply of their services, facilities and infrastructure on Barrow Island. The negotiation terms are to be based on 'reasonable commercial terms' and will be subject to availability of spare capacity.

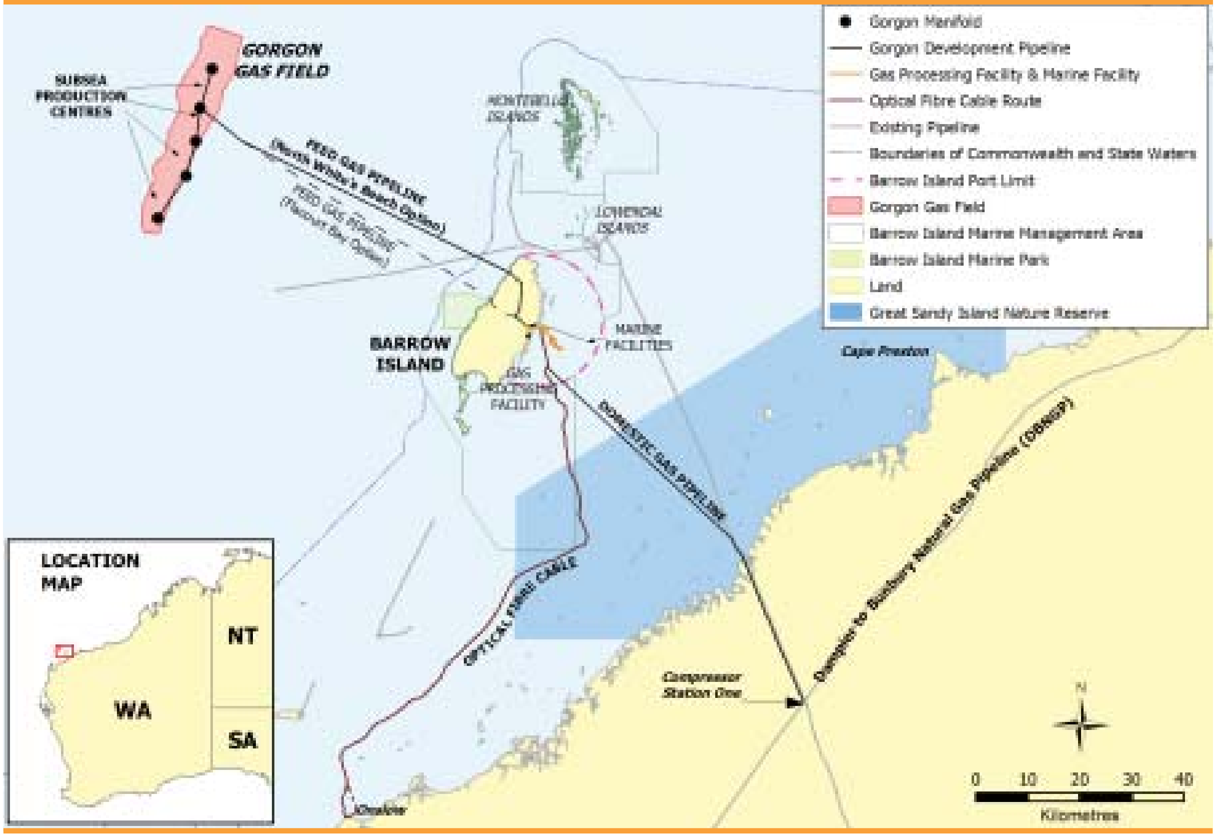
The proposed Development is now subject to regulatory environmental approvals as outlined in section 1.5 and described in Chapter 4.

1.2.4 Scope of the Proposed Development

The Gorgon Joint Venturers propose to develop a 10 million tonne per annum (MTPA) Liquefied Natural Gas (LNG) plant and a 300 TJ/day domestic gas plant on Barrow Island, which will be supplied from both the Gorgon and Jansz fields. Approximately 2000 m^3/day (12 000 bbl/day) of hydrocarbon condensate will also be produced.

Figure 1-3:
Existing Infrastructure on Barrow Island

Figure 1-4:
Development Concept



The scope of this Draft EIS/ERMP, as illustrated in Figure 1-4, covers:

- the Gorgon gas field wells and subsea installation
- a feed gas pipeline from the Gorgon gas field to the gas processing facility on Barrow Island
- an easement along the Gorgon gas field pipeline (onshore Barrow Island and traversing state waters) to accommodate additional feed gas pipelines
- a gas processing facility on Barrow Island (including two LNG trains, domestic gas and condensate facilities)
- port/marine facilities at Barrow Island
- water supply and disposal
- the construction village and associated facilities
- a proposal to dispose of reservoir CO_2 by injection into the Dupuy formation
- monitoring of CO_2 movement in the Dupuy formation
- an optical fibre cable connection to the mainland
- a domestic gas pipeline to the mainland.

For the purpose of cumulative impact assessment, this Draft EIS/ERMP addresses the impacts on, and near, Barrow Island associated with the installation of the Jansz feed gas pipeline to process gas from the Jansz field and other potential tieback opportunities associated with the Greater Gorgon area, or other nearby prospects. An easement along the Gorgon gas field pipeline corridor (onshore and traversing state waters) to accommodate the Jansz and additional feed gas pipelines is included in this environmental assessment and approval application with construction subject to conditions set for the Gorgon Development. Onshore and near shore construction of additional feed gas pipelines will be planned concurrently, where possible, to minimise the total environmental impact.

It is likely that gas from the Jansz field will supply the domestic gas processing plant. However, for the purposes of this Draft EIS/ERMP it was assumed that the gas will be supplied from the Gorgon gas field, as this provides a worse case CO_2 emissions profile.

Under the provisions of the Western Australian *Barrow Island Act 2003* (Chapter 2), no more than 300 ha of uncleared land is available for this and other future gas processing proposals on Barrow Island. This 300 ha is comprised of 150 ha that is reserved for the Gorgon Development and 50 ha that is reserved for easements for petroleum pipelines, control lines and ancillary services. The remaining 100 ha is reserved for future developments. Future phases of the Development will be subject to separate approval. However, the cumulative impacts of land clearing and habitat modification for the full 300 ha are considered in this Draft EIS/ERMP. Further details on specific components of the proposed Development are provided in Section 1.2.5.

The infrastructure and activities that are beyond the scope of this assessment and will be assessed under separate approvals processes are:

- Jansz field development and pipeline (operated by Mobil Exploration and Producing Australia (MEPA))
- subsea installations to develop additional gas fields in the Greater Gorgon area, or other nearby prospects
- feed gas pipelines from additional gas field developments in Commonwealth waters
- offshore marine seismic surveys
- shipping activities outside of the Barrow Island port facility.

The Jansz deepwater development and pipeline will be subject to a separate environmental approval process coordinated by MEPA as the operator of the Jansz field.

1.2.5 Principal Elements of the Proposed Development

Development of the Gorgon field will require a range of infrastructure to extract the gas and transport it to Barrow Island for processing and delivery to market. The principal physical components of the proposed Development are provided in Table 1-2 (details provided in Chapter 6).

The initial Development will consist of subsea infrastructure for the production and transport of gas from the Gorgon gas field to Barrow Island, and a gas processing facility at Town Point (Figure 1-4). A subsea development concept circumvents the need for an offshore platform as part of the initial development.

Liquefied Natural Gas and condensate produced at the gas processing facility will be shipped from Barrow Island to buyers. If commercially viable, gas for domestic use may be exported by a pipeline from Barrow Island to the domestic gas collection and distribution network on the mainland. Associated infrastructure will be required on the island and in the adjacent marine area. This will include administration and accommodation facilities, a materials lay-down area, a materials offloading facility, a CO_2 injection facility and a conventional loading jetty.

Table 1-2:
Key Elements of the Proposed Gorgon Development

Element	Description
Market objective	First shipment of LNG in mid-2010
Construction start (site preparation)	Late-2006
Development life	60 years
Size of recoverable resource: • Gorgon field	 0.27 Tm^3 (9.6 Tcf) (technically proven and certified)
Leases: • Gorgon field	 WA-2-R; WA-3-R
Typical gas composition: • Gorgon field • Jansz field*	 • CO_2 = 14–15%; N_2 = 2-3%; Hydrocarbon = remainder • CO_2 = < 1%; N_2 = 2%; Hydrocarbon = remainder
Wells (all subsea): • location • number	 • Gorgon gas field • 18–25

Pipeline lengths:
• feed gas pipeline
  • Gorgon (offshore)
  • Gorgon (onshore, Barrow Island)
  • state-water easement**
• domestic gas
  • offshore (state waters)
  • onshore (mainland)
• CO_2 injection
	
	• ~ 70 km
	• ~ 14 km (~ 42 ha easement)
	• ~ 5.6 km
	
	• ~ 70 km
	• ~ 30 km (~90 ha easement)
	• < 5 km (< 6 ha easement)

Gas processing facility: • location • components	 • Town Point, Barrow Island • 2 x 5 MTPA LNG trains • 300 TJ/day domestic gas plant • 2000 m^3/day hydrocarbon condensate
Port facility	• materials offloading facility (MOF) with an 800 m causeway • LNG load-out facility with a 3.1 km jetty
Other associated facilities	• mainland supply base • optical fibre cable • construction village • administration and maintenance facilities • offshore spoil ground (1500 ha) • widened roads • water supply, treatment and disposal facility • power generation and supply • extended airport
Air emissions: • greenhouse gases (with CO_2 injection) • total NO_x • total SO_x • total particulates (PM10)	 • 4.0 million tonnes of CO_2 equivalents per annum • 4430 tonnes per annum • 0.15 tonnes per annum • 241 tonnes per annum
Dredging: • MOF channel and turning basin • shipping channel and turning basin	 • 0.8 Mm^3 over ~ 21 weeks • 7.0 Mm^3 over ~ 45 weeks

Table 1-2: (continued)
Key Elements of the Proposed Gorgon Development

Shipping: • LNG export • condensate export	 • ~ 3 shipments per week • ~ 1 shipment per month
Element	**Description**

Total direct employment:
• construction (on Barrow Island at peak)
• operations:
  • on Barrow Island
  • on rotation (off the island)
  • in Perth office
	
	• ~ 3300 people
	• ~ 600 people:
	• 150–200
	• 150–200
	• 200–300

Development Investment	~ $11 billion

* *Composition of Jansz gas included here as the gas processing facility will receive gas from both Gorgon and Jansz fields and as such emissions calculations and modelling have been based on the total incoming gas stream.*

** *Potential impacts in the easement in state waters associated with construction and operation of the Jansz (or other) feed gas pipelines are considered for cumulative impact assessment purposes.*

1.2.6 Relationship to Other Proposals in the Region

The economy of Western Australia is dominated by the resources sector with more than three-quarters of Australia's identified natural gas resources. This extensive energy resource provides a significant competitive advantage to the state and will ensure continued economic growth to the region. Currently Western Australia has almost 500 resource projects in commercial production, underwriting the strong economic foundation of the state.

Within Western Australia, one of the most vital and dynamic wealth producing regions is the Pilbara, which accounts for more than 55% of the mineral and energy production at a value of more than $15 billion per annum. This region currently produces 100% of Australia's LNG.

As shown in Table 1-3, from data published by the Western Australian Department of Industry and Resources (DoIR), the proposed Gorgon Development is one of a number of substantial oil and gas, mining and associated downstream processing developments planned for the Pilbara region.

Table 1-3:
Current Commissioned and Committed Pilbara Minerals and Energy Projects

Project	Project Value ($ M)	Employment – Construction	Employment – Operations	Construction Commencement
Oil and Gas				
Woodside Energy: Enfield Oilfield	1 480	100	80	Production 2006
Santos: Mutineer-Exeter Oilfields	480	540	90	Production 2005
Gorgon Joint Venturers: Gorgon Development, LNG (2 trains)*	11 000	3 300*	600*	2006
North West Shelf Partners: 5th LNG Train, 2nd Trunkline**	1 600	–	–	Not yet determined
BHP Petroleum: Pilbara LNG	Under evaluation	–	–	–
Petrochemicals				
Burrup Fertilisers: Ammonia Plant	630	700	60	Production 2005
Japan DME: Dimethyl-ether Plant	1 000	1 000	150	Operational 2007
Deepak Resources: Burrup Peninsula Ammonium Nitrate	300	700	150	NA
Sasol-Chevron gas to liquids plant	2 000	2 500	200	–
Iron and Steel				
BHP Billiton Iron Ore: Rapid Growth Project 1	145	–	–	2004
Hamersley Iron: Dampier Parker Point Expansion	700	600	–	2004 (expected completion end 2005)
Hamersley Iron: Yandicoogina Mine Expansion	290	330	–	Production 2005
Hope Downs: Iron Ore Mine	1 050	500	300	–
Robe River Mining Company: West Angelas Mine Expansion	–	–	–	Completion mid-2005
Fortescue Metals Group: (Cape Preston) Mine and HBI Plant	3 000	5 000	1 050	Mid-2005
Other				
Newcrest Mining: Telfer Gold Mine Expansion	1 400	1 222	620	Full production 2005
Hamersley Iron: Power Infrastructure Enhancement	–	30-40	–	2005
Robe River Mining Company: Rail Duplication from Tunkawanna to Rosella Siding	200	–	–	Completion mid-2006
TOTAL VALUE	**25 275**	**16 532**	**3 300**	

Source: DoIR website: www.doir.wa.gov.au/investment

Note: Only projects that are commissioned or committed are included in this list. Projects under consideration are not included and account for a significant amount of potential investment and employment.

* *Figures as per DoIR website: www.doir.wa.gov.au/investment/mineralsandpetroleum/Status of ResourceProjectsFeb2005.pdf*

** *Figure as per www.smh.com.au/news/Business 26/4/05*

Given the amount of other resource activity planned, the regional economy is not large enough to provide all labour, goods and services required for the Gorgon Development. Whilst economic modelling (Chapter 15) shows that the proposed Development would result in little 'crowding out' of the investment potential for other projects, there is a risk that short-term demand (e.g. labour for construction) will cause regional price rises. Total employment in the Pilbara region ranged between 22 000 and 24 000 from 1999 to June 2003 (Department of Local Government and Regional Development 2003). At its peak, the Gorgon Development construction workforce is expected to require some 3300 people on the island which is more than 14% of the entire Pilbara workforce. This means that the regional economy will not be able to provide sufficient labour when required, so additional labour will need to be employed from other areas.

Depending on the execution schedule of the other proposed projects, construction of the Gorgon Development could smooth out manpower and demand for materials and services if it is ramping up when other projects are ramping down. There could also be a fifth LNG train constructed for the North West Shelf Joint Venture (NWSJV) by 2008, the Sunrise project in the Timor Sea in 2009, and the remote Scott Reef on the north-west Shelf in 2012 according to Australian newspaper reports. The approach described in the State Agreement (Chapter 2) and Australian Industry Participation Policy (Chapters 8 and 14) offers a good balance between the development of local capacity and the commercial drivers for the Gorgon Development.

1.2.7 Development Timeline

The actual timing for the commencement of construction on Barrow Island is subject to government approval processes. An indicative schedule for the proposed Development is provided in Figure 1-5 , which shows that the first shipment of LNG is expected in mid-2010. The production life of the proposed gas processing facility will fall within the first long-term lease period of 60 years allowed under the State Agreement annexed to the *Barrow Island Act 2003.*

Figure 1-5:
Indicative Environmental Approval and Development Schedule

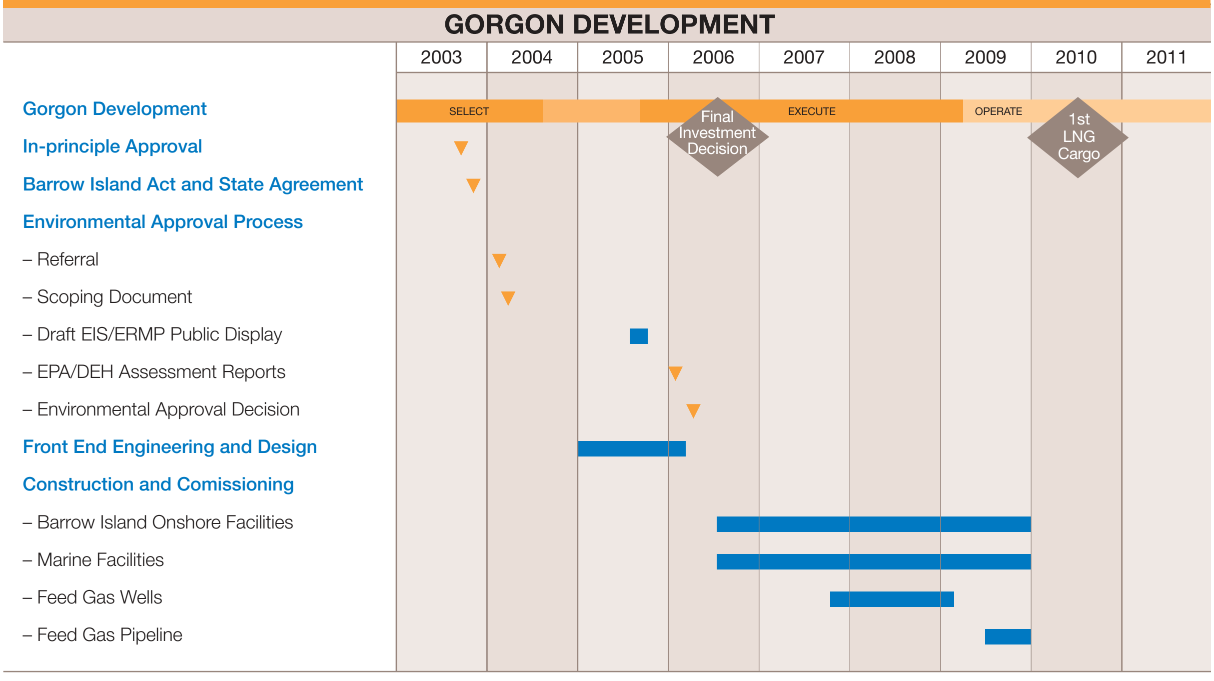
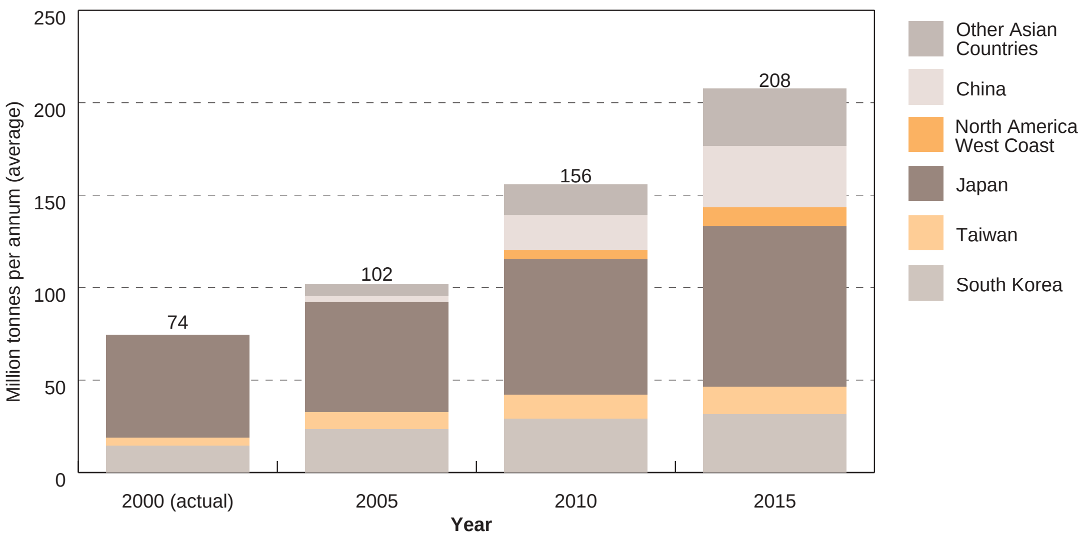


Figure 1-6:
Asia–Pacific LNG Demand Forecast



1.3 Development Rationale

The Western Australian and Commonwealth governments both identify the resource industry as a key to economic growth, so have legislation and policy objectives designed to expedite development of the nation's resources. The retention leases issued to the Joint Venturers obligate the proponents to actively seek development opportunities for these resources.

There is a growing demand for energy in the Asia–Pacific region (Figure 1-6) and the Australian domestic gas market. At the international market level, particularly in the Asia–Pacific region, the Development will supply LNG for the next generation of gas-based industries.

At the Australian market level, the proposed Development will double the size of the gas industry in Western Australia at a time when there is a projected shortfall in energy supply. Further, the development of an additional strategic gas supply hub in Western Australia will significantly improve the availability of long-term, competitive supplies of gas to the state, and help build Australia's standing as a reliable gas supplier.

1.3.1 Market Opportunities

China

The opportunity to sell Gorgon gas to China was bolstered in October 2003 by the signing of an agreement between the China National Offshore Oil

Plate 1-1:
Signing of the CNOOC Agreement

Corporation (CNOOC) and the Joint Venturers. Whilst the formal exclusivity within that agreement has expired the parties are continuing to negotiate both the (conditional) Sales and Purchase Agreements for Equity and LNG sales.

Subject to the completion of formal contracts, it is proposed that CNOOC Limited will purchase a substantial equity stake in the Gorgon Development, and Zhejian LNG will purchase significant volumes of LNG from the Gorgon Development for use in China. CNOOC will also assist the Joint Venturers to secure markets in China for a further designated amount of LNG.

North America

Progress has also been made with marketing in North America. Shell has committed capacity from the Energia Costa Azul LNG receiving terminal in Northern Mexico to take its share of gas from the Gorgon Development. These marketing arrangements provide Shell with the capacity to divert Gorgon gas to other markets if it is commercially attractive to do so. This facility, which is currently under construction, will be the first LNG receiving terminal on the North American west coast. This secures a market for 25% of LNG production from the Gorgon Development (up to 2.5 MTPA).

Discussions continue with Chevron Global Gas for the sale of further volumes of Gorgon LNG to the North American west coast market.

Other Markets

Negotiations continue to secure a place for Gorgon LNG to major gas buyers in Japan and Korea for the window of opportunity seen in 2010.

The Gorgon Development thus has the potential to secure Australia's position as a leading gas producer and provide a large source of additional wealth to Australia and Western Australia (refer to Chapter 15; and ChevronTexaco Australia 2003).

1.3.2 Consequences of Missing the Current Development Opportunity

Federal and state legislation and policy require Australia's resources to be developed expeditiously. As holders of the retention leases, the Joint Venturers are obliged to bring the hydrocarbon resources into commercial production as soon as reasonably practicable.

Furthermore, if the Development does not proceed, the economic, social and strategic benefits described in this document will not be realised. Even a short delay to the Gorgon Development could trigger a long delay in capturing and transferring these benefits to Australia, Western Australia and the Pilbara. This is because the market opportunities currently available to the Joint Venturers could be easily won by competing countries such as Indonesia, Malaysia, Russia and Qatar. Future market opportunities may not become available for a considerable period if the current opportunity is lost.

1.4 Development Objectives

The primary objective of the Gorgon Joint Venturers is to commercialise the proven recoverable gas from the Greater Gorgon area in a sustainable manner. This includes continuing to protect the conservation values of Barrow Island, managing environmental, health and safety requirements responsibly, and implementing best practice environmental management throughout all phases of the Development.

To meet this objective, the Joint Venturers established a set of sustainability principles and assessment criteria for the proposed Development on Barrow Island during the ESE Review process (Box 1-4 and Chapter 2). These principles and criteria are based on widely accepted sustainability principles and address the key concerns, particularly those concerning environmental protection, expressed by stakeholders consulted about the proposed Development. They are also consistent with the EPBC Act principles of ecologically sustainable development and the direction of the State Government of Western Australia, including the EPA Principles of Environmental Protection (EPA 2004a). These principles will be applied to all phases of the Development, and provide a framework for the Joint Venturers to sustainably unlock the value of Greater Gorgon area.

Box 1-4:
Gorgon Development Sustainability Principles

Clean Energy Supply	The Development will meet Western Australian, Australian and international demands for competitive, clean energy sources. It will also enhance energy competition and security of supply in Australia.
Economic Benefit Delivery	Current and future economic growth in Australia will benefit from the Development. It will foster economic growth and business development, generate government revenue, provide commercial returns to the Joint Venturers and contribute to the wealth generated by Australia's natural resource base.
Biodiversity and Ecological Integrity Protection	The Gorgon Development will not disrupt ecological structure and function, nor will it result in a loss of biological diversity on Barrow Island.
Social Equity and Community Well-being Enhancement	Communities will benefit from improved quality of life and well-being resulting from contributions of the Gorgon Development such as creation of jobs.
Future Generations Commitment	The Gorgon Development will meet the needs of the present generation and assist future generations to meet their needs.
Efficient Resource Use	International best practice and continual improvement principles will be applied to efficiently manage resources and wastes.
Precautionary Principle Application	Where there are threats of serious or irreversible damage, lack of full scientific certainty will not be used as a reason for postponing cost-effective measures to prevent environmental damage.
Community Respect and Safeguards	The Joint Venturers will respect community values, community diversity and safeguard the well-being of the public and workforce throughout the life of the Development.
Stakeholder Engagement	The Joint Venturers will seek the views of stakeholders and take their interests into account throughout development of the Gorgon gas field.
Accountability	The Joint Venturers are committed to the highest standards of governance and accountability. They will report regularly to the community on the sustainability performance of the Development.

The assessment criteria for these sustainability principles are outlined in the ESE Review (ChevronTexaco Australia 2003).

1.5 EIS/ERMP Process

The proposed Gorgon Development is subject to state and federal regulatory environmental assessment under the *Environmental Protection Act 1986* (EP Act) (WA) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth). A number of environmental assessment and management requirements would also apply to the Development under state and federal petroleum legislation as shown in Table 4-1 of Chapter 4.

The Commonwealth Department of the Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA) determined that the Gorgon Development should be formally assessed respectively at the levels of Environmental Impact Statement (EIS) and Environmental Review and Management Programme (ERMP).

The Commonwealth and Western Australian governments have agreed to a coordinated environmental assessment process. Accordingly, they will assess a single EIS/ERMP document that satisfies the requirements of both jurisdictions. The EIS/ERMP process is designed to comprehensively identify and examine environmental impacts associated with the proposed Development. This process also provides a means to address those impacts so that the Development is based on sound environmental protection and management criteria.

The approach to the environmental impact assessment and preparation of this Draft EIS/ERMP is summarised in the following section. Further details on the impact assessment process is provided in Chapter 4.

1.5.1 Approach to the Impact Assessment

Potential impacts to physical and biological systems and socio-economic systems are assessed through this EIS/ERMP process. Whether the risks that the proposed Gorgon Development poses to these factors can be managed to an acceptable level are also investigated through this process. The factors assessed during the EIS/ERMP process are presented in Table 1-4 as per the 'Guidelines for an Environmental Impact Statement and Environmental Scoping Document for an Environmental Review and Management Programme for the Proposed Gorgon Development' (ChevronTexaco Australia 2004) which is available at www.epa.wa.gov.au. The final version of this document, which was refined following public comment became the EIS guidelines endorsed and issued by DEH in accordance with the requirements of the EPBC Act. The acceptability of environmental risks needs to be considered in the context of the Class A Nature Reserve status of Barrow Island and the environmental and conservation values that the island represents.

A risk-based approach was adopted to assess the potential environmental impacts associated with the Gorgon Development. Where practicable, this approach was also applied to potential negative social and economic impacts. However, positive/ beneficial social and economic impacts should also be considered in the assessment process. Where beneficial impacts could not be assessed adequately using a risk-based approach, more traditional assessment approaches were applied. Details of the risk assessment process are presented in Chapter 9.

As part of a comprehensive environmental management program, proposed strategies to avoid, minimise, mitigate, rehabilitate or offset potential impacts are presented for each factor/stressor combination (refer to risk assessment tables in Chapters 10–15). In addition, a framework EMP, which collates environmental management strategies on an activity basis, is presented in Technical Appendix A.

Management of risks and potential impacts identified through risk assessment and stakeholder consultation processes will be further addressed in the detailed Environmental Management Plan series (EMP) as part of a comprehensive framework for environmental management of the Development. This series of EMPs will be developed and documented through a systematic and consultative process according to an agreed timetable, taking into consideration comments on this Draft EIS/ERMP and recommendations from relevant agencies.

The final stage of this process will be a series of Environmental Management Implementation Plans prepared by the engineering design and construction contractor. These will be internal project documents designed to bridge to the EMP series, provide greater site-specific details and document individual responsibilities, contact and other details (Chapter 16).

Table 1-4:
Environmental and Socio-economic Factors Assessed in the EIS/ERMP Process

Factor Type	Factor
Terrestrial Environment	Flora and Vegetation Communities
	Terrestrial Fauna
	Subterranean Fauna
	Soil and Landform
	Foreshore
	Water (Surface or Ground)
Marine Environment	Marine Fauna
	Marine Flora (mangroves, corals, seagrasses and algae and water quality)
	Benthic Habitats Intertidal Zone (including water quality)
Physical Environment	Air Quality
	Greenhouse Gas Emissions
	Ozone Depleting Substances
	Noise and Vibration
	Light
	Liquid and Solid Waste Disposal
	Hazards and Spills
Socio-economic	Local Communities
	Government Policy, Strategic Plans and Legislation
	Cultural Heritage
	Native Title
	Livelihood and Lifestyle
	Social Infrastructure
	Workforce and Public Health and Safety
	Economic Development
	Community Development

An important component of the Joint Venturers' approach to planning and assessing the proposed Development has involved a comprehensive stakeholder engagement program, as described in Chapter 5. This consultation will continue during the EIS/ERMP approval process and into the ensuing phases of construction, commissioning and operation of the proposed Development.

1.6 Key Concepts

A number of commonly used terms and concepts, used throughout this Draft EIS/ERMP, are often defined and interpreted in different ways depending on the document context and the reader. Box 1-5 provides the Joint Venturers' understanding and application of selected terms and concepts. Further definitions can be found in the Glossary.

Box 1-5:
Definitions of Key Concepts and Terms used in this Draft EIS/ERMP

Best Practice – the Joint Venturers have adopted the Western Australian EPA's definition which states that 'best practice' involves the prevention of environmental impact, or, if this is not practicable, minimising the environmental impact, and also minimising the risk of environmental impact through the incorporation of best practicable measures. No significant residual impact should accrue as a result of a proposal. The EPA defines best practicable measures as technological and environmental management procedures which are practicable, having regard to, among other things, local conditions and circumstances, including costs, and to the current state of technical knowledge, including the availability of reliable and proven technology (EPA 2003).

Biodiversity – collectively describes the variety and variability of nature which encompasses the genetic, species, and ecosystem level of organisation in living systems (ChevronTexaco 2004).

Conservation Values – are natural assets or attributes that are of conservation significance. Key conservation values of Barrow Island include:

- unique fauna species and a high level of biodiversity
- a suite of native marsupials that once occurred on the mainland but are now threatened or extinct there
- an absence of introduced fauna species
- potential as a source for controlled re-introductions to other areas
- a rich marine environment and its various components (e.g. coral reefs, intertidal flats, marine mammals and turtles)
- importance as a staging area for migratory birds
- various subterranean fauna components and their affinities to and differences from populations on the mainland (ChevronTexaco Australia 2003).

Cumulative Effects – describes progressive environmental degradation over time resulting from a range of activities in an area or region (ChevronTexaco 2004).

Environmental Management – is the sum of the day-to-day activities that are designed to mitigate a development's environmental impacts by either avoiding them or reducing them to within 'acceptable limits' (Conservation Commission of Western Australia 2003).

Mitigation Measures – are actions taken to minimise or lessen the impact of activity on the environment or surrounding communities (ChevronTexaco 2004).

These include (in order of preference):

- avoidance – completely avoiding an adverse environmental impact
- minimisation – limiting the degree or magnitude of an adverse impact
- rectification – rehabilitating an impacted site as soon as possible
- offsets – undertaking activities that counterbalance an adverse, residual environmental impact (EPA 2004b).

Net Conservation Benefits – are demonstrable and sustainable additions to, or improvements in, biodiversity conservation values of Western Australia targeting, where possible, the biodiversity conservation values affected or occurring in similar bioregions to Barrow Island (EPA 2004b); in addition and separate to environmental offsets.

Offsets – are any environmentally beneficial activities undertaken to counterbalance an environmental impact or harm, with the aim of achieving 'no net environmental loss' or 'net environmental benefit' outcome. There are two key types of 'offsets', these are 'primary' and 'secondary' offsets. The terms 'primary' and 'secondary' reflect a sequence of approach, rather than a ranking of importance. A primary environmental offset is any environmentally beneficial activity undertaken to counterbalance an adverse environmental impact or harm, with the goal of achieving 'no net loss' and preferably a 'net environmental benefit'. A secondary environmental offset is any environmentally beneficial activity undertaken to complement and enhance the primary offset activity. Secondary offset activities do not contribute to a 'no net loss' outcome, but instead adds materially to environmental knowledge, research, management, protection, etc. (EPA 2004b).

Preventative (Preventive) Measures – are actions taken in advance to keep something possible or probable from happening or existing (Safety and Quality Council 2001).

Box 1-5: (continued)
Definitions of Key Concepts and Terms used in this Draft EIS/ERMP

Risk – is defined as the chance of something happening that will have an impact on objectives. Risk is measured in terms of consequences and likelihood. Consequence refers to the outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage, or gain. There may be a range of possible outcomes associated with an event. Likelihood is a qualitative description of probability or frequency (AS/NZS 4360:2004).

Risk Assessment – is the overall process of risk analysis and risk evaluation (AS/NZS 4360:2004).

Risk Management – is the culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects (AS/NZS 4360:2004).

Sustainable Development – is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987).

1.7 Draft EIS/ERMP Purpose and Structure

This Draft EIS and ERMP (Draft EIS/ERMP) is the primary source of information for the public and regulatory decision-makers in their assessment of the potential environmental impacts of the proposed Gorgon Development.

For the reader to identify the factors that may be affected by the Development and the significance of the risks and their management at local, regional, state and national levels, this document provides:

- relevant background information on the proposed Development
- a description of the proposed Development, its emissions and the receiving environment
- a risk-based assessment of all significant environmental impacts that could occur within state and federal jurisdictions
- management measures to prevent and/or minimise significant adverse environmental impacts
- a description of residual risks
- a list of environmental management commitments.

The structure of the presentation of this information is provided in Figure 1-7. This Draft EIS/ERMP consists of a stand-alone executive summary, a main report and technical appendices, which include reports on technical studies undertaken by specialists. The structure of the main report generally follows the format set out in the 'Guidelines for an Environmental Impact Statement and Environmental Scoping Document for an Environmental Review and Management Programme for the Proposed Gorgon Development' (ChevronTexaco Australia 2004).

The first group of chapters provide the reader with background information. The proposed Development is then put in context before the potential risks and their management are presented. In the final section, the Environmental Management System is described before the conclusions reached by the Joint Venturers are provided.

A summary is provided at the beginning of each subsequent chapter to assist readers who wish to understand the whole document but intend to focus on specific sections.

Only metric units are used in this document, although industry standards such as gas quantities are also given as imperial measurements (e.g. Tcf). As such, quantities of liquids are expressed as cubic metres (m^3), pipe sizes are in millimetres (mm), areas are in hectares (ha) and distances are in kilometres (km). Conversion factors are included in the Glossary to allow conversion of these units to commonly used imperial measurements.

Throughout this document a number of common oil and gas industry terms are used. To assist readers with industry terminology, a Glossary that describes relevant terms in more detail is provided. Other supplementary information such as references, acknowledgements and acronyms and abbreviations are also provided after the final chapter.

Figure 1-7:
Structure of this Draft EIS/ERMP

Draft EIS/ERMP for the Proposed Gorgon Development

Executive Summary

Main Report

Technical Appendices

A: Framework Environmental Management Plan
B: Physical Environment Studies
C: Ecological Studies
D: Quarantine Studies and Reports
E: Social Environment Studies
F: Economic Environment Studies

Development Overview and Background

Chapters:
1. Introduction
2. Background to this Proposal
3. Development Alternatives
4. Legislative Framework
5. Stakeholder Engagement

Development Context

Chapters:
6. Development Description
7. Emissions from the Development
8. Existing Environment
9. Risk Assessment Process

Development Risks and Management

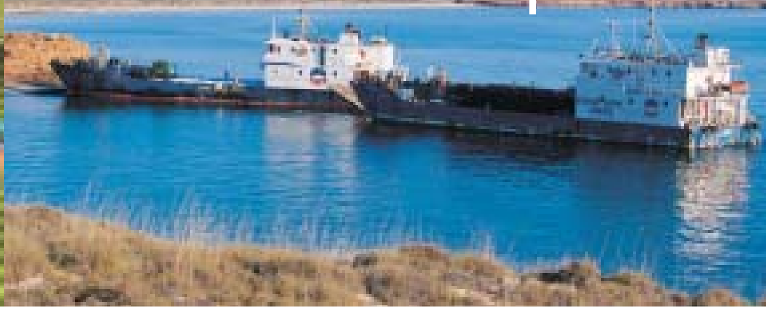
Chapters:
10. Terrestrial Environment
11. Marine Environment
12. Quarantine
13. Greenhouse Gases
14. Social Environment
15. Economic Environment
16. Environmental Management System

Conclusions and Supplementary Information

Chapters:
17. Conclusion

Supplements:
- References
- Abbreviations
- Glossary
- Acknowledgements
- General Appendices

02: Background to the Proposal



Before proceeding with the federal and state regulatory environmental approvals processes, the Gorgon Joint Venturers sought from the Government of Western Australia in-principle approval for restricted access to Barrow Island for a foundation development. In a progressive step towards formally assessing the sustainability of the proposed Development, the government in consultation with the Joint Venturers developed an environmental, social and economic review and assessment process (ESE Review process).

The ESE Review process required the Joint Venturers to present a report to the government and public that examined relevant environmental, social, economic and strategic issues, and demonstrate that the proposed Development would yield net conservation benefits to the state. The process was a first in Western Australia and one of the few sustainability assessment processes documented internationally for a specific development. A key feature of the ESE Review process was a high level of public consultation to encourage all interested stakeholders to contribute to the government's decision.

In-principle approval for restricted access to Barrow Island was granted in September 2003. If full federal and state regulatory environmental approval is granted for the proposed Development, the associated terms and conditions will be governed by the Western Australian *Barrow Island Act 2003* and the *Gorgon Gas Processing and Infrastructure Project Agreement* (the State Agreement) that has been signed by the State Government of Western Australia and the Gorgon Joint Venturers.

This chapter outlines the ESE Review process, the decision by Cabinet to grant in-principle approval for restricted access to Barrow Island, and the legislation that resulted from that decision.

2.1 ESE Review Process

In 2001 Chevron Australia, on behalf of the Gorgon Joint Venturers, approached the State Government of Western Australia about the possibility of building a gas processing facility on Barrow Island (refer to Chapter 3 for an explanation of the site selection process for the proposed Development). In response, the Minister for State Development advised that the government was prepared to consider granting access to Barrow Island after all relevant environmental, social, economic and strategic issues had been examined; and provided that the proposed Development would yield net conservation benefits.

In the absence of an existing process in Western Australia, a strategic assessment process was established to allow the government to assess the environmental, social, economic and strategic costs and benefits of allowing the development of a gas processing facility on Barrow Island. The Western Australian Government developed this process, which is summarised in Figure 2-1, in consultation with the Joint Venturers. The process essentially mirrors Part IV of Western Australia's *Environmental Protection Act 1986* (EP Act) in the requirements for public comment and government agency advice and recommendations to government. A key feature of the ESE Review process was a high level of public consultation to encourage all interested stakeholders to contribute to the government's decision.

2.1.1 ESE Review Scoping Phase

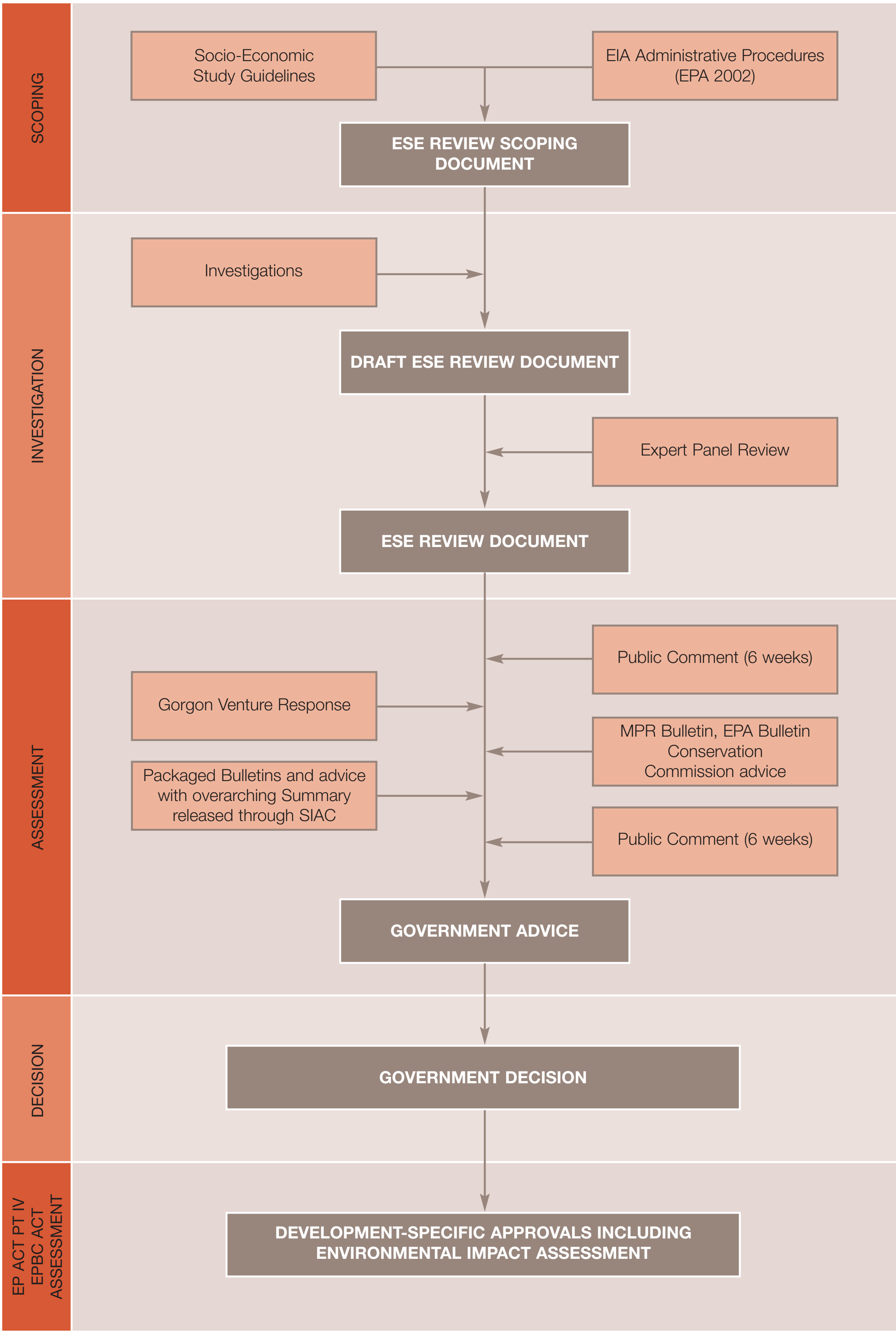
In May 2002, the government released guidelines for evaluating the social, economic and strategic (SES) aspects of the proposed Development. In June 2002, the Joint Venturers published the scoping document for the review of the environmental, social and economic aspects of the proposal. This document integrated the SES requirements with the Western Australian Environmental Protection Authority (EPA) administrative requirements on environmental aspects.

2.1.2 ESE Review Investigation Phase

After completing the scoping document, the Joint Venturers commenced the investigations required to complete the ESE Review of the proposed Development on Barrow Island. It contained:

- a study of alternative locations for the Gorgon Development
- a site selection process for where to site the facility on Barrow Island
- a review of a range of internal technical, engineering and commercial studies on the proposed Development
- specialist studies to identify and broadly quantify potential impacts
- strategies to mitigate adverse impacts and enhance positive impacts
- a net conservation benefit strategy
- a summary of stakeholder consultation

Figure 2-1:
Summary of the ESE Review Process (source: ChevronTexaco Australia 2003)



- a set of sustainability principles and measurement criteria
- a sustainability framework to integrate environmental, social, economic and strategic issues.

The factors addressed in the ESE Review were identified through consultation with stakeholders and investigated by the Joint Venturers with input from specialist consultants (refer Box 2-1) (ChevronTexaco Australia 2003).

Box 2-1
Factors Addressed in the ESE Review Process

Factors Addressed in the ESE Review Process

The ESE Review process examined, at a high level, the Joint Venturers' ability and commitment to:

- identify a development site that is commercially viable and meets technical, environmental and social criteria
- prevent accidental introductions of exotic plants, animals and diseases
- minimise vegetation/habitat loss/disturbance
- reduce disturbance to fauna by light or noise
- protect wildlife health
- avoid impacts on marine fauna
- mitigate modifications to water currents
- reduce greenhouse gas emissions
- generate economic development and employment opportunities
- protect cultural heritage sites
- maximise regional education and training opportunities
- enhance the supply of clean gas to Western Australia and Australia
- improve domestic gas competitiveness
- increase demand for local business services
- provide significant revenue to government
- develop the Gorgon gas field in a manner consistent with the Development's sustainability principles
- maintain a publicly transparent assessment process.

The objective of the ESE Review was to present information to enable government and the community to consider, at a strategic level, whether the proposed Development would:

- generate economic and social benefits for the Pilbara, Western Australia and Australia
- provide net conservation benefits
- mitigate potential on-site environmental impacts.

Prior to the distribution of the ESE Review for public comment and government assessment, the document was reviewed by an independent panel to ensure that the investigations satisfied the requirements of the ESE Review Scoping Document. Membership of the panel was determined in consultation with the EPA and Department of Industry and Resources (DoIR). The ESE Review process provided a comprehensive, open and transparent review of the Venturers' development proposal for all stakeholders.

2.1.3 ESE Review Assessment Phase

The ESE Review was released for public comment and government review in February 2003. At the end of a six-week public comment period, public submissions on the ESE Review were received by the EPA and the Department of Minerals and Petroleum Resources (MPR now the Department of Industry and Resources (DoIR)). Chevron Australia responded to all questions raised in the public submissions and the 'whole of government' evaluation commenced.

Consideration of the ESE Review was coordinated by the Standing Interagency Committee of Chief Executive Officers (SIAC). SIAC advises the Minister for State Development on whole of government strategic and approvals matters relating to major resource development projects. Members of SIAC represent the state agencies with responsibility for project assessment and decision-making (ChevronTexaco Australia 2003, p. 20). During the ESE Review process, core representatives included the Department of Land Administration (now the Department of Land Information), Department of Treasury and Finance, Environmental Protection Authority, Department of Environment, Water and Catchment Protection, Department of Indigenous Affairs and Department of Mineral and Petroleum Resources (now the DoIR).

In addition to core representatives, three additional government agencies were asked to provide independent advice on the ESE Review in accordance with their areas of expertise and responsibility. The EPA advised on the environmental aspects of the proposal; the Conservation Commission commented on biodiversity conservation; and DoIR appointed The Allen Consulting Group to advise on social, economic and strategic issues (Allen Consulting Group 2003). These reports were provided to the government in an Overview and Information Pack released by SIAC in July 2003 for a six-week public comment period (Government of Western Australia 2003a).

On environmental grounds, the EPA recommended that industrial development not be allowed to proceed on Barrow Island given the threats to the high environmental and unique conservation values of Barrow Island (EPA 2003). The EPA considered the most important potential threats to the conservation values of Barrow Island to be terrestrial and marine invasive organisms, land clearing and shifts in frequency or intensity of fire. However, in recognition that the Western Australian Government might grant in-principle approval for the proposed Development on economic and industrial development grounds, the EPA noted that if in-principle approval was granted the proponent should be required to develop standards for acceptable risk to the conservation values of Barrow Island, and they should implement a package of management plans to address those risks.

Similarly, the Conservation Commission of Western Australia advised the government, on the basis of biodiversity conservation values, that national parks and nature reserves are not appropriate places for industrial development. However, the Commission concluded that if in-principle approval for restricted access to Barrow Island were granted, further work would be required to define the necessary environmental management and risk management requirements, and to finalise an appropriate net conservation benefits package.

In its report to the Department of Industry and Resources, the Allen Consulting Group concluded that under current circumstances, Barrow Island represents the only commercial option for monetising the Gorgon gas resource which is a substantial national asset.

2.2 Cabinet Decision

On 8 September 2003, after government considered the collective agency advice and public comment, Cabinet granted in-principle approval for restricted access to Barrow Island as a foundation for the development of Gorgon gas.

A media statement released on that day by the Premier and the Minister for State Development outlined the reasons for the decision:

> The approval to allow development on 300 hectares of land representing only 1.3 per cent of the island was made conditional on the Joint Venture meeting strict State and Commonwealth environmental safeguards.
>
> This will ensure that Barrow Island's unique environment continues to be preserved.
>
> Premier Geoff Gallop said the $11 billion two-stage Gorgon Development had the potential to be Australia's biggest industrial project and would double the size of Western Australia's gas industry.
>
> He said the project had significant local, national and global benefits.
>
> 'The Gorgon project has the potential to underpin Western Australia's and Australia's economic prosperity for decades to come, delivering thousands of new jobs and billions of dollars in revenue for the country,' Dr Gallop said.

In that statement, the Premier also said the world was looking increasingly towards natural gas as a clean and reliable energy source and the state government was positioning Western Australia as a major global supplier into the future (Government of Western Australia 2003b).

2.3 Barrow Island Legislation

In parallel with the ESE Review process in the months before the Cabinet decision, state agencies were instructed to prepare legislation (*Barrow Island Bill 2003*) to put into effect its decision in the event that Cabinet granted in-principle access to Barrow Island. At the same time, the terms of a State Agreement were negotiated with the Joint Venturers, who are parties to the Agreement.

The reasons for this were provided to State Parliament by the Minister for State Development on 18 June 2003:

> 'The Government has not said whether it will proceed with this proposal. It will make that decision in late August. If it does agree to the process, it will introduce legislation into the House. That legislation will be passed by both Houses by 31 December 2003, or the Government will not proceed with it,' (Brown 2003).

To be in a position to meet the government's timetable, detailed work on both the draft legislation and a draft agreement was completed just prior to Cabinet's considerations.

On 9 September 2003, the day after Cabinet made its in-principle decision, the Premier, on behalf of the state and representatives of the Joint Venturers signed the *Gorgon Gas Processing and Infrastructure Project Agreement* (State Agreement) (Plate 2-1).

On 16 September 2003, the *Barrow Island Bill 2003* (with the Agreement scheduled) was introduced into State Parliament by the Minister for State Development. The Bill completed its passage through both Houses of Parliament on 14 November 2003 and received assent on 20 November 2003.

2.3.1 Barrow Island Act 2003

The purpose of the *Barrow Island Act 2003* (WA) as summarised in the legislation is:

- 'to ratify, and authorise the implementation of, an agreement between the state and the Gorgon Joint Venturers relating to a proposal to undertake offshore production of natural gas and other petroleum and a gas processing and infrastructure project on Barrow Island; the agreement having been entered into having regard to the need to minimise environmental disturbance on Barrow Island (a Class A Nature Reserve) and providing for the support of conservation programs relating to Barrow Island and other parts of the state;
- to make provisions to enable land on Barrow Island (but no more than 300 ha in total of uncleared land) to be used, under the *Land Administration Act 1997*, for gas processing project purposes; and
- to make provisions as to the conveyance and underground disposal of carbon dioxide recovered during gas processing on Barrow Island.'

Plate 2-1:
Signing of the State Agreement

2.3.2 State Agreement

The State Agreement contains a range of state and proponent commitments and obligations. In terms of the timing of the Development, the Joint Venturers are required to lodge with the Minister for Development a proposal for an LNG development on Barrow Island by 31 December 2008. The proposal must include a range of detail including the proposed plant design, management of quarantine risk, disposal of CO_2, a social impact management plan, use of local labour and materials and a closure plan including rehabilitation and long-term management of disposed reservoir CO_2.

The following subsections outline the provisions of the State Agreement.

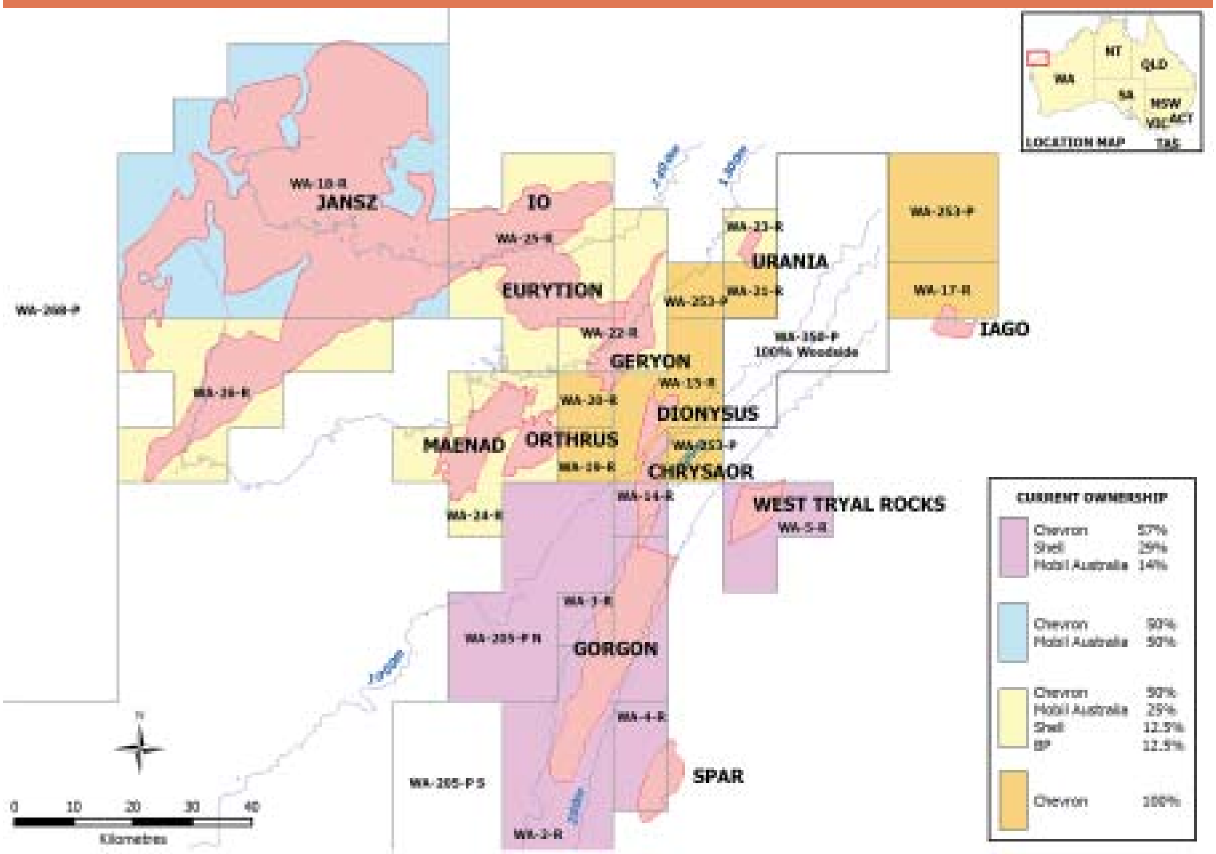
Title Area

The State Agreement limits gas processing on Barrow Island to gas from the Title Areas, the Greater Gorgon area, and Barrow Island. It defines a project as processing gas from those areas to produce: (i) LNG or other petroleum products; (ii) gas for other projects on Barrow Island; (iii) domestic gas for pipeline transportation to the mainland; and (iv) all related activities including construction, operation and maintenance of pipelines, transport and CO_2 disposal.

The initial Title Areas are subject to the Retention Leases in the purple-shaded area of Figure 2-2; and the northern part of Exploration Permit WA-205-P.

The initial Greater Gorgon area is defined as the area subject to Retention Leases and Exploration Permits in the area shaded orange, yellow and blue (Figure 2-2).

Figure 2-2
Exploration Permit and Retention Lease Areas for the Title Areas and Greater Gorgon Gas Fields



NB: Ownership is subject to change pursuant to an agreement between Chevron Australia, Mobil Australia Resources Company and Shell Development Australia to align their interests on a 50/25/25 basis in certain permits. This change requires government approval before it becomes effective.

Land Tenure under the Agreement

If environmental and State Agreement approval for construction of a gas processing facility on Barrow Island is granted, the area allowed for new disturbance will be limited to a total of 300 ha. Of that area, 50 ha have been set aside for petroleum pipeline easements and 150 ha reserved until 31 December 2009 for the Joint Venturers. The remaining 100 ha is reserved for other projects to process or use gas from the Title Areas or the Greater Gorgon area. Tenure over this land will not be granted until a development proposal has been approved. The proposal could be for LNG or other petroleum-based products, processed gas for use on Barrow Island and/or a domestic gas plant for gas for the mainland.

A lease for gas processing would be granted under the *Land Administration Act 1997* for a period of 60 years but this land would remain part of the Class A Nature Reserve. Lease rent and charges would be similar to those paid by other large gas processing projects in the Pilbara region. The lease would be subject to local government (Shire of Ashburton) rates.

Gas to the Mainland

The State Agreement covers delivery of gas to the mainland. The Joint Venturers are required to submit, by 31 December 2010, a proposal for a domestic gas project to deliver gas to the mainland by 31 December 2012. This project must have the capacity to be progressively expanded to at least 300 Terajoules per day (TJ/day). If the domestic gas project is not commercially viable, the government can extend the deadline for delivering gas to the mainland. There is provision for an independent expert to advise the government on commercial viability.

The Joint Venturers are required to actively market domestic gas, including investigating proposals for using gas for petrochemical feedstock, and report annually to the government on its domestic gas marketing activities.

The Joint Venturers are obliged to reserve 2000 Petajoules (PJ) of gas for domestic gas purposes from the Title Areas and, unless the government agrees, cannot expand beyond the first phase of an LNG project until they have submitted a domestic gas proposal which has been approved by the government.

Net Conservation Benefits

In the State Agreement, net conservation benefits (NCBs) are defined as demonstrable and sustainable additions to, or improvements in, ‘biodiversity conservation values’ of Western Australia. As noted in the ESE Review, the key conservation values of Barrow Island are associated with its unique fauna population particularly the suite of native marsupials, migratory birds and subterranean fauna. These values are enhanced because it is an island free from introduced fauna. Where possible, NCBs should target these biodiversity conservation values on Barrow Island or in similar bioregions of Western Australia.

As outlined in the Agreement, NCBs will be delivered by the Joint Venturers by paying $40 million (indexed) in instalments to a special purpose Barrow Island NCB Trust Account. The Trust will be administered by the Executive Director of the Department of Conservation and Land Management (CALM). An Advisory Board will be established and this Advisory Board will be entitled to receive reports on, and make recommendations about, the administration and activities of the Trust. A representative of the Joint Venturers will sit on the Advisory Board, along with nominees of the CALM Act Minister.

The first payment of $3 million will be due once the Trust Account has been established. A further $2 million will be payable if the first phase of the proposed Development is approved, $5 million on approval of the second phase, or after 30 years if the second phase is not approved, and thereafter, $1 million per year will be payable. The annual $1 million payments are to continue until an aggregate of $40 million (plus indexation amounts) has been paid into the Trust Account.

CALM Costs on Barrow Island

The State Agreement also sets the terms for the Joint Venturers to provide services and facilities for a permanent presence of officers from CALM on Barrow Island. The Joint Venturers are required to provide services and facilities for up to three officers during construction and for up to two officers at other times. The role of these officers may include ensuring all onsite and offsite areas are appropriately monitored, researched and managed for direct and indirect environmental impacts. They may also ensure that an ecological knowledge base of the island is being suitably developed.

The Joint Venturers will also pay certain costs CALM incurs in maintaining this presence on Barrow Island, including salaries and operating costs. These costs will be capped at $1 million per year during construction and $750 000 (indexed) per year at other times.

Barrow Island Coordination Council

Under the State Agreement, the Joint Venturers and the Barrow Island Joint Venture (the operator of the existing oil operations on Barrow Island) would be required to establish and fund a Barrow Island Coordination Council (BICC). Any other future holders of tenure on Barrow Island would also be required to participate in the BICC.

The BICC will:

- provide a single point of contact and interaction between CALM and the operators on Barrow Island
- liaise with CALM on the environmental management of the island
- establish, monitor and review quarantine procedures
- plan and coordinate emergency response and remediation for quarantine breaches, spills and fires.

Reservoir Carbon Dioxide (CO_2) Disposal

In addition to the environmental approvals required under the EPBC Act and EP Act (refer to Chapter 4) to develop a gas processing facility on Barrow Island, it will also be necessary to submit a separate application to the government for approval for disposal of reservoir carbon dioxide (CO_2) under the Barrow Island Act.

The application must provide technical advice and data, and explain the:

- position, size, capacity and geological structure of the underground formation
- rate of disposal, volume and composition of the CO_2 and expected duration of disposal
- method of CO_2 injection and disposal
- capability of the formation to confine the disposed CO_2.

When examining a proposal for CO_2 disposal, the Government of Western Australia will consult with other relevant parties. It may also seek advice from anyone it considers relevant and request the Joint Venturers to inform other parties of its application.

Australian Industry Participation

Western Australian Government policy requires Australian industry to be given full, fair and reasonable opportunity to participate in resource development projects. It encourages the opening of early lines of communication between contractors, service providers and resource developers.

For this reason, the State Agreement requires the Joint Venturers to adhere to Australian Industry Participation (AIP) requirements. As such, the Joint Venturers are required to:

- use Western Australian (the Pilbara region if possible or, if Western Australians are not available, Australian) labour, except where it is unreasonable or economically impractical
- use Western Australian (or if Western Australians are not available, Australian) engineers, surveyors, architects, other consultants, specialists, project managers, manufacturers, suppliers and contractors, as far as it is reasonable and economically practicable
- give due consideration, or preference where possible, to Western Australian (or, if Western Australians are not available, Australian) suppliers, manufacturers and contractors when letting contracts for placing orders for works, materials, plant, equipment and supplies where price, quality, delivery and service are equal to, or better than those obtainable elsewhere.

In cases where a contract is to be made with an international supplier, manufacturer or contractor, wherever possible preference should be given to proposals that include Australian participation where price, quality, delivery and service are otherwise equal or better. In contracts entered into with a third party, that party must be required by the Joint Venturers to adhere to AIP requirements.

Participation by Australian industry in the Gorgon Development will be monitored through regular reports submitted to the government by the Joint Venturers. These reports will be required monthly after a development proposal is submitted. Further, the Joint Venturers are required to notify the government of work, materials or equipment it proposes to obtain from outside Australia. Reporting on local content is also required during preparatory work.

2.4 Conclusion

The establishment of the strategic ESE Review process allowed the Government of Western Australia to make an informed decision on whether to grant in-principle approval for restricted access to Barrow Island to site a gas processing facility. This process was designed to review and assess the potential net conservation benefits and all relevant environmental, social, economic and strategic issues associated with the proposed Development with significant input from interested stakeholders.

After the government received and considered collective agency advice and public comment on the ESE Review document released by the Joint Venturers, Cabinet granted in-principle approval for restricted access to Barrow Island as a foundation development for Gorgon gas.

In parallel with the ESE Review process in the months before the Cabinet decision, the state prepared legislation to put into effect Cabinet's decision in the event that it granted access to Barrow Island. At the same time, the terms of a State Agreement were negotiated with the Joint Venturers.

Assent to the *Barrow Island Act 2003* saw Western Australia take the first significant steps towards unlocking the vast reserves of natural gas in the Greater Gorgon area situated some 130 km off the Pilbara coastline. However, before proceeding with the proposed Development, it is first necessary for the Joint Venturers to receive environmental approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the Western Australian *Environmental Protection Act 1986.* Further details on the assessment process under these Acts are provided in Chapter 4 of this Draft EIS/ERMP.

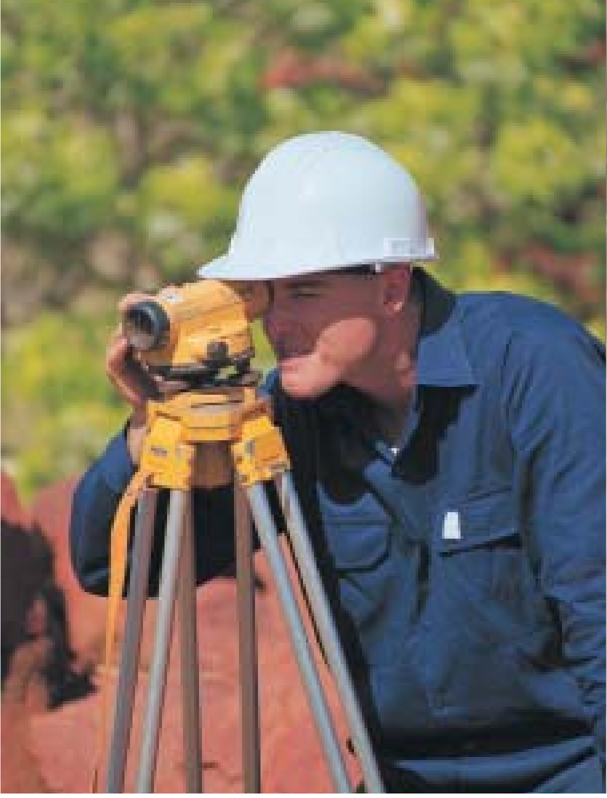
03: Development Alternatives

In the 10-year period before the Gorgon Joint Venturers decided to seek in-principle approval for restricted access to Barrow Island for a foundation development, a number of alternative locations, within a 200 km radius of the Gorgon gas field, were investigated. Pursuing these concepts required the completion of many engineering, commercialisation, marketing and environmental studies at a cost of almost $1 billion.

A commercialisation attempt on the Burrup Peninsula was terminated when it became clear the proposed development would be internationally uncompetitive. Subsequently, a systematic and stepwise process was used to identify and assess alternative development locations. The alternative locations examined extend from the Burrup Peninsula in the north to Exmouth in the south together with island locations and potential floating concepts. Candidate locations were assessed against a suite of technical, commercial, social and environmental constraints and requirements. The results of the assessment led the Joint Venturers to the conclusion that Barrow Island, the closest landfall to the gas field, was the only commercially viable location to develop this important resource. This finding was verified by an independent review (and cost audit) commissioned by the Western Australian Department of Industry and Resources (DoIR).

The naturally high levels of carbon dioxide (CO_2) in Gorgon gas must be removed in order to produce Liquefied Natural Gas (LNG) and meet domestic gas specifications. Barrow Island provides the unique opportunity to dispose of this reservoir CO_2 by injection into the Dupuy Formation that lies deep beneath the island. The proposed gas processing facility on Barrow Island would be sufficiently close to a suitable injection site to be an economically feasible undertaking and make the Gorgon Development one of the most greenhouse gas efficient LNG plants in the world.

An assessment of these regional alternative locations against the controlling provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) showed that all the locations have similar potential for impacts on Commonwealth Marine Areas and only the Exmouth south location has the potential to impact a Commonwealth Marine Protected Area. Similarly, all locations have potential for impacts to species listed as threatened or migratory under the EPBC Act.



An assessment of potential sites on Barrow Island led to the selection of Town Point as the preferred location for the gas processing facility. Compared to other feasible sites on Barrow Island, this site will have a low overall level of environmental impact and offers safe and reliable marine operating conditions due to the sheltered nature of the adjacent waters. Other considerations included a range of technical, operational and cost-related issues.

After investigating alternative shore crossing locations, and associated onshore feed gas pipeline route, North White's Beach was selected as the preferred location. Flacourt Bay is being carried as a fall-back option through the current design phase pending more detailed geological investigations. An onshore pipeline route from North White's Beach will run along existing roads and other disturbed land as much as possible.

A summary of the consequences of not proceeding with the Gorgon Development during the current window of market opportunity (the 'no development alternative') is also provided.

This chapter is a description of the process used to evaluate alternatives that led to the decision to develop a gas processing facility at Town Point on Barrow Island.

Alternative engineering or design options and environmental impact mitigation strategies are dealt with as they arise elsewhere in this document (particularly Chapters 6, 7 and 10–15).

3.1 Introduction

The various assessments that have been undertaken to select a location for the gas processing facility, and associated infrastructure for the proposed Gorgon Development are discussed in this chapter. It details the options considered and addresses the following questions:

- Why utilise Barrow Island for the gas processing facility rather than one of the other potential locations?
- Why was Town Point on Barrow Island selected as the site for the gas processing facility?
- Why is the shore crossing proposed at North White's beach?
- Why is it proposed to directionally drill the shore crossing?
- What happens if the proposed Development does not proceed?

The process used to identify Barrow Island as the only feasible location to inject reservoir CO_2 is discussed in Chapter 13.

3.2 Previous Development Attempts

The Gorgon gas field was discovered in 1980 and since that time the Gorgon Joint Venturers have invested nearly $1 billion in exploration, development, and marketing in an effort to commercialise the resource. A wide range of development options and potential gas processing locations were evaluated; and during the 1990s the Joint Venturers began to actively seek a customer base sufficient to underwrite development of the Gorgon gas field.

Initial development concepts focused primarily on a large, conventional Liquefied Natural Gas (LNG) facility on the mainland. In 1998, the development case was based on a two-train, 8 million tonne per annum LNG development on the Burrup Peninsula. This concept involved an attempt to optimise economies of scale and synergies with adjacent infrastructure operated by the North West Shelf Joint Venture (NWSJV). However, due mainly to the high cost of the pipeline between the field and plant location, this concept proved to be uncompetitive in the LNG market. In addition, large volumes of carbon dioxide (CO_2) would have had to be emitted to the atmosphere due to the lack of a suitable site for CO_2 injection at, or reasonably close to, the Burrup Peninsula. The lack of international competitiveness, absence of a suitable site for injection of reservoir CO_2, and changes in the LNG market in 1998, led to the termination of this commercialisation attempt.

Since that time, the Joint Venturers actively sought a domestic gas customer base sufficient to fund development of the Gorgon gas field. However, it was concluded that a domestic gas project would not be commercially viable in isolation and that a much larger project (such as LNG production) would be required to underwrite a domestic gas development.

3.3 Overview of the Development Concept

In recent years the LNG market has grown and LNG is being sought in both new and existing markets in Asia–Pacific countries. Other regions are also emerging as potential markets. The scale of these opportunities is significant as the proposed Gorgon Development must be large enough to capture economies of scale whilst being consistent with market capacity.

In parallel with marketing assessments, preliminary engineering studies were executed by the Joint Venturers on alternative concepts covering a vast area spanning from the Burrup Peninsula to Exmouth on the mainland to offshore and island-based concepts located on the Montebello Islands and Thevenard Island. Floating and gravity based offshore LNG processing facilities have also been considered.

Included in these studies was an assessment to determine whether Barrow Island could be an environmentally acceptable and commercially viable development alternative. Barrow Island is a Class A Nature Reserve and conservation of its flora and fauna presents significant challenges to the development of a gas processing facility. However, 40 years of oil production operations on Barrow Island demonstrates that a carefully managed development is compatible with maintaining its conservation values. After a review of the environmental issues that could be associated with a development on the island, the Joint Venturers concluded that a development could be undertaken in an environmentally acceptable manner. Therefore, Barrow Island was selected as a site for the gas processing facility. In parallel, development and execution concepts were further defined to capture a maturing market, which may not recur for a substantial period of time.

The Gorgon Development concept is based on a gas processing facility to produce LNG for the international market and domestic gas for the Western Australian market. LNG plants are typically built in ‘trains’ of processing capacity. Two trains of up to five million tonnes per annum (MTPA) notional capacity each are currently viewed as providing a good balance of technical efficiency, marketable capacity and economies of scale.

The Development concept, described in more detail in Chapter 6, is based on the initial installation of a subsea gas gathering system and pipeline (approximately 70 km) from the offshore reserves to Barrow Island. The gas would be processed at a facility located at Town Point on the east coast of the island. It is proposed to inject CO_2, naturally contained in the gas, into the Dupuy Formation that lies deep below the island. The LNG will be transported by ship to international markets and natural gas delivered via a subsea pipeline to the Western Australian mainland for use by industrial and domestic customers. Condensate associated with the gas stream would be separated and loaded onto ships for market directly from Barrow Island.

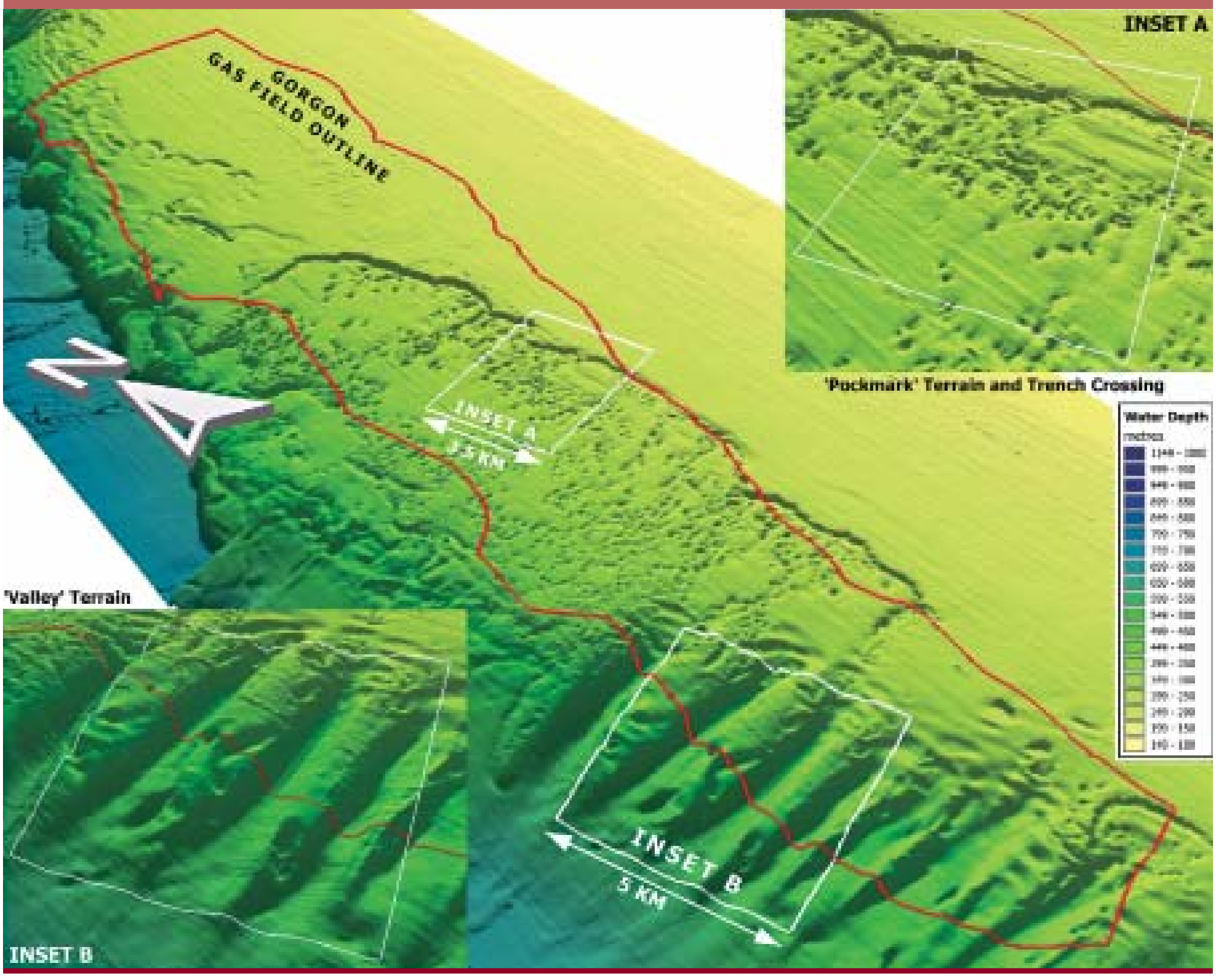
The following sections describe the process that led to this development proposal.

3.4 Technical and Commercial Constraints

Studies over the past 20 years demonstrate that, in addition to environmental challenges, there are significant technical and commercial constraints that affect development of the Gorgon gas field and the other fields of the Greater Gorgon area. The proposed Development must effectively address the following challenges:

- **Deep water** – as gas will be produced from at least 220 m of water, it will be one of the deepest production systems off the coast of Western Australia.

Figure 3-1:
Seabed Terrain of the Gorgon Gas Field



- **Carbon dioxide (CO_2)** – gas from the Gorgon gas field contains approximately 14 vol% CO_2, a feature that requires additional investment in materials and equipment; and specific greenhouse gas emission management strategies.
- **Liquid yield** – while the gas fields are high quality reservoirs and are very productive, the gas contains a very low proportion of liquid hydrocarbon (such as oil or condensate). Consequently, the proposed Development will not generate large revenue from the sale of liquids which are commonly associated with gas fields.
- **Geotechnical conditions** – the water depth combined with the seabed conditions on the scarp at the Gorgon field location are such that it is impractical to install a bottom-founded structure, such as a platform, directly over the producing reservoirs (Figure 3-1).
- **Development size** – the Development must be of sufficient size to underwrite the initial investment and capture the economies of scale, but not so large that the market cannot absorb the output, or that the deliverability of the reservoir is overstressed.

These challenges constrain the development alternatives open to consideration and underline the need to minimise costs, for example, by reducing the distance between the gas fields and the gas processing facility.

3.5 Assessment of Regional Locations

This section describes the process and reasons for selecting Barrow Island as the preferred location for the gas processing facility.

Barrow Island was selected as the preferred development location in 2003. As the regional assessment studies concluded other locations were not commercially viable, further engineering and environmental studies were restricted to a Barrow Island-based development. As a result, the development concept has been refined in response to this greater level of detail, resulting in the current concept as presented in Chapter 6. The following comparisons are based on the development concepts as tested through the ESE Review process.

A stepwise, systematic screening process was used to identify and assess possible development locations as shown schematically in Figure 3-2, and discussed in more detail throughout this Chapter.

The first step of the assessment was to identify location selection criteria. The most important of these selection criteria, their relevance and particular constraints are outlined in Table 3-1. These constraints are based on the knowledge and experience of the Joint Venturers' engineering staff and specialist consultants. Each of the Development requirements and constraints listed in this table were assigned a weighting that reflected their relative importance in a multi-criteria analysis.

Using the results of this multi-criteria analysis, and assuming that CO_2 injection would occur on Barrow Island (refer to Chapter 13 for an explanation), the second stage of the assessment identified a short-list of potential development locations.

The area within an approximately 200 km radius of the Gorgon gas field, as shown in Figure 3-3, was divided into 500 x 500 m grid squares and assigned a score that reflected the level of constraint it had when requirements, constraints and associated weightings were considered (ChevronTexaco Australia 2003, Technical Appendix C). Areas that broadly met the Development requirements and constraints were then identified and a Geographic Information System (GIS)-based model was used to analyse the data. Detailed economic criteria were not included until the analysis of the short-list of potential locations was available. This reduced the risk of biasing the outcome and also allowed the next evaluation phase to concentrate on fewer locations.

The Maitland Estate was initially excluded due to its unacceptably long distance from the coast. However, because this location is a formally designated industrial zone, with few significant environmental or social constraints, it was considered in combination with West Intercourse Island. This island, which also offers a potentially suitable ship-loading point, was also retained as a possible stand-alone location.

Varanus Island was excluded because the majority of useable space on the island is already occupied by the existing facilities operated by Apache Energy.

Initially it was considered that a site at Onslow might also be feasible. However, more detailed assessment showed that the deep water contours did not extend as close to the coast as was initially indicated. This site would have therefore required a very extensive and prohibitively expensive dredging operation, and so was excluded from the short list and further assessment. (It is to be noted that, similar to other mainland sites, the distance from the gas field would increase development costs in the order of $1 billion. Refer to Table 3-3).

Figure 3-2:
Selection Process for Potential Development Locations

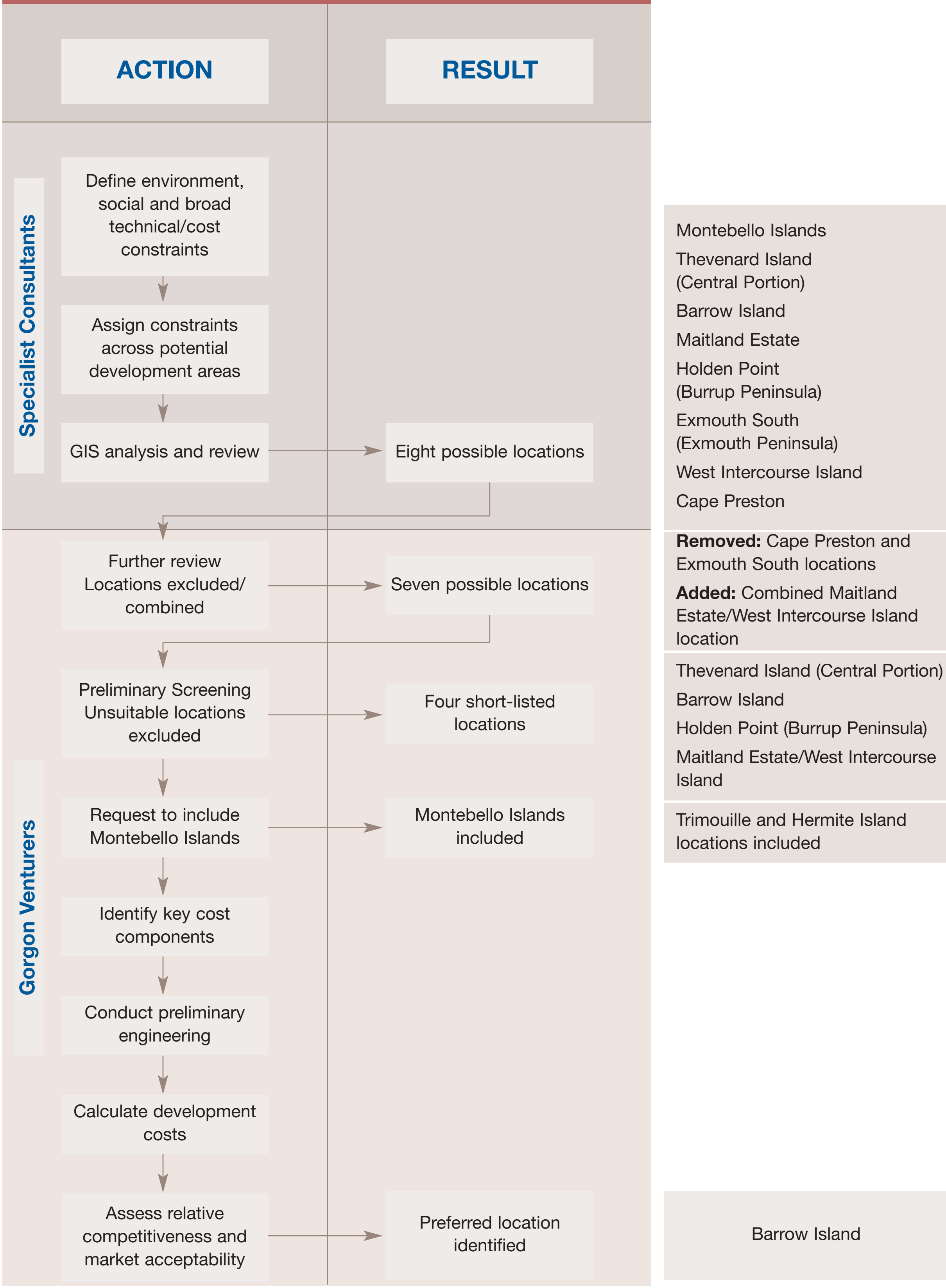


Table 3-1:
Key Requirements and Constraints for the Gorgon Gas Processing Facility (source: ChevronTexaco Australia 2003)

Requirement/Constraint	Parameter	Rationale
Technical/Cost		
Proximity to Gorgon gas field	Facility to be located within 200 km of Gorgon gas field.	Cost of large diameter gas supply pipelines become increasingly prohibitive with distance from the Gorgon gas field.
Sufficient available area	At least 300 ha of land available for development.	To safely accommodate plant, infrastructure and construction needs.
Proximity to coastline	Processing facility to be located within 10 km of coastline.	To allow the liquefied gas to be piped to export ships – i.e. jetty requirements and plant location are closely linked. Plant-to-ship pipeline length and costs will be reduced by minimising distance of the plant site from the shipping berth.
Proximity to deep water	Deep water within 5 km of adjacent coastline.	To keep dredging/jetty requirements within reasonable limits.
Sheltered water	Docking facilities will be located within sheltered, navigable waters.	To allow safe berthing of LNG carriers and loading of product.
Slope	Less than five per cent slope at plant location.	To keep earthworks disturbance during construction within reasonable limits.
Elevation	At least 5 m – Australian Height Datum (AHD).	To avoid storm surge flooding the site must be elevated.
Proximity to existing infrastructure	Preference for locations with existing infrastructure.	To minimise costs and associated impacts. This also includes proximity to tie-in to the existing domestic gas infrastructure.
Pipeline crossings	Avoid crossing existing subsea pipelines.	To minimise cost increases and risks.
Environment		
Mangroves	No development within 200 m of mangrove habitat.	To protect important habitat and key primary producers.
Declared rare flora	Exclusion zone of 1 km in areas where declared rare flora species are present.	To protect important species.
Fauna species and habitats	Avoid protected species and habitats. Small islands of less than 1000 ha to be avoided.	To protect important species and habitat. Small islands avoided as they have less resilience to habitat loss.
Conservation reserves	National and Marine Parks and other conservation reserves to be avoided where practicable.	To avoid disturbance to conservation reserves established for protection of flora, fauna and habitats.
Saline coastal flats	Avoid saline coastal flats.	To avoid disturbance to coastal flats considered to have habitat value.
Water courses	No development within 100 m proximity of water courses.	To avoid disruption on or near water courses including natural drainage patterns, as it may lead to erosion and loss of habitat.
Groundwater reserves	No development in areas where prescribed groundwater reserves exist.	To minimise risk of contamination of groundwater.

Table 3-1: (continued)
Key Requirements and Constraints for the Gorgon Gas Processing Facility (source: ChevronTexaco Australia 2003)

Requirement/Constraint	Parameter	Rationale
Social		
Settlements	No development within 3 km of settlements.	Development close to a settlement is considered unacceptable and counter to fundamental planning principles. Due consideration to amenity, visual impact, pollution potential, disturbance and health and safety risks.
Tourism and recreation reserves	No development within 3 km of tourism and recreation reserves or specific attractions or venues.	Due consideration to amenity and landscape values.
Aboriginal heritage sites	No development within 500 m of known Aboriginal heritage sites.	Protection required by legislation and buffer required to adequately protect sites.
Native Title claims	Avoid development in areas subject to Native Title claims where practicable.	Conflicting land use and potential to lead into protracted and complex negotiation and compensation.
Mineral deposits	Development to avoid known mineral deposits.	Preferable for a Development not to sterilise a mineral resource.
Mining tenements	Avoid development in areas subject to mining tenements.	To avoid conflicting land use and compensation requirements.
Pearling leases	No development within 2 km of areas covered by pearling leases.	To avoid potential disruption to pearling activities.

Large areas of the Pilbara coastline were not considered suitable for development due to the environmental values along the coastal fringe. This is reflected in extensive areas of saline coastal flats and mangroves, places on the Register of the National Estate, Conservation and Land Management (CALM) estate and proposed reserves. The mainland coastline from southern Exmouth Gulf to Cape Preston is also characterised by extensive areas of shallow water which further restrict development in this area. Cape Preston was ruled out primarily because it was already occupied by mining operations.

Hermite Island in the Montebello Islands was ruled out because of the lack of useable space and its history associated with nuclear weapons testing.

A gravity based offshore structure in sheltered waters was also excluded because such a facility of this scale would present significant technical challenges and considerable costs.

After eliminating these sites from consideration, the remaining locations were subjected to the second stage of assessment, which included preliminary engineering studies and an assessment of commercial competitiveness.

This process resulted in the following list of potential locations for further assessment:

- Montebello Islands
- Thevenard Island (central portion only)
- Barrow Island
- Maitland Estate/West Intercourse Island
- Burrup Peninsula (Holden Point)
- Exmouth South (Exmouth Peninsula)
- West Intercourse Island.

These locations are shown in Figure 3-3.

The key attributes of these locations were compared and are presented in Table 3-2, while Section 3.5.1 provides a detailed assessment of each site against the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Figure 3-3:
Potential Locations for the Gorgon Gas Processing Facility

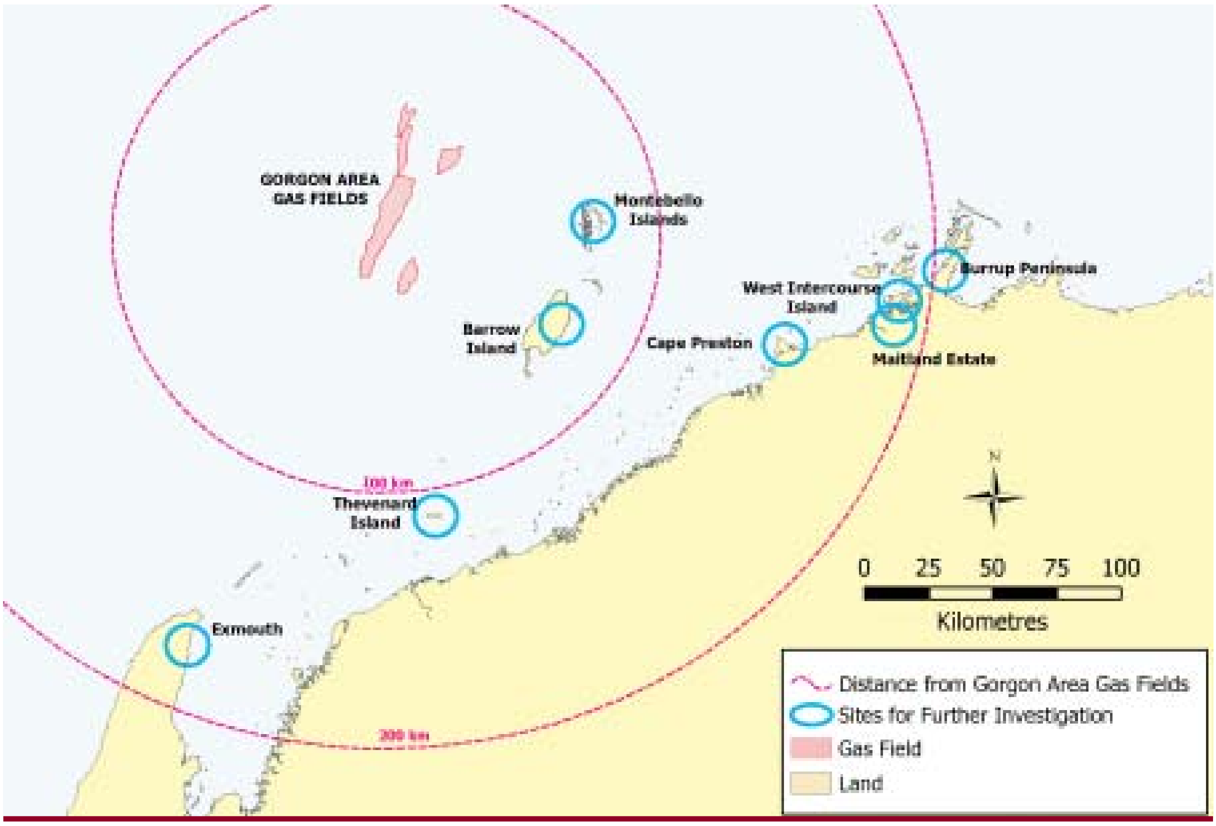


Table 3-2:
Comparison of Key Attributes of Potential Locations

Constraints	Possible Locations						
	Montebello Islands (Trimouille Island)	**Thevenard Island**	**Barrow Island**	**Maitland Estate (ME)/ West Intercourse Island (WII)**	**Burrup Peninsula (Holden Point)**	**Exmouth South (Exmouth Peninsula)**	**West Intercourse Island**
Technical/Cost							
Pipeline distance to Gorgon gas field	Approx. 90 km	Approx. 120 km	Approx. 70 km	Approx. 250 km	Approx. 230 km	Approx. 200 km	Approx. 200 km
Sufficient available area	Area available for development is extremely restricted.	Area available for development is limited.	Sufficient area available for development requirements.	Sufficient area available for development requirements.	Sufficient area available for development requirements.	Sufficient area available for development requirements.	Sufficient area available for development requirements.
Proximity to coastline	Immediately adjacent to coast.	Immediately adjacent to coast.	Immediately adjacent to coast.	Maitland Estate 10 km inland, coastal access via West Intercourse Island.	Immediately adjacent to coast.	Coastal.	Immediately adjacent to coast.
Proximity to deep water	Good access to deep water.	Good access to deep water.	Moderate access to deep water.	Moderate access to deep water.	Moderate access to deep water.	Moderate access to deep water.	Moderate access to deep water.
Sheltered water	Limited sheltered waters.	Limited sheltered waters.	Sheltered waters.	Sheltered waters.	Sheltered waters.	Sheltered waters.	Sheltered waters.
Slope	Stable soils and minimal amount of earthworks required.	Soils would have to be stabilised.	Stable soils and minimal amount of earthworks required.	ME – stable soils with a minimal amount of earthworks required WII – moderate geotechnical conditions.	Difficult geotechnical conditions at site.	Stable soils and minimum earthworks required.	Moderate geotechnical conditions.
Elevation	No elevation constraints.	No elevation constraints.	No elevation constraints.	ME – low lying site. WII – no elevation constraints.	No elevation constraints.	No elevation constraints.	No elevation constraints.

Table 3-2: (continued)
Comparison of Key Attributes of Potential Locations

Constraints	Possible Locations						
	Montebello Islands (Trimouille Island)	Thevenard Island	Barrow Island	Maitland Estate (ME)/ West Intercourse Island (WII)	Burrup Peninsula (Holden Point)	Exmouth South (Exmouth Peninsula)	West Intercourse Island
Technical/Cost (continued)							
Proximity to existing infrastructure	No existing infrastructure.	Adjacent to existing oilfield infrastructure.	Adjacent to existing oilfield infrastructure.	No existing infrastructure at site. Good regional infrastructure.	Site is adjacent to the NWS LNG development. Good regional infrastructure.	No existing infrastructure. Good regional infrastructure.	No existing infrastructure. Good regional infrastructure.
Distance to potential CO_2 injection site at Barrow Island	40 km	115 km	14 km	165 km	~200 km	~200 km	~150 km
Pipeline crossings	No	No	Yes	Yes	Yes	No	Yes
Environment							
Mangroves	No mangroves.	No mangroves.	Relatively few areas of mangroves.	WII – surrounded by mangroves.	No mangroves.	No mangroves.	Surrounded by mangroves.
Declared rare flora	Locality has relatively few significant flora.	Locality has relatively few significant flora.	Locality has relatively few significant flora.	Locality has relatively few significant flora.	Locality has relatively few significant flora.	Locality has relatively few significant flora.	Locality has relatively few significant flora.
Fauna species and habitats	Locality has relatively few significant terrestrial fauna and habitats. High marine environmental and habitat values.	Locality has relatively few significant terrestrial fauna and habitats. High marine environmental and habitat values.	High ecological values. Several fauna are endemic to Barrow Island. High marine environmental and habitat values.	Locality has relatively few significant terrestrial fauna and habitats. Presence of seasonal wading and water birds.	Locality has relatively few significant fauna and habitats.	Locality has relatively few significant fauna and habitats. High marine environmental and habitat values.	Locality has relatively few significant fauna and habitats.
Conservation reserves	Class A Conservation Reserve. Surrounding waters considered for a Marine Park.	Class C Nature Reserve.	Class A Nature Reserve. Surrounding waters considered for a Marine Management Area.	None.	None.	Close proximity to Ningaloo Marine Park.	None.

Table 3-2: (continued)
Comparison of Key Attributes of Potential Locations

Constraints	Possible Locations						
	Montebello Islands (Trimouille Island)	**Thevenard Island**	**Barrow Island**	**Maitland Estate (ME)/ West Intercourse Island (WII)**	**Burrup Peninsula (Holden Point)**	**Exmouth South (Exmouth Peninsula)**	**West Intercourse Island**
Environment (continued)							
Saline coastal flats	No saline coastal flats.	No saline coastal flats.	No saline coastal flats.	WII surrounded by tidal mudflats.	No saline coastal flats.	No saline coastal flats.	Surrounded by tidal mudflats.
Water courses	No water courses.	No water courses.	Water courses exist (intermittent).	Water courses exist.	Water courses exist.	Water courses exist.	Limited numbers of water courses.
Prescribed groundwater reserves	None	None	None	None	None	Prescribed groundwater reserve exists.	None
Social							
Settlements	No settlements.	Small tourist resort accom-modation.	No settlements.	Relatively close to Dampier.	Relatively close to Dampier.	Relatively close to existing settlements and major highway.	Relatively close to Dampier.
Tourism and recreation reserves, attractions or activities	Existing recreational boating and yachting activity. Islands support increasing tourism.	Existing recreational boat and yachting activity. Island also supports tourism.	No tourism or recreation.	No tourism or recreation.	Area used extensively for recreation and tourism.	High regional tourism activity and high tourism industry growth potential.	No island tourism or recreation. Nearby recreational fishing occurs.
Aboriginal heritage sites	Relatively few Aboriginal heritage sites exist.	One Aboriginal heritage site.	Few registered Aboriginal heritage sites.	Many Aboriginal heritage sites recorded.	High occurrence of Aboriginal heritage sites.	Aboriginal heritage sites in general area.	High occurrence of Aboriginal heritage sites.
Native title claims	No native title claims.	Native title claim exists.	No native title claims.	Native title claims settled.	Native title claims settled.	Native title claim exists.	Native title claims settled.

Table 3-2: (continued)
Comparison of Key Attributes of Potential Locations

Constraints	Possible Locations						
	Montebello Islands (Trimouille Island)	Thevenard Island	Barrow Island	Maitland Estate (ME)/ West Intercourse Island (WII)	Burrup Peninsula (Holden Point)	Exmouth South (Exmouth Peninsula)	West Intercourse Island
Social (continued)							
Mineral deposits	No mineral deposits.	No mineral deposits.	No mineral deposits.	No mineral deposits.	No mineral deposits.	No mineral deposits.	No mineral deposits.
Mining tenements	No mining tenements.	No mining tenements.	No mining tenements.	No mining tenements.	No mining tenements.	Some mining tenements.	No mining tenements.
Pearling leases	Several existing pearling leases in adjacent waters.	Pearling leases.	Pearling lease in adjacent waters on east coast of island.	No pearling leases in adjacent waters.	No pearling leases in adjacent waters.	No pearling leases in adjacent waters.	No pearling leases in adjacent waters.

Prior to detailed commercial assessments three potential locations were excluded from further assessment:

- **Exmouth South** was excluded because it has high environmental, social and technical/cost constraints. It was considered highly unlikely to be viewed more favourably following detailed analysis.
- **West Intercourse Island** was excluded as a separate location because it was incorporated into the **Maitland Estate/West Intercourse Island** concept with the island being used for storage and jetty facilities due to its proximity to deep water. Also it did not offer any significant advantages as a stand alone option over the nearby Burrup Peninsula or Maitland Estate/West Intercourse Island concepts.
- **The Montebello Islands** were ruled out because of the background with testing of nuclear weapons.

Four locations, Barrow Island, Thevenard Island, Maitland Estate and the Burrup Peninsula, were included in the short-list for further analysis of commercial competitiveness.

Cape Preston and two of the islands in the Montebello group, which were initially excluded, were re-included in the assessment in response to stakeholder requests during the ESE Review process.

The commercial competitiveness assessment was a multi-factor analysis that considered economics, market acceptance, technical and environmental considerations and social and strategic considerations. The components of the proposed Development concept that have the greatest impact on the cost of construction and operation of selected sites are listed in Table 3-3.

For each location, a number of development concepts were considered (e.g. corrosion resistant alloy (CRA) pipeline vs. a platform and carbon steel pipeline to shore; and site options within the general area). Well fluids from the Gorgon gas field reservoir contain water and approximately 14 vol% CO_2, which significantly increase the risk of corrosion. This makes it essential to use a comprehensive corrosion management system from the wellhead to the point of first gas treatment to ensure pipeline integrity. The use of CRA is one strategy that will ensure the pipeline integrity, while another is the use of carbon steel with continuous injection of corrosion inhibitor chemicals. As CRA material is expensive, beyond a distance of 100 km it becomes more economic to install an unmanned offshore platform with water removal facilities. This would allow a carbon steel pipeline (with the aid of continuous corrosion inhibitor injection) to be used to transport the well fluids to shore (refer to Chapter 6 for

Table 3-3:
Comparison of Key Cost Driver Components

Key Cost Attributes	Short-listed Locations				Other Potential Locations		
	Thevenard Island	Barrow Island	Maitland Estate/West Intercourse Island	Burrup Peninsula	Cape Preston	Montebello Islands Trimouille	Montebello Islands Hermite
Gas Pipeline Length	120 km	72 km	250 km	230 km	175 km	93 km	115 km
Offshore Platform	Required	Not Required*	Required	Required	Required	Not Required*	Not Required*
Jetty Length	1.1 km	3.9 km	1.1 km	0.5 km	1.9 km	0.5 km	2.9 km
Distance from Coast	0.1 km	0.7 km	12.1 km	0.1 km	3.4 km	0.2 km	0.1 km
Volume of Dredging	0.86 Mm^3 soft soils/sand	6.9 Mm^3 soft soils/ sand	6.7 Mm^3 hard soils/rock	7.8 Mm^3 hard soils/rock	3.25 Mm^3 soft soils/sand	0.75 Mm^3 soft soils/sand	2.94 Mm^3 soft soils/sand
Extent of earthworks	1.4 Mm^3 soft soils/sand	1.4 Mm^3 soft soils/sand	1.4 Mm^3 soft soils/sand	1.7 Mm^3 hard soils/rock	3.0 Mm^3 soft soils/sand	1.4 Mm^3 soft soils/sand	1.7 Mm^3 soft soils/sand
CO_2 Pipeline Length	115 km	14 km	165 km	200 km	95 km	40 km	30 km
Relative Cost, Millions	+ $500	Reference Point	+ $1100	+ $1000	+$720	+ $70	+ $300
Useable Land (300 ha available)	Yes	Yes	Yes	Yes	Yes (but covered by an existing mining tenement)	No	No

** Not required for initial development.*

additional information). However, for the purpose of cost comparison, the most economic concept for each regional location was used.

Disposal of reservoir CO_2 is considered to be a critical issue for a number of stakeholders, and was included in all development concepts. Extensive work, beginning in 1997, identified that the only feasible site for disposal of reservoir CO_2 for Gorgon gas was the Dupuy Formation beneath Barrow Island (Chapter 13). Therefore the cost to deliver CO_2 from each potential location to Barrow Island is included in the comparison.

The following section provides a detailed commentary on each site against the provisions of the EPBC Act. It has been intentionally kept separate from the main discussion but the information was integrated into the decision making assessment.

3.5.1 Comparison against EPBC Act Provisions

The seven potential locations for the gas processing facility, as listed in Table 3-2, were also assessed in detail against the provisions of the EPBC Act.

Only three of the seven matters of National Environmental Significance (NES), protected under the EPBC Act, are considered relevant to the proposed Gorgon Development: Listed Threatened Species ('Endangered' and 'Vulnerable'); Listed Migratory Species; and Commonwealth Marine Areas, including one Marine Protected Area. None of the other four matters (i.e. World Heritage Properties; National Heritage Places; Ramsar Wetlands of International Significance; and Nuclear Activities) are considered to relate to any of the alternative locations.

The following sections discuss the three controlling provisions of the EPBC Act as they relate to each of the seven alternative locations (listed above) for the proposed Gorgon Development.

Regional Commonwealth Marine Areas

The Commonwealth Marine Area extends from the offshore boundary of Western Australian state waters at 5.6 km (3 nautical miles) out to 370 km (200 nautical miles) from the coast. The Gorgon gas field lies within this area. Thus the proposed gas pipelines for the Gorgon Development run through the Commonwealth Marine Area before crossing into Western Australian state waters. Although shore crossings for the proposed Development are within Western Australian state waters, there is potential for impacts on marine species that are protected under the EPBC Act. Therefore, activities in state waters have also been assessed against the controlling provisions of the EPBC Act.

Marine species listed as 'Threatened' or 'Migratory' are generally widespread throughout the region and are likely to occur at all of the alternative locations. Therefore, each site is considered to have equal potential for impacts on Commonwealth Marine Areas. Marine protected species that are likely to be widespread within the Commonwealth Marine Area, or in the adjacent Western Australian state waters, are discussed below, while further information is included in Technical Appendix C6.

Listed Threatened Species known to occur, or likely to occur, in the Commonwealth Marine Areas of the region comprise:

- two 'Endangered' turtle species (loggerhead turtle – *Caretta caretta,* olive ridley sea turtle – *Lepidochelys olivacea*)
- one Endangered seabird species (southern giant petrel – *Macronectes giganteus*)
- one Endangered whale species (blue whale – *Balaenoptera musculus*)
- one 'Vulnerable' seabird species (soft-plumaged petrel – *Pterodroma mollis)*
- four Vulnerable turtle species (green turtle – *Chelonia mydas,* flatback turtle – *Natator depressus,* leatherback turtle – *Dermochelys coriacea,* hawksbill turtle – *Eretmochelys imbricata*)
- three Vulnerable shark species (whaleshark – *Rhincodon typus*, grey nurse shark – *Carcharias taurus*, great white shark – *Carcharodon carcharius*)
- one Vulnerable whale species (humpback whale – *Megaptera novaeangliae*).

Some of these species have a predominantly southern distribution and rarely venture into the tropical waters of the proposed Development area. For example, grey nurse and great white sharks are only likely to visit the region at rare frequency (Last and Stevens 1994). The great white shark is more likely to be found in the southern-most alternative location, Exmouth south. The Endangered southern right whale (*Eubalaena australis*) and the southern giant petrel (*M. giganteus*) were identified in searches of the Department of the Environment Heritage (DEH) website (www.deh.gov.au/epbc/assesmentapprovals/index.html); however these species are very unlikely to venture further north than North West Cape.

The migratory species protected under the EPBC Act that are likely to occur within the marine areas of the region comprise:

- three seabird species (wedge-tailed shearwaters – *Puffinus pacificus,* bridled tern – *Sterna anaethetus,* Caspian tern – *Sterna caspia*)
- six wetland bird species (ruddy turnstone – *Arenia interpres*, oriental plover – *Charadrius veredus*, oriental pratincole – *Glareola maldivarum*, little whimbrel – *Numenius minutus*, whimbrel – *N. phaeopus*, greenshank – *Tringa nebularia*)
- seven cetacean species (blue whale – *B. musculus*, Antarctic minke whale – *B. bonaerensis*, Bryde's whale – *B. edeni*, humpback whale – *M. novaeanalgiae*, killer whale – *Orcinus orca*, sperm whale – *Physeter macrrocephalus*, spotted bottlenose dolphin – *Tursiops aduncus*)
- dugong – *Dugong dugon*
- six turtle species (loggerhead turtle – *Caretta caretta*, green turtle – *Chelonia mydas*, flatback turtle – *Natator depressus*, leatherback turtle – *Dermochelys coriacea*, hawksbill turtle – *Eretmochelys imbricata*, olive ridley turtle – *Lepidochelys olivacea*)
- two shark species (whaleshark – *R. typus*, great white shark – *C. carcharias*).

Other listed migratory cetacean species such as sei *(B. borealis),* fin *(Balaenoptera physalus)* and sperm *(Physeter macrocephalus)* whales occur in deep waters off the Western Australian coast and may occasionally visit the shelf waters between the Gorgon gas field and the mainland.

While leatherback and olive ridley sea turtles rarely breed in Australian waters, green, flatback and hawksbill turtles nest throughout the region.

The white-bellied sea-eagle *(Haliaeetus leucogaster)* and the barn swallow *(Hirundo rustica)* are protected as migratory terrestrial birds. While sea-eagles are likely to occur throughout the region, they are generally considered to be non-migratory. The barn swallow is unlikely to occur at any of the alternative locations.

Commonwealth Marine Protected Areas

The only Commonwealth Marine Protected Area in the region of the proposed Development is the Ningaloo Marine Park, which runs along North West Cape and extends 16.7 km (9 nautical miles) from the 5.6 km (3 nautical miles) limit of Western Australian coastal waters. A pipeline from the Gorgon gas field to the Exmouth south alternative location would run past the northern end of the Ningaloo Marine Park.

Threatened Species

Unlike most of the Threatened and Migratory marine species described above, some marine and terrestrial fauna species are more restricted in distribution with closer associations to one or a few of the alternative locations.

The 'Vulnerable' djoongari *(Pseudomys fieldi)* is listed for the region, but is only known to occur naturally on Bernier Island in Shark Bay.

Two Vulnerable reptiles, the Hermite Island worm-lizard *(Aprasia rostrata)* and the Airlie Island ctenotus *(Ctenotus angusticeps)* are known from a few offshore locations, but may occur in similar habitats on other offshore islands such as Barrow Island, Trimouille Island and Thevenard Island. These species have not been recorded at the other alternative locations.

The 'Threatened' species with restricted distribution known to occur, or likely to occur, at each alternative location are discussed below and a summary is provided in Table 3-4.

The following sections examine each of the seven potential locations as listed in Table 3-3 in light of the above information.

Trimouille Island (Montebello Islands)

The Montebello Islands have regionally important rookeries of migratory wedge-tailed shearwaters and roseate terns.

There are no data available on stygofauna from Trimouille Island but it is possible that two protected species (blind cave eel – *Ophisternon candidum* and blind gudgeon – *Milyeringa veritas*) occur in the subterranean limestone structures of the island (Humphreys, B. pers. comm.).

Although not confirmed, it is possible that one and/or both of the Vulnerable reptiles, the Hermite Island worm-lizard (*Aprasia rostrata*) and the Airlie Island ctenotus (*Ctenotus angusticeps*) occur on Trimouille Island.

Thevenard Island

Limited sampling for stygofauna has been carried out on Thevenard Island however none have been collected to date (Humphreys, B. pers. comm.).

Two Vulnerable reptiles, the Hermite Island worm-lizard *(Aprasia rostrata)* and the Airlie Island ctenotus *(Ctenotus angusticeps)* could possibly occur on the island.

Flatback turtles *(Eretmochelys imbricata)* and green turtles *(Chelonia mydas)* nest on Thevenard Island.

Barrow Island

Barrow Island is home to six Vulnerable species of terrestrial mammal, one Vulnerable land bird species, three Vulnerable sea turtle species and two Vulnerable subterranean fish species. The terrestrial fauna are listed as Vulnerable due to their localised island population and restricted distribution.

The listed Vulnerable terrestrial mammal species comprise: the burrowing bettong *(Bettongia lesueur)*, the black-flanked rock wallaby *(Petrogale lateralis lateralis)*, the spectacled hare-wallaby *(Largorchestes conspicillatus conspicillatus)*, the Barrow Island golden bandicoot *(Isoodon auratus barrowensis)*, the Barrow Island euro *(Macropus robustus isabellinus)* and the Barrow Island chestnut mouse *(Pseudomys nanus ferculinus)*.

The Vulnerable white-winged fairy wren (*Malurus leucopterus edouardi)* is endemic to Barrow Island where it is abundant.

Of the Vulnerable subterranean fish species, the blind gudgeon *(M. veritas)* occurs on Barrow Island and the blind cave eel *(O. candidum)* is likely to occur on the island.

The Vulnerable reptiles, the Hermite Island worm-lizard *(Aprasia rostrata)* and the Airlie Island ctenotus *(Ctenotus angusticeps)* may also occur on the island, but have not been found to date.

Green and flatback turtles commonly nest on beaches around Barrow Island. Hawksbill turtles nest on nearby Varanus Island and infrequently on Barrow Island.

Maitland Estate

One Vulnerable bat species (Pilbara leaf-nosed bat – *Rhinonicteris aurantius)* is likely to occur on or near Maitland Estate. The Vulnerable terrestrial mammal, the mulgara *(Dasycercus cristicauda)*, and the Pilbara subspecies of the Olive python *(Liasis olivaceus barroni)* may also occur in this area.

There is no information available regarding stygofauna at Maitland Estate.

Loggerhead, hawksbill, flatback and green turtles nest on beaches within the Dampier Archipelago. These turtles are likely to visit the waters off the Maitland Estate during breeding time.

West Intercourse Island

Listed Threatened Species known to occur, or likely to occur, on or near West Intercourse Island comprise one Vulnerable mammal, the Pilbara leaf-nosed bat *(R. aurantius)* and one vulnerable reptile, the Pilbara subspecies of the Olive python *(Liasis olivaceus barroni)*.

There is no information available regarding stygofauna at West Intercourse Island.

Loggerhead, hawksbill, flatback and green turtles nest on beaches within the Dampier Archipelago.

Holden Point (Burrup Peninsula)

Listed Threatened Species known to occur, or likely to occur, in the area surrounding Holden Point comprise two Vulnerable mammal species (Pilbara leaf-nosed bat – *R. aurantius;* and the mulgara – *Dasycercus cristicauda)* and one Vulnerable reptile, the Pilbara subspecies of the Olive python – *Liasis olivaceus barroni*).

There is no information available regarding stygofauna at Holden Point.

Loggerhead, hawksbill, flatback and green turtles nest on beaches within the Dampier Archipelago.

Exmouth South

Listed Threatened Species known to occur, or likely to occur, in the area surrounding the Exmouth south site comprise two Vulnerable subterranean fishes (blind cave eel – *O. candidum* and blind gudgeon – *M. veritas),* one Vulnerable subterranean remipede (*Lasionectes exleyi)*, two Vulnerable mammals, (the mulgara – *Dasycercus cristicauda;* and the black-flanked rock wallaby – *Petrogale lateralis lateralis*).

In 1993, the Vulnerable Shark Bay Mouse *(Pseudomys fieldi)* was translocated to Doole Island in Exmouth Gulf in order to enhance the conservation of this extremely restricted native rodent.

Loggerhead turtles nest on the Muiron Islands to the north of Exmouth, while other turtle species nest on the beaches in the Exmouth region.

3.5.2 Most Suitable Development Location

All of the locations evaluated are considered to have similar potential for impacts on Commonwealth Marine Areas. Ningaloo Marine Park is the only Commonwealth Marine Protected Area in the Development area and would be potentially impacted by the proposed pipeline from the Gorgon gas field to the Exmouth South alternative location. Numerous marine protected species occur in the region including turtles, seabirds, whales and sharks. These are likely to be widespread within the Commonwealth Marine Area, or in the adjacent Western Australian state waters. Overall, in regard to listed threatened species, none of the locations contain critically endangered species and all locations contain four endangered species and 27 migratory species. Vulnerable species are found at all locations with Thevenard Island, Holden Point and West Intercourse Island likely to contain the least number (11) and Barrow Island the greatest number (20).

Findings from the various studies indicate that Barrow Island is the only location where the Gorgon Development can be commercially viable (refer also to Section 3.5.4 for a discussion on independent verification of this finding). Barrow Island is close enough to the gas field to use a CRA-lined pipeline all the way to landfall without the need for a platform.

Utilisation of Barrow Island would therefore minimise costs of the initial development, which is critical to making the Gorgon Development competitive in international markets. Infrastructure developed by the existing oil operations on Barrow Island may be re-used and the island is relatively close to existing infrastructure for transport of domestic gas.

Barrow Island also provides safe access to relatively sheltered water, especially on the east coast. Access to deep water for LNG carriers can be provided economically with a cost effective combination of dredging and a jetty (Chapter 6). A relatively flat, adequately elevated site of 300 ha can be accommodated on this island without significant adverse impacts to sensitive vegetation or fauna habitats (Chapter 10). A gas processing facility on Barrow Island would avoid impacts on: residential areas and industrial or commercial land users, tourism and recreational areas, mineral deposits and mining tenements, and Aboriginal heritage sites and existing native title claims. Due to existing oilfield operations, Barrow Island already supports logistical infrastructure,

Table 3-4:
Fauna Protected under the EPBC Act Likely to Occur at Alternative Sites

Fauna Type and Status	Trimouille Island	Thevenard Island	Barrow Island	Maitland Estate	Holden Point	Exmouth South	West Intercourse Island
Critically Endangered	0	0	0	0	0	0	0
Endangered	4	4	4	4	4	4	4
Vulnerable	13	11	20	12	11	15	11
Migratory	27	27	27	27	27	27	27
Threatened Ecological Communities	0	0	0	0	0	0	0

including an airfield, accommodation and communications and marine services. The management of the island oilfield is widely recognised as an industry benchmark for the coexistence of petroleum development and biodiversity protection.

This island also provides a unique opportunity to dispose of the CO_2, contained naturally in the reservoir fluid, by injection into reservoirs deep beneath the island. Carbon dioxide disposal is explained in more detail in Chapter 13, but Barrow Island offers the only viable site to inject and dispose of this CO_2.

The assessment of the shortlist of alternative development locations is summarised in Figure 3-4.

3.5.3 Less Suitable Development Locations

Some of the key attributes of each of the other sites are briefly explained in the following, but the focus is on why each of the sites on the short-list is less suitable overall than Barrow Island.

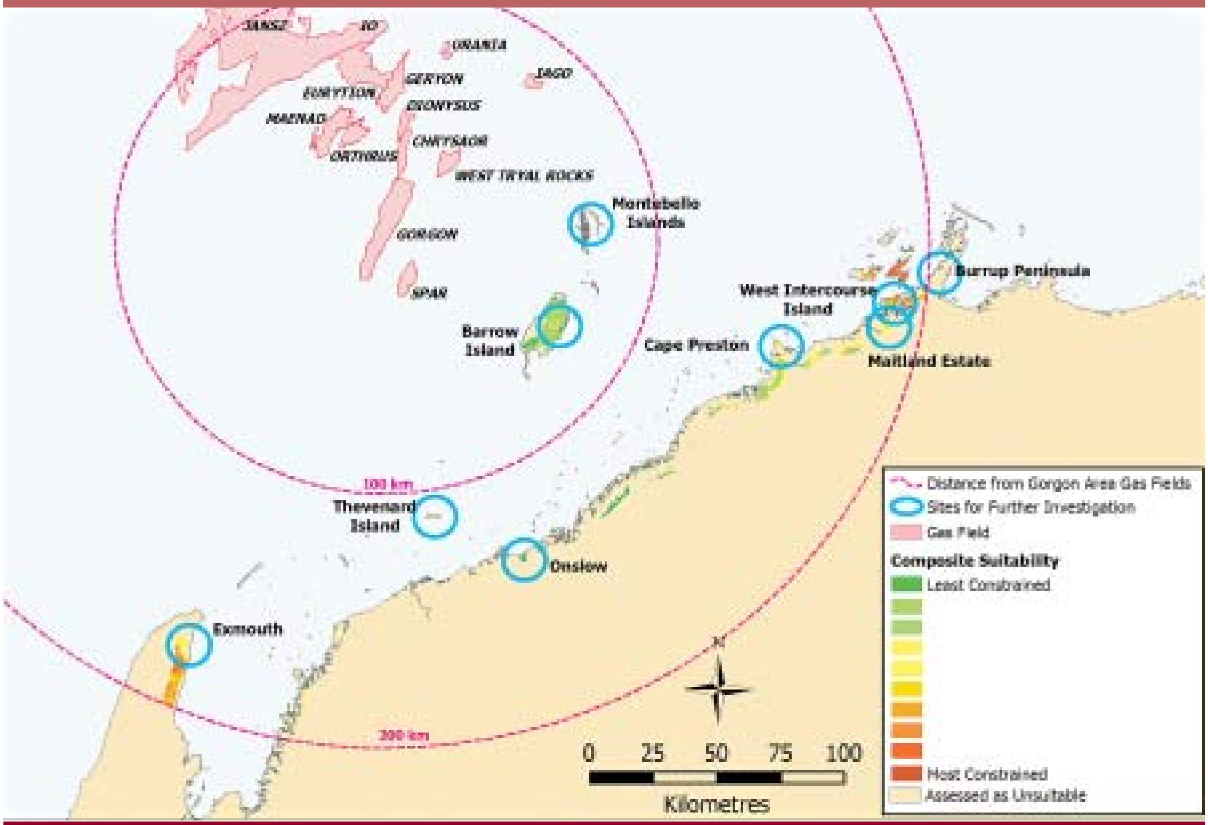
Montebello Islands

The Montebello Islands were initially excluded from consideration due to the lack of usable land and history as a nuclear weapons test site.

This island group was the location of nuclear weapon testing in 1952 and 1956 and elevated radiation levels are still found in some parts of the islands. Radiation Hazard Area covers two-thirds of Trimouille Island and no works involving digging and/or excessive dust movement should be carried out in the contaminated areas (Western Radiation Services 2002). The inhalation hazard from alpha-emitting radionuclides in these areas will not change appreciably over several hundreds of years (Western Radiation Services 2002).

In response to requests during the ESE Review process the only two islands (Trimouille and Hermite) that could possibly support significant infrastructure were included in a short list for assessment of their commercial competitiveness in response to stakeholder comments.

Figure 3-4:
Results Summary of the Location Assessment



Trimouille Island is considered inappropriate as a location for the Gorgon Development due to the potential for long-term exposure to radiation. The Gorgon Joint Venturers are not prepared to expose workers to such risks. Stakeholder engagement has also confirmed that this would be a serious industrial relations issue.

No trace of radioactivity above normal background levels have been found in soil samples from Hermite Island (Western Radiation Services 2002). However, data on re-suspension and deposition is not available and a thorough survey would be required before the site could be considered (Western Australian Department of Health, pers. comm.).

The connection of the Montebello Islands to nuclear weapons testing would also expose the Development to negative public and customer perceptions, adversely impacting the ability of the Gorgon Joint Venturers to attract and retain customers.

In addition to occupational health concerns, neither Trimouille nor Hermite Island has sufficient land available to safely accommodate the Gorgon Development. Trimouille Island is approximately 450 ha and contains less than 100 ha of useable land. Hermite Island is approximately 950 ha, but is such a convoluted shape that it does not provide sufficient contiguous consolidated area for practical planning and establishment of a gas processing facility.

Further, as indicated in Table 3-3, cost penalties are greater than those for Barrow Island (i.e. $300 million for Hermite Island; and $70 million for Trimouille Island).

This option would still require considerable construction activity, operating facilities and a substantial footprint on Barrow Island, mainly associated with injection of CO_2.

Thevenard Island

Thevenard Island is a moderate distance from the Gorgon gas field and provides good access to the coast and deep water. The island is relatively unconstrained from an environmental perspective, although it is surrounded by a rich marine environment and is designated as a Class C Nature Reserve. However, this option is $500 million more expensive than Barrow Island. The main factors contributing to the higher costs include the need for:

- site-specific ground improvements to prevent movement of the soil and equipment during a seismic event
- additional feed gas pipeline length
- levees to protect against storm surge associated with cyclones
- an additional pipeline to connect to the CO_2 injection site
- personnel to be transferred from Barrow Island or Onslow via boat and/or helicopter
- relocation of the existing airstrip as, for safety reasons, fixed wing aircraft movements are incompatible with a gas processing facility in such a limited area.

Other disadvantages of Thevenard Island include:

- limited area available for development
- lack of sufficiently sheltered waters for LNG carrier berthing and loading, which would reduce the reliability of the marine export system and adversely affect the ability to satisfy market delivery requirements
- compromised operational safety if cyclones trigger the evacuation of personnel by helicopter
- limited utility for future expansion due to being well south of the Greater Gorgon area reserves
- potential impacts to recreational fishers, boat users and tourists, all of whom visit the island and its waters
- lack of a jetty location – unless the only feasible location, on the south-east end of the island, is acquired from Mackeral Islands Resort.

This concept would require twin construction sites – one on Thevenard Island and the other on Barrow Island. Compression facilities for injection of CO_2, with associated utilities and infrastructure would be required on both Thevenard and Barrow Islands, and as such this option would still require considerable construction activity, operating facilities, additional quarantine controls on all activities and a substantial footprint on Barrow Island.

Maitland Estate/West Intercourse Island

The combined Maitland Estate/West Intercourse Island option is over $1 billion more costly than the Barrow Island development option. In terms of gas supply, these costs arise from the need for a remote hub platform and an additional 180 km of carbon steel gas pipeline. In terms of gas processing, the location is more distant from the coast (12 km) and would impact on a sensitive shore crossing. In terms of CO_2 injection and disposal, this option would also require an additional 150+ km of CO_2 pipeline, CO_2 compression and booster compression at Barrow Island.

The use of West Intercourse Island for LNG storage and load-out is seen as a distinct disadvantage as this option would require a 12 km long interconnecting causeway and a pipeline easement for LNG pipe-work between the gas processing facility and load-out facility. It would also require construction of LNG storage tanks on a rocky environment at West Intercourse Island, disturbance to a significant number of aboriginal sites, mangroves, and significant dredging would be required to reach the Hamersley Channel. It may also be necessary to dredge a new channel to avoid congestion or to avoid conflicts with other shipping traffic.

This option would still require considerable construction activity, operating facilities and a substantial footprint on Barrow Island.

Holden Point, Burrup Peninsula

The Burrup Peninsula option was significantly more costly (+$1 billion) than the Barrow Island development option. This extra cost is due to the distance from the gas field, which necessitates a remote hub platform, and an additional 160 km length of carbon steel gas pipeline. For CO_2 injection and disposal, an additional 200 km length of CO_2 pipeline would be required along with CO_2 compression and booster compression at Barrow Island.

This option would still require considerable construction activity, operating facilities and a substantial footprint on Barrow Island. This location also failed to meet many of the social and technical cost requirements. Failure to secure a customer for a Burrup Peninsula-based development in 1998 supports this conclusion.

Cape Preston

Cape Preston was originally eliminated from consideration due to potential conflict with an existing mining tenement and a proposal to load treated iron ore. This was primarily because multiple use results in competition for the limited space available, and LNG loading activities require intrinsically safe operations to avoid ignition sources, and so cannot coexist directly alongside iron ore operations.

During the ESE Review process, and in response to stakeholder comments, a civil engineering study was conducted specifically for Cape Preston using the same criteria applied to other short-listed locations based on the assumption that the Joint Venturers would have exclusive use of Cape Preston. The study confirmed preliminary conclusions that the site offered no significant cost advantage over a Burrup Peninsula location as development at Cape Preston would cost $720 million more than Barrow Island.

This option would still require considerable construction activity, operating facilities and a substantial footprint on Barrow Island, primarily to inject reservoir CO_2.

3.5.4 Independent Technical Audit of Relative Costs

As noted in Chapter 2, the Allen Consulting Group was commissioned by DoIR to undertake a detailed and confidential review of the Joint Venturers' assessment of development alternatives. This detailed review included examining the justification of the Joint Venturers' selection of Barrow Island as the preferred location for the proposed Development; and provided an opinion on the likelihood of an alternative, feasible location being available in a similar cost range. The Allen Consulting Group undertook a technical audit of the relative costs in various locations as proposed by the Joint Venturers (The Allen Consulting Group 2003).

This analysis relied substantially on information provided by the Joint Venturers under a confidentiality agreement. During that review process, commercially sensitive information, such as detailed relative costs of gas supply and break-even gas price analysis results, were shared with The Allen Consulting Group but not made public to avoid exposing this information to potential customers and competitors.

The analysis presented by The Allen Consulting Group stated that:

> Barrow Island clearly represents the most competitive location for a large-scale facility to process Gorgon gas. The Montebellos do not meet the GJV's commercial criteria because of unsuitable terrain (Hermite) or perceived risks from nuclear contamination (Trimouille). While Thevernard Island may well be competitive if the sequestration of CO_2 were not undertaken, the GJV is unwilling to accept the commercial risk of not sequestering this greenhouse gas. On that basis, and in the absence of very substantial support, Thevenard Island would not offer a competitive location…
>
> …From an economic and commercial perspective the Barrow Island site has three clear advantages, all relating to distance. …None of the other locations, other than perhaps Trimouille Island which is ruled out for other reasons, can match these advantages.
>
> …we conclude that Barrow Island represents the only commercial option for monetising the substantial national asset represented by the Gorgon resource.

3.5.5 In-Principle Approval

As outlined in Chapter 2, the site selection process was documented in the ESE Review, public comments were sought and responded to by the proponent, an independent review and cost audit was conducted and bulletins were issued by the Western Australian Environmental Protection Authority (EPA) and Conservation Commission of Western Australia. Consideration of the ESE Review was coordinated by the Standing Interagency Committee of Chief Executive Officers (SIAC). This was supported by an extensive proponent-led stakeholder consultation program where the selection of the regional location was a key issue.

As a result of this process and after considering all arguments presented, State Cabinet granted in-principle approval for restricted access to Barrow Island as a foundation development for the Gorgon Development. The *Barrow Island Act 2003* resulted from this comprehensive evaluation process which simultaneously assessed technical, commercial, social, economic, and environmental aspects of the proposed development.

3.6 Assessment of Barrow Island Sites

This section is a description of the process and reasons for selecting Town Point as the preferred site for the gas processing facility.

Selection of a preferred site on Barrow Island is based on an LNG development reference case of two 5 MTPA notional capacity trains, and an associated domestic gas plant. This includes an allowance for a controlled area within which construction materials can be stored and construction accommodation can be established. It also accounts for potential for future growth in the LNG market and the capability to meet projected Western Australian domestic gas demand.

Protection of the conservation values of Barrow Island, which are not evenly distributed over the island, was a major consideration in determining the site for the gas processing facility. Other considerations include a range of technical, operational and cost-related issues such that the site will be safe, practical and allow the development to remain economically viable.

A process was designed to systematically identify and assess potential sites for the gas processing facility and is shown in Figure 3-5.

Figure 3-5:
Basic Steps in the Site Selection Process

Define broad site selection criteria → Identify possible sites → Refine Development concept → Assess sites against selection criteria → Select preferred site

3.6.1 Selection Criteria

A gas processing facility and associated infrastructure on Barrow Island will require an area of approximately 300 ha to accommodate plant, equipment and pipeline easements.

Sites were assessed giving consideration to the following main criteria:

- safety
- degree of environmental impact
- marine operability for approaching and berthing LNG carriers (such as impacts of currents
- constructability for a gas processing facility – including potential for expansion and ease of construction as well as environmental conditions such as cyclones and geology)
- relative costs.

These aspects are discussed in more detail later in the chapter for a shortlist of sites.

3.6.2 Possible Sites for the Gas Processing Facility

Figure 3-6 provides an indication of water depths around Barrow Island and classifies the island into two broad categories, namely, preferred for development or unfavourable for development. Areas of greater environmental sensitivity are placed within the latter group and are based upon the known distribution of environmental factors such as threatened fauna habitat, EPBC listed species distributions and restricted vegetation communities.

Figure 3-6 shows the six areas on Barrow Island which were considered as potential locations for the gas processing facility. It includes the potential footprint associated with the gas processing facility together with the offloading facility and the associated approach channel.

The potential locations identified for the gas processing facility were:

- Latitude Point on the east coast
- Town Point on the east coast
- Surf Point at the north-east corner
- Flacourt Bay on the west coast
- The Chair on the west coast
- Bandicoot Bay at the south end of Barrow Island.

3.6.3 Redefine Development Concept

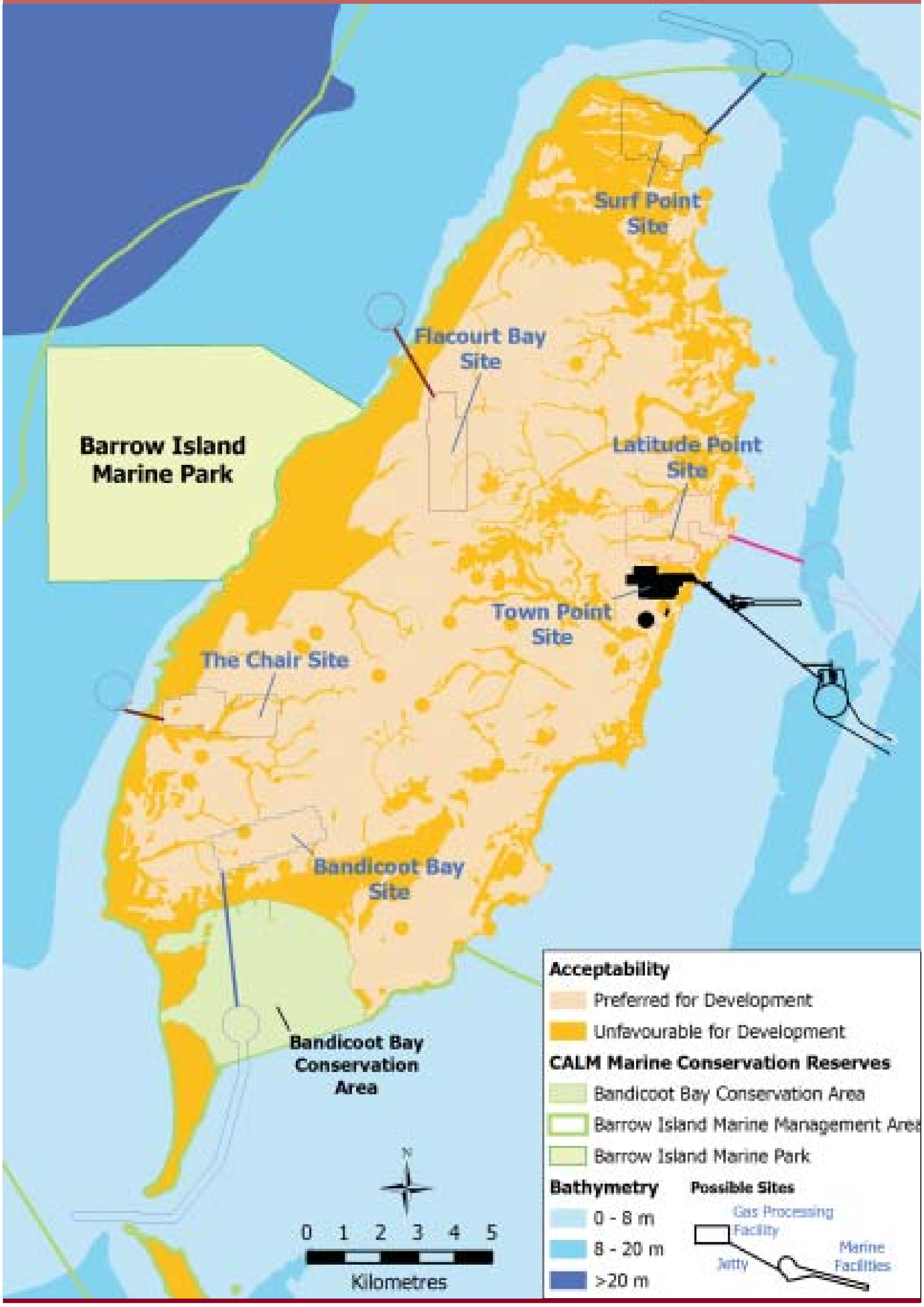
It should be noted that the locations shown in Figure 3-6 are as assessed over the period 2001 to 2002 and were presented in the ESE Review (ChevronTexaco Australia 2003). Further environmental and engineering studies since that time have resulted in the refinement of the development footprint and concept as outlined in Chapter 6. Changes have been made to the preliminary site location to further reduce overall environmental impacts.

3.6.4 Assessment of Sites Against Selection Criteria

The suitability of Camp Point (in the vicinity of the Chevron camp) as a potential site has been raised by stakeholders. However, this location has been excluded from the short list because, although the site offered some environmental benefits over other sites, such as proximity to airport and existing accommodation and thus reduced requirement for clearing of transport corridors, these benefits were outweighed by other factors, which include:

- The gas processing facility site would be situated approximately 500 m upwind from the existing oilfield operations camp under the prevailing south westerly winds. The existing camp would need to be moved to avoid potential human health and safety impacts from the plant, and so result in additional land use.
- It is located approximately 2.5 km north-east of the airport runway and in the direct approach path of aircraft. To avoid the flare stack, minimise thermal impacts and to meet regulatory requirements, the runway would need to be significantly re-aligned. This re-alignment would require an additional footprint of approximately 30 ha. It would also require additional manpower, and significant volumes of aggregate to be brought onto the island under quarantine restrictions (refer to Chapter 12 for details on quarantine). The re-alignment would also have an impact on the current oil field operations.
- The Material Offloading Facility (MOF) would require a dredged channel 1.5 to 2 km longer than that required at Town Point. This would result in an additional 16 ha of seabed directly impacted by the dredging operation and up to 30 ha of additional seabed disturbed by the disposal of dredge spoil. The dredge operation would also be closer to the coral communities off the south-east coast of Barrow Island and pose a greater risk of dredge related impacts to these communities.

Figure 3-6:
Potential Sites for a Gas Processing Facility on Barrow Island



- It would require an additional 3 km of pipeline easement for the feed gas pipeline, and the CO_2 line resulting in 10 ha of additional footprint.
- The south-east and south of the island have been shown to have the highest abundances of migratory shorebirds on Barrow Island.

From the short list of six sites, Bandicoot Bay and The Chair were rejected during the initial screening process.

Bandicoot Bay was excluded primarily because it was intended as a Marine Conservation Area for benthic fauna and seabird protection (CALM 2004) and it provides very restricted access to deep water. The construction of a gas processing facility at this site would require a 3 km jetty connecting the loading platform to the site and a 9 km dredged approach channel. This exceptionally large amount of dredging would incur unacceptable construction and maintenance costs and pose safety hazards for shipping and produce unacceptable environmental impacts on areas important for marine benthic fauna and migratory birds.

The Chair was excluded because of its exposure to severe ocean conditions that would limit the safe operation of the port for approaching and berthing LNG carriers.

The remaining four locations were the subject of more detailed engineering studies to confirm whether the facility and associated equipment could be built in a manner that would avoid significant environmental impacts and meet technical requirements. A summary of the findings of these studies are presented in Table 3-5.

3.6.5 Most Suitable Development Site

After comparing site characteristics, Town Point was selected as the preferred site for the gas processing facility, despite being the most expensive of the short listed locations.

The selection of Town Point was based on both technical and environmental merit.

From a technical perspective, this site offers:

- The safest and most reliable marine operating conditions, due to the more sheltered nature of the adjacent waters.
- A west coast shore crossing for the feed gas pipeline, rather than using a circuitous route around the island through strong-current areas (refer to Section 3.7).
- A 3.1 km long jetty (with 800 m causeway) and a relatively short dredged approach channel for the LNG carriers could be used, which is less than many of the alternative sites.
- Geological stability.
- Relatively flat terrain that would minimise earth works at the site.
- A rocky headland that would provide excellent coastal access, with minimum disturbance.
- Good proximity to existing operations, or is close to areas that have been previously utilised by oil operations.
- One of the shortest routes to connect to the domestic gas network.

Table 3-5:
Summary of Comparison among Potential Development Sites on Barrow Island

	Site/Concept			
	Town Point	**Latitude Point**	**Flacourt Bay**	**Surf Point**
Site Characteristic	**Reference Point**	**Relative Cost: -$60 million**	**Relative Cost: -$130 million**	**Relative Cost: -$180 million**
Environmental				
Development would be in close proximity to existing oil operations	Yes	Yes	Yes	No
Development area contains a high percentage cover of restricted vegetation associations	No	No	No	Yes (located in the relatively pristine northern portion of the island)
Development infrastructure would avoid rock wallaby habitat	Yes	Yes	No (pipeline and plant transport corridor through habitat)	Yes (if feed gas pipeline located at the northern end of island)
Development infrastructure would avoid habitats of 'mobile' EPBC listed macrofauna (bettong, spectacled hare-wallaby, golden bandicoot, euro, chestnut mouse)	No (some translocation maybe required, e.g. bettongs)	No (some translocation maybe required, e.g. bettongs)	No (some translocation maybe required, e.g. bettongs)	No (some translocation maybe required, e.g. bettongs)
Development infrastructure would avoid habitats of subterranean EPBC listed fauna (blind gudgeon, possibly blind cave eel)	Unlikely (given the karstic nature of the island)	Unlikely (given the karstic nature of the island)	Unlikely (given the karstic nature of the island)	Unlikely (given the karstic nature of the island)
Development infrastructure would avoid nesting beaches of EPBC listed turtles (green turtle, leatherback turtle, hawksbill turtle, flatback turtle)	No (important flatback nesting beaches in close proximity)	No (important flatback nesting beaches in close proximity)	No (important green and hawksbill nesting beaches in close proximity)	No (important green and hawksbill nesting beaches in close proximity)
Development infrastructure would avoid habitats of EPBC listed marine birds (white-bellied sea eagle, southern giant petrel, soft-plumaged petrel, migratory waders etc)	No (although marine birds tend to be concentrated in the south and south-east of the island)	No (although marine birds tend to be concentrated in the south and south-east of the island)	No (although marine birds tend to be concentrated in the south and south-east of the island)	No (although marine birds tend to be concentrated in the south and south-east of the island)
Development infrastructure would avoid habitats of EPBC listed terrestrial bird (white-winged fairy wren)	No (although this species is widely distributed over the island)	No (although this species is widely distributed over the island)	No (although this species is widely distributed over the island)	No (although this species is widely distributed over the island)
Development infrastructure would avoid habitats of EPBC listed marine mammals (whales, dolphins, dugongs)	No (although significant impacts are unlikely)	No (although significant impacts are unlikely)	No (except dugongs)	No (except dugongs)

Table 3-5: (continued)
Summary of Comparison among Potential Development Sites on Barrow Island

	Site/Concept			
	Town Point	**Latitude Point**	**Flacourt Bay**	**Surf Point**
Site Characteristic	**Reference Point**	**Relative Cost: -$60 million**	**Relative Cost: -$130 million**	**Relative Cost: -$180 million**
Environmental (continued)				
Coastal stability would be maintained	Yes (rocky headland)	Yes (rocky headland)	No (sandy beach)	No (sandy beach/dune systems)
Marine dredging would be distant from coral communities	No	No	No (very close to proposed marine protected area)	Yes (although plume modelling would be required to confirm area of impact)
Technical				
Stable soils and minimal amount of earthworks required at site	Yes	Yes	Yes	No
Good coastal access for jetty and MOF via rocky outcrop	Yes	Yes	No	Moderate
Close to existing oilfield infrastructure	Yes	Yes	Yes	No
Access to deep water via jetty and dredged channel	Moderate (via jetty=3.9 km; dredged channel=2.3 km)	Moderate (via jetty=2.0 km; dredged channel=4.3 km)	Good (via 1.4 km jetty)	Good (via jetty=2.0 km; dredged channel=1.9 km) but the East Spar and Wonnich pipelines would need to be relocated to allow construction of the dredged channel.
Low-to-moderate impacts from nearshore currents on marine operations	Yes	No	No	No
Close proximity to domestic gas connection	Yes (closest)	Yes	No	Yes

** Note: 'Relative Cost' relates to those components of the Development concept that vary between sites. That is, these are not total construction costs.*

Furthermore, Town Point is considered to have a reasonably low overall level of environmental impact compared to other locations since:

- Vegetation communities within the Development area extend outside that area.
- Vegetation communities are larger outside the proposed Development areas than those within these respective areas.
- No part of the proposed Development on Barrow Island is within 200 m of mangroves, or within 100 m of water courses that lead to mangrove communities at their seaward end.
- The Development area does not appear to have any intrinsic value to mammal or herpetofauna above that of adjacent and surrounding habitats.
- The gas processing facility is distant from Vulnerable black-flanked rock wallaby communities.
- The coastline in the vicinity of the proposed Development is of relatively low importance for coastal water birds compared with other points of Barrow Island.
- Town Point is not an important waterbird foraging or roosting site, as evidenced from low abundances, in relation to other parts of the Barrow Island shoreline.
- The proposed Development area is not locally or regionally significant for land birds and has no unique features that might constitute critical habitat.
- There are no known features in the Development area or its surrounds to suggest that significant concentrations of protected marine invertebrates, fish or cetaceans would be expected to occur.
- Although the proposed Development area is within an important feeding and breeding ground for marine turtles, primarily flatback turtles on the east coast and green turtles on the west coast, the Gorgon Joint Venturers consider that risks to turtles (e.g. lighting) can be appropriately managed through the rigorous implementation of safeguards (Chapter 11).

3.6.6 Less Suitable Development Sites

Latitude Point

Latitude Point is similar to Town Point as it is in close proximity. Latitude Point also offers:

- more sheltered waters than west coast locations
- geological stability
- relatively flat terrain
- proximity to existing operations, or is close to areas that have been previously utilised by oil operations
- a west coast shore crossing for the feed gas pipeline (Section 3.7)
- a 2 km jetty connecting a loading platform and a 4.3 km dredged approach channel for the LNG carriers, which requires less infrastructure than many options.

Access to deep water is a critical issue. A site at Latitude Point would require a 2 km jetty connecting a loading platform and a 4.3 km-long dredged approach channel. Thus, an additional 2 km of dredging would be required to construct the approach channel for LNG carriers at this site compared to Town Point. The Gorgon Joint Venturers consider that the potential impacts to significant coral communities located nearby from a larger dredging program, without any other obvious technical or environmental benefit over the Town Point site, is unacceptable. Thus, Latitude Point was considered to be a less favourable option than Town Point.

Surf Point

Situated at the north-east corner of Barrow Island, Surf Point offers deep water relatively close to shore, but is exposed to strong tidal currents which may adversely affect the safe operation of LNG carriers in the area. Potential development sites at this location are heavily restricted due to the presence of sensitive vegetation associations and sandy, unstable soils. The north of the island is also relatively undisturbed and is the furthest point on the island from the existing oil operations infrastructure. Stakeholder consultation has identified a strong preference for avoiding direct impacts to the less disturbed northern portion of the island.

The Surf Point site does offer some environmental benefits over other sites. For example, the onshore section of the feed gas pipeline between the shore crossing and the facility would be relatively short, resulting in fewer disturbances to vegetation communities (and their associated fauna) than at other sites. However, much of the disturbance would be to restricted vegetation communities. A Surf Point site would also require less dredging, resulting in fewer impacts to surrounding marine habitats. However, the strong currents in the area make it unlikely that LNG carriers would be able to operate safely.

Flacourt Bay and The Chair

Flacourt Bay and The Chair are situated on the west-side of Barrow Island with access to deep water close to the shoreline. A gas processing facility at either of these sites would also be closer to the landfall of the feed gas pipeline, but further from the domestic gas pipeline on the mainland. However, marine terminal operations would be subjected to more severe swells that would adversely affect port availability for unprotected jetty sites. This makes a jetty with no protection impractical, and breakwater alternatives extremely expensive. The terrain is relatively flat and stable in structure. However, both sites are adjacent to sensitive rock wallaby habitat.

A facility at Flacourt Bay would require no dredging, but would require a 700 m breakwater and a 1 km jetty connecting a loading platform to shore, so it was assessed as a much less favourable site than Town Point.

A facility at The Chair would require a jetty of approximately 1 km, but the site would not require dredging. However, The Chair site was rejected during the initial screening as it is exposed to severe ocean conditions due to a steeply shelving sea floor and significant wave loading and thus would require a prohibitively expensive breakwater shelter for protection. Such a breakwater would also potentially have significant environmental impacts during construction and subsequent operations, such as sourcing materials, smothering, silt movement, and impact on water flows.

Bandicoot Bay

The potential site at Bandicoot Bay is situated within the existing oil operations in an area of relatively flat topography away from significant vegetation associations and terrestrial fauna habitats. However, the south of Barrow Island offers no access to deepwater close to shoreline, so would require a 3 km jetty connecting the loading platform to the site and a 9 km dredged approach channel. As this exceptionally large amount of dredging would incur unacceptable construction and maintenance costs, pose safety hazards for shipping and impact on areas important for marine benthic fauna and migratory birds, it was rejected during the initial screening process and excluded from preliminary engineering studies.

3.7 Assessment of Feed Gas Pipeline Alternatives

This section describes the process and reasons for selecting North White's Beach as the preferred site for the shore crossing of the feed gas pipeline and horizontal directional drilling as the preferred shore crossing technique.

It examines potential shore crossing locations and routes for the feed gas pipelines on Barrow Island. While these locations and routes are closely related to the location of the gas processing facility, the discussion is presented separately here so that more detailed information can be provided. This assessment also includes details on the construction technique and onshore feed gas pipeline route as these decisions are all linked.

3.7.1 Selection Criteria

To enable a rational selection of the preferred site, a series of criteria were established against which the various sites could be evaluated. These are shown in Table 3-6.

3.7.2 Potential Sites for the Shore Crossing

During the selection process five potential shore crossing locations were considered as sufficiently feasible to warrant further evaluation. These were:

- Flacourt Bay
- North White's Beach
- Obe's Beach
- Cape Dupuy
- Town Point (via a marine route).

Refer to Figure 3-7.

3.7.3 Assessment of Potential Sites for the Shore Crossing

Cape Dupuy and Town Point (marine route) were screened-out relatively early. A marine route to Town Point would have required a large dredging campaign (in addition to that required for the materials offloading facility and LNG load-out), and involved high cost and complexity associated with a longer offshore pipeline installation in shallow water. Cape Dupuy was ruled-out because of the greater footprint and technical challenges of operating installation vessels in the strong currents around the cape. The remaining sites Flacourt Bay, North White's Beach and Obe's Beach were assessed in more detail.

The base case for each of the three west coast locations initially included the requirement to dredge a trench at shore crossing. Detailed assessment has since shown that dredging is not technically feasible due to the prevailing rough sea conditions on the west coast of Barrow Island, and the presence of very high strength rock. Other construction techniques, such as, 'post trenching' and 'rock ploughing' were not considered technically feasible due to the high rock strength.

Feasibility studies for horizontal directional drilling (HDD) and tunnelling were undertaken. It was concluded that HDD would be feasible at North White's Beach, and to a lesser extent at Flacourt Bay and Obe's Beach. Tunnelling requires considerable dredging to construct a receival pit. Due to the ocean conditions on the west coast and the proximity of (and potential impacts to) the Barrow Island Marine Park, this technique was not considered feasible. As such, HDD was determined to be the only feasible below-ground construction technique.

Three above-ground alternatives were considered and included: laying the feed gas pipelines on the seabed and beach; running the pipelines over a jetty; and establishing a groyne upon (or in) which the feed gas pipelines would run. These were less preferred for various technical and environmental reasons which included:

- the complication of accessing the shallow water area to be able to stabilise the pipe. In most cases this requires a temporary jetty/groyne to be constructed from the shore out to approximately the 5 m water depth point. This is both costly and intrusive to the near shore environment
- the potential to alter existing beaches through an artificial change to the mobility of suspended/deposited sediment
- seabed disturbance during construction.

The key differences between the construction techniques are: the quantity of seabed disturbance; the amount of imported material required; construction duration; vegetation clearing; blasting and excavation; plume generation; light and noise; and weather dependency.

Table 3-6 shows the results of the assessment for each of the feasible shore crossing options against the key criteria.

3.7.4 Preferred Shore Crossing Location

From the assessment of shore crossing options, the preferred shore crossing location is North White's Beach, constructed using HDD. The key benefits of this option over the other feasible alternatives are that it:

- presents lower risks to rock wallabies, turtle habitat and the Marine Park
- requires less earthworks and footprint
- involves a shorter construction period due to the bathymetric conditions
- offers the lowest construction risk due to the preferred geology for HDD and open beach that provides route flexibility to avoid geohazards
- provides cost-saving opportunities associated with being able to install the pipe from onshore through a drilled hole (which removes dependency on sea state and lay barge standby rates)
- allows for relatively simple stabilisation techniques.

Figure 3-7:
Potential Shore Crossing Locations

Table 3-6:
Comparison of Shore Crossing Sites with Short-Listed Construction Technique (HDD)

Characteristic	Flacourt Bay (HDD)	North White's Beach (HDD)	Obe's Beach (Jetty)
Complies with land use limit of 50 ha for feed gas pipelines as specified by the Barrow Island Act.	Yes Construction easement = 31 ha. Permanent additional footprint after construction = 9 ha.	Yes Construction easement = 40 ha. Permanent additional footprint after construction = 13.1 ha.	Yes Construction easement = 42 ha. Permanent additional footprint after construction = 12.7 ha.
Key Environmental Factors • rock wallabies • marine park • turtles	 • High risk • High risk • Medium/High risk	 • Low risk • Low risk • Low risk	 • High risk • Low risk • Medium/High risk
Avoid existing oilfield infrastructure/activities	Yes	Yes	Yes
Wave climate	Acceptable	Acceptable	Expected downtime during construction due to rough weather.
Bathymetry	Requires drilling length of 1200 m.	Requires drilling length of 600 m.	Jetty construction approximately 800 m long.
Site layout	Narrow site does not accommodate flexibility for re-routing.	Open site with good flexibility to avoid geo-hazards.	Narrow site not flexible to re-routing.
Earthwork requirements	Significant earthworks required for construction site. Hard rock will require blasting.	Very little earthworks required, Predominantly sandy material.	Significant excavation work required on the beach in establishing the foundations for the jetty and to accommodate vehicle traffic across the beach.
Site access	Existing roads along 83% of route. Beach approach is narrow and steep.	Existing roads along 70% of route. Wide open beach.	Existing roads along 80% of route. Narrow and inclined track to beach.
Floodways/Drainage channels	Pipeline route does not interfere with any significant drainage channels.	Pipeline route does not interfere with any significant drainage channels.	Pipeline route does not interfere with any significant drainage channels.
Pipeline stabilisation requirements	Standard stabilisation (rock dumping in shallow water approach).	Standard stabilisation (rock dumping in shallow water approach).	Standard stabilisation (rock dumping in shallow water approach).
Pipeline damage risk	Acceptable	Acceptable	Acceptable
Geological hazards	Paleo channels may exist but should be avoided by HDD. No other geotechnical impediments identified to date.	Surface geology and data collected indicate that the ground is suitable for HDD, most competent rock is at depth between 6-9 m.	Paleo channels are expected to exist but are not expected prevent construction of piles.

3.7.5 Less Preferred Shore Crossing Locations

Flacourt Bay is the preferred fall-back option as it provides a pipeline route which is adjacent to existing oil field operations and infrastructure and provides the shortest pipeline route across the island.

The geology at Obe's Beach does not support the HDD technique due to the suspected presence of channelling, and therefore requires more environmentally intrusive and costly construction techniques which makes it of lower preference to the other two sites.

If there is an unexpected geohazard for HDD at North White's Beach, then other construction concepts would be considered at North White's Beach before opting to change the site to the fall-back site of Flacourt Bay. The possible construction techniques include drilling offshore piles and stabilising the pipeline above the seabed.

3.8 Defer or Not Develop Alternative

This section addresses the question of what would happen if the proposed Gorgon Development does not proceed.

The Joint Venturers have identified a market window of opportunity for deliveries of gas from the Gorgon gas field as mentioned in Chapter 1. A delay in meeting this delivery schedule may result in losing LNG market opportunities to an international competitor and/or losing industrial gas customers to alternative investments. International competitors may not be as energy efficient as the Gorgon Development and alternative investments may mean coal or oil which have significantly greater greenhouse gas emissions. Refer to Chapter 13 for additional details of both of these aspects.

Economic models run for the proposed Development predict that the investment phase would result in flow-on benefits in the Australian community of a peak increase of 15 500 jobs driven by the $6 billion initial investment by the Joint Venturers (ChevronTexaco Australia 2003).

During the operations phase, gross domestic product (GDP) may increase by an average of $3.6 billion per year as a direct result of the proposed Development. If the development opportunity is realised, it is predicted to sustain an average of over 6000 jobs through the decades of the Development's operation.

If this opportunity is missed, it will risk not realising national, state and regional economic benefits that would increase general economic growth, sustain regional development, and increase competition in domestic gas markets. Missing the current development opportunity would also risk the loss of a substantial increase in government revenues, both through the direct payment of taxes by the Joint Venturers and the workers and businesses associated with the Development (Chapter 15). This would deny Australians and Western Australians the associated social benefits such as an increase in community services and highly skilled employment opportunities.

At a regional level, the Pilbara region of Western Australia in particular, would be at risk of losing the benefits of growth in employment and business opportunities (Chapter 15), but the area on Barrow Island would remain undisturbed. Other opportunities at risk include technology transfer and capacity building from the design, construction and maintenance of the Development to Western Australian businesses that may enable them to service other resource and industrial projects in the state.

3.9 Conclusion

The gas fields in the Greater Gorgon area are a substantial national asset. The initial development of the Gorgon gas field to a new gas processing facility is needed to initiate the development of these resources. Extensive studies have shown that Barrow Island is the only commercially viable location to develop those resources. This finding has been verified by an independent review undertaken for the State Government of Western Australia (The Allen Consulting Group 2003).

Following a detailed investigation the preferred location for the gas processing facility on Barrow Island is Town Point. Of the possible shore crossings (and resultant onshore pipeline routes on Barrow Island), North White's Beach is considered the base case for the development with Flacourt Bay being carried as a fall-back option.

04: Legislative Framework

The Gorgon Development proposal was referred to the Commonwealth Department of the Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA) in November 2003. These agencies then determined that the Gorgon Development should be formally assessed at the Environmental Impact Statement (EIS) and Environmental Review and Management Programme (ERMP) levels respectively. These are detailed levels of assessment that are generally applied to major projects which have significant environmental issues, many of which are complex or of a strategic nature.

The Commonwealth and Western Australian governments agreed to a parallel coordinated environmental assessment process. A single EIS/ERMP document, which satisfies the requirements of each jurisdiction, is required under this process.

The Joint Venturers have prepared this Draft EIS/ERMP in accordance with the requirements of the 'Guidelines for an Environmental Impact Statement and Environmental Scoping Document for an Environmental Review and Management Programme' (the Scoping Document) (ChevronTexaco 2004). The Draft EIS/ERMP is being placed on public exhibition for 10-weeks during which time public submissions will be sought. The DEH and EPA will assess the Draft EIS/ERMP following receipt of public submissions, and the Joint Venturers' response to those submissions. They will then report to relevant Ministers for a final decision on whether the Development should be approved and, if so, under what conditions.

4.1 Introduction

The Commonwealth Department of the Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA) have agreed to a parallel coordinated process to concurrently assess the proposed Gorgon Development. Under this process, the Western Australian Department of Environment (DoE) is responsible for coordinating the environmental impact assessment on behalf of the EPA. The Western Australian Department of Industry and Resources (DoIR) also has responsibility for coordinating and facilitating effective communication between the Joint Venturers' Development Team and various state agencies.

A coordinated assessment requires preparation of a Draft Environmental Impact Statement (Draft EIS) and an Environmental Review and Management Programme (ERMP) consolidated as a single document (Draft EIS/ERMP) that satisfies the assessment requirements of both government jurisdictions. The primary purpose of this Draft EIS/ERMP is to provide information to the community, the EPA and DEH on the proposed Development within a local and regional framework. This Draft EIS/ERMP includes an explanation of how the proposal may impact on relevant environmental and socio-economic factors and how any negative impacts may be avoided or otherwise mitigated and managed, so as to be acceptable to government agencies under relevant regulatory requirements. (Refer to Section 4.2.4 for an explanation on when/how the document will become a 'Final EIS/ERMP').

4.1.1 Key Environmental Approvals

The environmental impact assessment process for the Gorgon Development is being undertaken in accordance with the requirements of two key pieces of environmental legislation: the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Western Australian *Environmental Protection Act 1986* (EP Act).

EPBC Act

The EPBC Act sets out the national environmental impact assessment and approvals framework which is administered by DEH. The Commonwealth approvals process is triggered by an action which will, or is likely, to have a significant impact on a matter of national environmental significance of which the following three are considered relevant to the Gorgon Development:

- nationally threatened species and ecological communities
- listed migratory species
- Commonwealth marine areas.

In addition, DEH determined that an application for a permit under the Commonwealth *Environment Protection (Sea Dumping) Act 1981* is also required to be assessed under the EPBC Act. As such, the assessment to support the application for a Sea Dumping Permit is included in this Draft EIS/ERMP.

EP Act

Part IV of the EP Act establishes provisions for the EPA to carry out environmental impact assessment in Western Australia.

The environmental impact assessment provisions of the EP Act are triggered by proposals within state jurisdiction that have the potential, if implemented, to have a significant effect on the environment.

4.2 Environmental Impact Assessment Process

The environmental impact assessment and approval processes of the EPBC Act and EP Act broadly follow four phases: referral, scoping, investigation and document preparation, and finally government assessment.

The keys steps in the Gorgon Development environmental impact assessment process are summarised in Figure 4-1.

4.2.1 Referral

Western Australia

The Gorgon Development proposal was referred to the Western Australian EPA under the EP Act on 18 November 2003. The EPA determined that the Western Australian sector of the Development should be subject to a formal ERMP level assessment under the EP Act. This is a comprehensive and detailed level of assessment and is applied to major projects which have significant environmental issues, many of which are complex or of a strategic nature. Such proposals require substantial assessment to determine whether environmental issues can be managed and, if so, how they can be managed in a manner that is considered acceptable by relevant government agencies. Two appeals were lodged against the decision on the level of assessment and were considered by the Minister for Environment. On 2 January 2004, the appeals on the level of assessment were dismissed.

Commonwealth

The proposal for the Gorgon Development was referred to the Commonwealth Minister of the Environment and Heritage for consideration under the provisions of the EPBC Act on 21 November 2003.

Following the provision of Preliminary Information from the Joint Venturers, a delegate of the Minister determined on 19 December 2003 that the proposed action must be assessed (in terms of potential environmental impacts) through the preparation of an EIS.

An application for a permit to dispose of dredge spoil was lodged with DEH. On 10 March 2004 a delegate of the Minister for the Environment and Heritage decided that the proposed activity was a prescribed action for the purposes of section 160(2)(d), and as such considered analogous to a controlled action requiring assessment under the EPBC Act. The Joint Venturers were directed to include the assessment of dredge disposal in this Draft EIS/ERMP.

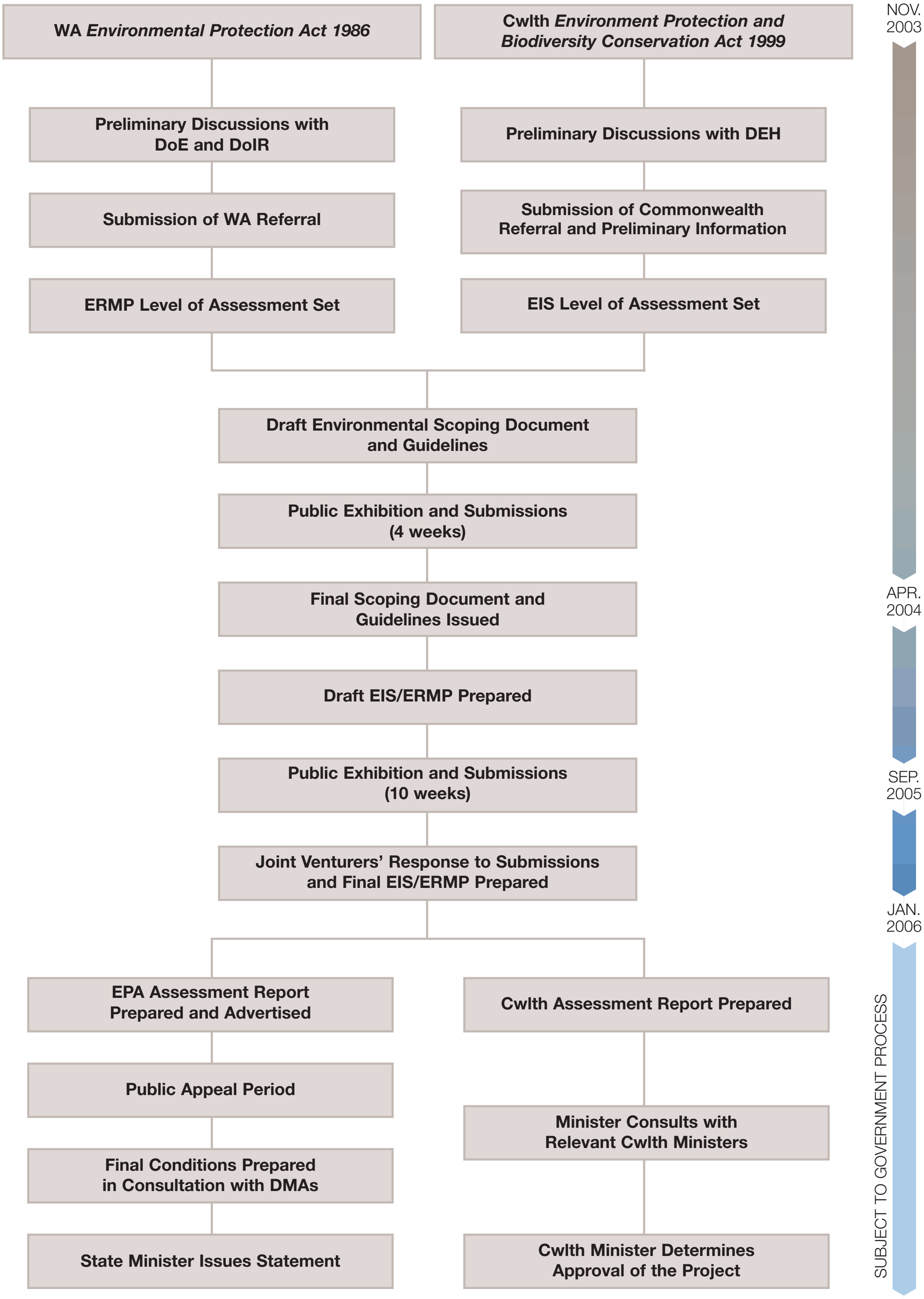
During the course of the environmental impact assessment studies, engineering works identified the need for an optical fibre connection between Barrow Island and the mainland (refer to Chapter 6). This was outside the scope of the original EPBC Act referral. In response a separate referral was lodged in May 2005. A delegate for the Minister determined that the activity was a controlled action. As the telecommunication connection is an integral part of the Development, an assessment of the environmental risks associated with the construction and operation of the cable have been included in this Draft EIS/ERMP, under a Bilateral Agreement between the Commonwealth and Western Australian Government.

4.2.2 Scoping

A draft environmental scoping document and guidelines for an EIS/ERMP were released for public comment on 26 January 2004 for a period of 28-days (ChevronTexaco Australia 2004). A finalised environmental scoping document and guidelines were issued by DEH and the EPA on 19 April 2004 following consideration of public comments. The scoping document was prepared to meet both Western Australian and Commonwealth legislative requirements and is based on the: *Environmental Impact Assessment Act 1986* – Environmental Impact Assessment (Part IV division 1) Administrative Procedures; and the Environment Protection and Biodiversity Conservation Regulations 2000, Schedule 4.

The final environmental scoping document and guidelines identify issues to be addressed in the EIS/ERMP and the actions and investigations to be undertaken in addressing these issues. A checklist of the scoping requirements with the contents of this Draft EIS/ERMP is provided in Appendix 1 (this document) with a full copy available at www.epa.wa.gov.au/docs/1744_Gorgon_EIS_ERMP.pdf.

Figure 4-1:
Environmental Impact Assessment Process



4.2.3 Investigations and Document Preparation

This Draft EIS/ERMP was prepared by the Joint Venturers in accordance with requirements outlined in the environmental scoping document and guidelines. The overall approach to the preparation of the Draft EIS/ERMP involved:

- identification of potential impacts on environmental and socio-economic factors considered relevant to the Gorgon Development and assessment of level of associated risk
- development of strategies to avoid, mitigate or manage consequences
- analysis of residual consequences and risks.

This process has involved completion of specialist studies to determine and broadly quantify potential impacts and benefits associated with the proposed Development and extensive consultation with government and community stakeholders.

This Draft EIS/ERMP was reviewed by DEH and EPA prior to public exhibition to ensure compliance with the requirements of the environmental scoping document and guidelines. The Draft EIS/ERMP will be placed on public exhibition for 10-weeks during which time public submissions will be sought.

During this time, a package of additional information will be issued, which presents the results of subterranean fauna species identification (refer to Chapter 10), the results of the field validation for the dredge plume modelling (refer to Chapter 11), and the selected barriers for the three key quarantine pathways (refer to Chapter 12). The Additional Information Package will be available for comment for the last four weeks of the period of public exhibition.

4.2.4 Government Assessment

Once the public comment period is closed, in consultation with the EPA and DEH, the Joint Venturers will identify issues requiring a response. The Joint Venturers will respond to issues and matters identified in submissions. Once the DEH and EPA have accepted that responses to public submissions are adequate, the document will become the Final EIS and ERMP (Final EIS/ERMP).

The EPA and DEH will then review the EIS/ERMP, public submissions and the Joint Venturers' responses to submissions, and prepare environmental assessment reports for relevant Commonwealth and State Ministers. The Commonwealth Minister for the Environment and Heritage and the Western Australian Minister for the Environment would then be in a position to determine whether the Development should be approved and, if so, under what conditions.

4.3 Other Relevant Legislation

4.3.1 Subsequent Approvals for the Proposed Development

Table 4-1 is a list of the key federal and state approvals that will be required if the proposed Gorgon Development receives environmental approval. Environment Plans and Oil Spill Contingency Plans will also be required for drilling and pipelines.

Table 4-2 is a list of other key associated Commonwealth and Western Australian legislation and international agreements that may apply to subsequent approvals of relevance to the proposed Gorgon Development.

4.4 EPA Guidance Statements

The EPA has developed a series of 'environmental protection Guidance Statements' that are applicable to environmental impact assessments. Several of these EPA guideline documents have been utilised during investigations and studies for this Draft EIS/ERMP including:

- Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 1 (Final)
- Risk Assessment and Management: Offsite Individual Risk from Hazardous Industrial Plant – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 2 (Final)
- Deep and Shallow Well Injection for Disposal of Industrial Waste – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 4 (Final)
- Environmental Noise – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 8 (Draft)

- Guidance Statement for Minimising Greenhouse Gases – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 12 (Final)
- Guidance Statement for Emissions of Oxides of Nitrogen from Gas Turbines – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 15 (Final)
- Management of Surface Run-off from Industrial and Commercial Sites – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 26 (Draft)
- Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 29 (Final)
- Linkage between EPA Assessment and Management Strategies, Policies, Scientific Criteria, Guidelines, Standards and Measures Adopted by National Councils – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 34 (Final)
- Assessment of Aboriginal Heritage – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 41 (Final)

Table 4-1:
Key Subsequent Approvals Required for the Gorgon Development

Approval Required	Associated Statutes
Access Authorities	*Petroleum (Submerged Lands) Act 1967* (Commonwealth)
Authority to Excavate, Disturb or Damage Cultural Heritage Sites	*Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Commonwealth) *Aboriginal Heritage Act 1972* (WA)
Barrow Island Lease	*Barrow Island Act 2003* (WA) *Land Administration Act 1997* (WA)
CO_2 Injection	*Barrow Island Act 2003* (WA)
Dangerous Goods Transport Licences	*Dangerous Goods (Transport) Act 1998* (WA)
Drilling and Workover Approvals	*Petroleum (Submerged Lands) Act 1967* (Commonwealth)
Infrastructure Licences	*Petroleum (Submerged Lands) Act 1967* (Commonwealth)
Licence to Operate/Emit	*Environmental Protection Act 1986* (WA)
Major Hazard Facility Safety Report (Operation)	Explosives and Dangerous Goods Act 1961 (WA)
Pipeline Licences	*Petroleum (Submerged Lands) Act 1967* (Commonwealth) *Petroleum (Submerged Lands) Act 1982* (WA) *Petroleum Pipelines Act 1969* (WA)
Pipeline Management Plan (Safety Case) (offshore)	*Petroleum (Submerged Lands) Act 1967* (Commonwealth) *Petroleum Safety Act 1999* (WA)
Ports Approvals	*Marine and Harbours Act 1981* (WA) *Shipping and Pilotage Act 1967* (WA) *Jetties Act 1926* (WA)
Production Licence	*Petroleum (Submerged Lands) Act 1967* (Commonwealth)
Safety Case for Fixed and Mobile Units for Hydrocarbon Production	*Petroleum (Submerged Lands) Act 1967* (Commonwealth)
Sea Dumping Permit	*Environment Protection (Sea Dumping) Act 1981* (Commonwealth)
Sea Installations Permit	*Sea Installations Act 1987* (Commonwealth)
Vegetation Clearing Permit	*Environmental Protection Act 1986* (WA) *Environmental Protection Amendment Act 2003* (WA)
Works Approval Permit	*Environmental Protection Act 1986 (WA)*

Table 4-2:
Key Commonwealth and Western Australian Environmental and Petroleum Legislation

Commonwealth Legislation

- Environment Protection and Biodiversity Conservation Regulations 2000
- *Petroleum (Submerged Lands) Act 1967*
- *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999*
- *Australian Heritage Commission Act 1975*
- *Australian Maritime Safety Authority Act 1990*
- *Environment Protection (Sea Dumping) Act 1981*
- *Historic Shipwrecks Act 1976*
- *Native Title Act 1993*
- *Navigation Act 1912*
- P(SL)A Schedule of Specific Requirements as to Offshore Petroleum Exploration and Production 1999
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*

Western Australian Legislation

- *Barrow Island Act 2003*
- *Conservation and Land Management Act 1984*
- *Environmental Protection Act 1986*
- *Environmental Protection Amendment Act 2003*
- *Fish Resources Management Act 1994*
- *Heritage of Western Australia Act 1990*
- *Land Administration Act 1997*
- *Local Government Act 1995*
- *Occupational Safety and Health Act 1984*
- *Petroleum Act 1967*
- *Petroleum Pipelines Act 1969*
- *Petroleum (Submerged Lands) Act 1982*
- *Pollution of Waters by Oil and Noxious Substances Act 1987*
- *Soil and Land Conservation Act 1945 (WA)*
- *Town Planning and Development Act 1928*
- *Wildlife Conservation Act 1950*

International Conventions

- International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 (MARPOL 73/78)
- China Australia Migratory Birds Agreement (CAMBA)
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
- Japan Australia Migratory Birds Agreement (JAMBA)

- Guidance to assist proponents in understanding the EPA's requirements in relation to the environmental condition on Environmental Management Systems – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 43 (Draft)
- Assessment of Odour Impacts from New Proposals – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 47 (Final)
- Groundwater Environmental Management Areas No. 48 (Draft)
- Terrestrial flora and vegetation surveys for Environmental Impact Assessment in Western Australia No. 51 (Final)
- Consideration of subterranean fauna in groundwater and caves during environmental impact assessment in Western Australia – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 54 (Final)
- Implementing best practice in proposals submitted to the environment impact assessment process – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 55 (Final)
- Terrestrial fauna surveys for Environmental Impact Assessment in Western Australia No. 56 (Final).

These guidance statements provide the basis for the EPA's evaluation of, and advice on, development proposals subject to formal environmental impact assessment. Accordingly, the Joint Venturers have considered and applied these guidelines where appropriate.

05: Stakeholder Engagement

The Gorgon Joint Venturers are committed to open and accountable processes that encourage stakeholder engagement throughout all stages of the Development. The Joint Venturers have established an extensive and ongoing stakeholder engagement program that builds on the pro-active approach to consultation that commenced in early 2002 during the ESE Review process. Stakeholders consulted include a broad range and diverse cross-section of government, industry and community representatives.

Active participation in the carefully designed and implemented stakeholder engagement program has provided opportunities for stakeholders to obtain both technical and environmental information on potential issues and to express their views directly to the Development Team. Input from these stakeholders has provided the Joint Venturers with valuable feedback and contributes to guiding the assessment and management of the proposed Development. This input will continue to be sought throughout the ensuing phases of the Development.

In this chapter, the stakeholders are identified, the primary issues they have raised are grouped and the management and mitigation measures that address these concerns are outlined.

5.1 Introduction

In 2002, as part of the ESE Review process, the Joint Venturers embarked on an extensive program of community consultation with a broad range of government, industry and community stakeholders to discuss the proposed Development on Barrow Island. This level of stakeholder involvement has continued and is a vital part of the EIS/ERMP process.

The Gorgon Development is unique in that prior to starting the formal environmental approvals process in late 2003, it had already undergone intensive community scrutiny and involvement through the ESE Review process, which included two periods of public comment (Chapter 2). As a result, the community, governments and the Venturers have a solid understanding of the major issues surrounding the proposal. However, this level of community involvement does not mean that all stakeholders support development on Barrow Island. As the Western Australian Department of Environment (DoE) points out in its publication Interim Industry Guide to Community Involvement (DoE 2003):

> …it should be recognised that community involvement does not necessarily produce solutions that are acceptable to all parties or resolve all differences of opinion. Successful community involvement relies on the quality and appropriateness of the engagement processes used. Ideally these should provide for a sound, fair and transparent process that the community can be satisfied with, regardless of the outcome.

While stakeholder engagement activity has been substantial since early 2002, this chapter focuses on the stakeholder involvement since the Joint Venturers formally commenced the EIS/ERMP process. While consultation in the ESE Review process (2002 and 2003) was generally at a strategic level (ChevronTexaco 2003a), the stakeholder engagement process since that time has focussed on specific issues of interest.

A broad range of organisations and key individuals including environmental, quarantine, resource planning and development experts throughout Australia have been consulted through briefing sessions, discussions, workshops, community meetings, conferences and familiarisation tours to Barrow Island. The engagement has involved senior Joint Venturer representatives, its specialist contractors and consultants to provide meaningful discussion and review of important topics and issues. This is particularly evident in the approach to quarantine management on Barrow Island where the work of a Quarantine Expert Panel provided guidance in the development of a Quarantine Management System. The work of the Expert Panel was regularly reported to interested parties. This community involvement was strengthened through a number of Community Consultation Meetings which led to Community Workshops.

Similarly, as part of the EIS/ERMP process, specialists were retained to carry out a Social and Economic Impact Assessment of the Development. In order to assist in identification of the impacts, they undertook comprehensive stakeholder consultation in Perth and the Pilbara Region. The breadth of stakeholders consulted can be categorised as:

- federal and state ministers and their advisers
- federal and state members of parliament
- federal and state government agencies
- local government representatives
- industry and regional development groups
- conservation groups
- local and regional community groups
- indigenous groups
- employees and contractors
- research centres, including universities
- potential customers and suppliers
- media and general public
- land and lease holders
- banking and commercial sector representatives.

The following initiatives and activities have all contributed to focusing attention on the proposed Gorgon Development:

- signing of the State Agreement, the passage through State Parliament of the *Barrow Island Act 2003*
- preliminary agreements to provide Gorgon LNG to the Chinese and North American markets
- visits by senior federal and state political leaders to China, the United States, Mexico, Korea and Japan
- the Western Australian Government Local Industry Forum
- a national geosequestration conference in Perth
- public release of the EIS/ERMP Scoping Document.

This attention has generated considerable media coverage and increased public knowledge of the proposal and awareness of key issues associated with the proposed Development.

5.2 Methods of Engagement

A number of methods were used to engage the public on the proposed Development, depending on the issue or information required. Complicated and scientific topics and issues were generally handled through workshops and panel discussions while information meetings and briefings were held to disseminate general Development details and schedules. The methods are explained in more detail below.

5.2.1 Community Consultation – Quarantine

The ESE Review and response to submissions identified the importance of Barrow Island and the need for a robust Quarantine Management System to protect the biodiversity of the island. In November 2003, the Joint Venturers established a Quarantine Expert Panel of respected, experienced, and independent technical specialists. The purpose of the Panel was to specifically provide independent expert advice with the aim of developing a world-class Quarantine Management System for the Gorgon Development. The Panel was chaired by a former Chairman of the Western Australian Environmental Protection Authority, Dr Bernard Bowen. Advertisements were placed in Western Australian newspapers seeking interested members of the public to attend technical workshops and meetings organised by the Expert Panel secretariat; and to become involved with the development of plans, studies and programs designed to identify and address quarantine management issues.

By September 2004, there had been four quarantine community consultation meetings, four community workshops, eight Expert Panel meetings (plus a special meeting held to consider the Quarantine Management System) and 14 technical workshops involving over 40 recognised experts. Outputs, such as the technical design of baseline surveys to investigate the existence of non-indigenous (introduced) marine and terrestrial species, summaries from the community consultation meetings and brief reports of each Expert Panel Meeting were posted on the Gorgon Australian Gas website (www.gorgon.com.au). Further information on Quarantine aspects of the proposed Development are detailed in Chapter 12 and associated Technical Appendices.

5.2.2 Technical Workshops for Government and Industry Stakeholders

The Gorgon Joint Venturers have organised a number of technical workshops with stakeholders to examine specific aspects of the impacts of the Development. In addition to quarantine, consultation workshops have been held to assist in the planning and design of environmental studies and identification of potential issues. In May 2004, the Joint Venturers held seminars with key federal and state government stakeholders to discuss the preliminary findings of environmental field studies conducted for the Draft EIS/ERMP and in August and September 2004, proposed environmental management strategies to reduce potential impacts and risks were discussed at informal workshops with government agencies.

The Gorgon Development proposal is contributing to the national debate on greenhouse gas management and geosequestration regulation through membership of the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) and a reference group advising the Geo-Sequestration Regulatory Working Group. This Group, which was established by the Ministerial Council on Minerals and Petroleum Resources, comprises federal and state/territory officials who are developing principles for a nationally consistent regulatory framework for geosequestration.

5.2.3 Briefings and Meetings

Since gaining in-principle approval for the Gorgon Development in late 2003, the Joint Venturers have continued to be pro-active in talking and listening to a diverse range of stakeholders. Key stakeholders at all levels of government, industry, non-government organisations (NGOs), the media and the community generally have indicated an eagerness to know more about the Development and provide views across a broad spectrum of topics. Joint Venturer representatives, including senior management, the Development Team, Subsurface Team, Health, Environment and Safety, Government and External Affairs, and Marketing, continue to be involved in these discussions with stakeholders.

5.2.4 Regional Visits – Pilbara

There have been numerous discussions with stakeholders in the Pilbara region of Western Australia. The Joint Venturers established a Pilbara Community Reference Group in 2003 as a means of seeking early input from the community. While this is a focal point for stakeholder engagement in the Pilbara, discussion of the Development has not been exclusively through this group. Senior Development Team members have discussed the Development with officials of both the Roebourne and Ashburton Shire Councils. A town meeting was held in Onslow and a number of the Ashburton Shire Councillors visited Barrow Island to inspect the proposed Development site in June 2004.

The Gorgon Development Team and Cultural Heritage consultants have met with representatives of Pilbara Indigenous communities and organisations to discuss the Development and identify potential opportunities for local employment and businesses. Dialogue with these communities, focusing on cultural heritage, education, training, employment, and methods to enhance positive social and economic aspects of the Development, will continue throughout the current phase of design and in the lead up to construction. This consultation and engagement form part of the Social Impact Management Plan (SIMP) that is being developed as required under the State Agreement.

5.2.5 Stakeholder Consultation Plan as Part of the Social and Economic Impact Assessment

As part of the Social and Economic Impact Assessment for this Draft EIS/ERMP, a Stakeholder Consultation Program was developed. Specialist consultants sought comment from a broad range of stakeholders including members of state and federal parliaments, state government advisers, government agencies (state and local), community and Indigenous organisations, educational institutions and special interest groups located both in the Pilbara and Perth regions.

The issues identified during the Social and Economic Impact Assessment have been considered in detail in the relevant sections of this Draft EIS/ERMP, and a summary of the key issues raised during the consultation is included in section 5.4.

5.2.6 Conferences and Forums

The Joint Venturers sponsored and addressed a Carbon Capture and Storage Conference in Perth organised by the Conservation Council of Western Australia in April 2004. The conference brought together industry, government and community representatives with scientific experts to examine the role of geosequestration in Australia's energy future.

The President of Chevron Global Gas, John Gass, addressed the 2004 Australian Petroleum and Exploration Association (APPEA) about the future of global gas markets and the important role the Gorgon Development will have. The Managing Director of Chevron Australia, James W Johnson, participated in a local content forum of government, industry and union representatives convened by the Western Australian Government. As a result of the forum, James W Johnson is now a member of the Oil and Gas Coordination Council, established by the State Development Minister.

In 2003 and 2004, the General Manager of Gorgon Gas, Paul Oen, addressed luncheons organised by the Liberal and Labor Parties on the markets and milestones for the Gorgon Development.

In 2003 and 2004, Mark Watson, Gorgon Development Environmental Coordinator, addressed the APPEA Environmental Workshop, the LandCorp Sustainable Urban Development Forum, the Sustainability Working Group (established by the Department of Premier and Cabinet) and the National Conference of Parliamentary Committee. These presentations related specifically to the Gorgon Development, its schedule, environmental approval requirements, environmental topics and potential issues.

5.2.7 Barrow Island Site Visits

During the ESE Review process, a comprehensive program of Barrow Island site visits was carried out to ensure key stakeholders could observe the island's environment, the current oilfield operation and the proposed development site. During the preparation of this Draft EIS/ERMP, the program of stakeholder visits has continued. It has included: state and federal ministers, representatives of the Ashburton Shire Council, officers from government agencies and representatives of the Conservation Council of Western Australia, Members of the Quarantine Expert Panel, Quarantine Advisors, the Waterbird Conservation Group, the West Australian Weeds Council, and the California Foundation on the Environment and Economy.

5.2.8 Supplier Communication

A dedicated on-line supplier registration system for the Gorgon Development has been established using Supply-base Vendor Registration System (VRS), a supplier registration system for the oil and gas industry. This service is provided free of charge for suppliers registering with the Gorgon Development. Regular project updates and supplier-related information can be accessed at www.supplybase.com.au. Part of Chevron Australia's display at the 2004 APPEA exhibition was dedicated to an online supplier registration facility. Currently there are more than 3600 vendors registered with the system. These vendors cover an extremely wide range of services and products.

In May 2004, Chevron Australia sponsored representatives of four Western Australian suppliers to attend the global oil and gas industry key supply exhibition – the Offshore Technology Conference in Houston, USA. The purpose of the trip was to initiate business contact with international companies to identify potential alliance and partnering opportunities for the Gorgon Development.

5.2.9 Media Announcements

The proposed Gorgon Development is a significant capital project, having global commercial impact. In 2003, two market announcements by the Joint Venturers attracted local, national and international media attention (Plate 5-1). The first was the signing of preliminary sales agreements to supply LNG to proposed terminals on the West Coast of North America. The second was a preliminary equity and sales agreement with the China National Offshore Oil Corporation (CNOOC). Other statements released by the Venturers announced the establishment of the Gorgon Development Quarantine Expert Panel and the opening of a marketing office in China.

The Joint Venturers have also responded to numerous inquiries for information about the Gorgon Development from international, national, state and regional media organisations. These have included television and radio stations, newspapers, magazines, trade journals and newsletters and industry publications. The majority of media interest has focused on the LNG market prospects although generally there has also been interest on the importance of the Development on the health and future of Australia and Western Australia, the significance of the Development to the Joint Venturers, and potential impact to trade, employment, investment and the environment.

Plate 5-1:
Media Conference on Barrow Island

5.2.10 Gorgon Australian Gas Website

The Gorgon Development has a dedicated website at www.gorgon.com.au which contains considerable detail of the proposed Development. The website was designed to provide interested stakeholders with the current description of the Development. It allows them to keep abreast of critical approvals and decisions being made, and provides the opportunity to contact the Development Team.

5.3 Key Gorgon Development Stakeholders

5.3.1 Western Australian State Ministers, their Advisers and Members of State Parliament

Briefings, meetings, discussions and Barrow Island site visits have been held with a number of members of the Western Australian Cabinet, their advisers and Members of Parliament, in particular those with portfolio or electorate interests in the proposed Development (Plate 5-2). They include the:

- Premier
- Deputy Premier, Treasurer and Energy Minister
- Minister for State Development
- Minister for the Environment
- Minister for Local Government and Regional Development, the Kimberley, Pilbara and Gascoyne
- Minister for Consumer and Employment Protection; Indigenous Affairs Minister Assisting the Minister for Public Sector Management
- Parliamentary Secretaries to the Premiers and Ministers for State Development and Environment and Heritage
- Leader of the Opposition
- Leader of the National Party
- Western Australian Greens member with responsibility for Energy and Mining
- Members of the Legislative Council representing the Mining and Pastoral Region
- Members for Pilbara and Burrup.

Plate 5-2:
Premier and Members of State Cabinet Visit to Barrow Island September 2003

5.3.2 Federal Ministers, their Advisers and Members of Federal Parliament

Briefings, meetings, discussions and Barrow Island site visits have been held with a number of members of Federal Cabinet, their advisers and Senators and Members of House of Representatives, in particular those with portfolio or electorate interest in the Gorgon Development (Plate 5-3). They include the:

- Prime Minister's Office
- Deputy Prime Minister
- Minister for Industry, Tourism and Resources
- Minister for the Environment
- Minister for Trade
- Minister for Foreign Affairs
- Minister for Finance
- Treasurer's Office
- Federal Opposition Shadow Minister for Resources
- Western Australian Senators and Members of the House of Representatives.

5.3.3 State Government Agencies of Western Australia

Briefings, meetings, discussions, workshops and Barrow Island site visits have been held with a range of state agencies and advisory bodies. They include the:

- Standing Inter-Agency Committee of Chief Executive Officers
- Environmental Protection Authority
- Department of Industry and Resources (specifically the Petroleum Division, the Office of Major Projects and the Office of Aboriginal Economic Development)
- Department of Environment
- Conservation Commission
- Department of Conservation and Land Management
- Department of Agriculture
- Department of Treasury and Finance
- Department of Premier and Cabinet, Policy Unit
- Department of Planning and Infrastructure
- Marine Parks and Reserves Authority
- Department of Indigenous Affairs
- Botanic Gardens and Parks Authority
- Department of Health
- Department of Fisheries.

5.3.4 Federal Government Agencies

Briefings, meetings, discussions, workshops and Barrow Island site visits have been held with a range of federal agencies and advisory bodies. They include the:

- Department of Prime Minister and Cabinet
- Department of Industry, Tourism and Resources
- Department of the Environment and Heritage
- Invest Australia
- Treasury
- Department of Finance and Administration
- Australian Tax Office
- Australian Greenhouse Office
- Australian Quarantine and Inspection Service
- Department of Foreign Affairs and Trade
- AusIndustry
- Department of Defence
- Foreign Investment Review Board.

5.3.5 Regional Stakeholders – Pilbara

Briefings, meetings, discussions, workshops and Barrow Island site visits have been held with a range of Pilbara stakeholders. They include the:

- Shire of Roebourne
- Shire of Ashburton
- Gorgon Pilbara Reference Group
- Pilbara Development Commission
- Pilbara Regional Council
- Pilbara Area Consultative Committee
- Department of Community Development
- Department of Fisheries
- Department of Indigenous Affairs
- Department of Education and Training
- Department of Health
- Karratha Fire and Emergency Services
- Karratha Police
- Lifeline Karratha

Plate 5-3:
EPA Visit to Barrow Island

- Salvation Army Karratha
- Dampier Port Authority
- Karratha and Districts Chamber of Commerce and Industry
- Karratha Business Enterprise Centre
- Pilbara College of TAFE
- Karratha Visitor Centre
- Western Australian Tourism Commission
- Point Samson Community Association
- Dampier Community Association
- Yabburara/Mardudhunera Indigenous Community
- Kurama Marthudunera Indigenous Community
- Buurabalyji Thanlanyji Association
- Ngarda Ngarli Yarndu Regional Council
- Ngarda Civil and Mining
- Carey Mining
- Bujee-Nhoor-Pu Aboriginal Cultural Enterprises
- Pilbara Aboriginal Chamber of Commerce
- Juluwarlu Aboriginal Corporation
- Pilbara Native Title Service
- Roebourne Indigenous Job Seekers Working Group
- Pilbara Trap Fisheries
- Pilbara Trawl Fisheries
- Onslow Prawn Fisheries
- Pearl Producers Association
- Mardie Station leaseholder.

5.3.6 Conservation Organisations

Briefings, meetings, discussions, workshops and Barrow Island site visits have involved a range of regional, state, national and international conservation organisations. These organisations had a primary interest in how the proposed Development would potentially impact the environment, how the Joint Venturers plan to manage these impacts, the opportunities for public and community input into the Draft EIS/ERMP and the approval process. For example, the Quarantine Community Meetings and Risk Standards Workshops (refer to Chapter 12) have resulted in the involvement of a wide range of conservation groups. It should be noted that there was also valuable discussion and engagement with these organisations on general Gorgon Development information, planning and design. Stakeholders consulted include the:

- Conservation Council of Western Australia
- Marine and Coastal Communities Network
- Waterbird Conservation Group
- Wildflower Society of Western Australia
- Australian Marine Conservation Society
- Western Australian Naturalists' Club
- West Australian Weeds Committee
- Royal Society of Western Australia
- Pilbara Wildlife Carers Association
- Speleological Group (Western Australia)
- Wilderness Society of Western Australia
- Environmental Weeds Action Network of Western Australia
- Birds Australia (Western Australia Group)
- Care for Hedland Environmental Interest Group
- Cape Conservation Group
- Nickol Bay Naturalists Club
- Greenpeace
- Australian Conservation Foundation
- Worldwide Fund for Nature.

Also included in this group is Dr Harry Butler, a well-known conservationist, who has had some 40 years of active involvement with and stewardship for Barrow Island. Dr Butler helped establish the system and policies for quarantine on Barrow Island as early as the 1960s.

5.3.7 Industrial Interests and Organisations

Briefings, meetings, discussions, workshops, conference presentations and Barrow Island site visits have been held with a range of industry stakeholders. They include the:

- Chamber of Minerals and Energy of Western Australia
- Chamber of Commerce and Industry Western Australia (including Apprenticeships WA)
- Australian Petroleum Production and Exploration Association
- Australian Pipeline Industry Association
- Australian Gas Association
- American Chamber of Commerce
- Petroleum Club of Western Australia
- Oil and gas companies with interests in the area (including Apache Energy, Woodside Petroleum and Santos Limited)
- Resources and support companies with interests in the Pilbara and Kimberley (Pilbara Iron, BHP Billiton, Argyle Diamonds, ESS, Newcrest Mining, Burrup Fertilisers)
- Australian Marine Complex
- Australian Council of Trade Unions
- UnionsWA
- Representatives of industrial unions.

5.3.8 Academic and Scientific Organisations

Briefings, meetings, discussions, workshops, conference presentations and Barrow Island site visits have been held with a range of scientific stakeholders. The primary focus was to inform and engage these stakeholders in matters related to their specific area of interest. For instance, discussions and workshops with the CO2CRC related to the potential impact of the Gorgon Development on the disposal of reservoir carbon dioxide (CO_2) by injection and the design and implication of national CO_2 disposal principles and policies. The stakeholders include the:

- Commonwealth Scientific Industrial Research Organisation
- Cooperative Research Centre for Greenhouse Gas Technologies
- Australian Institute of Marine Science
- Australian Marine Science Association
- Curtin University of Technology
- Edith Cowan University
- Murdoch University
- University of Western Australia
- Western Australian Museum.

5.3.9 Other Stakeholders

Briefings, meetings, discussions, workshops, Barrow Island site visits and formal presentations on the Gorgon Development were undertaken to provide a wide range of information and issues to the following stakeholders:

- employees and contractors in Perth and on Barrow Island (Plate 5-4)
- Joint Venturer representatives
- potential customers.

Plate 5-4:
Development Team Members in Environmental Familiarisation Tour of Barrow Island

5.4 Key Issues Identified by Stakeholder Groups

The Joint Venturers have been consulting and engaging with a wide number of stakeholder groups since 2002 about locating a gas processing facility on Barrow Island to develop the Greater Gorgon gas resources. Stakeholder engagement for this Draft EIS/ERMP needs to be viewed in the context of the Venturers' ongoing commitment to consultation which includes understanding and addressing stakeholder concerns and issues.

The ESE Review contains a detailed list of questions raised by stakeholders directly with the Joint Venturers (ChevronTexaco Australia 2003b). The release of the ESE Review was followed by a public review and comment period after which the Environmental Protection Authority (EPA) and the Department of Industry and Resources (DoIR) summarised the questions raised by stakeholders. The Venturers then responded to the matters raised by the EPA and DoIR (ChevronTexaco Australia 2003a).

Many of the matters raised by stakeholders since 2002 were addressed during the ESE Review process such as size of development footprint (300 ha), and Barrow Island as a development location. Other matters such as quarantine, impact on the marine environment, stygofauna, endangered species that were raised in the ESE Review process are specifically dealt with throughout this Draft EIS/ERMP. The following tables (Table 5-1, Table 5-2, Table 5-3 and Table 5-4) are summaries of key questions about various factors that were raised by stakeholders during the EIS/ERMP process. Questions that are addressed in greater detail in subsequent chapters and/or technical appendices of this document are noted. As expected, there is often overlap between, and duplication of, questions received from the stakeholders. In an attempt to minimise the duplication and make the document easier to read, similar questions have been grouped.

Table 5-1:
Key Questions Raised by Stakeholders about Strategic Factors

Factors	Stakeholder Question	Response
Development location	Have other Development location options been fully explored?	As documented in the ESE Review, the Joint Venturers conducted an exhaustive examination of alternative development sites before concluding that Barrow Island was the only location that would enable gas from the Gorgon gas field to be competitive in today's market. This position was supported by an independent report prepared for the Western Australian Government by The Allen Consulting Group which concluded that based on all the available information '…Barrow Island represents the only commercial option for monetising the substantial national asset represented by the Gorgon resource.' This was accepted by the Government of Western Australia and the *Barrow Island Act 2003* was passed. (Refer to Chapter 3 for additional details.)
Level of detail in the Draft EIS/ERMP	Will the Draft EIS/ERMP be sufficiently detailed to demonstrate that all potential impacts can be mitigated appropriately?	The scope (including the level of detail) for the environmental, social and economic studies was strongly influenced by the results of the extensive stakeholder engagement program. The Venturers allocated substantial resources to the work and employed a large team of over 100 specialist consultants from over 20 companies over a period of 18-months to conduct the research, modelling, field surveys and assessments. The assessment scope and methodology was discussed with regulatory agencies and the preliminary findings presented to agency workshops.

Table 5-2:
Key Questions Raised by Stakeholders about Environmental Factors

Factors	Stakeholder Question	Response
Quarantine Risk and Management	Will the Gorgon Development result in a substantial increase in the risk of a quarantine breach?	The Joint Venturers are actively engaged in developing a Quarantine Management System that will deliver a world's best practice level of quarantine protection for Barrow Island. This effort involves a team of 25 experts dedicated to develop a system that will continue to manage risks to the conservation values of Barrow Island and the marine environs. Furthermore, the Gorgon Quarantine Expert Panel was established to oversee and provide expert advice on the development of quarantine measures for the proposed Development. The Venturers are confident the level of risk can be effectively assessed, managed, and mitigated to a level considered acceptable by technical experts, the community, and relevant government agencies. (Refer to Chapter 12).
	Will the proposed Development remain commercially viable on Barrow Island with the substantial incremental cost of quarantine management?	The Joint Venturers have conducted an exhaustive assessment of a number of possible sites for the proposed Gorgon Development. These assessments, which include the cost of quarantine, consistently identify Barrow Island as the only commercial site for the proposed Development.
Injection of reservoir CO_2	Can the Joint Venturers be confident that the injected CO_2 will remain underground?	Studies undertaken by the Development Team have established that the technical risk of the CO_2 injection project failing is very low. In the remote event of a leak, impacts on the island would be minor and would not jeopardise the island's conservation values. (Refer to Chapters 10 and 13).
	Will the Joint Venturers be responsible for the sequestered CO_2?	The Joint Venturers will hold a licence for this facility and are responsible for ensuring the planned CO_2 injection project does not pose a threat to other assets or the conservation values of Barrow Island. (Refer to Chapter 13).
Subterranean Fauna	Can the Joint Venturers be confident that risks to subterranean fauna biodiversity will be adequately understood and managed?	In consultation with experts from CALM and the Western Australian Museum, the Joint Venturers and specialist consultants designed and implemented the most comprehensive, rigorous and robust subterranean fauna investigation yet undertaken by a proponent as part of an environmental impact assessment.

Table 5-2: (continued)
Questions Raised by Stakeholders about Environmental Factors

Factors	Stakeholder Question	Response
Dredging	How will potential impacts on sensitive marine flora and fauna from dredging the shipping channel, MOF and spoil disposal sites be approached?	Sensitive reef areas will be considered when selecting the location of marine facilities. The volume of dredging required for marine facilities has been reduced to as low as reasonably practicable. Specialist studies have been undertaken in potentially affected marine areas. Sensitive periods for marine primary producers have been identified. Particle-size of marine sediments and substrates has been incorporated into a comprehensive mathematical model of marine currents around Barrow Island resulting in the appropriate location of dredge disposal sites. Management plans will be developed to monitor coral health and guide actions to further reduce potential impacts. (Refer to Chapters 8 and 11).
Air Emissions	How will potential impacts of air emissions on public health and the flora and fauna on Barrow Island be approached?	Air emission specialists were retained to model existing and planned emission sources, types (NOx, SO_2, Particulates, H_2S and ozone depleting substances) and dispersal contours and ground concentrations. Modelling results predict negligible impacts to local and regional receiving environments with impacts to flora and fauna unlikely. (Refer to Chapters 7 and 10 and Technical Appendix B1).

Note: All acronyms and abbreviations are provided in the supplementary information section of this document.

Table 5-3:
Key Questions Raised by Stakeholders about Economic Factors

Factors	Stakeholder Question	Response
Australian Industry Participation	Will there be opportunities for Australian industry to compete to supply goods and services to the proposed Development?	The Joint Venturers actively support Australian industry participation as a core business policy. Part of this commitment is to provide full, fair and reasonable opportunity for Australian industry to supply goods and services to the Development. The Joint Venturers will utilise the services of the Industry Capability Network (ICN WA) to assist in identifying potential Australian companies to provide goods and services. A dedicated supplier registration system for the Gorgon Development has already been established for Australian suppliers, with more than 3600 vendors currently registered. Clause 15(1)(c) of the State Agreement imposes requirement on the Gorgon Joint Venturers that Western Australian suppliers, manufacturers and contractors be given fair and reasonable opportunity to tender and quote.
Regional Opportunities	Will there be opportunities for the Pilbara Region to participate in the proposed Development through local employment and use of local businesses?	Through the Barrow Island State Agreement and the ESE Review, the Joint Venturers are committed to providing opportunities for the Pilbara Region. A Pilbara Community Reference Group has been formed to provide advice to the Joint Venturers on socio-economic issues for Pilbara communities, businesses and organisations arising as a result of the Gorgon Development. Several studies are also currently underway to assess the ability of the Pilbara to support various development requirements such as a supply base, logistics and lay-down area.

Table 5-4:
Key Questions Raised by Stakeholders about Social Factors

Factors	Stakeholder Question	Response
Unemployment	As unemployment is a growing concern for the Pilbara Region, will there be employment opportunities from the proposed Development for groups such as youth and Indigenous people?	The Joint Venturers are considering opportunities for establishing partnerships with existing government and community (including Indigenous) groups to contribute to, or create, employment and/or training programs and opportunities for people in the Pilbara region. (Refer to Chapter 14).
Opportunities for Onslow	Will the Onslow area receive benefits from the Development?	Pursuant to current legislation, the Shire of Ashburton will have the ability to levy reasonable and appropriate rates on the portion of the Barrow Island that will be used for the Development. This will generate a beneficial source of income without a substantial cost to the community. The Joint Venturers are also considering other opportunities to contribute to improved social infrastructure and services in Onslow. (Refer to Chapter 14).
Workforce Health and Safety	Have the social impacts associated with using a fly-in fly-out workforce been recognised?	The potential impacts associated with use of fly-in fly-out on workers are recognised, however it is common in the oil and gas industry. Fly-in and fly-out options will be available from Perth and Karratha such that employees can be based in the Pilbara. The Gorgon Development health and safety management system will consider health impacts of fly-in fly-out. (Refer to Chapter 14).
Use of Fly-in Fly-out Workforce	Will the use of a fly-in fly-out regime reduce the opportunities for the Pilbara region to benefit from the Development; and will it contribute to negative social effects on community stability such as family breakdowns, reduced public participation and volunteering in local activities, increases in single persons/decline in family numbers?	Currently there are not enough workers in the Pilbara region to meet the high labour demand during the construction of the Development, regardless of its location. Fly-in fly-out is the only practical method to meet the labour requirement and places the least demand on existing social infrastructure. During operations, workers will be sourced where they have the necessary skills; some of these will be from the Pilbara region. There is an existing Chevron camp on Barrow Island for the WA Oil operations and there will be a construction village for the Gorgon Development. Because the only economical location for the Development is currently on Barrow Island, fly-in fly-out is the only option available.

Table 5-4: (continued)
Key Questions Raised by Stakeholders about Social Factors

Factors	Stakeholder Question	Response
Capacity of local services and infrastructure	Will the existing services/social infrastructure in Karratha and the Pilbara be adequate to service the Gorgon Development? That is, will the proposed Development result in increased pressure on: health and emergency services in Onslow and Port Hedland; childcare facilities in Karratha; men's health and related issues; facilities and services for youth particularly indigenous youth; secondary and tertiary education facilities?	The Development is not expected to a have a significant impact on population numbers in the region; however the Joint Venturers will be developing a SIMP during the next stage of development. The SIMP will consider the issues identified in the Social and Economic Impact Assessment and identify management measures. Further consultation will be conducted to ensure that proposed management measures are appropriate. (Refer to Chapter 14).
Impacts on other land and sea uses	Will activities associated with the Gorgon Development restrict other land uses or values including Mardie Station, commercial fishers, native title and cultural heritage?	The Joint Venturers have consulted with relevant stakeholders including Mardie Station, commercial fishers, Indigenous people and Local Government to identify specific impacts. A draft Cultural Heritage Management Plan has been prepared and the SIMP will address in further detail other potential impacts. (Refer to Chapter 14).
Increased traffic to and from supply base	How will the potential for increased traffic and congestion with associated safety issues for other road users and businesses operating nearby be addressed?	The Joint Venturers will prepare a detailed traffic management plan in consultation with local government to ensure that this issue is managed.

5.5 Conclusion and Further Engagement Plan

Comprehensive and effective community consultation, engagement and participation are planned for all stages of the Gorgon Development. The Joint Venturers understand that involving the community in development planning represents best practice in environmental management. Effective community engagement has been, and remains, a key element of the Gorgon Development, and will be incorporated into the SIMP pursuant to the State Agreement.

The Gorgon gas field was discovered over two decades ago and since that time, stakeholder input has helped shape the Development's location, concept and plans. Participatory engagement was undertaken at a very early stage of the Development planning, well before the preparation of the ESE Review. This active engagement has continued during the scoping of environmental and social issues and the planning of comprehensive studies. The wide range of community interest and involvement in these activities has, for the most part, been a very positive influence on the Development.

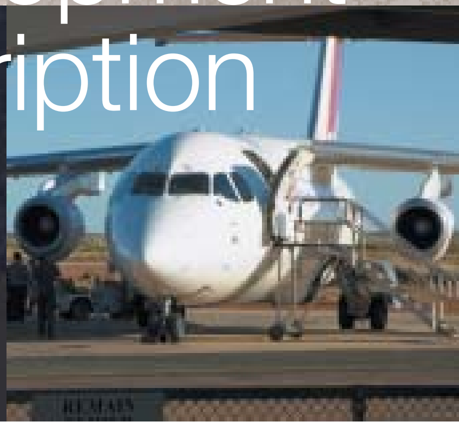
The commitment to community involvement identified in the earlier ESE Review remains unchanged. That is to 'maintain open and accountable processes through all stages of the Development that encourages stakeholder engagement in relation to the Gorgon Development' (ChevronTexaco Australia 2003b). The record of community involvement by the Venturers since the government granted in-principle access to Barrow Island demonstrates the importance the Venturers place on that commitment.

The Joint Venturers will continue to meet with stakeholders, answer questions and seek feedback throughout the EIS/ERMP process. The federal and state government review of this Draft EIS/ERMP document and the 10-week public comment period will provide stakeholders with further opportunity to provide formal input into the environmental approval process. The Venturers will then address these submissions.

The comprehensive consultation plan implemented as part of the approvals process will continue following the release of this Draft EIS/ERMP and through all stages of the Development. Specifically during the public comment period, the plan is designed to encourage stakeholder participation in the public submission process.

Feedback from submissions received through the formal public comment period will further assist the Venturers in formulating responses and addressing the issues raised.

06: Development Description



The Greater Gorgon area contains a number of known and prospective hydrocarbon resources, with the most well-known being the Gorgon gas field, which gives the region its name. Following a rigorous and extensive review (as discussed in Chapter 3), the Gorgon Joint Venturers are proposing to develop the Gorgon gas field resources through a gas processing facility to be built on Barrow Island from where various gas and liquid products will be directed to market.

The proposed Development includes the installation of approximately 25 offshore wells and associated flowlines and manifolds. The offshore facilities initially required to develop the Gorgon resources will be entirely subsea in approximately 200+ m of water. The flow from each well will be controlled from Barrow Island and will be delivered via a 70+ km-long, high pressure pipeline.

The gas processing facility will be located at Town Point on the east coast of Barrow Island and will consist of a Liquefied Natural Gas (LNG) plant, a domestic gas plant, hydrocarbon condensate handling facilities, and associated utilities. The LNG plant will initially comprise two LNG trains capable of producing a nominal capacity of 10 million tonnes per annum, requiring approximately three LNG shipments from Barrow Island per week, which will be loaded from a dedicated jetty. The domestic gas plant will be designed to deliver in the order of 300 Terajoules per day (TJ/day), which will be transported via a pipeline tying into the existing domestic gas transmission pipeline network. Condensate associated with the feed gas will be separated and stored prior to loading into ships for market (approximately one ship per month).

Carbon dioxide (CO_2) will be removed from the feed gas to meet market quality specifications for domestic gas, and to prevent the CO_2 in the feed gas from freezing and causing a blockage in the LNG equipment. It is proposed that it will then be compressed, dried and injected into subsurface formations some 2000 m beneath Barrow Island. Limited venting of the reservoir CO_2 will be required during commissioning, periods of maintenance, injection equipment downtime, or reservoir constraints. Waste water that cannot be recycled or safely discharged to the environment will be injected deep beneath Barrow Island.

Infrastructure will be required to support the construction activities and subsequent operations. This infrastructure will include a construction village with associated amenities and utilities (such as power generation facilities), mainland supply bases in the Pilbara region and Perth, and upgrades to the current airport, roads, and services on Barrow Island.

Construction is expected to occur over a period of approximately 45 months and require a peak island-based workforce of approximately 3300 personnel.

The life of the proposed Development is nominally 60 years, during which time an operational workforce of around 150–200 personnel will be accommodated on Barrow Island, in addition to the existing operations personnel and contractors. The operational workforce is expected to increase by approximately 250–500 people for approximately one to two months in most years for planned maintenance.

In the future, it may be proposed to expand the capacity of the gas processing facility by adding a third and possibly a fourth LNG train, with associated feed gas pipelines, utilities and other infrastructure. A number of activities are included in the scope of the initial development to enable such an expansion with minimal environmental impact. Depending on the nature of the proposed expansion, separate environmental approval may be required, but any such expansion will occur within the 300 ha area designated under the *Barrow Island Act 2003.*

This chapter is a description of the various components of the facility, as well as relevant aspects of their construction and operation, to serve as a basis for the environmental impact assessment outlined in Chapters 10 to 15.

6.1 Introduction

The Greater Gorgon area is located off the west coast of Australia. The area is abundant in hydrocarbon resources, as outlined in Chapter 1. A gas processing facility located on Barrow Island will enable the long-term development of the Greater Gorgon area. Each of the fields in the Greater Gorgon area contains a different gas composition, so the gas processing facility will be designed to handle a range of feed gas compositions.

The Gorgon Joint Venturers are proposing to initially develop these resources as feed gas for a nominal 10 million tonne per annum (MTPA) LNG facility with a 300 TJ/day domestic gas plant on Barrow Island. Approximately 2000 m^3/day (12 000 bbl/day) of hydrocarbon condensate will also be produced from the hydrocarbon liquids associated with the gas fields.

Two additional LNG trains and associated infrastructure may be added in the future. If this expansion occurs, it may happen as a single activity or as several smaller expansions.

This chapter describes the facilities and activities associated with the proposed Development. It also describes the facilities that are proposed to be installed, and activities that are proposed to be undertaken, within the scope of the proposed Development to assist future expansion and minimise the cumulative environmental impact. Any future expansion will be located within the 300 ha area designated for development under the *Barrow Island Act 2003.*

6.1.1 Gas Compositions – Feed and Product

Table 6-1 shows the feed gas composition of the Gorgon field, the Jansz field, a typical specification for LNG, and the current domestic gas specification. These compositions will vary slightly over the production life of the field due to natural variations in the gas composition within each field and in response to the changing pressure in the reservoirs resulting from the extraction of the natural gas. The reservoir gas compositions presented here are the anticipated gas compositions at approximately year 20 of production. This table shows that the reservoir fluids are predominantly methane with a very small proportion of liquid hydrocarbon components (i.e. butane and heavier).

6.2 Major Infrastructure Components

Development of the hydrocarbon reserves in the Greater Gorgon area will require a number of phases, and a variety of infrastructure to extract and transport natural gas to Barrow Island for processing and delivery to market. The Development will initially consist of a subsea development for the production and transport of gas from the fields to Barrow Island; and a gas processing facility located at Town Point on Barrow Island (Figure 6-1). Utilising a subsea development removes the initial need for an offshore processing platform.

In the future, the pressure in the reservoirs will be insufficient to sustain peak production rates. At that time it may be necessary to install compression

Table 6-1:
Feed Gas and Product Gas Compositions

Component*	Gorgon	Jansz**	Typical LNG Specification	Current Domestic Gas Specification
CO_2	14–15 volume%	0.28 volume%	<100 ppm	<3.6 volume %
N_2	2–3 volume%	2.35 volume%	<1 volume%	Total inert gases <6.5 volume %
Hydrocarbons				
– Methane	76.71	91.48	–	–
– Ethane	3.23	3.75	–	–
– Propane	0.89	1.06	–	–
– Butane	0.30	0.41	–	–
– Pentane and heavier	0.13	0.63	–	–
Total	83+ volume%	97.4 volume%	99 volume%	93.5+ volume%

* *The feed gas will also contain traces of Hydrogen Sulphide (H_2S), mercury, and aromatics from the reservoirs.*

** *Composition of Jansz gas included here as the gas processing facility will receive gas from both Gorgon and Jansz fields and as such emissions calculations and modelling have been based on the total incoming gas stream.*

facilities. This may be a platform, but subsea technology is evolving rapidly and so it could be a subsea facility. The compression facility is outside the scope of this Draft EIS/ERMP, and if required will be the subject of a separate approval process. Other fields may also be tied into the gas processing facility through the subsea systems.

LNG and condensate produced at the gas processing facility will be shipped to buyers directly from Barrow Island. Provided it is commercially viable (refer to Chapter 2 for more specific details), treated gas for domestic consumption will be exported by a subsea domestic gas pipeline to tie into the domestic gas transmission network.

It is proposed to remove the reservoir CO_2 from the feed gas and inject it into the Dupuy formation deep beneath Barrow Island, this is discussed in more detail in Chapter 13. Waste water that cannot be recycled or discharged to the environment will also be injected deep beneath Barrow Island. In addition, a range of associated infrastructure will be required on the island and in the adjacent marine area.

The main components of the proposed Development are:

- the Gorgon gas field wells and subsea installation
- a feed gas pipeline from the Gorgon gas field to the gas processing facility on Barrow Island
- an easement along the Gorgon gas field pipeline (onshore and traversing state waters) to accommodate additional feed gas pipelines
- a gas processing facility on Barrow Island (including two LNG trains, domestic gas and condensate facilities)
- port/marine facilities at Barrow Island
- water supply and disposal
- a construction village and associated facilities
- a proposal to dispose of reservoir CO_2 by injection into the Dupuy formation
- monitoring of CO_2 movement in the Dupuy formation
- an optical fibre cable connection to the mainland
- a domestic gas pipeline to the mainland
- utilities to support the hydrocarbon processing facilities including power generation, instrument air and nitrogen
- site works to accommodate selected aspects for future expansion
- a mainland supply base
- other associated infrastructure such as upgrades to the airport, roads, and other utilities.

For the purpose of cumulative impact assessment, this Draft EIS/ERMP addresses the impacts on, and near, Barrow Island associated with the installation of the Jansz feed gas pipeline to process gas from the Jansz field and other potential tieback opportunities associated with the Greater Gorgon area, or other nearby prospects.

The Gorgon Joint Venturers have completed the concept selection phase for the design of the gas processing facilities. As the design of the Development proceeds, a number of components of the facilities will be reviewed and significant additional engineering detail completed. As a result, some of the information presented in the chapter is subject to change. Where a range of options is still open, the range is presented and the subsequent assessment is based on the impacts likely to be associated with that range. Thus, these options are not expected to significantly change predicted environmental impacts. Furthermore, potential and actual impacts will be frequently reviewed and managed to further reduce the environmental impact as the design develops.

6.2.1 Wells and Subsea Facilities

The proposed Development will utilise an all subsea concept for wells and manifolds. Consequently all offshore facilities are proposed to be placed on the seafloor with no initial need for any permanent surface facilities.

Up to 25 subsea wells will be drilled in the Gorgon gas field throughout its production life. These wells will be in water depths ranging from approximately 190–250 m. They will be directionally drilled from a small number of drill centres located across the field. The final number of wells and their locations will be optimised prior to drilling.

Figure 6-1:
Proposed Gorgon Gas Development

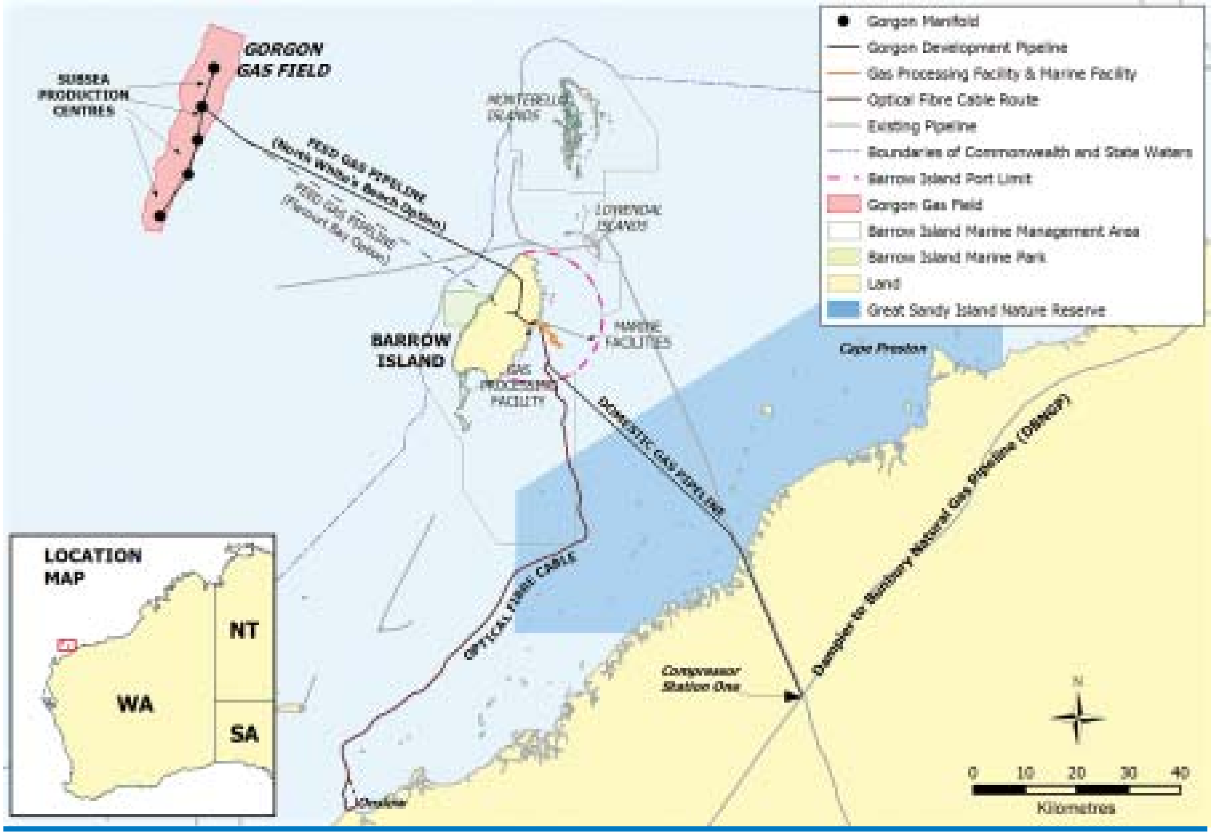


Plate 6-1:
Typical Drilling Rig used in North-West Australia

Wells will be drilled using a vessel similar to that shown in Plate 6-1. Such vessels are commonly used in north-west Australia in similar water depths.

Each well will be fitted with an arrangement of valves, controls and instrumentation referred to as a 'subsea tree' which is located on the seafloor.

A subsurface safety valve will be installed in each well approximately 300 m below the seabed to enable isolation of the gas reservoir. These valves (as well as the valves on the subsea tree) are designed to close automatically in the event of a mechanical failure or loss of system integrity. A 'choke' valve will also be included in the tree to control the fluid flow and pressure from the well to the pipeline.

Each group of wells will use 'well jumpers' to connect them to their 'cluster manifolds'. Each cluster manifold will serve between one and eight wells. From these cluster manifolds, an 'intrafield flowline' will transfer fluids to the export feed gas pipeline(s). The production fluids (gas, water and some condensate, with production chemicals) will then be piped to Barrow Island via the feed gas pipeline(s).

Feed gas pipeline(s) will be corrosion resistant alloy (CRA) clad carbon steel or carbon steel. The well flow rates could range from less than 13 m^3(st)/s to more than 110 m^3(st)/s (40–340 million standard cubic feet per day (MMscfd)), with flow reducing over time as reservoir pressure declines.

To support the operation of the wells and manifolds, as shown in Figure 6-2, they will be connected to the gas processing facility by an umbilical bundle. The umbilical bundle will include:

- electrical power and signal lines
- control line (water-based control fluid)
- chemical injection lines
- spare lines.

Separate (Mono Ethylene Glycol (MEG)) injection lines and utility lines and other essential service lines will also be required.
This chemical is used as a hydrate inhibitor which is discussed in more detail below.

Natural gas hydrates (solid crystalline compounds like ice but consisting of water and natural gas components) have the potential to form in the flowlines if they are subject to elevated pressures and reduced temperatures. These conditions may occur with the decrease of pressure across the choke and as the gas cools along the various flowlines and pipelines and/or as a result of other operating, shut-down and transient conditions. The resulting hydrates can adversely affect the normal operation of equipment and so must be prevented. Monoethylene glycol is the preferred hydrate inhibitor, and it will be stored at, and pumped from, the gas processing facility located at Barrow Island to the field through a dedicated line. It will flow back with the gas stream to shore through the feed gas pipeline. At the gas processing facility, it will be recovered for treatment and re-use.

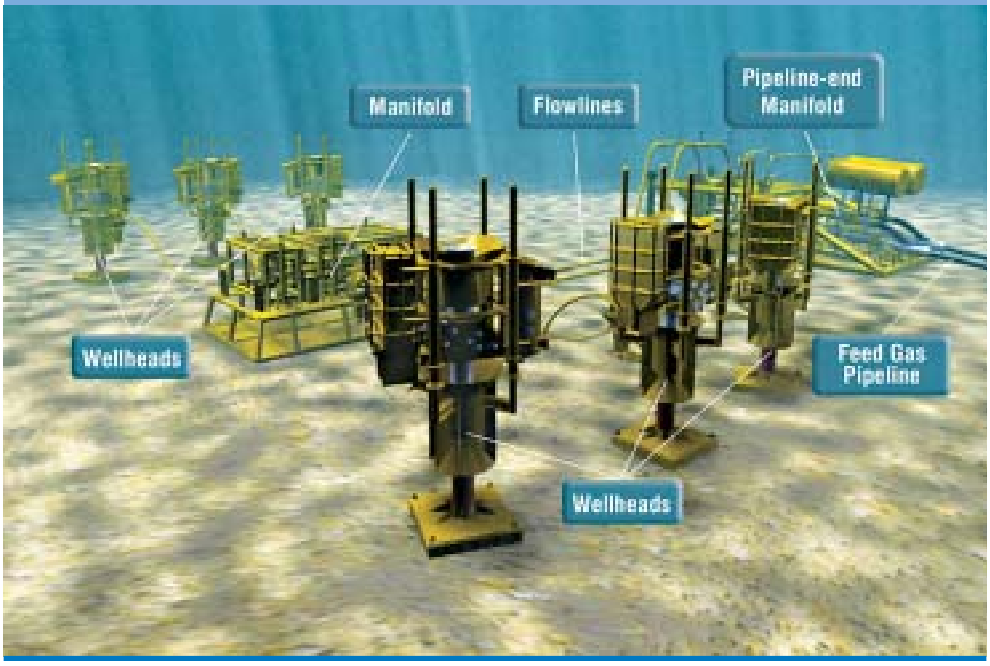
An electrohydraulic control system will be adopted to control the valves on the subsea trees, with control fluid powering valve movements controlled by solenoid valves. The control fluid will be a water-based fluid (with glycol), which has been designed and selected to be suitable for release to the environment. The control fluid is widely used internationally and in the north-west of Australia in similar applications with regulator approval. Small quantities of this water-based control fluid will be released to the ocean during operation of the well and pipeline control valves. Alternative 'closed loop' systems exist but react too slowly for this service. Final selection of the water-based control fluid will ensure environmental impacts are as low as reasonably practicable.

A multipurpose utility line will be used to maintain operational flexibility and to depressurise subsea components connected to the gas processing facility or feed gas pipeline to allow for maintenance.

Corrosion inhibitors and other chemicals may also be injected into the wells and flowlines in the future via the umbilical bundle which will follow the path of the main feed gas pipeline. Other chemicals that may be required in the future include scale prevention chemicals, pH stabiliser, and acids for well maintenance.

An alternative concept was considered for offshore production prior to deciding on the subsea development concept as summarised in Box 6-1.

Figure 6-2:
Schematic of Typical Subsea Trees and Cluster Manifold Layout



Box 6-1:
Alternative Considered – Offshore Processing

During the concept selection process, an offshore platform was considered for pre-processing the gas. The primary purpose of the platform would be to remove and dispose of the produced water to sea or back into the reservoir. This would remove the need for any special corrosion resistant pipelines or corrosion inhibitor injection. However, it would incur the additional cost of a platform with permanent or temporary personnel presence.

The elimination of a platform reduces the safety risks associated with helicopters by avoiding the need for personnel to be permanently based offshore, or periodically required to visit the platform. It also avoids emissions associated with operation of the platform and significantly reduces overall capital costs; which improves the international competitiveness and overall viability of the proposed Development.

6.2.2 Feed Gas Pipelines

As described in Chapter 3, Town Point is the preferred site for the proposed gas processing facility with the feed gas pipelines crossing the shore at North White's Beach. Flacourt Bay is also being carried into subsequent design phases as an alternative fallback shore crossing location to allow for unforeseen geological conditions at North White's Beach. The feed gas pipelines will transport the production fluids from the gas fields to the gas processing facility at Town Point. Figure 6-1 shows the overall development.

The feed gas pipelines will be constructed in accordance with appropriate standards which include AS2885 and DNV OS-F101. During subsequent phases of design for the Development, the pipeline design will continue to be reviewed, and the route will be refined as further information and knowledge becomes available. Any changes will result in environmental impacts which are similar to, or less than, those assessed in this Draft EIS/ERMP.

During normal operation, the pipeline flow and pressure will be primarily controlled by the choke valves at the wellheads such that the normal operating pressure in the feed gas pipeline will be significantly less than the maximum allowable operating pressure.

Table 6-2:
Indicative Feed Gas Pipeline Specifications

Parameter	Specification
• Length (offshore)	• ~ 70 km
• Length (onshore, Barrow Island)	• ~ 14 km (~ 42 ha easement)
• Length of state-water easement*	• ~ 5.6 km
Diameter	600 to 900 mm (24–36 inch)
Maximum Design Pressure	~ 26 500 to 36 500 kPa
Material	Carbon Steel with a Corrosion Resistant Alloy (CRA) lining for corrosion resistance or carbon steel with stabilisation chemicals.
Concrete Coating	50 to 100 mm (density 3040 kg/m^3) for stability

* *Potential impacts in the easement in state waters associated with construction and operation of the Jansz (or other) feed gas pipelines are considered for cumulative impact assessment purposes.*

Due to the CO_2 and water content of the gas from the Gorgon field, the production fluids will be corrosive. This will require special design of the pipeline to ensure it meets environmental, safety and operational requirements for the required service life of the Development. Indicative specifications for the pipeline are provided in Table 6-2, while alternatives for the pipeline material are discussed in Box 6-2.

Box 6-2:
Alternative Feed Gas Pipeline Material

An alternative to CRA pipeline material is carbon steel with high corrosion allowance and with continuous injection of corrosion inhibitor chemicals. This option is currently undergoing further technical engineering and laboratory assessment. A decision to utilise carbon steel will only be made if the integrity of the pipeline can be assured, and if the proposal receives the regulatory approval.

Frequent ‘pigging’ of the pipelines for cleaning or inspection is not expected to be required. However, the pipeline will be designed to allow the use of conventional or instrumented ‘intelligent pigs’ for pipeline integrity testing. Such testing is expected to occur in the order of once every five years, and so may occur approximately 5–10 times during the life of the Development for each pipeline.

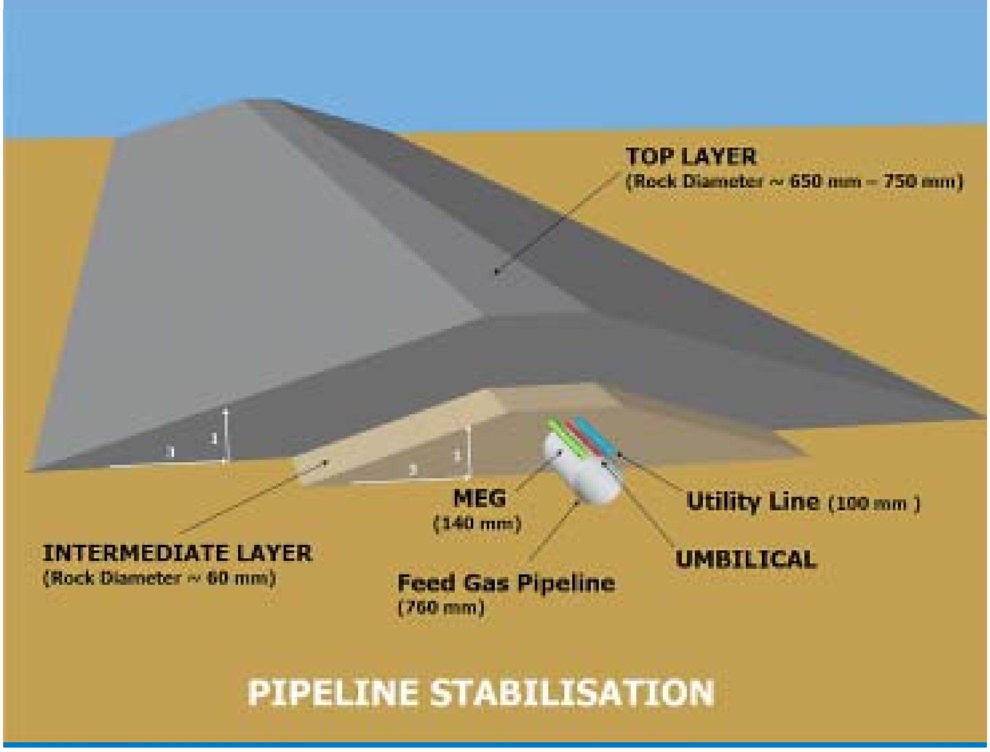
To meet government regulations and safety requirements, corridors centred on the offshore pipelines and all subsea infrastructure will be established in which anchoring by commercial vessels will be prohibited, and access restricted. The corridors, which will extend approximately 500 m on either side of the pipeline and around subsea equipment, will be gazetted and marked on navigation charts.

Offshore Pipeline Stabilisation

The offshore sections of pipelines will be stabilised by a combination of measures to protect against hydrodynamic forces such as waves and currents and, where necessary, to protect from external impacts such as ship anchors. Potential measures include concrete coating, trenching into the seabed, rock bolting, stabilisation mattresses or rock stabilisation. The final decision about which measure, or combination of measures, will be employed will be made as the design develops, but the following provides an explanation of the most likely concept. The environmental implications of each option being considered are similar.

A concrete coating will be used as necessary to stabilise the pipelines from the gas fields to a water depth of approximately 40 m (approximately 15 km from Barrow Island). The coating thickness will vary based on the degree of stabilisation required. Other stabilisation methods such as rock bolting may be considered as alternatives during finalisation of the design details.

Figure 6-3:
Pipeline Rock Stabilisation Detail



Rock stabilisation (e.g. placing rocks on top of the pipeline) will be used where appropriate to protect the feed gas pipelines from the increased hydrodynamic forces as the pipelines approach the shore (Figure 6-3). The pipelines will be initially covered with smaller rocks (approximately 60 mm diameter) and then larger rocks overlaid (approximately 750 mm diameter). This is expected to be required from approximately the 40–50 m water depth contour toward the shoreline (e.g. to the drilled shore crossing breakout point).

Shore Crossings and Near Shore Zone

Conventional shore crossing techniques involve the use of excavation equipment, such as cutter suction dredges or backhoe dredges, to create a pipeline trench. The pipes would then be pulled into the trench from a shore based winch, and the pipes buried under dumped rock for protection. Due to the constant swell and high seabed rock strength identified on the west coast of Barrow Island, the use of rock dredging equipment is not considered technically feasible. Therefore, the range of possible shore crossing techniques was short-listed to horizontal directional drilling (HDD), tunnelling, and laying the pipe on/above the seabed. More detailed assessment (as discussed in Chapter 3) has shown that tunnelling will also require dredging at the offshore breakout point and so has also been ruled out as not being technically feasible due to sea conditions on the west coast.

Laying the pipe on/above the seabed requires the construction of a temporary jetty/groyne out to approximately 5 m water depth (~200 m from the shore line). This is required to provide access for equipment to stabilise the pipeline. This option is not preferred over directional drilling since it will have a higher environmental impact, higher cost, and longer installation schedule.

Exclusion of these techniques leave directional drilling as the preferred technique. This technique would require a directionally drilled hole extending from approximately the 12 m water depth contour (1 km from the shore), continuing under the seabed and beach, to surface on dry land at the rear of the beach. A typical directional drilling setup is shown in Plate 6-2.

Further design work will be undertaken to determine the optimal number and size of holes required during the initial development. Directional drilling would involve holes of up to approximately 1067 mm diameter. Approximately seven holes will be required for two complete feed gas pipeline systems. There is a possibility that additional feed gas pipelines and associated shore crossings will be required in the same area to enable future phases of development. This would require the creation of new directionally drilled holes of similar number and size and these have been allowed for in the design layout but are outside the scope of this approval.

Plate 6-2:
Horizontal Directional Drilling Operation

Onshore Section of Pipelines

The proposed pipeline route across Barrow Island follows existing road easements as much as possible from North White's Beach to the gas processing facility at Town Point. Provision is being made in the proposed Development for the initial installation of two feed gas pipelines (and associated auxiliary lines), and to allow for another two feed gas pipeline bundles in the future to run parallel to the initial lines from the shore crossing. Optimisation of the pipeline route and shore crossing will continue throughout the design phases of the Development.

The onshore section of the pipelines will be supported above ground with sufficient clearance to ensure that fauna can pass freely underneath the pipeline. The pipelines will be buried under roads with appropriate culvert and right-of-way systems to enable installation of future pipelines. Trenching and/or excavation will be restricted to the pipeline supports and road crossings. This option will minimise the overall level of ground disturbance that would take place during construction, as well as the quantity and duration of excavation and blasting required, and therefore will minimise direct impacts associated with construction activities. It will also minimise the amount of land requiring rehabilitation. Seasonal water crossings may be traversed or trenched depending on their size, surrounding terrain, geology and other factors.

If the feed gas pipelines were to be buried for the entire onshore length, blasting and trenching across Barrow Island would be required. Box 6-3 is a summary of a number of alternative designs for the pipeline.

Box 6-3:
Alternative Onshore Pipeline Designs

Three alternative pipeline configurations were considered for the onshore section:

Above Ground Installation – An above ground pipeline would ensure that fauna can pass freely underneath the pipeline and that ground disturbance is minimised during construction. The pipelines would be trenched to pass under roads, with appropriate culvert and right-of-way systems to enable installation of future pipelines. Trenching and/or excavation will be restricted to the pipeline supports and road/water crossings. This option minimises the overall level of ground disturbance that takes place during construction, minimises the quantity and duration of excavation and blasting required, and therefore minimises direct impacts associated with construction activities.

An elevated pipeline may create condensation due to the temperature of the fluids flowing through the pipeline, which will affect flora and fauna by providing additional water and shade. The elevated pipeline would also have a 'permanent' visual impact over the life of the Development. At the end of field life, it would be possible to remove the above ground sections of the pipelines without significant environmental impact, while buried sections would remain *in situ.*

Surface installation – a pipeline laid across the natural ground surface would offer low installation costs, but is not considered technically acceptable to the Joint Venturers due to the potential for unconstrained movement of the pipeline resulting from thermal expansion and/or wind loading. The large diameter of the pipelines would also create obstructions for fauna and water movement. A variation of this option would be to lay the pipes on the natural ground surface and provide earthen mounds over them to assist the movement of fauna.

Box 6-3: (continued)
Alternative Onshore Pipeline Designs

This option was ruled-out as it would increase site disturbance and create a barrier to natural water movement.

Trenched installation – this option would lead to increased land disturbance from grading, trenching and soil stockpiles. Burial could also require extensive blasting to achieve the required trench depth. The open trench during construction could prove to be a hazard to fauna, requiring careful management. The increased depth of disturbed or tilled soil over the backfilled pipeline trench could lead to permanently changed vegetation associations along the pipeline route. Bedding material, used to protect the pipe in the trench, would most likely have to be imported to the island, representing a potential quarantine threat. Soil excavated (to accommodate the volume of the pipelines and bedding material) would have to be moved away from the area to avoid significantly changing the topography. Some of this material may be able to be utilised at the gas processing facility. Burial is considered to have a slightly higher installation cost. At the end of field life leaving these pipelines buried would have less impact on the environment than re-excavation and removal, followed by backfilling and reinstatement of vegetation and original land contours.

On balance of these aspects, an above ground pipeline installed on supports is the preferred option, however the final decision will be made during subsequent design phases.

Figure 6-4 shows an indicative pipeline support concept, but final details will not be available until later design phases. The layout of the feed gas pipelines and the accompanying supports will be designed to allow for future expansion with minimal environmental impact.

The distance between the pipeline supports would vary between 5 and 20 m depending on the pipeline diameter. The key aspects which determine this spacing are the strength of the pipe and the terrain.

The current base case for each of the feed gas pipelines is that there will be no valves in the pipeline outside of the gas processing facility area. This will minimise the need for access to the pipeline and reduce the likelihood of leaks outside the gas processing facility boundary. In this case, the main pipeline isolation valve will be located at the front end of the gas processing facility within the plant boundary. This valve is required to enable the contents of the pipeline to be isolated from the gas processing facility in the event of an incident or for maintenance.

There is also the possibility, due to safety (Chapter 14) and operability constraints that this valve station may have to be located outside the plant, such as near the shore crossing. The final decision on valve location will be made during subsequent design phases.

6.2.3 Gas Processing Facility

The gas processing facility will produce three main products for export from Barrow Island:

- Liquefied Natural Gas (LNG) for international export
- domestic gas for use on the Australian mainland if economically feasible
- hydrocarbon condensate (light oil) for domestic or international consumption.

Production from the gas fields will have to be pre-treated prior to processing them into these three products. Pre-treatment involves separating the liquids from the gas, then separating the liquids into water, MEG, and condensate.

Carbon dioxide and hydrogen sulphide (H_2S) will be removed from the gas stream in an Acid Gas Removal Unit. The hydrocarbon gas will then be dehydrated and passed through a mercury removal unit from where it will pass to the main liquefaction portion of the gas processing facility.

A schematic representation of the gas treatment process is shown in Figure 6-5, while a likely layout for the proposed gas processing facility is presented in Figure 6-6.

At the gas processing facility, some of the gas would be treated to meet domestic gas specifications before being compressed and exported through the domestic gas pipeline to the existing domestic gas network.

Figure 6-4:
Indicative Pipeline Support Detail

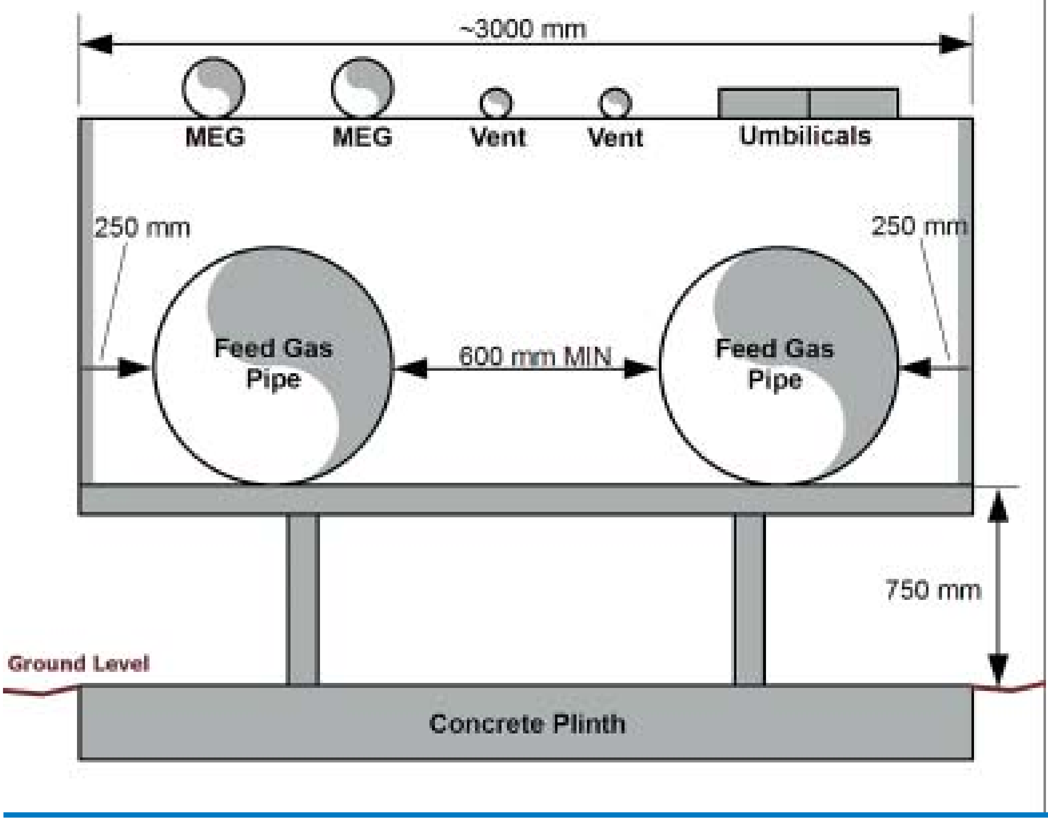


Figure 6-5:
Typical LNG Plant Process

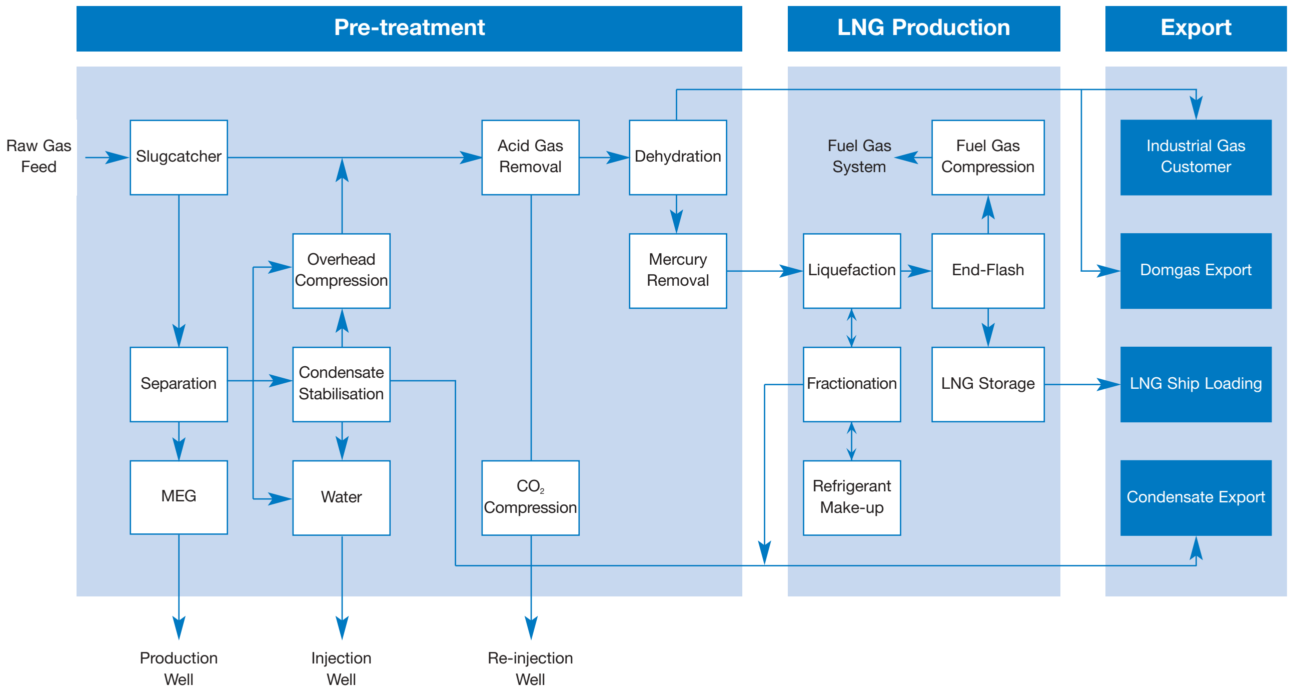
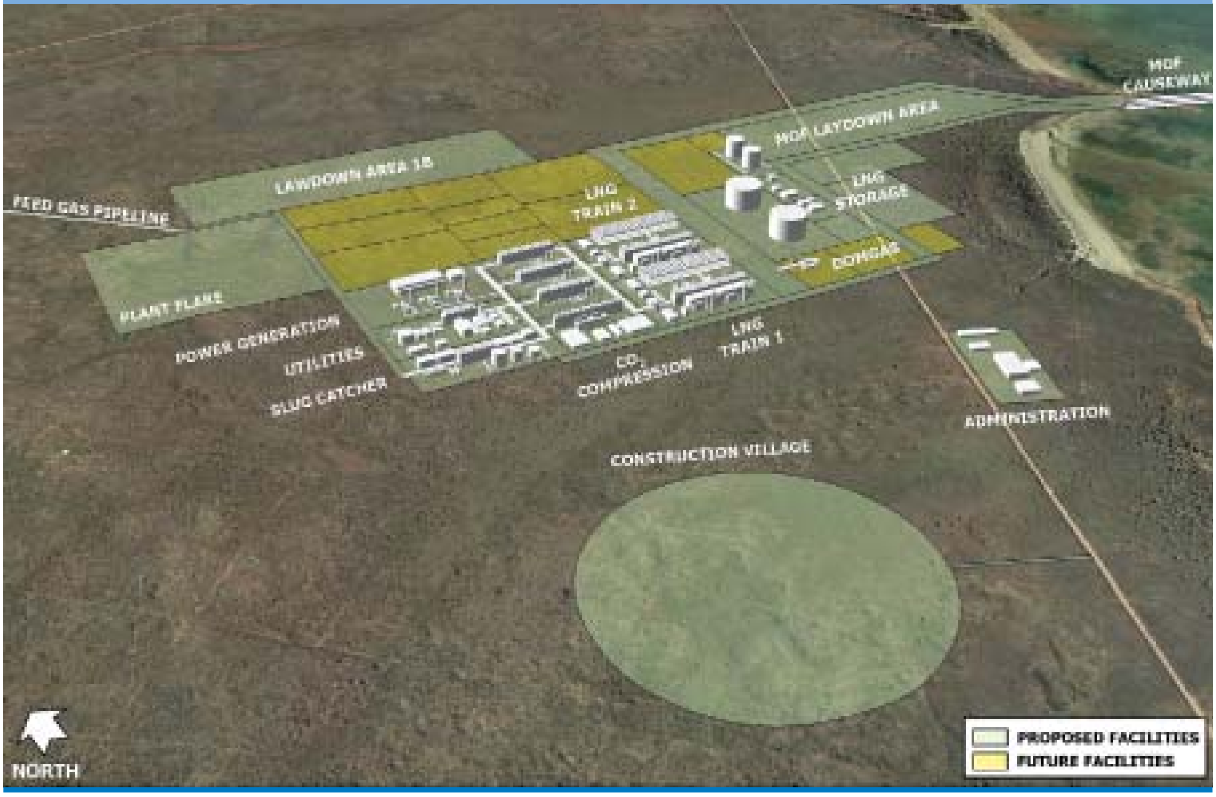


Figure 6-6:
Indicative Gas Processing Facility Layout



Condensate will be stabilised for storage in tanks before being shipped to customers.

The gas processing facilities will be designed to allow some flexibility in the supply of the feed gas. This will ensure the facilities can be utilised for other fields in the Greater Gorgon Area in the future with no, or relatively minor, modifications.

A key design philosophy for the gas processing facility is to recover products from the feed gas wherever practicable, rather than flaring the streams as waste. This typically requires the use of compressors to increase the pressure of 'waste' hydrocarbon gas streams, then directing the stream back into the process, or to the fuel gas system. Specific aspects are discussed where relevant in subsequent parts of this chapter.

The following describes each of the main components of the gas processing facility.

Main Components of the Gas Processing Facility

Slugcatcher

Production fluids from the feed gas pipelines will be fed into a slugcatcher(s) to separate the natural gas from the liquids. The slugcatcher(s) will be either a 'finger-type' or a 'vessel-type'. The advantage of the vessel-type is a significant reduction in required land area compared with the more traditional finger-type slugcatcher, which is based on long runs of straight pipes. However, the size of the liquid slugs expected may require use of the finger-type slugcatcher. The decision on slugcatcher type will be made during subsequent design phases. Current land use estimates assume the greater of the two.

Three-Phase Separator and Overhead Compression

The liquids from the bottom of the slugcatchers will be directed to a three-phase separator. Gas that is liberated in this separator will be compressed in the overhead compression section and returned to the gas stream from the slugcatcher. Hydrocarbon condensate will be separated from the water phase and directed to the condensate stabilisation process. Water (containing MEG, other water-soluble chemicals and salt naturally contained in the reservoir water) will be directed to the MEG recovery system.

Hydrate Inhibitor (MEG) Recovery System

The water and MEG (plus salt and other water-soluble chemicals) from the bottom of the three-phase separator will be directed to the Hydrate Inhibitor Recovery (HIR) package. This package will heat the liquids to vaporise the water, thus concentrating the MEG, so it is suitable for re-use. The MEG will be cooled before storage prior to being pumped back to the wellheads and re-used. Hydrocarbon gases liberated from the MEG regeneration process will be captured and may be utilised as fuel in the plant. Recovered produced formation water containing dissolved salts will be sent to the water treatment facilities for injection. Rich MEG (i.e. MEG with a large amount of water) will be stored in tanks prior to HIR processing. After HIR processing, the lean MEG (i.e. MEG with a smaller amount of water) will be stored in tanks ready for re-use. The size of these tanks will be determined in a subsequent phase of engineering; however, they are likely to be in the order of 3–5000 m^3 and 6–10 000 m^3. The MEG tanks will be contained within impervious bunds designed to meet Australian Standard AS 1940.

The MEG recovery process concentrates salt, which is naturally present in the formation water, into the lean MEG product. A salt reclamation system is an integral part of the HIR package. This package will maintain salt concentration below specified levels by separating salts from the lean MEG via crystallisation and centrifugation or other suitable technology. Salt recovered in this way will be injected with the effluent water along with a small amount of residual MEG into a formation deep beneath Barrow Island. Other options may arise as the design develops such as sale or disposal on the mainland.

Condensate Stabilisation

The hydrocarbon condensate from the three-phase separator will be stabilised by heating the condensate to drive off the volatile components (as gaseous vapours). These gaseous vapours will be compressed with the gas from the three-phase separator in the overhead compression system and returned back to the process feed gas. Stabilised condensate will be fed to the condensate storage tanks to await export. Condensate storage and offloading are discussed later in this chapter.

Acid Gas Removal

The gas from the slugcatcher will be rich in CO_2 with trace levels of H_2S. These two gases are collectively referred to as 'acid gases'. The acid gases must be removed to meet the LNG product specification and domestic gas specification, and to ensure that the CO_2 does not freeze in the liquefaction process and block the main cryogenic heat exchanger or other equipment. It is likely that a total of three acid gas removal units will operate in parallel for the proposed Development.

The acid gas removal units will utilise accelerated-methyldiethanolamine (accelerated-MDEA or a-MDEA) in water as the solvent for CO_2 and H_2S removal. Alternatives to the a-MDEA process are discussed in Box 6-4.

The a-MDEA/water solution will flow in the opposite direction to the feed gas within a contactor vessel. During this process, the CO_2 and H_2S will be chemically removed from the hydrocarbon gas stream along with a very small amount of hydrocarbons. One of the significant advantages of selecting the a-MDEA process is that it selectively removes CO_2 (and H_2S) whilst absorbing very little hydrocarbon compared to other commonly used amine-based solvents.

The a-MDEA, rich in CO_2 (and H_2S), will then be fed to a 'flash vessel'. Here the pressure will drop and 'flash off' the majority of the hydrocarbons and some of the CO_2. The resulting stream of 'flash gas', primarily containing hydrocarbons with a small amount of CO_2, will be compressed, utilised as fuel gas or otherwise directed back to the process. This flash gas will also be treated (such as with a water scrub) to remove carryover of a-MDEA so that it does not impact the fuel system and fuel consumers.

From the flash vessel, the rich a-MDEA will be directed to a regeneration column which operates at close to atmospheric pressure. The rich a-MDEA solution will be heated in the regenerator by hot oil. The heating process and reduced pressure will liberate the CO_2 with minor quantities of H_2S and hydrocarbon gases (including some benzene, toluene, ethylbenzene and xylene (BTEX)). The regenerated a-MDEA will then be cooled and pumped back to the contactor vessel to start the cycle again.

Lean–rich heat exchangers in the acid gas removal system will be provided to improve the overall energy efficiency of the process.

Should storage areas be required for a-MDEA, these will be designed, operated and maintained in accordance with appropriate Australian Standards.

The liberated CO_2 and minor quantities of H_2S and hydrocarbon gases will be piped to the CO_2 compression unit. During normal operations, none of the impurities removed from the feed gas will be emitted to the atmosphere as they will be injected along with the CO_2.

During non-routine conditions (such as when an injection compressor stops) the CO_2 and associated gases will be vented via a gas turbine exhaust (or dedicated vent) to ensure adequate dispersion.

For further details on the injection of CO_2 refer to Chapter 13, and refer to Chapter 7 for a discussion on the dispersion of the reservoir CO_2 vent stream when it is operating.

Box 6-4:
Alternative CO_2 Removal Options Considered

During the concept selection stage of the Development, several CO_2 removal concepts were assessed. These included cryogenic distillation, a chemical solvent (a-MDEA) process, and a combined physical and chemical solvent process.

In the cryogenic process, CO_2 would be liquefied by chilling the gas stream, enabling separation. Although this option was studied in detail, the increased complexity and cost of processing made it an undesirable option.

The chemical solvent process (a-MDEA) and combined physical and chemical solvent process are very similar. From an environmental perspective, the major difference is the quantity of hydrocarbon that is entrained in the solvent in the CO_2 absorption process. Hydrocarbon entrainment is considered undesirable as it is a valuable product and during those times when the CO_2 is vented to the atmosphere (Chapter 13), this entrained hydrocarbon would be emitted. The a-MDEA process was selected as the preferred process due to its proven application, reduced cost, and because it entrains significantly less hydrocarbons than competing solvent technologies. The existing North West Shelf Project LNG plant in Karratha has recently converted to a-MDEA in the acid gas removal system.

CO_2 Compression and Dehydration

The CO_2 stream (containing minor quantities of H_2S, BTEX and other hydrocarbons (refer to Chapter 13 for concentrations of these compounds in the reservoir CO_2 stream) will be fed from the regeneration column to CO_2 injection compressors. The injection compressors will compress the CO_2 stream from approximately atmospheric pressure to the required injection pressure. This is likely to be achieved via multiple compression trains, consisting of 4 x 25% compressors driven by electric motors. Dehydration of the gas stream will be accomplished through the interstage knock-out facilities. The exact compressor configuration and location will be determined during detailed design.

Following compression, the CO_2 will be fed into a pipeline to the injection wells which are described in Section 12.2.4. Chapter 13 describes the expected availability of this system and estimates CO_2 emissions from the proposed Development.

Dehydration

The CO_2-free (and H_2S-free) hydrocarbon gas from the slug catchers will be directed to one of the two proposed LNG trains. The hydrocarbon gas stream from the acid gas removal units must be dehydrated to prevent ice forming in the downstream cryogenic equipment. To achieve this, the treated gas will first be cooled using a combination of air and propane refrigerant to condense the bulk of the water, which will then be removed in a separator vessel and sent to the water treatment facilities for deep well injection. Gas from the dehydration separator will be passed through molecular sieve beds, which will remove any remaining water to below 1 part per million by volume (ppmv).

The molecular sieves will be regenerated using hot gas to drive the moisture out of the beds. The regeneration gas will be heated with waste heat from the gas turbines rather than a separate fired heater/furnace. This hot, water-rich stream will be cooled to condense the water, which will be directed to the waste water treatment facilities and the gas will be returned upstream to ensure complete removal of CO_2. It is common to have multiple vessels (typically three) in this service so that two can be online, while one is undergoing regeneration.

The recovered water will contain small amounts of hydrocarbons and possibly solids which could cause significant process upsets if it were recycled back to the acid gas removal unit. It may be possible to clean this water sufficiently to allow it to be reused within the process and this will be examined as the design progresses.

Mercury Removal

Elemental mercury in the feed gas will occur in ultra trace amounts, but any amount can cause degradation of the aluminium used in the LNG process equipment. To prevent this, gas will be passed through a mercury removal unit downstream of the dehydration unit.

A mercury removal unit is a vessel that typically contains an absorbent such as activated carbon granules treated with elemental sulphur. As the gas passes through the vessel, traces of mercury in the feed gas will react with the sulphur and remain chemically trapped on the carbon granules. The bed material acts as a filter and will need to be removed periodically for disposal. The management and disposal of the bed material impregnated with the resulting mercury sulphide is discussed in Chapter 7.

An alternative design could utilise a special zeolite without sulphur impregnation. Hot and dry natural gas would be used to regenerate the zeolite beds. The regeneration gas can be cooled and elemental mercury collected as a product. Further information will be collected on this alternative prior to a final decision during subsequent design phases of the Development, but selection of this option is highly unlikely.

Scrub Column and Fractionation

Heavier hydrocarbons (i.e. those heavier than methane) known as liquefied petroleum gas (LPG) (primarily ethane and propane) will be recovered from the gas for use as refrigerant in the liquefaction process for the LNG system.

First, the main gas stream will be chilled with propane refrigerant to liquefy the heavier hydrocarbons. These hydrocarbons will be separated from the main gas stream in the scrub column, and the resulting lean gas stream will be directed to the main cryogenic heat exchanger to ultimately become LNG.

The liquids from the scrub column will be directed to a fractionation unit. The fractionation unit will use a combination of heat and pressure to separate the various components. Lighter components (methane, ethane, propane, and butane) in excess of those required for refrigerant makeup will be returned to the LNG process. Remaining stable liquid, stripped of all light components, will be directed to the condensate storage tanks for export.

The ethane and propane storage will be located in a separate refrigerant storage area located outside of the process area. The approximate stored volume of ethane and propane will be 500 m^3 and 1800 m^3 respectively. It will be necessary to import ethane and propane to start the LNG process but after a period of time the system will be self-sufficient in these products.

There will be insufficient quantity of LPG in the Gorgon reservoirs to be commercially produced for export. However, an alternative to returning the excess ethane, propane and butanes (collectively referred to as natural gas liquids) to the main process, on a continuous basis, is to store these liquids for blending into a limited number of LNG cargoes to meet the heating value requirements of specific LNG customers. This alternative requires additional pressurised storage for approximately 6000 m^3 of natural gas liquids. This situation is factored into the public risk assessment included in Chapter 14, to be conservative at this early stage of the design.

Cryogenic Heat Exchanger and Refrigeration Process (Liquefaction)

The main cryogenic heat exchanger and the associated refrigeration process comprise the core of each LNG train. Their combined purpose is to chill the natural gas to create LNG, so this exchanger and the refrigeration process are also referred to as the liquefaction section of the plant. The Joint Venturers will utilise a commercially available and proven liquefaction technology. Approximately 90% of current LNG plants around the world use a variation of the propane pre-cooled liquefaction technology from Air Products and Chemicals, Inc (APCI). This process is based on a mixed refrigerant process that utilises nitrogen, methane, ethane and propane as refrigerants. This technology is used for assessment in this Draft EIS/ERMP, and is the preferred technology.

The overall process uses the same fundamental principles as a household refrigerator. The main cryogenic heat exchanger is similar to the evaporator plate inside a refrigerator or freezer. A compressor compresses the refrigerant and provides the energy for the cooling process. The condenser that is usually found on the back of a refrigerator is replaced in an LNG plant with a large bank of fan-cooled heat exchangers.

The main cryogenic heat exchanger is a large vertical vessel containing internal tubing. This provides an enormous surface area to efficiently transfer heat from the main gas stream to the refrigerant.

Currently the most common configuration for an LNG train, at the size proposed for this Development, includes direct drive gas turbines on the refrigerant compressors and separate gas turbine drivers of a roughly similar size to generate electrical power required for these facilities. For the purposes of this Draft EIS/ERMP, it is assumed that the refrigerant compressors on each LNG train will be driven by two large industrial gas turbines. This aspect is discussed in more detail in Chapters 7 and 13. These turbines will be assisted by electric motor starter/helper drivers that provide mechanical power for starting the turbines, and additional energy for production. Gas turbines will also be used for generation of electrical power.

Gas turbine exhaust waste heat recovery units will provide the heat for the hot oil system and the dehydration regeneration gas.

The LNG leaving the main cryogenic heat exchanger will be at a temperature of approximately minus 150°C, prior to the end flash process section.

End Flash

The final process in the production of LNG will be to drop the pressure of (to flash) the LNG from the main cryogenic heat exchanger to near atmospheric pressure, thus reducing the temperature to -161°C. At this temperature and near to atmospheric pressure, the LNG will be a liquid and can be effectively stored and shipped around the world at a volume approximately 1/600th of the volume of natural gas at normal atmospheric pressure and temperature.

As part of the 'flashing process', some of the LNG will be turned back to a vapour. This 'flash gas' will be relatively rich in nitrogen (expected to be approximately 25 vol %), allowing the remaining LNG product (mostly methane) to meet the nitrogen sales specification. The nitrogen-rich flash gas will be compressed and used as the main source of fuel gas for the gas processing facilities on Barrow Island.

LNG Storage and Offloading

LNG product from the liquefaction process will be stored in two full containment storage tanks of approximately 135 000 m^3–155 000 m^3 net each.

The tanks are expected to be approximately 35–40 m high and 70–80 m in diameter. LNG tanks come in three different configurations referred to as single containment, double containment, or full containment type. The Development team will use a full containment tank design. A full containment type tank is shown in

Figure 6-7:
Schematic of Full Containment LNG Tank

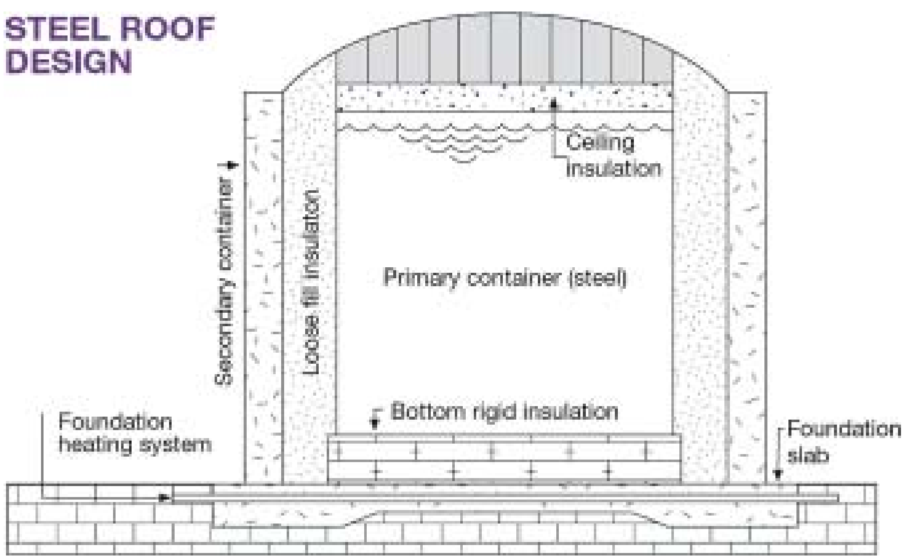


Plate 6-3:
Typical LNG Carrier

Figure 6-7. The final LNG tank size and number will be further optimised as they are dependent on the ultimate market for LNG and the size of ship used, but environmental impacts will not change significantly. The design of LNG tanks is carefully controlled through British Standard EN1473 ‘Installation and Equipment for LNG – Design of Onshore Installations’. Plate 6-3 shows a typical LNG ship which the Barrow Island terminal will be designed to receive.

The LNG will be stored in the tanks at approximately -161°C at slightly above atmospheric pressure. The LNG storage system will include submerged pumps, control/monitoring systems, pressure relief valves, a loading platform and a fire suppression system for the loading platform. Heat leakage through the insulation will produce a small amount of boil-off vapours, which will be recycled through the LNG plant or consumed as fuel in the LNG plant. Vapours displaced from the tanker being loaded will be directed back to the boil off gas recycle compressor in a closed loop under normal operations. All filling and loading operations will be conducted through the top of the tank to minimise the chance of a leak. All nozzle connections will be located on the top of the tank. LNG tanks will not be exposed to internal corrosion risks as all materials will be contained in a methane atmosphere and there will be negligible water in the stored product.

In the unlikely event that a leak occurs, it would be detected by thermal sensors in the leak detection system. In addition to leak detection, other protective systems for the tanks will include pressure relief valves, vacuum relief valves, overfill protection systems, and fire and heat detection systems with water sprays and/or foam dispensers.

In the extremely unlikely event that an LNG tank was close to over-pressurisation and the normal boil-off gas compressors could not handle the vapour load, surplus pressure would be relieved to a dedicated storage and loading flare. A dedicated flare is required because the tanks cannot withstand backpressures associated with the main plant flare. A final level of overpressure protection will vent vapour to atmosphere, but this is extremely unlikely to occur.

The tanks will be designed to withstand cyclonic wind forces and any impact from items caught by cyclonic winds.

The LNG product will be transferred from the storage tanks to the ship loading facility via submerged pumps in the LNG tank and insulated loading lines via loading arms.

Condensate Storage and Offloading

Condensate production will be in the order of 2000 m^3 per day. Condensate will be stored in two conventional floating roof storage tanks located within bunds meeting Australian Standard AS 1940. Condensate tanks, bunds and associated piping will be designed, tested, operated and monitored to prevent leakage into underlying soil.

The tanks are expected to have a capacity of approximately 35 000 m^3 net each. The condensate will most likely be loaded onto ships using the existing Barrow Island oil loading facilities; therefore several tie-ins to the existing systems will be required. The use of vapour recovery from the export tankers while loading condensate is not currently envisaged due to the infrequent offloading requirements and low emissions. Refer to Chapter 7 for further details.

One of the options that may be considered during later phases of engineering design is to run a new condensate load out line along the LNG jetty. The condensate line would run subsea from the LNG jetty to a Single Buoy Mooring. This alternative condensate loading line is carried as an option in the event that the use of the existing subsea load out line proves to be infeasible. Another alternative being considered is to load condensate from the LNG jetty.

Domestic Gas Facilities

Following acid gas removal, the gas destined for the domestic gas market will be dehydrated and the hydrocarbon dew point controlled to meet the domestic gas specification.

Dehydration will be achieved through a Triethylene glycol (TEG) system that is similar to that proposed for the CO_2 injection system. There will be a very low pressure waste stream from the TEG regeneration system containing water vapour and a small amount of hydrocarbons. This low pressure gas stream (typically containing low concentrations of benzene, toluene, xylene components) will be directed to the flare system. The hydrocarbon dew point specification will be met by cooling the dehydrated gas with propane refrigerant followed by simple vapour/liquid separation.

Alternative process technologies for dehydration (molecular sieve), hydrocarbon dew point control (Joule Thompson (JT)) valve expansion, turbo-expander, and both dehydration and dew point control (regenerable adsorbent silica gel, other new technologies), are being considered for domestic gas treatment. Further information will be collected on these alternatives prior to a final decision during later design phases of the Development, but environmental aspects will be similar.

The domestic gas stream will require compression prior to export via the domestic gas pipeline to the existing domestic gas network. The current design concept is to utilise a compressor driven by an electrical motor, negating the need for a dedicated gas turbine. This configuration will be reviewed as part of the energy optimisation process (Box 6-5) as the design is developed, but overall emissions will be comparable between options.

Heating Medium

A number of the processes within the gas processing facility will require heat. For a heating medium system to remain efficient and cost-effective, it is important to keep the heat sources close to the heat users. Process heat will be supplied by a closed loop hot oil circulation system. Alternative heating media (hot water and steam) have been considered and ruled out.

The largest requirement for heat will be the acid gas removal system for the regeneration of the a-MDEA. Other heat demands include the hydrate inhibitor recovery system, condensate stabilisation, the TEG regeneration systems, the LNG scrub column and fractionation distillation columns. The heat for these users will be provided by a waste heat recovery system.

The design of these systems is part of an ongoing energy optimisation process which is discussed in Box 6-5.

Various chemicals are often associated with heating medium systems. These will be stored in accordance with relevant legislation.

Electrical Power Generation System

As mentioned above, electrical power for the gas processing facility will be provided by gas turbines. The main users of electrical power will be motors for the process compressors, gas turbine helper motors, pumps and the air cooler fans. The optimum use of waste heat recovery on these gas turbines will be included in the energy optimisation study.

Box 6-5:
Energy Optimisation

The Joint Venturers are committed to adopting best practices in environmental management, which includes emissions to the atmosphere. As standard practice, Chevron requires all large developments to implement energy optimisation as part of the design process. The process is driven by both the economic value that can be obtained from an efficient plant and the environmental benefits of reduced energy consumption and associated emissions. As part of this process all major heat, motive, and electric users and sources are reviewed for optimisation opportunities.

The proposed gas processing facility on Barrow Island will require energy in the order of approximately 600 MW of direct power (motive and electrical) from the gas turbines and a similar quantity of heat. The base design case assumes that this energy will be provided by:

- 5 x 80 MW industrial gas turbines for electricity production (or equivalent system)
- 4 x 80 MW industrial gas turbines for the refrigerant compressors (two on each train)
- 4 x waste heat recovery units on the compressor gas turbines.

A heating medium system is coupled with this to distribute the heat.

Details on greenhouse gas emissions from the proposed Development can be found in Chapter 13, while details on other atmospheric emissions are discussed in Chapter 7 and Chapter 10.

Plant Lighting

Minimising light spill is an important design criterion for the proposed Development due to potential impacts on turtle hatchlings. To minimise the potential impact, a hierarchical lighting strategy has been prepared. In general, lighting levels will be minimised to those required for safe working and security.

In areas where colour definition is not required for safety or operational purposes, shielded red or mono-chromatic lights are proposed. This includes areas such as the MOF causeway, jetty, roads within the gas processing facility and general open areas. In areas where minimal colour definition is required, a reduced spectrum yellow/orange type of shielded light, such as sodium vapour, will be used. These lights will form the primary lighting for the facility.

Areas that require inspection during operator rounds and/or regular maintenance (e.g. filter change outs) will utilise fully shielded full spectrum white lights that are normally off. These lights will be switched on only as required. For an emergency situation, additional lights will be required for safety, including perimeter flood lights.

The lighting regime will continue to be reviewed during subsequent phases of design and is subject to confirmation that it is acceptable from a health and safety perspective. For further details on lighting levels refer to Chapter 7, and for further details on light management and mitigation strategies refer to Chapter 11.

Flare System

The proposed Development will have a 'no routine flaring policy' incorporated into the design of the gas processing facility. This means that during normal day-to-day operation, the flare will not be used as a waste gas disposal route.

A total of three flares will be required for the safe operation of the gas processing facility (Plate 6-4). The two main flares will be located on a flare tower which is expected to be 150 m high and located to the west of the facility, although a ground flare concept is also being evaluated. These flares would be used during plant emergencies, start-up, shut-down and short-duration upset conditions. Short-term (several hours) flaring can avoid the need for a full plant shut-down which would result in a greater volume of gas being flared.

For safety reasons the flare will require a pilot light (or alternative ignition system) to ensure that the gas from any flaring event is ignited. To avoid an explosion in the flare system, it is also necessary to provide a low level purge of the flare system with fuel gas (or other gas) to ensure that oxygen does not enter the system. The feasibility of using exhaust gas, CO_2 or nitrogen, as the purge medium will be reviewed in subsequent design phases.

The third flare is similar to the other two but will be located near the LNG storage tanks and will be used if the boil off gas compressor, which will be used to recover the vapours from the LNG tanks or LNG carriers, stops. These vapours and gases will be recovered back to the process as much as possible. This flare may also be used if an arriving LNG carrier requires cooling. As the carrier is cooled to receive LNG the inert gases and associated LNG vapours from the vessel would be directed to the flare.

Alternatives to reduce anticipated flaring loads, and possibly the size of the main flare stacks, will be reviewed during subsequent design phases of the Development.

Other Utilities

The proposed Development will also require other utilities such as nitrogen, instrument air, and demineralised water which will be generated onsite.

6.2.4 CO_2 Injection Facilities

After the CO_2 is compressed (estimated at 21.5 MPa discharge) within the gas processing facility, it will be transported via pipeline to the injection wellheads. The pipeline will be above ground and approximately 250–350 mm diameter made from carbon steel, which will be fully pressure-rated to the compressor output and injection reservoir pressure.

The injection wells will be arranged into a small number of drill centres with approximately three to four wells at each centre. Wells will be directionally drilled from each drill centre to the bottom-hole injection location. Careful selection of the bottom-hole locations of the wells will be required to achieve the desired injection rates and distribution. The use of a cluster arrangement with directional or deviated drilling will ensure that land use is minimised. Figure 6-8 shows the proposed CO_2 injection well drill centres and bottom hole locations.

One option that may prove feasible is the use of fewer drill centres but the resultant increased well deviation will increase the likelihood of using non-water based

Plate 6-4:
Typical Flare Tower

muds (such as synthetic based drilling fluids mentioned for the offshore wells) which have their own potential environmental impacts. The injection wells will be constructed from corrosion-resistant materials to ensure well integrity in the sub-surface corrosive environment created by CO_2 injection.

The CO_2 injection pipeline will follow the most direct path practicable to the injection well locations while preferentially using as much previously disturbed land as possible. One key aspect in routing the CO_2 pipeline is to ensure the safety of personnel in the unlikely event of a pipeline release. Measures taken to protect people will also generally protect flora and fauna.

6.2.5 CO_2 Monitoring Activities

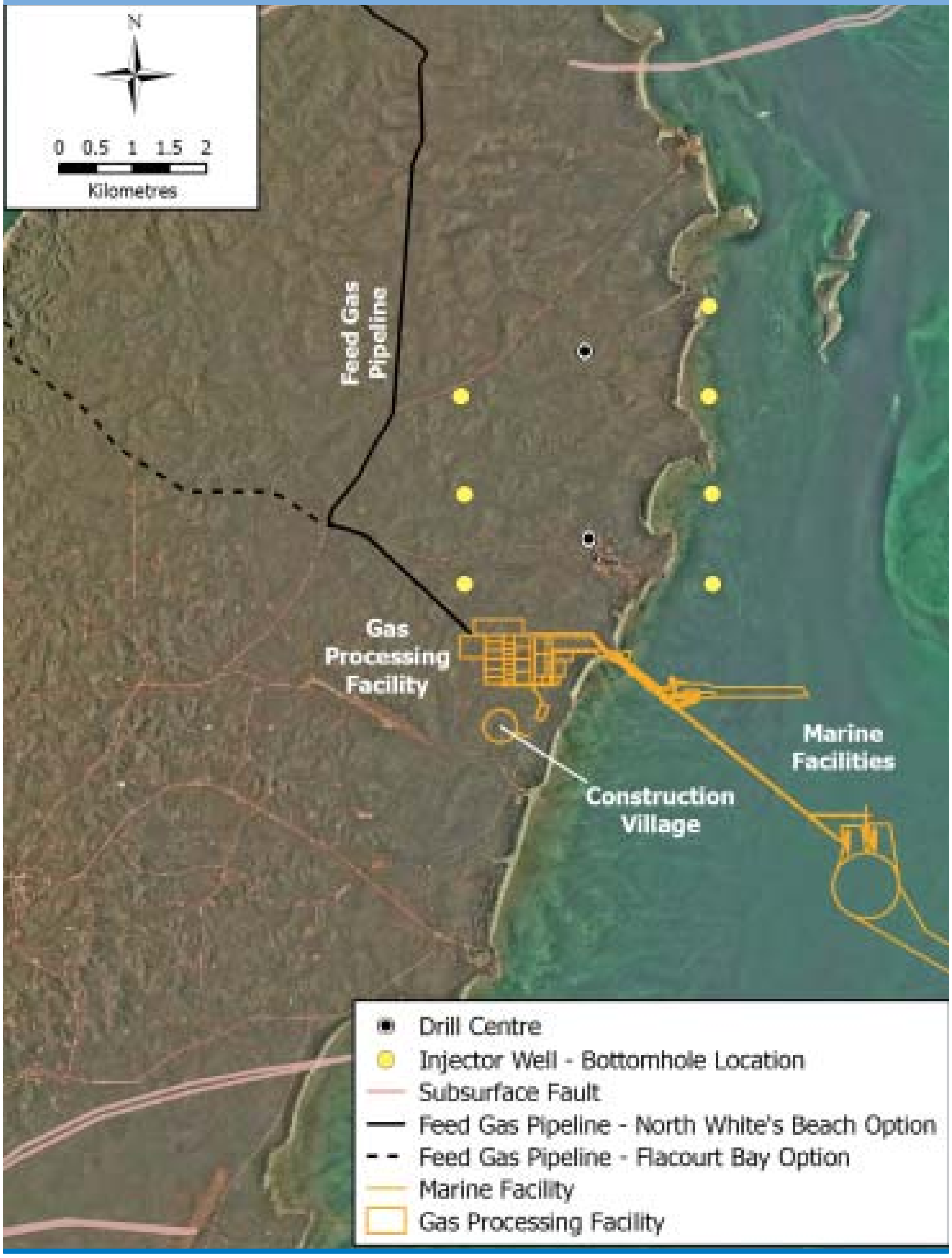
The movement of CO_2 within the Dupuy formation will be monitored to determine if it is behaving as predicted. Refer to Chapter 13 for a discussion of the behaviour of CO_2 in the subsurface once it is injected. The monitoring program has yet to be designed. As such, the following description should be considered as the reference case for the purposes of environmental impact assessment. The final concept and design of the monitoring program will be developed to ensure that the nature and extent of potential environmental impacts are consistent with those described herein.

The reference case monitoring program involves a combination of monitoring wells and seismic data acquisition. An investigation into established and developing CO_2 monitoring methodologies indicates that time lapse seismic (often referred to as '4-D') is the most effective technology for direct detection and mapping of the plume migration. The injection of CO_2 is expected to significantly alter the seismic response, therefore time lapse seismic will reveal the movement of the CO_2. The basic steps in time-lapse analysis for CO_2 monitoring are:

- acquire a 'baseline' seismic survey (3-D) prior to any gas injection to establish a dataset unaffected by the presence of CO_2
- acquire repeat seismic surveys
- subtract the baseline data from each of the 'repeat' datasets.

Acquiring good quality seismic data suitable for 4-D monitoring on Barrow Island is difficult due to a near-surface cavernous karst limestone layer. Numerous 2-D and 3-D seismic surveys have been acquired on Barrow Island, all of which have provided variable data quality due to problems associated with the karst layer. The most extensive survey was the 1994 3-D, which covered the entire northern half of the island. It was acquired on a grid with source lines 500 m apart and receiver lines 300 m apart; and used an array of four surface vibrators and 12 geophone receiver arrays spread over 25 m. Processing tests have shown the data acquired in the 1994 3-D survey is unsuitable for a 4-D baseline survey.

Figure 6-8:
Proposed CO_2 Injection Well Drill Centre Locations



Future surveys need to improve data quality while using considerably less land. Acquisition modelling and processing tests indicate that suitable data quality can be achieved through improved survey design and advances in technology.

The source and receiver lines in the 1994 3-D grid were cleared, and the survey used approximately 220 ha of land which can now be reduced to below 40 ha with careful planning and new technology. The challenge remaining is to balance the need to acquire seismic data of sufficient quality with the desire to minimise environmental impact.

The survey design options therefore include the following:

- use of pre-existing roads wherever possible
- use of pre-disturbed source lines (from the 1994 3-D survey) wherever feasible, where off-road source lines are necessary
- hand carrying of all surface receiver equipment from existing access roads, tracks and source lines.

The surface seismic program will include both onshore and offshore acquisition methods, even though the majority of the plume will remain under the island. Key technologies and design improvements need to be tested to ensure acquisition of sufficient quality data while minimising environmental impact. It is imperative that all repeat surveys are acquired with the same parameters as the baseline survey (i.e. all source and receiver locations will be revisited for each survey).

Previous surveys were not optimised to create an accurate near surface model, which is a critical factor in improving data quality. The model is used in the data processing stage to correct for variations introduced by the karst layer. An 'up-hole survey' will be used to provide input to the required model, which will involve the installation of one to two hundred 30–50 m deep holes. These will be located on the seismic source lines.

Onshore Seismic

The preference for using areas previously disturbed by 3-D seismic survey places the following constraints on the monitoring survey:

- source line spacing will be 500 m
- receiver line spacing will be 150 m (half the 1994 3-D spacing).

The grid layout will be altered to avoid sensitive areas (e.g. source lines can be curved to avoid bettong warrens). The other two main considerations when designing seismic surveys are the type of source and receiver and their spacing, which are described below.

Source

There are three main source types in seismic land acquisition, namely: vibroseis, accelerated weight drops and explosives. Each source type will be tested in order to determine the optimum and are discussed below.

Option 1: Vibroseis – A vibroseis truck is approximately 3.8 m high, 10.8 m long, 3.5 m wide, and is fitted with vibrator pads that are approximately 1.4 m x 2.3 m. The vibrator induces a controlled vibratory force which is transferred through a base plate into the ground to create seismic waves. An electronic control system generates a low amplitude sinusoidal signal that varies in frequency, from 8 to 80 Hz over 6 to 10 seconds. The vehicles can be fitted with rubber tracks or extra wide tyres to minimise both ground pressure and impact on vegetation. The previous acquisitions on Barrow Island used between two and four vibroseis units arranged in a line. New technology may allow the use of a larger single hydraulic vibrator unit, which will reduce the environmental impact by reducing the number of times each 'shot' (or vibration) location is revisited by 75%. Multiple smaller vibroseis units may still be required technically; if this is the case, land usage will decrease as the smaller units are approximately 2.5 m wide.

Option 2: Accelerated Weight Drop – Accelerated weight drops use a hydraulic system to raise and lower a weight of just over 1200 kg. The weight is released under pressure, causing it to hit the base plate previously lowered onto the ground creating a short duration impulsive energy source similar to explosives. The pad size is approximately 1.3 m in diameter. The accelerated weight drop is mounted on the back of a manoeuvrable but oversized 4WD, with a width of 2.5–3.0 m and a total weight of approximately 12 000 kg. This flexibility and manoeuvrability allows the source locations, density of source points and source effort, to be tailored to minimise the environmental impact. This is the environmentally preferred source option due to its reduced line width, increased manoeuvrability (over vibroseis) and holes will not need to be drilled.

Option 3: Explosives – Explosives are the preferred technical option as they have been shown to provide the best data quality on Barrow Island, particularly in areas which have a thicker karst limestone cap. Placing explosive charges beneath the air-filled caverns greatly reduces the amount of scattered energy created, and significantly enhances data quality through improving waveform, amplitude and frequency content of the energy reaching the target layer. In order to minimise the use of explosives and the amount of drilling, explosives will only be used if and where absolutely necessary. If testing shows explosives are required, it is likely to only be in areas of higher elevation or with significant karst limestone. Vibroseis or accelerated weight drop will be used for the remaining source locations. This will significantly reduce the number of shot-holes required for the survey (expected to be much less than 1000 holes).

Explosive charges are used commonly in seismic acquisition and, in the majority of cases, the explosives are placed below the water table. Each explosive charge is usually less than 5 kg and is placed in a PVC cased hole 5–10 m below the water table (average depth of hole is 25 m). The shot-holes will not be back-filled and will use a small head of water for detonation. A 2 m wide source line is required for the drilling program which uses small percussion drilling rigs mounted on the back of a 4WD. The percussion drilling will eliminate the need for drilling fluids and all cuttings will be used as fill material at the gas processing facility site. Contrary to common perception, explosive charges used in seismic surveys lead to minimal surface disturbance. Very few detonations result in any visible evidence that a charge has been detonated. The only observable event is a small ‘thud’ equivalent to a fist striking a table.

Receivers

Land receivers (geophones) will be firmly planted into the topsoil (e.g. a 7 cm brass spike pushed into the ground). All receivers will be hand carried from the nearest source line or access track to minimise off-road vehicle traffic. Flexibility in the placement of each receiver element will allow environmentally sensitive areas to be avoided. The receivers will be recovered after each survey is completed.

The 1994 3-D survey used receiver lines separated by 300 m and groups of 12 geophones spread over 25 m along the receiver line, and a geophone every two metres along the receiver line. This type of receiver layout did not adequately attenuate the back scattered energy commonly seen on Barrow Island. Improving the receiver response is critical to the success of any seismic monitoring program.

The main differences between the methods for improving seismic response are largely logistical in nature. For example, if 24-geophone groups are used, then approximately 200 000 individual geophone elements will need to be transported and handled in a manner that meets quarantine requirements, and then planted in the ground. However, if the single three-component geophones are technically acceptable, then less than 10 000 individual geophone elements will be required. The 24-geophone group option requires significantly more people, as well as 24 times the weight and volume of equipment than the three-component option. If the improvements in the receiver response from these changes are significant, the receiver station spacing may be increased from 25 m to 37.5 m or even 50 m, reducing the number of receivers required by approximately 50%. In practice, this may result in groups of 12 geophones spaced every 18.75 m, with two adjacent groups of 12 geophones being combined to form one aerial array of geophones.

From a logistical point of view, minimising the number of surface geophones per group and increasing the receiver group interval are critical items.

Another option is to place special ‘4-C’ receivers at or below sea level. This would require many thousands of boreholes to be drilled to sea-level, involving the creation of a 2 m wide access track for the percussion drilling rig and hence a considerable amount of land usage. The very large number of holes required for this receiver option and the large land use required makes this option impracticable for a full 3-D survey. However, the use of 4-C receivers below sea level may be required for a small portion of a 3-D survey where data quality is particularly poor. It is highly likely that this technique would be required for any 2-D program.

Overall the reference case for impact assessment is estimated to require 81 km of off-road source line length and a total receiver line length of 850 km. Contingency is required to allow for such matters as deviation of source lines from the grid of the 1994 3-D to avoid environmentally sensitive areas or changes in track width.

Marine Seismic

The water depth to the east of Barrow Island is typically shallower than 20 m. Shallow draft vessels are required to allow seismic acquisition in water depths to 1 m. Receiver cables, containing pressure sensitive receivers, will be laid on the sea floor with each cable being up to 4000 m in length. Alternatively, individual receiver pods may be deployed on the sea floor and recovered after each survey is completed. The survey will be carefully designed to ensure receiver locations and cables will avoid any sensitive areas such as corals. In deeper water, no equipment needs to be placed on the sea floor as towed streamer vessels can be used. The source will be a standard marine seismic survey airgun, which generates an acoustic wave in the 10 to 300 Hz frequency range by releasing high pressure compressed air.

The Commonwealth Department for the Environment and Heritage (DEH) guidelines for seismic acquisition will be used. These require that activities be suspended when whales are within 3 km of the seismic vessel. Trained observers will be onboard vessels to scan the ocean surface for the presence of marine mammals, and shut-down operations accordingly. When restarting operations a 'ramp-up' procedure will be used. This procedure gradually increases the emitted sound levels by turning on the array's airguns over a period of time. Surveys will be scheduled to avoid critical cetacean migration and turtle breeding periods. Shot locations will be planned to take maximum advantage of the tides and to avoid any impact on coral. Ideally, the timing will be such that the energy from the offshore sources can be recorded by the onshore receiver grid.

Refer to Chapter 13 for additional details regarding CO_2 monitoring and to Chapters 10 and 11 for a discussion of potential impacts associated with this program and their management.

6.2.6 Domestic Gas Pipeline

Gas for domestic use may, if proven to be commercially viable, be exported by a domestic gas pipeline from Barrow Island to the domestic gas distribution network. For the purposes of this Draft EIS/ERMP, it is assumed that the domestic gas pipeline will tie-in at Compressor Station One (CS1) on the Dampier to Bunbury Natural Gas Pipeline. The proposed pipeline route is shown in Figure 6-9. Alternative concepts are described in Box 6-6.

It is proposed that the pipeline will be routed directly from Town Point, on Barrow Island, to the mainland.

Box 6-6:
Domestic Gas Pipeline Alternatives

Alternatives to the installation of a new pipeline from Barrow Island directly to Compressor Station 1 (Dampier to Bunbury pipeline), involve tying the domestic gas pipeline into existing domestic gas supply facilities operated by Apache Energy on and around Varanus Island. Alternative concepts include:

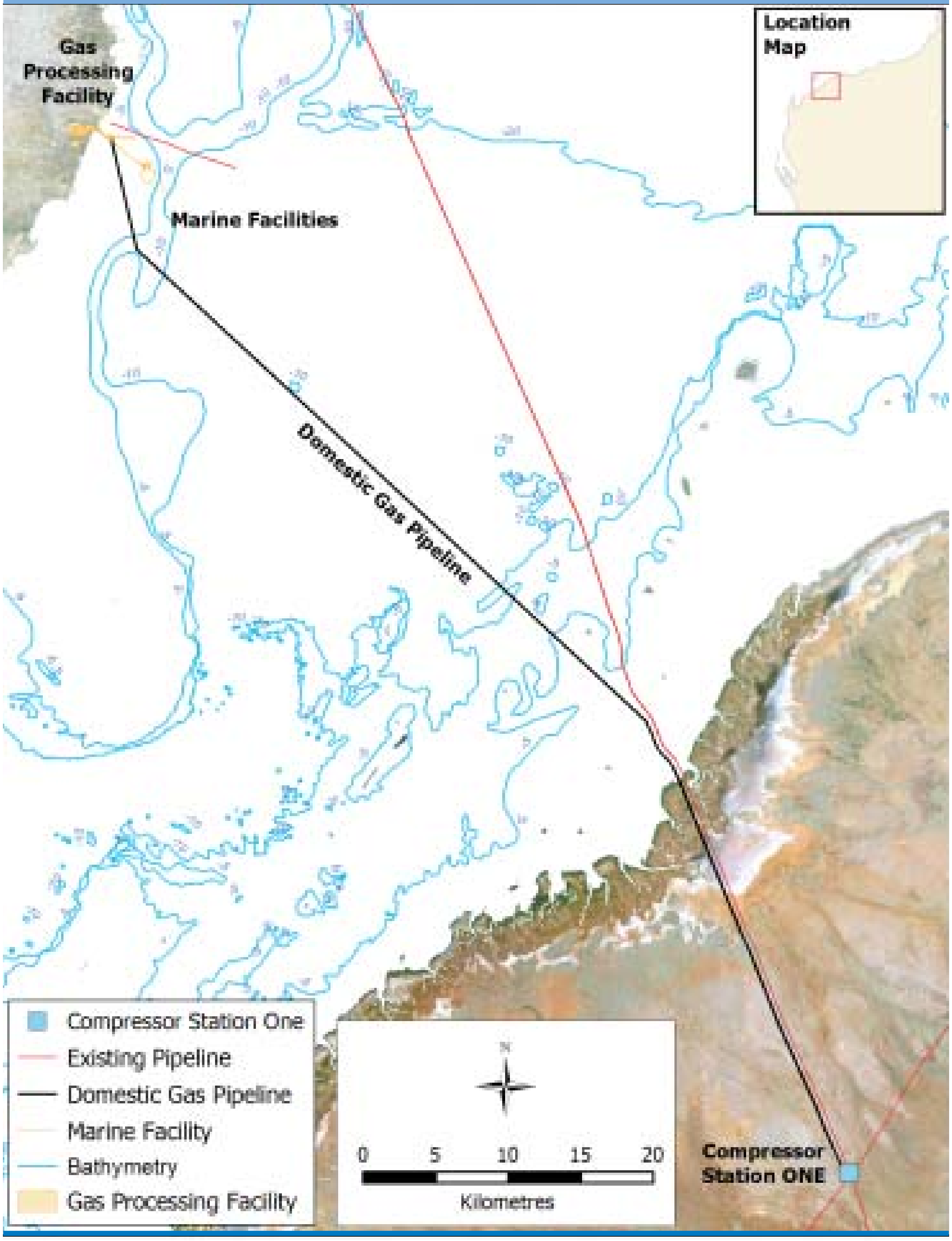
- a pipeline from Town Point to the Apache Sales Gas Pipeline, with 'hot-tap' subsea connection and installation of subsea isolation/pig receiving facilities
- a pipeline across Barrow Island, and subsequent offshore pipeline to Varanus Island with tie-in at the Apache Onshore Gas Plant
- a pipeline across Barrow Island to Cape Dupuy area, and a subsequent offshore pipeline to the Apache East Spar Pipeline and hot tap subsea connection and installation of subsea isolation/pig receiving facilities.

The latter two have been ruled out.

The route shown is essentially a straight line but this will be modified to avoid sensitive habitat as the design develops. This pipeline will approach the mainland immediately adjacent to the existing Apache Energy Gas Sales Pipeline to reduce the environmental impact associated with the development of a new shore crossing. The pipeline will be concrete weight-coated for protection and stability; and will be further stabilised by a combination of burial by jetting, rock bolting and other appropriate stabilisation techniques commonly used in the area. Pipeline installation will require the use of construction vessels moored in shallow water at both the Barrow Island and mainland ends. The potential for directional drilling at the mainland shore crossing will be considered as the design progresses.

From the mainland shore crossing point to Compressor Station 1, the pipeline will run parallel to the Apache Energy Gas Sales Pipeline. Except for valves that are required for pipeline maintenance, this pipeline will be buried for the entire route. The easement required for the pipeline will be approximately 30 m wide. Tie-in to the mainland pipeline network may involve hot-tapping, and will necessitate installation of adjacent pipeline isolation and 'pig-receiving' facilities to enable future maintenance of the domestic gas pipeline without impacting gas transportation in the main trunkline.

Figure 6-9:
Proposed Domestic Gas Pipeline Route



6.2.7 Water Supplies

Water will first be required during the construction phase and this aspect is addressed in the section on construction in this chapter.

6.2.8 Drainage and Waste Water System

The objective of the waste water system is to maximise the reuse of water, and to protect soils, subterranean fauna, groundwater and the marine environment from contamination. To achieve this, a tiered waste water management approach has been adopted, which comprises the following:

- diverting water, which flows naturally onto clean areas of the site during rainfall events, to natural drainage areas
- allowing water from unpaved areas and paved non-process areas (e.g. roads, and building runoff) at the site, where no contamination is likely to soak naturally into the ground, or directing this water to natural drainage channels

- directing water in areas that could be contaminated, but are usually considered to be relatively clean, to a holding basin for water quality testing before discharge. (Uncontaminated water will be discharged back to natural drainage areas, while contaminated water will be pumped to a treatment system.)
- directing water from areas that are expected to be contaminated (e.g. sumps and areas around pumps, turbines) to an oil recovery system.

The design of this tiered waste water facility will take into account the increased flows associated with severe storm events and potential firewater runoff (which may be contaminated with hydrocarbons, chemicals and salt).

All process water plus hydrocarbon contaminated surface runoff water will be treated in an oil recovery system. Any recovered hydrocarbons will be recycled (most likely by directing them back into the process), requiring them to be returned to the mainland for recycling or other appropriate treatment.

To cater for the infrequent periods when the water disposal system is not operational waste water storage facilities will be provided. This system will be designed to cater for the longest expected duration of such downtime, and the most likely volume of water produced during such a period. As this water will be contaminated, the storage tank will be bunded in line with Australian Standards.

The Code of Practice CP25 – Wastewater Management at Bulk Petroleum Storage Sites (AIP 1994) will be used in the design of the waste water treatment system. Appropriate water quality guidelines, such as the Australian Water Quality Guidelines for Fresh and Marine Waters (Australian and New Zealand Environment and Conservation Council 2001) will be used to design the water treatment facilities, and as a basis for assessment of contamination.

Waste water management is also discussed in more detail in the construction section of this chapter as these facilities will be required during the construction phase.

6.2.9 Port and Marine Facilities

The major components of marine infrastructure required to support the proposed Gorgon Development include: a Materials Offloading Facility (MOF) and causeway, jetty facilities, a shipping channel and turning basin. Each of these is described in the following section.

Materials Offloading Facility and Causeway

A MOF will be needed to receive construction materials including heavy pieces of equipment and prefabricated modules during the construction phase. The facility will also be used to receive maintenance material and provisions during the operational phase. Ocean going vessels, similar to that shown in Plate 6-5, are likely to be used for the delivery of large equipment such as the main cryogenic heat exchangers, absorber columns, and modules. The larger equipment will be unloaded and positioned on-site using multi-wheeled vehicles.

Plate 6-5:
Typical Construction Equipment Delivery Vessel

Access to the MOF will be provided via an 800 m long causeway from Town Point. The MOF will extend a further 325 m from the offshore end of the causeway. This concept will significantly reduce the volume of material to be dredged and associated blasting of the limestone platform that would otherwise be required to provide an access channel to a shore-based facility. Vessels will access the MOF via a dredged channel approximately 1.3 km long, 120 m wide and dredged to 6.5 m relative to chart datum. At this depth the channel will be tidally restricted for the larger vessels required during construction. A deeper pocket will be dredged against the MOF to enable these larger vessels to be unloaded during all tidal conditions.

The MOF will also incorporate mooring facilities for tug boats and other vessels required to support the LNG carriers, and refuelling capabilities for the smaller vessels (such as tugs). The details of the MOF specification will be reviewed with respect to module and equipment sizes determined as the design proceeds, however the basic concept will not change.

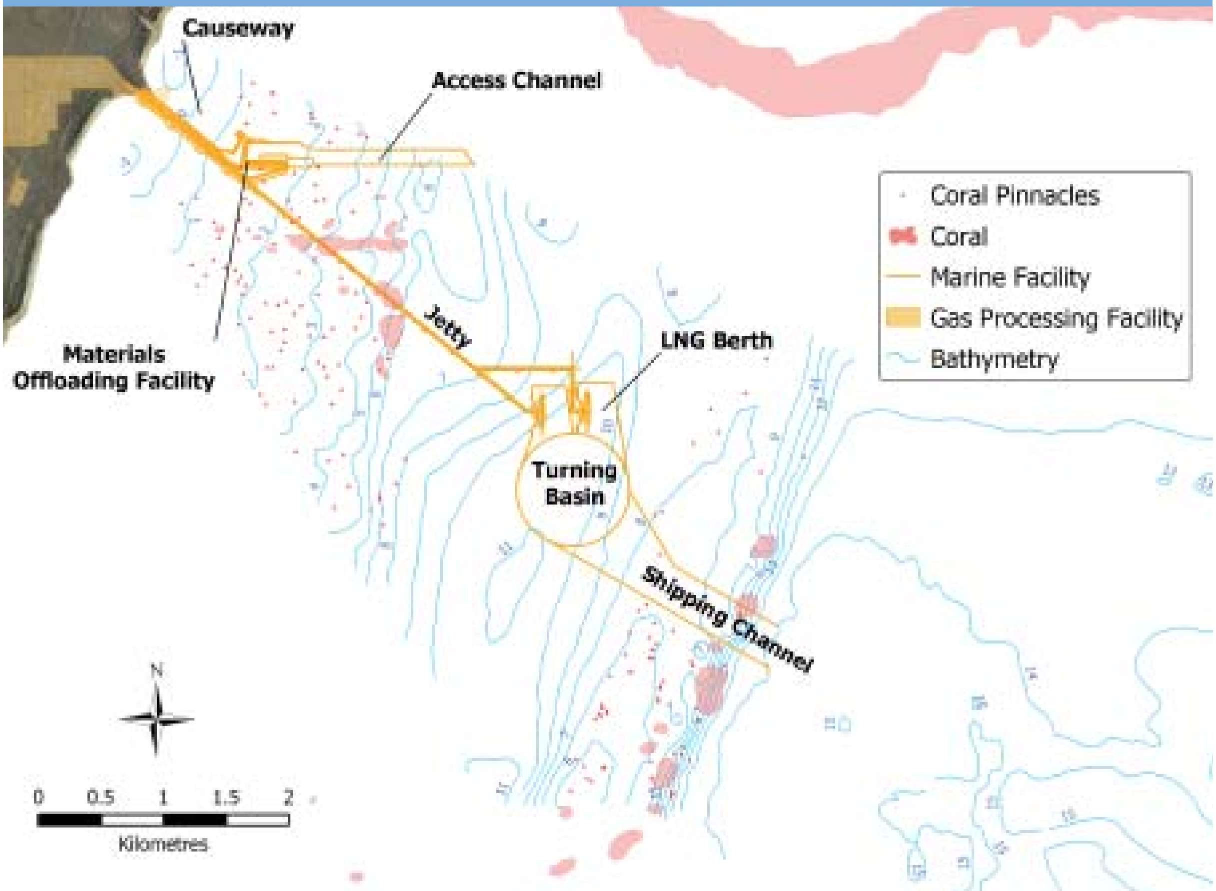
Jetty Facilities

A jetty will be built with mooring facilities to receive LNG carriers. The proposed jetty location and configuration is presented in Figure 6-10. The LNG export facility will include vapour recovery equipment. Emergency shut-down systems will be installed to minimise the risk of product spills.

The proposed facility will be capable of handling various sized LNG carriers between 125 000 m^3 and 215 000 m^3. The regular fleet is expected to be 165 000 m^3 vessels, however smaller and larger vessels may be accommodated to load spot cargoes.

The jetty will be approximately 3.1 km long commencing from the offshore end of the causeway. The final length, orientation and method of construction will be confirmed after further geotechnical and geophysical surveys, berth orientation modelling and simulated navigational studies are completed, but environmental impacts will not be significantly different.

Figure 6-10:
Offshore Facilities East Coast Barrow Island



The export facilities will include a loading platform, breasting and mooring dolphins, a field auxiliary room and substation, navigational aids and other infrastructure. The loading platform will accommodate:

- LNG loading arms for liquid transfer and vapour recovery, equipped with emergency shut-down and release systems and quick connect/disconnect couplers
- nitrogen purging facilities to drain the gas loading arms after use
- loading arm power pack and controls
- gas and fire detection and fire fighting equipment and fire monitors
- gangway tower for ship access
- life-saving equipment
- a drainage system incorporating spill containment
- space for maintenance plant and equipment
- a small boat landing.

The jetty will accommodate an access roadway, pipe racks and electrical cabling. The approach trestle and loading platform will be constructed with a steel open pile design and the height will be sufficient to avoid wave forces on the underside of the deck. The access roadway and loading platform deck will most likely be constructed of pre-cast concrete units fabricated off-site and lifted into position from construction barges. The jetty will also support a diesel powered seawater fire pump which will provide backup firewater to the gas processing facility in case of emergency.

The Joint Venturers have considered alternatives to the base case for the jetty design as described in Box 6-7, but the option of using a cryogenic line has been ruled out.

Shipping Channel and Turning Basin

The LNG carriers will require safe access via a shipping channel. The safety of the approach is determined by aspects such as depth, width, alignment and the presence of other marine traffic. The location of the proposed LNG loading berth has been developed in consultation with the Barrow Island shipping pilots, and is located several kilometres from the existing crude oil loading mooring.

The minimum required depth for the LNG carriers will be 14 m relative to the chart datum to allow access/egress at any tidal condition. The approach route will have an alignment as straight as possible with any bends at least 1000 m radius, if bends cannot be avoided. The approach channel will require a minimum width of approximately 300 m. The channel will be equipped with appropriate navigation aids. An exclusion zone will be established around the LNG jetty and channel in accordance with industry guidelines. The proposed shipping channel and turning basin are shown in Figure 6-10.

During the operations phase the Barrow Island port will be controlled by a Loading Master/ Harbour Master who will control all activities within the port limits. During construction, these duties will be assumed by a Marine Operations Manager, or similar role.

Box 6-7:
Jetty Alternatives

Alternative	Considerations vs. Base Case
A conventional jetty to deeper water.	• Higher capital cost • Longer construction schedule • Less dredging
A simpler trestle structure to deeper water.	• Lower or neutral capital cost • Higher operating cost • Less dredging • No vehicle or personnel access to loading platform • Not as safe
Subsea cryogenic pipeline technology	• Capital cost slightly less or neutral • Higher operating cost • Less dredging • Unproven technology

During severe adverse weather conditions, LNG ships and condensate ships will be either diverted, delayed, or released to avoid being caught in shallow or confined waters. Tugs will also be released to avoid the weather. During severe adverse weather conditions, construction vessels will shelter in the Dampier archipelago, which is common practice in the region.

6.2.10 Supporting Facilities

The key facilities to support the gas processing facility are outlined below.

Administration and Maintenance Facilities

An administration building and maintenance facilities will be constructed either within the gas processing facility site, or in the vicinity. This area will contain offices and workshop facilities for the maintenance of the gas processing facility equipment. Some of these facilities may be shared with the existing oil operations on Barrow Island.

Accommodation

The main operations workforce will be accommodated on Barrow Island. The location of the accommodation for the operations work force is still under consideration and may be within an extension to the existing camp or within a dedicated section of the proposed construction village. Refer to Section 6.3.6 for details on the site selection process, and additional details on the construction village. A portion of the construction village will be retained to support potentially larger maintenance campaigns, such as planned shut-downs, or to support construction of future expansions.

Diesel Supply

A diesel storage facility and distribution system will be required for the operating phase of the proposed Development. Diesel will also be required during the construction phase and this is discussed in the construction section of this chapter. The diesel required by the gas processing facility will supply the back-up firewater pumps and emergency generator and similar equipment, and supply the vehicles and other equipment required to support the operation on Barrow Island.

The diesel will be stored in an above-ground tank, bunded to Australian Standard AS1940. The tank size will be determined during later phases of design, but is likely to be relatively small (currently expected to be in the order of 30 m^3). A bunded area will also be provided for vehicle refuelling and all diesel day-tanks. Pipes from the tank will distribute fuel to the various day-tanks associated with the emergency equipment, but alternatives such as distribution by truck are currently being considered. It is currently envisaged that diesel storage facilities will be above-ground. However, should below-ground tanks or piping be required, they will be designed in accordance with AS1940 and the Code of Practice CP4 – The Design, Installation and Operation of Underground Petroleum Storage Systems (Australian Institute of Petroleum 2002).

Diesel will most likely be supplied by trucks carried on barges which will be unloaded at the MOF, but there is potential for diesel to be bunkered in barges and pumped to shore.

The option to produce a diesel-like fuel on Barrow Island from the local crude oil was explored. This would have avoided the need to handle diesel from the mainland but following further investigation was not considered feasible.

Resupply of fuel to support vessels will be undertaken at the mainland and at the MOF. Dry break couplings will be used on bulk diesel transfer lines.

Roads

The construction of the gas processing facility will require the re-alignment and upgrading of several existing roads on Barrow Island. These upgrades will be between the proposed gas processing facility and the construction village. The upgrades will involve widening, grading and sealing. These upgrades will increase the safety of the road for both personnel and fauna due to increased visibility. Paving the main roads will also reduce dust generation. Strict procedural controls will be placed on drivers to minimise environmental impacts, such as when driving at dusk or dawn. Stormwater runoff management will be a criterion in the design to ensure potential for scour is minimised and pooling on the sides of roads is reduced. These aspects are discussed in more detail in Chapter 10.

Interconnections with Existing Operations

There are likely to be a number of interconnections with existing facilities on Barrow Island, such as:

- condensate loadout
- power supplies
- water injection systems
- water supplies
- communications
- construction fuel gas supply.

Where possible, these facilities will be installed along currently disturbed areas (e.g. power lines along existing roads), or along a common corridor, to reduce environmental impact.

6.2.11 Mainland Supply Base(s)

Logistical support facilities are required to support both offshore and Barrow Island operations. Mainland supply bases (Figure 6-11) will allow for consignment, loading and refuelling of support vessels and subsea construction vessels (if adjacent), storage of construction materials, and offloading of deliveries requiring transport and the return of waste. For these facilities the preferred option is to utilise existing facilities that either meet the construction requirements, or that can be upgraded readily. The exact location and nature of the facilities have yet to be decided; however, it is anticipated that existing infrastructure in the King Bay area near Dampier and at the Australian Marine Complex south of Perth may be utilised with various locations in the Perth metropolitan area. The facilities will incorporate lay-down and storage areas, warehouses, quarantine facilities (such as wash down bay, fumigation facility, inspection pit, etc), administration and wharf facilities (if adjacent), together with appropriate waste management systems and waste water collection and treatment systems. These facilities will also support the Development quarantine management system, and will have security surveillance.

Should a new supply base(s) be required, then these will be the subject of a separate approval.

6.2.12 Estimated Land Use

The *Barrow Island Act 2003* establishes the basis for land available to be cleared for gas processing and associated infrastructure. The Development team is actively managing land requirements on Barrow Island to minimise footprint and vegetation clearing. The land required for the Development will be monitored during later phases as the design progresses. Table 6-3 presents an estimate of land requirements against the allocation stipulated in the Barrow Island Act.

6.3 Construction Activities

6.3.1 Construction of Offshore Wells

The initial development phase for the Gorgon gas field is anticipated to require 5–10 wells to be drilled. Additional wells in the Gorgon gas field will be drilled over the next 30 years, with the final number expected to be in the order of 18–25 wells.

Drilling requires approval by the Western Australian Department of Industry and Resources (DoIR) under the Commonwealth *Petroleum (Submerged Lands) Act 1967* (P(SL)A). Detailed Environment Plans, Oil Spill Contingency Plans and drilling fluid management procedures will be produced as part of this process.

Wells will be drilled in groups to optimise the efficiency of rig operations and to minimise footprint on the seafloor. Most wells will be drilled using directional drilling technology as it will allow the clustering of wells and subsea facilities. Drilling will be undertaken using typical offshore petroleum industry equipment such as semi-submersible rigs (Plate 6-1) or drill-ships (Plate 6-6), which are anchored on location.

The drilling process commences with boring a hole (typically in the order of 1 m diameter) in the seabed to a depth of approximately 150 m. A steel liner (tube or ‘casing’) is then placed inside the hole and cement is pumped through the steel liner and allowed to flow back up the annular section to fill the gap between the hole and the liner.

Figure 6-11:
Proposed Mainland Supply Base Area in Karratha

Table 6-3:
Estimated Land Use

	Estimated Land Use (ha)*		
Barrow Island Act 2003 reference	Gas Processing Clause 6(2)	Pipeline Easements Clause 6(3)	Future Development Clause 6(10)
Land Allocation	150	50	100
Development Component			
Gas Processing and Associated Facilities	142**		55
Onshore feed gas pipelines		40	
CO_2 injection pipeline	8		
Total	150	40	55

* *These figures are approximate only and may change during design phase. Any changes will be maintained within the allocated limits.*

** *Includes 35 ha for CO_2 wells and monitoring*

When the cement has set, a smaller diameter hole is then drilled through the bottom of the cemented liner and continues to a depth of approximately 1000 m. At that point another liner (slightly smaller than the new hole) is placed inside the hole and cemented in place in a manner similar to the first. This process of ever decreasing sizes of hole and liner continues until the reservoir section is reached.

During the drilling process, the rock (or 'drilled cuttings'), which is crushed and ground by the drill bit, must be continuously removed from the hole. This is achieved using a specially formulated drilling fluid. The fluid serves many other purposes such as to cool the drill bit and ensure the reservoir fluids are controlled once this section is penetrated. Equipment is provided on the drilling rig to pump the drilling fluid down through the drill pipe and drilling bit, and then when it returns to the rig other equipment separates the drilling fluid from the cuttings. The fluid is re-used as much as possible and the cuttings discharged overboard.

It is currently proposed that a water based drilling fluid will be used for the majority of drilling activities for the proposed Development. However, a synthetic based fluid may be required for technical reasons in the lower section(s) of some wells. These synthetic fluids are frequently used in the north-west of Australia and around the world. Should a non-water based mud be required, then cuttings driers will be considered in line with current best practice in the region, and details will be provided in the Environment Plan.

Drilling fluids, cuttings and other drilling wastes to be discharged during drilling activities are discussed in more detail in Chapter 7, while the associated environmental impacts and their management are covered in Chapter 11.

Plate 6-6:
Typical Drill Ship (Courtesy: Deepwater)

6.3.2 Construction of Onshore CO_2 Injection Wells

The onshore CO_2 injection wells will be drilled using a similar process to that described above for the offshore production wells, but using a rig similar to that shown in Plate 6-7.

The drilling operation will also require the following:

- access roads for personnel and equipment
- water and other materials required for the drilling fluid
- a level work site on which to place the rig
- excavated and lined pits or tanks in which to store fluids
- facilities to remove cuttings from the drilling fluid
- systems to manage cuttings disposal
- facilities to enable each well to be cleaned up.

The proposed safeguards associated with drilling are proven and environmental management processes well established on Barrow Island. However, the Development team is currently examining alternatives for cuttings disposal to meet current day practices and international best practices. The options being considered include: cuttings re-injection, chemical flocculation, stabilisation with cement (such as for use in earthworks associated with the gas processing facility and associated infrastructure), collection in skips or dedicated bulk bags for disposal on the mainland or for storage until future disposal options are developed.

One of the critical components of the CO_2 injection wells will be the CO_2 resistant cement used to fix the casing in place, and to avoid the release of CO_2 via the wells. CO_2 leakage is discussed in more detail in Chapter 13.

Details of, and the rationale for, the selected alternative will be included in the drilling approval documentation.

6.3.3 Construction and Installation of Subsea Systems

The following section describes the installation of the various components that will collectively comprise the subsea facilities.

Subsea Trees

The subsea trees will form the interface between the well and the seabed facilities and will be installed by the drilling rig as part of the drilling process. Rigorous

Plate 6-7:
Onshore Drilling Rig

safety and functional tests will be carried out at that time to ensure that pressure integrity is achieved and that all safety and control systems are working correctly.

Cluster Manifolds and Pipeline End Manifolds

The manifolds will be designed and built so that they can be installed by a drilling rig or construction vessel with suitable crane and deck space capacity.
The current manifold design is based on a piled foundation concept.

In this case, the drilling rig or other construction vessel will install one or more piles in the seabed. Then the manifold assembly (Figure 6-2) will be lowered to the seabed and latched on to the top of the pile foundation at the seabed. Other options, such as skirt foundations, are also being examined but further geotechnical work is required to enable this decision to be confirmed. Other concepts will have a similar environmental effect.

Plate 6-8:
Remotely Operated Vehicle (Courtesy: COVUS Corporation)

Suitably equipped Remotely Operated Vehicles (ROVs), similar to that shown in Plate 6-8 and other construction equipment will be used to tie-in the connecting flowlines and control umbilical jumpers between each tree and the manifold.

Umbilical Bundle

The control umbilical bundles, which will interconnect and control the subsea facilities, will be loaded onto specially modified construction vessels, similar to those shown in Plate 6-9, and installed progressively from the gas processing facility to the offshore wells. Umbilicals will be reeled off the vessel's deck to the seabed and pulled through pre-installed conduits at the shore crossing. The vessel will then move away from the shore and pay-out the umbilical, laying it on the seabed in a corridor close to the subsea flowlines and pipelines. The length of time that the vessel will operate near the shore is expected to be limited to a few days.

At the gas field, the umbilical will be laid on the seabed close to the Pipeline End Manifold (PLEM), pulled in and connected to the subsea facility using an ROV deployed from the construction vessel. Once connected, the umbilical and the control system it serves will be pressure-tested and function-tested to ensure all safety and production systems are operating correctly.

6.3.4 Construction of the Feed Gas Pipeline

Pipeline fabrication facilities in Australia are not currently able to produce pipe to comply with the Development's requirements. As such, it is anticipated that the pipe will be manufactured overseas. The pipeline will comply with AS 2885 (onshore) and appropriate International codes, such as DNV OS-F101 (offshore).

The pipe will be coated either overseas, in Australia or in Western Australia. If coating is undertaken in Australia, a coating area will be required on the Australian mainland for up to two years. Subsequent approvals will be sought for this area as required, by either the Joint Venturers, or contractors acting on their behalf.

Plate 6-9:
Typical Offshore Installation Equipment (Courtesy: Clough Limited)

Construction of the Shore Crossing

From approximately 150 m inland at North White's Beach to approximately the 12 m water depth contour, the pipelines will be located underground. The installation technique used to achieve this will be HDD (Figure 6-12 and Plate 6-2). This involves establishing a construction site at the entrance point onshore and then boring a hole of approximately 1 km in length to the subsea exit point. The majority of the drill cuttings and drilling fluids will be separated at the onshore end, while the separated drilling fluids will be re-used, and the drill cuttings set aside for disposal.

At completion of the hole-boring operation, the pipelines can be passed into the hole. A key advantage of the North White's Beach site is that it allows pipeline stringing to take place onshore behind the HDD holes, and the pipe can be fed down the hole from onshore to offshore using a pipe thrusting machine. An additional length of approximately 300 m will be fed through and left on the seabed for recovery by the pipeline construction vessel.

At the subsea exit point, a small amount of jetting or rock dumping will be required to create a gentle transition from the exit angle to the natural seabed contour to prevent a large unsupported pipeline span being generated as shown in Figure 6-13 and Figure 6-14.

The shore crossing construction is anticipated to take up to 12 months to complete. The drilling operation is estimated to take between 3–5 months, with the remainder of the time involving site preparation work, pipeline installation and site rehabilitation.

It is currently envisaged that in the offshore area close to Barrow Island, the feed gas pipelines will be separated as shown in Figure 6-14. The spacing is only 5 m apart at the entrance point onshore and the holes fan out to approximately 10 m at the exit point. There are drivers to have the spacing as close as possible such as to facilitate recovery of the pipeline by the lay barge, keep the drilling in similar ground conditions, and minimise land use. However there is a practical limit of how close the lines can be positioned, this is due to the survey equipment used and the potential

Figure 6-12:
Schematic of HDD Procedure

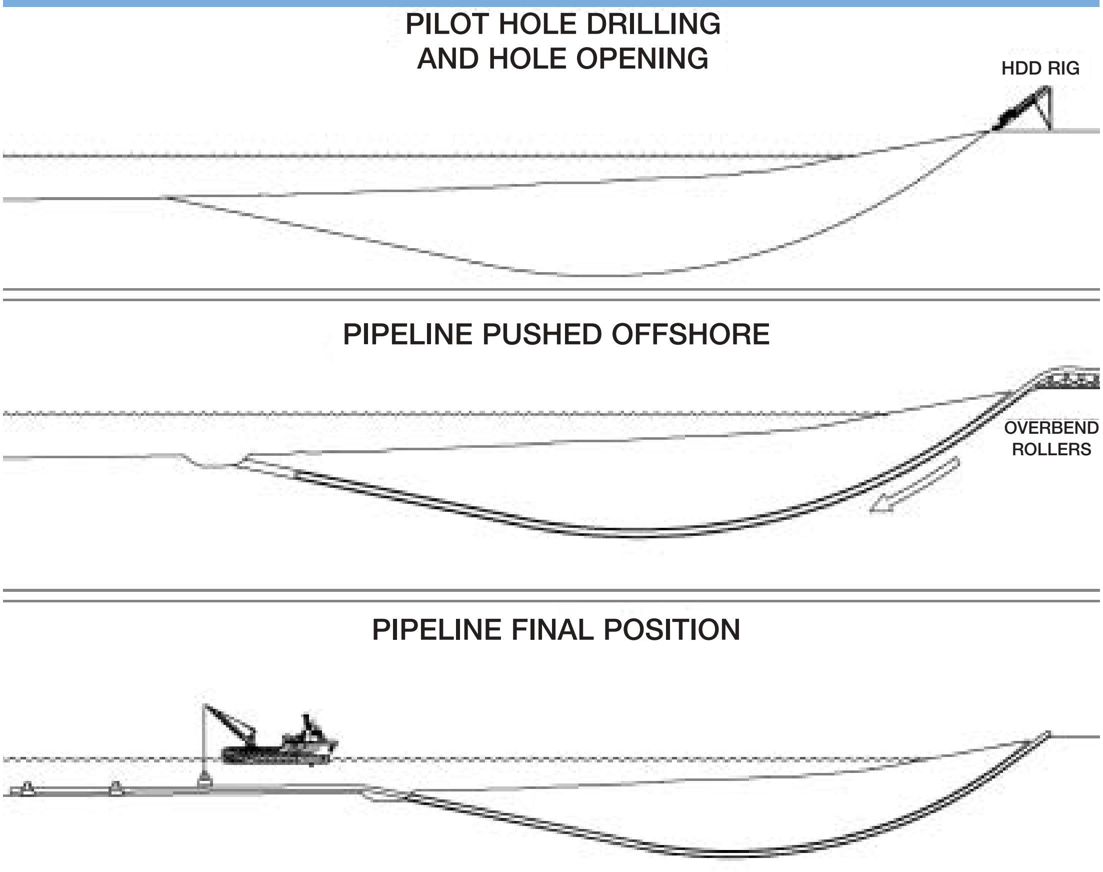


Figure 6-13:
HDD Breakout Point

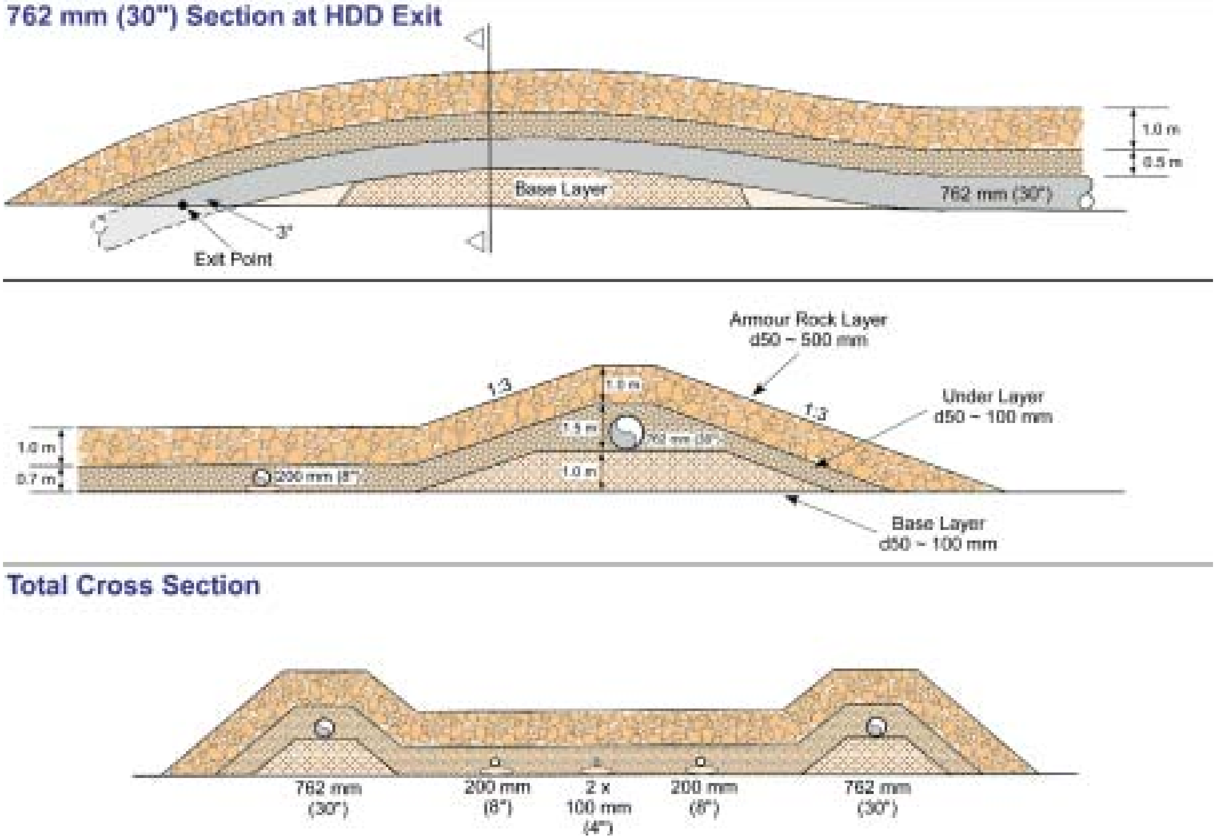
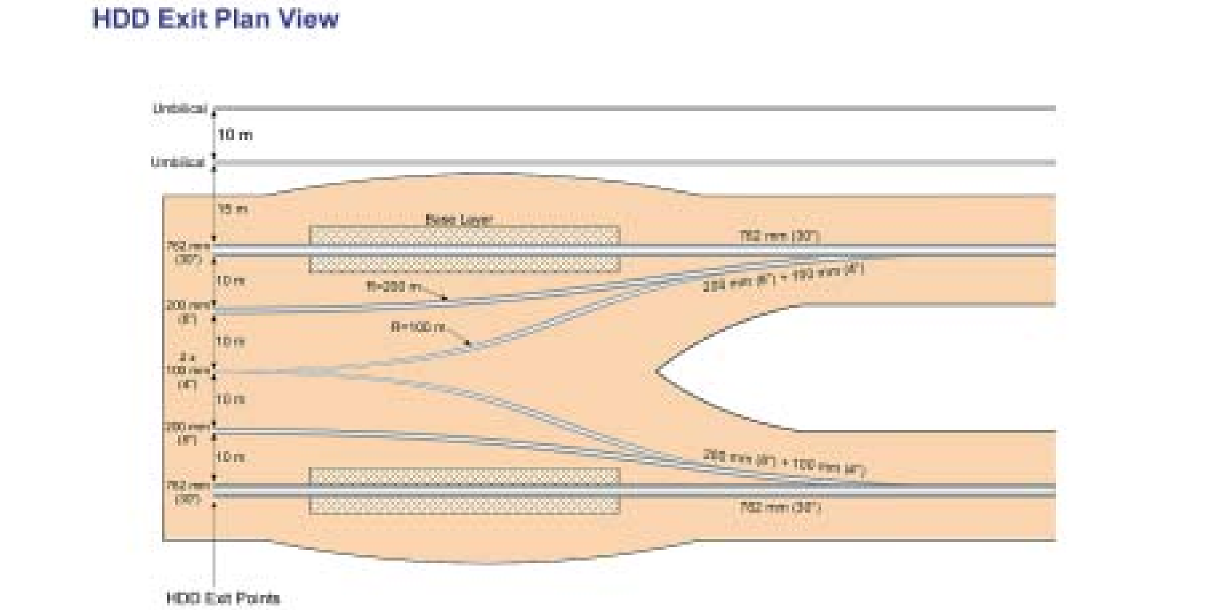


Figure 6-14:
HDD Operation in Plan View



positioning error. There is also magnetic interference to the survey equipment when drilling along side installed pipelines if the holes are too close together. This spacing offshore is also required to enable the installation vessels to safely return to install future feed gas pipelines while installed feed gas pipelines remain fully operational.

The pipeline lay barge will need to approach within approximately 1 km of the shore in order to recover the pipeline tail (i.e. 300 m section). In this area, at least 6–8 anchors will need to be deployed (3–4 either side) to hold the vessel on location. If the pipeline construction vessel is not dynamically positioned then anchors will need to be routinely reset as the pipeline is installed. In shallow water the anchors will need to be reset more frequently than in deep water.

Away from the immediate shore crossing area, the pipeline will be installed from a pipe-lay barge (Plate 6-10). The pipe-lay barge will be utilised for welding the pipeline lengths together and stringing them across the seabed. The shallower, near shore sections to approximately the 40 m depth contour (approximately 15 km), will most likely be covered with rock to stabilise the exposed pipeline.

Plate 6-10:
Typical Pipe-lay Barge

Shore Crossings

The areas required for construction will be limited to the minimum practicable area necessary for safe operation. Where feasible, activities will be conducted away from shore areas. To facilitate the pipeline installation, and provide area for construction equipment, laydown, and other temporary works, an area of approximately 4 ha may be required close to shore (which includes land use for future expansion).

6.3.5 Construction of the Onshore Feed Gas Pipelines

The installation of the onshore pipelines will be performed in a manner that causes minimum ground disturbance and optimises rehabilitation potential. The feed gas pipelines, auxiliary lines, CO_2 injection pipeline, water lines and domestic gas pipeline will all be installed in a broadly similar manner.

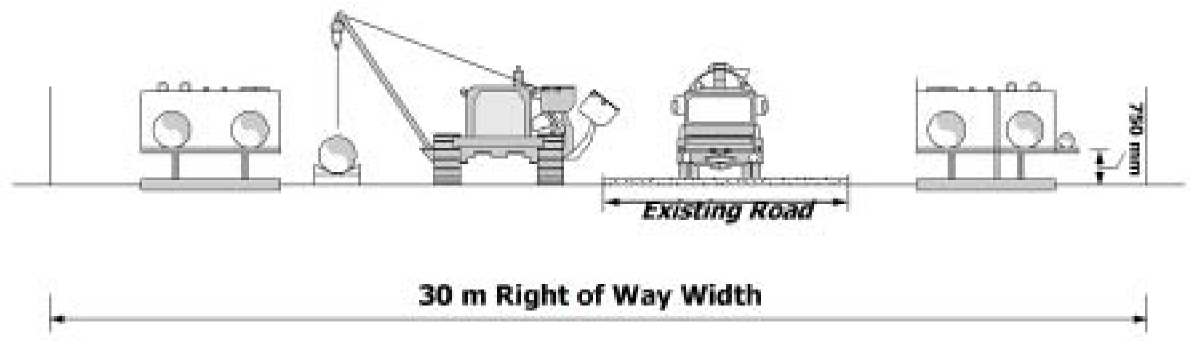
The feed gas pipeline construction activities will be located within a 30 m easement, but as the design develops endeavours will be made to improve on this. This width will provide adequate space for short-term stockpiling of vegetation and topsoil where it exists, as well as safe manoeuvrability for construction machinery and associated traffic. Vegetation along the easement will be slashed to prevent outbreak of fire associated with welding and promote successful regrowth. The easement will be graded, where necessary, to provide a safe and level working area and to minimise the potential for impacts associated with water runoff, such as erosion and sediment transport. Easements for smaller lines will be much smaller.

The onshore feed gas pipelines will be separated by a distance that allows safe installation of future lines while the existing lines remain fully operational. This distance, which will be determined as the design develops, will also provide sufficient access for future maintenance and inspection programs to be carried out.

Once the access has been completed as required, the foundations for the pipeline supports will be installed. To achieve this, holes will either be drilled or excavated for the plinth foundations. The plinths can then be installed ready for the pipeline supports.

Pipe sections will be strung alongside the supports. The pipe ends will be prepared (which involves grinding and heating) and welded together. Welds will be inspected by visual examination and radiography so that any defects can be detected and repaired.
The pipe will be lifted into place on the supports by a series of pipe-lifting machines holding the pipe in slings. An alternative is to lift the larger pipe diameters individually onto the pipe supports and weld them in place. The pipeline installation technique is illustrated in Figure 6-15.

Figure 6-15:
Pipeline Installation Technique



6.3.6 Construction of the Gas Processing Facility and Infrastructure

Construction of the gas processing facility will take almost four years. Given the complexity of the facility, the numerous equipment items which will be installed, and the preliminary nature of the construction planning at this stage, it is not currently possible to provide a full description of the construction process. However, the process used will be consistent with the current industry standard for developments of this type, such as most recently used on North West Shelf LNG Train 4 on the Burrup Peninsula. To reduce work and workforce on Barrow Island, it is likely that some equipment will be brought to the island as prefabricated packages. The actual configuration for each section of the gas processing facility will be determined as the design proceeds.

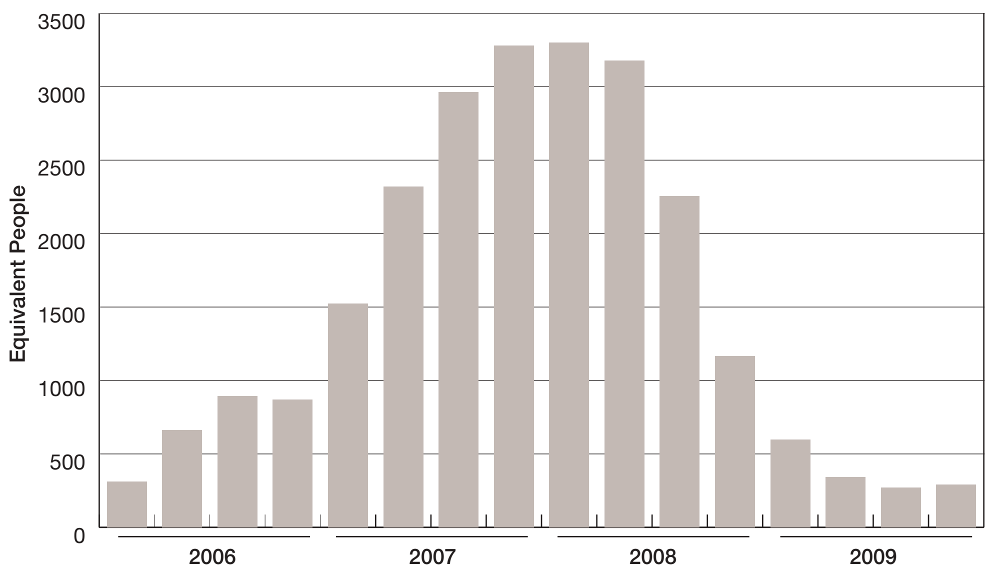
Site establishment works will dominate the early stages of the proposed Development to prepare for the main construction activity on the gas processing facility. This work includes construction of a construction village, site preparation works, the MOF and other infrastructure as described below.

Workforce and Accommodation

Figure 6-16 illustrates the estimate of the expected workforce size over the construction period. It shows a ramp up from 2007, a peak is expected to occur during 2008, then the numbers taper off to the level required for steady operations.

Most of the personnel involved in marine activities such as drilling, pipe-laying, dredging and transportation will be accommodated on their

Figure 6-16:
Estimate of Barrow Island Workforce



respective vessels. These crew will not require routine access to Barrow Island, but if they do require access to the island for any reason they will be subject to the full quarantine requirements discussed in Chapter 12.

Approximately 140 additional crew will also be required at the mainland of which around 95 people will be working at any time during the peak of construction. There will also be approximately 70–90 personnel operating barges and tugs, with 50–60 working at any time during the peak of construction.

Pioneer Camp

The existing oil field operations camp currently has the capacity to support a workforce of approximately 200 personnel. A pioneer camp is required to accommodate an additional workforce of approximately 250 people.

The additional workforce will undertake mobilisation activities, site preparations, installation of the main construction village and associated utilities and other infrastructure required for the proposed Development.

The pioneer camp will require additional amenities such as water treatment, sewage treatment and waste management.

This workforce will also require approximately one additional flight to Barrow Island per week.

The pioneer camp does not form part of the proposal covered by this Draft EIS/ERMP as it will be constructed during the EIS/ERMP assessment period and will be subject to a separate approval process. The camp has been included here for completeness and to allow consideration of cumulative impacts.

Construction Village

The existing camp on Barrow Island including pioneer facilities will be too small to accommodate the expected number of people required to construct the gas processing facility and associated infrastructure or to operate the facilities on a long-term basis. Therefore a construction village will also be required.

A construction village will be established to cater for a peak workforce of approximately 3300 personnel. It is envisaged that approximately 12 additional flights will be required to Barrow Island each week and approximately two bus trips per day from the airport to the village and return during the peak of construction. If a decision is taken to evacuate the site for a cyclone, (an average of six are announced per year but not all require evacuation), it will require approximately 38 additional flights from Barrow Island. A similar number of flights will be required to return the workforce to Barrow Island after the cyclone passes. An option which is currently being investigated is to upgrade the design of facilities so personnel do not have to be removed from the island.

A section of the village will be designed as a permanent installation to support large-scale maintenance campaigns, or as an operational village. Decommissioning of the village will be assessed based on foreseeable work and requirements.

The construction village will require facilities and utilities such as:

- power generation
- water supply
- waste water management
- sewage treatment (with connection to the water injection system)
- recreational facilities
- mess facilities
- laundry
- bus parking facilities
- incinerator
- other waste management facilities
- medical facilities
- fire station
- telecommunications (including internet and phone).

Box 6-8:
Floating Accommodation Concept

Floating accommodation in the form of a ‘floatel’ or converted cruise ship was considered as an option for the construction workforce. However this option was discarded for several reasons, including logistics, quarantine aspects, industrial relations, and safety issues. The problems include moving personnel from the accommodation to shore, as the vessel will be located some distance offshore due to the vessel draft requirements. During a cyclone, all personnel would require evacuation from the vessel. Further, the vessel may need to be moved to a safe harbour or out to sea to avoid being in the path of the cyclone.

Where technically and economically feasible, the utilities and infrastructure installed for the construction village will be designed to meet the requirements of the gas processing facility.

An alternative considered for accommodating construction personnel is discussed in Box 6-8.

A detailed study was undertaken to identify alternative locations for siting of the construction village to support approximately 3300 people. The study involved:

- determining site evaluation criteria and assigning a level of significance
- analysing the relative values of each site in accordance with the evaluation criteria and short listing priorities
- undertaking ecological surveys of the priority sites and assigning values
- ranking each site
- reviewing the process, criteria and findings with stakeholder groups.

The factors used in the construction village site selection process included:

- topography (geotechnical issues, geology, earthworks, drainage requirements, effects on existing drainage)
- buffer distance to the gas processing facility (risk and noise, travel time, air quality, visual amenity, aircraft noise)
- proximity to associated sites (LNG plant construction site, airport, new roads, old airstrip and laydown areas)
- supply of infrastructure (electricity, water, sewage treatment, telecommunications)
- environmental aspects (potential for road kills, light spill, existing vegetation cover, rare and endangered flora and fauna, cultural heritage sites)
- exposure to weather (prevailing weather conditions, cyclone exposure and height above sea level)
- effects on existing infrastructure (old air strip, lay down area, gas/oil lines and facilities, water pipelines, power cables/overhead lines).

A total of seven sites were identified (Figure 6-17) to be of potential interest, and these were:

- LNG (basecase)
- CVX Camp Site 2
- Old Airstrip
- CVX camp Site 1
- Dove Point
- Airport
- Howard's Landing.

The airport site and Howard's Landing were eliminated due primarily to their remoteness from the proposed LNG construction site and the resultant economic implications for supply of infrastructure.

Dove Point was eliminated due to its remoteness, requirement to establish new roads, potential to fall within noise limit boundaries and its significant potential for light spill onto beaches which could adversely impact turtles. Dove Point scored lowest on the latter aspect.

Four priority sites remained to undergo a detailed ecological survey. Preliminary findings showed that the majority of flora and fauna species identified are representative of the composition and diversity across Barrow Island.

The combined assessment included safety and environmental considerations and ranked all sites similarly overall, however not all sites are equal in all respects. Sites closer to the existing Chevron campsite offer reductions in site works and opportunities for synergies with that camp, but present increased service routes and travel distance to the gas processing facility. The Old Airstrip campsite is closer to the LNG site, but also close to oilfield production facilities and as it is low lying it is susceptible to inundation.

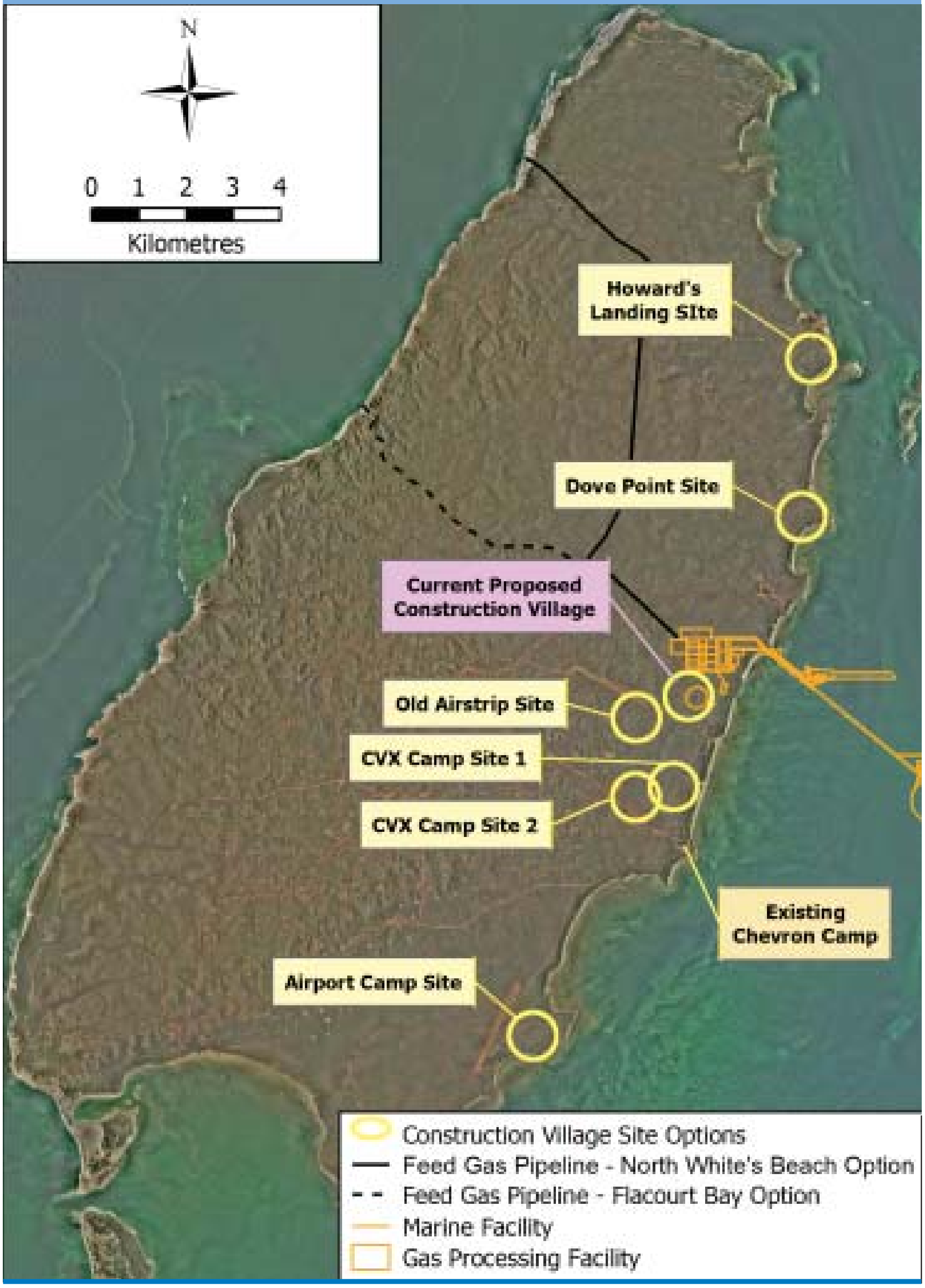
Further work will be undertaken in later phases of Development to narrow this selection to one site on the basis of equal or reduced environmental impact, social and economic factors.

Further details on the utility requirements are provided later in this chapter.

Site Establishment Works

Site preparation will commence with clearing by dozers, together with drilling and blasting of rock. This rock will be used as fill within the site area, as road base material and for the MOF. The approximate volume of material to be excavated and filled is 1.5 million m^3. Sand and aggregates required for concreting, service trench bedding and other needs will be met either by material from the facility site or imported from third-party operated quarries on the mainland. No new quarries or borrow pits will be created for the Development on Barrow Island.

Figure 6-17:
Potential Construction Village Sites



Earthworks around the airport may also be required for potential extensions to, and realignment of, the runway and any expansion of the terminal.

Plant Construction

The equipment required for the gas processing facility will be sourced locally, nationally and internationally, depending on the nature of the equipment and local availability. The larger processing vessels and equipment items, such as the main cryogenic heat exchanger and gas turbines, will be prefabricated prior to delivery to site. Preference will be given to sourcing materials and equipment locally where economically and technically practicable.

Following completion of the bulk earthworks, construction will commence on utility trenching and foundation installation.

Construction will require the use of lay-down areas for staging of equipment delivered by barges at the MOF facility. Construction will require the use of several large cranes and a concrete batching plant. Activities during the main construction phase will include steel and pipe erection, equipment setting, welding, electrical and instrument installation, along with insulation and application of coating materials.

During construction, various workshops and other temporary buildings such as offices, and warehouses will be required.

To ensure future expansion options are not technically compromised, the initial Development will include various works, such as:

- piping corridors – the location, layout and design of piping corridors will allow for installation of additional feed and product pipes alongside operational pipelines
- plant layout – the plant layout will account for the construction of the additional facilities next to an operational facility
- LNG tank pads – if blasting is required for the foundations associated with the additional LNG tanks required for a potential plant expansion, the necessary blasting will be undertaken during the initial phase of development.

No additional condensate tanks are envisaged for potential future expansion options as any increase in production could be accommodated by an increase in the frequency of off-take tanker movements.

Construction Utilities

A single utilities area comprising power generation, fresh and potable water plant and waste water treatment facilities and fuel storage will be established to accommodate the construction utilities plant. The utilities area will be established at an early stage to support early construction activities and provide services to the construction village.

The preferred location for the utilities area is either near the construction village or near the gas processing facility site. A utilities corridor will be established between the utilities area, the construction village and the gas processing facility to house the various services.

Utilisation of the existing infrastructure on Barrow Island will be considered to realise potential synergy opportunities where the existing operation can provide such utilities and services.

Water Storage

Two of the existing crude storage tanks on Barrow Island are redundant and are currently out of service. It is proposed to refit these tanks and utilise them to store treated construction water and potable water for commissioning activities. This will include installation of impervious liners within the tanks.

Tanks will also be provided within the utilities area and within the construction village to store potable water.

Sanitary Waste

Sanitary waste water systems are required to support all phases of the works from site preparation and infrastructure development through construction to the operating phases of the Barrow Island gas processing facility. The facility installed during the pre-construction phase will be modified, as necessary, to support the permanent operations. Investigations are currently examining alternatives for split stream processing, whereby the black (toilet) and grey (all other) water systems are dealt with separately to enable re-use of the treated grey-water for construction purposes.

Treated effluent will be disposed of via one or a combination of the following systems/methods:

- re-use for construction, hydrotesting and/or land farming
- utilisation of the existing produced water disposal system
- injection to drilled deep wells.

The treated process water and the effluent from the demineralisation plant will be combined with the treated water from the sewerage plant and injected into subsurface formations below Barrow Island.

It is anticipated that sludge will be removed from Barrow Island and disposed of on the mainland.

Power Generation and Distribution

Power generation and distribution to support the construction workforce accommodation facilities, construction works and utilities will be required to be installed early in the construction schedule. Planning is underway to install a connection to the existing Barrow Island central power station. This connection would provide initial power and allow electricity transfer from the Gorgon Development facilities in the future. It is presently considered this approach would be able to service a construction workforce until numbers reached approximately 600 personnel by which time the Gorgon Development power station would be commissioned.

The power station will provide power to the two major load centres; namely the gas processing facility construction site and the construction village. The power station will be located in the common utilities area. Current indications put the power station peak demand at approximately 15 MW which will be generated in a multi-unit configuration. The final configuration is yet to be finalised, but emissions will be similar regardless of configuration.

The power generator drivers will be dual fuel (i.e. gas/diesel) machines; both gas engines and gas turbines will be considered as the design proceeds. Construction fuel gas supply will be sourced from the existing facilities. Diesel fuel will be used as an alternative fuel in the event that fuel gas is not available at any time.

A power distribution network will be established to distribute power from the power station to the construction village, to provide construction power to the gas processing facility and to provide a link to the existing power system. The distribution network will be run over pre-disturbed land as much as possible. The distribution system will be an overhead power distribution system, 'ABC' conductors (insulated conductors) strung on power steel and/or concrete power poles. The use of insulated conductors will alleviate the necessity of regular maintenance intervals that would normally be required using bare conductors.

Telecommunications

A communications network will be installed at Barrow Island to support the gas processing plant and the construction activities. The network will provide for radio, telephone and data links between most facilities on the island as well as providing a reliable link to the mainland by way of an optical fibre cable.

Two mainland landfalls locations are currently under consideration for the optical fibre cable. These include Onslow and Peedamulla, (which provides a shorter subsea route but a significantly longer terrestrial route).

The submarine section of the optical fibre route in each case will traverse relatively shallow and highly trafficked marine areas; a risk mitigation study may require that the cable be provided with some form of protection either locally or along the entire cable route. The principal method of protection will be trenching; however, in close coastal areas, other methods may be utilised. To protect the terrestrial section the cable will be buried over its entire length.

Landfall at Barrow Island will utilise areas that have been previously disturbed and/or within utilities corridors. The preferred cable landing point on Barrow Island is the Marine Offloading Facility but other previously disturbed areas may be considered.

Refer to Figure 6-18 for a proposed optical fibre route from Barrow Island to the mainland.

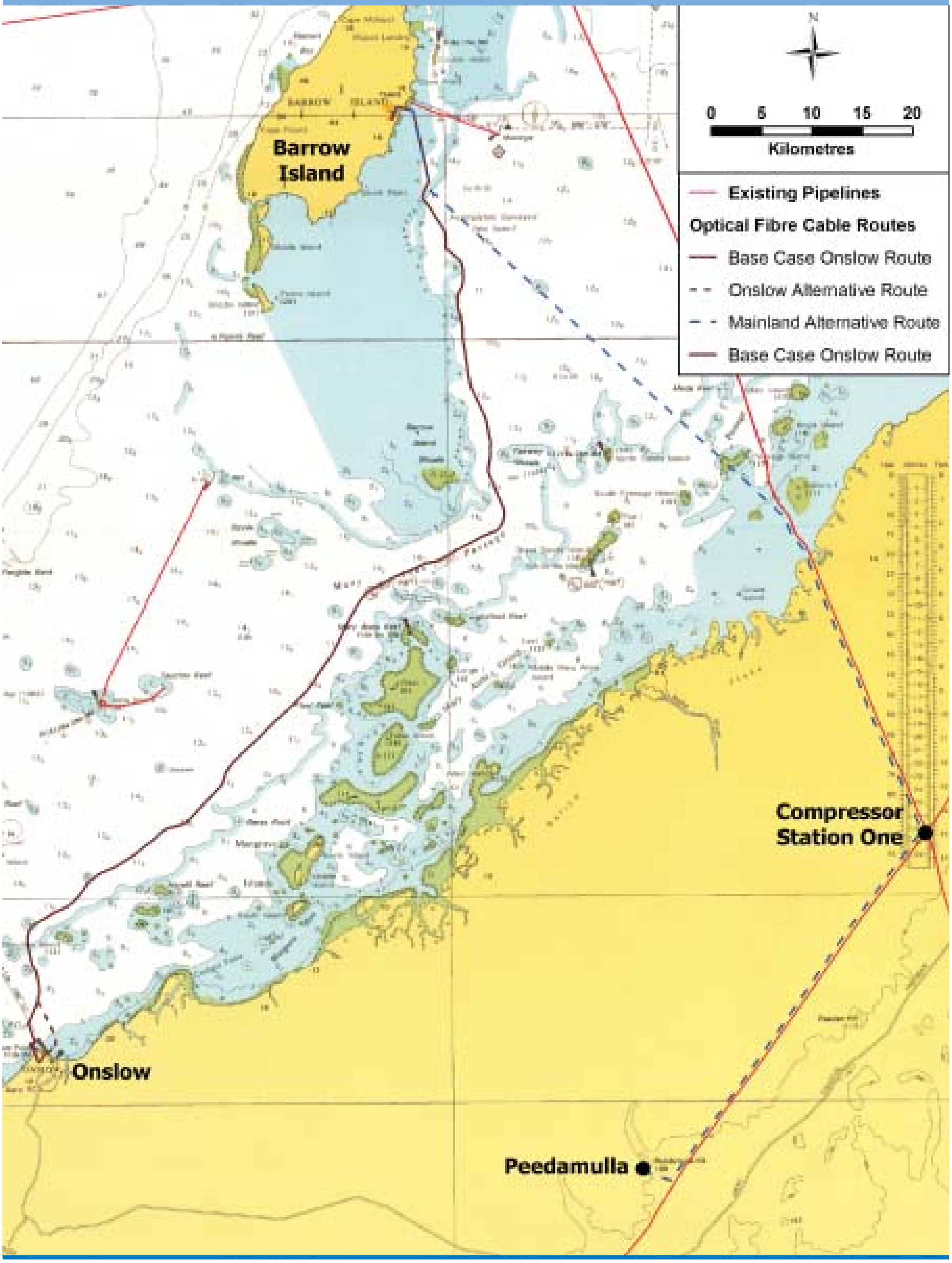
Diesel Supply

Diesel consumption during the construction phase has been preliminarily estimated at approximately 9 million litres. This figure excludes consumption that may be required for the new power station which is pending confirmation of gas supplies.

Diesel will be delivered to Barrow Island from the mainland via barges, which in the first instance will land at the existing barge landing. Later, as the MOF and associated facilities are commissioned, it will be used for fuel offloading as this will decrease the travel distance from the existing Barrow Island landing point to the major area of consumption.

For bulk storage, relocatable, self-bunded storage tanks designed, operated and maintained in accordance with AS1940 'The Storage and Handling of Combustible Liquids' and AS1692 'Tanks for Flammable and Combustible Liquids' will be used for storage volumes up to approximately 60 000 litres and

Figure 6-18:
Possible Routes for Optical Fibre Communications Link



may be used for as much as 100 000 litres. Alternative schemes for bulk storage will be considered in circumstances where the self-bunded tanks are either uneconomical or where permanent storage is required to support the operating phase of the Development.

Potable Water Supply

Potable water will be provided by a reverse osmosis plant or similar water making technology. A production capacity of 1000 m^3/day will be required with peak production capacity of approximately 1500 m^3/day fresh water output. The system will be designed to support all phases of the Development.

The most significant single requirement for water will be associated with hydrotesting the feed gas pipelines and the LNG tanks. This is discussed in the relevant sections for these activities.

Horizontal directional drilling will be used for the pipeline shore crossings, and this technique will also require a significant quantity of water (approximately 20 000 m^3) which would most likely be salt water, but may need to be fresh water depending upon the selection of drilling mud.

Three options are currently being considered for the supply of water to the water making facilities as discussed in Box 6-9.

Brine Waste Water Disposal

The water making process will produce approximately 3000 m^3/day of waste brine during peak fresh water demand. The waste water from the water making plant will be disposed of via one of two alternatives presented in Box 6-10. Options are currently being assessed.

Waste Staging Area

Various wastes will be generated through all stages of the Development as described in Chapter 7. The principles of 'avoid, reduce, re-use, and dispose in an environmentally responsible manner' will be followed. The principal focus will be on avoiding waste at the source by working with the suppliers in the tendering and contracting processes. Appropriate waste segregation and storage facilities will be provided, such as for food wastes (e.g. covered where possible to keep out fauna), scrap steel (i.e. for recycling), hazardous wastes (e.g. bunding for liquid wastes in line with relevant Australian Standards), and other similar appropriate facilities. These facilities will be designed in accordance with Australian Standards and incorporate best practice principles.

Box 6-9:
Water Supply Alternatives

Alternatives for the water supply that are currently being considered are:

- groundwater
- seawater
- the Dupuy formation.

One option is to provide source water from a new saline water bore field located close to the Development site. The design, location and number of the water extraction wells has not been finalised but it is anticipated that saline water will be drawn from Tertiary limestone aquifers at 150–250 m below the surface. The extraction rates and design of the well(s) will ensure that the halocline (freshwater/salt water interface) remains stable, and the associated draw down will be minimised, so that any impact to the freshwater lens is avoided or minimal. The water from this location is expected to have salinity similar to seawater.

Direct supply from the ocean will require dedicated infrastructure for the intake, consisting of a pipeline secured to the sea floor via rock anchors, burying or concrete mattresses, as the LNG jetty or MOF will not be completed when the water is first required for construction. The intake line will require chemical treatment, such as chlorine, to prevent fouling by marine organisms. A dedicated seawater intake (and offshore disposal of water maker effluent) is still being evaluated as an option. If this option is selected, the intake pipeline will be designed in accordance with good engineering practice and it is currently anticipated that the flow rates will be accommodated by a 300 mm line. The intake will be located away from areas of marine vessel activity in an area that remains submerged during low tides. It is possible, due to suction head requirements, that the intake will not be operable during some tidal conditions.

The third option is to drill wells deep into the sands of the Dupuy formation, potentially using the CO_2 injection monitoring wells. This option will provide a lower salinity water source than seawater or alternative groundwater which minimises the energy requirement of the reverse osmosis plant and avoids the need for the use of extensive corrosion resistant materials. The cost of drilling wells over 2 km deep, the temperature of the extracted water, the energy to pump from this depth and the risk of hydrocarbon contamination in the Dupuy formation is likely to

Box 6-9: (continued)
Water Supply Alternatives

result in this option being discarded. A data well into the Dupuy formation is being undertaken for CO_2 injection testing and the well will be completed to enable testing the Dupuy formation as a water supply option.

However, selection of this method of saline water extraction is dependent upon hydrogeological investigations, which are scheduled for the third quarter of 2005. The investigations will be focussed on:

- potential impacts to subterranean fauna habitat
- well design for extraction and re-injection
- definition of the fresh/brackish water lens, the halocline and the seawater interface
- sustainable yield of the Tertiary limestone aquifers for both the construction period, and ongoing operations
- aquifer parameters including permeability and porosity
- aquifer recharge
- groundwater extraction impacts including water quality and water table levels
- groundwater management procedures
- bore field design to maximise yield and reduce water level impact.

These investigatory water wells do not form part of the proposal covered by this Draft EIS/ERMP as they will be constructed during the EIS/ERMP assessment period and will be subject to a separate approval process. Information is provided here only to provide background to the reader.

6.3.7 Construction of Onshore Water Supply/ Re-Injection Wells

Onshore water supply and injection wells (if required) will be drilled using conventional water well drilling methodology, i.e. mud rotary drilling. Drilling mud, consisting of a suspension of bentonitic clay in water, is the most common drilling fluid used. This drilling mud coats the wall of the hole which provides stability of the hole and prevents the loss of drilling fluid to permeable formations. If the drilling mud cannot prevent the caving in of the walls, a well casing will be placed as the drilling proceeds. The wells will be drilled to approximately 350 mm diameter to install 200 mm diameter casing.

Box 6-10:
Alternative Brine Waste Water Disposal Options

The options for disposal of waste brine from the water making facilities essentially fall into two categories: injection and offshore disposal.

The injection option involves disposal of the effluent water into a formation approximately 200 m beneath Barrow Island.

The option for disposing brine from the water making system (i.e. reverse osmosis unit or similar) directly to the ocean is currently being investigated. This water will essentially be concentrated seawater and so will pose negligible environmental risk. The benefit of this option is that it avoids using up capacity of the injection system. The offshore disposal option would occur via an ocean outfall as is common practice and is currently being employed for the disposal of brine from the 500 m^3/day Rottenest Island potable water production facility. This method of disposal will be subject to further investigation to assess the requirements for pre-treatment additives (if any) and their impact. If this option is selected, a mechanism of diffusion will be employed to ensure suitable dispersion in the proximity of the discharge.

The alternative method of disposal of the brine is via re-injection wells drilled in a location close to, but sufficiently remote from, the saline source wells to avoid cross contamination of the groundwater. This option is being assessed as part of the groundwater assessment discussed above.

Refer to Chapters 7, 10 and 11 for additional details on these options.

To support the drilling operations a pad of approximately 20 m x 40 m will be required and the following will also be required:

- access tracks for personnel and equipment
- water and other materials required for the drilling muds
- a level work site on which to place the rig
- excavated lined pits or tanks in which to store drilling muds and measure well yields
- facilities to remove cuttings from the drilling fluid
- systems to manage cuttings disposal
- facilities to enable each well to be cleaned up.

6.3.8 Construction of Marine Facilities

A MOF will be required as early as possible in the construction cycle to move equipment and materials to Barrow Island. The initial equipment will be landed at the existing barge landing (Plate 6-11) until a landing can be developed at the MOF site.

The initial concept was to dredge a channel into a land-backed MOF wharf at Town Point using a cutter suction dredge and hopper barges, then disposing dredge spoil at nominated sites shown in Chapter 7.

However, investigations indicated that the material near the shore will need to be drilled and blasted prior to dredging. To reduce this impact, an alternative concept was developed to construct a causeway out into deeper water. While there is still a requirement to dredge, the material appears softer and the quantities have been significantly reduced from that expected in the original concept. Should any isolated pockets of hard material be encountered, it may be necessary to undertake limited drilling and blasting. However the existence of such material is not indicated in any of the geotechnical or geophysical investigations. It is currently expected that the MOF channel will require dredging of approximately 800 000 m^3.

The causeway and MOF head will be constructed from a core material, faced with armour protection. The core material will comprise a combination of cut material from preparation of the plant site and as much dredge spoil from the MOF channel as practical. This will alleviate the need to import core material from the mainland and reduce the amount of dredge spoil at the disposal site. Armour protection will comprise rock imported from the mainland and precast concrete units.

The construction will commence by utilising rock material from the site preparation to construct a containment bund around the perimeter of the MOF and causeway. The bund will be lined with a geotextile to prevent sediments dispersing through the bund. A cutter suction dredge will excavate material which will be piped directly into the bund area. Fine suspended particles will pass through the geotextile and overtop the bund as the infill material is dewatered by the construction process. This method alleviates overflow and propeller wash from hopper barges which would be required if offshore disposal was adopted.

Any remaining dredge spoil not accommodated within the bunded area will be transferred by hopper barges and deposited at the nominated dredge disposal sites shown in Chapter 7. However, the final design will be based on balancing the MOF size and dredge quantities.

Utilisation of dredge spoil onshore for general fill material is a practical engineering solution for the disposal of the material. However, this was discounted due to the salt content of the spoil potentially impacting the surrounding vegetation and/or the existing groundwater regime.

Figure 6-10 shows the proposed MOF and associated channel layout.

Plate 6-11:
Existing Barge Landing

Shipping Channel and Turning Basin

Dredging will be necessary to create a shipping channel and turning basin that is approximately 14 m deep (Figure 6-10). The current estimate of the volume of dredge material produced is approximately 9 million m^3. It is proposed that the channel will be dredged by removing unconsolidated material by trailer suction hopper dredge, then using a cutter suction dredge to break the hard material and load into hopper barges moored alongside the vessel. In order to further reduce the impact of surface turbidity, an alternative dredging method is being assessed which makes greater use of the trailer suction hopper dredge. This alternative method has the potential to minimise the abrasion caused by handling of the dredged material through pumps and pipelines. This method would also minimise aeration. The selection of the alternative will be based upon demonstrable reduction in predicted environmental impacts based on modelling, technical feasibility and equipment availability.

Should any isolated pockets of hard material be encountered, it may be necessary to undertake limited drilling and blasting. However the existence of such material is not indicated in any of the geotechnical or geophysical investigations. Further investigation drilling will be undertaken. For further details on management of dredging operations refer to Chapter 11.

Dredging from the LNG berth and turning basin areas is expected to result in 2–4 million m^3 of fist sized rock fragments and coarse sand. This material will be used elsewhere in the Development if feasible.

Jetty Construction

The LNG jetty will be installed with equipment similar to that shown in Plate 6-12. This typically requires a combination of drilling and driving jetty piles. Small plumes of drilling fluid and cuttings will be associated with these activities, but these are very low volumes.

To ensure potential future expansion options are not technically compromised, the proposed Development will include the following:

- Jetty location – the location of the jetty was selected such that the additional LNG ships associated with any potential future expansion can use the same approach channel.
- Jetty design – the location and design of the jetty will be such that an additional berth can be added to accommodate the additional LNG carriers associated with a potential plant expansion.

Maintenance Dredging

Modelling of three significant tropical cyclones indicated a maximum of 50 mm of sediment could be deposited in the dredged area as a result of the cyclonic conditions. This indicates a need for only infrequent maintenance dredging to remove these silts and maintain the required water depth. Dredged material will be disposed to the same location as the spoil removed during the original dredging operation.

Plate 6-12:
LNG Jetty Construction Equipment

6.3.9 Construction of the Domestic Gas Pipeline

The domestic gas pipeline will be constructed from the gas processing facility to Town Point extending along the MOF causeway and the jetty. From the jetty, the pipeline will be located on the seabed. One option which is currently being examined is the opportunity to install a conduit in the MOF structure through which the domestic gas pipeline could be installed.

As the pipeline approaches the mainland it will again be trenched, backfilled and stabilised for the shore crossing. Near shore, the pipeline will be laid using a shallow water lay-barge which minimises dredging requirements. Surface materials at the mainland shore approach are unconsolidated marine sediments. The current base case is to use the existing Apache Energy Gas Sales Pipeline approach to shore and the existing shore crossing on the mainland. Tidal variation will be used to maximise the shore crossing construction from the onshore side.

The onshore pipeline section to Compressor Station One on the Dampier to Bunbury Natural Gas Pipeline will be buried to a depth to allow for approximately 750 mm of cover except where valving stations are required. This section of pipeline will require an easement width of approximately 30 m and will be aligned parallel and adjacent to the existing pipeline through pastoral grazing land. The construction of the pipeline will be confined to the easement and will involve:

- clearing the easement, including retention of topsoil
- trenching, using either backhoe or wheeled ditching machine
- bending, aligning, welding coating (joints)
- non-destructive testing of the weld joints
- placing the pipeline in the trench
- backfilling the pipe trench, and restoring topsoil as far as practicable and installing surface breakers and water control structures as required
- hydrostatic testing of the installed pipeline
- remediating and revegetating the easement.

6.3.10 Installation of the Optical Fibre Cable

The main portion of the optical fibre cable will be installed using offshore vessels and shore crossing equipment which is broadly similar to that already discussed. Under the *Telecommunications Act 1997* all of the methods to be used are deemed 'low impact'. The offshore component is expected to take less than two weeks to install. A preliminary desktop study has identified a preferred alignment based on computerised modelling of bathymetric and environmental considerations. A detailed submarine route survey is yet to be undertaken to determine the optimal alignment of the marine section of the route.

The mainland onshore section is expected to be buried below the natural surface of the ground using conventional earthmoving equipment.

6.3.11 Construction of Other Pipelines

The following pipelines will be installed in a manner that is largely consistent with that described for the fee gas pipeline:

- CO_2 pipeline
- onshore water supply/disposal pipeline(s)
- offshore water supply/disposal pipeline(s)
- new condensate loadout line
- common interconnections.

6.3.12 Pipeline Hydrotesting

Prior to operation, the feed gas pipelines, domestic gas pipeline, CO_2 pipelines, and auxiliary pipelines will be filled with treated water, leak-tested and pressurised to confirm their integrity in accordance with AS 2885 and other applicable codes. This will require approximately 35 000 m^3 of water for the feed gas pipeline. Fresh water will most likely be required to test the feed gas pipeline because corrosion resistant alloy pipe cannot withstand the high chloride content of seawater. Where fresh water is required, it will be sourced from the water-making facilities installed at the gas processing facility. Hydrotesting will also require approximately 5500 m^3 water for the domestic gas pipeline and additional water for the auxiliary pipelines. The water will be re-used between services where practicable.

Hydrostatic test (hydrotest) liquids will remain in the pipeline sections until they are discharged at the commencement of the pre-commissioning works (e.g. dewatering, swabbing, and drying if required). If the hydrotest liquids must be discharged to the sea, this will occur at a location and flow rate that will minimise environmental impacts. It is proposed that the feed gas pipelines and auxiliary lines will be dewatered from the Barrow Island end toward the offshore facilities to utilise the seabed profile and minimise the environmental impact.

Unlike the feed gas pipelines, the domestic gas pipeline is land-locked at both ends. Water will most likely be provided from Barrow Island because sourcing water from the mainland would create another quarantine pathway. The base case concept is that the domestic gas pipeline will be dewatered from the mainland towards Barrow Island, so that the maximum possible re-use of water can be made prior to being injected into the deep water disposal wells. Other potential options for disposing of the water from the domestic gas pipeline include to:

- pump the water to the mainland and store in a constructed bund, allow natural evaporation to occur and then reclaim the contaminants for disposal
- pump to the mainland and use road tankers to transport the water to a designated disposal site (which will require around 800 tanker loads)
- dispose of the water off the east coast of Barrow Island such as off the jetty at a rate which presents acceptable level of environmental risk.

Based on current technology, typical treatment chemicals which will be used as part of the hydrotest program include oxygen scavenger, biocide, corrosion inhibitor and a dye to detect any leaks. Chemicals used during the hydrotesting process will be pre-approved by regulatory authorities in compliance with the pipeline permit application and will be consistent with current industry practice. Minimum volumes of chemicals will be used and the toxicity of chemicals and potential disposal techniques will be considered during the selection process to avoid potentially adverse environmental consequences of testing and commissioning activities. All aspects associated with managing the hydrotest operation, and alternatives considered, will be included in hydrotest water management procedures.

An alternative which may prove feasible (subject to safety considerations) for the subsea pipelines is the use of pneumatic testing (i.e. using a gas such as nitrogen or hydrocarbon gas) instead of hydrotesting (i.e. water). This will be examined in more detail as the design progresses.

6.3.13 Onshore Equipment Hydrotesting

As the LNG tanks, MEG tanks and condensate tanks will be built on Barrow Island, they must be hydrotested *in situ.* They will also require a significant volume of water which, in the case of the LNG tanks, is expected to be fresh water.

The hydrotest water used for pressure testing the pipes, vessels and tanks will be re-used several times through the various gas processing facility components wherever reasonably practicable. The hydrotest water will be similar in composition to the pipeline hydrotest water. Once the hydrotest water is no longer required, the current base case is that it will be disposed of through the waste water injection system. However, offshore disposal (such as via the feed gas pipeline) may be an option depending on the required timing of activities and technical requirements regarding hydrotest water quality.

A number of options may prove feasible for disposal of the hydrotest water from the LNG tanks. An option that will be available if no chemicals are used (or are minimal) is disposal into natural water courses, or use as a dust suppressant. However, these uses may require short-term (days) storage to enable the water to be re-oxygenated. If this is not possible, then offshore disposal may be feasible. As a last resort, test water will be injected with other waste water streams. Pneumatic testing may also prove to be feasible for some equipment, subject to safety considerations.

6.4 Pre-Commissioning, Commissioning, and Start-Up

Once installed the facilities must be commissioned. This involves checking that all equipment works, expelling air from hydrocarbon systems, introducing hydrocarbons into the systems and starting equipment for the first time. The following section examines the main aspects requiring commissioning and briefly describes the commissioning process.

6.4.1 Commissioning of the Gas Processing Facility

Commissioning the gas processing facility comprises a number of steps. However, as the design of the plant and specific equipment components is only conceptual at this early stage, detailed commissioning requirements have not been developed. Environmental management procedures will be developed to cover this phase once further definition is available.

The major steps in the commissioning process will be:

- cleaning of some systems (e.g. an acid wash, such as using citric acid to clean the pipework and vessels of scale; steam and air blowing, flushing of the compressor lube oil systems to remove debris; and a 'caustic' wash to remove grease and oil from the a-MDEA system)
- commissioning of rotating equipment (turbines and pumps)
- pressure testing of the various vessels, piping systems and tanks
- bulk loading of the various solvents and chemicals required in the process (e.g. a-MDEA, TEG and MEG)
- bulk loading of the various adsorbents required in the process, such as molecular sieve for dehydration, and activated carbon for the mercury removal unit
- first fill of refrigerants
- introducing gas into the facility and the cooling and stabilisation of the process
- testing the various systems.

Once equipment has been installed, it will be necessary to confirm that the system has no leaks. This will be accomplished by leak testing systems at their operating pressure using air or some other safe fluid. The initial introduction of gas into the process equipment will be undertaken very carefully. First gas will be introduced to slightly pressurise the equipment. Potential leak sources, such as flanged connections, will be checked to confirm their integrity and rectified if necessary. As the system is further pressurised, potential leak sources will be rechecked. This process will continue in stages until the system is up to operating pressure and has no leaks.

Any water present in equipment will be removed as it could freeze in the cold conditions associated with LNG production and impact the process. Moisture in the air cannot be tolerated, so a dry source of feed gas will be heated, passed through the process equipment systematically and (normally) directed to the flare, as it will not meet product specifications.

Once the system has been confirmed to have no leaks and has been defrosted, it will be ready to commence cooling the equipment to normal operating temperatures. As the system will initially be too warm to create LNG, the gas will be directed to the flare in line with normal practice. However as the process continues, and systems cool down toward their normal operating conditions, LNG will begin to be produced. The system throughput can then be slowly increased until steady operation is achieved for the first time.

Recycling gas back to the plant inlet is one option that may prove feasible in reducing flaring associated with these operations. This option will be examined in the later design phases.

6.5 Operation of the Gorgon Development

6.5.1 Operation of the Offshore Facilities

The offshore production wells will be controlled from the control room located at Barrow Island. Remotely Operated Vehicles (ROV), offshore work vessels and drilling rigs will be used for inspection and maintenance of the wells and subsea facilities. The flowlines, manifolds, and PLEMs will be periodically inspected by an ROV to monitor the exterior surface and surroundings and to detect any problems with seafloor conditions.

There may be a periodic requirement to maintain wells using a drilling rig similar to that already described or inspect the subsea infrastructure using an ROV. There will be very little other operational activity in the field.

6.5.2 Operation of the Gas Processing Facility

The initial start-up of an LNG plant typically takes several weeks. However, there is a strong economic incentive to stabilise operations as soon as possible to produce LNG product for export. Previous experience on similar facilities shows that during the first year, and in particular the first few months, the gas process typically has a lower availability than in subsequent years. This can result in unplanned equipment outages and thus some flaring of gas during the outage and subsequent restart.

The gas processing facility on Barrow Island will have a stable process, using well-proven technologies designed for continuous operation. As a result, it is expected that the facility will operate for more than 90% of the year. LNG loading will occur approximately one day in three when an LNG carrier is berthed at the jetty. During the remaining time, no ships will be present and all of the LNG will be directed to the storage tanks. The gas processing facility is expected to continue operating during cyclones, as currently occurs in the region, although shipping movements will be curtailed.

The gas processing facility will be controlled and its integrity monitored by a computer based Integrated Control System that includes a Process Control System, a Safety Instrumented System, a Subsea Control System and a Fire and Gas System.

The gas processing facility will have a comprehensive computerised maintenance database of all equipment items. This system will ensure that all inspection requirements are fulfilled, appropriate preventative maintenance of equipment items is conducted, and planned and unplanned downtime is monitored. Major shutdowns will be conducted on a regular basis (every few years) and will involve significant planning. Appropriate maintenance of facilities will ensure the integrity of facilities.

The number of unplanned shut-downs of the facilities is difficult to predict. However, based on operational experience on similar facilities, it can be expected that approximately 10 shut-downs will occur per annum. These shut-downs could be initiated by the operators for maintenance, or if the gas processing facility is at risk of operating outside of its design limits. The automatic safety instrumented shut-down system could also initiate a shut-down. Depending on the cause of the shut-down, the gas processing facility could be either shut-in with no depressurisation to the flare, or undergo partial or complete depressurisation.

6.5.3 Operational Workforce

The operational workforce on Barrow Island is anticipated to be 150–200 people, with approximately the same number on rotation off the island. One option is to accommodate the operational workforce in the existing oil field operations camp. This will require an expansion of the existing facilities and upgrade of some of the supporting infrastructure. The expansion will occur within existing disturbed areas. Various support personnel will also be required in Perth.

6.5.4 Transportation during Operations

The gas processing facility will require relatively few raw materials beyond the production fluids from the wells. However various production chemicals, such as antifoam, corrosion inhibitor, a-MDEA, MEG, TEG, lube oil for rotating equipment and similar materials, will be required on first fill and subsequent routine basis. It will be necessary to bring ethane and propane onto the island for the first fill of the cooling circuits to enable the system to operate, until such a point that it is self-sufficient in these essential materials for the refrigeration system.

The current Barrow Island oilfield operation is supported by 1–2 barges and five planes per week (although aircraft currently service supports a range of other operators in the area). Gorgon Development (at steady state conditions) is expected to require two additional barges per week and two additional planes per week.

6.6 Decommissioning

The gas processing facility and equipment will be decommissioned when operations are no longer economically viable. Specific equipment may be decommissioned when no further use can be found for that equipment. Prior to any decommissioning, re-use and recycling alternatives will be considered where feasible. These may include: removal from Barrow Island for use by another operator; removal from Barrow Island for sale to a third party; transport of hydrocarbons for a future development; and/or access to the plant and equipment for additional field(s).

If none of the above options are feasible, the facilities (or parts of) and associated infrastructure will be decommissioned. The aim is to leave the areas utilised by the Development in an appropriate condition which allows them to be transferred back to state or federal agencies. This generally means that whatever remains after decommissioning, it should pose negligible risk to safety and the environment.

The decommissioning of all offshore facilities is covered under International Maritime Organisation (IMO) resolutions, the Commonwealth *Environment Protection (Sea Dumping) Act 1981* (which implements the IMO's London Convention 1972) and *Petroleum (Submerged Lands) Act 1967.* Relevant pipelines will also be covered by the Western Australian *Petroleum (Submerged Lands) Act 1982* and the *Petroleum Pipelines Act 1969.* The requirements of all these legislative instruments have been included in the possible decommissioning options outlined below. The main considerations of the above regulations are: that safety of navigation will be ensured; that marine pollution will be prevented or controlled; and that the marine and terrestrial environment will continue to be protected.

As the life of the proposed Development is expected to be in the order of 60 years, it is reasonable to assume that there will be changes to decommissioning procedures and regulatory requirements that incorporate advances in technology and information. Rather than making definite commitments to exact procedures now, the Joint Venturers will adopt best practices in environmental management at the time of decommissioning. However, the basic principle is that all surface equipment will be removed and the site rehabilitated.

The strategies outlined below indicate current industry practice in decommissioning. The general principle will be to flush and purge any equipment of hydrocarbons, ensuring that there is no, or minimal, adverse release to the environment and that a maximum amount of hydrocarbon product will be safely recovered.

The equipment will then be recovered for its existing use, recovered for scrap, or if the impact of removing the facility is greater than leaving it in place, abandoned *in situ.* For larger equipment items, it may be necessary to undertake a lifecycle analysis, which includes consideration of the energy, safety and resource requirements involved in recovery and the recycling of the equipment if recovered, together with other environmental impacts associated with the recovery process. This is of particular relevance to the offshore facilities that will be at a water depth greater than 200 m.

6.6.1 Decommissioning of Production Wells, Subsea Facilities and Flowlines

An assessment of decommissioning options will be undertaken approaching the end of the Development life. Current industry practice is to plug production wells and recover some elements such as manifolds, well flowlines and well heads. Larger elements such as the intrafield flowlines will be treated in the same manner as pipelines. The assessment will give due consideration to all regulatory requirements and industry standards.

6.6.2 Decommissioning of Pipelines

The current industry methodology for decommissioning offshore pipelines is:

- flush the pipeline of hydrocarbon liquids and vapour
- flood the pipeline with seawater
- seal the pipeline openings with mechanical plugs
- abandon all subsea sections of pipeline in place (including rock dumping) to minimise disturbance
- remove other ‘above-seabed’ facilities including the tie-in spool, subsea isolation valve assembly and the control umbilical
- update navigation charts for offshore areas to show what remains.

The current industry methodology for decommissioning onshore pipelines is:

- flush the pipeline of hydrocarbon liquids and vapour
- flood the pipeline with water
- seal the pipeline openings with mechanical plugs
- leave *in situ* all onshore sections that are buried
- remove above ground facilities including piping, equipment, controls, instrumentation and fencing and valve stations (including backfilling any valve pits)
- fill all major road/water crossings
- remove all warning signs along the onshore pipeline route
- rehabilitate disturbed land.

6.6.3 Decommissioning of the Gas Processing Facility

The decommissioning of the gas processing facility will be completed to standards that reflect community expectations and industry best practice at that time. Current expectations are that equipment which can be salvaged will be re-used/resold off Barrow Island. Where feasible, material which can not be used for its original purpose will be recycled/scrapped. The aim will be to minimise the amount of waste requiring disposal during decommissioning.

Prior to the removal of any equipment, it will be depressurised, purged and flushed of hydrocarbons to ensure that the removal process does not result in significant or adverse hydrocarbon releases. Advances in the management of the decommissioning processes will be utilised.

The hydrocarbon product to be processed will be predominantly gaseous, therefore soil contamination is not expected to be an issue, as precautionary measures will be adopted in the design process to minimise the potential for soil contamination. However, a soil contamination survey will be conducted to determine if there has been any inadvertent contamination. If any significant contamination is discovered, a comprehensive soil remediation program will be instigated, consistent with best practice environmental management as it stands at the time of decommissioning. The aim will be to obtain certification from the relevant government authority that the site has been left to agreed standards.

Once gas processing facility equipment has been removed from the site, the land will be rehabilitated to a condition which is consistent with the surrounding environment. This will involve re-establishment of representative indigenous flora species, and contouring to match the surrounding landscape. Appropriate funds will be made available for rehabilitation and maintenance.

6.6.4 Decommissioning of the Marine Facilities

The jetty facilities associated with the ship loading operations will be flushed and removed in a similar fashion to the gas processing facility components.

As the removal of the jetty facilities has the potential to cause significant local turbidity effects, and therefore adverse environmental impacts, a comprehensive decommissioning plan will be developed beforehand. This plan will take into consideration any advances in technology that will reduce the impact of removal. It should also incorporate lifecycle considerations to ensure that removal is the best option. It may be found that removal of all hydrocarbon contamination and transfer of ownership to the relevant government authority is the preferred option. As the jetty will have been in operation for approximately 60 years, the local seabed area will have adapted to its existence. Thus, removal may actually cause more disturbance to the local benthic and aquatic flora and fauna than leaving it in place. The current assumption is that the jetty piles will be cut off at the mud line, removed and disposed of to the mainland.

The dredged shipping channel will not be refilled as the resulting environmental damage would be greater than leaving the channel to reach a natural equilibrium.

The MOF causeway will be left *in situ,* because disturbing it is likely to result in a greater level of environmental impact than allowing it to remain.

The new condensate line (if provided) and water supply/effluent lines (if provided) will be recovered because they are in shallow water.

6.6.5 Decommissioning of the Optical Fibre Cable

An environmental assessment will be conducted at the time of decommissioning to determine whether the optical fibre cable should be recovered or allowed to remain in place. After some 60 years of service, it is likely that its recovery cannot be justified due to the resultant impacts. However, if the cable were to be removed it is likely to require equipment similar to that used for installation.

6.6.6 Decommissioning of the CO_2 Injection Facilities

Decommissioning of the CO_2 compression facilities will be undertaken in a similar way to that described for the gas processing facility mentioned in Section 6.6.3. The CO_2 pipeline will be decommissioned in a similar way to that described in Section 6.6.2. The CO_2 wells will be decommissioned in line with the principles used for other wells as described in Section 6.6.1 and as further detailed in Chapter 13.

6.6.7 Decommissioning of the Water Supply/Injection Facilities

Decommissioning of the water supply/injection facilities will be undertaken in a similar way to that described for the gas processing facility mentioned in Section 6.6.3. The water supply/injection pipelines will be decommissioned in a similar way to that described in Section 6.6.2. The water supply/injection wells will be decommissioned in line with the principles used for other wells as described in Section 6.6.1.

6.6.8 Decommissioning of the Dredge Spoil Disposal Site

No specific decommissioning actions are proposed for the dredge spoil disposal site.

07: Emissions from the Development

A range of emissions will be associated with the proposed Gorgon Development. In the context of this chapter, the term 'emission' refers to atmospheric emissions, discharges to the marine environment and solid wastes.

Numerical modelling has been applied to predict atmospheric, noise and light emissions and the trajectory of a number of potential hydrocarbon spill releases, should a release occur. Other aspects, such as solid and liquid wastes, are also described. Where appropriate, the predicted or expected emissions are compared to existing legislative standards and guidelines.

Some emission levels, such as solid wastes, dust and light will be greatest during the construction period. Other emissions, such as atmospheric emissions and waste water, will be greatest during operation of the gas processing facility.

The modelling results indicate that the proposed Gorgon Development will meet or measure below established emission regulations and guidelines and standards for air quality (EPA 1999a) and National Environmental Protection Measure (NEPM) requirements. Similarly, noise standards for workers and residences will be achieved or bettered by the Development.

The light emissions expected from the proposed Development were also modelled with design and management measures proposed to reduce the light spill from the gas processing facility and marine facilities.

The risk estimates (primary, secondary and joint risk) of hydrocarbon spills from potential manifold and pipeline incidents, tanker groundings, and refuelling accidents are described for a range of worst-case but credible scenarios. The reservoir gas has a low percentage of liquid hydrocarbons and this will naturally reduce the magnitude of many spill scenarios and potential impacts. This combined with robust design and engineering standards, construction and operational management and maintenance practices, will keep the risk of a potential spill to the lowest reasonably practicable. The fate of hydrocarbons, in the unlikely event of a release, was also modelled to determine the area potentially affected during different seasons. The results of the modelling are provided in this chapter, and an assessment of the potential environmental impacts provided in Chapters 10 and 11, while full details of the studies are provided in the Technical Appendices.

The Gorgon Joint Venturers are proposing to employ currently applied, best practice technology to reduce emissions to the lowest level practicable. New technology will continue to be considered during further planning and design of the Gorgon Development where it can be demonstrated that the technology could benefit the environment with due consideration of reliability, efficiency, personnel safety, and overall capital and operational costs.

7.1 Introduction

Emissions will occur during the construction, commissioning, operation, maintenance and decommissioning phases of the proposed Gorgon Development. In the context of this chapter the term 'emission' refers to atmospheric emissions, discharges to the marine environment and solid wastes.

The major emission sources associated with the Gorgon Development are identified and discussed in this chapter. Emissions will be both routine and non-routine. The emissions from the existing Barrow Island facilities are also included in order to address the potential cumulative levels. Conservative emission data and equipment specifications were used at this stage of Development planning to establish benchmark emission levels that can be used to identify potential issues. Opportunities to further reduce emission levels exist and will be pursued during the detailed design phases of the Development.

This chapter provides a summary of the results of a number of technical studies prepared by consulting companies specialising in predictive atmospheric emission, noise level, light, spill and trajectory modelling (Technical Appendices B1–B5).

Predicted emission levels are compared to existing legislative standards and guidelines where they exist. The potential impact, consequences, mitigation and management of these emissions are discussed in Chapters 10 and 11 of this Draft EIS/ERMP.

From the results of the ESE Review (ChevronTexaco Australia 2003a), carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions were identified as being topics of particular interest. These emissions and proposed mitigation strategies are addressed in Chapter 13.

7.2 Atmospheric Emissions

7.2.1 Predicted Emissions from Construction Activities

Atmospheric emissions from the proposed Development will be associated with marine vessel engines required during construction (e.g. drilling rigs, pipe-lay barges, tugs, dredges, hopper barges, supply boats and barges). There will be an increase in emissions from additional airline flights to and from Barrow Island and from vehicles and equipment required to support the large construction crew on the island. Incidental to this will be the increased traffic and construction related to the mainland supply base. These sources have been considered and will contribute to overall emission levels. However, the volume and duration of the emissions from the 15–20 marine vessels used during construction, the additional air traffic to Barrow Island and increased number of construction vehicles and equipment will not be significant in comparison to emission levels during the operation of the Gorgon Development. Further, they will not be concentrated in a single location for an extended period of time.

Dust emissions will be generated during construction and site development for the gas processing facility, onshore well drilling, construction of pipeline infrastructure and associated facilities such as roads, and through a number of activities including:

- clearing of vegetation and removal of topsoil
- earthmoving activities such as levelling of the site, excavation and the transport of fill within the Development site
- movement of heavy machinery and vehicles on unpaved surfaces
- blasting for site levelling and trenching.

Dust arising from some or all of these activities has the potential to adversely impact on human health, visual amenity, water catchment, vegetation and fauna in the immediate area. Use of water to reduce and control dust will limit the extent of this emission. Some of the major road and access surfaces will be sealed to further reduce dust emissions.

7.2.2 Predicted Emissions from Normal Operation of Gas Processing Facility

During operation of the gas processing facility on Barrow Island, there will be atmospheric emissions of greenhouse gases, other combustion products and waste gases.

Atmospheric emissions can have potential global, regional and local impacts. For example, global effects are caused by the accumulation of greenhouse gases and the depletion of ozone in the stratosphere. Regional impacts are those that could be encountered several kilometres to several hundred kilometres from the source, while local impacts would be those considered adjacent or within a few kilometres of the proposed Development.

The Gorgon Joint Venturers are proposing to employ the currently applied best practice technologies to reduce emissions to the lowest levels practicable. For example, specifying high quality valves, seals, fittings, and piping will significantly limit potential fugitive emissions from these point sources. Consequently the emission sources will be primarily restricted to the combustion and exhaust from natural gas turbines used in the LNG process and as power generators. The principal emission from the Development, after CO_2, will be oxides of nitrogen (NO_x).

It is recognised that while Dry, Low NO_x (DLN) burners are practical in reducing NO_x emissions in gas turbines which are running at full power, they may not be practical or efficient in the power generation turbines which will be running at low load and may actually increase NO_x emissions. The emission modelling described in this chapter has used DLN burner technology for all the process and power gas turbines as the base reference case. The final power and process design will determine the optimum application of DLN burners on the gas turbines to most effectively reduce NO_x and greenhouse gas emissions.

Typically almost all benzene, toluene, ethylbenzene, and xylene (BTEX) emissions from the gas processing facility occur during the CO_2 removal process.
The Joint Venturers have implemented several strategies to virtually eliminate hydrocarbon (including BTEX) emissions from the Development under normal operations. The Joint Venturers will approach this issue in the following ways:

- disposing of reservoir CO_2 by injecting it into the Dupuy formation along with associated traces of hydrocarbon, BTEX and hydrogen sulphide (H_2S). Note: some venting of this stream will occur during equipment downtime as discussed in Chapter 13.
- using of accelerated-Methyl Diethanolamine (a-MDEA) solvent to minimise the removal of hydrocarbon and BTEX from the gas stream.

Another potential source of BTEX from the facility will be from the regeneration of monoethylene glycol (MEG), which will be redirected to the LNG process stream.

Combustion Products

The principal emissions from the LNG process arise from combustion of natural gas. The most significant products of natural gas combustion include: CO_2 and NO_x together with some carbon monoxide (CO) and uncombusted hydrocarbons or volatile organic compounds (VOCs). There may also be traces of particulate matter and sulphur dioxide (SO_2) but such emissions will be negligible because of the efficient combustion equipment and the very low sulphur content of the natural gas.

Atmospheric emissions from the gas processing facility will vary depending on the operating and tanker loading conditions. These include normal plant operations, ship loading and non-routine operations such as commissioning, plant start-up and shut-down. Emission modelling for the Development assumed that normal operating conditions will occur in excess of 90% of the time. During normal operating conditions, LNG production will be accompanied by the loading of product onto LNG tankers for up to 30% of the time. Based on a typical 6-year maintenance cycle for gas turbines, the planned maintenance outages could result in an average of approximately 13 days/train/year. LNG production would be reduced during these periods.

Non-routine operations, including process upset situations, requiring some plant or equipment depressurising to flare or shut-down may occur approximately 10 times per year. A shut-down for planned and emergency situations will normally result in less than 1-hour of peak flaring as the high pressure gas streams are stopped and the process equipment depressured. Flaring during a normal start-up will be approximately 6 hours duration. Flaring during the initial plant commissioning will be more extensive, but this will be a once only occurrence

While the selection of the gas turbine drivers for the LNG facility has been determined, engineering options for the configuration of the gas turbines for electrical power generation are currently being studied with selection of the final configuration due after the release of this Draft EIS/ERMP for public review. At the time the atmospheric emissions modelling was undertaken, it was anticipated that the sources of atmospheric emissions would be dominated by:

- three 116 MW industrial gas turbines with DLN burners for electrical power generation
- four 80 MW industrial gas turbines with DLN burners for mechanical drive in the LNG processing facility
- two package boilers raising the equivalent of 150 MW of steam.

Table 7-1:
Predicted Combustion Emissions During Normal Operations

Source/Equipment	Emission Estimates			
	Total NO_x		Total Particulate	
	Kilograms/hour (kg/hr)	Tonnes per annum (tpa)	(kg/hr)	(tpa)
Basis of Atmospheric Modelling				
Electrical Generation: 3 x 116 MW gas turbines	190	1700	12	105
LNG Process Drivers: 4 x 80 MW gas turbines	240	2100	10	80
2 x Boilers (150 MW)	70	630	7	56
Total (Basis of Modelling)	500	4430	29	241
Current Design Reference Case				
Electrical Generation: 5 x 80 MW gas turbines operated at 67% load	240	2100	10	80
LNG Process Drivers: 4 x 80 MW gas turbines	240	2100	10	80
Total (Current Design Reference Case)	480	4200	20	160

The atmospheric emissions modelling documented in Appendix B1 is based on this configuration.

Engineering work completed recently has eliminated the option of the 116 MW industrial gas turbines. Consequently, the design reference case is now based on five, 80 MW gas turbines operated at 67% load for electrical generation and has eliminated package boilers. (Hot oil has replaced steam as the base case for the heating medium. Refer to Chapter 6.) The level of atmospheric emissions from this configuration is anticipated to be slightly less than that assumed in the atmospheric modelling. Table 7-1 lists the emissions estimated by the atmospheric modelling and the level of emissions anticipated from the revised design reference case design. Consequently, the modelled atmospheric emissions should be considered as worse than expected.

Emissions of sulphur oxides are expected to be extremely low, as 75% of fuel gas would be sourced from ‘end-flash’ gas (Chapter 6) which has negligible sulphur content. Sulphur levels in the raw feed gas are also predicted to be very low.

Carbon monoxide emissions will also be negligible and have not been examined in detail for this phase of the Development because modern combustion equipment has an extremely high conversion efficiency. Hydrogen sulphide in the raw feed gas will be removed along with CO_2 in the ‘acid gas’ removal process and disposed of by injection into the Dupuy formation 2000 m below Barrow Island. There will be no significant continuous hydrocarbon vents or emissions.

Non-Combustion Products

Volatilisation from storage and loading of hydrocarbon products, compressor seals and component leaks (e.g. valves, flanges and pumps) are all sources of non-combustion products that can be classified as potential non-combustion emissions.

Historically, compressor seals have been a significant source of fugitive emissions in LNG facilities. The proposed Gorgon Development will use dry-gas compressor seals or similar technology that virtually eliminate fugitive emissions from this source. The adoption of appropriate plant design and equipment has significantly reduced the potential level of these emissions from the gas processing facility.

Vapour recovery will be used on LNG storage and loading/handling facilities and other specific locations where practicable (Chapter 6). LNG boil-off gas will be captured and returned to the gas processing facility where it will be used as fuel gas. There will be two large condensate storage tanks which will have internal floating roofs to minimise fugitive emissions. During the subsequent phases of engineering design and equipment selection there will be further opportunities to consider eliminating and/or reducing hydrocarbon emissions.

There will be a vapour recovery system installed on the LNG tanker loading system. As with the storage tanks, LNG boil-off gas and displaced vapours will be captured and returned to the gas processing facility where it will be used as fuel gas. It is proposed to load condensate through the existing Chevron Australia tanker loading facility at Barrow Island. This loading facility does not have a vapour recovery system because the production rate of condensate is low. There will be minor VOC emissions of approximately 33 tonnes per year based on the use of floating roof tanks.

Volatile Organic Compound emissions will also occur when loading the trading tankers, but it is extremely complex to recover these emissions because:

- Tankers will be selected from the spot market, so it is not possible to add any equipment to the tanker fleet.
- Very few tankers (if any) are likely to have appropriate VOC recovery technology.
- VOC treatment would require either a barge mounted incineration facility or a dedicated subsea pipeline back to Barrow Island.
- A barge mounted facility adds a number of significant safety aspects and only burns VOCs instead of recovering them.
- If a subsea pipeline were used to recover the VOC, then some of the components would remain in the gaseous form while others would be in the liquid state. This two-phase mixture creates a number of technical difficulties.
- Recovery (if at all technically feasible and safe) would come at a very significant cost.

7.2.3 Predicted Emissions from Non-Routine Operation of Gas Processing Facility

Non-routine operations which may result in emissions include certain planned and unplanned events, including: commissioning, start-up and shut-down procedures; plant or process upset conditions; and emergency situations where there is a realistic threat/danger to personnel or facility. In these situations, high pressure gases will be collected and directed to the flare system in line with industry practice.

Where practicable and without compromising the safety of the facility and personnel, all significant continuous flaring or venting sources will be eliminated. The design will incorporate a high efficiency flare to minimise the portion of uncombusted hydrocarbon and particulates to as low as reasonably practicable (ALARP). The height of the flare will depend on the final facility layout and flare structure location, but is expected to be approximately 150 m. As mentioned in Chapter 6, one option currently being considered is the use of a ground flare similar to that installed at the Darwin LNG plant.

During Development commissioning, the emission levels will be higher as the compression and power equipment is tested and tuned to meet specifications. It is expected that during this period, the emission levels will be similar to those during start-up and shut-down procedures (Table 7-2).

Commissioning is much longer in duration than a typical shut-down, but is an essential activity which is only conducted once.

It is expected that the gas processing facility will be partially shut-down on approximately ten occasions per year. Following each of these shut-downs, the subsequent restart is expected to take approximately 6 hours, during which time approximately 30% of the normal flow rate of a single LNG train may be directed to the flare as the LNG is brought to product specification. Maximum predicted emissions of particulate matter and oxides of nitrogen are shown in Table 7-2. Emissions are unlikely to remain at the maximum for the full duration of the start-up process, but as subsequent detailed design phases develop this 30% of the normal flow rate figure will be challenged with the intention of reducing it to the lowest reasonably possible.

During a cold start, power will be supplied by a diesel generator (approximately 5 MW), which is expected to discharge approximately 75 kg/hr of oxides of nitrogen. The only appreciable emissions of SO_2 will occur from operation of the diesel generator where a maximum emission of 3.6 kg/hr may occur (based on an average sulphur content of the diesel supply).

Modelling for sulphur oxides is based on the assumption of 500 ppm which is the level in diesel that is currently available. However, by the time the Gorgon Development is operational, diesel will be either 50 ppm (1 January 2006) or 10 ppm sulphur (from 2009) in line with Australian legislation. Therefore modelling results shown are conservative.

Shut-downs of the gas processing facility will occur for different reasons. They will be required for planned maintenance programs, in which case there will be the opportunity to minimise emissions by reducing the amount of gas directed to the flare system. Alternatively, there could be a shut-down of one train requiring some flaring, or a total shut-down of both LNG trains requiring discharge to flare of the total process inventory of LNG (not the tank inventory) and other plant piping and systems. It is anticipated that such circumstances will occur less than ten times per year and be of less than one hour peak flaring.
The design capacity of the flare system is expected to be approximately 2100 t/hr. This capacity will be refined during subsequent design phases. Maximum emissions of particulate matter and oxides of nitrogen from each of the two flares are shown in Table 7-2.

When activated, the main process flare has the potential to partially impact the approach and departure pathway of the Barrow Island airport. The Civil Aviation Safety Authority (CASA) has established a number of regulations for the safety of aircraft movements, some of which pertain to the flight path of aircraft for take-offs and landings (CASA 2003). In particular, CASA has drafted guidelines for Plume Rise Assessment and the need to assess the potential hazard to aviation where the vertical velocity from gas efflux (flare) may cause airframe damage and/or affect the handling characteristics of an aircraft in flight. This assessment will be undertaken during further detailed engineering planned for the subsequent design phases of development. It is assumed that the results of the CASA analysis will either determine that aircraft safety is not compromised, or other actions (such as change in approach and take-off procedures or navigational headings, slightly re-aligning the runway or possible relocation of the flare) will take place.

Reservoir CO_2 is proposed to be injected into the Dupuy formation beneath Barrow Island (Chapter 13). Non-routine situations may occur, for example stoppage of one or more of the CO_2 compressors, whereby the entire injection system is not available. In this event, it will be necessary to vent CO_2 from the acid gas removal unit to the atmosphere. As trace amounts of H_2S are also present in the feed gas and normally removed with CO_2, during a non-routine situation a trace amount will also be vented to atmosphere with the CO_2. It is estimated that approximately 100 kg/hr of uncombusted H_2S will be vented under these circumstances. It should be noted that H_2S may be oxidised to SO_2 if vented through one of the turbine stacks due to the presence of heat and excess oxygen (O_2). The gas processing facility will continue to operate normally whilst venting of the CO_2 and H_2S occurs. The CO_2 stream will also contain some hydrocarbons including BTEX. Refer to Section 7.2.5 for additional details.

Table 7-2 is a summary of predicted emissions resulting from non-routine operation of the gas processing facility.

7.2.4 Air Quality Criteria

Within Western Australia, the Environmental Protection Authority (EPA) assesses all new projects in terms of air emissions at the stack or vent outlet and the resultant ambient ground level concentrations.

Emission Standards and Limits

For emissions from industrial sources, the EPA requires that ‘all reasonable and practicable means should be used to prevent and minimise the discharge of waste’ (EPA 1999a). For new projects, the EPA requires an assessment of the best available technologies for minimising the discharge of waste for the processes and justification for the adopted technology.

Best practice for NO_x reduction is currently Selective Catalytic Reduction (SCR). This relies on the principle that ammonia reacts with NO_x to produce nitrogen and water. It involves injecting a solution of ammonia (or a solution of urea) into a gas turbine exhaust and the exhaust gases then pass over a catalyst. Transporting large quantities of ammonia or urea to Barrow Island, and using these materials introduces additional safety, quarantine and other operational implications which collectively weigh too strongly against using this technology. Therefore it is not considered best practice overall for use on Barrow Island and as discussed in Section 7.2.2 the Development will use DLN burner technology where appropriate.

Table 7-2:
Predicted Emissions from Non-routine Operation of Gas Processing Facility

Operating Scenario	Emission Estimates			
	NO_x (kg/hr)	H_2S (kg/hr)	SO_2 (kg/hr)	Particulate (kg/hr)
Shut-down Emissions are for worst-case, shut-down of both trains	160	0	0	2500
Start-up For both LNG trains	378	0	3.6	440
CO_2 Injection System Stoppage	0–500	0–100*	< 1	0–30
For Comparative Purposes Emissions from Routine Operation	500	0	0	30

** Based on the assumption that all is vented – otherwise it will be SO_2*

The EPA has developed a guidance statement for oxides of nitrogen emissions from gas turbines, with limits for emissions following the Australian Environmental Council/Natural Health and Medical Research Council (AEC/NHMRC) National Guidelines. These limits are 0.07 g/m^3 (Standard Temperature and Pressure, dry and 15% O_2) for gaseous fuels and 0.15 g/m^3 for other fuels. Modern natural gas-fired systems, employing NO_x control technology can be expected to achieve lower emissions than 0.07 g/m^3 (EPA 1999b). Current indications from gas turbines of a similar size are that NO_x emissions may be half to a third of this concentration (Woodside 2005); however the following evaluation is based on 0.07 g/m^3 and so is expected to be very conservative.

Ambient Air Quality Standards

The EPA does not have state-wide standards for ambient ground level concentrations. For these, the EPA requires that pollutants meet the NEPM standards (NEPC 1998) as listed in Table 7-3. These specify a maximum concentration and the goal that is to be achieved in a specified timeframe, but new developments should strive to meet the standard from the commencement of operations.

These standards apply outside industrial areas and to residence-free buffer areas around industrial estates. With no formally defined industrial buffer zone applied to Barrow Island, the Joint Venturers have elected to apply the NEPM at the nearest permanent residence, namely the existing Chevron camp.

These NEPM standards and goals have not been implemented in legislation throughout Western Australia as yet; however the Department of Environment (DoE) has indicated their intention to implement them through the development of a state-wide Environmental Protection Policy (EPA 1999a). Table 7-4 presents a comparison of the standards and goals of NEPM, World Health Organisation (WHO 2000) as well as the USEPA National Ambient Air Quality Standards (NAAQS) (USEPA 2004).

For other pollutants, the DoE tends to reference the lowest standards that are in use throughout Australia. For the Gorgon Development, the Victorian State Environmental Protection Policy (EPA (Vic.) 2001) design ground level concentration of 470 µg/m^3 (0.32 ppm) of H_2S for a 3-minute average has been adopted as it is the most stringent.

Table 7-3:
Relevant Environmental Protection Measures – Standards and Goals

Pollutant/Emission	Averaging Period	Maximum Concentration	Goals Maximum Allowable Exceedences
Nitrogen dioxide	1 hour 1 year	0.12 ppm (246 µg/m^3) 0.03 ppm (62 µg/m^3)	1 day per year none
Photochemical oxidants (as ozone)	1 hour 4 hours	0.10 ppm (214 µg/m^3) 0.08 ppm (171 µg/m^3)	1 day per year 1 day per year
Sulphur dioxide	1 hour 1 day 1 year	0.20 ppm 0.08 ppm 0.02 ppm	1 day per year 1 day per year none
Particles as PM10	1 day	50 µg/m^3	5 days per year
BTEX	Annual average	0.003 ppm (investigation level)	n/a

7.2.5 Atmospheric Dispersion Modelling – Methodology

Two different atmospheric dispersion models were used to predict the impact on air quality due to the operation of the proposed gas processing facility on Barrow Island (Technical Appendix B1). These models were:

- DISPMOD, the Western Australian coastal model, which was employed to estimate local ground level concentrations of the emissions from various operating scenarios.
- TAPM, the CSIRO's prognostic meteorological and air pollution model, which was used to address regional air quality impacts and local deposition rates.

Routine Operations

Figure 7-1 and Figure 7-2 present the local distribution of the maximum 1-hour and annual NO_2 concentrations (ppm) for normal gas processing facility operations. The maximum 1-hour concentration predicted over the entire modelling grid is 0.06 ppm, compared to the NEPM value of 0.12 ppm. Similarly, maximum annual concentrations of NO_2 are predicted to be very low: typically being 10% of the corresponding NEPM value. Most of the NO_x deposition occurs over water due to the prevailing winds.

In addition to CO_2, NO_2, and SO_2, particulate matter (expressed as PM10) is another product of combustion that will be released from the proposed gas processing facility during routine operations. The maximum predicted 24-hour PM10 concentration is 3 µg/m^3, which is approximately 5% of the corresponding NEPM value of 50 µg/m^3 (Technical Appendix B1).

Figure 7-1:
Maximum 1-hour NO_2 Concentration (in ppm)

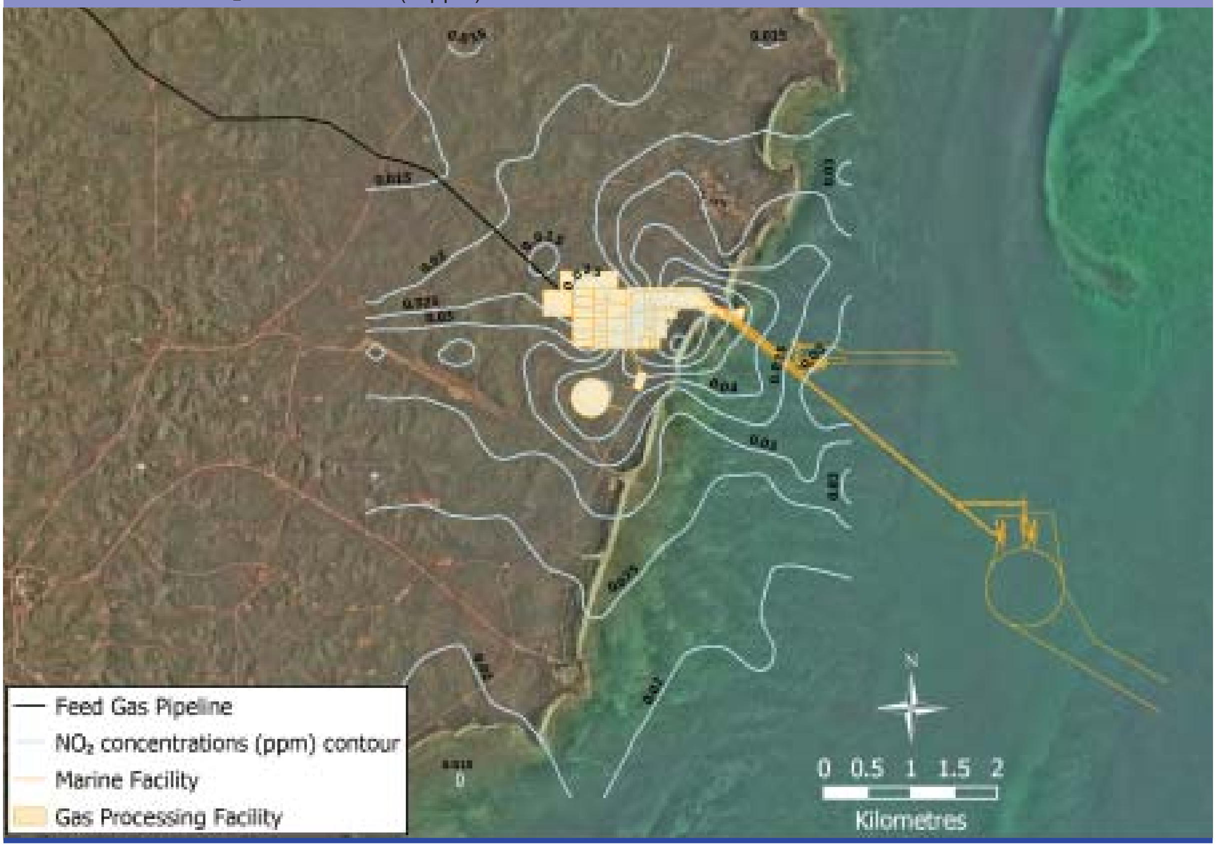
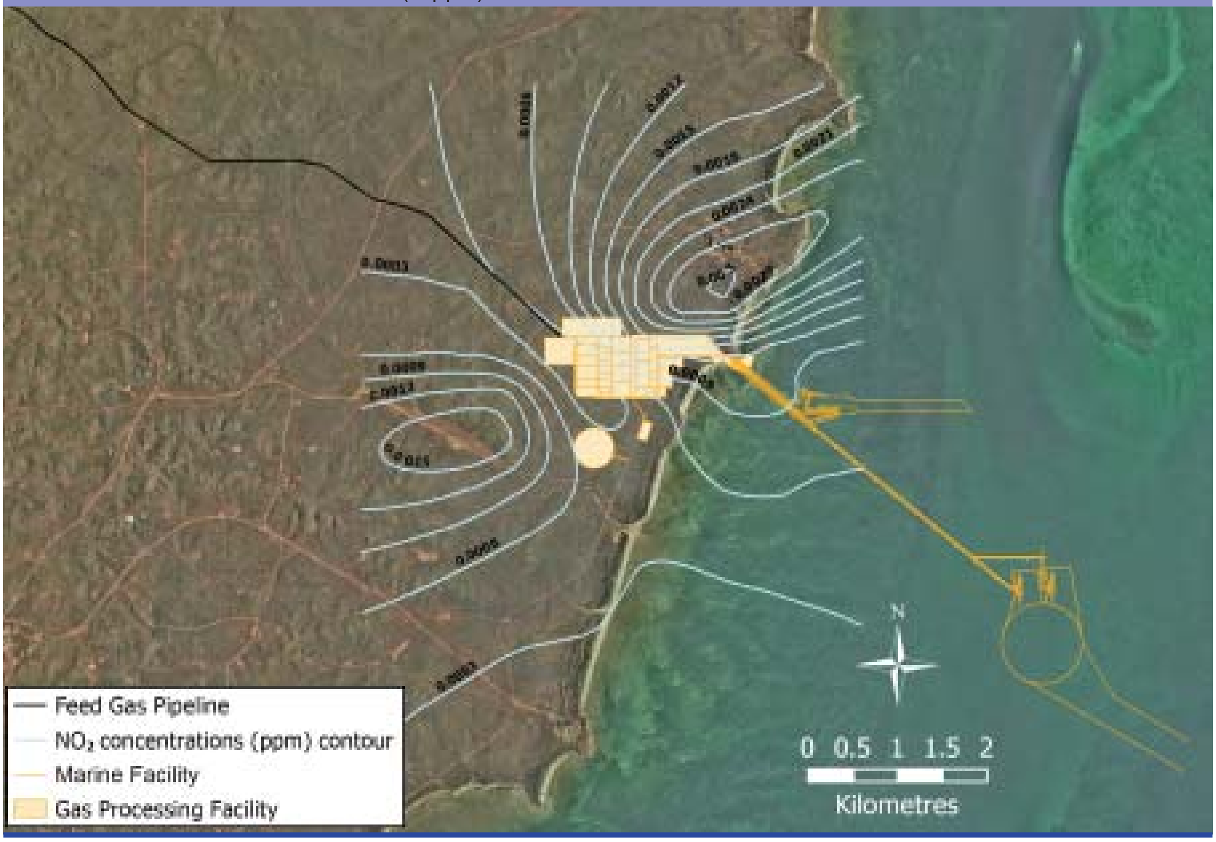


Figure 7-2:
Maximum Annual NO_2 Concentration (in ppm)



Some studies in other countries have indicated that more deaths are attributable to the concentration of particulate matter of diameter below 2.5 µm (PM2.5) than to the concentration of PM10. Particles with sizes between 2.5 and 10 µm may be more important in relation to asthma and respiratory illnesses.
There are few regular PM2.5 measurements undertaken in Australia, and no air quality standard has been set for PM2.5. The NEPM 24-hour PM10 standard of 50 µg/m^3 limits the atmospheric PM2.5 concentrations to between 20 and 40 µg/m^3 depending on the city and the season. This means that the NEPM provides an upper limit to the PM2.5 concentration that is more stringent than the United States EPA 24-hour PM2.5 standard of 65 µg/m^3 set in 1997.

It should also be emphasised that modern gas turbines are extremely efficient and so particulate matter from this source will be negligible, also flaring will be minimised as the natural gas is a valuable resource.

A summary of the maximum predicted concentrations of the various emissions for normal (routine) operations as well as a range of emission levels during start-up and plant upset conditions are presented in Table 7-5.

Table 7-4:
Comparison of NEPA, USEPA and WHO Ambient Air Quality Standards and Guidelines with Predicted Gorgon Development Emissions

Emission	NEPM		USEPA		WHO		Gorgon Development – Model Predictions	
	Averaging Period	Maximum Concentration	Averaging Period	Maximum Concentration	Averaging Period	Maximum Concentration	Normal Operations (Max)	Non-Routine Conditions
Nitrogen dioxide	1 hour	0.12 ppm (246 µg/m^3)					0.063 ppm (1 hr)	0.037–0.049 ppm (1 hr)
	1 year	0.03 ppm (62 µg/m^3)	Annual	0.053 ppm (100 µg/m^3)	NO_x – Annual	0.016 ppm (30 µg/m^3)	0.003 ppm (annual)	N/A
Photochemical oxidants (as ozone)	1 hour	0.10 ppm (214 µg/m^3)	1 hr	0.12 ppm		0.2–10 ppm	regional cumulative concentration (<0.1 ppm)	regional cumulative concentration (<0.1 ppm)
	4 hours	0.08 ppm (171 µg/m^3)	8 hr	0.08 ppm	5 days – 6 months			
Sulphur dioxide	1 hour	0.20 ppm	SO_x – 3 hr	0.5 ppm (1300 µg/m^3)			N/A (<0.001 ppm)	0.001 ppm (1 hr)
	1 day	0.08 ppm	SO_x – 24 hr	0.14 ppm (human)	24-hr	100 µg/m^3	N/A	N/A
	1 year	0.02 ppm	SO_x – Annual	0.03 ppm (human)	Annual	10–30 µg/m^3	N/A	N/A
Particles as PM10	1 day	50 µg/m^3	24 hr	150 µg/m^3 (human)			3 µg/m^3 (24 hr)	54–330 µg/m^3
			Annual mean	50 µg/m^3				
Nitrogen deposition					15–20 kg/ha/yr		0.06–0.55 kg/ha/yr	N/A

Non-Routine Operations

During non-routine operations, emissions from the flare and diesel generators may be much greater than under normal operations and could lead to higher ground level concentrations of NO_2, SO_2 and particulates. Dispersion modelling was conducted to predict the maximum concentrations of these emissions resulting from three non-routine operating scenarios: shut-down, start-up and non-operation of the CO_2 injection system. Despite being unlikely, the worst-case data was used in the modelling to predict the emission levels when both LNG trains would be in the non-routine mode.

Start of Both LNG Trains

Maximum predicted 1-hour concentrations of NO_2 resulting from a cold start of both trains of the gas processing facility are presented in Figure 7-3. Maximum concentrations are predicted to be well below the corresponding NEPM values. Other emissions released during a cold start would include small quantities of sulphur dioxide (SO_2 < 5 g/s) and particulate matter. The dispersion modelling confirms that the predicted ground level concentrations of both emissions would also be well below the NEPM standards.

Shut-Down of Both LNG Trains

Emissions due to a shut-down of both LNG trains would include oxides of nitrogen, CO_2, uncombusted hydrocarbons and particulates. Maximum predicted 1-hour concentrations of NO_2 resulting from a total shut-down of the gas processing facility are presented in Figure 7-4. The maximum value of 0.049 ppm is less than 50% of the relevant NEPM values. The predicted maximum 1-hour concentration of particulates during such an event, assuming that flaring occurred under the worst-case meteorological conditions, is 4561 µg/m^3. This equates to a 24-hour average of approximately 200 µg/m^3 during that day of occurrence. The maximum concentration would occur within the boundary of the gas processing facility. The maximum values decrease rapidly with distance from the gas processing facility, such that at the construction village the maximum 24-hour particulate concentration is estimated to be 30 µg/m^3, which is below the NEPM standard of 50 µg/m^3.

Figure 7-3:
Maximum Predicted 1-hour NO_2 Concentration (in ppm) from a Cold Start

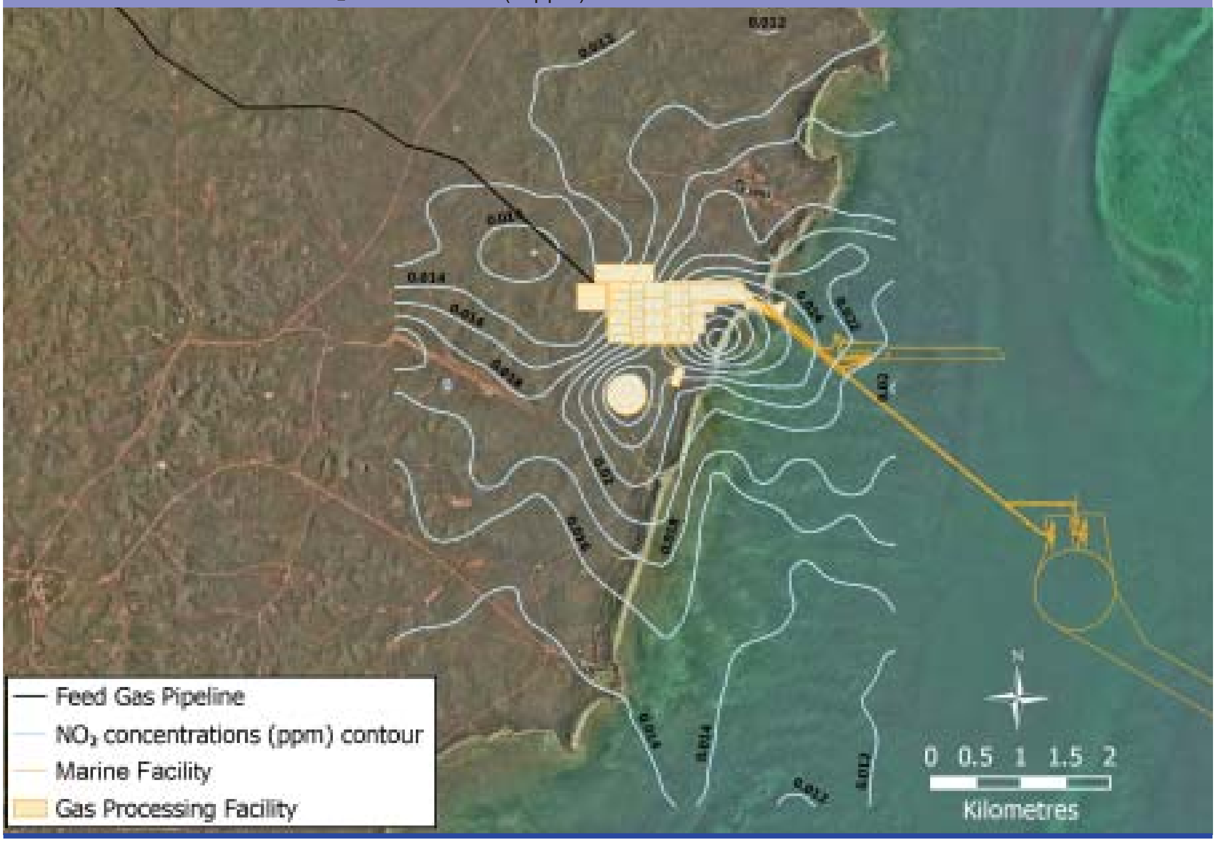
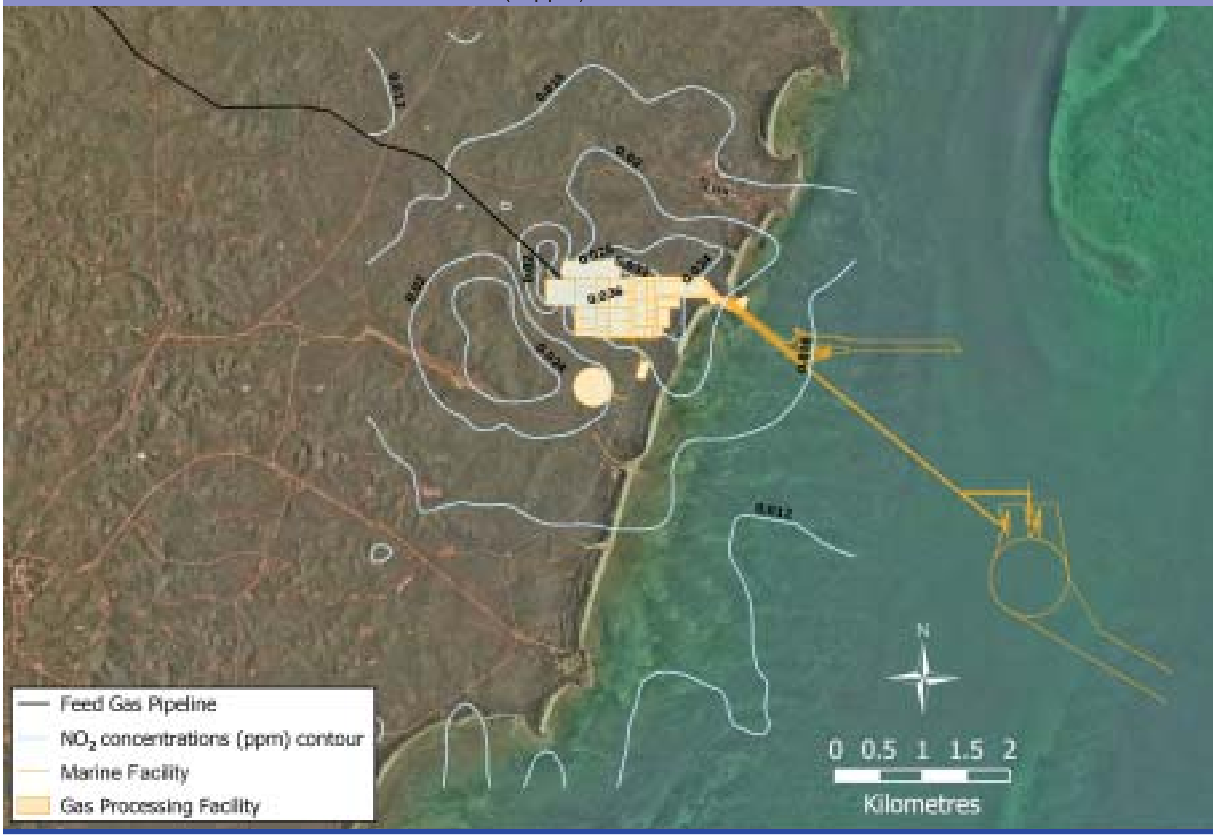


Figure 7-4:
Maximum Predicted 1-hour NO_2 Concentration (in ppm) from a Total Shut-Down



Shut-Down of CO_2 Injection System

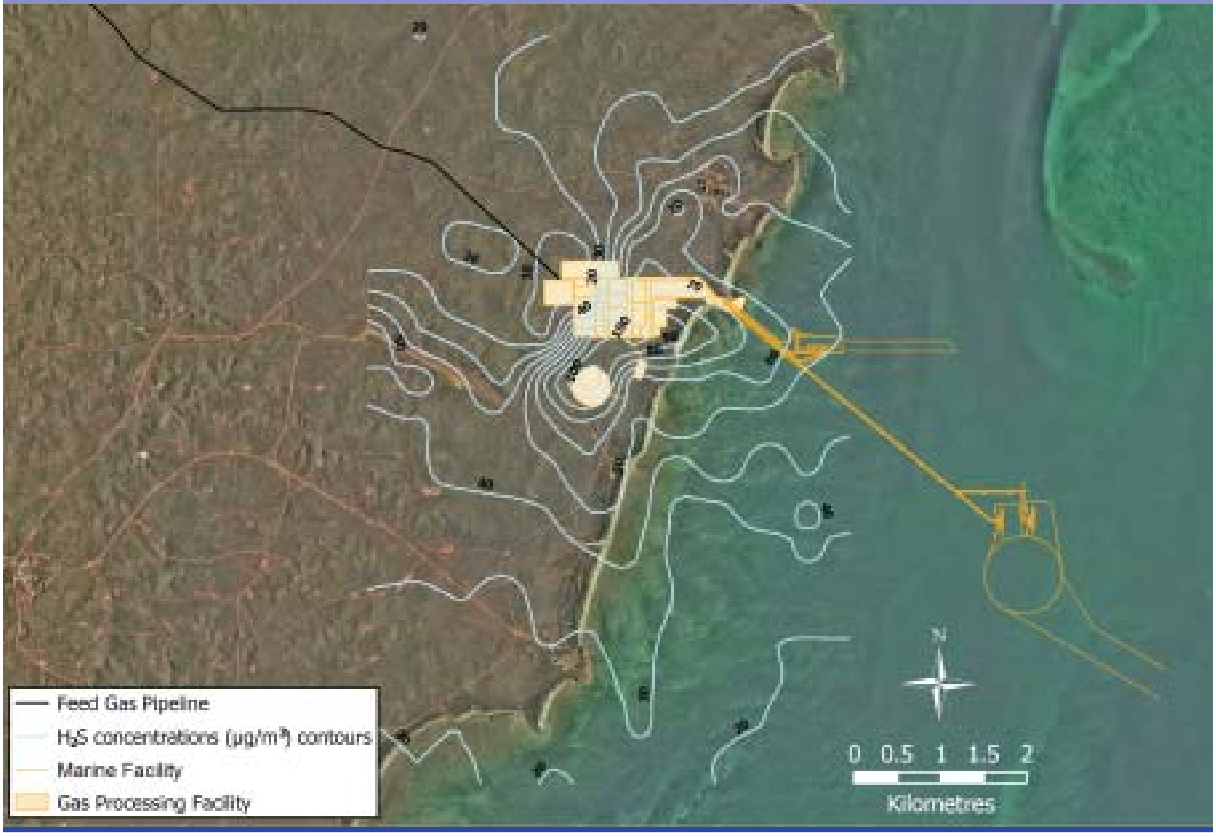
Maximum predicted 1-hour concentrations of NO_2 occurring during a shut-down of the CO_2 injection system would be the same as those presented under normal operating conditions, as illustrated in Figure 7-4. This is because the NO_x would be emitted from the gas turbines in the power generation system and the gas turbines driving the refrigerant compressors, which would all still be operating.

The maximum 3-minute concentrations of H_2S associated with the venting during the shut-down of the CO_2 injection system are presented in Figure 7-5. The maximum value of 113 $\mu g/m^3$ is less than a quarter of the Victorian EPA ground level concentration of 470 $\mu g/m^3$. Refer to Chapter 13 for further details on the availability of the CO_2 injection system.

Modelling has recently been undertaken directly by the Gorgon Joint Venturers for the full discharge of CO_2 from the acid gas removal unit through a dedicated vent 30 m above grade. An alternate case of 10% of the design flowrate has also been examined. The H_2S concentration in the CO_2 stream is predicted to be in the order of 200 ppm. The results show that for the 100% case, the maximum ground concentration of CO_2 will be approximately 400 ppm above ambient (750 ppm absolute) and the maximum H_2S ground level concentration will be approximately 0.1 ppm. For the 10% flow case, the velocity of the discharge is lower and modelling shows that the ground level concentrations are also lower, indicating that the full flow scenario is the worst-case. BTEX concentrations are expected to be in the order of 10% of the H_2S concentration and so BTEX ground level concentrations are expected to be less than 0.01 ppm. Assuming that the CO_2 system was operating 90% of the year, this would result in an annual average of 0.001 ppm which is below the NEPM investigation trigger levels for benzene.

The Gorgon Joint Venturers will undertake additional modelling during subsequent design phases to ensure that ground level concentrations of all components are safe.

Figure 7-5:
Maximum Predicted 3-Minute H_2S Concentration (in μg/m^3) from a Total Shut-Down



A summary of the maximum concentrations of the various emissions for non-routine operations (gas processing facility start-up, total plant shut-down and shut-down of the CO_2 injection system) is presented in Table 7-5.

Local Deposition Rates

Deposition of atmospheric pollutants can occur through both wet and dry mechanisms. Wet deposition or 'acid rain' describes the deposition of acidic pollutants through rainfall. The opportunity for potential acid rain deposition and impact is remote for Barrow Island because of the dry climate and prevailing winds over a vast marine receiving environment. When precipitation occurs, it tends to be during the summer and autumn months and is often associated with cyclones (Chapter 8). These large rainfall events occur over short periods of time which significantly dilute wet deposition rates.

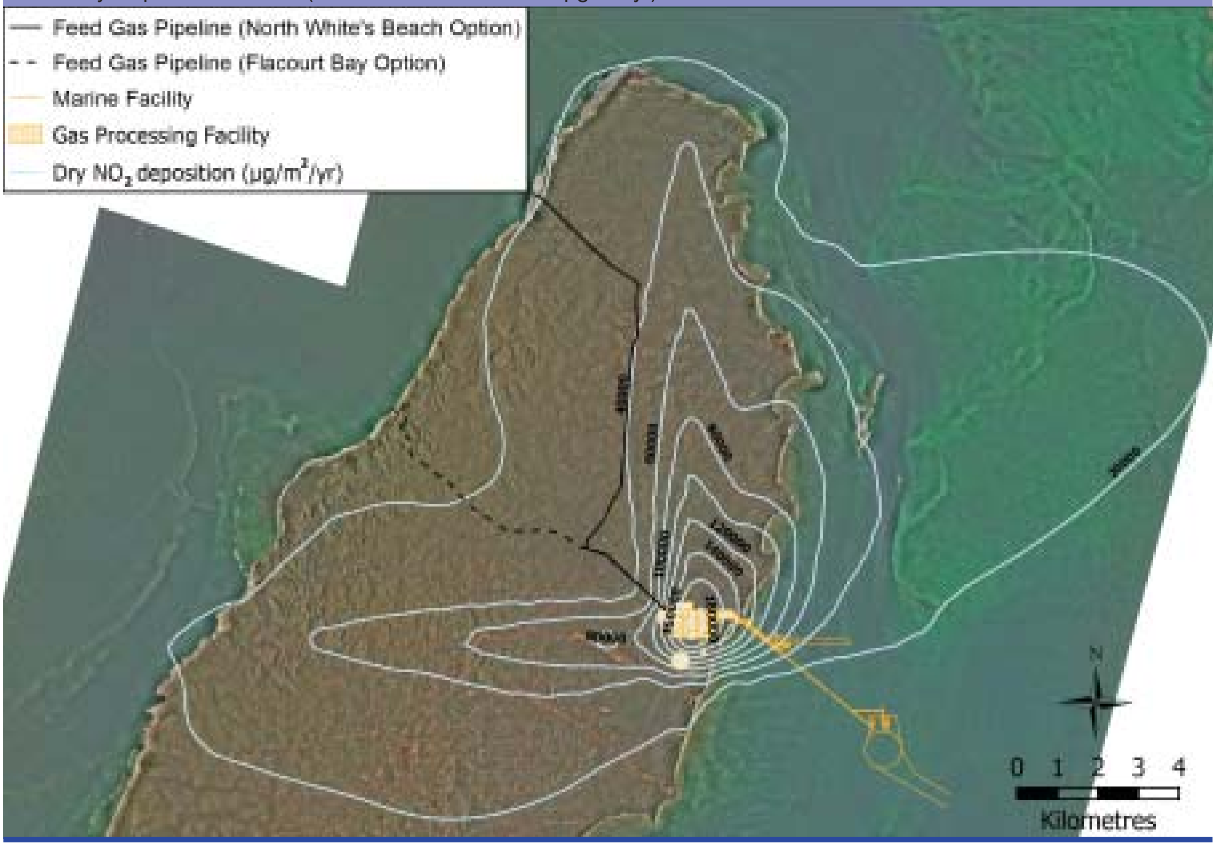
Dry deposition refers to the fall-out of gases and particulates to the ground surface without any interaction with water. Dry deposition tends to occur close to the source of pollution particularly in dry climates, but depends upon prevailing weather conditions and dominates in dry climates (Environmental Protection Authority (SA) 2001). The dominant mechanism on Barrow Island is dry deposition for both the terrestrial and aquatic environments.

The total dry deposition to the ground (vegetation, soil/rock and any water bodies) of NO_2 as predicted by TAPM modelling is presented in Figure 7-6. The highest NO_2 deposition rates are predicted to be over water where the dilution and dissociation in the marine environment would occur rapidly because of the warm water temperature, current and tidal influences and wave action. The receiving waters are not considered sensitive to nitrogen deposition as they are not entrained or eutrophic. Rates over land would be lower primarily due to the deposition to vegetation being dependent on daylight and the photosynthetic process; and because TAPM uses a moderately high solubility factor for NO_2. The maximum dry deposition would be approximately 180 000 μg/m^3 (or the equivalent of 1.8 kg/ha/year).

Table 7-5:
Maximum Ambient Concentrations with DLN Burners for Various Operating Scenarios

Operating Scenario	NO_x		NO_2		PM10	H_2S		SO_2	
	1-hour (ppm)	Annual (ppm)	1-hour (ppm)	Annual (ppm)	24-hour (µg/m^3)	3-minute (µg/m^3)	1-hour (µg/m^3)	1-hour (ppm)	24-hour (ppm)
Normal Operations	0.287	0.003	0.063	0.003	3	N/A	N/A	N/A	N/A
Start-up	0.150	N/A	0.037	N/A	54	N/A	N/A	0.001	N/A
Shut-down	0.212	N/A	0.049	N/A	200	N/A	N/A	N/A	N/A
Shut-down of CO_2 injection system	0.293	N/A	0.064	N/A	3	113	62	N/A	N/A

Figure 7-6:
Total Dry Deposition of NO_2 (Ground Concentration – µg/m^2/yr)



Comparison to the WHO (2000) critical load for Nitrogen (N) deposition of 15–20 kg/ha/year for dry heathland (the only vegetation studied which is 'similar' to Barrow Island), indicates that the deposition over land of between 0.2 to 1.8 kg NO_2/ha/year (0.06 to 0.55 kg N/ha/year) is relatively insignificant (0.4–3.6% of the criteria).

7.2.6 Current Emissions from Facilities on Barrow Island

The current operations on Barrow Island are described here as part of the cumulative assessment of local emission levels. Current atmospheric emissions on Barrow Island are associated with existing oil field operations and include emissions from diesel and gas engines, the local power station, ground-based flaring and hydrocarbon storage and transport.

The Central Power Station for power generation on Barrow Island currently consists of 2 x 2 MW gas turbine generators, 1 x 4 MW gas turbine generator, and 5 x 1 MW gas engines, all fuelled by natural gas. Combustion products are the most significant emissions from the turbines, with oxides of nitrogen (NO_x) being the major emission product after CO_2.

A summary of current atmospheric emissions is presented in Table 7-6.

It should be noted that the Gorgon Development provides the opportunity to eliminate many (if not all of these emission sources), e.g. power supplied to the existing operations from the more efficient equipment provided at the gas processing facility, or recovery of gas which is currently flared. However, the remainder of this chapter refers to the combined emissions from the Gorgon Development and existing emissions and therefore is conservative.

Regional Impacts of the Gorgon Development on Air Quality

As the emission levels for NO_x, SO_x, H_2S and particulates from the existing Chevron Australia operations on Barrow Island and the proposed Gorgon Development all fall within guidelines for the immediate (local) area, they will have a negligible impact on the regional air quality levels.

The potential impact of the Gorgon Development on regional air quality was investigated using TAPM to model peak ozone concentrations.

Table 7-6:
Current Annual Atmospheric Emissions from Barrow Island (ChevronTexaco Australia 2003b)

Source Description	SO_x (tonne)	NO_x (tonne)	VOC (tonne)	CO (tonne)
Diesel engines	3	0	0	0
Barrow Island power station	0	927	23	736
Barrow Island well field operations	0	638	19	582
Crude oil transport and storage	0	0	33	0
Flaring	26	31	246	169
Flashing	0	0	18	0
Venting	0	0	502	0
Fugitive emissions	0	0	544	0
Total	29	1596	1385	1487

Ozone (O_3) is a recognised atmospheric pollutant. Symptoms of exposure to O_3 include irritation of the airways and minor lung function changes in both healthy and susceptible individuals. Some plant species, including crop species, demonstrate a reduction in growth and visible injury when exposed to prolonged O_3 concentrations at levels lower than those that cause adverse effects in humans.
The concentration of O_3 in a polluted atmosphere is usually taken as an indicator of the amount of photochemical smog, because O_3 usually comprises about 85% of the total photochemical smog concentration. The rate of production of photochemical smog is limited by the amount of sunlight and reactive organic compounds available. The quantity produced is generally limited by the amount of NO_x available.

In Western Australia there are two primary standards for ambient O_3, a 1-hour average of 0.10 ppm and a 4-hour average of 0.08 ppm. Each of these concentrations may not be exceeded more than one day per calendar year.

The modelling was based on emissions from the current Chevron Australia operations on Barrow Island, regional emissions (e.g. publicly available data for industrial plants currently in operation or under construction on the Burrup Peninsula (Technical Appendix B1)) and the proposed Gorgon Development.

The maximum peak 1-hour ozone concentrations for the region are predicted to be below the NEPM standard of 0.10 ppm. With the inclusion of emissions from the proposed Gorgon Development, the maximum 1-hour ozone concentration increased only slightly (0.005 ppm) from 0.087 ppm to 0.092 ppm. Consequently the concentrations predicted for the Burrup Peninsula and Dampier/Karratha region exhibit very little, if any, change with the inclusion of emissions from the proposed Gorgon Development (further details are available in Technical Appendix B1).

Ozone Depleting Substances

It is Chevron Australia's policy to exclude the use of Ozone Depleting Substances (ODS) in new plant facilities such as the refrigeration and fire control systems. However use of ODS in quarantine systems may be required as there may be a need to use methyl bromide. This substance is mainly used as a fumigant in agriculture, for pest control in structures and stored commodities, and in quarantine treatments. Certain fire fighting (e.g. halon deluge systems) and refrigeration systems in older model dredges, drilling rigs and supply vessels could also potentially result in a release of ODS.

In the unlikely event of a fire, only small volumes of halons would be released. Potential environmental impact of such a small volume of halons released into the atmosphere is considered slight (Chapter 10) and would be reported in accordance with Australian Standard AS 4211.3. The risk of releasing ozone depleting substances during replacement of older-style refrigerant systems is also considered to be very low. Any systems containing ODS that need recharging or replacement will be exchanged to an ozone 'friendly' systems, wherever options are available.

7.3 Light Emissions

Extensive lighting for industrial plants is mandatory for general worker and public safety; therefore, the gas processing facility and associated facilities will be lit and a potential source of light spill. Shipping will require lighting for similar reasons and will also be a potential source of light spill. The following sections explain the lighting strategy for the proposed Development, while Chapters 10 and 11 include assessment of the potential environmental risks of the lighting regime.

7.3.1 Current Light Emissions

There are no permanent light sources in the area of the Gorgon gas field, although there is some lighting from occasional shipping and the existing drilling platform/monopods in the general offshore area. There are permanent light sources located at various sites on Barrow Island for the existing operations of Chevron Australia. These lights are associated with the central processing facility, airport and base area, all located inland from the coast. The main sources of artificial lights adjacent to the coast are the Chevron camp and associated recreational facilities, the terminal tanks and the barge landing site, all located on the eastern coast of Barrow Island. There are also permanent lights associated with the facilities at Varanus Island and a number of monopod production facilities in the immediate offshore area, mainly to the north of Barrow Island.

A recent survey (Technical Appendix C7) identified the most common outdoor lighting type in use at Barrow Island as sodium vapour (nominally 80 W and 400 W). These lights are typically atop 6–8 m tall poles and are oriented at approximately 20° from vertical. Metal halide, fluorescent and mercury vapour lights are less commonly used. While these lights are visible over long distances as point sources, their spectral emissions were not detectable as electrical signals over more than several hundred metres.

7.3.2 Light Emissions from Construction Activities

Most external work lights on floating drilling rigs and pipe-lay barges should be kept on 24 hours per day in accordance with safety requirements. Lights will also be required on the vessels (e.g. dredges, hopper barges, tenders, tugs and barges) during LNG plant construction, pipeline and optical fibre cable installation, MOF, jetty and shipping channel/basin construction.

It is anticipated that construction of the offshore sections of the feed gas and domestic gas pipelines will each require a construction period of approximately eight to ten months. For much of this time, construction activities will be remote to Barrow Island; therefore, lighting will be offshore.

The onshore feed gas pipeline construction will take approximately 10 months with the majority of the construction activities being undertaken during daylight hours, although night time activities will occur. Most of the onshore feed gas pipeline route is well away from the coast and so will provide a negligible source of light spill to the marine environment that could potentially impact turtles. Nevertheless the same basic principles discussed in Chapters 6, 7, 10 and 11 will be used to minimise potential for light spill reaching the coast.

The shore crossing construction activity will extend for approximately 12 months, with 3–5 months associated with the directional drilling operation. The remainder of the time will be spent in site preparation, pipeline pulling and clean up activities. These activities are expected to run for 24 hours per day; however where practical some construction activities will be scheduled for daylight shifts to avoid unnecessary disturbance at night. Also, where possible, the peak drilling activity will be scheduled to minimise coincidence with the turtle breeding season.

The CO_2 pipeline and water pipelines will be constructed primarily onshore away from the beaches. However lighting will be undertaken using the same principles as discussed in Chapters 6, 7, 10 and 11, so light spill from these facilities will be minimal.

It is planned that once the LNG site preparation is complete, the onshore construction of the gas processing facility will occur 24 hours per day, seven days per week. Safety considerations will require that the construction site is illuminated in accordance with safe working conditions. Most of the construction activity will be located at the gas processing site, away from the shore areas. Lights that emit at longer wavelengths (narrow spectrum) will be used and directed onto the construction activities to reduce light spill.

Two other basic principles will be followed which are considered to be the most important to protect turtles from light spill, namely:

- using fully shielded lights
- facing lights away from the beach so that there is no direct light visible from the shore where turtles may occur, but also not shining lights directly at large reflective surfaces.

As the design progresses, the Gorgon Joint Venturers will also continue to apply the principles contained within Witherington and Martin (1996) to minimise light spill from the onshore and offshore construction equipment.

7.3.3 Light Emissions from Operation of Proposed Development

The gas processing facility will normally be in operation on a continuous basis (24-hour operation) and lighting will be required. Specific facilities include: the gas processing facility, export jetty and tankers, village and recreational facilities. Lighting at these facilities will create some light spill.

Gas Processing Facility

The light spill generated from the gas processing and marine facilities will depend upon the actual light source (wavelength and intensity), location/placement of light fittings and the method of light switching. The characteristics of the potential light spill from the gas processing facility were predicted using an illumination model (using AGI32 software program – Technical Appendix C7) to estimate isolux contours over the affected areas.

Modelling of the light emissions from the gas processing facility predicts that, for a conventional lighting regime, the 20 lux isoline will be retained within the confines of the gas processing facility area, in general around 2 m from the nearest point sources of light.

Light intensity will diminish by the square of the distance to the source. A light intensity of 0.1 lux would therefore be achieved at a distance of around 30 m from the gas processing facility and therefore may be visible from the near shore and beaches located to the east. In comparison, moonlight provides between 0.25 and 1 lux depending on the phase of the moon and the weather conditions (Encyclopedia 2005).

To examine the sensitivity of the lighting contours to the lighting configuration a number of modelling runs were conducted which included:

- the base case with conventional lighting regime – ‘Base Case’ (250 watt high pressure sodium)
- turning lights so they face away from turtle beaches – Case A (all onshore lights face north and/or west away from the beach)
- reducing the height of the lights – Case B (10 m^{-5} m)
- reducing the wattage of the lights – Case C (250–150 watt).

The results (Figure 7-7) show that there is a difference between the Base Case and Case A, another marked difference between Case A and Case B, but the changes between Case B and Case C are minor to negligible. This modelling confirms expectations that the measures proposed by the Gorgon Joint Venturers will dramatically reduce lighting effects over a conventional lighting regime.

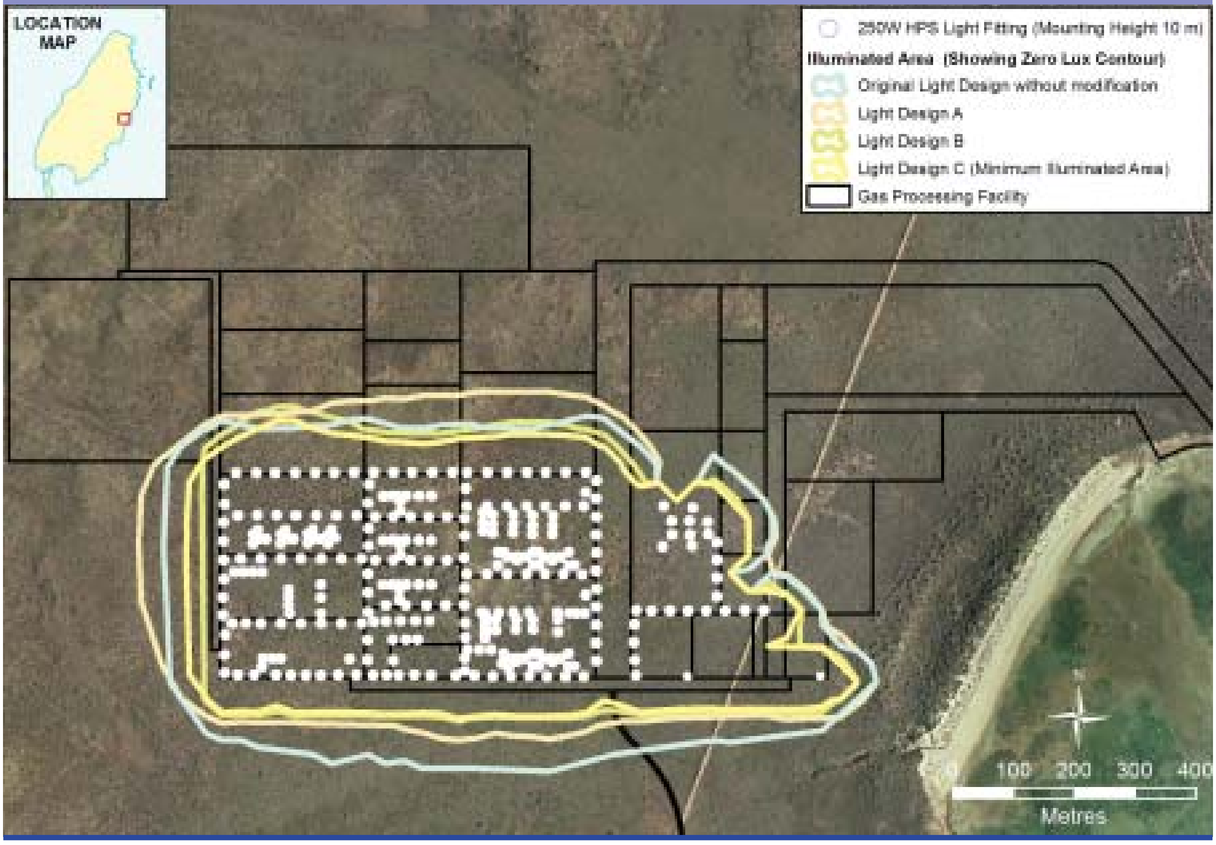
Various design measures will avoid the need for significant flaring of gas, which is a potential source of light which could disturb turtles. However, certain situations will require gas flaring including: Development commissioning; periods of process of shut-down and start-up; and upset conditions. Of these potential flaring scenarios, the process of shut-down and start-up will occur most frequently with each event typically lasting between one-to-six hours in duration. Commissioning will occur only once. During these periods, light produced by the flare will be visible during the night from the beaches adjacent to the gas processing facility and offshore.

One option which is currently being evaluated is the use a ground-based flare instead of the elevated flare, as the ground flare has the benefit of potentially reducing the effects of a light source on turtles.

It is anticipated that each LNG ship loading will take approximately 24 hours and occur once every three days. The loading of LNG tankers will be a 24-hour operation, thus both the LNG berth and the tankers will be lit in order to provide a safe working environment.

Currently there is a single shipment of crude oil from Barrow Island each month. An additional condensate ship loading will also occur once every month. These tankers will be lit to ensure personnel safety, but also to enable early detection of oil spills should one occur.

Figure 7-7:
Isolux Contours – Gas Processing Facility



Therefore, at the marine facilities there will be increased light emissions from an increase in tankers, associated tugs and pilot vessels, barges, the MOF and dedicated loading jetty and vehicle headlights on the jetty at night. Safe lighting at these facilities during loading and unloading operations will be designed with due consideration to minimise light spill as outlined in the following section.

Light Management

A lighting strategy will be updated for the Development with the objective to further minimise the amount of off-site illumination as much as reasonably possible. The LNG plant site, construction village and administration office will be constructed away from the beach areas. Keeping the elevation of the plant to a low, safe height and partially shielded by the existing dune formation will reduce light spill to the beach areas.

To minimise the potential impact of lighting on fauna (Chapters 10 and 11), a hierarchical lighting strategy has been proposed for the Development as described in Box 7-1.

Box 7-1:
Gorgon Development – Hierarchical Lighting Strategy

- Light levels will be minimised to those required for safe working conditions and security of the Development. Lights will be directed away from turtle beaches where possible.
- In certain areas, shielded or recessed lighting with long wavelength, reduced spectrum properties will be employed. Areas include the MOF causeway, jetty, parking and open areas.
- Areas that require routine night inspection and monitoring will have shielded white type lights (full spectrum) that would normally be in the off position and switched on as required.
- During commissioning, shut-down, or start-up extra lighting would be required for worker safety and potential evacuation.

In general, lighting levels will be minimised to those required for safe working conditions and for the security of the Development. Management of light spill can be achieved by designing and incorporating several simple measures (e.g. motion detection and localised switching) which will be applied, as appropriate, to the activities occurring at particular sites within the gas processing and marine facilities or at particular times (e.g. turtle nesting and emergence).

In specific areas, shielded red, long wavelength and/or lighting of a minimum necessary wattage rating will be provided. This includes areas such as the MOF causeway, jetty, access roads within the gas processing facility and general open areas. In areas where colour definition is required, a yellow/orange type of shielded light will be used, such as low pressure sodium vapour.

During construction of the Development, temporary lighting will be focused on the areas that are being worked on. Onshore on the east coast, where possible and during sensitive periods, lights will be shielded, mounted as low as practical and directed towards the west (and north) and not towards the coastline. Similarly on the west coast, where possible and during sensitive periods, lights will be shielded, mounted as low as practical and directed towards the east and not towards the coastline.

Areas and equipment that require inspection and monitoring during routine operator rounds and/or regular maintenance (e.g. filter change-outs) will utilise shielded white-type (full spectrum) lights that would normally be off. These lights are to provide adequate colour definition and shall be switched on as required. During an emergency, additional lights will be available for safety and security, including perimeter flood lights which will be activated on an ‘as required’ basis. Perimeter security lighting, cameras and motion detectors may be used in strategic locations. It may be possible to use lights with a long wavelength for these locations. One option which may prove feasible is the use of infrared cameras and new low lux cameras for perimeter surveillance.

These and further measures for managing and controlling light spill will be considered during subsequent design phases and will include options identified in Box 7-2.

Box 7-2:
Light Management Options

- Only installing necessary lights – ‘unnecessary lighting’ includes lighting in unused areas, decorative lighting or lighting that is brighter than needed.
- Minimising beach lighting from outdoor sources – this would be achieved by reducing wattage in sensitive areas, using focused luminaires to concentrate light, shielding light sources, using artificial or natural screens, recessing sources, lowering mountings, using timers or motion sensors, and possibly integrating screening in critical areas.
- Installing lighting along the MOF causeway and LNG jetty which will be activated by vehicles passing a specified shoreline checkpoint. Lighting along the MOF causeway and LNG jetty would be mounted low, shielded and focused towards the travelled pathway to avoid or reduce potential light spill into the surrounding waters. Floor lighting similar to that used in cinemas and aircraft will also be considered where appropriate.
- Scheduling routine maintenance work to avoid sensitive turtle hatching periods and maximise use of daylight conditions.
- Using torches to see equipment which does not normally require inspection (if safe).
- Minimising beach lighting from indoor sources – this will be achieved by avoiding or reducing the number of east-facing windows; applying window treatments (e.g. tinting); using curtains or opaque blinds after dark; and dimming lights near windows during times when sensitive fauna are using the surrounding area.
- Using alternative, long-wavelength (reduced spectrum) light sources – if light spill does reach fauna, the impact would be lessened if it has appropriate spectral properties. Low-pressure sodium vapour lamps, yellow filters, bug lights and red light-emitting diodes (LEDs) are examples of lights that could reduce impacts upon sea turtles.
- Directing lights away from large plant and equipment so that the surface does not act as a large light reflector.

Box 7-2: (continued)
Light Management Options

- Minimising the use of reflective surfaces, paints or coatings (e.g. using matt paints and colours such as greys or shades of brown/olive instead of white). This would reduce the amount of reflected light contributing to glow.
- Using directed beams of light similar to car headlights to minimise the spread of light outside areas that require lighting.
- Using spotlights instead of area flood lights.
- Locating and mounting shielded lights in locations which would be naturally blocked by other vessels, process equipment and/or structures.
- Installing entry doors, ladders and walkways on the western side of structures so that their lighting will be naturally blocked from and not reflected towards the eastern coastline. Where these aspects are not feasible, consideration will be given to enclosing stairs on the eastern side. The same principle will apply on offshore structures.
- Minimising the lighting required during the vessel loading to safe levels with due consideration to reducing light spill. This would reduce the visibility of these lights from the eastern beaches.
- Installing navigation aids on marine structures.
- Using infrared cameras for perimeter surveillance.
- Using cameras that offer detection in the visible spectrum down to 0.01 lux.

A combination of these lighting measures will be incorporated into the next level of design to minimise the potential impact of light spill from the Gorgon Development and still maintain acceptable worker safety and site security levels. As the design progresses, the Gorgon Joint Venturers will also apply the principles contained within Witherington and Martin (1996) to minimise light spill from the operational gas processing facility, and associated onshore and offshore equipment and activities.

A similar approach will be taken to reduce the light spill from all vessels operating within the vicinity of Barrow Island during the construction and operation phases of the Development. Refer to Chapters 10 and 11 for additional details.

7.4 Noise Emissions

7.4.1 Current Noise Emissions

The offshore Gorgon Development area is currently only subjected to noise generated by naturally occurring sources, such as wind, wave activity and marine animals, and noise associated with marine transport and drilling when it occurs. Barrow Island is subjected to noise generated by wind, weather and artificial sources. The artificial sources are associated with the existing Barrow Island Joint Venture operations and include: production and export facilities, support services such as planes and helicopters transporting the workforce to and from Barrow Island, mainland barge transport, an accommodation camp and vehicular traffic.

A survey of the existing noise levels at various proposed Development locations on Barrow Island was undertaken between 20 January and 10 February 2004 (further details are supplied in the Technical Appendix B2). The background noise levels at each location are summarised in Table 7-7.

Ambient noise at the existing Chevron camp site was dominated by noise from air conditioners. At the three other sites, ambient noise showed a pronounced diurnal cycle, with minimum levels occurring just prior to sunrise and peaking mid-afternoon. This is attributed to bird activity (and/or activities of other fauna), as the locations selected were remote from human activity. Wind generated noise also significantly contributed to the measured noise levels.

7.4.2 Noise Emissions from Construction Activities

Offshore Construction

Noise will be generated during drilling, installation, commissioning, production and decommissioning stages of the proposed offshore development, the MOF and jetty works. The potential sources of significant underwater noise are: support and installation vessels (tugs and tenders); drilling rigs and pipe-lay barges; possible pile driving; blasting; horizontal directional drilling (HDD) of the shore approaches; and from dredging and sea dumping activities. Typical noise levels and frequencies of vessels and marine construction equipment are identified in Table 7-8.

The noise characteristics of, and level from, various vessels that will be present during construction of offshore Development facilities will vary considerably between vessel types and their activities. Drilling rigs

Table 7-7:
Background Noise Levels (Natural and Artificial Sources)

Location	'L90' of LA90 noise levels – dB(A)		
	0700–1900 hours Monday to Saturday	**1900–2200 hours Monday to Saturday and 0900–2200 hours on Sundays**	**2200–0700 hours Monday to Saturdays and 2200–0900 hours on Sundays**
Chevron Camp Site	50	50	49.5
Proposed gas processing facility site	30	24.5	23.5
T-Tree (north-end of Barrow Island)	30.5	36.5*	30.5*
Flacourt Bay (proposed feed gas pipeline shore crossing) – but also typical for west coast	40.2	42	41.5

** The second week of continuously monitored data at this location contains anomalous results and has therefore been excluded from the calculations of L90 of LA90 noise levels.*

Table 7-8:
Comparison of Sound Source Levels From Marine Vessels and Equipment (source: URS 2004)

Source	Peak Frequency or Band	Peak Source Level/s (re 1 µPa @ 1 m)
Large tankers and bulk carriers*	10–30 Hz	180–186 dB
Container ship**	7–33 Hz	181 dB
64 m Rig supply tender*	Broadband	177 dB
Tug towing barge*	1000–5000 Hz	145–171 dB
Cutter-suction dredge (working)	100 Hz tonal	~180 dB
Clamshell dredge (working)	250 Hz pulses	150–162 dB
Pile driving operations	Low tonal pulses	170–180 dB
20 m Fishing vessel*	Broadband	168 dB
Trawler#	100 Hz	158 dB
25 m Small Waterplane Area Twin Hull (SWATH) ferry with 2 x 950 hp inboard diesel engines**	315 Hz	166 dB
Bertram cabin cruiser with 2 x 165 hp inboard diesel engines*	400 Hz	156 dB
8 m Rigid Hull Inflatable Boat (RHIB) with 2 x 250 hp outboard motors*	315–5000 Hz	177–180 dB
Power boat with 2 x 80 hp outboard motors#	630 Hz	156–175 dB
Zodiac inflatable with 1 x 25 hp outboard motor#	6300 Hz	152 dB

** Recorded at 10–11 knots*
*** recorded at ~15 knots; # unrecorded speed or speed range*

emit noise from onboard machinery and the drill pipe. McCauley (1998) measured noise emitted from a drilling rig in the Timor Sea and found the broadband noise level to range from 169 dB re 1 μPa during drilling to approximately 146 dB re 1 μPa on standby. Under normal operating conditions, when the vessel is idling or moving between sites, support vessel noise would be detectable only over a short distance (2 km). The noise from a vessel holding its position using bow thrusters and strong thrust from its main engines, may be detectable above background noise levels during calm weather conditions for 30 km or more from the vessel.

The underwater noise generated by a typical drilling rig used in the Australian offshore petroleum industry was also measured by McCauley (1998). The drilling rig was found to have a maximum audible range of 11 km under ideal listening conditions while drilling and only 1–2 km while not drilling.

Noise from jetty construction activities may include the hammering sounds of pile driving or vibratory hammer operations. These can generate underwater sound pulses with received levels to 135 dB re 1 μPa at 1 km from the source, and an audible range extending to 10–15 km (URS 2004). A recent (2002) sound study of pile-driving operations (to construct a new Australian Defence Force wharfing area in Twofold Bay, near Eden, NSW) reported more intense underwater noise (McCauley et al. 2003). Maximum recorded average mean-squared pressure was 167 dB re 1 μPa (at 300 m from the operation), falling to 145 dB and 136 dB re 1 μPa at 1.8 and 4.6 km respectively. Curve-fitting of nine sets of measurements indicated that average signal strength fell from 150 dB to 140 dB re 1 μPa between 1 km and 3.1 km from the operation.

There will be noise associated with the pipe lay barge. In shallow waters the lay barge forward movement will via a series of winches and heavy anchors with tugboats placing the anchors. The pipe-laying vessels will likely use dynamic positioning (DP) in deeper water. Other sources of noise will be on-board diesel-driven cranes, compressors and generators. Near-field cumulative sound levels (i.e. overall received levels at some places within the near field) could be as high as 177 dB re 1 μPa rms. Continuous broad-band sounds will be transmitted through the vessel's hull from the gas turbines used to produce power for pipe welding station(s), movement of pipe sections and the welded pipe string, and other shipboard sound (Sakhalin Energy 2003).

Noise levels from some large trailer suction hopper dredges (TSHD) have been recorded in excess of 150 dB re 1 μPa at 1 km, while large cutter suction dredges (CSD) can emit strong tones from the water pumps which are audible to >20 km (Richardson *et al.* 1995). Noise from a dynamically positioned rig tender or TSHD may be detectable for 20–25 km during calm weather conditions, that is, when background noise levels fall below 80 dB re 1 μPa. Such conditions are most likely during the seasonally transitional periods in autumn (March–April) and spring (September–October), but are not common in the region of Barrow Island. Little noise is expected in the marine environment because the majority of the HDD process occurs from shore and the HDD equipment is located onshore.

Onshore Construction

Noise levels for various gas processing facility construction activities (e.g. site blasting, grading, excavating, levelling, material off-loading, grinding, erecting, etc) were predicted using an acoustic model, assuming a worst-case cumulative sound power level of 140 decibels (dB(A)) originating from the proposed site location (Technical Appendix B2). Consistent with the conservative approach to modelling, the screening effects of buildings and barriers at the site were excluded. Noise level predictions were produced for worst-case sound propagation conditions (e.g. 3 m/s winds combined with 2°C/100 m temperature inversion). Three wind directions were investigated: north, east, and south. Table 7-9 presents the predicted noise levels at the construction village site during construction.

Table 7-9:
Predicted Noise Levels at Village Site during Construction

Wind Direction	Wind Speed (m/s)	Temperature Inversion Rate (°C/100 m)	Predicted Noise Level dB(A)
North	3	2	44
East	3	2	41
South	3	2	31

Noise and Vibration from Blasting

The Western Australian Environmental Protection (Noise) Regulations 1997 specify maximum allowable noise levels resulting from blasting. The most stringent noise level, 90 dB $L_{\text{inear peak}}$, applies at any premises outside of the period from 0700 hours to 1800 hours. Considering the distance between the proposed gas processing facility site and the existing Chevron camp site (approximately 3.5 km) it is predicted unlikely that air blast energy levels will reach the 90 dB limit, even for very large blasts.

Further detailed information on the size and type of blasting to be used and the ground composition between the proposed development site and the existing Chevron camp is required before being able to predict vibration levels at the village site. However, assuming blast sizes are sequenced or limited to prevent structural damage to the existing oil tanks and pipeline terminal to the north of the proposed Development, it is unlikely that there will be any impact at the village site.

Noise and Vibration from Dust Removal Activities

During commissioning, a number of systems will use steam or air to remove dust and other trace construction contaminants. The commissioning will generally be conducted over a 6-month period as each system is completed and tested. Each of these activities will be very short in duration and result in localised noise, depending on pressures and volumes of piping involved.

7.4.3 Noise Emissions from Operation of the Proposed Development

Emissions from Operation of Offshore Gas Field

Gas pressure at the subsea gas wellheads and manifolds will be reduced and controlled, creating a noise source at the choke. McCauley (2002) measured the noise produced by an operating wellhead and found that the broadband noise level was low, 113 dB(A) re 1 μPa, which is only marginally above the ambient noise of rough sea conditions. For a number of nearby wellheads, the sources would have to be in very close proximity (<50 m apart) before their signals summed to increase the total noise field (adjacent sources only increase the total noise level by 3 dB(A). Therefore multiple wellheads and manifolds in the arrangement proposed in Chapter 6 are not expected to be much greater than 116 dB(A) re 1 μPa.
This would reduce quickly to ambient conditions with increasing distance from the wellhead. Moving towards the shore of Barrow Island, there will be no flow restrictions in the feed gas pipeline that would create a noise source. There will be some minor noise created by the turbulent flow of gas and liquids within the pipeline. The pipeline will have an external coating of concrete which will reduce noise from the turbulent flow from reaching the surrounding water column. It is probable that under moderate sea conditions, any pipeline noise will be lost to the background sea noise within a short distance (<100 m).

Given the constant noise from the wells, manifolds and pipelines, and the fact that these noise sources will be stationary, it is expected that any marine fauna in the area would habituate to the noise. The potential impact of noise on marine life is discussed in more detail in Chapter 11.

Emissions from the Operation of the Proposed Gas Processing Facility

A preliminary environmental noise assessment of the proposed gas processing facility on Barrow Island was undertaken (full details are available in Technical Appendix B2) as summarised below.

An acoustic model was developed using the Environmental Noise Model (ENM) developed by RTA technology. The ENM program calculates sound pressure levels at nominated receiver locations or produces noise contours over a defined area of interest around the noise sources. The inputs required are noise source data, ground topographical data, meteorological data and receiver locations.

The model has been used to generate noise contours for the area surrounding the gas processing facility and also to predict noise levels at the Chevron camp and the proposed construction village sites. The model does not include predictions of noise emissions from any sources other than the proposed gas processing facility because they are relatively small in comparison and unlikely to contribute to the sound levels of the Development. Pipelines to and from the gas processing facility are not included in the noise model as it is not expected that they will emit any significant noise.

The acoustic model was used to predict noise levels for the following scenarios:

- normal gas processing facility operation
- emergency blow-down of gas processing facility
- current power station operated by the Barrow Island Joint Venture.

Noise contours and noise levels were predicted for a range of meteorological conditions, including: calm conditions and worst-case wind conditions for sound propagation in the eight cardinal directions. The effects of temperature inversions on the modelling results were also reviewed (refer to Technical Appendix B2).

Barrow Island is a Class A Nature Reserve and a producing oilfield, consequently public access to the island is limited and there are no noise sensitive premises. The Chevron camp site is located approximately 3.5 km to the south-south-east of the proposed gas processing facility site and the proposed construction village will be located approximately 400 m south. These are the only facilities located on the island where noise could be considered to have any social impact.

Since these facilities are designed to service industry on the island, they have been classed as industrial premises according to Schedule 1, clauses 7 and 8, of the Environmental Protection (Noise) Regulations 1997 (The Regulations). The assigned noise levels are therefore 65 dB(A), 80dB(A) and 90 dB(A) for the L_{A10}, L_{A1} and L_{Amax} descriptors respectively. The most significant of these descriptors for continuous plant noise is the L_{A10} assigned level of 65 dB(A).

Routine Operations

At this early stage of design, noise levels for normal operation of an LNG plant of this capacity are predicted to result in an overall sound power level of 126 dB(A) +/- 3 dB(A). Based on the analysis of equipment specifications, and experience from other LNG projects of this magnitude, air coolers, piping noise and large machinery constitute the most significant sources of noise.

Noise contours produced for night-time conditions and 3 m/s winds from the north-east combined with a 2°C/100 m thermal inversion are presented in Figure 7-8. These meteorological conditions typically generate the highest noise levels over the largest areal extent. The 65 dB(A) noise contour borders the near edge of the proposed construction village. It is approximately 36 dB(A) at the existing Chevron camp site.

The predicted noise levels for routine gas processing facility operation at the existing Chevron camp site for a range of meteorological conditions ranged from 23 dB(A) to 36 dB(A) with the highest noise levels predicted for northerly wind conditions (Figure 7-9). This is far below the assigned level of 65 dB(A) and it is likely that noise from the gas processing facility will be

Figure 7-8:
Predicted Night-Time Noise Contours (north-east) – Routine Operating Conditions

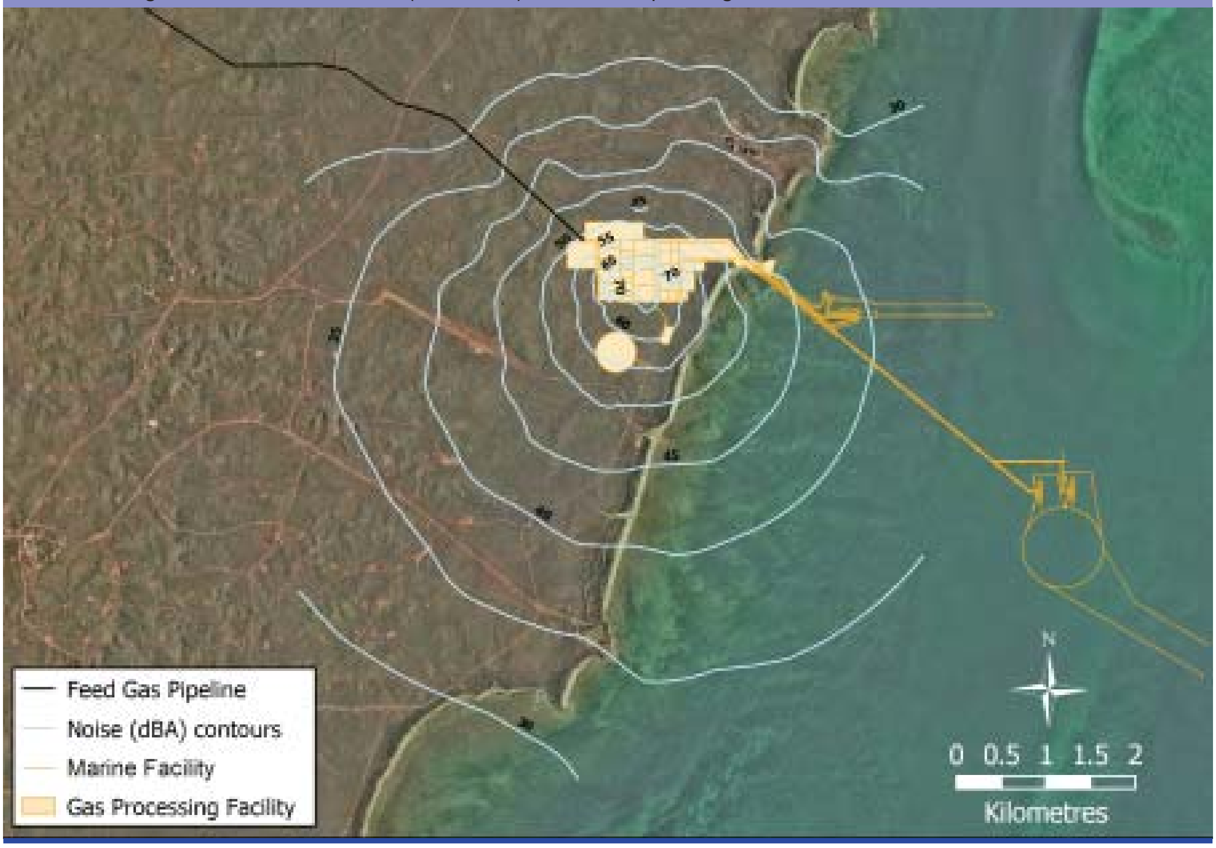
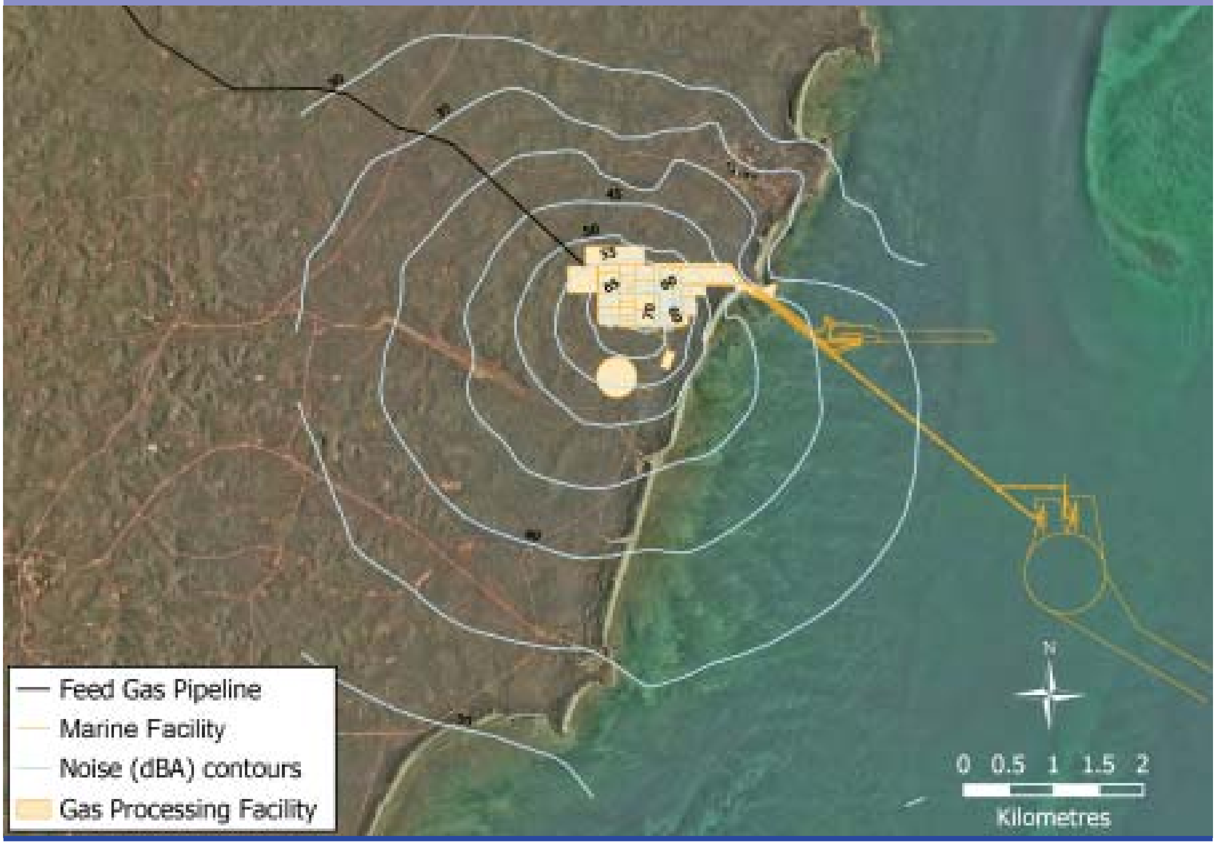


Figure 7-9:
Predicted Night-Time Noise Contours (north) – Routine Operating Conditions



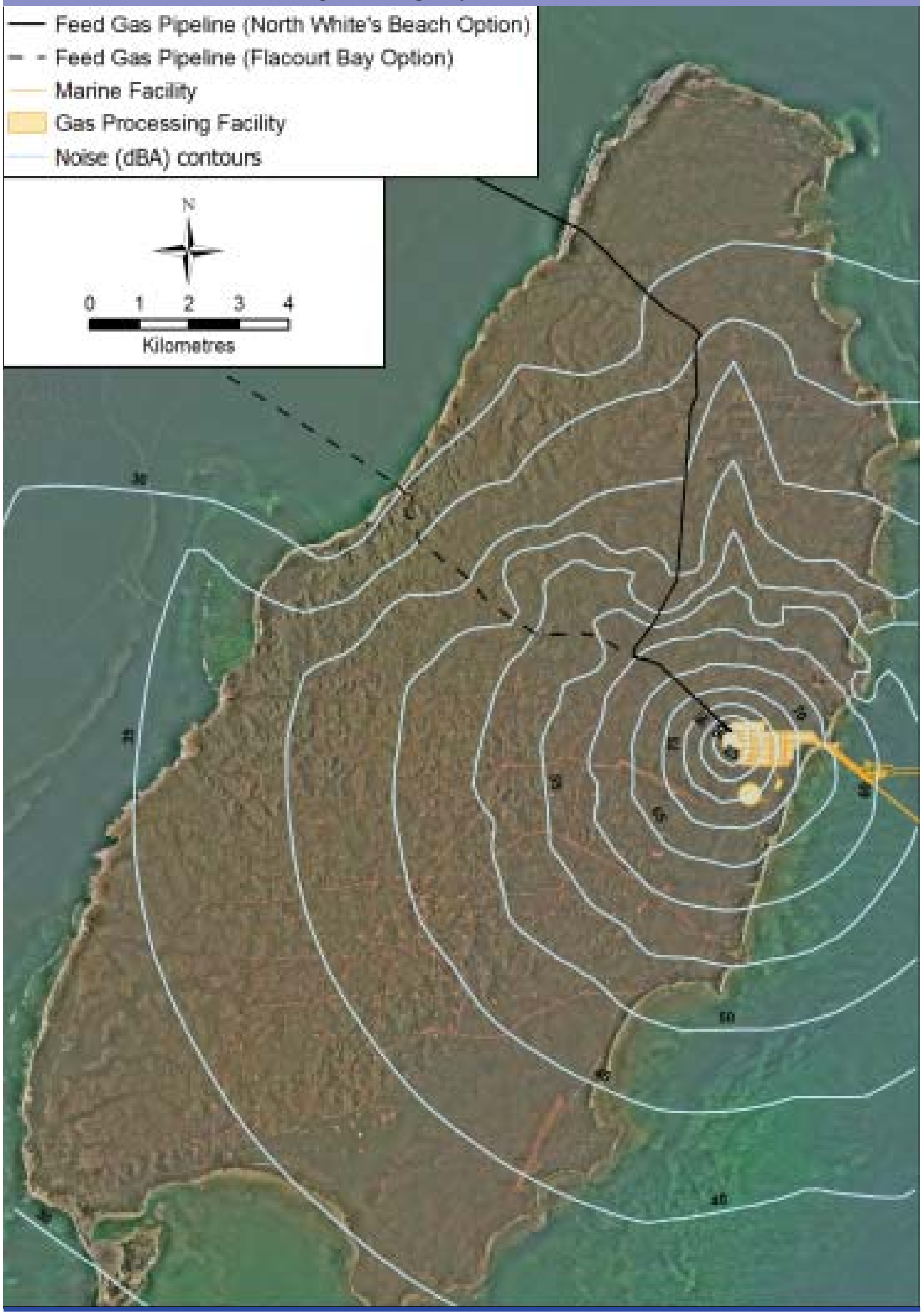
inaudible during normal operations. Under the same meteorological conditions, the noise levels at the Gorgon construction village during routine operations will range from 53 dB(A) to 65 dB(A), also within the assigned level of 65 dB(A).

As baseline information on noise levels, the noise contours were also predicted for the existing power station under worst-case sound propagation conditions. The acoustic model was used to predict noise contours using, as inputs, calculated noise levels from the existing power station and night-time wind and thermal inversion conditions. Maximum existing noise levels are predicted to be of the order of 55 dB(A) at the power station and diminishing to approximately 30 dB(A) within 2 km of this site. These levels do not contribute to the noise level at either the Chevron camp or the proposed construction village (Technical Appendix B2).

Non-Routine Operations

In terms of noise emissions, the most significant non-routine operation will be the flare used during an emergency shut-down of the gas processing facility. It was assumed that a sonic flare would be used in this situation; and a sound power level of 158 dB(A) was assigned for the flare when in operation. It is estimated that this flare will be operated approximately 10 times per year, but not all of these will be for process upset. Noise predictions for an emergency shut-down scenario were undertaken for worst-case sound propagation conditions, e.g. 3 m/s winds from the north combined with a 2°C/100 m thermal inversion. Three wind directions were investigated: north, east, and south. Predicted noise contours (Figure 7-10) for flaring associated with an emergency shut-down of the gas processing facility reach a maximum of 59 db(A) at the existing Chevron camp under worst-case meteorological conditions for sound propagation. This predicted level is below the assigned level of 65 dB(A). However, the level could exceed the existing background noise levels at the camp and may, therefore, be audible under some meteorological conditions. At the proposed construction village, the sound level during an emergency flaring could approach 80 db(A) for a short period of time.

Figure 7-10:
Predicted Noise Contours During an Emergency Shut-Down



7.5 Solid Non-Hazardous Wastes

7.5.1 Current Waste Generation

Solid non-hazardous waste is currently generated on Barrow Island from existing oilfield operations. Putrescible and office paper wastes are segregated and burned in the existing high temperature incinerator and the ashes are buried in a small landfill site on the island. Non-recyclable waste rubber and plastic are separated and compacted on Barrow Island and buried in the local landfill on Barrow Island without burning. In 2003, 390 tonnes of non-hazardous waste solid waste were disposed at the local landfill on Barrow Island. The landfill accepts only clean fill and inert (type 1) waste.

Other solid non-hazardous wastes are removed from Barrow Island for recycling or disposal on the mainland. Any recyclable wastes are segregated and stockpiled at the old airport hardstand area prior to shipment. In 2003, 265 tonnes of scrap metal, aluminium cans, tyres, oil filters, separators, 25 litre drums and thread protectors were removed from the island and recycled.

7.5.2 Expected Development Waste Streams

Solid non-hazardous wastes that will be generated by the Gorgon Development typically include plastic, packaging, scrap metal, general domestic waste, food waste, tyres, waste pipe, concrete and non-hazardous drums and containers.

Solid non-hazardous wastes will be generated in varying amounts throughout all phases of the Gorgon Development; however, it is expected that the majority of waste will be generated during the construction phase on Barrow Island. Wherever practical the following wastes will be re-used or recycled:

- vegetation, rock and soil overburden from site levelling, foundation preparation, pipe-laying, and drilling activity
- drilling fluids, cuttings and dredge spoil material
- scrap pipe, metal fabrication, insulation, concrete and general construction materials
- packaging.

Onshore construction and drilling wastes not reused or recycled will be collected, stored or contained on location at designated collection sites. Wastes generated on Barrow Island will generally be removed from the island for disposal at an approved disposal facility. Dredge spoil from excavation at the MOF, channel and turning basin will be disposed of in designated sites (location provided in Chapter 11) pursuant to the terms and conditions of the Commonwealth Sea Dumping Permit (*Environment Protection (Sea Dumping) Act 1981*) and National Ocean Disposal Guidelines for Dredged Material.

Drill cuttings from offshore activity will be separated from drilling fluids and disposed to the marine environment. Injection of cuttings into a suitable sub-surface formation is extremely unlikely in a subsea wellhead development program at the water depth (>190 m depth) and receiving environment in the Gorgon area. Drill cuttings and fluids from the onshore HDD associated with the shore approaches for the feed gas pipelines will initially be collected, separated and the fluid reused in the drilling process. However, once the drill has broken through the seafloor, some bentonite and drill cuttings will be discharged to the marine environment.

Subsea control fluids will be used to operate, protect and maintain the upstream manifolds and wellheads in the offshore field area. These fluids are specifically designed for this purpose and are commonly used in subsea exploration and development wells in north-west Australia, the Gulf of Mexico, the North Sea and offshore Brazil. An open loop system for subsea control fluids is planned with small volumes of control fluid released from the valves on the seabed when they are operated. Control fluids will be selected for low toxicity and biodegradability while meeting operational requirements. Details will be available in the Environmental Management Plan (EMP).

In the subsequent design phases, it will be possible to provide a better estimate of the volume of construction phase waste that will be generated. Development wastes will be identified, categorised, handled, stored and managed in accordance with a Development-specific Waste Management Plan to be approved prior to any construction activity. Wastes will be greatest during the period of construction when wells and shore crossings are being drilled, the shipping channel and MOF are being dredged and constructed, the gas processing facility and associated pipeline(s) are being constructed. Waste volumes generated during operations and maintenance of the Gorgon Development will be substantially less.

7.6 Liquid Wastes

7.6.1 Liquid Waste Management

Table 7-10 shows the major liquid discharges that will be associated with the Gorgon Development.

Ballast Water

Ballast water is sea water that is taken on to maintain ship/vessel stability. Ballast water will be discharged from the drilling rig, dredges, heavy haul cargo ships, possibly lay-barges and the LNG and condensate tankers. Ballast water tanks on modern vessels are usually segregated from other fuel and product tanks; consequently the potential for contamination from hydrocarbons is very low. Australian ballast water management requirements are consistent with International Maritime Organisation (IMO) Guidelines for minimising the translocation of harmful aquatic species in ships. The potential for introducing non-indigenous marine pest species as part of the ballast water is described in Chapter 12.

Currently all tankers visiting Chevron Australia's marine terminals have been informed of the 'Australian Quarantine and Inspection Service (AQIS) Voluntary Guidelines for the Handling and Treatment of Ballast Water Carried in Ships Entering Australian Waters.'

Since 1993, the source and volume of ballast water discharged from tankers visiting the Barrow and Thevenard Island marine terminals has been monitored.

The options available for managing ballast water include:

- exchange at sea (beyond the 12 nautical mile limit) by an approved method is deemed acceptable
- commitment not to discharge ballast water in Australian ports or waters
- use of the Ballast Water Decision Support System (BWDSS). While not mandatory, this application can provide vessels with a risk assessment of ballast water.

Deck Drainage

Clean deck drainage water on the drill rig, dredges, tankers and support vessels will be directed overboard. If it contains traces of oil, grease or hydrocarbon it will be directed to a sump and oily water separator. The discharge of surfactants, dispersants and detergents will be minimised. Detergents or dispersants used for wash-down will be biodegradable and phosphate free. All endeavours will be made to keep detergents out of oily water separation systems as they adversely affect the separation.

Table 7-10:
Major Liquid Discharges

Liquid Waste – Major Discharges	Development Phases or Activities			
	Drilling	Construction and Commissioning	Operations	Decommissioning
Ballast water	✓	✓	✓	✓
Deck washing and run-off	✓	✓	✓	✓
Treated sewerage/ grey-water	✓	✓	✓	✓
Drilling fluids	✓	✓	✓	
Produced water	✓	✓		
Wellhead control fluids	✓	✓	✓	✓
Pressure testing/ hydrostatic test water		✓	✓ small	
Desalination brine from potable water system		✓	✓	✓
Storm water		✓	✓	✓

If not stored, or directed to onboard tanks, all wastewater prior to discharge will meet or be better than all regulatory requirements. The discharge will be introduced below the surface of the water (if the particular vessel allows this) and will have no significant sheen, visible oil or foam. Sewage and grey-water will be stored in tanks and then pumped to an approved shore-based treatment system if a vessel is operating less than 12 nautical miles from land, or otherwise discharged in line with legislation. Offshore food wastes will be macerated so that they can pass through a 25 mm mesh before being discharged to sea, in compliance with Clauses 222 and 616 of the Schedule to the Petroleum (Submerged Lands) Act, and the International Convention for the Prevention of Pollution from Ships (MARPOL) regulations. Waste management measures are outlined in the Framework Environmental Management Plan (Technical Appendix A).

Onshore, a waste water system will be designed to protect soils, groundwater and the marine environment from contamination. To achieve this, a multi-tiered waste water management approach has been adopted (Chapter 6) in order to minimise the discharge of contaminants and nutrients.

Drilling Fluids

Drilling fluids used in the Gorgon Development are likely to be a combination of water-based and non-aqueous drilling fluids (non-aqueous drilling fluids (NADF)-low toxicity fluids, such as synthetic based fluids which are commonly used in north-west Australia with Regulator approval). The specific fluid systems will be selected when geological information, well development and operating designs are sufficiently advanced for each well. The drilling fluid used offshore is expected to be primarily bentonite with silica, salts, polymers, barite (which often contains heavy metals) and a very small amount of other chemicals, mixed with fresh or sea water. However, technical challenges in the offshore drilling program may require drilling fluids with drilling properties that exceed those of water based fluids. Directional and extended reach drilling may be required to develop many new resources economically. Such drilling requires fluids that provide high lubricity, stability at high temperatures and well-bore stability. These challenges have led to the development of more sophisticated NADFs (e.g. synthetic based mud) that deliver high drilling performance and ensure environmentally sound operations.

The introduction of NADFs into the marine environment is associated with fluid adhering to discharged cuttings following treatment. Significant advances have been made to reduce the toxicity and environmental impacts of NADFs. Where NADF cuttings discharge is allowed, diesel and conventional mineral oils have largely been replaced with fluids that are less toxic and less persistent. Polyaromatic hydrocarbons, the most toxic component of drilling fluids, have been reduced from 1–4% to less than 0.001% for newer fluids (International Association of Oil and Gas Producers 2003). New generation drilling fluids, such as paraffins, olefins and esters are less toxic and are more biodegradable than early generation diesel and mineral oil base fluids. Synthetic based muds and ester based muds are currently used widely in north-western Australia with regulatory approval.

Drilling fluid will be mixed, stored, maintained and recycled in surface tanks. In a closed circulation system used during the drilling of the lower hole sections, the fluid will return to the surface equipment where it will be processed and separated using a range of solids-removal equipment. Drilling fluids and drill cuttings will become wastes at different stages of the drilling process. Drill cuttings are generated throughout the drilling process as formation is cut and removed, although higher quantities of cuttings are generated when drilling the first few hundred metres of the well because the borehole diameter is the largest during this stage.

Waste fluid is handled at completion of drilling because the entire drilling fluid system is removed from the hole as it is replaced by completion equipment and fluids. After completion of drilling, fluid components can be recovered by treatment at the rig or by returning the entire fluid to the supplier. As discussed in Section 7.5.2, a small portion of fluid will be lost during the separation of drill cuttings. The drilling fluid components proposed will have very low to extremely low toxicity to marine life. Further details on mud selection and cuttings management will be included in the Environment Plan required under the P(SL)A for Department of Industry Resources (DoIR) approval.

Produced Formation Water

Produced formation water from the gas fields along with additives such as monoethylene glycol (MEG) and corrosion inhibitor will be brought to the gas processing facility and separated from the gas stream at the slugcatcher. The liquids will then be separated into a water phase and condensate. Monoethylene glycol will pass with the water and will be recovered from the water stream and recycled and condensate will be sent off for stabilisation and storage. If a corrosion inhibitor is used, then any present in the water phase would be directed with the produced water into dedicated injection wells on Barrow Island.

Hydrostatic Test Water

Pressure testing the feed gas pipeline and domestic gas pipelines will require the lines to be filled with chemically treated hydrotest water. Following successful testing, the hydrostatic test water would be emptied prior to commissioning of the pipelines. Chemicals added to the test water would typically include an oxygen scavenger (e.g. ammonium bisulphite, or OS2) and a biocide (e.g. phosphonium sulphate or Bactron). Ammonium bisulphite reacts with the oxygen within the hydrotest water to form ammonium sulphate, consuming all oxygen in the water.

Where possible and practical, test water will be re-used to test other components of the gas processing facility. Following successful testing, the hydrostatic test water will either be discharged by injection into dedicated disposal wells on Barrow Island. If it meets testing requirements, it will be discharged into the marine environment at an approved location and discharge rate. Hydrostatic testing is not a continuous operation and once the facilities have been tested, approved and commissioned, there will be little need for additional test water.

The principal environmental consideration of this discharge would be the anoxic state of the hydrotest water, potential toxicity presented by the phosphonium sulphate and the potential scavenging of oxygen from the ambient seawater. Modelling was applied to quantify whether dilution of the hydrotest water discharge and subsequent dispersion by ambient currents would be sufficient to ensure that oxygen concentrations in the receiving waters will not be significantly reduced.

For the feed gas pipeline, modelling was undertaken on a typical hydrotest water composition which included Bactron at 150 mg/L and OS2 at 100 mg/L. It was assumed that the water is discharged at a depth of 200 m, at production manifold station 2, through a pipe with an internal diameter of 697 mm to represent the feed gas pipeline scenario. The total volume of hydrotest water was estimated at 32 000 m^3 which was discharged in a 23-hour period.

Modelling was applied to determine whether concentrations of phosphonium sulphate would be below the ‘no-effect’ concentration (nominally <0.19 mg/L), and where this no-effect concentration would occur.

Discharge of hydrotest water at the offshore production area (probable location for the feed gas pipeline discharge) was predicted to generate 10-minute average concentrations of 1750 ppb. The concentration of phosphonium sulphate near the discharge is predicted to be maintained below 0.0016 mg/L (i.e. lower than the no-effect concentration) and that oxygen concentrations are estimated above 99% of ambient concentrations. The release rate of hydrostatic test water can be controlled. A reduction in the discharge rate would further increase dilution rates and decrease phosphonium sulphate concentrations.

For the domestic gas pipeline, modelling was undertaken on a typical hydrotest water composition which included Bactron at 150 mg/L and OS2 at 100 mg/L. It was assumed that the water is discharged at a depth of 2 m, 1 km from Barrow Island adjacent to the MOF, through a pipe with an internal diameter of 440 mm to represent the domestic gas pipeline scenario. The total volume of hydrotest water was estimated at 13 600 m^3 which was discharged in a 25-hour period.

For the domestic gas pipeline, the discharge of hydrotest water into the tidal channel off the eastern shore of Barrow Island was predicted to generate maximum 10-minute average concentrations near the discharge of 19 566 ppb. Thus, the maximum concentration of phosphonium sulphate near the discharge would be maintained below 0.0018 mg/L (lower than the no-effect concentration) and oxygen concentrations should similarly be above 99% of ambient concentrations. Concentrations during periods of tidal flow were predicted to be generally lower than 5000 ppb within the immediate area of the discharge. As mentioned above, the release rate of hydrostatic test water can be controlled and any reduction in the discharge rate will increase dilution rates.

Water Maker Brine

As mentioned in Chapter 6, the potable water supply for the Gorgon Development will be provided by a reverse osmosis plant, or similar water making technology. One option currently being examined is to discharge effluent (water maker brine) from this system back into the ocean.

The water maker brine is essentially sea water which has been concentrated by approximately 50% and is close to ambient temperature. It is likely that approximately 3000 m^3/day of this brine would be discharged, which is approximately the volume of an Olympic-sized swimming pool. This will be discharged along the LNG jetty, or subsea line, at an appropriate disposal location. Due to the currents and large volume of water passing the jetty area, each tidal cycle the effluent will be dissipated quickly into the receiving waters and would have negligible environmental impact.

Storm Water

The volumes and quantities of waste water, stormwater, fire water runoff, food and village wastes that will be generated cannot be accurately quantified until subsequent design phases have been completed. Stormwater treatment systems are discussed in Chapter 6.

Waste management measures are outlined in Technical Appendix A. During detailed design, development wastes will be identified and characterised, their volumes estimated and management and disposal options (e.g. avoidance, reduction, recycle and re-use, storage, evaporation, injection and potential marine discharge) prescribed in a Development-specific Waste Management Plan.

7.7 Hazardous Waste

7.7.1 Waste Generation and Expected Hazardous Waste Streams

Hazardous wastes are defined as the waste stream which has one or more components that pose a threat to human health, safety or the environment. Hazardous waste will be generated in varying amounts throughout all phases of the Gorgon Development. It is expected that the majority of hazardous waste will be generated during the construction phase of the Development. In subsequent design phases, it will be possible to estimate the volume of potential hazardous wastes that will be generated and will include recovered solvents, excess or spent chemicals, paints, oil and process-contaminated materials (e.g. sorbents, filters and rags), certain drilling fluid constituents (polymer, bacterial control and corrosion inhibition additives), spent X-ray films, used lubricating oils and filters.

The Gorgon Joint Venturers will implement routine maintenance where many of the filters, spent catalyst and other production wastes will be systematically removed from service, collected, stored or contained on location at designated collection sites and removed from Barrow Island to an approved disposal facility.

All hazardous wastes associated with the Gorgon Development will be managed in accordance with a Development-specific Waste Management Plan. The Plan will include systems and details for tracking wastes from source to final destination or disposal.

Scale

Under certain natural pressure, temperature and chemical conditions, solid minerals (scale) will form from the produced water, usually where there is a significant pressure drop. The most common scales consist of barium sulphate ($BaSO_4$), strontium sulphate ($SrSO_4$) and calcium carbonate ($CaCO_3$). The potential for scale in the Gorgon Development has been assessed and appropriate inhibitors will be used throughout the production process as required. If scales form, they will be treated as hazardous waste and appropriate management and controls will be implemented bearing in mind that they might contain low specific activity materials.

Mercury

Trace amounts of elemental mercury occur naturally in Gorgon feed gas, as in many other oil and gas reservoirs. The mercury removal unit is a vessel which usually contains a bed of granules. As gas passes through the vessel containing the granules, the traces of mercury react and remain chemically trapped. The bed material essentially acts like a filter and so will be removed periodically during routine maintenance (likely to be in excess of six years) and will be returned to the supplier for recycling and handling or disposed on the Australian mainland at an approved facility.

7.8 Dredging and Dredge Spoil Disposal

Dredging on the east coast of Barrow Island is located within the existing Barrow Island port boundary and the proposed dredge spoil disposal site is located over the south-eastern section of the boundary (Figure 7-11).

Construction of the causeway, MOF, jetty and dredged channels and other infrastructure on the east coast of Barrow Island will involve direct disturbance to the seabed in these areas. The dredging and other construction activities required to create the channels and berth areas for the Development will result in physical disruption to localised areas of the seabed, direct loss of some coral habitat, and the generation of turbidity plumes at both the dredging and disposal regions.

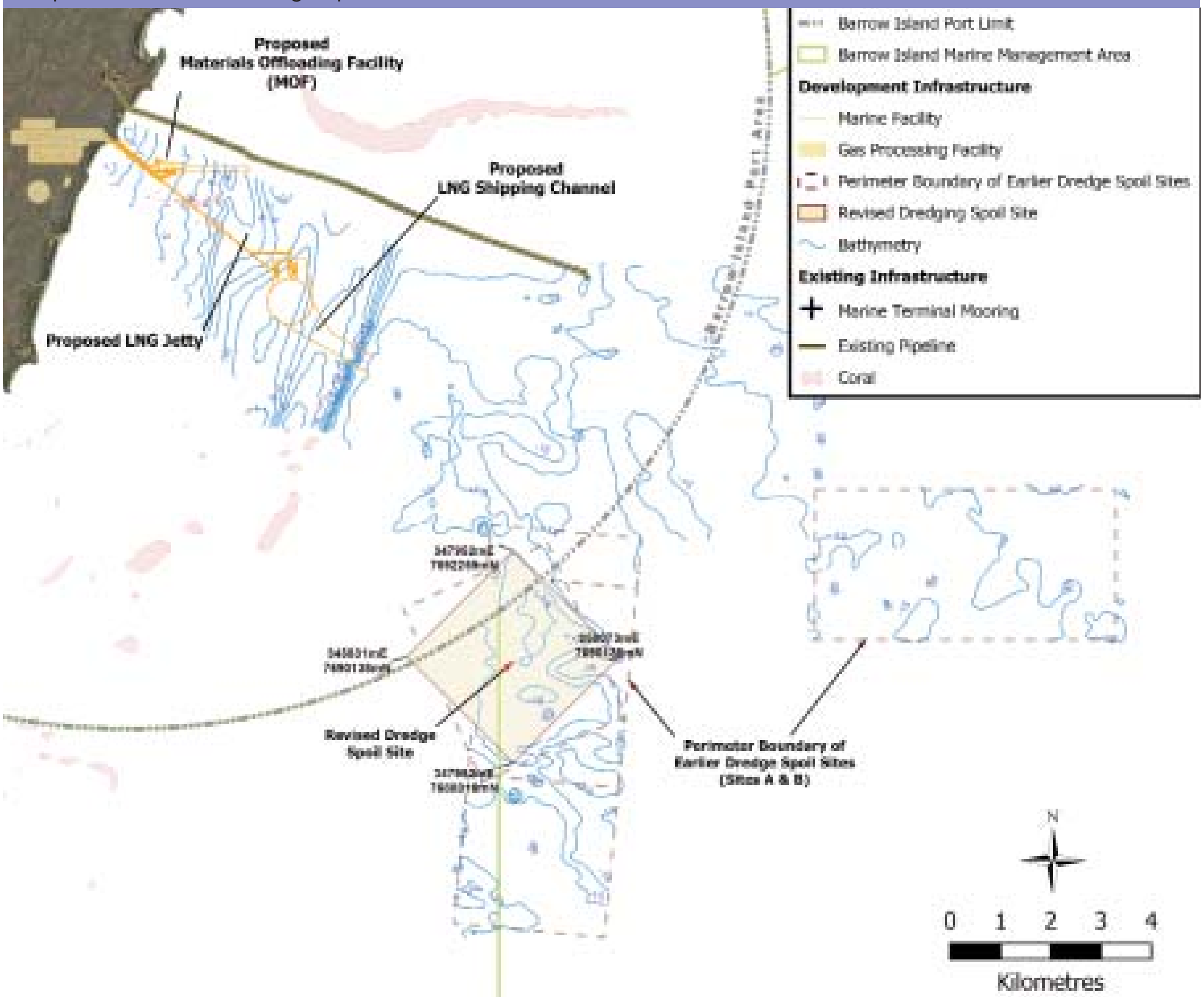
Dredge spoil will be disposed to the seabed at a defined dredge spoil disposal location and will modify the substrate characteristics in the receiving area.

An area of sandy seabed and appropriate bathymetry has been selected for dredge spoil disposal to minimise the changes in substrate type and to minimise migration of the spoil from the disposal ground (Figure 7-11).

Marine Benthic Surveys were undertaken in accordance with a draft Sampling and Analysis Plan (SAP) prepared and submitted to the Department of the Environment and Heritage (DEH) in support of a Sea Dumping Permit for the Development. The program involved:

- sampling at forty sites in areas of potential disturbance (MOF, LNG shipping channel/basin and proposed disposal sites)
- twenty-nine sledge surveys to collect baseline data and investigate the potential concentration of benthic primary producers and other epifauna
- an extensive towed video survey (MOF, LNG shipping channel/basin, proposed disposal sites and other areas of interest).

Figure 7-11:
Proposed Location of Dredge Spoil Site



A series of settlement plates and sediment traps have been installed in the proposed dredging area to provide further information on marine flora and colonisation as well as natural levels of sediment deposition in the areas planned to be dredged (Plate 7-1). The sediment trap data will assist the Joint Venturers in determining the amount of sediment that may potentially infill the dredged channels and turning basins and hence maintenance dredging requirements. In addition, the sediment traps will allow quantification of the natural deposition rate of sediment that corals are presently exposed to and serve as monitoring locations during dredging.

The dredging required to create the channels and berth areas for the Development (Chapter 6) will result in physical disruption to localised areas of the seabed and the generation of turbidity plumes at both the dredging and disposal regions. In order to adopt a conservative approach to potential environmental impacts, prediction of the disturbed areas and plumes has relied on:

- surveying marine habitats and species sensitivities in the proposed Development area
- examining the range of dredging equipment which will be used and potential impacts, such as turbidity at the dredge site due to the action of the cutter head
- reviewing two hydrodynamic models and their dispersion results under a number of seasons to identify potential worst-case scenarios
- using material distributions (as relevant) from past dredging projects in Western Australia, namely the Geraldton Port Enhancement, Hamersley Iron's (Pilbara Iron) Dampier Port Upgrade and the Dampier Port Authority's Bulk Liquids Berth Project since some of the dredging techniques and particle sizes will be similar to the Gorgon Development
- using available preliminary geophysical and geotechnical data supplemented with recent bathymetric and geotechnical (near shore drilling and vibrocore program) information
- using results from sediment analysis of 40 sample locations taken in the Development area
- surveying the physical and availability constraints of the site and/or equipment (i.e. potential restriction of certain dredges due to shallow waters or sea states).

Table 7-11 identifies the proposed locations, equipment, volumes and duration for the dredging program.

To predict and assess the potential impacts on corals and determine the monitoring that will be required, numerical modelling was undertaken using a particle tracking technique (Technical Appendix B5).
The modelling was carried out in two steps. Firstly, the 3-dimensional ocean circulation of the region from south of Barrow Island to north of the Montebello Islands was predicted for 16 months using the GEMS coastal-ocean model GCOM3D. Then the total dredging program was simulated over 450 days using a sophisticated particle tracking model which simulates the daily behaviour of the dredge(s) based on an estimated dredge log. Refer to the Technical Appendix B5 for full details of the modelling and results.

For the modelling simulation of the dredged MOF, several assumptions were made as outlined in Box 7-3.

For the simulation of the dredged LNG access channel and turning basin, several assumptions were made and are outlined in Box 7-4.

Plate 7-1:
Installation of Settlement Plates and Sediment Traps – Barrow Island

Table 7-11:
Location, Equipment and Estimated Volumes and Duration of Dredging Activity

Dredging Location/Activity	Dredger/Equipment Proposed	Volume (Mm^3)	Duration
MOF Channel and Basin to -6.5 m LAT	Cutter suction dredge Discharge pipeline to MOF causeway for fill	~0.80	~21 weeks
LNG channel and turning basin to –14 m LAT	Cutter suction dredge and trailer suction hopper dredge and self-propelled hopper barges with bottom dump	~8.0–9.0	~ 45 weeks
Disposal of dredged material to proposed 3 x 3 km spoil disposal site taking advantage of local bathymetry (Figure 7-11)	Self propelled hopper barges with bottom dump	Capacity to handle 12.0	≥45 weeks

Box 7-3:
Summary of Assumptions for MOF Dredging – Cutter Suction Dredge (CSD) Pumping to Bund

- A bund wall in the MOF outline will be filled with dredge spoil pumped directly from the CSD.
- The volume of cut and fill is estimated to be 800 000 m^3.
- According to the geotechnical data available, the material to be dredged is crystalline limestone with a capping of calcarenite.
- The hardness of the rock is believed to be harder on average than that encountered at the recent Geraldton dredging program.
- The characteristics of the spoil is anticipated to be similar to that generated at Geraldton (i.e. a high proportion of fines/flour and coarse limestone rubble).
- The duration of the dredging/reclamation program is estimated to be 18 weeks plus 2+ weeks weather downtime.
- Vessels will work 24-hours per day but a mean dredge work rate of 96 hours of dredging per week should be achieved. (Rate will vary depending on hardness of rock).
- Lost time is due to dredge stopping and changing teeth every few hours (more frequently in harder rock) and for maintenance or refuelling activities.
- Maintenance will occur only in response to difficulties. However, when dredging rock there will be shut-downs each 7 to 14 days in harder material and longer in softer materials. Refuelling will be undertaken each four to six weeks for 2 days.
- The dredge will start at outer end of the access channel and gradually work towards the shore creating a 6.5 m deep channel (LAT).
- It is assumed that 5% of total material cut will fragment to a size below 75 microns and that the distribution of these particle sizes will be similar to the Geraldton dredging program.
- It is assumed that 50% of these fines will be released at the cutter head and 50% from the tailwater discharge.

Box 7-4:
Summary of Assumptions for the LNG Access Channel and Turning Basin

- The total volume to be dredged is estimated to be between 7 and 8 Mm^3.
- Roughly 40% of the total volume in the LNG access channel and turning basin will be sediment, or soft or fragmented rock, which can initially be removed by TSHD.
- The TSHD dredging and disposal cycle period will be approximately 2.5 hrs (based on 90 minutes of dredging, 1 hour of travel to and from spoil ground including 10 minutes for dumping at the spoil ground).
- TSHDs are less weather dependent than CSDs and will be able to deliver about 134 hours production per week which equates to 53 loads per week on average.
- Assuming an average load of 6 000 m^3, giving a bulk production rate of approx. 300 000 m^3 per week, the sands can be removed in 11–12 weeks.
- In general, maintenance will be undertaken travelling to and from the spoil grounds but the TSHD will cease operations for two days every 4 to 6 weeks to refuel and undertake major maintenance.
- Overflow will operate for the last 60 minutes of dredging and will be released under the keel of the THD (–6 m depth).
- Overflow discharge will be approximately 8 m^3/sec (2 x 4 m^3/sec dragheads).
- As the surface sediments are coarse this material is expected to remain low in the water column.
- Fines within the sediments may be released.
- When dredging, the principal source of fines is anticipated to be from propeller action. Overflow of fines from the hopper are added to this from beneath the keel.
- Given that the sands are coarser than the ‘rock flour’, this activity is anticipated to release less fines than CSD operations.
- The particle size distribution used in this part of the simulation is based on laboratory analyses of field samples taken from Development area.
- A large CSD pumping directly into one of two self propelled hopper barges that will transport the material to the spoil ground for disposal.
- Dredge behaviour and production rates are anticipated to be similar to the MOF Dredging rates described in Box 7-3 above (effective production of 96 hours/week).
- The duration of dredging is anticipated to be 55 weeks.
- Fines/flour will be generated at the CSD cutter head and at the hopper barge overflow which will be beneath the keel of the barge.

Modelling has relied on the best available metocean, meteorological, and bathymetric information available to date, including assumptions and details from other recent dredging programs throughout Western Australia. The model will be further validated through more geotechnical, baseline water quality, coral health, and metocean data that will be collected for the Development area and will be available prior to any dredging activity. In addition, a monitoring program will be developed and form part of the comprehensive Dredge and Spoil Disposal Management Plan.

Modelling predicted the daily distribution of Total Suspended Solids (TSS) and seabed coverage to be developed over the total dredge program (approximately 450 days). The daily output was analysed to derive periods of continuous exposure to turbidity and/or sedimentation above defined thresholds. The result of this analysis is summarised in maps of exposure zones showing regions affected by turbidity or sedimentation that result in total mortality, partial mortality or no mortality. Figures showing TSS distributions and the derived exposure zones are shown in Chapter 11 along with the discussion of the assessment and management of potential impacts. Where there was uncertainty in model parameters, conservative values were chosen such that the model would tend to overestimate the extent and magnitude of impact. The model predictions were aligned to the current dredging schedule, which is throughout the year except for the period(s) of coral spawning.

The modelling predicts a build up of deposited sediments in the immediate vicinity of the dredging area and spoil disposal site from the settlement of the larger sediments (>75 µm). Finer sediment fractions remain suspended for longer periods and lead to increased turbidity which varies significantly in space and time. These variations are due to the active ocean circulation around Barrow Island driven by strong tides and marine winds.

The assessment of the potential impacts of dredging and spoil disposal on the marine environment and the basis of the dredge monitoring program are described in detail in Chapter 11.

Recent dredging and spoil disposal programs undertaken by Hamersley Iron for their Port Upgrade at Parker Point and the Dampier Port Authority's Bulk Liquids Berth Project involved prolonged dredging (10 months in total) of significant quantities of material (4.1 Mm^3 and 4.9 Mm^3 respectively), similar in volume to that proposed for the Gorgon Development. Comprehensive water quality and coral monitoring studies for the two programs were incorporated into a single monitoring program (MScience 2005).

The key findings of the studies are as follows:

- Turbidity needs to be elevated for extended periods to produce impacts on coral species. Some species are more sensitive than others.
- While turbidity was high at many sites during the dredging programs, the one site where coral mortality occurred was characterised by high TSS levels, suggesting that the cause of coral mortality during the program was one or more acute episodes of sedimentation. In the case monitored, suspended sediment concentrations from bottom samples which exceeded 60 mg/L in waters within a few hundred metres of coral appeared to be the sole cause of mortality. Chronic sedimentation with TSS levels below 40 mg/L did not appear to result in elevated coral mortality in the two dredging and disposal programs.
- Dissolved oxygen and pH varied little between sites and times and there was no evidence that these parameters were influenced by dredging effects.
- Modelling of TSS levels was used to predict areas where corals could be impacted and where impact monitoring should take place as well as where reference sites should be located. The model provided conservative estimates and actual effects appeared more localised and ephemeral than predicted, principally because the sediments settled out of the waster column much faster than had been predicted.
- Monitoring of TSS and sedimentation rates appear to provide predictive measures of potential coral impacts prior to coral mortality taking place.
- Resuspension of deposited sediment takes place relatively quickly (~10 weeks) and is an important mechanism for removal of the fine sediment from coral areas into deeper soft sediment regions where impacts are minimal.

7.9 Accidental Releases (Spills) to the Marine Environment

The nature of LNG production and supply necessitates robust and reliable design and execution to meet corporate and stakeholder expectations. Consequently, control and planning during execution should achieve optimum supply reliability. This, in turn, will provide the lowest possible risk of hydrocarbon release by ensuring that the highest standards of design, material selection and construction and operation are applied.

The potential hydrocarbon releases that were identified for the Gorgon Development include:

- an onshore release from the feed gas pipeline, condensate from the rupture or leak from a pipeline or tank within the gas processing facility. The risk and management of onshore releases and management are described in the Leaks and Spills section of Chapter 10 and the Public Risk section of Chapter 14.
- a release of condensate and produced water (containing dissolved hydrocarbons and monoethylene glycol (MEG)) from the subsea production equipment, subsea flow lines or the feed gas line running from the supply fields to the western shore of Barrow Island
- release of processed condensate from either of the subsea condensate off-loading pipelines (existing or new) on the eastern side of Barrow Island
- a release of diesel from shore facilities or small vessels operating around facilities on the east and west coasts of Barrow Island
- a release of condensate, crude oil (from other sources) and bunker fuel oil from tankers brought to the export terminal.

Potential releases of other, non-hydrocarbon, fluids from the Development include: accidental spills of MEG which will be piped from Barrow Island to the subsea production wells; heat transfer fluid from a ruptured pipeline or tank within the processing facility, and the controlled discharge of hydrotest water prior to commissioning of the feed gas and domestic gas pipelines and other large inventories (i.e. LNG tanks).

Chemical and product storage areas will be engineered and designed to handle the volumes and operating conditions (both normal and upset conditions) specifically required for each substance, including product identification, transportation, storage, control and loss prevention (e.g. bunding and drainage). If a spill occurs, close adherence to product Material Safety Data Sheets (MSDS) will assist in the appropriate handling and clean-up will reduce the potential impact to the environment. Tank and storage areas will be provided with appropriate bunding and drainage systems in line with Australian Standards (as a minimum) to reduce the extent of potential spills, and to assist containment and subsequent clean-up.

For liquid spills outside of bunded areas, valves will be provided to enable shut-in of production and limit the volume of any release. Areas of surface flow that can be contaminated would be contained within the gas processing facility and directed to the oil recovery system with the risk of spills outside of hardstand areas very low. Soil potentially contaminated by a hydrocarbon or chemical spill will be evaluated and treated by a method that will have the least environmental harm while meeting operational requirements (refer to Chapter 10).

To fully understand the potential environmental risks associated with spills, it is necessary to examine three independent aspects, namely:

- the likelihood that a spill occurs – this is often referred to as ‘Primary Risk’
- if a spill occurs, the way that the material moves with wind and currents and ambient/water temperature (hence there are seasonal aspects) and how the material behaves with other natural processes such as evaporation, dissolution into the water column, and natural degradation – this is often referred to as ‘Secondary Risk’
- given the above two aspects, and for any given spill scenario in specific weather conditions, it is necessary to consider whether the material will reach sensitive receptors. If so, what are the possible impacts on those receptors – this is often referred to as ‘Tertiary Risk’ or ‘Joint Risk’.

The modelling assessment undertaken for the Gorgon Development therefore took into account the following risk categories:

Primary Risk – the potential of an accidental hydrocarbon release occurring from a pipeline, refuelling accident, a marine vessel collision or grounding, and other similar scenarios. For this study, worst-case release scenarios were assessed for the pipelines. This involved a full pipeline rupture and release of contents. For the refuelling and marine collision or grounding scenarios, realistic release volumes were assessed. Spills from onshore tanks were not examined as these will be bunded in line with Australian Standards, as a minimum. The assessment of primary risk is considered to be very conservative, i.e. frequency used in the assessment is much higher than is actually likely. Refer to Technical Appendices B3 and B4 for full details.

Secondary Risk – assuming that a spill has occurred, the secondary risk is the probability of any released hydrocarbon reaching a shoreline or environmentally sensitive area. For this study, the hydrocarbon concentration limit used was 0.8 g/m^2. At this concentration, the hydrocarbon would take on the appearance of a rainbow or dull sheen on the water. The modelling was undertaken during different seasonal climatic conditions and the worst-case was selected. Modelling assumes that no intervention (i.e. booms or dispersants) has taken place and so is a worst-case scenario. (Refer to Technical Appendices B3 and B4 for modelling details).

Tertiary or Joint Risk – represents the overall risk of exposure of sensitive receptors and is very conservative. It is the likelihood that a release occurs and it reaches an area of potential significance and has an effect on sensitive receptors. This conservatively assumes that no intervention (e.g. booms, dispersants, etc) has taken place and so is a worst-case assessment. Refer to Chapter 11 for full details.

Determining the environmental risk associated with a hydrocarbon release to the marine environment requires an assessment of primary, secondary and joint risk which is discussed collectively in Chapter 11. Conservative factors were included in the assessment such that credible ‘worst-case’ release volumes were modelled for each of the scenarios (refer to Table 7-12). For example, the primary risk of pipeline failure has assumed a large/full bore rupture which generates the most significant hydrocarbon losses. In general, for pipelines over 406 mm outside diameter (OD) (16 inch OD), these ruptures only comprise approximately 30% of the recorded incidents within the recorded database (refer to Technical Appendices B3 and B4). In addition, to date there have been no known incidents of full bore rupture of large diameter (609 mm OD to 1067 mm OD) offshore trunklines in operation. Such pipelines are extremely robust and are protected (or kept remote) from known significant risk factors such as vessel anchoring or dropped objects. The data sets applied for the spill modelling relate to failure frequencies of smaller pipelines and are therefore inherently conservative.

There has not been a blowout of a subsea well in the North West Shelf of Australia, therefore spills associated with blowouts are not considered a credible scenario. A blowout is also not considered credible for the Gorgon Development because:

- several wells have already been drilled in the formations and the reservoir pressures are well-known
- blowout prevention equipment is provided and tested in line with legislation
- personnel are fully trained in the use of this blowout equipment.

7.9.1 Control Measures used to Reduce Primary Risk of Hydrocarbon Release

The Gorgon Venturers will employ best practice measures to reduce the primary risk of hydrocarbon releases. Significant focus in the design will ensure that releases from the pipeline systems and the gas processing facility will not occur. The equipment design, material selection and construction standards and techniques adopted for the Gorgon Development will be based upon proven, robust solutions used worldwide and extensively in similar environments and applications.

Given that the feed gas pipeline transports potentially corrosive products, and will be exposed to severe environmental forces over the operational life, some challenges exist with respect to assurance of long-term integrity. The main risks that could result in an unplanned release of hydrocarbons and production water, together with the design mitigation/control measures, planned are summarised in the following sections.

Potential Internal and External Pipeline Corrosion/Reduction in Wall Thickness

As described in Chapter 6, the base case pipeline material for the feed gas pipeline is a lining of Corrosion Resistant Alloy (CRA). In addition to material selection and inhibitor injection, a corrosion management plan will be implemented over the operating life of the pipeline system to monitor corrosion products and sand production. Thresholds will be established and monitored to identify any increase in parameters that may signify increased corrosion or erosion rates within the system. Investigation (including intelligent pigging) and potential intervention will be initiated to define and resolve any technical problems.

Externally, a combination of anodes, cathodic protection, corrosion coatings and monitoring will be employed to eliminate the risk of external corrosion. Systems will be designed with additional capacity beyond the design life to provide contingency. Periodic inspection of the effectiveness of the system will be performed throughout the operating life of the Development.

Potential Pipeline Buckling or Damage During Installation

The subsea pipelines will be designed and installed in accordance with recognised world-class design codes (AS 2885 1997; and DNV OS-F101 1996). Installed pipelines will be inspected and monitored to identify any buckles, coating damage and free-spans greater than design specifications. All damage will be assessed and remedial work performed as required to assure long-term pipeline integrity.

Potential Pipeline Movement or Displacement During Storm Conditions

The pipeline systems will be designed to remain stable during severe environmental loadings created by cyclonic events and major winter storms. For the subsea pipelines, stability will be achieved by the most appropriate stability technique, such as addition of concrete coating, lowering of the pipeline below the seabed and, where necessary, the placement of rock berm(s) or armouring over the installed pipeline(s).

Where pipeline spanning occurs which may result in pipeline overstress during severe weather conditions, the free-span lengths will be reduced by placement of rock or grouted supports. Monitoring of scouring effects that may create or extend free-spans during the design life will be performed by remotely operated vehicle (ROV) and intervention will be initiated as required.

Potential Hydrate Blockage and Overpressure During Operation

The feed gas pipelines will have continuous hydrate inhibitor (MEG) injection over the field life to prevent hydrate internal build-up/blockage. Should a hydrate blockage or leakage occur past a wellhead valve causing pipeline pressure to build up beyond normal operating levels, the pipeline integrity will not be impacted due to protective measures built into the pipeline design.

Potential Pipeline Weld Failure During Operation

Offshore pipeline material and welding process selection will be performed in accordance with design standard DNV OS-F101 (1996). Steel grades selected will be of high strength. Weld materials will be carefully matched to assure the same or improved strength. Stress concentration effects will be assessed during pipeline installation analysis.

All weld procedures and welders used offshore will be fully tested, qualified and approved by third party inspection agencies. Installation will be performed by world-class contracting companies using automatic or semi-automatic welding processes, automatic ultrasonic inspection/testing systems or other appropriate non-destructive testing techniques.

The pipelines will also be hydrostatically tested in line with legislation to ensure their integrity.

Potential Flange/Connector Failure During Operation

The main feed gas pipeline(s) will be fully welded along the length, but some flanged connections will be required within the pipeline system and these connections will be inspected and tested. Connections used subsea will be extensively tested onshore and will have facilities to verify seal integrity during subsea make-up before hydrocarbon pressurisation.

The entire pipeline systems will be fully hydrotested and gauged to verify strength and connection integrity, in accordance with AS 2885 requirements before commencing operation.

During the operational life of the pipeline system, a number of risks exist from external sources that could result in leakage of hydrocarbons. The various risks which have the potential to result in hydrocarbon release, together with controls and mitigation measures that could/will be adopted are summarised below.

Dropped Object Risk

Dropped objects of a size capable of significantly damaging a large diameter pipeline comprise drilling equipment (drill collars, blow-out preventer etc) or vessel anchors. During subsequent drilling phases and subsea well work-over operations, handling of heavy equipment will be performed some distance from the pipeline, with procedures in place to minimise the risk and consequences of such an incident.

The pipeline will be clearly identified on navigation charts with clear warnings to avoid anchoring within a set exclusion zone along the pipeline. The pipeline corridor will run over a very exposed (unsheltered) area which is unlikely to be used for large vessel anchoring except in emergency situations.

The pipeline will also be concrete weight coated over most of its length. It is expected to have a wall thickness in excess of 40 mm which will provide very significant impact resistance in the unlikely event of an anchor being dropped (recreational vessel anchors will not significantly damage the pipeline). In some areas it is also likely that rock berm will be placed over the pipeline for stability reasons, further reducing levels of risk from dropped objects.

The smaller utility pipelines associated with the feed gas pipeline will also be protected. They will be largely protected by the presence of the feed gas pipeline itself.

Fishing Gear Interaction

Currently, there are no significant risks envisaged along the pipeline routes from fishing activities. Based on the co-existence of operating pipelines and the fishing industry in the Onslow/Dampier area, the potential for snagging and significant displacement of one or more of the pipelines with consequential damage to the pipelines is considered extremely low. Generally the boats involved in the commercial fishery (prawn trawl and trap) are small, manoeuvrable and their activities are controlled by limited entry, seasonal and area closures, gear controls and catch reduction devices. Pipelines can affect trawling activities as they create a ‘no-go zone’, but equally can act as an artificial reef which attracts fish life and increases yields. No pipeline appurtenances will be on the pipeline design that could be damaged and result in leakage.

Vessel Sinking/Grounding

Vessel sinking and impacting directly onto the pipeline is a very remote risk, given the limited vessel traffic in the area. Should such an event occur, it is likely that only large vessels would result in significant pipeline damage and that smaller vessels (e.g. cray boats, pleasure and recreational fishing craft) would be unlikely to have sufficient mass to cause a release.

The remote risk of a large vessel running aground is restricted to the shallow water shore crossing area. On the west coast, the feed gas pipeline will be installed under the seabed in the near shore area. It will be protected by a rock berm or similar covering material outside of this shore crossing area to assure near shore pipeline stability. The LNG and condensate tankers will have an experienced navigational pilot on the bridge when within the port boundaries. These tankers will be escorted/assisted by tugs during berthing and departure. A tug will be on standby during cargo loadings. In the event of a cyclone, the ships will depart the loading terminals and standby at sea until favourable docking and loading conditions return.

Vessel Anchor Dragging

Anchor dragging has the potential to damage the pipeline; however, only large vessels are likely to have anchors of a sufficient size to pose a significant threat. As noted for dropped objects, the pipeline will be clearly identified on navigation charts with clear warnings to avoid anchoring within a set exclusion zone along the pipeline.

The level of risk this presents to the pipeline will be assessed as part of a Quantitative Risk Assessment during subsequent design phases of the Development. If required, a rock berm could be placed over the pipeline to deflect dragged anchors in areas where the risk of large vessel anchoring is considered credible.

Sabotage

Sabotage of the pipeline is a credible risk only in areas where it is accessible. Given that the offshore and shore crossing areas are inaccessible (either subsea or encased in a drilled conduit or backfilled trench), the sabotage risk with subsequent hydrocarbon leakage is a very low risk for the offshore pipeline system.

Refuelling

The probability of hydrocarbon release is highest for refuelling vessel/ships, especially during construction. A number of basic procedures that will be carried out during refuelling to avoid or reduce the possibility of a release include:

- undertaking fuel transfer activities in accordance with established procedures and adhering to all port authority and pollution regulations
- refuelling within established safety boundaries and during weather/sea/visibility conditions that will minimise potential release risk
- training personnel involved with refuelling or fuel transfer in their roles, functions and responsibility, including emergency response
- maintaining open communication channels
- deploying spill prevention systems in accordance with established procedures and regulatory requirements
- maintaining emergency response equipment to ensure that it is readily available.

7.9.2 Fate and Transport of Spilled Hydrocarbon

The fate and consequences of hydrocarbon spills, in terms of their trajectory, change in nature due to weathering. The potential for harmful effects upon shoreline and shallow water habitats are a product of the nature of the oil type, the release conditions and the environmental conditions prevailing during and after the spill occurs (French 2000). Modelling of such spills has been undertaken and is based on the assumption that no intervention has taken place to contain the spill should one occur. Thus the modelling represents the worst-case for each spill scenario. The Gorgon Joint Venturers will have in place a comprehensive spill contingency plan, which will include pre-approved use of dispersants in line with current best practice. Neither of these response considerations is included in the results of spill modelling discussed below.

Numerical modelling was applied to determine where a hydrocarbon or other liquid release could spread in the unlikely event of a full pipeline rupture (worst-case scenario). Table 7-12 is a summary of the release source (location), the type of fluid released, the depth of the release, the volume and the duration (the estimated time from initial release to its control). Table 7-13 is a summary of the risk of exposure associated with various release scenarios.

Table 7-12:
Hydrocarbon Release Scenarios used for the Prediction of Spill Trajectories

Release source	Released fluid	Depth (m)	Volume (m^3)*	Break-down	Duration (hours)
Rupture at central manifold of Gorgon production area	Condensate & formation water	200	2200	630 m^3 condensate, rest water and MEG	3
Rupture of feed gas pipeline 14 km from Barrow Island	Condensate & formation water	50	1600	590 m^3 condensate, rest water and MEG	4.5
Rupture of feed gas pipeline 200 m from Barrow Island	Condensate & formation water	12	1600	590 m^3 condensate, rest water and MEG	4.5
Rupture of condensate export pipeline 2.2 km from Barrow Island	Condensate	2	1550	100% condensate	3
Refuelling accident during the supply of the pipe-laying barge 10 km west of Barrow Island	Diesel fuel oil	Surface	2.5	100% diesel	<1
Refuelling or incident or spill of fuel from the port facilities adjacent to the MOF jetty	Diesel fuel oil	Surface	0.1–10**	100% diesel	<1
Work vessel collision within port approaches. Randomised within 2000 m radius of a location 2.7 km west of the proposed MOF jetty	Diesel fuel oil	Surface	2–20**	100% diesel	1–6**
Randomised most likely grounding site for a tanker along the 12 m depth contour. Most likely grounding site during each major wind season.	Processed condensate, light crude oil or bunker fuel oil	Surface	10–100**	100% hydrocarbon	1–24**

** Volume is total fluid (i.e. condensate, MEG and water)*

*** Release duration and volume randomised within this range*

The nature of each discharge, potential release conditions and seasonally varying environmental conditions was modelled as described in more detail in the following sections. A stochastic model was used to determine the fate of 100 simulations for a given release scenario and season combination. A threshold thickness of 0.01 mm (0.8 g/m^2 or the equivalent to a dull sheen/'rainbow' film on water) was defined as a threshold for recording episodes of contact with surface cells by surface-bound hydrocarbons. A minimum concentration of 10 parts per billion (ppb) was defined for entrained oil.

Results of the multiple simulations were analysed to provide a statistical weighting to potential spill outcomes following the procedures defined in French et al. (1999). The following sections describe each of these scenarios in greater detail.

Essentially this process summarises the likelihood, if a spill occurs, that it will move in a certain direction under the forces of wind and currents. For example, if 75% of the year the wind and currents both move from the south-west to the north-east, for 24% of the year they move from the north-west to the south-east and for the remaining 1% of the year they move from the east to west, if a spill occurred, there is a chance of 1 in 100 that a sensitive receptor located west of the spill site might be affected. If a spill had a primary risk of occurring of 1 in ten million (1 x 10^{-7} per year), then the chance of impacting that specific sensitive receptor is 1% of 1 x 10^{-7} per year or 1 x 10^{-9} per year.

It is also highly unlikely that, if a spill occurred, the material would move to have any impact on a sensitive receptor which is situated north-west or south-west of the spill site.

In the following section, the term per cent probability (%) refers to the same concept, assuming a spill has occurred, but using real wind and current data. It should be noted that the probabilities given in this section as percentages must be combined with the primary risk to reach a conclusion regarding risks to sensitive receptors.

Releases of Condensate and Reservoir/Formation Water from the Upstream Supply

Fluids within the production well, production flowlines and feed gas pipeline to Barrow Island are expected to include water, MEG and hydrocarbon condensate. The natural gas component (predominantly methane) will not be a liquid under these operating conditions. The worst-case scenario for these facilities is a rupture at one of the offshore manifolds, the infield flowlines or the feed gas pipeline to the island during production, at normal operating pressures.

From statistical and actuarial records, submarine facilities and pipeline constructed in Australian waters are inherently safe. As mentioned previously, to date there has been no known incidents of full bore rupture of large diameter (609 mm OD to 1067 mm OD) offshore trunklines in operation.

For the purpose of this assessment, failure data for smaller lines has been used and so it has been assumed that there is very low probability (primary risk) of hydrocarbon spills occurring (2.81 x 10^{-5} per kilometre year, or the probability of 2.81 incidents every 100 000 years for a 1 km segment of pipeline). Further discussion on the probability of release and the risk to workers and the public are described in Chapter 14 and in the Technical Appendix B4. As described earlier (Section 7.9.1), the primary risk will be further reduced by incorporating physical and chemical/electrical protection measures, modern construction and operating procedures, as well as developing appropriate navigational hazard identification and exclusion zones. However, in the unlikely event of an incident, such a rupture is assumed to result in a release of gas and all entrained liquids within the pipeline. The assumption that all of the liquids are released is also a very conservative assumption.

Modelling of the three scenarios involving high-pressure release from the manifold and feed gas pipeline indicated that the atomised plume of condensate would tend to rise towards the surface, where it would pool to form a thin slick. Dissolved hydrocarbon plumes generated in this process were also predicted to rise, due to entrainment by the rising plume of condensate.

Potential Manifold Rupture

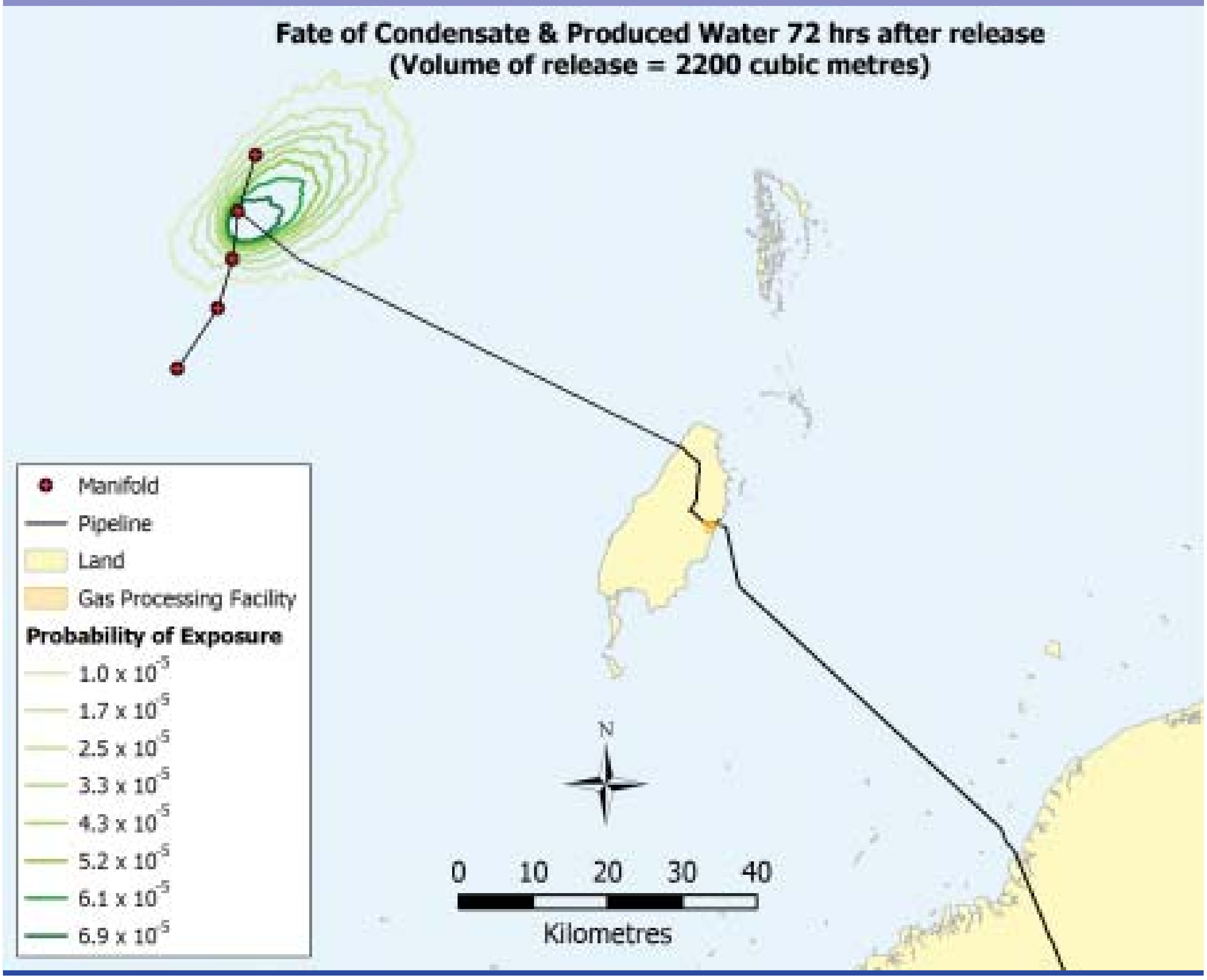
The probability of the manifold or feed gas pipeline rupturing is very unlikely. However, if a rupture occurred, the risks of exposure from surface slicks and dissolved hydrocarbons would vary markedly among the three release sites modelled (Technical Appendix B4). Stochastic modelling indicated that a floating condensate slick generated by a rupture at the manifold would most commonly drift towards the north-east to the seaward side of the Montebello Islands (Figure 7-12). Further, this slick was predicted to thin to a rainbow-sheen 72 hours after the release. A rainbow-sheen is a very thin layer of oil less than 0.0003 mm in thickness. The sheen could potentially extend to a distance of approximately 40 km, so could dissipate before landfall. Peak concentrations of aromatic hydrocarbons in the surface layer were predicted to decrease to <10 ppb within 30 km. Consequently, if such a release occurred, the probability of exposure to shallow water habitats by potentially harmful concentrations of floating oil or aromatic hydrocarbons was predicted to be very low (<1%). Therefore the combined primary and secondary risk is two orders of magnitude less than the primary risk which is already very low.

Potential Feed Gas Pipeline Rupture

Modelling of the fate of a feed gas pipeline rupture 14 km off Barrow Island predicted that the resultant slick of condensate could reach landfall before thinning to a rainbow-sheen. However, as this does not represent the worst-case scenario, it is not described further (specific details are provided in Technical Appendix B3).

The worst-case scenario (albeit extremely unlikely) is a full pipeline rupture 200 m from the western shore of Barrow Island. In the unlikely event that this scenario eventuated, the probability of condensate and production water washing onto the shoreline was predicted to be very high year-round (Figure 7-13). It is estimated that the maximum extent of the slick would occur within 72 hours of the release. After this

Figure 7-12:
Release of Condensate and Produced Water from Central Manifold



time, the condensate would evaporate due to the weathering caused by wind, waves, tides, water and air temperature. Under light wind conditions, all volatile hydrocarbons were expected to evaporate within 48 hours.

The potential length of affected shoreline and the potential volume that could wash ashore are also markedly larger (up to 43 km and 159 m^3, respectively) than for a rupture further offshore. Concentrations of aromatic hydrocarbons exceeding 300 ppb could reach shallow water habitats between the Montebello Islands and the Lowendal Islands, while concentrations up to 4 ppm are predicted for the central-west and north-west coasts of Barrow Island. Simulations indicated a high probability that these elevated concentrations could be trapped inshore for extended periods (>12 hours) under onshore wind conditions, especially during summer, indicating a high potential of exposing resident biota.

Release of Processed Condensate from the Condensate Offloading Pipeline

The condensate offloading pipeline and the future option to run a dedicated condensate loadout line along the proposed LNG jetty and then subsea to a single buoy mooring are both located within the Barrow Island Port boundary. The existing offloading pipeline is, and if required the new offloading line would be, marked on navigational charts with an appropriate exclusion zone. To date there has never been a spill recorded from the existing export pipeline in its 40 years of operation.

Figure 7-13:
Predicted Release of Condensate and Produced Water from Feed Gas Pipeline (200 m from Barrow Island)

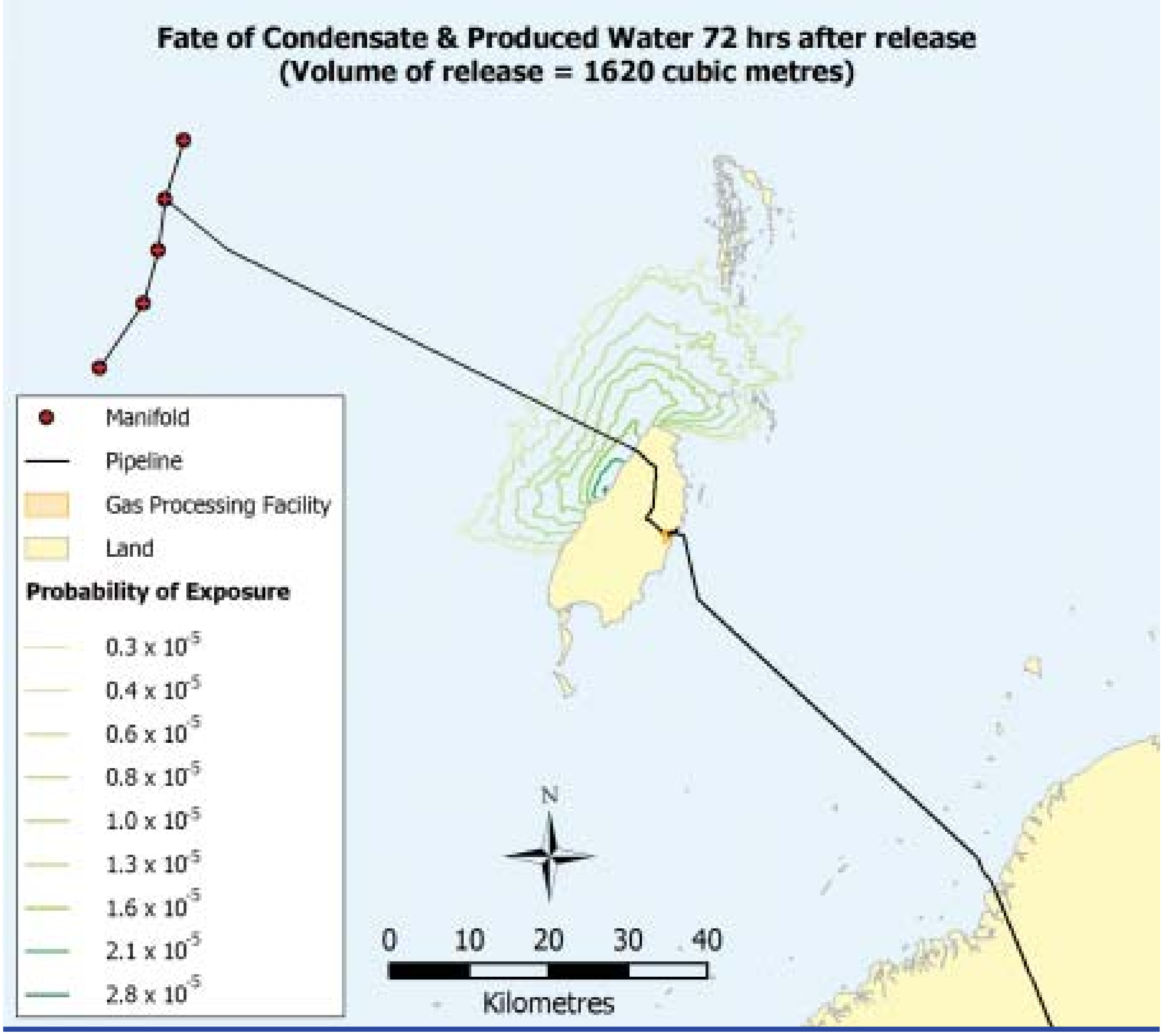


Table 7-13:
Estimates for the Risks of Exposure Associated with Defined Release Scenarios**

Spill Scenario				Risk Estimates			Shoreline Exposed (km)		Volume on Shore (m^3)	
Spill Source	Season	Spilled Fluid	Approximate Spill Volume (m^3)	Primary Risk of Spill Occurring	Secondary Risk of Oil Onshore (per incident)	Joint Risk of Spill Occurring	Maximum	Mean ± St. dev.	Maximum	Mean ± St. dev.
Rupture at central manifold	Summer	Condensate & water	2200 total (630 cond)***	7.50 x 10^{-5}/y	<1 x 10^{-2}	<7.50 x 10^{-7}	NC	NC	NC	NC
	Annual	Condensate & water	2200 total (630 cond)***	1.50 x 10^{-4}/y	NT	NT	NT	NT	NT	NT
Rupture of feed gas pipeline	Summer	Condensate & water	1600 total (590 cond)***	1.41 x 10^{-5}/kmy	9.9 x 10^{-1}	1.39 x 10^{-5}	43.4	14.4 ± 6.3	158.6	129.4 ± 25.9
200 m from Barrow Island on route 1	Transitional	Condensate & water	1600 total (590 cond)***	4.68 x 10^{-6}/kmy	1.0 x 10^{-0}	4.68 x 10^{-6}	37.9	15.6 ± 6.9	116.6	75.9 ± 10.4
	Winter	Condensate & water	1600 total (590 cond)***	9.37 x 10^{-6}/kmy	9.6 x 10^{-1}	8.99 x 10^{-6}	20.6	9.3 ± 5.3	39.1	12.8 ± 3.6
	Annual	Condensate & water	1600 total (590 cond)***	2.81 x 10^{-5}/kmy	9.8 x 10^{-1}	2.76 x 10^{-5}				
Rupture of condensate offloading pipeline	Summer	Condensate	1550	7.40 x 10^{-5}/kmy	7.2 x 10^{-1}	5.33 x 10^{-5}	57.9	10.2 ± 15.0	22.4	3.8 ± 1.1

Table 7-13: (continued)
Estimates for the Risks of Exposure Associated with Defined Release Scenarios**

Spill Scenario				Risk Estimates			Shoreline Exposed (km)		Volume on Shore (m^3)	
Spill Source	Season	Spilled Fluid	Approximate Spill Volume (m^3)	Primary Risk of Spill Occurring	Secondary Risk of Oil Onshore (per incident)	Joint Risk of Spill Occurring	Maximum	Mean ± St. dev.	Maximum	Mean ± St. dev.
2.2 km from Barrow Island	Transitional	Condensate	1550	2.47 x 10^{-5}/kmy	9.6 x 10^{-1}	2.37 x 10^{-5}	49.6	24.5 ± 13.5	47.8	33.8 ± 8.6
	Winter	Condensate	1550	4.93 x 10^{-5}/kmy	1.0 x 10^{-0}	4.93 x 10^{-5}	81.3	32.4 ±17.9	605.8	295 ± 137
	Annual	Condensate	1550	1.48 x 10^{-4}/kmy	8.5 x 10^{-1}	1.26 x 10^{-4}				
Release alongside MOF jetty	Summer	Diesel	0.1–10*	4.50 x 10^{-3}/y	8.4 x 10^{-1}	3.78 x 10^{-3}	17.8	3.6 ± 3.8	0.5	0.2 ± 0.2
	Transitional	Diesel	0.1–10*	1.50 x 10^{-3}/y	7.2 x 10^{-1}	1.08 x 10^{-3}	21.7	4.8 ± 4.2	0.5	0.4 ± 0.1
	Winter	Diesel	0.1–10*	3.00 x 10^{-3}/y	1.6 x 10^{-1}	4.80 x 10^{-4}	30.6	6.6 ± 5.0	0.5	0.4 ± 0.1
	Annual	Diesel	0.1–10*	9.0 x 10^{-3}/y	5.9 x 10^{-1}	5.34 x 10^{-3}				

NC – No Contact

NT – Not Tested because of very low risk and probability of shoreline exposure

* *Release volume randomised within this range*

** *Results are for hydrocarbon concentrations exceeding 0.8 g/m². Seasonal rates for primary spill risk assume a proportion of the annual risk based on the number of months in summer (6), winter (4) and transitional (2) seasons. The joint risk is calculated as the product of the primary and secondary risk. The volumes and shoreline expose assume no intervention of any kind, but the Gorgon Joint Venturers will have in place a comprehensive spill contingency plan, which will include pre-approved use of dispersants in line with current best practice.*

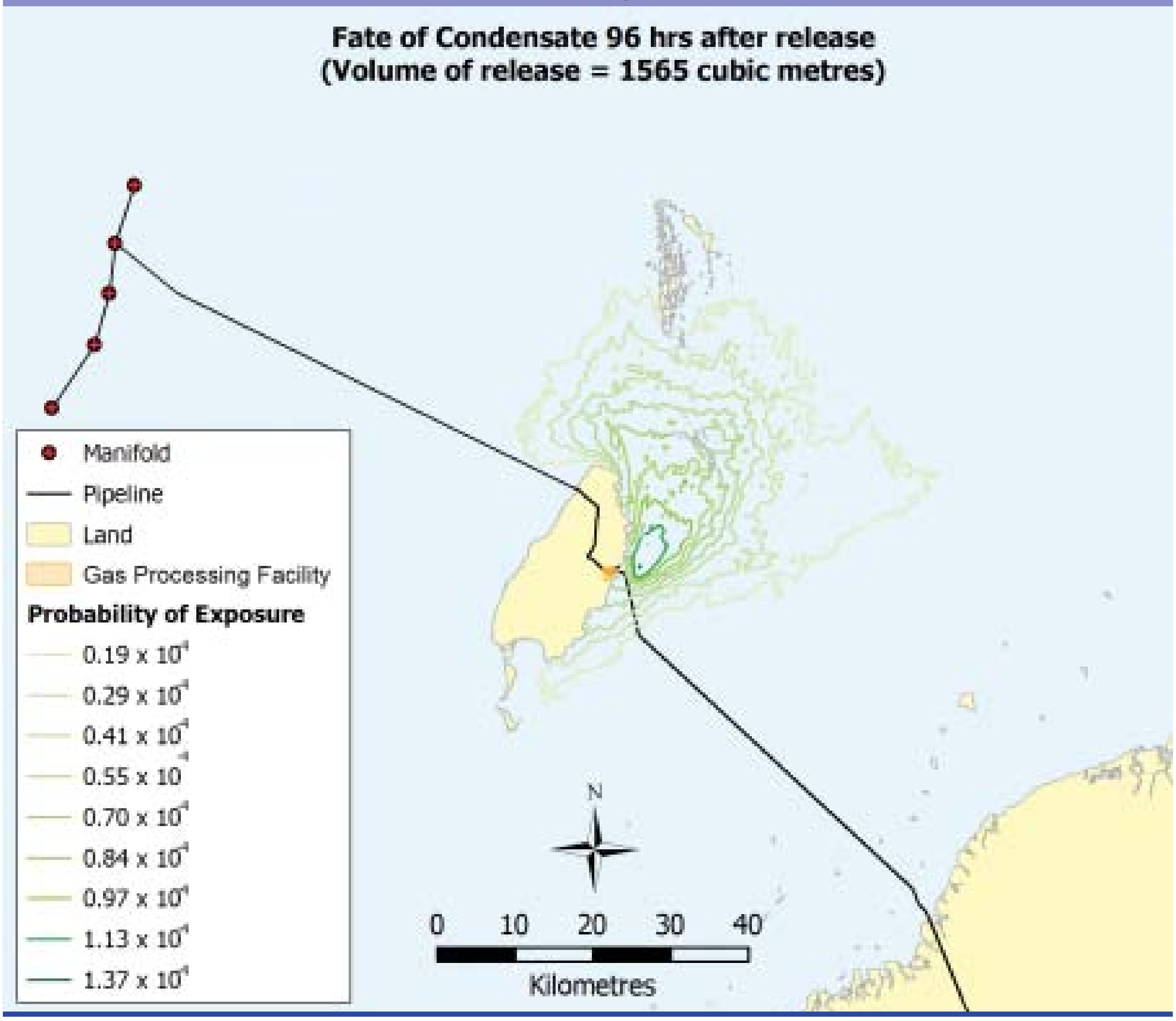
*** *Represents the condensate (hydrocarbon) component of the spilled fluid*

A complete rupture of the existing condensate offloading pipeline, when pressurised and delivering condensate to a tanker, was identified as the worst-case scenario. A rupture point about 2 km offshore was identified as the worst-case location, due to the proximity of shallow reef habit and the strong currents between Barrow Island and the Lowendal Islands (Figure 7-14).

Simulation of this spill scenario predicted that if such a release occurred (joint risk of 4.93×10^{-5}) a slick of floating condensate would most commonly drift along a north-south axis with the prevailing tidal currents. Depending on climate and metocean conditions, after 96 hours, parts of the slicks were predicted to have a high probability of washing onto shorelines throughout the adjacent islands, year-round (72–100% depending upon the season). The highest probability of shoreline exposure (100%), the largest potential shoreline area (81%), and the highest potential volumes of condensate (606 m^3) were predicted for winter when prevailing easterly winds would tend to force the hydrocarbon slick onto Barrow Island. During winter, the probability of the Lowendal Island shorelines receiving floating condensate at the concentration of 0.8 g/m^2 was predicted to be 60% and those at the Montebello Islands was up to 30%. Dissolved aromatic hydrocarbons within the intertidal and shallow sub-tidal areas along the east coast of Barrow Island were of the order of 10–30 ppm, while the average predicted concentrations among simulations were 1–3 ppm.

The lighter and more variable winds during the transitional months (April and September) were predicted to increase the risk of exposure to the Lowendal Islands (to 70%) and reduce the risk of

Figure 7-14:
Predicted Release of Condensate from Condensate Offloading Pipeline (2 km from Barrow Island)



exposure to the west coast of Barrow Island. Slicks were still predicted to most commonly drift along a north-south axis with the prevailing tidal currents under summer wind conditions. However, the high frequency of winds from the south-east is expected to increase the probability that slicks would drift to the east and pass south of the Lowendal Islands. This would result in the probability of exposure to shorelines (the average length of affected shoreline and the average volume of stranding condensate) being lower.

The modelling shown in Figure 7-14 was for the existing condensate loadout line. If the new condensate line failed, the consequences, especially the worst-case scenarios mentioned above, would be similar to those already described. It must also be emphasised that at the 2 km point the new line (either to the single buoy mooring or the LNG jetty head) would be on the jetty structure, and the likelihood of such a failure is less than the existing line.

It is not considered credible that both lines would fail simultaneously.

Releases from a Grounded Tanker

Export tankers that arrive or leave the Barrow Island tanker terminal could potentially be carrying bulk quantities of condensate, crude oil from other sources, and bunker oil (as fuel). There have been no spills resulting from a grounded tanker in the 40 years of operations at Barrow Island. The probability of a spill from a grounded and holed tanker is low, based on data from other areas, and is estimated to be 2.34×10^{-5} per cargo transfer (refer to Chapter 14 on Public Risk). The use of single hulled tankers is assumed, so with the international trend to use double hulled tankers, the assessment in this section is very conservative.

The likelihood of a hydrocarbon spill from a grounded and holed tanker in the vicinity of the tanker terminal is remote. However, if a spill occurred, it would pose a relatively high risk of oil and dissolved aromatic hydrocarbon exposure to shorelines and shallow habitats throughout the east coast of Barrow Island, the Lowendal and Montebello archipelago. The potential risks to marine flora and fauna are described in Chapter 11 and will vary depending upon the oil type that may be released and the prevailing season. Factors associated with the oil

type that affect risks include the spreading rate of the oils (a function of the viscosity) and the rates of evaporation (a function of the volatility of the oil components).

Condensate spills are predicted to spread quickly, increasing the areas potentially affected, but reducing the thickness involved. In contrast, a heavy bunker fuel is predicted to spread and evaporate more slowly so that higher loads could potentially come ashore from a grounded tanker spill.

During summer and the transitional months, the most likely grounding site predicted for a tanker that drifts from the tanker terminal without power is on the north-east side of the tanker terminal. Slicks of floating oil from this area are expected to most commonly drift to the north-east, passing to the south of the Lowendal Islands. However, if a spill occurred, shorelines of the Lowendal group are predicted to have up to 20% probability of exposure depending upon the oil type. Shorelines along the eastern coast of Barrow Island have a 10% probability of exposure.

Overall, the probability that some shoreline would be affected is estimated to range from 25 to 51%, depending on the oil type. Potential shoreline exposure for bunker fuel, crude oil and condensate spills is estimated to be up to 39%, 18% and 6% of the spill volume, respectively. Aromatic hydrocarbons associated with the slicks are predicted to expose the shallow pavement areas and coral to the south and south-east of the Lowendal Islands during these seasons, at concentrations up to 500 ppb.

Under winter wind conditions, the shallow water west of the existing tanker terminal is predicted to be the most likely grounding site. Slicks are most likely to drift with the strong current operating along the Barrow Island channel before traversing west around the north or south ends of Barrow Island. Consequently, Barrow Island was predicted to have the highest risk of exposure (50 to 70%) from this type of event. There is also the potential that other shorelines on adjacent islands will be at risk. Potential shore loads are predicted to be up to 50% of the spill volume for a bunker fuel spill and 12% for a condensate spill. Sub-surface plumes of aromatic hydrocarbons are predicted to affect the east coast of Barrow Island (at up to 260 ppb) and would reach Barrow Island shoals (at >10 ppb).

If a dedicated condensate loadout line is provided for the Gorgon Development (and the existing condensate loadout line is still used by the Barrow Island Joint Venture) then there is an extremely remote possibility that two condensate ships could be in the vicinity at the same time. The total number of condensate ship movements in a year would still be the same. A collision could theoretically occur between the two ships, but given the large distance between the two offloading systems and the port controls which will be in place to control vessel movements, a collision is not a credible scenario.

Diesel Spills from Operational Vessels

The probability of a diesel spill from an operating vessel is low and the volumes of fuel transferred are usually quite small; however, this type of spill has the highest probability rating of occurring and is estimated to be 9.0×10^{-3} per cargo transfer (or 9 incidents every 1000 transfers (refer to Chapter 14 on Public Risk). Diesel spills onto water tend to spread rapidly and to entrain readily. Diesel fuel is also unique in that the toxicity of the oil is not directly related to the aromatic content, but is thought to relate to other less volatile components within the entrained oil (French 2000). Thus, concentrations of entrained diesel are more indicative of the potential for toxicity to submerged habitats.

Modelling to predict risks of exposure to either surface oil or entrained oil at shorelines from a refuelling spill off the west coast predicted a decrease with distance offshore, especially during summer (Table 7-13). For the volumes modelled, the rate of contact with shorelines during summer is predicted to be 84% at 2.5 km offshore, 60% at 5 km offshore and 16% at 10 km offshore. In addition, the longer time required for diesel to drift towards shore from 10 km offshore increases the probability for effective dispersal of entrained and floating diesel before exposing shallow waters off Barrow Island or the adjacent islands.

Surface slicks of diesel generated by spills at the MOF are not expected to travel more than about 12 km before entraining and dispersing to a thin sheen (Figure 7-15). Entrained diesel is predicted to affect a larger area. Entrained diesel is predicted to drift along a north-south axis from the strong currents along the Barrow Island channel. Wind driven currents during winter and the transitional months are expected to force plumes of entrained diesel against the shore (99% probability; Figure 7-15), resulting in highest concentrations (up to 2.4 ppm) within the shallow waters along the east coast of Barrow Island. A higher risk of exposure to the shallow pavement areas west of the Lowendal Islands is predicted for summer.

Larger spills of diesel generated further offshore within the port approaches are predicted to potentially affect a larger area at higher concentrations. Visible diesel slicks were predicted to potentially drift as far as the Lowendal Islands to the north and potentially extend to the southern ends of Barrow Island. Entrained diesel is expected to affect similar areas, at similar concentrations to those predicted for a diesel spill at the MOF.

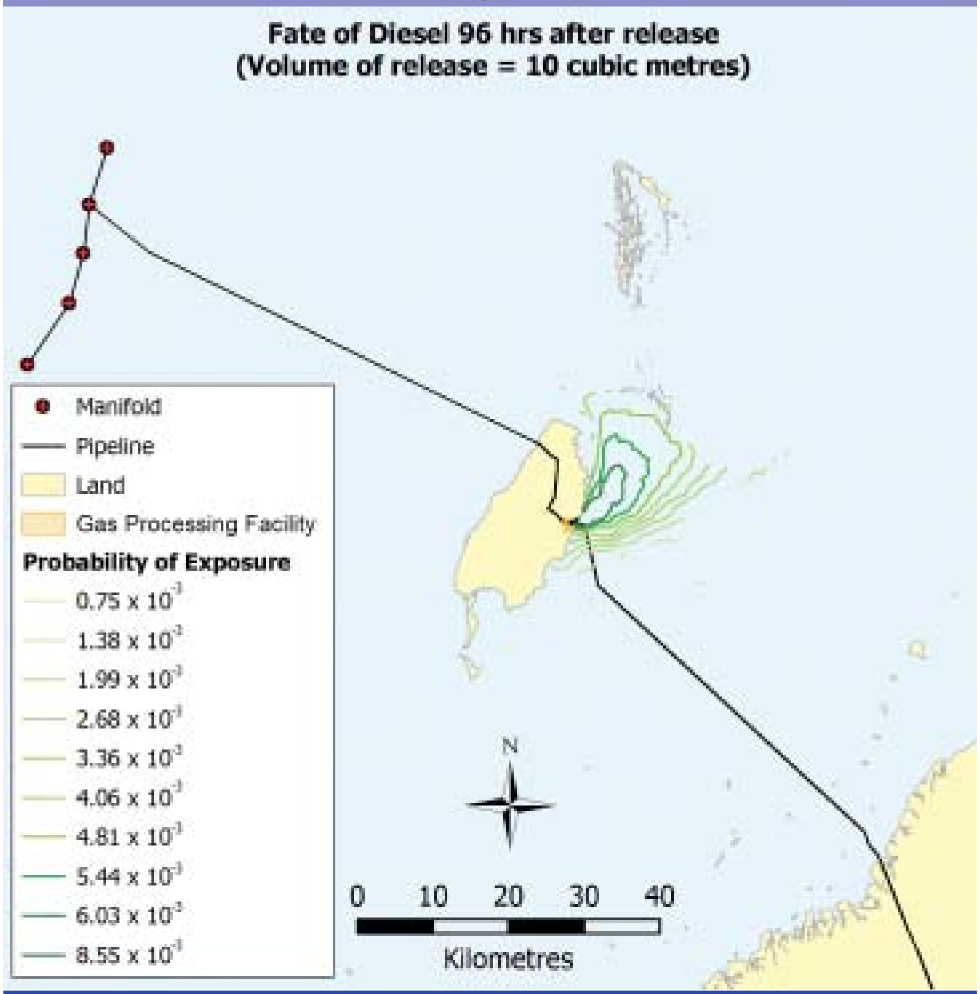
7.9.3 Other Potential Releases (Non Hydrocarbon)

Spills of Monoethylene Glycol (MEG)

Monoethylene glycol would be pumped from Barrow Island to the production wells via a separate pipeline running parallel with the feed gas pipeline. Rupture probability is remote and estimated at 4.32 x 10^{-5} per kmy. Rupture of the line is expected to result in rapid (within 2 minutes) depressurisation, releasing about 11 m^3 of MEG before the supply is isolated automatically in response to the pressure drop.

Simulation of this release scenario at 50 m depth along the pipeline indicated that the MEG will be initially dispersed by the velocity of the release, resulting in peak concentrations of around 6000 mg/m^3 of MEG adjacent to the discharge, which would disperse to <50 mg/m^3 within about three hours. Stochastic modelling of this scenario under randomly selected currents indicated that the plume would tend to drift along the axis of the local tidal currents and dilute to <10 mg/m^3 within 3 km of the discharge.

Figure 7-15:
Predicted Release of Diesel from an Operating Vessel (at MOF)



08: Existing Environment

The area of the proposed Gorgon Development lies in the tropical waters of Australia's north-west shelf approximately 1200 km north of Perth and 120 km west of Dampier and the Burrup Peninsula. This coastal environment is scattered with numerous small islands, the largest of which is Barrow Island. Barrow Island supports an operating oilfield and is a Class A nature reserve for the purpose of conservation of flora and fauna.

The Gorgon gas field lies in approximately 200 m water depth on the edge of the continental shelf. The proposed feed gas pipeline corridor from the gas field to the west coast of Barrow Island will include areas of deep water sediments, high profile limestone reefs, low profile limestone reefs and shallow water sediments. Each of these benthic habitats is widespread throughout the Montebello/Lowendal/Barrow Island region.

High wave energy strongly influences the physical structure of intertidal habitats on the west coast of Barrow Island. The nearshore section of the feed gas pipeline will be constructed beneath high-profile reef, a rocky platform and the sandy beach at North White's Beach.

Landforms on Barrow Island are predominantly developed by coastal processes that are dominated by the effects of wind and water. The terrain along the onshore feed gas pipeline route on the island ranges from undulating sand dunes and plains on the western side to gently undulating rocky terrain on the eastern side. The terrain in the proposed Development area is flat to undulating and gradually slopes upward from the coastline.

The proposed causeway and materials offloading facility will extend from Town Point across the intertidal and subtidal limestone pavement reef that fringes the east coast of Barrow Island. The shipping channel area is mainly limestone pavement reef with macroalgae, especially *Sargassum*, scattered hard and soft corals and thin sand veneers. The proposed jetty will dissect two areas of coral reef with variable cover of live coral and patches of coral bombora.

The proposed domestic gas pipeline and optical fibre cable routes between the east coast of Barrow Island and the mainland generally lie in water depths of approximately 16 m. Benthic habitats along this route are characterised by sparse filter-feeding assemblages on pavement reef and scattered

seagrass meadows on soft sediments. All of the faunal assemblages that occur along the domestic gas pipeline route and optical fibre cable route are expected to be widespread throughout the Pilbara nearshore bioregion.

On the mainland coast, sand and mud flats interspersed with areas of rocky pavement reef are backed by an extensive mangrove and samphire system. The mangrove community adjacent to the proposed domestic gas pipeline shore crossing on the mainland represents the most significant marine plant assemblage in any of the proposed Development areas.

A total of 406 vascular plant taxa have been recorded on Barrow Island which constitutes approximately 23% of the flora records documented for the Pilbara region. Fourteen vascular plant taxa have been introduced to Barrow Island, the majority of which occur in, or near, previously disturbed sites.

No Declared Rare Flora species, as listed under subsection (2) of Section 23F of the *Western Australian Wildlife Conservation Act 1950* and as listed by the Department of Conservation and Land Management occur on Barrow Island. Two Priority species grow on Barrow Island: *Helichrysum oligochaetum* (Priority 1); and *Corchorus interstans* (ms) (Priority 3).

No vegetation communities listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* have been recorded or are known to occur on Barrow Island. Further, no Threatened Ecological Communities as listed on the Department of Conservation and Land Management Threatened Ecological Database have been recorded or are known to occur on Barrow Island.

Barrow Island supports 13 species of resident terrestrial mammal, with a further two species of bat recorded as vagrants to the island. Six of these species are listed by the state as rare or likely to become extinct. Many of the mammals are widespread and abundant on Barrow Island including the burrowing bettong, spectacled hare wallaby, golden bandicoot, Barrow Island euro and northern brushtail possum. All mammal species recorded within the Development area are widespread on the island, with the exception of the the water-rat which is restricted to coastal habitats around the island.

The black-flanked rock-wallaby does not occur within any of the proposed Development areas. There are no distinctive habitat features within the proposed Development area that are likely to support unusually high population densities of any mammal species.

Important bird species on Barrow Island include migratory shorebirds and visiting seabirds. Barrow Island is known as a staging site for many migratory birds. Waterbird abundances are highest on the coast in the south-east and south of Barrow Island. The intertidal habitats in the vicinity of Town Point, and other infrastructure associated with the Development, are of relatively low importance for coastal waterbirds. The proposed Development area is not of higher ecological significance than surrounding areas for any landbird species. The endemic white-winged fairy wren has been recorded within the Development area and is widespread on Barrow Island.

Green sea turtles nest on all sandy beaches along the west coast of Barrow Island. Before and during the summer nesting season mating aggregations are present off the west coast and females are frequently found resting on sandy beaches and intertidal platforms along the coast. Resident (non-nesting animals) forage on the algae covered rocky platforms throughout the year. The area of the proposed feed gas pipeline shore crossing at North White's Beach is not a locally important green turtle nesting site.

Nesting flatback turtles favour mid-east coast beaches on Barrow Island. The beaches either side of the proposed Development area at Town Point (Terminal Beach and Bivalve Beach) are important components of this regionally significant rookery.

Many species of terrestrial reptiles live on Barrow Island; one species of blind snake is restricted to the island and one skink species has a disjunct distribution that includes only Barrow Island in Western Australia. The invertebrates, including short range endemics on Barrow Island, are generally known from several locations on the island. The only exceptions are a new species of scorpion and a new species of pseudoscorpion that were recently recorded within the proposed Development area. The wider distribution of these species on Barrow Island is not yet known; however, they are expected to occur in similar habitats at other parts of the island.

Subterranean fauna from Barrow Island are important from a biodiversity perspective due to their endemicity at high taxonomic levels and uncertain distributions at the species level. Surveys have indicated that stygofauna occur in groundwater habitats across the island. In addition to stygofauna, areas of karst within the Development site also provide habitat for troglobitic fauna (terrestrial subterranean fauna). However, these assemblages may not be as diverse as those recorded from caves and more developed karstic areas in other parts of Barrow Island.

There are 13 registered archaeological sites on Barrow Island although none are close to the proposed Development site, and there are no listed ethnographic sites. There are two ethnographic sites located close to the proposed domestic gas pipeline route on the mainland and nine identified cultural heritage sites within the vicinity of the pipeline route.

The Pilbara resident population is approximately 40 000 people, with most people living in close proximity to the coast. The Pilbara region is one of the most important wealth producing regions in Western Australia. The region is responsible for the production of goods and services worth more than $16 billion per annum. The mining and petroleum industries are the predominant earners for the region.

The Western Australian economy is dominated by the resources sector which also contributes largely to the Australian economy. Western Australia is now the major oil and gas producer in Australia, and has more than three-quarters of Australia's identified natural gas resource within its jurisdiction.

8.1 Introduction

This chapter describes the key physical, ecological, social and economic values of the proposed Gorgon Development area (Figure 8-1, Figure 1-4). This information supports the assessment of impacts and risks presented in Chapters 10, 11, 14 and 15.

Locations of various Barrow Island features that are discussed throughout this chapter are shown in Figure 8-2.

8.2 Physical Environment

8.2.1 Introduction

This section of Chapter 8 describes the existing physical environment in the proposed Development area.
It includes discussion on the regional setting, climate, bathymetry and sea floor topography, oceanography, topography and landforms, geology and soils, seismic activity, surface hydrology and groundwater.

Figure 8-1:
Overview of Chapter Structure

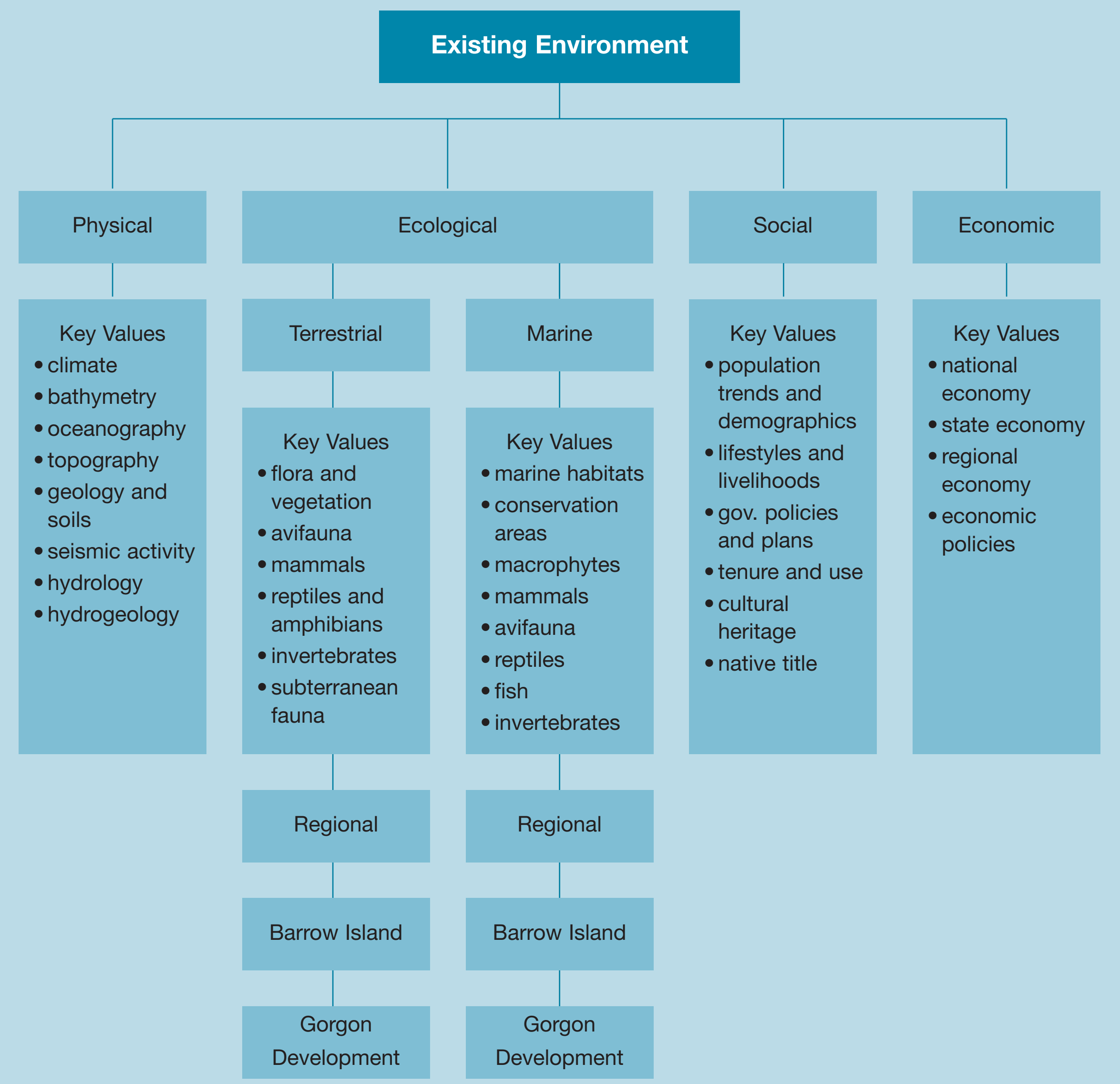


Figure 8-2:
Barrow Island Location Map

8.2.2 Regional Setting

The proposed Gorgon Development is located on Australia's north-west shelf approximately 1200 km north of Perth and 120 km south-west of Dampier. This region is scattered with islands, the largest of which is Barrow Island at 25 km in length, 10 km in width, and approximately 234 km^2 in area.

The Gorgon gas field is located in Commonwealth waters approximately 70 km west of Barrow Island. Barrow Island is the nearest landfall to the Gorgon gas field; lying directly between the field and the mainland (refer to Figure 1-1, Chapter 1).

8.2.3 Climate

The southern portion of the north-west shelf, including Barrow Island, is characterised by an arid, sub-tropical climate.

The summer season occurs from October to March and is characterised by high temperatures, high humidity and predominantly south-west winds (Worley 2003). In contrast, the winter season, June to August, is characterised by clear skies, fine weather and predominantly strong east to south-east winds. The months of April, May and September are considered a transition season during which either the summer or winter weather regime may predominate or conditions may vary between the two. The characteristics of the climate in the Gorgon Development area are summarised in Table 8-1.

Table 8-1:
Climate of the Gorgon Development Area

Temperature	In summer, mean daily maximum temperatures reach 34°C with mean daily minimum temperatures averaging 20°C. During winter, mean daily maximum temperatures reach 26°C with mean daily minimum temperatures of 17°C.
Relative Humidity	Barrow Island experiences regionally high relative humidity that remains fairly constant throughout the year. Early periods of the day experience an annual average of about 65% relative humidity with afternoon periods experiencing between 47% and 59%.
Rainfall	Rainfall on Barrow Island varies significantly from year-to-year and is dependent on rain-bearing low pressure systems, thunderstorm activity and passage of tropical cyclones. The historic annual average rainfall for the area is 320 mm. During the early winter months rainfall is received from frontal systems passing to the south. These events can result in up to 50 mm of rain and account for approximately 35% of annual rainfall (Bureau of Meteorology 2004). In summer, cyclonic events range from storms of 300 mm to milder 30 mm events. Wet years typically receive a large portion of rainfall from tropical cyclones.
Evaporation	The annual evaporation rate is approximately 3500 mm for the region (based on records from the Dampier Salt Weather Station). Daily evaporation rates range from about 11 mm/day during the summer months to 7 mm/day during winter months.
Winds	Wind patterns on the north-west shelf are dictated by seasonal movement of atmospheric pressure systems. During the summer months, high pressure cells produce south to south-westerly winds which vary between 10-13 ms^{-1}. During the winter months, high pressure cells over central Australia produce north-easterly to south-easterly winds with average speeds of between 6-8 ms^{-1}. Seasonal and annual wind roses measured on Barrow Island between 1980 and 1996 are shown in Figure 8-3.
Cyclones	Tropical cyclone activity occurs in the north-west region of Western Australia from November to April. On average, two cyclones pass through the Barrow Island area per year, generating localised wind gusts of over 150 km/hr.

Figure 8-3:
Annual Wind Roses Measured on Barrow Island

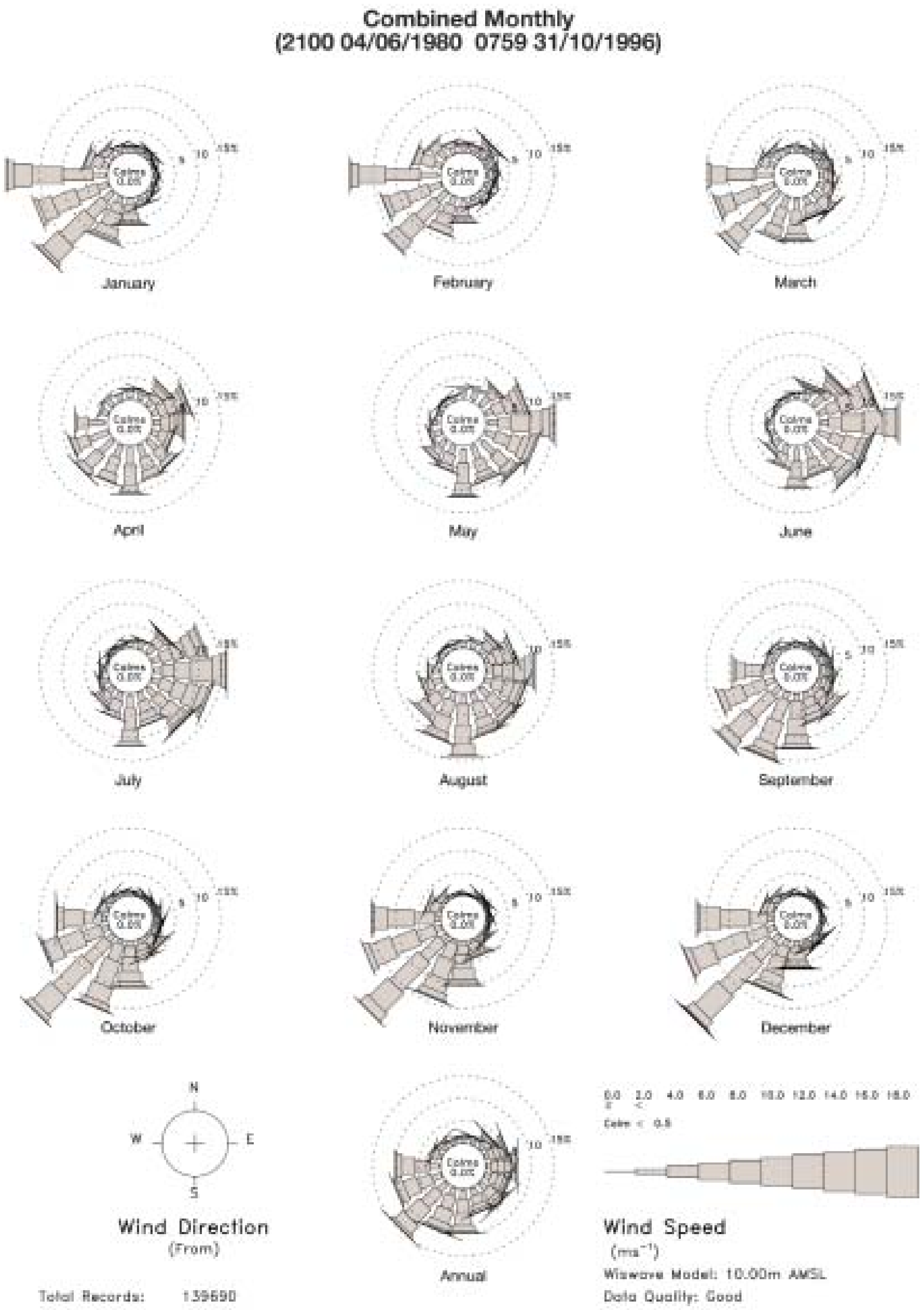
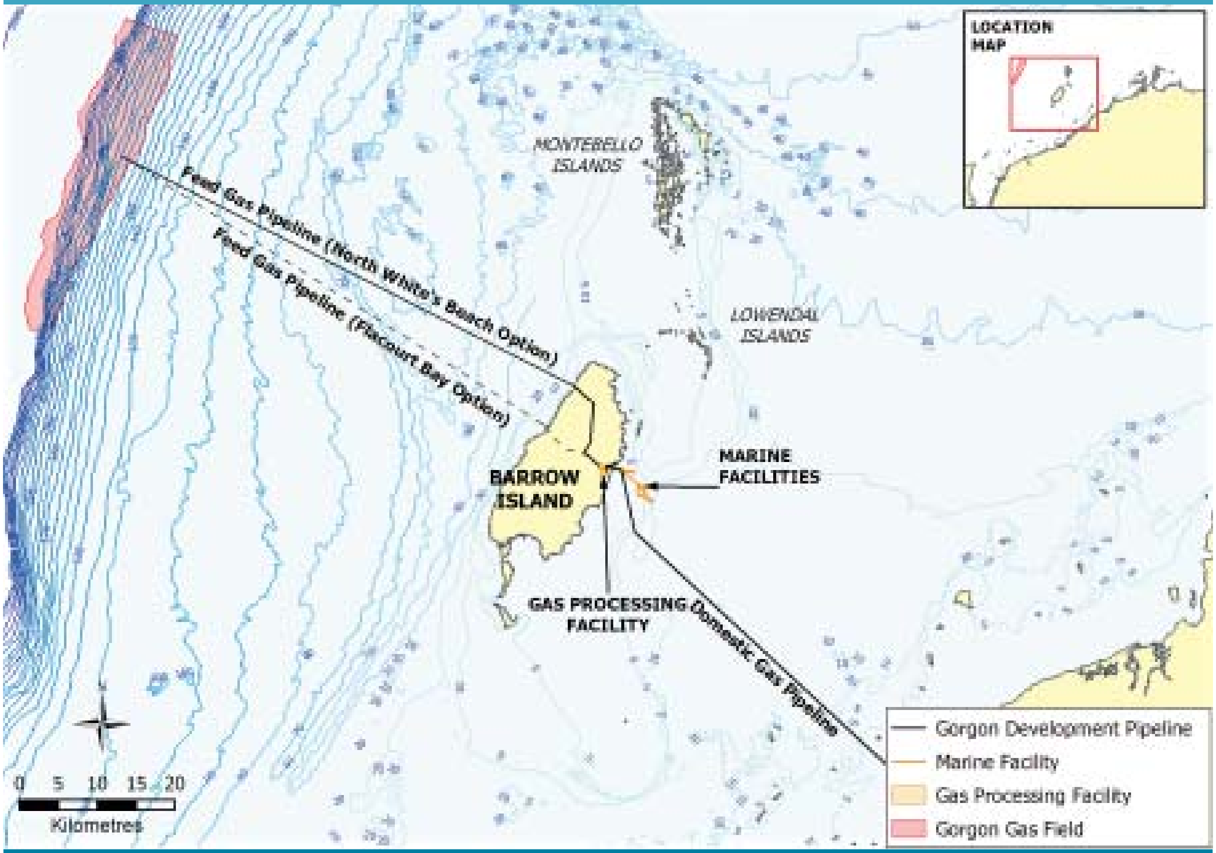


Figure 8-4:
Bathymetry of the Gorgon Gas Field Area



8.2.4 Bathymetry and Sea Floor Topography

The Gorgon gas field lies on the continental slope at a water depth of approximately 200 m. The northern-most portion of the gas field is gently sloping and dissected by a north-west to south-east aligned ridge (Figure 8-4). The southern extent of the gas field is characterised by deeply undulating valley terrain.

The seabed along the majority of the proposed feed gas pipeline route is level with areas of moderate relief comprising rock and reef outcrops.

Water depths adjacent to the east coast of the island vary due to seabed outcrops and the presence of numerous pinnacles. Further offshore, the seabed is generally more level. The proposed domestic gas pipeline route is located in water depths of about 16 m that occur between the island and the mainland.

Substrate and Sediment Characteristics

The sediments in the Barrow Island area are generally undisturbed with the exception of some areas of localised impact from previous and existing activities (e.g. petroleum exploration and production) in the region.

Within the immediate vicinity of the proposed well heads the seabed is characterised by coarse sandy sediments with shell fragments. Three sediment types have been identified for the gas field:

- sandy sediments/carbonate sandy silt (from seabed to ~3 m)
- homogenous carbonate silts/muds (~3 m to ~110 m)
- variably cemented carbonate silts, sandy silts and calcisiltites (~110 m to > 250 m deep).

The shallow geology along most of the proposed feed gas pipeline route consists of unconsolidated sediments overlying a cemented calcarenite substrate. The sediments are generally calcareous and range in grain size from graded silts (4-60 μm) through to coarse sand (<2000 μm) with shells and shell fragments. The thickness of sediment layers varies, ranging from more than 5 m in the proximity of the gas field to a very thin patchy veneer, or absence, over large areas of seabed.

On the east coast of the island, intertidal reef flats and shallow pavements progress to deeper sands offshore. Nearshore limestone or calcarenite pavements are variably covered by sand, gravel and coral. Bare sands overlay limestone pavements in many parts of the area with increased quantities of rubble on exposed pavement where strong water currents are present. The thickness of uncemented sediments overlying limestone pavements are expected to vary between 0.5 m and 3 m (URS 2002).

Along the length of the domestic gas pipeline route, the seabed comprises areas of unconsolidated sediments overlying variably cemented calcarenite substrate, bare sand with occasional rocky outcrops and limestone pavement reef with a veneer of sand. The sediments are calcareous and range from fine sands through to coarse sands with shells and shell fragments. The ocean depth between Barrow Island and mainland Australia is very shallow nearshore, and relatively flat, with a range of 0-20 m. Detailed bathymetry has recently been collected for the Marine Offloading Facility (MOF), the LNG shipping channel and jetty areas (Figure 8-5).

8.2.5 Oceanography

General oceanographic characteristics in the vicinity of the proposed Gorgon Development are summarised in Table 8-2.

Figure 8-5:
Sea Floor Bathymetry, East Coast of Barrow Island

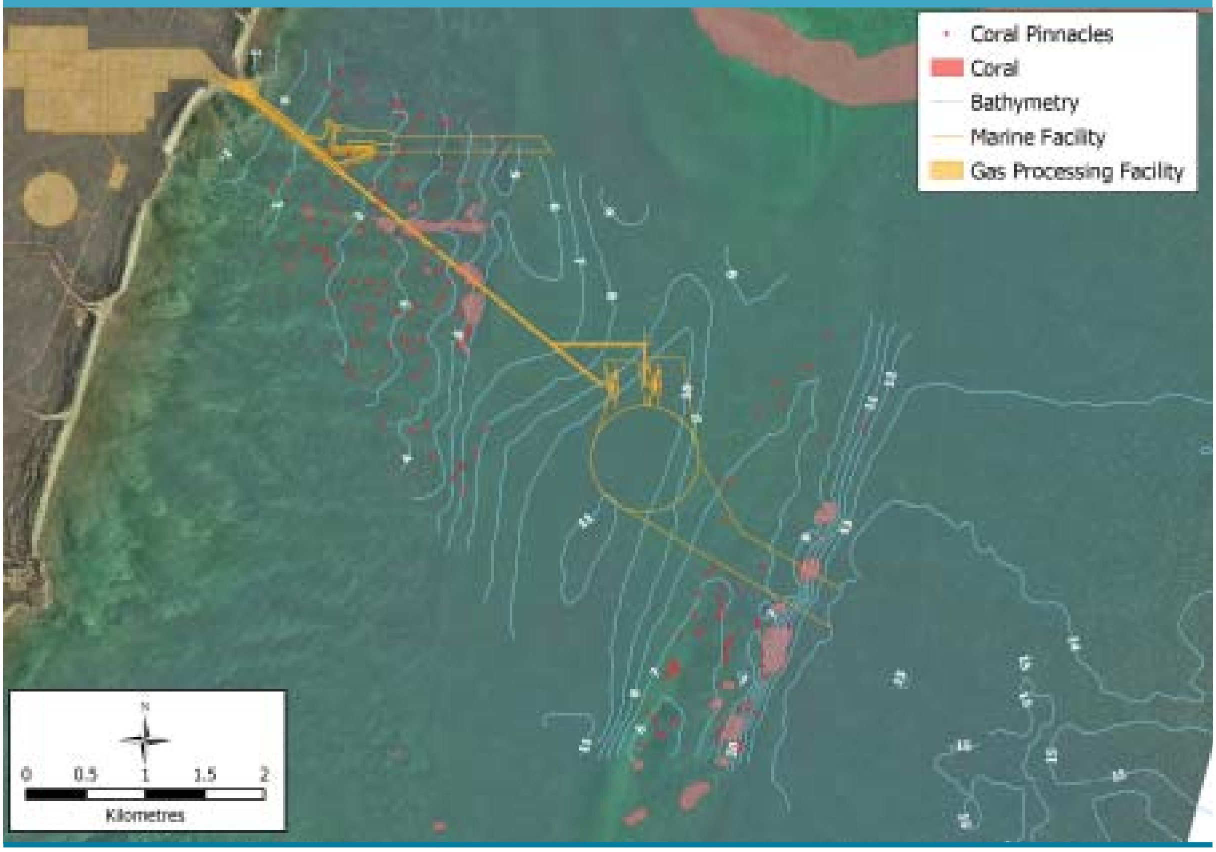


Table 8-2:
Oceanographic Characteristics of the Gorgon Development Area

Waves	The prevailing oceanic conditions in the Gorgon Development area are governed by a combination of sea and swell waves. Sea waves are shorter period waves generated by local winds whereas swell waves are generated by distant storms. The west coast of Barrow Island is affected by the southern ocean swell which refracts around the northern and southern ends of the island. On the east coast, periods of greatest wave activity correspond to periods of strong easterly winds (ChevronTexaco Australia 2003a). Figure 8-6 illustrates the directionality, seasonality and magnitude of the combined wave field at the existing tanker loading facility 9 km off the east coast of Barrow Island.
Tides	Tides in the Barrow Island region are semi-diurnal, comprising two high tides and two low tides per day. The tidal gradients are strong and aligned in a north-south direction. The combination of moderate tidal ranges, and shallow bathymetry, results in large areas of exposed seabed at low tide (West Australian Petroleum 1989).
Currents	Currents are principally driven by semi-diurnal tidal forcing. Near Barrow Island, tidal currents run strongly parallel to the eastern shore and funnel through the offshore channel north of the Town Point site. Current measurements at the tanker mooring confirm the tidal nature of these currents, reflecting a distinct spring-neap (14-day) tidal cycle and a semi-diurnal pattern. The maximum current measured at this point was 0.62 m/s. The direction of the tidal currents (for both spring and neap) was a flood flow towards the south-west and an ebb flow towards the north-east (Chevron Texaco Australia 2003a) (Figure 8-7 and Figure 8-8).
Water Temperature	Surface water temperatures in the vicinity of the Gorgon gas field and the offshore portions of the proposed feed gas pipeline vary between 22°C and 31°C. From the surface to a depth of 100 m, the water column is generally well-mixed. The mean for depths between 200 and 250 m is around 10°C (ChevronTexaco Australia 2003a). Water temperatures at the proposed tanker terminal range from a late summer peak of about 30°C to a winter low of about 21°C during July and August (ChevronTexaco Australia 2003a). The seawater in the region of the proposed domestic gas pipeline is generally well-mixed with uniform temperatures throughout the water column.

Figure 8-6:
Wave Data – East Coast of Barrow Island

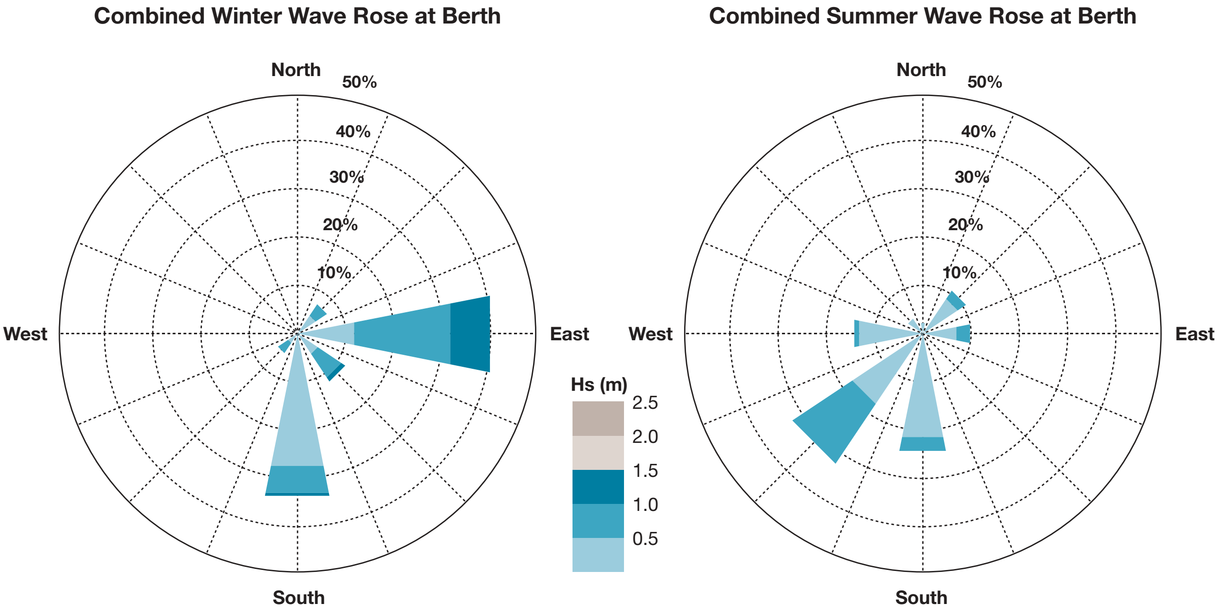


Figure 8-7:
Near Surface Current – Barrow Island

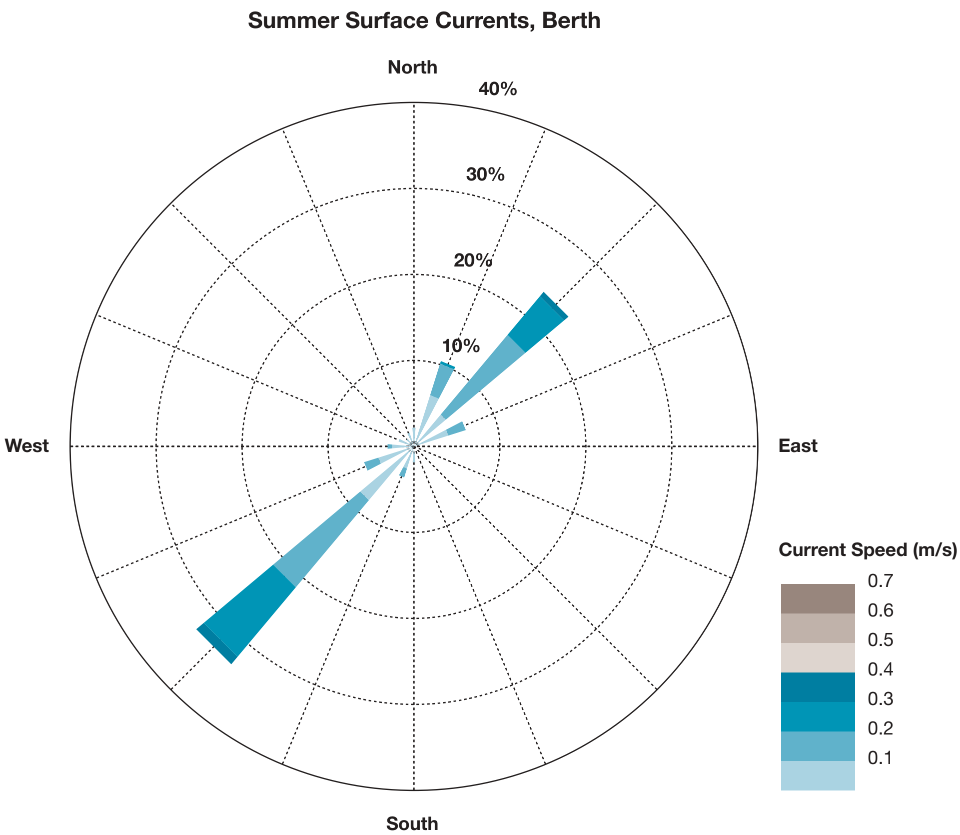


Figure 8-8:
Near Bottom Current – Barrow Island

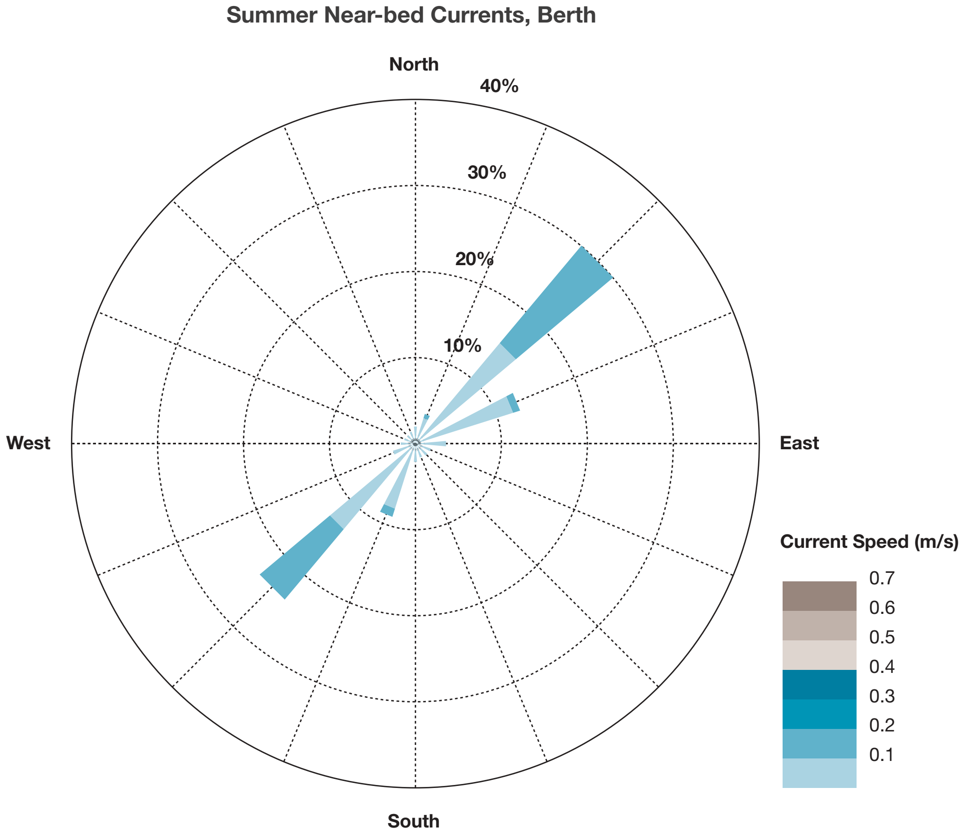


Table 8-3:
Landscape Units of Barrow Island

Landscape Unit	Description
West Coastal Complex	The west coast of Barrow Island is exposed to direct wind and wave action from the Indian Ocean. The coastline topography varies from rocky weathered sheer cliffs to less steep, traversable inclines. Typically narrow sandy beaches occur between weathered rocky headlands. This coastline is a significant feature of Barrow Island.
East Coastal Complex	The eastern coastline is protected with a slight land gradient to the ocean. This coastline is characterised by vegetated sand dunes and expansive tidal flats. Vegetation types along the east coast are dominated by *Triodia angusta*.
Valley Slopes and Escarpments	The western half of Barrow Island is characterised by steep formed valleys, escarpments and exposed limestone ridges. Typical vegetation on valley slopes and escarpments is described as open, low shrubland dominated by *Triodia wiseana*. Mixed emergent lower growing shrub species such as *Acacia bivenosa, Petalostylis labicheoides* and *Pentalepis trichodesmoides* occur on the southern escarpments.
Limestone Ridges	This landscape unit occurs generally throughout the central upland plateaus of the island. The terrain ranges from steeper slopes in the west to flatter more gentle undulations as the ridges continue east. Typical vegetation on the limestone ridges includes hummock grassland of *Triodia wiseana* with low mixed shrubs including *Acacia gregorii* and *Melaleuca cardiophylla.*
Creek or Seasonal Drainage lines	This landscape unit occurs generally in the broad valleys and flats of limestone ridges and is located adjacent to the coastal fringes. This landscape has deeper alluvial soil structure and denser and taller vegetation. The vegetation in this unit type is described as mixed hummock grassland of *Triodia angusta* with pockets of dense shrubs along major creek lines.

8.2.6 Topography and Landforms

Five landscape units have been identified on Barrow Island. These units are described briefly in Table 8-3.

The topography of Barrow Island in relation to proposed infrastructure and facilities is illustrated in Figure 8-9. The gas processing facility area is undulating and facilities will be terraced to suit the terrain.

The mainland section of the domestic gas pipeline crosses the Onslow Coastal Plain. The plain extends south of Robe Point, to Mary Anne Point and north to Cape Preston. Terrain along the 30 km length of this section of the pipeline is generally flat and only reaches approximately +50 m AHD.

The Onslow Coastal Plain comprises saline flats that fringe the coastline and extensive sandy plains with longitudinal dunes trending north-west or north. Broad clay plains are also present with numerous base clay pans and circular grassy depressions (Payne et al.1988). Near the coastline, the clay plains become increasingly masked by aeolian sand.

8.2.7 Geology and Soils

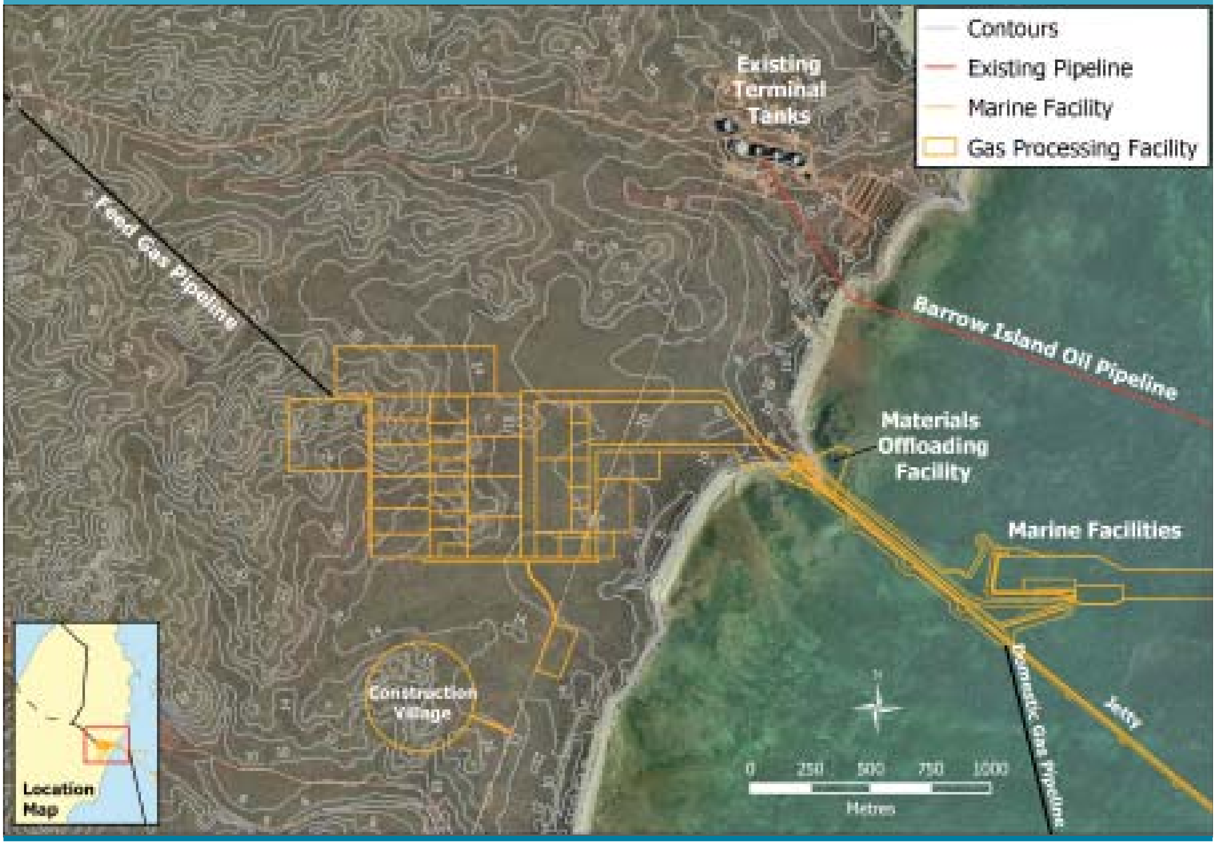
Barrow Island is a geological extension of the Cape Range Peninsula, which became separated from mainland Australia between 8000 and 6000 years ago as a result of rising sea levels.

The island is composed of coastal deposits overlying tectonically folded limestone. Three broad geomorphic units have been identified:

- limestone uplands
- near coastal lowlands
- coastal fringe.

The geology of the proposed incoming pipeline landfall location at North White's Beach and the alternative Flacourt Bay site consists of minor coastal sands overlying shoreline sandstone platforms. North White's Beach has a headland to the south, while Flacourt Bay is bounded by headlands to the north and south. These headlands are comprised of cliffs consisting of cemented calcirudite overlain by cemented siliceous calcarenite (coastal Tamala limestone). Exposure to

Figure 8-9:
Topography of Gas Processing Facility Area



the open ocean, storm events and general climatic conditions has resulted in the erosion of areas of weaker limestone to form cavities and caves in the rock face.

On the feed gas pipeline route between the landfall and the gas processing facility site, the surface geology consists of outcrops of variably weathered Trealla limestone, interspaced with alluvial and colluvial deposits. These deposits are associated with the intermittent dendritic drainage system present on the island and primarily consist of calcarenitic sands and gravels.

The surface geology at the proposed gas processing facility consists of limestone (Tamala limestone), floodplain deposits, dune sands and gravels. Investigations conducted near the gas processing facility site encountered up to 10 m of sands and clays overlying limestone. Solution holes in limestone up to 450 mm in diameter and 1.2 m deep have been observed at several locations at the proposed gas processing facility site. Drilling logs for investigations conducted at the existing terminal tanks nearby suggests the possible presence of solution cavities. Based on historic borehole information, it is likely that cavernous zones are present in the vicinity of the water table throughout the limestone substrata across the proposed gas processing facility site.

The geology of the proposed domestic gas pipeline shore crossing at Town Point consists of a calcrete ridge, cliffs and beach sands. Tidal lagoons are present in the shoreline rock platforms present to the north and the south of Town Point.

The geology along the domestic gas pipeline route on mainland Australia is dominated by alluvium deposits influenced by the Robe and Fortescue Rivers that are located some distance on either side of the proposed pipeline route. The two major geological units recorded are:

- Pleistocene alluvium and eluvium consisting of loosely consolidated red to brown clay, silt, sand, sandy clay, gravel, gravel veneer in places and gilgais that is common. This is the main Quaternary unit overlying basement rocks in low lying areas.
- Recent alluvium consisting of mainly clay silt and sand, some gravels in an unconsolidated matrix. These are flood deposits in the form of silt sheets, levees and clay pans related to present day drainage patterns.

Soils of the coastal plains are mainly neutral and alkaline earths with areas of acid and alkaline red earths, often with a cover of surface gravel (Dames and Moore 1990). These soils are generally well-drained particularly nearer to the coast where sands and sandy loams are present (Payne et al. 1988). In low lying plains, the soils are dominated by hard alkaline red soils with the occasional presence of dispersive clay soils. The clay content impedes drainage resulting in water-logging during heavy periods of rainfall and gilgai formations (i.e. shallow depressions in the land surface). The soils are low in nutrients (nitrogen and phosphorus).

8.2.8 Seismic Activity

Barrow Island is located within a linear zone of seismicity known as the North West Shelf Zone. The Barrow Fault, located at the southern end of the island, is represented topographically by a low, east-west trending scarp. The surface expression of the fault is marked by occasional clay pans and rare deposits of sulphur. Barrow Island occurs in an area of relatively low seismic activity.

Few tsunamis have been observed along the Western Australian coast. Tsunamis are water gravity waves associated with submarine seismic disturbances. The Sunda Arc, south of the Indonesian islands is the most likely source of earthquake generated tsunamis affecting the north-west coast of Western Australia (Worley 2004). Records show that of the eight or so major earthquakes expected to occur in the Sunda Arc region every hundred years, two or three could be felt in Western Australia. For large tsunami wave heights to develop, the transition from deep sea floor to coastline must be sudden. Western Australia has a wide, shallow continental shelf, therefore it is unlikely that severe tsunami effects will ever be experienced in Western Australia, either from a close offshore earthquake as in the case of Geraldton in 1885, or from more distant earthquakes (Worley 2004).

8.2.9 Surface Hydrology

The surface hydrology on Barrow Island is characterised by:

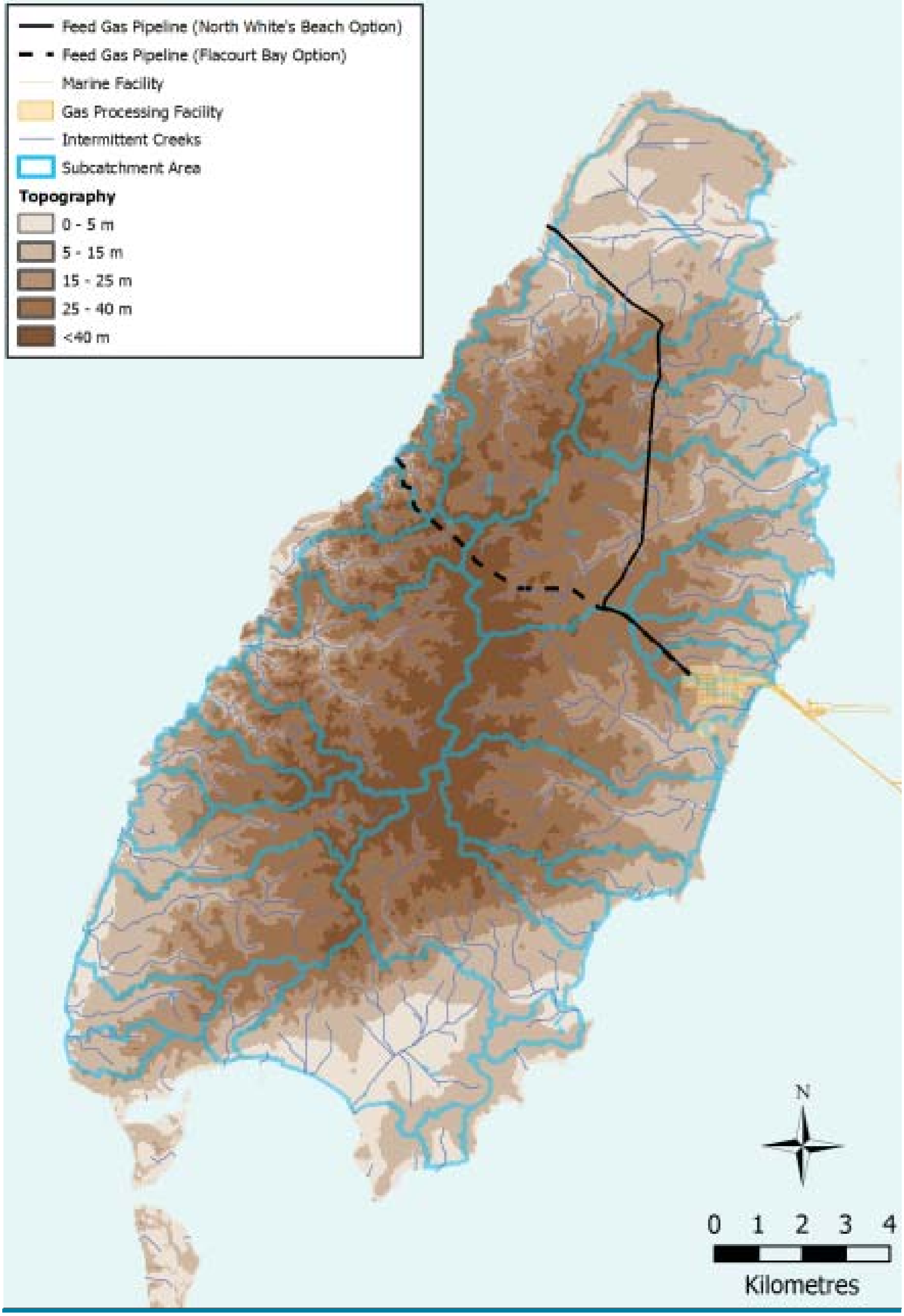
- unpredictable, but sometimes very intense, rainfall resulting in significant runoff and short-term ponding
- consistently high rates of evaporation resulting in extremely low soil moisture content
- high infiltration capacities of the surface sands and limestones which is conducive to recharge of relatively deep groundwater aquifer(s).

The hydrological regime of the island is split by a water divide running north to south along a central, elevated ridge. Creeks flow along a largely east-west orientation on either side of this divide but are highly ephemeral and usually dry. Figure 8-10 shows the drainage basins Barrow Island including those crossed by the various pipeline routes and within the gas processing facility site.

Permanent surface water sources occur in freshwater seeps. The largest of these occurs near the mouth of Biggada Creek on the west of the island and a smaller one at The Ledge, both on the west coast of Barrow Island. Both these seeps are outside of the Gorgon Development area (greater than 5 km from the nearest pipeline alignment). Other seeps are ephemeral and generally only appear after rain events. The nearest ephemeral freshwater seep is located approximately 500 m south of the North White's Beach pipeline shore approach option. Freshwater seeps provide an important water source for the island's fauna.

The mainland section of the proposed domestic gas pipeline route is located between the two major drainage lines of the Fortescue River and Robe River. These rivers are ephemeral and only flow following heavy rainfall. The rivers comprise permanent water holes which are maintained by sub-surface drainage (Bowman, Bishaw and Gorham 1991). Minor creek lines occur between these two major drainage lines; however the majority of creek lines are undefined and flow as sheet flow across the coastal saline flats. Sholl Creek, Trevarton Creek and Gerald Creek are located approximately 5 km to

Figure 8-10:
Surface Hydrology – Drainage Basins



the north of the proposed domestic gas pipeline route. Drainage lines to the south include Peter Creek, Myanore Creek and the Robe River.

There are approximately 13 locations along the length of the mainland section of the domestic gas pipeline route that will intersect ephemeral drainage lines. None of these support significant stream flows.

8.2.10 Hydrogeology

Two aquifers are located below Barrow Island: a confined, saline aquifer known as the Flacourt Sands Aquifer which is situated at depths of between 900 m and 1200 m; and a shallow unconfined aquifer (watertable) located predominantly within Tertiary limestone. The two aquifers are hydraulically separated from one another by a thick sequence of low permeability material (lower Gearle siltstone). These two aquifers are currently used to supply the Chevron Australia oilfield operations on the island.

The shallow unconfined aquifer forms a lens of fresher groundwater floating upon denser, more saline seawater. The boundary between the fresh and saline water is not a sharp boundary line, but a transition zone of brackish water caused by seasonal fluctuations in rainfall, tidal action, and amount of water extraction and discharge.

Recharge to the aquifer is principally from rainfall. Groundwater discharge is predominantly to the ocean, although given the high evaporation rates, some loss of groundwater is expected to occur from evaporation in areas where the watertable is shallower than about 2 m below ground surface.

On mainland Australia, the hydrogeological properties of the two major geological units within the development area are described in Table 8-4 from information detailed in the hydrogeological investigations undertaken north of Fortescue River (HGM 2000).

Aquifer Hydraulics

Available monitoring data shows that the watertable elevation is highest toward the centre of the island, resulting in a north-south oriented watertable mound along the length of the island.

Observed hydraulic gradients are low, ranging from 0.001 to about 0.01 (or a drop in water level of between 3.0 and 30.5 cm over a 30.5 m distance). This is consistent with observed groundwater monitoring data, which shows watertable elevations of not more than a few metres above sea level towards the central part of the island. In areas where karst features occur, preferential recharge would result in highly variable watertable geometry, which could explain some of the local variability in watertable elevations observed on the island.

Groundwater Dynamics

A relationship between tidal fluctuations and groundwater levels has been observed on some parts of Barrow Island. Although a dynamic relationship between groundwater and the ocean would normally be expected, the influence of tidal fluctuations generally decreases with increasing distance from the coast. This has not been consistently observed at Barrow Island, most likely because of the low hydraulic gradient of the watertable and the significant effects of karstic limestone that enables strong hydraulic connection with the ocean.

Table 8-4:
Hydrogeological Properties of Major Mainland Geological Units

Unit	Characteristics
Fortescue River Alluvium	• gravels from major aquifer with high permeability • aquifer covers extensive area beneath floodplain • groundwater is fresh in most floodplain area • groundwater is marginal to brackish on edge of floodplain • groundwater is brackish to saline at depth near coast
Eluvium-Residual Soils	• mostly above the water table • forms local aquifer where saturated, connected to alluvium

Source: HGM, 2000. Iron Ore Mine and Downstream Processing, Cape Preston, Western Australia. Public Environmental Review. Prepared for Austeel Pty Ltd.

Groundwater Use

Groundwater is utilised on the island for both processing and domestic uses. Process water is pumped from the confined Flacourt Sands Aquifer, while the shallower unconfined aquifer is used for domestic purposes.

Salinity

Groundwater salinity rates from the upper aquifer vary considerably across the island, ranging from about 250 milligrams per litre (mg/L) total dissolved solids (TDS) to about 25 000 mg/L TDS (ChevronTexaco Australia 2000). The large variations in salinity reflect variable recharge rates and the sensitive balance of the fresh water/seawater interface.

Lower salinities occur in areas where recharge is rapid. Rapid recharge generally occurs in areas of highly permeable soils overlying porous karst limestone. Higher salinities occur where recharge is slower, represented by clays and silts overlying massive limestone, and in areas where the fresh/seawater interface is close to the surface of the watertable. The salinity of seawater is about 35 000 mg/L TDS, therefore the higher ranges of groundwater salinities (i.e. 25 000 mg/L TDS) represent areas of significant seawater intrusion.

Groundwater Contamination

There are no indications of groundwater contamination from current operations at any of the sites associated with the proposed Development (ChevronTexaco Australia 2000). Groundwater has, however, been impacted by hydrocarbons at the tank farm about 1 km north of the proposed gas processing facility site. It is unlikely that this impacted groundwater could extend far enough southwards to affect the proposed site. Moreover, during periods in which the creek immediately south of the tank farm is flowing, it would act as a temporary hydraulic barrier to south-flowing groundwater.

8.3 Ecology

8.3.1 Introduction

This section of Chapter 8 describes the existing biological environment in the Development area. It includes discussion of terrestrial and marine habitats and associated flora and fauna (including subterranean fauna) within the context of the Pilbara region, Barrow Island and the Gorgon Development areas.

The information presented on the terrestrial and marine environments of Barrow Island are based on numerous field surveys which commenced in early 2002 as part of the ESE Review process. Work has been ongoing since that time with additional surveys planned through to 2006.

8.3.2 Terrestrial Ecology

Flora and Vegetation Communities

Floristic diversity is an important component of terrestrial biodiversity on Barrow Island. Taxonomic surveys were conducted to identify possible rare and endangered plant species within the proposed Development areas and to assess whether these species are represented in areas outside the Development areas.

Vegetation communities and vegetated habitats are critical to the integrity of the Barrow Island ecosystem. The vegetation communities in the proposed Development areas and adjacent areas were mapped to identify potentially restricted communities and assess their representation outside proposed Development areas.

Botanical survey methods are summarised in Box 8-1. A full technical report is included in Technical Appendix C1.

Box 8-1:
Vegetation and Flora Survey Methodology

Vegetation was mapped within a greater study area of approximately 1683 ha surrounding the proposed gas processing facility, administration building, construction village and optical fibre cable route on Barrow Island (Figure 8-2). Seventy-two vegetation plots, each containing 25, 10 m x 10 m quadrats where possible, were established within the greater study area. Six of these plots were within the proposed gas processing facility footprint. Flora lists were compiled within each plot.

Vegetation plots on Barrow Island were established and surveyed in September and October 2003 and January 2004. The proposed gas processing facility area was re-surveyed in April and May 2004, following cyclonic rains, to collect annual species. Pipeline routes were surveyed in April and May 2004 and additional surveys to determine the extent of possibly restricted communities were conducted in May and July 2004.

Box 8-1: (continued)
Vegetation and Flora Survey Methodology

Vegetation maps for the proposed pipeline routes on Barrow Island were developed from detailed site observations, aerial photograph interpretation and plant specimen collections.

The areas to the north and south of the existing runway at the Barrow Island airport and alongside all of the roads between the airport and the barge landing were surveyed in July 2004 to identify major vegetation sensitivities in these areas. A preliminary survey of the proposed CO_2 seismic monitoring area was conducted in April 2005 to identify major constraints on disturbance in this area and to identify requirements for further survey work.

Surveys of the proposed domestic gas pipeline route on the mainland were undertaken on foot and by helicopter in May 2004. Major vegetation boundaries were identified from the air or from aerial photographs and the dominant vegetation within these areas described from site observations and plant collections.

Surveys were undertaken in accordance with EPA Guidance No. 51 (Environmental Protection Authority 2004b). Survey methodology and limitations are detailed in Technical Appendix C1.

Regional

Barrow Island lies in the Fortescue Botanical District, a subdivision of the Eremaean Botanical Province as defined by Beard (1980). The Eremaean province occupies approximately 70% of the state and is described by Beard (1980) as part of the arid zone which is dry and contains significant areas of 'barren, rocky and sandy country' but receives sufficient rainfall to maintain vegetated cover.

The Fortescue botanical district, or Pilbara region, covers approximately 178 000 km^2 and extends from north of Onslow, south and east to Paraburdoo and Newman, bounds the east side of the Oakover River and extends north and west to Goldsworthy.

The Fortescue Botanical District consists of 'tree and shrub steppe communities with *Eucalyptus* trees, *Acacia* shrubs, *Triodia pungens* and *Triodia wiseana'* (Beard 1990). [Note: *T. pungens* is a synonym of *T. epactia*]. Beard (1990) also notes the presence of mulga in valleys and 'short-grass' plains in alluvial areas. Mineral exploration since the 1960s has increased the knowledge of the area.

Barrow Island

Flora – The Eremaean nature of the flora on Barrow Island is demonstrated by the dominance of *Triodia* and *Acacia* and families such as Poaceae (grasses), Chenopodiaceae (chenopods), Papilionaceae (legumes), Malvaceae and Asteraceae (daisies) (Mattiske Consulting 1997).

The flora of Barrow Island is typical of the arid Pilbara region but has floral affinities with the Cape Range area on the mainland (Trudgen 1989; Mattiske Consulting 1997). Trudgen (1989) suggested that similarities between the vegetation on the Cape Range, which lies within the Carnarvon Botanical District, and the vegetation on Barrow Island, reflect past linkages to the mainland.

A total of 68 families, 180 genera and 406 vascular plant taxa have been recorded on Barrow Island. It is estimated that at least 90% of the vascular flora of Barrow Island has been documented. Approximately 20 to 30% of species are expected to occur only after cyclonic events or fires. Fourteen introduced vascular plant taxa have been recorded on Barrow Island, the majority of which have been recorded in or near previously disturbed sites. Table 8-5 summarises the regional affinities of the Barrow Island flora.

Two Priority species, protected under the *Wildlife Conservation Act 1950*, have been collected on Barrow Island: *Helichrysum oligochaetum* (Priority One) and *Corchorus interstans* (ms) (Priority Three).

Taxa that tend to be restricted to creek beds and gullies on Barrow Island are of conservation significance due to the relative rarity of this habitat on the island. The taxa associated with these habitats include *Abutilon otocarpum*, *Dysphania kalpari*, *Euphorbia* sp. 'A', *Gossypium australe* and *Hibiscus*

Table 8-5:
Summary of Geographical Spread of Species and Taxa Recorded on Barrow Island

Geographical Range	Number of Species/Taxa
Potentially restricted distribution on Barrow Island	17
Extensions from Kimberley	122
Extensions from Pilbara	193
Extensions from Cape Range and southern districts	50
Widespread (multiple botanical districts)	115

sturtii var. *platychlamys*. Most of these species occur only after favourable seasonal rains and were not recorded in 2003 and 2004 surveys, with the exception of *Abutilon otocarpum* which previously had only been recorded in Terminal Creek on the upper east part of Barrow Island (Mattiske and Associates 1993a, b).

Taxa that are restricted in distribution in the region or are only known from a few locations on Barrow Island are of conservation significance. Vegetation communities that are defined by the occurrence of these taxa are described in the following section.

Seventeen plant taxa require further attention in order to confirm their classification, distribution and conservation status on the island including variants of:

- *Acacia bivenosa*
- *Abutilon* sp.
- *Calandrinia* aff. *remota*
- *Ficus brachypoda* (hairy variant – ex *Ficus platypoda* var. *lachnocaula*)
- *Heliotropium* sp.
- *Lechenaultia* sp.
- *Sida* sp.

These seventeen species are considered to be locally significant pending confirmation of their conservation status (Technical Appendix C1).

Vegetation Communities – The vegetation of Barrow Island is unique amongst the islands of the north-west shelf (Astron Environmental 2002). The Barrow Island vegetation, and the soils, geology and topography show stronger affinities with Cape Range than with other Pilbara sites.

Barrow Island was originally classified into eight major vegetation units by Buckley (1983). These units were subsequently refined by Mattiske and Associates (1993b) who mapped 34 vegetation types based on major landforms, soil type and species composition over the whole island.

No vegetation communities listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or Threatened Ecological Communities as listed in the Department of Conservation and Land Management (CALM) Threatened Ecological Communities Database (www.naturebase.net/plants_animals/watscu/tec.html) have been recorded on Barrow Island.

Vegetation communities which either have restricted distribution on the island, or contain threatened or restricted species, represent evolutionary significant units and are considered to be of conservation significance. Communities of conservation significance on Barrow Island include:

- Communities containing *Grevillea pyramidalis* ?subsp. *leucadendron* which are restricted on the island (Plate 8-1).
- Communities at the western end of the alternative feed gas pipeline at Flacourt Bay (C1d, C2e, C5b, C5c and C4e) which are restricted to the near-coastal areas (Plate 8-2).
- The limestone community (L3c) near the proposed pipeline shore crossing at North White's Beach which appears to be restricted on the island (Plate 8-3).
- Limestone communities containing, or expected to contain, *Tephrosia clementii* (F5d and F5e) which appear to be restricted on the island.

Plate 8-1:
Grevillea pyramidalis ?subsp. *leucadendron* Community (L6b) on Proposed North White's Beach Pipeline Route

Plate 8-2:
Coastal Community (C5c) on Limestone at Flacourt Bay

Plate 8-3:
Limestone community (L3c) on the Proposed North White's Beach Pipeline Route

Gorgon Development Area

Flora – The number of vascular plant taxa and families recorded within the proposed gas processing facility footprint and along the proposed pipeline routes from Flacourt Bay and North White's Beach are shown in Table 8-6. The flora of the proposed optical fibre cable route will be surveyed in winter 2005 to facilitate selection of the final alignment.

No introduced species were recorded in any of the proposed Development areas during the 2003 and 2004 surveys (Technical Appendix C1). One introduced species, *Setaria verticillata*, was recorded near the proposed North White's Beach pipeline corridor during post cyclonic rain surveys. This individual plant was a new record for the Island.

Table 8-6:
Tally of Plant Taxa and Families Recorded Within Proposed Development Areas on Barrow Island

Proposed Development Area	No. Taxa	No. Families	Dominant Families
Proposed gas processing facility footprint	48	26	Euphorbiaceae (7 taxa), Papilionaceae (4 taxa), Poaceae (3 taxa), Asteraceae (3 taxa)
Proposed North White's Beach pipeline route	67	27	Chenopodiaceae (9 taxa), Poaceae (9 taxa) and Asteraceae (7 taxa)
Proposed alternative Flacourt Bay pipeline route	60	27	Poaceae (12 taxa), Asteraceae (5 taxa) and Papilionaceae (4 taxa)

No Declared Rare Flora as listed under Section 179 of the EPBC Act, or listed by CALM were found within proposed Development areas.

Helichrysum oligochaetum (Priority One) was not recorded within any of the proposed Development areas. *Corchorus interstans* (Priority Three) was recorded in nine of the twelve communities within the proposed gas processing facility area and within the proposed North White's Beach pipeline corridor (Technical Appendix C1). *Corchorus interstans* is widely distributed on Barrow Island and occurs on the Pilbara mainland. *Corchorus interstans* recovers well from disturbance and is not considered under threat on Barrow Island.

Plant species which are of conservation significance, due to restricted or unknown distribution on Barrow Island, or high ecological significance, are discussed in full in Technical Appendix C1. Those that occur within or adjacent to the proposed Development areas are listed in Table 8-7 with notes on their local, island and wider distribution.

The conservation status of taxa of unresolved identity, including morphological variants of known species, is uncertain and their wider distribution on the island is unconfirmed. Their identities cannot be resolved until the taxonomy of their groups is revised. They represent genetic diversity in the Barrow Island flora and are treated as evolutionary significant units until their taxonomy can be resolved. Unresolved taxa that occur in Development areas are part of communities that are well represented outside impact areas.

Table 8-7:
Restricted or Poorly Known Species

Species	Distribution	Distribution in Development Area
Grevillea pyramidalis ?subsp. *leucadendron*	Scattered populations on slopes with limestone outcropping on Barrow Island.	South of the proposed gas processing facility and along the proposed North White's Beach pipeline route.
Hakea lorea subsp. *lorea*	Widespread within several vegetation communities on Barrow Island.	In communities associated with valleys, drainage systems, limestone slopes and ridges along proposed pipeline routes and within the proposed gas processing facility area.
Melaleuca cardiophylla	Widespread on Barrow Island. Significant for unknown regrowth abilities and as habitat for the endemic white-winged fairy wren.	Occurs within the proposed gas processing facility area and pipeline routes in vegetation communities associated with drainage systems, flats, limestone ridges and slopes, and valley slopes and escarpments. Just over 3% of this community is likely to be affected by the proposed gas processing facility footprint and pipelines (51.48 ha of 1583 ha across the island as a whole).
Hybanthus aurantiacus	Extends from Barrow Island to the Kimberley and Pilbara regions.	Occurs within the proposed gas processing facility area.
Whiteochloa airoides	Extends from Barrow Island to the Kimberley and Pilbara regions. Has been recorded on the west coast and in inland areas of Barrow Island.	Occurs in one area towards the western end of the proposed feed gas pipeline route from Flacourt Bay.
Acacia synchronicia	Is very restricted on Barrow Island but appears to be widespread in mainland areas.	This species occurs to the north and north-east of the existing airstrip.

Vegetation Communities – Eighty-three vegetation communities were mapped within the area encompassing the proposed gas processing facility, associated infrastructure near Town Point and along the proposed pipeline corridors (Figure 8-11 to Figure 8-15). The mapping units for the vegetation communities were based on data from the current surveys and previous studies by Mattiske and Associates (1993b) and Astron Environmental (2002).

Vegetation communities within the proposed Development areas are described in Table 8-8.

Table 8-8:
Summary of Vegetation Communities Recorded within Proposed Development Areas on Barrow Island

Development Area	Vegetation Communities
Proposed Gas Processing Facility	Twelve vegetation communities were mapped within the proposed gas processing facility footprint. The proposed footprint also includes areas of disturbance and unvegetated rocky ground. The dominant communities within the proposed footprint are V1m, F8a and L3i. Community V1m consists of *Melaleuca* and *Acacia* heath over mixed *Triodia* hummock grassland on limestone slopes and ridges. Community F8a consists of *Acacia bivenosa* shrubland over mixed *Triodia* hummock grassland on flats and valley floors. Community L3i consists of *Acacia bivenosa* shrubland over mixed *Triodia* hummock grassland on limestone slopes, small rises and flats. 0.092 ha of major drainage line vegetation community which is restricted in distribution on the island is likely to be affected by the proposed gas processing facility area. There are two small *Grevillea* communities to the south of the proposed gas processing facility outside the proposed Development area.
Proposed Optical Fibre Cable Route	The proposed optical fibre cable route runs through coastal vegetation communities between the proposed gas processing facility and the coast. The communities affected by the cable route will be determined when the final route has been selected. Impacts to restricted communities will be avoided in selecting the cable route.
North White's Beach Feed Gas Pipeline	The pipeline corridor contains 44 vegetation communities over an area of approximately 36 ha. The corridor contains three communities dominated by the restricted species *Grevillea pyramidalis* subsp.?*leucadendron*, with a total area of 3 ha which would be impacted by the proposed pipeline. Limestone community L3c on this proposed pipeline route is very restricted and up to 0.1 ha of this community may be impacted by the proposed pipeline.
Alternative Flacourt Bay Proposed Feed Gas Pipeline	The alternative pipeline corridor from Flacourt Bay to the gas processing facility contains 23 vegetation communities over an area of about 22 ha. The proposed pipeline route includes five communities: C1d, C2e, C5b, C5c and C4e which are restricted to low beach dunes and coastal limestone flats. Approximately 0.5 ha of major drainage communities, which are restricted on the island would be impacted by the alternative pipeline.
Proposed CO_2 Injection Well Sites and CO_2 seismic monitoring area	The locations for the proposed CO_2 injection wells and seismic source/receiver lines have not been finalised, pending further geophysical modelling. The wells and the seismic monitoring grid will be overlain on the 1994 seismic grid, as much as possible, to maximise re-use of previously disturbed vegetation communities. Previously undisturbed, restricted vegetation communities will be avoided. Preliminary survey of the general area indicates that the vegetation communities that will need to be avoided include major drainage communities, coastal dune communities and clay pan communities to the north. The area will be mapped and the final sites chosen to avoid areas of high conservation value.
Airport Extension and Road Widening	Vegetation communities containing *Acacia synchronicia* to the north of the existing airstrip are restricted on the island. These communities have not been fully described or mapped and will be surveyed to assist in selecting the final alignment of the extended runway if it is required. Roadside communities are well represented in the areas adjacent to the roads. The areas immediately abutting the roads are frequently disturbed due to the accumulation of grader spoil and are dominated by *Triodia angusta*.

Mainland – Domestic Gas Pipeline Corridor

The proposed domestic gas pipeline corridor on the mainland is 50 m south of, and parallel to, the existing Apache Energy Sales Gas Pipeline corridor which extends through coastal mangrove and samphire associations, salt pans and inland terrestrial vegetation associations to Compressor Station 1 on the Dampier to Bunbury Natural Gas Pipeline. The terrestrial section of the corridor is on a pastoral lease and the area has been heavily affected by introduction of weed species and disturbance by domestic stock.

The terrestrial vegetation communities along the proposed domestic gas pipeline route are dominated by three major and two minor vegetation units with isolated occurrences of the introduced species *Prosopis* sp. and *Cenchrus ciliaris* (Dames and Moore 1998). In general, these vegetation units recovered successfully along the Apache Energy Sales Gas Pipeline easement in the 5–6 years subsequent to the initial pipeline installation.

Terrestrial Avifauna

Terrestrial avifauna (landbirds) populations were surveyed to assess the importance of the proposed Development areas in relation to other parts of Barrow Island and the Pilbara region. Surveys focussed on the only listed landbird species, the ‘Vulnerable’ and endemic white-winged fairy wren (*Malurus leucopterus edouardi*). The methodology used in the surveys is described in Box 8-2 and a full technical report is provided in Technical Appendix C3. Seabirds and shorebirds are discussed in Section 8.3.3 and are also included in Technical Appendix C3.

Box 8-2:
Avifauna Survey Methodology

Landbirds were surveyed twice a month along 1 km transects within the proposed Development area from September 2003 to October 2004. Surveys involved walking along fixed transects and recording landbirds within 25 m and beyond 25 m of each transect. Landbird locations were related to major vegetated habitat types within the Gorgon Development area.

A more intensive survey was conducted in October 2004 to examine habitat preferences of the white-winged fairy wren. Further surveys of the nesting habitat preferences of white-winged fairy wrens are planned for winter 2005.

Surveys were conducted in accordance with EPA Guidance No. 56 (Environmental Protection Authority 2004a). Survey methodology and limitations are described in Technical Appendix C3.

Regional

The landbirds of the Pilbara region include transient species that move throughout the region and resident or regular visitors that are more loyal to particular sites. Landbirds regularly travel between the Pilbara mainland and the offshore islands within the Montebello/Lowendal/Barrow Island groups. Consequently, many of the landbirds on the offshore islands are vagrants from the mainland. The white-winged fairy wren is widely distributed through the region, but does not travel between the islands and the mainland. It no longer occurs on the Montebello Islands (Burbidge 2004) and isolated populations have diverged genetically.

Figure 8-11:
Vegetation Legend (Page 1)

Barrow Island 2003/2004 Vegetation Community Legend

C1a	Open Grassland of *Spinifex longifolius* with low scattered *Atriplex isatidea, Myoporum montanum, Euphorbia myrtoides* and *Salsola tragus* shrubs and herbs on seaward face of white sandy fore dunes.
C1d	Low Open Shrubland of *Scaevola cunninghamii, Corchorus* sp. and *Heliotropium glanduliferum* over Very Open Grassland of *Spinifex longifolius* over scattered *Cynanchum floribundum* creeper on lower slopes at the base of primary sand dunes.
C1e	Grassland of *Spinifex longifolius* over Low Open Shrubland of *Threlkeldia diffusa* with scattered *Rhagodia preissii* subsp. *obovata* and *Frankenia pauciflora* var. *pauciflora* on ridges and back slopes of white sandy foredunes.
C2a	Shrubland to Tall Shrubland of *Acacia coriacea* over Low Open Shrubland to Open Shrubland of *Acacia bivenosa* with low scattered *Olearia dampieri* subsp. *dampieri* shrubs over Open Hummock Grassland to Grassland of *Triodia angusta* on dune swales, slopes and ridges.
C2b	Open Shrubland of *Acacia coriacea* over Low Open Shrubland of *Acacia bivenosa* and *Pentalepis trichodesmoides* with scattered *Acanthocarpus verticillatus* over Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on red/brown sandy flats.
C2c	Shrubland to Tall Shrubland of *Acacia coriacea* over Low Open Shrubland to Open Shrubland of *Acacia bivenosa* with low scattered *Olearia dampieri* subsp. *dampieri* shrubs over Open Hummock Grassland to Grassland of *Triodia angusta* on dune slopes and ridges.
C2d	Low Open Shrubland of *Acacia coriacea* and *Myoporum montanum* over Grassland to Hummock Grassland of *Spinifex longifolius* with patches of *Triodia epactia* in swales between dunes.
C2e	Low Open Shrubland of *Myoporum montanum* with *Corchorus* sp. over Grassland to Hummock Grassland of *Spinifex longifolius* with *Triodia angusta* over scattered *Cynanchum floribundum* creeper on crest of primary dunes.
C2f	Open Shrubland of *Acacia coriacea* over Low Open Shrubland of *Olearia dampieri* subsp. *dampieri* and *Acacia bivenosa* with occasional *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on sandy dune ridges (over scattered *Heliotropium glanduliferum* and *Diplopeltis eriocarpa* on back of red/brown sandy flats and dunes).
C2g	Shrubland of *Acacia coriacea* over Low Shrubland to Shrubland of *Olearia dampieri* subsp. *dampieri, Stylobasium spathulatum* and *Acacia bivenosa* over Hummock Grassland of *Triodia epactia* over low scattered *Threlkeldia diffusa* herbs in swales between dunes.
C2h	Low Shrubland of *Acacia coriacea* with *Rhagodia preissii* subsp. *obovata* over Very Open Herbland of *Threlkeldia diffusa* over Grassland to Hummock Grassland of *Triodia epactia* and *Spinifex longifolius* on secondary dune slopes and ridges.
C3a	Open Heath of *Acacia bivenosa* over Low Open Shrubland of *Olearia dampieri* subsp. *dampieri* with low scattered *Myoporum montanum* and *Enchylaena tomentosa* var. *tomentosa* shrubs over Open Hummock Grassland of *Triodia epactia* on red/brown sandy flats behind dunes.
C4e	Open Shrubland of *Trichodesma zeylanicum* over Low Open Shrubland of *Corchorus* sp., *Olearia dampieri* subsp. *dampieri, Scaevola cunninghamii* and *Whiteochloa airoides* over Open Hummock Grassland of *Triodia angusta* over *Cynanchum floribundum* scattered creepers on upper slope to mid slopes of sandy dunes.
C5a	Low scattered *Frankenia pauciflora* var. *pauciflora* shrubs with scattered *Oldenlandia crouchiana* herbs and *Cyperus cunninghamii* subsp. *cunninghamii sedges* on coastal limestone cliffs and in major drainage lines in coastal areas.
C5b	Low scattered *Pentalepis trichodesmoides, Olearia dampieri* subsp. *dampieri, Corchorus* sp. and *Tephrosia rosea* shrubs over Hummock Grassland of *Triodia angusta* over scattered *Cynanchum floribundum* creepers on limestone ridges and flats (plateaus).
C5c	Very Open Hummock Grassland of *Triodia angusta* over low scattered *Scaevola cunninghamii, Corchorus* sp., *Frankenia pauciflora* var. *pauciflora* and *Heliotropium glanduliferum* scattered herbs and shrubs on lower slopes on limestone.
C5d	Low Open Shrubland of *Myoporum montanum* over Very Open Grassland of *Spinifex longifolius* with scattered Hummocks of *Triodia epactia* over Low Open Shrubland of *Frankenia pauciflora* var. *pauciflora* with scattered *Heliotropium glanduliferum* on flat sandy swales with occasional limestone outcropping behind primary dunes.
D1a	Scattered tall *Acacia coriacea* shrubs over Low Shrubland to Shrubland of *Stylobasium spathulatum* and *Acacia bivenosa* over Very Open Herbland of *Acanthocarpus verticillatus* over Closed Hummock Grassland of *Triodia angusta* with scattered *Triodia wiseana* on valley floors and deep gullies. This unit contains occasional *Hakea lorea* subsp. *lorea.* Unit also contains areas of scoured drainage channel in areas of heavy seasonal flow.
D1c	Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* with *Triodia epactia* at edges in major drainage lines.
D1d	Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia epactia* with patchy *Triodia angusta* and *Triodia wiseana* on lower slopes and broad drainage flats.

Figure 8-11:
Vegetation Legend (Page 2)

	D1e	Open Shrubland of *Stylobasium spathulatum, Pentalepis trichodesmoides* with *Trichodesma zeylanicum* over Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over Low Open Shrubland of *Acacia bivenosa* and *Acacia gregorii* in some locations on lower slopes, drainage flats and wide drainage lines.
	D1f	Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum* with patchy *Petalostylis labicheoides* over Hummock Grassland to Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* in major drainage lines. This unit contains occasional *Hakea lorea* subsp. *lorea.*
	D1g	Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over low scattered *Tephrosia rosea* and *Indigofera monophylla* shrubs in wide drainage lines.
	D2c	Scattered tall *Trichodesma zeylanicum* shrubs over Hummock Grassland of *Triodia angusta* with *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* in disturbed drainage lines.
	D2d	Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia epactia* and *Triodia wiseana* over Low Shrubland of *Acacia gregorii* in minor creek and drainage lines.
	D2f	Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum* with patchy *Petalostylis labicheoides, Acacia gregorii* and *Acacia bivenosa* over Hummock Grassland to Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* in minor drainage lines. This unit contains occasional *Hakea lorea* subsp. *lorea.*
	F4a	Low Open Woodland of *Erythrina vespertilio* over Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* with occasionally emergent *Ficus brachypoda* on flats with shallow red/brown sands and emergent limestone.
	F5a	Low Open Shrubland of *Stylobasium spathulatum* with scattered *Pentalepis trichodesmoides* and *Senna glutinosa* over Hummock Grassland of *Triodia angusta* with *Triodia epactia* over Low Open Shrubland of *Diplopeltis eriocarpa* on gentle low slopes and flats.
	F5b	Scattered low *Ficus brachypoda* trees over scattered low *Pentalepis trichodesmoides, Acacia bivenosa, Corchorus* sp. , *Tephrosia rosea* and *Streptoglossa decurrens* shrubs over Closed Hummock Grassland of *Triodia epactia* with *Triodia angusta* on flats.
	F5c	Low Open Shrubland of *Pentalepis trichodesmoides* over mixed Hummock Grassland of *Triodia epactia* with occasional *Triodia angusta* over Low Open Shrubland of *Diplopeltis eriocarpa* and *Acacia gregorii* on limestone ridges, slopes and flats.
	F5d	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* over scattered low *Corchorus* sp., *Scaevola cunninghamii* and *Heliotropium glanduliferum* herbs and shrubs on upper slopes and mid slopes of small limestone rises.
	F5e	Scattered low *Ficus brachypoda* trees over low scattered *Pentalepis trichodesmoides* shrubs over Open Hummock Grassland of *Triodia angusta* with *Triodia epactia* over low scattered *Scaevola cunninghamii, Diplopeltis eriocarpa* and *Acacia bivenosa* shrubs on limestone flats and rises with shallow pale pink sands.
	F6a	Low Open Shrubland of *Acacia bivenosa* and *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on red/brown sandy flats.
	F6b	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia epactia* with on sandy slopes and flats with occasional limestone outcropping.
	F6c	Tall Open Shrubland of *Acacia coriacea* over low scattered *Stylobasium spathulatum* shrubs over Open Hummock Grassland of *Triodia epactia* on light red/brown sandy flats.
	F6d	Open Shrubland of *Trichodesma zeylanicum* over low scattered *Pterocaulon sphacelatum* shrubs over Hummock Grassland of *Triodia epactia* on limestone flats with shallow sands.
	F7a	Low scattered *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* shrubs over Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and scattered *Acacia gregorii* on limestone slopes.
	F7b	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia wiseana* with patches of *Triodia angusta* on sandy flats.
	F7c	Open Shrubland of *Senna glutinosa* over Low Open Shrubland of *Pentalepis trichodesmoides* and *Tephrosea rosea* over Closed Hummock Grassland of *Triodia angusta* on red/brown sandy flats.
	F7d	Scattered *Hakea lorea* subsp. *lorea* shrubs over Low Scattered *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* shrubs over Closed Hummock Grassland of *Triodia epactia* and *Triodia wiseana* on mid slopes and flats.
	F7e	Low Open Shrubland of *Pentalepis trichodesmoides* over low scattered *Corchorus* sp. and *Sarcostemma viminale* subsp. *australe* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy flats (with pockets of *Eriachne mucronata* on valley floors).
	F8a	Low Open Shrubland to Open Shrubland of *Acacia bivenosa,* with occasional scattered *Pentalepis trichodesmoides, Stylobasium spathulatum* and *Acanthocarpus verticillatus* shrubs over Hummock Grassland to Closed Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* on flats and valley floors.

Figure 8-11:
Vegetation Legend (Page 3)

	F8b	Scattered tall *Hakea lorea* subsp. *lorea* shrubs over Low Open Shrubland of *Pentalepis trichodesmoides* over low scattered *Tephrosia rosea* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy flats.
	L1a	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over low scattered *Stylobasium spathulatum* and *Petalostylis labicheoides* shrubs over Hummock Grassland of *Triodia wiseana* with occasional *Cymbopogon ambiguus, Tephrosia rosea* and *Triodia angusta* on limestone ridges and upper slopes.
	L1b	Scattered low *Ficus brachypoda* trees over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on limestone slopes and ridges.
	L1c	Scattered low *Ficus brachypoda* over Low Open Shrubland of *Acacia bivenosa* over Closed Hummock Grassland of *Triodia angusta* with *Triodia epactia* and occasional *Triodia wiseana* on limestone slopes and ridges.
	L1d	Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and *Heliotropium glanduliferum* on limestone flats (plateau).
	L1e	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees (with *Mallotus nesophilus)* over Hummock Grassland of *Triodia wiseana* with patchy *Triodia angusta* over low scattered *Diplotepltis eriocarpa* shrubs on limestone slopes and flats.
	L1f	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over Hummock Grassland of *Triodia wiseana* and patchy *Triodia angusta* on limestone slopes and ridges.
	L3a	Low Open Shrubland of *Stylobasium spathulatum* with *Petalostylis labicheoides* over Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* over Low Open Shrubland of *Acacia gregorii* on limestone slopes and ridges.
	L3b	Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* with *Triodia epactia* over low scattered *Acacia gregorii* and *Diplopeltis eriocarpa* shrubs on limestone slopes and ridges.
	L3c	Low scattered *Diplopeltis eriocarpa* shrubs with scattered *Cymbopogon ambiguus* and *Cyperus cunninghamii* subsp. *cunninghamii* herbs and grasses on small exposed limestone flats.
	L3d	Low scattered *Stylobasium spathulatum* and *Petalostylis labicheoides* shrubs over Low Open Shrubland of *Diplopeltis eriocarpa, Acacia gregorii* and *Hannafordia quadrivalvis* subsp. *recurva* over Hummock Grassland of *Triodia angusta* with *Triodia wiseana* on limestone ridges.
	L3e	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over low scattered *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* shrubs over mixed Hummock Grassland of *Triodia wiseana, Triodia angusta* and *Triodia epactia* over low scattered *Diplopeltis eriocarpa* shrubs on slopes and ridges.
	L3f	Low scattered *Petalostylis labicheoides* and *Indigofera monophylla* shrubs over Hummock Grassland of *Triodia wiseana* on limestone ridges and upper slopes.
	L3g	Low Open Shrubland of *Stylobasium spathulatum* over Hummock Grassland of *Triodia wiseana* with *Triodia angusta* and *Cymbopogon ambiguus* over Low Open Shrubland of *Diplopeltis eriocarpa* on limestone hillslopes.
	L3h	Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* over low scattered *Diplopeltis eriocarpa* shrubs on limestone ridges and flats.
	L3i	Low Open Shrubland to Low Shrubland of *Acacia bivenosa* with occasional low scattered *Stylobasium spathulatum* and *Petalostylis labicheoides* shrubs over Hummock grassland of *Triodia angusta* with occasional *Triodia wiseana* on limestone slopes, small rises and flats.
	L4a	Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Acacia bivenosa* with scattered *Petalostylis labicheoides* and *Stylobasium spathulatum* over Hummock Grassland of *Triodia wiseana* on limestone ridges and midslopes with patches of *Triodia angusta.* This unit contains occasional *Hakea lorea* subsp. *lorea.*
	L5a	Scattered tall *Hakea lorea* subsp. *lorea* shrubs over low scattered *Petalostylis labicheoides* shrubs over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* over low scattered *Acacia gregorii* and *Corchorus interstans* shrubs on limestone ridges.
	L5b	Scattered *Hakea lorea* subsp. *lorea* shrubs over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy midslopes.
	L6a	Low Open Shrubland of *Grevillea pyramidalis* subsp. *?leucadendron* and *Acacia bivenosa* over Hummock Grassland of *Triodia angusta* low scattered *Acacia gregorii, Scaevola cunninghamii* and *Heliotropium glanduliferum* shrubs and herbs on limestone midslopes.
	L6b	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Grevillea pyramidalis* ?subsp. *leucadendron* with occasional *Pentalepis trichodesmoides, Trichodesma zeylanicum* with scattered *Acacia gregorii* over Closed Hummock Grassland of *Triodia epactia, Triodia wiseana* and *Eriachne* sp. over Low Open Shrubland of *Acacia gregorii* on upper slopes and midslopes of small rises.
	L6c	Low Open Shrubland of *Pentalepis trichodesmoides* with *Grevillea pyramidalis* ?subsp. *leucadendron (Grevillea* only in eastern section of community) over Hummock Grassland of *Triodia wiseana* with patchy *Triodia epactia* over Low Open Shrubland of *Diplopeltis eriocarpa* on mid to upper slopes with red/brown sands and occasional limestone outcropping on rocky rises and slopes.

Figure 8-11:
Vegetation Legend (Page 4)

L6d		Low Open Shrubland of *Pentalepis trichodesmoides* with *Indigofera monophylla* and scattered *Grevillea pyramidalis* ?subsp. *leucadendron* over Hummock Grassland of *Triodia epactia* in minor drainage lines.
L7a		Low Shrubland of *Melaleuca cardiophylla, Stylobasium spathulatum, Pentalepis trichodesmoides, Trichodesma zeylanicum* over Hummock Grassland of *Triodia wiseana* with *Triodia angusta* over Low Open Shrubland of *Acacia gregorii, Acacia bivenosa* shrubs on rocky limestone ridges, slopes and minor gullies, with occasional pockets of *Gossypium robinsonii*.
L7b		Low Shrubland of *Melaleuca cardiophylla* over Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* over low scattered shrubs to Low Open Shrubland of *Acacia gregorii* on limestone upper slopes and ridges.
L9a		Low Open Woodland of *Ficus brachypoda* over low scattered *Pentalepis trichodesmoides* and *Sarcostemma viminale* subsp. *australe* shrubs over Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on coastal limestone flats.
S1a		Grassland of *?Eriachne flaccida* over scattered low *Pluchea dunlopii* and *Streptoglossa decurrens* herbs and shrubs on clay pans. (Community contains scattered emergent *Acacia bivenosa* and *Stylobasium spathulatum* shrubs and *Triodia angusta* at edges).
V1a		Low Open Shrubland of *Acacia bivenosa* with *Petalostylis labicheoides* over Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* over Low Open Shrubland of *Acacia gregorii* shrubs on limestone midslopes and occasional small rises. This unit contains some areas of disturbance by fauna.
V1b		Low Open Shrubland of *Acacia bivenosa* with *Petalostylis labicheoides* over Hummock Grassland of *Triodia wiseana* and some *Triodia angusta* over Low Open Shrubland of *Diplopeltis eriocarpa* on red/brown sandy flats.
V1c		Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over scattered low *Petalostylis labicheoides, Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana, Triodia epactia* and *Cymbopogon ambiguus* on limestone slopes and ridges, with *Stylobasium spathulatum* at edges on red/brown sandy drainage flats.
V1d		Low Open Shrubland of *Acacia bivenosa* with low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on limestone slopes and low ridges with occasional *Melaleuca cardiophylla.*
V1f		Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* on red/brown sandy flats.
V1g		Scattered tall *Acacia pyrifolia* shrubs over low scattered *Petalostylis labicheoides, Acacia bivenosa* and *Acacia gregorii* shrubs over Hummock Grassland of *Triodia wiseana* with some *Triodia angusta* and *Cymbopogon ambiguus* on red/brown sandy midslopes and in minor drainage lines with occasional outcropping.
V1h		Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum, Petalostylis labicheoides* and *Acacia bivenosa* over Closed Hummock Grassland of *Triodia wiseana* and *Triodia angusta* over Low Open Shrubland of *Acacia gregorii* on limestone slopes. This unit contains occasional *Hakea lorea* subsp. *lorea.*
V1i		Hummock Grassland of *Triodia epactia* with occasional *Triodia wiseana* over Low Open Shrubland *Acacia gregorii* with *Diplopeltis eriocarpa* on gentle slopes and flats.
V1j		Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and scattered *Acacia gregorii* on limestone slopes.
V1k		Scattered *Acacia pyrifolia* and occasional *Hakea lorea* subsp. *lorea* shrubs over Low Open Shrubland to Low Shrubland of *Melaleuca cardiophylla* over Hummock Grassland of *Triodia wiseana* with patchy *Triodia angusta* over low scattered *Acacia gregorii* shrubs on limestone hillslopes and minor drainage lines.
V1m		Low Open Heath of *Melaleuca cardiophylla* with *Acacia bivenosa, Sarcostemma viminale* subsp. *australe* over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* on limestone ridges and slopes.
V1n		Scattered *Hakea lorea* subsp. *lorea* shrubs over low scattered shrubs to Low Open Shrubland of *Melaleuca cardiophylla* with *Acacia bivenosa, Stylobasium spathulatum* and *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia angusta* on flats and edge of drainage lines.
V3a		Scattered low *Ficus brachypoda* trees over scattered *Acacia pyrifolia* shrubs over Hummock Grassland of *Triodia wiseana* on limestone slopes. This community contains minor drainage lines.
V3b		Scattered *Acacia pyrifolia* shrubs with occasional *Hakea lorea* subsp. *lorea* over low scattered shrubs to Low Open Shrubland of *Petalostylis labicheoides* and *Stylobasium spathulatum,* occasional *Acacia bivenosa* and *Acacia gregorii* over Hummock Grassland of *Triodia wiseana* with patches of *Triodia angusta* on limestone slopes.
R		Rocks
Dist		Disturbed, cleared, roads.
D1a Dist		Disturbed Community D1a drainage areas.

Figure 8-12:
Proposed Northern Pipeline Corridors

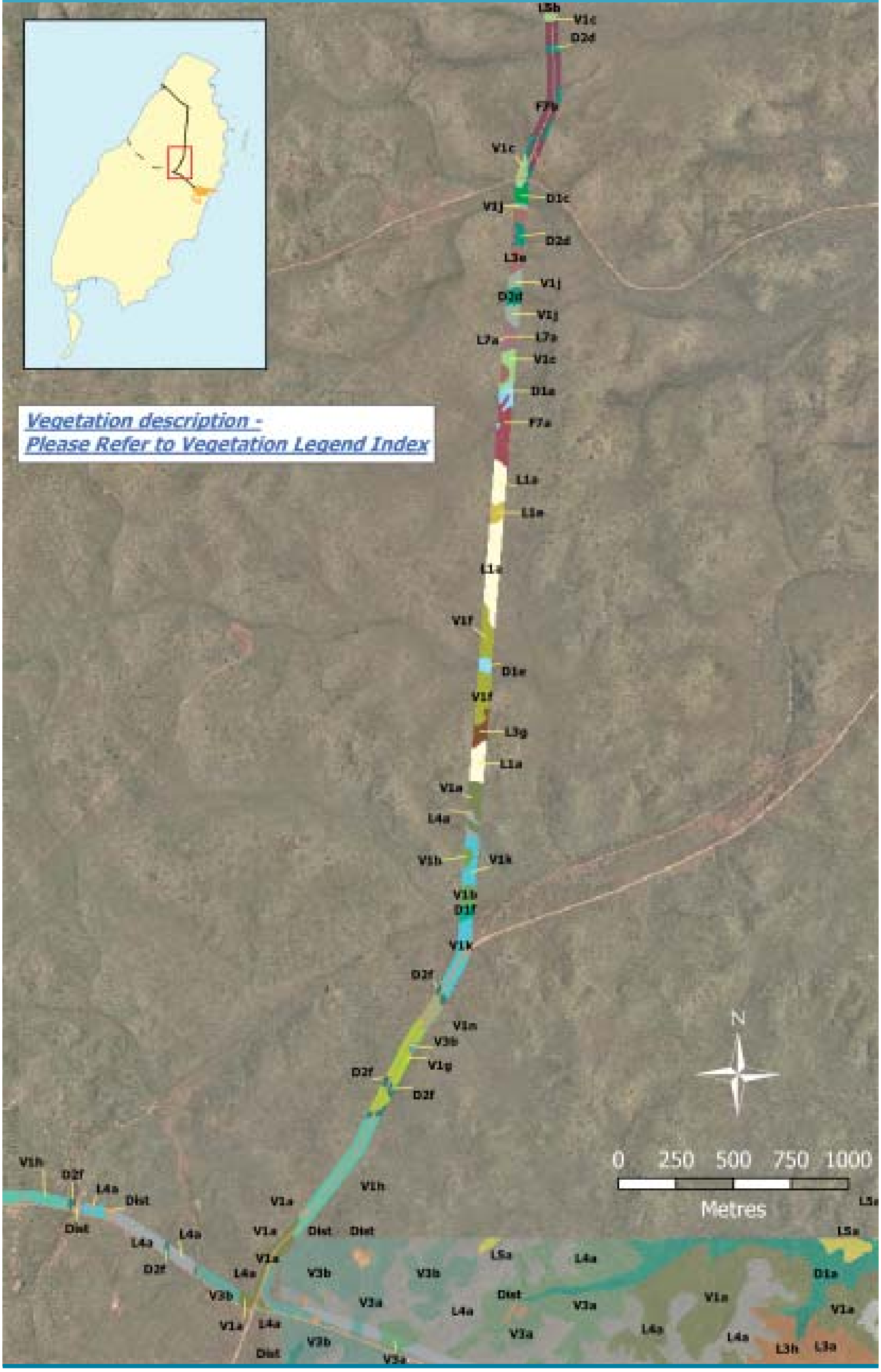


Figure 8-13:
Proposed Northern Pipeline Corridors *(continued)*

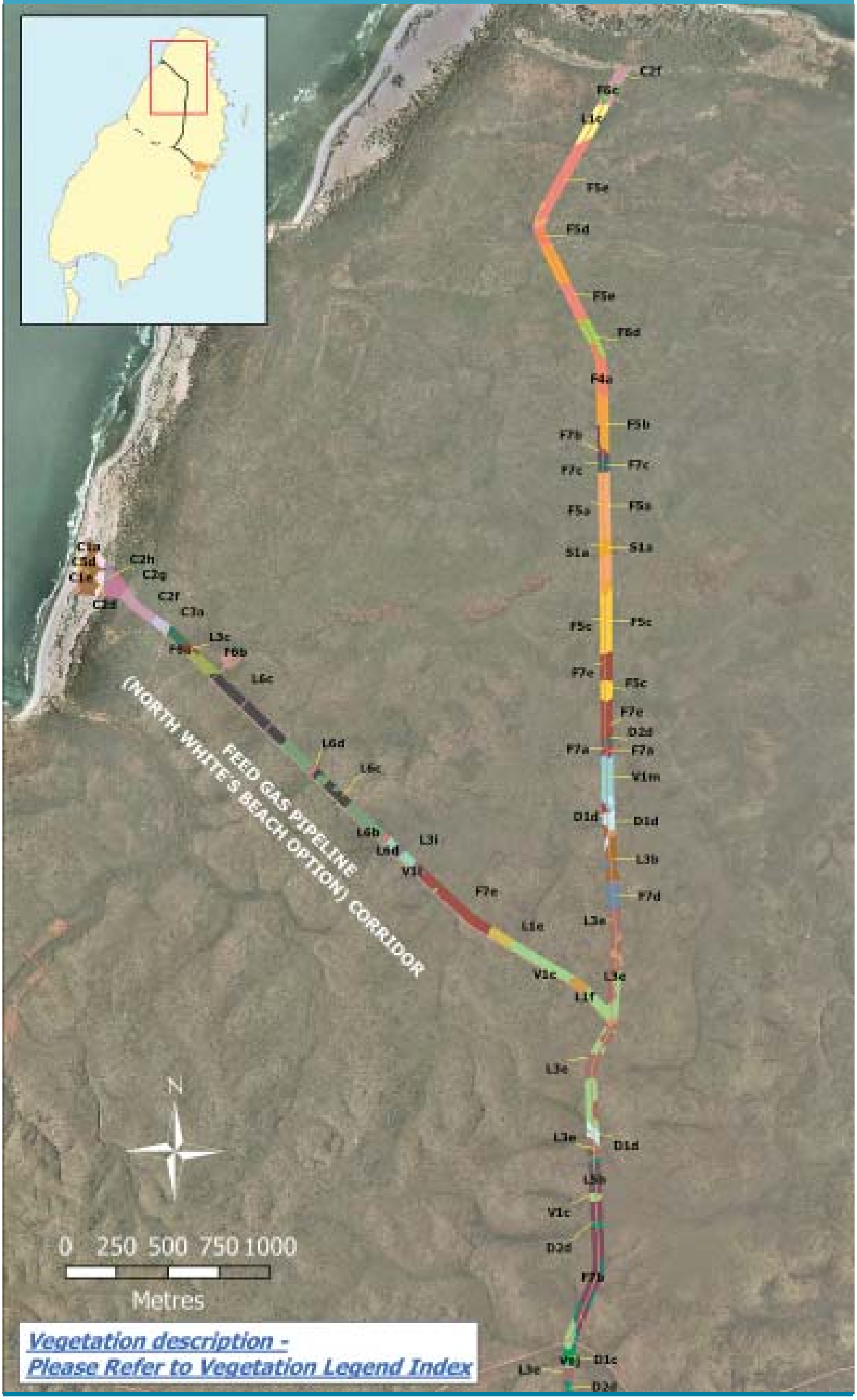
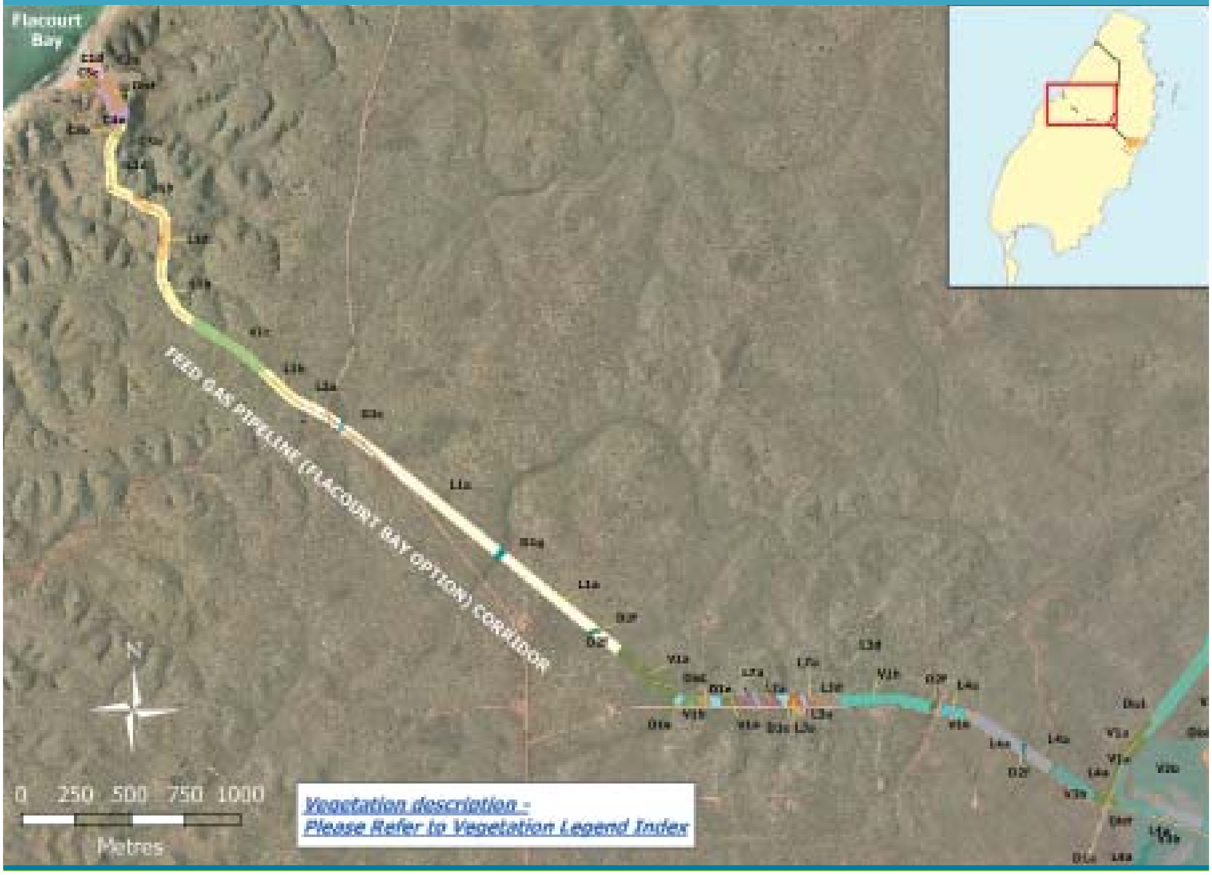


Figure 8-14:
Proposed Feed Gas Pipeline Vegetation



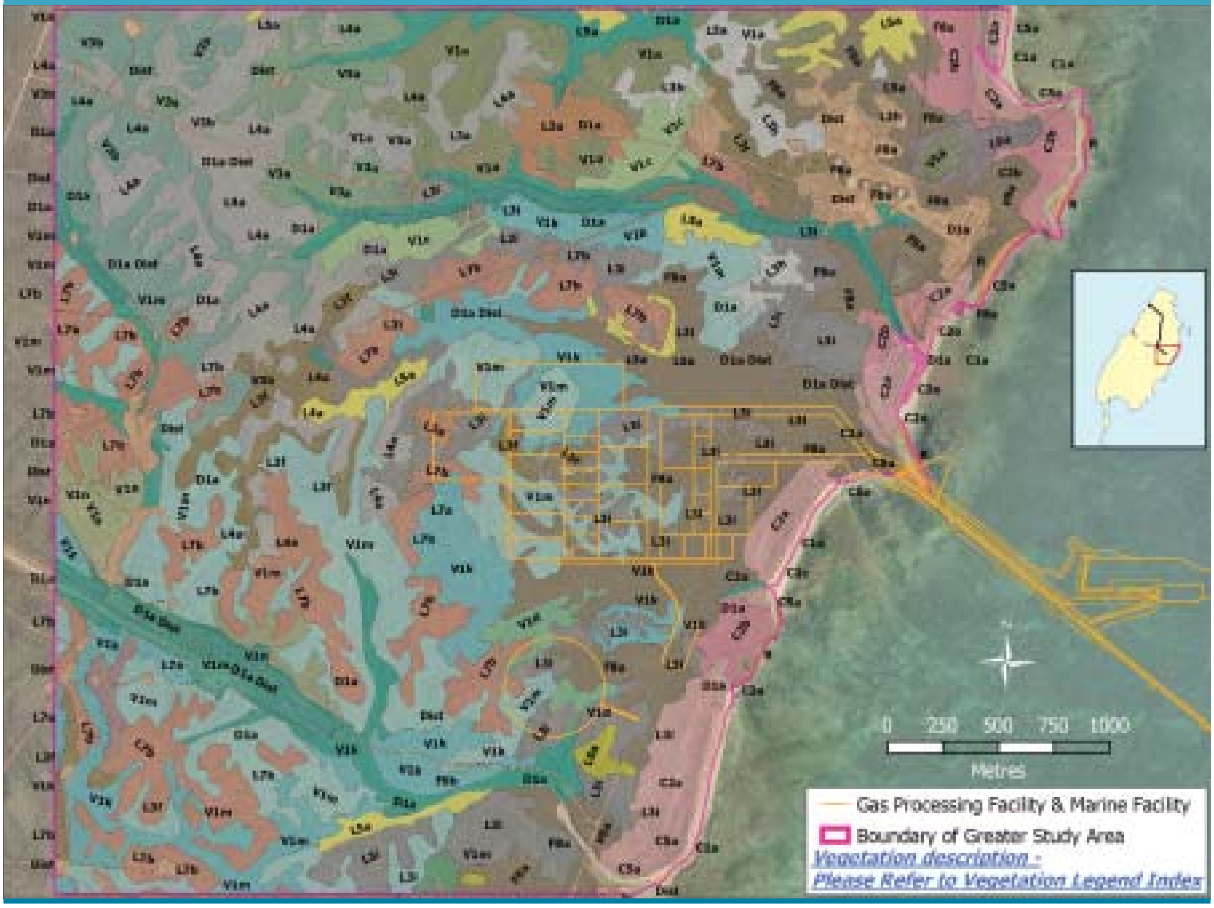
Barrow Island

Fifty-one species of terrestrial avifauna have been recorded on Barrow Island; however only 16 of these species are residents or regular migrants to the island. Most species are considered to be vagrants from the adjacent mainland. The most common landbirds on Barrow Island are the spinifexbird, white-winged fairy wren, singing honeyeater, white-breasted wood swallow and the welcome swallow (Technical Appendix C3).

White-winged Fairy Wrens – The Barrow Island white-winged fairy wren (Plate 8-4) is an endemic subspecies that is abundant, but restricted to Barrow Island. It is listed under Schedule 1 of the Wildlife Conservation Act and as a threatened species (Vulnerable) under the Commonwealth EPBC Act. The white-winged fairy wren is the second most abundant landbird on Barrow Island and is generally associated with complex vegetation structures in the upland areas of Barrow Island (Pruett-Jones and Tarvin 2001) and near-coastal shrublands (Technical Appendix C3). White-winged fairy wrens are part of a stable resident population on Barrow Island that has diverged from other island and mainland subspecies.

Plate 8-4:
Pair of Nesting White-Winged Fairy Wrens on *Melaleuca* Shrub

Figure 8-15:
Gas Processing Facility Footprint



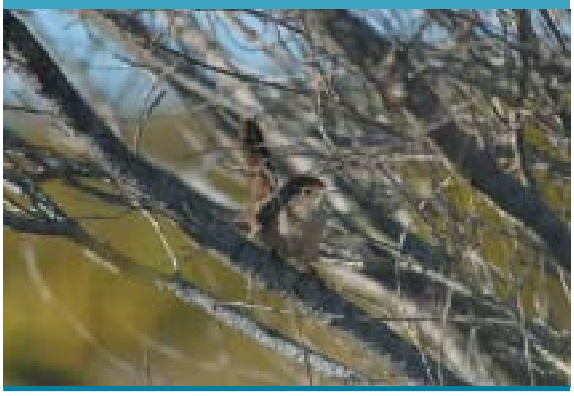
Gorgon Development Area

The abundance of landbirds in the Development area varies across different vegetated habitats. Species richness is highest in coastal *Acacia* shrublands where both the singing honeyeater and the spinifexbird (Plate 8-5) are abundant. White-winged fairy wrens tend to be more abundant in inland *Melaleuca* and *Acacia* shrublands.

Landbirds commonly roost in the scattered emergent shrubs along the side of the roads and may occur at higher densities on roadsides than in adjacent habitats (Pruett-Jones and O'Donnell in prep). There are no critical avifauna habitats in the proposed Development areas that are of higher ecological significance than surrounding areas for any landbird species.

White-winged Fairy Wrens – White-winged fairy wrens are widely distributed across the island and are expected to occur in all of the proposed Development areas. Transect surveys through the area surrounding the proposed gas processing facility indicated that white-winged fairy wrens prefer vegetation communities with emergent shrubs such as *Melaleuca* and *Acacia*. These communities are widespread in the Town Point hinterland and white-winged fairy wrens are abundant within the Development area. The proposed Development areas contain approximately 3–4% of the preferred emergent shrubland communities on Barrow Island and are

Plate 8-5:
Spinifexbird in *Acacia* Shrubland



expected to support a similar proportion of the island's total white-winged fairy wren population.

Mainland – Domestic Gas Pipeline Corridor

Five listed, migratory terrestrial or wetland species (EPBC Act) or their habitats may occur within the vicinity of the mainland domestic gas pipeline corridor. These species include: the white-bellied sea-eagle *Haliaeetus leucogaster*, the barn swallow *Hirundo rustica*, the oriental plover *Charadrius veredus*, the oriental pranticole *Glareola maldivarum* and the little curlew *Numenius minutus*. Four other listed bird species or their habitats may occur within the vicinity of the domestic gas pipeline corridor including: the fork-tailed swift *Apus pacificus*, the great egret *Ardea alba*, the cattle egret *Ardea ibis* and the rainbow bee-eater *Merops ornatus*.

Due to the degraded state of the vegetation communities in this area and the narrow width of the proposed easement, it is unlikely that the domestic gas pipeline corridor contains critical habitat for any listed avifauna. The mangroves in this area are likely to support a more diverse avifauna, of which many species would be restricted to the mangrove zone. Further surveys of avifauna along the proposed pipeline route will be conducted during 2005.

Mammals

Barrow Island is recognised as an important refuge for native mammal species that have either declined in numbers or become extinct on the mainland. Department of Conservation and Land Management (CALM) monitoring has found that most mammal populations are abundant and secure on the island (Burbidge et al. 2003). The mammal fauna of the proposed gas processing facility were surveyed using methods consistent with CALM's monitoring program (Box 8-3).

Regional

The mammal fauna of the Pilbara region has significantly declined due to competition with, and predation from, introduced species. Some offshore islands have been less impacted by introduced species and are important refugia for many species that are under threat on the mainland. Barrow Island is the largest island in the Pilbara region and the second largest island off the Western Australian coast, and having remained largely free of introduced competitors and predators, supports an intact mammal assemblage. The importance of the Barrow Island Nature Reserve is apparent from the following description of the restricted regional distribution of the listed mammals that occur on the Island.

Box 8-3:
Mammal Survey Methodology

Mammals in the vicinity of the proposed gas processing facility area were surveyed in November – December 2003 and October 2004. Six trapping grids, consistent in trap design and layout with CALM's long-term monitoring program on Barrow Island, were established in the main vegetated habitat types within the proposed Development area. Twenty-five cage traps, Elliot traps and pit traps, were set at each grid.

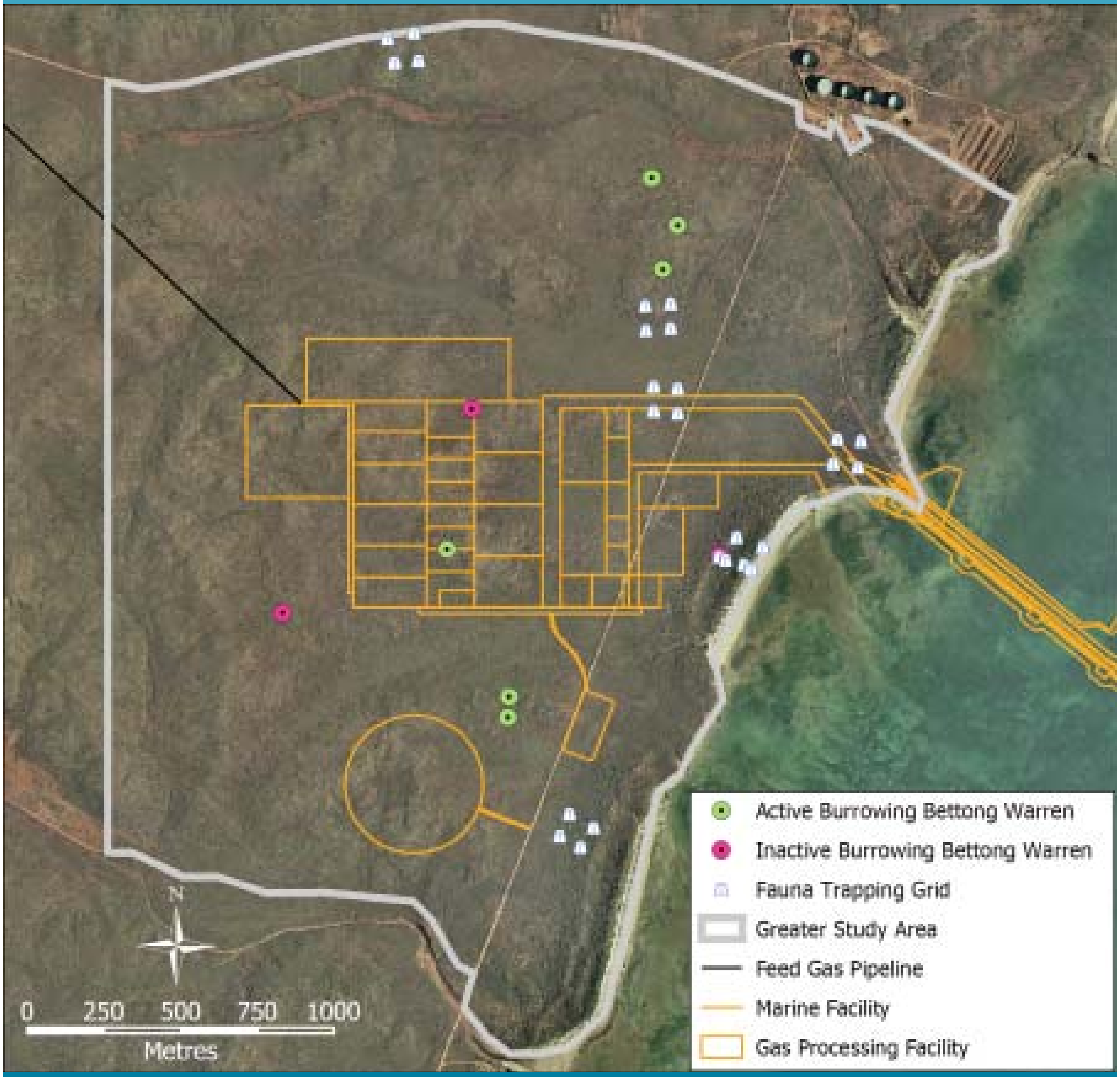
Captured mammals were measured, weighed and marked. Measurements included crown, pes and external gonad dimensions, while notes were made on reproductive condition and the presence of pouch young. Recaptures were accounted for in density estimates.

Burrowing bettong warrens and larger mammals such as spectacled hare wallabies were located using a systematic transect approach which involved walking the entire greater survey area (Figure 8-16) in transects 50 m apart. Observers investigated features such as rocky outcrops or dense vegetation between adjacent transects. Transects were progressively surveyed from October to December 2003. When burrowing bettong warrens were located, the position, number of entrances and signs of recent faunal activity were recorded.

The surveys were undertaken consistent with EPA Guidance No. 56 (EPA 2004a). Survey methodology and limitations are detailed in Technical Appendix C2.

Proposed pipeline routes were surveyed in 2004 for signs of mammal activity, especially burrowing bettong warrens. Bettong warrens in the vicinity of the proposed airport extension and road widening areas were surveyed in July 2004. Fauna in the vicinity of the proposed CO_2 injection sites and seismic monitoring grid will be assessed as part of final site selection. A preliminary survey of mammal habitats in the CO_2 seismic monitoring area was conducted by helicopter and by foot in April 2005.

Figure 8-16:
Fauna Trapping Grids, Burrowing Bettong Warrens and Transect Survey Area



Burrowing Bettong – Burrowing bettongs (*Bettongia lesueur*) (Plate 8-6) were originally widespread across the Pilbara and in other parts of the Australian mainland. They are now confined to a few populations such as those on Barrow Island and Boodie Island in the Pilbara. In the Gascoyne region, the Shark Bay burrowing bettong subspecies (*Bettongia lesueur lesueur*) exists on Bernier Island and Dorre Island. Burrowing bettong populations have been successfully translocated to the mainland and persist at Faure Island and Heirrison Prong in Shark Bay (Burbidge 2004). The continued survival of the mainland population depends on the success of predator control programs such as CALM's Western Shield Fauna Recovery Program.

Barrow Island Golden Bandicoot – The Barrow Island golden bandicoot (*Isoodon auratus barrowensis*) is abundant on Barrow Island and nearby Middle Island. Genetic studies suggest that Barrow Island animals may not be a separate subspecies to mainland golden bandicoots (Burbidge 2004) which are not abundant, but widespread on the mainland.

Spectacled Hare Wallaby – The island subspecies of spectacled hare wallaby (*Lagorchestes conspicillatus conspicillatus*) now exists only on Barrow Island. Populations on Hermite Island and Trimouille Island in the Montebello group were driven to extinction by feral cat and possibly black rat predation (Burbidge 2004).

Barrow Island Euro – The Barrow Island euro subspecies (*Macropus robustus isabellinus*) occurs only on Barrow Island (Burbidge 2004). The subspecies is listed as vulnerable due to its restricted distribution; however the Barrow Island population is considered to be secure.

Black-flanked Rock Wallaby – Remnant populations of the black-flanked rock wallaby (*Petrogale lateralis lateralis*) persist in Cape Range, the southern edge of the Pilbara, the Calvert Ranges, Barrow Island and Salisbury Island (Burbidge 2004). Mainland populations are small and have been impacted by fox predation and large wildfires.

Barrow Island Chestnut Mouse – The Barrow Island subspecies (*Pseudomys nanus ferculinus*) is restricted to Barrow Island where it occupies all vegetated habitats (Burbidge 2004).

Water Rat – Water rats (*Hydromys chrysogaster*) are widely distributed on the east coast of Australia, in southern Western Australia and along the Pilbara coast and offshore islands. There are populations on Barrow Island in the Pilbara and on Bernier and Dorre islands in the Gascoyne region.

Pilbara Leaf-nosed Bat – The Pilbara form of the orange leaf-nosed bat (*Rhinonicteris auratus* – Pilbara form) occurs in small populations at a few known roost sites. Many of these sites are in old mine adits that are likely to collapse in the future. They are very sensitive to human interference and may abandon their roost if disturbed (Burbidge 2004).

Mulgara – Formerly widespread in sandy deserts, mulgara (*Dasycercus cristicauda*) are now rare and have a patchy distribution. The mulgara has recently been recorded in the Pilbara area (Burbidge 2004).

Plate 8-6:
Burrowing Bettong

Barrow Island

Barrow Island is one of Australia's most important mammal conservation areas. The island supports 13 species of resident terrestrial mammal, with a further two species of bat recorded as vagrants to the island. Six species of resident mammals are included either as specially protected fauna under Schedule 1 of the Western Australian Wildlife Conservation Act or listed as Vulnerable on the EPBC Act threatened species list.

Burrowing Bettong – Burrowing bettong warrens are widely distributed on Barrow Island (Figure 8-17). Unlike the more mobile mammal fauna, they are dependant upon their warrens for shelter. Their use of surrounding areas for foraging is unknown however they appear to have home ranges of several kilometres (Donaldson, F. 2004 Personal communication). Occupancy of burrowing bettong warrens appears to fluctuate from year-to-year.

Barrow Island Golden Bandicoot – Golden bandicoots are widespread and abundant throughout their range on Barrow Island. They are the most abundant mammal on the island, with an estimated population of 60 000–80 000 (McKenzie et al. 1995).

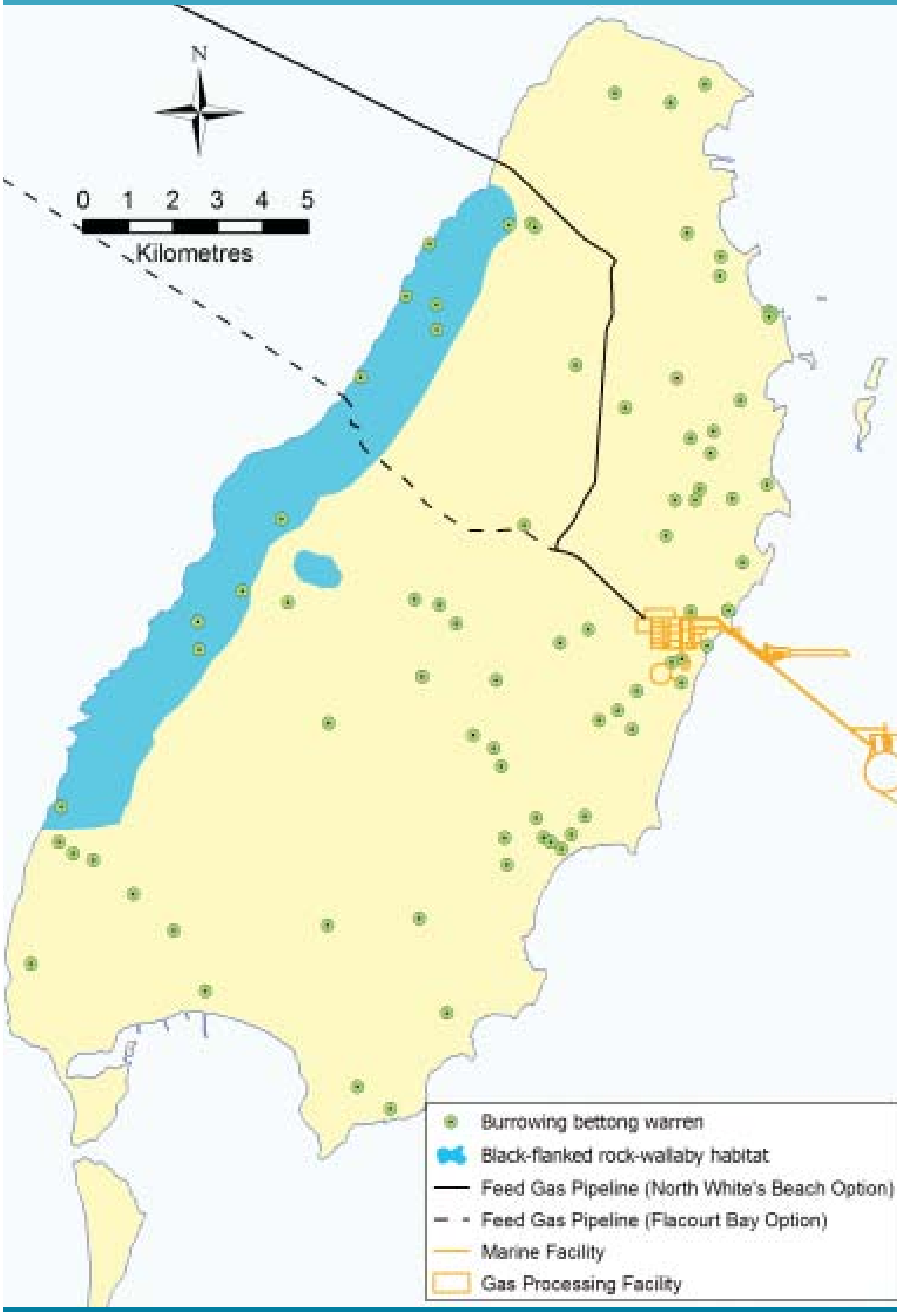
Spectacled Hare Wallaby – Spectacled hare wallabies are widely distributed on Barrow Island (Plate 8-7), generally inhabiting the tall, dense *Triodia angusta* grasslands of drainage systems. However, they forage widely at night in other areas such as *Melaleuca* and *Triodia* on limestone hilltops.

Barrow Island Euro – Population estimates for the Barrow Island euro range from 528–914 (Burbidge et al. 2003) to 1500 (Short et al. 1998). Euros require shade, especially during the hotter months, and often use artificial shelter such as oilfield infrastructure (beam pumps) and buildings.

Black-flanked Rock Wallaby – The distribution of the black-flanked rock wallaby (Plate 8-8) on Barrow Island is limited to rocky outcrops on the west coast (Figure 8-17). Whilst the Barrow Island population is thought to be stable, the population is small and there are concerns that the population may be suffering from genetic depression.

Barrow Island Chestnut Mouse – The Barrow Island chestnut mouse is found in all vegetated habitats on the Island (Burbidge 2004). There are no population estimates for this species.

Figure 8-17:
Distribution of Black-flanked Rock Wallaby Habitat and Burrowing Bettong Warrens (Confirmed and Unconfirmed) on Barrow Island



Water Rat – The water rat has been recorded on the east coast near Town Point where tracks were seen and one specimen was caught in a cage trap (Technical Appendix C2). Tracks on beaches indicate that the water rat occurs all along the coastline on Barrow Island, especially where rocky shores alternate with sandy beaches.

Other Mammals – Other mammal species on Barrow Island, while not listed as threatened or vulnerable at present, are currently under taxonomic review and may be genetically distinct from mainland populations. These island 'races' are considered evolutionary significant units.

Plate 8-7:
Spectacled Hare Wallaby

Plate 8-8:
Black-flanked Rock Wallaby at Flacourt Bay

Gorgon Development Area

All of the terrestrial mammal species of Barrow Island, except bats, were either trapped (8 species) or observed within the proposed Development areas including the feed gas pipeline routes. The same species are also likely to occur in the vicinity of the optical fibre cable route and a subset is likely to occur in the vicinity of the potential airport extension and alongside roads proposed for widening. Bats are likely to forage in the Development areas, but have not been positively identified. All of these species are widespread on the island, with the exception of the black-flanked rock-wallaby and the water-rat. There are no distinctive habitat features within the proposed Development area that are likely to support unusually high population densities of any species. Protected species recorded in the vicinity of the proposed Development area are further discussed in the following sections.

Burrowing Bettong – Burrowing bettongs generally excavate warrens in upland areas of limestone cap rock and appear to feed in adjacent grasslands. There are nine burrowing bettong warrens within the vicinity of the proposed Development area, with a total of approximately 90 warren entrances (Plate 8-9). There is one active warren within the proposed gas processing facility footprint with a total of 20-30 entrances and approximately 10-15 burrowing bettongs (Figure 8-16) (Technical Appendix C2). These burrowing bettongs represent approximately 0.5% of the total Barrow Island population which is estimated to be in the order of 2900 individuals (Burbidge et al. 2003).

There were three active burrowing bettong warrens to the south and south-west of the existing airport runway, each with 10–20 entrances.

No burrowing bettong warrens were found along any of the proposed pipeline routes or along the proposed optical fibre cable route. Two bettong warrens occur in the vicinity of the roads between the airport and the barge landing (near the existing camp and barge landing) and will be avoided during road widening.

Plate 8-9:
Entrance to a Burrowing Bettong Warren

Barrow Island Golden Bandicoot – Densities of golden bandicoots in the proposed Development area are similar to, or less than, those recorded elsewhere on Barrow Island (Technical Appendix C2). If the density of bandicoots is assumed to be consistent over the island, the proposed Development footprint, including areas required for airport extension and road widening, would provide habitat for approximately 1.3% of the island's bandicoot population.

Spectacled Hare Wallaby – The Barrow Island population of spectacled hare wallabies may vary from approximately 5700 to approximately 8600 (Burbidge et al. 2003). Current density estimates of one hare wallaby per four hectares indicate a population of about 75 spectacled hare wallabies in the proposed Development area. This represents approximately 1–2% of the total island population.

Barrow Island Euro – Few euros have been observed in the proposed Development area and most of these have been observed sheltering in coastal and near-coastal limestone areas (Plate 8-10). Approximately ten euros occur in the proposed Development area. This represents approximately 0.7–2% of the island population estimated by Burbidge et al. (2003) and Short et al. (1998). A few euros were observed in the dense *Triodia* to the south of the existing airport.

Plate 8-10:
Euro Sheltering Under Coastal *Ficus*

Black-flanked Rock Wallaby – The population of black-flanked rock wallabies on Barrow Island is estimated at 150 to 200 (Strahan 1995; Burbidge et al. 2003) and is largely confined to limestone outcrops on the west of the island, including Flacourt Bay. The alternative feed gas pipeline from Flacourt Bay would therefore pass through coastal black-flanked rock wallaby habitat. The range of the rock wallabies on the west coast does not extend as far north as North White's Beach.

Black-flanked rock wallabies do not occur in the proposed Development areas at Town Point, along the roads that may be widened or near the existing airport, due to the absence of suitable habitat.

Barrow Island Chestnut Mouse – The Barrow Island chestnut mouse was caught on coastal sandy loams and sands in the vicinity of Town Point. However, the numbers of captures were too low for any conclusions to be drawn as to habitat associations within this area. Data from CALM monitoring in 1998, 2000 and 2003 indicate that the Barrow Island chestnut mouse is more common in other parts of the island, for example Bandicoot Bay. Small mammals were observed around the existing airport at night. Although unconfirmed, the Barrow Island chestnut mouse is likely to inhabit sandy areas in the vicinity of the potential airport extension.

Water Rat – Water rats were observed on beaches at Town Point and an individual was caught amongst rocks at Town Point. They generally inhabit rocky crevices and forage on adjacent sandy beaches and intertidal areas. There are no population estimates for water rats on Barrow Island; however, tracks have been observed on beaches on both the east and west coasts of the island. Water rats are expected to inhabit all of the rocky headlands around Barrow Island.

Mainland

Domestic Gas Pipeline Corridor

The proposed mainland pipeline route runs through the Mardie pastoral lease. This area has been degraded by introduced domestic stock and feral mammals such as cats. The native mammal fauna is therefore expected to be depauperate.

Mulgara – Due to the heavily modified landscape, the mulgara is not expected to occur in the vicinity of the domestic gas pipeline corridor.

Pilbara Leaf-nosed Bat – The Pilbara leaf-nosed bat is not expected to occur in the vicinity of the proposed domestic gas pipeline corridor due to the lack of suitable rocky cave habitat.

Reptiles and Amphibians

The terrestrial herpetofauna (reptile and amphibian fauna) of Barrow Island includes a range of taxa from small sand-dwelling skinks, dragons and snakes up to the large varanid lizards. Some of these species are protected or have been identified as being of conservation significance due their restricted range. The herpetofauna of the Development area was surveyed using the methods described in Box 8-4. The taxonomy of many reptile species on Barrow Island is uncertain and specimens were collected to aid the Western Australian Museum in their taxonomic investigations. A complete technical report is included in Technical Appendix C2. Important marine herpetofauna, such as turtles and sea-snakes, are included in the marine section of this chapter (Section 8.3.3) and in Technical Appendices C6 and C7.

Box 8-4:
Reptile and Amphibian Survey Methodology

Reptiles were surveyed in November–December 2003 and October 2004 using Elliot and pit traps in grids of 25 traps within the six main vegetation types in the proposed Development area. The trapping grid layout was the same as that used in CALM's long-term monitoring program on Barrow Island. The trapping was complemented by hand-collecting of reptiles and foraging and raking during the day and at night in summer 2003/2004 and winter 2004.

All of the trapped reptiles were measured (snout to vent and total length), sexed where possible, weighed and marked prior to release. Subsets of individuals of each sex were collected as voucher specimens and lodged with the Western Australian Museum.

Surveys were conducted in accordance with EPA Guidance No. 56 (EPA 2004a). Specific methodology and limitations of the surveys are presented in Technical Appendix C2.

Regional

The Pilbara region is home to a diverse arid-zone herpetofauna. The geographic separation of island populations from mainland populations is likely to have lead to the evolution of new species, or distinct genetic races, on offshore islands. The taxonomic affinities and conservation status of many species and subspecies is unresolved. CALM is undertaking a regional study of the Pilbara that will help elucidate some of the distributional patterns of various reptiles through range definition and through collection of specimens for taxonomic studies. In the current assessment, it is assumed that the island populations have diverged from the mainland stock and they are treated as distinct island races (or evolutionary significant units).

Ramphotyphlops – The subterranean blind snake, *Ramphotyphlops longissimus*, is not known from the mainland or other Pilbara islands and is currently accepted as highly likely to be endemic and restricted to Barrow Island. This species is listed by CALM as a Priority 2 species.

The blind snake, *Ramphotyphlops grypus,* has been recorded on Barrow Island (one specimen) and is widely distributed across the Pilbara region.

Ctenotus pantherinus acripes – The skink, *Ctenotus pantherinus acripes* (Plate 8-11), appears to be restricted to Barrow Island in Western Australia, but also occurs in the Northern Territory and Queensland. It is likely that this disjunct distribution will be reflected by genetic divergence between the eastern and western populations.

Pilbara Olive Python – The Pilbara olive python (*Lialis olivacea barroni*) occurs only in the Pilbara region and some islands off the coast of Western Australia. Pilbara olive pythons generally inhabit rocky piles during the day and emerge at night to hunt. They are adept swimmers and often hunt in waterholes.

Barrow Island

The reptile and amphibian assemblage on Barrow Island is depauperate in comparison with the herpetofauna of the adjacent mainland. Barrow Island is home to 43 species of reptiles comprising dragons (3 species), legless lizards (5), geckoes (5), skinks (19), blind snakes (3), monitors (3), snakes (5) and one frog species. While some species are known only from single specimens, most of these species, or their habitats, are widely distributed on Barrow Island.

All of the reptile taxa on the island may be distinct genetic races due to separation of the island from the mainland and hence represent evolutionary significant units.

Ctenotus pantherinus acripes – The skink, *Ctenotus pantherinus acripes* (Plate 8-11) appears to be restricted to Barrow Island in Western Australia. This species has been captured from a wide range of habitats on Barrow Island and is widely distributed across the Island (Technical Appendix C2).

Ramphotyphlops grypus – This species of blind snake is known to occur on the island from a single specimen within the Development area. Its distribution across Barrow Island is unknown.

Ramphotyphlops longissimus – The subterranean blind snake, *Ramphotyphlops longissimus*, is currently accepted as highly likely to be endemic and restricted to Barrow Island. This species is listed by CALM as a Priority 2 species.

Other Reptiles and Amphibians – None of the other terrestrial reptile species on Barrow Island are listed as threatened species under the Western Australian Wildlife Conservation Act or the Commonwealth EPBC Act.

The perentie (*Varanus giganteus*) (Plate 8-12) is widespread on Barrow Island and at over 2 m long is an important top order predator of mammals, other reptiles, birds and turtles. The short-tailed varanid, *Varanus brevicauda*, was discovered for the first time in the north of Barrow Island as part of the Gorgon Development environmental studies in 1997. It was found in the north again in the summer 2003/2004 surveys.

The single frog species (*Cyclorana maini*) on Barrow Island is widespread in the adjacent Pilbara region. It breeds in seasonal watercourses and is associated with habitats close to these sites.

Plate 8-11:
Endemic Skink *(Ctenotus pantherinus acripes)*

Plate 8-12:
Perentie *(Varanus giganteus)* and Flatback Turtle Egg

Gorgon Development Area

Twenty-seven species, or more than half of the terrestrial reptiles known to occur on Barrow Island, have been recorded in the vicinity of the Development area encompassing the proposed gas processing facility site. The current study has revealed that some species tend to be associated with particular habitats within the proposed Development area (Table 8-9). These habitats are widespread on the island and these species also occur in other areas outside the gas processing facility site.

Table 8-9:
Patterns of Habitat Association for Common Skinks in the Gorgon Development Area

Species	Habitat Association
Lerista bipes	Very abundant in coastal or near-coastal sandy or sandy-loam soils.
Lerista muelleri	Abundant across all sampled habitats.
Menetia greyii	Absent from coastal sites with sandy soils.
Notoscincus ornatus	Abundant in *Melaleuca* shrubland and *Triodia* grassland on shallow soil with exposed limestone.

Ctenotus pantherinus acripes – This species was caught or observed over a wide area during trapping and opportunistic surveys in the Development area and surrounding habitats (Technical Appendix C2). Seven specimens were caught in five of the six trapping grids over two survey periods in 2003 and 2004, whilst 11 specimens were caught or observed during two opportunistic surveys in 2003 and 2004. This species is expected to be widely distributed across Barrow Island.

Ramphotyphlops longissimus – This species is not known from the proposed Development areas.

Ramphotyphlops grypus – One specimen of this species was observed within the Development area in a *Triodia* grassland habitat that is broadly represented on the island. The distribution and abundance of this species on Barrow Island is unknown as it is the only record from the island.

Other Reptiles and Amphibians – The perentie (*Varanus giganteus*) has been observed on major tracks and beaches within the proposed Development area and in open grassland at Town Point (Technical Appendix C2). This species is widely distributed across the island. Additionally, two snake species (the Mulga snake *Pseudechis australis*, Stimson's python *Antaresia stimsoni*) were observed within or close to the proposed Development area.

The single frog species on Barrow Island is likely to breed in ephemeral water bodies in the Town Point area, in Airport Creek to the south of the proposed Development site, along the proposed pipeline routes and in other areas across the island.

Mainland

Domestic Gas Pipeline Corridor

The reptile assemblage along the proposed domestic gas pipeline route on the mainland is expected to be degraded by feral predators and habitat alteration through livestock grazing.

Pilbara Olive Python – The Pilbara olive python is restricted to rocky habitats in the Pilbara and is not expected to occur in the sandy habitats along the domestic gas pipeline corridor.

Invertebrates

Invertebrates are an important component of the faunal biodiversity of Barrow Island and other arid ecosystems. The term 'short-range endemics' is used to describe invertebrate species such as trapdoor spiders, snails and millipedes, that are restricted in range by poor dispersal and are generally endemic to small areas (<10 000 km^2). They represent a potential biodiversity peak due to genetic divergence of isolated populations. Short-range endemic groups likely to be important on Barrow Island were determined in consultation with the Western Australian Museum and were the focus of surveys for this environmental impact assessment. The methods used for surveying short-range endemics for the current assessment are described in Box 8-5 and a full technical report included in Technical Appendix C4.

Box 8-5:
Short-range Endemics Survey Methodology

The invertebrate groups Araneae, Pseudoscorpionida, Scorpionida, Diplopoda and Pulmonata were targeted by systematic pit trapping surveys in November and December 2003. Pit trapping was complemented by hand foraging methods including head-torching, burrow excavation, lifting rocks, peeling bark, and foraging through leaf litter and under *Triodia* hummocks in late 2003 and in August 2004. This enabled collection of particular spider taxa, camaenid land snails, insects, scorpions, millipedes, centipedes, and pseudoscorpions. Leaf litter and other debris found beneath *Triodia* clumps were collected and later sieved for cryptic invertebrates.

Voucher specimens were collected, preserved and lodged with the Western Australian Museum for ongoing taxonomic studies. Land snails were collected for ongoing genetic and evolutionary studies by the University of Western Australia.

Regional

Many invertebrate taxa have effective dispersal mechanisms, such as flying reproductive stages, and hence are widely distributed in suitable habitats across the Pilbara. These taxa are also likely to be able to disperse on strong offshore winds to offshore islands in the Montebello/Lowendal/Barrow Island group. The introduced American cockroach (*Periplaneta americanus*) is an example of an invasive invertebrate that may reach offshore islands through natural dispersal processes. Invertebrate groups that are adept at dispersal can readily exchange genetic material between populations; hence island populations are unlikely to be evolutionary significant units.

Conversely island populations of short-range endemic invertebrates have limited potential for dispersal and are likely to have diverged genetically from Pilbara mainland populations. The taxonomy of many of these endemic groups is poorly resolved and there may be many species restricted to individual islands or groups of islands in the Pilbara region.

Barrow Island

Over 40 potential short-range endemic invertebrate taxa were collected on Barrow Island during surveys. The collection comprised spiders (19 taxa), pseudoscorpions (4), centipedes (3), millipedes (1), scorpions (2) and land snails (4). A full description of the collection is included in Technical Appendix C4.

The mound building termites (Isoptera) are an important component of the terrestrial ecosystem on Barrow Island. In addition to their role in cycling organic matter, the termite mounds, which are widespread across the island, provide valuable shelter for reptiles, birds and mammals.

The landsnail fauna on Barrow Island is dominated by camaenids (*Rhagada* spp. and *Quistrachia barrowensis*) that may be endemic to the island. Three pupillid species that are widespread on the mainland have also been recorded on Barrow Island. Although morphologically close to the mainland populations, the Barrow Island taxa are assumed to be genetically divergent from the mainland taxa. Genetic analysis of the dominant species of *Rhagada* sp. '2' indicates that this taxon is endemic to Barrow Island and has diverged genetically from the mainland populations. This supports the approach that all of the probable short-range endemic taxa be treated as evolutionary significant units.

Several groups of spiders occur on Barrow Island including trapdoor spiders (Mygalomorph) (Plate 8-13), master weavers, net-casting, sac, white tailed and wolf spiders (Araneomorph spiders). None of these taxa are protected species. Ongoing research will determine whether they constitute significant evolutionary units.

Plate 8-13:
Trapdoor Spider (*Mygalomorph*)

Two species of centipede (*Ethmostigmus curtipes* and *Scolopendra laeta*) have been collected on Barrow Island. Both of these species have widespread distributions over the Pilbara and throughout Australia.

The pin cushion millipede (*Polyxenidae*) is also known to exist on Barrow Island. Due to their small size they can be difficult to collect but are known to occur in large (plague) proportions under certain conditions.

Gorgon Development Area

The taxonomy of most invertebrate groups needs to be advanced in order for taxa from Barrow Island to be confidently identified and their conservation significance assessed. The collections donated to the Western Australian Museum from the current study represent an important resource for the ongoing taxonomic resolution of these groups.

The invertebrate taxa collected from the proposed Development area are expected to be widely distributed on the island because the habitats from which they were collected are widespread on the island. Short-range endemism is expected to operate at an island-scale, rather than within parts of the island. Analysis of genetic divergence in *Rhagada* sp. snails found no evidence to suggest that specimens collected from within the Gorgon Development area were genetically distinct from specimens collected elsewhere on the island (Technical Appendix C4).

Plate 8-14:
Unidentified Scorpion (*Urodacus* sp.)

None of the invertebrate fauna known from the proposed Development area are listed under the Wildlife Conservation Act or as Priority fauna by CALM. However, a pseudoscorpion and a single specimen of a large, dark scorpion (*Urodacus* sp.), recently collected within the proposed Development area, appear to be new and undescribed species of conservation significance (Plate 8-14). The distribution of these species is unknown, but they are expected to inhabit similar habitats over much of the island.

Subterranean Fauna

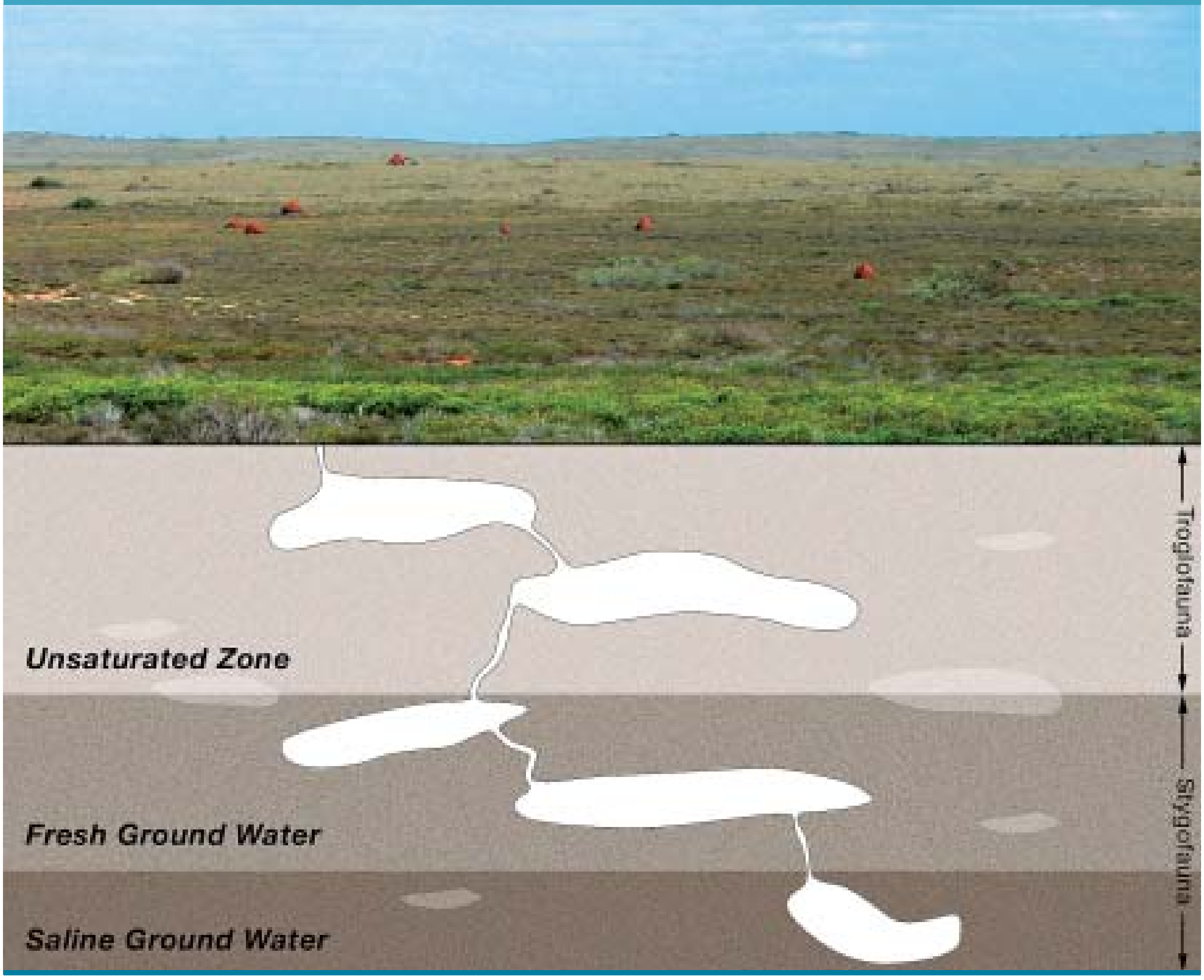
Stygofauna are aquatic subterranean fauna that inhabit cavities and interstices (small or narrow spaces) in groundwater-filled karst or other fractured geological formations. Troglofauna are terrestrial subterranean fauna that inhabit air-filled caves, cavities or interstices in the karst above the watertable (Figure 8-18).

Subterranean fauna are an important component of regional biodiversity for several reasons. The distribution of subterranean fauna species appears to generally be more restricted than that of similar surface fauna. High levels of endemicity are also characteristic of subterranean taxa, often at high taxonomic levels (e.g. genus, family). Endemic species tend to be concentrated in regions that support relatively diverse communities, rather than being distributed randomly (see review in Strayer 1994, also Humphreys 2000).

Stygofauna in Western Australia and Barrow Island in particular are regarded as geological relicts, descendants from ancient lineages with species characterised by restricted distributions and a low tolerance to disturbance. The stygofauna of Barrow Island represent relict lineages that have arisen from surface fauna ancestors that occurred prior to the break-up of Pangaea (see review in Humphreys 2001).

The Western Australian Museum has studied subterranean fauna from existing bores and caves on Barrow Island since the early 1990s (Humphreys in press). Subterranean fauna sampling methods used in the current study are outlined in Box 8-6. The establishment of permanent subterranean fauna sampling bores provides an important scientific resource for future studies. The full technical report on the preliminary results from subterranean fauna surveys for this proposal is included in Technical Appendix C5.

Figure 8-18:
Troglofauna and Stygofauna Habitat



Box 8-6:
Subterranean Fauna Survey Methodology

Stygofauna were sampled from bores, drill holes and disused wells across Barrow Island by means of modified plankton haul nets. This was carried out as part of a preliminary sampling program for the ESE Review in August 2002 and again during November 2003. Once the net reached the bottom of the hole, it was agitated gently to bring benthos and fauna above the net before hauling it up through the water column. On recovery, the net was flushed thoroughly with water bailed from the same hole. Samples were sorted fresh under a dissecting microscope and preserved in 100% ethanol, or stored in liquid nitrogen for genetic analyses.

Nineteen bores that had previously yielded subterranean fauna (either during sampling for this project or during earlier work by the Western Australian Museum) were sampled during these initial surveys. Each hole was sampled at least three times. Genetic analyses have been initiated to clarify taxonomic affinities of stygofauna from Barrow Island and the mainland. Troglofauna litter traps were installed in three shallow abandoned drill holes in the terminal tanks area. These comprised aviary mesh and PVC tubes baited with locally sourced leaf litter (soaked overnight and microwaved to sterilise and initiate decomposition).

Since this initial work (in 2002 and 2003), a comprehensive drilling program that was designed with the specific objective of sampling subterranean fauna in the gas processing facility area and in surrounding control or reference areas has been completed (Technical Appendix C5 – Attachment 3).

A total of 43 bores have been drilled of which 24 are located within the proposed gas processing facility footprint and 17 outside of the proposed gas processing facility footprint (i.e. reference sites). An additional two bores were drilled along the proposed feed gas pipeline corridor and a further four bores will be established at the North White's Beach and alternative Flacourt Bay shore crossing locations. Depth of bores ranged from approximately 5 m to 50 m with 10 bores (both reference and footprint) drilled to below the halocline. This program makes provision for stygofauna sampling from the freshwater superficial aquifer, saline groundwater below halocline and troglofauna sampling from the karst above the watertable. The subterranean fauna surveys have been conducted in accordance with EPA Guidance Statement 54 (EPA 2003).

Examination of cores from a geotechnical drilling program and ground penetrating radar surveys have also assisted in determining the distribution of karstic substrate in the proposed Development area. This has improved understanding of the subterranean fauna habitat and drill logs allow troglofauna traps to be set at appropriate depths. The bores established as part of this ongoing subterranean fauna sampling program were first sampled for stygofauna in November 2004 with subsequent stygofauna sampling completed in March 2005. Troglofauna traps were also installed in the bores. The sampling and analysis program will continue until construction to establish a baseline for monitoring during construction and operation of the Development.

Regional

The regional distribution and species diversity of subterranean fauna in northern Western Australia has been poorly known historically for most taxonomic groups, although ongoing work is improving this situation. Subterranean fauna have been known from Western Australia since the 1940s, with the blind gudgeon, *Milyeringa veritas* (Plate 8-15), amongst other fauna, being documented from groundwater beneath the coastal plain at Cape Range (Humphreys 2001). However, little work was carried out in relation to subterranean communities until the early 1990s.

Research conducted since this time has suggested a biogeographic link between Barrow Island and Cape Range. One of the true troglofauna species, the schizomid *Draculoides bramstokeri,* reinforces this biogeographical connection between the troglofauna of Barrow Island and the troglofauna of Cape Range on the mainland. *Draculoides bramstokeri* occurs in Ledge Cave and other sites on Barrow Island and has also been recorded from multiple sites on Cape Range. The occurrence of several stygal species in both localities, including the blind gudgeon, *Milyeringa veritas,* the decapod, *Stygiocaris stylifera,* and thermosbaenacean, *Halosbaena tulki,* also supports this model.

Plate 8-15:
Stygofaunal Blind Gudgeon *(Milyeringa veritas)*

Photo: Courtesy of Douglas Elford © Western Australian Museum

Barrow Island

Barrow Island is well recognised as being of high conservation significance for subterranean fauna communities at state, national and international levels. The subterranean fauna of the island demonstrates a high level of endemicity and species diversity, with over 20 species known only from Barrow Island. The fauna of the island includes one of only two stygal vertebrate species occurring in Australia and potentially the only troglobitic reptile known globally.

The stygofaunal assemblage of Barrow Island is known to comprise more than 20 described species with representatives from a diverse range of taxonomic groups. The most diverse group is the Amphipoda with 12 species, including two new species of anchialine hadziid amphipods (*Liagoceradocus* spp.) (Bradbury and Williams 1996 a, b). The other taxa represented in the groundwater fauna are largely also crustacean groups, including the Isopoda, Copepoda, Ostracoda, Thermosbaenacea and aytid decapods. Recent sampling for this study collected the first stygal polychaete worm for the island, highlighting the level of taxonomic richness which may remain to be documented.

The troglofauna of Barrow Island is also significant with most collecting to date having occurred from a few areas where there are caves open to the ground surface, for example Ledge Cave (Cave 6B1). The Western Australian Museum database includes 324 records of terrestrial invertebrates from caves or other subterranean habitats on Barrow Island. However, many of these records are of troglophiles (surface fauna associated with subterranean habitats) rather than true troglofauna.

In the absence of a comprehensive dataset for regional comparison, surveys to date have revealed a troglofauna assemblage with highly endemic elements. For example, *Speleostrophus nesiotes* is the first known troglobitic spiroboloid millipede (Hoffman 1994) and is only known from Ledge Cave on the south-west coast of Barrow Island. The possibly troglobitic reptile *Ramphotyphlops longissimus* is known from a single specimen from Barrow Island (Aplin 1998). These highly endemic taxa are likely to be restricted to sites of high local diversity such as the large caverns on the south-west and west sides of Barrow Island.

Several species of subterranean fauna are protected under the Wildlife Conservation Act and the EPBC Act (Technical Appendix C5). Some of the protected species known from Barrow Island, for example the Vulnerable blind gudgeon *(Milyeringa veritas),* are present in similar habitats at Cape Range on the mainland. It is also likely that other protected species that occur in similar habitats to the blind gudgeon at Cape Range, such as the blind cave eel *(Ophisternon candidum),* are present on Barrow Island.

It is possible that some components of the globally significant remipede community in Bundera sinkhole at Cape Range also occur on Barrow Island. Subterranean habitats on Barrow Island are tidally influenced and are stratified with a freshwater layer overlying deeper saline groundwater. This forms a similar anchialine system to that present in Bundera sinkhole and it is therefore possible that a similar fauna occurs, particularly given the biogeographic affinities between the areas.

Gorgon Development Area – Gas Processing Facility

Subterranean fauna sampling program records to date, confirm that the habitats under both the proposed gas processing facility and the adjacent parts of the island support both stygofauna and troglofauna.

This is consistent with the preliminary review of results from nearby sampling and interpretation of geotechnical data in assessing potential subterranean fauna habitat in the Development area. Caves and highly karstic rock appear to be most common in the west and south-west of Barrow Island. A geotechnical drilling program, comparing potential karst zones at Cape Range and Barrow Island (Dames and Moore 1996), indicated that the large cavities in the Miocene limestones on Cape Range Peninsula at Exmouth were not present in other limestones in the Exmouth area, at Surf Point or at the terminal tanks on Barrow Island.

Boreholes on the east coast of Barrow Island did not intersect significant cavities and the voids observed were <5 cm and did not appear interconnected.

Despite the lower likelihood of major caves in the gas processing facility area, preliminary interpretation of geotechnical drilling results and ground-penetrating radar work to date indicate a karstic environment is present below the site (Biota and Blandford 2004). The drilling logs and other data show a variable stratigraphy, comprising layers of sand and clay interbedded with substantial strata of more competent lithologies such as detrital, conglomeratic and crystalline limestone. The geologic evidence suggests that the area of the gas processing plant footprint contains a range of subterranean habitats in the form of both air and water-filled cavities, ranging in size from 1 mm to less than a metre. Other characteristics include abundant fractures in the more brittle, high strength lithologies; solution cavities in competent lithologies, voids developed in uncompacted sands and detrital sediment. This is supported by the collection of a range of stygal taxa from the terminal tanks area to the immediate north of the planned gas processing facility site.

As noted in Box 8-6, baseline surveys for subterranean fauna will continue on Barrow Island until construction commences. Stygofauna and troglofauna will continue to be sampled both within and outside of the gas processing facility footprint at a total of over 40 locations (Figure 8-19). The results of subsequent sampling, concluded prior to construction, will be published as a separate report. This will provide a species level analysis of subterranean fauna distribution, along with a more complete analysis of the physical nature of the subterranean environment, including stratigraphy, water table depths and groundwater chemistry profiles. The preliminary results of the work conducted up until March 2005 are summarised below.

Preliminary Stygofauna Sampling Results – Stygofauna were collected from 10 of the bores sampled during November 2004. One of the bores where stygofauna were collected was within the proposed gas processing facility area (18), with the remaining nine bores in 'control' areas outside of the development site (Table 8-10). The stygofauna collected during this first sampling phase represented three higher taxonomic groups; Class Malacostraca

Figure 8-19:
Subterranean Fauna Sampling Locations

(Order Amphipoda), Class Copepoda, Class Ostracoda and Class Decapoda (the aytid *Stygiocaris stylifera).* Stygofauna were collected from 12 bores during the March 2005 visit, five of which were located within the Development footprint (Table 8-10). Stygofauna were also recorded from five bores outside of the proposed Development footprint during this second phase. The higher order taxonomic diversity was similar to the initial round of sampling, with five stygofauna taxa represented amongst the collected specimens: Class Malacostraca (Order Amphipoda and Order Bathynellacea), Class Copepoda, Class Ostracoda and Order Decapoda *(Stygiocaris stylifera).*

The sampling to date has collected amphipods, bathynellaceans, isopods and copepods from five locations within the development footprint. All of these higher taxonomic groups are also represented from the control sampling sites and from other collecting localities elsewhere on Barrow Island. Detailed identifications and genetic analyses of the collected specimens are currently ongoing. This will enable the completion of a species level comparison of the stygal taxa collected from within the development site with those from control sites and other localities on the island.

One of the amphipod taxa collected from existing bores near the northern extent of the proposed gas processing facility was the same genetic type as amphipods from other parts of Barrow Island, whilst two of the taxa collected were only recorded from the terminal tanks area. Refer to Technical Appendix C5 for a full description of the preliminary genetic analyses. These findings were based on small sample sizes and the work to be completed as part of the subterranean fauna sampling program will substantially improve the resolution of this work.

Preliminary Troglofauna Sampling Results – Troglofauna specimens have been collected both opportunistically during stygofauna sampling (i.e. hauled dead from the groundwater), and from the dedicated litter traps installed in the first phase of the troglofauna sampling program. The results available to date indicate that troglofauna are widespread both within the development footprint and in the other parts of Barrow Island. Invertebrates collected from the sampling included representatives of four Classes: Arachnida, Collembola, Insecta and Oligochaeta; comprising nine orders: Acarina, Archaeognatha, Haplotaxida, Hemiptera, Hymenoptera, Isoptera,

Table 8-10:
Preliminary Results of First Two Phases of Stygofauna Sampling

Boreholes	November 2004 *	March 2005 *
A4	–	Am (1), Is (remains)
4	–	**Am (5)**
18	**Am (1), Co (1)**	**Am (4)**
21	–	**Ba (4)**
24	–	**Am (1)**
27	–	**Is (1)**
BMW1	Col (1) Sc (2)	Is (1)
BMW4	Co (4)	–
BMW5	Col (1)	Is (1)
BMW7	Am (1), Co (1)	Am (1), Co (1)
S4	Co (2)	–
S5	Am (1) Co (3)	Am (1), St (4)
S6	Am (5) Co (4) St (3)	Co (10), Is (1), St (4)
S9	Os (1) St (9)	Am (1), Col (1), St (7)

** Am = Amphipod, Ba = Bathynellid, Col = Collembola, Co = Copepod, Is = Isopod, Os = Ostracod, St =* Stygiocaris stylifera. *Bores within the gas processing facility area shown in bold; numbers in brackets indicted number of specimens collected.*

Psuedoscorpionida, Thysanura and Schizomida. Preliminary reviews indicate that six of the taxa include potentially troglobitic specimens; the Schizomida (nominally *Draculoides bramstokeri),* Hemiptera, Isopoda, Pseudoscorpionida, Archaeognatha and the Thysanura. Troglobitic specimens were collected from a total of 13 bores, including sites inside and outside of the proposed Development footprint (Table 8-11).

To date, schizomids have been collected from almost all boreholes where troglofauna have been collected (11 of 13 holes; Table 8-11). *Draculoides bramstokeri* (Plate 8-16), is the only schizomid known from Barrow Island and the collected specimens have been nominally assigned this identification. The species is listed as Schedule 1 under the state Wildlife Conservation Act. Confirmation of identification based on morphology by the WA Museum is pending and genetic analysis (DNA comparisons) of the collected schizomid specimens are also currently underway. If the outcomes of these studies confirm a single widespread taxon on Barrow Island, then this may be indicative of a widespread linkage in subterranean karstic habitat and schizomid populations across the sampled area. The findings of this work, combined with the results of additional sampling currently underway, will enable a better assessment of the significance of the troglobitic taxa currently only recorded from the Development footprint (Table 8-11). This will be provided as a stand-alone technical report to be made publicly available.

Plate 8-16:
The Schizomid *Draculoides bramstokeri* Collected from Barrow Island

Photo: Courtesy of Dr Mark Harvey, Western Australian Museum

Table 8-11:
Preliminary Results of First Phase of Troglofauna Sampling

Boreholes	Collected during Stygofauna Sampling *	Collected from Troglofauna Traps *
10	**–**	**Ar (1)**
11	**–**	**Db (1)**
18	**–**	**He (1), Db (4)**
24	**–**	**Th (1)**
21nr	**–**	**I (1), Db (1)**
27	**Db (1)**	**–**
BMW1	Db (3)	–
BMW5	Db (2)	–
BMW6	Db (3)	I (1), Db (1)
BMW7	Db (1)	Ps (1)
S2	–	Db (1)
S4	–	Db (1)
S7	–	I (2), Db (2)

** He = Hemiptera, Is = Isopoda, Ps = Pseudoscorpionida, Ar = Archaeognatha, Th = Thysanura, Db =* Draculoides bramstokeri. *Bores within the gas processing facility area shown in bold; numbers in brackets indicted number of specimens collected.*

In the absence of the final analysis of the taxonomic affinities and the true level of endemism for subterranean fauna in the proposed gas processing facility area, all subterranean taxa found in the proposed impact areas should be treated as having conservation significance.

Gorgon Development Area – Feed Gas Pipeline Corridors

Subterranean fauna habitat is likely to be widespread on the west coast and across the centre of Barrow Island where the proposed feed gas pipeline will run to the proposed gas processing facility on the east coast.

The shore crossing at North White's Beach is not expected to be as significant a site for subterranean fauna as the alternative shore crossing location at Flacourt Bay because the coast and hinterlands are typically sandy with minimal karst development. There is also a high likelihood that any fractures and cavities present at North White's Beach would be sand-filled. However, some geotechnical investigations are planned for this site and the opportunity will be taken to complete and sample two of these drillholes for subterranean fauna.

An additional two dedicated subterranean fauna sampling holes will be drilled at Flacourt Bay as an extension to the existing sampling program. Rock in the vicinity of the alternative pipeline shore crossing at Flacourt Bay is karstic and may contain caves, mesocaverns and fissures that do not open to the ground surface. The subsurface geology from this area is unknown, but surface expressions of the geology indicate that such cavities are likely. Solution tubes and fractures in rock formations near Flacourt Bay suggest that this area is superficially similar to Cape Range and is likely to provide habitat for both troglofauna and stygofauna. Ongoing geotechnical drilling investigations will provide more data on the physical nature of these areas to validate this assessment.

8.3.3 Marine Ecology

Marine Habitats

Marine conservation planning is largely based on protection of marine benthic habitats that support biodiversity and maintain the integrity of the marine ecosystem. The draft Indicative Management Plan for the Proposed Montebello/Barrow Islands Marine Conservation Reserves (CALM 2004) is habitat-based, rather than taxon-based. Subsequently, management and assessment of impacts for the proposed Gorgon Development is generally focussed on biotic habitats, especially areas supporting benthic primary producers (BPPH) such as corals, seagrasses, macroalgae and mangroves.

Marine habitats were assessed by a combination of literature review and field survey. The survey methods are described in Box 8-7 and the full technical reports are included in Technical Appendix C8 (subtidal habitats) and Technical Appendix C9 (intertidal habitats).

Box 8-7:
Marine Habitat Survey Methodology

Intertidal habitats in the vicinity of the proposed causeway at Town Point and the mainland shore crossing of the domestic gas pipeline were surveyed during January and May 2004. The surveys also covered adjacent supratidal habitats.

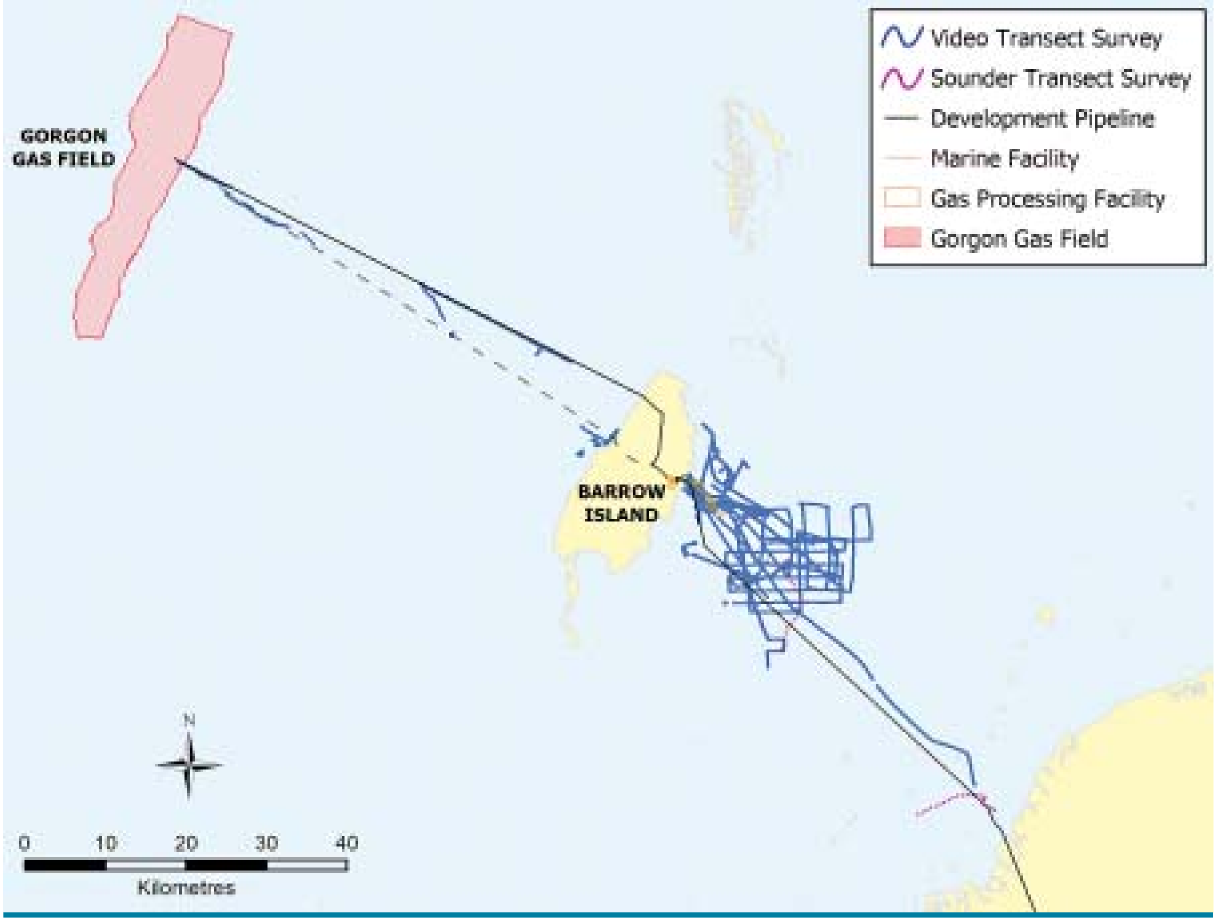
Intertidal areas were surveyed as close as possible to spring low tide to maximise duration of surveys and the area of exposed habitats.

Subtidal areas of high conservation significance within and adjacent to areas of potential impact were identified during surveys in August 2002, January 2003 and January 2004. The survey team examined subtidal benthic habitats near the existing and proposed offshore wells, along the feed gas pipeline route, in the areas associated with the proposed port facilities and along the domestic gas pipeline route to the mainland.

Benthic marine habitats were surveyed using a combination of aerial photography, side-scan sonar data, video transect and snorkel diver surveys. Video transect surveys involved towing an underwater video camera behind the survey vessel (Figure 8-20). Broad-scale habitat maps for the east and west coast Development areas were created from aerial photography and habitat classification was confirmed by ground-truthed data.

Marine habitats at Onslow are described from the literature.

Figure 8-20:
Marine Video Transect Surveys



Regional

The predominant habitats on the exposed west coasts of islands in the Montebello/Lowendal/Barrow Island region are sandy beaches, rocky shores and cliffs. The predominant physical habitats on the sheltered east coasts and the adjacent mainland coast are sand flats, mud flats, rocky pavements, calm sandy beaches and platforms. Mangroves have developed on sheltered coasts of the islands and along the mainland coast. Seagrasses are widespread on soft sediments throughout the region and corals and macroalgae are similarly widespread on hard substrates.

CALM (2004) estimated the linear extent of the four most common coastal habitats in the region as follows:

- beach – 22%
- beach/rocky shore – 11%
- mangal – 4%
- rocky shore – 63%.

Subtidal habitats in the region comprise a range of abiotic habitats such as sand, mud, pavement reef with variable and mobile sheets of sand, and higher profile rocky reefs. In addition to these, there are biotic habitats comprising macroalgal beds, coral habitats and seagrass meadows.

The local distribution of benthic habitats is affected by the frequent passage of tropical cyclones that shape sandy beaches; redistribute boulders and sand sheets over subtidal pavements; and, in extreme cases, cause widespread destruction of biotic habitats.

Barrow Island

Barrow Island is characterised by rocky headlands and low cliffs with sandy or rocky shores stretching between the headlands. It is almost entirely surrounded by limestone pavement reef that extends to the subtidal zone. Broad intertidal reef platforms with scattered mud and sand flats are widespread along the east coast of Barrow Island and in Bandicoot Bay to the south.

On the west and north coasts, the intertidal reef is much narrower, more eroded, supports dense macroalgal turf if exposed, but is often overlain by sand in the upper intertidal zone.

Sandy beaches are widespread around both the east and west coasts of Barrow Island and typically form above the intertidal reef between rocky headlands. CALM (2004) estimated that sandy beaches account for approximately 46% of the shoreline of Barrow Island. Sand cays have developed at Surf Point in the north of Barrow Island and at South End and at Middle and Boodie Islands, but are less common at Barrow Island compared with the rest of the region.

Intertidal mud or sand flats are most developed on the east and south coasts of Barrow Island where lower wave energy allows sediments to accumulate on the broad flat platform reefs.

The main subtidal habitats surrounding Barrow Island are:

- shallow subtidal limestone pavement reef with macroalgae
- deeper subtidal pavement with filter-feeding assemblages
- bare sediments
- coral reefs and bombora
- high profile limestone reefs.

The subtidal limestone platform reef surrounding Barrow Island is usually covered with a veneer of sand or silt of varying thickness and seasonally supports high biomass of brown macroalgae, in particular *Sargassum* (Plate 8-17). *Sargassum* is one of the more important primary producers in the region. Dense *Sargassum* beds provide shelter, food and substrate for a diverse array of invertebrates and fish.

Plate 8-17:
Macroalgae *(Sargassum)* on Shallow Subtidal Pavement Reef

Plate 8-18:
Biggada Reef on the Western Side of Barrow Island

In deeper areas, beyond the photic zone, macroalgae are replaced by filter-feeding assemblages. The dominant habitat forming fauna are sponges (laminar, cup and branching), soft corals (gorgonians and seawhips), hard corals *(Turbinaria)* and hydroids.

Bare sand sheets are a dynamic feature of the subtidal ecosystem. The sand sheets move in response to tidal and wind-driven currents and storms. In deeper offshore areas with less dynamic water movement, sediments are more stable and fine sediments in particular provide habitat for diverse epifaunal and infaunal assemblages.

Coral reefs and bombora are restricted to the photic zone and vary greatly structurally and ecologically in response to physical disturbance, water clarity and exposure to swell. Corals are abundant around Barrow Island, growing as high profile reefs and on pavement on both the west and east coasts. The most significant coral reefs around Barrow Island are Biggada Reef on the west coast (Plate 8-18), Dugong Reef and Batman Reef off the south-east coast and along the edge of the Lowendal Shelf on the east side of Barrow Island (Plate 8-19).

Gorgon Development Area

Gorgon Gas Field – Subtidal habitats near the Gorgon gas field, which lies in 200 m of water, comprise soft, bioturbated sediments. The benthos in this area is well below the photic zone so there are no marine macrophytes. Fine organic particles settle from the water column to form deep silt and mud.

Plate 8-19:
Porites Coral Bombora Reef on the East Side of Barrow Island

Fine sediments are often resuspended by ground swell and these deeper areas can be turbid near the seabed. The fine sediments also reduce oxygen exchange between the water and the underlying sediments so anoxic layers form generally within centimetres of the seabed surface.

Feed Gas Pipeline Corridor – The feed gas pipeline corridor from the offshore field to the west coast of Barrow Island includes areas of deep water sediments, high profile limestone reefs and shallow water sediments and reefs with macroalgae. The high profile reefs, in approximately 40 m water depth, are too deep to support well-developed benthic primary producer assemblages. The inshore section of the proposed pipelines crosses bare sand habitats and limestone reef covered by macroalgae such as *Sargassum, Dictyopterus* and *Halimeda,* and scattered small corals such as *Turbinaria.* Each of these benthic habitats is widespread throughout the region.

North White's Beach Shore Crossing – The proposed feed gas pipeline crossing at North White's Beach traverses an intertidal and shallow subtidal limestone reef platform and a sandy beach with exposed beach rock bench. The upper surface of the eroded reef platform is bare, presumably due to exposure to the sun at low tide. The holes and fissures in the reef support macroalgae with larger thalli than the turfing algae at Flacourt Bay. The exposed beach rock appears to experience cycles of sand burial and exposure.

The southern end of North White's Beach is sheltered from the sea and swells by the low cliffs of the headland and the intertidal and supratidal areas include boulders and vertical rock faces.

Flacourt Bay Shore Crossing – The alternative shore crossing at Flacourt Bay comprises a broad sandy beach running between two high rocky headlands (Plate 8-20). The beach is exposed to high wave energy and changes seasonally as sand is eroded or deposited. The limestone pavement underlying the beach is exposed at times in both the intertidal and supratidal zones.

The sandy beach slopes into the surf zone and has a narrow (<10 m) intertidal component. The remainder of the intertidal zone is a wave washed rock platform with deep fissures and holes.

Plate 8-20:
Flacourt Bay

Barrow Island Port Facilities – Town Point is a rocky headland with low cliffs descending to a field of boulders and intertidal limestone pavement reef with large pools open to the sea. The area has been modified by the construction and presence of a previous concrete landing/wharf area. Although the landing has been demolished, there is concrete and steel debris within the intertidal and supratidal zones.

The surface of the intertidal pavement is exposed at low tide and supports a low and sparse algal turf with a thin veneer of fine sand. The large rock pools in the intertidal pavement support larger macroalgae around the edge and often sparse seagrass on the sandy bottom.

Part of the proposed causeway and the MOF will be built over nearshore subtidal habitats at Town Point. The causeway will extend from Town Point across the intertidal and subtidal limestone pavement reef that fringes Barrow Island.

The access channel to the MOF will be dredged through limestone pavement reef with macroalgae, especially *Sargassum,* scattered hard and soft corals and thin sand veneers. Towards the offshore edge of the reef, the density and size of the hard corals increases and there are scattered bombora, generally less than 1.5 m high, along the edge of the reef. This habitat is widely distributed along the east coast of Barrow Island and across the Lowendal Shelf.

The proposed LNG export jetty will traverse the broad subtidal limestone pavement reef and extend into deeper water over the sandy seabed off the edge of the reef. The jetty will pass through the *Sargassum* dominated pavement habitats with scattered corals and bombora. The proposed jetty will dissect two areas of coral reef with variable cover of live coral and patches of coral bombora.

The offshore end of the jetty will traverse deeper pavement reef buried under sand of variable thickness. Benthic habitats in the vicinity of the tanker access channel to the offshore end of the jetty are similarly soft sediments over limestone pavement. The sediments support sparse, ephemeral *Halophila* seagrass meadows and seapens. In places where the underlying pavement reef is close to the sediment surface, soft corals such as seawhips, *Rumphella,* and gorgonians exist. These epifauna are not sufficiently dense to constitute a biotic benthic habitat.

The proposed tanker access channel crosses a rocky ridge running southward from the Lowendal Shelf. In the area proposed to be dredged, the ridge rises several metres above the surrounding seabed.
The ridge comprises pavement reef with scattered rocky lumps up to 1.5 m high and variable cover of macroalgae, soft corals and hard corals. While the coral bombora fields on the rocky ridge to the south of the dredged area provide complex habitat for a diverse array of marine fauna and are of conservation significance, there are no significant coral patches in the area proposed to be dredged.

The closest ecologically significant coral reef is on the south-western perimeter of the Lowendal Shelf, approximately 2 km from Town Point and 3.5 km north of the proposed LNG offloading facility. The coral reef comprises extensive and well-developed staghorn and tabular *Acropora* colonies in the shallower waters near the southern edge of the shelf. There are large *Porites* dominated coral bomboras in the deeper water along the edge of the shelf. The *Porites* bomboras are up to several metres high and are of conservation significance because they are probably several hundred years old. There are also large *Porites* bombora, scattered bombora and rocky outcrops with macroalgae and small corals on the rocky ridge to the south of the proposed tanker access channel.

Domestic Gas Pipeline Route – The proposed domestic gas pipeline corridor from Town Point on Barrow Island to the mainland coast will traverse a vast and relatively homogeneous expanse of pavement reef with a sand veneer. The underlying pavement supports filter-feeding assemblages where exposed. Closer to the mainland shore, the sandy seabed supports extensive *Halophila* seagrass meadows and crinoids. Scattered small corals and bivalve beds occur on areas of hard substrate. The area is strongly influenced by tidal resuspension of silt and clays that have been deposited from rivers along the mainland coast and is characterised by highly turbid water.

The domestic gas pipeline corridor passes small islands such as Cowle Island near the mainland coast, some of which have fringing coral reefs. These coral reefs are dominated by species resistant to the effects of turbid water and sedimentation. The pipeline route will be selected to avoid the coral dominated platform reefs adjacent the islands.

The mainland shore crossing for the proposed domestic gas pipeline from Barrow Island is adjacent the existing Apache Energy Sales Gas Pipeline easement.
The intertidal zone in this area is characterised by sand and mud flats backed by an extensive mangrove and samphire system (refer Figure 8-22).

Optical Fibre Cable Route – The optical fibre cable route from Barrow Island to Onslow will cross the inshore waters of the Rowley Shelf and is expected to traverse very similar habitats to those described for the domestic gas pipeline route above. The proposed optical fibre cable route follows the 7 m bathymetric contour around the southern end of the Barrow Island Shoals, heads south-west across a broad flat area and through the islands and reefs off Onslow (refer to Chapter 6). Most of the proposed route is expected to be limestone pavement reef with variable cover of sediments and scattered seagrasses and filter-feeding assemblages. The nearshore reef platform at Barrow Island supports significant macroalgae beds and scattered corals. The shore crossing at Onslow will cross the nearshore subtidal and intertidal reef near Beadon Point and may pass through nearshore seagrass meadows dominated by *Halophila* and *Halodule.* The final cable route in the shallower nearshore waters off Barrow Island and Onslow will be selected to avoid significant areas of corals and benthic primary producers.

Marine Conservation Areas

The waters surrounding Barrow Island are part of the area covered by the Montebello – Barrow Island marine conservation reserves (CALM 2004). The majority of the conservation area is zoned as a Marine Management Area, recognised for both commercial and conservation values. The Barrow Island Marine Park and Bandicoot Bay conservation area (benthic fauna/seabird protection) will provide additional protection for Biggada Reef and Bandicoot Bay (Figure 8-21). The Marine Park is comprised of a Sanctuary Zone that encompasses the Biggada Reef coral assemblages and the surrounding limestone reef.

A large area off the east coast of Barrow Island is currently a designated port (Figure 8-21). The Barrow Island port was created under the *Shipping and Pilotage Act 1967* and vested in the Minister for Transport under the *Marine and Harbours Act 1981* (refer Chapter 14).

Most of the islands in the region are either nature reserves or conservation parks. The terrestrial reserves in the region include:

- Barrow Island Nature Reserve (Class A nature reserve)
- Boodie, Double, Middle Islands Nature Reserve (reserve with a conservation order, previously referred to a Class C nature reserve)
- Great Sandy Islands Nature Reserve (Class B nature reserve).

The boundaries of these reserves extend to the low water mark, thereby encompassing the intertidal zone. This provides all the intertidal fauna with protection under the *Conservation and Land Management Act 1984.*

Marine Macrophytes

The marine flora comprises vascular, flowering plants such as mangroves and seagrasses and non-vascular, non-flowering plants such as macroalgae and microalgae. Samphire plants inhabit the upper intertidal zone in isolated, sheltered pockets throughout the region.

The marine macrophytes of the Montebello/Lowendal/Barrow Island region are generally widespread within the region although they tend to be restricted to particular substrates within a given area. The Leeuwin Current connects the marine plant assemblages of the Montebello/Lowendal/Barrow Island region with assemblages in the Dampier Archipelago and the Rowley Shoals to the north.

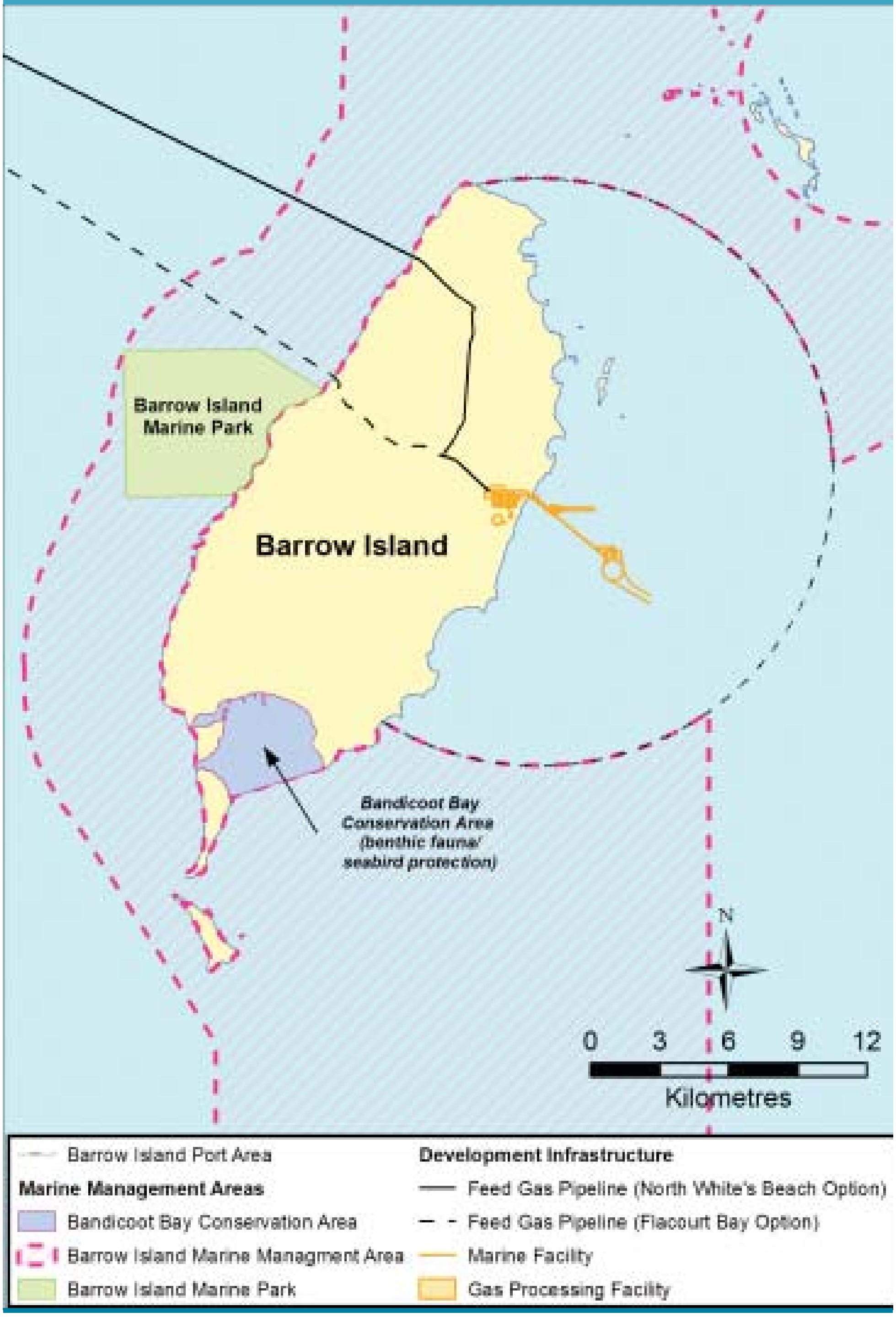
The distribution of marine macrophytes is dependent on substrate type, light availability and wave exposure. The biomass of most species varies seasonally in response to reproductive and growth cycles, water temperature and exposure to wave energy. Microalgae including the phytoplankton, zooxanthellae (coral symbionts) and benthic microalgae are ubiquitous and, being of low conservation significance, are not considered further in this assessment.

Marine macrophytes were surveyed during intertidal and subtidal habitat surveys. The distribution of subtidal macrophytes was derived largely from knowledge of habitat associations, from video surveys and aerial photography. Intertidal macrophyte surveys included reef walks at low tide with collection and subsequent identification of samples. Technical reports are included in Technical Appendices C8 and C9.

Regional

Mangroves – Mangrove forests are extensive and very well developed on the mainland Pilbara coast but restricted to sheltered embayments and coasts in the Montebello/Lowendal/Barrow region. The most common mangrove species in the Pilbara region are *Avicennia marina* and *Rhizophora stylosa.* Other species that occur in the region are *Ceriops tagal, Aegialitis annulata, Aegiceras corniculatum* and *Bruguiera exaristata.*

Figure 8-21:
Montebello – Barrow Islands Marine Conservation Reserves (Source: CALM 2004)



Mangroves in the Pilbara region are important primary producers and provide shelter for a vast array of fauna. They are generally of high conservation significance and the EPA (2001) has identified areas of very high conservation significance on the mainland coast.

Seagrass – Seagrasses are generally subtidal (down to approximately 15 m water depth), but some species also grow as stunted ecomorphs in very shallow coastal areas and intertidal rock pools. The main seagrasses of the region are small, ephemeral species that grow on soft sediments and have a seed bank in the surficial sediments that allows them to recover quickly from disturbance. Common species include *Halophila ovalis, Syringodium isoetifolium,* and *Halodule uninervis.* Less common species known from the region are *Cymodocea angustata, Halophila spinulosa, Thallassia hemprichii* and *Thalassodendron ciliatum.* Most seagrasses grow in soft sediments; however, *Thalassodendron* attaches to rock.

Macroalgae – Macroalgae are the dominant macrophyte in the Montebello/Lowendal/Barrow Island region, occupying approximately 40% of the benthic habitat area of the region (CALM 2004). The most numerically, and probably gravimetrically, abundant macroalgae are the species of *Sargassum* that cover the shallow subtidal rock platforms around the islands. Seasonally *Sargassum* grows large foliose thalli that generally produce reproductive structures and dehisce each year. When the reproductive thalli are shed, the plant persists as a short stipe on the rock. Consequently, the biomass of the macroalgal beds varies greatly with these seasonal changes.
Other abundant taxa include *Halimeda, Caulerpa, Dictyopterus, Dictyota, Cystoseira, Padina, Codium* and *Laurencia.* Macroalgae are generally attached to hard substrates such as rock. *Caulerpa* is one of the few macroalgae that attach to soft sediments and often grows in association with *Halophila* seagrass meadows.

Barrow Island

Mangroves – Mangroves are restricted to a few small *Avicennia marina* species on the east and southern coast of Barrow Island. There are mangroves at Mattress Point, south of the Chevron camp, near the airstrip, at Stokes Point and near Pelican Island on the western side of Bandicoot Bay. CALM (2004) calculated that mangroves make up approximately 6% of the coastline of Barrow Island. These mangroves are generally poorly developed and consist of a narrow band only a few trees in width. In comparison, the mangroves on the adjacent mainland coast are very well developed and extend up to 1 km inland from the coastline.

Seagrass – Ephemeral seagrasses are widespread along the east coast of Barrow Island on subtidal sands and in intertidal pools. The most common species are *Halophila ovalis* (Plate 8-21) on the deeper subtidal sand and *Halophila, Halodule* and *Syringodium* in the rock pools.

Plate 8-21:
Sparse Seagrass Meadow in Intertidal Rock Pool

Macroalgae – At least 132 macroalgal taxa occur in marine habitats around Barrow Island and most of these are believed to be distributed widely in the tropical Indo-Pacific region (Huisman J 2004, pers. comm.). Some species are known only from Barrow Island as systematic collections have not been undertaken for other north-west sites. For example, *Boergesenia forbessii, Yamadaella caenomyce, Halimeda velasquezii, Neomeris vanboseae, Gracillaria urvillei,* and *Valoniopsis pachynema* have only been recorded in Western Australia during surveys for the Gorgon Development.

The macroalgal habitats on the east coast of Barrow Island are typified by a horizontal platform reef with a thin layer of sediments. Macroalgal diversity is highest in the rock pools and towards the deeper edge of the intertidal zone. The dominant macroalgae on the east coast platforms are *Cystoseira trinodis, Sargassum* spp., *Caulerpa* spp. and *Halimeda.* Macroalgal turfs are widespread on the intertidal pavement reef and comprise red algae such as *Laurencia, Chondria, Ceramium, Centroceras clavulatum, Gelidiopsis* and *Hypnea.*

Large stands of *Sargassum* grow on both the west and east coasts of Barrow Island. On the west coast, the *Sargassum* grows mainly on shallow nearshore reefs, whereas on the east coast the *Sargassum* stands are on the gently sloping pavement reef. The ridge of rock running south from the Lowendal Shelf supports variable cover of *Sargassum.*

Other species in the area, such as *Avrainvillea* sp. and *Halimeda macroloba,* appear to be restricted to the east coast. *Udotea* grows on soft sediments on both coasts.

Gorgon Development Area

Mangroves – There are no mangroves in any of the proposed Development areas on Barrow Island. The closest mangroves to any proposed Development activities are in a small area at the Donald River mouth, approximately 5 km north of Town Point.

Seagrass – There are no significant seagrass meadows present in any of the proposed Development areas around Barrow Island. *Halophila* forms sparse meadows on soft sediments along the east coast. These meadows are spatially and temporally dynamic and are expected to occur where there are soft sediments throughout the area in waters less than 15 m deep. All of the areas of soft sediments off the east coast of Barrow Island are considered to be benthic primary producer habitats as they are likely to support seagrass at various times of year.

Macroalgae – All proposed Development areas with exposed, or seasonally exposed, hard substrate in the shallow waters (<15-20 m water depth) are likely to support macroalgae.

Fissures and holes in the shallow subtidal platform reef in the nearshore zone at North White's Beach support a dense macroalgal assemblage. The high profile reef offshore from North White's Beach supports dense and foliose macroalgal beds. Subtidal boulders and reef to the south of the proposed shore crossing at North White's Beach support better developed macroalgal assemblages and turtles have been observed browsing on the algae in that area.

The alternative feed gas pipeline shore crossing at Flacourt Bay crosses high profile reef near the shore that supports seasonal stands of dense *Sargassum.* The intertidal and shallow subtidal reef at Flacourt Bay is exposed to high wave energy and the macroalgal assemblage is limited to a dense turf of algae covering the rocks.

The broad intertidal reef platform and large rock pools at Town Point support a stunted assemblage of macroalgae on the exposed pavement and a better developed macroalgal assemblage, dominated by *Sargassum* and *Cystoseira,* around the edge of rock pools. The length of the *Sargassum* thalli increases with increasing water depth further from shore. The phaeophyte assemblage diversifies towards the offshore edge of the platform where there is a greater proportion of *Dictyopterus* and other large phaeophytes and chlorophytes.

Mainland – Domestic Gas Pipeline Shore Crossing

Mangroves – The proposed domestic gas pipeline would cross the mainland coast 50 m south of the existing Apache Energy Sales Gas Pipeline. The mangrove forest along the existing easement is dense and well developed (Plate 8-22). The forest comprises large *Avicennia marina* trees at the seaward edge, backed by tall *Rhizophora stylosa* trees and more *Avicennia* further inland. Scattered *Ceriops tagal* and *Aegiceras corniculatum* are also present. The inland edge of the mangrove comprises scattered small *Avicennia* and patches of samphire. Technical Appendix C1 contains a description of the results of the preliminary botanical survey on the mainland coast.

The proposed domestic gas pipeline route will affect a 30 m wide corridor through the mangrove zone to the south of the existing clearing for the Apache Energy Sales Gas Pipeline (Figure 8-22). The proposed pipeline route passes through two narrow zones of dense mangroves and a broader area of medium to low density mangroves. In total 2.3 ha of mangrove community and 3.5 ha of samphire community would be directly affected by the pipeline.

Plate 8-22:
Mainland *Avicennia marina* Mangrove with Existing Apache Energy Sales Gas Pipeline Corridor

Seagrass – The proposed domestic gas pipeline will cross the mainland coast adjacent to the existing Apache Energy Sales Gas Pipeline. The sandflats in the nearshore subtidal area and lower intertidal area support patchy, sparse meadows of *Halophila ovalis, H. spinulosa* and *Halodule* seagrass. These sandflat meadows appear to be extensive. The distribution of these seagrasses in areas further offshore is unknown. Mapping from aerial photography is not possible due to high water turbidity in coastal areas. It is assumed that all shallow sediments along the coast and between Barrow Island and the mainland support seagrass meadows at various times of year.

Macroalgae – There are no well developed macroalgal assemblages in the vicinity of the proposed domestic gas pipeline shore crossing.

Optical Fibre Cable Route

Mangroves – The proposed optical fibre cable route does not pass through any areas of mangrove. The shore crossing at Onslow will avoid the mangroves at Beadon Creek.

Seagrass – The proposed optical fibre cable route will cross scattered seagrass meadows in areas of soft sediments along the east coast of Barrow Island, between Barrow Island and the mainland and at the shore crossing at Onslow. Shallow subtidal pavement reef with sand veneers and sandflats at Onslow, in the vicinity of the proposed shore crossing, are expected to support better developed seagrass meadows. This will be confirmed and a final route selected to avoid important areas of seagrass.

Macroalgae – Macroalgal assemblages along the proposed optical fibre cable route are expected to be limited to the *Sargassum*-dominated assemblages on the pavement reef adjacent Barrow Island and areas of shallow reef offshore from Onslow.

Marine Fauna

The marine fauna of the Barrow Island area includes listed species of marine mammals, waterbirds, sea turtles, sea snakes, fishes and a vast array of lesser known vertebrate and invertebrate species that contribute significantly to regional biodiversity but are not listed individually as taxa of conservation significance.

The following sections provide a brief overview of the marine fauna of the proposed Development sites in relation to the conservation status of these fauna and their distribution throughout the region.

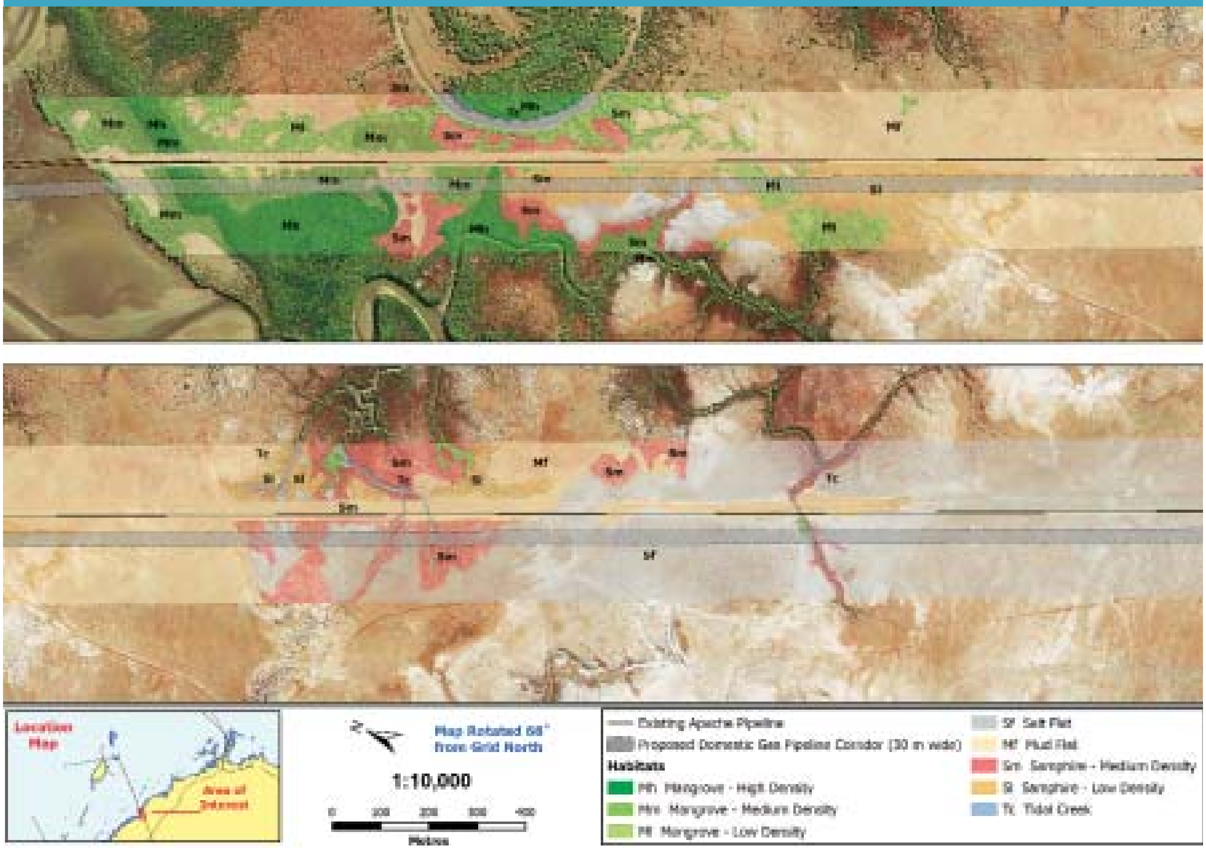
Marine fauna of high conservation significance, in particular species listed under state or Commonwealth legislation or international treaties, are described in more detail in Technical Appendix C3 (seabirds and shorebirds), Technical Appendix C6 (marine mammals, reptiles and fish) and Technical Appendix C7 (sea turtles).

Marine Mammals

Marine mammals are an important component of the biodiversity and ecology of the West Pilbara bioregion. The region supports migratory, transient and resident marine mammals such as whales, dolphins and dugong.

The suite of marine mammal species that are likely to occur in the Development area was derived from a desktop review of the available literature on marine species, liaison with state and federal government departments, liaison with research personnel, review of information from previous surveys and opportunistic observations during field surveys. A full technical report is included in Technical Appendix C6.

Figure 8-22:
Mainland Mangrove Communities in the Vicinity of the Proposed Domestic Gas Pipeline Route



Regional

Whales – The regional distribution of whales is generally poorly known and while many species may occur in the Pilbara region, most are likely to be transients or occasional visitors. All whales are protected under Schedule 1 of the Wildlife Conservation Act and the EPBC Act (refer Technical Appendix C6).

Humpback whales *(Megaptera novaeangliae)* are regular visitors to the region. Whale species that may occasionally visit the region include the short-finned pilot whale *(Globicephala macrorhynchus),* false killer whale *(Pseudorca crassidens),* killer whale *(Orcinus orca),* Bryde's whale *(Balaenoptera edeni),* minke whale *(Balaenoptera acutorostrata),* sei whale *(Balaenoptera borealis),* pygmy blue whale *(Balaenoptera musculus brevicauda),* fin whale *(Balaenoptera physalus),* melon-headed whale *(Peponocephala electra)* and the sperm whale *(Physeter macrocephalus).* Of these whales only the humpback whales are known to be regular visitors to the area. Pygmy blue whales *(Balaenoptera musculus brevicauda)* and other species may pass through the area (Appendix C6).

Dolphins – The regional distribution of dolphins is generally poorly known and while many species may occur in the Pilbara region, most are likely to be transients or occasional visitors. All dolphins are protected under Schedule 1 of the Wildlife Conservation Act and the EPBC Act (refer Technical Appendix C6).

Bottlenose dolphins *(Tursiops truncatus)* and Indo-Pacific humpback dolphins *(Sousa chinensis)* are resident throughout the shallow waters of the inner Rowley Shelf. Other dolphins known from the region include common dolphins *(Delphinus delphis),* striped dolphins *(Stenella coeruleoalba),* spinner dolphins *(Stenella longirostris),* Risso's dolphins *(Grampus griseus),* spotted dolphins *(Stella attenuata)* and rough-toothed dolphins *(Steno bredanensis)*.

Dugong – Dugong *(Dugong dugon)* are known to occur around the islands of the Rowley Shelf such as Barrow Island, the Lowendal Islands and the Montebello Islands, although their distribution within this region is poorly understood. Dugong populations are greater in Exmouth Gulf or Shark Bay than around the offshore islands

(Prince 1986; Prince 2001). They are protected under Schedule 4 of the Wildlife Conservation Act and are listed as threatened (Vulnerable) under the EPBC Act.

Barrow Island

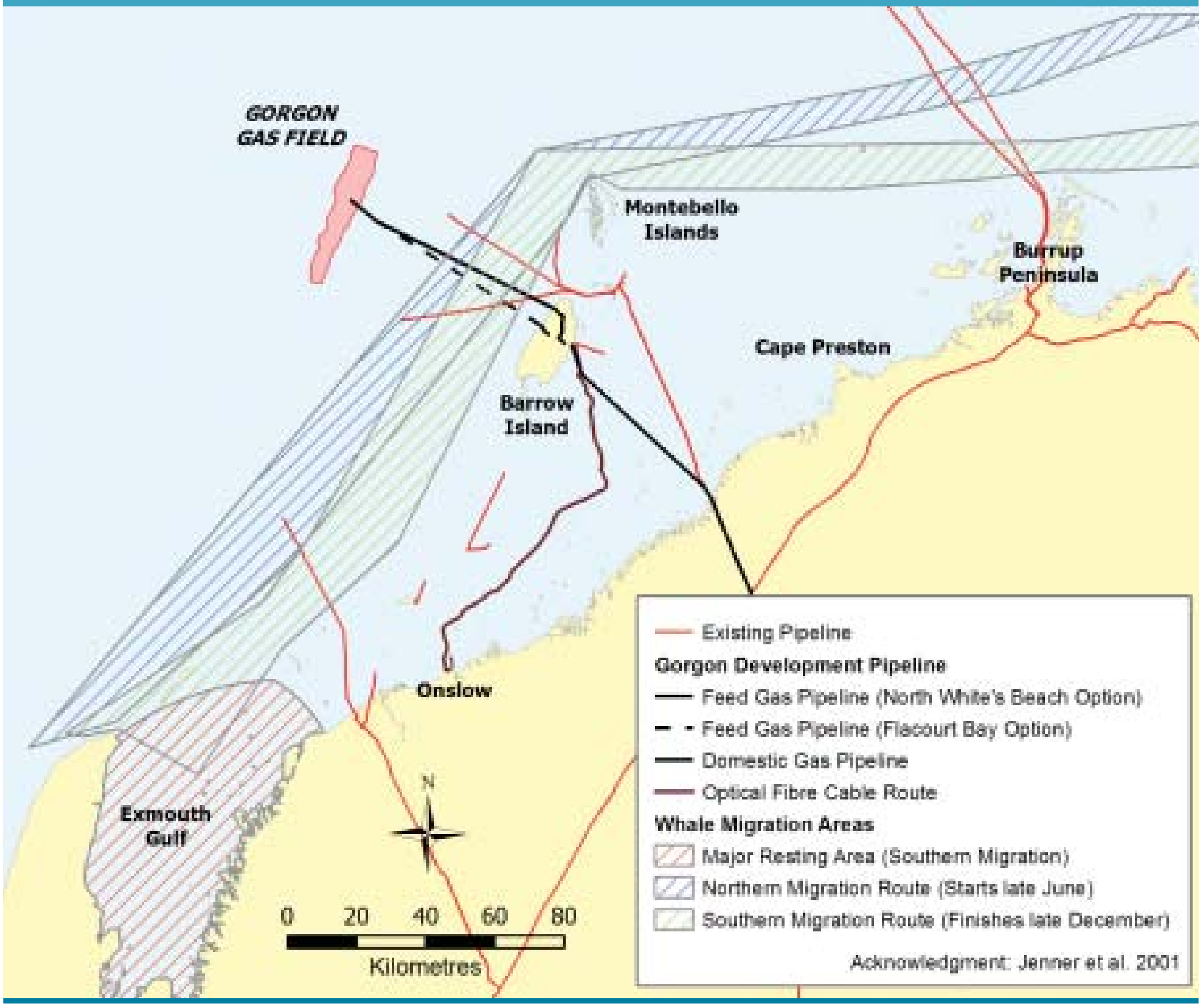
Whales – Humpback whales *(Megaptera novaeangliae)* pass through the Montebellos/Barrow Island region during June to October on their annual migration between their feeding grounds in Antarctic waters and their calving grounds in Pilbara/Kimberley waters. Their migration patterns, calving and rest areas are shown in Figure 8-23 and are described in Technical Appendix C6.

Northbound whales tend to remain on, or within, the 200 m contour, while southern migratory whales tend to be more dispersed. Southbound whales tend to come in closer to Barrow Island (Jenner et al. 2001). Small groups of humpbacks visit the coastal waters off both coasts of Barrow Island during both the northward and southward migration, but are more common on the west side.

Dolphins – Bottlenose dolphins *(Tursiops truncates)* and Indo-Pacific humpbacked dolphins *(Sousa chinensis)* have resident populations within the shallow waters of the inner Rowley Shelf, including Barrow Island. Bottlenose dolphins are abundant on both coasts of Barrow Island. Spinner dolphins *(Stenella longirostris),* common dolphins *(Delphinus delphis)* and striped dolphins *(Stenella coeruleoalba)* are also abundant in the waters around Barrow Island. These are generally oceanic species and are likely to be most abundant on the west coast of the island.

Risso's dolphins *(Grampus griseus),* spotted dolphins *(Stella attenuata)* and rough-toothed dolphins *(Steno bredanensis)* occur in the Barrow Island area. Rough-toothed dolphins have stranded on Barrow Island (Baker 1990).

Figure 8-23:
Whale Migrations



Dugong – Dugong are generally associated with shallow seagrass meadows on which they feed and have been observed in the shallow waters over the Barrow Shoals, along the east coast of Barrow Island and over the Lowendal Shelf to the north east. They are likely to be occasional visitors to any area of subtidal seagrass in the vicinity of the proposed east coast Development areas. There are no known major seagrass meadows along the east coast of Barrow Island that are likely to be critical feeding habitats for dugong.

Gorgon Development Area

Whales – Humpback whales are likely to be present in the offshore Development areas off the west coast of Barrow Island during the June to October migration period. They are also expected to occasionally visit the offshore areas of the proposed Development on the east coast, for example the tanker turning area and dredged shipping channel. There are no known critical habitats, such as feeding or calving grounds, for any whales in the water around Barrow Island.

Humpback and other whales are unlikely to occur in the shallower waters over the shelf between Barrow Island and the mainland where the domestic gas pipeline, optical fibre cable would run. Most whale species are more abundant in deeper waters and are expected to be rare visitors to the offshore waters close to the western shore of Barrow Island and are unlikely to visit the shallow, turbid inshore waters in the vicinity of the proposed domestic gas pipeline or optical fibre cable shore crossings.

Dugong – Dugong occur throughout the shallow waters between the offshore islands and the mainland and are expected to occasionally visit the areas proposed for the domestic gas pipeline and optical fibre cable route. Extensive, ephemeral seagrass meadows along the mainland coast in the vicinity of the proposed domestic gas pipeline shore crossing are likely to be feeding areas for dugong, however, no feeding scars were observed during surveys of the area. The seagrass habitats are very widespread along the Pilbara coast and the area in the vicinity of the shore crossings is not expected to be significant habitat for dugong.

Dolphins – Bottlenose dolphins *(Tursiops truncatus)*, common dolphins *(Delphinus delphis)* and striped dolphins *(Stenella coeruleoalba)* are likely to visit the offshore Development areas on the west coast of Barrow Island. Bottlenose dolphins are also likely to be regular visitors to the east coast Development areas.

Bottlenose dolphins are abundant over the Pilbara inshore region and may occur along all parts of the proposed domestic gas pipeline, optical fibre cable route and in the vicinity of the mainland shore crossings.

Marine Avifauna

Marine avifauna studies conducted for the Gorgon Development have revealed that Barrow Island is an internationally important site for migratory shorebirds. Prior to these studies, little was known about the seasonal changes in the abundance of migratory shorebirds on Barrow Island, or about the relative importance of different areas of habitat around the island. The information presented in the following section represents a significant advance in the knowledge of shorebirds in the region. The methodology used in the surveys is outlined in Box 8-8. The full technical report is included in Technical Appendix C3.

Box 8-8:
Avifauna Survey Methodology

Surveys of shorebirds (birds that utilise coastal environments) involved monthly counts around Barrow Island and detailed observations on the coastline north and south of Town Point. Monthly counts were carried out at high tide, when shorebirds were concentrated in beach and headland roosts. Surveys were carried out on foot by experienced observers and birds were identified using binoculars and spotting telescopes. Shorebirds were counted individually where possible, but when large flocks were encountered, standard approaches to estimation were used (Technical Appendix C3).

Shorebird assemblages expected to occur in the general vicinity of the proposed domestic gas pipeline and optical fibre cable shore crossings on the mainland were determined from the Birds Australia listings for these areas (Birds Australia 2004). While this gives an indication of the assemblages in the general area, the importance of potential roosting areas behind the mangroves near Robe River to migratory shorebirds will be determined in surveys later in 2005.

Regional

The marine avifauna of the Pilbara region includes migratory and resident shorebirds and seabirds (birds that frequent coastal waters and the open ocean). Many of the migratory species are protected under the international JAMBA/CAMBA treaties, the Wildlife Conservation Act and the EPBC Act.

Generally, migratory species visit the Pilbara from the northern hemisphere or close to the equator and pass through the region on their way southward, or may stay in the Pilbara region until ready to journey back to breed. Resident species remain in the Pilbara region throughout the year, but may move around within the region.

The Montebello/Lowendal/Barrow Island region has significant rookeries of 15 seabird species including the wedge-tailed shearwater *(Puffinus pacificus),* crested tern *(Sterna bergii),* bridled tern *(Sterna anaethetus)* and the roseate tern *(Sterna dougallii).* Of these, the wedge-tailed shearwater and the bridled tern are protected as migratory species under the EPBC Act. The offshore islands are also important feeding grounds for migratory shorebirds. The mainland areas of the Pilbara are frequently less suitable for shorebirds due to disturbance from humans and introduced predators.

Barrow Island

Barrow Island's marine avifauna comprises at least 67 species, including 25 species of migratory shorebirds and 20 resident shorebirds. A complete species list is included in Technical Appendix C3. The assemblage of EPBC listed species includes 14 seabird species and 25 wetland/littoral species (Table 8-12).

Although the 25 EPBC listed wetland/littoral species may occur on Barrow Island, none of the Development areas contain critical habitats for these species.

Ruddy turnstones are seasonally abundant on Barrow Island and the island represents an internationally important site for this species. While ruddy turnstones are one the more abundant species at Town Point during spring and summer, their densities in the proposed Development areas are much lower than in the south and south–eastern areas of Barrow Island (Technical Appendix C3). These are highly mobile birds that are not restricted to any of the habitats near Town Point.

Table 8-12:
EPBC Act Listed Marine Avifauna

Seabird Species	Wetland/Littoral Species
• wedge-tailed shearwater – *Puffinus pacificus* • yellow-nosed albatross – *Diomedea chlororhynchos* • Wilson's storm petrel – *Oceanites oceanicus* • masked booby – *Sula dactylatra* • brown booby – *Sula leucogastar* • lesser frigatebird – *Frigata ariel* • eastern reef egret – *Ardea (Egretta) sacra* • great egret – *Ardea (Egretta) alba* • osprey – *Pandion haliaetus* • common tern – *Sterna hirundo* • little tern – *Sterna albifrons* • bridled tern – *Sterna anaethetus* • caspian tern – *Sterna caspia* • white-winged black tern – *Chlidonias leucoptera*	• black-tailed godwit – *Limosa limosa* • bar-tailed godwit – *L. lapponica* • little curlew – *Numenius minutus* • whimbrel – *N. phaeopus* • eastern curlew – *N. madagascariensis* • marsh sandpiper – *Tringa stagnatalis* • common greenshank – *T. nebularia* • wood sandpiper – *T. glareola* • terek sandpiper – *T. (Xenus) terek* • common sandpiper – *T. hypoleucos* • grey-tailed tattler – *T. brevipes* • ruddy turnstone – *Arenaria interpres* • great knot – *Calidris tenuirostris* • red knot – *C. canutus* • sanderling – *C. alba* • red-necked stint – *C. ruficollis* • sharp-tailed sandpiper – *C. acuminata* • curlew sandpiper – *C. ferruginea* • pacific golden plover – *Pluvialis fulva* • grey plover – *P. squatarola* • lesser sand plover – *Charadrius mongolus* • greater sand plover – *C. leschenaultia* • oriental plover – *C. veredus* • oriental pratincole – *Glareola maldivarum* • Australian pratincole – *Stiltia isabella*

Barrow Island ranks equal tenth amongst 147 sites in Australia that have been identified as important for migratory shorebirds, due to the high abundance of grey-tailed tattlers, ruddy turnstones, red-necked stints, sanderlings, greater sand-plovers and lesser sand-plovers on the island (Bamford et al. in press).

Studies suggest that Barrow Island is both a staging site and an important non-breeding site for migratory shorebirds. Migratory shorebird abundances increase on the island as the birds arrive from the north during September to December. The abundances of some migratory shorebirds continue to increase during January and February, suggesting local movements of birds from the mainland to Barrow Island. Abundances decrease as the migratory species leave the region to return north at the end of summer.

The highest abundances of shorebirds on Barrow Island (over two-thirds of records for most species) are associated with the south-eastern and southern coasts of the island, from the existing Chevron camp to Bandicoot Bay. These concentrations appear to be associated with the extensive tidal mudflats in these areas.

Listed wedge-tailed shearwaters and bridled terns nest on Double Island, two rocky islets off the east coast of Barrow Island and the shearwaters nest on Boodie Island off the south end of Barrow Island.

Gorgon Development Area

Despite the presence of broad intertidal reef platforms adjacent to Town Point, only 1% of shorebirds on Barrow Island were observed foraging on the intertidal reef platforms near the proposed causeway in 2003 and 2004. The red-necked stint, grey-tailed tattler, ruddy turnstone, bar-tailed godwit, lesser sand plover, greater sand plover, silver gull, common tern and the fairy tern are the most abundant shorebird species that forage at Town Point. The distribution of shorebird roosts in areas surrounding the proposed gas processing facility area on the east coast of Barrow Island is shown in Figure 8-24.

Cormorants, eastern reef egrets, silver gulls and oystercatchers roost on the rocks at Town Point and the large-eyed northern race of the sooty oystercatcher *(Haematopus fuliginosus ophthalmicus)* nests on the headland (Plate 8-23). Barrow Island appears to be an important site for large-eyed sooty oystercatchers, with approximately 1% of the known world population. This race has not been censused thoroughly across northern Australia and is likely to be more abundant than the current estimate indicates. With approximately 30-40 breeding pairs of this race on the island, the nesting pair at Town Point represents approximately 2.5-3.3% of the island stock. Other shorebirds such as the pied oystercatcher *(Haematopus longirostris),* Caspian tern *(Sterna caspia),* red-capped plover *(Charadrius ruficapillus)* and osprey *(Pandion haliaetus)* may nest in the general area, but were not observed to nest there during surveys. No potential nesting habitats in the Town Point area are restricted to that area and it is not considered of local importance to any EPBC listed shorebird species.

The high-energy beaches at Flacourt Bay and North White's Beach on the west coast do not provide significant shorebird habitat and abundances are generally low in these areas.

Small flocks (10s) of shorebirds were observed on the extensive samphire flats inland from mangroves along the mainland coast and are likely to feed over wide areas of this habitat. The narrow strip of mangrove and samphire in the path of the proposed domestic gas pipeline route is unlikely to be more important for shorebirds and seabirds than adjacent areas of similar habitats. Further surveys during the southward migration in 2005 will further elucidate the distribution of shorebird habitat near the proposed shore crossing.

The sandy beaches in the vicinity of the shore crossing for the optical fibre cable at Onslow are likely to be seasonal roosts for a variety of migratory and resident shorebirds. The nearshore islands are also breeding sites for shorebirds and seabirds, such as terns *(Sterna* spp.). None of the nearshore islands are in the path of the proposed pipeline. As with most mainland areas, breeding will be reduced on the Onslow beaches due to feral animal predation and human disturbance.

Double Island, approximately 5 km north of Town Point off the east coast of Barrow Island, is a regionally significant rookery for bridled terns and a locally significant rookery for wedge-tailed shearwaters. The wedge-tailed shearwater rookery is small in comparison with other rookeries in the immediate region.

Plate 8-23:
Nesting Sooty Oystercatchers at Town Point

Marine Reptiles

The marine reptile fauna of the area comprises sea turtles and sea snakes (including kraits). Crocodiles may make rare visits to the region.

The methods used for surveying marine reptiles on Barrow Island are outlined in Box 8-9. Full technical reports are included in Technical Appendices C6 and C7.

Box 8-9:
Marine Reptile Survey Methodology

Marine turtle nesting activity on beaches around Barrow Island was surveyed by beach monitoring and track identification during the 2003-2004 and 2004-2005 breeding seasons (Technical Appendix C7). The surveys were aimed at determining the relative importance of different parts of the Barrow Island coast for sea turtle nesting. The regional importance of the Barrow Island sites was derived from literature.

The likely distribution of sea snakes and kraits in the area was derived from literature.

Regional

Sea Turtles – Six species of sea turtle are known from the Montebello/Lowendal/Barrow Island region: green turtles *(Chelonia mydas);* flatback turtles *(Natator depressus);* hawksbill turtles *(Eretmochelys imbricata);* loggerhead turtles *(Caretta caretta);* leatherback turtles *(Dermochelys coriacea);* and olive ridley turtles *(Lepidochelys olivacea)* (Figure 8-25). All Australian sea turtles are protected under Schedule 1 of the Wildlife Conservation Act, by the Bonn Convention for the protection of migratory animals and listed as threatened under the EPBC Act. Loggerhead turtles and olive ridley turtles are listed as endangered under the EPBC Act and the other species are listed as vulnerable.

Sea turtles in the region generally migrate over large distances and return to the same area to breed. The region also supports foraging grounds for turtles that nest elsewhere in Western Australia. Increasing pressure on these turtles in other parts of the world, make the Australian habitats and breeding areas globally important.

Green turtles *(Chelonia mydas)* are the most abundant sea turtles in northern Western Australian waters. The north-western Australian population is important due to high predation pressures on nesting and inter-nesting turtles in other parts of the Indo-Pacific region. The major green turtle rookeries in the region are at the Lacepede Islands with lesser rookeries on Barrow Island, North West Cape, the Muiron Islands, Serrurier Island and in the Dampier Archipelago (Prince 1990).

Flatback turtles *(Natator depressus)* are the second most abundant sea turtles in northern Western Australian waters (Pendoley 1997). They nest only in northern Australia and there are regionally important rookeries at Cape Thouin/Munda Station, Barrow Island, Lacepede Islands, Dampier Archipelago, Port Hedland, the Montebello Islands and the Lowendal Islands.

The Western Australian populations of hawksbill turtles, although small, are the largest remaining in the Indian Ocean (CALM 2004). Hawksbill turtles *(Eretmochelys imbricata)* have major rookeries on Rosemary Island in the Dampier Archipelago and have lesser rookeries within the Lowendal/Montebello Islands. Barrow Island is not a regionally important nesting site for hawksbill turtles.

Loggerhead turtles appear to be the least abundant of the marine turtles in the Western Australian region (Prince 1990). Loggerhead turtles nest on the Muiron Islands off Exmouth Gulf and at Dirk Hartog Island in Shark Bay.

Leatherback turtles and olive ridley turtles are not known to nest in Western Australian waters. Leatherback turtles are uncommon, but regular visitors to the region. Olive ridley turtles appear to frequent the far northern coastal waters of Western Australia in small numbers (Prince 1990).

Figure 8-24:
Shorebird Roosts in Areas Surrounding the Proposed Development Area on the East Coast of Barrow Island

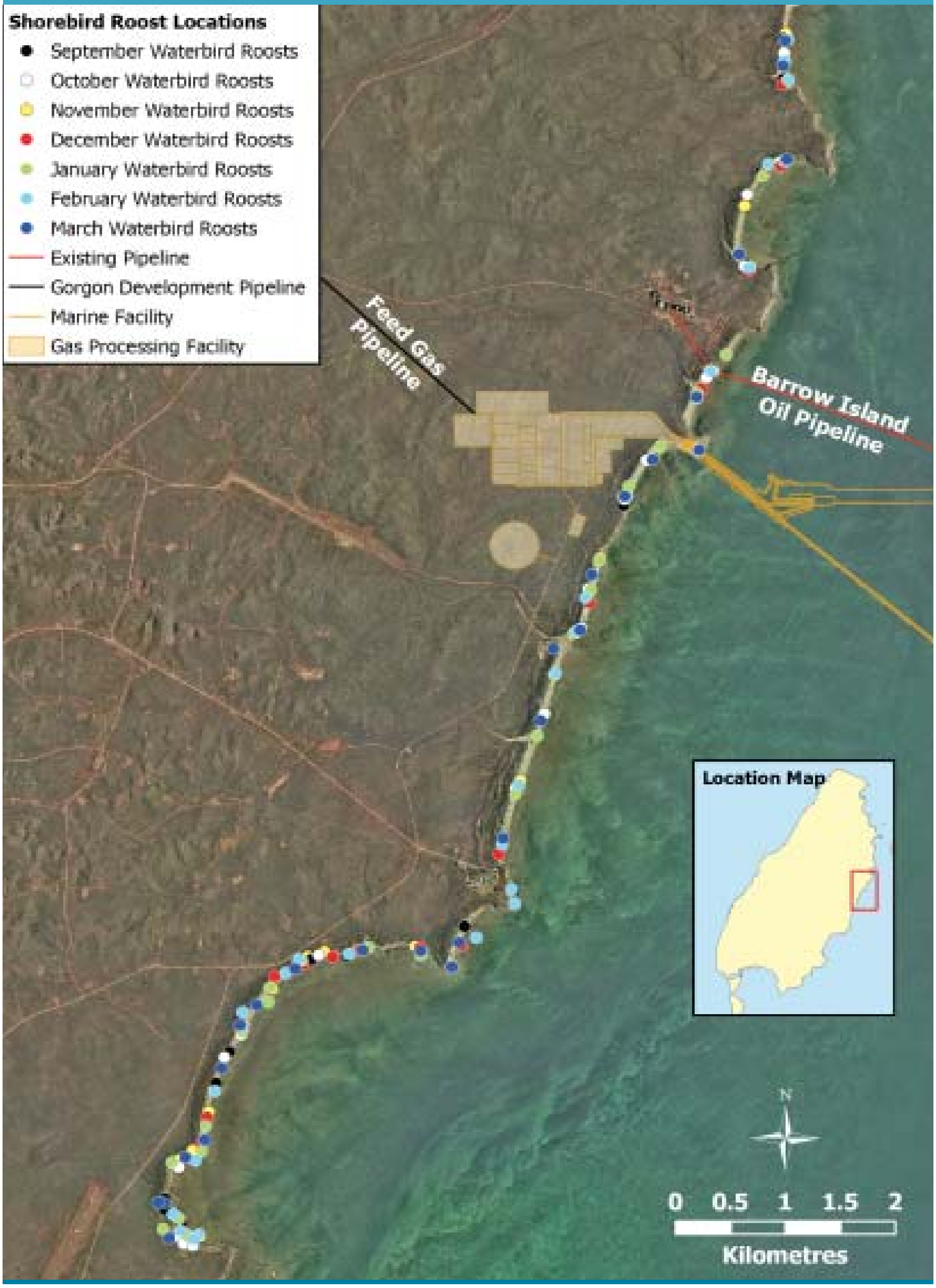
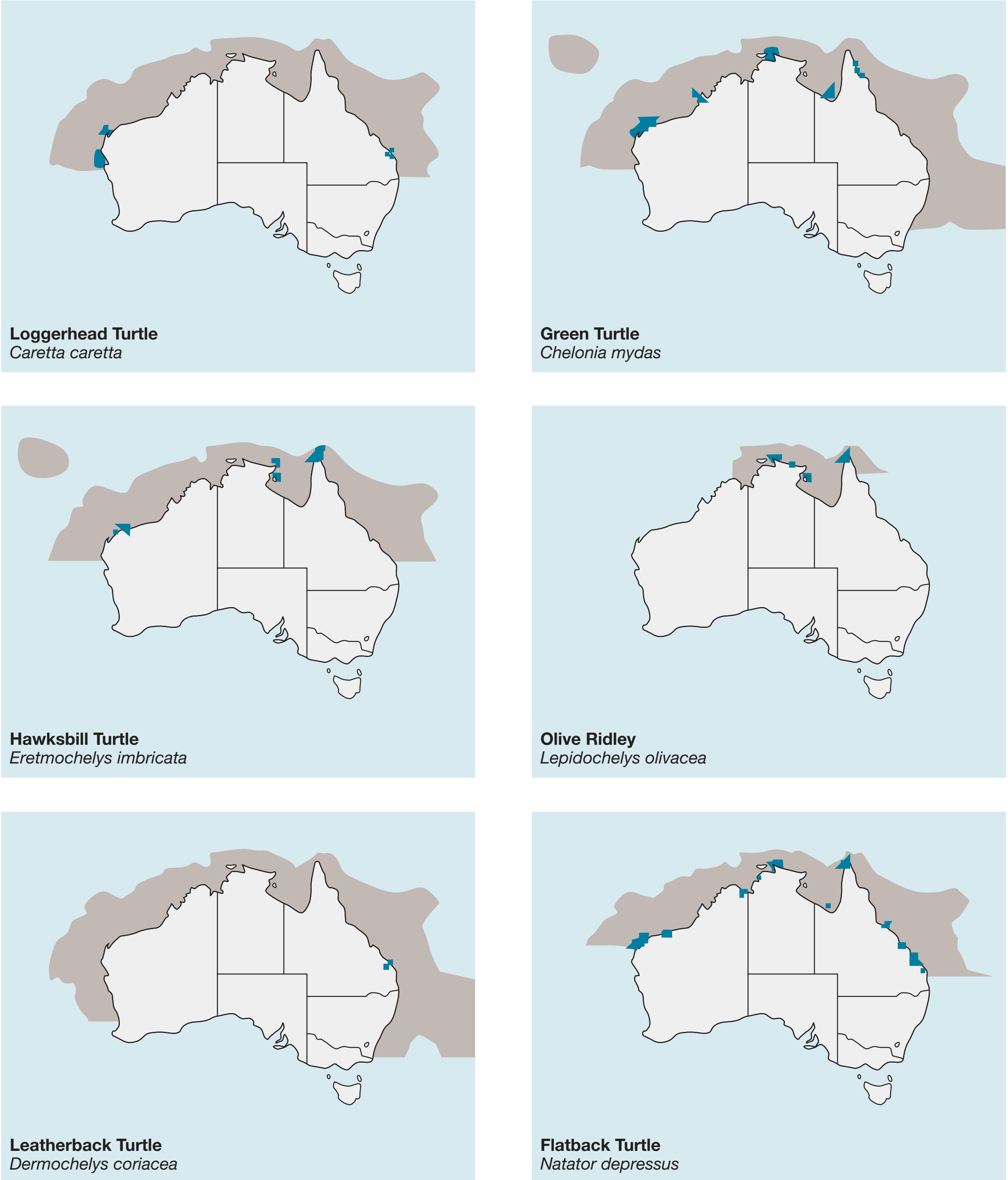


Figure 8-25:
Distribution of Australian Marine Turtles (Source: Environment Australia 2003)



Source: General distribution as indicated in Cogger, H. (1996). Reptiles and Amphibians of Australia. Reed. Breeding (rookery) distribution based on areas defined by Limpus, C.J. (1995) Conservation of marine turtles in the Indo-Pacific. Draft: 1 October 1995. Report to Australian Nature Conservation Agency; and Wildlife Management Section, Environment Australia and Marine Turtle Recovery Team (1998) Draft Recovery Plan for Marine Turtles in Australia.
Coastline 100K is © Commonwealth of Australia, Geoscience Australia 1990

Recorded Breeding Sites
Distribution within Australian

Projection: Geographics

Map produced by ERIN, Environment Australia, Canberra, July 2003.
© Commonwealth of Australia 2003

Sea Snakes and Kraits – Sea snakes and kraits are highly mobile and can cover large distances. Many species are restricted to relatively shallow coastal waters and some species must return to land to eat and rest.

Sea snakes and kraits are widespread throughout the Pilbara region in offshore and nearshore habitats. Storr et al. (1986) estimate nine genera and 22 species of sea snakes and kraits occur in Western Australian waters; however, little is known of the distribution of individual species. There is also very little known of sea snake and krait ecology, population sizes and dynamics. Sea snakes and kraits are protected under the Wildlife Conservation Act and the EPBC Act.

Barrow Island

The use of beaches around Barrow Island by nesting sea turtles was poorly known prior to the current study. Patterns of beach usage have been studied over the last two summer breeding periods.

Barrow Island is a regionally important nesting area for green turtles and flatback turtles. Hawksbill turtles nest at low densities around the island and loggerheads have been only occasionally recorded from the island.

The occurrence of green turtles and flatback turtles, both EPBC listed threatened species, on Barrow Island is described in the following sections.

Green Turtles – Green turtles nest predominantly on the sandy west coast beaches on Barrow Island (Figure 8-26, Table 8-13). In addition to nesting, green turtles mate and forage close to Barrow Island during the summer breeding season. Green turtles nest mainly in spring and summer and hatchlings emerge through summer and early autumn. While most green turtles migrate away from the area after breeding, some appear to be resident at Barrow Island, remaining near the island during the winter.

In addition to breeding beaches, the Barrow Island area appears to provide important inter-nesting and foraging habitats for green turtles. Green turtles feed on marine macrophytes (seagrass and macroalgae) on the seabed and jellyfish in the water column (Heithaus et al. 2002). Aggregations of green turtles have been reported from the shallow areas along the west coast of Barrow Island and the turtles forage on and around nearshore reefs. Green turtles have also been observed to the south and south-east of Barrow Island, around Dugong Reef and over the Barrow Shoals. Shallow subtidal, macroalgal covered reef platforms are widespread in the Montebello/Lowendal/Barrow Island region and no areas of critical inter-nesting or foraging habitat have been identified around Barrow Island.

Inter-nesting green turtles frequent nearshore waters and rest on the sandy beach during the summer breeding season. Resident turtles browse on the nearshore macroalgal dominated platform reefs all along the west coast of Barrow Island when the sea is calm. Their foraging areas are likely to be more restricted during rough weather.

The national Recovery Plan for Marine Turtles in Australia (Environment Australia 2003) identifies Barrow Island and all waters within a 20 km radius of the island as critical habitat to the survival of green turtles.

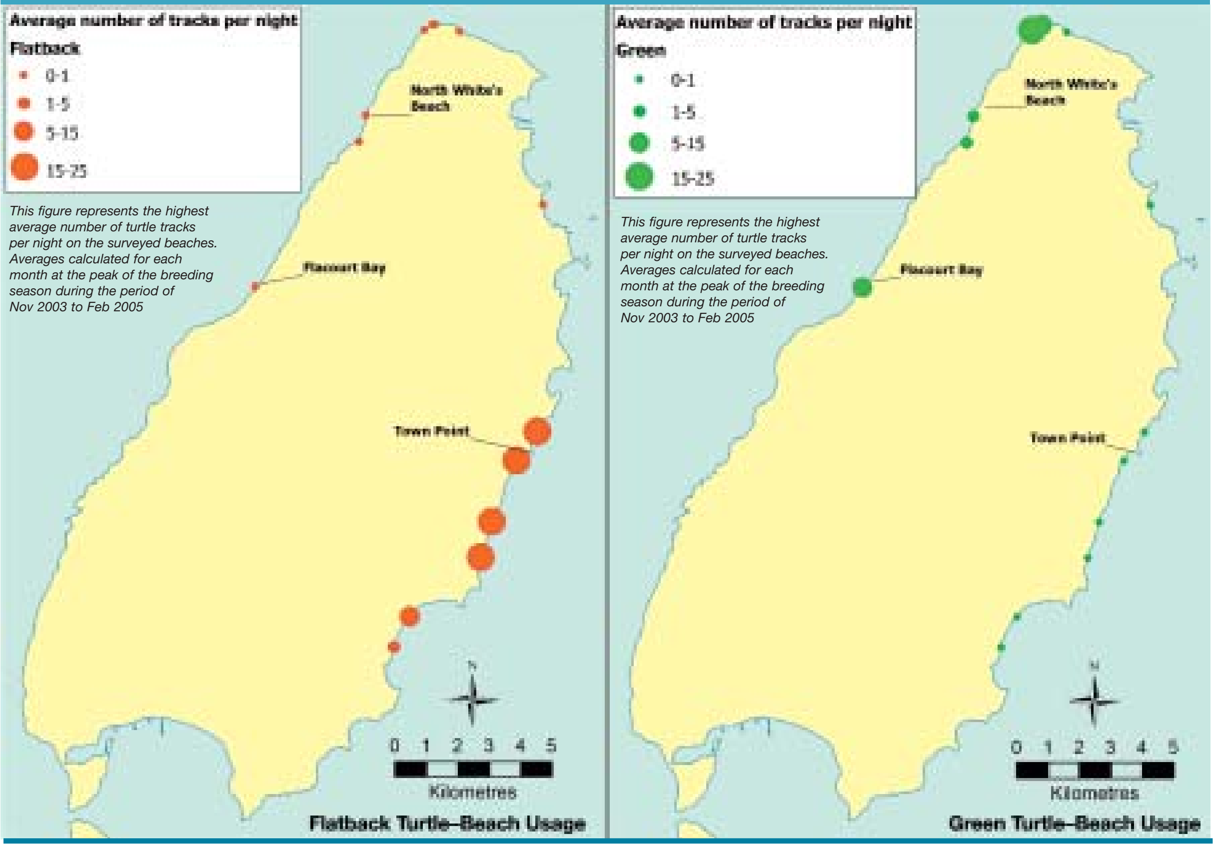
Plate 8-24:
Green Turtle *(Chelonia mydas)* in the Intertidal Zone at Barrow Island

Table 8-13:
Average Nesting Densities of Green Turtles (nests/night/km) on the West Coast of Barrow Island

Beach	V Beach	Tortuga	Flacourt	North White's	White's
2003/2004	138	43	83	–	–
2004/2005	–	50	60	4	28

Location of beaches is shown in Figure 8-2.

Figure 8-26:
Distribution and Intensity of Sea Turtle Nesting Across Barrow Island



Flatback Turtles – Nesting flatback turtles favour mid-east coast beaches on Barrow Island. The beaches either side of the proposed Development area at Town Point (Terminal Beach and Bivalve Beach) are important components of this regionally significant rookery (Figure 8-26). The highest density of flatback turtle tracks was recorded in January 2004 on Bivalve Beach (Table 8-14). In the summers of 2003-2004 and 2004-2005, flatback turtle nesting densities were highest on the central east coast between Mushroom Beach and Yacht Club South Beach, and decreased in a north and south direction (Table 8-14).

Little is known of the distribution and habitat use of flatback turtles during inter-nesting and outside the breeding period. Post-nesting females commonly sleep on the intertidal platform off the east coast rookery at low tide. Inter-nesting and foraging habitats for flatback turtles on the east coast of Barrow Island have not been identified. However, flatback turtles favour soft bottom habitats (Parmenter 1994) and during the inter-nesting period may frequent areas of sandy substrates off the edge of the wide intertidal platform that runs the length of the east coast.

Table 8-14:
Average Nesting Densities of Flatback Turtles (nests/night/km) on the East Coast of Barrow Island

Beach	Terminal	Bivalve	YCN	Bed	Junction
2003/2004	30	49	37	–	–
2004/2005	30	40	26	1	7

Location of beaches is shown in Figure 8-2.

Sea Snakes and Kraits – Sea snakes are common in shallow waters around Barrow Island, in offshore waters west of the island and in inshore waters between Barrow Island and the mainland. Little is known of the distribution of individual species within the area.

Gorgon Development Area

Green Turtles – The area of the proposed feed gas shore crossing at North White's Beach is not a locally important green turtle nesting site, probably due to the shallow sand and the emergent beach rock (Appendix C7). Other beaches in this area with deeper sand, such as V beach, White's Beach and Tortuga Beach support much higher nesting densities of green turtles (Table 8-13).

Flacourt Bay, where the alternative pipeline shore crossing is proposed, is an important green turtle nesting habitat (Plate 8-24). Surveys in the summers of 2003-2004 and 2004-2005, indicated that nesting densities at Flacourt Bay were consistently high in relation to other west and north-west beaches on the island (Table 8-13).

Green turtles are likely to occur across the shallow shelf between Barrow Island and the mainland and are likely to visit all areas of the proposed domestic gas pipeline route and optical fibre cable route to Onslow. The proposed shore crossing for the domestic gas pipeline is in mangroves and mudflats. While green turtles may feed in this area, the absence of sandy beaches makes it unsuitable for nesting.

Heavy fishing pressure on local sea turtle populations in the Onslow area last century is likely to have reduced the breeding stock in this area. Nesting densities are very low along the beaches adjacent to the optical fibre cable crossing at Onslow (K Pendoley 2005, pers. obs.).

Flatback Turtles – The beaches either side of the proposed Development area at Town Point are preferred flatback turtle nesting beaches. No flatback turtles were observed on the seabed during extensive towed video surveys of the seabed off Town Point for the current study and there are no benthic habitats restricted to the area of the proposed development at Town Point (Appendix C8). Surveys in winter 2005 will determine whether the sandy seabed off Town Point is important to inter-nesting or hibernating flatback turtles.

Flatback turtles occur across the shallow shelf between Barrow Island and the mainland and are likely to visit all areas of the proposed domestic gas pipeline route and optical fibre cable route to Onslow. The proposed shore crossing for the domestic gas pipeline is in mangroves and mudflats. While flatback turtles may feed in this area, the absence of sandy beaches and vast expanses of intertidal salt-flats behind the mangroves make it unsuitable for nesting.

A flatback turtle rookery has recently been identified at Back Beach, Onslow (K Pendoley 2005, pers. obs.). The limited information available on this rookery suggests it is not as large as the Munda Station rookery to the north or the Thevenard or Barrow Island rookeries offshore.

Sea Snakes and Kraits – Sea snakes are highly mobile and are likely to occasionally visit all of the deep offshore, shallow offshore and mainland Development areas.

The extensive mangroves along the mainland coast provide important habitat for these marine reptiles. However, all habitats in the proposed shore crossing area are well represented outside the proposed Development area. Sea snakes are expected to visit the mangrove area, nearshore islands and Onslow nearshore reefs to forage, but are not expected to be dependent on the small zone proposed for the shore crossings.

Fish

Fish are a ubiquitous component of the biodiversity of marine ecosystems. Most marine fish have a pelagic egg and larval phase that promotes dispersal over large distances. Consequently, the majority of species are widespread throughout the Indo-West Pacific region. However, some larger species, particularly sharks, are both migratory and endangered and are protected by state and federal legislation. Some species are also subject to fishing pressure and are protected under the Western Australian *Fisheries Resources Management Act 1994.*

The likely distribution of fish species of conservation significance, both within the proposed Development area and region, was derived from the literature. Further information is included in Technical Appendix C6.

The Montebello Islands region supports higher species richness of marine fish than most other parts of tropical Western Australia. The fish fauna (ichthyofauna) of the region is very species rich with over 450 species of fish recorded from the Montebello Island group alone (CALM 2004). In the Barrow Island area, no areas of regional importance to fish were identified during seabed surveys of the proposed Development areas. Pelagic fish are likely to be attracted to the high profile reef in 40-50 m water depth on the proposed feed gas pipeline route and trevally were observed schooling in this area in January 2004. These high profile reefs off the west coast of Barrow Island are likely to be home to a diverse fish assemblage, possibly including protected *Epinephelus* cod species.

Potato cod *(Epinephelus tukula)* are protected under the Wildlife Conservation Act and all large Serranid grouper are protected under the *Fisheries Resource Management Act 1994.* Other fish in the area are protected from over-fishing by legislated catch restrictions in Western Australian waters.

Regional

Sharks – The whale shark *(Rhincodon typus),* grey nurse shark *(Eugomphodus taurus)* and the great white shark *(Carcharodon carcharias)* may occasionally visit the Barrow Island area and are protected under both the Wildlife Conservation Act and the EPBC Act.

The whale shark *(Rhincodon typus)* is a listed migratory species under the EPBC Act and occurs along the northern Western Australian coast, including the offshore islands of the Montebello/Lowendal/Barrow Island region. Whale shark movements are thought to be associated with local productivity events (Last and Stevens 1994). Whale sharks congregate each year around March – April off Ningaloo Reef at Exmouth probably in response to local food availability.

Grey nurse sharks are widely distributed around Australia, from the surf zone down to at least 190 m water depth (Last and Stevens 1994). In Western Australia, they occur at Ningaloo Reef, Barrow Island and in temperate south-western waters.

Little is known of the conservation status of grey nurse sharks in Western Australia (Appendix C6). There have been no surveys of the grey nurse shark distribution in Western Australian waters. Therefore no aggregation sites or other sites critical to the survival of grey nurse sharks have been identified in Western Australia (Environment Australia 2002).

Sygnathids – Pipefish, pipehorses and sea horses are widely distributed in Western Australian waters, but the distribution of individual species within the region is little known. These fish are protected under the EPBC Act.

The Commonwealth Department of the Environment and Heritage (DEH) database indicates that Barrow Island lies within the general distribution area of 30 species of listed pipefish and seahorses. *Hippocampus hystrix* and *Phoxocampus belcheri* are the only listed species recorded from Barrow Island (G Moore 2004, Western Australian Museum, pers. comm.). The distribution of the other protected species is known only from a few records from the Pilbara region. It is assumed that they may be present in the Barrow Island and mainland areas with the exception of *Hippocampus kuda,* which is listed, but is not known from Australian waters.

Gorgon Development Areas

Sharks – Whale sharks are expected to be occasional visitors to the proposed Development area on either side of Barrow Island. Little is known of population sizes of the Western Australian stocks. There are no known up-welling areas, or other spatially restricted habitats, in the vicinity of any of the proposed Development area.

Grey nurse sharks are expected to occur in areas of the deeper, high profile reefs off the west coast of Barrow Island along the proposed route of the feed gas pipeline.

Great white sharks are highly mobile, but favour temperate waters and would rarely be encountered in the Development area. Barrow Island is the northern extreme of the documented distribution for great whites.

Sygnathids – Pipefish and seahorses are expected to be widespread through the shallower benthic habitats of the area. Some of the protected species are expected to occur in the vicinity of the proposed pipeline routes and nearshore infrastructure on the east coast of the island and on the mainland coast. Some pipefish or seahorse species may inhabit the mangrove areas and subtidal reefs of the mainland coast; however, the proposed crossing locations do not include any spatially restricted habitats and are not expected to be of particular significance to these species.

Marine Invertebrates

Marine invertebrates are a major component of the regional biodiversity. The group includes the molluscs (octopus, snails and squid), crustaceans (prawns, lobsters and crabs), echinoderms (sea stars, sea urchins and sea cucumbers), cnidarians (hard corals, soft corals, anemones and jellyfish) and annelids (worms). In addition to these well-known taxa, there are myriad other cryptic and minute species.

Marine invertebrate assemblages are typically diverse because they live in a range of habitats including the water column, soft sediments (infauna and epifauna), macrophyte and coral habitats (epifauna) and rocky reefs (filter-feeders).

The conservation significance of invertebrate assemblages within the Development area and region was derived from the literature. Additional information is included in Technical Appendix C6, Technical Appendix C8 and Technical Appendix C9.

Regional

The marine invertebrate fauna of the Montebello/Lowendal/Barrow Island region is species rich due to the diversity of habitats available. Invertebrate species richness is high at the Montebello Islands in comparison with other parts of tropical Western Australia. For example, there are 150 species of hard coral, 633 species of mollusc and 170 species of echinoderm (CALM 2004).

The marine invertebrate fauna of the Montebello/Lowendal/Barrow Island region has strong affinities with other areas of the Indo-West Pacific due to natural oceanographic links with these areas. This connectivity depresses levels of endemism within the region.

No marine invertebrates from the region have specific legislated protection status. Some species are of commercial interest and are protected under the *Fisheries Resource Management Act 1994* which regulates their harvest. The gastropod, *Amoria macandrewi,* is endemic to sand bars within the Montebello/Lowendal/Barrow Island region and is of higher conservation significance.

The invertebrate fauna of the rocky shores and intertidal mud and sand flats on the leeward sides of the offshore islands have strong affinities with the fauna of the nearshore intertidal areas of the mainland.

Barrow Island

The invertebrate assemblages of Barrow Island are typical of the region showing high diversity, strong affinities with more northern areas and divergence in assemblages between exposed and sheltered coasts.

The markedly different habitats of the western and eastern shores of Barrow Island support similarly different invertebrate assemblages. Of the 316 species of mollusc recorded from the shores of Barrow Island, less than a third occur on both coasts. Differences in the molluscan assemblage between the two sides of Barrow Island relate to the higher proportion of bivalve species in the muddier habitats on the east coast and more coral reef gastropod species on the west coast.

Invertebrate assemblages of the western and northern shores of the island are typical of the Pilbara offshore bioregion and have affinities with assemblages of the west coast of the Montebello Islands. Invertebrate assemblages of the eastern and southern shores are more similar to assemblages in the Pilbara nearshore bioregion along the mainland coast.

The giant clam, *Tridacna derasa,* was found on the east coast of Barrow Island during recent marine surveys. This is the first record for this species in Western Australia. *Tridacna derasa* occurs near Town Point and further south near Perentie suggesting a broad east coast distribution. This species has since been found off Dampier indicating that it has much wider distribution in Western Australia than thought previously (P Tod 2004, pers. comm.).

Coral habitats and rocky reefs around Barrow Island support highly diverse invertebrate assemblages. For example, 32 species of echinoderm and 75 species of shelled mollusc were found on the intertidal reef at Biggada Reef (Bowman Bishaw Gorham 1996). Crown-of-thorns seastars *(Acanthaster planci)* have been observed at low densities in coral areas east of Barrow Island (J Fitzpatrick 2004, pers. obs.).

Gorgon Development Area

All of the invertebrate assemblages in areas proposed for development are associated with habitats that are widely distributed in adjacent areas of the coast and regionally. None of the invertebrate assemblages are considered to be of high conservation significance.

The soft sediments on the seabed in the vicinity of the proposed subsea wellheads are heavily bioturbated indicating an active infauna assemblage. This assemblage type is typically dominated by polychaete worms and crustaceans that burrow into the sediment, together with larger demersal fish and crustaceans. This assemblage is probably very widely distributed in similar depths along the edge of the continental shelf. For example, the infaunal assemblages at the East Spar facility off the west coast of Barrow Island, in 80–90 m water depth, are similarly dominated by polychaete worms and crustaceans (Kinhill 1999). This is similar to most infaunal assemblages of northern Australia (Long and Poiner 1994).

The proposed feed gas pipeline route crosses large expanses of bare sediments and localised high profile reefs in 40-50 m water depth. The reefs support filter-feeding invertebrates including lithophagic sponges, gorgonians, black corals (cf. *Cirripathes*), seawhips, ascidians and bryozoans.

There are no invertebrate assemblages of particular significance where the proposed feed gas pipeline crosses the shore at Flacourt Bay or North White's Beach.

The broad intertidal reef platform and large rock pools at Town Point support diverse invertebrate assemblages typical of the east coast platform reefs. The invertebrate assemblage of the upper intertidal zone is dominated by barnacles, limpets, turbinid snails *(Turbo),* littorine *(Nodilittorina)* snails and rock oysters *(Saccostrea).* The large rock pools support a diverse assemblage of very small corals *(Turbinaria),* holothurians, chitons, hermit and portunid crabs, molluscs nudibranchs, squid, *Octopus,* ceriths, muricids *(Australium, Tridacna),* branching, encrusting and vasiform sponges.

The deeper parts of the pavement reef support soft corals *(Sarcophyton, Lobophyton, Dendronephthya,* and *Sinularia)* and hard corals *(Goniastrea, Euphyllia, Porites, Lobophyllia, Pleaseastrea, Favia, Favites, Turbinaria, Platygyra* and *Acanthastrea).* These taxa are all widespread along the east coast of Barrow Island.

The dense *Sargassum* bed covering the platform is home to a diverse assemblage of epifauna dominated by crustaceans, molluscs, small fish and worms. No significant invertebrate assemblages occur along the proposed causeway route or within the proposed access channels.

The soft sediments, where the tanker turning basin is proposed to be dredged, are largely bare of epifauna, with patches of seapens and occasional branching gorgonians. Outcropping rock on the ridge running south from Lowendal Shelf supports soft corals *(Rumphella),* seawhips *(Junceella),* gorgonians, fans, hydroids and small hard corals.

The infaunal assemblages of the dredged shipping channel are expected to be similar to those in the turning basin. Epifaunal assemblages on soft sediments in the turning basin and along the access channel are dominated by seapens and echinoderms (heart urchins, seastars, crinoids and holothurians) with seapens, sponges, hydroids and occasional gorgonians on exposed hard substrates.

All of the invertebrate taxa and assemblages along the proposed domestic gas route are expected to be widespread throughout the nearshore bioregion. The giant clam, *Tridacna derasa,* is only known from two locations on Barrow Island and one on the mainland and should be considered an evolutionary significant unit until its wider distribution can be confirmed.

The extensive intertidal sand and mud flat in the area of the mainland shore crossing supports a sparse invertebrate assemblage of crinoids, mud crabs *(Scylla),* molluscs *(Pinna, Polinices, Syrinx, Nassarius),* digitate sponges and sand dollars. This assemblage is typical of these habitats and well represented in adjacent parts of the coast.

Invertebrates inhabiting the mangroves in the vicinity of the shore crossing include barnacles attached to the trunks of the mangrove trees and fiddler crabs.

The invertebrate assemblages of the intertidal and subtidal pavement reefs and sandflats at Beadon Point and Beadon Beach are not of high conservation significance (LeProvost Environmental Consultants 1992). The habitats and assemblages in the vicinity of the optical fibre cable crossing at Onslow are expected to be well represented locally and regionally.

8.4 Social Environment

8.4.1 Introduction

This section summarises the area and regional demographics, population and lifestyle trends and livelihood, government policies and plans, land and sea tenure and use, aesthetics and existing cultural heritage aspects related to the Gorgon Development.

8.4.2 Population Trends and Demographics

The Pilbara region comprises the four local government areas of Port Hedland, Roebourne, Ashburton and East Pilbara. The vast majority of Pilbara residents are located in the western third of the region, which includes the main townships of Karratha, Port Hedland and South Hedland. A small number of Indigenous communities occur in the eastern portion of the region.

In 1993, the population of the Pilbara region was approximately 43 000 people. By June 2001, this had decreased to less than 40 000 people. This represents around 2% of Western Australia's population. Department of Local Government and Regional Development (2003a) statistics show that there has been a general population decline between 1996 and 2001 in the Pilbara Region (refer Table 8-15).

The following demographic trends have been identified for the Pilbara population:

- the population is generally younger, with less representation in the over 65 and 15-24 age categories, than for the state
- there is a higher proportion of Indigenous people as a portion of the population (13%) than for the state (3%)
- there is an uneven gender distribution within the region as compared to the state, with significantly more men (12%) than women living in the Pilbara.

8.4.3 Lifestyles and Livelihood

The development of the Pilbara has coincided with the discovery of vast deposits of iron ore and oil and gas resources in the region. Resource projects are the main economic and employment generators in the region and impact on the social profile and communities that support them.

The cyclical nature of many resource projects (i.e. peak workforce during construction phase, and a much smaller workforce during operations) leads to a corresponding boom/bust economy and transient populations in many service centres. Many operations also use a fly-in fly-out regime from Perth.

Pilbara residents generally earn an above average wage. Combined with an unemployment rate that is substantially lower than the state average, there is greater lifestyle flexibility available for Pilbara residents.

Because of the proximity of the majority of the regional population to the coast, fishing, diving and other marine-based recreational pursuits are common. In addition to this, the region's main towns contain many recreational facilities.

The region is also culturally and environmentally diverse, and is well-known for its heritage assets. While not in the specific Gorgon Development area, there are numerous examples of Aboriginal rock art

Table 8-15:
Regional and State Population Trends between 1996 and 2001

Region	1996	2001	Percent Change 1996–2001
Shire of Ashburton	7 379	5 945	–19%
Shire of East Pilbara	6 937	5 843	–15.85%
Town of Port Hedland	12 281	12 615	2.7%
Shire of Roebourne	13 829	14 841	7.3%
Pilbara Region	40 426	39 461	–2.4%
Perth Metropolitan Area	1 244 320	1 339 993	7.7%
Western Australia	1 726 095	1 851 252	7.3%

Source: Department of Local Government and Regional Development website: 'Regional Trends and Indicators' *(June 2003b): http://www.regional.wa.gov.au/rti/index.asp* throughout the Pilbara, and there are also a variety of natural attractions in the region, including the Karijini and Millstream/Chichester National Parks and the Dampier Archipelago.

Provision of social services in the Pilbara varies. While the main Pilbara towns have a reasonable level of social service provision, it is generally recognised that the health and welfare services in the remote communities of the Pilbara region are inadequate (Pilbara Development Commission 2003).

8.4.4 Government Policies and Plans

Overview

The Gorgon Development requires assessment under both federal and state legislation (refer to Chapter 4), and as such should consider government policies and plans at the federal, state, regional and local levels.

At the federal level, the Commonwealth Government is responsible for broad policy direction and decision making on issues of national applicability. States have reduced fiscal responsibility and power, but should assume responsibilities such as service provision under the general policy direction of the Commonwealth. Within Western Australia, local government authorities (LGAs) are responsible for service provision and are generally limited in terms of income generation and statutory responsibility. The Shires of Ashburton and Roebourne would be the two LGAs most affected by the proposed Gorgon Development.

Relevant Policies and Strategies

There are a wide range of existing government policies and strategies which are relevant to the proposed Gorgon Development. Relevant government policies are outlined in Table 8-16. The extent to which the Development meets current government policies and strategies is discussed in Chapter 14.

8.4.5 Land and Sea Tenure and Use

Commonwealth and State Jurisdiction

The Gorgon Development has components that will be located in both federal and state jurisdictions. The upstream well development will be within Commonwealth waters (outside the 3 nautical mile boundary west of Barrow Island), while the majority of the pipelines, gas processing facility, and marine infrastructure will be located on state land or within state waters (includes both 'internal' and 'coastal' waters).

Barrow Island Tenure and Use

Barrow Island was declared a Class A nature reserve in 1910 under the *Permanent Reserves Act 1899.* It was therefore deemed to be reserved under section 41 of the *Land Administration Act 1997* (schedule 3, clause 2(3) *Land Administration Act 1997).*

In 1966, the State Government of Western Australia granted a Petroleum Lease (L1H) to West Australian Petroleum Pty Ltd (WAPET). The *Petroleum Act 1936* was amended in order to allow WAPET to produce oil; however, the Class A nature reserve status of the island was not relinquished. Although the *Petroleum Act 1936* was repealed by the *Petroleum Act 1967,* the earlier Act continues to apply to the Barrow Island lease and its renewal. The lease is currently held by Chevron Australia, Santos Offshore and Mobil Australia Resources Company (the Barrow Island Joint Venture) and covers all but two small exploration areas (EP 61 and EP 62) held solely by Chevron Australia. Management of the nature reserve is overseen by CALM.

Land use on Barrow Island is restricted due to its classification as a reserve for conservation purposes. Barrow Island has been actively used for petroleum exploration purposes since 1964, and has since become Australia's largest onshore oilfield. Access to the island is restricted to personnel associated with oilfield operations and CALM.

The State Agreement provides that no more than 300 ha in total of uncleared land is to be leased, or the subject of licences or easements, for gas processing projects. Of this 300 ha, 150 ha of uncleared land is reserved for the Gorgon Development and 50 ha is reserved for easements for any petroleum pipelines, control lines and ancillary services.

Mainland Tenure and Use

A significant pastoral lease (Mardie Station) extends across the mainland coastline in the vicinity of the proposed domestic gas pipeline route. The lease is 226 445 ha in area and is held by Chininara Pty Ltd (Lease No. 453.1984 – formerly 3114/1027). The lease area contains numerous reserves for 'Water' purposes and the property is traversed by the De Grey – Mullewa Stock Route and unsurveyed public roads. The land is used for pastoral purposes.

Table 8-16:
Summary of Relevant Government Policies and Strategies

Government Policy or Strategy	Purpose/Objectives
'Stronger Regions, A Stronger Australia' (Commonwealth Department of Transport and Regional Services 2001; Commonwealth Government Regional Policy Statement)	In 2003, an Action Plan for the implementation of this Policy was created by an independent panel. The Action Plan assesses regional development issues according to the broad subject areas of business, government, people and infrastructure.
'Hope for the Future – The Western Australian State Sustainability Strategy' (Sustainability Policy Unit 2003)	This Strategy provides a framework for a whole of government approach to the state's development in accordance with sustainability objectives.
'The State Planning Strategy' (Western Australian Planning Commission 1997)	This Strategy indicates that, 'in the next three decades, the Pilbara region will be a world leading resource development area focusing on mineral extraction, petroleum exploration and production and the primary stages of downstream processing…'.
'Regional Western Australia – A Better Place to Live' (Department of Local Government and Regional Development 2003a)	This Policy provides a framework for the development of the state's non-metropolitan regions to achieve 'social, economic and environmental progress in a sustainable way'.
Western Australian Government's (draft) 'Pilbara Land Use Strategy'	The Pilbara Land Use Strategy is a strategic 25-year plan for the Pilbara, based on the principles of ecologically sustainable development and multiple land use principles. The Strategy sets broad objectives for the development of the Pilbara.
'Pilbara Regional Priority Plan' (Pilbara Development Commission 2003)	The Pilbara Regional Priority Plan was formulated in response to a Cabinet Standing Committee on Regional Policy determination in June 2003. The Plan was developed using the sustainability framework provided in the State Sustainability Strategy and involved the engagement of stakeholders. The Plan attempts to achieve the creation of a social environment that attracts and retains a skilled workface, and provides an attractive and safe environment for residents.
'Karratha Area Development Strategy' Western Australian Planning Commission (1998)	The Karratha Area Development Strategy was prepared as a comprehensive, integrated and far-sighted strategy to guide the rapid growth of Karratha, and the wider surrounding area. It is intended to resolve conflicting land and water use demand, guide and control the use of land and water, and coordinate infrastructure provision and urban expansion for the next 25 years. 'Town Planning Scheme No. 8'
Shire of Roebourne Town Planning Scheme No. 8 (2000)	The Shire of Roebourne's Town Planning Scheme (TPS) controls the planning and development of land within the Shire's jurisdiction. The Karratha Area Development Strategy, although a non-statutory planning document, provided guidance for aspects for the Roebourne TPS.
Shire of Ashburton Town Planning Scheme No. 7 (2004)	The Shire of Ashburton's TPS controls the planning and development of land within the Shire's jurisdiction.

Sea Tenure and Use

Barrow Island is located within the jurisdiction of the State Government of Western Australia. Any petroleum related exploration or production within state jurisdiction is controlled by the Western Australian *Petroleum (Submerged Lands) Act 1982.*

Beyond the 3 nautical mile state waters boundary, west of Barrow Island, the sea falls under Commonwealth jurisdiction for a further 200 nautical miles. Any petroleum related exploration or production within these waters is subject to the provisions of the Commonwealth *Petroleum (Submerged Lands) Act 1967.* The Gorgon gas field is located in Commonwealth waters and comprises a significant number of petroleum titles (Figure 1-2, Chapter 1).

There are several other tenures that should be considered:

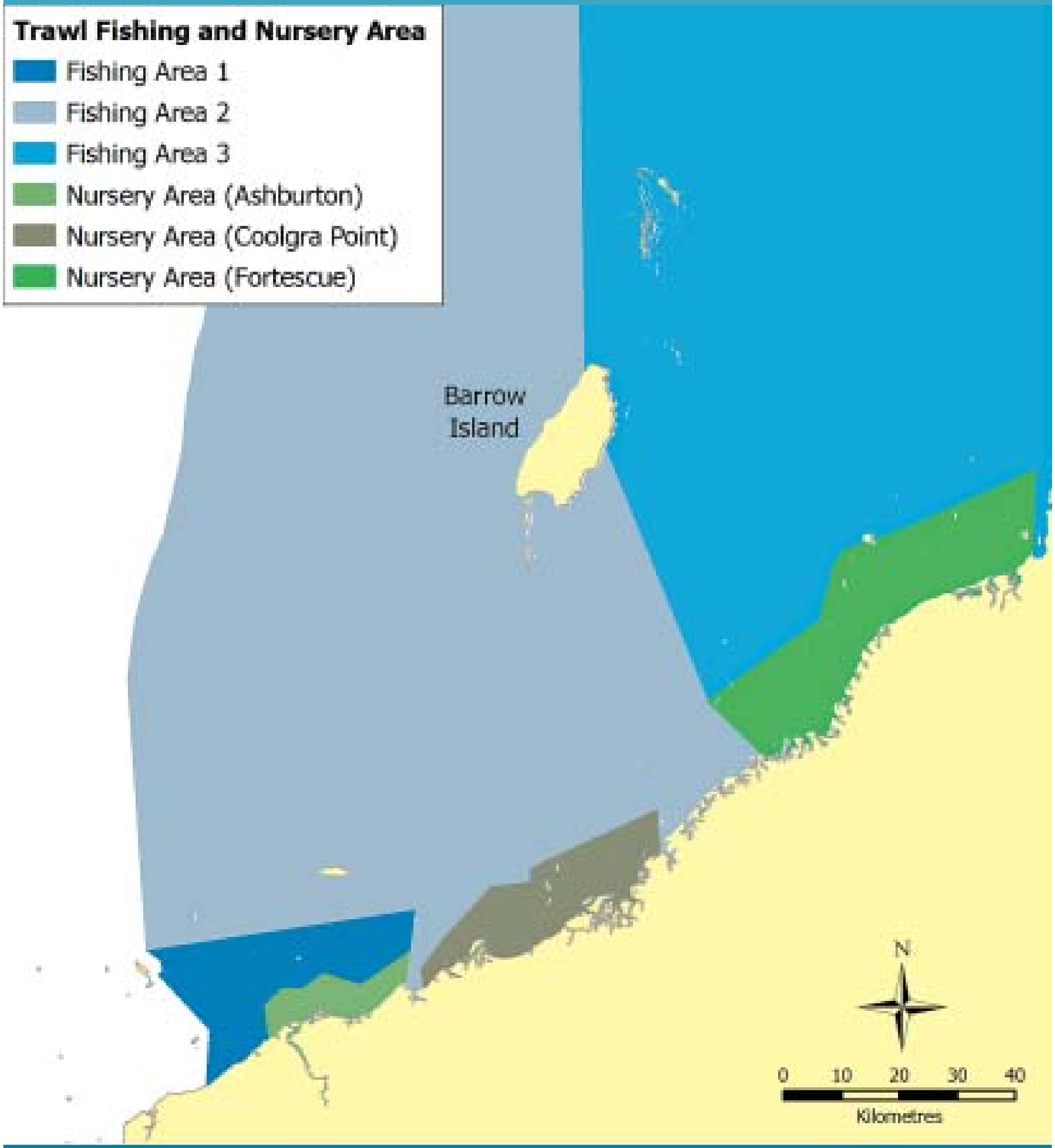
- Barrow Island port limit – pursuant to Section 10 of the *Shipping Pilotage Act 1967*, this limit enables the harbourmaster to restrict all shipping movements within the port limit (refer to Figure 8-21).
- Recommended track – this is the recommended path for shipping movements according to surveyed conditions. As such, a high level of shipping traffic may be expected along this route.
- Prohibited entry areas – these exclusion zones around wells, platforms and other oil and gas infrastructure vary between 4.5-9 nautical miles.
- Oil and gas pipelines – there are a number of subsea pipelines and wellhead platforms/monopods in the vicinity of the Gorgon Development, including: the Chevron Australia export pipeline located within the Barrow Island Port boundary; the Apache Energy East Spar; Wonnich, Harriet, and Double-Island pipelines (with their associated topside monopods and wellhead platforms); and two export natural gas pipelines running between Varanus Island and the mainland. There are also gas and oil processing and storage facilities on Thevanard and Varanus islands. Other oil and gas developments are located to the south (Griffin, Thevanard, Crest, Roller, Saladin and Yammaderry) as well as to the north (Goodwin, N. Rankin, Perseus, Cossack, Stag and Wandoo), but these are at a significant distance (> 40 km) and would not be affected by the construction and/or operation of the Gorgon Development.
- Montebello – Barrow islands marine conservation reserves – The Development falls within the multiple use area. Petroleum exploration, drilling and pipelines and dredging activities are subject to the *Environmental Protection Act 1986* and subject to assessment by relevant government agencies. The primary role of reserve management in relation to hydrocarbon exploration and production is ensure that these activities are ecologically and socially sustainable and to ensure equitable access to the proposed reserve for the industry (Figure 8-21).
- The proposed feed pipeline from the gas fields to Barrow Island transects an area (Zone 1 of the Pilbara Fish Trawl Interim Managed Fishery) that has been lightly trawled in the past and is the site of a trawl research area. However this area is currently not trawled.
- Pearl culture – There are no pearling areas/zones crossed by the proposed Gorgon Development. Pearl farms may be floating or fixed structures with associated moorings, generally marked by buoys or beacons. The nearest is on the Montebello Islands.
- Great Sandy Island Nature Reserve – A portion of the domestic gas pipeline and an optical fibre cable would cross this large nature reserve which extends from east of Cape Preston, approximately 110 km west towards Onslow (refer to Figure 1-5 in Chapter 1).

The busiest Australian ports, in terms of tonnes of cargo handled in 2000-2001 were Dampier, Newcastle, Port Hedland, Hay Point, Gladstone, Port Walcott, Port Kembla, Brisbane, Melbourne and Sydney (Bureau of Transportation and Regional Economics 2003). Barrow Island Port handles very few ships and very little cargo volume in comparison to these ports.

The north-west shelf supports an active commercial fishing, marine based tourism and recreation, and oil and gas exploration and production fleet. The Onslow Prawn Managed Fishery (OPMF) contributed $1.7 million in revenue to local fishers in 2001 (Department of Fisheries 2003).

The OPMF targets western king prawns, brown tiger prawns, endeavour prawns and banana prawns. Regulations ensure that prawn trawling is restricted to three areas (shown in Figure 8-27) with associated nurseries (Ashburton nursery, Coolgra nursery and Fortescue nursery). Prawn fishing is controlled by:

Figure 8-27:
Map Showing Commercial Fishing Boundaries



- limited entry
- seasonal and area closures
- gear controls
- boat size restrictions
- catch reduction devices (introduced in 2003).

There are currently 12 prawning vessels operating over the three management areas, employing approximately 25 people, including 10 local processing staff. Data obtained from the Western Australian Department of Fisheries indicates that the stretch of water between Barrow Island and the mainland supports a level of prawning activity at 60-130 tonnes for 2000/2001, which is well short of the catches in the Exmouth or Shark Bay fisheries. The trawling patterns indicate the highest level of activity in 'Area 3' within the Fortescue nursery and close to the mainland shore. Trawling within nursery areas is permitted except at those times when prawns are breeding. This generally occurs anytime between March and November and the Department of Fisheries operates rolling closures during this period in response to seasonal conditions.

8.4.6 Visual and Aesthetics

Offshore

The subsea gas-gathering system will be located on the sea floor at the Gorgon gas field, approximately 70 km west of Barrow Island, and so would not have any visual impact implications above the waterline.

Onshore – Barrow Island

The landscape of Barrow Island is arid and rugged. The coastline consists of weathered rocky headlands, interspersed with white sandy beaches. Landscape form consists of limestone uplands, dry creek beds, red sands, white dunes, beaches, clay and salt flats, and intertidal flats. There are five landscape units identified on the island. These units and a brief description of each are provided in Table 8-3.

Due to the arid climate, vegetation cover is low and generally sparse. Existing oil extraction infrastructure, including wells and associated pumping equipment are intermixed throughout the central region of the island with the tallest structure being the communication tower (120 m high) situated on the highest central upland point (65 m above sea level).

Onshore – Mainland

One option is to route the domestic gas pipeline parallel and adjacent to the existing Apache Energy Sales Gas Pipeline. This route would cross low-elevation (0-50 m AHD) and sparsely vegetated rural pastoral lands. The new pipeline will be buried underground, so will have very limited and temporary visual impacts.

8.4.7 Cultural Heritage

Barrow Island

Barrow Island occupies a potentially important position in the Indigenous archaeology of north-western and continental Australia. It is located between the Cape Range Peninsula and the Montebello Islands, both of which were initially occupied by Indigenous people at 34 200 ± 1050 years Before Present (BP) and 27 220 ± 650 years BP respectively. The presence of two areas with such long occupation records either side of Barrow Island strongly suggests that Barrow Island may also contain Indigenous archaeological material of great antiquity in both rock shelter and possibly stratified sites in sand dunes.

A search of the Register of Aboriginal Sites (the Register) held by the Department of Indigenous Affairs (DIA) indicates that no ethnographic sites are listed on Barrow Island. The Register indicates that the DIA has records of 13 archaeological sites located on Barrow Island (refer to Chapter 14 and Technical Appendix E2 for a description of these artefact scatter sites). The proposed pipeline routes, including shore crossings, and gas processing plant site area have been examined by archaeologists and no new Indigenous cultural sites or materials were discovered in areas likely to be disturbed. The possibility of finding new Aboriginal sites or materials, particularly along the coastal areas and drainage channels exists.

Mainland

The general area of the Pilbara coastline, where the domestic gas pipeline is proposed to come ashore, contains a range of archaeological sites that include shell scatters and middens, artefact scatters near claypans and Indigenous burials in dunes. These sites generally date to the last 7000-years when the coastline approximated its current position.

A number of Indigenous archaeological assessments have been conducted in the vicinity of the proposed onshore pipeline route. In this respect, the Register indicates that there are two ethnographic sites located close to the proposed pipeline route on the mainland. Altogether, there are nine identified cultural heritage sites within the vicinity of the onshore pipeline route.

Maritime Heritage

Records indicate that there are no known shipwreck sites along the proposed Gorgon Development subsea pipeline routes. However archival sources suggest that a number of significant vessels have been lost in the Onslow/Barrow Island region; and there is potential for lugger shipwreck sites to occur in the vicinity of Barrow Island. The existence of any residual wreckage (which would constitute an archaeological site) can only be determined on discovery. The proposed pipeline shore approaches, the MOF and shore areas around the proposed gas processing plant site area have been examined by a marine heritage expert and no shipwreck sites were discovered. Although shipwreck sites most often occur in shallow reef areas, sites may also occur in deep water. Marine underwater video survey work and review of side-scan sonar results to date have not revealed the presence of any shipwreck material.

8.4.8 Native Title

Barrow Island and Offshore Waters

There are no lodged Native Title claims over the Gorgon gas field and Barrow Island. However Native Title rights over onshore and offshore seas have been recognised by Australian courts, and it is possible that a future Native Title claim could be made to the offshore areas of the Gorgon gas fields.

In terms of Barrow Island, the High Court in the *Ward Case* (August 2002) held that vesting of reserves under the *Land Act 1933* has extinguished Native Title. Accordingly, the vesting of Barrow Island as a nature reserve will have extinguished Native Title to the island.

Mainland

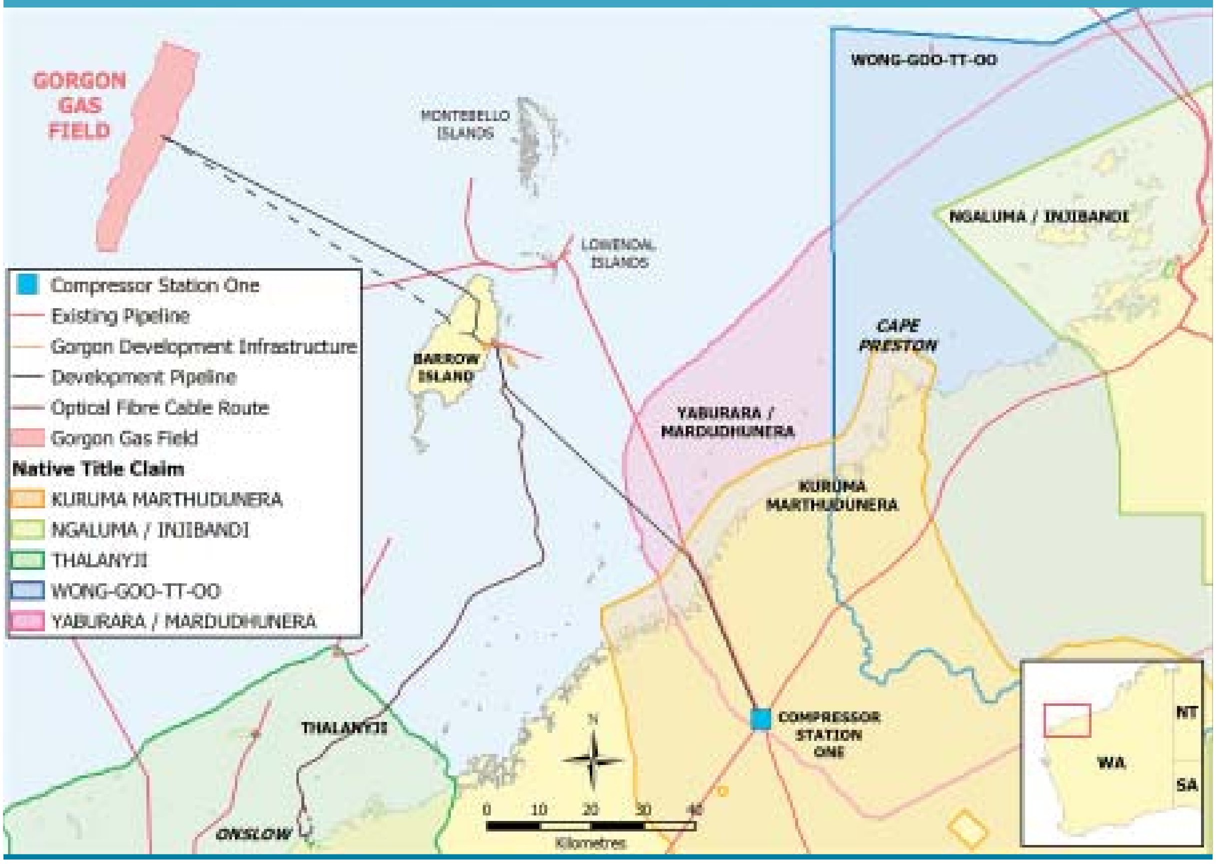
There are currently three registered Native Title claims that may overlap the proposed domestic gas pipeline route and onshore seas approach to the mainland (refer to Figure 8-28):

- Yaburara and Mardudhunera people (Tribunal No. WC96/89)
- Wong-goo-tt-oo (Tribunal No. WC98/40)
- Kuruma Marthudunera (combined) (Tribunal No. WC99/12).

Australian courts have upheld that a pastoral lease does not necessarily extinguish Native Title, and that various Native Title rights and interests can co-exist with the rights and interests of a pastoral lessee. However, where those native title rights and interests are inconsistent, the rights of the pastoral lessee may prevail. In other words, while Native Title is not necessarily extinguished by a pastoral lease, it cannot affect the ongoing operation of a pastoral lease.

These registered claims allow claimants to have procedural rights in relation to the compulsory acquisition of land for the proposed onshore pipeline easement. In addition, the claimants have a right to object within two months of being notified of the proposed grant of the easement, in so far as it affects their registered native title rights and interests (including rights and interests claimed in the onshore sea approaches to the mainland).

Figure 8-28:
Native Title Claim Boundaries in the Vicinity of the Development Area



8.5 Economic Environment

8.5.1 National Economy

The resource industry contributes largely to the Australian economy:

- mineral and petroleum production makes up 35% of Australia's good and service exports
- capital investment in the resources sector accounts for 12% of annual private capital investment in Australia.

Australia's balance of payments is critically dependent on a successful resources sector. In particular, Western Australia's resources sector is very significant in terms of the national economy, accounting for:

- over 48% of the nation's mining and petroleum production
- over 60% of the nation's mineral exploration investment
- 70% of the nation's petroleum exploration investment
- 79% of the nation's oil and condensate production
- 100% of the nation's LNG production.

Western Australia's extensive energy reserves provide a significant competitive advantage to the state. This state is now the major oil and gas producer in Australia and has more than three-quarters of Australia's identified natural gas resource within its jurisdiction and in adjoining Commonwealth waters. This means that Western Australia will continue to be an important contributor to the expected growth in global LNG supply over the medium-term. For example, the NW Shelf development, commissioned some 20 years ago, constitutes Australia's only operating large-scale, gas export project. In 20 years of operation, the NW Shelf project has supported significant economic activity, both directly and indirectly, through:

- significant export trade
- substantial revenue flows to the Australian and Western Australian communities via their governments, allowing for lower income and other taxes and higher disposable income
- better trade relations in the Asia-Pacific region for Australian industry, as well as improved international reputation as a reliable and competitive supplier of strategic goods
- employment opportunities and industrial growth
- an economic base to develop remote areas in the region
- substantial supply of natural gas to Western Australia, providing a cheaper and more greenhouse-friendly energy product to households and industry.

8.5.2 State Economy

The economy of Western Australia is dominated by the resources sector, and to a lesser extent, by the agriculture sector. The state economy is very export-oriented, which differs from the Australian economy as a whole. In 2002–03, the state resources sector (DoIR 2003):

- provided over 78% of the state's total exports, estimated at $25 billion in 2002–03
- contributed 23% of the state's Gross State Product (GSP), mainly through export income as well as downstream manufacturing and processing
- directly employed 5% of the state's workforce
- indirectly employed an additional 15% of the state's workforce.

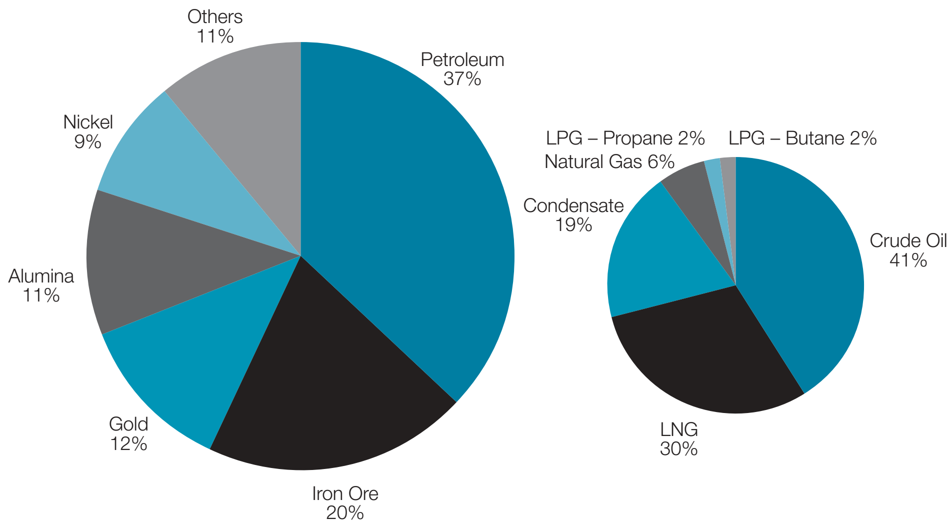
Petroleum and related products accounted for 37% of resource sales, as shown in Figure 8-29.

Western Australia is a major player in the resources sector with almost 500 projects and some 50 different minerals in commercial production. Over 60 State Agreements between the state and industry underwrite the contribution that the resources sector provides to the state economy (DoIR 2003):

- Western Australia's business investment in 2002–03 recorded a solid 19% increase compared to the previous year. Business investment in the state is highly dependent on activity in the state's resource sector, with around 55% or $3.9 billion of capital expenditure being accounted for by the mining sector in 2002–03.
- Within Western Australia, mining investment rose by 26% to $3.9 billion in 2002–03, compared to $3.1 billion in 2001–02.
- Western Australia accounted for 43% of the total Australian mining investment of $9.0 billion in 2002–03. This compares to 43% of Australian mining investment of $7.3 billion in 2001–02.

Comparisons of total new investments within Western Australia and Australia over recent years are presented in Figure 8-30.

Figure 8-29:
State Resources Sales 2002–03 – $27.9 billion

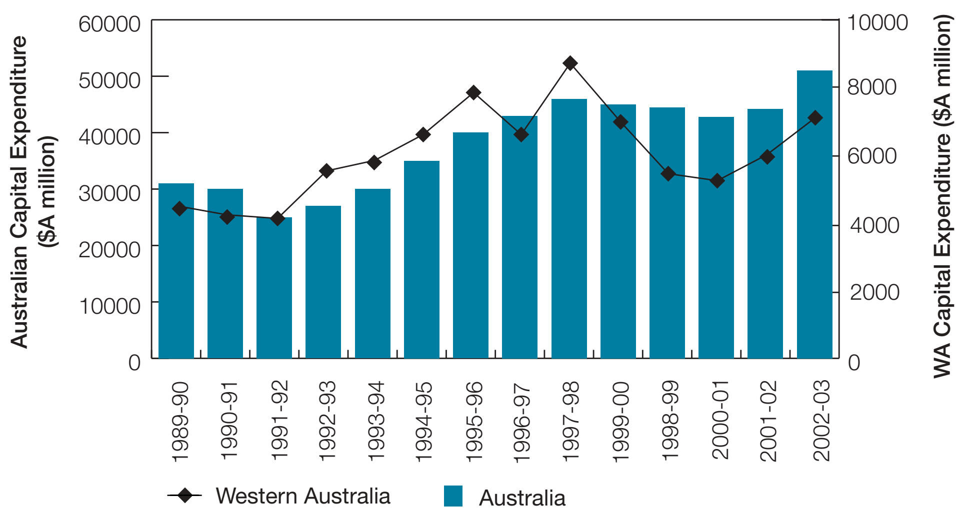


8.5.3 Regional Economy of the Pilbara

The Pilbara is one of the most vital and dynamic wealth producing regions in Western Australia, responsible for the production of goods and services worth more than $16 billion per annum. The mining and petroleum industries continue to be the predominant earners for the region, with a total value of production of $15.3 billion per annum, which accounts for more than 55% of the state's total mineral and energy production. While the mineral and petroleum sectors will continue to be the mainstay of the Pilbara's economy, the region is continuing to diversify and expand its economic base with the continued development of its tourism, retail, trade and agricultural industries.

The Pilbara economy is based primarily on petroleum, iron ore and solar salt production. The value of petroleum products contributes around 65% of the region's wealth derived from the mineral and petroleum industry. Sales of the main three output products of the proposed Gorgon Development, namely natural gas, petroleum condensate and liquefied natural gas, are

Figure 8-30:
Private New Capital Expenditure – Western Australia and Australia



increasing. In 2001–02 the production of natural gas was valued at $622 million, which was 97% of the state's natural gas production. The value of petroleum condensate for 2001–02 was $1.7 billion, virtually all of the state's production. LNG production was valued at $2.6 billion in 2001–02, all from the NW Shelf project located in the Pilbara (ChevronTexaco Australia 2003b).

Table 1-3, in Chapter 1, shows planned and proposed projects, their reported project value, employment characteristics and reported construction commencement dates. The viability of these projects is strongly tied to economics, including world market demand, commercial arrangements and many on the world cost to finance these endeavours.

8.5.4 Economic Policies Influencing the Gorgon Development

Barrow Island Act 2003

The *Barrow Island Act 2003* sets out and authorises an agreement between the state and Joint Venturers for the proposed Gorgon Development. Schedule 1 of the Act contains various conditions for the proposed Development, of which the relevant economic conditions are outlined in Table 8-17.

Australian Industry Participation Policy

The Joint Venturers have prepared a public policy regarding the support of Australian Industry for the Development (ChevronTexaco Australia 2003b, Appendix 6).

This policy benefits Australian industry, by:

- providing information and project briefings to Australian industry so that local suppliers have adequate time to identify potential opportunities and establish their competitive position
- assisting Australian industry in forming strategic joint ventures or alliances with offshore companies
- establishing a supplier diversity program and work with regional organisations, Indigenous organisations and Industrial Supplies Office to establish links between the Gorgon Development and local business, including a capability register and capacity building activities.

This issue is discussed further in the section on management of economic impacts (refer to Chapter 15).

Petroleum Resource Rent Tax

The Joint Venturers will be liable to pay Petroleum Resource Rent Tax (PRRT) to the Commonwealth Government of Australia. Royalty payments from the NW Shelf project are shared between the Commonwealth and Western Australia under a special arrangement. In the absence of a revenue sharing agreement, the Commonwealth will derive most of the tax revenue flowing from the Gorgon Development.

Greenhouse Policies

The *Barrow Island Act 2003* requires the Joint Venturers to submit proposals for management of carbon dioxide recovered from gas processing, by injection or sale. In the absence of such proposals, the Minister may decide not to consider proposals for activities and infrastructure on Barrow Island. The Act also contains clauses to enable disposal of carbon dioxide by injection, as the legal status of carbon dioxide disposal has been unclear.

The Western Australian Greenhouse Strategy was released in September 2004 (Western Australian Greenhouse Task Force 2004). The document contains a series of recommended 'Greenhouse Response Actions', some of which would apply to the proposed Development.

Currently there are no Commonwealth requirements for greenhouse gas management, although the Joint Venturers are participating in various voluntary programs.

Table 8-17:
Barrow Island Act Economic Conditions

Condition	Purpose
Section 7 – Proposals	• The Joint Venturers should submit detailed proposals for relevant activities and infrastructure. • If the proposals do not include a proposal to inject carbon dioxide recovered during gas processing, the Minister may decide not to consider the proposals. • This section links project approval with disposal of carbon dioxide from gas processing. It is discussed further in the section on greenhouse gas emissions.
Section 11 – Net Conservation Benefits	• Total amount of $40 million, indexed in accordance with the Consumer Price Index (CPI). • Special purpose Trust Account to be established pursuant to section 69 of the Western Australian *Conservation and Land Management Act 1984* (CALM Act). • Arrangements subject to agreement between Joint Venturers and the Barrow Island Minister in consultation with the CALM Act Minister. • Any proposal to increase the nameplate capacity of the LNG or other production facilities will attract a proportional increase in the amount to be paid. • This section of the Agreement is very important, as it seeks to establish a mechanism for economic management of the risks to conservation values.
Section 12 – Cost Recovery for Department of Conservation and Land Management	• This section requires the project to pay for additional costs to the Department of Conservation and Land Management. These costs include such aspects as monitoring and the salary of agreed CALM staff on Barrow Island.
Section 15 – Local Content	• Report regularly to the Minister on local content. • In summary, this section seeks to increase local content, and specifically, the employment of local workers from the Pilbara region. The Industry Participation Policy discussed below also addresses this point. This issue is discussed further in the chapter on management of economic impacts.
Section 17 – Domestic Gas	• Proposals for a domestic gas project by 2010, and first gas by 2012. • Process for determining whether domestic gas is commercially viable. • This section seeks to commit the Joint Venturers to producing gas for the domestic market. In particular, it recognises the risk that domestic gas may not be commercially viable, and sets out a process for determining this in the event of a disagreement.
Section 19 – No Discriminatory Charges	• No discriminatory taxes, rates or charges beyond those in the Agreement. • This section prevents state or local governments from applying discriminatory charges. However this does not appear to preclude general taxes or charges (such as carbon charges).

09: Risk Assessment Process

Environmental risk assessment is a process that evaluates the likelihood and consequence of adverse environmental impacts occurring as a result of exposure to one or more stressors. One of the advantages of this process over a more traditional environmental impact assessment approach is that it allows potential environmental hazards or threats to be considered on the basis of level of potential risk to the environment. This subsequently assists in prioritising development of management measures to achieve an overall acceptable level of risk.

Risk assessments have been undertaken in accordance with: AS/NZS 4360:2004, Risk management; SAA Handbook 203:2004, Environmental risk management – Principles and process; and AS/NZS 3931:1998, Risk analysis of technological systems – Application guide.

Risk assessments initially involved identification of stressors through a series of hazard identification workshops. Examples of stressors include light, noise and clearing and earthworks. This was followed by definition of consequence categories for groups of environmental factors. Prior to risk characterisation, ecological specialists identified groups of receptors (species or communities) which were considered to be sensitive to stressors associated with the Development (e.g. protected fauna, restricted flora and vegetation communities). Within each group of receptors, key receptor species were identified which were considered to be particularly sensitive to stressors and hence protective of the wider biological group. Risk levels (low, medium, high) were then estimated for each stressor and associated key receptor/s through an assessment of consequences and likelihood.

Risk assessments, including definition of consequences and identification of stressors and receptors, were undertaken by technical specialists with recognised expertise in a broad range of environmental fields. This included specialists with a long-standing knowledge and experience of working on Barrow Island.

9.1 Introduction

This chapter outlines the methodology used to assess risks associated with the proposed Gorgon Development. The methodology has been consultatively developed with specialist environmental and risk consultants (refer to Acknowledgements). The procedure was developed in accordance with the principles and guidelines contained in:

- AS/NZS 4360:2004, Risk management
- SAA Handbook 203:2004, Environmental risk management – Principles and process
- AS/NZS 3931:1998, Risk analysis of technological systems – Application guide.

The risk assessment methodology has been used primarily to assess the environmental risks associated with the proposed Development. Results and management strategies for the terrestrial and marine environment are presented in chapters 10 and 11. Where practicable, a risk-based approach was also applied to potential negative social and economic impacts. However, beneficial social and economic impacts must also be considered in the assessment process. Where beneficial impacts could not be assessed adequately using a risk-based approach, more traditional assessment approaches were applied as described in chapters 14 and 15.

One of the advantages of this process over a more traditional environmental impact assessment approach is that it allows potential environmental hazards or threats to be systematically identified and considered on the basis of potential risk to the environment. This subsequently assists in prioritising development of management measures to achieve an overall acceptable level of risk. This ability to focus on higher risk issues is particularly useful in assessing the implications of the Gorgon Development, which is a large and complex proposal that may have a multitude of potential impacts in an area of recognised conservation value.

9.2 Methodology

Environmental risk assessment is a process that evaluates the likelihood that adverse environmental impacts may occur as a result of exposure to one or more stressors (US EPA 1998). The overall environmental risk assessment process is shown in Figure 9-1 and broadly comprises the following steps:

- establishment of a risk assessment framework (definition of consequences and likelihood and establishment and validation of risk matrix)
- systematic identification of potential stressors (i.e. hazards or threats)
- identification of key receptor species or communities

- initial characterisation of environmental risks based on familiar management practices
- subsequent identification of additional management options to meet expectations for best practice environmental management, as required (i.e. elimination, substitution, reduction, engineering controls and management controls)
- analysis of residual risks based on additional management options, which reduce likelihood and/or potential consequences
- identification of preferred management option/s which will be adopted to reduce risks to acceptable levels.

Throughout the environmental risk assessment process the Joint Venturers have engaged specialists with recognised expertise in a broad range of environmental, social and economic fields. Risk assessments, including definition of consequences and identification of stressors and receptors, were undertaken by technical specialists with recognised expertise in a broad range of environmental fields (refer to Acknowledgments). This included specialists with a long-standing knowledge and experience of working within the proposed Development area, and on Barrow Island in particular.

An explanation of risk assessment terms used throughout this chapter and chapters 10 and 11 is provided in Table 9-1.

Figure 9-1:
Outline of Risk-based Environmental Assessment Process (after AS/NZS 4360:2004)

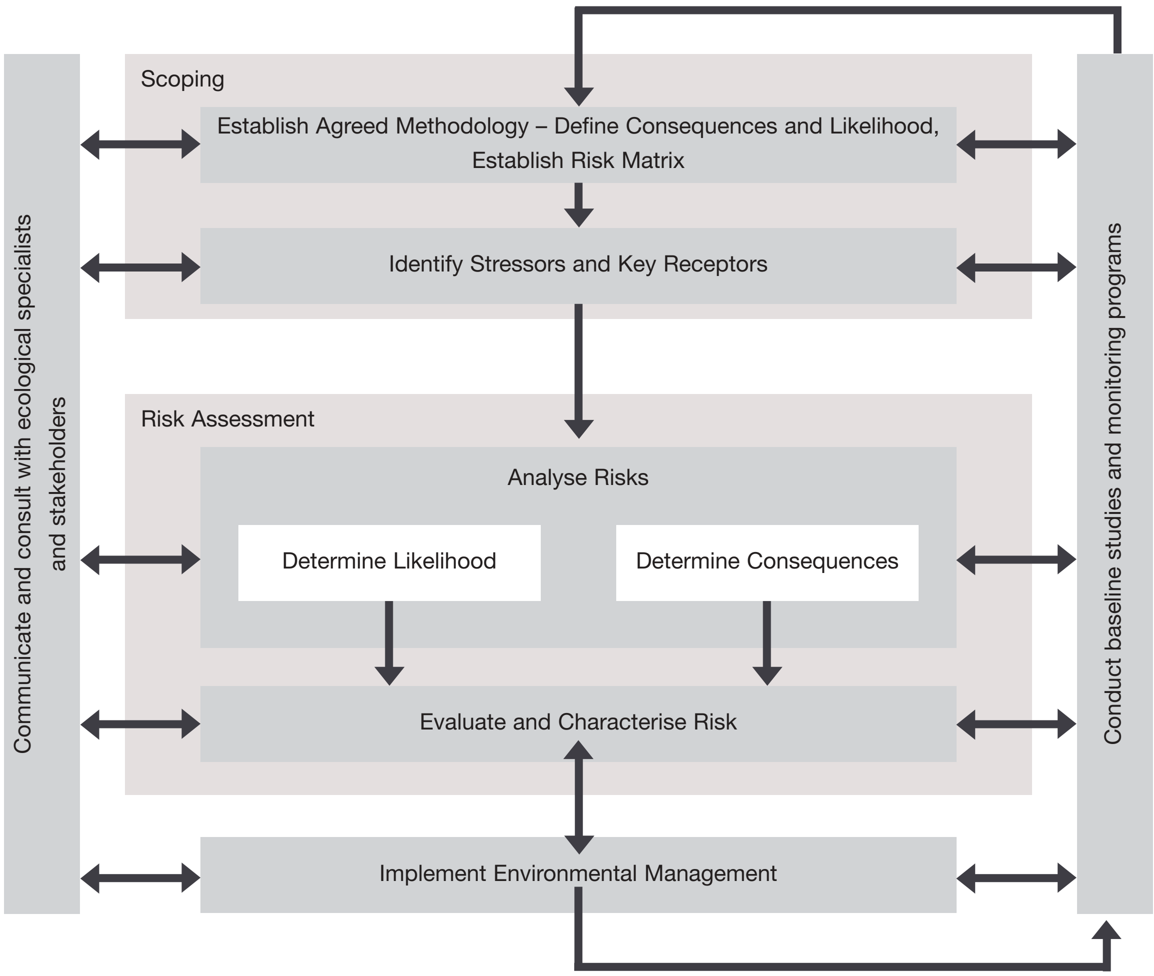


Table 9-1:
Risk Assessment Terminology

Term	Definition
Behavioural impact	Disruption of established behavioural patterns affecting reproductive or survival success.
Consequence	The implication of the impact (as defined).
Decrease in abundance	Loss of individual animals/plants.
Disruption	Interruption to the flow or continuity of biological processes and/or behaviour.
Hazard	A source of potential harm, or a situation with a potential to cause loss or adverse effect. Hazard has the same meaning as 'threat'.
Impact	Direct interaction of a stressor with the environment.
Impact on population	Decrease in abundance beyond natural variation in population size.
Immediate region	For aspects of the Development on Barrow Island or within the marine conservation reserves: Barrow Island, Lowendal Islands and Montebello Islands. For aspects of the Development offshore of Barrow Island: Pilbara Offshore Region. For aspects of the Development between Barrow Island and the mainland: Pilbara Nearshore Region. For aspects of the Development on the mainland: Pilbara.
Likelihood	The probability of a stressor impacting on the key receptors.
Local	Impacts restricted to the area directly affected by the Development and the immediate vicinity of the Development.
Long-term	Greater than five years.
Population	A group of organisms of the same species occupying an area.
Population viability	The ability of a group of organisms (occupying an area) to survive in that area.
Receptor	An ecological entity (e.g. species, population, community, and habitat) exposed to a stressor.
Reduced viability	Reduced ability of population to persist through time.
Region	Pilbara.
Short-term	Less than five years.
Species viability	The ability of the species to persist through time.
Stressor	A source of potential harm, or a situation with a potential to cause loss or adverse effect.
Widespread	Impacts extending to areas well-outside the direct impact zone from the Development.

9.2.1 Identification of Stressors

Potential stressors (hazards or threats) associated with the proposed Development were systematically identified through a number of HAZID (hazard identification) workshops. The main focus of the HAZID workshops was to identify credible threats to environmental values of the Development area as a result of planned activities. Workshops were also used to develop a shared understanding of the range of consequences that should be considered, so that consequence levels could be categorised for later risk assessment (Section 9.2.3).

The HAZID and risk assessment process relied on the expertise of workshop participants to identify hazards for specific activities under consideration. Therefore specialists with recognised expertise in a broad range of fields, knowledge of the proposed project and the environment within the development area were involved in the HAZID workshops. In addition, an environmental risk assessment expert facilitated the process, recorded outcomes, and maintained the integrity of the approach.

A comprehensive list of stressors associated with Development activities was prepared in advance of the risk assessment workshops with input from participants (Table 9-2). This list was used by environmental specialists to prompt consideration of the characteristics of various stressors in their assessment of potential consequences and likelihood of consequences.

Table 9-2:
List of Stressors Associated with Proposed Development Activities

Stressor	Associated development activities/facilities	Components
Atmospheric		
Light	• marine vessels • gas processing facility (construction/ operations) • construction village • marine facilities (MOF, LNG loadout, jetty) • pipeline construction • flaring	• direct light • diffuse glow
Combustion emissions	• construction equipment • power generation (electrical and mechanical) • flare	• particulates • NO_x, SO_x • VOC • BTEX
Fugitive emissions	• condensate tanks • condensate loading • valves and flanges	• VOC • BTEX
Dust	• construction (earthworks, vehicles, stockpiles, land clearing) • vehicles (operations)	
CO_2 discharge	• failure of CO_2 re-injection pipeline/well • reservoir leak/failure (fault structures, abandoned wells, etc)	• primarily CO_2 • minor VOC • minor BTEX • minor H_2S
Heated air	• air coolers • flare	

Table 9-2: (continued)
List of Stressors Associated with Proposed Development Activities

Stressor	Associated development activities/facilities	Components
Terrestrial		
Clearing and earthworks	• gas processing facility • construction village • airport extension • road re-alignment • pipelines • utility corridors • CO_2 monitoring (seismic and/or wells) • MOF/ jetty approaches	
Liquid and solid waste disposal	• grey-water for dust suppression (construction only) • system failure (all wastewater injected) • produced water (injected) • sewage (injected) • reverse osmosis brine (ocean discharge) • hydrotest water • domestic wastes • construction wastes • drilling waste	• BOD, COD • hydrocarbons • chemical additives • salinity • bacteria • heavy metals
Leaks or spills	• diesel storage and handling • condensate storage and handling • MEG, TEG storage and handling • aMDEA storage and handling • chemical storage and handling • pipelines	• BOD, COD • persistence/ biodegradability • toxicity • heavy metals • hydrocarbons • chemical additives
Fire	• construction and operation of facilities • vehicle exhaust • flare	• smoke • heat • nutrients • habitat modification
Noise and vibration	• built plant operations (turbines, air coolers, pressure letdown valves, pumps, etc) • blasting and earthworks • flaring • vehicles and equipment • drilling	
Physical interaction	• vehicle traffic • operation of equipment and machinery • workforce activities	• road kill • interaction/ disturbance

Table 9-2: (continued)
List of Stressors Associated with Proposed Development Activities

Stressor	Associated development activities/facilities	Components
Terrestrial		
Light and shading/ heat and cold	• pipeline • gas processing facility • construction village	
Dust	• vehicle and machinery movements	
Physical presence	• gas processing facility • construction village • sealed roads	
Marine		
Seabed disturbance	• dredging and blasting • dumping of dredge spoil • construction of marine facilities (MOF, causeway, LNG loadout, jetty, pipelines, optical fibre cable, subsea gathering system) • anchoring of drill rigs, pipelay vessels and dredge vessels	• habitat disturbance (benthic primary producers) • turbidity • smothering
Physical presence	• permanent presence of infrastructure (MOF, causeway, LNG loadout, jetty, pipelines, optical fibre cable, subsea gathering system)	• local flow change • habitat modification
Liquid and solid waste disposal	• hydrotest water • domestic waste and treated sewage • waste chemicals and oil • drilling waste (cuttings and drilling fluids) • produced formation water • reverse osmosis brine • stormwater runoff	• BOD, COD • persistence/ biodegradability • chemical additives • hydrocarbons • heavy metals
Leaks or spills	• storage and transport of chemicals, fuels or other hazardous material • MOF loading/unloading • vessel collision or grounding • failure of equipment or pipelines	• BOD, COD • persistence/ biodegradability • toxicity • hydrocarbons • chemical additives
Discharges	• marine construction vessels • dredge spoil • hydrotest water • drilling fluids • stormwater	• turbidity • anti-fouling leachate • chemicals

Table 9-2: (continued)
List of Stressors Associated with Proposed Development Activities

Stressor	Associated development activities/facilities	Components
Marine		
Physical interaction	• operation of vessels and barges • dredging of shipping channels • presence of construction workforce	• grounding • collision
Noise and vibration	• vessel movements • drilling (subsea facilities) • dredging (MOF, shipping channel, causeway) • pipelay (pipelines) • blasting (MOF, shipping channels) • piling (jetty) • HDD (west coast shore crossing) • operation of subsea gathering system	• disturbance • physiological effects

Note: all acronyms and abbreviations are provided in the supplementary information section of this document.

9.2.2 Identification of Receptors

Prior to undertaking risk assessments ecological specialists identified groups of receptors (species or communities) which were considered to be sensitive to stressors associated with the Development (e.g. protected fauna (listed/threatened species), restricted flora and vegetation communities) (Table 9-3). Within each group of receptors, key receptor species were identified which were considered to be particularly sensitive to stressors and hence protective of the wider biological group. Key receptors identified for protected fauna (listed/ threatened species) and general fauna are shown in Table 9-4. Similar information has been documented for all groups of receptors and is included in relevant sections of chapters 10 and 11.

9.2.3 Definition of Consequences

To describe the type and duration of potential impacts associated with the Development, definitions for five categories of consequences (minor, moderate, serious, major, critical) were developed. Specific scales of consequence were defined using criteria that were relevant to different groups of receptors, presented in Table 9-5. For example, in the case of a protected fauna species, consequences are analysed in terms of species behaviour and population size and viability, whereas consequences to soils and landform were defined in terms of soil contamination, soil characteristics and changes to landform.

Table 9-3:
Groups of Receptors and Associated Consequence Criteria

Groups of Receptors	Consequence Criteria
Terrestrial Environment	
Soils and landform	• soil contamination • soil characteristics • landform
Water quality (surface and groundwater)	• water quality • groundwater recharge
Air quality	• local air quality • regional air quality
Restricted flora and vegetation communities	• impact to species or community (abundance or distribution) • loss of species or community
General flora and communities	• impact to species or community (abundance or distribution) • loss of species or community
Protected fauna (listed/threatened species)	• species behaviour • population size and viability
General fauna (not listed/threatened)	• species behaviour • population size and viability
Subterranean fauna	• species behaviour • population size and viability
Marine Environment	
Water quality	• water quality
Seabed (subtidal and intertidal) Foreshore	• sediment contamination • benthic substrate characteristics
Benthic primary producers and significant communities	• impact to species or community • loss of species or community
General taxa and communities (flora)	• impact to species or community • loss of species or community
Listed species or evolutionary significant units	• species behaviour • population size and viability
General species and communities (not listed/threatened)	• species behaviour • population size and viability

Table 9-4:
Key Receptor Species for Listed and General Terrestrial Fauna Species

Key Receptor	Reason for Selection	Additional Species Represented by Receptor
Listed Threatened Species		
Euro, *Macropus robustus isabellinus*	Listed; largest marsupial on Barrow Island	
Black-flanked rock wallaby, *Petrogale lateralis*	Listed; low population size; significant issue on west coast	
Spectacled hare wallaby, *Lagorchestes conspicillatus conspicillatus*	Listed; non-burrowing; medium-sized marsupial	
Burrowing bettong, *Bettongia lesueur*	Listed; burrowing marsupial; site restricted	
Golden bandicoot, *Isoodon auratus barrowensis*	Listed; readily adapts to human presence	
Barrow Island chestnut mouse, *Pseudomys nanus ferculinus*	Listed; small mammals	Small mammals: *Zyzomys* sp., *Planigale* sp., *Pseudantechinus* sp.
White-winged fairy wren, *Malurus leucopterus edouardi*	Listed; restricted to Barrow Island; abundant	Landbirds
General fauna (evolutionary significant units)		
Land snail, *Rhagada* sp.	Short-range endemic	Land snails
Scorpion, *Urodacus* sp. nov. 'barrow'	New species restricted to Development site	Scorpions, pseudoscorpions, insects, arachnids, other invertebrates
Northern brush-tailed possum, *Trichosurus vulpecula arnhemensis*	Resident of rock holes and termite mounds	Small mammals
Termites, *Nasutitermes triodia*	Important ecological component; mound builders	Detritivores
Mygalomorph spiders	Burrowing spider; possible short-range endemic; susceptible to ground level impacts	Burrow-dwelling invertebrates
Spinifexbird, *Eremiornis carteri*	Abundant landbird	Landbirds
Leopard skink, *Ctenotus pantherinus acripes*	Restricted to Barrow Island in Western Australia	Skinks and other terrestrial reptiles
Perentie, *Varanus giganteus*	Major predator; largest terrestrial reptile on island	Monitors

Table 9-5:
Consequence Definitions for Risk-based Environmental Assessment

Consequence Category	Minor	Moderate	Serious	Major	Critical
Protected fauna species (listed/ threatened)	*Individual level effects*				
	Local, short-term behavioural impact.	Local, long-term or widespread, short-term behavioural impact.	Widespread, long-term behavioural impact.		
	Population level effects				
	Local, short-term decrease in abundance. No lasting effects on local population.	Local, long-term or widespread, short-term decrease in abundance. Loss of small number of individuals without reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Loss of individuals leads to reduction in viability of local population. No reduction in viability of race on Barrow Island.	Local, long-term or widespread, short-term impact leads to loss of local population/s and reduced viability of the race on Barrow Island.	Widespread, long-term impact on population. Extinction of Barrow Island race.
General fauna communities and species (not listed/ threatened)	*Individual effects*				
	Local, long-term or widespread, short-term behavioural impact.	Widespread, long-term behavioural impact.			
	Population level effects				
	Local, long-term or widespread, short-term decrease in abundance. Loss of small number of individuals without reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Loss of individuals leads to reduction in viability of local population. No reduction in viability on Barrow Island.	Local, long-term or widespread, short-term impact leads to loss of local population/s and reduced viability on Barrow Island.	Widespread, long-term impact on population. Extinction on Barrow Island.	Loss from immediate region.

9.2.4 Definition of Likelihood

The likelihood of an interaction between a stressor and a receptor causing a particular impact was defined based on a nominal Development lifecycle of 60 years. Five categories of likelihood were developed for the risk assessment, as shown in Table 9-6.

9.2.5 Characterisation of Risk

Risk levels were estimated for each stressor and associated key receptor/s through an assessment of consequences and likelihood. A qualitative scoring system was used to assess likelihood of consequences as described in Table 9-6. Likelihood relates to the probability of a stressor impacting on key receptors and does not equate to the probability of a stressor itself eventuating.

Based on the scoring of likelihood and consequences, risk was characterised as high, medium or low as illustrated in the matrix shown in Figure 9-2. A risk is considered acceptable if it falls in the low category without any further mitigation measures, and 'tolerable' if it falls in the medium risk category and is managed to reduce the risk to a level 'as low as reasonably practicable' (ALARP) (SAA HB 436:2004). Risk reduction measures must be applied to reduce high risks to tolerable levels. Taken together, these risk levels and corresponding requirements for risk treatment are the standards for acceptable risk to flora and fauna.

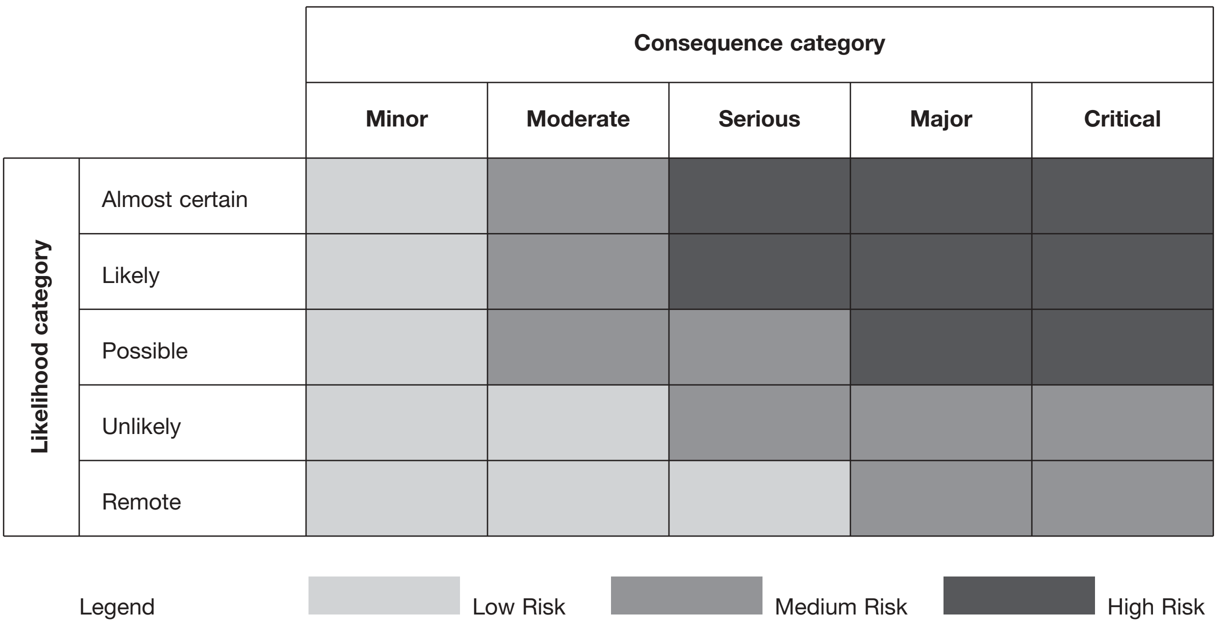
Table 9-6:
Likelihood Definitions for Risk-based Environmental Assessment

Likelihood category	Description
Almost certain	Very likely to occur on an annual basis. Includes planned activities. Socio-economic description includes the period during construction.
Likely	Likely to occur more than once during the life of the proposed Development.
Possible	May occur within the life of the proposed Development.
Unlikely	Not likely to occur within the life of the proposed Development.
Remote	Highly unlikely and unheard of in industry, but theoretically possible.

9.2.6 Risk Management

Ecological and environmental specialists finalised the risk assessment and provided advice to the Gorgon Development Team with options for managing risk. The Gorgon Development Team considered whether recommendations for reducing or eliminating high and medium risks were feasible. In the case of medium risk, they also considered whether the costs would balance the benefits derived from them.

Figure 9-2:
Gorgon Development Environmental Risk Matrix



As specific management measures were developed, high and medium risks were re-assessed to determine whether they were reduced to meet standards for acceptable risk (Section 9.2.5). In the case of medium risks, management measures were developed until no further practicable measures could be applied to reduce risk any further. In the case of high risks, ecological specialists were consulted to ensure that all possible management measures were considered.

Risk assessment results and management strategies for the terrestrial and marine environment are presented in chapters 10 and 11.

9.3 Uncertainty

Uncertainty in estimates of consequences and likelihood were approached in a precautionary manner. Generally, for planned activities, there was little uncertainty in the mechanisms of an exposure scenario. Even for unplanned accidents involving spills or leaks, scenarios are described on the basis of well-understood exposure mechanisms. However, it is widely recognised that the consequences of exposure can be more difficult to predict in complex ecological systems. Once a range of possible consequences was established, the more serious consequences were selected for estimating risk and proposing management measures to ensure that the 'lack of full scientific certainty was not used as a reason for postponing measures to prevent environmental degradation' (United Nations Environment Programme 1992). The same approach was applied to judgments of likelihood when some uncertainty existed, and the more frequent choice of likelihood was selected as a precautionary measure.

Where there was uncertainty in the judgments made during the risk analysis, it was handled in a manner which would not understate the overall risk. As such, in the case of high and medium risks, robust management strategies were proposed to reduce risk and prevent serious environmental impacts from occurring. Environmental monitoring will measure the actual impacts of development activities, and confirm whether management strategies are comprehensive enough to allow for the precautionary approach taken in the risk estimates.

9.4 Conclusion

Adoption of a risk-based environmental assessment process and identification of the most significant risks to the conservation values of the Development area are fundamental to the Joint Venturers' approach to this Draft EIS/ERMP. This process has been undertaken in accordance with Australian Standards for risk management and best practices in environmental risk assessment. By systematically identifying all stressors to conservation values and engaging ecological specialists to assist in the development of risk-based management strategies, potential environmental and socio-economic impacts will be reduced to meet standards for acceptable risk, or in some cases avoided altogether.

10: Terrestrial Environment – Risks and Management

No high risk stresssors to the physical environment (i.e. soil and landform and water resources) were identified through the risk assessment process. However, clearing and earthworks, physical presence of infrastructure, waste disposal and non-routine operations such as leaks and spills were assessed as a medium risk to the physical characteristics of the terrestrial environment.

Similarly no high risk stressors to terrestrial flora and vegetation communities were identified. Most stressors pose a low risk; however clearing and earthworks and fire were identified as medium risk stressors. The major stressor to the flora and vegetated habitats on Barrow Island from the proposed Gorgon Development will be land clearing and earthworks. Detailed botanical surveys of the proposed Development areas on Barrow Island have influenced the design and layout of the gas processing facility, pipelines and associated infrastructure. Consequently, the gas processing facility site has been selected to avoid drainage zones which contain restricted vegetation communities. Similarly, the location of the construction village has also been modified to avoid a restricted *Grevillea* community.

None of the stressors to terrestrial fauna will pose a high risk to the viability of fauna populations on Barrow Island. Clearing and earthworks and noise and vibration will pose the greatest risks to fauna. Leaks and spills and fire will also pose a medium risk. Unavoidable habitat loss and displacement of fauna will be mitigated by relocating selected fauna to suitable release sites.
A translocation program will be designed in consultation with the Western Australian Department of Conservation and Land Management and the Commonwealth Department of Environment and Heritage to augment existing endangered species relocation programs. All terrestrial fauna within the proposed Development area are represented in other areas of Barrow Island and the implementation of management measures will maintain risks to an acceptable level.

Preliminary assessment of risks to subterranean fauna from clearing and earthworks, noise and vibration and physical presence of the gas processing facility found residual risk associated with these stressors to be high. However, it is important to note that this level of risk primarily reflects uncertainty in the absence of data on the diversity and distribution of subterranean fauna in the Development area. Although a worst case risk assessment, based on a precautionary approach, has found there to be some high risk stressors to subterranean fauna, it is anticipated that further information from the current sampling program will provide a clearer model of the wider distribution of the subterranean taxa and result in a reduction in this risk level.

The majority of potential impacts resulting from the proposed Development will be associated with clearing of vegetation during the construction phase. Most impacts during routine operation of the Development will be minor.

10.1 Introduction

The existing biophysical environment of the Development area is described in Chapter 8 and is based on the findings of a range of specialist studies. This chapter discusses potential impacts and risks posed to environmental factors in the terrestrial environment and the management measures that will be implemented to reduce potential impacts to acceptable levels (Figure 10-1). Potential impacts and risks to marine environmental factors are examined in Chapter 11. Risks associated with the accidental introduction of non-indigenous species or pathogens are discussed in Chapter 12.

The risk-based assessment presented in this chapter follows the methodology outlined in Chapter 9. The results of the risk assessment for physical environmental factors including, air and water quality, and soils and landform are presented in Section 10.2. Risks to terrestrial flora and vegetation communities, terrestrial fauna and subterranean fauna are discussed in Sections 10.3, 10.4 and 10.5 respectively. The risk assessments conducted for each environmental factor are summarised in tables throughout these sections. Likelihood definitions are provided in Chapter 9 (Table 9-6) and consequence definitions for specific environmental factors are outlined in Table 10-1, Table 10-4 and Table 10-9. An explanation of risk assessment terms used throughout this chapter is provided in Table 9-1, Chapter 9.

10.2 Physical Environment

Potential stressors to the physical factors of the terrestrial environment were identified and risk estimated through an assessment of likelihood and consequences. Consequences to physical environmental factors are defined in Table 10-1. Risk assessment results are summarised in Table 10-2.

Figure 10-1:
Overview of Chapter Structure

Terrestrial Environment

Physical Environment	Flora and Vegetation	Terrestrial Fauna	Subterranean Fauna
Key Risks • clearing and earthworks • physical presence of facilities • liquid and solid waste disposal • leaks or spills	Key Risks • clearing and earthworks • fire	Key Risks • clearing and earthworks • physical interaction with facilities and workforce • noise and vibration • fire	Key Risks • clearing and earthworks • wastewater discharge • noise and vibration • leaks and spills • CO_2 leak • physical presence of facilities
Proposed Management Strategies	Proposed Management Strategies	Proposed Management Strategies	Proposed Management Strategies

Table 10-1:
Consequence Definitions for Physical Environmental Factors

Consequence category	Minor	Moderate	Serious	Major	Critical
Soils and landform	Local contamination that can be readily remediated. Negligible impact on soil characteristics. Local and minor change in recharge patterns within sub-catchments. Disturbance of well-represented landform habitats.	Local contamination requiring a long-term remediation effort. Local, short-term change in soil characteristics. Local and major change in recharge patterns within sub-catchments. Widespread and minor changes in recharge patterns. Local loss of well-represented landform habitats.	Local contamination that cannot be readily remediated. Local, long-term, or widespread, short-term change in soil characteristics. Major, widespread changes in sub-catchment recharge patterns. Widespread loss of well-represented landform habitats. Local loss of a unique landform habitat.	Widespread contamination requiring a significant long-term remediation effort. Widespread, long-term change in soil characteristics. Minor changes in regional recharge patterns. Widespread loss of a unique landform habitat.	Widespread contamination that cannot be readily remediated. Major changes in regional recharge patterns. Regional loss of a unique landform habitat.
Water quality (surface and groundwater)	Local, short-term and minor reduction in water quality.	Minor reduction in water quality which is widespread, short-term or local, long-term. Major reduction in water quality which is local, short-term.	Widespread, long-term reduction in water quality.	Regional, short-term reduction in water quality.	Regional, long-term reduction in water quality.
Air quality	Local, short-term and minor exceedance of standards.	Minor exceedance of standards that is widespread, short-term or local, long-term. Major exceedance of standards which is local, short-term.	Widespread, long-term exceedance of standards.	Regional, short-term change in air quality.	Regional, long-term change in air quality.

From the results of qualitative risk assessments, no high risk stressors to the physical environment were identified; however the following stressors were assessed as medium risk:

- clearing and earthworks (construction and commissioning)
- physical presence (construction, commissioning and operations)
- liquid and solid waste disposal (construction and commissioning)
- leaks or spills (construction, commissioning and operations).

These stressors are further discussed below in relation to relevant physical environmental factors and Development phases.

Priority has been given to the development of management measures for the medium risk activities. Environmental management measures are also proposed for low risk stressors and are identified in the summary tables. The management and mitigation measures proposed in this chapter are, in the main, specific to particular activities or stressors. System-based management requirements, such as auditing and induction measures, are broadly discussed in Chapter 16 and are not referred to specifically in this chapter.

The Joint Venturers are committed to adopting all the management measures outlined in this section to avoid or mitigate impacts to the physical environment. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses it may become necessary to modify proposed management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and targets will be developed.

All management measures identified in this section, and others identified as the design develops, will be captured in environmental management plans as described in Chapter 16.

10.2.1 Soil and Landform

Clearing and Earthworks

Clearing of vegetation and earthworks will be required during construction to provide a suitable profile and foundation for facilities such as the gas processing facility, construction village, access roads, onshore pipelines (Barrow Island and mainland), utility corridors and carbon dioxide (CO_2) injection wells. Land use requirements for for terrestrial components of the Development are outlined in Chapter 6. The most significant quantity of clearing and earthworks in the terrestrial environment will be associated with construction at the gas processing facility site.

The key potential impacts to soil and landform associated with clearing and earthworks include:

- erosion (wind and water) and sedimentation
- soil compaction
- soil inversion
- disturbance to significant geological features (e.g. karst)
- change in landform.

Management

Disturbance to soil and landform as a result of vegetation clearing and earthworks will be unavoidable. Management measures have been developed to ensure that impacts resulting from clearing and earthworks are minimised, and limited to the specific disturbance required to construct and operate the proposed Development. The Joint Venturers will:

- limit vegetation clearing and ground disturbance associated with the Development to that provided for under the Barrow Island Act
- use geotechnical data to identify areas of potential subsidence or collapse
- clearly mark areas of land disturbance on construction plans
- survey and peg proposed areas of disturbance to ensure clearing does not occur outside designated boundaries
- track clearing and ground disturbance using a landuse register
- locate facilities to avoid major drainage lines
- suppress dust generation through application of water
- install erosion control and flow diversion devices
- routinely inspect and maintain erosion and sediment control structures, particularly following heavy or prolonged rainfall
- keep all vehicle and equipment movement within designated areas (e.g. access tracks and turning circles)
- stablise uncovered areas of soil promptly.

Residual Risk

With the implementation of appropriate avoidance and management measures such as those described above, impacts to soil and landform associated with clearing and earthworks can be reduced to an acceptable level of risk (medium for construction, low for operations). There will be permanent impacts to soil and landforms in all areas of land use. However, as these areas are relatively localised, the consequences will be moderate.

Liquid and Solid Waste Disposal

Construction and operation of the proposed Development will produce a variety of liquid and solid wastes (Chapter 8). Potential for soil contamination will be the key environmental impact to soil and landform associated with waste disposal.

Management

To mitigate potential impacts associated with liquid and solid waste disposal, comprehensive waste management plans will be developed for all phases of the Gorgon Development.

Solid wastes generated during construction and operations will either be incinerated or returned to the mainland for re-use, recycling or disposal in approved facilities. Solid wastes will not be disposed of to landfill on Barrow Island. An exception is waste concrete which will be offered to the existing oilfield operation to enhance the deep gravel pit rehabilitation program.

Liquid wastes from construction and operation will be treated and then disposed into deep injection wells. Exceptions include use of treated grey-water for dust suppression and disposal of chemicals and oil at approved sites on the mainland (if re-use/recycling is not practicable).

The primary focus of waste management will be minimisation of waste generation based on the principles of eliminate, reduce, re-use, recycle, treat and dispose of in an environmentally responsible manner. The Joint Venturers will:

- specify waste avoidance/minimisation criteria in tendering and contract processes
- use established Chevron project management processes, such as Value Improvement Practices, to identify waste minimisation opportunities
- develop specific waste management measures for each waste stream prior to the commencement of any waste producing activities
- comply with Western Australian legislative requirements for waste handling and disposal, including requirements of the *Western Australian Environmental Protection Act 1986* (EP Act) and Environmental Protection (Controlled Waste) Regulations 2001
- comply with Commonwealth and international requirements for waste handling and disposal
- segregate re-usable, recyclable and hazardous and non-hazardous waste
- design and operate facility to ensure appropriate handling, treatment, storage and disposal of wastes.

Residual Risk

Impacts associated with liquid and solid waste disposal can be managed to achieve an acceptable level of risk to soil and landform (medium for construction, low for operations). Following implementation of waste management controls, impacts will be short-term and localised.

Leaks or Spills

Despite all preventative measures included in the design and operation of facilities, leaks or spills could occur in association with:

- pipeline or equipment failure
- storage and handling of product, fuels and chemicals
- waste storage and disposal
- horizontal directional drilling (HDD) fluid release.

The primary environmental impact to soil and landform of any leak or spill would be contamination of soil.

Management

The likelihood of spills and leaks occurring in the terrestrial environment will be reduced by the implementation of rigorous design controls and a program of verification and validation testing, inspection and monitoring and maintenance. This program will be in place throughout the construction, commissioning, operations and decommissioning phases of the Development. Management measures have been developed to reduce risks associated with various potential sources of leaks or spills. The Joint Venturers will:

- use highly experienced design and implementation construction contractors
- assess Material Safety Data Sheets prior to purchase of chemicals
- apply Australian standards for pipeline design, construction, operation and maintenance (AS 2885.1–1997; AS 2885.3–2001)
- apply industry standards for storage and handling of product, fuels and chemicals (e.g. bunding, level gauges, overflow protection, drainage systems and hardstands)
- implement a multi-tiered stormwater drainage management system at the gas processing facility (Chapter 7)
- use a closed drain system in fuel and chemical storage and refuelling areas
- implement regular testing of emergency shut-down systems
- implement a plant, equipment and pipeline corrosion monitoring and control program
- limit volumes of stored fuels and chemicals
- use low toxicity drilling fluids
- conduct vehicle maintenance and refuelling in specifically designated areas
- store HDD drilling fluids in a lined pit or prefabricated tank and transport all recovered fluids off-site following completion of HDD
- develop an emergency spill response plan, including spill clean-up procedures. Clear areas of responsibility, enabling effective response with minimal impact on the environment, will be defined in the plan.

Residual Risk

The risk of soil contamination from leaks or spills can be managed to achieve an acceptable level of risk (medium risk, non-routine operation). Due to the remote location of facilities there is a low risk of third party interference with pipelines resulting in leaks or spills. As appropriate controls and checks will be implemented, it is anticipated that spills or leaks which do occur will be minor, detected rapidly, and result in moderate, localised consequences. Most spills or leaks are likely to occur in areas of hardstand. Spills and leaks therefore pose a low risk to the terrestrial environment.

10.2.2 Surface Water and Groundwater Quality

Clearing and Earthworks

As discussed in Section 10.2.1, clearing and earthworks will be required primarily during the construction phase of the proposed Development. The bulk of clearing and earthworks during construction will occur at the gas processing facility site. The proposed gas processing facility site is on a high point between two alluvial catchment systems (Figure 10-2). No significant drainage lines traverse the Town Point gas processing facility site.

Potential environmental impacts to surface water that are associated with clearing and earthworks include:

- sedimentation of natural drainage systems
- disturbance to natural drainage patterns.

Management

Erosion and sedimentation control measures will be implemented to limit sediment generation and transportation to natural drainage systems. The Joint Venturers will:

- avoid locating facilities in natural drainage lines and subcatchments
- implement a multi-tiered stormwater drainage management system (Chapter 7)
- use culverts and similar devices at road crossings
- install erosion control and flow diversion devices
- install scour protection measures such as gabions where scouring is likely to occur
- clearly designate soil stockpile areas and install sedimentation control measures
- stablise uncovered areas of soil promptly
- inspect and maintain erosion and sediment control structures regularly, particularly following heavy or prolonged rainfall
- divert runoff from unstable areas to detention basins.

Residual Risk

The risk of sedimentation or disturbance to natural drainage systems can be managed to an acceptable level (medium for construction, low for operations). Although surface water will be affected by clearing and earthworks during construction, the risk will be at a medium level due to the predicted moderate consequence it is likely to have on surface water quality.

Physical Presence

Sealing of areas of the gas processing facility (as described in Chapter 6), construction village and roads will create impervious surfaces that may change the local pattern of surface water runoff and the rate of water infiltration to the watertable.

The key potential environmental impacts to surface water and groundwater that are associated with the physical presence of facilities include:

- change in water infiltration and recharge rates
- change in groundwater level.

Management

Conceptual design for the proposed Development is aimed at minimising impacts on groundwater recharge by constructing a number of separate facilities on hardstand, interspersed with open and unsurfaced areas. The drainage management system will be based on hydrogeological data to maximise on-site infiltration of uncontaminated water. Changes to recharge patterns are likely to be localised and will be mitigated through appropriate design and stormwater management strategies.

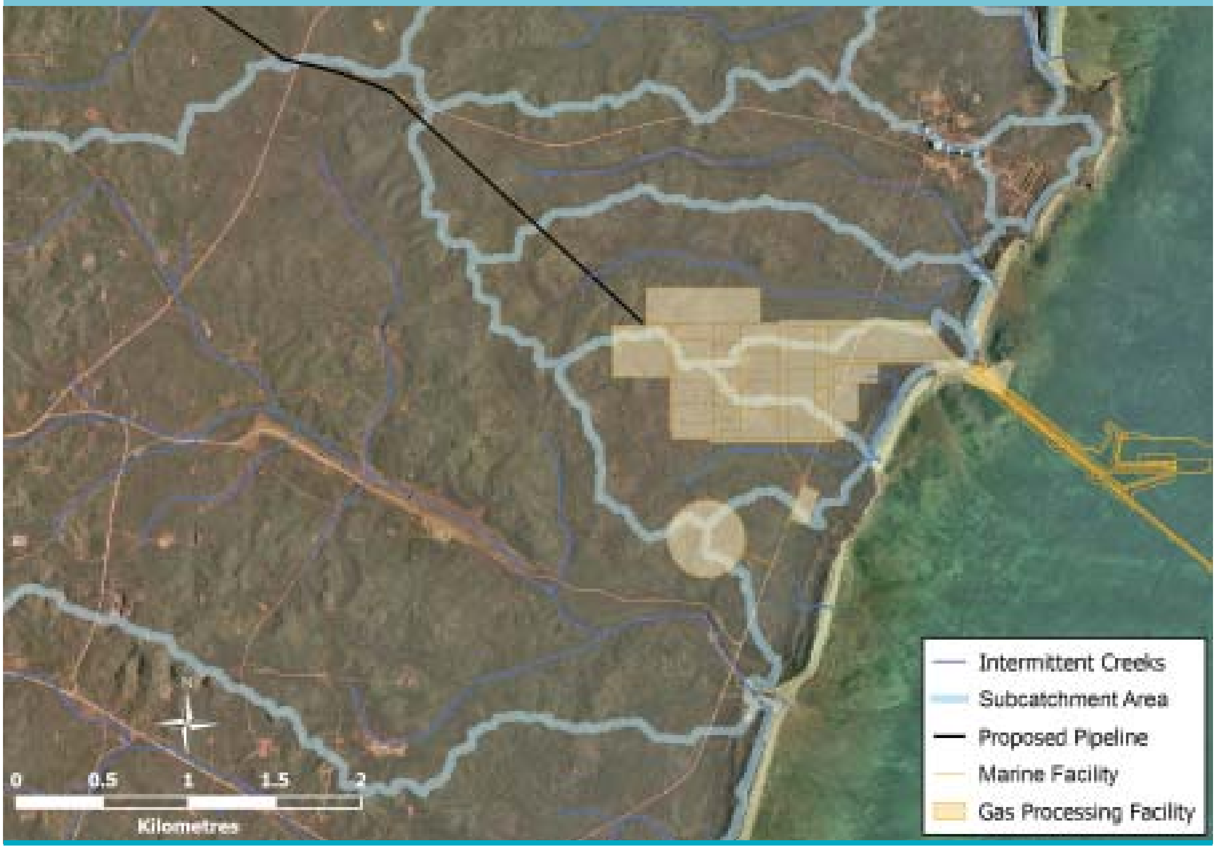
In order to minimise potential impacts to surface water and groundwater resources, the gas processing facility will be located on an area of higher elevation between two alluvial catchment systems (Figure 10-2). The Joint Venturers will also:

- implement a multi-tiered stormwater drainage management system which includes diversion of drainage from upper catchment to natural drainage/infiltration areas and discharge of uncontaminated water from the gas processing facility site (e.g. non-process hardstand) to natural drainage channels (Chapter 7)
- design the drainage strategy to maximise infiltration of non-contaminated runoff.

Residual Risk

The risk of altering water infiltration rates or watertable levels can be managed to an acceptable level (medium for both construction and operations). Although surface water will be affected by clearing and earthworks during construction, this stressor will pose a medium level risk due to the predicted moderate, short-term consequence it is likely to have on surface water quality.

Figure 10-2:
Watercourses and Sub-catchments in the Vicinity of the Proposed Gas Processing Facility



Creation of a physical barrier to surface water flows and groundwater recharge is predicted to have a moderate impact to surface water and groundwater in areas associated with Development infrastructure.

Liquid and Solid Waste Disposal

An overview of liquid and solid wastes expected to be produced from the proposed Development is provided in Chapter 7. The key environmental impact to surface water and groundwater associated with liquid and solid waste disposal could be contamination associated with storage and handling of wastes and disposal of liquid waste via injection to deep aquifers.

Management

To mitigate potential risks associated with liquid and solid waste disposal, comprehensive waste management plans will be developed for all phases of the Gorgon Development. The primary focus of waste management will be minimisation of waste generation based on the principles of eliminate, reduce, re-use, recycle and environmentally responsible disposal. Additional waste management measures are outlined in Section 10.2.1.

Residual Risk

With the implementation of appropriate avoidance and management measures, impacts to surface water and groundwater associated with liquid and solid waste disposal are expected to be moderate and can be reduced to an acceptable level of risk (medium for construction, low for operations).

Leaks or Spills

As discussed in 10.2.1, despite all preventative measures included in the design and operation of the facility, leaks or spills could occur in association with pipeline or equipment failure, waste disposal and storage, handling and transportation of chemicals and fuels. Contamination is the key potential impact to surface water or groundwater associated with a leak or spill.

Management

The likelihood of spills and leaks occurring will be reduced by the implementation of rigorous design controls and a program of verification and validation testing, inspection and monitoring and maintenance throughout construction and operation. Additional management measures are outlined in Section 10.2.1.

Residual Risk

The risk of surface water or groundwater contamination from leaks or spills can be managed to achieve an acceptable level of risk (medium risk, non-routine operation). Although areas prone to spills (e.g. fuel storage and handling) will be designed with appropriate controls (e.g. bunding), some minor leaks or spills could occur during the construction phase of the Development. Due to the small volumes involved and localised impact, the consequences will be moderate.

Table 10-2:
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Clearing and Earthworks (Soil and Landform) **Environmental Management Objective/s:** • To maintain the integrity, ecological functions and environmental values of soil and landform. • To minimise the potential for erosion due to stormwater flow.					
Construction and commissioning Vegetation clearing and earthworks for construction of gas processing facility, jetty approaches, construction village, access roads, pipelines, utility corridors, CO_2 injection wells and monitoring facilities and airport extension. **Operations** Minor clearing and earthworks.	• erosion (wind and water) and sedimentation • soil compaction • soil inversion • disturbance to significant geological features (e.g. caves) • changes in landform.	**Construction and commissioning** • locate facilities to avoid major drainage lines • limit clearing and earthworks to minimum required for safe construction • re-use topsoil and vegetation • track clearing and ground disturbance using a landuse register • routinely inspect and maintain erosion and sediment control structures, particularly following heavy or prolonged rainfall • keep all vehicle and equipment movement within designated areas (e.g. access tracks and turning circles) • stablise uncovered areas of soil promptly • install erosion control, grading and flow diversion devices • clearly designate all planned land disturbance • suppress dust generation with water. **Operations** • as above.	• Development footprint limited to that provided for under the Barrow Island Act • no soil erosion or sedimentation outside of Development footprint • no disturbance to significant geological features (e.g. caves).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular inspection and maintenance of erosion and sediment control structures, particularly following heavy or prolonged rainfall • regular inspection of construction areas to detect impacts to soil and landform associated with clearing and earthworks.	**Construction and commissioning** Consequence – moderate Likelihood – almost certain Risk – medium **Operations** Consequence – minor Likelihood – likely Risk – low

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Liquid and Solid Waste Disposal (Soil and Landform) **Environmental Management Objective/s:** • To ensure that liquid and solid wastes do not adversely affect groundwater or surface water quality or lead to soil contamination.					
Construction and commissioning Generation and disposal of liquid and solid wastes including: • hydrotest water • domestic waste and sewage • waste chemicals and oil • drilling waste (e.g. drill cuttings and fluid) • produced formation water. **Operations** Generation and disposal of liquid and solid waste, including: domestic waste and sewage and waste chemicals and oil (Chapter 7).	• soil contamination.	**Construction and commissioning** • eliminate, reduce, re-use, recycle/recover, treat and dispose in an environmentally responsible manner • avoid disposal of solid wastes to landfill on Barrow Island. An exception is waste concrete which will be offered to the existing oilfield operation to enhance the deep gravel pit rehabilitation program • include of waste avoidance, management and disposal requirements in tendering and contract documents • provide appropriate waste segregation and collection facilities at all work sites • use a wastewater treatment system • comply with *Environmental Protection Act 1986* and Environmental Protection (Controlled Waste) Regulations 2001, Commonwealth legislation and relevant international conventions	• no solid waste disposed to landfill on Barrow Island • no contaminated soils outside of Development footprint • contaminated areas remediated • no long-term detectable impact at hydrotest disposal site/s	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • environmental audits to determine compliance with licence conditions • establishment of waste targets and regular review of waste inventory • monitoring of sites potentially susceptible to soil contamination to detect any impact as a result of liquid and solid waste disposal.	**Construction and commissioning** Consequence – moderate Likelihood – likely Risk – medium **Operations** Consequence – minor Likelihood – possible Risk – low

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• conduct Chevron Waste Minimisation Value Improving Practice review • implement hydrotest water management plan • develop an emergency response plan • develop specific waste management measures for each waste stream • divert firewater run-off from hardstand areas into stormwater management systems. **Operations** • as above.			

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills (Soil and Landform) **Environmental Management Objective/s:** • To ensure that hydrocarbons and hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.					
Non-routine operations Spill during storage and transport of fuel or hazardous material. Spill or leak during waste storage and disposal. Failure of plant, equipment or pipelines. HDD drilling fluid release.	• soil contamination.	**Non-routine operations** • design equipment to include built-in safeguards such as relief valves and overflow protection, fabrication quality controls and operating procedures • apply industry standards for storage and handling of fuels and chemicals (e.g. bunding, level indication, overflow protection, drainage systems and hardstands) • assess Material Safety Data Sheets prior to purchase of chemicals • implement emergency response and spill contingency planning • implement plant, equipment and pipeline corrosion monitoring and control program • regularly audit, inspect and conduct maintenance of facilities • provide spill recovery equipment at work sites • contain and remediate contaminated soil	• no contaminated soils outside of Development footprint • contaminated areas within Development area remediated.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • implementation and regular testing of emergency shut-down systems to reduce potential volumes from spills and leaks • implementation of a plant, equipment and pipeline corrosion monitoring and control program • routine inspection of infrastructure, plant and equipment by designated personnel	**Construction and commissioning** Consequence – moderate Likelihood – likely Risk – medium **Operations** Consequence – serious Likelihood – unlikely Risk – medium

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• use dry break couplings where spill risk exists (e.g. fuel loading hoses) • implement built-in automatic shut-down systems in selected systems • rehabilitate any leak or spill sites • implement early leak detection and reporting systems • avoid valves on feed gas pipeline to gas processing facility site (exception is emergency shut-down valve) • place majority of remaining valves, and flanged connections, on hardstand surface within gas processing facility drainage system • 24-hour hold-up capacity on gas processing facility site for saline injection water.		• in the event of a spill or leak, monitor affected area to determine effectiveness of remediation.	

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Clearing and Earthworks (Surface Water and Groundwater) **Environmental Management Objective/s:** • To maintain the quantity and quality of water so that existing and potential environmental values, including ecosystem function, are protected.					
Construction and commissioning Vegetation clearing and earthworks required for construction of gas processing facility, jetty approaches, construction village, access roads, pipelines, utility corridors, CO_2 injection and monitoring facilities and potential airstrip extension. **Operations** Minor clearing and earthworks.	• sedimentation of natural drainage systems • disturbance to natural drainage patterns.	**Construction and commissioning** • avoid locating facilities and construction activities in natural drainage lines • locate gas processing facility on ridge to avoid drainage lines • implement a multi-tiered stormwater drainage management system • use sediment control measures to limit sediment generation and transportation • use HDD for feed gas pipeline shore crossing. **Operations** • stabilise unsealed surfaces • implement a multi-tiered stormwater drainage management system • segregate drainage • use sediment control measures to limit sediment generation and transportation.	• no measurable impact on groundwater • no contamination of surface water outside of Development area.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular inspection and maintenance of erosion and sediment control structures, particularly following heavy or prolonged rainfall • regular inspection of construction areas to detect impacts to surface water or groundwater associated with clearing and earthworks.	**Construction and commissioning** Consequence – moderate Likelihood – likely Risk – medium **Operations** Consequence – minor Likelihood – possible Risk – low

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Physical Presence (Surface Water and Groundwater) **Environmental Management Objective/s:** • To maintain the quantity and quality of water so that existing and potential environmental values, including ecosystem function, are protected.					
Construction and commissioning Sealing of gas processing facility site and road surfaces (30–40% of gas processing facility site i.e. 45–60 ha). **Operations** As above.	• change in water infiltration and recharge rates • increased runoff • change in groundwater level.	**Construction and commissioning** • implement a multi-tiered stormwater drainage management system • locate gas processing facility between two major alluvial catchment systems to reduce impact on groundwater recharge regime • design drainage strategy to maximise infiltration of non-contaminated runoff. **Operations** • as above.	• no measurable impact on groundwater regime (recharge and quality)	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular monitoring of groundwater levels and quality both within and outside of gas processing facility footprint.	**Construction and commissioning** Consequence – moderate Likelihood – possible Risk – medium **Operations** Consequence – moderate Likelihood – possible Risk – medium

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Liquid and Solid Waste Disposal (Surface Water and Groundwater) **Environmental Management Objective/s:** • To ensure that liquid and solid wastes do not adversely affect groundwater or surface water quality or lead to soil contamination.					
Construction and commissioning Generation and disposal of liquid and solid wastes including: • hydrotest water • domestic waste and sewage (inc. grey-water) • waste chemicals and oil • drilling waste (e.g. drill cuttings and fluid) • produced formation water. **Operations** Generation and disposal of liquid and solid waste, including: domestic waste and sewage and waste chemicals and oil (Chapter 8).	• surface water and groundwater contamination.	**Construction and commissioning** • eliminate, reduce, re-use, treat and implement an environmentally responsible disposal waste management philosophy • avoid disposal of solid wastes to landfill on Barrow Island. An exception is waste concrete which will be offered to the existing oilfield operation to enhance the deep gravel pit rehabilitation program • include waste avoidance management and disposal requirements in tendering and contract documents • provide waste segregation and collection facilities at all work sites • comply with *Environmental Protection Act 1986* and Environmental Protection (Controlled Waste) Regulations 2001, Commonwealth legislation and relevant international conventions • develop specific waste management measures for each waste stream. **Operations** • as above.	• no solid waste disposed to landfill on Barrow Island • no measurable impact on groundwater • no contamination of surface water outside of Development area.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • environmental audits to determine compliance with licence conditions • establishment of waste targets and regular review of waste inventory • regular monitoring of surface water and groundwater levels and quality both within and outside of gas processing facility footprint.	**Construction and commissioning** Consequence – moderate Likelihood – possible Risk – medium **Operations** Consequence – minor Likelihood – possible Risk – low

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills (Surface Water and Groundwater) **Environmental Management Objective/s:** • To ensure that hydrocarbons and hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.					
Non-routine operations Spill during storage and transport of fuel or hazardous material. Spill or leak during waste storage and disposal. Failure of plant, equipment or pipelines.	• surface water and groundwater contamination.	**Non-routine Operations** • design equipment to include built-in safeguards such as relief valves and overflow protection, fabrication quality controls and operating procedures • apply industry standards for storage and handling of fuels and chemicals (e.g. drainage systems, hardstand and bunding) • assess Material Safety Data Sheets prior to purchase of chemicals • implement emergency response and spill contingency planning • implement plant, equipment and pipeline corrosion monitoring and control program • provide spill recovery equipment at work sites • contain and remediate any contaminated soil • built-in automatic shut-down in selected systems • rehabilitate any leak or spill site • implement early leak detection and reporting	• no measurable impact on groundwater • no contamination of surface water outside of Development area.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • implementation and regular testing of emergency shut-down systems to reduce potential volumes from spills and leaks • implementation of a plant, equipment and pipeline corrosion monitoring and control program • routine inspection of infrastructure, plant and equipment by designated personnel	**Construction and commissioning** Consequence – moderate Likelihood – likely Risk – medium **Operations** Consequence – serious Likelihood – unlikely Risk – medium

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• avoid valves on feed gas pipeline to gas processing facility site (exception is emergency shut-down valve) • locate majority of valves, and flanged connections, on hardstand surface within gas processing facility drainage system • provide 24-hour hold-up capacity on gas processing facility site for saline injection water.		• in the event of a spill or leak, monitor affected area to determine effectiveness of remediation • monitoring of surface water and groundwater levels and quality both within and outside gas processing facility footprint.	

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Atmospheric Emissions (Air Quality) **Environmental Management Objective/s:** • To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards. • To minimise emissions of ozone depleting substances to levels as low as practicable on an ongoing basis.					
Construction and commissioning Low levels of emissions associated with vessels (e.g. drilling rigs, pipe lay barges, tugs, dredges, hopper barges, supply boats). Low levels of vehicle and equipment exhaust (NO_x, SO_x). **Operations** Combustion and fugitive emissions of SO_2, NO_x, CO_2, CO, CH_4, VOCs and particulates (Chapter 8). Low levels of vehicle and equipment exhaust (NO_x, SO_x).	• decrease in local and regional air quality • decrease in global air quality resulting from greenhouse gas emissions (Chapter 13).	**Construction and commissioning** • conduct regular maintenance of construction vehicles and equipment • avoid ozone depleting substances (with the exception of methyl bromide for quarantine purposes) • require contractors to advise of use of ozone depleting substances and develop management plans to avoid release • use of Australian standard low-sulphur diesel (where imported) • minimise fuel usage. **Operations** • adopt energy efficient technology and design • comply with EPA licence conditions for routine NO_x, SO_2, VOCs, and CO_2 emissions	• no breaches of environmental licence conditions.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of atmospheric emissions during commissioning and operations to ensure compliance with EPA licence conditions • establishment of stack sampling points in all fixed equipment exhausts • establishment of annual emission targets • reporting of emissions internally and externally.	**Construction and commissioning** Consequence – minor Likelihood – likely Risk – low **Operations** Consequence – minor Likelihood – likely Risk – low **Non-routine operations** Consequence – minor Likelihood – unlikely Risk – low

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Non-routine operations CO_2 leak. Pipeline or equipment failure. Flaring. Smoke and particulates from fire. Start-up and shut-down of gas processing facility.		• avoid ozone depleting substances (with the exception of methyl bromide for quarantine purposes) • use appropriate facilities to measure fuel and flare flow and other streams • implement greenhouse gas management plan • implement start-up and shut-down procedures • ensure system integrity to avoid leaks • specify and select equipment for quality control • use dry gas seals on compressors (or equivalent) • design and operate condensate storage tanks to reduce fugitive emissions • use high efficiency combustion in flare and fuel users to minimise CO and VOC emissions • use a-MDEA in CO_2 removal process • inject CO_2 removed from feed gas into deep well.			

Table 10-2: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Clearing and Earthworks (Air Quality) **Environmental Management Objectives:** • To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.					
Construction and commissioning Dust generation associated with clearing and earthworks and vehicle movement. **Operations** Localised dust generation associated with minor clearing and earthworks.	• localised reduction in air quality.	**Construction and commissioning** • implement dust suppression measures such as water carts • stabilise unpaved surfaces to reduce dust • minimise extent and period of exposed surfaces • restrict vehicle speed and access areas • use HDD for feed gas pipeline shore crossing. **Operations** • as above.	• dust emissions limited to immediate vicinity of earthworks.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • qualitative monitoring of dust levels surrounding construction sites to determine effectiveness of dust suppression measures.	**Construction and commissioning** Consequence – minor Likelihood – almost certain Risk – low **Operations** Consequence – minor Likelihood – likely Risk – low

Note: all acronyms and abbreviations are provided in the supplementary information section of this document.

10.3 Flora and Vegetation Communities

Potential stressors to flora and vegetation communities have been identified and risk estimated through an assessment of consequences and likelihood. Prior to assessing risk, key receptor species or communities (listed or evolutionary significant units) were identified. These species and communities were the focus of the risk assessment.

Likelihood definitions are provided in Table 9-6, Chapter 9. The key receptors are described in Table 10-3. Consequences to restricted and general flora and vegetation communities are defined in Table 10-4. Risk assessment results are summarised in Table 10-7.

Risk assessments, including definition of consequences and identification of stressors and receptors, were undertaken by technical specialists with recognised expertise in a broad range of environmental fields. Many of these specialists are experienced at working on Barrow Island and have a long-standing knowledge of the island.

High risk stressors to terrestrial flora and vegetation communities were not identified through the risk assessment process. Most stressors pose a low risk; however the following two stressors were assessed as medium risk:

- clearing and earthworks (construction and commissioning)
- fire (construction, commissioning and operations).

The potential impacts associated with these stressors and the proposed management measures that will be implemented to reduce residual risk to an acceptable level are discussed in the following sections. Risk of a quarantine breach leading to establishment of a non-indigenous species or pathogen on Barrow Island is addressed in Chapter 12.

Priority has been given to the development of management measures for medium risk activities. Environmental management measures are also proposed for low risk stressors and are identified in Table 10-7. The management and mitigation measures proposed in this chapter are, in the main, specific to particular activities or stressors. System-based management requirements, such as auditing and induction measures, are discussed broadly in Chapter 16 and are not referred to specifically in this chapter.

The Joint Venturers are committed to adopting all of the management measures outlined in this section to avoid or mitigate impacts to flora and vegetation communities. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses it may become necessary to modify proposed management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and targets will be developed.

While atmospheric emissions and a major leak of CO_2 present low risks to flora and vegetation, these issues are discussed in the following sections in recognition of stakeholder interest.

Table 10-3:
Key Receptor Species and Communities of Terrestrial Flora and Vegetation Communities (Restricted and General)

Key Receptor	Reason for Selection	Additional Receptors Represented by Key Receptor
Restricted Flora and Vegetation Communities		
Corchorus interstans ms	Priority 3 species; regenerates well	Shrubs that recover from disturbance readily
Helichrysum oligochaetum	Priority 1; annual	Herbaceous annuals
Acacia synchronicia	Restricted distribution on Barrow Island	
Grevillea pyramidalis community (L6a)	Restricted distribution on Barrow Island	
Erythrina vespertilio community (F4a)	Restricted distribution on Barrow Island	
Scaevola cunninghamii community (F5d)	Restricted distribution on Barrow Island; located near west coast	Coastal communities restricted to rocky slopes and lower dunes
General Flora and Communities		
Melaleuca cardiophylla	Potentially difficult to regenerate; habitat for threatened white-winged fairy wren	Woody shrubs
Euphorbia drummondii	Herbaceous	Herbs, including annuals
Spinifex longifolius	Coastal stabilising species; restricted to low stability coastal dunes	Sand dune vegetation
Acacia bivenosa–Triodia wiseana community (F8a)	Widespread on flats in proposed Development areas	All taxa within this community
Melaleuca–Triodia community (e.g. L7a)	Widespread on hillslopes in proposed Development areas	All taxa within this community
Setaria verticillata	Introduced species	Cenchrus *ciliaris, Prosopis* sp.

Table 10-4:
Flora and Vegetation Communities Consequence Definitions

Consequence category	Minor	Moderate	Serious	Major	Critical
Terrestrial Flora and Vegetation Communities					
Restricted flora and communities	*Impact on species or community*				
	Local and short-term decrease in abundance of flora or impact on community structure. Sublethal physiological impacts.	Widespread, short-term or local, long-term decrease in abundance of flora or impact on community structure.	Widespread, short-term or local, long-term decrease in abundance of flora or impact on community structure.	Widespread and long-term decrease in abundance of flora or impact on community structure.	Widespread and long-term decrease in abundance of flora or impact on community structure.
	Loss of species or community				
		No reduction in community/taxon viability in local area.	Reduced viability of community or taxon in local area, no reduction in viability on Barrow Island.	Reduced viability of taxon or community on Barrow Island.	Extinction on Barrow Island, or reduced viability in the immediate region.
General flora and communities	*Impact on species or community*				
	Widespread, short-term or local, long-term decrease in abundance of flora or impact on community structure. Sublethal to lethal physiological impacts.	Widespread, short-term or local, long-term decrease in abundance of flora or impact on community structure.	Widespread and long-term decrease in abundance of flora or impact on community structure.	Widespread and long-term decrease in abundance of flora or impact on community structure.	Widespread and long-term decrease in abundance of flora or impact on community structure.
	Loss of species or community				
	No reduction in community/taxon viability in local area.	Reduced viability of community or taxon in local area, no reduction in viability on Barrow Island.	Reduced viability of taxon or community on Barrow Island.	Extinction on Barrow Island, or reduced viability in the immediate region.	Extinction in immediate region.

10.3.1 Clearing and Earthworks

Barrow Island

Clearing and earthworks will be required to construct the gas processing facility, pipelines, CO_2 seismic monitoring grid and other associated infrastructure. Three hundred hectares, or approximately 1.3% of the island (total area of Barrow Island is 23 567 ha), would be cleared for the proposed Development (refer to Table 6-3, Chapter 6).

The cumulative impacts of clearing should be considered in light of previous disturbance on the island associated with the existing operating oilfield. Approximately 1050 ha, or 4.46% of Barrow Island, has been cleared for the development of infrastructure for existing oilfield operations as described in Table 10-5. An additional 172 ha (0.72%) of vegetation has been temporarily disturbed for seismic operations and installation of flow lines.

Clearing for the proposed Development represents an increase of approximately 1.3% in the area of cumulative disturbance from approximately 5.2% of the island to approximately 6.5% of the island. The significance of the vegetation and flora within the area to be impacted by the proposed Development is described in detail in Appendix C1 and summarised in the following.

The number of plant taxa and dominant families recorded within the proposed gas processing facility site are presented in Table 10-6. All communities that will be impacted by clearing associated with the proposed gas processing facility footprint are well represented outside of impact areas.

No Declared Rare Flora will be affected by clearing associated with the proposed Development. One Priority Three species, *Corchorus interstans* ms, will be affected. *Corchorus interstans* ms is broadly distributed within the proposed gas processing facility site, across Barrow Island and on the mainland. It occurs in eight of the nine communities within the proposed gas processing facility footprint and has been recorded along the proposed feed gas pipeline route from North White's Beach to Town Point.

Restricted communities along the proposed pipeline alignment are well represented outside the proposed Development area. However, some coastal vegetation communities at North White's Beach (and also the alternative feed gas pipeline route from Flacourt Bay) appear to be highly restricted and have not been found in other locations to date. The preferred pipeline route at North White's Beach would affect approximately 0.5 ha of a restricted limestone community.

Table 10-5:
Existing Disturbance on Barrow Island

Type of Disturbance	Area Cleared (ha)
Long-term disturbance	
Base – administration, workshops, warehouse	16.69 or 0.07%
Infrastructure (e.g. camp, major stations)	60.24 or 0.25%
Operating gravel pits	5.22 or 0.02%
Disused gravel pits	344.53 or 1.46%
Rehabilitated infrastructure	57.16 or 0.24%
Roads	284.14 or 1.21%
Bulk storage (terminal tanks)	10.63 or 0.05%
Well pads	220 or 0. 93 %
Airport	42.10 or 0.18%
Old airport – storage and laydown area	10.21 or 0.04%
Short-term disturbance	
Seismic lines	170.73 or 0.72%
Flow lines (carbon steel and glass reinforced epoxy)	1.2 or 0.005%

Earthworks during construction of the feed gas pipeline will be managed to avoid increasing the distribution of introduced species *Setaria verticillate.* Only one specimen of this species has been found and it was located outside of the proposed pipeline corridor. The location of this specimen has been added to the existing Barrow Island Joint Venture Weed Program database for the island. The distribution of this species in areas to be affected by earthworks along the proposed pipeline routes will be further assessed prior to construction to ensure it has been eradicated, and that proposed earthworks will not contribute to its spread on Barrow Island.

Possible extension of the runway at the existing airport and installation of the proposed optical fibre cable near Town Point will require clearing and have the potential to impact restricted communities if present within area to be disturbed.

The location and layout of the CO_2 seismic monitoring grid is still being developed therefore the monitoring area has not been fully surveyed. The conceptual preliminary CO_2 seismic monitoring grid will require approximately 35 ha (part of the total clearing provided for under the Barrow Island Act) of clearing for access across the monitoring area (Chapters 6 and 13). The seismic source lines will be overlain on seismic survey lines that were established in 1994 to the greatest extent practicable. The final grid layout will be refined on the basis of ongoing geophysical modelling and further botanical surveys. However, a preliminary survey of the area showed that there are some major drainage lines with restricted vegetation communities, restricted coastal dune communities and clay pan communities to the north. Each of these communities, and other restricted communities identified in subsequent surveys, will be avoided in the final grid selection.

The key environmental impacts to flora and vegetation communities associated with clearing and earthworks include:

- loss of and/or disturbance to restricted vegetation communities
- loss of and/or disturbance to priority or restricted species.

Risks associated with introduction of non-indigenous species or pathogens and quarantine management are discussed in Chapter 12.

Mainland

Clearing and earthworks for the proposed domestic gas pipeline easement on the mainland will affect approximately 75 ha of terrestrial and intertidal vegetation communities. These communities are generally degraded by livestock grazing and no restricted communities have been identified. Vegetated communities contiguous with those along the proposed pipeline route have generally recovered well from previous clearing, with the exception of the snakewood (*Acacia xiphophylla*) community which has not regenerated after 5–6 years (Dames and Moore 1998).

Earthworks may assist the spread of the introduced species *Prosopis* sp. and *Cenchrus ciliaris*.

Preliminary surveys conducted to date will be followed up by a detailed floristic and community survey during 2005.

Table 10-6:
Dominant Families Potentially Impacted by Development Infrastructure on Barrow Island

Development Area	Dominant Plant Families Impacted
Gas processing facility	26 families (48 taxa) will potentially be impacted. Dominant families include – Poaceae (5 taxa), Asteraceae (3 taxa), Euphorbiaceae (7 taxa), Papilionaceae (4 taxa)
Feed gas pipeline route from North White's Beach	27 families (67 taxa) will potentially be impacted. Dominant families include – Chenopodiaceae (9 taxa), Poaceae (9 taxa) and Asteraceae (7 taxa)
Alternative feed gas pipeline from Flacourt Bay	27 families (67 taxa) will potentially be impacted. Dominant families include – Poaceae (9 taxa), Asteraceae (7 taxa)

Management

Avoidance

Detailed botanical surveys of the proposed Development areas on Barrow Island have influenced the design and layout of the gas facility, pipelines and associated infrastructure. The gas processing facility footprint area has been selected to avoid drainage zones which contain restricted vegetation communities. The position of the construction village has also been modified to avoid the L6a *Grevillea pyramidalis* community near the original location.

Selection of the North White's Beach shore crossing avoids potential impacts to restricted coastal communities at Flacourt Bay. Impacts to restricted communities at North White's Beach will be minimised in final route selection.

Further botanical surveys of the proposed domestic gas pipeline route will be conducted to guide final route selection. Clearing of vegetation communities with limited or unknown potential for regrowth, for example *Acacia xiphophylla*, will be avoided. The location of introduced species will be mapped and these areas either avoided or the introduced species eradicated from the local area prior to construction.

Re-use of the 1994 seismic grid for the proposed CO_2 seismic monitoring program will avoid impacts to undisturbed land and will not add to the cumulative area of impact from oilfield activities on Barrow Island.

Mitigation

To avoid impacts to flora and vegetation from clearing and earthworks the Joint Venturers will:

- obtain relevant regulatory approvals prior to clearing
- limit clearing to designated areas at all times. Significant communities will be clearly marked to ensure they are not impacted inadvertently
- conduct flora and vegetation surveys prior to clearing to identify and mark significant vegetation species and restricted communities
- locate the proposed feed gas pipeline route from North White's Beach so that less than 10% of restricted *Grevillea pyramidalis* and limestone communities are affected (L6b, L6b, L6d, L3c)
- avoid communities with potentially restricted species such as *Tephrosia clementii*, *Eriachne flaccida* (southern Pilbara–Carnarvon coastal form), *Isolepis* sp., *Tribulus hirsutus* and *Corchorus congener*
- flag and avoid *Corchorus interstans* (Priority Three)
- rehabilitate areas no longer required for the Development, for example temporary lay-down areas.

Rehabilitation of the mainland pipeline easement will be assisted by stockpiling and re-using top soil where it has been cleared along the route. This will facilitate re-establishment of local species from seed and vegetative propagules in the soil.

Residual Risk

At the level of individual flora species, the risk associated with clearing will be low due to the absence of Declared Rare Flora or Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed species within proposed Development areas.

Clearing and earthworks for construction of the gas processing facility and associated infrastructure will pose a medium risk to flora and vegetation communities with restricted distribution on Barrow Island (evolutionary significant units). The consequences will generally be moderate due to localised, long-term changes in relative abundance within a restricted community, or loss of the community from the Development area, without affecting the viability of the population or community in surrounding areas.

The proposed lay-down area for the shore crossing at North White's Beach is very sparsely vegetated. Clearing for the feed gas pipeline route will have localised effects on a restricted limestone community, restricted *Grevillea* communities and coastal dune communities. The final pipeline route will be selected to minimise impacts on the limestone community (<10% of total area of the community). Although the *Grevillea* and dune communities are only known from the North White's Beach location, they form part of a large unit in the local area. The clearing is unavoidable (almost certain) and will have localised, but long-term effects on restricted communities. This moderate impact results in a medium risk to terrestrial vegetation communities.

In the unlikely event that the Flacourt Bay shore crossing option is reconsidered, the consequences of clearing the shore-crossing construction site would be serious to critical because the restricted coastal communities at Flacourt Bay are not known from other areas. Clearing and earthworks at Flacourt Bay would have long-term effects on a large proportion of these communities and may reduce the viability of these communities on the island. Clearing for construction at this location therefore presents a high risk to restricted vegetation communities.

Observations of the 1994 seismic grid lines indicate that affected vegetation communities are recovering well, with minimal edge effects evident. This suggests that re-use of these lines for the proposed CO_2 seismic monitoring program will not lead to further loss or modifications of the plant communities in the area. The proposed survey will cause localised, long-term impacts to general and restricted communities. This represents a moderate consequence of a planned activity (almost certain) and results in a low risk to terrestrial vegetation.

The results of further botanical surveys are necessary to fully assess the potential risks to terrestrial flora and communities along the domestic gas pipeline on the mainland. The homogeneity of the area and the documented regrowth of previously disturbed vegetated communities along the Apache Energy Sales Gas Pipeline corridor indicate that the impacts will be localised. Management of the earthworks, in particular tidal inundation and topsoil stockpiling and re-use, will mitigate potential impacts. The predicted impacts represent a minor consequence and pose a low residual risk to terrestrial vegetation communities along the mainland pipeline easement.

10.3.2 Emissions

The main source of atmospheric emissions associated with the proposed Development will be the operating gas processing facility. Emissions during construction will be minimal, for example vehicle and machinery exhausts. Emissions during construction and commissioning are not expected to affect terrestrial plant communities of individual taxa.

Atmospheric emissions associated with the operation of the proposed gas processing facility include:

- carbon dioxide (CO_2)
- carbon monoxide (CO)
- nitrogen oxides (NO_x)
- sulphur dioxide (SO_2)
- volatile organic compounds (VOCs)
- particulates and dust.

A comparison of expected emission levels from the Development against the National Environment Protection (Ambient Air Quality) Measure (NEPM) (National Environment Protection Council 2003), World Health Organisation (WHO) Air Quality Guidelines for Europe (WHO 2000) and United States Environmental Protection Authority (USEPA) National Ambient Air Quality Standards (USEPA 2004) is presented in Chapter 7. Emissions from the gas processing facility are predicted to meet all guideline levels.

Nitrogen oxides and CO_2 will be the principle emissions from the operating gas processing facility. Carbon dioxide does not pose a threat to plants at low concentrations. Potential effects due to large releases of CO_2 are discussed in Section 10.3.4. Nitrogen oxides are precursors of ‘wet’ and ‘dry’ acid deposition and ozone formation, both of which can injure vegetation (The World Bank Group 1998; Environmental Protection Authority 2004a). The uptake and effects of atmospheric NO_x on vegetation is influenced by humidity, temperature and light. Long-term deposition of nitrogen compounds can lead to increased acidity of the soil.

Australian arid zone vegetation is vulnerable to NO_x exposure, however arid zone vegetation is considered to be less susceptible to the effects of NO_x than temperate zone plants (Calquhoun et al. 1984, cited in URS 2002; EPA 2004a). This is due to adaptations that reduce their exposure to atmospheric pollutants, such as closure of stomata during the day. Further, NO_x is less corrosive in dry climates and arid zone plants are less susceptible to the effects of increased soil acidity due to soil water deficits (URS 2002).

Plants are most likely to suffer adverse physiological effects in areas subject to high nitrogen deposition to the soil surface. Terrestrial deposition of NO_x on Barrow Island is predicted to be highest to the north-east of the proposed gas processing facility (Technical Appendix B1). Nitrogen compounds (N) may accumulate on the soil surface in this area between significant rainfall events. Physiological impacts associated with increased nutrient availability and soil acidity vary among species and may alter species composition in affected communities. Regular flushing by cyclonic rains and buffering by alkaline soils is expected to substantially reduce the impact of these processes.

Predictions of whether levels of NO_x and ozone (O_3) would have adverse effects on vegetation communities is hampered by a lack of knowledge of the interaction and synergistic effects of NO_x with other pollutants such as SO_2 (EPA 2004a). In addition to this, maritime moisture forms dew, which attenuates the arid environment on Barrow Island. Humidity and condensation will dissolve NO_x and SO_x causing acid precipitation that may depress growth of affected vegetation because of the toxic effects of acidity or stimulate growth due to increased availability of nutrients (EPA 2004a).

Sulphur dioxide (SO_2) emissions on Barrow Island are expected to be negligible primarily due to the very low sulphur content of raw feed gas. Furthermore, hydrogen sulphide (H_2S) and CO_2 will be removed from the raw feed gas by the acid gas removal process and will be disposed of by injection into the Dupuy Formation. The greatest source of SO_2 emissions will be the diesel generator which will emit a maximum of 3.6 kg/hr. In situations where high SO_2 emissions occur plants such as lichens do suffer from temporarily reduced net photosynthesis (Nieboer et al. 1976); however given the low concentrations of SO_2 expected from the Development similar effects are unlikely.

Emissions of volatile organic compounds (VOCs) and particulates are predicted to be minor due to the use of high efficiency combustion equipment (e.g. gas turbines and efficient flare) and design and operation of condensate storage tanks to reduce fugitive emissions.

The ground level concentration of gaseous pollutants could increase slightly on days when there is no wind, particularly in valley systems. During extended periods without wind there is an increased risk that the emissions from the gas processing facility will have physiological effects on flora or vegetation communities. Associated effects are expected to be short-lived due to changes in wind patterns and rapid dispersal of ground level emissions.

Dust will be generated by vehicular traffic along unsealed roads, earthworks and wind erosion of stock-piled soil. Dust can increase thermal stress on plants and can reduce growth rates by affecting the photosynthetic efficiency of plants. The physiological effects of dust, including significant short-term reduction in photosynthesis and decreased water use efficiency, may have long-term effects on net primary production and shrub vigour (Sharifi et al. 1997).

Dust loading is expected to cause minor physiological impacts to plants in the immediate vicinity of the roads. However, observations from Barrow Island indicate that dust-covered vegetation growing adjacent unsealed roads generally attains equal or greater size than the same taxa away from the road, probably due to changes in soil depth.

Management

The potential effects of NO_x, SO_2, CO_2 and VOCs emissions from the gas processing facility on terrestrial flora and vegetation communities will be minimised through best practice design and operation.

NO_x, SO_2, and VOCs emissions from the gas processing facility are predicted to meet industry and NEPM air quality standards. The EPA Guidance Statement 15 (2000) for oxides of nitrogen emitted from gas turbines, with limits for emissions based on the AEC/NHMRC National Guidelines, will be followed. Modelling of emissions from the proposed gas processing facility indicates that deposition over the land surrounding the facility will be less than 2 kg/ha/year and mostly to the north-east of the facility (Chapter 7). WHO guidelines suggest 15–20 kg/ha/year as the critical load for nitrogen deposition on dry heathland. WHO guidelines provide a basis from which to set targets and monitor potential effects of emissions on vegetation as there are currently no accepted Australian air emissions guidelines for vegetation. This guideline has also been adopted in the Queensland Environmental Protection (Air) Policy 1997.

The use of dry gas seals (or equivalent) on compressors, a-MDEA as the CO_2 removal agent, and proposed injection of CO_2 will all significantly reduce VOC emissions. Accidental release of VOCs will be minimised by measures to control fugitive emissions such as high integrity valves, pump seals and flange gasket materials. The Joint Venturers have established a policy of burning VOCs to the maximum extent practicable, rather than venting during commissioning. Further, technology will be investigated to capture hydrocarbons that are vented during routine operations.

Emissions targets will be set and detailed emission management measures will be developed for commissioning and operations to achieve targets. Emissions from the gas processing facility and their impact on the surrounding vegetation will be monitored to ensure compliance during operations. The guideline limits will be periodically reviewed on the basis of results from vegetation monitoring. Vegetation monitoring plots will be established in locations adjacent to the proposed gas processing facility and in control locations well away from sources of emissions. If an unexpected increase in deposition, above guideline concentrations, or a significant decline in plant health is detected, operation of the gas processing facility will be reviewed and a corrective strategy developed.

Residual Risk

No operational gas emissions will exceed Australian or international air quality criteria. Deposition of atmospheric N is predicted to be less than 5% of the WHO (2000) critical load for dry heathland which suggests that the predicted deposition will have negligible effect on the surrounding vegetation. Occasional exceedance of air quality criteria during commissioning of the gas processing facility would only last a short time and would not have a measurable effect on terrestrial vegetation communities.

In the absence of data on the effects of low level emissions on Pilbara vegetation, a physiological effect must be assumed. If the emissions have an ongoing physiological effect on the vegetation or change soil chemistry and nutrient availability, this may cause a shift in the composition of the general vegetated communities in the local area. While the vegetated communities are expected to persist, the long-term modification in community composition would represent a minor consequence. Assuming that this level of impact is likely to occur, the risk level is low.

10.3.3 Fire

Barrow Island has been kept free of large, broad-scale fires for approximately 40 years. Fire ignition sources will increase on Barrow Island as a result of the proposed Development. Examples of ignition sources during construction and operations include hot works (welding and grinding) and vehicle exhausts. During commissioning and operations, hot carbon deposits released from the flare would be potential sources of ignition.

Due to the presence of a high fuel load on Barrow Island, a fire originating from construction or operations activities could result in a substantial wildfire under certain climatic conditions (e.g. high temperatures, low humidity and strong wind). A broad-scale wildfire on Barrow Island could result in hot burns in areas where restricted vegetation communities occur. While these communities are adapted to natural fire, hot fires can cause shifts in community composition in the short-term (<5 years). This may result from stimulation of seed germination, changes in dominance due to altered nutrient availability and changes in shading regime. The area of effect is unpredictable and varies according to wind speed, direction and fuel availability.

Arid zone vegetation has evolved within a regime of sporadic natural fires. Consequently the Barrow Island flora is expected to be able to regenerate or recolonise following fire. Natural fire regimes also help maintain a mosaic of vegetated habitats where a variety of successional stages are present in a given area. Artificial control of natural fires to protect infrastructure may decrease the diversity of vegetation communities.

Management

The Joint Venturers' policy will be to control fires that are either caused by construction or operations activities or which pose a risk to Development facilities or personnel. Naturally occurring fires that do not pose a threat to Development facilities or personnel will be responded to in accordance with policies and procedures agreed with the Department of Conservation and Land Management (CALM) through the Barrow Island Coordination Council.

Management of fire directly associated with construction or operations activities will focus primarily on prevention and control of fires. The Joint Venturers will also:

- establish a continuous firebreak along the boundary of the gas processing facility
- construct a fire station
- install fire and heat detection systems with automatically activated water sprays in areas where hydrocarbons and chemicals are stored and handled
- implement a hot work permit system
- conduct regular audit, inspection and maintenance of fire equipment and fire prevention mechanisms
- conduct majority of construction and operations activities in cleared areas
- implement employee awareness, induction and training programs including specific fire fighting training
- prohibit off-road vehicle driving under normal circumstances. Where off-road driving is necessary (e.g. CO_2 seismic monitoring), the vehicle/s will be fitted with fire extinguishers and exhaust guards or similar and procedures will be developed to prevent snagging vegetation

- remove bladed vegetation from work areas
- design and construct flares that minimise particulate build-up
- divert firewater run-off from hardstand areas into stormwater management systems
- establish a cleared firebreak around the flare.

Recent reviews (e.g. Casson 2003) of the potential impacts of the current fire management regime on Barrow Island have recommended the development of a patch-burn strategy. The Joint Venturers consider that the Barrow Island Coordination Council (BICC) (Chapter 2) is the most appropriate forum through which any change to the current fire management regime on Barrow Island would be considered and implemented.

Residual Risk

Existing fire prevention procedures and emergency response capabilities on Barrow Island, in combination with the management strategies outlined above reduce the likelihood of an uncontrolled fire originating from the Development and affecting a large area of bushland to unlikely. Under certain climatic conditions, a wildfire on Barrow Island could have a serious consequence to flora and vegetation communities given the existing fuel loads and the likelihood that some restricted communities could take longer than 5 years to recover fully. This represents a medium risk to terrestrial vegetation.

10.3.4 Unpredicted CO_2 Migration to Surface

The overall probability of injected CO_2 migrating to the surface is considered remote (Chapter 13). Potential events that could lead to unpredicted migration of CO_2 (as described in Chapter 13) and result in the release of CO_2 at the surface include:

- failure of the CO_2 injection compressors, pipelines or wellheads
- unpredicted migration along existing or decommissioned well penetrations, faults or fractures
- failure of structural seals.

In the unlikely event that CO_2 migrates to the surface it is expected that the resulting CO_2 flux rates would be between 1 and 100 micromol/m^2/sec. At the low end of this range the resulting CO_2 flux rate is anticipated to be below background levels. At the higher end of this range, the leaking CO_2 would have localised effects on terrestrial vegetation. Depending on climatic conditions, CO_2 residence times and concentrations, flora and vegetation communities in the immediate vicinity of the leak may exhibit an increase or decrease in growth rate. It is possible there will be a synergistic effect of increased CO_2 concentrations on the ability of individual plants to use elevated N that may have been deposited on the soil (see Section 10.3.2).

Prolonged leakage of CO_2 could adversely affect restricted or general plant communities in the local area. Under prolonged exposure to high CO_2 concentrations, such as those that may occur at the leak point, there may be localised plant mortality.

A significant leak from a pipeline or injection well would trigger an emergency shut-down of the CO_2 injection system. Residual CO_2 would disperse into the atmosphere and surrounding terrestrial environment. Short-term leakage of CO_2 is not expected to have adverse effects on surrounding vegetation.

Management

The preferred CO_2 injection location was identified on the basis of several studies, including predictive modelling of the behaviour of injected CO_2, with the objective of minimising the risk of unpredicted migration. The Joint Venturers will also:

- establish a CO_2 monitoring program to provide for early detection (if CO_2 is migrating to unexpected locations) and allow for the implementation of mitigation measures
- implement a well remediation/abandonment program to prevent unpredicted migration through wells
- accelerate well remediation if CO_2 migrates toward an unremediated well
- conduct design validation and verification testing
- regularly inspect and maintain CO_2 injection and monitoring equipment
- implement automatic and manual emergency response systems to reduce release volumes.

Further details on mitigation measures are described in Chapter 13.

Restricted vegetation communities and flora in the vicinity of the CO_2 injection sites will be mapped and included in the development of the emergency response procedures. This will facilitate preferential protection of these areas.

Residual Risk

A long-term leak resulting in high CO_2 concentrations at ground surface could lead to mortality or long-term, sub-lethal effects on plant growth in the local plant communities. If restricted vegetation communities are present around the leak site, the consequence of the leak would be moderate and if general communities surround the leak site, the consequences would be minor. The likelihood of CO_2 leaking and having these impacts is remote due to the design of the injection system, careful selection of a suitable geological formation for injection, and the active monitoring and reservoir management program. Therefore, the residual risk to terrestrial vegetation is considered low.

10.3.5 Cumulative Risk

The major stressors to terrestrial vegetation and flora from activities associated with the proposed Development are clearing and earthworks and fire Table 10-7. These are both medium risk stressors. Other stressors pose a low risk to terrestrial vegetation; however none of these stressors act in isolation and their additive effects may pose a higher level of cumulative risk.

The cumulative loss of vegetation communities through clearing (medium risk) and possible fire (medium risk) would not result in a higher overall risk due to the small scale of clearing relative to possible fire effects.
The long-term effects on a local population of a restricted taxon or community caused by an uncontrolled fire would represent a serious consequence and would not be exacerbated by a small area of clearing nearby. The overall residual risk is therefore considered to remain as medium.

The physiological effects of shading, dust and emissions will possibly have a cumulative effect on plants in the direct vicinity of the Development.
The area of potential additive effect is therefore small and, although operating over the long-term will only affect a local area, and still pose a low risk.

Cumulative effects of an unpredicted CO_2 leak from the injection zone and routine emissions from the operating gas processing facility are theoretically possible, but unlikely due to the very low probability (remote) of a CO_2 leak. These stressors pose a low cumulative risk to terrestrial vegetation.

Table 10-7:
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Stressor: Clearing and Earthworks **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of flora through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened species and Threatened Ecological Communities (TECs). • To protect Declared Rare and Priority Flora, consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning Clearing for gas processing facility, pipelines, jetty approaches and associated infrastructure. Clearing for CO_2 seismic baseline survey. **Operations** Minor clearing and earthworks restricted to previously disturbed ground. Re-clearing survey lines for CO^2 seismic monitoring, every 5–10 years.	• loss and/or disturbance to vegetation species and communities • erosion or removal of topsoil and seed bank • spread of Mesquite (*Prosopis* sp.) or Buffel grass (*Cenchrus ciliaris*) on mainland (associated with domestic gas pipeline construction) • spread of *Setaria verticillata* (associated with North White's Beach feed gas pipeline construction) • change in soil profile and drainage due to earthworks may change dominance patterns in communities.	**Construction and commissioning** • conserve and replace topsoil along mainland pipeline easement • locate infrastructure to maximise use of previously disturbed areas • locate Development footprint to avoid restricted flora and vegetation communities • locate construction village to avoid L6a *Grevillea* community • minimise impact feed gas pipeline route from North White's Beach on restricted *Grevillea* communities (L6b, L6b and L6d) and a limestone vegetation community (L3c) • gain appropriate regulatory approvals prior to any clearing • conduct further survey work during detailed engineering phase, at optimum survey times, as input to final alignments and management measures	• Development footprint limited to that provided for under the Barrow Island Act • <10% estimated island-wide distribution of any community or taxa impacted • long-term viability of restricted communities and taxa maintained • no spread of introduced species • L6a *Grevillea* community avoided • mangroves rehabilitated in mainland shore crossing area.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring and control of introduced species along domestic gas pipeline easement • monitoring and control of introduced species along feed gas pipeline route	**Construction and commissioning** *Restricted Flora and Vegetation* Likelihood – almost certain, restricted flora and communities will be avoided where possible, but both pipeline options impact on restricted communities. Consequence – serious, due to local, long-term loss of restricted communities at North White's Beach – critical due to reduced viability of restricted communities at Flacourt Bay. Risk – medium (North White's Beach option) – high (Flacourt Bay option).

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
		• restrict disturbance to designated work areas • clearly mark clearing boundaries and monitor clearing operation • develop and implement site specific rehabilitation procedures to reduce duration of potential impact • minimise pooling of water from road runoff through design of cleared areas and roads • rehabilitate mangrove vegetation along mainland section of domestic gas pipeline route • roll or slash mangroves (rather than uprooting) along mainland section of domestic gas pipeline route • investigate use of erosion control devices/geotextile mud mats during construction of mainland section of domestic gas pipeline to minimise impacts to mangroves • prevent salinisation due to tidal ingress of seawater along domestic gas pipeline trench on the mainland.		• audit against EMP requirements to determine if vegetation clearing and earthworks practices and procedures are appropriately implemented • monitoring of mangrove recovery along mainland section of the domestic gas pipeline easement (Chapter 11).	*General Flora and Vegetation* Likelihood – almost certain, up to 300 ha (cumulative – proposed and possible future development) of general communities will be cleared for infrastructure. Consequence – minor, local, long-term reduction in the extent of general communities. No effect on viability of local populations. Risk – low **Operations** *Restricted Flora and Vegetation* Likelihood – unlikely, disturbance to restricted communities will be avoided. Consequence – minor, local, long-term loss of restricted community. No effects on long-term survival. Risk – low

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
		Operations • rehabilitate cleared areas that are no longer required for operations or future works • gain appropriate regulatory approvals prior to any clearing during operations • conduct vegetation surveys prior to clearing, avoid restricted vegetation communities • overlie CO_2 monitoring grid on 1994 seismic grid to minimise disturbance to undisturbed areas of vegetation to the extent practicable.			*General Flora and Vegetation* Likelihood – possible, clearing will be restricted to previously cleared areas, but some areas may have regrown. Consequence – minor, localised loss of general flora. Risk – low

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Stressor: Fire **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of flora through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened species and Threatened Ecological Communities (TECs). • To protect Declared Rare and Priority Flora, consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning Welding, grinding and vehicle exhausts can be ignition sources. **Operations** Maintenance activities and vehicle exhausts can be ignition sources. Fall-out of burning particles from flare.	• long-term loss of vegetation community • alteration of community composition • maintenance of unnatural fire regime to protect infrastructure with consequent loss of habitat diversity • secondary effects if infrastructure damaged, for example, may cause leakage of grey-water pipes.	**Construction and commissioning** • establish hot work permitting systems • perform audit, inspection and maintenance of fire equipment and fire prevention mechanisms regularly • conduct majority of activities in cleared areas • prohibit off-road vehicle driving under normal circumstances. Fit any off-road vehicles with exhaust guards • remove stockpiled vegetation from work areas • identify potential sources of ignition in Job Hazard Analysis • fit fire extinguishers to all vehicles • use diesel engines.	• long-term viability of restricted communities and taxa maintained • establishment of fire management program through BICC • no broad scale fires originating from Development facilities.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular audit, inspection and maintenance of fire equipment and fire prevention mechanisms • participate in a research program, managed by CALM, on the ecological effects of fire regimes on Barrow Island.	**Construction and commissioning** Likelihood – possible, fire may burn large area and only be controlled near installations. Consequence – serious, potential for local, but long-term decrease in restricted community, may have long-term effect on community composition of restricted or general communities. Risk – medium **Operations** Likelihood – possible, as above, potential ignition sources throughout life of facility, but natural fires permitted to take their course. Consequence – serious, as above. Risk – medium

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
		Operations • prohibit off-road vehicle driving under normal circumstances. Fit any off-road vehicles with fire extinguishers and exhaust guards and develop procedures to prevent snagging vegetation • use hot work permitting systems • design flare to minimise particulate build-up • clear area around flare • maintain a buffer zone around gas processing facility to avoid bushfire impact on gas processing facility.			

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Stressor: Atmospheric Emissions **Environmental Management Objective/s:** • To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.					
Construction and commissioning Low levels of vehicle and equipment exhaust (NO_x, SO_x). Flaring and venting during commissioning. **Operations** Combustion and fugitive emissions of SO_2, NO_x, CO_2, VOCs and particulates (Chapter 7). Low levels of vehicle and equipment exhaust (NO_x, SO_x).	• physiological effects of deposition of pollutants • localised change in taxon dominance due to N enrichment and soil acidity • alteration of community composition • reduced growth due to soil acidity or CO_2 • increased growth due to uptake of N or CO_2.	**Construction and commissioning** • limit commissioning emissions • maintain and service vehicles and equipment regularly • minimise period of commissioning. **Operations** • comply with EPA licence requirements for routine NO_x, SO_2 and CO_2 emissions • avoid venting of significant quantities of process hydrocarbons • implement air emissions management procedures • minimise use of ozone depleting substances and avoid use in new refrigeration or fire control systems • base design on 'no routine flaring' policy • use Australian standard low-sulphur diesel (where imported).	• long-term viability of restricted communities and taxa maintained • no breaches of environmental licence conditions • no loss of vegetation surrounding facility from emissions.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of emissions from the gas processing facility and their impact on the surrounding vegetation to ensure compliance with EPA licence requirements • establishment of stack sampling points in all fixed equipment exhausts • establishment of annual emission targets • reporting of emissions internally and externally.	**Construction and commissioning** Likelihood – unlikely Consequence – minor, possible local and short-term physiological effects on vegetation. Risk – low **Operations** Likelihood – likely Consequence – minor, possible localised, long-term changes in general community composition. Risk – low

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Non-routine operations Gas leak through pipeline or equipment failure. Flaring. Smoke and particulates from fire. Gas venting during start-up and shut-down of gas processing facility.		**Non-routine operations** • monitor and conduct preventative maintenance of all pipelines and other equipment routinely • maximise system reliability • connect gas pipelines to gas processing facility flare in case they must be depressurised for maintenance (e.g. pigging).			**Non-routine operations** Likelihood – unlikely Consequence – minor, due to localised and short-term physiological effects on vegetation around emission source. Risk – low

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Stressor: Light/ Shading/ Heat/ Cold **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of flora through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened species and Threatened Ecological Communities (TECs). • To protect Declared Rare and Priority Flora, consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning Temporary shading from stockpiles, equipment. **Operations** Long-term shading from pipelines. Heat and reflected light from infrastructure. Condensation from cool feed gas pipeline.	• trampling of regrowth vegetation below pipelines due to increased fauna activity (i.e. seeking shade) • higher faunal grazing pressure in regrowth areas • decrease in plant growth or localised loss of vegetation within shaded areas • increased plant growth due to ongoing condensation under feed gas pipelines.	**Construction and commissioning** • minimise Development footprint and locate to avoid restricted flora and vegetation communities • locate infrastructure to avoid priority species or restricted vegetation communities. **Operations** • clearing around infrastructure will provide buffer to heat and light effects.	• long-term viability of restricted communities and taxa maintained • no loss of vegetation surrounding facilities.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular inspection of pipeline easements and facilities to assess impacts of shading etc. on vegetation.	**Construction and commissioning** Likelihood – likely Consequence – minor, due to localised physiological effects, e.g. growth rates. Risk – low **Operations** Likelihood – likely Consequence – minor, localised effects on regrowth under pipelines, long-term change in general community composition. Risk – low

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Stressor: Dust **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of flora through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened species and Threatened Ecological Communities (TECs). • To protect Declared Rare and Priority Flora, consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning Clearing and earthworks. Vehicle and machinery movement on unsealed roads and exposed surfaces. Wind erosion of stockpiles. **Operations** Vehicle and machinery movement on unsealed roads and exposed surfaces.	• reduced photosynthetic activity of plants (Thompson et al. 1984) • increased absorption of near-infrared radiation and elevated leaf temperatures (Sharifi et al. 1997).	**Construction and commissioning** • seal frequently used roads • minimise vehicle movements (e.g. use of buses to transport workforce) • restrict vehicle speed and access • use water to suppress dust • prevent driving off designated roads and tracks without appropriate approval. **Operations** • as above • rehabilitate all cleared areas not required for operations.	• long-term viability of restricted communities and taxa maintained • no loss of vegetation surrounding earthworks from dust emissions.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • qualitative monitoring of dust levels surrounding construction sites to determine effectiveness of dust suppression measures.	**Construction and commissioning** Likelihood – almost certain, creation of dust is unavoidable during earthworks and use of unsealed roads. Consequence – minor, limited to possible short-term decrease in growth rates of dust affected plants. Risk – low **Operations** Likelihood – almost certain, will be a continuing aspect of use of unsealed areas. Consequence – minor, dust levels low and effects limited to decreased growth rate of plants adjacent roads. Risk – low

Table 10-7: (continued)

Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Stressor: Unpredicted CO_2 Migration (and release at ground surface) **Environmental Management Objective/s:** • To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.					
Non-routine operations Failure of CO_2 injection facilities. Failure of subsurface containment.	• increased or decreased plant growth depending on concentration of CO_2 • mortality of plants in the event of an ongoing severe leak.	**Non-routine operations** • avoid release through system design, testing and maintenance • undertake design validation and verification testing and maintenance of CO_2 equipment • select injection location to minimise risk of leakage • implement automatic emergency response engineered systems to reduce release volumes • implement active subsurface monitoring program and reservoir management plan to mitigate risk of CO_2 migration to surface • implement well remediation program to prevent migration through disused wells • accelerate well remediation if CO_2 migrates toward an unremediated well.	• long-term viability of restricted communities and taxa maintained • no breaches of environmental licence conditions • no loss of vegetation surrounding facility from emissions • no CO_2 leak from subsurface formation.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring and modelling program to provide for early detection (if CO_2 is migrating to unexpected locations) and allow for the implementation of mitigation measures • CO_2 pipeline corrosion monitoring and control program.	**Non-routine operations** Likelihood – remote Consequence – moderate, potential for localised long-term effects on restricted vegetation in the vicinity of an ongoing leak. Risk – low

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
Stressor: Leaks or Spills **Environmental Management Objective/s:** • To ensure that hydrocarbons and hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.					
Non-routine operations Spill during storage and transport of fuel or hazardous material. Spill or leak during waste storage and disposal. Failure of plant, equipment or pipelines. Leakage of storage tanks and bunds.	• localised loss of vegetation • reduced plant growth • soil contamination affecting regrowth.	**Non-routine operations** • avoid release through system design, testing operations and maintenance • apply industry standards for storage and handling of fuels and chemicals (e.g. bunding, hardstand and drainage systems) • conduct assessment of Material Safety Data Sheets prior to purchase of chemicals • implement emergency response and spill contingency planning • provide spill containment and recovery equipment at work sites • contain and remediate contaminated soil • install built-in automatic and/or manual shut-down in selected systems where required • rehabilitate any leak or spill site • implement early leak detection and reporting • implement hydrotest water management plan	• long-term viability of restricted communities and taxa maintained • no spills of stored chemicals contacting receptors outside bunded areas • all affected soils and vegetation communities remediated successfully.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular audit, inspection and maintenance of facilities • implementation and regular testing of emergency shut-down systems to reduce potential volumes from spills and leaks • implementation of a plant, equipment and pipeline corrosion monitoring and control program	**Construction and commissioning** Likelihood – unlikely Consequence – minor, potential localised, long-term change in composition of restricted communities at leak site. Risk – low **Operations** Likelihood – unlikely Consequence – minor, potential localised, long-term change in composition of restricted communities at leak site. Risk – low

Table 10-7: (continued)
Summary of Risk Assessment for Terrestrial Flora and Vegetation Communities

Activities/ Causes	Potential Environmental Impact/Consequence	Proposed Management Measures	Target	Proposed Measurement Strategies	Residual Risk
		• ensure pipeline routes minimise potential exposure of restricted vegetation communities • avoid valves on feed gas pipeline to gas processing facility site (exception is emergency shut-down valve) • locate majority of valves, and flanged connections, on hardstand surface within gas processing facility drainage system • provide 24-hour reserve capacity on gas processing facility site for saline injection water.		• routine inspection of infrastructure, plant and equipment by designated personnel • in the event of a spill or leak, monitor affected area to determine effectiveness of remediation.	

10.4 Terrestrial Fauna

Potential stressors to terrestrial fauna have been identified and risks estimated through an assessment of consequences and likelihood. The risk assessment focused on potential impacts to terrestrial mammals, reptiles, avifauna and invertebrates.

The risk assessment process focussed on fauna that are listed as threatened under state or Commonwealth legislation. Key receptor species were identified as described in Table 10-8. Key receptors were selected to represent species of particularly high conservation significance, groups of ecologically similar taxa, or species that are at higher risk due to a sensitive life stage or particular ecological attribute.

The consequences to listed species, other taxa of conservation significance (evolutionary significant units) and general species of terrestrial fauna were categorised using the definitions provided in Table 10-9. Likelihood definitions are provided in Table 9-6, Chapter 9. Residual risk was characterised by evaluating the potential environmental consequences of each stressor and estimating the likelihood of those consequences occurring to key receptor species given the proposed management measures. Risk levels were defined according to the risk matrix in Figure 9-2, Chapter 9. Risk assessment results are summarised in Table 10-11.

Risk assessments, including definition of consequences and identification of stressors and receptors, were undertaken by technical specialists with recognised expertise in a broad range of environmental fields. Many of these specialists are experienced at working on Barrow Island and have a long-standing knowledge of the island.

No high risk stressors to terrestrial flora and vegetation communities were identified through the risk assessment process. Risk assessments indicate that the following stressors pose a medium risk to terrestrial fauna:

- clearing and earthworks (construction and commissioning)
- physical interaction (construction, commissioning and operations)
- noise and vibration (operations)
- fire (construction, commissioning and operations).

Risk assessments indicate that the following stressors pose a low risk to terrestrial fauna:

- leaks or spills (construction, commissioning and operations)
- clearing and earthworks (operations)
- light or shade (construction, commissioning and operations)
- atmospheric emissions (construction, commissioning and operations)
- dust (construction, commissioning and operations)
- unpredicted CO_2 migration or release (construction, commissioning and operations)
- heat and/or cold (construction, commissioning and operations)
- noise and vibration (construction and commissioning).

Priority has been given to the development of management measures for these medium risk activities. Activities initially identified as a high risk to terrestrial fauna (prior to applied management) have been targeted for additional management to reduce risk to an acceptable level (i.e. low to medium risk). The medium level risks from these activities are the focus of the following discussion. The following also includes discussion of the low risk of impacts from leakage of injected CO_2 and atmospheric emissions from the gas processing facility in recognition of stakeholder interest. Quarantine risks are discussed in Chapter 12.

The Joint Venturers are committed to adopting all of the management measures that are outlined in this section for avoiding or mitigating impacts to terrestrial fauna. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses it may become necessary to modify proposed management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and targets will be developed.

The management and mitigation measures proposed in this chapter are, in the main, specific to particular activities or stressors. System-based management requirements, such as auditing and induction measures, are broadly discussed in Chapter 16 and are not referred to specifically in this chapter.

Table 10-8:
Key Receptor Species for Listed and General Terrestrial Fauna Species

Key Receptor	Reason for Selection	Additional Receptors Represented by Key Receptor
Listed Threatened Species		
Euro (*Macropus robustus isabellinus)*	Listed; largest marsupial on Barrow Island	
Black-flanked rock wallaby *(Petrogale lateralis)*	Listed; low population size; significant issue on west coast	
Spectacled hare wallaby (*Lagorchestes conspicillatus conspicillatus)*	Listed; non-burrowing; medium-sized marsupial	
Burrowing bettong (*Bettongia lesueur)*	Listed; burrowing marsupial; site restricted	
Golden bandicoot (*Isoodon auratus barrowensis)*	Listed; readily adapts to human presence	
Barrow Island chestnut mouse (*Pseudomys nanus ferculinus)*	Listed; small mammals	Small mammals, *Zyzomys* sp., *Planigale* sp., *Pseudantechinus* sp.
White-winged fairy wren (*Malurus leucopterus eduardii)*	Listed; restricted to Barrow Island; abundant	Landbirds
General fauna and ecologically significant units		
Land snail (*Rhagada* sp.)	Short range endemic	Land snails
Scorpion (*Urodacus* sp. nov. '*barrow*')	New species restricted to Development site	Scorpions, pseudoscorpions, insects, arachnids, other invertebrates
Northern brush-tailed possum (*Trichosurus vulpecula arnhemensis)*	Resident of rock holes and termite mounds	Small mammals
Termites (*Nasutitermes triodia)*	Important ecological component; mound builders	Detritivores
Mygalomorph spiders	Burrowing spider; possible short range endemic; susceptible to ground level impacts	Burrow-dwelling invertebrates
Spinifexbird (*Eremiornis carteri)*	Abundant landbird	Landbirds
Leopard skink (*Ctenotus pantherinus acripes)*	Restricted to Barrow Island in WA	Skinks and other terrestrial reptiles
Perentie (*Varanus giganteus)*	Major predator; largest terrestrial reptile on island	Monitors

Table 10-9:
Terrestrial Fauna Consequence Definitions

Consequence category	Minor	Moderate	Serious	Major	Critical
Protected fauna species (listed/ threatened)	*Individual level effects*				
	Local, short-term behavioural impact.	Local, long-term or widespread, short-term behavioural impact.	Widespread, long-term behavioural impact.		
	Population level effects				
	Local, short-term decrease in abundance. No lasting effects on local population.	Local, long-term or widespread, short-term decrease in abundance. Loss of small number of individuals without reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Loss of individuals leads to reduction in viability of local population. No reduction in viability of race on Barrow Island.	Local, long-term or widespread, short-term impact leads to loss of local population/s and reduced viability of the race on Barrow Island.	Widespread, long-term impact on population. Extinction of Barrow Island race.
General fauna communities and species (not listed/threatened)	*Individual effects*				
	Local, long-term or widespread, short-term behavioural impact.	Widespread, long-term behavioural impact.			
	Population level effects				
	Local, long-term or widespread, short-term decrease in abundance. Loss of small number of individuals without reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Loss of individuals leads to reduction in viability of local population. No reduction in viability on Barrow Island.	Local, long-term or widespread, short-term impact leads to loss of local population/s and reduced viability on Barrow Island.	Widespread, long-term impact on population. Extinction on Barrow Island.	Loss from immediate region.

10.4.1 Clearing and Earthworks

Clearing and earthworks will be required to construct the gas processing facility, pipelines and other associated infrastructure on Barrow Island. Under the provisions of the *Barrow Island Act 2003*, no more than 300 ha of uncleared land is available for gas processing projects. Should 300 ha be cleared for the proposed or possible future gas developments, this would represent 1.3% of the island. Approximately 90 ha will be cleared for construction of the domestic gas pipeline on the mainland. No vegetation clearing will be required for the mainland section of the optical fibre cable at Onslow.

Barrow Island

The majority of clearing and earthworks will be associated with construction of the proposed gas processing facility and associated infrastructure near Town Point. Clearing vegetation and removing structural habitats, for example termite mounds and rock holes, in the gas processing facility footprint will result in displacement or loss of the fauna in this area. Six fauna species listed as threatened under the EPBC Act and the Western Australian *Wildlife Conservation Act 1950*, and identified as key receptors for the risk assessment (Table 10-8), live in the area to be cleared. These fauna are:

- burrowing bettong (*Bettongia lesueur*)
- Barrow Island golden bandicoot (*Isoodon auratus barrowensis*)
- spectacled hare-wallaby (*Lagorchestes conspicillatus conspicillatus*)
- Barrow Island euro (*Macropus robustus isabellinus*)
- Barrow Island chestnut mouse (*Pseudomys nanus ferculinus*)
- white-winged fairy-wren (*Malurus leucopterus eduardii*).

Other non-listed, key receptors (evolutionary significant units) that will be affected are:

- water rat (*Hydromys chrysogaster*) (CALM Priority 4 species)
- land snail (*Rhagada* sp.)
- scorpion (*Urodacus* sp. nov. '*barrow*')
- northern brush-tailed possum (*Trichosurus vulpecula arnhemensis*)
- termites (*Nasutitermes triodia*)
- mygalomorph spiders
- spinifexbird (*Eremiornis carteri*)
- perentie (*Varanus giganteus*)
- leopard skink (*Ctenotus pantherinus acripes*).

The area of clearing and earthworks required for the feed gas pipeline shore crossing at North White's Beach (approx. 4 ha) and the feed gas pipeline route have been surveyed and avoids all significant fauna habitats (Technical Appendix C2). Similarly areas of clearing for road widening have been surveyed and do not contain significant fauna habitats. Given the limited scale of disturbance and the presence of surrounding unaffected areas of similar habitat, these aspects of the Development will cause minimal disruption to fauna.

The CO_2 seismic monitoring grid will involve earthworks for drill pad construction and slashing of approximately 35 ha of vegetated habitat along seismic source grid lines which will be approximately 3–4 m wide. Important fauna habitats will be avoided in the selection of seismic grid lines and drill pad locations.

Fauna habitats within all of the areas proposed to be cleared are well represented outside Development areas and there is no indication that these habitats are of critical importance to terrestrial fauna. Trapping and spotlighting data, from both CALM monitoring programs and field surveys for the Gorgon Development, indicate similar densities of most mammals across the island (Technical Appendix C2). The reptiles, birds and invertebrates in Development areas also appear to be widely distributed across the island, or at least within areas of similar habitat (Technical Appendices C2, C3, and C4).

The approximate number of individuals that will be affected by the proposed clearing and earthworks on Barrow Island has been estimated for mammal and bird species for which there are current density estimates or population estimates (Table 10-10). As the total proposed and possible future Development areas correspond to approximately 1.3% of the island, it is assumed that clearing and earthworks will affect a corresponding proportion (approximately 1.3%) of the terrestrial fauna on the island. This assumes that the faunal habitats are evenly distributed across the island and that the fauna densities in these habitats are similar across the island.

These estimates are indicative only and rely on published population sizes and the assumptions listed above, but do not account for inter-annual fluctuations in population sizes. Where fauna are known to deviate from these assumptions, their densities were calculated separately. For example, the white-winged fairy wren does not appear to be evenly distributed across the island but tends to favour the coastal shrublands that are common in the proposed Development area at

Town Point. The disproportionate amount of white-winged fairy wren habitat in the Town Point Development area leads to a higher estimate of the proportion of the population that would be affected by clearing and earthworks. Approximately 2% of the total populations of white-winged fairy wrens on the island are expected to be affected by clearing and earthworks.

The conservation significance of listed mammal fauna that will be displaced through removal of habitat has been assessed in relation to the status of the populations of these taxa on the island. The predicted 1.3% decrease in the abundance of other listed fauna is likely to fall within natural variability in population sizes, although it is expected to reduce the maximum population sizes on the island due to habitat removal. With the exception of the black-flanked rock wallaby, all of the listed terrestrial fauna on Barrow Island are in secure populations and a 1.3% decrease in population sizes is not predicted to affect their viability on the island. The black-flanked rock wallaby population on Barrow Island is critically small and any reduction in the population size of this species is potentially significant. Black-flanked rock wallabies do not occur in any of the preferred Development areas. The preferred location for the feed gas pipeline shore crossing at North White's Beach avoids the black-flanked rock wallaby population on Barrow Island.

Clearing and earthworks may affect small numbers of the EPBC listed Barrow Island chestnut mouse (*Pseudomys nanus ferculinus*) and other small mammals (tan antechinus (*Pseudantechinus roryi*), *Planigale* sp. and common rock rat (*Zyzomys argurus*). These taxa have been trapped from areas surrounding the proposed Development area and are likely to also occur within the Development areas.

There are at least nine burrowing bettong warrens in the Town Point area. The local bettong population use a subset of these burrows at any time and move over large distances in the area. Only one active warren lies within the proposed Development area at Town Point.

Clearing and earthworks will lead to loss of habitat for reptiles, avifauna and invertebrates. The effects are likely to be greatest for those taxa with limited home-ranges or limited dispersal ability. The significant herpetofauna of the proposed Development area includes perenties (*Varanus giganteus*), leopard skinks (*Ctenotus pantherinus acripes*) and possibly the blind snake (*Ramphotyphlops longissimus*).

The impacts to other evolutionary significant terrestrial fauna such as invertebrates, reptiles and landbirds cannot be quantified in the absence of extensive distributional or density data. These fauna appear to be widely distributed in similar habitats around Barrow Island (Technical Appendices C2, C3 and C4). Therefore, decreases in the populations of these taxa will be proportional to the area of habitat loss and will represent approximately 1.3% of total populations.

Minor clearing and earthworks may be necessary during operations, for example for additional CO_2 seismic monitoring or development of injection wells. Clearing will be minimised through use of previously cleared land and surveys will be conducted prior to clearing to ensure that no habitats of critical importance to listed or evolutionary significant species are impacted.

Table 10-10:
Estimated Abundance of Terrestrial Fauna Species within the Total Development Area on Barrow Island

Species	Estimated abundance (number of individuals) in total proposed and possible future Development area (300 ha)
Burrowing bettong	10–15* (one warren)
Euro	10*–20**
Golden bandicoot	780–1040**
Northern brushtail possum	20**
Spectacled hare wallaby	75*
White-winged fairy wren	315*

** based on direct estimate from surveys; ** based on 1.3% of estimated total island abundance*

Mainland

Approximately 90 ha of clearing and associated earthworks will be required along the proposed domestic gas pipeline route from the mainland coast to Compressor Station 1 on the existing Dampier to Bunbury natural gas pipeline. Clearing and earthworks will occur within a 30 m wide corridor along a 30 km easement. An access track will be retained for routine inspection. The clearing will affect the coastal mangal and degraded hinterland habitats.

Clearing a 30 m wide corridor through the coastal fringe of mangroves may affect terrestrial fauna on the mainland. Shorebirds utilise the mangrove and samphire zone and terrestrial avifauna roost and feed in mangroves. However, mangroves are extensive along the mainland coast and the area to be cleared for the proposed pipeline easement represents a very small proportion of the mangroves in the immediate region (i.e. less than 1% of the surrounding 5000 ha of mangroves). The loss of such a small proportion of the mangrove habitat will have little effect on local terrestrial fauna populations.

Fauna habitats along the inland section of the domestic gas pipeline route have been degraded by ongoing effects of cattle grazing and introduced species. Due to the narrow zone of impact, the clearing and earthworks for the proposed pipeline will to lead to displacement of most fauna rather than loss.

Three EPBC listed vulnerable terrestrial fauna, also listed as Schedule 1 fauna under the Wildlife Conservation Act, are recorded from the general region of the domestic gas pipeline route. They are the:

- olive python (*Morelia olivacea barroni*)
- mulgara (*Dasycercus cristicauda*)
- Pilbara (orange) leaf-nosed bat (*Rhinonicteris aurantius*).

Of these listed species, the mulgara is the only species likely to occur in sandy habitats along the proposed pipeline route. The olive python and the Pilbara leaf-nosed bat are restricted to rocky habitats comprising boulders and caves. No areas of this latter habitat type occur along the proposed domestic gas pipeline route.

The proposed domestic gas pipeline route will be located approximately 50 m south of the existing Apache Energy Sales Gas Pipeline easement which extends from Varanus Island to Compressor Station 1 on the Dampier to Bunbury natural gas pipeline. Any habitat fragmentation effects due to the existing easement and access track are not likely to be exacerbated by clearing and earthworks for the proposed Gorgon Development domestic gas pipeline. The normal movements of medium and large macropods through the area will not be affected by the underground pipeline. Small fauna may modify movement patterns at a micro-scale to avoid the open ground along the easement.

At this stage there are no density estimates for the mulgara or other terrestrial fauna along the proposed pipeline route. No mulgara burrows were observed during the preliminary survey of the proposed pipeline route. Additional surveys of the pipeline route in 2005 will further investigate the use of this area by the mulgara and other fauna.

Management

Management strategies designed to avoid or mitigate potential impacts to terrestrial fauna species on Barrow Island are discussed below with an emphasis on effects on key receptor species (Table 10-8). Development of management strategies has focussed firstly, on avoiding impacts to important fauna habitats through site selection and secondly, on mitigating unavoidable impacts.

Avoidance

The proposed location and layout of the gas processing facility and associated infrastructure was selected with reference to the distribution of significant terrestrial fauna species and their habitats. A large area surrounding the proposed gas processing facility and along the feed gas pipeline route was intensively surveyed for active burrowing bettong warrens and other fauna habitats of particular conservation significance. The proposed locations of the gas processing facility and feed gas pipeline avoid black-flanked rock wallaby habitat and comprise fauna habitats that are widespread on Barrow Island.
The proposed Development areas will directly impact only one active bettong warren.

The Joint Venturers will implement the following management measures to avoid and mitigate impacts to terrestrial fauna associated with clearing and earthworks on Barrow Island:

- conduct additional fauna surveys prior to clearing
- trap or shepherd large fauna out of areas to be cleared
- rehabilitate cleared areas that are not required for future works
- enforce prescriptive guidelines on any future clearing (e.g. CO_2 seismic survey grid), including requirements for fauna surveys prior to site selection and establishment buffer zones around important fauna habitats
- develop protocols for relocation of fauna in consultation with CALM and other relevant stakeholders
- apply strict controls during construction to ensure clearing and earthworks remain restricted to pre-designated, surveyed areas.

The final CO_2 seismic survey grid has not been selected, pending results of ongoing geotechnical, geophysical and environmental investigations in the area. However, clearing and earthworks within the proposed CO_2 seismic monitoring area will be constrained to avoid impacts to important faunal habitats. A preliminary survey of the area indicates that these constraints (listed below) will likely be achievable without compromising the seismic survey objectives. Constraints that will be placed upon clearing and earthworks for CO_2 seismic surveys will include, but not necessarily be limited to, the following:

- surveying all proposed seismic source lines prior to final route selection
- avoiding burrowing bettong warrens by at least 50 m when clearing access tracks for source lines and drill pads
- ensuring that seismic source holes (dynamite), vibroseis sites and drill pads avoid burrowing bettong warrens by 100 m (unless the geophysical model indicates a smaller range of effect)
- avoiding vegetation containing white-winged fairy wren nests. Clearing of potential nesting habitat (*Melaleuca cardiophylla shrubs*) will be minimised
- avoiding restricted structural habitats, such as termite mounds, rocky ledges, caves and sink holes
- avoiding clearing of restricted vegetated habitats
- carrying receiver lines and geophones by hand to avoid clearing for vehicle access for this purpose
- prohibiting ground surface grading along seismic source lines
- prohibiting vehicle access to dune areas
- prohibiting CO_2 seismic monitoring activities in areas of rock wallaby habitat.

Mitigation and Offset

Fauna displaced from Development areas into surrounding habitats are likely to encounter high intra- and inter-specific competition and territorial aggression.

Unavoidable habitat loss and displacement of fauna will be mitigated by relocating selected fauna to suitable release sites. Selected fauna are those that are suitable for translocation, present in sufficient numbers for a translocated group to survive and breed. Selected fauna are also species that fit in with existing translocation or recovery programs. A translocation program will be designed in consultation with CALM and DEH to augment existing endangered species relocation programs. The aims of translocation are consistent with existing state and Commonwealth endangered mammal recovery plans. For example, the Commonwealth Action Plan for Australian Marsupials and Monotremes (Maxwell et al. 1996) recommends reintroduction of threatened marsupials, such as rock wallabies and golden bandicoots, into parts of their former range where feral predators have been eradicated. CALM's management plan for the burrowing bettong on Barrow Island includes reintroducing the species to mainland sites (CALM 2005).

While the success of any translocation program is difficult to predict, fauna of the same species as those on Barrow Island have previously been successfully translocated. The 10–15 burrowing bettongs that would be displaced from the proposed gas processing facility site near Town Point will be captured and translocated to a suitable release site. This species has previously been successfully translocated on the mainland (Short and Turner 2000) and from Barrow Island to Boodie Island in 1993 after the natural population on Boodie Island became extinct (Burbidge 2004). Release sites will be determined in consultation with CALM to be consistent with existing relocation programs. The translocation of additional animals to Boodie Island could boost the genetic diversity of that population, potentially increasing the population's long-term viability.

Other species will be assessed for relocation potential in consultation with CALM. The recovery plan for the Barrow Island golden bandicoot includes plans for reintroducing this species to Hermite Island in the Montebello Islands (Maxwell et al*.* 1996). Bandicoots and hare wallabies from within the Development area may present a suitable source of individuals for such a translocation program. Translocation of bandicoots to a mainland site in 1992 failed due to feral cat predation. The translocation of displaced fauna to the Montebello Islands would only be successful if feral cats and rats are eradicated.

Since CALM's Western Shield Fauna Recovery Program to control feral predators began in 1996, more than 60 groups of 16 animal species have been translocated. Translocations on the whole have been successful (Possingham et al. 2003).

In addition to translocation programs, effects on fauna in the immediate vicinity of the proposed Development areas will be offset by the scientific benefits of extensive fauna surveys and collections undertaken for the Gorgon Development, including during clearing. In light of the paucity of museum collections of most of the invertebrate and reptile groups in the region, clearing of the gas processing facility area presents a valuable opportunity to collect information, including voucher specimens, of the fauna that occur in the area. The additional knowledge gained on these species will represent a significant scientific resource and will further the understanding of both Barrow Island and regional biodiversity.

Residual Risk

Barrow Island Chestnut Mouse

Loss of habitat due to clearing and earthworks will cause a permanent decrease in the populations of small mammals in Development areas, such as the Barrow Island chestnut mouse (*Pseudomys nanus ferculinus*), other small mammals (tan antechinus (*Pseudantechinus roryi*)), *Planigale* sp. and common rock rat (*Zyzomys argurus*). The threatened Barrow Island chestnut mouse occupies all vegetated habitats on the island (Burbidge 2004) and the proposed clearing will affect a small proportion of the total available habitat. The consequences of this localised impact will be minor, as populations of these taxa are expected to persist along the pipeline route and in the Town Point area, particularly in the non-impacted vegetated habitats between the Development and the coast and in uncleared areas adjacent the proposed gas processing facility. The impact is unavoidable during construction of the Development and therefore the residual risk is medium.

Burrowing Bettong

Of the medium-sized mammals that occur on Barrow Island, burrowing bettongs are the most site-restricted because their ability to relocate from one warren to another is unknown. Two burrowing bettong warrens will be directly affected during earthworks associated with construction of the gas processing facility. One of these warrens was inactive when surveyed; the other was found to be inhabited by approximately 10–15 burrowing bettongs. These burrowing bettongs represent a small proportion of the burrowing bettongs on the island (0.5%) and are part of a nominal local population that inhabits a number of warrens within the local area, including some that support considerably more individuals. For example, the large warren immediately north of the Terminal Tanks has up to 30 individuals (Donaldson, F. Personal communication 2004). Bettong warrens within the proposed seismic monitoring area will be avoided during clearing for seismic acquisition. No bettong fatalities are anticipated during the seismic operations.

There is potential to relocate displaced burrowing bettongs. However, as the success of translocation is uncertain, this precautionary risk assessment is based on the assumption that the affected burrowing bettongs will not survive.

Burrowing bettongs may travel several kilometres while foraging at night and, over a week, may visit several of the local warrens (Parsons et al. 2002). With the presence of other warrens in the immediate vicinity that will not be impacted by the clearing and earthworks, the populations of burrowing bettongs are expected to persist along the pipeline route and in the Town Point area. Large areas of foraging habitat will exist between the Development and the coast and in uncleared areas adjacent the proposed gas processing facility. The localised impact on a single warren will therefore result in moderate consequences, but as this impact is unavoidable during construction of the Development, the residual risk to fauna from earthworks and clearing is medium.

Black-flanked Rock Wallaby

The feed gas pipeline route from North White's Beach avoids rock wallaby habitat so there is very low risk of adverse impacts to black-flanked rock wallabies associated with clearing and earthworks for construction along this route. The CO_2 seismic monitoring area is similarly outside the range of rock wallabies on the island.

In the unlikely event that the North White's Beach route is found to be technically infeasible, earthworks for the shore crossing at Flacourt Bay would be predominantly in low-lying areas and it is anticipated that no black-flanked rock wallaby refugia habitat will be directly affected. Earthworks would be required along the pipeline route from Flacourt Bay to Town Point and these may lead to loss of a small area of foraging and refugia habitat on hilltops along the route. Earthworks in these habitats would be timed to avoid the spring–summer breeding time for the rock wallaby to avoid disturbance of breeding behaviour and females with pouch young. A survey of the potential pipeline routes would be conducted prior to route finalisation to identify important refugia in case this route requires further consideration. Important refugia would be avoided in selecting the final pipeline alignment.

Given these management measures, particularly selection of the North White's Beach site, the consequences of clearing and earthworks are predicted to be minor as they would not affect the breeding success of the local rock wallaby population. The risk of adverse impact on rock wallabies is low for clearing and earthworks.

Barrow Island Euro and Spectacled Hare Wallaby

Euros and spectacled hare wallabies within the proposed gas processing facility area will be displaced when the area is cleared. These medium size mammals will be considered for translocation. Spectacled hare wallabies were present in the Montebello Islands (Burbidge 2004) and would be considered for reintroduction to those islands. However, the Barrow Island euro is a subspecies known only from Barrow Island and no other areas of previous range are available as recipient sites. The risk assessment assumed total fatality as a worst case due to uncertainty in their survival in the adjacent habitats and direct loss during clearing.

The small number of euros and spectacled hare wallabies that are likely to be displaced by clearing and earthworks within the proposed gas processing facility area will not reduce the viability of local populations and represents only a small proportion of the total populations on the island. Populations of euros and spectacled hare wallabies will persist in the adjacent habitats that will not be impacted, particularly between the Development and the coast and in uncleared areas adjacent the proposed gas processing facility.
The localised, long-term impact to local populations would represent only a moderate consequence to these listed fauna species, but as this impact is unavoidable during construction of the Development, is a medium level of residual risk.

Golden Bandicoot and Northern Brushtail Possum

Habitat loss through removal and modification of vegetation and structural habitats such as rock holes and termite mounds during clearing and earthworks will displace golden bandicoots and brush-tailed possums within Development areas. These mammals are part of large local populations and the loss represents a low threat to the viability of local populations along the pipeline route, in the CO_2 monitoring area and in the Town Point area. Clearing and earthworks will not reduce the viability of these taxa in the areas surrounding the Development infrastructure. Bandicoots in particular tend to adapt well to the presence of humans and infrastructure.

Golden bandicoots would be considered for translocation to Hermite Island in the Montebello Islands, a part of their former range (Burbidge 2004).

Golden bandicoots and brush-tailed possums are expected to persist along the pipeline route outside the narrow swathe of clearing and in the Town Point area in the habitat that will not be impacted between the Development and the coast and in uncleared areas adjacent the proposed gas processing facility.
The potential long-term reduction in the local populations represents a moderate consequence; however, as this impact is unavoidable during construction of the Development, the likelihood is rated almost certain and therefore the residual risk is medium.

White-winged Fairy Wren

White-winged fairy wrens are distributed widely across the island and are the second most abundant bird on the island after the spinifexbird (Pruett-Jones and Tarvin 2001). Clearing in Development areas is likely to lead to displacement of a small proportion (approx. 2%) of the total population of fairy wrens on Barrow Island.

White-winged fairy wrens will be considered for translocation to the Montebello Islands where they may have occurred up until the 1950s (Burbidge 2004).

The potential long-term reduction in the local abundances on Barrow Island is not expected to threaten local population viability. White-winged fairy wrens will persist in adjacent habitats along the pipeline route and in the Town Point area in uncleared areas adjacent the proposed gas processing facility. These localised effects represent a moderate consequence, because the wrens will persist at lower numbers in the Town Point area. Clearing and earthworks are unavoidable during construction of the Development. Therefore, they pose a medium residual risk.

General Fauna

The loss of potential habitat within the area cleared for the Development is likely to affect a small proportion of the total reptile populations on the island, including populations of more significant species, such as perenties and leopard skinks. The distribution of the blind snake is unknown due to difficulties in sampling these troglobitic reptiles; however, they are expected to be widespread in similar habitats across the island. Effects on herpetofauna will be minor being limited to permanent, but localised, decreases in abundance without threat to the viability of populations in the areas adjacent the Development area. This impact is unavoidable during construction of the Development; the likelihood is rated almost certain and the residual risk is low.

The significant invertebrates of the area include a previously undescribed scorpion species (*Urodacus* sp. nov. '*barrow*'), a new pseudoscorpion species (*Synsphyronous* sp. nov. *'barrow'*), land snails and mygalomorph spiders. These taxa are potentially short-range endemic species and are likely to be distinct from the mainland races of the same species.

All of these taxa are expected to occur in similar habitats across Barrow Island. However, the scorpion and the pseudoscorpion have been found only in the vicinity of the Development area at Town Point. In light of their low abundances in this area, potential permanent, localised decreases in the abundance of these taxa in the proposed Development area engenders a moderate consequence due to potential effects on the viability of the local populations. This impact is unavoidable during construction of the Development and the likelihood is rated almost certain, therefore the residual risk is medium.

The *Rhagada* sp. land snails in the Development area occur widely across the island and there is very little genetic divergence amongst populations on the island (Johnson 2004). This indicates that localised loss of the snails from the Development areas at Town Point and along the pipeline route is unlikely to cause loss of unique genetic races. Invertebrates associated with soil or vegetated habitats would be lost in areas of clearing and earthworks but are expected to be similarly well represented in areas outside the Development area. Local population viability will not be threatened by the earthworks or clearing. Effects on land snails, mygalomorphs and other invertebrates will be minor being limited to permanent, but localised, decreases in abundance without threat to the viability of populations in the areas adjacent the Development area. This impact will be unavoidable during construction of the Development; the likelihood is assessed as almost certain and the residual risk is low.

10.4.2 Physical Interaction

Barrow Island

The main impact associated with physical interaction between the workforce, vehicles and gas processing facility and local fauna will be accidental road kill. Lesser impacts include injuries or fatalities in hazardous areas within the facilities. Behavioural disturbance may also result from vehicles and pedestrian traffic, or presence of construction personnel, outside of facilities. Potential impacts due to physical interaction between the workforce and fauna are more likely in areas of higher traffic, such as around the proposed gas processing facility and between the accommodation camp and the work site. Above-ground pipelines will not interfere with the natural movements of fauna because they will be designed to allow transit of fauna across or under the pipes.

Physical interactions will be more frequent during construction due to greater numbers of personnel and vehicles on Barrow Island during this phase of the Development. Furthermore, during construction, particularly during the early stages of construction, fauna will not be habituated to the presence of the facilities, vehicles or personnel. As there will be considerable traffic of large and small vehicles, some road kills are expected. A small number of listed species may be killed on the roads and within the construction areas. The fauna that are most likely to be affected by road traffic are:

- burrowing bettong (*Bettongia lesueur*)
- Barrow Island golden bandicoot (*Isoodon auratus barrowensis*)
- spectacled hare wallaby (*Lagorchestes conspicillatus conspicillatus*)
- Barrow Island euro (*Macropus robustus isabellinus*)
- Barrow Island chestnut mouse (*Pseudomys nanus ferculinus*)
- white-winged fairy-wren (*Malurus leucopterus eduardii*).

Other non-listed, key receptors (evolutionary significant units) that will be affected are:

- northern brush-tailed possum (*Trichosurus vulpecula arnhemensis*)
- spinifexbird (*Eremiornis carteri*)
- perentie (*Varanus giganteus*)
- leopard skink (*Ctenotus pantherinus acripes*).

During the operational phase of the Development, vehicle numbers will be reduced. However, road fatalities will have an ongoing impact on terrestrial fauna for the life of the Development. The warmth of dark, sealed roads is likely to attract reptiles which will increase their risk of encountering a vehicle. This will be offset by greater visibility of fauna on the sealed roads and improved stopping distance for vehicles.

Workforce activities during operations have the potential to disturb fauna in sensitive areas, such as caves and beaches. Further, fauna are expected to be attracted to the food, shelter and water around the accommodation facilities. This could have a long-term effect on the behaviour of the affected fauna within the immediate area of the Development.

Mainland

There are no anticipated effects of the physical presence of the domestic gas pipeline near Robe River, or the optical fibre cable at Onslow, on any listed fauna species. The domestic gas pipeline will be buried and access for maintenance inspections will be infrequent. Faunal impacts are very unlikely because inspection vehicles will travel slowly and faunal densities are low. The optical fibre cable at Onslow will be associated with existing infrastructure and will not affect fauna.

Management

Although some level of road kill is highly likely when vehicles are regularly travelling through fauna habitat on Barrow Island, there are a number of management measures that can be implemented to minimise fatality rates. Road kills associated with the existing oil operations on Barrow Island have been reduced by enforcing speed limits on all roads, particularly between dusk and dawn. Management measures have been developed to ensure that road kills and injuries will be reduced in the proposed Development area. The Joint Venturers will:

- reduce vehicle numbers by using buses for workforce transport rather than individual vehicles
- establish slow vehicle speed limits and strictly monitor and enforce limits (Plate 10-1)
- monitor number of road kills to ensure that management is successful and impacts are not greater than predicted (management measures will be revised if roads kills are higher than predicted)
- prohibit feeding of fauna
- educate the workforce about the times and places that fauna will be most at risk.

Plate 10-1:
Fauna Protection Speed Limit Sign on Barrow Island Roads

Behavioural disturbance to fauna will be minimised by restricting the workforce access to areas outside the facilities. Access to beaches and bushland will be strictly controlled and feeding of fauna will be prohibited. Beach access will be prohibited during the peak of the turtle nesting and hatching season when terrestrial fauna such as bandicoots and perenties forage on the beaches (refer Chapter 11). Unnecessary access to caves and areas of undisturbed bushland will not be permitted to avoid behavioural disturbance to fauna.

Hazardous areas associated with the gas processing facility will be fenced to prevent fauna access (and possible injury). Lighting in the facility will be designed to minimise attraction of fauna to the facility, whilst maintaining lighting levels required for safety.

The proposed feed gas pipelines from North White's Beach to the gas processing facility at Town Point will be raised above the ground and buried at road crossings. This will reduce the effects of this potential barrier to natural movements of fauna. The elevated pipeline would be high enough for the euro, the largest of the Barrow Island marsupials, to pass underneath.

Residual Risk

Listed Fauna

Low numbers of listed species, including small and medium sized mammals (burrowing bettong, Barrow Island golden bandicoot, spectacled hare wallaby, Barrow Island euro, Barrow Island chestnut mouse) and the listed white-winged fairy wren are likely to be accidentally killed on the roads. The threat to individual species will be proportional to their relative abundance on the island. Abundant fauna such as bandicoots are the most likely to be killed. Mortalities will be minimised, but not totally prevented, through active management of road traffic and education of the workforce. Road kills will reduce the abundance of these listed fauna in the vicinity of the Development areas for the life of the project, but will not reduce the viability of local fauna populations as only a small proportion of the populations will be affected.
This represents a moderate consequence that is almost certain to occur during both construction and operations. The risk of impacts to listed terrestrial mammals from physical interaction therefore represents a medium risk for both construction and operations.

Selecting the North White's Beach pipeline route greatly reduces the risk of black-flanked rock wallaby road kills as it removes the requirement for vehicular traffic to Flacourt Bay, or other areas of rock wallaby habitat, for maintenance inspections. The moderate consequence of the possible death or injury of a small numbers of rock wallabies represents a medium risk.

Faunal impacts associated with physical interaction are possible for the mainland sections of the proposed Development. However, these would be limited to occasional fauna deaths from animals becoming trapped in the trench dug for the pipeline trench.
The consequences of this impact are minor and the resultant risk is low.

General Fauna

Occasional road kills of non-listed fauna, including evolutionary significant units such as northern brush-tailed possums, spinifexbirds, perenties and leopard skinks, will not affect the viability of their populations in the areas adjacent to the proposed Development.

Impacts to smaller reptiles and invertebrates, such as landsnails, scorpions and pseudoscorpions, are expected to be minimal as these animals generally remain under vegetated cover to avoid predators.
They are also less likely to cross roads and therefore are at less risk of road injury.

During construction and operation, road kills and injuries will have a localised impact on fauna over the life of the proposed Development without threatening their local populations. The minor consequence of a small number of road kills is almost certain to occur and represents a low risk to non-listed fauna.

10.4.3 Noise and Vibration

The major sources of noise and vibration during construction on Barrow Island will be associated with:

- blasting and earthworks for site preparation at the gas processing facility
- aircraft traffic
- seismic CO_2 monitoring
- construction of the feed gas pipeline shore crossing.

Construction and commissioning activities will generate occasional peaks in noise and vibration, whereas operations will generally produce a constant source of noise. The operating gas processing facility will generate relatively low levels of noise and vibration, but there will be irregular noise peaks while gas is discharged through the flare tower. Flaring is expected to be frequent during commissioning of the gas processing facility (continuous for 1–2 weeks) and infrequent following the first few years of operation (approx. once per month). Seismic monitoring of the underground CO_2 plume will generate localised peaks in vibration every 5–10 years during operations.

Irregular loud noise is expected to have a short-term behavioural impact on animals in the local area. Fauna are expected to be alarmed by sudden loud noises so will temporarily vacate the immediate area and return to normal behaviour when the noise has stopped. Noise and shock waves from blasting operations are not expected to have a significant impact on fauna in the vicinity of major earthworks for the gas processing facility.

The fauna that would be affected by noise and vibration include the listed species of mammal (burrowing bettong, Barrow Island euro, spectacled hare wallaby, Barrow Island chestnut mouse, Barrow Island golden bandicoot), the listed white-winged fairy wren and non-listed fauna (northern brushtail possum, *Planigale* sp., rock rat, water rat, landbirds and invertebrates) in the vicinity of the proposed pipeline and gas processing facility on Barrow Island.

Fauna are expected to habituate to noise from aircraft traffic and the operating gas processing facility.
The persistence of euros, burrowing bettongs, golden bandicoots, hare wallabies, brush-tail possums and other small mammals in close proximity to the existing Barrow Island airport indicates that these animals tolerate ongoing but infrequent loud noises. Aeroplanes and helicopters land and take-off from the airstrip at Barrow Island at least four days per week with noise levels of approximately 80 dB(A) at 100 m from the aircraft. The Barrow Island airstrip is fenced to prevent larger fauna from entering.

Pressure waves from blasting during construction may have physiological effects on fauna in the immediate vicinity of construction works. A small number of fatalities of listed species, for example golden bandicoots and spectacled hare wallabies, from blasting over pressure are likely. Any such fatalities would be restricted to individuals hiding in the immediate vicinity of the earthworks and are not expected to decrease the viability of local populations.

Seismic source vibrations or shock waves would cause startle responses in fauna in the immediate vicinity of the discharge. If in close proximity to the seismic source, marsupials may exhibit severe responses such as ejecting pouch young.

White-winged fairy wrens and other landbirds are expected to exhibit localised avoidance behaviour in response to blasting or infrequent loud noise. Except for a small number of individuals that would be killed in the direct impact area, invertebrates and reptiles are expected to show minimal disruption. Localised decreases in abundance of these taxa are not expected to affect the viability of local populations.

Noise and vibration associated with construction of the domestic gas pipeline on the mainland would be negligible and unlikely to affect local fauna populations. If blasting was required for excavation of the pipe trench, there could be potential disruption of mulgara in their burrows if they occur nearby.

Management

Avoidance

Impacts due to noise and vibration will be minimised by avoiding noise, vibration and blasting in sensitive fauna habitats. The gas processing facility will be designed to minimise the noise levels in accordance with human health standards that will also protect fauna in the surrounding areas.

The effects of noise and vibration from seismic sources during acquisition for the proposed CO_2 monitoring program would be minimised by avoiding sensitive fauna habitats. Most fauna would actively avoid the operating seismic truck and personnel. However, fauna seeking refuge in burrows, rock holes and termite mounds, would still be susceptible to impact. The following constraints on the seismic program will alleviate such impacts on cryptic fauna:

- selection of seismic source sites (dynamite, vibroseis, or accelerated weight drop) to avoid burrowing bettong warrens by an appropriate buffer (a nominal buffer of 100 m will be set unless geophysical model indicates that range of effects is greater or less than 100 m)
- avoidance of burrowing bettong warrens by at least 50 m when clearing access tracks for source lines and drill pads
- avoidance of areas of potential fauna habitat such as rock ledges, caves, holes or termite mounds.

Blasting management procedures will comply with Australian Standard AS 2436 Guide to Noise Control on Construction, Maintenance and Demolition Sites (Australian Standard 1981). Management measures aimed at minimising impacts to fauna from blasting noise and vibration have been developed. The Joint Venturers will:

- obtain approvals and permits for the storage and use of explosives under the provisions of the *Dangerous Goods and Safety Act 2004*
- use noise suppressants on heavy equipment
- avoid development in areas of rock wallaby habitat
- use best practical equipment and procedures available if development in rock wallaby habitat is not avoidable
- maintain and operate all equipment and vehicles in good condition
- develop a blast design that incorporates perimeter control techniques
- schedule blasting for daylight hours only to avoid activity peaks for nocturnal mammals (dawn, dusk, night)
- defer blasting when listed or evolutionary significant fauna are detected within the immediate area
- conduct visual monitoring for fauna over entire blast site and shepherd fauna to outside the blast zones.

The selection of North White's Beach as the preferred shore crossing location eliminates the risk of impacts to black-flanked rock wallabies from noise and shock waves associated with blasting. If North White's Beach is found to be infeasible following ongoing geotechnical surveys, Flacourt Bay would be considered as an alternative shore crossing site. This would require additional management to minimise impacts to black-flanked rock wallabies in the area.

Rock wallabies are most likely to be affected by blasting at dawn, dusk and night, while they are foraging. During the day, they take refuge in caves and ledges so are less susceptible to blasting impacts. Rock wallabies inhabiting the rocky hills adjacent to the alternative feed gas pipeline shore crossing at Flacourt Bay would be susceptible to shock from prolonged blasting should this route be selected. Blasting would be managed to minimise effects on local black-flanked rock wallabies as follows:

- blasting restricted at Flacourt Bay and the west coastal hinterland to daylight hours. This would significantly reduce the risk of potential impacts to black-flanked rock wallabies.
- blasting requirements at Flacourt Bay kept to the absolute minimum required to safely conduct site preparation and earthworks.

Noise and vibration associated with construction of the domestic gas pipeline on the mainland would have negligible effect on local fauna populations. Mobile fauna would actively avoid the construction areas. Possible mulgara burrows would be identified during the pre-construction surveys and avoided if blasting is necessary for excavation of the pipe trench.

Residual Risk

Burrowing Bettong

Management of seismic surveys and blasting around the proposed gas processing facility will reduce the impacts to burrowing bettongs to a negligible level. Bettongs are nocturnal and are only likely to be exposed to the loud, but short-duration, noises associated with daytime blasting while in their warren. Establishing suitable buffers around warrens during seismic acquisition, blasting and drilling would avoid more serious impacts such as ejection of pouch young.

Emergency flaring at night would elicit short-term and localised behavioural changes of minor consequence. These impacts are almost certain during construction and the resultant risk level is low.

Black-flanked Rock Wallaby

The preferred shore crossing at North White's Beach will avoid impacts to the black-flanked rock wallabies on the west coast of Barrow Island. If this option is infeasible and the Flacourt Bay alternative is pursued, the potential for reduced breeding success or mortality of pouch young in the rock wallaby population at Flacourt Bay would potentially result in a higher level of risk.

Any fatalities or depression of the reproductive output of the rock wallaby population at Flacourt Bay, through stresses associated with prolonged blasting in adjacent areas, may have a long-term (>5 years) effect on the local population. This serious consequence is possible, even given the proposed management responses and, therefore, poses a medium risk.

Mulgara

Blasting along the mainland domestic gas pipeline route could have moderate consequences to mulgara as they are expected to occur at very low densities in the area and any loss of individuals could have a long-term effect on the local population. The avoidance of blasting in close proximity to possible mulgara burrows would make impacts unlikely to occur and the residual risk level would be low.

Other Listed Species

Highly mobile fauna (Barrow Island euro, spectacled hare wallaby, Barrow Island chestnut mouse, Barrow Island golden bandicoot, white-winged fairy wren) in the vicinity of the proposed pipeline and gas processing facility on Barrow Island are likely to display localised and short-term avoidance responses to noise and vibration. Fauna in the vicinity of the operating gas processing facility are expected to become habituated to the ongoing, low level noise associated with the facility. Infrequent flaring is expected to cause startle responses in nearby fauna; however these will be short-term and are not expected to have any impact on the local populations.

None of these taxa are likely to suffer mortality or reduced breeding success due to construction or operational noise and vibration. While loud noise and ongoing low level noise associated with operating facilities are almost certain to elicit some behavioural response in these taxa, the minor effects will result in a low risk level.

General Fauna

Highly mobile non-listed fauna (northern brushtail possum, *Planigale* sp., rock rat, water rat, landbirds and invertebrates) in the vicinity of the proposed pipeline and gas processing facility are likely to display the same localised and short-term avoidance responses to noise and vibration as highly mobile listed species.

While loud noise and ongoing low level noise associated with operating facilities are almost certain to elicit some behavioural response in these taxa, the minor effects will result in a low risk level.

10.4.4 Fire

Potential ignition sources during construction and operations include 'hot works' (welding and grinding) and vehicle exhausts. Welding during pipeline construction has the potential to start fires on both Barrow Island and the mainland. During commissioning and operations, hot carbon deposits released from the flare will be a potential source of ignition. Hot works will be more frequent during construction than during operation of the gas processing facility and pipelines.

Potential impacts to fauna from a fire include temporary loss of habitat and direct injury or mortality. The ecological impacts of fire in Pilbara landscapes, although not well understood, include temporary loss or modification of fauna habitat, direct mortality, stimulation of plant growth, nutrient release and population increases in opportunistic species.

Most of Barrow Island has not been burned during the operation of the existing oil field and fuel resources have built up over this period. A fire under these circumstances is generally hotter than a fire in bush with low fuel resources and causes more faunal mortality and loss of habitat. Habitat loss on a broad scale may lead to increased predation and reduced food supplies for many faunal groups.

All of the listed fauna on Barrow Island are susceptible to the effects of a broad scale, hot fire. Small scale fires are likely to increase the habitat diversity by stimulating a series of successional stages in vegetated habitats and may also stimulate faunal populations. Some faunal populations, such as the Barrow Island chestnut mouse, fare better in long unburnt areas (Burbidge 2004).

Native fauna typically survive well in fire due to evasive strategies. Listed fauna such as burrowing bettongs, Barrow Island chestnut mice and bandicoots and non-listed fauna such as *Planigale*, *Pseudantechinus*, rock rats, possums, perenties and other reptiles, and invertebrates shelter in structural habitats such as termite mounds, rock holes and warrens that provide protection from fire. These fauna may be more likely to survive a severe fire than free-ranging fauna such as euros, hare wallabies, white-winged fairy wrens and other landbirds.

The EPA recognises that there are serious issues regarding fire management throughout the Pilbara and has called on CALM to review fire management procedures in this region (Environmental Protection Authority 2004b).

Secondary effects of fire control such as production of large volumes of foam, or run-off from fire damaged facilities, have the potential to cause localised contamination of soil and groundwater.

Management

Fires that are either caused by construction or operational activities or which pose a risk to Development facilities, existing oil field infrastructure or personnel will be controlled. Naturally occurring fires that do not pose a threat to Development facilities or personnel will not be controlled; and will help in re-establishing a mosaic of vegetated habitats of varying stages. This policy will be revised in consultation with CALM following release of their review of fire management practices in the Pilbara.

The proposed pipelines on the mainland will be buried so will not be at risk during operations of causing fires, or sustaining damage from them.

Management of fire directly associated with construction or operations activities will focus primarily on prevention and control of fires. Proposed management measures are outlined in Section 10.3.3.

Run-off from fire damaged facilities and foam from fire-fighting would be minimal due to bunding around the storage areas for flammable liquids and tiered stormwater management system for control of possible contaminants in stormwater. This would allow potential contaminants to be removed without contacting undisturbed areas around the proposed Development.

Residual Risk

A broad scale fire on Barrow Island is likely to cause widespread loss of fauna, including listed species. Some populations may take many years to recover, whilst others may not recover at all. This critical impact would represent the worst-case scenario, but has a remote likelihood as it would require an unusual combination of climatic conditions: probably multiple ignition points and failure of the fire response strategies. This would represent a medium risk to terrestrial fauna as many will survive the fire.

More likely scenarios are associated with patchiness in the fire as it passes through the vegetated habitats. In some localised areas of hot fire there would be high mortality rate which would lead to a long-term decrease in abundance in that area and possibly a reduction in the viability of the population. In other areas where the fire raced through due to wind or lack of fuel, there may be a general decrease in abundance over a wide area from which the populations would recover through breeding. These serious consequences are unlikely to occur as a result of activities associated with the Development and engender a medium level of risk during construction and operations.

Fires associated with the proposed Development would be very unlikely to reach areas of black-flanked rock wallaby habitat on the west coast due to rapid response to control the fire; and the presence of roads running parallel to the coast which would provide fire breaks and access points for back-burning.

The policy of letting natural fires run their course outside areas of existing and proposed infrastructure would assist in re-establishing a more natural mosaic of fire history. This would reduce the potential for serious – critical impacts on biodiversity from fires on Barrow Island.

10.4.5 Emissions

During construction emissions will be limited to vehicle and machinery exhausts. Discharges during commissioning of the proposed gas processing facility would be short-term, but involve greater volumes due to the release (venting) of unprocessed gases. Operational emissions would continue for the life of the facility. See Chapter 7 for a full discussion of atmospheric emissions over the life of the proposed Development.

Atmospheric emissions associated with the operation of the proposed gas processing facility include:

- carbon dioxide (CO_2)
- carbon monoxide (CO)
- nitrogen oxides (NO_x)
- sulphur dioxide (SO_2)
- volatile organic compounds (VOCs)
- particulates and dust.

Dispersion of atmospheric pollutants has been modelled and is described in Chapter 7. Greenhouse gas emissions are discussed in Chapter 13. A comparison of expected emission levels from the Gorgon Development with NEPM (National Environment Protection Council 2003), WHO (2000) guidelines and USEPA (2004) National Ambient Air Quality Standards is presented in Chapter 7. Emissions from the gas processing facility are expected to meet all guideline levels for NO_x, SO_2, particulates and nitrogen deposition.

Generally, atmospheric emissions will be rapidly dispersed by local winds and mostly deposited (dry) over the ocean (Chapter 7). During periods of low wind and high humidity, atmospheric emissions may accumulate in low lying areas around the gas processing facility. Under these conditions particulates may settle and accumulate on land. These depositions would be diluted and washed away by cyclonic rain.

Fauna may ingest contaminants at very low concentrations from the foliage of plants. This may have minor physiological effects on individual animals, but is unlikely to have any measurable impact. There is very little information on the effects of atmospheric emissions on fauna and no Australian guidelines have been established specifically for arid zone fauna. USEPA (2004) guidelines for protection of fauna suggest that the predicted concentrations of pollutants will not affect fauna. However the applicability of these guidelines to fauna in the Pilbara is unknown. The EPA in its review of emission impacts on the Burrup Peninsula, states that there is currently a lack of knowledge on the effects of air quality, in particular NO_x and O_3 (ozone), on fauna (Environmental Protection Authority 2004a). Human health standards can be used as a surrogate for standards for other mammals. Emissions from the operating gas processing facility will comply with the relevant human health criteria for atmospheric emissions (Chapter 7).

Secondary effects to fauna may arise due to possible impacts of emissions on vegetated habitats, as discussed in Section 10.3.2, and water sources. Contaminants bound to the particulates or carried in water vapour tend to become entrained in the surficial soils and over a long period can lead to acidification and nutrient enrichment of soil and water. Under these conditions, there is an increased risk that the cumulative emissions from the gas processing facility may have an impact on vegetated habitats and soil organisms adjacent to the gas processing facility. There is no free water in the vicinity of the proposed gas processing facility.

Direct impacts on listed and evolutionary significant fauna may occur in the remote event of a major leak of toxic or asphyxiant gas. Hydrogen sulphide, BTEX (benzene, toluene, ethylbenzene and xylene) or CO_2 released accidentally to the surrounding environment could accumulate in low lying areas of the landscape and potentially cause mortality of listed fauna in the immediate vicinity.

Listed fauna (burrowing bettongs, golden bandicoots and chestnut mice) and non-listed fauna (brushtail possums, small mammals, reptiles and birds) inhabiting burrows, termite mounds and rock holes in the vicinity of the proposed gas processing facility will be most at risk from accidental discharge of toxic or asphyxiant gases during extended periods of calm weather.

Management

Environmental management measures which complement the vegetation protection measures (Section 10.3.2) have been developed to minimise the risk of emission impacts on terrestrial fauna. The Joint Venturers will:

- minimise emissions by efficient design and operation and injection of CO_2. For further details see Chapters 7 and 13.
- optimise reliability of CO_2 injection system as described in Chapter 7 and Section 10.3.2
- optimise dispersion of vented CO_2 when injection system is shut-down
- vent commissioning gases through flare to maximise dilution and wind dispersion
- meet statutory requirements and acceptable standards for emissions
- monitor emissions from the gas processing facility to ensure ongoing compliance with relevant guidelines and licence conditions.

Refer to Chapter 13 for additional measures to minimise potential effects associated with CO_2 emissions.

Residual Risk

Avoidance

Operational emissions will be reduced through facility design and operation. Emissions from the gas processing facility will comply with national and international air quality guidelines, including the USEPA guidelines for protection of fauna. Discharge of waste gases during commissioning and operations through the flare tower will maximise dilution of the emissions and therefore minimise ground level concentrations that may affect fauna and their habitat. Most of the dry deposition of air pollutants will be over the sea.

Consequences to terrestrial fauna would be limited to negligible or, at worst, minor physiological impacts due to routine emissions from the operating gas processing facility. The effects on listed fauna are possible, but predicted to be negligible. Exposure to concentrations that would have physiological effects is unlikely, due to rapid dilution of the emissions and use of the flare tower for venting gas. This represents a low risk of adverse impacts to terrestrial fauna.

The consequences to listed fauna of possible indirect impacts through effects on vegetation would also be minor and pose a low risk to terrestrial fauna, as emissions are not expected to reduce the habitat or forage value of the plant communities.

In the remote event that a large volume of toxic or asphyxiant gas is accidentally discharged at ground level on a still day, there may be moderate consequences to listed fauna. Such a discharge could be expected to cause localised mortality of fauna in the immediate vicinity of the discharge.

Under the worst-case scenario with no wind to disperse an accidental discharge of toxic or asphyxiant gas, listed fauna such as burrowing bettongs, bandicoots, hare wallabies, Barrow Island chestnut mice and euros in the immediate vicinity of the leak could be affected. Small taxa may be killed in the event of a large leak and larger fauna may suffer physiological effects such as respiratory tissue damage. A large spill of toxic gas (BTEX, H_2S) or asphyxiant gas (carbon monoxide (CO), CO_2) could cause localised mortality of listed fauna in their burrows or shelters. This unlikely scenario could have moderate consequences, by causing a local, long-term decrease in the abundance of listed fauna, but would not affect the viability of the local populations. This represents a low level of risk to listed terrestrial fauna.

10.4.6 Cumulative Risk

Although clearing and earthworks, physical interactions, fire, noise and vibrations and emissions may each individually affect terrestrial fauna, none constitute a high risk of acceptable impact to listed or non-listed fauna. However, the possible effects of these stressors cannot be viewed in isolation as their effects may be additive in some Development areas.

Of the stressors discussed above, clearing and earthworks and road kills (physical interaction) are almost certain to have an effect on terrestrial fauna populations. The cumulative effects of these stressors on populations of listed and non-listed fauna would not pose an elevated level of risk to the fauna. Clearing and earthworks and road kills will both have a localised, but long-term effect on faunal populations in the immediate vicinity of the Development areas.

Potential cumulative effects of road kills and disturbance from blasting on black-flanked rock wallabies have been avoided by selecting the North White’s Beach site for the proposed feed gas pipeline shore crossing. If the Flacourt Bay option needed to be reconsidered, the potential additive effect of these stressors on rock wallabies would be of serious consequence as the viability of the local population may be reduced. The cumulative risk level to rock wallabies at Flacourt Bay would be medium.

Population densities of listed or non-listed fauna that would not be part of the relocation program, or collected to augment Western Australian Museum collections, would increase in areas adjacent to the Development through displacement of individuals during clearing and earthworks. This would lead to increased physical interaction and road kill frequency. However, this does not increase the risk level from low because total mortality of these taxa was assumed in the risk assessment.

The remote combination of events that would be necessary to impose a critical threat to the terrestrial fauna populations, perhaps through a catastrophic fire that led to the uncontrolled release of toxic gases at ground level, could lead to the loss of local populations of listed fauna. This represents a medium level of risk due to the low probability of the events.

Table 10-11:
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Clearing and Earthworks **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the *Wildlife Conservation Act 1950.* • To protect evolutionary significant units, including genetic races on Barrow Island.					
Construction and commissioning Clearing of vegetation and structural habitats in the vicinity of the proposed North White's Beach feed gas pipeline shore crossing, CO_2 seismic monitoring area, Town Point gas processing facility, and associated infrastructure.	• direct displacement or loss of individuals • increased resource competition in adjacent areas • habitat fragmentation.	**Construction and Commissioning** • build gas processing facility at a site that will minimise impact to fauna (i.e. Town Point) • inspect sites prior to clearing • translocate selected fauna from Development areas • minimise clearing and destruction of important fauna habitats • maximise use of existing disturbed areas • rehabilitate areas no longer required for future works • additional surveys of possible presence of mulgara along domestic gas pipeline route • prevent fauna mortalities in open trench while laying domestic gas pipeline.	• Development footprint limited to that provided for under the Barrow Island Act • <5% estimated island-wide population of any species impacted • viability of listed fauna species maintained • critical/restricted fauna habitats avoided • translocation of listed fauna to suitable recipient sites.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives and performance targets. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). To assess performance against targets the following strategies will be adopted: • a land-use register has been established and will be used to track overall area of clearing associated with the Development	**Construction and commissioning** Likelihood – almost certain, clearing and earthworks planned and necessary for construction. Consequences – moderate on Barrow Island due localised, long-term reduction of populations of listed fauna (burrowing bettongs, Barrow Island euros, spectacled hare wallabies, Barrow Island chestnut mice, Barrow Island golden bandicoots, white-winged fairy wrens) and rare invertebrates (*Urodacus* scorpion and pseudoscorpion). All fauna in secure populations on Barrow Island. Chestnut mouse, scorpion

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Operations Limited clearing and earthworks of previously cleared areas. Periodic clearing on previous survey grid for CO_2 seismic monitoring.		**Operations** • rehabilitate all cleared areas that are no longer required for operations or future works • gain appropriate regulatory approvals prior to any clearing • avoid important fauna habitat • overlie CO_2 monitoring grid on 1994 seismic grid to minimise disturbance to undisturbed areas where practicable.		• monitoring of activity in burrowing bettong warrens in the vicinity of Development areas during construction and initial operations phase • establishment of monitoring programs for key fauna species (e.g. white-winged fairy wren) during construction and initial operations phase • translocated fauna will be monitored to assess the success of translocation program/s • regular inspection of hazardous areas (e.g. open trenches) • fauna 'ladders' in open trenches to allow trapped fauna to escape • regular inspection or audit of implementation of management measures.	and pseudoscorpion populations unknown but habitat widespread. No critical habitats for any listed fauna within the proposed Development areas – moderate on mainland due to ability to avoid impacts to listed species (mulgara). Mulgara rare and susceptible to predation – unlikely to occur on domestic gas pipeline route, but will be avoided if present. Residual Risk – medium **Operations** Likelihood – unlikely, clearing and earthworks will be minimal during operations and all important fauna habitats will be avoided. Consequences – minor on Barrow Island and minor on mainland, as above. Residual Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Physical Interaction **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the *Wildlife Conservation Act 1950.* • To protect evolutionary significant units, including genetic races on Barrow Island.					
Construction and commissioning Vehicular traffic. Operation of equipment and machinery. Workforce activities. **Operations** As above, but at lower frequency. Presence of infrastructure, e.g. pipelines.	• direct behavioural disturbance • injury or fatality (i.e. road kill) • possible obstruction of fauna movements.	**Construction and commissioning** • enforce workforce rules on interaction/ interference with flora and fauna under terms of employment • implement vehicle use policy, including speed limits, signage and access restrictions • use buses to reduce the number of vehicle movements • restrict recreation in designated sensitive areas at critical times • provide recreational facilities within construction village • prohibit fishing, surfing, caving, or recreational boating • establish workforce conservation programs (e.g. beach cleanup and turtle tagging) • provide driver induction course • educate the workforce in being vigilant for fauna on roads, especially at dusk and dawn	• <5% estimated island-wide population of any species impacted • viability of listed fauna species maintained.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of road kills to determine effectiveness of management measures • periodic revision of management strategies and assessment against objectives • where appropriate, injured fauna will be rehabilitated	**Construction and commissioning** Likelihood – almost certain, several road kills of listed fauna (burrowing bettongs, hare wallabies, bandicoots, euros, chestnut mice, white-winged fairy wrens) are expected each year in the vicinity of the gas processing facility and accommodation. No rock wallaby mortalities expected due to avoidance of their habitats in route selection. Consequences – moderate, localised, ongoing reduction in local abundance due to occasional mortality of listed species along roads in the vicinity of facilities without threatening population viability in local area.

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• provide clear information to all visitors at induction regarding personal interaction with fauna, including a policy on littering, feeding and approaching fauna • fence hazardous areas within gas processing facility. **Operations** as above, and • facilitate fauna movements by raising pipelines and burying at crossings on Barrow Island • permit limited fishing during operations • bury mainland pipeline.		• regular inspection or audit of implementation of management measures.	Risk – medium **Operations** Likelihood – almost certain, as above, frequency of road kills will decrease, but persist for the operational phase of the Development. Consequence – moderate, as above Risk – medium

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills **Environmental Management Objective/s:** • To ensure that hydrocarbons and hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.					
Non-routine operations Spill during storage and transport of fuel or hazardous material. Spill or leak during waste storage and disposal. Failure of plant, equipment or pipelines.	• smothering or acute toxicity to habitat and/or fauna • chronic toxicity to sensitive habitat and/or fauna • increased risk of fire.	**Non-routine operations** • design, verify, test, operate and maintain equipment • apply industry standards to storage and handling of fuels and chemicals (e.g. bunding, drainage systems and hardstand areas) • assess Material Safety Data Sheets to select least toxic option • implement emergency response and spill contingency planning • implement plant, equipment and pipeline corrosion monitoring and control program • provide spill containment and recovery equipment at work sites where fuel or chemicals are used or stored • implement early leak detection and reporting • install automatic and/or manual shut-down in selected systems • rehabilitate leak or spill site, including remediation of contaminated soil • implement hydrotest water management plan	• viability of listed fauna species maintained • critical/restricted fauna habitats protected • fauna prevented from entering spill sites • no contaminated soils outside of Development footprint • contaminated areas within Development area remediated.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular inspection or audit of implementation of management measures • regular audit, inspection and maintenance of facilities • implementation and regular testing of emergency shut-down systems to reduce potential volumes from spills and leaks	**Construction and commissioning** Likelihood – unlikely to impact fauna due to prevention and clean up procedures. Consequence – moderate, potential worst-case is localised, long-term decrease in the abundance of listed fauna due to irremediable contamination affecting habitat. No effect on viability of local population. Burrowing fauna, e.g. burrowing bettong, at most risk due to long-term effects of spill on underground burrows. No risk of spill effects on rock wallabies. Risk – low **Operations** Likelihood – unlikely, as above Consequence – moderate, as above. Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• avoid valves on feed gas pipeline to gas processing facility site (exception is emergency shut-down valve) • locate majority of valves, and flanged connections, on hardstand surface within gas processing facility drainage system • provide 24-hour reserve capacity on gas processing facility site for saline injection water.		• implementation of a plant, equipment and pipeline corrosion monitoring and control program • routine inspection of infrastructure, plant and equipment by designated personnel • monitoring of any affected areas to determine the effectiveness of remediation in the event of a spill or leak • erect exclosure around contaminated areas to reduce faunal contact with contaminants.	

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Light or Shade **Environmental Management Objective/s:** • To avoid or manage potential impacts from light overspill and shade and comply with acceptable standards.					
Construction and commissioning Shading from infrastructure. Artificial lighting at night from construction sites and flare. **Operations** As above. **Non-routine operations.** Flaring during process upset or emergency.	• congregation of fauna in areas of shade • risk to sheltering fauna from periodically moving machinery • possible increase in range of shade dependent fauna • attraction of insects to light will increase the availability of food for adaptable birds and bats • possible changes in community structure in area affected by light spill.	**Pre-construction** • design gas processing facility and flare to minimise light spill. **Construction and commissioning** • minimise lighting levels to that required for safe working • fence hazardous construction areas within gas processing facility • minimise flaring at night. **Operations** • minimise lighting levels to those required for safe working • implement a lighting strategy (Chapter 7) including use of shielded lights and non-white lights e.g. low pressure sodium vapour, to reduce fauna attraction • continue review of the lighting regime during design, subject to confirmation that it is acceptable from a health and safety perspective • use light modelling to assist design of optimal lighting strategy	• viability of listed fauna species maintained • compliance with tiered lighting strategy • no listed fauna fatalities in hazardous areas within the gas processing facility • adherence to 'no routine flaring policy'.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular inspection or audit of implementation of management measures • routine light audits to assess compliance with tiered lighting requirements • regular inspection of pipeline easements.	**Construction and Commissioning** Likelihood – almost certain, restricted areas of light and shading will be an unavoidable aspect of construction. Consequence – minor, short-term and localised reduction in general fauna abundance through increased predation, e.g. by silver gulls. Only minor impacts on listed fauna. Risk – low **Operations** Likelihood – almost certain, gas processing facility will be lit, facilities will create shade. Consequence – minor, long-term and localised reduction in general fauna through increased predation, e.g. by silver gulls. Long-term behavioural changes in shade seeking listed fauna,

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• avoid routine flaring design philosophy (this includes ship loading) • fence or safeguard shaded areas that are likely to be used by fauna. **Non-routine operations** • ensure non-routine flaring is infrequent and short-term.			e.g. euros resting under pipelines. Possible long-term behavioural changes in listed fauna (bandicoots, hare wallabies, bettongs) attracted to light pool. Risk – low **Non-routine operations** Likelihood – possible, emergency flaring is expected, but will rarely affect fauna. Consequence – minor, as above Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Atmospheric Emissions **Environmental Management Objective/s:** • To ensure atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.					
Construction and commissioning Low levels of vehicle and equipment exhaust (NO_x, SO_x). **Operations** Combustion and fugitive emissions of SO_2, NO_x, CO_2, VOCs and particulates (refer to Chapters 7 and 13). Low levels of vehicle and equipment exhaust (NO_x, SO_x).	• sublethal effect from inhalation of pollutants • sublethal effect from ingestion of pollutant on vegetation or in water • potential direct toxic effect on fauna from non-routine emission of H_2S or BTEX • asphyxiation from CO_2 inhalation in burrows or low-lying habitats.	**Construction and commissioning** • maintain and service vehicles and equipment regularly • shorten period of commissioning. **Operations** • base design on no routine flaring (very low sulphur content of the fuel ensures negligible sulphur emissions) • comply with EPA licence requirements for routine NO_x, SO_2, and VOCs emissions • avoid planned venting of significant quantities of process hydrocarbons except for minor levels associated with maintenance activities • implement air emissions management procedures • reduce use of ozone depleting substances and avoid use in new refrigeration or fire control systems • minimise BTEX emissions by injection and use of a-MDEA solvent.	• viability of listed fauna species maintained • critical/restricted fauna habitats protected • adherence to 'no routine flaring' policy • no breaches of environmental licence requirements • effects of emissions on surrounding vegetation monitored.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • routine monitoring and preventative maintenance of all pipelines and other equipment • regular inspection or audit of implementation of management measures.	**Construction and commissioning** Likelihood – unlikely, due to rapid dilution of emissions. Consequence – minor, negligible effects abundance of fauna from vehicle emissions. Risk – low **Operations** Likelihood – possible Consequence – moderate, potential localised, long-term reduction in abundance of listed fauna (bettongs, bandicoots, hare wallabies, chestnut mice, euros, white-winged fairy wrens) if productivity of system is reduced through emission effects on vegetation near facilities. Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Non-routine operations Pipeline or equipment failure resulting in the emission of H_2S, BTEX, CO_2 or hydrocarbons. Flaring releasing combustion products or unburnt gas. Smoke and particulates from fire and flaring. Unscheduled start-up and shut-down of gas processing facility.		**Non-routine operations** • maximise system reliability.			**Non-routine operations** Likelihood – unlikely, dependent on right climatic conditions at time of leak. Consequence – moderate, release of large volume of toxic or asphyxiant gas may cause localised, short-term decrease in abundance of listed species (bettongs, bandicoots, hare wallabies, chestnut mice, euros, white-winged fairy wrens). Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Dust **Environmental Management Objective/s:** • To ensure atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.					
Construction and commissioning Clearing of vegetation and removal of topsoil. Earthmoving, such as levelling of the site, excavation, drilling and transport of fill within the Development site. Movement of heavy machinery and vehicles on unpaved surfaces. Blasting. **Operations** Movement of vehicles and machinery on unsealed surfaces. Wind erosion of unsealed surfaces.	• minor physiological affects on fauna in immediate area • effects on vegetated habitats and forage plants negligible.	**Construction and commissioning** • seal frequently used roads • reduce vehicle movements (e.g. use of buses to transport workforce) • restrict vehicle speed • use water to stabilise pits and stockpiles. **Operations** • rehabilitate all cleared areas that are no longer required for operations or future works • reduce vehicle movements and restrict vehicle speed.	• viability of listed fauna species maintained • critical/restricted fauna habitats protected • workforce compliance with speed limits • no loss of vegetation surrounding earthworks from dust emissions.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • qualitative monitoring of dust levels surrounding construction sites to determine effectiveness of dust suppression measures • regular inspection or audit of implementation of management measures.	**Construction and commissioning** Likelihood – almost certain, clearing and use of unsealed roads will generate dust that will settle on roadside vegetation. Consequence – minor, dust will have negligible effects on listed and non-listed fauna. Risk – low **Operations** Likelihood – almost certain, as above, but sealed roads will reduce exposure of fauna. Consequence – minor, as above. Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Unpredicted CO_2 Migration or Release **Environmental Management Objective/s:** • To ensure atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.					
Non-routine operations Failure of CO_2 injection facilities, or subsurface containment. Emergency venting of CO_2 to atmosphere if injection system breaks down.	• release of large volumes of CO_2 to the atmosphere with potential for accumulation at ground surface during still weather • asphyxiation of fauna in low-lying areas (e.g. fauna burrows) • exceedance of greenhouse gas emission budget (see Chapter 13).	**Pre-construction** • avoid release through equipment systems design, testing operations and maintenance • minimise risk of leakage through selection of injection location to (located below existing oil fields) • model CO_2 injection into Dupuy Formation (Chapter 13). **Operations** • avoid release through system design, testing operations and maintenance • design, verify, test, operate and maintain equipment • implement active subsurface monitoring program and reservoir management plan to mitigate risk of CO_2 migration to surface • implement well remediation program to prevent migration in wells • accelerate well remediation if CO_2 migrates toward an unremediated well. **Non-routine operations** • implement automatic and manual emergency response systems to reduce release volumes.	• long-term viability of listed fauna species maintained • critical/restricted fauna habitats protected • no breaches of environmental licence conditions • no CO_2 leak from subsurface formation.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring and modelling program for early detection (if CO_2 is migrating to unexpected locations) and to allow for the implementation of mitigation measures • implementation of CO_2 pipeline corrosion monitoring and control program • regular inspection or audit of implementation of management measures.	**Non routine operations** Likelihood – remote, low probability of leak coupled with low probability of leaking CO_2 affecting listed species, such as burrowing bettongs in their warrens, due to rapid dilution of plume by wind. Consequence – serious, potential for localised and long-term decrease in the abundance of listed fauna in the event of an ongoing leak in the vicinity of an active burrowing bettong warren or other low-lying fauna habitats. Possible decrease in viability of local populations of bettongs, bandicoots and the chestnut mouse. Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Heat and/or Cold **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the *Wildlife Conservation Act 1950.* • To protect evolutionary significant units, including genetic races on Barrow Island.					
Construction and commissioning Heat from sources such as power generators, turbines, air coolers, pipelines, earthmoving equipment, welding units and vehicles. Cold from pipelines. **Operations** Heat from power generators, air, coolers, turbines, flare etc. Feed gas pipeline will be at ambient temperature.	• heat plume from flare and air coolers could injure/kill avifauna flying over gas processing facility • attraction of insects and reptiles to heat in cold weather • attraction of fauna to condensation under feed gas pipeline.	**Preconstruction** • adopt engineering best practice to insulate all cryogenic vessels and avoid leaks. **Construction and commissioning** • fence high risk areas e.g. construction areas where fauna may come into contact with hot or cold surfaces. **Operations** • where appropriate insulate hot or cold surfaces for thermal efficiency and for the protection of personnel and fauna.	• viability of listed fauna species maintained • critical/restricted fauna habitats protected.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular inspection of pipeline easements and facilities to assess impacts of heat and/or cold on fauna • regular inspection or audit of implementation of management measures.	**Construction and commissioning** Likelihood – unlikely, low probability that individual birds or bats may be injured by flaring during commissioning. Listed white-winged fairy wrens unlikely to venture as high as flare and will not be affected. Consequence – minor, localised and short-term decrease in abundance of unlisted species. No effects on viability of local population. Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
					Operations Likelihood – likely, small reptiles and invertebrates attracted to gas processing facility will perish in hazardous areas, other larger fauna, including euros, bettongs, bandicoots, hare wallabies, chestnut mice may seek water under feed gas pipeline. Consequence – minor, localised, long-term behavioural changes in listed fauna, potential small decrease in abundance of unlisted fauna. No effects on viability of local populations. No adverse impacts on listed species. Risk – low

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Noise and Vibration **Environmental Management Objective/s:** • To avoid adverse noise and vibration impacts to fauna.					
Construction and commissioning Blasting. Earthworks, vehicle movements and the operation of equipment. Seismic survey. **Operations** Gas processing facility operation. Operation of vehicles and equipment. Flaring. Seismic monitoring every 5–10 years.	• physiological impacts to fauna in immediate vicinity due to blast over pressure • short-term behavioural changes • disturbance of fauna in vicinity of seismic source discharges.	**Construction and commissioning** • obtain approvals and permits for the storage and use of explosives under the provisions of the *Dangerous Goods and Safety Act 2004* • use noise suppressants on heavy equipment • maintain and operate all equipment and vehicles in good condition • incorporate perimeter control techniques in blast design to limit blast noise and vibration • schedule blasting for daylight hours only to avoid activity peaks for nocturnal mammals (dusk to dawn) • defer blasting when fauna are detected within the immediate area • visually monitor for fauna over blast site and 'shepherd' fauna to outside the blast zone • use HDD for shore crossing (i.e. minimising blasting requirements) • use drill and blast techniques which minimise zone of effect	• viability of listed fauna species maintained • critical/restricted fauna habitats protected • no seismic source discharge within prescribed sensitivity buffers • no long-term behavioural impact from noise and vibration.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • use of blast monitors to determine if noise and vibration generated from blasting is within acceptable limits • regular inspection or audit of implementation of management measures • review seismic shock and noise propagation properties for various source options to assist in setting buffers around sensitive habitats.	**Construction and commissioning** Likelihood – possible, unlikely to occur but may occur during the life of the Development. Consequence – moderate. Short-term impact in local area with no lasting effects to local population viability. Risk – low (Flacourt Bay shore crossing option: Consequence would be serious (and risk high). Potential impacts on rock wallaby breeding success may reduce the viability of the local population). **Operations** Likelihood – likely, noise from infrequent, planned flaring will affect fauna in local area.

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk

		• visually monitor and use warning noise for fauna in vicinity of the blast site and adjacent areas prior to and during blasting
		• impose constraints on seismic surveys to avoid impacts to listed fauna. These include, but will not be limited to:
		  • avoiding drilling and seismic source discharge in critical fauna habitats
		  • avoiding rock wallaby habitats
		  • establishing buffer zones for seismic discharge around sensitive habitats.
		• shorten period of commissioning (i.e. reduce associated flaring noise).
		Operations
		• meet occupational health and safety personnel limits of 85 dB(A) over an eight-hour period at a minimum.
					Consequence – moderate, impacts of noise from flaring will cause localised, short-term behavioural responses.
					Risk – medium

Table 10-11: (continued)
Summary of Risk Assessment for Terrestrial Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Fire **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the *Wildlife Conservation Act 1950.* • To protect evolutionary significant units, including genetic races on Barrow Island.					
Non-routine operations Vehicles, welding sparks are potential ignition sources. Flare event dislodging hot build-up from inside flare tower. Runoff of water or foam used in fire control near infrastructure.	• temporary loss of habitat • injury or mortality in fire • damage to infrastructure potentially causing gas or liquid leaks • effects on soil or water quality from runoff containing nutrients and chemicals.	**Construction and commissioning** • implement hot work permitting system to control use of potential ignition sources • identify potential sources of ignition in Job Hazard Analysis • establish permitting system for off-road driving • install fire extinguishers in all vehicles • use diesel engines • fit exhaust guards to vehicles that are used for a significant proportion of designated off road work • stockpile and remove vegetation from the immediate works site to reduce fuel loads • remediate soils contaminated during fire fighting. **Operations** • as above • bunding around facilities will reduce potential runoff and soil contamination during fire control at facilities.	• viability of listed fauna species maintained • critical/restricted fauna habitats protected • monitoring and research program on fire regime established through BICC • all fires caused by Development related activities successfully extinguished without long-term effects on local fauna or their habitats.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular audit, inspection and maintenance of fire equipment and fire prevention mechanisms • work with BICC and CALM to establish a monitoring and research program on the ecological effects of fire regime on Barrow Island • regular inspection or audit of implementation of management measures.	**Construction and commissioning** Likelihood – unlikely that a fire will be started by activities associated with the Development and can not be controlled. Consequence – serious, potential short-term but widespread decrease in the abundance of listed fauna in areas of fast burn. Potential localised, long-term loss of listed fauna leading to reduction of local population viability in areas of intense burn. Effects similar to natural fires to which the fauna and general ecosystem resilient. Risk – medium **Operations** Likelihood – unlikely, as above Consequence – serious, as above Risk – medium

10.5 Subterranean Fauna

Potential stressors to subterranean fauna have been identified and risks estimated through a preliminary assessment of consequences and likelihood. Potential impacts to both stygofauna and troglofauna were considered during risk assessments. Risks associated with introduction of non-indigenous species or pathogens to Barrow Island are discussed in Chapter 12.

Risk assessments are based on the worst-case assumption that the whole gas processing facility site is karstic and that stygofauna and troglofauna are likely to occur across the Development area and in surrounding areas. Preliminary data on the distribution of subterranean fauna from areas within the proposed gas processing facility site are available (Chapter 8). The results from the first phases of the subterranean fauna sampling program are limited in taxonomic resolution. However, the results to date are consistent with this preliminary assessment with subterranean taxa recorded from several locations inside and outside of the Development area. The current state of knowledge on subterranean fauna from karst ecosystems on Barrow Island is presented in Chapter 8 and Technical Appendix C5.

A preliminary review of the physical nature of the karst below the gas processing facility site was completed by Biota and Blandford (2004) (Chapter 8). This utilised available drill logs and geophysical survey data to obtain a better understanding of the nature of the stratigraphy below the proposed gas processing facility site. The geological interpretation is that there are substantial competent limestone strata beneath the Development area, interbedded with layers of sand. The preliminary assessment also indicates a relatively complex lithology which does not lend itself to developing a definitive stratigraphic model of the area.

The results to date indicate that there is habitat suitable for both troglofauna and stygofauna beneath the gas processing facility site and that this appears to be relatively widespread across the area, with some possible discontinuities (both vertically and horizontally) (Biota and Blandford 2004).

Prior to undertaking the risk assessments, representative key receptors (evolutionary significant taxa) were chosen for each stressor. The key receptor subterranean fauna species are shown in Table 10-12. Fauna protected under state or Commonwealth legislation were the focus of the risk assessment with the recognition that all subterranean fauna on Barrow Island are likely to be of conservation significance.

Only one listed species has been confirmed as occurring inside the proposed Development footprint: Barrow Island Schizmod *Draculoides bramstokeri* (Schedule 1 Wildlife Conservation Act).

Other non-key receptors that may be affected by the proposed Development include all other stygal and troglobitic taxa recorded from the area to date (Chapter 8).

The consequences to subterranean fauna were categorised using the definitions provided in Table 10-9. Likelihood definitions are provided in Table 9-6. Risk has been characterised by evaluating environmental consequences associated with each stressor and the likelihood that the stressor will impact on the representative key receptor taxa. Risk assessment results are summarised in Table 10-13.

Risk assessments, including definition of consequences and identification of stressors and receptors, were undertaken by technical specialists with recognised expertise in subterranean environments.

Table 10-12:
Subterranean Fauna – Key Receptors

Key Receptor	Reason for Selection	Other Taxa
Stygofauna		
Blind gudgeon (*Milyeringa veritas*)	EPBC Listed and Schedule species; known to occur on Barrow Island	Other stygofauna, potentially including the blind cave eel (*Ophisternon candidum*)
Troglofauna		
Schizomid (*Draculoides bramstokeri*)	Schedule species; known to occur on Barrow Island	Other troglofauna, potentially including the troglobitic reptile (*Ramphotyphlops longissimus*)

Due to the limited data available on the distribution and diversity of subterranean fauna within the gas processing facility site at the time of this risk assessment, risks to subterranean fauna were assessed as either medium or high level. This is in keeping with the conservative approach as discussed in Section 10.1. High risk stressors based on the current assessment include:

- clearing and earthworks (construction and commissioning)
- physical presence of gas processing facility (operations).

Medium risk stressors consist of:

- wastewater discharge (construction and commissioning)
- noise and vibration (construction and commissioning)
- leaks and spills (operations)
- CO_2 leak (operations).

Priority has been given to the development of management measures for medium and high risk activities. Environmental management measures are also proposed for lower risk stressors and are identified in Table 10-13. The management and mitigation measures proposed in this chapter are, in the main, specific to particular activities or stressors. System-based management requirements, such as auditing and induction measures, are broadly discussed in Chapter 16 and are not referred to specifically in this chapter.

The Joint Venturers are committed to adopting all of the management measures that are outlined in this section for avoiding or mitigating impacts to subterranean fauna. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses it may become necessary to modify proposed management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and targets will be developed.

Final assessment of the risk to subterranean fauna associated with the proposed Development is dependent on the outcomes of ongoing survey work. Risk levels will be reviewed when the detailed results from the subterranean fauna sampling program become available. It is anticipated that greater Development definition and availability of additional information on the distribution and diversity of subterranean fauna will provide greater certainty in the assessment of potential impacts.

A sampling plan for the ongoing survey work was developed in consultation with relevant stakeholders and experts from CALM and other agencies (Technical Appendix C5). The objectives of the proposed sampling plan are to:

- complete adequate, targeted sampling of stygofauna and troglofauna within the Development impact areas
- complete, at least, equivalent sampling within reference areas outside of the Development footprint
- assess species level representation of fauna within the impact area against the reference data set and other records
- complete impact assessment based on the outcomes of the above objective and analysis of Development impact mechanisms
- improve regional knowledge of subterranean fauna.

Bores established for subterranean fauna monitoring were first sampled in November 2004 and again in March 2005. This has comprised two rounds of stygofauna sampling and one completed round of troglofauna sampling (a second is currently underway). Final results, completed to species level, will be available in the latter part of the public exhibition period. Sampling results will be publicly available on the Gorgon Development website (www.gorgon.com.au) and provided to key stakeholders. Results of previous survey work conducted on Barrow Island are discussed in Chapter 9 and Technical Appendix C5.

10.5.1 Clearing and Earthworks

Clearing of vegetation and earthworks will be required during construction to provide a suitable profile and foundation for the gas processing facility. Preparation of the site will involve removal of up to 8 m of the soil and rock profile in some sections of the gas processing facility site. This excavation may intersect subsurface caverns and karstic fracture zones if they are present, so may directly impact troglofauna habitat. Runoff from cleared areas may also transport sediments into subterranean habitats, blocking pore spaces and reducing the suitability for subterranean fauna.

The feed gas pipeline route from North White's Beach will avoid high profile limestone headlands and is unlikely to intersect significant karst features. The western-most portion of the alternative feed gas pipeline route from Flacourt Bay would pass through an area of more developed karst with greater potential to provide mesocavern-type subterranean fauna habitat.

The key potential impacts to subterranean fauna associated with clearing and earthworks are:

- direct loss of troglofauna and habitat within gas processing facility footprint
- runoff during construction causing sedimentation of habitats and groundwater
- localised loss of stygofauna.

Management

The Joint Venturers have installed sampling bores within and outside of the gas processing facility site. The sampling program has commenced and will provide baseline information on the diversity and distribution of subterranean fauna in the Development area. Runoff during cyclones and severe storms will be managed through design of the detention basins and overflow baffles and contours to reduce erosion. Cleared surfaces will be compacted or stabilised to further reduce erosion of fine sediments.

Residual Risk

Residual risk cannot be fully calculated until the detailed results of the ongoing geotechnical and subterranean fauna sampling are available. Preliminary results from the work completed to date indicate that the area contains karst and that both troglofauna and stygofauna occur below the gas processing facility site. This includes the Schedule 1 species *Draculoides bramstokeri* and other taxa of undetermined conservation status. Habitat suitable for troglofauna appears to occur across the area, therefore the impacts of excavation will be frequent (almost certain). If troglobitic taxa are restricted to the local area, the consequences of excavation would be critical. However, the preliminary results of the sampling program suggest that *Draculoides bramstokeri*, may not be restricted to the Development area (Chapter 8). This species is listed as Schedule 1, so the consequences remain major. Thus, the residual risk from clearing and excavation, as currently understood, is high, but this is based on the worst-case scenario that troglobitic taxa are restricted to the impact area; or that listed species are directly impacted. The detailed results from the ongoing sampling program will provide a clearer model of the wider distribution of the subterranean taxa and may result in a reduction in risk to a medium or low level.

10.5.2 Physical Presence of Gas Processing Facility

The presence of hardstand could impact the natural recharge of the groundwater aquifer under the proposed gas processing facility and in the receiving drainage basin. The significance of this effect will be assessed when the groundwater hydrology is better understood. Contaminants may become entrained in the runoff from areas of contaminated hardstand and may enter subterranean habitats.

Because the area is karstic in nature, horizontal groundwater migration, or recharge from unaffected adjacent areas, may tend to buffer subterranean ecosystems from the effects of any local changes to surface hydrology.

Key potential impacts to subterranean fauna from the physical presence of hardstand in the gas processing facility include:

- potential lowering of watertable levels over the long-term due to reduced groundwater recharge affecting troglofauna and stygofauna habitat
- local loss of troglofauna and stygofauna.

Management

The proposed Development has been designed to minimise impacts on groundwater recharge by comprising a number of separate facilities on hardstand, interspersed with open and unsurfaced areas. The drainage management system (tiered system described in Chapter 7) will be designed to allow for on-site infiltration of uncontaminated water.

Changes to recharge patterns are likely to be localised and will be mitigated largely through appropriate design and stormwater management strategies.

The drainage management system will also avoid entrainment of contaminants in groundwater recharge by:

- diverting drainage from upper catchment to other natural drainage/infiltration areas
- discharging uncontaminated water (e.g. non-process hardstand) to natural drainage channels
- direct drainage from potentially contaminated areas (e.g. hardstand around process) to a holding basin for testing and treatment
- treating contaminated water, for example, from sumps under equipment (i.e. contaminants removed) and sending to an injection system
- designing drainage systems to manage peak cyclone rainfall and minimise overflow of contaminants.

Residual Risk

Residual risk cannot be calculated until the results of the current geotechnical, hydrological and subterranean fauna sampling programs are completed and analysed. If significant karst formations are present, changes to surface drainage patterns may have a widespread, long-term impact on the underlying subterranean habitats. The level of hydrogical connection with other unaffected karst systems upstream will also have bearing on this evaluation. The residual risks of these activities will depend on the conservation significance of the associated subterranean faunal assemblages and species and the success of the management measures to reduce the likelihood of the impact. The final level of risk may be reduced to a medium level if:

- habitats below the gas processing facility site are hydrologically linked to, and recharged by, unaffected groundwater areas upstream of the gas processing facility site
- subterranean taxa present below the gas processing facility site are represented elsewhere and management measures are adequately implemented.

10.5.3 Wastewater Discharge

Dust from roads, stockpiles, pits and transport of soil will be controlled using treated grey-water during construction of the gas processing facility and pipelines. The volume of grey-water generated by the Development, and that required for dust suppression and other construction purposes, cannot be accurately quantified until the design phase has been completed. Treated grey-water will possibly contain some nutrients and other chemicals. There is a potential for rainfall to transport these materials into subterranean fauna habitats.

It is currently planned that treated grey-water will be used for dust suppression and other construction purposes for a period of between 3 to 4 years. A peak application of over 400 m^3 of treated grey-water per day will occur over a four-month period early in construction when the bulk of earthworks will be undertaken.

Management

Liquid wastes will be identified and characterised, their volumes estimated and management and disposal options (e.g. avoidance, reduction, recycle and re-use, storage, evaporation, injection and potential marine discharge) prescribed in a Development-specific Waste Management Plan. Proposed management measures include:

- treating grey-water in the waste water treatment plant (ultra-violet sterilisation and chlorination)
- not applying treated grey-water to areas of open karst (e.g. sink holes)
- compacting construction pads and lay down areas (crowned profile) to limit infiltration of treated grey-water to the subsurface environment.

Residual Risk

In the absence of data documenting the hydrogeology, composition of treated grey-water and distribution of subterranean fauna species, wastewater discharge is considered to pose a high risk of impact to subterranean fauna. This risk level is based on the worst case scenario that taxa may be restricted to the Development area (see Section 10.5.1). The outcomes of the geotechnical and subterranean fauna sampling program will enable this risk to be better assessed once the wider distribution of the taxa occurring in the gas processing facility site area is known. If these data show that the subterranean fauna present occur more widely on Barrow Island, then the risk level associated with grey-water use will be reduced.

10.5.4 Noise and Vibration

Physical vibration associated with earthworks on the site, particularly the shock waves associated with any blasting, could impact subterranean fauna and/or habitat at the gas processing facility site. This and other sources of vibration, such as seismic surveys, could impact the integrity of karstic strata, small fissures or crevices in the karst that provide habitat to subterranean fauna.

Management

Management of blasting and vibration impacts will comply with Australian Standard 2436, Guide to Noise Control on Construction, Maintenance and Demolition Sites. Management will include the following elements to reduce blasting impacts to subterranean fauna:

- geotechnical investigation to identify areas of highly karstic formation (i.e. caves)
- minimisation of blasting and constraint to surface geological strata.

Residual Risk

In the absence of data documenting the distribution of subterranean fauna species, blasting has been assessed as posing a high risk of impact to subterranean fauna. This position will again be reviewed on the basis of further data from the geotechnical and subterranean fauna sampling program once available (see Section 10.5.1).

10.5.5 Spills and Leaks

Key potential impacts to subterranean fauna from leaks and spills include:

- potential contamination of subterranean habitat
- acute toxicity to troglofauna and/or stygofauna.

In the absence of definitive data on the toxicity of various chemicals to subterranean fauna, and the lack of information on the sensitivity of these fauna to changes in water chemistry (for example salinity changes), any input of potential contaminants into the subterranean ecosystem has been regarded as likely to cause adverse impacts.

Leakage of the low pressure saline injection pipeline from the reverse osmosis plant, based on injection to the existing Barrow Island Joint Venture disposal facility on Barrow Island, could result in loss of saline water with low concentrations of contaminants such as biocides, corrosion inhibitors and/or treated grey-water. A catastrophic failure along the pipeline is highly unlikely. However, if a failure did occur, an early warning detection system would trigger an appropriate response and shut-down of the injection system which is estimated to result in the loss of a maximum of 0.5 ML of brine to the surrounding environment. Under the alternative option of injecting waste brine via wells located within relatively close proximity to the proposed gas processing facility, it is estimated that a catastrophic leak would result in the loss of approximately 0.02 ML of brine.

The failure of a pipeline during hydrotesting could result in the potential contamination of soil and groundwater and subsequent toxicity to troglofauna and/or stygofauna.

All chemicals will be stored in fully bunded areas and could only enter the subterranean environment if the storage container and the bund failed. Other sources of potential spills or contamination of surface soil that could eventually enter the subterranean ecosystem include: transport of chemicals; refuelling; leakage from pipelines and valves; fallout from the flare; and use of saline water for fire-fighting within the gas processing facility site.

Management

Best practice gas processing facility and pipeline design, coupled with careful selection of low sensitivity routes and chemical selection criteria, will reduce the risk of adverse impacts to subterranean fauna and their habitats.

Liquid hydrocarbons and other chemicals will be processed and stored on impermeable hardstand with bunding and appropriate drainage systems. Pipeline corridors will be selected to avoid any cave openings and the pipelines will be located above ground.

To mitigate potential risks associated with spills or leaks, comprehensive spill prevention and response procedures will be developed for all phases of the Gorgon Development. Spill and leak management measures are outlined in Section 10.2.1.

Residual Risk

Spills are unlikely to occur and, in order to affect subterranean fauna, would need to be of significant volume to infiltrate the surface soils; or be directly above a point of entry, such as a solution tube, to the subterranean environment.

In the unlikely event that a spill or leak occurs over a highly karstic system, and is of sufficient volume to contaminate subterranean habitats, the scale of impact would depend on the movement of the contaminant through the aquifer. The impact could have a localised or a widespread impact depending on the volume of the spill, the nature of the material introduced to the aquifer and the hydrogeology of the site. The residual risks of these activities will depend on the conservation significance of the associated subterranean assemblages.

Residual risk will be determined when the results of the current geotechnical and subterranean fauna sampling are completed and analysed, but current precautionary assessments indicate a medium level of risk.

10.5.6 Unpredicted CO_2 Migration

Migration of CO_2 into the near surface cave systems, via fault or well penetrations, could impact stygofauna by acidifying the groundwater. However, the alkaline limestone of the aquifer would buffer the pH changes in the groundwater. There is also potential for leaking CO_2 to accumulate above the surface of the water table and reduce the concentration of oxygen available for troglofauna and stygofauna.

Key potential environmental impacts to subterranean fauna as a result of a CO_2 leak include:

- acidification of groundwater with potential loss of stygofauna
- asphyxiation of troglofauna due to accumulation of CO_2 above the water table.

Management

The preferred CO_2 injection location was identified on the basis of several studies, including predictive modelling of the behaviour of injected CO_2 with the objective of reducing the risk of unpredicted migration. Proposed design and management measures are outlined in Section 10.3.4. Further details of the CO_2 injection are provided in Chapter 13.

Residual Risk

Residual risk cannot be calculated until results of the current geotechnical and subterranean fauna sampling are completed and analysed. If karst is present, and widespread, CO_2 migration to the near surface is expected to have widespread impact on the subterranean habitats. The likelihood of a leak is considered remote; however the consequences could be critical if evolutionary significant taxa occur in the area. The residual level of risk to subterranean fauna from CO_2 migration is medium.

10.5.7 Cumulative Risk

The results of the assessment of risks to subterranean fauna from clearing and earthworks, noise and vibration and physical presence of the gas processing facility indicate that residual risk associated with these stressors will be high. Residual risk associated with leaks or spills and unpredicted CO_2 migration was assessed as medium. The risk of adverse impacts from wastewater discharge (i.e. use of grey-water for dust suppression at the gas processing facility site) cannot be calculated until results of the current geotechnical and subterranean fauna sampling are completed and analysed. Although a worst-case risk assessment, based on a precautionary approach, indicates some high risk stressors to subterranean fauna, further information from the current sampling program will provide a clearer model of the wider distribution of the subterranean taxa. This could result in a reduction to this precautionary high risk level. Cumulative risk cannot be estimated until risk assessment for individual stressors are finalised.

Table 10-13:
Summary of Risk Assessment for Subterranean Fauna

Activities/ Causes	Potential Environmental Impact/Consequences	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Clearing and Earthworks **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened species. • To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and Commissioning Clearing and earthworks for the gas processing facility and associated infrastructure. Excavation of material to a depth of 8 metres during site preparation. Shallow blasting of cap rock over 40–60% of gas processing facility site. Installation of approximately 750 piles, possibly to a depth of approximately 32 m. **Operations** Minor clearing and earthworks.	• direct loss of troglofauna and habitat within gas processing facility footprint • runoff during construction causing sedimentation of aquifer • localised loss of stygofauna.	**Pre-construction** • conduct geotechnical investigations to identify significant karst formations • implement sampling program to determine the significance of the subterranean fauna in potential impact and reference areas. **Construction and Commissioning** • limit clearing and ground disturbance to the minimum extent necessary for safe construction • minimise exposure of unstable/uncovered areas of soil • install erosion control and flow diversion devices • inspect and maintain erosion and sediment control structures regularly, particularly following heavy or prolonged rainfall • locate proposed gas processing facility site on a ridge, within smaller catchment areas and outside major natural drainages.	• no loss of restricted subterranean fauna species • long-term viability of restricted subterranean fauna species maintained.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of subterranean fauna within and outside of impact areas during construction and initial operations phase • regular monitoring of surface and groundwater levels and quality both within and outside of gas processing facility footprint.	**Construction and Commissioning** Likelihood – almost certain Consequences – serious to severe Risk – high **Operations** Likelihood – almost certain Consequence – minor Risk – low

Table 10-13: (continued)
Summary of Risk Assessment for Subterranean Fauna

Activities/ Causes	Potential Environmental Impact/Consequences	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Wastewater Discharge **Environmental Management Objective/s:** • To ensure liquid and solid wastes do not adversely affect groundwater or surface water quality or lead to soil contamination.					
Construction and Commissioning Use of treated grey-water to control dust at gas processing facility site.	• contamination and nutrient loading of subterranean habitats.	**Construction and commissioning** • treat grey-water prior to application for dust suppression • avoid application of water on open flow karst formations • compact construction pads and lay down area (crowned profile) to limit infiltration of treated grey-water to the subsurface environment.	• no loss of restricted subterranean fauna species • long-term viability of restricted subterranean fauna species maintained • no contamination of subterranean habitats.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of subterranean fauna within and outside of impact areas during construction and initial operations phase • regular monitoring of surface and groundwater levels and quality both within and outside of gas processing facility footprint • environmental audits to determine compliance with licence conditions • establishment of waste targets and regular review of waste inventory.	In the absence of data documenting the hydrogeology, composition of treated grey-water and distribution of subterranean fauna species, wastewater discharge is considered to pose a high risk of impact to subterranean fauna. This position will be reviewed on the basis of further data from the geotechnical and subterranean fauna sampling program once available.

Table 10-13: (continued)
Summary of Risk Assessment for Subterranean Fauna

Activities/ Causes	Potential Environmental Impact/Consequences	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Noise and Vibration **Environmental Management Objective/s:** • To avoid adverse noise and vibration impacts to fauna. • To ensure that noise impacts emanating from the proposed gas processing facility comply with statutory requirements specified in the Environmental Protection (Noise) Regulations 1997.					
Construction and Commissioning Shallow blasting of cap rock over 40–60% of gas processing facility site. Installation of approximately 750 piles, possibly to a depth of approximately 32 m.	• direct loss of habitat or rupture of subsurface karst lenses • vibration effects (sedimentation/partial collapse of karstic formations).	**Pre-construction** • undertake geotechnical investigations to identify significant karst formations; and subterranean fauna surveys to identify extent of fauna populations. **Construction and commissioning** • obtain approvals and permits for the storage and use of explosives under the provisions of the *Dangerous Goods and Safety Act 2004* • develop a blast design that incorporates perimeter control techniques to limit blast noise and vibration • use drill and blast techniques which reduce zone of effect. **Operations** • meet occupational health and safety personnel limits of 85 dB(A) over an eight hour period at minimum.	• no loss of restricted subterranean fauna species • long-term viability of restricted subterranean fauna species maintained.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of subterranean fauna within and outside of impact areas during construction and initial operations phase • use of blast monitors to determine if noise and vibration generated from blasting is within acceptable limits.	**Construction and commissioning** Likelihood – almost certain Consequences – serious Risk – high

Table 10-13: (continued)
Summary of Risk Assessment for Subterranean Fauna

Activities/ Causes	Potential Environmental Impact/Consequences	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills **Environmental Management Objective/s:** • To ensure liquid and solid wastes do not adversely affect groundwater or surface water quality or lead to soil contamination.					
Non-routine operations Failure of proposed bulk storage tanks (MEG, TEG, diesel, condensate) and containment bund. Spill during storage and transport of fuel or hazardous material. Spill or leak during waste storage and disposal. Failure of plant, equipment or pipelines.	• potential contamination of subterranean habitat • acute toxicity to troglofauna and/or stygofauna.	**Non-routine operations** • implement equipment design, verification, testing, operations and maintenance • apply industry standards for storage and handling of fuels and chemicals (e.g. bunding, drainage systems and hardstand areas) • assess Material Safety Data Sheets prior to purchase of chemicals • implement emergency response and spill contingency planning • provide spill containment and recovery equipment at work sites • contain and remediate contaminated soil • install built-in automatic and/or manual shut-down in selected systems where required • rehabilitate leak or spill sites • implement early leak detection and reporting • develop and implement hydrotest water management plan • construct pipelines to required engineering standards	• no loss of restricted subterranean fauna species • long-term viability of restricted subterranean fauna species maintained • no contamination of subterranean habitats.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular monitoring of surface and groundwater levels and quality both within and outside of gas processing facility footprint • monitoring of plant, equipment and pipeline corrosion and control program • regular audit, inspection and maintenance of facilities.	**Construction and commissioning** Likelihood -unlikely Consequences – serious to severe Risk – medium **Operations** Likelihood – unlikely Consequences – serious to severe Risk – medium

Table 10-13: (continued)
Summary of Risk Assessment for Subterranean Fauna

Activities/ Causes	Potential Environmental Impact/Consequences	Management Measures	Target	Measurement Strategies	Residual Risk
		• apply industry standards for storage and handling of fuels and chemicals (e.g. bunding) • avoid valves on feed gas pipeline to gas processing facility site (exception is emergency shut-down valve) • locate majority of remaining valves, and flanged connections, on hardstand surface within gas processing facility drainage system • provide 24-hour hold-up capacity on gas processing facility site for saline injection water • select pipeline routes to avoid surficial evidence of karst formations.			

Table 10-13: (continued)
Summary of Risk Assessment for Subterranean Fauna

Activities/ Causes	Potential Environmental Impact/Consequences	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Unpredicted CO_2 Migration **Environmental Management Objective/s:** • To ensure atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.					
Non-routine operations Failure of CO_2 injection facilities, or subsurface containment.	• acidification of groundwater with potential loss of stygofauna • potential for leaking CO_2 to settle above the water table (due to difference in density to water and air) affecting troglofauna (i.e. asphyxiation).	**Non-routine operations** • implement system design, testing operations and maintenance to avoid release • undertake initial design validation and verification testing and maintenance of CO_2 equipment • select injection location to minimise risk of leakage (located below existing oil fields) • implement automatic emergency response engineered systems to reduce release volumes • implement active subsurface monitoring program and reservoir management plan to mitigate risk of CO_2 migration to surface • implement well remediation program to prevent migration in wells • accelerate well remediation if CO_2 migrates toward an unremediated well.	• no loss of restricted subterranean fauna species • long-term viability of restricted subterranean fauna species maintained • no breaches of environmental licence conditions • no CO_2 leak from subsurface formation.	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of subterranean fauna within and outside of impact areas during construction and initial operations phase • monitoring and modelling program will provide for early detection (if CO_2 is migrating to unexpected locations) and allow for the implementation of mitigation measures • CO_2 pipeline corrosion monitoring and control program	**Operations** Likelihood – remote Consequences – critical Risk – medium

Table 10-13: (continued)
Summary of Risk Assessment for Subterranean Fauna

Activities/ Causes	Potential Environmental Impact/Consequences	Management Measures	Target	Measurement Strategies	Residual Risk
				• regular inspection or audit of implementation of management measures.	
Stressor: Physical Presence **Environmental Management Objective/s:** • To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge. • To maintain the quantity and quality of water so that existing and potential environmental values, including ecosystem function, are protected.					
Operations Impermeable surfaces with no groundwater recharge over 30–40% site (45–60 ha). Abstraction of groundwater for reverse osmosis plant.	• change to local hydrology from drawdown (salinity and water table depth) reducing stygofauna habitat • reduced groundwater recharge under gas processing facility affecting (humidity, free water) where surface water is diverted to drains • local loss of troglofauna and stygofauna.	**Operations** • locate gas processing facility on ridge between two major alluvial catchment systems to reduce effects on groundwater recharge regime • design drainage strategy to maximise on-site infiltration of non-contaminated runoff • abstract water from well below freshwater lens (up to 150 m below ground level) • locate extraction well close to the coast.	• no loss of restricted subterranean fauna species • long-term viability of restricted subterranean fauna species maintained • no measurable impact on groundwater regime (recharge and quality).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular monitoring of surface and groundwater levels and quality both within and outside of gas processing facility footprint • monitoring of subterranean fauna within and outside of impact areas during construction and initial operations phase.	**Operations** Likelihood – likely Consequences – serious to severe Risk – high

10.6 Conclusion

Table 10-14 is a summary of the potential stressors and assessed level of residual risk to terrestrial environmental factors. The residual risks posed by stressors associated with each phase of the proposed Development were assessed as low to medium for all environmental factors except subterranean fauna. In each of these cases, the potential consequences to the terrestrial ecology of Barrow Island will be greatly reduced by implementation of the proposed management measures. Thus, they pose an overall acceptable level of risk to the conservation values of Barrow Island and meet the environmental management objectives for the Development.

Assessment of risks to subterranean fauna indicate that clearing and earthworks, noise and vibration and physical presence of the gas processing facility pose a high risk to subterranean fauna. However, it is important to note that this level of risk primarily reflects uncertainty in the absence of data on the diversity and distribution of subterranean fauna in the gas processing facility site and surrounding areas. Although a worst-case risk assessment, based on a precautionary approach, has indicated there to be some high risk stressors to subterranean fauna, further information from the current sampling program will provide a greater understanding of the wider distribution of the subterranean taxa. If a wider distribution is found, it could reduce the risk to medium or low levels.

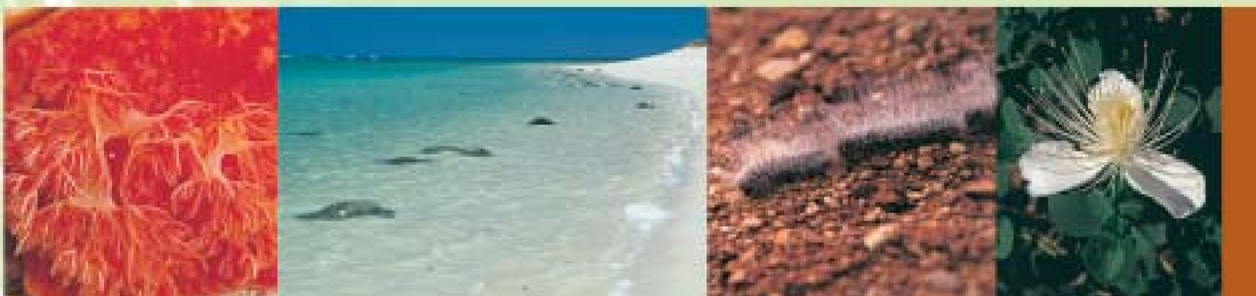
Table 10-14:
Summary of Residual Risk Levels

Environmental Factor/Stressor	Residual Risk		
	Construction and Commissioning	Operations	Non-routine
Soil and Landform			
• Clearing and earthworks	M	L	–
• Liquid and solid waste disposal	M	L	–
• Leaks or spills	M	M	–
Surface and Groundwater			
• Clearing and earthworks	M	L	–
• Physical presence	M	M	–
• Liquid and solid waste disposal	M	L	–
• Leaks or spills	M	M	–
Air Quality			
• Atmospheric emissions	L	L	L
• Clearing and earthworks	L	L	–
Flora and Vegetation Communities			
• Clearing and earthworks (restricted flora and vegetation communities)	M	L	–
• Clearing and earthworks (general flora and vegetation communities)	L	L	–
• Fire	M	M	–
• Atmospheric emissions	L	L	L
• Light/shading/heat/cold	L	L	–
• Dust	L	L	–
• Unpredicted CO_2 migration	–	–	L
• Leaks or spills	L	L	–
Terrestrial Fauna			
• Clearing and earthworks	M	L	–
• Physical interaction	M	M	–
• Leaks or spills	L	L	–
• Light or shade	L	L	–
• Atmospheric emissions	L	L	L
• Dust	L	L	–
• Unpredicted CO_2 migration	–	–	L
• Heat and/or cold	L	L	–
• Noise and vibration	L	M	–
• Fire	M	M	–

Table 10-14: (continued)
Summary of Residual Risk Levels

Environmental Factor/Stressor	Residual Risk		
	Construction and Commissioning	Operations	Non-routine
Subterranean Fauna			
• Clearing and earthworks	H*	L	–
• Physical presence	–	H*	–
• Wastewater discharge	H*	–	–
• Noise and vibration	H*	–	–
• Leaks or spills	M	M	–
• Unpredicted CO_2 migration	–	M	–

* *In the absence of finalised sampling results documenting distribution of subterranean fauna species, a worst-case approach to risk assessment has been taken. Although a worst-case risk assessment, based on a precautionary approach, has indicated there to be some high risk stressors to subterranean fauna, further information from the sampling strategy will provide a greater understanding of the wider distribution of the subterranean taxa. If a wider distribution is found, it could result in a reduction in risk to medium to low levels.*



Main Report

Volume II

Draft

Environmental Impact Statement/ Environmental Review and Management Programme

for the Proposed Gorgon Development

September 2005

GORGON
AUSTRALIAN GAS

Disclaimer

Note on Name Change

During the production of this Draft EIS/ERMP, ChevronTexaco Corporation changed its name to Chevron Corporation. As a consequence of this, ChevronTexaco Australia Pty Ltd changed its name to Chevron Australia Pty Ltd.

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Main Report

Draft

Environmental Impact Statement/ Environmental Review and Management Programme

for the Proposed Gorgon Development

September 2005

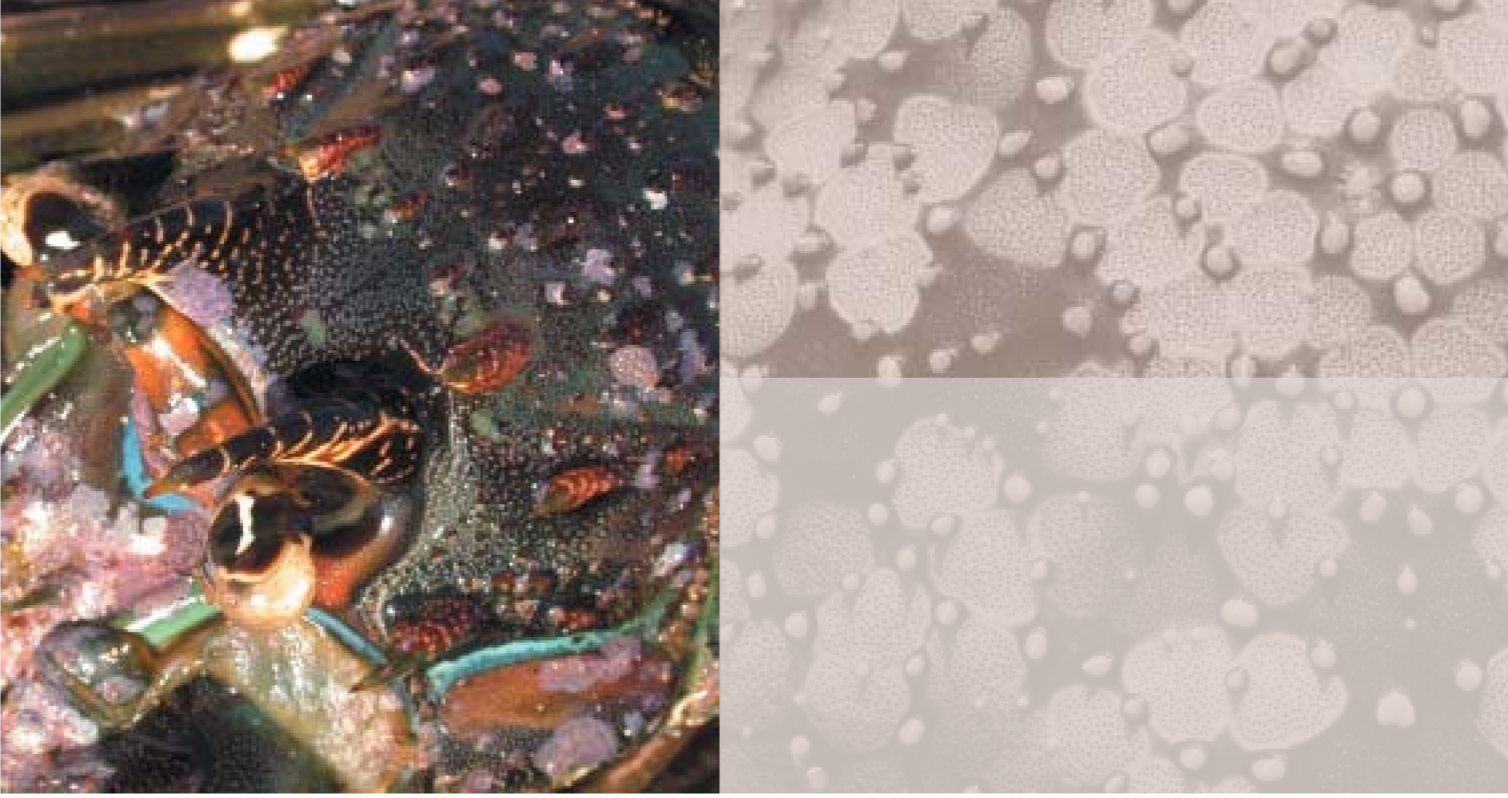
11: Marine Environment – Risks and Management

A risk-based assessment for each phase of the proposed Development was undertaken for the marine physical environment (pelagic, subtidal and intertidal habitats), marine benthic primary producers and marine fauna. The Environmental Protection Authority's risk-based benthic primary producer habitat guidance was applied to consider risks and cumulative impacts to benthic primary producer habitats.

No high risk stressors to the physical environment were identified through the risk assessment process. Physical disturbance during construction is the only stressor that poses a medium risk of adverse impact to the physical environment. Other stressors, such as discharges and leaks or spills were assessed as low risk to physical environmental factors.

There was a focus on higher taxa and principal communities comprising mangroves, seagrasses, macroalgae and corals during the risk assessment for marine benthic primary producers. Seabed disturbance and leaks and spills are both stressors that pose a medium level of risk during the construction phase. Leaks and spills will also be a medium risk during the operations phase of the Development. The physical presence of the facilities and wastewater discharge were assessed as low risks during both construction and operations.

Permanent loss of benthic primary producer habitats are predicted to exceed EPA cumulative loss threshold levels in three of the fourteen management units established in accordance with EPA Guidance Statement No. 29. While these losses exceed the benthic primary producer habitat cumulative loss threshold levels, they do not represent a threat to the ecological integrity of the surrounding benthic primary producer habitat or to the conservation values of the Barrow Island Marine Conservation Area. The flat sandy seabed in both of the dredge spoil ground management units is very well represented in both the local area and the region. It is close to the depth limit for the seagrasses and is likely to be of marginal value in terms of seagrass productivity compared to shallower areas closer to Barrow Island. Similarly benthic primary producer habitats in management unit 8 within the port area are well represented throughout the Montebello/Lowendal/Barrow Island region and permanent loss of some areas of benthic primary producer habitat is not predicted to affect ecosystem integrity in the port area.



A number of stressors pose a medium to high risk of adverse impacts to marine fauna. These stressors include seabed disturbance during construction, physical interaction (turtles), light (turtles), noise and vibration, and leaks and spills during construction. The most sensitive receptors are resident and internesting flatback turtles on the east coast of Barrow Island. The implementation and effectiveness of lighting strategies and management measures will be critical to reducing risk associated with lighting. Similarly, if it is assumed that resident and/or migratory internesting flatback turtles do utilise areas that are proposed to be dredged, then the effectiveness of management strategies will be critical to keeping risk to turtles associated with dredging to an acceptable level.

Impacts can be avoided or minimised to an acceptable level through the development and implementation of strict environmental mitigation and management measures which are described throughout the chapter. The potential environmental consequences of the Development are unlikely to have long-term implications for the marine environment surrounding Barrow Island or mainland components of the Development. The overall level of risk to marine conservation values is therefore considered to be acceptable and environmental management objectives for the Development achievable.

11.1 Introduction

Chapter 8 describes the existing biophysical environment of the Development area based on the findings of a range of specialist studies. The risks posed to the key components and sensitivities in the marine environment of Barrow Island are presented in this chapter and the management measures to reduce potential impacts to acceptable levels are outlined (Figure 11-1). Quarantine risks to the marine environment are discussed in Chapter 12. Risks to key factors and sensitivities of terrestrial flora and fauna are discussed in Chapter 10.

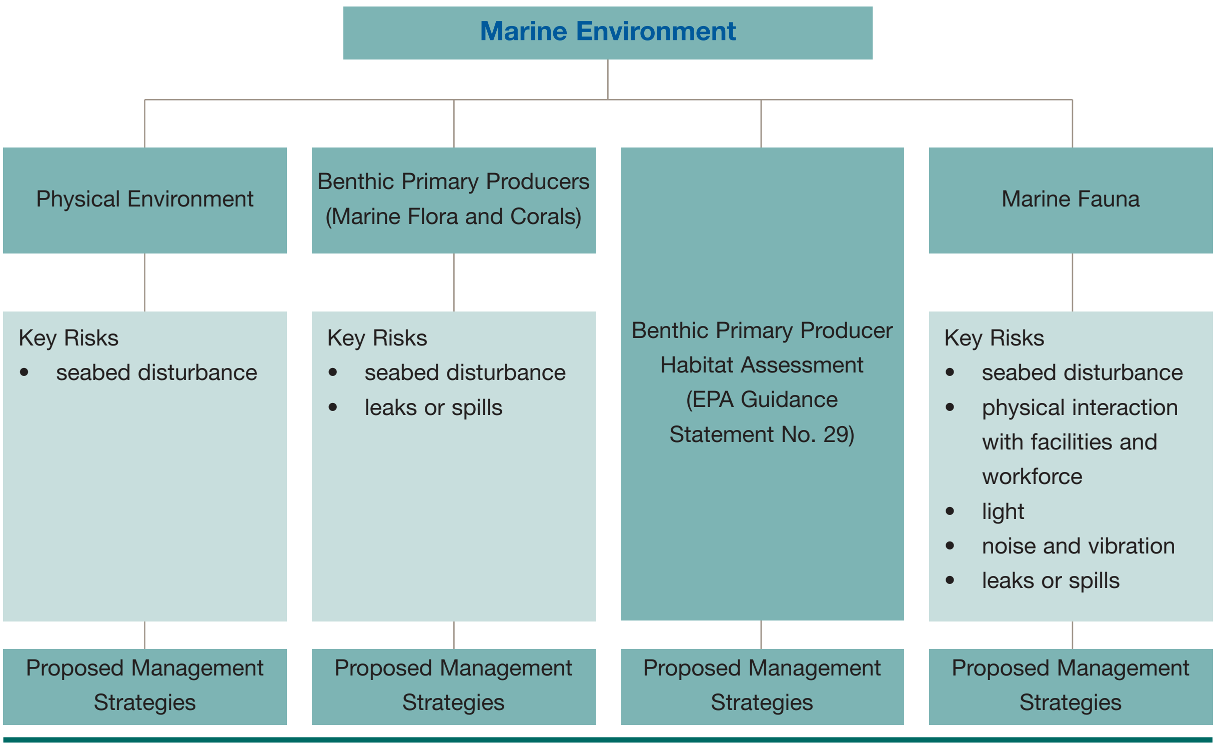
The risk-based assessment presented in this chapter follows the methodology outlined in Chapter 9.
The risks to physical environmental factors including seabed (subtidal and intertidal), water quality and foreshore are presented in Section 11.2. Risks to intertidal and marine flora and corals are discussed in Section 11.3, with a focus on benthic primary producers. Cumulative impacts to benthic primary producer habitat within the proposed Development area are assessed in Section 11.4 in accordance with Environmental Protection Authority (EPA) Guidance Statement No. 29 (EPA 2004). Section 11.5 considers risks posed to marine fauna. The risk assessments conducted for each environmental factor are summarised in tables in each of these sections. Stressors that pose a medium to high level of risk to environmental factors, either prior to or post implementation of management measures, are discussed in more detail in the text. Low risk stressors and associated mitigation strategies are presented in summary tables (Table 11-3, Table 11-12, Table 11-23). Likelihood definitions are provided in Chapter 9 (Table 9-6) and consequence definitions for specific environmental factors are outlined in Table 11-1, Table 11-5 and Table 11-21. An explanation of risk assessment terms used throughout this chapter is provided in Table 9-1, Chapter 9.

11.2 Physical Environment

Risks to the physical factors of pelagic habitats (water quality), intertidal and subtidal habitats (seabed) and supratidal marine habitats (foreshore) were assessed (Figure 11-2). Potential stressors to these physical factors include:

- physical disturbance during construction, commissioning and operations

Figure 11-1:
Overview of Chapter Structure



- physical presence of marine infrastructure during construction, commissioning and operations
- liquid and solid waste disposal during construction (subtidal and intertidal seabed)
- leaks and spills during non-routine operations
- discharges during construction, commissioning and operations (water quality).

These potential stressors to the physical characteristics of areas within and surrounding the proposed Development were identified and risk estimated through an assessment of likelihood and consequences. Likelihood definitions are provided in Table 9-6, Chapter 9. Consequence definitions are provided in Table 11-1. Results of risk assessments are summarised in Table 11-3.

No high risk stressors to the physical environment were identified through the risk assessment process. Physical disturbance during construction is the only stressor that poses a medium risk of adverse impact to the physical environment. Other stressors, such as discharges and leaks or spills were assessed as low risk to physical environmental factors.

The Joint Venturers are committed to adopting all the management measures outlined in this section to avoid or mitigate impacts to the physical environment.
The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses, it may become necessary to modify management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and targets will be developed.

Details of risk assessments and safeguards to minimise risk are discussed in the following sections. Assessment of low risk stressors is included in Table 11-3.

11.2.1 Seabed Substrates

Physical Disturbance

Construction of the following marine components of the proposed Development will disturb areas of the subtidal and intertidal seabed:

- subsea natural gas gathering system (e.g. drilling and installation of wellheads, manifolds and flowlines)
- feed gas and domestic gas pipelines (e.g. anchoring of pipelay vessel and pipeline stabilisation)

Figure 11-2:
Marine Benthic Habitats

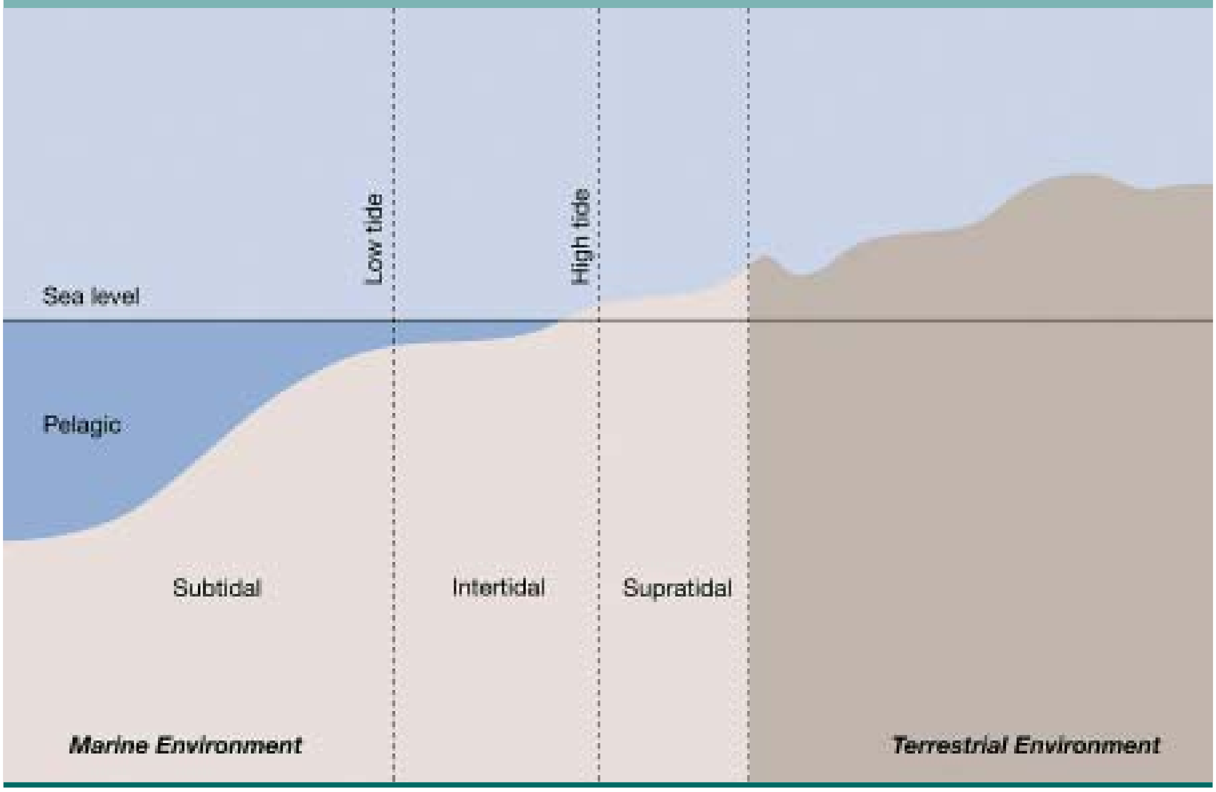


Table 11-1:
Consequence Definitions for Factors of the Physical Marine Environment

Consequence category	Minor	Moderate	Serious	Major	Critical
Water quality	Local, short-term and small reduction in water quality.	Small reduction in water quality which is widespread, short-term or local, long-term. Large reduction in water quality which is local, short-term.	Widespread, long-term reduction in water quality.	Regional, short-term reduction in water quality.	Regional, long-term reduction in water quality.
Seabed (subtidal and intertidal) **Foreshore**	Localised contamination of low toxicity, or disturbance that can be readily rectified. Negligible impact on benthic substrate characteristics. Disturbance of well-represented landform habitats.	Localised contamination or disturbance requiring a long-term restoration effort. Local, short-term change in benthic substrate characteristics. Local loss of well-represented landform habitats.	Localised contamination or disturbance that cannot be readily rectified. Local, long-term, or widespread, short-term change in benthic substrate characteristics. Widespread loss of well-represented landform habitats. Local loss of a unique landform habitat.	Widespread contamination or disturbance requiring a significant long-term restoration effort. Widespread, long-term change in benthic substrate characteristics. Widespread loss of a unique landform habitat.	Widespread contamination or disturbance that cannot be readily rectified. Regional loss of a unique landform habitat.

- causeway, Materials Offloading Facility (MOF) and open-pile jetty
- dredged vessel access channels to the MOF and tanker offloading facility (including turning basin)
- optical fibre cable.

Approximate areas of seabed disturbance associated with construction of marine infrastructure are provided in Table 11-2.

Subsea Gathering System – Construction of the subsea gathering system will involve drilling of production wells using a semi-submersible drilling rig and installation of seabed infrastructure, such as wellhead manifolds and flowlines, as described in Chapter 6. Physical disturbance to the marine environment caused by the installation of subsea facilities will cause negligible impact relative to the widespread distribution of affected habitats. Primary impacts will be limited to the seabed directly beneath infrastructure and the area disturbed by anchor and chain scour and discharged drill cuttings (Table 11-2). Secondary effects from sediment resuspension will also be localised and short-term. Drill cuttings will form areas of deposition on the seafloor. This will result in some localised alteration in sediment composition. Drilling fluids (synthetic or water based) and cuttings have demonstrable low toxicity; hence changes will not be significant. Existing evidence suggests that seabed substrates in the deeper offshore areas of the Gorgon gas field and feed gas pipeline routes will rapidly recover from physical disturbance and require no rehabilitation.

Table 11-2:
Proposed Direct Disturbance to Seabed

Facility	Approximate Area of Disturbance (ha)	Sediment Types
Temporary anchors for drilling and installation activities	Approx. 8–12 anchors, total area of 40 m^2	Carbonate sandy silts to silts and muds, outcrops/reefs.
Subsea trees and manifolds	2.5 (25 wells)	Carbonate sandy silts to silts and muds, outcrops/reefs.
Flowlines (intrafield flowlines)	15.5	Carbonate sandy silts to silts and muds, outcrops/reefs.
Feed gas pipelines	200	Carbonate silts and muds to silty sands with shells and shell fragments, outcrops/reefs, groynes.
Domestic gas pipeline	200	Calcareous silty sands with shells and shell fragments. Occasional rocky outcrops and limestone reef platform.
MOF and access channel (includes causeway)	42	Calcareous silty sands with shells and shell fragments. Occasional rocky outcrops and limestone reef platform.
Jetty	6	Calcareous silty sands with shells and shell fragments. Occasional rocky outcrops and limestone reef platform.
Optical fibre cable	123 (123 km x 10 m)	Calcareous silty sands with shells and shell fragments. Occasional rocky outcrops and limestone reef platform.
Turning basin and shipping channel	144	Calcareous silty sands with shells and shell fragments. Occasional rocky outcrops and limestone reef platform.
Dredge spoil ground	900	Predominantly fine to medium sands over limestone reef platform.

Subsea Pipelines – Subsea pipelines will traverse a range of seabed substrates, mainly unconsolidated sediments and limestone reef platforms. Construction of the feed gas and domestic gas pipelines will involve direct disturbance to the seabed along the pipeline route and through anchor and chain scour from the pipelay vessels. Where required, the feed gas pipelines will be concrete weight-coated for protection and stability; and further stabilised by a secondary measure, such as rock armouring, in nearshore areas off the west coast of Barrow Island. Similarly, the domestic gas pipeline and optical fibre cable will require burial or stabilisation over the entire length of their routes from Barrow Island to the mainland. This will involve direct disturbance of the seabed along a corridor approximately 30 m wide for the domestic gas pipeline and a corridor of 10 m for the optical fibre cable.

Marine Facilities – Construction of the causeway, MOF, jetty, access channels and turning basin off the east coast of Barrow Island will involve direct disturbance to the seabed in these areas. The dredging required to create access channels and berth areas for the Development will result in physical disruption to localised areas of the seabed and the generation of elevated levels of sedimentation and turbidity. Anchoring of construction vessels, dredge vessels and support vessels will disturb an additional small area of seabed. These substrates are widely distributed along the east coast of Barrow Island and throughout the Montebello/Lowendal/Barrow Island region.

Dredge spoil will be disposed to the seabed in defined locations and will modify the substrate characteristics in the receiving area (Chapter 7). An area of sandy seabed has been selected for dredge spoil disposal to minimise the changes in substrate type and migration of the spoil from the disposal ground. Maintenance dredging is expected to be infrequent but necessary to maintain the operable depth of the access channels.

Dredging and spoil disposal will produce a temporary turbidity plume in the water column. Within and beneath the plume, the levels of suspended sediment and sediment deposition will be increased. It is predicted that levels of total suspended solids (TSS) will be elevated in the immediate vicinity of dredging activity and will decrease rapidly beyond this area (refer Section 11.3).

Potential impacts associated with seabed disturbance include:

- change in the seabed profile
- short-term increase in turbidity and sedimentation levels.

Management

The management of drilling operations is covered by the Commonwealth *Petroleum (Submerged Lands) Act 1967.* The drilling programs will be subject to review and approval by the Department of Industry and Resources (DoIR). A detailed Environment Plan and Oil Spill Contingency Plan will be produced as part of this process.

Similarly, prior to the commencement of dredging and spoil disposal activities, the Joint Venturers will prepare a comprehensive Dredging and Spoil Disposal Management Plan (DSDMP). The Plan will be developed with advice and input from Commonwealth and state regulatory agencies and the Gorgon Development's dredging contractor.

The following management measures will be implemented to minimise impacts associated with seabed disturbance. The Joint Venturers will:

- stabilise pipelines to prevent impact from heavy seas
- conduct pre-construction planning to minimise requirement for anchor set in nearshore areas
- examine feasibility and effectiveness of using dynamically positioned vessels, to reduce potential anchoring impacts
- reduce dredging through construction of a solid-fill causeway
- reduce maintenance dredging through the design of channels
- select low points in high profile reefs for pipeline crossings
- develop appropriate erosion control methods to reduce water flow rates and control erosion of intertidal sediments along the mainland section of the domestic gas pipeline route.

Residual Risk

The physical habitats potentially affected by the proposed Development are widely represented throughout the Montebello/Lowendal/Barrow Island region. Impacted areas along the pipeline routes and optical fibre cable route will recover from physical disturbance. Some seabed substrates impacted by dredging and installation of port facilities off the east coast of Barrow Island will be permanently impacted by the Development; however affected substrates are widely distributed and losses will be partially offset by the creation of new substrates that provide increased availability of habitat (e.g. causeway and channel substrates).

The consequences of the impacts will be minor to moderate and are restricted to temporary disturbance to, or localised loss of, habitats that are regionally widespread. The likelihood of these consequences is almost certain because seabed disturbance for construction of the Development is unavoidable. The residual level of risk is therefore considered acceptable (low to medium for construction, low for operations) as there is no threat to the ecological integrity of seabed areas.

11.2.2 Foreshore

Physical Disturbance

Where clearing and earthworks are required along the foreshore, there is potential for erosion and changes to sediment transport along beaches. Clearing and earthworks in foreshore areas is mainly required for pipeline construction (feed gas and domestic gas pipeline shore crossings) and construction of port facilities (primarily the MOF and causeway). Key impacts to the foreshore associated with clearing and earthworks are:

- soil compaction
- erosion
- changes in the foreshore profile.

Foreshore disturbance on Barrow Island will be confined to sandy or rocky areas which support very little vegetation. The mainland shore crossing for the domestic gas pipeline will pass through an area of coastal mangroves.

Mangrove areas in northern Australia can have soils with high pyrite levels that form acid on exposure to air, with subsequent acidic runoff into surrounding waterways. There are no signs of acid scalding along the existing mainland Apache sales gas pipelines easement which is immediately adjacent to the proposed domestic gas pipeline, suggesting soils in the area are not highly acidic.

No clearing or earthworks are expected in foreshore areas during routine operation of the proposed Development.

Management

The following management measures will be implemented to ensure that impacts resulting from clearing and earthworks are minimised and limited to the specific disturbance required to construct infrastructure in foreshore areas. The Joint Venturers will:

- undertake horizontal directional drilling (HDD) to construct the shore crossing for feed gas pipelines (rather than conventional trenching which would result in greater impact to foreshore areas)
- select shore crossing locations that minimise disturbance and potential for long-term impacts
- restrict clearing and earthworks to the minimum extent necessary for safe construction
- install erosion and sediment control structures where required
- conduct regular inspection and maintenance of erosion and sediment control structures
- promptly restore shore crossing construction areas
- integrate contingency plans into operating procedures to cover rough weather and cyclones
- investigate potential for acid sulphate soils along domestic gas pipeline corridor on the mainland and develop remediation strategy as necessary.

Residual Risk

Consequences of clearing and earthworks on foreshore areas will be minor to moderate. Minor consequences include short-term disturbance of well-represented landforms such as sandy beaches. Moderate consequences include the loss of the headland at Town Point and the potential localised, long-term modification of the sediments at the mainland shore crossing. These landforms are widely distributed in the local area and the region.

The risk of impacts to the foreshore associated with clearing and earthworks can be managed to an acceptable level (medium for construction, low for operations). Development on the foreshore will not affect the ecological integrity of the surrounding physical habitats.

Physical Presence

The construction of a causeway and MOF will impose a physical barrier on the east coast of Barrow Island with a potential impact on the dynamics of the existing foreshore environment. The most significant potential impacts are:

- erosion and/or accretion of the shore line
- a surge in water level due to a concentration effect of causeway
- disruption of circulation at the Town Point/causeway interface
- change of wave climate due to refraction/reflection.

Field measurement provides the most accurate assessment of longshore drift rates. Common techniques include sediment tracing (e.g. using dyed sand, radioactive isotopes), measurement of sediment build-up against coastal barriers (e.g. groynes, headlands), and the analysis of beach changes over time from survey plans or aerial photography. An assessment of historic aerial photography determined that between 1976 and 2001 there has been:

- no significant change in the dense vegetation line along beaches to the north and south of Town Point

- minimal change in the majority of the sparse vegetation line along beaches to the north and south of Town Point (one relatively short section of the sparse vegetation line on both the north and south beaches appeared to shift landwards)
- no evidence of accretion against headlands or the existing export pipeline
- no evidence of movement of sediments around headlands.

These results suggest that the existing beaches in the vicinity of Town Point are low energy zones with limited longshore drift. Furthermore, during low tides the shoreline is several hundred metres from the beach exposing a continuous rock platform with little or no sediment coverage.

To further investigate the impact of the causeway on the shoreline, a two-dimensional numerical model was applied which used a particle tracking method (MetOcean Engineers 2005). The model was based on a fine resolution grid (20 m) covering the proposed causeway and adjacent beaches. The model was used to investigate sediment transport through the surf zone, dune erosion and onshore transport following a storm. Results indicated minimal change in the shoreline position for all six scenarios modelled (i.e. tropical cyclones Monty, Bobby and Olivia each considered with and without the proposed causeway structure). This may be attributed to the rock platform in front of the beach, breaking and dissipating incoming wave energy before waves reach the shoreline.

Metocean buoys were used to gather wave data and prepare a wave climate model of the area. The highest wave height recorded was 1 m at a distance of 2.5 km from the shoreline at Town Point. These waves are predominantly from the east-south-east and occur at the edge of a rock platform in approximately 6 m water depth. It is predicted that these waves attenuate over the shallow rock platform to such an extent that waves in the shore zone are likely to be locally generated wind waves. The attenuation of waves across the rock platform contributes to creating a low energy coastal environment in the Town Point area.

The potential for the causeway to create channelling and subsequent surging of water toward Town Point was also considered. If surging occurs and affects water circulation, water quality (e.g. turbidity) in the area adjacent to the causeway may be reduced. Some surging may occur to the south of the proposed causeway; however tidal exchange of water will continue as the area to the south of the causeway empties every day at low tide thereby providing diurnal flushing.

The open pile structure of the proposed jetty will not significantly impact sediment transport processes or wave patterns in the vicinity of Town Point.

Management

The proposed causeway will be perpendicular to the shoreline and prevailing waves which will minimise wave refraction. The construction of the causeway armour units will provide a permeable surface which will absorb wave energy resulting in little or no reflection off the causeway.

Monitoring of the beach alignment either side of Town Point will be conducted post-construction until stabilised.

Residual Risk

The natural protection afforded by several hundred metres of rock platform and the confinement of the beach areas between rocky headlands results in a relatively low energy coastal environment. Due to the relatively sheltered nature of this zone and the alignment of the causeway with respect to the beach and prevailing waves, the risk that the presence of the causeway results in significant detrimental impact on coastal processes is low.

Table 11-3:
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Physical Disturbance – Seabed (Subtidal and Intertidal) **Environmental Management Objective/s:** • To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones.					
Construction and commissioning Dredging and blasting for MOF, causeway, LNG loadout facility and jetty. Dumping of dredge spoil. Construction of feed gas pipelines, domestic gas pipeline and optical fibre cable. Drilling of subsea wells and installation of subsea gathering system. Anchoring of drill rigs, pipelay vessels and dredge vessels. **Operations** Localised maintenance dredging as required (e.g. after cyclone or storm surge). Resuspension of sediments in vessel turning areas. Additional wells.	• change in seabed profile • change in water quality (nutrients, turbidity, oxygen depletion) • sedimentation • damage to high profile reef structures • change in seabed type (e.g. sand to rock) • smothering of seabed.	**Pre-construction** • locate MOF, causeway, jetty, optical fibre cable, pipelines and anchors to avoid areas of conservation significance • select dredge spoil ground based on sediment characteristics of receiving environment • reduce required dredging volumes by constructing a causeway to the MOF • locate and orientate causeway and jetty to minimise impacts to nearshore sediment movements and patterns of wave refraction • develop Environment Plans outlining management practices associated with drilling and installation of the subsea gathering system in accordance with the Commonwealth *Petroleum (Submerged Lands) Act 1982* • select drilling fluid and surface equipment to reduce impacts • specify heavy metal limits in drilling chemicals (e.g. barite) • specify relevant EIS/ERMP commitments in tenders and contracts.	• compliance with EPA guidance statement for benthic primary producer habitat disturbance • compliance with long-term management targets and Key Performance Indicators (KPI) (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • auditing against management requirements outlined in Environment Plans for drilling and construction of pipelines • routine monitoring in accordance with the Sea Dumping Permit conditions • developing Dredging and Spoil Disposal Management Plan (refer Section 11.3).	**Construction and commissioning** Likelihood – almost certain Consequence – minor to moderate Risk – low to medium **Operations** Likelihood – likely Consequence – minor Risk – low

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		Construction and commissioning • refine design and location of facilities to consider seabed sensitivities • use HDD in favour of trenching at feed gas pipelines shore crossing • restrict anchoring of support vessels • examine feasibility and effectiveness of using dynamically positioned vessels to minimise potential impacts associated with anchoring • utilise appropriate erosion control methods to reduce water flow rates and control erosion of intertidal sediments in the cleared area of the mainland coast where required • use sediment curtains where feasible • specify relevant EIS/ERMP commitments in tenders and contracts. **Operations** • design dredge channel to reduce the necessity for maintenance dredging.			

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Physical Presence – Seabed (Subtidal and Intertidal) **Environmental Management Objective/s:** • To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones.					
Operations Permanent presence of: MOF, causeway, jetty, subsea wellheads, flowlines and optical fibre cables. Feed gas and domestic gas pipelines.	• localised change in seabed profile • localised change in longshore coastal sediment dynamics.	**Pre-construction, construction and commissioning** • construct jetty as an open pile structure • assess coastal processes and longshore coastal sediment transport dynamics adjacent to proposed causeway • locate and orientate the causeway and jetty to minimise impacts to nearshore sediment movements and patterns of wave refraction • specify relevant EIS/ERMP commitments in tenders and contracts. **Operations** • as above.	• no detectable long-term change in longshore coastal sediment dynamics • compliance with long-term management targets and KPIs (CALM 2004).	Establish an environmental monitoring program to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of beach alignment either side of Town Point until stabilised.	**Operations** Likelihood – almost certain Consequence – minor Risk – low

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Liquid and Solid Waste Disposal – Seabed (Subtidal and Intertidal) **Environmental Management Objective/s:** • To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones.					
Construction and commissioning Generation and disposal of liquid and solid wastes including: • hydrotest water • domestic waste and sewage • waste chemicals and oil • drilling waste (e.g. drill cuttings and fluid). **Operations** Generation and disposal of liquid and solid wastes, including (refer to Chapter 7): • domestic waste and sewage • waste chemicals and oil • fire water runoff • stormwater runoff.	• localised pollution or contamination of marine sediments and water column • alteration of sediment characteristics (sediment size and anoxic conditions).	**Construction and commissioning** • design equipment to include built in safeguards such as relief valves and overflow protection, fabrication quality controls and operating procedures • include waste avoidance and management requirements in tendering and contract documents • limit discharges of domestic waste to food scraps, sewage and grey-water from vessels when greater than 12 nautical miles offshore • comply with the requirements of MARPOL 73/78 Annex IV for discharges of sewage and food scrap material (i.e. macerated to less than 25 mm diameter prior to disposal) • no sewage or putrescible waste discharged within 12 nautical miles of land • use biodegradable detergents only • store all oily water for onshore disposal or pass through oily water separator prior to discharge	• no long-term contamination outside of Development areas • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • environmental audits to determine compliance with licence conditions • establishment of waste targets and regular review of waste inventories.	**Construction and commissioning** Likelihood – almost certain Consequence – minor Risk – low **Operations** Likelihood – almost certain Consequence – minor Risk – low

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• collect and process potentially oil contaminated drainage from decks and work areas through an oily water separation system • process bilge water through an oily water separation system • discharge only clean water directly overboard • comply with AQIS ballast water guidelines (Chapter 12) • use low toxicity drilling fluids • recycle drill fluids within the drill system • select drilling fluid treatment technique to reduce residual fluid on cuttings • specify heavy metal limits in drilling chemicals (e.g. barite) • discharge hydrotest water into high exchange areas if directed into the ocean • segregate all solid non-hazardous waste and retain onboard for appropriate disposal onshore • provide areas for waste segregation to enable recycling • close all waste containers to prevent loss overboard • specify relevant EIS/ERMP commitments in tenders and contracts. **Operations** • as above.			

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills – Seabed (Subtidal and Intertidal) **Environmental Management Objective/s:** • To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones.					
Non-routine operations Storage and transport of chemicals, fuel or other hazardous material. Vessel collision or grounding. Failure of equipment or pipelines.	• contamination of subtidal sediments and water quality • contamination of intertidal reef or sediments.	**Non-routine operations** • audit vessels before commencing operations • design equipment to prevent spills and leaks • specify heavy metal limits in drilling chemicals (e.g. barite) • implement protocols for transfer of fuel from support vessels • develop detailed environmental management plans (EMP) for each main contract covering spill prevention • have in place Material Safety Data Sheets for all chemicals reviewed for health, environment and safety (HES) requirements prior to purchase • store chemicals, fuels and oils in accordance with Material Safety Data Sheet requirements as a minimum • conduct refuelling during daylight hours where possible, depending on sea conditions • provide detailed procedures outlining sea state conditions and other controls • close scuppers on vessels to ensure any contaminants on deck are not discharged into the ocean	• no long-term contamination outside of Development areas • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • audit against management requirements outlined in Environment Plans for drilling and construction of pipelines • audit against OSCP requirements • equipment and pipeline corrosion monitoring and control program.	**Construction** Minor spill (<10 m^3) Likelihood – unlikely Consequence – minor Risk – low Spill (>10 m^3) Likelihood – unlikely Consequence – moderate Risk – low **Operations** Minor spill (<10 m^3) Likelihood – unlikely Consequence – minor Risk – low Spill (>10 m^3) Likelihood – unlikely Consequence – moderate Risk – low

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• store fuel in large, internal tanks/bunkers onboard • close all waste containers to prevent loss overboard • design equipment (e.g. tank integrity, level devices, overflow to bunded area) appropriately • apply industry standards for storage and handling of fuels and chemicals (e.g. bunding) • develop well design and testing protocols • develop drilling Environment Plan such that it outlines management of drilling waste discharges at the offshore field, including monitoring of possible effects • transfer hoses fitted with ‘dry’ coupling • implement approved OSCP and emergency response planning • provide spill kits where spills are possible, including on small vessels • have on hand oil and chemical spill containment and cleanup material (e.g. absorbent) at all times • contain onboard spills and clean up immediately • specify relevant EIS/ERMP commitments in tenders and contracts.			

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Discharges – Water Quality **Environmental Management Objective/s:** • To maintain the quality of water so that existing and potential environmental values, including ecosystem function, are protected.					
Construction and commissioning Discharges from marine construction vessels – stormwater (deck drainage), brine from desalination, sewage, grey-water and macerated food. Dredge spoil. Hydrotest water. Drilling fluids. **Operations** Maintenance dredging as required. Runoff from hardstand areas such as the jetty and MOF. Ballast and bilge water from loading vessels. Leaching of anti-fouling compounds from vessel hulls and marine structures.	• localised pollution of the water column • increases in localised turbidity • localised copper or tributyltin (TBT) pollution from vessel anti-fouling leachate.	**Construction and commissioning** • use low toxicity, water based fluid systems for drilling, where technically feasible or substitute with low toxicity synthetic based fluids • recycle drill fluids within the drilling system • use drilling fluid/cutting separation equipment • prepare drilling Environment Plan • specify heavy metal limits in drilling chemicals (e.g. barite) • limit discharge of domestic waste to treated/processed food scraps, sewage and grey-water • comply with requirements of MARPOL 73/78 Annex IV for discharge of sewage and food scraps (i.e. macerated to less than 25mm diameter prior to disposal) • prohibit sewage or putrescible waste discharge from vessels when less than 12 nautical miles from land • use biodegradable detergents only	• no long-term contamination outside of Development areas • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • auditing against management requirements outlined in Environment Plans for drilling and construction of pipelines • auditing against OSCP requirements • establishment of waste targets and regular review of waste inventory • routine monitoring in accordance with the Sea Dumping Permit conditions	**Construction and commissioning** Likelihood – likely Consequence – minor Risk – low **Operations** Likelihood – likely Consequence – minor Risk – low

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• collect and process any contaminated drainage from decks and work areas to remove oil • avoid TBT use on any new equipment • discharge hydrotest water into high exchange areas offshore if hydrotest water is discharged to the sea • consider options for disposal of sewage effluent and brine from fresh water supply • maintain optimum four metre under keel clearance on the trailer suction hopper dredge to reduce sediment resuspension • specify relevant EIS/ERMP commitments in tenders and contracts. **Operations** • comply with AQIS ballast water guidelines (Chapter 12) • process bilge water through an oily water separation system • containerise and return spent oils and lubricants to shore upon program completion • prohibit discharge of sand-blasting wastes during maintenance of vessels • implement drainage segregation and tiered management.		• development and implementation of a Dredging and Spoil Disposal Management Plan (refer Section 11.3).	

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills – Water Quality **Environmental Management Objective/s:** • To maintain the quality of water so that existing and potential environmental values, including ecosystem function, are protected.					
Non-routine operations Storage and transport of chemicals, fuel or other hazardous material. Vessel collision or grounding. Failure of equipment or pipelines.	• localised pollution of the water column from minor spill • more widespread pollution from spill >10 m^3.	**Non-routine operations** • design equipment to include built-in safeguards such as relief valves and overflow protection, fabrication quality controls and operating procedures • conduct Material Safety Data Sheet review for HES requirements prior to any purchase of chemicals • develop protocols for transfer of fuel from support vessels • fit transfer hoses with 'dry' couplings • store chemicals, fuels and oils in accordance with Material Safety Data Sheet requirements as a minimum • provide oil and chemical spill containment and cleanup material (e.g. absorbent) at all times • refuel during daylight hours, depending on sea conditions • contain onboard spills and clean up immediately • close scuppers to ensure materials on the deck of vessels are not discharged into the ocean • store fuel and diesel in large, internal tanks/bunkers onboard	• no long-term contamination outside of Development areas • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • audit vessels before commencing operations • regular audit, inspection and maintenance of facilities • implementation and regular testing of emergency shut-down procedures to reduce potential volumes from spills and leaks • implementation of a gas processing facility, equipment and pipeline corrosion monitoring and control program.	**Construction** Minor spill (<10 m^3) Likelihood – unlikely Consequence – minor Low risk Spill (>10 m^3) Likelihood – unlikely Consequence – moderate Risk – low **Operations** Minor spill (<10 m^3) Likelihood – unlikely Consequence – minor Risk – low Spill (>10 m^3) Likelihood – unlikely Consequence – moderate Risk – low

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
		• close all waste containers to prevent loss overboard • apply industry standards for the storage and handling of fuels and chemicals (e.g. bunding) • develop and implement approved OSCP and emergency response and spill contingency planning • segregate and store waste appropriately • specify relevant EIS/ERMP commitments in tenders and contracts.		• routine inspection of infrastructure, gas processing facility and equipment by designated personnel.	

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Physical Disturbance – Foreshore **Environmental Management Objectives:** • To maintain the integrity and stability of beaches.					
Construction and commissioning Clearing and earthworks mainly required for pipeline construction (feed gas, optical fibre cable and domestic gas shore crossings) and construction of port facilities – MOF and causeway. Exposure of potential acid sulphate soils on mainland domestic gas pipeline and optical fibre cable easements. **Operations** No clearing or earthworks are expected in foreshore areas during routine operation.	• soil compaction • erosion • changes in the foreshore profile • acidity effects on sediments and receiving waters (i.e. acid sulphate soils).	**Construction and commissioning** • limit clearing and earthworks • install erosion and sediment control structures as required • limit period between construction and re-instatement • re-instate pipeline shore crossings to a level consistent with surrounding terrain • further assess potential for acid sulphate soils on the mainland • develop acid sulphate soil remediation plan if required • rehabilitate mangrove vegetation along mainland section of domestic gas pipeline route • roll or slash mangroves (rather than uprooting) along mainland section of domestic gas pipeline route • investigate use of geotextile mud mats where required during construction of mainland section of domestic gas pipeline to minimise impacts to mangroves • specify relevant EIS/ERMP commitments in tenders and contracts. **Operations** • implement revegetation/ rehabilitation plan for shore crossing sites.	• foreshore profiles re-instated • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • routine inspection and maintenance of erosion and sediment control structures • monitoring of revegetation/ rehabilitation works.	**Construction and commissioning** Likelihood – almost certain Consequence – moderate Risk – medium **Operations** Likelihood – likely Consequence – minor Risk – low

Table 11-3: (continued)
Summary of Risk Assessment for Physical Environment

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Target	Measurement Strategies	Residual Risk
Stressor: Physical Presence – Foreshore **Environmental Management Objectives:** • To maintain the integrity and stability of beaches.					
Operations Causeway and dredged channels may potentially affect longshore coastal sediment transport dynamics. Cleared domestic gas pipeline corridor on mainland.	• localised change in seabed profile • localised, minor change in longshore coastal sediment dynamics • localised surge in water level due to entrapment by causeway.	**Pre-construction** • conduct numerical modelling of coastal processes and longshore coastal sediment transport dynamics adjacent to proposed causeway • orientation of the causeway to minimise impact on wave refraction patterns. **Operations** • utilise appropriate erosion control methods to reduce water flow rates and control erosion of intertidal sediments in the cleared area of the mainland coast where required.	• no detectable long-term change in longshore coastal sediment dynamics • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of beach alignment either side of Town Point until stabilised.	**Operations** Likelihood – almost certain Consequence – minor Risk – low

Note: all acronyms and abbreviations are provided in full in the supplementary information section.

11.3 Benthic Primary Producers (Marine Macrophytes and Corals)

Benthic primary producers are photosynthetic organisms that are attached to marine intertidal and subtidal substrates and contribute to the productivity of marine ecosystems. They include marine macrophytes (plants) and corals. Benthic primary producers are restricted to the photic zone where light is sufficient to support photosynthesis. Mangroves, seagrasses, macroalgae and corals are the most important benthic primary producers in the tropical marine ecosystems surrounding Barrow Island and on the mainland Pilbara coast. Corals are primary producers due to photosynthesis of microalgae (zooxanthellae) living in their cells.

The marine macrophyte and coral assemblages in the waters surrounding Barrow Island are dominated by tropical and sub-tropical species that are widely distributed within the Montebello/Lowendal/Barrow Island region and across the Rowley Shelf. Mainland taxa are similarly widespread along the Pilbara coast (refer Chapter 8).

Benthic primary producers will be impacted during construction of the marine facilities by direct removal during dredging and drilling, burial under infrastructure, smothering by deposited sediments and shading by fine sediments suspended in the water (i.e. increased turbidity). The main construction activities (including non-routine operations) that will impact benthic primary producers are:

- dredging and earthworks for the causeway, MOF, access channels and turning basin
- construction of the open piled jetty and tanker loadout facility
- installation of the domestic gas pipeline from Barrow Island to the mainland
- installation of the optical fibre cable from Barrow Island to the mainland
- installation of the feed gas pipelines in the nearshore waters at North White's Beach or the alternative shore crossing at Flacourt Bay.

Permanent changes to seabed substrate type or water depth will have ongoing impacts on benthic primary producers in affected areas throughout the operations phase of the Development. Some of these changes to the seabed substrate type will enhance growth of macroalgae and corals. The main operations activities (including non-routine operations) that will impact benthic primary producers are:

- maintaining the depth of the dredged shipping channels for the MOF and LNG loadout facility
- modification of the seabed within the dredge spoil disposal area
- creation of hard substrates (e.g. causeway, jetty pilings) that will support macroalgae and corals
- creation of hard substrates along the domestic gas pipeline from Barrow Island to the mainland that will support macroalgae and corals
- creation of hard substrates along parts of the feed gas pipeline off North White's Beach or Flacourt Bay that will support macroalgae and corals.

Potential stressors that may affect benthic primary producers have been identified and risk estimated through an assessment of consequences and likelihood. Risk assessment methods are detailed in Chapter 9. The risk assessment for marine benthic primary producers focuses on higher taxa and principal communities comprising mangroves, seagrasses, macroalgae and corals. Prior to undertaking the risk assessment for marine benthic primary producers, key receptors were identified (Table 11-4).

The consequences of impacts on marine flora and corals are defined in Table 11-5. Likelihood definitions are provided in Table 9-6, Chapter 9. Risk assessments have included evaluation of environmental consequences and the likelihood of those consequences occurring to key receptors. Risk assessment results are summarised in Table 11-12.

Seabed disturbance and leaks and spills are both stressors that posed a low to medium level of risk to benthic primary producers during the construction phase. Leaks and spills also present a medium risk during the operations phase of the Development. The physical presence of the facilities and wastewater discharge were assessed as low risks to benthic primary producers during both construction and operations (Table 11-12). Detailed assessment and additional management of the higher risk stressors is described in the following sections.

Table 11-4:
Key Receptors – Marine Benthic Primary Producers (Marine Macrophytes and Corals)

Key Receptor	Reason for Selection	Additional Receptors (represented by key receptor)
Mangroves		
Avicennia marina	Most abundant mainland species.	Samphire communities behind mangrove zone.
Rhizophora stylosa	Secondary species on mainland.	*Ceriops tagal, Aegiceras corniculatum.*
Seagrasses		
Halophila ovalis	Most abundant and widespread genus; ephemeral.	*Halodule, Syringodium, Thalassia.*
Macroalgae		
Sargassum spp.	Most widespread and abundant genus on hard substrates.	*Dictyopteris;* phaeophytes on rock substrates.
Caulerpa spp.	Widespread on soft sediments.	*Penicilium;* chlorophytes on sediment.
Corals		
Porites lobata	Large colonies; widespread; important ecologically; resilient but slow growing.	Massive corals of great age; Poritids.
Acropora spp.	Small colonies; large thicket on southern Lowendal Shelf; sensitive but fast-growing.	Fast growing fragile species; Acroporids and Pocilloporids.
Turbinaria bifrons	Widespread; small colonies; common amongst macroalgae and on reef platforms in deeper areas.	Other species of *Turbinaria;* encrusting species scattered amongst macroalgae.

The Joint Venturers are committed to adopting all the management measures outlined in this section to avoid or mitigate impacts to the benthic primary producers. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses it may become necessary to modify management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and outcomes/targets will be developed.

11.3.1 Seabed Disturbance

The major, long-term impact of seabed disturbance on benthic primary producers is associated with direct removal of substrates with attached marine macrophytes and corals, such as excavation of vessel access channels by dredging, and installation of infrastructure on the seabed (e.g. construction of the MOF). Marine substrates will also be buried at the spoil disposal site. Marine construction activities, particularly dredging and drilling, can also temporarily affect the seabed, most notably through increased levels of sedimentation and turbidity. The areas of seabed disturbance associated with the Development activities are outlined in Table 11-2.

Construction of the feed gas pipeline to North White's Beach (or alternatively Flacourt Bay) on the west coast of Barrow Island would have negligible direct impact on the macroalgal beds and scattered corals growing on nearshore reefs off the west coast of Barrow Island. The feed gas pipelines shore crossing will be constructed by HDD under the main benthic primary producer zone near the shore. Drilling fluids will be discharged to the seafloor where the pipeline emerges 600 m offshore. A small amount of jetting or rock dumping will be required at the subsea pipeline exit point to create a gentle transition from the exit point to the natural seabed contour.

Table 11-5:
Consequence Definitions for Marine Benthic Primary Producers

Consequence category	Minor	Moderate	Serious	Major	Critical
Restricted and significant benthic primary producer communities	*Impact on species or community*				
	Local and short-term decrease in abundance or impact on a community.	Widespread, short-term or local, long-decrease in abundance or impact on a community. No reduction in community/ taxon viability in local area.	Widespread, short-term or local, long-term decrease in abundance or impact on a community. Reduced viability in local area. No reduction in community/ taxon viability in waters surrounding Barrow Island.	Widespread and long-term decrease in abundance or impact on a community. Reduced viability of taxon or community in waters surrounding Barrow Island.	Widespread and long-term decrease in abundance or impact on a community. Extinction on Barrow Island, within mainland management unit, or in surrounding waters or reduced viability in the immediate region.
General taxa and communities	*Impact on species or community*				
	Widespread, short-term or local, long-decrease in abundance or impact on a community. No reduction in community/ taxon viability in local area.	Widespread, short-term or local, long-term decrease in abundance or impact on a community. Reduced viability in local area. No reduction in community/ taxon viability in waters surrounding Barrow Island.	Widespread and long-term decrease in abundance or impact on a community. Reduced viability of taxon or community in waters surrounding Barrow Island.	Widespread and long-term decrease in abundance or impact on a community. Extinction on Barrow Island, within mainland management unit, or in surrounding waters or reduced viability in the immediate region.	Widespread and long-term decrease in abundance or impact on a community. Extinction in immediate region.

The subsea section of the feed gas pipelines, in deeper water beyond the nearshore limestone reef platform, is not expected to impact benthic primary producers. Macroalgae and corals are widespread along the west coast of the island but limited to the nearshore waters. Seagrasses are uncommon on these parts of the coast due to high wave energy. Anchoring of construction vessels during installation of the feed gas pipelines at North White's Beach may impact small areas of macrophyte and coral communities. The coral communities of high conservation significance on Biggada Reef, further to the south, will not be directly affected by drilling of the feed gas pipelines shore crossing at North White's Beach. Corals in the area of direct impact are limited to isolated, small colonies of non reef-forming taxa such as *Turbinaria.* These corals are widespread in the Montebello/Lowendal/Barrow Island region.

Construction of the causeway, MOF, jetty, access channels and turning basin off the east coast of Barrow Island will directly impact:

- beds of macroalgae and scattered corals that grow on fringing reef platforms
- scattered seagrasses on soft sediments
- small coral communities.

The macrophyte and coral assemblages in the vicinity of proposed marine facilities off the east coast of Barrow Island are widespread and are capable of readily colonising new substrates. Any new area of hard substrate, such as the causeway, will be colonised by macroalgae and corals. Areas affected by anchor scour will recover fully. Areas of bare sand, for example in the bottom of dredged channels, may be colonised by seagrasses.

The area proposed for dredge spoil disposal comprises mostly bare substrates, with sparse epibenthic assemblages. This area will be substantially modified as a result of spoil disposal but will become more productive, due to the creation of hard surfaces that will encourage coral and algae recruitment. In some areas, sparse *Halophila* will be buried by dredge spoil. *Halophila* is a genus of mostly ephemeral seagrass species that are known to flourish in the Montebello/Lowendal/Barrow Island region after disturbance, and will be among the first taxa to recolonise the spoil ground. Brown algae, such as *Sargassum,* and corals will colonise the rocky substrates created within the spoil ground. This benthic primary producer will persist and complex communities will develop if the substrate is stable over the long-term.

The open-pile jetty will traverse isolated coral communities. Some corals may be smothered by cuttings associated with pile drilling. Corals may be physically damaged by anchor scour in areas adjacent to the jetty. These communities will recover from disturbance and corals will colonise the jetty piles. The taxa in affected coral communities are widespread along the eastern coast of Barrow Island and throughout the Montebello/Lowendal/Barrow Island region.

The domestic gas pipeline from Barrow Island to the mainland will directly disturb a narrow corridor of the seabed. Sparse seagrass is expected to occur in sandy areas within the photic zone (up to approximately 15 m depth). Disturbance from installation of the domestic gas pipeline and optical fibre cable will be temporary, as seagrasses that occur in affected areas are adapted to a dynamic environment with constant cycles of colonisation and burial or erosion. The main seagrass, *Halophila,* maintains a seed stock in the surface sediments and disturbed areas can be recolonised from seed or from vegetative fragments. The recolonising abilities of *Halophila* in the region were apparent after Cyclone Vance, when extensive areas of disturbed seabed virtually devoid of attached benthos supported vigorous *Halophila* meadows within eighteen months of disturbance (Loneragan et al. 2003).

The shore crossing for the domestic gas pipeline on the mainland will impact a 30 m wide corridor through coastal fringing mangroves (Figure 8-22, Chapter 8). The mangrove system is dominated by *Avicennia marina* and *Rhizophora stylosa.* These species are very widespread throughout the Pilbara region. The species that will be most affected, *Avicennia marina,* is expected to recover from the disturbance in the long-term through natural regrowth. The EPA (2001) lists this species as one with potential for restoration. Observations of the existing clearing for the Apache sales gas pipelines indicate that there has been some regrowth of *Avicennia* seedlings since the second sales gas pipeline was installed in 1999.

The proposed optical fibre cable will traverse some sparse, shallow subtidal macroalgal and seagrass communities near Onslow. Benthic primary producer assemblages are generally not well developed in this nearshore area, due to naturally high levels of turbidity and sedimentation. The optical fibre cable will run along an existing jetty to avoid impacts to benthic primary producers in the area. Alternatively, the optical fibre cable would be trenched into the seabed if construction along the jetty is not possible.

Effects of Sedimentation and Turbidity on Corals

Sedimentation and turbidity are major causes of degradation of scleractinian corals (e.g. Rogers 1983; Cortés and Risk 1985; Pastorok and Bilyard 1985; Hodgson 1990). However, the extent and severity of impacts is highly variable and depends on a range of factors including the coral species affected, sediment concentration, grain size, water depth and water temperature (refer to review by Rogers 1990).

Coral assemblages can persist in areas subject to periods of high natural turbidity and sedimentation; (e.g. during cyclones and river floods). These events expose corals to high concentrations of TSS and high sedimentation rates for short periods of time. Generally, the species composition of coral communities in areas regularly exposed to these perturbations is different to the composition of clear water communities. Taxa resilient to turbidity and sedimentation dominate in these areas and the coral assemblage can survive the short-term impacts from sedimentation and turbidity. However, in certain cases such events can also cause mass mortality of corals and some coral reefs do not recover but shift to a macroalgae dominated reef, particularly if the subsequent recruitment of corals is affected. Coral assemblages at Barrow Island are comprised of both turbid water communities, which occur on the shallow, nearshore limestone pavements, and clear water communities, such as the *Acropora* thickets on the southern Lowendal Shelf, which occur further offshore.

Corals can also cope with fluctuations in light and sedimentation due to tidal changes over periods of hours. Flood tides generally carry clean, offshore water into coral areas where it is made turbid by particulate material resuspended near the coast. The periods between short episodes of high turbidity allow the corals to recover sufficiently to maintain positive energy budgets. During large perturbations, such as cyclones, the corals are exposed to extended periods of consistently high turbidity and sedimentation. It is during these periods of persistent low light and sedimentation load that corals are likely to die.

Excessive sedimentation and turbidity adversely affects coral communities by altering both biological and physical processes. Sediments deposited on coral tissues can cause necrosis through smothering or bacterial infection and suspended sediments can abrade polyps (Rogers 1983; Brown et al. 1990; Hodgson 1990; Wesseling et al. 1999). Active sediment removal by corals, through ciliary movements and mucus secretion, and reduced light availability due to smothering also place increased energy stress on corals (Dallmeyer et al. 1982; Stafford-Smith and Ormond 1992; Reigl and Branch 1995). Physiological stresses may reduce growth and calcification rates, and if persistent will cause coral bleaching and death (Dodge and Vaisnys 1977; Bak 1978; Rogers 1983; Wesseling et al. 1999; Torres and Morelock 2002). Increased levels of sedimentation and turbidity also have the ability to inhibit the fertilisation, survival, recruitment and settlement of juvenile corals (Babcock and Davies 1991; Te 1992; Gilmour 1999).

Both the length of time and the amount of suspended and deposited sediment, that corals are exposed to will affect the severity of the impacts to corals or marine macrophytes. Therefore, impacts of HDD and dredging programs were assessed by setting threshold criteria for both the level and duration of turbidity and sedimentation which relate to coral response. In the absence of adequate literature on the relationships between seagrass or macroalgal survival and TSS concentrations and sedimentation, the criteria for adverse impacts on corals were taken as a conservative indicator of the response of all benthic primary producer communities. This approach is conservative because macrophyte benthic primary producer habitats are expected to be less susceptible than corals to long-term impacts from sedimentation and turbidity.

For the risk assessment, three zones of differing levels of impact were established:

- 'zone of high impact' with high to total mortality of corals and seagrasses
- 'zone of moderate impact' with potential for low to high levels of mortality of sensitive coral species and partial loss of resilient species
- 'visible plume and extent of sedimentation' where turbid water plumes and/or sedimentation will occur, but will not have a measurable impact upon benthic primary producers.

Each of these three zones were defined on the basis of both sediment load and exposure time above background levels, taking into account published values for acute (short-term), medium-term and chronic (long-term) responses to both sedimentation and elevated TSS. Within each zone there is potential for a range of impact levels to occur. For example, in the high impact zone, effects may range from total mortality of all corals to mortality of specific coral taxa, mortality of individual colonies, or partial death of colonies.

The spatial extent of the three zones of impact (high, moderate, no effect) was predicted by three-dimensional hydrodynamic modelling incorporating regional and local bathymetry, tidal and wind-driven water currents, predicted sediment characteristics and conservative estimates of the quantities of sediment to be released during dredging and HDD (refer Chapter 7 and Technical Appendix B6).

Each zone of impact varies for best, worst and anticipated scenarios. The best case assumes that corals will fall into the lower end of the range of possible responses to TSS and sedimentation stress. The anticipated and worst case scenarios are highly conservative and assume that corals exhibit the higher end responses to these stressors.

All of the literature reviewed on the effects of turbidity and sedimentation on corals report effects due to persistent reductions in water quality. Similarly, laboratory studies on these stressors generally maintain a constant experimental treatment throughout the study period. Hydrodynamic modelling indicated that persistent plumes are predicted to last for weeks, rather than short pulses of a few days. The greatest effects of sedimentation and elevated TSS on corals are assumed to be due to a continuous reduction in the light climate, represented by consecutive days of high TSS, rather than cumulative impacts from pulses of elevated TSS levels every few days. In this assessment of the impacts of dredge related sedimentation and turbidity, it has been assumed that by delineating areas of persistent stress using highly conservative coral health criteria, the full range of potential short-term 'pulse' stress scenarios are also covered.

Predictions from the hydrodynamic model suggest that the majority of liberated sediment will not accumulate, except in areas close to marine infrastructure (based on the fine nature of the material forecast to be mobilised during dredging for the proposed Development and the consistent tidal flows and winds in the region). Most sediment will continually re-suspend into the water column, being slowly dispersed and diluted by the action of wind and waves. As a conservative measure, sedimentation rates were chosen for consecutive days and assume no re-suspension of the material, whereas the model suggests that much of the material will be removed by tidal currents and will not tend to accumulate.

Ongoing modelling is examining the likelihood that corals outside the high and moderate impact zones will be subjected to short-term pulses of turbidity or sedimentation that may lead to coral mortality over a protracted period. Results of this modelling will be made available for public comment during the last four weeks of the Draft EIS/ERMP public exhibition period. These results will be provided in a package of additional information.

Highly conservative criteria for impacts to corals and other benthic primary producers have been selected to account for uncertainty in the light attenuating characteristics of the dredged sediments at Barrow Island; possible differences between natural and dredge generated sediments; and potential additive effects of other stressors such as high water temperatures, gamete production and natural turbidity. The criteria used in predicting the zones of impact are described in the following sections.

Zone of High Impact

The zone of high impact from Development activities is based on the susceptibility of resilient coral taxa such as *Turbinaria* and *Porites,* and in some cases, sensitive taxa such as *Acropora,* to acute, medium-term and chronic levels of turbidity and sedimentation. The high impact criteria selected below reflect sedimentation and TSS regimes that have been found to have serious impacts to these taxa in previous studies. Conservative threshold values have been selected for the anticipated and worst case scenarios. Total coral mortality below these thresholds is highly unlikely. In addition to threshold criteria, the identification of high impact zones assumes that the potential effects of TSS on corals will be limited to daylight hours. Hence, total suspended solids criteria are based on a concentration above background which exceeds set values for at least half of the daylight hours (6 out of 12 hours) in any day.

There is a paucity of information on how long individual coral taxa can withstand different rates of sedimentation; however corals are known to vary widely in their sensitivity to sedimentation. For example, *Acropora cervicornis, Montastraea anularis* and *Diploria stigosa* can survive sedimentation at 200 mg $cm^{-2}d^{-1}$ for 45 days without extensive damage (Rogers 1983) whereas other acroporids appear to suffer significant bleaching and partial mortality at sedimentation rates of >30 mg cm^{-2} d^{-1} for one week (Stafford-Smith et al. 1994). This is the basis for the best case scenario described in following sections, where it is assumed that the corals are more resistant to turbidity and sedimentation effects than indicated by the highly conservative criteria used for setting the zones under the anticipated and worst case scenarios.

Acute Sedimentation

Sedimentation rates at ≥25 mg cm^{-2} d^{-1} above background that persist for at least five consecutive days are likely to cause widespread coral mortality, including impacts to *Porites* bombora. Below this value, total mortality of corals is highly unlikely. Hodgson (1990) reported that *Oxypora labra* exposed to 40 mg cm^{-2} d^{-1} developed tissue necrosis after two days and was completely dead after seven days. Similarly, one third of *Porites* colonies died after exposure to 30 mg cm^{-2} d^{-1} for 10 days (Hodgson 1990). Wesseling et al. (1999) reported that massive *Porites* colonies suffered 50% mortality and 90% bleaching after being completely buried for five to six days.

The conservative criterion of ≥25 mg cm^{-2} d^{-1} for five days is supported by observations of coral bleaching, and associated mortality, during dredging for the Nelly Bay development at Magnetic Island (Stafford-Smith et al. 1994). Sedimentation at >30 mg cm^{-2} d^{-1} during the third week of dredging was followed by mortality of approximately 10% of the coral cover and almost complete bleaching of 70% of *Acropora* colonies during the fourth week of the dredging (Stafford-Smith et al. 1994). Although the coral mortality rates were low at Nelly Bay, bleaching is indicative of severe stress in corals and if such conditions occurred at other stressful times, for example in combination with significant light attenuation after a cyclone, or during spawning, they are likely to cause high mortality.

Medium-term Sedimentation

Sedimentation rates at ≥10 mg cm^{-2} d^{-1} above background that persist for at least 20 consecutive days are expected to have a high impact on coral assemblages. This conservative criterion is based on reported sediment load effects and chronic sedimentation rate criteria for turbid water reefs.

Rogers (1990) suggests that persistent sedimentation rates at >10 mg cm^{-2} d^{-1} have detrimental effects on coral assemblages, such as reduced coral diversity, live coral cover, growth rates and recruitment. Similarly, Pastorok and Bilyard (1985) reported sedimentation rates of 10-50 mg cm^{-2} d^{-1} as likely to have moderate to severe impacts on coral communities.

Sedimentation loads above 200 mg cm^{-2} cause tissue necrosis in *Acropora* spp. (Rogers 1983). At a sedimentation rate of 10 mg cm^{-2} d^{-1} it is likely that enough sediment (200 mg cm^{-2}) will accumulate over 20 days without resuspension of deposited sediments and cause adverse impacts to acroporid corals.

Chronic Sedimentation

Sedimentation rates of 5 mg cm^{-2} d^{-1} for more than 40 days are predicted to have high impacts on coral assemblages. This criterion was selected to represent a zone of high impact caused by a small, yet chronic increase in the rate of sediment settling on coral surfaces. The 5 mg cm^{-2} d^{-1} rate represents approximately twice the natural rate of sedimentation. Chronic increases in sedimentation rates significantly affect the abundance, diversity, morphology and recruitment of coral communities (e.g. Randall and Birkeland 1978).

Mean sedimentation rates for coral reefs not affected by human activities are estimated to be <1 to 10 mg cm^{-2} d^{-1} (Rogers 1990), although other authors have reported effects on corals at these low levels. For example, sedimentation rates of 1 – 10 mg cm^{-2} d^{-1} are estimated to have a slight to moderate impact on coral communities by Pastorok and Bilyard (1985), leading to possible reductions in recruitment and numbers of coral species.

Rogers (1983) reported that *Acropora palmata* suffered significant tissue necrosis under a sediment load of 200 mg cm^{-2}. Thus, at a rate of 5 mg cm^{-2} d^{-1}, a level of 200 mg cm^{-2} would be reached in 40 days, assuming no resuspension.

Whilst some coral species will be affected at these rates, it is likely that more sediment tolerant species, such as *Turbinaria,* will not. However, the synergistic interaction between chronic sedimentation stress and other stressors, such as light attenuation or high water temperatures is expected to exacerbate impacts on coral communities.

Acute Total Suspended Solids

Intense, short periods (acute) of high TSS, (i.e. ≥25 mg l-1) above background for at least six daylight hours each day for at least five consecutive days, are likely to have a high impact on corals through shading, abrasion and decreased filter-feeding efficiency. During the recent Dampier Port Authority and Hamersley Iron dredging programs in Dampier the Supply Base was the only site to experience several episodes of TSS above 30 mg l-1 and was the only site to experience widespread dredge related coral mortality (Stoddart and Anstee 2005, Stoddart et al. 2005). While the corals at this site were probably already stressed by relatively high levels of TSS (>10 mg l-1) it appeared to be the intense pulses of TSS over 30 mg l-1 that caused coral mortality.

The difference in the properties of the dredged material between Dampier and Barrow Island are likely to be reflected in different response levels by the corals. The fine material to be generated by rock cutting at Barrow Island is predicted to have greater light attenuating properties than the coarser sediments at Dampier. Hence the shading effects are predicted to be greater for the Barrow Island TSS plumes.

Dredging for the Nelly Bay development resulted in suspended solids concentrations between 20 and 50 mg l^{-1} and persistent low light levels for a number of four to five day periods (Larcombe et al. 1994). These episodes led to severe and widespread coral stress resulting in 10% coral mortality (Stafford-Smith et al. 1994). Whilst the corals at these locations also suffered episodic sedimentation, the above TSS values have the ability to significantly affect coral communities, particularly if they persist for many days or occur in concert with other stressors, such as high water temperatures or low dissolved oxygen conditions.

Medium-term Total Suspended Solids

Total suspended solids concentrations above 10 mg l^{-1} (above background) for at least six daylight hours each day for at least 20 consecutive days are predicted to have a high impact on coral communities. Rogers (1979) reported that TSS concentrations of 9–16 mg l^{-1} can decrease light intensities to 65 microeinsteins m^{-2} sec^{-1} at a depth of 2 m and that shading at this level for three weeks causes widespread bleaching of *Acropora*.

Total suspended solids concentrations of 16 mg l^{-1} for a period of two months resulted in energy deficiency in the reef building coral *Porites* due to lack of light for photosynthesis and its inability to gain enough energy from filter-feeding (Anthony and Fabricus 2000). These authors concluded that *Porites* was not physiologically able to cope with high turbidity. Physiological stress due to light deprivation in combination with other stressors, such as sedimentation, could result in high impacts to corals.

Medium-term elevation of TSS concentrations may increase the susceptibility of corals to peaks in TSS or sedimentation. For example, corals at the Supply Base site in Dampier were frequently exposed to TSS concentrations above 10 mg l^{-1} (Stoddart and Anstee 2005). The coral assemblage at this site was dominated by turbidity resilient *Turbinaria* spp., but after exposure to peaks in TSS concentrations and probably sedimentation, it suffered approximately 80% mortality (Stoddart et al. 2005).

The diversity and distribution of corals around the Whitsunday Islands in Queensland, at the same latitude and with a similar suite of coral species as Barrow Island, is influenced by TSS concentrations (van Woesik et al. 1999). Coral communities in the more turbid areas (>10 mg l^{-1}) are dominated by faviids, *Montipora* and encrusting *Porites* species, whereas *Acropora* dominate communities in areas of low suspended particulate material (>10 mg l^{-1}) (van Woesik et al. 1999).

Regionally significant coral communities on the southern edge of the Lowendal Shelf are typically *Acropora* dominated communities. The conservative medium-term criterion for TSS accounts for the possible high impact of medium-term (20 days) TSS concentrations ≥10 mg l^{-1} in this area.

Chronic Total Suspended Solids

A conservative criterion of ≥5 mg l^{-1} above background for at least six daylight hours each day for at least 80 consecutive days was chosen to represent high impact to corals exposed to a small, yet long-term increase in TSS. The effects of low level, chronic increases in TSS on corals are difficult to quantify (Rogers 1990). Several authors have correlated levels of TSS (as well as other environmental factors) with the geographical distribution, vertical zonation and species composition of coral reefs (e.g. Cortés and Risk 1985; Wittenberg and Hunte 1992; Edinger et al. 1998). In general, reefs with long-term average suspended sediment concentrations below 5 mg l^{-1} support higher species diversity and suffer lower coral mortality than reefs under more turbid regimes (i.e. > 5 mg l^{-1}) (Wittenberg and Hunte 1992).

Evidence for a correlation between long-term elevated TSS levels and coral diversity and cover has been derived from observations of coral distribution and diversity which are likely to be influenced by TSS levels on temporal scales of tens if not hundreds of years. For example, Cortés and Risk (1985) suggest that reefs under stress from anthropogenic influences have high concentrations of TSS (probably > 5 mg l^{-1}), high concentrations of resuspended sediments (>30 mg cm^{-2} day^{-1}), reduced coral growth rates and diversities, low live coral coverage (except for monospecific stands of sediment tolerant species), morphological changes in surviving species and low recruitment rates. These observations were, however, based on a Costa Rican coral reef that had been exposed to suspended material and sedimentation for more than 15 years.

The selection of a TSS value of ≥5 mg l^{-1} for a period of 80 days to delineate a zone of high impact in the longer term is a highly conservative measure. However, given the paucity of information on the impacts of low levels of TSS on coral reefs, and the synergistic effects of TSS with other environmental variables, a precautionary approach has been followed.

Zone of Moderate Impact

Moderate impacts to coral communities include mortality of susceptible coral taxa (e.g. *Acropora)* and possible partial mortality of resilient coral taxa (e.g. *Porites*). Moderate impacts are not expected to have long-term consequences, due to the recovery of the fast growing corals such as acroporids by recruitment, and the recovery of massive, more resilient taxa such as *Porites* by regrowth from tissue margins.

Criteria for defining a zone of moderate impact from elevated TSS concentrations and sedimentation rates for the anticipated and worst case scenarios have been derived from estimates of the lowest levels at which these stressors are expected to affect corals and is primarily based on highly susceptible coral taxa. At TSS concentrations and sedimentation rates below these criteria, adverse effects on corals are not predicted to be detectable above natural variation in coral health.

Under the best case scenario, coral responses are assumed to be more similar to those of turbid water taxa, rather than the most sensitive taxa, and elevated sedimentation and TSS concentrations are predicted to have only moderate effects.

Acute Sedimentation

Sedimentation in excess of 25 mg cm^{-2} d^{-1} for at least two consecutive days is likely to have a moderate impact on corals and cause partial mortality of some coral species. This is based on the observations of Hodgson (1990) who reported that *Oxypora labra* exposed to 40 mg cm^{-2} d^{-1} developed tissue necrosis after only two days and died after seven days. The criterion selected for moderate impacts to corals is conservative to allow for inter- and intra-specific differences in coral sensitivity to sedimentation.

Medium-term Sedimentation

A medium-term sedimentation criterion of ≥10 mg cm^{-2} d^{-1} for at least seven days was selected to represent the medium-term response of corals to sedimentation rates that are expected to have moderate adverse impacts.

Corals in north-western Australia are exposed to peaks of high sedimentation during cyclones and other severe weather (Forde 1985). Generally severe storms affect an area for approximately seven days. Corals in the vicinity of Barrow Island are expected to be adapted to such medium-term periods of elevated sedimentation. Sedimentation for periods beyond the normal pattern of a severe storm is expected to have moderate impacts on coral assemblages.

Chronic Sedimentation

A chronic sedimentation criterion of 5 mg cm^{-2} d^{-1} for at least 20 consecutive days was selected to represent moderate impacts on corals caused by a small, long-term increase in sedimentation.

Pastorok and Bilyard (1985) estimate that sedimentation rates of 1–10 mg cm^{-2} d^{-1} have a slight to moderate impact on coral communities and may reduce recruitment success and coral diversity. Hence it is assumed that sedimentation rates below 10 mg cm^{-2} d^{-1} can cause moderate impacts on coral communities.

Acute TSS

Total suspended solids concentrations at ≥25 mg l^{-1} above background (for at least six daylight hours each day for two consecutive days) was selected as an acute exposure criterion which could result in moderate impacts to corals.

The criterion for the zone of moderate impact was based on the predicted persistence of intense turbidity during storms (conservatively estimated at two days before the plume begins to disperse). This is an indicator which reflects the natural ability of many corals to cope with short periods of high TSS concentrations.

Medium-term TSS

Total suspended solids concentrations at ≥10 mg l^{-1} above background (for at least six daylight hours each day for at least seven consecutive days) was selected as a medium-term exposure criterion which could result in moderate impacts to corals.

This TSS concentration was based on Rogers (1990) conclusion that concentrations of TSS above 10 mg l^{-1} can adversely affect coral assemblages. Furthermore, during recent dredging in Dampier mean TSS only exceeded 10 mg l^{-1} at the one site where coral died (Stoddart and Anstee 2005). This TSS concentration represents approximately four times the anticipated background concentration of TSS in the waters surrounding Barrow Island.

The medium-term period is based on the anticipated time of exposure to elevated TSS following cyclones. Corals in the Montebello/Lowendal/Barrow Island region are predicted to be tolerant to TSS concentrations above 10 mg l^{-1} for periods of up to seven days, as they are probably exposed to similar concentrations during and after summer cyclonic storms.

Chronic TSS

A criterion of ≥5 mg l^{-1} TSS (approximately twice background) for at least six daylight hours each day for 20 consecutive days was selected as a long-term exposure criterion which could result in moderate impacts to corals. Cortés and Risk (1985) suggest that coral reefs subjected to concentrations of TSS above 5 mg l^{-1} and concentrations of resuspended sediments above 30 mg cm^{-2} day^{-1} have reduced growth rates, diversities, live coral cover and recruitment rates.

The period over which low level TSS would have a moderate impact on corals was based on Rogers (1979) observation that complete shading of corals for three weeks, simulating very high TSS, resulted in the widespread bleaching of *Acropora.* Although 5 mg l^{-1} is a relatively low concentration of TSS and is unlikely to cause complete shading, any shading of corals already growing at their maximum depth under the natural turbidity regime may result in adverse impacts.

Visible Plume and Extent of Sedimentation

The visible plume and extent of sedimentation represent the outer limit of elevated sedimentation and turbidity generated by dredging and HDD. Areas outside the zone of moderate impact, but within this outer limit of elevated TSS and sedimentation, are not predicted to suffer any measurable impact from marine construction activities.

The visible plume covers areas in which TSS reach concentrations sufficient to create a visible plume, either at the surface or the bottom of the water column. Total suspended solids concentrations that create a plume visible are estimated at 2 mg l^{-1} above background. Background data for TSS concentrations in the Montebello/Lowendal/Barrow Island region are scarce (CALM 2000). Background TSS concentrations of 2.5 mg l^{-1} are suggested as typical for reefs <10 km from shore (ANZECC/ARMCANZ 2000).

The extent of sedimentation is defined as the area of the seabed where sedimentation rates are at least 1 mg cm^{-2} d^{-1} above the background sedimentation rate. This is not predicted to have adverse impacts on benthic primary producers. Background rates of sedimentation in the region range between 2.9–9.0 mg cm^{-2} d^{-1} (IRCE 2002).

Predicted Location of Zones

Three-dimensional hydrodynamic plume modelling (refer to Section 7.8, Chapter 7) was used to predict zones of high impact, moderate impact and the limit of elevated sedimentation and turbidity. Impact zones have been predicted for best, anticipated and worst case scenarios and have been mapped to indicate where these zones coincide with areas of benthic primary producers (Figure 11-3 to Figure 11-6). Benthic primary producer mapping is based on information from the CALM regional benthic habitat database and baseline surveys conducted for the Gorgon Development.

Impacts to benthic primary producers from HDD on the west coast and dredging and spoil disposal on the east coast of Barrow Island are expected to decrease with increasing distance from the sediment discharge points as the plumes are diluted and dispersed by water currents. The modelling results suggest that no regionally significant benthic primary producers will be adversely affected by TSS or sedimentation when under keel clearance on the trailer hopper suction dredge is maintained at an optimum of 4 m.

The concentrations of TSS generated during the dumping of spoil at the disposal site, and subsequent resuspension, are likely to be much lower than at the dredge location because the majority of fines are liberated from the dredge cutter head and subsequent barge overflow.

The following best, worst and anticipated scenarios are based on the range of coral sensitivities to various combinations of TSS and sedimentation under different modelling and management scenarios.

Best Case Scenario

The best case scenario (Figure 11-3) is based on the following assumptions:

- Barrow Island corals are similar to turbid water coral taxa and will suffer only moderate impacts from turbidity and sedimentation.
- An optimum of 4 m under keel clearance is maintained below the trailer suction hopper dredge.
- Polymer drilling fluids are used during HDD instead of bentonite.
- Sediment accumulation does not occur due to rapid resuspension and export associated with the daily tidal cycle.
- Verification of dredge simulation modelling confirms the predicted behaviour of sediment and TSS plumes.

The zone of high impact represents the zone of high mortality of corals and marine macrophytes. It is assumed that benthic primary producers will be seriously damaged or high rates of mortality will occur in this zone. In the best case scenario, high impacts are limited to the areas directly removed or built upon. This includes a small buffer zone to allow for edge effects surrounding dredging and HDD programs. The loss of benthic primary producer communities in areas directly affected by the Development will be offset by the growth of macroalgae and corals on pipelines, the causeway and the jetty piles.

The small area (~15 ha) to the north of the dredge spoil area that will be dredged comprises unconsolidated sediments that will be removed over several days by a trailer suction hopper dredge. The modelling indicates that dredging in this area and disposal at the dredge spoil ground would create minimal sedimentation or turbidity outside areas of direct impact.

The zone of high impact also includes a small area at the exit point of the feed gas pipeline on the west coast of Barrow Island where drilling fluids and cuttings will accumulate. Modelling results suggest that the discharge of a small volume of polymer during HDD will have localised effects on benthic primary producers (Figure 11-3).

The zone of moderate impact extends approximately two kilometres from the proposed marine infrastructure on the east coast of the island. An area of moderate impact is also predicted to occur over the eastern edge of the Lowendal Shelf, extending south from Varanus Island for approximately 10 km. A small area of seabed on the north-east coast of Barrow Island, just to the north of the existing Barge Landing, may also suffer moderate impacts. Moderate impacts from HDD using polymer drilling fluids on the west coast are generally restricted to within 100 m of the high impact zone and allow for dispersal of drilling fluids and cuttings (Figure 11-3).

The effects on benthic primary producers in the moderate impact zone would range from bleaching of individual colonies, to partial (< 30%) mortality of long-lived reef building corals such as *Porites* and total mortality of sensitive corals, such as *Acropora.* No well developed *Acropora* communities occur within the moderate impact zone under this scenario. Mortality of smaller colonies of these species is considered a short-term impact as these corals will rapidly recolonise affected areas. No long-term effects on benthic primary producer communities are predicted under the best case scenario. Furthermore, no impacts to locally or regionally significant benthic primary producer communities will occur.

Worst Case Scenario

The worst case scenario (Figure 11-4) is based on the following assumptions:

- Barrow Island corals are highly sensitive to elevated sedimentation and turbidity.
- An optimum of 4 m under keel clearance is not maintained below the trailer suction hopper dredge, otherwise only standard management practices are adopted.
- Bentonite drilling fluids are used for HDD and a large proportion of fluids are discharged to the seabed.

Figure 11-3:
Predicted Best Case Scenario for Sedimentation and Turbidity Impacts Associated with HDD, Dredging and Spoil Disposal

- Sediment deposited on seabed accumulates during dredging program.
- Verification of dredge simulation models confirms the predicted behaviour of sediment and TSS plumes.

Under this scenario, the zone of high impact encompasses the total area that may suffer high mortality from direct removal, burial, elevated TSS or sedimentation. Corals in the moderate impact zone of elevated TSS and sedimentation are expected to suffer partial mortality of resilient species to total mortality of sensitive species.

The zone of high impact extends 1 – 2 km around the proposed marine facilities on the east coast of Barrow Island, including the dredge spoil ground and offshore dredging areas. It also extends up to approximately 4 km from infrastructure close to shore due to wind forcing (Figure 11-4). High impact zones around the northern end of the island result from bentonite discharges during HDD on the west coast. While these high impact zones extend up to 10 km from the construction site around the north-east coast, they are unlikely to have long-term (i.e. < 5 years) impacts on benthic primary producer communities. The small zone of high impact on the eastern edge of the Lowendal Shelf (Figure 11-4) is due to persistent and elevated TSS concentrations. This high impact zone covers an area of unconfirmed corals. Further field surveys are planned for 2005 to determine the distribution and composition of the coral assemblage at this site.

The predicted moderate impact zone on the east coast is larger under the worst case scenario than other scenarios due to the additional sedimentation associated with resuspension by trailer suction hopper dredge propellers. This zone covers part of the regionally significant *Acropora* community on the south-western corner of the Lowendal Shelf. The zone of moderate impact also extends along the east coast, as far north as Ant Point (Figure 11-4). The moderate impact zone to the south of the Lowendal Islands covers a large area of unconfirmed coral. Further field surveys are planned for 2005 to determine the distribution and composition of the coral assemblage in this area.

Anticipated Area of Impact

The anticipated scenario (Figure 11-5) is based on the following assumptions:

- Barrow Island corals are sensitive to elevated TSS and sedimentation levels (less resilient than turbid water coral species but not as susceptible to turbidity and sedimentation as clear-water oceanic coral species).
- An optimum of 4 m under keel clearance is maintained below the trailer suction hopper dredge.
- Bentonite drilling fluids are used for HDD and a large proportion of fluids are discharged to the seabed.
- Sediment accumulation does not occur due to rapid resuspension and export associated with the daily tidal cycle.
- Verification of dredge simulation modelling confirms the predicted behaviour of sediment and TSS plumes.

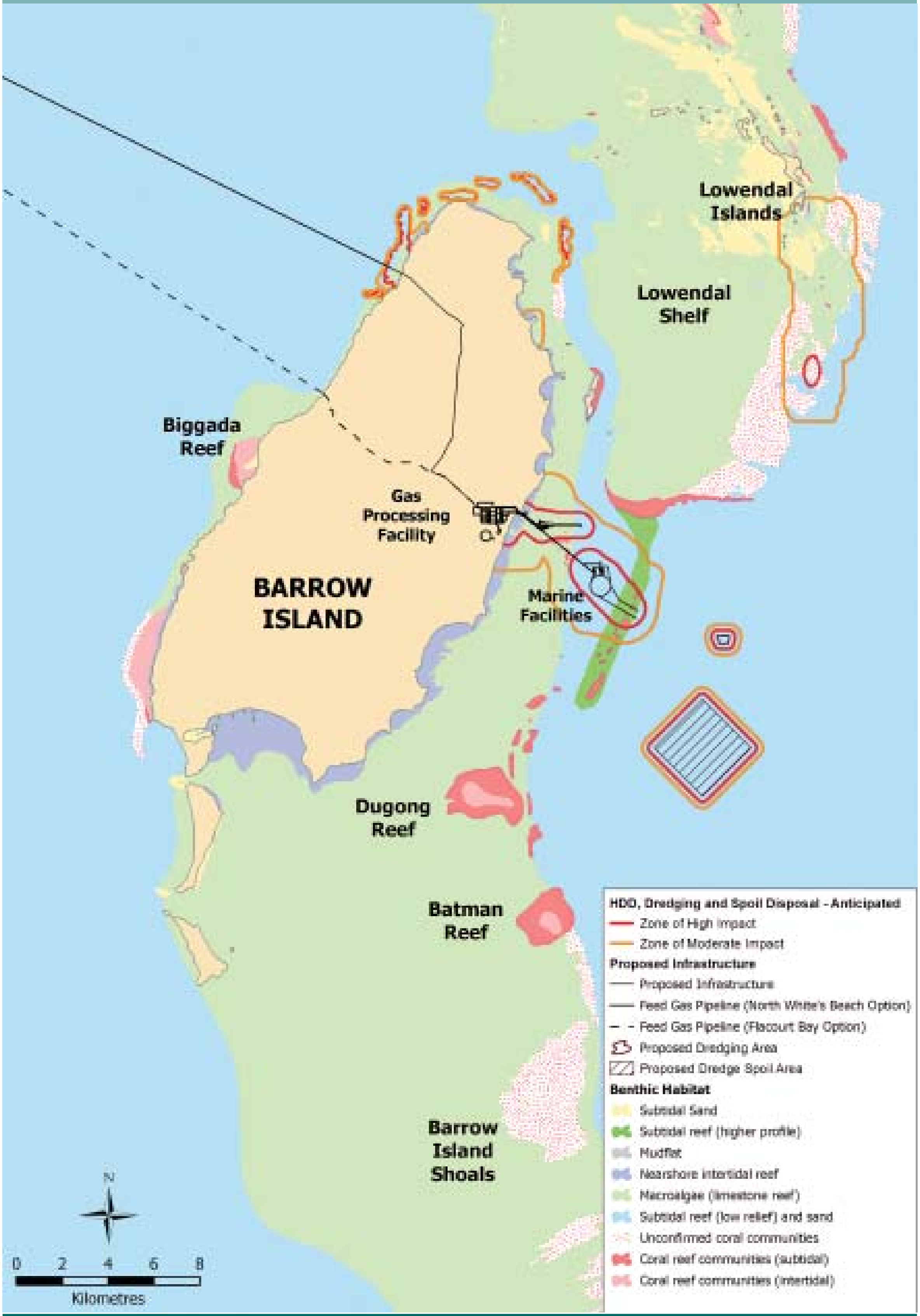
The anticipated scenario (Figure 11-5) represents the areas of seabed most likely to be influenced by the proposed Development.

Under this scenario, the zone of high impact includes the area directly lost to infrastructure and areas expected to suffer high mortality from high TSS and sedimentation levels. The high impact zone is smaller than the predicted worst case scenario due to the reduction in sedimentation through management of under keel clearance on the trailer suction hopper dredge. No significant *Acropora* communities or *Porites* bombora fields occur within the high impact zone under the anticipated scenario.

The zone of moderate impact is smaller than the predicted worst case scenario and does not cover the Acropora community on the south-western corner of the Lowendal Shelf (Figure 11–5). The main benthic primary producer communities in the moderate impact zone are macroalgae dominated pavement and seagrass dominated sand. These communities will recover rapidly following dredging and HDD activities. No long-term impacts on benthic primary producers are expected under the anticipated scenario outside the areas directly lost to infrastructure. No regionally significant coral assemblages would be affected by dredging, HDD or spoil disposal.

Figure 11-4:
Predicted Worst Case Scenario for Sedimentation and Turbidity Impacts Associated with HDD, Dredging and Spoil Disposal

Figure 11-5:
Anticipated Area of Impact Associated with HDD, Dredging and Spoil Disposal



The high and moderate impact zones to the south of the Lowendal Islands cover a large area of unconfirmed coral and may include areas of long-lived *Porites* or well developed *Acropora* corals. Further field surveys are planned for 2005 to determine the distribution and composition of the coral assemblage in this area.

Potential Visible Plume and Extent of Sedimentation

The maximum extent of the visible turbidity plume and the extent of sedimentation are shown in Figure 11-6 to Figure 11-9. These figures do not represent areas of persistent turbidity or sedimentation, but rather areas affected by these stressors on at least one day during the entire HDD and dredging programs.

Figure 11-7 and Figure 11-9 show all areas that could potentially receive at least 2 mg l^{-1} TSS above background levels at some stage of the HDD and dredging programs. This level of TSS will not result in measurable impacts to benthic primary producers. Figure 11-6 and Figure 11-8 show areas that could potentially receive at least 1 mg cm^{-2} d^{-1} sedimentation above background levels at some stage of the HDD and dredging programs. This level of sedimentation will not result in measurable impacts to benthic primary producers.

Management

Direct impacts to macroalgal beds and scattered corals around Barrow Island will be minimised through site selection and anchor management for pipelay barges and other vessels. An anchor management plan will be developed to avoid unnecessary anchor set and anchor chain scour in areas where corals and macroalgae occur. Possible direct impacts to marine macrophytes and corals within the Sanctuary Zone of the proposed Barrow Island Marine Park near Flacourt Bay have been avoided by selecting the North White's Beach option for the feed gas pipeline shore crossing.

Initial modelling indicated that turbidity plumes and sediment deposition associated with trenching for the pipeline shore crossings on the west coast would pose an unacceptable level of risk to benthic primary producers, including coral communities of high conservation significance in the Barrow Island Marine Park Sanctuary Zone. Consequently, HDD is now the preferred shore crossing construction technique on the west coast.

Indirect impacts to benthic primary producers on the east coast will be minimised by facility design and active management of dredging operations. The Joint Venturers will adopt the following management strategies to avoid impacts to benthic primary producers in the vicinity of marine infrastructure:

- select route for feed gas pipelines, domestic gas pipeline and optical fibre cable to avoid significant benthic primary producer communities
- design the solid fill causeway and open pile jetty to minimise interruption of local hydrodynamics and sediment transport
- develop an anchoring management plan to avoid anchoring in areas of significant coral cover and to avoid unnecessary anchor movements
- maintain optimum 4 m under keel clearance on the trailer suction hopper dredge
- select dredge spoil ground location which avoids adverse impacts to significant benthic primary producer communities
- select optical fibre cable route to the mainland which avoids well developed coral and macrophyte communities near the mainland coast and nearshore islands.

Mangroves along the mainland pipeline easement will be slashed or rolled rather than uprooted to maximise recolonisation through vegetative reproduction (Dames and Moore 1998). A mangrove rehabilitation plan will be implemented following construction. The effectiveness of using geotextile mats during construction to reduce impacts to vegetation and sediments at the mainland shore crossing will be investigated. The impact of erosion and scouring associated with tidal movement will be minimised by the installation of erosion control measures along the pipeline easement. The success of this strategy is supported by observations of minor regrowth from root stock, establishment of new mangrove seedlings and re-establishment of natural drainage channels in the mangrove zone at the seaward end of the existing Apache sales gas pipelines (Dames and Moore 1998).

Figure 11-6:
The Extent of Sedimentation Associated with HDD of the Feed Gas Pipeline at North White's Beach

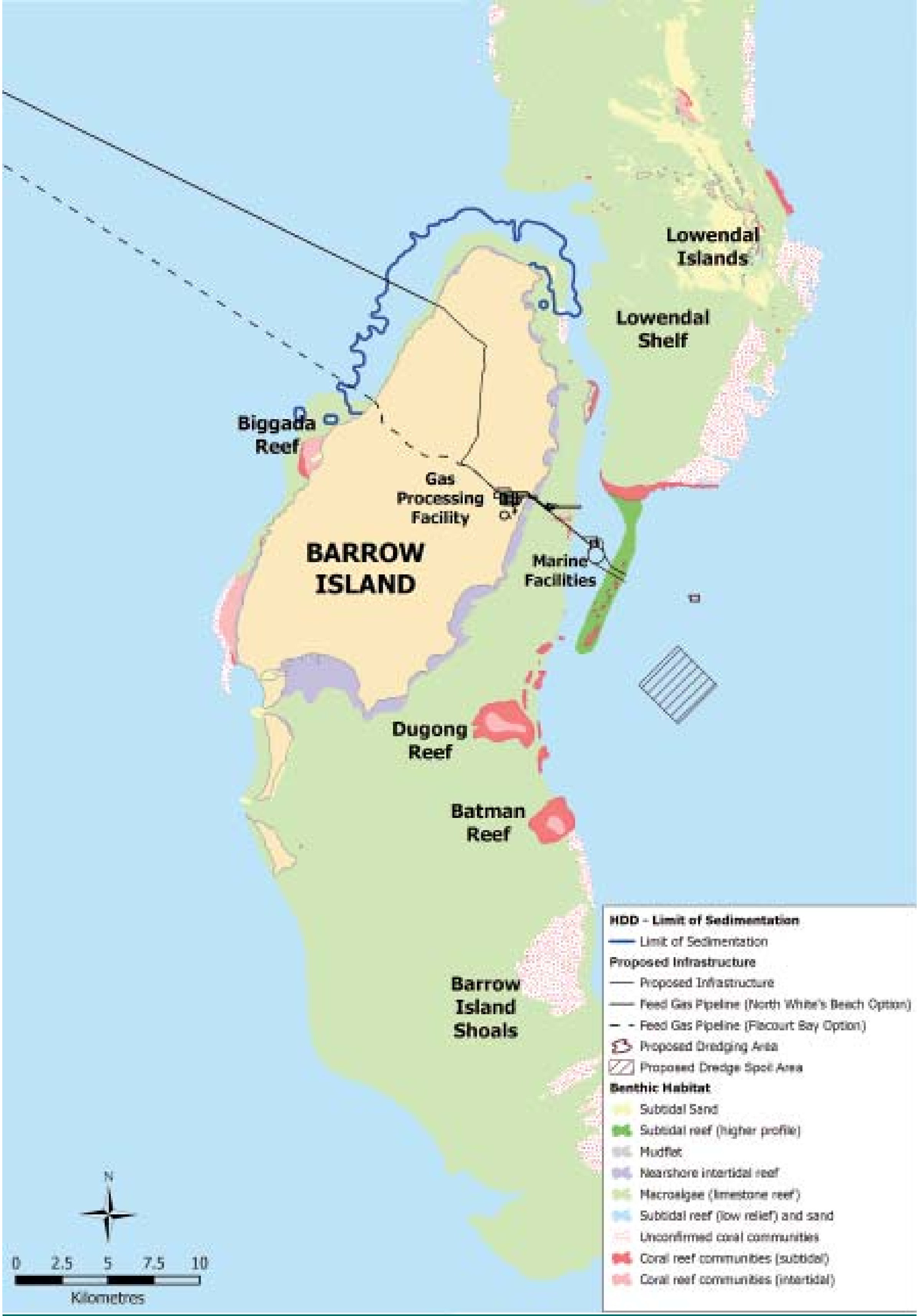


Figure 11-7:
The Potential Visible Plume Associated with HDD of the Feed Gas Pipeline at North White's Beach

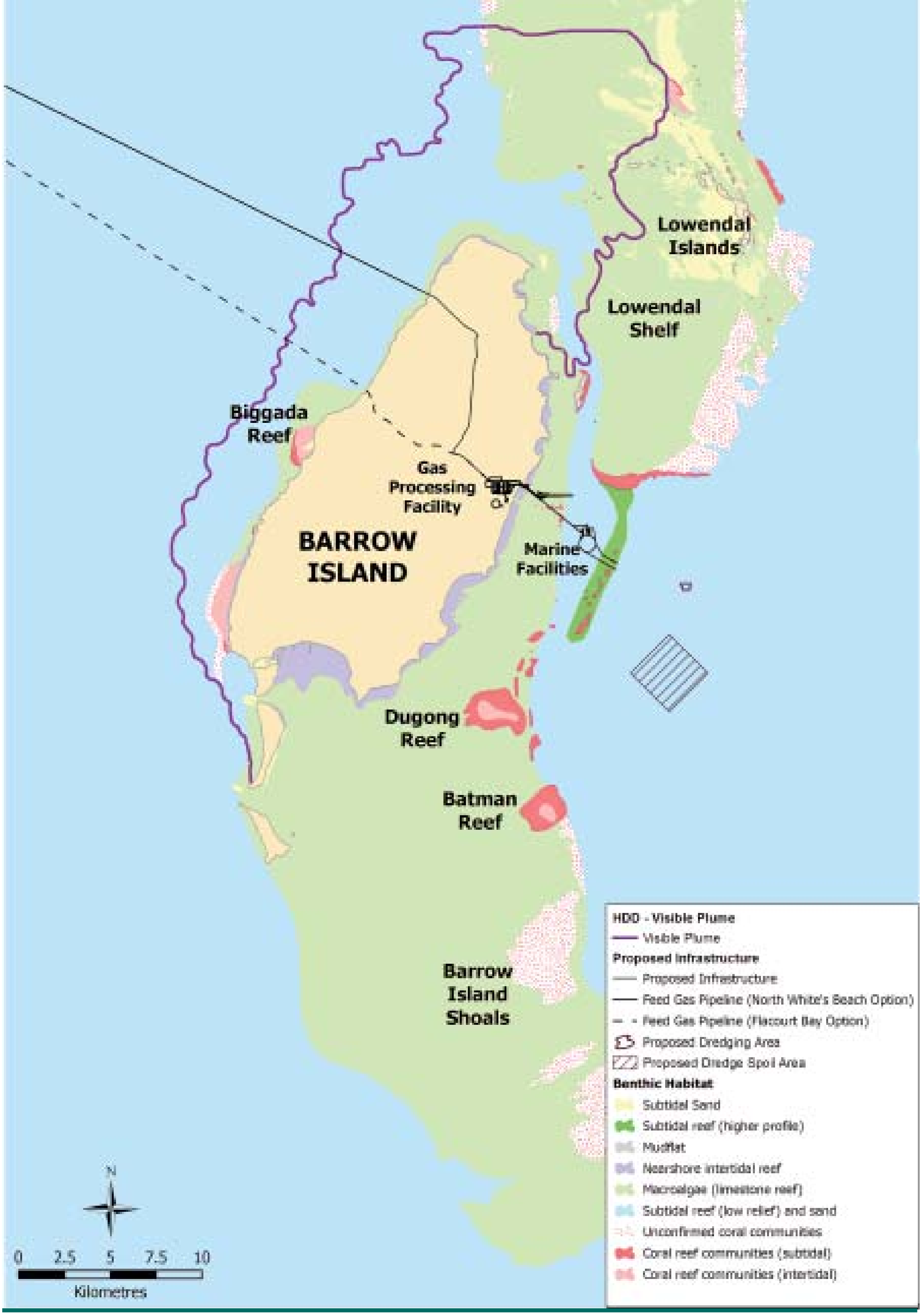


Figure 11-8:
The Extent of Sedimentation Predicted to Occur During the Dredging Program off the East Coast of Barrow Island

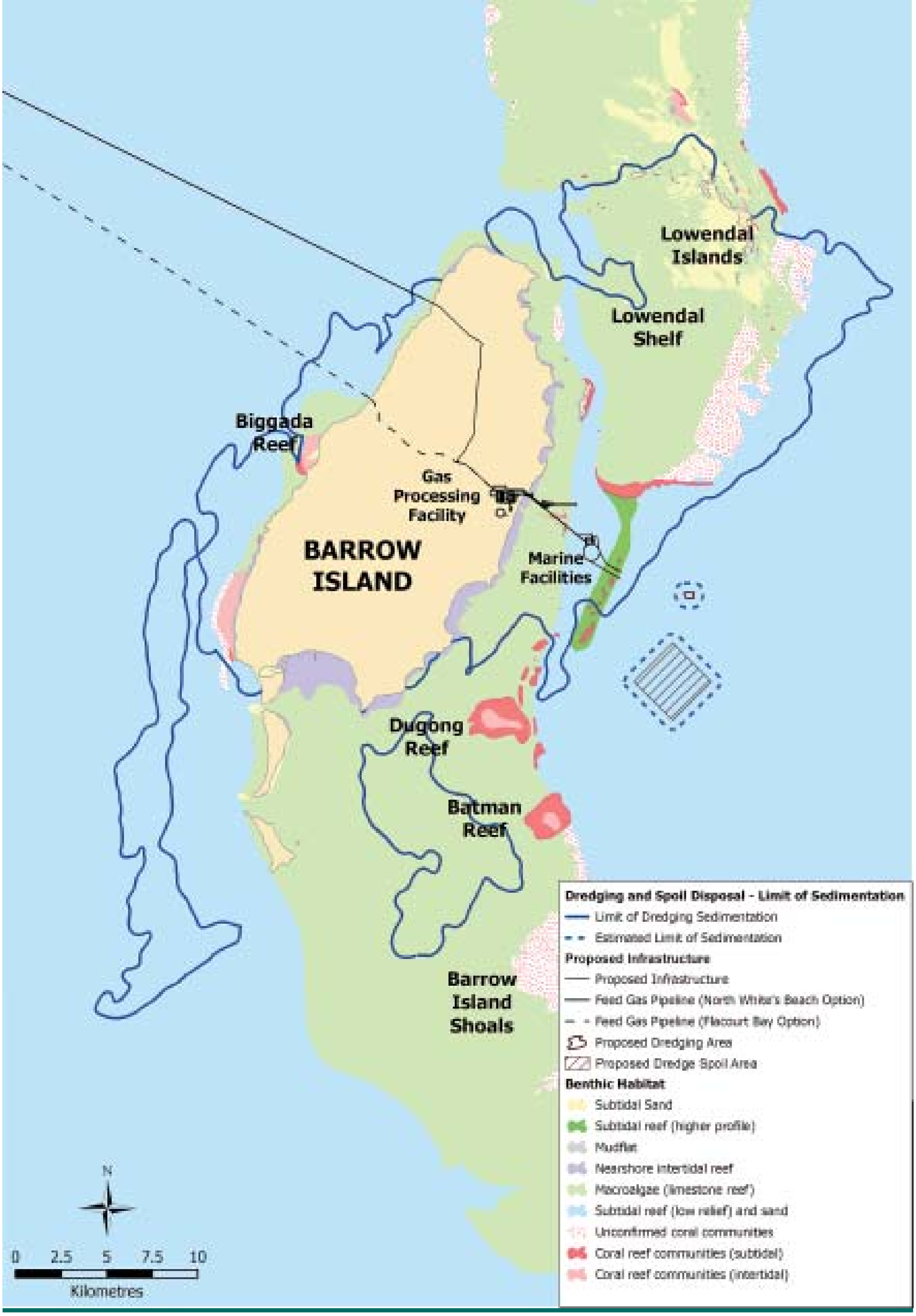
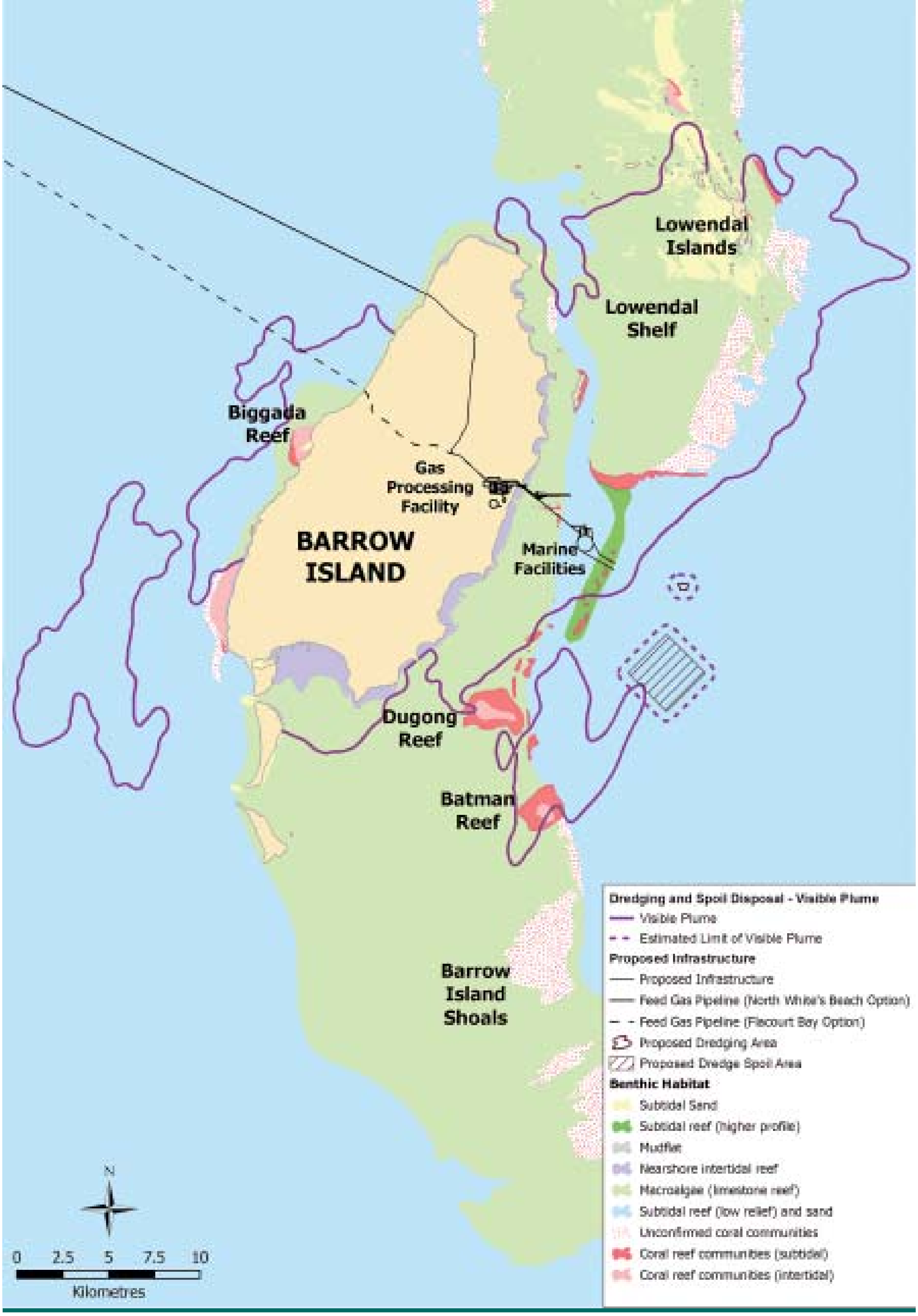


Figure 11-9:
The Visible Plume Predicted to Occur During the Dredging Program off the East Coast of Barrow Island



The risk of impact to benthic primary producers from HDD, dredging and dredge spoil disposal during construction will be adaptively managed to restrict the potential effects. A preliminary outline of a monitoring and management program for HDD, dredging and dredge spoil disposal during the construction phase of the Development is provided below. A comprehensive plan will be developed as detailed design progresses.

Preliminary Dredging and Spoil Disposal Management Plan

A preliminary dredging and spoil disposal management plan has been developed and is based on proposed management for dredging operations in the Port of Dampier. The plan will be refined in consultation with Commonwealth and state regulatory agencies. This will form part of the final HDD, dredging and dredge spoil disposal management plan for the Development.
The preliminary plan is described in the following sections.

Management Zones

The preliminary dredging and spoil disposal management plan is based on the three management zones used in the risk assessment (outlined in the preceding sections). These zones have been delineated using the results of 3-D hydrodynamic plume models (Chapter 7), published literature on the tolerance of coral species to turbidity and sedimentation, results of other dredging programs and a local knowledge of the coral communities in the Development area.

The three management zones (Figure 11-5) are defined as follows:

- Zone 1 – (zone of high impact). This zone represents an area where long-term impacts to corals are predicted to result directly from disturbance during HDD, dredging or construction of infrastructure on the seabed and burial during dredge spoil, or indirectly from smothering due to elevated sedimentation and/or from deterioration in water quality. This area includes the MOF and LNG channels and berthing areas, the dredge spoil disposal area, the HDD site and the proximate area surrounding these locations.
- Zone 2 – (zone of moderate impact). This zone represents an area where short-term, moderate impacts (e.g. some partial mortality of corals) is predicted to result indirectly from HDD, dredging and dredge spoil disposal, due to deterioration in water quality and/or an increase in sedimentation rates. Moderate impacts are likely to include some partial mortalities among fast growing, more sensitive coral species (e.g. *Acropora)* but less, if any, mortality of longer living, generally more resilient species (e.g. *Porites, Turbinaria).* Monitoring and management at potential impact sites within this zone are prescribed for water quality, sedimentation and coral health. Monitoring results from this area will trigger management and control actions within Zone 1, as well as further monitoring within Zone 2. Results will also be used to verify HDD and dredge modelling results.
- Zone 3 – (potential visible plume and extent of sedimentation). This area is predicted to be indirectly influenced by dredging and spoil disposal activities (e.g. marginal increases in turbidity and sedimentation), but at levels that will have no measurable impact on corals. Monitoring is prescribed for this area to confirm modelling predictions. Management options will be implemented in the event that set criteria are exceeded.

It is the Joint Venturers' intent to construct the feed gas pipeline shore crossing, MOF and access channels and berthing areas whilst maintaining water quality, sediment loading and coral health objectives that are consistent with predicted impact zones. Impact (Zone 1), potential impact (Zone 2), monitoring (Zone 3) and reference locations for water quality, sedimentation and coral health monitoring have been selected to provide extensive data collection sites at varying distances and directions from the potential sources of turbidity and sedimentation.

Prior to approval of the dredging and spoil disposal management plan the Joint Venturers will undertake additional geophysical, metocean, bathymetric and biological surveys to enhance the knowledge and understanding of the marine environment around Barrow Island, particularly where impacts from HDD, dredging and spoil disposal are predicted to occur. The surveys will include the installation of additional current meters and drift mat tracking to verify the performance of the dredge simulation model. Results of model verification will be made available for public comment during the last four weeks of the Draft EIS/ERMP public exhibition period. These results will be provided in a package of additional information.

Modelling will continue to investigate various sensitivities to seasonal variations, non-typical environmental conditions, adjustments to the dredging schedule and refinements to the dredging work method. The modelling will remain 'live' during HDD and dredging programs. Real-time water quality and coral health monitoring data will feedback into the monitoring and management plan, to further validate the model and to optimise management of dredging operations.

Aerial Monitoring of Dredging Program

Aerial surveys of the management zones will be undertaken regularly (i.e. weekly or fortnightly) throughout the dredging and spoil disposal program. The frequency and coverage of aerial surveillance monitoring will be reassessed based on monitoring results. Aerial surveys will be correlated with field monitoring data. Where practical, flights will be undertaken during the middle of the day to reduce potential glare from the surface of the ocean, thereby increasing visibility of the dredge plume. Photographs and video will be taken of the monitoring sites and surrounding areas. Any natural sedimentation/turbidity events associated with storms or terrestrial runoff, as well as other events, such as coral spawning and algal blooms will be recorded.

Satellite imagery will be evaluated for quality and coverage as a potential alternative to aerial monitoring or may be used to augment aerial survey data.

Water Quality, Sedimentation and Coral Health Monitoring

Water quality, sediment loading and coral health will be monitored regularly. The monitoring results will be assessed against alert trigger levels for ongoing management of HDD and dredging operations to ensure that environmental impacts do not exceed predictions. Feedback of monitoring data into the monitoring and management plan will further increase the ability to determine when predicted impacts may be exceeded and to react to prevent those exceedances in a timely manner.

Alert Trigger Levels and Proposed Tier 1 Management Actions

The initial trigger for managing dredging and spoil disposal activities is based on water quality, sedimentation data and coral health information collected within the zone of moderate impacts (Zone 2) and at monitoring sites within the visible plume and extent of sedimentation (Zone 3). The alert water quality and sedimentation trigger values are set at a level or concentration where corals are highly unlikely to suffer impacts and provide an early warning to the Joint Venturers that management may be required. Should monitoring show that water quality (TSS), sedimentation rates or impacts to corals at potential impact sites in Zone 2 or at monitoring sites in Zone 3 has increased above the trigger levels, a series of management measures will be progressively implemented by the Gorgon Joint Venturers aimed at improving water quality, reducing sediment loading and preventing further impacts to corals.

If Alert Trigger Levels (refer to Table 11–6 and Table 11–7) are exceeded, the following Tier 1 management procedures will be considered and agreed in consultation with the Gorgon Site Manager (or their designate) and the dredging contractor.

- Advise the Gorgon Dredging Site Manager by phone/e-mail immediately of the water quality and/or sedimentation alert trigger level exceedance and where it occurred.
- The Gorgon Joint Venturers will check and verify the tidal, wave, and wind forecasts and predict the likely duration of the event(s) that caused the trigger level exceedance and review recommended management, control and/or potential action options available in the event that the monitoring results progresses to the coral health trigger level.
- The Gorgon Joint Venturers will confirm and ensure compliance with the contractor's approved work practices.
- The Gorgon Joint Venturers will meet with the dredging contractor to review, adjust and potentially improve work practices as required.
- Alert and notify the Dredging Site Manager and appropriate dredging contractor and equipment personnel of the potential need to adjust dredging or spoil disposal operations or temporarily halt operations should the exceedance continue.
- Water quality (TSS) and sedimentation monitoring will intensify in the exceedance area to verify the level, duration, concentration and/or rate of these two variables and identify the likely source(s) of turbidity and sedimentation and any confounding factors.
- Coral health monitoring will be undertaken within eight days of the exceedance as part of the ongoing coral health monitoring program.

Table 11-6:
Zone 2 Alert Trigger Levels

Parameter	Trigger Level	Time (Consecutive Days)
TSS	Median TSS at moderate impact sites is greater than three times the median TSS at appropriate reference sites.	Two consecutive days of non-achievement will trigger Tier 1 management.
Sedimentation	Mean daily rates of sedimentation at moderate impact sites is greater than three times the mean daily rate of sedimentation at appropriate reference sites. Mean rates of sediment accumulation are calculated over the 14-day deployment period.	Fourteen days of non-achievement will trigger Tier 1 management.
Coral Health	Impacts to coral health, as evidenced by a statistically detectible increase in coral bleaching compared to appropriate reference sites. A level of 10% is likely to be the minimum level of detection using current coral monitoring techniques.	

Table 11-7:
Zone 3 Alert Trigger Levels

Parameter	Trigger Level	Time (Consecutive Days)
TSS	The five-day running median of TSS at monitoring sites within the visible plume is greater than the 80th percentile of the five-day running median TSS at appropriate reference sites.	Two consecutive days of non-achievement will trigger Tier 1 management.
Sedimentation	Mean daily rates of sedimentation at monitoring sites within the limit of sedimentation is greater than 1.5 times the mean daily rate of sedimentation at appropriate reference sites. Mean rates of sediment accumulation are calculated over the 14-day deployment period.	Fourteen days of non-achievement will trigger Tier 1 management.
Coral Health	Impacts to coral health, as evidenced by a statistically detectible increase in coral bleaching compared to appropriate reference sites. A level of 10% is likely to be the minimum level of detection using current coral monitoring techniques.	

Tier 1 management procedures will cease if TSS and sedimentation rates at moderate impact sites (Zone 2) and sites within the visible plume or limit of sedimentation (Zone 3) fall below Alert Trigger Levels. In addition, coral bleaching in Zone 3 needs to be below detectable levels for tier 1 management to cease.

Coral Health Threshold Values and Proposed Tier 2 Management Actions

The Gorgon Joint Venturers will undertake sedimentation and coral health monitoring fortnightly at sites in the zone of high impact (Zone 1), zone of moderate impact (Zone 2), visible plume and limit of sedimentation zone (Zone 3) and reference sites (as required). The coral health monitoring area may be extended to other reference sites or areas if required. Monitoring within Zone 1 is for investigative purposes only and may be restricted by low visibility during dredging and spoil disposal. No management responses will be triggered by deterioration in water quality or coral health in the high impact zone.

If coral health threshold levels are exceeded (refer to Table 11–8 and Table 11–9), the following tier 2 management procedures will be considered and agreed in consultation with the Gorgon Site Manager (or his designate) and the dredging contractor.

- Gorgon Joint Venturers will undertake additional monitoring (frequency and location) and testing to verify coral health results are a consequence of HDD or dredging operations. Monitoring of sediment and coral health is designed to confirm that no single area of coral habitat will be continuously affected and that bleaching levels are maintained at acceptable levels over potential impact sites (levels below the agreed coral health threshold levels).
- Direct the dredging contractor to modify dredging and disposal sequence to reduce potential impact.
- Direct the dredging contractor to reduce the hours of continuous dredging until water quality and sediment loading return to acceptable levels at the affected location(s).
- Consult and seek agreement and approval with the approving authority to modify the dredging and/or spoil disposal operations to allow works to continue.

Coral Health Limit Levels and Proposed Tier 3 Management Actions

The Gorgon Joint Venturers will commit to undertaking tier 3 management and control actions in the event that the coral health limit values in Zones 2 and/or 3 are exceeded.

If coral health limit levels are exceeded (refer to Table 11–10 and Table 11–11) the following tier 3 management procedures will be considered and agreed in consultation with the Gorgon Site Manager (or his designate) and the dredging contractor.

- Direct the dredging contractor to cease dredging and disposal sequence to reduce potential impact.

Table 11-8:
Zone 2 Coral Health Threshold Level

Parameter	Threshold Level (Coral Bleaching)
Coral Health	Partial bleaching of large, reef building corals (e.g. *Porites*) or relatively resilient species (e.g. *Turbinaria*) exceeds 10%, or partial bleaching of fast growing, sensitive species (e.g. *Acropora*) exceeds 50%, compared to appropriate reference sites.

Table 11-9:
Zone 3 Coral Health Threshold Level

Parameter	Threshold Level (Coral Bleaching)
Coral Health	Impacts to coral health, as evidenced by a statistically detectible increase in coral bleaching compared to appropriate reference sites. A level of 10% is likely to be the minimum level of detection using current coral monitoring techniques.

Table 11-10:
Zone 2 Coral Health Limit Level

Parameter	Limit Level (Coral Mortality)
Coral Health	Partial mortality of large, reef building corals (e.g. *Porites*) or relatively resilient species (e.g. *Turbinaria*), as evidenced by a greater than 30% decrease in live coral cover compared to appropriate reference sites.

Table 11-11:
Zone 3 Coral Health Limit Level

Parameter	Limit Level (Coral Mortality)
Coral Health	Mortality of coral species, as evidenced by a statistically detectible decrease in live coral cover compared to appropriate reference sites. A level of 10% is likely to be the minimum level of detection using current coral monitoring techniques.

If dredging and spoil disposal has to be suspended because coral mortality is above the coral health limit levels, they will not recommence until such time that it can be demonstrated to the satisfaction of the Minister for the Environment, upon advice from the EPA that:

- Any activity that is proposed to recommence would not contribute to further net mortality of corals at any potential impact (Zone 2) or monitoring site(s) (Zone 3) at which the limit level has been exceeded.
- The ambient environmental conditions at any potential impact (Zone 2) or monitoring site(s) (Zone 3) at which the limit level has been exceeded would not prevent recovery.

The monitoring and management plan for the zone of moderate impacts (Zone 2) and the visible plume and limit of sedimentation zone (Zone 3) are illustrated in Figure 11-10 and Figure 11-11, respectively.

Field verification of dredge simulation models will be undertaken to confirm the predicted behaviour of sediment and TSS plumes and associated assessment of ecological impacts. Results of the model verification will be available for public comment during the last four weeks of the draft EIS/ERMP public exhibition period. These results will be provided in a package of additional information.

Residual Risk

The residual risks to macrophytes and corals from seabed disturbance are discussed below for both direct and indirect impacts. To a large extent, the areas affected overlap. That is, the area that would suffer direct impact is generally within the area subject to indirect impacts. Macrophyte and coral communities are very extensive throughout the Montebello/Lowendal/Barrow Island region and it is expected that there will be significant recruitment and regrowth in most areas affected by the proposed Development.

Direct Impacts

The residual risk of significant adverse consequences to marine macrophytes (macroalgae and seagrasses) and corals from construction or operation of the feed gas pipeline, causeway, MOF, LNG jetty and shipping channel is low.

The likelihood of direct impacts to marine macrophytes (macroalgae and seagrasses) and corals from construction or operation of the feed gas pipeline, causeway, MOF, LNG jetty and shipping channel is almost certain because the disturbance is an unavoidable element of the proposed Development. The consequence of the impacts is considered minor because potential impacts will be limited to a local, long-term impact on the communities and there will be no reduction in community or taxon viability in the local area. Macroalgal meadows and coral communities of the type that are likely to be impacted by the Development are widely distributed throughout the region. There will also be significant regrowth and recolonization in many Development areas. The area of macroalgae or coral may significantly increase due to the creation of hard substrates (e.g. spoil ground).

Figure 11-10:
HDD, Dredging and Dredge Spoil Disposal Monitoring and Management Plan for Zone 2 (Zone of Moderate Impact)

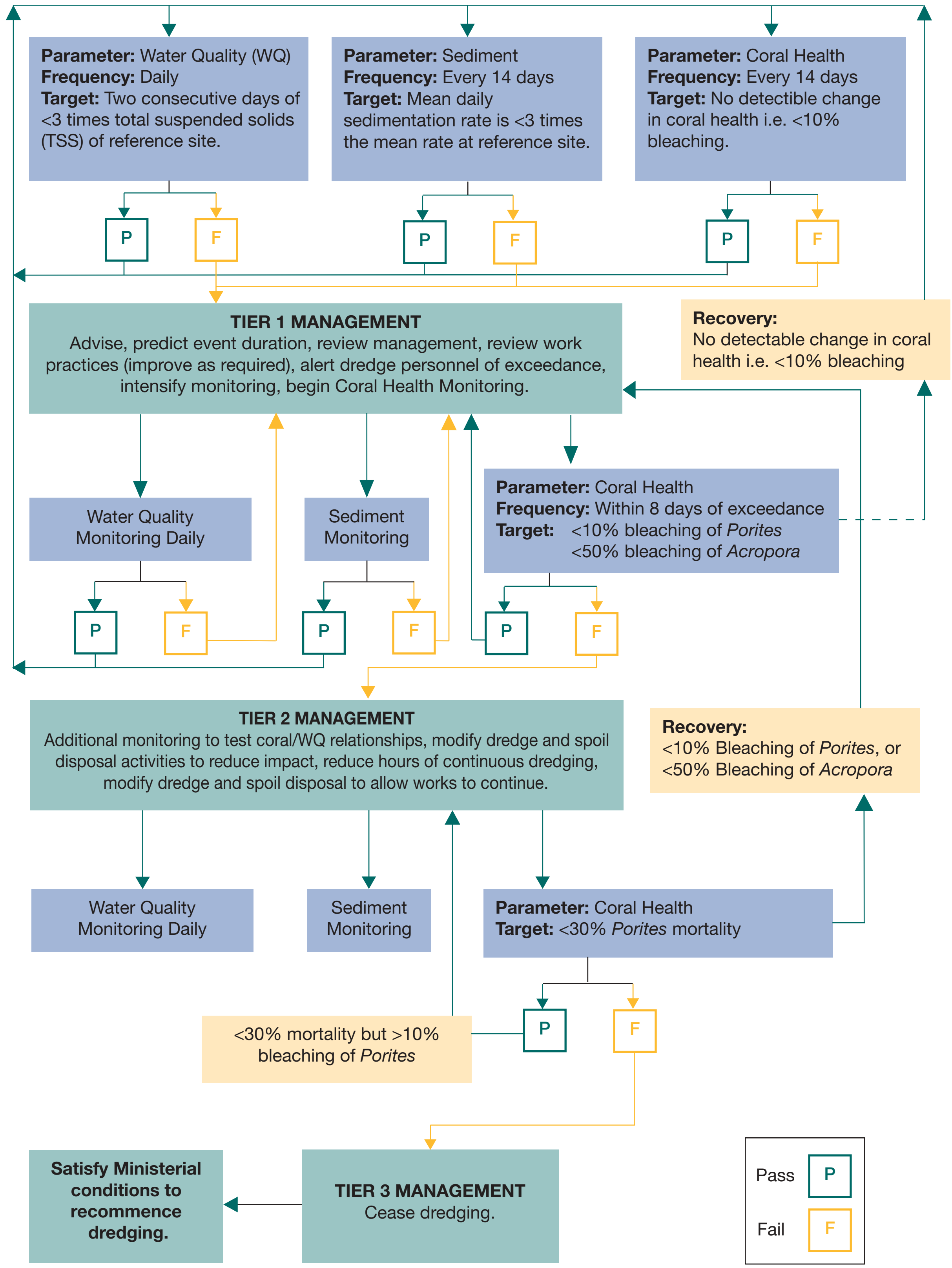
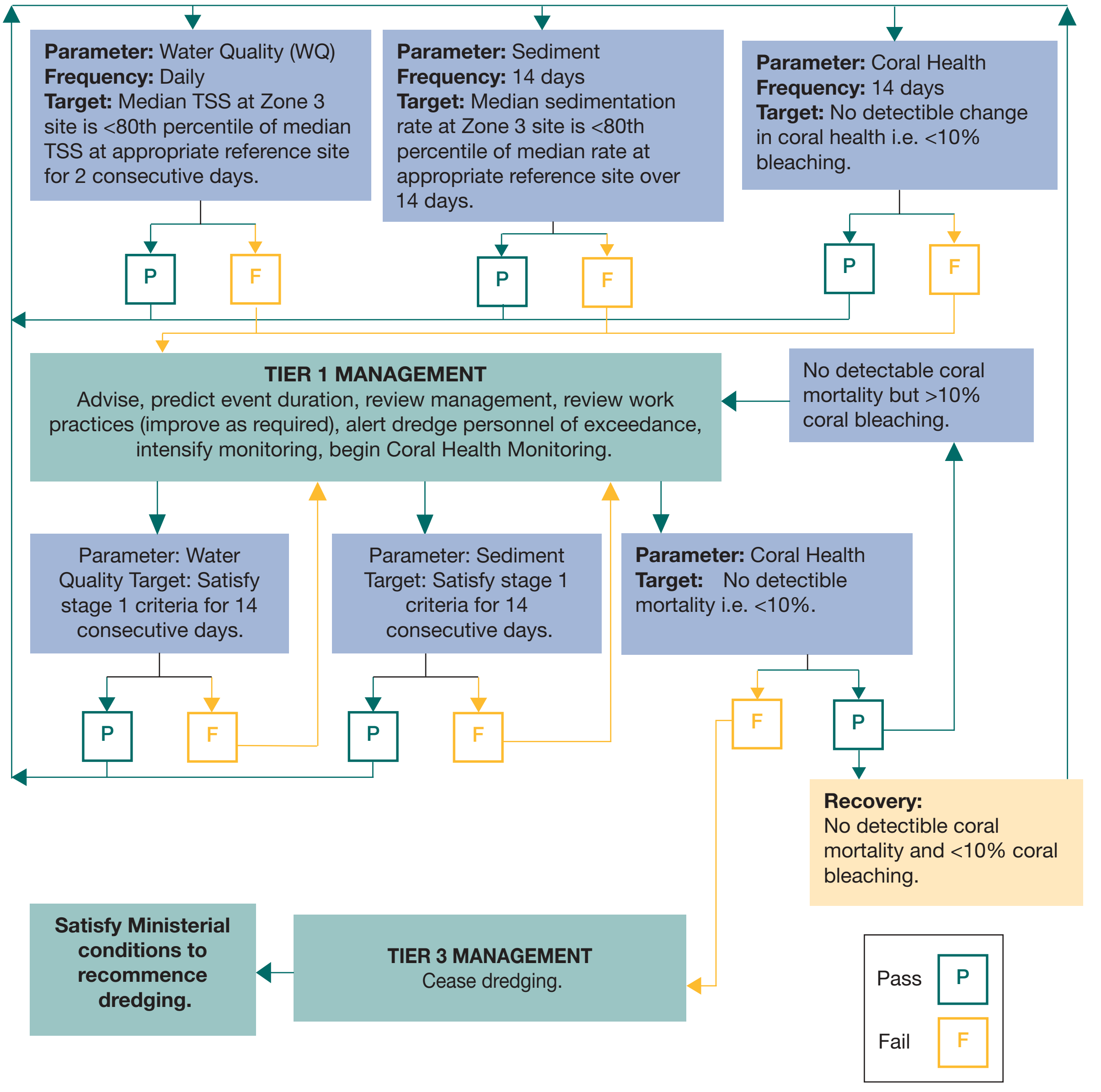


Figure 11-11:
HDD, Dredging and Dredge Spoil Disposal Monitoring and Management Plan for Zone 3 (Visible Plume and Extent of Sedimentation)



The jetty will not directly affect any regionally significant coral communities. The loss of locally significant corals in the vicinity of the jetty piles will be minimised through alignment of the jetty and will be partially offset by coral growth on jetty piles and the causeway. Regrowth on jetty piles at Point Murat in Exmouth Gulf included 10–15% hard coral cover, although the colonies were limited in size (Halford and McIlwain 1996; McIlwain and Halford 2001).

The residual risk of significant adverse impacts to mangroves on the mainland from construction of the domestic gas pipeline is medium. The likelihood of impacts is categorised as almost certain because clearing is unavoidable for construction of the domestic gas pipeline to proceed. The consequence of impacts is considered moderate because the impacts are restricted to a small area of a regionally significant mangrove system that is well represented along the Pilbara coast. The absence of observable edge effects along the existing pipeline easement indicates that the integrity of the local mangrove habitat will not be reduced by the proposed Development.

It is expected that mangroves will regrow from seedlings as observed in preliminary surveys of the proposed route. Long-term impacts on the mangroves will be mitigated by regrowth from root stock, establishment of mangrove seedlings and re-establishment of natural drainage channels in the mangrove zone at the seaward end of the existing Apache sales gas pipelines (Dames and Moore 1998).

Indirect Impacts

The implications to benthic primary producer communities of increased suspension and deposition of sediments resulting from construction operations will vary considerably depending on the extent and nature of impacts, including the taxa affected. The residual risks for the three potential impact scenarios are discussed in the following.

Under a best case scenario the zones of impact are predicted to be limited to areas adjacent to the proposed Development and to areas along the north-eastern shoreline of Barrow Island and the eastern Lowendal Shelf. No effects on the regionally significant corals on the southern Lowendal Shelf, Dugong Reef or Batman Reef are predicted. Impacts on the scattered coral communities on the limestone pavements would be restricted to some of the faster growing species and rapid recovery would occur. The consequences of these impacts would be minor, with a short to long-term reduction in local abundances with no reduction in the viability of significant communities. Indirect impacts on benthic primary producers from construction activities are unavoidable and, although the assessment of the extent of impacts is still conservative, these consequences are considered almost certain. The residual risk is therefore low.

In the event of a worst case scenario impacts would extend over a portion of nearshore habitats of the western coast of Barrow Island and the southern and eastern portions of the Lowendal Shelf, extending to areas adjacent to Abutilon and Varanus islands. Although benthic primary producers would recover, particularly the more rapidly growing species (e.g. acroporids), it is not certain that the communities would recover to their existing condition in the short-term. Seagrass and algal communities would be expected to recover within a few years.
The consequences of these impacts would be moderate, with a short to long-term reduction in local abundances with no reduction in viability in the local area. With the management measures that will be implemented, such as the maintenance of 4 m of under keel clearance, and the degree of conservatism built into the prediction of impacts under the worst case, the likelihood of these consequences is possible.
The residual risk is therefore medium.

The anticipated impacts would result in a local long-term impact on benthic primary producers in areas adjacent to the Development area and an area of short-term impacts along the eastern edge of the Lowendal Shelf and northern coast of Barrow Island. There would be no effects on the regionally significant corals on the southern Lowendal Shelf, Dugong Reef or Batman Reef. The consequences of these impacts would be minor, representing a short to long-term reduction in abundances but no reduction in community/taxon viability in the local area. The likelihood of these consequences is considered likely. Therefore, the level of residual risk is low.

11.3.2 Leaks and Spills

The potential for significant impacts to marine benthic primary producers from a leak or spill incident associated with the Development relates primarily to a spill of condensate or liquid hydrocarbons from work vessels, LNG ships and work barges that will have bunkers of diesel and possibly other liquid fuels on board. Unlike other liquid hydrocarbons, LNG is not toxic and produces a buoyant vapour cloud when spilled on to water (ABS Consulting 2004). As this cloud mixes with air, it warms and disperses into the atmosphere. The potential for environmental impacts from a release of LNG are therefore considered negligible (ABS Consulting 2004).

The predicted dispersion trajectories of credible hydrocarbon spill scenarios have been modelled and are presented in Chapter 7 and Technical Appendix B3. Briefly, sources of a marine hydrocarbon spill include release of:

- condensate and reservoir/production water from the subsea production equipment, subsea flow lines or the feed gas pipelines
- processed condensate from the subsea condensate off-loading pipeline on the eastern side of Barrow Island
- diesel from shore facilities or vessels operating around facilities on the east and west coasts of Barrow Island and on the mainland
- condensate, crude oil (from other sources) and bunker fuel oil from tankers brought to the export terminal.

The domestic gas pipeline will not carry liquid hydrocarbons; therefore a hydrocarbon spill near mainland mangroves is not considered a credible scenario.

Modelling for each of the above scenarios has provided quantitative data on the potential frequency of a release of liquid hydrocarbon and indicates that the overall risk of a spill or leak under each scenario is unlikely (2.43×10^{-2} to 3.75×10^{-7} per year). The modelling was based on conservative, worst case, credible spill scenarios for the Development. The likelihood of a large spill is extremely low. Offshore oil and gas exploration and production activities have been occurring in Australian waters for more than 30 years and in this time the largest recorded spill involved 60 m^3 diesel (Woodside Energy Ltd. 2003). The most likely spill event involves a small (2.5 m^3) refuelling incident off the west coast of Barrow Island during construction.

Spilled liquid hydrocarbons can adversely affect marine benthic primary producers if there is direct contact at low tide, through the dispersal of oil droplets into shallow subtidal areas or by dissolution of toxic hydrocarbons into the water column. The extent to which a spill will affect benthic primary producers in any area depends on a complex suite of interacting physical, chemical and biological factors. Of particular importance will be the physical and chemical properties of the oil involved, the prevailing sea and weather conditions, the pre-existing stress and energy levels in the receiving environment and the species composition of the community affected. The timing of an incident in relation to the lifecycle stage of an impacted community can also be of considerable significance. For example, an oil spill during mass coral spawning, when coral spawn floats at or near the surface of the ocean, could affect recruitment rates in local communities.

Coral, seagrass and mangrove communities are particularly sensitive to liquid hydrocarbons. In general, deeper subtidal communities tend to be buffered from the effects of a spill by the water overlying them. Although strong winds and rough sea conditions can disperse oils through the water column, light oils such as diesel and condensate have a strong tendency to float and dissolution of even the most soluble aromatic components is approximately a hundred times slower than evaporative loss (Kagi et al. 1988).

Within the area potentially at risk from a leak or spill, the intertidal coral communities at Biggada Reef on the west coast of Barrow Island are the most vulnerable benthic primary producer community with high conservation significance. Significant coral communities on the east coast are mostly subtidal, as are the denser macroalgae and seagrass communities on both coasts. Modelling indicates that a small-volume spill from a refuelling incident on either the west or east coasts of Barrow Island would be unlikely to result in significant exposure of benthic primary producers to hydrocarbons.

A large-volume leak of liquid hydrocarbons from the condensate export line or from a vessel grounding or collision on the east coast may impact benthic primary producers over a large area and could cause widespread and long-term impacts to significant coral communities or mangroves along the south-east coastline of Barrow Island. However, these scenarios are extremely unlikely.

Management

Management of hydrocarbon spills within the offshore petroleum industry is focussed on prevention of incidents, combined with comprehensive contingency response planning, integrated at national, state and local levels. Control measures used to reduce the primary risk of a hydrocarbon spill or leak are discussed in Section 7.9.1, Chapter 7. Equipment design, material selection and construction techniques and standards adopted for the Development are based upon proven, robust solutions used extensively in similar environments and applications worldwide.

The offshore Pilbara north-west shelf region is a major petroleum exploration and production province. Detailed contingency planning is in place to reduce the risk of a significant spill and substantial oil spill response capacity is currently maintained at the Port of Dampier and on the islands of the north-west shelf, including Barrow Island, to provide for rapid intervention if an incident occurs.

Extensive oil and gas development has been undertaken in the region and the Development will incorporate best practice standards developed through these many years of experience to ensure incident free operations in the prevailing environmental conditions.

Activities with increased potential for loss of hydrocarbons, such as refuelling and tanker loading, will be subject to stringent technical and procedural controls (e.g. dry break couplings and floating hoses will be used in all offshore refuelling operations to minimise the potential volumes that could be lost). Transfer operations will be subject to continuous monitoring and fitted with emergency shut-down valves, automated where appropriate, to minimise spill volumes. All facilities constructed for the Development will utilise industry best practices and will be designed to optimise the safety of operations. Strict requirements will be placed on the condition, maintenance and operational procedures for vessels servicing the Development.

Designated refuelling locations will be identified for construction to minimise the risk of spills affecting sensitive areas. Refuelling will only be permitted during suitable weather and sea conditions and additional response equipment and personnel will be held onsite during these activities to facilitate containment and/or recovery of any spilled fluids.

Response to major spills is managed by the Australian Maritime Safety Authority (AMSA) through the National Plan for Prevention of Pollution of the Sea by Oil (NATPLAN) and coordinated by the appropriate state agencies. A Gorgon Development Spill Contingency Plan for Barrow Island operations will be developed to fulfil the requirements of AMSA, the Western Australian Department of Industry and Resources (DoIR) and NATPLAN. Existing spill response resources on Barrow Island will be bolstered to meet specific requirements of the Development and, in the event of a large spill; additional external resources are expected to be available through industry affiliations and the relevant agencies.

Residual Risk

A small spill of diesel close to shore due to a refuelling incident on either coast could result in localised impacts to benthic primary producers and, if it involved coral or mangrove communities, full recovery could take a number of years. The extent of effects would vary according to the timing and location of a spill and ecological consequences could range from minor to moderate. Historical data indicates that the probability of a small spill from a refuelling accident is 2.43×10^{-2}/yr and with the management proposed, it is considered unlikely that a spill would occur and result in these consequences. The residual level of risk is therefore low.

The probability of a large leak or spill is very low (2.76×10^{-5}/yr) and the likelihood of a large spill occurring and affecting benthic primary producers is categorised as remote. However, depending on prevailing conditions, a large release of liquid hydrocarbons close to shore could result in local to widespread impact on intertidal and shallow subtidal coral communities or mangroves at Barrow Island. A widespread impact might reduce the viability of local populations and the ecological consequences could be serious. Large leaks or spills at Barrow Island are considered a low risk.

The probability of the mainland mangroves being impacted is very unlikely due to the lack of large vessels operating in that area and the management measures to minimise the exposure of benthic habitats to hydrocarbons. This would have a moderate consequence on the mangroves, as it would be a localised, long-term effect. During construction, a potential small spill of diesel from the pipe lay vessel, optical fibre cable installation vessel or support vessels presents a low risk of unmanageable impacts to the mangroves.

Table 11-12:
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
Seabed Disturbance **Environmental Management Objective/s:** • To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.					
Construction and commissioning Dredging and blasting for: • MOF • causeway • LNG load out facility • jetty Dumping of dredge spoil. Construction of feed gas and domestic gas pipelines and optical fibre cable. Construction of open pile jetty. Drilling of subsea wells. Installation of subsea gathering system. Anchoring of drill rigs and pipelay vessel.	• loss and/or disturbance to marine flora and coral communities within and adjacent to marine infrastructure • smothering/burial of marine flora/corals in dredge spoil area • turbidity, light attenuation and reduced photosynthetic potential in dredge plume • decreased water quality (nutrients and oxygen depletion) • loss of mangroves along domestic pipeline route on mainland.	**Pre-construction** • identify significant macrophyte and coral habitats and describe spatial and temporal sensitivities of subtidal and intertidal areas • reduce dredge requirements through causeway construction, use tidal access to reduce target depth for MOF, and construction of open structure jetty • locate marine infrastructure to avoid sensitive habitats • specify heavy metal limits in drilling chemicals (e.g. barite) • specify relevant EIS/ERMP commitments in tenders and contracts • conduct benthic primary producer habitat assessment in accordance with EPA Guidance Statement No. 29 • consult EPA Guidance Statement No.1 for arid zone mangrove protection for mangroves of special significance (EPA 2001) • use HDD or tunnelling in favour of trenching at feed gas pipelines shore crossing (eliminates risks associated with trenching and potential impacts to Biggada Reef)	• significant habitats and sensitive areas mapped and avoided. • heavy metal limits not exceeded • risks associated with trenching eliminated • requirements of *Environment Protection (Sea Dumping) Act 1981* recorded and met • alternative locations within the spoil sites and dredge areas used when trigger values exceeded • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring to establish water quality limits (impact, potential impact, monitoring and reference sites) in accordance with Sea Dumping Permit conditions • modelling and monitoring of turbidity plume dispersion • aerial monitoring of plume • monitoring of water quality, sedimentation rates and coral health prior to, during and following completion of dredging.	**Construction and commissioning** **Direct impacts** Likelihood – almost certain, dredging is required for shipping channel construction Consequence – moderate, minor impacts on locally significant coral communities. Communities are well represented in the area and loss will not affect ecosystem function. Moderate impact to mangroves due to a local, long-term decrease in the abundance on mainland without impact on the local population viability. **Risk – medium** Indirect Impacts Likelihood – likely Consequence – minor to moderate; local long term impact on benthic primary producers in areas adjacent to the Development and possible

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
Operations Localised maintenance dredging as required, probably every 3-5 years. Resuspension of material at spoil disposal site.		**Construction and commissioning** • identify significant habitats and avoid • determine final location of open pile jetty on the basis of coral distribution • select infrastructure and dredge spoil grounds to avoid significant marine flora and coral communities • design and operate east coast dredging in accordance with requirements of the *Environment Protection (Sea Dumping) Act 1981* • implement adaptive planning which includes identification of alternative spoil sites and dredge areas if impacts in a particular location exceed permit conditions • avoid where practical dredging in areas adjacent to significant corals during coral spawning • develop appropriate erosion control methods for the mainland section of the domestic gas pipeline • maintain optimum 4 m under keel clearance on the trailer suction hopper dredge to reduce sediment resuspension • use sediment curtains where practicable			short-term impacts that encompass coral and macroalgae communities on the Lowendal Shelf and northern coast of Barrow Island. Risk – low to medium **Operations** Likelihood – likely, dredging probably required every few years Consequence – minor, local, short-term reductions in abundance of macrophyte communities, e.g. seagrass regrowth lost from dredge channel and minor loss of corals and macroalgae due to burial by mobile sediment. Risk – low

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
		• minimise anchor scours and position strategically to avoid sensitive marine habitats. **Operations** • dredge channel design to reduce the necessity for maintenance dredging • routinely monitor in accordance with the Sea Dumping Permit conditions • independent sediment control measures.			

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills **Environmental Management Objective/s:** • To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.					
Non-routine operations Smaller spill/leak ($<10m^3$) potentially caused by small vessel grounding or collision, refuelling, transferring and transport of hydrocarbons and/or chemicals during construction or operations Larger spill/leak ($>10m^3$) potentially caused from pipeline failure, process or operator failure or vessel grounding or collision during construction or operations	• acute and chronic toxicity to marine flora and corals • smothering of intertidal marine flora and coral (e.g. heavier hydrocarbons) • smothering of mangrove pneumatophores • toxicity to shallow subtidal coral	**Non-routine operations** • specifiy relevant EIS/ERMP commitments in tenders and contracts • design of equipment to include built in safeguards such as relief valves and overflow protection, fabrication quality controls and operating procedures • undertake transfer of fuel from support vessels in accordance with normal operating procedures which take into account sea-state and wind conditions and require good communications between vessels as a minimum • transfer hoses with 'dry' coupling, will be fit-for-purpose, not outside design life limits and regularly check for damage to prevent leaks • document, track and segregate all hazardous wastes from other waste streams and stored onboard for disposal ashore • review Material Safety Data Sheet for HES requirements prior to chemical selection	• incidents reduced and/or avoided • hazardous materials transported and stored safely • spill management efficient and effective • standards for storage and handling of fuels and chemicals met • corrosion monitored and managed • leaks detected, reported and managed • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular audit, inspection and maintenance of facilities • audit against management requirements outlined in Environment Plans for drilling and construction of pipelines • audit against OSCP requirements • equipment and pipeline corrosion monitoring and control program	**Minor spill ($<10m^3$)** Likelihood – unlikely to possible, small spills expected occasionally. Minor spills of 80 L to $10m^3$ not expected, but possible Consequence – minor to moderate, a hydrocarbon spill near a significant mangrove or coral community could cause a local, long-term decrease in abundance. No impact on local population viability will be expected. Risk – low to medium **Major Spill ($>10m^3$)** Likelihood – unlikely, the probability of a major spill is very low and the probability of the spill contacting sensitive receptors over a wide area is similarly low.

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
		• store chemicals, fuels and oils will be in accordance with Material Safety Data Sheet requirements as a minimum • keep a complete inventory of all chemicals to allow sufficient and appropriate recovery equipment and materials to be on hand in the event of a spill (i.e. Material Safety Data Sheets, labelling and handling procedures) • refuel during daylight hours, depending on sea conditions • contain and clean up onboard spills immediately • provide oil and chemical spill containment and cleanup material (e.g. absorbent) where spills are possible, including on small vessels • close scuppers on vessels to ensure pollution on the deck is not discharged into the ocean • store fuel and diesel in large, internal tanks/bunkers onboard • close all waste containers to prevent loss overboard • design LNG loadout facility for safe operation within defined weather conditions • locate LNG loadout facility away from sensitive areas of benthic habitat (e.g. intertidal areas)			Consequence –serious to major, a large spill in unfavourable conditions could cause a widespread, long-term decrease in abundance of significant corals or mangroves. Possible reduction in the viability of intertidal corals on the west coast of Barrow Island. Possible reduction in the viability of mangroves in mainland management unit or on east coast of Barrow Island. Risk – low to medium

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
		• apply industry standards for storage and handling of fuels and chemicals (e.g. bunding) • implement approved OSCP and emergency response and spill contingency planning • implement plant, equipment and pipeline corrosion monitoring and control program • contain and remediate contaminated soil to be disposed of, if necessary • include in-built automatic shut-down systems where necessary • implement early leak detection and reporting system.			

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
Stressor: Physical Presence **Environmental Management Objective/s:** • To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.					
Construction Tanker, barge and other vessel movements. **Operations** Permanent presence of MOF, causeway, jetty, subsea equipment (e.g. wellheads, flowlines), feed gas and domestic gas pipelines and optical fibre cable. Tanker and other vessel movements.	• physical disturbance and turbidity effects to macrophyte and coral communities adjacent to marine infrastructure due to propeller wash • introduction of exotic taxa on vessel hulls (refer to Chapter 12) • enhanced growth of macroalgae and corals on causeway and jetty • possible erosion along mainland section of domestic gas pipeline easement due to tidal currents • reduced growth due to shading from jetty, causeway • changes in distribution of macrophytes and corals due to changes in sediment distribution associated with causeway and pipelines.	**Planning and pre-construction** • numerical modelling of nearshore sediment transport • design and site feed gas pipelines, MOF, causeway and jetty and optical fibre cable appropriately to minimise potential effects on longshore sediment transport. **Construction and commissioning** • specify relevant EIS/ERMP commitments in tenders and contracts • numerically model nearshore sediment transport used in causeway design • align causeway into wave front to reduce influence on nearshore hydrodynamics • bury feed gas and domestic gas pipeline shore crossings • use HDD in favour of trenching at feed gas pipelines shore crossing.	• longshore sediment transport minimised • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of beach alignment in vicinity of Town Point.	**Construction** Likelihood – almost certain, vessel traffic required for construction activities. Consequence – minor, local, short-term impact on communities adjacent to infrastructure. Risk – low **Operations** Likelihood – almost certain, infrastructure will be necessary for Development to proceed. Consequence – minor, impacts to macroalgae due to local, long-term change in distribution of benthic substrates with increased growth along causeway and jetty. Localised burial of macrophytes and corals by sediments resuspended by propeller wash. No expected decrease in local population viability. Risk – low

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
		Operations • establish permanent moorings for support tugs to avoid anchoring • restrict barge and vessel speeds within the approach channels and associated with the MOF.			

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
Stressor: Wastewater and Other Discharges **Environmental Management Objective/s:** • To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.					
Construction and commissioning Stormwater (potentially containing chemicals, hydrocarbons and sediment) from construction areas on shore. Deck wash from rigs and other construction vessels. Drilling fluids and cuttings discharged at offshore field. Ballast water discharge. Discharge of hydrotest water containing biocides and corrosion inhibitors.	• locally reduced water quality from stormwater runoff containing sediment or chemicals, such as hydrocarbons • potential smothering of corals from sediment run off or infauna from drilling solid discharge • possible acute or chronic toxicity effects of toxicants in discharges • potential eutrophication effects due to nutrients in discharged food scraps or sewage (offshore) • possible introduction of exotic macrophyte or coral taxa that may be competitors or parasites (refer to Chapter 12).	**Construction and commissioning** • specify relevant EIS/ERMP commitments in tenders and contracts • use runoff bunds and flow control to reduce erosion and transport of sediment • avoid discharge of potentially contaminated water from land to the marine environment • divert firewater run off from hardstand areas into stormwater management systems • inject hydrotest water or discharge to high current areas • permit offshore discharge (>12 nm from land) of treated sewage in accordance with P(SL)A clause 222 and MARPOL 73/78 • incorporate MARPOL requirements for ballast water, discharge criteria and harmful substances in management plans • use biodegradable detergents only • develop drilling Environment Plan such that it outlines	• longshore sediment transport minimised. • impact of discharged contaminated water minimised and managed • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • environmental audits to determine compliance with licence conditions • establishment of waste targets and regular review of waste inventory • drainage and bunding systems subject to ongoing monitoring and maintenance program to ensure integrity and capacity • monitoring of contaminant concentrations in sediments adjacent to marine facilities and run off areas.	**Construction and commissioning** Likelihood – unlikely, due to control of contaminant concentrations in waste water discharges and rapid dilution of all runoff and discharges. Consequence – minor, possible local, short-term physiological effects or decrease in abundance of macrophytes or corals. Risk – low **Operations** Likelihood – possible, chronic toxicity is possible over the life of the Development in the main berthing areas.

Table 11-12: (continued)
Summary of Risk Assessment for Marine Primary Producers

Activities/ Causes	Potential Environmental Impact/Consequence	Management and Mitigation Measures	Outcome/Target	Measurement Strategies	Residual Risk
Operations Runoff from hardstand areas such as the MOF and jetty containing chemicals including hydrocarbons. Runoff from decks of tankers and support vessels. Ballast and bilge water discharge.		management of drilling waste discharges at the offshore field, including monitoring • develop a quarantine management plan that incorporates a ballast water management plan (refer to Chapter 12). **Operations** • dispose uncontaminated runoff water in a natural drainage system • implement a multi-tiered stormwater drainage management system (Chapter 7) • use sediment control measures to limit sediment generation and transportation • clean and maintain all holding basins regularly.			Consequence – minor, removal of contaminants from waste waters and rapid dilution of discharges by tidal currents, will restrict potential chronic effects to the immediate vicinity of the discharge point. Potential entrainment of contaminants in sediments under facilities may affect local infauna. No listed fauna are expected to be affected. Risk – low

11.4 Benthic Primary Producer Habitats

Benthic primary producer habitats comprise both benthic primary producer communities and the substrates that support these communities. Areas of seabed within the photic zone and within the distributional range of benthic primary producers are considered by the EPA to be benthic primary producer habitat, irrespective of whether they support benthic primary producers at a given time or not.

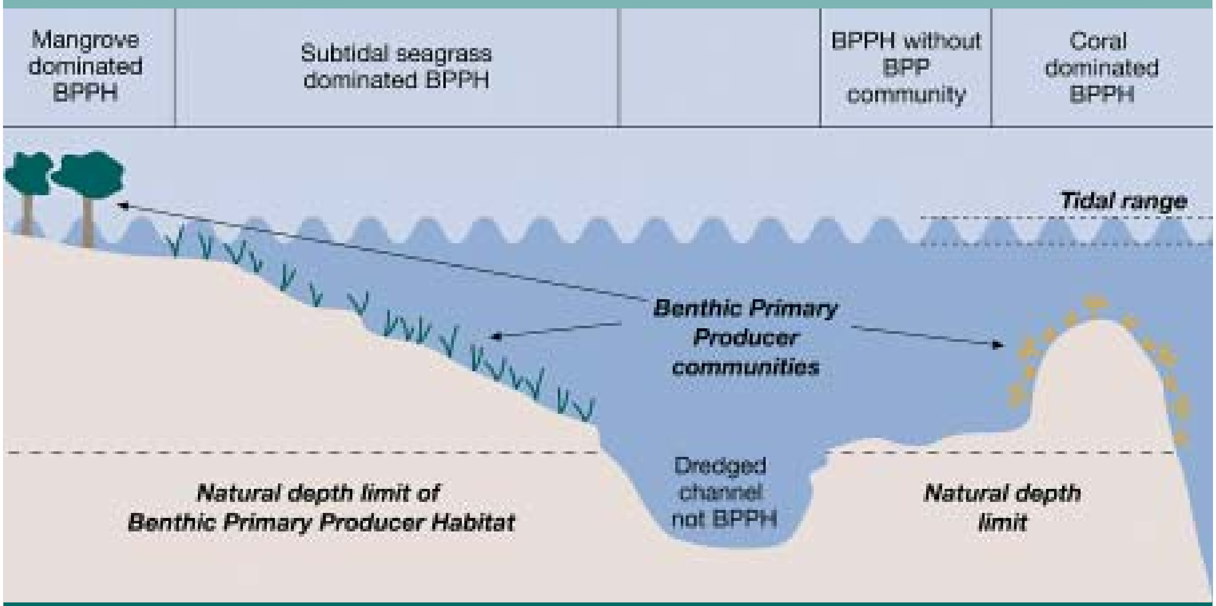
Examples of benthic primary producer habitats in the Pilbara region include coral reefs, seagrass meadows, macroalgae beds and mangrove forests as well as the intertidal and subtidal substrates that support them (Figure 11-12). Benthic primary producers are important as they are a key source of energy (primary production) in marine ecosystems, provide substrate and shelter for other marine organisms and increase substrate stability (EPA 2004).

The EPA has developed a Guidance Statement No. 29 aimed at protecting benthic primary producer habitat (EPA 2004). This statement specifically applies to development proposals that may result in removal or destruction of, or damage to, benthic primary producer habitats. The guidelines provide for the protection and maintenance of ecosystem integrity by applying a risk-based environmental protection framework which includes quantitative cumulative loss thresholds (EPA 2004).

Consistent with the intent of the EPA Guidance Statement No. 29, the coastal aspects of the Development have been sited to avoid impacts to important benthic primary producer habitats where possible. Preliminary plans included coastal facilities at Latitude Point which would have presented a greater risk of loss of significant coral habitats around the southern end of the Lowendal Shelf. The move to Town Point has significantly reduced the risk of adverse impacts to these habitats. Similarly, the selection of North White's Beach as the preferred west coast shore crossing site for the feed gas pipeline, has avoided potentially unacceptable impacts to important benthic primary producer habitats within the Barrow Island Marine Park that would have been potentially impacted by a shore crossing at Flacourt Bay.

Unavoidable impacts on benthic primary producer habitat have been assessed as either 'loss' or 'damage' as recommended by the EPA (2004). A 30 year recovery period has been selected as the basis for distinguishing between permanent loss of, and temporary damage to, benthic primary producer habitat on the advice of the Department of Environment (DoE). Loss indicates that an area of benthic primary producer habitat is no longer able to support primary producer communities that existed prior to disturbance or that full recovery will take greater than 30 years to occur. A permanent change in the substrate type is also

Figure 11-12:
Conceptual Diagram of Benthic Primary Producer Habitats and their Associated Benthic Primary Producer Communities. *The dashed line represents the natural depth limit of benthic primary producers (source: modified after EPA 2004)*



treated as benthic primary producer habitat loss, although there is frequently a mitigating shift to another benthic primary producer habitat type.

Damage to benthic primary producer habitat indicates that there are temporary or sublethal impacts that may reduce or remove the current standing crop of benthic primary producers, but that the substrate will retain its ecological function and will recover fully within 30 years. Full recovery indicates the recovery of the biomass of benthic primary producer and the full diversity of marine life associated with the original benthic primary producer community.

Impacts to benthic primary producer habitats from the Development will comprise direct loss by removal (dredged areas) or burial (infrastructure, dredge spoil, drilling solids) and temporary damage (anchor scars, sedimentation, and increased turbidity). Most of the damaged areas will recover fully during the post-construction period when water quality and sediment depth return to within their natural range. Much of the permanent loss of benthic primary producer habitat will be offset by colonisation of new hard substrates created by the Development, for example the causeway, jetty piles and dredge spoil ground.

Seagrasses, such as *Halophila,* that are common to the Development areas on the east coast, are ephemeral species that rapidly recolonise disturbed areas of seabed. Large areas of seagrass that were lost from Exmouth Gulf during Cyclone Vance in 1999 recovered both in terms of seagrass biomass and prawn nursery function within the two years of disturbance (Loneragan et al. 2003). *Sargassum,* the main macroalgal taxon around Barrow Island, is also able to rapidly recolonise disturbed areas and naturally undergoes major seasonal changes in biomass related to its reproductive and growth cycles. Adult *Sargassum* plants are elevated above the seabed on a non-photosynthetic stem (stipe). This morphological feature reduces their susceptibility to burial by sediments (Umar et al. 1998).

All benthic primary producer habitats in the Montebello/Lowendal/Barrow Island region are occasionally exposed to natural perturbations, such as cyclones, that impact them at much larger scales than are expected from the Development. Their persistence in the region is testament to their ability to recover from major impacts as long as substrates remain suitable for recolonisation.

The Joint Venturers have adopted the EPA's risk-based approach, as outlined in Guidance Statement No. 29 (EPA 2004), to assess unavoidable cumulative impacts to benthic primary producer habitats within the proposed Development area. As specified by the Guidance Statement, management units were defined in consultation with the Western Australian DoE and existing and proposed disturbance to benthic primary producer habitats assessed against relevant cumulative loss thresholds. The recommended size for a management unit to represent an ecological unit is nominally 5 000 ha although larger and smaller units can be established (EPA 2004).

Cumulative loss thresholds are used by the EPA to provide an indication of the acceptability of the impacts associated with a particular proposal. However, given the lack of a scientific basis for setting boundaries of management units, difficulty in reliable measurement of the area of some benthic primary producer habitats, and given the difficulty in determining the ecological significance of their loss, these thresholds are not considered as rigid limits (EPA 2004). The acceptability of benthic primary producer habitat damage/loss is, in all cases, a judgement of the EPA, based primarily on its assessment of the overall risk to the ecosystem integrity within a defined management unit if a proposal were to be implemented. Expected recovery of the benthic primary producer communities is taken into account in assessing the ecological implications of the habitat disturbance.

Fourteen management units have been defined to assess impacts to benthic primary producer habitats associated with the proposed Development. This consists of eleven management units around Barrow Island and three on the mainland coast (Figure 11-13, Figure 11-14 and Figure 11-15). The management units include significant benthic features and benthic primary producer habitats that will potentially be affected by the Development. Definition of the management units around Barrow Island also took into account Montebello/Barrow Island Marine Conservation Reserves management zones and the Varanus Island and Barrow Island port boundaries. All of the management units are approximately 5 000 ha as recommended by the EPA (2004), although to achieve this size, the boundaries are somewhat arbitrary and some contiguous benthic features are dissected by management unit boundaries. Consequently, the boundaries do not necessarily reflect natural boundaries of functional ecological units.

Direct and permanent removal of benthic primary producer habitat by excavation or replacement by infrastructure, permanent modification of benthic primary producer habitat type and loss of benthic primary producer communities that may take greater than 30 years to recover have been assessed as loss against the cumulative loss threshold criteria (EPA 2004). Impacts due to temporary loss from sedimentation, direct disturbance (anchoring), and turbidity have been assessed as damage from which full recovery is predicted within 30 years. Sedimentation and turbidity (TSS) impacts are considered as loss only if the sediment deposits on the seabed are predicted to persist long enough to prevent benthic primary producers recolonising a hard substrate seabed, or if either sedimentation or turbidity impacts lead to total mortality of a benthic primary producer assemblage or serious damage to a benthic primary producer habitat that would not recover within 30 years. There are four areas of benthic primary producer habitat in the vicinity of the proposed Development that would not be expected to recover within 30 years if they suffered high mortality. These benthic primary producer habitat areas are:

- mature *Avicennia/Rhizophora* mangrove on the mainland
- large *Porites* bombora along the south-western edge of the Lowendal Shelf
- large *Acropora* thicket on the south-western corner of the Lowendal Shelf
- large *Porites* bombora on the southern end of the rocky ridge running south from the Lowendal Shelf.

Serious damage to these benthic primary producer habitats would be considered loss and assessed against the cumulative loss threshold criteria within the appropriate management units. Serious damage would arise from direct removal or from sedimentation and TSS stress above the high impact criteria for the *Porites* and moderate impact criteria for the *Acropora* benthic primary producer habitat as described in Section 11.3 and in the following.

Criteria for predicting high and moderate impacts on benthic primary producer habitat, due to sedimentation and elevated TSS concentrations were established on the basis of a literature review of sensitive corals. The coral sensitivity criteria are explained fully in Section 11.3. The criteria for adverse impacts on corals were taken as a conservative indicator of the response of all benthic primary producer communities. This approach is conservative because macrophyte benthic primary producer habitats are expected to be less susceptible than corals to long-term impacts from sedimentation and turbidity. The dominant *Halophila* seagrass rapidly recolonises disturbed sediments and the dominant *Sargassum* macroalgae is elevated above the seabed and can regenerate from its stipe if the plant thallus is damaged. While burial or light deprivation may kill these benthic primary producer communities, these stressors are not predicted to persist beyond the HDD or dredging programs and the primary producers will rapidly recover through recolonising or regenerating in affected habitats.

The predicted area of impacts on benthic primary producer habitat from elevated TSS and sedimentation due to the dredging and HDD operations, were derived from modelling results. Model outputs were analysed to predict areas of high impact and moderate impact based on elevated TSS and sedimentation exceeding conservative criteria for impacts on corals. Section 11.3 assesses the risks of impacts to benthic primary producers based on the same criteria and Figure 11-3 to Figure 11-5 illustrate zones of predicted high impact and moderate impact under the best, worst and anticipated (most probable) scenarios.

Within the high impact zones (Figures 11-3 to 11-5) damage to benthic primary producer habitat is considered temporary unless it affects benthic primary producer habitat that have been identified as probably requiring greater than 30 years to recover from total mortality of the benthic primary producer community. For example, mortality of large *Porites* bombora in a high impact zone would be considered permanent (>30 years) loss, whereas mortality of small corals, macroalgae or seagrass would be considered temporary (<30 years) damage.

Within the moderate impact zone, damage to benthic primary producer habitat is only considered permanent if it affects a well developed expanse of *Acropora* that could suffer total mortality and may take greater than 30 years to fully recover. High mortality of large *Porites* is not expected in this zone and these benthic primary producer habitats are expected to recover from up to 30% mortality within 30 years.

The areas that are predicted to be influenced by a turbid plume or sedimentation at some stage during the dredging or HDD programs are shown in Figure 11-6 to Figure 11-9. No impacts to benthic primary producer habitat are expected within these areas.

The areas of permanent loss of each type of benthic primary producer habitat have been assessed against the cumulative loss threshold criteria (EPA 2004) within each management unit, under the best, worst and anticipated scenarios (refer Section 11.3).

11.4.1 West Coast and North Coast

Benthic primary producers in the vicinity of the proposed Development areas on the west coast of Barrow Island comprise macroalgae, mainly *Sargassum,* and other large phaeophytes, growing on the limestone reef platform and shallow nearshore reefs that fringe the coast. There are also scattered small corals amongst the macroalgae, but no known coral reefs. The macroalgal beds are part of an extensive system of nearshore reef that fringes the whole west coast of Barrow Island.

The proposed feed gas pipeline shore crossing location at North White's Beach, and the alterative crossing at Flacourt Bay, are separated by approximately 6.5 km of undisturbed rocky coast and sandy beaches. Horizontal directional drilling is the proposed construction method and would involve discharge of drilling fluids and cuttings to the seabed at the pipeline exit point approximately 600 m offshore.

Sedimentation and turbidity associated with the discharge of drilling fluids and cuttings will affect benthic primary producer habitats on the west coast of Barrow Island. The behaviour of the turbidity plume and the area affected by sedimentation has been modelled for the anticipated June to December period of HDD. The hydrodynamic modelling predicted the areas that would be affected by sedimentation and elevated TSS associated with the proposed HDD at North White's Beach and Flacourt Bay (Technical Appendix B6). The modelling also compared the size of the areas likely to be affected by plumes of bentonite and polymer drilling fluids. While the smaller volume of polymer drilling fluids affect a much smaller area of the seabed than bentonite fluids, this is unproven technology and polymer is only included in the best case scenario. The zones of high and moderate impacts for bentonite in the anticipated and worst case scenarios (Figure 11-4, Figure 11-5) are conservatively based on the discharge of a high proportion of the drilling fluids to the seabed at the exit point during drilling. Options for reducing the volume of drilling fluid discharge, through recirculation of a higher proportion of fluids, are being investigated and may reduce the area influence by bentonite discharges.

Turbidity and sedimentation associated with dredging on the east coast of Barrow Island for construction of shipping access channels are also predicted to reach the north and north-west coasts of Barrow Island although no impacts to benthic primary producers are predicted in these areas. The east coast dredging and the west coast HDD will affect water quality in these areas mostly during the June to December period when water currents are predicted to drive the turbidity plumes from both operations to the north of the island. These low level stresses are not predicted to lead to loss of benthic primary producers, but may temporarily reduce benthic primary producer productivity due to light reduction during the growing season.

While turbid water is predicted to be present at any point along the west coast of Barrow Island at some stage during the two-year construction period (Figure 11-7), no impacts on benthic primary producer habitat are expected along the central and southern parts of the west coast. The Sanctuary Zone of the Barrow Island Marine Park lies immediately to the south of the north-west coast management unit. This is a Category A protection area where permanent benthic primary producer habitat loss is not acceptable. Modelling of the zone of effect from HDD at Flacourt Bay indicated potentially unacceptable impacts on the benthic primary producer habitat within the Barrow Island Marine Park sanctuary zone. This was a major factor in selecting the North White's Beach shore crossing site over the Flacourt Bay alternative (Chapter 3). Flacourt Bay has been retained as an alternative, in case geotechnical data indicates that construction at North White's Beach is unfeasible, but would require further assessment such as additional modelling, assessment of alternative drilling methods and additional field surveys.

North West Coast Management Unit

Management Unit 1 encompasses 6180 ha of the north-west coast of Barrow Island from the northern boundary of the Barrow Island Marine Park to the north-eastern tip of Barrow Island near the northern limit of the Barrow Island Port at Surf Point (Figure 11-13).

The benthic primary producer habitat is continuous within this area and appears to be connected by the dominant northerly and easterly current regime. Modelling of the HDD plume indicates that this whole area is connected hydrographically, indicating ecological connection among the benthic habitats within the unit. This area is part of the multiple use area of the Montebello/Barrow Islands Marine Conservation Reserves. It is a Category C management unit with a cumulative loss threshold of 2%.

There are approximately 773 ha of subtidal and intertidal macroalgae-dominated benthic primary producer habitat within this management unit (Table 11–13). This coast is too exposed for development of seagrass meadows. Coral reefs are limited to the southern and central parts of the west coast and corals in the management unit are limited to scattered small corals, such as *Turbinaria* spp., which are considered part of the macroalgae dominated benthic primary producer habitat unit.

Much of the area of impact in this management unit is expected to be either beyond the photic zone or in areas unsuitable for benthic primary producers and is not predicted to cause any loss of benthic primary producer habitat. The presence of the pipelines is expected to marginally increase the area of macroalgae-dominated benthic primary producer habitat within the management unit through provision of hard substrate for macroalgal colonisation. In the longer-term, the proposed Development will not threaten the ecological integrity of the benthic primary producer habitats in the area nor will it affect dependent parts of the ecosystem. The impacts to benthic primary producer habitat will be significantly lower if the alternative polymer drilling fluid is found to be technically feasible and is used to drill the shore crossing for the feed gas pipeline at North White's Beach.

Under the best case scenario using polymer drilling fluids, there would be a small area (<0.5 ha) of macroalgae dominated benthic primary producer habitat that would be within the high impact zone and a further 7 ha in the moderate impact zone. These benthic primary producer habitats are predicted to fully recover within five years. There would be no permanent benthic primary producer habitat loss and there may be a net increase in benthic primary producer habitat in the management unit due to the feed gas pipeline and if rock is dumped at the exit point of the pipeline.

Under the anticipated and worst case scenarios using bentonite drilling fluids, impacts to benthic primary producer habitats would comprise damage due to shading from turbidity and due to smothering and possibly biocidal effects of drilling solids deposited on subtidal and intertidal reef habitats. Temporary loss of up to 22% of the macroalgae dominated benthic primary producer habitat in the intertidal and subtidal areas of the management unit is predicted for the high impact zone under the worst case scenario. A further 46% of the intertidal and 10% of the subtidal benthic primary producer habitat in the moderate impact zone may suffer short-term loss of benthic primary producer or decreased productivity. These areas of damage would be smaller in the anticipated scenario where the volume of drilling fluids is expected to be significantly reduced by more effective recirculation.

A large proportion of the affected benthic primary producers are expected to survive and the benthic primary producer habitat is predicted to resume full functionality within five years. While the persistence of drilling fluids may reduce the potential for recolonisation in areas such as rock pools, the rest of the impacted benthic primary producer habitat would recover fully within 30 years. Conservative allowances of 10 ha for the worst case and 5 ha for the anticipated case were allowed for permanent loss of benthic primary producer habitat due to persistent deposits of the highly cohesive bentonite in the offshore area around the feed gas pipeline exit point. During the recovery stage, macroalgae colonising the hard substrates along the pipeline and possibly the rock dumped at the pipeline exit point, would offset the temporary loss of benthic primary producer productivity.

Figure 11-13:
Barrow Island Management Units, Benthic Habitats and Predicted Area of Effects

Sediment distribution along this coast is very dynamic, as evident from seasonal changes in the profiles of west coast beaches. Only a small area surrounding the discharge point is expected to retain sufficient volume of the highly cohesive drilling fluids (bentonite) to prevent recolonisation by macroalgae. The effects of sedimentation are generally predicted to be short-term (less than five years) over most of the affected area due to ongoing redistribution of the sediments into deeper waters through wave action and along shore currents. Areas where sedimentation and turbidity are sufficient to cause mortality of macroalgae would be recolonised when the substrate is re-exposed and the turbid plume dispersed. The macroalgal assemblages are adapted to seasonal and inter-annual cycles of loss and recolonisation and most of the benthic primary producer habitat will regain its full ecological function within five years of HDD.

There has been no permanent loss of benthic primary producer habitat due to anthropogenic disturbance in the area and less than 1% of the benthic primary producer habitat has been damaged. Previous impacts are limited to less than one hectare of disturbance due to anchoring by survey vessels in nearshore areas. These impacts on benthic primary producer habitats would have been short-term and are not included in the estimated cumulative loss associated with the proposed Development.

11.4.2 East Coast

Benthic primary producer habitats in the vicinity of the proposed Development on the east coast of Barrow Island include coral habitats, macroalgae-dominated limestone platform and sparse seagrass meadows on sand. Preliminary modelling of water currents along the east coast of Barrow Island indicates that the whole east coast is connected hydrographically. This connection also represents biological connection in terms of propagule dispersal and ecological functioning.

The main coastal components of the proposed Development are concentrated in the mid-east coast of Barrow Island at Town Point and include the causeway, MOF, dredged shipping channels, open-pile jetty, domestic gas pipeline, optical fibre cable and possible condensate load-out pipeline as described in Chapter 6.

Six management units of approximately 5000 ha were established within the Barrow Island Port Area. Two management units (management units 2 and 3) were established to the north-east of the port limit to encompass potential impacts from dredge plumes on the benthic primary producer habitat near the Lowendal Islands. Two additional management units (management units 10 and 11) were established to the south of the port limit to reflect the two management regimes within the area that will be affected by the dredge spoil disposal ground (Figure 11-13).

Table 11-13:
Cumulative Loss Calculations for Benthic Primary Producer Habitat within North West Coast Management Unit

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Management Unit 1					
Macroalgae-dominated intertidal limestone reef platform	51	0	<1	<1	2%
Subtidal limestone reef platform with macroalgae and scattered corals	722	0	<1	<2	2%

[1] *Cumulative loss threshold (EPA 2004)*

Lowendal Islands Management Units

Benthic primary producer habitats around the Lowendal Islands, to the north-east of Barrow Island, include coral reefs and macroalgae dominated reefs. Although accurate maps of benthic habitats in the areas are not available, the broad scale CALM (2004) map of the area indicates that there are coral reefs, scattered coral bombora, large expanses of macroalgae dominated platform reef and sediments supporting sparse seagrasses in the area (Figure 11-13). The majority of the mapped coral in this area has not been confirmed by field surveys.

Dredge simulation modelling indicates that a plume of elevated TSS would persist in the vicinity of the Lowendal Islands. This is assumed to have moderate to high impacts on coral benthic primary producer habitat under the anticipated and worst case scenarios, but only moderate impacts under the best case scenario. This reflects the range of coral sensitivities incorporated into the conservative threshold criteria used to determine zones of impact.

There are no known areas of benthic primary producer habitat in these management units that would take longer than 30 years to recover under the worst case scenario. However, in the absence of adequate mapping data, it is assumed that all of the unconfirmed coral benthic primary producer habitat in the high and moderate impact zones may be long-lived *Porites* bombora or well developed *Acropora* communities. This approach is expected to greatly over estimate the representation of these benthic primary producer habitat types, given their rarity in other areas, and will similarly over estimate the extent of potential impacts. Ongoing field surveys will confirm the distribution of these communities on the Lowendal Shelf and around the Lowendal Islands.

Two management units were established to encompass the area of possible damage to benthic primary producer habitats around Varanus Island and Abutilon Island (management units 2 and 3). The management units are each approximately 5000 ha and include the Lowendal Islands and surrounding reef platforms and islets. Management unit 2 lies within the Port of Varanus Island and has a cumulative loss threshold of 10% (Table 11–14). Management unit 3 lies within the multiple use area of the Barrow Island Marine Management Area and has a cumulative loss threshold of 2% (Table 11–14).

Under the anticipated scenario there is potential for loss of up to 7% of known coral habitat in management unit 2 and up to 1% of coral habitat in management unit 3. It is estimated that for areas of unconfirmed coral habitat up to 25% and 63% loss may occur in management units 2 and 3 respectively. Only 1% of the assumed distribution of coral in these management units, as identified by the CALM (2004) marine habitat mapping, has been confirmed by field surveys. Although the predicted potential losses of unconfirmed areas of coral habitat exceed the cumulative loss thresholds for both management units this loss would only represent a threat to ecosystem integrity if field surveys confirm that there are extensive areas of coral in the management units. It is anticipated that only a small proportion of the areas affected by persistent turbid plumes represent coral habitat and that these coral communities would fully recover from sedimentation and turbidity impacts.

The effects on other benthic primary producer habitats and associated faunal assemblages in these management units are predicted to be limited to short-term (< 5 years) reduction in productivity through temporary shading. Partial mortality of corals and macroalgae will be offset by recolonisation of affected areas once the turbidity has been dispersed by currents. No permanent loss of macrophyte-dominated benthic primary producer habitat is predicted for these management units.

Previous impacts in the area comprise exploration and production oil wells and pipelines associated with the Apache Energy operations on Varanus Island. These historical impacts are estimated to have affected less than 1% of the seabed in these management units, mostly within the predicted moderate impact zone from dredging and do not add to the cumulative loss of benthic primary producer habitat.

Barrow Island Port Management Units

Six management units lie within the Barrow Island Port Area, designated by the *Shipping and Pilotage Act 1967* and vested under the *Marine and Harbours Act 1981*. Under the benthic primary producer habitat Guidance Statement (EPA 2004), a port may be classified as a Development Area (Category E) with a cumulative loss threshold of 10%. The whole port area represents an overall management area across which the significance of the predicted cumulative benthic primary producer habitat losses can be assessed.

Table 11-14:
Cumulative Loss Calculations for Benthic Primary Producer Habitat within Lowendal Islands Management Units 2 and 3

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Management Unit 2					
Macroalgae-dominated intertidal limestone reef platform	7	0	0	0	10%
Subtidal limestone reef platform with macroalgae and scattered corals	1483	0	0	0	10%
Reef platform/sand with scattered seagrass	2826	0	0	0	10%
Confirmed coral habitat	113	7	7	7	10%
Unconfirmed coral habitat	408	25	25	25	10%
Management Unit 3					
Macroalgae-dominated intertidal limestone reef platform	0	0	0	0	2%
Subtidal limestone reef platform with macroalgae and scattered corals	2424	0	0	0	2%
Reef platform/sand with scattered seagrass	2221	0	0	0	2%
Confirmed coral habitat	5	< 1	< 1	< 1	2%
Unconfirmed coral habitat	613	63	63	63	2%

[1] *Cumulative loss threshold (EPA 2004)*

The port management units encompass a large proportion of the benthic habitats along the east coast of Barrow Island. They include nearshore reef platform adjacent to the east coast of Barrow Island, the southern Lowendal Shelf, the reef ridge running south from the Shelf and areas of deeper sand veneers over pavement reef (Figure 11-13). All of these areas are within the photic zone and are considered potential benthic primary producer habitat. The distribution of benthic primary producer communities within this area varies spatially and temporally due to natural patterns of sand movement that lead to burial and exposure of rocky substrates. Exposed rocky substrates support macroalgal communities and corals. Rocky substrates covered by a thin sediment veneer support both seagrasses and macroalgae, whereas deeper sediments are likely to support only seagrasses.

The limestone platform adjacent the coast is macroalgae-dominated benthic primary producer habitat and there are significant areas of coral within the port limits. Large *Porites* bombora on the southern edge of the Lowendal Shelf and the reef ridge running south from the Shelf and the large *Acropora* thicket on the south western edge of the Shelf are well developed and would probably take greater than 30 years to recover from serious damage. The nearshore intertidal zone supports a stunted and low biomass macroalgae bed on the reef top, with macroalgae and sparse seagrasses and small corals in the rock pools. The deeper sands of the area support scattered meadows of sparse, ephemeral seagrass, dominated by *Halophila* that rapidly recolonises after disturbance. Corals are scattered at low densities across the subtidal platform reef and are more abundant along the offshore edge and in the larger coral assemblages as shown in Figure 11-13.

The direct disturbance within these management units is associated with proposed construction of the solid causeway and MOF, the dredged access channel for the MOF, domestic gas pipeline (30 m disturbance corridor), open-piled jetty (18 m disturbance corridor), dredged tanker turning/loading basin, dredged shipping channel and optical fibre cable (10 m corridor). Sources of direct disturbance also include damage from anchors during jetty construction and geotechnical drilling and sand accumulation along the causeway (10 m). The areas calculated for infrastructure footprint and corridors include a buffer to allow for edge effects. For example, sediments may persist in sheltered areas in the lee of infrastructure and, while permitting colonisation by seagrasses, may prevent the regrowth of corals and macroalgae

Areas of sedimentation and high, persistent turbidity that are predicted to affect benthic primary producer habitats were predicted by hydrodynamic modelling (Section 11.3 and Chapter 7). Elevated TSS concentrations will lead to short-term loss of benthic primary producers and temporarily reduce the suitability of the substrates for supporting their pre-impact benthic primary producer communities. Sediments deposited on the reef platform are expected to be remobilised over time and transported away from the site by tidal currents. Benthic primary producer habitats within the high and moderate impact zones are predicted to be temporarily damaged unless the zones include benthic primary producer habitat that may not recover to the same pre-disturbance benthic primary producer communities within 30 years. The predicted areas of high or moderate impact do not include any benthic primary producer habitats that would take greater than 30 years to recover.

Previous disturbance within the management unit comprises the existing Barrow Island oil load-out line. A conservative 10 m wide corridor of disturbance was allowed to estimate historical impacts from construction of this pipeline. Aerial photography indicates that the area of current disturbance is approximately 5-10 m wide, although the area in the vicinity of the load-out line still functions as benthic primary producer habitat. Exposed sections of the line support macroalgae and small corals.

Possible historical impacts on the limestone reef platform associated with installation of the terminal tanks at Town Point were not included in cumulative loss calculations because aerial photographs indicate that the reef platform has recovered. Disturbance associated with the previous wharf at Town Point has not been included in the calculations because this area is to be subsumed within the proposed Development area.

Under the best case scenario, the effects of elevated TSS and sedimentation on corals are assumed to be at the lower end of the range of potential impacts to corals. High impacts are only expected in the areas directly modified by infrastructure or spoil disposal including the buffers described above to allow for edge effects. Moderate impacts ranging from bleaching of individual colonies to loss of a large proportion of sensitive species, but not resilient species are expected for areas subjected to persistent and elevated TSS and sedimentation. This is considered realistic in light of the highly conservative nature of the coral health criteria used to delineate the zones of impact. Sedimentation and TSS impacts to most of the benthic primary producer habitat in the moderate impact zones within these management units are short-term (< 5 years) due to predicted sediment resuspension and rapid flushing of turbid water out of the area. Permanent loss of benthic primary producer habitat is predicted to be less than 8% within any of the management units. These losses are below the cumulative loss threshold (10%) for the port management units and are considered sustainable as they would have no impact on ecosystem integrity within either the individual management units, or the port area.

Under the anticipated case, the effects of elevated TSS and sedimentation on corals are assumed to be at the higher end of the range of potential impacts to corals. High impacts are expected in areas exposed to TSS and sedimentation above the conservative criteria outlined in Section 11.3. This is a highly conservative approach that allows for uncertainties in coral response and dredge plume behaviour. The anticipated case also incorporates non-standard management of the trailer hopper suction dredge operation which significantly reduces the amount of sediment resuspension from the dredge propellers. The modelled dredge plumes were based on the trailer suction hopper dredge maintaining an optimum of 4 m of water depth under the keel at all times.

Management unit 8 is the only area within the high impact zone which includes benthic primary producer habitat that would take greater than 30 years to recover. Scattered large *Porites* bombora on the rocky ridge running south from the Lowendal Shelf may take longer than 30 years to fully recover from the effects of turbidity and sedimentation. Permanent loss of benthic primary producer habitat, including the areas removed or buried by infrastructure, may affect up to 23% of the coral in this management unit. While these losses exceed the cumulative loss threshold (10%), they are considered sustainable as not all of the corals are long-lived taxa such as *Porites* bombora. Any *Porites* bombora permanently impacted by sedimentation or TSS will support regrowth of faster growing coral taxa and the associated faunal assemblages are expected to recover almost full functionality within less than ten years.
The permanent loss of benthic primary producer habitat, including up to 23% loss in one management unit, is not predicted to affect ecosystem integrity in the port area.

The worst case scenario assumes the effects of elevated TSS and sedimentation are at the higher end of the range of potential impacts to corals and that the dredge cannot maintain an optimum of 4 m under keel clearance. The impact zones are larger than in the anticipated case due to the increase in sediment resuspension and subsequent sedimentation in surrounding areas. However, as the trailer hopper suction dredge is not a significant source of fine suspended particulate matter that would cause a turbid plume, the inability to maintain an optimum of 4 m under keel clearance does not affect the size of the area affected by elevated TSS concentrations. The high impact zone would affect 23% of the coral benthic primary producer habitat in management unit 8 and the affects are expected to persist for longer than 30 years. The predicted moderate impact zone includes the large *Acropora* thicket on the south-western edge of the Lowendal Shelf (management unit 6) and may cause up to total mortality to this benthic primary producer habitat. The moderate impact zone covers approximately 20% of the confirmed and unconfirmed coral benthic primary producer habitat in management unit 6. The loss of this coral is assumed to be permanent and exceeds the 10% cumulative loss threshold criterion for the management unit. The loss of the *Acropora* thicket in management unit 6 is not considered sustainable as it may have permanent affects on ecosystem integrity in the port area. This supports the need to maintain sufficient under-keel clearance for the THSD to avoid sedimentation impacts to the *Acropora* reef.

A summary of the area of different benthic primary producer habitat types within the Barrow Island Port Area management units and the total cumulative losses of each benthic primary producer habitat expected in each unit, including loss through direct removal, sedimentation and turbidity effects of dredging and existing anthropogenic disturbance is presented in Table 11-15.

Table 11-15:
Cumulative Loss Calculations for Benthic Primary Producer Habitat within Barrow Island Port Management Units

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Management Unit 4					
Macroalgae-dominated intertidal limestone reef platform	435	<1	<1	<1	10%
Subtidal limestone reef platform with macroalgae and scattered corals	2690	2	2	2	10%
Reef platform/sand with scattered seagrass	982	<1	<1	<1	10%
Coral habitats	157	<1	<1	<1	10%

Table 11-15: (continued)
Cumulative Loss Calculations for Benthic Primary Producer Habitat within Barrow Island Port Management Units

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Management Unit 5					
Macroalgae-dominated intertidal limestone reef platform	0	–	–	–	10%
Subtidal limestone reef platform with macroalgae and scattered corals	4652	0	0	0	10%
Reef platform/sand with scattered seagrass	595	0	0	0	10%
Coral habitats	311	8	8	8	10%
Management Unit 6					
Macroalgae-dominated intertidal limestone reef platform	0	–	–	–	10%
Subtidal limestone reef platform with macroalgae and scattered corals	2270	0	0	0	10%
Reef platform/sand with scattered seagrass	1769	0	0	0	10%
Coral habitats	1328	5	5	20	10%
Management Unit 7					
Macroalgae-dominated intertidal limestone reef platform	509	0	0	0	10%
Subtidal limestone reef platform with macroalgae and scattered corals	4032	<1	<1	<1	10%
Reef platform/sand with scattered seagrass	331	<2	<2	<2	10%
Coral habitats	175	0	0	0	10%
Management Unit 8					
Macroalgae-dominated intertidal limestone reef platform	0	–	–	–	10%
Subtidal limestone reef platform with macroalgae and scattered corals	724	0	0	0	10%
Reef platform/sand with scattered seagrass	3424	0	0	0	10%
Coral habitats	61	2	23	23	10%

Table 11-15: (continued)
Cumulative Loss Calculations for Benthic Primary Producer Habitat within Barrow Island Port Management Units

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Management Unit 9					
Macroalgae-dominated intertidal limestone reef platform	0	–	–	–	10%
Subtidal limestone reef platform with macroalgae and scattered corals	0	–	–	–	10%
Reef platform/sand with scattered seagrass	4941	4	7	7	10%
Coral habitats	0	–	–	–	10%

[1] *Cumulative loss threshold (EPA 2004)*

The permanent loss of benthic primary producer habitats supporting coral and macroalgae under the proposed open pile jetty, causeway and in dredged areas will be offset by the growth of macroalgae and corals on the causeway and the jetty piles (Halford and McIlwain 1996; McIlwain and Halford 2001). Potential for enhancing coral community development through provision of additional habitat (e.g. large boulders from the dredge program) will be further investigated as an offset for loss of coral benthic primary producer habitat above the cumulative loss threshold criterion in management unit 8.

The predicted cumulative loss of macroalgae-dominated limestone platform will be offset by regrowth along the rocky edges of the dredged channel and by the provision of elevated hard substrates associated with the jetty and causeway. This could facilitate development of areas of higher macroalgal biomass than in existing areas. Additional macroalgae habitat will be created in the dredge spoil disposal area to the south-east (management units 9, 10 and 11). The net productivity of the port area may be increased by the provision of elevated hard substrates.

Sedimentation and elevated TSS concentrations are predicted to cause temporary damage to benthic primary producer habitats in management units within the port area. The largest temporary losses are predicted for management units adjacent to the dredged areas. These areas will recover their function as benthic primary producer habitat when excess sediment and TSS levels return to levels which allow substrates to support benthic primary producer communities. Water currents and storms are expected to mobilise sediment deposits and facilitate their export from the coastal areas. Recovery is predicted to take less than five years except in sheltered areas. Sediment deposits adjacent the causeway and in coastal embayments on the east coast of Barrow Island are expected to take longer to be mobilised and exported. However, all of the damaged benthic primary producer habitats supporting macrophytes on the east coast are predicted to fully recover in less than 30 years.

Dredge Spoil Ground Management Units

The spoil ground management units (management units 10 and 11) encompass the area proposed for the disposal of dredged material (Figure 11-13). The management units are each 5000 ha and encompass the potential seagrass benthic primary producer habitat surrounding the proposed spoil disposal ground. Management unit 10 lies within the Marine Conservation Reserve boundary and has a cumulative loss threshold of 2%. Management unit 11 is outside the reserve and as a general coastal area has cumulative loss threshold of 5%.

The benthic primary producer habitats within the dredge spoil management units are characterised by deep sandy seabed with occasional emergent pavement reef which supports scattered seagrass meadows dominated by *Halophila.* It is assumed that the whole area is potential benthic primary producer habitat as it may support seagrass at some time, depending on the season and sediment stability. The disposal of boulders and rubble at this site, will lead to a change in the substrate type from sandy seabed to boulder reef. This is expected to be a permanent change to the characteristics of the benthic primary producer habitat in the area.

Under the best case scenario, with no edge effects around the spoil disposal area, the proposed dredge spoil area will permanently modify approximately 5% and 11% of the seabed in management units 10 and 11 respectively (Table 11-16). While these losses exceed the benthic primary producer habitat cumulative loss threshold levels, they do not represent a threat to the ecological integrity of the surrounding benthic primary producer habitat or to the conservation values of the Barrow Island Marine Management Area. The flat sandy seabed in both of these management units is very well represented in both the local area and the region. It is close to the depth limit for the seagrasses and is likely to be of marginal value in terms of seagrass productivity compared to shallower areas closer to Barrow Island.

Under the anticipated and worst case scenarios, an allowance has been made for some edge effects around the spoil ground due to possible redistribution of boulders during cyclones. This buffer zone corresponds to total losses of seagrass dominated benthic primary producer habitat of approximately 6% and 14% within management units 10 and 11 respectively (Table 11-16). These losses exceed the cumulative loss threshold criteria, but are considered sustainable due to the extremely wide distribution of this benthic primary producer habitat type in the area and in the region.

Macroalgae and corals are expected to colonise parts of the spoil ground over the short-term (< 5 years) and the area will regain function as benthic primary producer habitat. However, seagrasses are unlikely to successfully colonise the area and there will be a permanent shift in benthic primary producer community type. This shift to macroalgae and corals is predicted to increase the local productivity and will not affect the ecological attributes of the surrounding seagrass benthic primary producer habitat.

There are no known historical impacts to benthic primary producer habitat in this area and this shift in benthic primary producer habitat is considered ecologically benign. The creation of new macroalgae benthic primary producer habitat in this area will act as an offset to the unavoidable loss of this benthic primary producer habitat type in the nearshore management units.

The nominal 5000 ha management units do not relate to ecologically discrete areas, but are part of a large expanse of relatively homogeneous benthic primary producer habitat of low ecological significance. The spoil ground is predicted to become macroalgae dominated benthic primary producer habitat and will support a diverse assemblage of associated fauna. The local biodiversity is expected to increase due to creation of a new habitat type in the area without affecting the persistence of ephemeral seagrasses in the general area. The permanent loss of the *Halophila* is not expected to effect local populations of turtles or dugong as these areas are expected to be less productive than shallower sandy areas and this benthic primary producer habitat type is very well represented in the region.

Table 11-16:
Cumulative Loss Calculations for Benthic Primary Producer Habitat within Management Units 10 and 11

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Management Unit 10					
Reef platform/sand with scattered seagrass	5000	5	6	6	2%
Management Unit 11					
Reef platform/sand with scattered seagrass	5000	11	14	14	5%

[1] *Cumulative loss threshold (EPA 2004)*

11.4.3 Mainland Coast

Benthic primary producer habitats in the vicinity of the proposed Development on the mainland coast include mangroves, sparse seagrass meadows and limestone platform reef with macroalgae. The proposed Development activities in this area that will affect benthic primary producer habitat comprise the shore crossing of the domestic gas pipeline and the shore crossing of the optical fibre cable.

The proposed domestic gas pipeline traverses a broad mangrove zone adjacent Mardie Station, but does not intercept any regionally significant mangroves. The closest regionally significant area of mangroves identified in the EPA Guidance Statement for the Protection of Tropical Arid Zone Mangroves Along the Pilbara Coastline (EPA 2001) is approximately 6 km to the south of the proposed pipeline crossing (Guideline 1 Level – Robe River Delta area).

The nearshore reef off Onslow where the proposed optical fibre cable will cross the shore supports macroalgae and scattered seagrass on sand (LeProvost Environmental Consultants 1992).

Intertidal and shallow subtidal seagrasses in the vicinity of the domestic gas pipeline and optical fibre cable shore crossings are dominated by ephemeral species, such as *Halophila ovalis* and *Halophila spinulosa.* The benthic habitats that support these seagrasses are very widespread along the Pilbara coast and the shore crossing area is of low conservation significance.

Three management units were established to represent the ecological units of the area as discussed below (Figure 11-14 and Figure 11-15).

Mainland Management Unit 1

This management unit was established to represent the extensive mangrove system that grows along the mainland coast in this region. The coastal mangroves, dominated by *Avicennia marina* and *Rhizophora stylosa,* form an apparently homogeneous linear feature and the management unit encompasses 10 km of coastline centred on the proposed shore crossing, in accordance with the benthic primary producer habitat guidelines (EPA 2004). Although the Development area is outside the 'very highly significant' mangrove area, the EPA mangrove protection guidelines (EPA 2001) require a high level of protection for all mangroves in the Pilbara region. Accordingly the management unit is considered a Category B management unit with a cumulative loss threshold of 1%.

The proposed disturbance within the management unit comprises the domestic gas pipeline (30 m disturbance corridor).

Previous disturbance within the management unit comprises the two existing Apache sales gas pipelines from Varanus Island to Compressor Station 1, operated by Apache Energy. Installation of these pipelines has affected a 30 m wide corridor through the mangrove zone. There has been minor regrowth along the corridor and there has been no detectable additional loss of habitat along the edge of the clearing. Barriers to water movement have been installed across the clearing at the seaward end of the mangrove zone to control tidal erosion of the exposed mud substrate.

Table 11-17 summarises the area of mangrove benthic primary producer habitat within the management unit and the total cumulative loss expected including the proposed Development activities and existing anthropogenic disturbance within the benthic primary producer habitat.

The best case scenario would involve significant regrowth of mangroves on the cleared easement within 30 years, resulting in less than 1% cumulative loss of mangrove benthic primary producer habitat. The anticipated scenario includes minor regrowth, but this has not been taken into account in the cumulative loss calculations. The total cumulative loss would still be less than 1%.

Under the worst case scenario, there would be no regrowth of mangroves along the cleared easement and potential erosion of the strip of mangroves between the Apache easement and the proposed easement. This would lead to loss of up to 2% of the mangrove benthic primary producer habitat in this management unit.

Figure 11-14:
Mainland Management Units, Benthic Habitats and Proposed Infrastructure

Table 11-17:
Cumulative Loss Statistics for Benthic Primary Producer Habitat within the Mainland Management Unit 1

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Mangrove Habitat	920	< 1	<1	2	1%

[1] *Cumulative loss threshold (EPA 2004)*

The cumulative loss of mangrove benthic primary producer habitat under the best and anticipated scenarios is within the guidance threshold. The loss of mangrove benthic primary producer habitat will be offset by predicted regrowth of mangrove and samphire species along the pipeline in the short-term and by restoration of this mangrove if necessary in the longer term. The EPA (2004) lists the main mangrove species *Avicennia marina* as having potential for restoration.

The potential for exceeding the cumulative loss threshold due to the loss of the "island" of mangroves between the two easements under the worst case will be avoided by implementing effective erosion control. Erosion along the Apache easement has been controlled and mangrove trees are regrowing over the pipelines.

Mainland Management Unit 2

This management unit was established to represent the extensive, but variable, seagrass meadows that grow in the shallow subtidal zone along the mainland coast in this region (Figure 11-14). Coastal seagrass meadows are widespread in the Pilbara and are generally spatially and temporally dynamic. The management unit encompasses 10 km of coastline centred on the proposed shore crossing in accordance with the benthic primary producer habitat guidelines (EPA 2004). This area lies within ‘General Coastal Waters’ and it is a Category D management unit with a cumulative loss threshold of 5%.

The proposed disturbance within the management unit comprises the domestic gas pipeline (30 m corridor). Previous disturbance within the management unit comprises the existing Apache sales gas pipelines from Varanus Island to Compressor Station 1, operated by Apache Energy. For the purposes of estimating cumulative impacts, disturbance associated with this pipeline is assumed to extend over the full 30 m wide corridor. This is a conservative approach because seagrass is expected to have recolonised disturbed substrate after the pipelines were buried.

Table 11-18 provides the area of seagrass benthic primary producer habitat within the management unit and the total cumulative loss expected including the proposed Development activities and existing anthropogenic disturbance within the benthic primary producer habitat.

It is anticipated that the seagrasses will recolonise the disturbed sediments within 5 years of construction and there will be no permanent loss of this benthic primary producer habitat. The worst case scenario would involve ongoing erosion adjacent the pipeline that could prevent recolonisation by seagrasses. This would result in permanent loss of less than 1% of the area of seagrass benthic primary producer habitat in the management unit.

Table 11-18:
Cumulative Loss Statistics for Benthic Primary Producer Habitat within the Mainland Management Unit 2

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Seagrass Habitat	2537	0	0	<1	5%

[1] *Cumulative loss threshold (EPA 2004)*

The predicted cumulative loss of seagrass benthic primary producer habitat is within the guidance threshold. *Halophila* is the dominant seagrass in the area and this genus rapidly recolonises disturbed areas of sediment.

Onslow Management Unit

This management unit was established to represent the area of the shore crossing for the proposed optical fibre cable at Onslow (Figure 11-15). The management unit encompasses 10 km of coastline centred on the proposed shore crossing in accordance with the benthic primary producer habitat guidelines (EPA 2004). This area lies within 'General Coastal Waters' and it is a Category D management unit with a cumulative loss threshold of 5% (Table 11-19).

The optical fibre cable is proposed to run along the existing Onslow Salt off-loading jetty at Onslow. This will avoid impacts to benthic primary producers as the cable route will finish in deeper waters (> 7 m deep) beyond the benthic primary producer habitat zone. It is anticipated that there will be no loss of benthic primary producer habitat in this management unit.

Under the worst case scenario, if using the jetty is not practicable, the cable will have to be trenched across the reef platform and an additional 10 m wide swathe of disturbance through the zone of macroalgae and seagrass is assumed (4.3 ha). The disturbance associated with installing the optical fibre cable (10 m corridor) across intertidal and shallow subtidal macroalgae and seagrass beds would represent less than 1% of the benthic primary producer habitat in the management unit. These benthic primary producer habitat habitats have been mapped from nautical charts and regional Geographic Information System data supplied by CALM.

Previous disturbance within the management unit comprises the existing Onslow jetty (3 ha) and the dredged access channel and the dredge spoil ground (Figure 11-15). The dredge spoil ground and dredged channel are expected to be beyond the range of seagrasses in these turbid inshore waters. It appears that the jetty has impacted less than 1% of the benthic primary producer habitat within the management unit.

Figure 11-15:
Onslow Management Unit, Benthic Habitats and Proposed Infrastructure

Table 11-19:
Cumulative Loss Statistics for Benthic Primary Producer Habitat within the Onslow Management Unit

Benthic Primary Producer Habitat Type	Total area of BPPH before disturbance (ha)	Permanent BPPH loss -Best Case- (%)	Permanent BPPH loss -Anticipated- (%)	Permanent BPPH loss -Worst Case- (%)	CLT[1]
Macroalgae and Seagrass Habitat	2127	<1	<1	<2	5%

[1] *Cumulative loss threshold (EPA 2004)*

The cumulative loss of benthic primary producer habitat is within the threshold value for general coastal waters. This disturbance is considered acceptable as it is not expected to affect the integrity of the local benthic primary producer habitat or dependent ecosystem.

11.5 Marine Fauna

The marine fauna of the Montebello/Lowendal/Barrow Island region is typical of the west Pilbara area of the Northern Australian Biogeographic Region (Wilson and Allen 1987). This area also has strong affinities with other areas of the Indo–West Pacific. Many taxa are widely distributed throughout the greater region.

Potential stressors have been identified and the risks of adverse impacts on marine fauna estimated through an assessment of consequences and likelihood. Prior to undertaking risk assessment, key receptors were chosen to represent a range of marine taxa and sensitivities as described in Table 11-20. As the implications of effects of the Development on marine fauna are dependent on the conservation status of the taxa involved, consequence categories were defined for listed (threatened and migratory) and general fauna communities and species (Table 11-21). Likelihood definitions are provided in Table 9-6, Chapter 9. Risk assessment results are summarised in Table 11-23. The risk of introducing marine pests to Barrow Island and surrounding waters is discussed in Chapter 12.

The following stressors pose a medium to high risk of adverse impacts to marine fauna:

- seabed disturbance (construction)
- physical interaction (construction and operations)
- light (construction and operations)
- noise and vibration(construction)
- leaks and spills (construction and operations).

The following stressors pose a low risk of adverse impact to marine fauna:

- seabed disturbance (operations)
- physical presence (construction and operations)
- wastewater discharge (construction and operations)
- noise and vibration (operations).

The stressors that were assessed as posing a medium to high level of residual risk to marine fauna are discussed in the following sections. A summary of the risk assessment for low risk stressors, including management measures that reduce the residual risk to low, is included in Table 11-23.

The aims of the management strategies are consistent with the objectives of fauna recovery plans and action plans developed by the Commonwealth Department of the Environment and Heritage (DEH). The overall objective of the recovery plans is to reduce detrimental impacts on Australian populations of threatened fauna and hence promote their recovery in the wild.

The management strategies outlined in Table 11-23 are consistent with the specific objectives of the Recovery Plan for Marine Turtles (DEH 2003). Specific objectives of the marine turtle recovery plan that relate to the proposed Development on Barrow Island, and the relevant management strategies to meet these objectives, are:

- prevent accidental death, for example by boat strike – speed limits and turtle watches during dredging will minimise boat strikes
- identify information gaps – monitoring programs and field experiments will contribute to greater understanding of the turtle populations around Barrow Island and in Australian waters

- manage factors that affect successful nesting – management of potential effects of light spill onto nesting beaches and nearshore waters and preventing disturbance from vehicles will minimise the disruption of nesting success
- identify and protect critical habitats (natal beaches, mating areas, inter-nesting habitat, feeding areas and pelagic waters) – ongoing surveys of marine turtle nesting around Barrow Island are confirming the critical habitats and management strategies are based on potential impacts within these habitats.

The action plan for Australian cetaceans (Bannister et al. 1996) lists threatening processes as:

- entanglement in lines/plastic debris – waste management will avoid exposure of cetaceans to these threats
- shipping strikes – vessel watches during construction on the west coast will minimise risk of collisions
- oil spills – spill response procedures and absence of ongoing sources of potential spills on the west coast will minimise this risk
- exposure to human wastes/disease – deep well injection of sewage will avoid exposure to human wastes
- pollutants – waste management strategy will avoid exposure of cetaceans to threatening concentrations of contaminants.

Humpback whales are regular visitors to the Montebello/Lowendal/Barrow Island region. The Humpback Whale Recovery Plan (DEH 2005) lists identified threats to humpback whales as:

- the resumption of commercial whaling and/or the expansion of scientific whaling
- habitat degradation.

Potential threats include:

- climate and oceanographic change
- prey depletion due to over harvesting.

Table 11-20:
Key Receptors – Listed Marine Species and General Marine Species

Key Receptor	Reason for Selection	Additional Receptors (represented by key receptor)
Listed Marine Taxa		
Whale shark *(Rhincodon typus)*	Migratory; likely to occur in area	Migratory sharks: great white shark, grey nurse shark
Rock pipefish *(Phoxocampus belcheri)*	Intertidal and subtidal on Barrow Island	Listed pipefish, pipehorses, seahorses
Potato cod *(Epinephelus tukula)*	Listed territorial fish	Large Serranid fishes, non-migratory reef fish
Humpback whale *(Megaptera novaeangliae)*	Migratory whale that passes west coast of Barrow Island annually	Baleen whales: southern right whale, blue whale, pygmy blue whale, Bryde's whale, fin whale, minke whale, sei whale
Sperm whale *(Physeter macrocephalus)*	Occasional visitor to Barrow Island	Beaked and toothed whales: Andrews' beaked whale, Arnoux's beaked whale, strap-toothed beaked whale, Blainville's beaked whale, Cuvier's beaked whale, dwarf sperm whale, ginkgo-toothed beaked whale, Gray's beaked whale, Hector's beaked whale, Longman's beaked whale, melon-headed whale, pygmy sperm whale, Shepherd's beaked whale, southern bottlenose whale, True's beaked whale

Table 11-20: (continued)
Key Receptors – Listed Marine Species and General Marine Species

Key Receptor	Reason for Selection	Additional Receptors (represented by key receptor)
Listed Marine Taxa (continued)		
Common dolphin *(Delphinus delphis)*	Occurs at offshore field and west coast	Dolphins: long-finned pilot whale, short-finned pilot whale, pygmy killer whale, dusky dolphin, Fraser's dolphin, Irrawaddy dolphin, pantropical spotted dolphin, Risso's dolphin, rough-toothed dolphin, southern right whale dolphin, spinner dolphin, spotted bottlenose dolphin, striped dolphin, spotted dolphin
Bottlenose dolphin *(Tursiops truncatus)*	Widespread including nearshore east coast	Nearshore dolphins, Indo – Pacific humpback dolphin
Dugong *(Dugong dugon)*	Occurs off east coast of Barrow Island and along mainland coast	
Green turtle *(Chelonia mydas)*	Nests on west coast of Barrow Island	Leatherback turtle, loggerhead turtle, hawksbill turtle, olive ridley turtle, west coast turtles
Flatback turtle *(Natator depressus)*	Nests on east coast of Barrow Island	East coast turtles
Olive sea snake *(Aipysurus laevis)*	Common off Barrow Island and mainland coast	Listed sea snakes and kraits: short-nosed sea snake, Dubois' sea snake, spine-tailed sea snake, Stokes' sea snake, spectacled sea snake, olive-headed sea snake, turtle-headed sea snake, north-western mangrove sea snake, fine-spined sea snake, elegant sea snake, yellow-bellied sea snake.
Osprey *(Pandion haliaetus cristatus)*	High order avian predator on Barrow Island	Littoral raptors: white-breasted sea eagle *(Haliaeetus leucogaster)*, brahminy kite *(Haliastur indus)*
Greater sand plover *(Charadrius lescheriaultii)*	Barrow Island is important staging site for species	Migratory shorebirds listed under JAMBA/CAMBA and EPBC Act: lesser sand-plover, ruddy turnstone, grey-tailed tattler, red-necked stint
Wedge-tailed shearwater *(Puffinus pacificus)*	Nests on Double Island; juveniles sensitive to light pollution	Migratory seabirds protected under JAMBA/CAMBA and EPBC Act
General Marine Taxa and Communities		
Infauna communities	Widespread in deeper offshore areas of soft sediments	Soft sediment invertebrates
Filter-feeding communities	Widespread on hard substrates in deeper areas	Hard substrate invertebrates

Table 11-21:
Consequence Definitions for Marine Fauna and Marine Benthic Communities

Consequence Category	Minor	Moderate	Serious	Major	Critical
Listed species or evolutionary significant units	*Species behaviour*				
	Local and short-term behavioural impact.	Widespread, short-term or local, long-term behavioural impact.	Widespread and long-term behavioural impact.		
	Population viability				
	Local and short-term decrease in abundance.	Local, long-term or widespread, short-term decrease in abundance. No reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Reduced local population viability. No reduction in population viability on Barrow Island or in surrounding waters.	Local, long-term or widespread, short-term impact on population. Reduced population viability on Barrow Island or in surrounding waters.	Widespread, long-term impact on population. Extinction on Barrow Island or reduced viability in the immediate region.
General fauna species and communities (not listed)	*Species behaviour*				
	Widespread, short-term or local, long-term behavioural impact.	Widespread and long-term behavioural impact.			
	Population viability				
	Local, long-term or widespread, short-term decrease in abundance. No reduction in local population viability.	Local, long-term or widespread, short-term decrease in abundance. Reduced local population viability. No reduction in population viability on Barrow Island or in surrounding waters.	Local, long-term or widespread, short-term impact on population. Reduced population viability on Barrow Island or in surrounding waters.	Widespread, long-term impact on population. Extinction on Barrow Island or reduced viability in the immediate region.	Extinction in the immediate region.

The Joint Venturers are committed to adopting all the management measures outlined in this section to avoid or mitigate impacts to marine fauna. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses, it may become necessary to modify management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and targets will be developed.

11.5.1 Seabed Disturbance

The seabed will be disturbed in the areas proposed for the offshore wells, pipelines, shipping channels, jetty, causeway, MOF, optical fibre cable and the dredge spoil ground. Disturbances to the seabed include impacts from placement of infrastructure, modification of seabed type and temporary disturbance from activities such as vessel anchoring. The areal extent of seabed disturbance is provided in Table 11-2 and the impacts on benthic primary producer habitats, including corals, are described in Section 11.4. The effects on fauna associated with the seabed disturbance are described below with particular reference to species listed as threatened or migratory under the EPBC Act or the Wildlife Conservation Act.

The key receptors that are likely to be impacted are:

- listed rock pipefish (and possibly other listed Sygnathids)
- general infauna communities
- general filter feeding communities.

Seabed disturbance associated with development of the offshore Gorgon gas field will not affect any listed marine threatened or migratory species. General marine fauna assemblages will be affected through disturbance and modification of benthic substrates. Seabed disturbance during construction will have a direct and immediate impact on benthic communities in the vicinity of proposed marine infrastructure. During operations, loss or modification of habitats will have an ongoing impact on fauna associated with seabed substrates. However, in both cases, areas that will be affected do not represent critical habitat to any listed species and disturbance will be localised. No impact on ecosystem integrity is expected.

Subsea Gathering System – Drill cuttings will form primary areas of deposition on the seafloor, with mounds and layers of disposal solids, and secondary halos comprising thin veneers of dispersed solids. Although drilling fluids and cuttings will be of low toxicity and cuttings from the well bore will be treated to remove the majority of drilling fluids prior to disposal, there may be some alteration in community composition due to the shift in physical sediment characteristics. Burrowing fauna beneath the outer halos are likely to migrate through the solids, with some limited mortality to some species. The primary deposits may bury or smother pre-existing infauna, which will recolonise affected areas over time. Losses of habitat and sediment infauna will be insignificant relative to the widespread distribution of homogeneous habitat in the deep water areas of the region. Furthermore, impacts to infauna will be short-term and offset by recolonisation from surrounding habitat and settlement of planktonic larvae.

Changes to benthic habitats through deposition of drill cuttings are not expected to impact any of the listed species in the region. The listed marine fauna that occur in the area include humpback whales and possibly sperm whales, common dolphins and whale sharks. None of these species have a close association with the seabed in deep water (>200 m) around the proposed well sites and no direct or indirect impacts on listed species are anticipated.

Physical disturbance to the marine environment caused by the installation of the subsea trees, manifolds and flowlines will cause negligible impact relative to the likely widespread distribution of affected habitats. Primary impacts are expected to be limited to the seabed beneath facilities and the area disturbed by lay-barge anchors. Secondary effects from sediment resuspension will also be localised with rapid recovery by vertical migration or resettlement by larval and migratory infauna. Experience in similar environments of the North West Shelf has shown that subsea structures provide an increased availability of habitat niches and are rapidly recolonised by a diverse biota. Provision of hard substrates and three dimensional structures in an area dominated by vast expanses of silty sediments will increase the diversity of habitats available for recolonisation after construction. Installation of subsea facilities is therefore expected to have a localised impact on community composition and increase biodiversity as both soft and hard substrate communities develop.

Subsea Feed Gas Pipelines – Construction of the feed gas pipelines from the gas fields to the west coast of Barrow Island is expected to cause localised disturbance to soft sediment infauna communities over most of the route. Filter-feeding invertebrate communities may also be affected during construction activities in sections of the route where they occur. Two areas of higher profile reef will also be traversed by the pipelines. The impacts to sediment communities are expected to be localised and short-term. The pipelines may cause a change in community composition at a local scale by increasing the area of hard substrate in an environment where it is limited. Impacts on reef areas are expected to be very localised and restricted to slight changes in the distribution of filter-feeders and fish. Potentially, listed grey nurse sharks and large Serranid fish could occur in reef areas impacted by the pipelines. These could be temporarily disturbed during installation, but no mortality is likely to occur. These changes are not expected to affect ecosystem function or viability.

Feed Gas Pipelines Shore Crossing – Horizontal directional drilling is the favoured construction method for the shore crossing for the feed gas pipelines (Chapter 6). This method of construction will reduce the area of direct seabed disturbance in inshore areas, but may result in the short-term deposition of drilling fluids and cuttings at the pipeline exit points. Turbidity may also be generated from jetting seaward of the pipeline exit points to create a gentle transition between the exit angle and the seabed. The very energetic nature of this area under normal conditions will result in dispersion of drilling fluids.

The non-preferred alternative method for the shore crossing is laying the pipe on/above the seabed (Chapter 6). This would require a temporary jetty/groyne out to approximately 5 m water depth (~200 metres from the shore line) to provide access for equipment to stabilise the pipelines.

Green turtles are very common in the shallow waters off the west coast of Barrow Island, where they feed and congregate to breed and nest on beaches. Green turtles feed on macroalgae on the subtidal reefs along the west coast throughout the year. Hawksbill turtles are less abundant around Barrow Island, but nest on the north-western beaches of the island and are likely to occur in small numbers in the area of the proposed North White's Beach shore crossing. The shallow portion of the pipelines will disturb a small proportion of the substrate where green turtles graze on algae and hawksbill turtles may forage on invertebrates. Changes to benthic substrates will not affect the local populations of these turtles apart from some minor behavioural changes (i.e. temporary avoidance).

Rock pipefish *(Phoxocampus belcheri)* and other Sygnathid fishes are widely distributed throughout the region and may occur on the western side of Barrow Island. The substrates that will be affected by installation of the pipelines may provide habitat for these listed fish. However, these habitats are widespread and no areas of particular importance are likely to occur along the pipeline routes.

Port and Marine Facilities – The proposed MOF and solid causeway will overlie an area of intertidal and shallow limestone pavement. Dredging for the MOF access channel will change the benthic habitats from a rock platform to a sandy channel. Loss and modification of the substrate could directly impact EPBC listed species of Sygnathid fishes. The rock pipefish *(Phoxocampus belcheri)* has been recorded from intertidal rock pools on Barrow Island and other Sygnathids may occur within the area to be disturbed. Intertidal and shallow limestone shelf habitats occur extensively along the entire Barrow Island east coast, and the area to be covered by the proposed marine port facilities comprises considerably less than 1% of that habitat. Green *(Chelonia mydas)* and loggerhead (*Caretta caretta)* turtles have been observed feeding in the general area, while flatback *(Natator depressus)* and to a lesser extent, hawksbill *(Eretmochelys imbricata)* turtles nest on the beaches and can occur in the shallows during their breeding season. The loss of substrate from construction of the port facilities will not significantly reduce the feeding and resting areas available to these turtles.

Dugong *(Dugong dugon)* are uncommon visitors along the east coast of Barrow Island, but will occasionally move through the area affected by the proposed marine facilities. Although seagrasses that may be grazed by dugong occur in the area of seabed to be disturbed, these are not extensive and the minor loss will not affect dugong populations.

The area proposed to be dredged includes limestone pavements and sand veneers supporting sparse communities of algae and filter feeding animals, such as sea pens and gorgonians. These communities will be lost and the seabed converted into a deeper, sandy substrate environment. Infaunal communities that develop in these channels may be disturbed each time the channel is dredged for maintenance.

The change in seabed depth and physical characteristics due to dredging is not expected to affect any listed species. Syngnathid fishes may occur in the area, but the benthic substrates are widely represented in the local area and it is highly unlikely that the areas to be dredged include any critical habitat.

The proposed jetty traverses two coral communities and there may be localised, long-term changes in the faunal communities at these locations. Generally, benthic communities are expected to recover rapidly from disturbance and, in instances where subsea structures provide an increased availability of habitat niches, new faunal communities will develop.

Domestic Gas Pipeline and Optical Fibre Cable – The optical fibre cable and the domestic gas pipeline will disturb the seabed between Barrow Island and their respective shore crossings, at Onslow and near Robe River. Surveys to date have found that the seabed along the majority of these routes comprises bare sands. The main areas of hard substrate and associated increased biotic assemblage occur in the shallower areas adjacent to the shore crossings.

The disturbance to the seabed along these corridors will include plough burial of the optical fibre cable, placement and stabilisation of the domestic gas pipeline on the seafloor and anchoring necessary to maintain the position of construction barges during installation. Installation of the domestic gas pipeline and optical fibre cable will cause minimal disturbance to marine biota between Barrow Island and the mainland shore crossings. The width of the disturbance zone is narrow (30 m) and areas of significant biotic abundance are limited. Effects on EPBC listed Sygnathid fishes are expected to be very limited and would most likely relate to short-term displacement as infrastructure is being installed.

The shore crossing for the domestic gas pipeline on the mainland will pass through intertidal sand flats which support sparse faunal communities and mangroves which support more diverse faunal communities. Disturbance of sand flats is expected to cause highly localised and short-term changes to benthic communities. Disturbance of mangrove habitat is expected to cause a shift in mangrove infaunal and epifaunal taxa in the immediate area of disturbance. The outer sand flats support sparse seagrasses, and these are a food source for dugong. Dugong occur in the area and are expected to feed on the extensive shallow areas in the region that support seagrasses. Disturbance to seagrasses through the narrow pipeline corridor will not have any significant affect on dugong.

Mangroves are recognised as important habitats with numerous obligate inhabitants and are well distributed around the tropical Australian coastline. This wide geographical range ensures a broad distribution of most of the inhabitants, and none of the obligate species are EPBC listed.

Management

Planning and construction management measures will primarily target: minimisation of the extent of seabed disturbance from dredging and other construction activities during the detailed design phase.
These measures include:

- selecting dredge spoil grounds to avoid areas that support well developed epifaunal assemblages
- adhering to an anchor management plan that specifies anchoring positions
- avoiding impacts to areas of particular habitat value (e.g. Biggada Reef)
- implementing approved drilling Environment Plan as per Commonwealth *Petroleum (Submerged Lands) Act 1967*
- selecting final mainland shore crossing location to avoid critical shorebird habitat
- reducing dredge plume effects by incorporating the results of modelling studies and biological surveys into mitigation measures that are applied during construction.

Habitat created by seabed structures such as the causeway and exposed areas of pipeline may enhance the local pipefish populations.

Residual Risk

The proposed Development will disturb the seabed during development of the Gorgon gas field, installation of the feed gas pipelines from the gas field to Barrow Island, construction of the port facilities, and construction of the domestic gas and optical fibre cable to the mainland. A number of species protected under the EPBC and Wildlife Conservation Acts are known to occur in the areas to be affected. The key receptor species that could be affected by the Development are:

- whale shark *(Rhincodon typus)*
- rock pipefish *(Phoxocampus belcheri)*

- potato cod *(Epinephelus tukula)*
- humpback whale *(Megaptera novaeangliae)*
- sperm whale *(Physeter macrocephalus)*
- common dolphin *(Delphinus delphis)*
- bottlenosed dolphin *(Tursiops truncatus)*
- dugong *(Dugong dugon)*
- green turtle *(Chelonia mydas)*
- flatback turtle *(Natator depressus)*
- olive sea snake *(Aipysurus laevis)*
- osprey *(Pandion haliaetus cristatus).*

Other non-listed, key receptors (evolutionary significant units) that will be affected are:

- infauna communities
- filter feeding communities.

Whale Shark – Whale sharks, great white sharks and grey nurse sharks have not been described from Barrow Island waters, but may occur in low numbers as vagrants travelling through the area. They are most likely to occur in the deeper waters off the west coast of Barrow Island.

The effects of seabed disturbance on these sharks species is considered minor. Direct impacts will not occur, nor are significant indirect effects likely. The only possible residual risks are low, and relate to possible behavioural responses, such as temporary attraction to the wellheads or pipelines.

Rock Pipefish – The distribution of the listed Sygnathid fishes around Barrow Island is unknown, but at least one species, the rock pipefish, has been identified in the area. Potentially, members of this family could occur in any of the marine areas proposed to be developed where the seabed comprises hard substrate.

The possible effects on rock pipefish range from minor to moderate. The greatest possible effect is mortality or displacement of some individuals within proposed dredge areas. Habitats represented in dredge areas are not unique, but are typical of the broad intertidal and shallow limestone pavement on the east coast of Barrow Island. Any loss of habitat would be negligible relative to the total area of similar habitat elsewhere.

The residual risk of effects to Sygnathid fishes is low to medium with most risk related to the short-term impacts associated with construction of marine infrastructure.

Potato Cod – The scale of effects of the proposed Development on potato cod and the other large protected Serranid fishes is minor. These species potentially occur throughout the Development area predominantly in areas of high profile reef. The effects of seabed disturbance are expected to be limited to localised, short-term behavioural changes. These fish are commonly associated with the existing offshore petroleum industry infrastructure and could possibly be attracted to high profile components of the Gorgon subsea facilities. The residual risk to these fish from disturbance of the seabed is low.

Cetaceans – Humpback and other baleen whales may move through the areas where the seabed disturbance will occur. The associated effects to these species from seabed disturbance will be minor. Whales may possibly exhibit some behavioural responses to the dredged channels, but are unlikely to respond to other marine infrastructure. The residual risk to baleen whale species is low.

The deep water toothed whales and dolphins, represented by sperm whales and common dolphins, are occasional transients through the deep waters to the west of Barrow Island. Little is known about the behaviour of many of these cetaceans; however it is highly unlikely that any disturbance of deep water substrates caused by establishment of subsea wells and pipelines will affect these species. The resultant risk of any effects is low.

Bottlenose and Indo – Pacific humpbacked dolphins are abundant on the shallow Rowley Shelf, including Barrow Island. They are commonly observed in very shallow waters adjacent to the east coast of the island. The effects of seabed disturbance to these taxa are expected to be minor. The change in substrate and depth could possibly change the population of prey species in areas where the seabed has been disturbed, and dolphins could modify their feeding patterns in response. These behavioural modifications represent a minor consequence and the residual risks are considered low.

Dugong – The disturbance to the seabed caused by the Development is expected to have a minor effect on dugongs. These animals are uncommon visitors to Barrow Island, but more common further inshore, including the area where the domestic gas pipeline shore crossing will occur. The narrow corridor of seabed disturbance across areas that presently support seagrasses may result in some minor modification to feeding patterns. These seagrasses are widespread in the shallow nearshore zone and the discreet area of seabed disturbance will have either no, or only minor effects on dugong behaviour. The residual risks to dugong posed by seabed disturbance are low.

Sea Turtles – Change in seabed substrate may have minor effects on green, hawksbill or loggerhead turtles and will mostly be related to feeding and resting behaviour. Small areas on the west coast of Barrow Island which presently support algae utilised by green turtles could be disturbed. The increased micro-habitat provided by the solid facilities and the pipelines could support prey species for hawksbill and loggerhead turtles and members of these taxa could be attracted to the structures. Turtles have been observed resting on the seabed adjacent to artificial structures and could similarly rest beside and under the pipelines.

Flatback turtles are occasionally observed in the shallow nearshore waters during the day. Areas of habitat which will be overlain by the port facilities will be lost. This displacement should be of minor consequence to flatback turtles, and the residual risk is considered to be low.

Olive Sea Snake – Sea snakes are common inhabitants of the waters around Barrow Island and the shallow Rowley Shelf. These animals do not appear to be territorial or migratory and are not generally found in association with specific habitats. Disturbance to the seabed is not expected to affect this group other than to restrict them from the area to be overlain by the port facilities. The consequence of this restriction is minor and the resultant risk to sea snakes from seabed disturbance is low.

Shorebirds – The effects of the seabed disturbance to migratory shorebirds will be limited to the loss of a small area of intertidal foraging habitat at Town Point. This area is not important to listed shorebirds (Technical Appendix C3) and the consequences will be minor. The risk to shorebirds is low.

Infauna Communities – The majority of the seabed at the gas fields and along the pipelines and optical fibre cable is comprised of sand and silt substrates. These support filter feeding and burrowing fauna. The burrowing fauna, termed infauna, is diverse with typically extensive distributions. The disturbance to the seabed will have localised effects pertaining to the direct areas disturbed. The change in substrate type caused by the deposition of drill solids while drilling the production wells will probably favour some species, possibly resulting in a localised population shift. The narrow zone of seabed overlain by the pipelines will also be unavailable to burrowing organisms. The very extensive distribution of soft sediments and the infaunal communities they support means that localised changes in populations resulting from seabed disturbance are of minor consequence and will not affect the viability, distribution or diversity of any community or individual species. The residual risk to these communities and individual taxa are low.

Filter Feeding Communities – A number of filter feeding taxa and communities occur within the areas proposed to be disturbed by the Development. In deeper offshore areas, sea pens (Order Pennatulacea) and hydroids (Order Hydroida) are the dominant soft substrate filter feeders. These occur in sparse, widespread distributions and any disturbance caused by the Development will be minor. The population of filter feeders along the deeper section of the feed gas pipeline routes will increase, provided the pipelines are exposed, as various species colonise the available hard substrate.

The shallower areas of the Development area support filter feeding species and communities comprised mainly of Phyla Porifera (sponges) and Cnidaria (soft corals and hard corals). Generally, hard corals require light and are most abundant in depths less than 40 m. Sponges and soft corals are not light dependant and their distribution is more dependant on substrate availability, food source and competition.

The consequences of disturbance of the seabed to the local filter feeding organisms and communities will be minor to moderate. The area to be dredged includes a discrete area supporting hard coral colonies and more extensive areas of sparse soft corals. Those areas will be lost and will not re-colonise the deeper channels. There are also scattered corals in the shallow area to be overlain by the port facilities. Hard and soft corals will probably comprise part of the colonising fauna on the submerged component of the rock walls and exposed surface of the shallow sections of the pipelines. The residual risk to these communities and individual organisms are low to moderate.

11.5.2 Physical Interaction

Potential impacts due to physical interaction between construction activity (workforce, machinery and equipment) and fauna include:

- collisions between marine fauna and vessels
- mortality of sea turtles entrained in the dredge
- fishing pressure on local fish stocks
- workforce disturbance to beach fauna such as turtles.

There is potential for collisions between vessels and marine fauna (e.g. whales, turtles and dugongs), particularly during construction. The period of greatest potential impact will occur during construction of marine facilities which will take approximately 18 months to complete and require numerous vessels, including cutter suction and trailer suction hopper dredge barges, over an area of approximately 214 ha. The operations phase of the Development will require considerably fewer vessels with approximately two barges travelling to and from the island per week, one LNG tanker visit every three days and one condensate tanker per month (in addition to existing oilfield operations).

Dredging will result in a localised risk to benthic fauna. Turtle fatalities caused by dredging in shipping channels have been recorded in other parts of the world. The capture and mortality of sea turtles by hopper dredges was first identified as a problem in the late 1970s. Since this time incidental takes of sea turtle have primarily been documented from hopper dredge operations that use trailing suction drag heads (Dickerson et al. 2004). Thus far, no incidental takes of sea turtles have been reported from cutter suction or other types of dredges operating in coastal channels in south-eastern United States of America (Dickerson et al. 2004). It is observed elsewhere (Plotkin 2003). Other species likely to be at risk from dredging include dugongs and sea snakes. Cetaceans are expected to avoid the area of the dredging operation.

The location of flatback foraging grounds and internesting habitat surrounding Barrow Island is not known. Their preference for soft bottom habitat (Plotkin 2003) suggests they may be found in the area of the proposed shipping channel off the east coast of Barrow Island, although this area does not typically have the turbidity that is also preferred (Parmenter 1994). In the absence of evidence to the contrary, it is assumed that resident and/or breeding flatback turtles may be present on the seabed in areas proposed for dredging off the east coast.

Two summer turtle nesting seasons could potentially be affected by the 18-month dredging program. Preliminary survey results of flatback nesting at Barrow Island suggest that the bulk of annual nesting (~90%) occurs during December and January (Technical Appendix C7 – Attachment 1). Nest count data (2004/2005 nesting season) suggests that the total nesting population using the east coast of Barrow Island may be less than 5000 animals. Individuals from this population are thought to return to the Barrow Island nesting grounds every 1–3 years to nest, with an average remigration period of over 2 years (Parmenter 1994; Pendoley 1999). Sea turtles are long lived animals that take up to 30 years to reach sexual maturity. The habitats and life stages potentially at risk from dredging off the east coast of Barrow Island include:

- resident foraging (sexually immature) juvenile and adult green and flatback turtles year round
- migratory mating male and female turtles and internesting female green and flatback turtles during the summer breeding period
- resident post-hatchling and sub-juvenile flatback turtles in their nursery habitat surrounding Barrow Island year round.

Internesting females may be sensitive to disturbance from dredging with potential impacts ranging from mortality to interrupted or delayed egg development as a result of stress. The consequences of these impacts are loss of breeding females from the population and/or a reduction in nesting success for a given season. Protection of adults and large juveniles is critical to ensuring the long-term viability of turtle populations (Chaloupka and Musick 1997; Heppell et al. 2003).

Fishing by the operations workforce (approx. 150–200 personnel) has the potential to put increased pressure on local fish stocks and to increase the likelihood of hooking or line entanglement of juvenile green turtles. Increased pressure on fish stocks may be offset by aggregation or enhancement of fish populations around infrastructure.

Pedestrians on beaches at night can deter nesting female turtles from emerging onto the beach and lead to displacement of nesting activity to adjacent beaches. Pedestrians can also compact the sand on top of turtle nests and reduce the ability of turtle hatchlings to leave the nest.

Management

The Joint Venturers are committed to adopting the following planning and operational measures to avoid or mitigate disturbance to marine fauna. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses it may become necessary to modify management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and performance standards/targets will be developed.

The priority for management is to conduct surveys to investigate utilisation of seabed habitats by resident and internesting flatback turtles off the east coast of Barrow Island. Results from surveys and satellite tracking studies will establish whether or not flatback turtles are using seabed areas off the east coast of Barrow Island as resting and internesting habitats and if management strategies such as relocation of turtles and modification of dredge specifications (i.e. turtle deflection devices) will be necessary.

The Joint Venturers will adopt management strategies that avoid and mitigate impacts to marine fauna caused by dredging, vessel collisions and workforce activity.

Workforce management strategies that will be adopted are to:

- conduct employee induction, awareness and training aimed at building a culture of environmental awareness and understanding of the conservation values of Barrow Island and surrounding waters
- enforce workforce rules on interaction/interference with marine fauna through terms of employment
- restrict recreation in designated areas at selected times (e.g. control of workforce access to beaches including strict regulation of beach access during the turtle nesting period)
- provide recreational facilities within the construction village to limit requirement for recreational activity outside of the construction village
- continue the current ban on shell collecting in accordance with Department of Conservation and Land Management (CALM) regulations
- prohibit fishing or recreational boating during construction phase of the Development
- implement strict controls of fishing during operations to avoid pressure on fish stocks.

Engineering and design strategies that will be adopted are to:

- use turtle deflection devices on the dredge barge. A common type of turtle deflection device comprises chains welded onto the suction pipe a short distance (approx. 5 m) forward of the drag head. As dredging occurs at low speed (less than 2 knots), resting turtles will be alerted by the chains dragging along the seabed and will move away. Another type of turtle deflection system involves installation of a shaped skirt just forward of the drag head. As it lightly ploughs the surface of the seabed it should deflect turtles (and any other marine life) away from the drag head (akin to a bull-nose on a train). The effectiveness and applicability of these and other deflection devices will be further investigated and will be applied during the dredging program if surveys confirm that flatback turtles are using seabed habitat in the proposed dredge area off the east coast of Barrow Island for resting and internesting.

Operational control strategies what will be adopted are to:

- enforce vessel speed limits during construction and operations dredging
- relocate turtles using controlled trawling methods if turtle deflection devices are not satisfactory and turtles are being entrained, and injured or killed, by operation of dredge barges (standardised trawl techniques have been developed by the US Army Corps of Engineers – http://www.saj.usace.army.mil/pd/trawl.htm)
- plan maintenance dredging to avoid the peak sea turtle summer breeding seasons
- review management if deflection devices or physical removal is not satisfactory and turtles are colliding with vessels or becoming entrained in the dredge.

Survey and monitoring strategies that will be adopted are to:

- establish a turtle tagging and monitoring program on the east coast of Barrow Island, designed in conjunction with CALM, to investigate turtle population size and distribution. Program will include a control site (e.g. within the Montebello Island group)
- survey flatback turtles over winter 2005 to determine and understand their movements in nearshore areas off the east coast of Barrow Island

- conduct satellite tracking program over the summer of 2005/2006 to identify flatback turtle internesting grounds off the east coast of Barrow Island and migratory pathways to and from foraging grounds
- use fauna monitors stationed on the dredge to document presence of sea turtles in intake screens (will allow effectiveness of deflection devices to be determined)
- monitor and document stranding of turtles on beaches during the dredging program.

Residual Risk

Sea Turtles – In the absence of data on flatback turtle habitat use, population size and threats to the nesting population in remote foraging grounds, the level of risk associated with the dredging program off the east coast of Barrow Island has been assessed for two scenarios:

- that resident and internesting flatback turtles are not using areas to be dredged and are therefore not at direct risk from mortality or disturbance
- that flatback turtles are present in the area to be dredged.

The majority of the dredging in the MOF access channel and shipping channel and turning basin will be undertaken by a cutter suction dredge, which will have low incidence of turtle entrainment. If the proposed shipping channel does not represent habitat for either resident or internesting flatback turtles, then the likelihood of significant numbers of flatback turtles being directly impacted (i.e. 10s) while moving through, or foraging in, the dredge area is not likely to occur. The consequence will be moderate as only a small number of individuals are likely to be affected. The residual level of risk is therefore low.

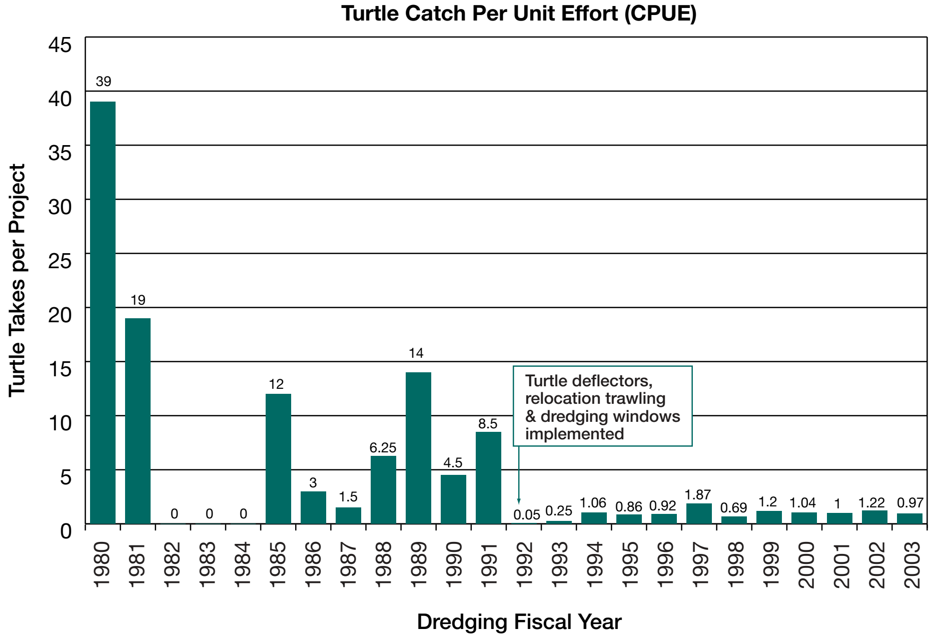
If it is assumed that resident and/or migratory internesting flatback turtles do utilise the dredge areas then the effectiveness of management strategies is critical to keeping risk associated with dredging to an acceptable level.

There are numerous examples both domestically and internationally which demonstrate that protective measures such as turtle deflection devices can be very effective in reducing turtle mortality associated with dredging. During a 3-month period in 1980, dredging operations in the Port of Canaveral, Florida, were responsible for the mortality of at least 71 sea turtles (National Research Council 1990). Since this time a significant reduction in incidental takes of sea turtles has been achieved by the implementation of management measures such as turtle deflectors, relocation trawling and selected dredging windows. Monitoring by the US Army Corps of Engineers has found that prior to 1992, when protective measures were starting to be widely adopted, figures for sea turtle incidents per project ranged from 3 to 39, whereas starting in 1992, these numbers dropped to 0.25 to 1.87 turtle takes per project (Dickerson et al. 2004) (Figure 11-16). The most recent results of this monitoring program are based on more than 50 dredge projects in south-eastern USA (Dickerson et al. 2004). The Port of Brisbane Corporation has also implemented protective equipment and techniques on dredging operations in the last two years, including fitting turtle deflectors to drag heads, site-specific scheduling of dredging to avoid peaks in turtle abundance and monitoring and consequently has also achieved a reduction in turtle mortality (http://www.portbris.com.au/asp/environment/initiatives/2001/study10.asp [accessed 26 April 2005]). Underwater video footage has confirmed the effectiveness of the Corporation's modified dredging procedures.

Potentially two-thirds of the local migratory nesting turtle population could be present during dredging operations (the local flatback population returns to nest on a 1– 3 year remigration cycle). A proportion of these may utilise the shipping channel for internesting. A component of the resident flatback turtle population may also forage in the area. If not displaced by dredging noise and vibration, and if the protection measures are not effective, mortalities could affect both populations. Vessel strikes associated with construction activity could also cause turtle injuries or mortalities, although speed restrictions and fauna watches will reduce this risk.

Loss of internesting females would cause a decrease in the abundance of the Barrow Island nesting population until large juveniles reach sexual maturity and replace nesting females lost to dredging (approx. 10 years based on 14% recruitment rate as estimated by Parmenter and Limpus 1995). Removal of large sexually immature juveniles would also increase the period of reduced population numbers since they are no longer available to recruit into the breeding population.

Figure 11-16:
Catch Per Unit Effort (CPUE) for Sea Turtle Takes Per Dredging Projects with Sea Turtle Monitoring (Source: Dickerson et al. 2004).



Vessel collisions are unlikely to involve significant numbers of turtles. Based on effectiveness of protective measures on other dredging operations, and the Gorgon Joint Ventures' commitment to use turtle defectors and trawling if necessary, dredging operations are unlikely to result in the loss of large numbers of turtles. The consequence of the long-term, local reduction in abundance would be moderate. The likelihood of this consequence is almost certain. The residual risk is therefore medium.

If the dredging area supports significant numbers of resident turtles and protection measures do not successfully reduce mortalities, the reduction in the size of the resident population would have an impact on the number of sexually mature animals that are available to migrate from Barrow Island to remote (and currently unidentified) nesting beaches. This could result in reduction in nesting populations away from Barrow Island and a reduction in sexually immature juveniles available to recruit into the nesting population at the remote nesting grounds. As the status of the populations of these remote nesting populations is unknown, these losses could affect local population viability. This would be considered a serious consequence. The likelihood of dredging resulting in this consequence is possible to likely. The residual risk is therefore medium to high.

Reduction in mating success through sub-lethal collisions is unlikely to have long-term population level consequences since the disturbance is of short duration relative to the potential 30-year breeding period of flatback turtles (Parmenter and Limpus 1995). Internesting females are the life stage most sensitive to dredge or trawl induced stress. The biological consequence of reduced egg development and/or retention rates in internesting females is reduced nesting success rates over two consecutive summers. It is unlikely this loss will be detectable over the inherently high hatchling mortality rates (Parmenter and Limpus 1995 estimate flatback hatchling survivorship to maturity at 1 in 400). Therefore, the consequence of this effect would be minor. Likelihood of this consequence is almost certain and residual risk is low.

Periodic maintenance dredging will be necessary to remove silts which accumulate in the shipping channel and maintain the required water depth. Modelling of sedimentation rates indicates that very infrequent maintenance dredging will be required. Maintenance dredging will be scheduled to avoid the turtle nesting season.

If the proposed shipping channel does not represent habitat for either resident or internesting flatback turtles then dredging is considered to pose a low level of risk to flatback turtles. If flatback turtles do utilise the seabed off the east coast of Barrow Island, and management measures effectively mitigate impacts to flatback turtles as anticipated, then the level of risk is considered to be medium. However, if the trailer suction dredge cannot be successfully modified to prevent turtle mortality, then the consequence of potentially reduced viability of the resident flatback population results in a high level of risk. The overall risk to flatback turtles from dredging is therefore considered to be low to high.

If worker access is limited and controlled the consequence of workforce disturbance to turtles will be minor. Startled nesting females are likely to return to nest later the same night or the next day. The residual risk of adverse impacts from physical interaction between sea turtles and the workforce is therefore low.

Fishing impacts on juvenile turtles will be significantly reduced to a minor level if fishing is banned during construction and strictly controlled during operations.

Whale Sharks

The whale shark *(R. typus)* is a listed migratory species under the EPBC Act. Little is known about its population size or distribution in Western Australian waters but it is estimated that between 200 and 400 whale sharks appear off Ningaloo Reef each autumn (Davis et al. 1997). It has not been recorded from Barrow Island, but is known to occur on the North West Shelf, including the offshore islands of the Montebello/Lowendal/Barrow Island region, and may occur in areas associated with the Development. Large numbers of this species in the vicinity of the Development are unlikely given the apparent absence of upwellings or other habitats thought to encourage aggregations.

Whale sharks are large and highly mobile. With the management proposed, collisions with vessels associated with the Development are not expected, but could occur. Injury or fatality to a very small number of these sharks may result. If mortalities occurred, the consequences would be moderate, causing a short-term decrease in the abundance of whale sharks in the local area but not affecting population viability. It is considered possible to unlikely that physical interaction would result in this consequence. The residual risk of adverse impacts from physical interaction between whale sharks and the workforce or vessels is therefore low to medium.

Whales

Listed EPBC Act threatened and migratory whale species that may occur in areas affected by the Development include the blue whale, humpback whale, Antarctic minke whale, Bryde's whale, killer whale, sperm whale and sei whale. There are no recognised feeding or breeding areas for whales in the immediate region surrounding Barrow Island.

Physical interaction with whales is could possibly cause local, short-term behavioural impacts, such as avoidance of the dredge and pipe-lay vessels. In the event that whales do not successfully avoid vessels, collisions could result in injury or fatalities. The bulk of construction and operational vessel activity will occur off the east coast of Barrow Island where there are unlikely to be significant numbers of whales. Vessel movements off the west coast, particularly during the humpback migration period, would be more likely to encounter whales. Management measures, which include reduced vessel speeds and marine fauna watches, would reduce the likelihood of collisions with whales but it remains possible that collisions resulting in mortality could occur. The consequence of this short-term decrease in the abundance of whales is considered to be moderate, since the likely number of whales involved represents only a very small proportion of the population and would have no impact on its long-term viability. Therefore, the residual risk from physical interaction with whales will be medium.

Dolphins

The only dolphin that is listed as an EPBC Act threatened or migratory species that may occur in areas affected by the Development is the bottlenose dolphin. Individuals of this species are residents in the shallow waters of the inner Rowley Shelf and are abundant in the waters off both coasts of Barrow Island.

Physical interaction with bottlenosed dolphins will generally have only minor consequences, such as a short-term behavioural impact due to increased vessel movements or active pipelaying by vessels to. It is likely that these highly mobile marine mammals will be able to avoid vessels, particularly since marine fauna watches will be employed and the vessels will only be travelling at very slow speeds. However, in the event that collisions occur, the injury or fatality of a small number of dolphins would lead to a short-term, local reduction in the abundance of this species. Although the population size of this dolphin in Australian waters is not known, they are regionally widespread and occur in reasonably large numbers around Barrow Island. Thus, a short-term, local reduction in the population of this species is considered to be of moderate consequence, with no impacts on local population viability.

The probability of physical interaction with dolphins during the construction and operation of the Gorgon Development is unlikely, but possible. Such interaction will have moderate consequences and there remains a medium level of residual risk to dolphins from the Development.

Dugongs

Dugongs are known to occur around the islands of the Rowley Shelf such as Barrow Island, the Lowendal Islands and the Montebello Islands. Recent population estimates suggest that approximately 2000 individuals of this EPBC Act listed species occur in the region (Prince et al. 2001).

During construction and commissioning, it is likely that physical interaction between vessels, equipment or marine infrastructure and dugongs will occur. Behavioural changes due to the presence of marine infrastructure will only be local and of short duration and thus of minor consequence. Collisions between vessels and dugongs are unlikely, but possible and will have moderate consequences, leading to the injury or fatality of a small number of individuals. This will lead to a short-term decrease in the abundance of dugongs in the local area. Management practises, such as reduced vessel speeds and marine fauna watches, will be implemented. Therefore, it is envisaged that only a very small number of dugongs will be affected by physical interaction during the construction and operation of the proposed Development. This represents only a very small percentage of the total population and no impacts to the viability of the local population are expected.

The possibility of moderate impacts occurring means that the level of residual risk to dugongs from the proposed Development is medium.

Seabirds

One threatened seabird species, the southern giant petrel, and 39 migratory seabird or shorebird species may occur in the Development area. In general, the littoral avifauna is concentrated in the south-east and south of Barrow Island and the proposed Development area is of relatively low importance for avifauna compared with other parts of the island (Technical Appendix C3).

Effects on seabirds and shorebirds from physical interaction will range from short-term behavioural impacts, such as temporary displacement to adjacent areas, longer term behavioural changes, such as roosting on marine infrastructure, to potential collisions with vessels or other Development infrastructure (e.g. fences, buildings). Collisions with vessels or infrastructure may result in injury or mortality of birds. The numbers involved are likely to be low, particularly with the management that will be applied, and would represent a small proportion of their populations (refer to Technical Appendix C3). The consequence of this impact would be moderate, with no impact on population viability. The likelihood of some mortalities occurring is almost certain. Therefore, the residual risk is considered to be medium.

11.5.3 Light

Lighting associated with construction and operation of the Development has the potential to affect marine fauna, notably sea turtles and some seabirds (e.g. shearwaters and gulls). Behavioural responses to light can alter foraging and breeding activity in turtles, seabirds, fish and dolphins, conferring competitive advantage to some species and reducing reproductive success and/or survival in others.

The effects on marine fauna of increased artificial lighting are dependent on the intensity and wavelength of the light. It also depends on the extent to which light spills into areas that are significant for breeding and foraging, the timing of overspill relative to breeding and foraging activity and the resilience of the fauna populations that are affected. Within the areas potentially affected by the Development, the marine fauna most sensitive to the effects of artificial lighting are sea turtles.

Elevated light levels on nesting beaches can be detrimental to sea turtles because it alters critical nocturnal behaviours, namely how sea turtles choose nesting sites, how they return to the sea after nesting, and how hatchlings find the sea after emerging from nests (Witherington and Martin 2000).

Nesting females and hatchlings are most susceptible to light impacts. High levels of light spill on sea turtle nesting beaches can deter females from emerging from the sea, resulting in eggs potentially being shed at sea or nesting effort being redirected to adjacent, less suitable, beaches. Turtles choose nesting sites based upon favourable conditions for safe nesting and hatchling survival (Hays et al. 1995). Therefore nesting on less suitable beaches may result in compromised hatchling numbers, reduced survivorship and altered hatchling sex ratios (Witherington and Martin 2000). Although there is a tendency for nesting female turtles to prefer dark beaches, some will nest on artificially lit beaches, thereby also exposing emerging hatchling turtles to the effects of artificial light.

Although not definitively established, there is evidence that sea turtle hatchlings rely on two sets of visual cues to find the ocean (Lohmann et al. 1996). The most important is horizon elevation and profile, with hatchlings orientating away from elevated, uneven horizons (such as dunes) toward lower, more even horizons (such as the sea). Light gradients also provide an additional cue, but it appears this will only override horizon based cues where the light intensity is highly polarised in one direction and of sufficient intensity (five times open horizon levels) to 'blind' hatchlings to the presence of an elevated horizon.

Studies on the response of sea turtle hatchlings to different light wavelengths suggest that, while they are able to see light up to 640 nanometres (nm), hatchlings respond most strongly to short wavelengths, particularly when there are low natural light levels (Witherington and Bjorndal 1991; Witherington 1992) (Table 11-22). Witherington (1992) concluded that the most disruptive wavelengths are in the range of 300–500 nm. Most common artificial light sources (e.g. fluorescent and metal halide) generate light within these wavelengths (Figure 11-17). If sufficiently intense, artificial lighting (including light generated by flares) on beaches can cause hatchlings to move away from the sea or wander for extended periods along beaches, resulting in mortality or reduction in subsequent survival rates.

Once in the ocean, hatchlings are thought to orient by wave fronts and to swim offshore for several days. During this period, light spill onto the ocean (e.g. from vessels) may 'entrap' hatchlings swimming offshore and potentially reduce the success of seaward dispersion and/or increase their exposure to predation.

Figure 11-17:
Spectral Distribution of Metal Halide, Fluorescent and Sodium Vapour Lights

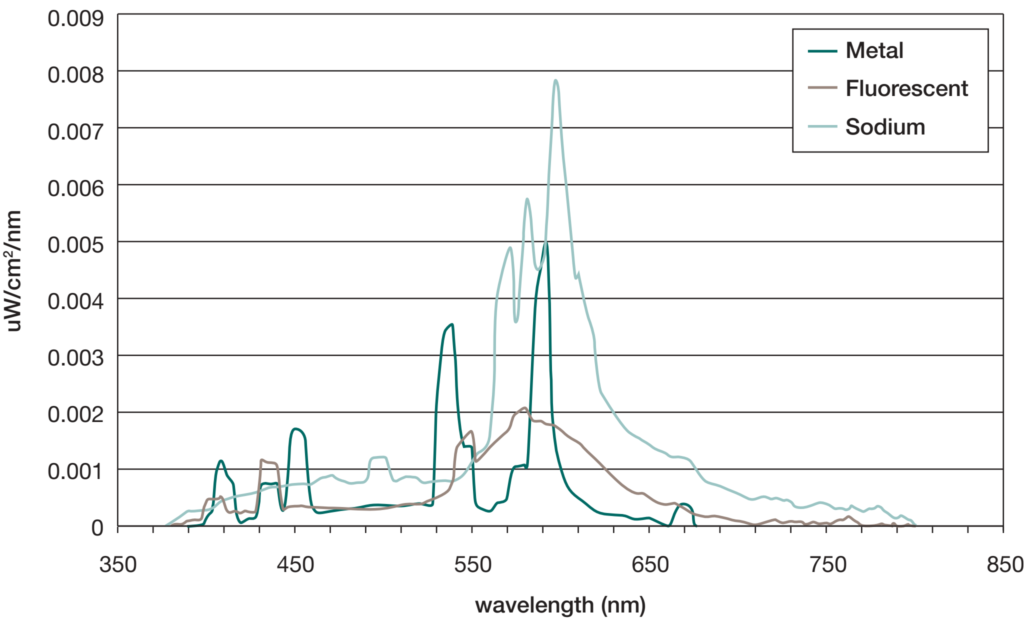


Table 11-22:
Disruptive Light Sources to Turtles

Parameter	Most Disruptive	Least Disruptive
Light	White lights	Yellow light (less atmospheric scatter than white lights)
Wavelength	Short wavelength light	Long wavelengths (moonlight, orange and red lights)
Colour emissions	Blue/green emissions	Yellow emissions (less glow and scatter)
Examples	Fluorescent, metal halide and mercury vapour, flares (no moon light)	Low pressure sodium vapour lights and flares (with moon light)

Construction and Commissioning

Construction lighting (onshore and on work vessels) typically consists of bright white (metal halide, halogen, fluorescent) lights that are disruptive to sea turtles. Light associated with offshore vessel operations and onshore construction activities has the potential to affect sea turtles on both the east and west coasts of Barrow Island. Effects on the west coast would predominantly involve green turtles whereas construction activity on the east coast will affect mainly flatback turtles (Technical Appendix C7).

Construction of the shore crossing on the west coast will take approximately 12 months and will occur 24-hours per day. Construction operations will be confined (approx. 4 ha site) and shielded by dunes and nearby headlands.

On the east coast of Barrow Island construction will take approximately 3 years and will occur 24-hours per day. During the commissioning phase the flare will operate continuously for approximately 1 – 2 weeks. The extent, intensity and location of light spill are likely to vary with different stages of construction. The dunes backing the beaches adjacent to the Development will tend to shield nesting beaches from lighting associated with construction at the gas processing facility site and retain the elevated horizon important for hatchling sea-finding activity. Lighting associated with construction of nearshore marine facilities (causeway, MOF) will produce light levels that could deter nesting activity on beaches immediately adjacent to facilities for the duration of construction (approx. 12 months). Construction lighting in this area, and offshore construction lighting (MOF, LNG shipping channel and turning basin) will also disorient hatchlings.

Management

Because there is no single, measurable level of artificial brightness on nesting beaches that is acceptable for sea turtle conservation, the most effective conservation strategy is simply to use 'best available technology' to reduce effects from lighting (Witherington and Martin 2000). Best available technology includes many light management options that have been used by lighting engineers for decades and others that are unique to protecting sea turtles. To protect sea turtles, light sources can be minimised in number and wattage, repositioned behind structures, shielded, redirected, lowered, or recessed so that light does not reach the beach. To ensure that lights are on only when needed, timers and motion detector switches can be installed. Best available technology also includes light sources that emit a colour of light that has minimal effects on sea turtles (Witherington and Martin 2000).

The Joint Venturers are committed to adopting the following planning and operational measures to avoid or mitigate impacts to sea turtles caused by artificial light.

Engineering and design management strategies that will be adopted are to:

- locate flare and proposed gas processing facility behind dunes to reduce light spill from construction and/or commissioning activity onto the beach and maintain dark dune silhouette behind nesting areas
- set the gas processing facility back from the coast (behind 6–10 m high coastal dunes)
- design gas processing facility so that no permanent 24-hour lighting is located within 500 m of turtle nesting beaches

- incorporate modelling and line-of-sight studies into lighting design, with focus on eliminating non-essential lighting and reducing essential lighting whilst still meeting health and safety standards
- design paint schemes and civil works for reduced reflectivity
- manage construction activity to avoid nearshore areas at night during peak turtle breeding periods
- prohibit all non-essential lighting (minimum requirement to meet health and safety standards) during turtle nesting and hatchling emergence) periods
- use reduced spectrum (i.e. long wavelength yellow/orange) lighting with lights shielded, mounted as low as practical and directed away from the coastline.

Survey and monitoring strategies that will be adopted are to:

- conduct experiments to investigate response of flatback hatchlings to light glow generated by metal halide, fluorescent, sodium vapour light during summer 2005/2006
- establish a turtle tagging and monitoring program on the east coast of Barrow Island, designed in conjunction with CALM, over the 2005/2006, 2006/2007 and 2007/2008 nesting seasons to investigate population size and distribution on the island. The program will include a control site (e.g. within the Montebello Island group)
- monitor hatchling behaviour on nesting beaches and implement contingency responses if light levels are causing disorientation in hatchlings.
- conduct regular lighting inspections to assess compliance with lighting strategy (Chapter 7, Section 7.3)
- conduct regular inspections of dune areas to assess whether hatchlings are becoming disorientated and moving inland
- undertake intervention (manual collection and relocation of hatchlings) under the supervision of CALM in any areas where a significant effect on hatchling orientation is resulting from lighting
- manage lighting on LNG tankers at night during January to April (turtle nesting season) to minimise attraction to hatchlings (shield and direct lights onto work areas, use long wavelength light sources and turn lights off when not in use).

The implementation detail for these strategies will be developed, in consultation with CALM and the DoE, and submitted for approval as part of the EMP for the Development.

Residual Risk

Sea turtles – The three year construction period on the east coast could expose a substantial portion of the local breeding population (primarily flatback turtles) to up to three to four seasons of reduced reproductive output, with a smaller proportion affected in three seasons and some affected for one season only. Lights will be shielded and directed away from the coast; however safety considerations will require that construction areas are illuminated in accordance with safe working conditions. Consequently, light during some stages of construction on the east coast is likely to result in avoidance of beaches immediately adjacent to the Development by female turtles during the nesting season. Furthermore, it is likely that construction lighting will reduce hatchling survival rates on beaches adjacent to the Development, although management strategies employed will reduce the impact of these potential effects.

The assumptions and risk assessments for the life stages involved are discussed separately below.

Nesting Females: If light causes nesting females to move to adjacent beaches for up to four nesting seasons, this will result in an increase in the density of nests at adjacent beaches and consequently greater potential for nests to be disturbed or destroyed. Adjacent beaches may also provide less suitable nesting habitat (e.g. moisture content or depth of sand) thereby reducing the success of egg development and subsequent hatchling survival rates.

The consequences of deterred nesting and selection of less suitable beaches is considered to be moderate with a loss of a proportion of three to four seasons of hatchlings and possibly a short-term decrease in recruitment (i.e. a reduction, over three to four years, in juveniles recruiting into the adult breeding population 30 – 40 years following the construction period). This consequence is considered likely; therefore the residual risk is medium.

Hatchlings: Construction light spill onto the beaches adjacent to the Development is unlikely to be of sufficient intensity to deter all nesting activity for the entire duration of construction. Therefore, hatchlings on Bivalve and Terminal beaches, and possibly Yacht Club South (YCS) and Yacht Club North (YCN) beaches (which represent 20% of east coast nesting beaches and 50% of hatchling emergence), may be affected by onshore lights. If it is conservatively assumed that all of the management measures failed, and construction lighting resulted in complete mortality of all the hatchlings on all of these beaches, there would be a significant reduction over 3 years in juveniles recruiting into the breeding population in 30 – 40 years This may reduce the viability of the local population and therefore would be considered a serious consequence. The likelihood of this consequence is possible. The residual risk is therefore considered medium.

If management successfully reduced the effects of light spill from construction lighting, there would be a correspondingly reduced impact on hatchling survival on beaches adjacent to the Development over the three years of construction. Local population viability would be unlikely to be affected, but there may be widespread short-term or local long-term decrease in abundance and the consequences would be moderate. The likelihood of this effect is likely and the residual risk is medium. The overall risk to turtles associated with construction lighting on the east coast is therefore medium.

Construction lighting on the west coast of Barrow Island would potentially cause similar effects on green and hawksbill turtle reproduction as described for the east coast, but would affect only one full nesting season. The scale of effects are also considered to be lower due to the greater shielding of adjacent rookeries provided by dunes and rocky headlands and significantly smaller scale of proposed works. The construction lighting will cause a local, short-term reduction in abundance, which is considered to be a minor consequence. This consequence is considered likely. The residual risk to turtles on the west coast is therefore low.

Seabirds – Of the seabirds that occur in the area, wedge-tailed shearwaters *(Puffinus pacificus)* are susceptible to adverse effects from artificial light, which can disrupt navigation behaviour, particularly nest finding. Wedge-tailed shearwaters are resident on Double Island off the east coast of Barrow Island. Light spill into the ocean can also alter foraging behaviour in some seabirds, such as gulls, which can in turn confer competitive advantage and have flow on effects to other birds. These temporary effects would be very localised and unlikely to result in impacts to any species. The potential for secondary effects from alterations in feeding behaviour will be limited given the relatively short duration of the offshore construction operations.

The resident wedge-tailed shearwaters on Double Island may be affected by construction light, particularly during periods when offshore construction on the east coast coincides with breeding activity. Given the distance of the colony from nearest construction light sources (approx. 15 km) and the management that will be applied to offshore construction lighting, the number of animals potentially impacted would be low. The consequences of short-term behavioural changes would be minor, with no impact on population viability. The probability of the effect is likely. Therefore the residual risk is low.

Other Listed Marine Fauna – Listed marine fauna in areas immediately adjacent to offshore construction operations, including dolphins and fish, may be locally affected by light spill from construction vessels or offshore infrastructure, either directly or through changes to other predator/prey species. These effects would be temporary at any location and very limited in spatial extent, particularly given the management that will be applied to minimise light emissions from offshore vessels. Impacts would be restricted to short-term behavioural changes and possibly short-term reductions in local abundances. The consequences would be minor, with no effects on population viability. These consequences are almost certain, and the residual level of risk is low.

Operations

Light will be emitted from the proposed gas processing facility and associated port facilities on the east coast of Barrow Island for the life of the Development. There will not be any permanent light emissions from west coast infrastructure during operations.

Evidence from other offshore islands in the region suggests that turtles can continue to nest in areas adjacent to well lit infrastructure (Pendoley K. 2004. pers comm.). However, evidence is growing to suggest that a brightly lit skyline will reduce adult nesting populations in the long-term (Salmon et al. 2000 in Limpus 2004).

To assist with the assessment of potential impacts of light emissions, a number of studies have been undertaken to evaluate:

- existing light conditions on Barrow Island (Technical Appendix C7 – Attachment 4)
- effects of different light types and intensities on the sea finding behaviour of green and flatback sea turtle hatchlings (Technical Appendix C7 – Attachment 2 and 3)
- light spill from the proposed gas processing facility using an illumination model (Section 7.3, Chapter 7).

The results of the light survey indicate that existing oilfield lighting at Barrow Island has had little effect on the natural light environment of nearby turtle nesting beaches.

Results from experiments aimed at investigating the impact of light on sea turtle hatchlings at different light intensities show that in the absence of moonlight and under clear skies:

- high pressure sodium vapour light causes disorientation of flatback hatchlings up to, but not beyond, 500 m from the light source (250W and 500W) (Figure 11-18)
- metal halide light causes disorientation of flatback hatchlings up to, but not beyond, 800 m from the light source (250W and 500W) (Technical Appendix C7 – Attachment 3)
- fluorescent light causes disorientation of flatback hatchlings up to, but not beyond, 800 m from a 250W fluorescent light source. Significant disorientation of hatchlings was observed at 800 m from a 500W fluorescent light source (Technical Appendix C7 – Attachment 3).

These results support the findings by Witherington (1992) who found that the threshold intensity of different light wavelengths eliciting a response in loggerhead hatchlings was lower for short wavelength (green, blue) light than it was for higher wavelength (yellow and red) light. Higher wavelength high-pressure sodium vapour lighting will be the primary light source for all Development facilities.

Light modelling of the proposed gas processing facility (Section 7.3, Chapter 7) indicates that light spill onto nesting beaches adjacent to the Development will be below the threshold intensity required to cause a response (i.e. disorientation) in flatback hatchlings. However the model does not include spread and visibility of light glow.

Preliminary studies on the effects of light glow suggest flatback hatchlings are affected by light glow (Technical Appendix C7 – Attachment 3). It is reasonable to assume that in the absence of moonlight and/or on cloudy nights, glow from the Development and the flare will be visible to hatchlings and will cause disorientation in a proportion of them.

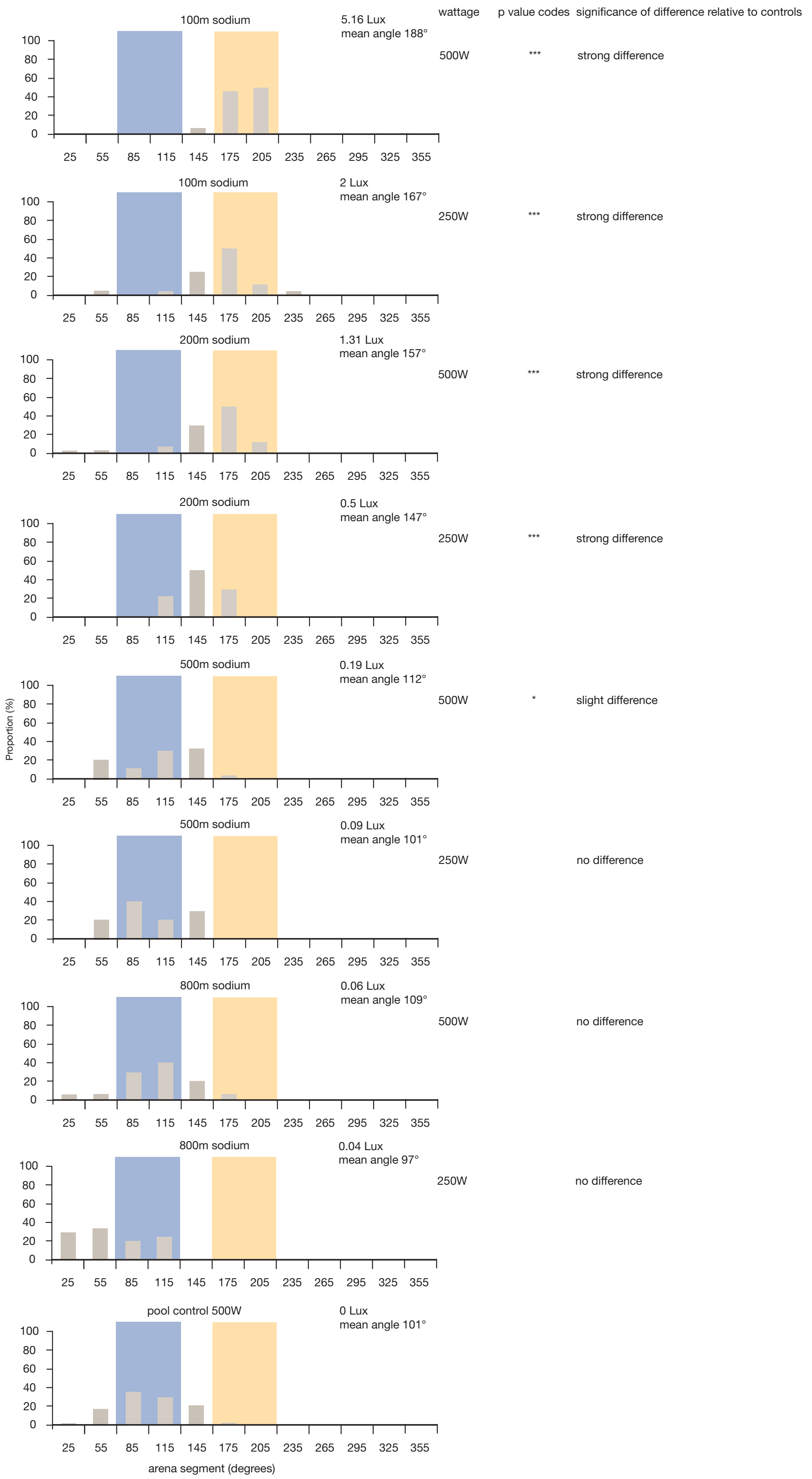
Offshore light sources, including the causeway, jetty, MOF and shipping berth, have the potential to attract hatchlings. Light-spill in these locations could ‘entrap’ hatchlings that enter the lighted zone thereby resulting in reduced hatchling dispersion and/or localised increases in predation.

The proposed Development will have a ‘no routine flaring policy’ incorporated into the design of the gas processing facility. However, flaring will be required during commissioning and in the event that a component fails or maintenance disrupts normal operations. Flaring may produce a visible glow in addition to the glow from the proposed gas processing facility. If this occurs at night, the flare will be visible over an extensive area and, if coincident with breeding activity, may adversely affect turtles or seabirds. It is estimated that non-routine flaring will occur on approximately five nights during the main turtle nesting season each year.

Management

A number of studies have identified successful measures for reducing the effects of lighting in urban or industrial developments on marine life, particularly turtle breeding activity (Witherington and Martin 1996). Management of light spill can be achieved by designing and incorporating several simple measures which will be applied to activities that occur at particular sites (e.g. motion detection and localised switching), or at particular times (e.g. turtle nesting and emergence) within the gas processing and marine facilities.

Figure 11-18:
Arena Experiment Results for High-Pressure Sodium Vapour Lighting Trials (250 W and 500 W). Blue wash represents arena segments oriented most closely to the ocean, yellow wash represents arena segments oriented towards the light array on the coast.



In specific areas, shielded red, long wavelength and/or lighting of a defined wattage rating will be used. This includes areas such as the MOF causeway, jetty, access roads within the gas processing facility and general open areas. In areas where more colour definition is required, a yellow/orange type of shielded light will be used, such as high pressure sodium vapour. These lights will form the primary lighting for the Development.

The Joint Venturers are committed to adopting the following planning and operational measures to avoid or mitigate light impacts to sea turtles. The Development is currently in the early design phase with less than 10% of engineering design completed to date. As detailed design progresses it may become necessary to modify management strategies, particularly those with an engineering element. If this occurs, alternative management strategies that achieve stated environmental objectives and performance standards/targets will be developed. Numerous design and management measures that will be incorporated into the proposed Development to ensure that light emissions are minimised are described in Section 7.3, Chapter 7.

The management measures outlined below are consistent with the approach recommended by Witherington and Martin (2000) which involves reducing the 'effects of light to the greatest extent practicable' by:

- turning off problem lights (i.e. lighting that results in unacceptable effect to turtles)
- minimising outdoor sources of light (i.e. wattage, shielding, recessing, reducing height, redirect, use timers and motion-detectors)
- minimising light-spill from indoor sources of light
- using alternative, long-wavelength light sources
- using light screens and enhancing dune profile
- developing a strategy for minimising effects of artificial lighting.

The Joint Venturers will adopt the following management strategies to avoid and mitigate potential effects of lighting from the proposed Development on sea turtles.

Engineering and design management strategies that will be adopted are to:

- implement a hierarchical lighting strategy as described in Chapter 7 (Section 7.3). This lighting regime will continue to be reviewed and refined during ongoing engineering design
- restrict lighting to the minimum required for safe operational requirements, with no permanently lit areas (except for mandatory navigation lights) on the offshore facilities and a no routine flaring design philosophy (this includes ship loading)
- select light types that are least disruptive to sea turtles, such as shielded or recessed lighting with long wavelengths, on the causeway and MOF. Alternatively, any white-type lights on these facilities should be shielded and only switched on as required in areas subject to routine night-time inspections
- connect area lighting to personnel location monitoring, gate control, or motion sensors. Areas of the gas processing facility will be lit (automatically) when personnel are present
- locate lights on the inland side of the equipment it serves. Seaward areas of the gas processing facility where personnel are not normally located will have lighting normally switched off
- use blinds at night to eliminate light spill from indoors to outdoor areas
- use low-pressure sodium vapour lighting as the primary source of lighting for the facility
- sections of the gas processing facility that require routine visits from operations and maintenance staff will be enclosed/shielded if light spill poses a risk to sensitive habitats
- minimise the height of lighting
- processing facility (and) flare will be set back behind coastal dunes so that construction lighting from the gas processing facility will not be directly visible during the night from the beaches.

Operational control management strategies that will be adopted are to:

- schedule routine gas processing facility maintenance operations for daylight hours. Only necessary gas processing facility rounds and critical unscheduled maintenance will occur at night
- schedule major turnarounds and other periods requiring high-level lighting for periods of the year that will not affect turtle hatchlings
- manage lighting on LNG tankers at night during January to April (turtle nesting season) to minimise attraction to hatchlings (shield and direct lights onto work areas, use long wavelength light sources and turn lights off when not in use).

Survey and monitoring management strategies that will be adopted are to:

- conduct experiments to investigate response of flatback hatchlings to light glow generated by metal halide, fluorescent, sodium vapour light during summer 2005/2006
- establish a turtle tagging and monitoring program on the east coast of Barrow Island, designed in conjunction with CALM, to investigate population size and distribution on the island. Program will include a control site (e.g. within the Montebello Island group) and will be undertaken in conjunction with the tagging program in the immediate vicinity of the Development (i.e. YCS, YCN, Bivalve, Terminal beaches) over the 2005/2006, 2006/2007 and 2007/2008 nesting seasons
- implement an intensive turtle tagging program during December and January across the four main flatback nesting beaches (i.e. YCS, YCN, Bivalve, Terminal beaches) on the east coast of Barrow Island over the 2005/2006, 2006/2007 and 2007/2008 nesting seasons. This will quantify the size of the flatback nesting population using the mid east coast nesting beaches
- conduct regular lighting inspections during construction and operations to assess compliance with lighting strategy (Chapter 7, Section 7.3)
- monitor hatchling behaviour on nesting beaches during construction and initial operations phase and implement contingency responses (i.e. possible manual collection and relocation of hatchlings) if light levels or effects are causing disorientation in hatchlings
- conduct regular inspections of dune areas during construction and initial operations phase to assess whether hatchlings are becoming disorientated and moving inland
- use directional, downcast and shielding lighting on the jetty. When night-time operations (loading) occur during the hatchling emergence season, illuminated areas will be monitored and if unacceptable numbers of hatchlings are entrained appropriate response strategies (e.g. manual translocation to dark offshore areas) will be implemented in consultation with CALM.

The implementation detail for these strategies will be developed, in consultation with CALM and the DoE, and submitted for approval as part of the EMP for the Development.

The philosophy for design is no routine flaring (this includes ship loading). There will be a boil-off gas flare next to the LNG tanks. This flare will operate in the case of a failure of either of the compressors. The gas processing facility (and) flare will be set back behind coastal dunes so that construction lighting from the gas processing facility will not be directly visible during the night from the beaches.

Residual Risk

Sea Turtles – Twenty-four hour operational lighting is likely to affect turtle hatchlings adjacent to the proposed gas processing facility and marine facilities on the east coast of Barrow Island. The greatest potential impacts primarily relate to flatback hatchlings emerging on east coast beaches adjacent to the Development. Light spill from the Development could result in localised reductions in hatchling sea-finding or sea-dispersion success and/or localised increases in predation. These effects are likely to be most significant during periods of little or no moonlight or under overcast sky conditions.

The Western Australian flatback population distribution extends from the North West Shelf to the Lacapede Islands (Technical Appendix C7). All Western Australian flatback turtles are of the same genetic stock and form a single management unit. Preliminary demographic surveys suggest that Barrow Island supports up to 50% of the flatback nesting within the Barrow, Lowendal, Montebello Island complex. Assuming turtles at Barrow Island display the same nesting site fidelity seen elsewhere, impacts on flatback nesting populations at Barrow Island should not have an affect on nesting populations on Lowendal and Montebello islands.

In the absence of detailed demographic data on local populations and full engineering design detail for the Development, a conservative approach forms the basis for this assessment. The implementation and effectiveness of lighting strategies and management measures is critical to reducing risk associated with lighting.

Implementation and compliance with management measures which reduce light spill and glow to near ambient conditions will mitigate adverse impacts to the local flatback turtle population. Although a proportion of hatchlings on beaches adjacent to the Development may be disoriented during certain combinations of coincident operational and environmental conditions (e.g. no moonlight and cloud cover reflecting the glow from the plant or the flaring at night) the consequence of the loss of the occasional nest is considered minor and the risk to the Barrow Island population medium.

If lighting strategies and management measures fail to adequately mitigate effects from direct lighting or glow, lighting could impact up to 50% of hatchlings that emerge annually from the four turtle nesting beaches adjacent to the Development. This could result in losses of these hatchlings every summer which, over the life of the Development, could lead to a reduced viability the local flatback turtle population. This is considered to be a major consequence which is possible. The associated level of risk is considered high. Manual intervention will reduce the consequences by assisting the hatchlings in reaching the ocean; however the long-term implications for the survivability of these hatchlings (as a result of impacts on imprinting and dispersal) are unknown.

The overall risk to turtles associated with operations lighting on the east coast is therefore medium to high.

The impacts of the Development will not impact on flatback nesting habitat on the Montebello Islands, ensuring the regional viability of the flatback nesting population. The risk assessment for operations light and the impacts on hatchlings will be re-evaluated further based on results of ongoing field surveys investigating flatback movements and their responses to artificial light.

Seabirds – Monitoring of shearwater colonies which occur in close proximity to gas facilities on Varanus Island indicates that lighting associated with operation of these facilities has had little effect on the adjacent shearwater population (Astron 2002). Consequently, it is considered that operational lighting from the gas processing facility also poses a low risk of adverse impact to the Double Island shearwater colony.

The potential effects to seabirds from collision if attracted to lit facilities are assessed in Section 11.5.2. Long-term behavioural changes in visual feeding seabirds, such as gulls, could result in long-term reductions in the local numbers of other birds, for example by increased egg predation. If this involved a listed species, the consequences would be moderate with no impact on population viability. The probability of the effect is possible to likely. Therefore the residual risk is medium.

Other Listed Marine Fauna – Potential effects from operations lighting would be very localised, possibly causing long-term local changes in abundances but with no effect on population viabilities. The consequences would be moderate and likely to occur. This represents a medium risk to marine fauna.

The Terminal Beach and intertidal areas adjacent to the proposed Town Point site represent approximately 2% of the available nesting habitat along the east coast. Lighting associated with the facility will be localised and the risks from a more regional perspective are not considered high.

With the design and management considerations proposed, effects on marine fauna from lighting associated with operations are likely to be limited to animals using areas immediately adjacent to certain infrastructure. This will involve local populations of species that have widespread regional and broader distributions.

The greatest risks are related to potential effects on sea turtles, primarily flatback hatchlings emerging on the east coast beaches adjacent to the Development. Light spill from the Development may result in localised reductions in hatchling sea-finding or sea-dispersion success and/or localised increases in hatchling predation. However, these effects are likely to be significant only during periods of little or no moonlight. Further it would involve only a small proportion of the hatchlings that emerge on the beaches adjacent to the proposed Development, which represent approximately 2% of the available turtle nesting habitat on the east coast.

The environmental consequences of the effects of operations lighting are therefore expected to be minor with local impacts but affect on local population viability. This represents a medium risk to marine fauna.

Flaring light will be emitted on approximately five nights during the main turtle breeding season (i.e. approximately once per month) and will be of short duration (except during commissioning); therefore the risk to hatchlings and turtles is considered low. Given the properties of the light, and the short duration of flaring, the risk to marine fauna is considered low.

11.5.4 Noise and Vibration

Construction

Underwater noise and vibration can affect marine fauna behaviour and, at extreme levels, have adverse physiological effects. The characteristics of noise and vibration generated during drilling, dredging, piling, seismic surveys and blasting vary with equipment, vessel type and activity. The frequency, intensity and persistence of underwater noise and vibration are important in determining effects on different marine species.

Cetaceans are recognised to be sensitive to the effects of underwater noise. Baleen whales communicate using low frequency sound and are more likely to be affected by low frequency noise. Toothed whales, including dolphins, generally have a hearing range adapted to suit their echo-location (sonar) capabilities in higher frequencies.

Normal ocean noise levels in exposed areas are around 90 – 110 dß re 1 μPa (APPEA 2005). Avoidance or behavioural changes in marine mammals may occur where continuous industrial noise levels are above 120 dß re 1 μPa. Studies on whales suggest that migration behaviour can be disturbed at levels of 150 dß re 1 μPa (Environment Australia 2001) with whales in feeding, breeding or resting areas sensitive to levels of 140 dß re 1 μPa. Cow/calf pairs are more likely to exhibit an avoidance response to sounds to which they are unaccustomed (McCauley et al. 1998) and may be more susceptible to disturbance.

The hearing capabilities of turtles are known mostly from electrophysical studies. These indicate that sea turtles hear best in the range 100–700 Hz. No absolute thresholds are known for the sensitivity to underwater sounds of the levels required to cause pathological damage (Swan et al. 1994).

Recent studies of drilling activity (drilling and supply vessel movements) found that noise levels at 2 km from the rig exceeded 120 dß re 1 μPa for only 2% of the time and estimated that significant effects of underwater noise may be confined to within 3 km of the rig. (APPEA 2005) Vessel noise under normal operating conditions, such as when a vessel is idling or moving between sites, will be detectable above background only over a short distance (several kilometres). The level of vessel noise in deep water is generally higher than in shallow waters, as a result of the tendency for low frequency sound to be attenuated in shallow water (Nedwell et al. 2002).The noise from a vessel holding its position using bow thrusters and strong thrust from its main engines may be detectable above background noise levels, during calm weather conditions, for 20 km or more (Woodside 2003) but this an intermittent short duration activity. General noise produced by vessels in construction activities occurs at frequencies much less than 20 kHz, with most energy below 2 kHz. McCauley (1998 in Woodside 2003) measured underwater broadband noise of approximately 182 dß re 1 μPa from a rig support vessel holding station (Timor Sea) with levels of 145 dß re 1 mPa at 5km from similar activity in the Otway Basin (in APPEA 2005).

A cutter suction dredge will emit noise levels within the range of 165–185 dß re 1 mPa (Richardson et al. 1991). Seismic and pile-driving may generate higher peak levels of noise than dredging, but involve short impulsive events whereas dredging has a more continuous noise output. The peak pressures for pile driving vary somewhat from one strike to another with the average about 170 dß re 1 μPa (Nedwell et al. 2002).

With the possible exception of underwater volcanic eruptions and major earthquakes, underwater explosions are the strongest point sources (higher peak levels and very rapid rise times) of sound in the sea (Richardson et al. 1995). The use of explosives creates pressure fluctuations over a wide frequency range. High frequency pressure fluctuations are perceived as noise, whilst low range pressure fluctuations create vibrations.

Blasting associated with the excavation of the access channels has the highest risk of impacting listed cetaceans and turtles. Detonation of explosive charges underwater (both noise and shockwave) can have impacts that range from behavioural effects to physical injury or death (particularly within close range). Invertebrates tend to be little affected by explosive shockwaves, but fish can be affected at varying distances, depending on the size of the charge.

Whales are unlikely to be present in areas where blasting will be undertaken but dolphins or dugongs may be vulnerable to unmanaged blasting operations. Dolphins, seabirds and turtles may be attracted to feed on dead marine life killed by explosions, and thus exposed to impacts from subsequent charges. For this reason, warning charges are no longer used in some areas (Richardson et al. 1995). According to Klima et al. (1988) turtles have been rendered unconscious from simultaneous explosions of four 23 kg explosions at 915 m. These studies confirmed that explosions can result in both near and far field injuries to turtles.

West Coast

Drilling and installation of infrastructure at the offshore Gorgon field and for the feed pipelines will create noise off the west coast. Pipeline construction in the nearshore areas at North White's Beach, or Flacourt Bay if a North White's Beach shore crossing becomes unfeasible, will involve drilling the pipelines below the beach.

Offshore components of the program will be expected to cause minor disturbance to whales and possibly to small numbers of sea turtles. There are no whale resting, feeding or breeding grounds in the vicinity of the west coast operations but underwater noise generated by drilling and infrastructure installation activity is likely to result in avoidance of the immediate area (3 – 5 km). Migrating humpbacks may locally modify their swimming direction to maintain standoff distances to any activities that occur during the migration season.

Nearshore construction activity has a higher potential to affect turtles, particularly green turtles. Underwater noise and vibration may cause individual turtles to re-locate to adjacent habitats along the west coast of Barrow Island. If this coincided with breeding periods, there may be a localised reduction in reproductive output for a small proportion of the local breeding population.

East Coast

During construction on the east coast, noise emissions will be generated by drilling, piling, dredging, possible blasting, and transportation of equipment and materials (from support vessels and installation vessels). A small scale CO2 baseline seismic acquisition survey will be undertaken near the coast north of Latitude Point prior to construction and subsequently at 5 – 10 year intervals.

Underwater noise and vibration on the east coast may affect local turtle populations, but is unlikely to affect whales. Sea turtles, in particular flatback turtles, may be disturbed in inter-nesting or foraging habitats adjacent to proposed Development areas. This disturbance is expected to cause individual turtles to re-locate to adjacent habitats along the east coast of Barrow Island and may reduce reproductive output of the local breeding population.

Dugongs and other marine fauna may also be temporarily and locally disturbed by different aspects of the east coast construction program. There are no habitats of particular importance to these fauna in the vicinity of Development areas and long-term effects are unlikely.

Vibration on beaches from construction activity could affect shorebird and turtle eggs, potentially reducing hatching success.

Management

Piling will occur during the construction phase of the Development. Although geophysical investigations suggest the material within the MOF access channel and LNG shipping channel and turning basin can be removed by dredging some blasting may be necessary. Management strategies will focus on avoidance to ensure risks to marine fauna remain low and will include:

- conducting baseline surveys of flatback turtles over nesting periods prior to construction (2002–2006) to enhance the current understanding of their movements and inform the development of specific management measures
- using smaller, more frequent blasts, as opposed to less frequent, larger blasts
- using sequential explosive charges, staggered to minimise cumulative effects of the explosions
- collecting and removing fish kills between blasts to avoid subsequent exposure to blasting in scavenging marine fauna
- considering marine fauna activities (e.g. nesting, migration) when planning drilling, piling and dredging operations
- applying best practice industry standards for individual explosive weights
- training monitors to undertake vessel-based monitoring for mammal or turtle activity prior to and during operations through sensitive periods (e.g. nesting, migration)
- establishing and managing an exclusion zone appropriate to activity
- restricting vessel speed and access
- scheduling blasts for daylight hours only (as required by Mining Regulations), avoiding dawn and dusk to allow for effective visual monitoring
- reporting all incidents and assess corrective measures implemented.

Residual Risk

Marine Mammals – Noise associated with construction activity will result in avoidance of construction areas by marine mammals. Migratory whales, particularly humpbacks, may incorporate a localised deviation in their migratory route to maintain a separation distance of a few kilometres from higher intensity noise sources. The construction activities that cause higher noise levels, such as vessel stand off, will be of short duration and have peak noise levels that are unlikely to cause physiological damage. Development areas do not support aggregations of marine mammals and there are no whale breeding, feeding or resting areas in or surrounding construction locations. The marine survey area for the baseline seismic acquisition is distant from whale migration routes and will be managed in accordance with DEH and DoIR guidelines to ensure adverse affects to marine mammals are avoided. Management of blasting will avoid physiological risks to marine mammals and potential disturbance to dugongs and dolphins from nearshore construction noise is likely to be limited to temporary displacement into similar habitats in adjacent areas. The consequences of these short-term changes in marine mammal behaviour are considered to be minor, with no population effects. It is almost certain that noise and vibration will result in disturbance to marine mammals. The residual risk is low.

Sea Turtles – The nearshore construction noise and vibration, particularly on the east coast where construction will occur over two nesting seasons, may disturb sea turtle breeding behaviour and reduce reproductive output. If management of blasting is not entirely successful, injury or mortality of some turtles may occur.

Flatback turtles, and to a lesser extent green and hawksbill turtles, may rest or internest in intertidal and inshore areas adjacent to the Development. Nearshore construction activities likely to generate significant noise emissions, such as pile installation for the jetty and dredging for the MOF will be scheduled to avoid nesting seasons if practicable. Blasting noise is likely to disturb turtles in these areas, but will be intermittent and of short duration. If jetty and MOF construction works cannot avoid the nesting season, these activities would also result in short-term disturbance to turtle breeding. The extent to which this underwater noise and vibration may affect adult breeding behaviour, eggs or hatchlings is uncertain, but it must be assumed that there will be short-term reduced reproductive success in a proportion of the local population.

Sea turtle populations tend to be resilient to occasional short-duration losses at localised phases in their life cycle (Limpus 2002). Therefore the consequences of the impact from noise will be moderate, a short-term decrease in local abundance with no effects on population viability. Given the management that will be applied, the likelihood of this consequence is likely. The residual risk to flatback turtles from noise and vibration is medium. The risk to green and hawksbill turtles is low.

Seabirds – There is little potential for underwater noise to impact seabirds, except where diving activity coincides with blasting operations. The birds most at risk are diving species attracted to fish killed by preceding blasts. The use of marine fauna watches and the removal of any dead fish floating on the sea will reduce the likelihood of these effects.

Noise and vibration may disturb seabirds using shorelines adjacent to the Development and nesting activity could be affected. In general, the birds using the areas potentially affected would be likely to relocate to similar habitats in adjacent areas. Eggs laid by birds which did not move may have reduced hatching success as a result of vibration from nearby blasting or pile driving activity and reduced reproductive output could also occur where eggs are abandoned by birds disturbed by noise that commenced after nesting. The scale of these impacts relative to the number of birds in local populations would be low.

Other Listed Species and General Fauna – Blasting will cause injury or mortality to fish and benthic fauna in the immediate vicinity, but the effects of the shockwaves are spatially limited. Elevated underwater noise will also cause short-term behavioural reactions in fish, including stress and avoidance.

Based on recognised methods for estimating the lethal and sublethal ranges of underwater blasting, a confined blast of 78 kg of explosive in 10 m water depth would result in 50% mortalities in large (10 kg) demersal fish at 200 m, falling to 1% at approximately 300 m. There are no habitats of particular significance to listed fish species in the areas that will be subject to high levels of underwater noise (including blasting), nor any species with restricted distribution.

The short-term behavioural changes and reduction in local abundances that will result from noise and vibration are considered to have minor consequences. The likelihood of effects is almost certain. Residual risk is low.

11.5.5 Leaks or Spills

Construction and operation of the Development will introduce the possibility of a leak or spill of hydrocarbons or chemicals to the marine environment. The potential for significant impact to marine fauna from a leak or spill incident associated with the Development primarily relates to a spill of condensate or liquid hydrocarbons from work vessels, LNG ships and work barges that will have bunkers of diesel and possibly other liquid fuels on board. LNG is not toxic and rapidly evaporates; therefore the potential for environmental impacts from a release of LNG considered negligible (ABS Consulting 2004).

The environmental effects of a liquid hydrocarbon spill (condensate, diesel or other liquid fuels) are dependent to a large degree on the chemical characteristics of the oil involved. Lighter oils have a high proportion of toxic aromatic hydrocarbons. These are the most volatile components of oils and hence are the first to evaporate. Consequently light oils weather rapidly and leave minimal amounts of the original spill as heavy residues.

The action of light oils on biological resources tends, therefore, to reflect the potential elevated toxicity of fresh oil rather than the physical smothering associated with heavier oils. Generally, this toxicity attenuates rapidly as the lighter components evaporate. For condensate in the tropical environment the time frame involved will be minutes to a few hours (Kagi et al. 1988). For diesel, the majority of the toxic constituents will have dissipated within 6 hours.

The toxicity of North Gorgon condensate was investigated by the Ecotoxicology Program, Curtin University of Technology. Tests were performed on the Tiger Prawn, *Penaeus monodon,* the copepod, *Gladioterem imparipes,* and the tropical unicellular alga *Isochrysis sp.* In common with ecotoxicity testing of other North West Shelf condensates (Woodside 1997) these studies confirmed the acute toxicity of the water-soluble fraction of Gorgon condensate to the organisms tested. Fresh condensate could be expected to be acutely toxic to seagrass infauna and most intertidal biota, and will be likely to cause irritation or damage to the more sensitive membranes of the eyes and mouth in marine mammals and turtles. Evaporated condensate in the air immediately above a spill may also lead to damage to the respiratory tract and absorption of hydrocarbons into body tissues if inhaled.

The effects of a spill of condensate or diesel on marine fauna will depend on a range of variables, particularly the volume of the spill, the prevailing weather conditions and the timing of the incident relative to lifecycle events of fauna within the area affected. Most biological communities are susceptible to the effects of oil spills and recovery is dependent on the type of ecosystem.

The credible spill release scenarios for the Development and their respective probabilities are described in Chapter 7, along with an assessment of the likely (modelled) fate and transport of released hydrocarbons. For the purposes of assessing the risks to marine fauna, the scenarios identified can be grouped into smaller spills, that have a higher probability of occurrence but limited area of potential exposure, and larger spills that could result in more widespread effects but are extremely unlikely to occur. Risks during construction and operations phases of the Development are summarised in these terms in Table 11-23.

The spill scenarios that have been identified as having highest probability (spill from a vessel refuelling during construction off the west coast) or the greatest potential for impacts to marine fauna (large spill on the east coast during operations) are discussed in the following sections. Emphasis is placed on the risks to the more sensitive groups of conservation significance, namely marine mammals, reptiles (turtles) and seabirds. The residual risks to species listed as threatened or migratory under the EPBC Act are assessed separately for each of these marine fauna groups.

Smaller Spill

The effects on marine fauna of a smaller accidental release associated with vessel refuelling during construction off the west coast will largely depend on the season and location of the spill, the prevailing conditions and the success of contingency responses. The trajectory modelling indicates that the likelihood of nearshore areas being affected is highest in summer but reduces significantly with increasing distance offshore (Technical Appendix B3). The fate and transport modelling indicates that a spill of up to 2.5 cubic metres of diesel close to shore may impact west coast Barrow Island nearshore benthic or intertidal fauna, although the extent of shoreline potentially exposed would be limited (<10 km), the volumes that would reach the shoreline would be small and concentrations in the water column in nearshore areas would be low. The communities potentially affected tend to be characterised by relatively rapid recovery once hydrocarbons have degraded.

Impacts are likely to be elevated if fresh hydrocarbons are entrained into nearshore areas and/or persist during sensitive periods. Areas that are sufficiently shallow for the benthos to be affected by entrained or dissolved hydrocarbons do not support extensive seagrass meadows or have particular importance otherwise to mammals or turtles. These animals surfacing within a slick may suffer lethal and/or sublethal effects due to inhalation or ingestion of hydrocarbons and irritation/damage to sensitive tissues through direct contact, but this would tend to be limited to the period immediately following a spill while the aromatic components were evaporating.

Effects on turtles would be exacerbated if diesel reached inshore areas during the nesting season. Being located in the supratidal zone, nesting sites would not be directly impacted by a spill, except during high tidal surges associated with a cyclone. Hydrocarbons reaching adjacent intertidal zones may affect nesting females or hatchlings as they left or entered the water. This would probably affect few of the multiple nesting events that females undertake each season they nest and would involve only a portion of the local breeding population, as not all turtles in a population breed each year.

Seabirds foraging in the area of a spill are likely to be affected by physical contact with diesel, although the impacts will depend on the degree to which the hydrocarbons had weathered, the proportion of the population that was involved and whether the spill occurred during the breeding season. The low persistence of diesel on the sea surface and the low volumes that could be spilt through a refuelling incident will limit the potential exposure period of a spill. Seabirds of the area tend to have widespread regional distributions and the modelling suggests that the habitats of Bandicoot Bay, the area with the highest density of shorebirds, have low likelihood of exposure to a spill.

Larger Spill

Although extremely unlikely to occur, the potential environmental impacts from a large spill of condensate, as the result of a failure along the existing or proposed condensate offloading pipelines during construction or operations, may be extensive.

A worst case scenario, where prevailing weather and sea conditions entrained a large volume of condensate onto the east coast of Barrow Island and/or onto other islands in the immediate region, could result in widespread effects in intertidal and shallow water habitats. These areas support seasonally high breeding and/or feeding activity by regionally important populations of marine fauna such as threatened turtles and migratory shorebirds (Technical Appendices C3 and C7). An incident that coincided with the peak flatback turtle breeding period may substantially reduce their reproductive success. Condensate pollution of intertidal flats along the south-east coast of Barrow Island could have significant impact on the ability of migrating shorebirds to recover from their southward migration or prepare for their northward migration. The east coast of Barrow Island includes low energy environments, such as intertidal sand and mud flats, where recovery from acute impacts may be retarded due to hydrocarbons becoming entrained in the sediments.

The very high evaporation rates of condensate in the tropical environment will tend to reduce the extent of effects with the concentrations of aromatic compounds likely to be substantially reduced by the time the spill reaches areas beyond Barrow Island. The recovery of local populations of fauna with extended reproductive cycles, such as wedge-tailed shearwaters and turtles, may nevertheless be slow.

Management

Management of hydrocarbon spills within the offshore petroleum industry is focussed on prevention of incidents. It is also combined with comprehensive contingency response planning, integrated at national, state and local levels to reduce environmental consequences in the event that a spill occurs.

The offshore Pilbara region is a major petroleum production province. Detailed contingency planning is in place to reduce the risk of a significant spill, and substantial oil spill response capacity is currently maintained at the Port of Dampier and on the islands of the North West Shelf, including Barrow Island, to provide for rapid intervention if an incident occurs.

Extensive oil and gas development has been undertaken in the region and the proposed Development will incorporate best practice standards developed through these many years of experience to ensure incident free operations in the prevailing environmental conditions.

Activities that have the potential for loss of hydrocarbons, such as refuelling and tanker loading, will be subject to stringent technical and procedural controls. Transfer operations will be subject to continuous monitoring and emergency shut-down valves, automated where appropriate, will reduce spill volumes. All facilities constructed for the Development will utilise best practice technology and will be designed to optimise the safety of operations. Strict requirements will be placed on the condition, maintenance and operational procedures for vessels servicing the Development.

All offshore refuelling will utilise dry break couplings and floating hoses to ensure that the potential volumes that may be lost will be minimised. Designated refuelling locations will be identified for construction, with reference to spill modelling for the specific period and location involved, to minimise the risk of spills affecting sensitive areas. Refuelling will only be permitted during suitable weather and sea conditions and response equipment and personnel will be held at Barrow Island during these activities to facilitate containment and/or recovery of any spilled fluids.

The response to major spills is managed by AMSA through NATPLAN and coordinated by the appropriate state agencies. A Gorgon Development Spill Contingency Plan for Barrow Island operations will be developed to fulfil the requirements of AMSA, DoIR and NATPLAN. Existing spill response resources on Barrow Island will be bolstered to meet specific requirements of the Development where necessary and, in the event of a large spill, additional external resources will be available through industry affiliations and relevant government agencies.

Residual Risk

With the management in place both to prevent spills and to contain and clean up hydrocarbons in the unlikely event of a spill, the likelihood of a large spill incident with the potential for significant impact on marine fauna populations is very low. Over 1000 tanker loadings and 300 million barrels of crude oil have been exported without incident from the east coast of Barrow Island in the last 35 years.

A spill of condensate or diesel associated with the Development would be unlikely to result in significant impacts to marine fauna at a regional level. The species of marine fauna potentially affected by an accidental spill have widespread regional distributions and tend to be adapted to periodic natural perturbations. For example, cyclones can destroy all of the turtle nests on a coast-wide scale, by flooding and erosion. While these events may have major consequences, they are infrequent and the local populations survive such perturbations.

The residual risks to each of the groups of key marine fauna are discussed in the following.

Large Spill

Whales – A number of listed threatened species of whales may occur in the open waters of the immediate region (Table 11-20) and some or all of these species could potentially be affected by a large spill.

There is limited information on the effects of spilled oil on different species of whales; however the potential sources and impacts of exposure are likely to be similar for all the threatened species that occur in the area. The potential sources of effects include:

- direct surface contact
- inhalation of evaporated hydrocarbons
- direct and/or indirect digestion.

The possibility of adverse effects to whales from a spill is primarily a function of coincident presence. For most threatened whale species, their low population densities combined with the limited spatial and temporal nature of a spill would restrict the potential scale of impact. The modelling for a large spill associated with the Gorgon Development indicates that 88% of the original volume of a condensate spill would have dispersed within 48 hours (Technical Appendix B3). Bunker fuel would persist longer but also has a lower level of toxicity and aromatic components. The highly mobile nature of whales reduces the probability of prolonged exposure to floating or evaporated oil. There are no recognised whale breeding or feeding grounds within the areas that the modelling has shown may be affected by a spill.

Humpback whales are the species most at risk, particularly to a large spill off the west coast of Barrow Island, as they are seasonally numerous in the area and have a relatively short resurfacing interval. Based on estimates of migrating humpback densities in the region (Jenner et al. 2001), a spill persisting for up to 3 days during the peak migration period could potentially affect 90 humpback whales, or approximately 1% of the population. The Western Australian humpback population is thought to be increasing at approximately 10% per year and this level of effect would be unlikely to affect population viability. It is likely that most whales temporarily exposed to hydrocarbons would not suffer significant effects, but if it is assumed that mortalities could result following exposure, the ecological consequences of this impact would be minor to moderate. As the probability of this type of spill is remote, the residual risk to whales is low to medium.

Sea Turtles – A large spill of condensate off the east coast could potentially affect turtle eggs (via nesting females traversing an intertidal slick), hatchlings entering the sea or adult turtles. In the unlikely event of a large spill during summer where contingency responses could not successfully protect nesting beaches, widespread effects on east coast egg/hatchling survival could result. However, the very limited persistence of condensate in the tropical environment would restrict effects to a small proportion of the seasons nesting effort. Sea turtle populations tend to be resilient to occasional short-duration major losses at localised phases in their life cycle (Limpus 2004) and population level effects would be unlikely.

A large spill, particularly one that reached inshore areas during the nesting season, could also potentially expose significant numbers of adult turtles to hydrocarbons. The impacts of oil spills on turtles are not well documented, although there were reports of lesions and mortalities being apparent following the Gulf War spill (Sadiq and McCain 1993). It is likely that the potential impacts of oil on turtles would be similar to those for marine mammals. Turtles found in the region are both carnivores and herbivores so severe impacts on reef or algal/seagrass communities could also reduce available food resources. Whether turtles would ingest contaminated biota is unknown as is whether ingestion could have a deleterious effect on an animal's health or reproductive success.

The relatively short persistence of a condensate spill at any location and its limited propensity to affect deeper subtidal areas would reduce the potential scale of effects to turtles. Nevertheless, a worst case scenario may result in widespread impacts to east coast turtles. If significant numbers of the flatback nesting population suffered mortalities, local or even Barrow Island level population viability might be affected with serious to major consequences. The probability of this sort of spill is extremely low (7.40 x 10-5/kmy) and an incident with these consequences would be remote. Therefore, the residual level of risk is medium.

Seabirds – Although seabird mortalities due to plumage fouling or oil ingestion are usually the most apparent effects of an oil spill, the most significant risk to bird populations is through interference to breeding (Scholz et al. 1992). Contact with an egg via fouled plumage can kill the embryo (Volkman et al. 1994) and ingested oil may depress egg laying or reduce the fertility of eggs laid (Ainley et al. 1981). Physical disturbance during clean up operations if a spill occurred during the breeding season may further disrupt breeding activities.

The extent of impact of an oil spill on bird populations would vary considerably according to the location of the spill and its timing. The light and evaporative nature of condensate and diesel would limit the potential exposure period of a spill of these oils. The tropical climate of the area could be expected to reduce the significance of hypothermia, which has been identified as the greatest cause of mortalities in oil affected birds (Scholz et al. 1992).

The seabirds potentially at risk from a spill have widespread distributions and, given the relatively localised and short-lived nature of a condensate spill, long-term consequences to populations are unlikely. Recovery of populations of EPBC Act listed threatened species such as wedge-tailed shearwaters could, however, be slow if considerable mortalities of breeding animals occurred. The consequences of this level of impact would be serious, potentially reducing the viability of the local population. The probability of such a spill occurring and coinciding with the presence of significant numbers of the breeding population is rare. Therefore the residual risk is medium.

Small Spill

The potential impacts to marine fauna from a smaller spill off the west coast of Barrow Island are correspondingly lower. Consequences range from moderate to serious with potential effects on local turtle population viability if a spill occurred close to shore and persisted in inshore areas during turtle nesting. With the management measures proposed, it is considered unlikely that these consequences would occur from a small spill. Therefore small spills represent a medium risk to marine fauna.

11.5.6 Cumulative Risk

Marine Mammals

Whales and Offshore Dolphins – Humpback whales are the only whale species likely to be affected by the proposed Development. The most likely impact on humpback whales is behavioural disturbance from construction activities and noise off the west coast of Barrow Island. Underwater noise from construction vessels may temporarily displace whales from the immediate vicinity and migrating humpbacks may deviate from their preferred route to avoid the source of noise. Migration success would not be compromised and as the whales would maintain separation distances from the source of noise, physiological injury is very unlikely. Resting humpbacks are occasionally observed in the shallow waters to the east of Barrow Island. These individuals are expected to avoid the construction areas around Town Point during the construction period. Vessel strikes and accidental oil spills on either coast could result in injury or mortality of individual whales, but these events are very unlikely due to the low density of whales and the whale watch procedures on board each vessel.

There are no critical habitats for humpbacks or other whales around Barrow Island or between Barrow Island and the mainland and none of the recognised feeding, breeding or resting areas would be affected. Cumulative impacts due to localised disruption of behaviour and migratory routes and possible mortality of a few transitory individuals from vessel strike or oil spill may reduce whale abundance in the immediate area, but would not affect the viability of the regional whale populations.

Nearshore Dolphins – Nearshore dolphins, such bottlenose dolphins, are abundant in the shallow waters around the proposed marine construction sites on the east coast of Barrow Island. These dolphins are at greater risk of injury or mortality from possible blasting operations and vessel movements, particularly on the east coast. Potential localised, short-term disturbance may continue for the life of the Development due to vessel movements but adverse impacts to individuals or populations are unlikely. Infrastructure presence and lighting could cause localised long-term alterations in feeding behaviour and prey availability. Accidental oil spills could cause direct and indirect effects, including individual mortalities, but no population level effects. Cumulatively, the Development is expected to result in short-term displacement and longer-term but localised behavioural changes. Effects on population viability are not expected for any species.

Dugong – Dugong are at risk of impact from underwater noise and physical interaction with vessels, particularly during the construction phase. These impacts are expected to be localised and short-term. Development infrastructure, including dredged areas, may cause local, long-term loss of non-critical habitat and operational vessel movements may cause ongoing low levels of injury or mortality through collisions. The viability of local, Barrow Island and regional dugong populations is not expected to be affected by the cumulative effects of multiple stressors.

Marine Reptiles

Flatback Turtles – Effects from the Development on flatback turtles could potentially range from short-term behavioural disturbance to reduction in local population viability through loss of breeding adults and hatchlings. Disturbance from noise, light and physical interaction during construction may effect up to three years of breeding behaviour in, under extreme worst case scenarios, up to 50% of the east coast population. Many of the identified stressors are antagonistic rather than compounding, for example if underwater noise caused displacement of nesting females from beaches around Town Point, the adults and hatchlings would not be as exposed to effects of light as they would not emerge in lit areas. Given that not all of the population breed each year (1 – 3 year remigration) and management that will be implemented, including monitoring and contingency responses if impacts are evident, it is likely that the actual extent of impact will be considerably less than the worst case prediction. The short duration of construction effects relative to the breeding age of the species would tend to reduce impacts at the population level. The viability of populations on Barrow Island, in the immediate region and at broader levels, is not expected to be compromised.

Risks from the operations phase relate primarily to light spill and associated disturbance to hatchling survival rates. Infrastructure, particularly the shipping access channels, will potentially reduce available foraging habitat although the habitat types involved are widespread locally and throughout the immediate region. Increased vessel movements could result in occasional ongoing injury or mortalities due to collisions. Overall, impacts are expected to involve a small proportion of the local population for the duration of the Development. Commitment to continuous improvement and to extensive studies to improve scientific knowledge of the species should lead to increasingly effective management and corresponding reduction in effects. In worst case scenarios, the viability of the local population may be compromised but the species is expected to persist in adjacent areas on the east coast of Barrow Island. The Development will not affect the viability of the species in the immediate region. Improved understanding of flatback lifecycles, demographics and susceptibility to artificial lighting through monitoring and research programs will improve capacity for regional conservation management and offset local impacts.

Green Turtles and Hawksbill Turtles – A small proportion of the breeding and resident populations of green and hawksbill turtles on the west coast of Barrow Island may be affected by construction activities associated with pipelay, particularly drilling for the shore crossing at North White's Beach. A few turtles may be injured or killed in collision with construction vessels. Local reproductive output may be reduced for one or two seasons if inter-nesting females are temporarily displaced from the area. Smaller numbers of these turtles will also potentially be exposed to impacts from construction and operations on the east coast. Operations vessels will present an ongoing risk of collision, but green and hawksbill turtles are less common on the east coast.

Accidental oil spills, on either coast, could cause broader spatial impacts to breeding activity similar in scale to cyclonic perturbation. Such impacts could affect the success of a cohort of recruits within a given year. Population viability at local, Barrow Island or regional levels is not expected to be affected and the cumulative impact of a few collision mortalities would be small.

Sea Snakes and Kraits – Cumulative impacts to sea snakes and kraits are expected to be restricted to short decreases in local abundance or localised behavioural changes. The Development is expected to have no affect on the viability of populations of any of the species that occur in the Development area.

Sharks and Fishes

Potential impacts on whale sharks and other migratory sharks are primarily related to construction and commissioning activities that may cause localised, short-term behavioural changes. Disturbance of the seabed, physical interaction and noise and vibration are expected to cause avoidance of the area by whale sharks. Construction activities on the east coast, particularly blasting, may cause physiological harm to very low numbers of individuals. Cumulative impacts are considered to be minor with no effects on population viability.

Effects to potato cod and other non migratory reef fish include disturbance of the seabed and loss of habitat caused by dredging, blasting and pipelay. Blasting could cause localised mortalities. Artificial structures would create additional habitat and may enhance local abundance. Localised short-term changes in behaviour may result from underwater noise and vibration as reef fish avoid the noise source. Localised short-term changes in behaviour may also occur in response to physical interaction with vessels. The cumulative impacts of disturbance are expected to be limited to localised short-term behavioural changes and potential local short-term decreases in abundance mainly associated with construction and commissioning activities.

Impacts on rock pipefish and related receptors are primarily associated with construction and commissioning activities. Disturbance to the seabed during dredging and piplelay may cause loss of non-critical habitat. Mortality could occur as a result of dredging (including blasting) operations. A localised increase in abundance may occur around artificial marine structures such as the causeway, MOF and jetty. Accidental leaks or spills could result in mortality of rock pipefish in shallow subtidal habitats.
The cumulative impacts may result in local, long-term decreases in abundance but no reduction in population viability is likely.

Sea Birds

Noise and vessel movements during construction are likely to cause localised, short-term disturbance to seabird behaviour. Light emissions during both construction and operations (including flaring) may affect foraging success, navigation and breeding success (e.g. shearwaters). The areas affected do not have particular significance to listed species.

The seabird species that will be affected by the Development have widespread distributions and are generally both locally and regionally abundant. Cumulative impacts may comprise long-term changes in localised behaviour and potential reductions in abundance in worst case scenarios (e.g. major oil spill coinciding with shearwater breeding season). The viability of listed shorebird populations on Barrow Island, in the immediate region and at a broader regional viabilities are not likely to be threatened.

Table 11-23:
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Stressor: Seabed Disturbance **Environmental Management Objective/s:** • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning Dredging and blasting for: • MOF • causeway • LNG load out facility • jetty. Dumping of dredge spoil. Construction of feed gas and domestic gas pipelines (inc. jetting at HDD exit point). Construction of causeway and open pile jetty. Drilling of subsea wells. Installation of subsea gathering system. Anchoring of drill rigs and pipelay vessel. Installation of optical fibre cable to the mainland.	• loss of, or disturbance to, marine fauna habitat • direct loss of benthic faunal communities, including potential loss of listed pipefish • decline in marine water quality (e.g. sedimentation, nutrient increase and/or oxygen depletion) • burial of infaunal communities by drilling solids • avoidance of Development area by mobile megafauna • loss of fauna associated with coral communities • burial of deepwater infauna communities near offshore wells.	**Construction and commissioning** • specify relevant EIS/ERMP commitments in tenders and contracts • minimise areas of seabed disturbance, by constructing open pile jetty, through causeway design and channel location and by minimising area and volume of dredging • select spoil grounds, anchoring sites and facilities locations to reduce impacts on fauna • model dredge sediment plumes on the east coast to provide input to dredging schedules/management to minimise extent/severity of impacts • model plumes associated with HDD on west coast • dispose of spoil in accordance with Sea Dumping Permit conditions • implement DoIR approved Environment Plan for offshore drilling including control of drill	**Construction and commissioning** • no long-term impacts to significant marine communities • long-term viability of listed fauna species maintained • adherence to DoIR approved Environment Plan • no breach of environmental licence conditions • compliance with EPA guidance statement for benthic primary producer habitat disturbance • implementation of anchor management plan • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • establish a turtle tagging and monitoring program on the east coast of Barrow Island, designed in conjunction with CALM, to investigate population size and distribution on the island. Program will include a control site (e.g. within the Montebello Island group) and will be undertaken in conjunction with the tagging program in the	**Construction and commissioning** Likelihood – likely Consequence – minor Risk – medium Effects of seabed disturbance on marine fauna during construction are expected to be mainly minor being localised, short-term to long-term decreases in general fauna abundance. Affected communities are widespread within the region. Areas affected by long-term alterations to seabed characteristics do not represent critical habitat to any listed species. Possible loss of listed pipefish or locally significant coral communities are minor consequences. No effects on local population viability are expected.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Operations Localised maintenance dredging as required e.g. after cyclone. Resuspension of materials at spoil disposal site.		cuttings disposal and monitoring of seabed impacts • maintain optimum of four metres under keel clearance on the trailer suction hopper dredge to reduce sediment resuspension • use sediment curtains on east coast where practicable • schedule shore crossing activities on the west coast to reduce activities during peak turtle nesting period • avoid dredging on west coast to protect benthic fauna from disturbance through sedimentation • implement anchor management plan to reduce impacts. **Operations** • establish permanent moorings to minimise need for further anchoring.		immediate vicinity of the Development (i.e. at YCS, YCN, Bivalve, Terminal beaches) over the 2005/2006, 2006/2007 and 2007/2008 nesting seasons • presence of marine monitors during all relevant marine construction activities • monitoring in accordance with the Sea Dumping Permit conditions • routine audit against management requirements outlined in drilling and pipeline Environment Plans, EPA licence conditions, Sea Dumping Permit and EMPs.	**Operations** Likelihood – likely Consequence – minor Risk – low Effects of seabed disturbance on marine fauna during operations are expected to be limited to localised episodic decreases in general fauna abundance over the Development lifetime. No effect on local population viability is expected.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Stressor: Physical Interaction **Environmental Management Objective/s:** • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning Vessels and barges for MOF, drilling, dredging, pipeline construction and transport of equipment, materials and personnel. Dredging of shipping channels. Presence of construction workforce on Barrow Island – recreational use of beaches and fishing. **Operations** Vessels and barges for transport of equipment and materials including export tanker movements Maintenance operations at marine facilities, e.g. cleaning piles and dredging	• behavioural changes in listed marine megafauna (e.g. cetaceans, dugong and turtles) in response to structures and to avoid encounters with workforce • vessel collision with listed marine fauna resulting in injury or mortality • injury or fatality of turtles or sea snakes hit by dredge cutter • some pressure on fish stocks.	**Construction and commissioning** • specify relevant EIS/ERMP commitments in tenders and contracts • provide employee induction, awareness and training aimed at building a culture of environmental awareness and understanding of the conservation values of Barrow Island • enforce workforce rules on interaction/interference with flora and fauna, under terms of employment • restrict recreation areas for construction workforce to designated areas and times • control and restrict access to beaches and intertidal reefs • enforce vessel speed restrictions • time higher risk construction activities to avoid peak sensitive periods (e.g. peak migration, nesting)	• long-term viability of listed fauna species maintained • no breach of environmental licence conditions • adherence to workforce rules regarding interaction with flora and fauna • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • presence of marine monitors during all relevant marine construction activities • establish a turtle tagging and monitoring program on the east coast of Barrow Island, designed in conjunction with CALM, to investigate population size and distribution on the island. Program will include a control site (e.g. within the	**Construction and commissioning** Likelihood – likely Consequence – minor, occasional turtle, dugong or sea snake injury or mortality through vessel collision. Effects are expected to be limited to short-term, local changes in behaviour or reductions in abundance of listed fauna with no impact on the local population viability. Risk – medium

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Presence of operations workforce on Barrow Island, pressure on local fish stocks.		• use warning chains on dredge if surveys confirm presence of turtles on the seabed in areas to be dredged • conduct surveys to determine flatback turtle use of channel areas in summer of 2005/2006. **Operations** • restrict recreation for operations workforce to designated areas and times • time operations activities (eg. maintenance) to avoid peak sensitive periods • restrict vessel speed and access • check seabed for resting turtles prior to maintenance dredging and use warning chains on dredge if surveys confirm presence of turtles on the seabed in areas to be dredged • controls over fishing areas and bag limits in accordance with WA Fisheries regulations.		Montebello Island group) and will be undertaken in conjunction with the tagging program in the immediate vicinity of the Development (i.e. at YCS, YCN, Bivalve, Terminal beaches) over the 2005/2006, 2006/2007 and 2007/2008 nesting.	**Operations** Likelihood – likely Consequence – minor Risk – medium Minor consequence due to occasional turtle, dugong or sea snake injury or mortality through vessel collision. Effects are expected to be limited to short-term local changes in behaviour or reductions in abundance of listed fauna with no impact on the local population viability.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Stressor: Physical Presence **Environmental Management Objective/s:** • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Operations Permanent presence of: • MOF • causeway • jetty • subsea infrastructure (e.g. wellheads, flowlines) at offshore field • feed gas and domestic gas pipelines • optical fibre cable • dredged channels.	• disturbance to marine fauna behavioural patterns (i.e. some obstruction of movement along east coast) • impact or modification to habitats (e.g. turtle beaches) • creation of 'artificial' habitat associated with subsea facilities • aggregation of fish and other fauna around jetty and causeway • possible change in sediment transport causing change shape of turtle nesting beaches • possible change in wave direction due to refraction around causeway causing disorientation of hatchling turtles • development of infaunal community in sediments of dredged channels.	**Construction and commissioning** • specify relevant EIS/ERMP commitments in tenders and contracts • locate and orientate causeway to minimise potential effects on wave direction and longshore sediment transport • implement open pile jetty design (minimises impediments to water flow, and sediment and marine fauna movement) • bury pipeline shore crossings (i.e. HDD) • rehabilitate beaches to pre-construction profile. **Operations** • design causeway to minimise the effects on near-shore wave climates that are important cues for hatchling sea dispersal orientation.	**Construction and commissioning** • no long-term impacts to significant marine communities • long-term viability of listed fauna species maintained • no breach of environmental licence conditions • compliance with EPA guidance statement for benthic primary producer habitat disturbance • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of beach alignment either side of Town Point.	**Operations** Likelihood – likely Consequence – minor Risk – low Physical presence effects on marine fauna may include local, long-term behavioural impacts to general fauna and local, long-term increases in abundance of some taxa leading to changes in community composition. These changes are not expected to affect the viability of local populations.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Stressor: Wastewater Discharges **Environmental Management Objective/s:** • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning • stormwater containing chemicals, hydrocarbons and sediment • deck washdown • deck runoff and domestic discharges from rigs and other construction vessels • discharge of hydrotest water from feed gas pipeline containing biocides and corrosion inhibitors • drilling fluids.	• acute toxicity of discharges to marine fauna • chronic toxicity of contaminants accumulating in sediments adjacent to infrastructure.	**Pre-construction** • reduce discharges to environment through engineering design reduce e.g. subsea development avoids the need for an offshore platform and associated discharges. **Construction, commissioning and operations** • specify relevant EIS/ERMP commitments in tenders and contracts • limit domestic waste discharges food scraps, sewage and grey-water • avoid/disallow sewage or putrescible waste discharge within 12 nm of land • conform to the requirements of MARPOL 73/78 Annex IV; offshore sewage and putrescibles disposal will macerate to less than 25 mm diameter prior to disposal • use only biodegradable detergents	• no long-term impacts to significant marine communities • long-term viability of listed fauna species maintained • no breached of environmental licence conditions • MARPOL 73/78 and ANZECC/ ARMCANZ requirements • no sewage or putrescible waste discharged within 12 nm of land • all sewage and macerated waste macerated to less than 25 mm diameter prior to disposal • no contamination outside of immediate Development area • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • environmental audits to determine compliance with EPA licence conditions, and Environment Plan, MARPOL and ANZECC/ARMCANZ requirements • establishment of waste targets and regular review of waste inventory.	**Construction and commissioning** Likelihood – likely Consequence – minor Risk – low The effects of wastewater discharge will be limited to a localised, short-term decrease in abundance of general fauna with no impact on population viability. **Operations** Likelihood – likely Consequence – minor Risk – low The effects of wastewater discharge will be limited to a localised, long-term decrease in abundance of general fauna with no impact on population viability.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Operations • runoff from hardstand areas such as the jetty containing chemicals, or hydrocarbons and entering the marine environment • runoff from decks (operations vessels) • leaching of anti-foul compounds from painted infrastructure and vessel hulls.		• collect any potentially contaminated drainage from decks and work areas through a closed drain system and processed to remove oil prior to discharge • meet ANZECC/ARMCANZ (2000) water quality standards after dilution at discharge point • store all oily water (bilge) for onshore disposal or passed through oily water separator prior to discharge • manage ballast water in accordance with AQIS requirements.			

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Stressor: Light **Environmental Management Objective/s:** • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning Artificial light from vessels, gas processing facility, construction camp, MOF, jetty and pipeline construction areas on east and west coast. Flaring during commissioning (continuous for a number of weeks). **Operations** Night-time operation of proposed gas processing facility and associated infrastructure (onshore and marine).	• reduced turtle nesting, by deterring the female turtles from emerging onto the beach • presence of operations artificial lighting could cause a longer-term shift of flatback turtle nesting effort to adjacent beaches • hatchlings are attracted to artificial lights and will move towards these lights rather than the ocean leading to reduced survival rates • offshore lights attract hatchlings already at sea and expose them to increased predation in the light pool • increased availability of food (e.g. turtle hatchlings) favours adaptable species, such as silver gulls and may lead to a change in community composition	**Pre-construction** • set gas processing facility and flare back from coast shielded by coastal dunes • design gas processing facility so that no permanent 24-hour lighting is located within 500 m of turtle nesting beaches • design lighting in accordance with tiered lighting strategy. **Construction and commissioning** • specify relevant EIS/ERMP commitments in tenders and contracts • minimise lighting levels to those required for safe working • minimise artificial lighting in nearshore areas and on beaches at night during peak turtle breeding seasons. **Operations** • minimise lighting levels to those required for safe working • implement policy of no routine flaring (this includes ship loading)	• long-term viability of listed fauna species maintained • no light sources directly visible from nesting beaches • no permanent 24-hour gas processing facility lighting located within 500 m of nesting beaches • compliance with tiered lighting strategy • adherence to no routine flaring policy • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • monitoring of hatchling behaviour during construction and initial operations phase with additional mitigation strategies implemented if adverse impacts are identified, for example during peak hatchling emergence periods, hatchlings that become disorientated will be relocated to 'dark' beaches	**Construction and commissioning** Likelihood – almost certain Consequence – minor Risk – medium Substantial evidence suggests that brightness of light is an important cue used by turtle hatchlings. Construction lighting (given 24-hour construction) has the potential to disorientate turtle hatchling thereby reducing their sea-finding ability and survival rates. This could result in a local, long-term decrease in abundance of listed flatback turtles without threatening the viability of the local population. Construction lighting may also induce local, long-term changes in behaviour of turtles, seabirds, dolphins and other fauna that are susceptible to light induced behavioural change.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Non-routine operations Flaring during non-routine operations (estimates are five night events during the main turtle nesting season).	• juvenile wedge-tailed shearwaters attracted to the lights of the gas processing facility may by injured through collision with infrastructure • bottlenose dolphins will use light spill over water to assist in hunting and are likely to congregate in lit areas at night.	• use shielded red lights in areas where colour definition is not required for safety or operational purposes. This includes areas such as the MOF, causeway, jetty, roads within the gas processing facility and general open areas • use shielded yellow/orange type of reduced spectrum light, such as sodium vapour, where colour definition is required. These lights will form the primary lighting for the facility • use shielded white type lights in areas that require inspection during operator rounds and/or regular maintenance (e.g. filter replacement). These lights will be switched off when not required. **Non-routine operations** • non-routine flaring will be infrequent and of short duration (estimates are five night events during the main turtle nesting season).		• establish a turtle tagging and monitoring program on the east coast of Barrow Island, designed in conjunction with CALM, to investigate population size and distribution on the island. Program will include a control site (e.g. within the Montebello Island group) and will be undertaken in conjunction with the tagging program in the immediate vicinity of the Development (i.e. at YCS, YCN, Bivalve, Terminal beaches) over the 2005/2006, 2006/2007 and 2007/2008 nesting seasons • routine light audits to assess compliance with lighting requirements and monitor light spill into marine areas.	**Operations** Likelihood – likely Consequence – minor Risk – medium Substantial evidence suggests that brightness of light is an important cue used by turtle hatchlings. Operation lighting has the potential to disorientate turtle hatchling sea-finding and survival rates. This could result in a local, long-term decrease in abundance of hatchlings (through episodic short-term events) with no effect on the local population viability. Operations lighting may also induce local, long-term changes in behaviour of turtles, seabirds, dolphins and other fauna that are susceptible to light induced behavioural change. **Non-routine operations** Likelihood – likely Consequence – minor Risk – low Effects from non-routine lighting may include short-term behavioural impacts on listed and general fauna with no decrease in abundance expected.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Stressor: Noise and Vibration **Environmental Management Objective/s:** • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction and commissioning • noise and vibration from vessel movements, drilling, dredging, pipelay and piling • intermittent blasting will be required during dredging on the east coast and during the construction of the causeway, jetty and MOF • HDD for west coast shore crossing. Operations • noise from vessel and tanker movements • low level noise from subsea gathering system.	• localised impact on listed marine megafauna (turtles, dugong, dolphins, whales) due to noise and vibration • potential disturbance to turtle nesting, breeding and feeding activity. Sea turtle eggs are at risk from movement induced mortality during a 12-hour to 14-day window after laying • blasting will cause physiological impacts to marine fauna in immediate vicinity due to shock waves • behavioural effects to marine fauna as a result of underwater noise • low level noise not expected to cause behavioural changes in marine megafauna.	**Construction and commissioning** • specify relevant EIS/ERMP commitments in tenders and contracts • schedule blasting for daylight hours only, avoiding sunset and sunrise • reduce noise through vessel speed restrictions • minimise overlap of construction schedules in nearshore areas with key breeding periods for sensitive protected fauna (e.g. turtles) • use drill and blast techniques which reduce zone of effect • use warning charges to encourage animals to move away from the construction area prior to a blast. This will be supported by visual marine monitoring for sensitive marine fauna (e.g. cetaceans and turtles) • defer blasting when sensitive marine fauna are detected within a specified radius.	• no blasting outside of daylight hours • long-term viability of listed fauna species maintained • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • visual monitoring during blasting operations to determine the presence of listed taxa near the blast area.	**Construction and commissioning** Likelihood – likely Consequence – minor Risk – medium Some sea turtles and other listed marine megafauna may suffer physiological effects or mortality from blasting on the east coast if within close proximity. Long-term, local decreases in abundance may occur if noise and vibration disrupt sea turtle breeding at local beaches. No effect on the local population viability is expected.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
		Operations • implement vessel speed and access restrictions • schedule or plan seismic monitoring for times outside the peak turtle nesting period • prohibit vehicular traffic or other sources of noise and vibration on turtle nesting beaches during the peak turtle nesting season.			**Operations** Likelihood – likely Consequence – minor Risk – low Noise from vessel and tanker movements and subsea gathering systems is likely to have a localised short or long-term impact on behaviour of marine species including listed marine fauna.

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
Stressor: Leaks or Spills **Environmental Management Objective/s:** • To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*					
Construction, commissioning and operations Smaller spill/leak (<10 m^3) potentially caused by small vessel grounding/collision, vessel refuelling, transferring and transport of hydrocarbons and/or chemicals during construction or operations. Larger spill/leak (>10 m^3) potentially caused from pipeline failure, larger vessel severely damaged by grounding or collision, process or operator failure or collision during construction or operations.	• acute toxic effects to intertidal and shallow subtidal biota • smothering of exposed intertidal biota or mobile fauna that contact a surface slick of heavy oil • possible chronic toxic effects to sensitive habitats from oil contacting low energy shorelines and becoming entrained in sediments • acute and/or chronic toxic effects to foraging seabirds in the intertidal zone that contact oil • acute and/or chronic toxic effects to emergent turtle hatchlings traversing oiled sediments in the intertidal zone • acute physiological effects on listed marine fauna (dolphins, turtles, dugong, whales) surfacing in a surface slick or gas plume.	**Construction, commissioning and operations** • specify relevant EIS/ERMP commitments in tenders and contracts • site LNG loadout facility 4 km from shore, reducing probability of spilled fuel reaching intertidal areas • Offshore field 60–70 km from Barrow Island reduces risk of spill reaching the island • use best available design and construction of all infrastructure to minimise risks of spills • use of dry break couplings, floating hoses and strict restriction on refuelling operations • use in-built automatic shut-down systems • implement early leak detection and reporting system • use best practice procedures to ensure safe operations • apply industry standards/best practice for storage and handling of fuels and chemicals (e.g. bunding)	• no breaches of environmental licence conditions • contamination remediated • compliance with long-term management targets and KPIs (CALM 2004).	An environmental monitoring program will be established to determine whether the Development meets environmental objectives. The monitoring program will measure against the requirements of the Development's EMS and construction and operations EMPs (Chapter 16). Elements of the monitoring program will include: • regular audits of vessel safety and environmental performance • regular audit, inspection and maintenance of facilities, including ongoing corrosion monitoring and control program • implementation and regular testing of emergency shut-down procedures to reduce potential volumes from spills and leaks	**Construction, commissioning and operations** Smaller spill (<10 m^3) Likelihood – likely to possible Consequence – minor to serious Risk – medium Environmental effects of a hydrocarbon spill depend on a number of variables. Most biological communities are susceptible to the effects of oil spills and recovery is dependant on the type of ecosystem. Generally a small spill will not reach sensitive areas and will have minor consequences to marine fauna. However, a small spill could result in a widespread, short- to long-term impact on general intertidal fauna. If a small spill was concentrated on a few beaches, turtles may be prevented from nesting,

Table 11-23: (continued)
Summary of Risk Assessment for Marine Fauna

Activities/ Causes	Potential Environmental Impact/Consequence	Management Measures	Targets	Measurement Strategies	Residual Risk
		• develop comprehensive emergency response including oil spill contingency • model spill trajectory to assist in predicting behaviour of possible oil slicks • maintain spill response resources maintained at Barrow Island • pre-plan additional external response resources available through industry/government arrangements • make spill recovery equipment available at all work sites • use local pilots to berth ships • create of navigational exclusion zones around seabed infrastructure to prevent accidental damage to facilities.		• monitor in the event of a spill or leak affected area to determine effectiveness of remediation.	causing a long-term, local impact on abundance. Local population viability is not expected to be affected. Larger spill (>10 m^3) Likelihood – unlikely Consequence – serious to major Risk – medium Environmental effects of a hydrocarbon spill depend on a number of variables. If a large spill coincided with the peak breeding season of flatback turtles and oil washed into the intertidal zone, becoming entrained in sediments, it may reduce nesting success and hatchling survival causing local, long-term population effects. In a worst case scenario, the population viability on Barrow Island and surrounding waters may be reduced. Surface slicks and associated gas plumes could cause physiological harm to sensitive membranes or mortality of listed fauna such as turtles, whales, dolphins, dugong and seabirds that may contact the slick.

11.6 Conclusion

Table 11-24 is a summary of potential stressors and assessed level of residual risk to marine environmental factors. The residual risks posed by stressors associated with each phase of the Development were assessed as low to medium for all marine environmental factors except for marine fauna where the implementation and effectiveness of management measures for light and dredging will be critical to reducing risk to sea turtles to an acceptable level. The potential environmental consequences of the Development are unlikely to have long-term implications for the marine environment surrounding Barrow Island or mainland components of the Development. The overall level of risk to marine conservation values is therefore considered to be acceptable and environmental management objectives for the Development achievable.

Table 11-24:
Summary of Residual Risk Levels

Environmental Factor/ Stressor	Residual Risk		
	Construction and Commissioning	Operations	Non-routine
Seabed (subtidal and intertidal)			
• Physical disturbance	L – M	L	–
• Physical presence	–	L	–
• Liquid and solid waste disposal	L	L	–
• Leaks or spills (minor <10 m^3)	L	L	–
• Leaks or spills (>10 m^3)	L	L	–
Water Quality			
• Discharges	L	L	–
• Leaks or spills (minor <10 m^3)	L	L	–
• Leaks or spills (>10 m^3)	L	L	–
Foreshore			
• Physical disturbance	M	L	–
• Physical presence	–	L	–
Marine Primary Producers			
• Seabed disturbance	L – M	L	–
• Leaks or spills (minor <10 m^3)	–	–	L – M
• Leaks or spills (>10 m^3)	–	–	L – M
• Physical presence	L	L	–
• Wastewater and other discharges	L	L	–
Marine Fauna			
• Seabed disturbance	M	L	–
• Physical interaction	M	M	–
• Physical presence	–	L	–
• Wastewater discharges	L	L	–
• Light	M – H	M – H	L
• Noise and vibration	M	L	–
• Leaks or spills (minor <10 m^3)	M	M	–
• Leaks or spills (>10 m^3)	M	M	–

A summary of results from the assessment of cumulative impacts to benthic primary producer habitats within the proposed Development area using EPA guidelines is shown in Table 11-25.

Permanent loss of benthic primary producer habitats are predicted to exceed EPA cumulative loss threshold levels in three of the fourteen management units established in accordance with EPA Guidance Statement No. 29. While these losses exceed the benthic primary producer habitat cumulative loss threshold levels, they do not represent a threat to the ecological integrity of the surrounding benthic primary producer habitat or to the conservation values of the Barrow Island Marine Conservation Area. The flat sandy seabed in both of the dredge spoil ground management units is very well represented in both the local area and the region. It is close to the depth limit for the seagrasses and is likely to be of marginal value in terms of seagrass productivity compared to shallower areas closer to Barrow Island. Similarly benthic primary producer habitats in management unit 8 within the port area are well represented throughout the Montebello/Lowendal/Barrow Island region and permanent loss of some areas of benthic primary producer habitat is not predicted to affect ecosystem integrity in the port area.

Losses of unconfirmed coral habitat in the two Lowendal Islands management units also exceed cumulative loss thresholds; however the majority of the assumed distribution of coral habitat in these management units, as identified by the CALM (2004) marine habitat mapping, has not been confirmed by field surveys. It is anticipated that only a small proportion of the areas affected by persistent turbid plumes represent coral habitat and that these coral communities would fully recover from sedimentation and turbidity impacts.

Field verification of dredge simulation models will be undertaken to confirm the predicted behaviour of sediment and TSS plumes. Results of the model verification will be available for public comment during the last four weeks of the draft EIS/ERMP public exhibition period.

Table 11-25:
Summary of Benthic Primary Producer Habitat Assessment

Management Unit	% Benthic Primary Producer Habitat -Permanent Loss*	EPA Cumulative Loss Threshold (%)
North West Coast MU 1		
Macroalgae dominated intertidal limestone platform	<1	2 (category C)
Subtidal limestone reef platform with macroalgae and scattered corals	<1	
Lowendal Islands MU 2		
Macroalgae-dominated intertidal limestone platform	0	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	0	
Reef platform/sand with scattered seagrass	0	
Confirmed coral habitat	7	
Unconfirmed coral habitat	25	
Lowendal Islands MU 3		
Macroalgae-dominated intertidal limestone platform	0	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	0	
Reef platform/sand with scattered seagrass	0	
Confirmed coral habitat	<1	
Unconfirmed coral habitat	63	
Barrow Island Port Area MU4		
Macroalgae-dominated intertidal limestone platform	<1	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	2	

Table 11-25: (continued)
Summary of Benthic Primary Producer Habitat Assessment

Management Unit	% Benthic Primary Producer Habitat -Permanent Loss*	EPA Cumulative Loss Threshold (%)
Barrow Island Port Area MU4 (continued)		
Reef platform/sand with scattered seagrass	<1	10 (category E)
Coral habitats	<1	
Barrow Island Port Area MU5		
Subtidal limestone reef platform with macroalgae and scattered corals	0	10 (category E)
Reef platform/sand with scattered seagrass	0	
Coral habitats	8	
Barrow Island Port Area MU6		
Subtidal limestone reef platform with macroalgae and scattered corals	0	10 (category E)
Reef platform/sand with scattered seagrass	0	
Coral habitats	5	
Barrow Island Port Area MU7		
Macroalgae-dominated intertidal limestone platform	0	10 (category E)
Subtidal limestone reef platform with macroalgae and scattered corals	<1	
Reef platform/sand with scattered seagrass	<2	
Coral habitats	0	
Barrow Island Port Area MU8		
Subtidal limestone reef platform with macroalgae and scattered corals	0	10 (category E)
Reef platform/sand with scattered seagrass	0	
Coral habitats	23	
Barrow Island Port Area MU9		
Reef platform/sand with scattered seagrass	7	10 (category E)
Dredge Spoil Area MU10		
Reef platform/sand with scattered seagrass	6	2 (category C)
Dredge Spoil Area MU11		
Reef platform/sand with scattered seagrass	14	5 (category D)
Mainland MU1		
Mangrove habitat	<1	1 (category B)
Mainland MU2		
Seagrass habitat	0	5 (category D)
Onlsow MU		
Macroalgae and seagrass habitat	<1	5 (category D)

** Figures for benthic primary producer habitat loss are based on the anticipated impact scenario.*

12: Quarantine – Risks and Management

Quarantine management of Barrow Island was first implemented by operators of the oilfield in the 1960s, and through continuous improvement has provided an effective layer of protection to the conservation values of the island. Quarantine management will form an essential component of the environmental management system for the Gorgon Development because the construction and operation of a gas processing facility on Barrow Island will result in a substantial increase above the current number of vessel shipments and aircraft flights to the island. Consequently, this will increase the potential for the introduction of non-indigenous species which could lead to irreversible and detrimental impacts to the ecological composition and function of the island's ecosystem through competition, predation, or habitat modification. To protect Barrow Island from potential introductions of non-indigenous species, the Gorgon Joint Venturers (the Joint Venturers) have developed a new approach to quarantine by developing a risk-based Quarantine Management System.

As there is no precedent for a quarantine program of such rigor anywhere else in the world, the Joint Venturers have been guided by the specific advice of the Environmental Protection Authority to develop quarantine protection for Barrow Island. As a consequence of this advice, the Joint Venturers established a Quarantine Expert Panel, initiated an extensive and transparent process of community consultation, and in concert with the community and experts, developed of a set of standards for acceptable risk.

The Joint Venturer's approach to quarantine management, which has been developed with input from the community and independent experts, is focused on the pre-border prevention of introduction of non-indigenous species, supported by contingencies for border and post-border quarantine controls. In this Draft EIS/ERMP, the application of this risk-based methodology is demonstrated for three priority pathways of entry to Barrow Island, and includes a description of potential quarantine barriers at significant steps in each pathway. The cumulative effect of such barriers will reduce quarantine risk to an unprecedented level of protection for the conservation values of Barrow Island. This process will be duly applied to all entry pathways to the island prior to the commencement of pathway activities, and will continue to be applied to subsequent phases of the proposed Development.

12.1 Introduction

Barrow Island is internationally recognised for its conservation values and is an important asset to the conservation estate of Western Australia. It supports a diversity of species, some of which have naturally evolved in isolation from the mainland for over 8000 years and do not occur elsewhere. The island's conservation significance has been recognised under statute since 1908 when it was declared a Nature Reserve, and later proclaimed a 'Class A' Nature Reserve in 1910. The subsequent provision for petroleum exploration and production operations on Barrow Island in the 1960s presented challenges to the ongoing protection of the conservation values of the island. However, through cooperative environmental management practices developed and implemented by the oilfield operator and Department of Conservation and Land Management (CALM), the conservation values of Barrow Island remain protected. An effective part of this environmental management regime has been quarantine management which has mitigated the possibility of introduction, and prevented the proliferation of potentially destructive non-indigenous species on Barrow Island.

The Gorgon Development on Barrow Island would pose new quarantine challenges to the conservation values of the island. Activities associated with the proposed Development would increase the volume of cargoes and number of personnel movements compared to historical or current oilfield operations. These numbers would be particularly pronounced during the construction phase, and would remain at higher than current levels during the operational phase. The higher number of personnel and cargo movements to Barrow Island therefore presents a substantial increase in the potential for non-indigenous organisms to be transported to the island.

In recognition of this increase in quarantine risk to Barrow Island, the Gorgon Joint Venturers (Joint Venturers) have adopted a risk-based approach to manage the risk down to an acceptable level. This approach has involved the adaptation of established risk management practices; and included the involvement of independent technical experts and members of the community to pursue the development of a world class Quarantine Management System (QMS).

12.1.1 Quarantine Management Objectives

The overarching objective of a quarantine strategy for the proposed Gorgon Development is to facilitate the construction and operation of a gas processing facility on Barrow Island and simultaneously protect the conservation values of the island.

To support this objective, the Joint Venturers have developed a 'Barrow Island Quarantine Policy' (Box 12-1). The Joint Venturers commit to support this policy through the development and implementation of a QMS, and in doing so, believe with a high degree of confidence that the conservation values of Barrow Island can and will be protected.

Box 12-1:
Barrow Island Quarantine Policy

Barrow Island Quarantine Policy

Chevron Australia Pty Ltd, the operator of the Barrow Island oilfield and the proposed Gorgon gas facility, is proud of its environmental reputation and performance on Barrow Island. As operator of both oil and gas ventures, Chevron will continue to hold overall management responsibility for operational activities on the island, and for operating in a manner that protects the conservation values of the Barrow Island Nature Reserve and the surrounding waters.

Central to this responsibility is our goal to prevent the establishment of introduced species on Barrow Island and in the surrounding waters. This will be achieved through the implementation of a Quarantine Management System that delivers world class performance and integrates quarantine management into business planning and operational processes.

Chevron will:

- Not compromise quarantine requirements;
- Identify and manage quarantine risks arising from our operation, with the objective of preventing the introduction and establishment of species to Barrow Island;
- Develop and maintain a positive quarantine culture in our staff, contractors and suppliers;
- Engage only contractors and suppliers who have demonstrated a willingness to meet or exceed our quarantine standards;
- Maintain a system of continuous improvement in our management of quarantine;
- Meet or exceed all legal requirements, be a responsible corporate citizen and demonstrate leadership in quarantine management;
- Provide the appropriate training to support the implementation and ongoing operation of the quarantine programmes;
- Set measurable quarantine targets and performance objectives;
- Ensure conformity with this policy by a comprehensive compliance program including audits;
- Have an open and transparent quarantine process that includes stakeholder engagement and reporting;
- Recognise and address government and community concerns on quarantine; and
- Respond quickly and effectively to any quarantine emergency with the potential to impact the biodiversity of the area.

Chevron will commit the necessary resources to ensure the effectiveness of this policy.

This policy, its intent and each person's responsibility will be communicated to employees, contractors, subcontractors and visitors. All are required to comply with the processes, procedures and systems of work developed in accordance with this policy.

This policy applies to all activities on Barrow Island and in the surrounding waters.

Signed

James W Johnson – Managing Director
Chevron Australia Pty Ltd
August 2005

12.1.2 Key Quarantine Terminology

In consultation with the community, a Quarantine Expert Panel (section 12.2.2) and independent technical experts, the Joint Venturers have developed a glossary of quarantine terms. The key quarantine terms used throughout the chapter are provided in Box 12-2. Additional definitions are provided in the Glossary.

12.1.3 Chapter Outline

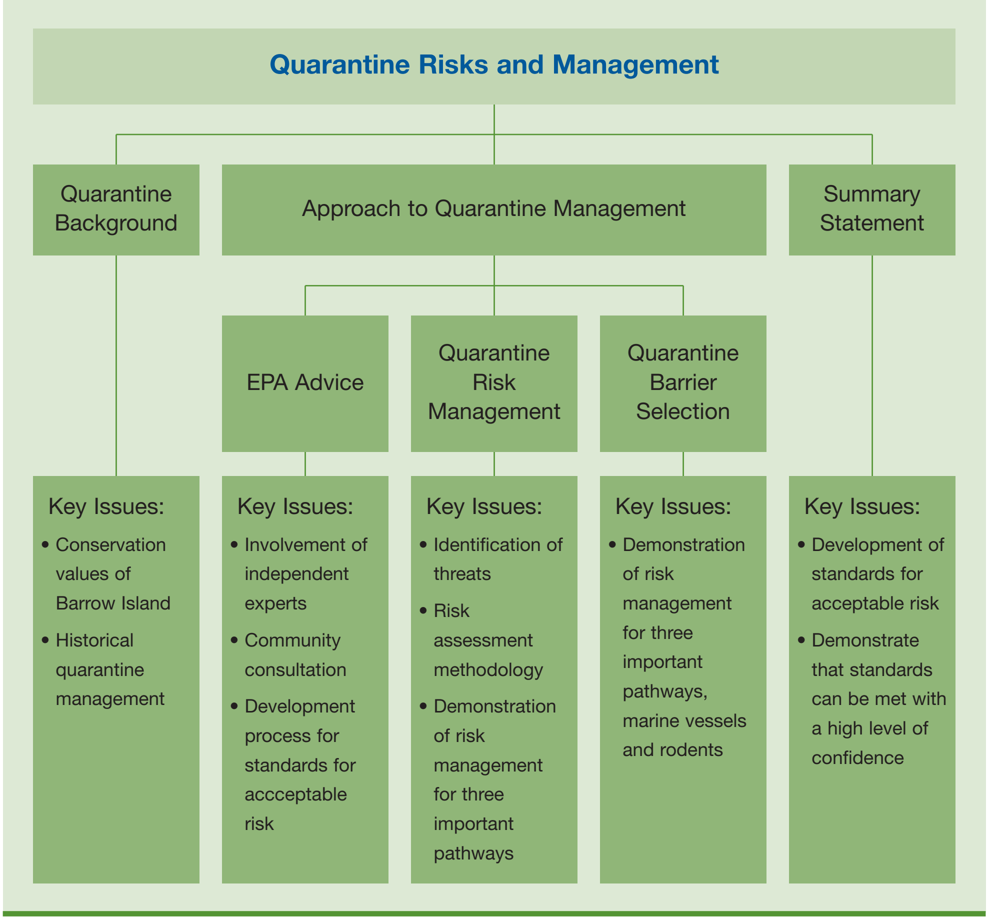
This chapter is a description of the Joint Venturers' approach to the development of quarantine management options, and demonstrates the application of those options to the Gorgon Development. Section 12.2 details the approach to quarantine management on the basis of Western Australian Environmental Protection Authority (EPA) advice, and Section 12.3 provides an overview of the existing Barrow Island environment. Section 12.4 describes the risk-based methodology developed to manage quarantine and provides an illustration for the three priority exposure pathways. Section 12.5 is a description of the process of selection of quarantine barriers to reduce risk to acceptable levels. Section 12.6 provides an outline of the QMS. The chapter concludes with a summary statement that details how the Joint Venturers have addressed quarantine to date, and will continue to address quarantine in the event that the Gorgon Development proceeds.

An outline of this chapter is illustrated in Figure 12-1.

Box 12-2:
Key Quarantine Definitions

Term	Definition
Barrier	For the purposes of assessing and managing quarantine risk, any physical, chemical, biological, procedural or administrative process which prevents a non-indigenous species from being introduced to a native environment outside of its natural range.
Border	The point of entry of cargoes, vessels or people to Barrow Island. (e.g. The 'marine pathway' border is the waters surrounding Barrow Island; the 'air pathway' border is the Barrow Island airport; and for the 'personnel', 'food and perishables pathway', the border is the village).
Breach	The failure to undertake all of the requirements of the quarantine management protocol.
Establishment	The process of an introduced non-indigenous species successfully producing viable offspring with the likelihood of continued survival.
Incursion	The discovery on Barrow Island of a live non-indigenous species.
Infection	The contamination at any step in an exposure pathway of cargoes, vessels or personnel by non-indigenous species.
Introduction	The arrival of live non-indigenous species at Barrow Island via a pathway (e.g. cargo, vessels, personnel). Introduction is an outcome of infection at steps along a pathway.
Non-indigenous species (also taken here to mean: 'introduced', 'invasive', 'alien', 'exotic' and 'pest' species).	Any species of plant, animal or micro-organism not occurring naturally on Barrow Island and marine environs whose presence there is due to intentional or accidental introduction as a result of human activity.
Pathway	A route of exposure which might enable non-indigenous species to be introduced to a native environment outside of their natural range.

Figure 12-1:
Chapter Outline – Quarantine Risks and Management



12.2 Approach to Quarantine Management

In recognition of the need to continue protecting the conservation values of Barrow Island, the Joint Venturers developed a multi-faceted approach for the management of quarantine for the Gorgon Development. This approach involved the adaptation of risk-based methodologies focused on pre-border prevention of the introduction of non-indigenous species, and is supported by contingencies for border and post-border quarantine controls. Implementation of quarantine management across all facets of the Gorgon Development will be facilitated within the framework of the QMS. It is intended that Joint Venturer and stakeholder responsibilities and authority for quarantine management will also be formalised through the Barrow Island Coordination Council (BICC) which will involve key government agencies such as CALM.

The Joint Venturers have developed this approach with the assistance of a range of biosecurity and conservation specialists, and have been guided by the outcomes of the Environmental Social and Economic Review of the Gorgon Development on Barrow Island (ESE Review) (ChevronTexaco Australia 2003).

12.2.1 EPA Advice

In response to the ESE Review (ChevronTexaco Australia 2003), the EPA prepared a report entitled Environmental Advice on the Principle of Locating a Gas Processing Complex on Barrow Island Nature Reserve (EPA 2003). In this report, the EPA states in regard to the conservation values of Barrow Island, that the 'primary potential threat is the introduction of invasive organisms, particularly animal pests and weeds, including disease' (EPA 2003, p. 2). The EPA also advised on a range of issues which should be addressed in any proposal referred for environmental impact assessment under section 38 of the *Environmental Protection Act 1986.* EPA advice relevant to the development of a quarantine strategy for the Gorgon Development is detailed below:

> **Precautionary approach:** 'This approach requires any decision to proceed with development to be based on sound data, enabling sound judgement. If the project were to proceed, it could only be with a policy of "zero tolerance of invasions" target and an associated quarantine regime of sufficient, demonstrated rigor to achieve this' (EPA 2003).
>
> **Independent expert advice, transparent public processes, and development of acceptable risk standards:** 'The EPA recommends that the proponent engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island. Such a process should include appropriate technical experts and be structured to ensure a high level of transparency and community involvement.
> The proponent be required to demonstrate to the EPA, on the advice of DLCM and the DoE, that the risk standards can be met, with a very high level of confidence' (EPA 2003).
>
> **Beyond best practice environment and conservation management: '**The EPA recommends that the developer be advised that the formal environmental impact assessment process under Part IV of the Environmental Protection Act will require clear demonstration of the developer's ability to meet any environmental and conservation risk standards. In doing so, they can expect to set new benchmarks in conservation management performance that go significantly beyond current best practice' (EPA 2003).

The approach adopted by the Joint Venturers to prevent the establishment of non-indigenous species on Barrow Island is consistent with the advice of the EPA. Specifically, this has involved the creation of the Quarantine Expert Panel, a transparent process of community involvement and engagement of independent experts, the development of a set of risk standards, and a study of quarantine programs to benchmark quarantine practices. These aspects of the approach to develop a quarantine management regime for the Gorgon Development are discussed in the following section.

12.2.2 Quarantine Expert Panel

The Joint Venturers established a Quarantine Expert Panel (QEP) of recognised and experienced independent technical specialists to obtain the best possible advice to guide the development of an effective QMS for the Gorgon Development. Experts invited to participate represented a broad cross-section of expertise especially relevant to the management of quarantine issues. Such expertise included quarantine and biosecurity management, risk management, conservation, marine and terrestrial ecology, pest management and government regulation.

The QEP consisted of ten members including an independent Chairman, and two observers representing Western Australian government agencies (Box 12-3). The Joint Venturers supported the QEP with a four person Secretariat which provided administrative support and advice pertinent to the proposed Gorgon Development. Participants (members, observers and the secretariat) at Panel meetings entered fully into all of the discussions, and brought the benefit of their expertise to discussions.

The QEP initially developed a Charter to guide the conduct of its activities. Included in this Charter were the six specific objectives of the QEP, which are to:

- Establish standards for acceptable risk which are developed in consultation with stakeholders and which are broadly acceptable for the purpose of establishing an effective quarantine management system.
- Identify the major organism groups of concern and the required baseline surveys (designed to incorporate future monitoring).
- Provide the community with the opportunity to engage in the process for setting standards and delivering a world class Quarantine Management System.
- Establish practicable policies, processes, and responsibilities which meet the risk standards.
- Establish monitoring programs for detection of introduced species and compliance with procedures.
- Establish contingency and response plans.

Box 12-3:
Quarantine Expert Panel

Quarantine Expert Panel

Purpose:

'To advise and steer the direction of quarantine management for Barrow Island, to meet the goal of no introduced species on Barrow Island and in the surrounding waters as an essential element in conserving the biodiversity of the area.'

Members	
Bernard Bowen	Chairperson
Andrew Burbidge	Conservation Specialist
David Carter	Commonwealth Department of the Environment and Heritage
Keith Collins	Risk Management Specialist
Diana Jones	Western Australian Museum
Malcolm Nairn	Biosecurity Specialist
Greg Pickles	Western Australian Department of Agriculture
Sandra Potter	Australian Antarctic Division
Andre Schmitz	Australian Wildlife Conservancy
John Scott	Commonwealth Scientific and Industrial Research Organisation
Observers	
Warren Tacey	Western Australian Department of Environment
Norm Caporn	Western Australian Department of Conservation and Land Management
Secretariat	
Russell Lagdon	Health, Environment and Safety Manager, Gorgon Development
Sean Reddan	Environmental Advisor, Gorgon Development
Richard Stoklosa	Risk Advisor, Gorgon Development
Geoff Prior	Construction and Logistics Advisor, Gorgon Development

The QEP first convened in November 2003 with a familiarisation tour to Barrow Island and the Welshpool logistics depot where existing Barrow Island quarantine facilities and practices were observed. The QEP met formally on eight occasions, during which time it considered a number of issues, provided advice on information needs, engaged in the community consultation process, reviewed research papers and made recommendations to the Joint Venturers.

The QEP delivered a report to the Joint Venturers on 30th September 2004 (Technical Appendix D1).

The outputs and strategic advice provided by the QEP can be summarised as:

- Contributed to the development of an appropriate risk assessment methodology for the protection of the conservation values of Barrow Island – the 'How-to Guide for Conducting a Risk-based Assessment of Quarantine Hazards on Barrow Island' (Technical Appendix D2).
- Provided advice on the development of an annotated bibliography of published and unpublished works related to Barrow Island.
- Provided advice on the application of the biosecurity management concept (i.e. pre-border, border, and post-border management of quarantine risk).
- Recommended the definition of biological groups of concern in order to facilitate efficient risk management practices.
- Provided advice on the potential pathways for the transport of organisms to Barrow Island.
- Provided advice on area of quarantine protection for the waters surrounding Barrow Island (refer to Section 12.3.4).
- Identified three high-risk exposure pathways for priority attention to demonstrate the application of the risk management methodology, those being: i) sand and aggregate, ii) food and perishables, and iii) personnel and accompanying luggage.
- Reviewed and commented on the development of risk standards – Report to the Community Consultation Meeting on the Risk Standards Workshops (Technical Appendix D3).
- Provided advice to guide the design and conduct of ecological terrestrial and marine field surveys.
- Provided advice to assist the development of protocol for corrective actions.
- Provided advice to guide the preparation of the QMS and a Quarantine Management Plan (QMP).

The QEP also advised the Gorgon Joint Venturers that:

- The establishment of a non-indigenous species on Barrow Island would be unacceptable.
- Zero risk (i.e. zero chance of an introduction) is not practical.

- The ecological consequences of the introduction of a non-indigenous species to the Barrow Island environment can not be predicted with any degree of confidence.
- Quarantine risk data are not available.
- The arrival of some non-indigenous species at Barrow Island would be outside the control of the Joint Venturers (i.e. natural causes and/or third parties may play a significant role in the introduction of species).
- In practical terms, not all non-indigenous species can be prevented from arriving at Barrow Island. This is particularly the case with micro-organisms as it would be impossible to describe the wide range of micro-organisms which may be transported to the island via a range of vectors.
- Potential threats posed by micro-organisms, and threats to the marine environment, present unique problems that can be managed through an adaptation of the risk-based approach.

The proceedings of each QEP meeting were captured in the form of a one-page 'Brief Summary' which was distributed to stakeholders shortly after each meeting. More detailed records of the discussions and proceedings of each meeting were recorded in an 'Outputs Document' which was subsequently reviewed and ratified by the QEP as an official meeting record. These documents were made available to the public through the Joint Venturers' website (www.gorgon.com.au), at Community Consultation Meetings and through direct postal distribution to interested persons or organisations.

The QEP was also closely associated with the community involvement process. The QEP provided expert advice to the community through direct involvement by some members who attended Community Consultation Meetings, Technical Community Workshops, and Risk Assessment Workshops (Section 12.2.3). The QEP regularly reviewed and commented on proceedings and issues raised by the community in such forums, and supported the process and outcomes of the Risk Standards Report prior to submission to the EPA.

The Joint Venturers and the community have benefited from the high-quality specialist advice provided by the QEP. This has instilled confidence in both the process and outcomes delivered to date in the development of quarantine management options for the proposed Gorgon Development on Barrow Island. The Joint Venturers value the input provided by the QEP and commit to the ongoing engagement of such experts in future phases of the Gorgon Development.

12.2.3 Community Involvement

Consistent with EPA advice, the Gorgon Joint Venturers have actively encouraged stakeholders and the community to become involved in discussions regarding the quarantine risk to Barrow Island. The Gorgon Joint Venturers' approach has provided ongoing opportunities for all stakeholders to access relevant information and to express their opinions via a number of communication channels which are discussed in detail below.

Community Involvement Process

The community involvement process began with the identification of relevant community groups, independent experts, government and non-government organisations, sections of private industry, and members of the general public who have a potential interest in the quarantine management of Barrow Island. These organisations were subsequently invited by the Joint Venturers to participate in the community involvement process to address the quarantine issue for the proposed Gorgon Development on Barrow Island. A list of stakeholder groups identified and contacted during the consultation process is provided in Box 12-4.

Box 12-4:
Stakeholder Groups and Organisations Invited to Participate in the Community Involvement Process

Apache Energy Ltd
Australian Institute of Marine Science
Australian Marine Conservation Society
Australian Marine Science Association (WA)
Australian Petroleum Production and Exploration Association
Australian Quarantine and Inspection Service
Birds Australia (WA Group)
Botanic Gardens and Parks Authority
Bowman Bishaw Gorham Consulting Ltd
Cape Conservation Group
Care for Hedland Environmental Interest Group
Chamber of Commerce and Industry Western Australia
Chamber of Minerals and Energy of Western Australia Inc
Commonwealth Department of Defence
Conservation Commission WA
Conservation Council of Western Australia Inc

Box 12-4: (continued)
Stakeholder Groups and Organisations Invited to Participate in the Community Involvement Process

Curtin University of Technology
Dampier Port Authority
Edith Cowan University
Environ Australia Pty Ltd
Environmental Resources Management Australia Pty Ltd
Environmental Weeds Action Network (WA) Inc
Fremantle Container Depot
Marine Parks and Reserves Authority
Murdoch University
Nickol Bay Naturalists' Club
Pilbara Wildlife Carers' Association
Royal Society of WA
Sinclair Knight Mertz Pty Ltd
Technip Oceania Pty Ltd
University of Western Australia
WA Department of Agriculture
WA Department of Conservation Land Management
WA Department of Environment
WA Department of Fisheries
WA Department of Industry and Resources
WA Museum
WA Speleological Group Inc
Waterbird Conservation Group Inc
Western Australian Naturalists' Club Inc
Wilderness Society WA Inc
Wildflower Society of WA Inc
World Wide Fund for Nature
WorleyParsons Ltd

The Joint Venturers' approach to community involvement was designed to encourage a high level of community input. This was achieved through direct notification of the Joint Venturers' plans to engage in a process of consultation through:

- personal letters of invitation addressed to community and professional organisations with a potential interest in quarantine and conservation issues
- a series of newspaper advertisements in *The West Australian*
- internet access to quarantine material via the Joint Venturers' website
- routine mail-outs of meeting proceedings and outcomes to parties who had registered an interest.

The Joint Venturers also solicited direct consultation with members of the community to obtain feedback and facilitate an understanding of their respective positions and concerns. This was achieved through:

- community consultation meetings
- site familiarisation tours of Barrow Island and the Welshpool logistics facilities
- an interactive question and answer facility on the Joint Venturers' website
- face-to-face meetings and discussions.

Direct involvement of key members of the community in the development of quarantine options was achieved through workshops to address specific issues identified at Community Consultation Meetings (e.g. Risk Standards Workshops to develop community risk standards), and a QMS/QMP Workshop to assist the development of a Quarantine Management System. This process also included Technical Risk Assessment Workshops to investigate and assess levels of risk along particular pathways of entry to Barrow Island, and to develop quarantine barriers.

The Joint Venturers have conducted four Community Consultation Meetings (Plate 12-1) and four separate Community Workshops up to the point of preparation of this Draft EIS/ERMP document.

Community Involvement Achievements

The direct involvement of the community has influenced the development of quarantine management options for the Gorgon Development, and has contributed to the following key outcomes:

- A report from the community on proposed quarantine standards for acceptable risk to protect the conservation values of Barrow Island.
- The establishment of priorities for work to be undertaken by technical experts. This included identifying priority pathways to be addressed.
- Preparation of a quarantine Risk Register and Draft Quarantine Design Guide for the QMS/QMP Community Workshop, with regard to the sand and aggregate pathway. The Risk Register and Design Guide were used as an example of the barriers being analysed by the Joint Venturers to address the community standards for acceptable risk.
- Establishment of an interactive question and answer facility on the Joint Venturers' website to facilitate transparent community dialogue with the proponent.

Plate 12-1:
Barrow Island Quarantine Community Consultation Meeting, 16th June 2004

- Commitment by the Joint Venturers to continue the process of consultation with an understanding that a further Community Consultation Meeting will be convened during the period of public review of the Draft EIS/ERMP document.
- Review by the Joint Venturers of the timing for the release of the Draft EIS/ERMP document.

The series of Barrow Island Quarantine Risk Standards Workshops provided the opportunity for the Joint Venturers to gain an understanding of community expectations of acceptable risk standards. Through this consultation process, the community stated that 'consequences which resulted in the establishment of an introduced species would be unacceptable'. Details of the Barrow Island Quarantine Community Consultation Meetings and Workshops are provided in Technical Appendices D3 and D4.

The development of community expectations for a quarantine risk standard has been a major accomplishment of the community consultation process and has provided the Joint Venturers with guidance in the development of quarantine controls to manage such risks.

The community involvement process has drawn community participants and the proponents together in a manner that has allowed all parties to participate in a transparent and inclusive manner. The Joint Venturers value the relationship that has developed between the proponents and the community, and commit to an ongoing process of engagement which will seek community input into decisions that affect quarantine management of Barrow Island.

12.2.4 Best Practice Benchmarking

The substantial volume of materials and high number of personnel movements associated with the proposed Gorgon Development represents a significant increase in opportunities for the introduction of non-indigenous species to Barrow Island. Preliminary estimates suggest that 1.2 million freight tonnes will land on Barrow Island, and approximately 94 000 person-landings will occur during the construction phase. In light of this increased scale, the level of quarantine performance required to protect the conservation values of Barrow Island will need to set new benchmarks that extend beyond current quarantine best practice.

As there was no existing description of quarantine best practice, the Joint Venturers researched quarantine programs world-wide in order to determine a quarantine benchmark for the protection of the conservation values of nature reserves. A description of this process and key outcomes is provided below.

Quarantine Best Practice

A procedural review of quarantine practices was undertaken for quarantine programs in Australia, New Zealand, Japan, the United States of America, and the United Kingdom. This review showed that there are procedures and features of national quarantine systems that can be regarded as best practice, but no single system involves all such elements. This is because quarantine systems depend on the specific quarantine objective and environmental values of the region to be protected. There are also a number of complicating factors including inextricable and complex linkages between quarantine and trade, and prevailing circumstances and operational constraints (further details are provided in Technical Appendix D5).

Quarantine Program Objectives

The primary objective of national quarantine agencies is to prevent the introduction and spread of pests and diseases into areas where they do not occur, whilst minimising any adverse effects on trade. Such objectives are usually motivated by the need to protect economic and social assets of the importing country. National quarantine authorities therefore tend to design quarantine programs which meet the dual purpose of providing an adequate level of quarantine protection, and facilitating viable international trade. Such quarantine programs therefore tend to employ practices that are the least restrictive.

Quarantine programs designed to protect conservation values are less common than international cross-border quarantine programs that facilitate trade. There are four relevant examples of island quarantine programs with a conservation imperative, those being: Heard and McDonald, and Macquarie Islands respectively under the Australian Antarctic Program; Galapagos Islands, some New Zealand islands and Barrow Island. In contrast to national quarantine services, such quarantine programs typically demand substantially higher levels of protection to prevent potential introductions of non-indigenous species. Quarantine programs motivated by a conservation imperative are therefore highly restrictive on the import of goods and personnel, and provide standards of quarantine protection that typically extend well beyond those of national quarantine agencies. However, the current Barrow Island quarantine program is unique in that it is designed with a dual purpose: to protect the conservation values of the island, whilst facilitating ongoing commercial operations. Barrow Island quarantine practices are therefore generally more restrictive than those of national quarantine agencies, but also facilitate the operational requirements of the oilfield.

Beyond Best Practice Quarantine Management

The Joint Venturers' approach to quarantine management has included a new application of risk assessment principles. Conventional import risk analyses generally have a very narrow focus on a specific species or pathway (e.g. Biosecurity Australia 2003). The approach by the Joint Venturers sets a new standard in the assessment of quarantine risk as it focuses on all possible introduction pathways and the exclusion of all non-indigenous species.

Through this risk assessment process, a number of entry pathways to Barrow Island were examined and a range of potential quarantine barriers were generated, as described in Section 12.5. This range of conceptual barriers has not been developed for the purpose of quarantine protection anywhere else, and in combination with established quarantine procedures, will extend quarantine measures significantly beyond current best practice.

12.2.5 Expert Advice

Experts were engaged in a variety of forums including the QEP, Risk Assessment Workshops, Community Workshops, and where required, direct dialogue to address specific issues (for example, marine baseline survey strategies). A list of agencies and organisations from which experts were drawn to provide specialist advice is provided in Box 12-5. The involvement of experts in these processes facilitated the following key outcomes:

- High-quality expert assessment of the risk of introduction of non-indigenous species via key pathways (through Risk Assessment Workshops).
- Development of a suite of potential quarantine barriers that in the opinion of experts would be effective in preventing the introduction of non-indigenous species.
- Development of a set of standards for acceptable risk.
- Input into the development of strategies for the detection and eradication of non-indigenous species.
- Development of an innovative risk assessment method to assess quarantine risks to the conservation values of Barrow Island.
- Development and execution of preliminary baseline marine surveys.
- Development of an invertebrate baseline survey strategy.

The Joint Venturers commit to further engagement of experts in the development of quarantine management options for the Gorgon Development on Barrow Island.

Box 12-5:
Organisations and Agencies that Provided Specialist Quarantine Advice

Government Departments & Agencies

Australian Antarctic Division

Australian Quarantine and Inspection Service

Commonwealth Department of the Environment and Heritage

Commonwealth Scientific and Industrial Research Organisation

Queensland Department of Primary Industries & Fisheries

Western Australian Department of Environment

Western Australian Department of Conservation & Land Management

Western Australian Museum

Tertiary Institutions

Curtin University of Technology

Murdoch University

University of Sydney

University of Western Australia

University of Tasmania

Non-Government Agencies & Community Groups

Australian Wildlife Conservancy

Conservation Council of Western Australia

Waterbird Conservation Group

Private Industry

Astron Environmental

Compass Group Pty Ltd

Marine Management Consulting

Skelton Tomkinson

Technip Coflexip Oceania Pty Ltd

URS Consulting Pty Ltd

Toll Holdings Ltd

Mermaid Marine Australia Ltd

And various independent consultants specialising in conservation, biosecurity, risk management

12.2.6 Standards for Acceptable Risk

It is widely acknowledged that the field of risk assessment for invasive species is in its infancy and that there is a pressing need to formulate sound new methods and approaches in this field (Andersen et al. 2004). It is not possible to attempt to quantify 'acceptable risk' for Barrow Island in a manner similar to that undertaken for individual risk in relation to, for example, hazardous industrial plants, because there are no ecological risk databases for quarantine incidents available.

The risk-based approach to quarantine management developed by the Joint Venturers required the development of a standard for acceptable risk as there was no pre-existing risk-based quarantine standard for the protection of conservation values of nature reserves. This process facilitated input from the QEP, expert advice by means of Workshops, and community input via a number of Community Consultation Meetings. The standard developed by this process involves specific combinations of estimates of the likelihood of the following four parameters:

- introduction (of non-indigenous species to Barrow Island and surrounding waters)
- survival (of non-indigenous species to Barrow Island and surrounding waters)
- detection of non-indigenous species at Barrow Island
- eradication of non-indigenous species.

The specific application of these community expectations of risk standards is described in greater detail in section 12.4.3.

12.3 Existing Environment

12.3.1 Conservation Values of Barrow Island

Barrow Island is a Class A Nature Reserve and forms an important natural refuge for some species of rare and threatened species of animals and plants, some of which are endemic to the island. Barrow Island is known to support 24 terrestrial species and subspecies which are not known to occur elsewhere, and another five terrestrial species with restricted distributions elsewhere. These populations, particularly the mammal populations, form a genetic reservoir that is important to biodiversity and conservation and are important as a source for controlled re-introductions of these species to other areas.

The marine environment surrounding Barrow Island comprises an abundance of coral reefs, intertidal flats, and sandy beaches which provide important habitat for a variety of marine organisms including marine mammals and turtles. The island also plays a significant role in the migration patterns of many bird species. A more detailed discussion of the conservation values of the existing Barrow Island environment can be found in Chapter 8 of this Draft EIS/ERMP.

The unique biodiversity of Barrow Island can be attributed to its natural isolation from the mainland and protection afforded it under its statutory status. Collaborative environmental management by oilfield operators and CALM have protected the island from incursions by non-indigenous species, some of which would be certain to disrupt the natural ecological function of the island through unnatural predation, competition, or habitat destruction. Quarantine management is therefore a key component of the Joint Venturers' strategy to protect and sustain the conservation values of the island.

12.3.2 Quarantine Experience

In recognition of the internationally significant conservation values of Barrow Island, quarantine management was pioneered by West Australian Petroleum Limited (WAPET) soon after oilfield operations began in the mid-1960s. WAPET consisted of Chevron, Texaco, Shell and Ampol (now ExxonMobil) which trace a direct lineage to the same Joint Venturers in the Gorgon Development. Early oilfield efforts to protect Barrow Island from the introduction of non-indigenous species reflected the limited knowledge available at that time in regard to the protection of conservation values. Since then, quarantine management of Barrow Island has continually evolved and improved, as the level of quarantine experience and knowledge of threats has continued to mature.

Logistical support of oilfield operations has been substantial, with over 10 000 cargo landings of both marine barges and aircraft since the 1960s. Personnel movements to the island during this period also number several hundred thousand. Despite this immense volume of movements to Barrow Island, only a limited number of quarantine incidents have been recorded. On the few occasions when non-indigenous species have reached the island, quarantine management has been effective in preventing their proliferation. In most cases, such species were detected and eradicated; or in the case of some weed species, are controlled and limited to highly localised distributions.

12.3.3 Historical and Existing Presence of Non-indigenous Species

There are currently no known non-indigenous species of vertebrate fauna on Barrow Island, although the proposed invertebrate baseline surveys are expected to detect species such as the cosmopolitan American cockroach and daddy long legs spider. Historically however, there have been occasions when non-indigenous species were brought to the island. An example is the black rat (*Rattus rattus*) which is thought to have been introduced to Barrow Island prior to the existence of any quarantine program by pearlers in the latter part of the nineteenth century. Cooperative eradication programs between the operator of the Barrow Island Joint Venture and CALM led to the complete removal of the black rat from Barrow and Middle islands by 1998. Another example involved house mice (*Mus domesticus*) which breached quarantine barriers via food cargoes and drilling equipment on three occasions. Coordinated operator–CALM trapping and baiting efforts ensured the mice were eradicated on each occasion.

Fifteen non-indigenous plant species have been detected on Barrow Island over the last 40 years, four of which were deliberately introduced and the remaining 11 classified as environmental weeds. Only six of the environmental weed species are known to persist on the island, those being Buffel grass (*Cenchrus ciliaris*), spiked malvastrum (*Malvastrum americanun*), black berry nightshade (*Solanum nigram*), sow thistle (*Sonchus oleraceus*), kapok (*Aerva javanica*) and whorled pigeon grass (*Setaria verticillata)*. These are known to occur in highly localised distributions which are often characterised by episodic detections of a small number of juvenile individual plants. Such environmental weed species are the subject of an ongoing monitoring and eradication program conducted by the operator of the existing oilfield.

Non-indigenous plant species were approved for deliberate introduction to Barrow Island in order to moderate the human environment in the early years of oilfield operations. These include various mainland species of eucalypts and couch grass. The distributions of deliberately introduced plant species are restricted to the area surrounding the oilfield accommodation facilities and workshops.

Twenty-seven quarantine incidents have been officially recorded on Barrow Island over the 40-year history of oilfield operations. Quarantine management strategies such as detection, containment and eradication have successfully addressed these incidents.

It is acknowledged that this quarantine record does not represent a complete history of all incursions that are likely to have occurred, due in part to the limited ability of the record to capture all anecdotal incidents. This is particularly true of the quarantine record captured in the earlier years of oilfield operations. Nevertheless, the quarantine record provides a reasonable indication of the effectiveness of quarantine management over this 40-year period.

Development of Quarantine Management

The quarantine incidents described above have provided opportunities for the oilfield operator to develop more effective approaches to quarantine management. Through an iterative process of continuous improvement, the lessons learnt from quarantine incidents have delivered new information which has been incorporated into quarantine management initiatives. This has contributed to a continually growing body of quarantine knowledge and delivered incremental improvements to the level of quarantine protection for Barrow Island.

Current Barrow Island quarantine practices capture elements of the supply chain commencing at the point of supply, continuing through to checking upon receipt at logistics facilities in both Welshpool (Perth) and Dampier. These practices include quarantine provisions for air, land and sea transport by aircraft, truck and barge respectively. Quarantine restrictions extend to all personnel travelling to Barrow Island, including transit passengers that pass through the Barrow Island air terminal en route to, or from, other offshore operations. The air transport consortium which operates on the island is an active stakeholder in the Barrow Island quarantine program.

The effectiveness of the Barrow Island quarantine program to date is evidenced by a comparison to other offshore islands. Nearby islands to the north of Barrow Island, such as those in the Montebello Islands Conservation Park, and Dirk Hartog Island to the south have been, or remain infested with a range of non-indigenous species such as the black rat and feral cat, or weeds such as kapok and buffel grass. The widespread presence of such species on these islands has resulted in irreversible changes to the natural environments and ecological functions of these islands. Lessons learnt from the management of these and other islands have provided valuable insights into ways to prevent the establishment of similar undesirable species on Barrow Island.

Throughout the preparation of this Draft EIS/ERMP, the Joint Venturers conducted a number of site visits for various stakeholders and technical experts to Barrow Island and the Welshpool logistics facility. These visits facilitated observation of current Barrow Island quarantine practices, and provided an opportunity for direct interaction with members of the oilfield workforce. Informal judgements of the suite of pre-border, border and post-border Barrow Island quarantine practices by a number of individual stakeholders commended the high level of quarantine protection and the strong quarantine culture which was evident in the oilfield workforce (e.g. Nairn, M. 2004 Personal communication).

12.3.4 Baseline and Early Survey Strategies

An understanding of the present composition and function of the ecology of Barrow Island is necessary to detect ecological changes which may occur over time. This is particularly important where the associated construction and operational activities of the proposed Gorgon Development may have direct or indirect impacts on the island's natural environment.

It is therefore necessary to establish a baseline dataset of species currently present on Barrow Island and in the surrounding waters. This includes those species which are considered native to the island, and those which are thought to have been introduced to the island. A discussion of non-indigenous species present on the island is provided in Sections 12.3.5 and 12.3.6 for the terrestrial and marine environments respectively.

To assist this process, the QEP proposed an area of quarantine protection for Barrow Island and its surrounding waters, which is illustrated in Figure 12-2. This area includes the nearby islands of Boodie, Middle, Pascoe, Boomerang, Double and Prince Rock. It also accommodates the proposed marine offloading and jetty facilities associated with the Gorgon Development.

Baseline surveys are intended to provide a set of critical observations or data which will be used for comparison of subsequent data captured as part of an ongoing, long-term monitoring program. Due to the different nature of the terrestrial and marine environments, different strategies have been developed for each of these environments.

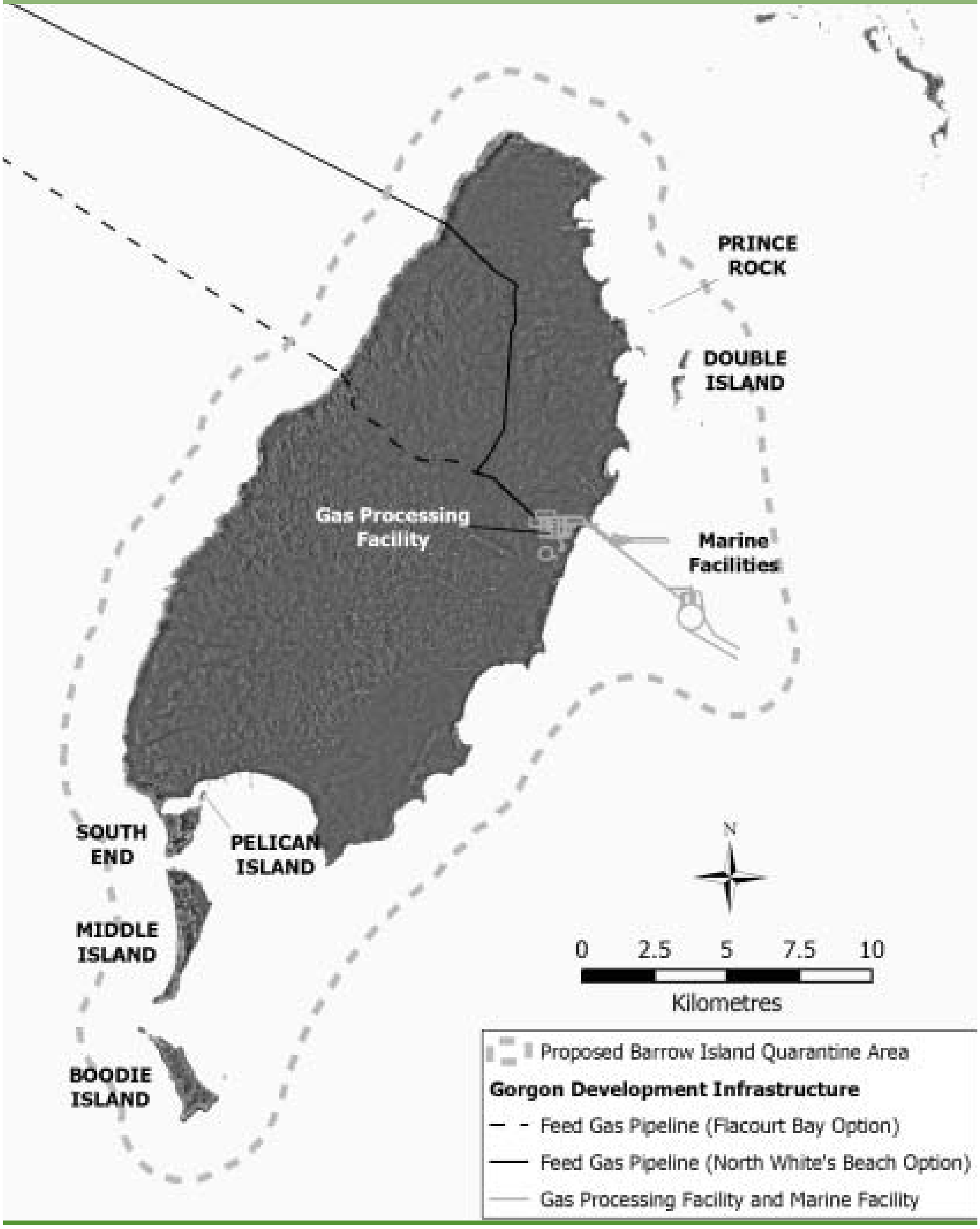
Barrow Island has a long history of ecological field surveys which extend back to the early 1900s. The accumulated data associated with these surveys has produced a sound level of knowledge of species presence for some biological groups. However, additional surveys are required to complement pre-existing data and determine a robust baseline of species presence.

The starting point for creation of a baseline dataset for Barrow Island is the collation of species data from prior ecological surveys. This dataset will be augmented by a field program which is targeted at biological groups of special interest or those which have a limited amount of information. Such surveys will involve appropriate technical experts to ensure an adequate level of scientific rigor is incorporated into sampling methods. Some initial opportunistic field surveys have already been conducted in concert with other field activities for selected biological groups, and some initial marine surveys have been conducted already.

Consistent with advice contained in the Report on Baseline Studies and Data Gaps (Technical Appendix D6), a survey to establish a baseline invertebrate dataset has been initiated on Barrow Island. This multi-phase survey commenced in April 2005 and is focussed on both native and disturbed areas to sample for a variety of invertebrate organisms including but not limited to, ants, spiders and scorpions, beetles and sucking bugs. Further field surveys are planned for late-2005, with scope for opportunistic surveys subsequent to significant rainfall events. Voucher material of animal species will be deposited in the Western Australian Museum so identifications can be checked if necessary in the future.

Field surveys to address ancillary baseline data gaps are planned for execution in the second half of 2005. The extent of field surveys required for this task is

Figure 12-2:
Proposed Barrow Island Quarantine Area



relatively minor, given the breadth and quality of vegetation and vertebrate data gathered on Barrow Island to date.

Baseline surveys will continue until the Joint Venturers commence work on the proposed Gorgon Development on Barrow Island. Thereafter, the emphasis of the field program will transform into a long-term monitoring program. Field surveys will involve the collection of information on flora, vertebrates, invertebrates, marine species and micro-organisms. Monitoring programs will address two distinct objectives: (i) to detect the presence of non-indigenous species (surveillance); and (ii) to determine environmental change.

12.3.5 Terrestrial Baseline Data

Numerous field surveys of Barrow Island terrestrial fauna and flora have been conducted by various teams and individuals, including a number of government agencies. The earliest such survey was conducted circa 1902. The collation of field data collected since this first survey provides a logical starting point for a baseline dataset of Barrow Island fauna and flora.

Terrestrial Fauna

Ecological field surveys conducted for the purpose of this Draft EIS/ERMP provide the most detailed and recent source of baseline data. These surveys focused on the proposed Gorgon Development site at Town Point, and have yielded information that complements data previously collected over broader spatial areas of the island.

Vertebrate species have been the primary focus of the majority ecological field surveys on Barrow Island. Details of mammal and reptile surveys are described in Technical Appendix C2. Attachments 2 and 3 of this appendix provide a list of reptile and mammal species respectively based upon recent surveys, CALM and the Western Australian Museum records and historical WAPET records. From this aggregation of information, it is concluded that there are 15 mammal species, 42 reptile species and one frog species on Barrow Island.

Subterranean field surveys undertaken by the Joint Venturers, CALM and the Western Australia Museum have recorded the presence of 20 stygal taxa which are thought to be mostly endemic to the island. Technical Appendix C5 provides further details of these surveys.

A study conducted to identify baseline data availability and gaps (Technical Appendix D6) highlighted that further surveys need to be conducted on invertebrate groups including: ground-dwelling arthropods, web-building spiders, terrestrial molluscs, termites and earthworms. It is not a simple task to determine an exact number of invertebrate species on Barrow Island due to the difficulty in identifying many invertebrate taxa beyond family level. However, focused invertebrate sampling restricted to the proposed Gorgon Development site confirmed the presence of 19 spider taxa, four pseudoscorpion, three centipede, one millipede, and four land snail species (Technical Appendix C4). This dataset is limited, but will be enhanced by ongoing field surveys.

Terrestrial Flora

Ecological flora surveys of Barrow Island have been extensive in both space and time and provide a sound understanding of vascular plant species presence on the island. Current data indicates that 406 vascular plant species have been recorded on Barrow Island. Of these, a total of 15 non-indigenous plant species have been detected with six of these in highly restricted distributions (Section 12.3.2). Full details of these flora surveys and species lists are provided in Technical Appendix C1.

12.3.6 Marine Baseline Data

In contrast to the terrestrial environment, the marine environment is characterised by widespread and disperse patterns of species distributions. The primary reason for these widespread distributions is that the majority of marine animal species have a planktonic larval stage, providing an effective means of dispersal. Even species which lack a planktonic larval stage tend to be widely distributed through the attachment of organisms to algae and other free-floating and transient vegetation. Marine algae are distributed in a similar manner and are transported over large distances as spores or fragments (which can often survive and grow).

There are no major distributional limits of marine organisms on the north coast of Western Australia (Wells 1980; Wilson & Allen 1987; Jones 2003; Huisman in press). Marine current patterns in the Dampier region are complex, and can change with seasons, tides and wind patterns. However, the general flow is towards North West Cape as part of the diffuse origins of the Leeuwin Current. This provides a ready mechanism for species to move from the Dampier region to Barrow Island and North West Cape. The distance of 70 nautical miles between the Dampier Archipelago and Barrow Island is only a small fraction of the range of almost all species that live in the shallow waters of north-western Australia.

While no extensive surveys of marine species have been undertaken at Barrow Island, those that have been conducted in nearby waters show species composition typical of the Indo–West Pacific biota. This is evidenced by the extensive survey of the Montebello Islands undertaken in 1993 as part of the arrangements for transferring the islands from Commonwealth control back to the state (Berry and Wells 2000).

More recently, the Western Australian Museum/Woodside Energy Limited partnership conducted a study of the marine biota of the waters of the Dampier Archipelago and found the area to be high in biodiversity. Of more than 3300 species of fishes, sponges, corals, crustaceans, molluscs, echinoderms and benthic marine flora collected, the majority are warm water species with ranges centred in the tropics, e.g. fishes 91%, barnacles 90%, echinoderms 92% (Jones 2004a). In addition, whilst this study did not specifically target introduced marine species, it is noteworthy that six barnacle species regarded as introductions (*Balanus amphitrite, B. cirratus, B. reticulatus, B. trigonus, Megabalanus tintinnabulum* and *M. rosa*) were recorded (Jones 2004b). Previously, Jones (1991; 1992) has suggested that *M. tintinnabulum* and *M. rosa* were introduced into the waters of the Dampier Archipelago as a result of shipping activities.

There is at present little information on non-indigenous marine species and limited data on marine species naturally present off Barrow Island. A strategy has been developed to establish a baseline understanding of potential pest species that may have already been introduced to Barrow Island, Dampier and possibly Onslow; and a strategy to monitor for future introductions (Western Australian Museum 2004).

The Joint Venturers have committed to a comprehensive suite of field surveys in order to establish a marine baseline dataset. These efforts include:

- Specifically targeted surveys at Barrow Island – that is, surveys of areas where species are most likely to have been introduced, particularly species on the Commonwealth's list of declared marine pest species (NIMPIS 2002). This includes a preliminary baseline survey undertaken in August 2004, which also surveyed for possible introductions of a broader group of species to the Barrow Island marine environment. A report of the August survey results revealed that pest species included in the NIMPIS were absent at all survey sites. Further details of these surveys are provided in Technical Appendix D7.
- A broader scope baseline survey of Barrow Island – to develop information on taxonomic groups which are relatively large (> 10 mm) and relatively well known, including molluscs, fish, crustaceans, corals, echinoderms, bryozoans, hydroids, macroalgae and seagrasses.
- Focused inspection of mainland ports of origin – much of the smaller and most frequent vessel movements to Barrow Island will be from Dampier, though there may also be some vessels from Onslow and Fremantle. The Ports of Dampier and Onslow have not yet been the subject of a baseline survey, although the Joint Standing Committee on Conservation/Standing Committee on Fisheries and Aquaculture (SCC/SCFA) National Task Force on the Prevention and Management of Marine Pest Incursions (SCC/SCFA 1999) has recommended that baseline surveys be undertaken for all Australian first ports of call. Port areas in Dampier, and possibly Onslow and Fremantle, should be surveyed in 2006 or 2007 to determine which introduced species are in those ports that may subsequently be transferred to Barrow Island. The responsibility for undertaking such a survey of a commercial port has not yet been determined; however, the Joint Venturers support a collaborative baseline survey of the Port of Dampier.
- Results of these survey efforts will be used as a basis for planning additional surveys and ongoing monitoring of Barrow Island, involving marine scientists and methodology developed by the CSIRO Centre for Research on Introduced Marine Pests (Hewitt & Martin 2001).

Voucher material of animal species will be deposited in the Western Australian Museum so identifications can be checked if necessary in the future. Macroalgae and seagrasses will initially be curated and examined at Murdoch University with permanent herbarium vouchers lodged at the Western Australian Herbarium.

Specific barriers to prevent the introduction of marine species from vessel movements have been identified through a risk-based management approach and are discussed in Section 12.5.6.

12.4 Gorgon Quarantine Risk Management

12.4.1 Introduction to Risk-based Management

There are no precedents for undertaking risk-based management of threats to conservation values in a Class A Nature Reserve which would address the assessment guidelines provided by the EPA in its Bulletin 1101 (EPA 2003). Establishing such a process was a challenging task which involved the QEP, stakeholders and ecological specialists (Box 12-6).

The development of this risk-based management approach has been a rigorous and transparent process, undertaken in accordance with AS/NZS 4360, Risk Management (Standards Australia 2004). The purpose of this systematic risk management process was to: set standards for acceptable risk; identify potential threats to conservation values from the proposed Development activities; analyse the risks; suggest appropriate quarantine barriers for consideration; select barriers which will meet standards for acceptable risk; and ultimately, develop an effective QMS to keep information up to date in a process of continuous improvement.

The risk-based assessment was the basis for identifying quarantine threats to Barrow Island and its surrounding waters, and identifying specific ways in which cargoes, marine vessels, aircraft and personnel could be 'infected', or contaminated, with non-indigenous organisms. To reduce the likelihood of introductions, preventive quarantine barriers are suggested for each potential threat at various steps along each pathway. Feasibility studies of suggested barriers lead to the selection of a number of barriers for detailed analysis and further risk assessment to ensure that the standards for acceptable risk will be met. Once barriers are selected to address specific risks, appropriate performance indicators will be established and implemented through the QMS.

12.4.2 Risk Assessment Method

The risk-based assessment method was developed in consultation with the QEP, a wide range of technical experts and community stakeholders. The methodology reflects experience gained with its practical application through numerous quarantine risk assessment workshops. The adopted methodology and rationale for its development is documented in Technical Appendix D2.

Three threat identification and risk assessment techniques have been adopted in this methodology following a thorough review of possible approaches:

- Infection modes and effects analysis (IMEA), adapted for identification of pathway threats from the engineering analogy of failure modes and effects analysis (Hayes 2002).
- Preliminary barrier analysis (PBA) for analysis of the efficacy of conceptual quarantine barriers, consistent with the engineering analogy of preliminary hazard analysis (PHA) (CCPS 1992). The PBA step is only required during the early conceptual phases of the Development due to a lack of design detail which prevents execution of full-scale QHAZ workshops. The PBA step is therefore intended as an interim step to provide information that will support this Draft EIS/ERMP. It is not required where sufficient design detail is available to support the QHAZ step.
- Quarantine hazard (QHAZ) analysis of detailed barrier designs, derived from the engineering technique of hazard and operability (HAZOP) analysis (CCPS 1992, RCEP1991).

Box 12-6:
Key Aspects of Community and Expert Involvement in the Quarantine Risk-based Management Process

1. The EPA advice to the government for the Joint Venturers to develop standards for acceptable risk was very helpful in driving the risk assessment processes that were used. These standards were developed with a high level of involvement of community stakeholders and technical experts.
   The result was a shared understanding of how risk would be managed to prevent the establishment of non-indigenous species on Barrow Island.
2. The Joint Venturers' community consultation process facilitated the participation of stakeholders in three workshops, which enabled community views and expectations to be incorporated in the proponent's standards for acceptable risk. Progress made on the development of standards for acceptable risk was reported back to the wider community stakeholder group for consultation in public meetings following each workshop. Community stakeholders considered the outcomes of the workshops, as reflected in the Report to the Community Consultation Meeting on the Risk Standards Workshops.
3. The quarantine risk assessment methodology was developed in consultation with the QEP and stakeholders. It became clear that it was not

Box 12-6: (continued)
Key Aspects of Community and Expert Involvement in the Quarantine Risk-based Management Process

possible to quantify ‘acceptable risk’ in the same manner as is used to quantify individual risk in the more familiar case of industrial plants, where sufficient data and human exposure criteria is available to do so.

In particular, the consequences of introducing non-indigenous species to the Barrow Island environment cannot be confidently predicted for the vast majority of species. To address the Joint Venturers’ preventive goal of ‘no introductions’, the QEP advised a more precautionary approach for risk assessment, centred around identifying and classifying threats of introducing non-indigenous species to Barrow Island within the qualitative likelihoods of infection, survival, detection and eradication.

4. Community stakeholders stated that it is very important that the final quarantine barriers (procedural controls and engineering designs) be analysed by independent experts in risk assessment workshops. This analysis is a planned step in the Joint Venturers’ risk assessment process, which was discussed with stakeholders, to confirm the effectiveness of selected barriers in relation to the standards for acceptable risk. A community workshop to discuss the development of the QMS acknowledged that the description of conceptual quarantine barriers contained in ‘Design Guides’ was the level of detail that stakeholders expected, subject to independent analysis by technical experts. Accordingly, the community expressed the view that there is a need for the transparent risk-based assessment process to continue well after the release of the Draft EIS/ERMP document.

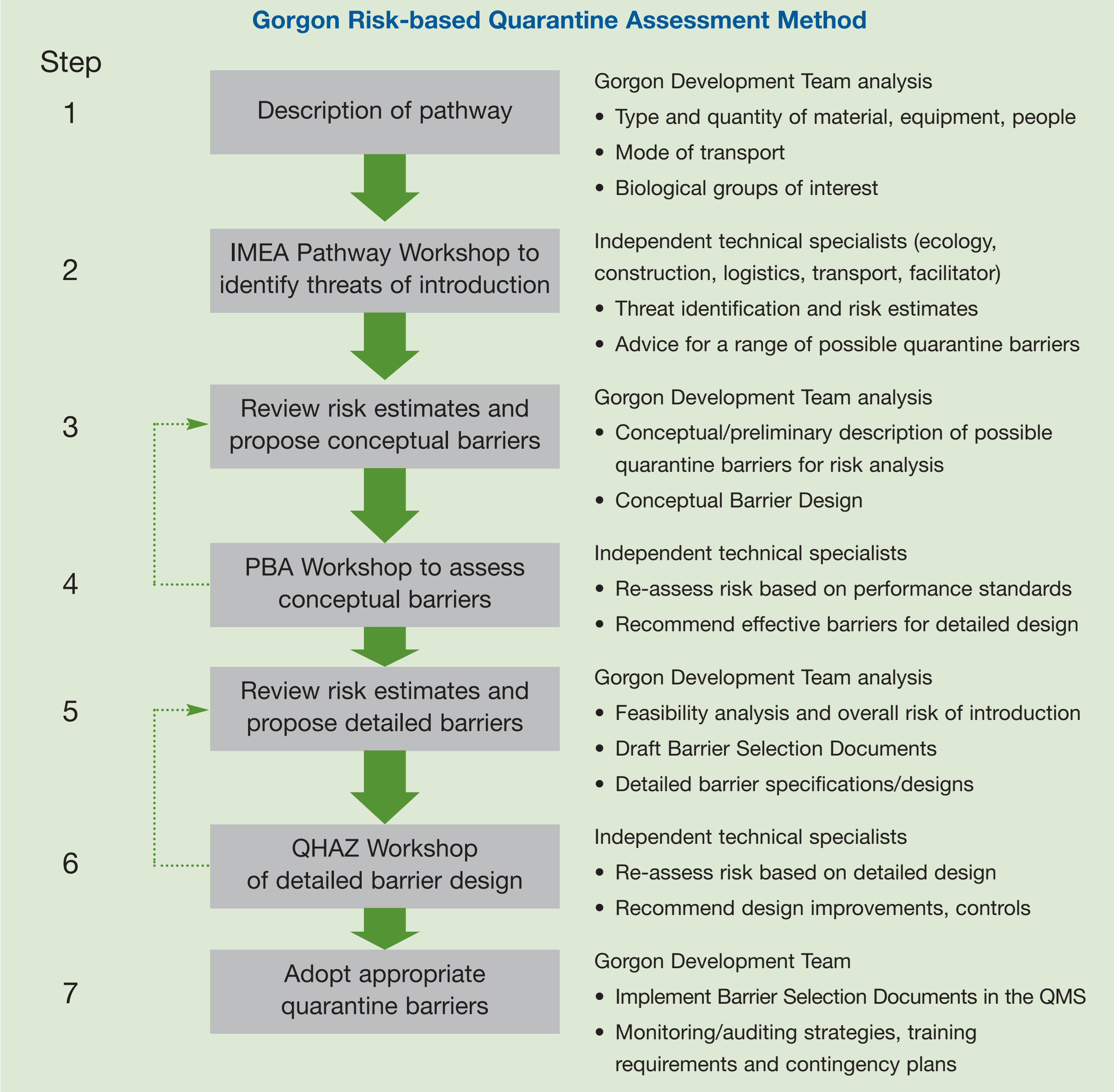
A step-by-step flowchart of the risk assessment method is presented in Figure 12-3. At the time of the release of this Draft EIS/ERMP, this risk assessment has progressed through to Step 4 for most pathways (refer to Section 12.4.4 for a detailed description). The community meetings expressed a clear desire for the transparent risk-based assessment process to continue well after the release of the Draft EIS/ERMP document. The community anticipates future QHAZ analysis of detailed quarantine barrier specifications and designs, which is captured at Step 6 of the process outlined in Figure 12-3.

The risk assessment process is a pathway-driven means of comprehensively identifying quarantine threats, developing specific quarantine barriers to reduce the overall likelihood of introduction and estimating the resulting level of risk. The risk analysis was qualitative, due to the complexity of ecological systems and the lack of data and experience in the scientific and regulatory communities to apply quantitative methods to ecological assessments.

This risk assessment methodology sets a new benchmark for managing quarantine threats to conservation values. The few previous examples of risk assessments for invasive species with regard to conservation values have focused on problem formulation and very broad classification of risk based on expert opinion (Russell et al. 2003; Andersen et al. 2004). Previous risk assessments of invasive species, with regard to wider economic and environmental values, support the approach for pathway-driven identification of threats and management strategies (FAO 1996; Hayes and Hewitt 1998).

In view of the difficultly of predicting the potential impact of almost any type of introduction of non-indigenous species to Barrow Island, the risk assessment did not aim to estimate the likelihood of consequences. Estimates of risk are therefore not defined as the product of likelihood and a range of predictable consequences. Instead, a precautionary approach was taken to focus the risk assessment on the pre-border prevention of introductions. This is a common goal of biosecurity efforts elsewhere that aims to prevent accidental introductions from occurring in the first instance. The effort to eradicate an established species is generally considered a very difficult task. As such, the risk-based assessment does not seek to assess only ‘quarantine pests’, as this could underestimate the risk from species which might become a pest on Barrow Island. Therefore, estimates of risk are focused on the likelihood of introducing non-indigenous species to Barrow Island; and to a lesser extent the likelihoods of survival, detection and eradication as these cannot be as confidently estimated by technical experts for a wide range of species. The likelihood of introduction is therefore a surrogate for risk in the context of this methodology.

Figure 12-3:
Step-by-step Flowchart of the Quarantine Risk Assessment Method



The QEP have advised that a qualitative scoring system is a legitimate approach for estimating the likelihood of introduction of a non-indigenous species, as there would be little confidence in predicting the likelihood or consequences of invasion by a non-indigenous species. The risk analysis of potential quarantine threats at each pathway step enables experts to make informed, qualitative judgments of the likelihood that cargoes will be infected, and in some cases the chances of survival of organisms. Experts may also be able to estimate the likelihood of detecting the arrival of organisms on Barrow Island and surrounding waters; and the likelihood of eradicating introductions that might arrive. Infection and survival scores represent pre-border quarantine risk estimates, and detection and eradication scores represent post-border quarantine risk estimates. The scoring system used to make these judgments is presented in Table 12-1.

Each pathway was subject to the same comprehensive risk assessment process for analysing and scoring the risk of exposure to potential introductions. The details of the risk-based quarantine assessment method (Figure 12-3) are presented below. The following seven steps were taken to identify, design and implement appropriate quarantine barriers with priority given to pre-border prevention:

Table 12-1:
Risk-Score Definitions

Pre-border quarantine (pathway-specific)		Post-border quarantine		Score
Infection	**Survival**	**Detection**	**Eradication**	
The infection is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect early enough to consider eradication strategy.	Virtually certain to eradicate without significant impacts to the native environment.	1
The infection is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection early enough to consider eradication strategy.	Very high likelihood of eradication without significant impacts to the native environment.	2
There is a slight chance of infection.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection early enough to consider eradication strategy.	High likelihood of eradication without significant impacts to the native environment.	3
There will be a small number of infections each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection early enough to consider eradication strategy.	Moderate chance of eradication without significant impacts to the native environment.	4
An occasional number of infections are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection early enough to consider eradication strategy	Medium chance of eradication without significant impacts to the native environment.	5
Infections have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection early enough to consider eradication strategy.	Low chance of eradication without significant impacts to the native environment.	6
Infections occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection early enough to consider eradication strategy.	Slight chance of eradication without significant impacts to the native environment.	7
There is a high occurrence of infections each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection early enough to consider eradication strategy.	Very slight chance of eradication without significant impacts to the native environment.	8
There is a very high occurrence of infections each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection early enough to consider eradication strategy.	Remote chance of eradication without significant impacts to the native environment.	9
Infections occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect early enough to consider eradication strategy.	Almost impossible to eradicate without significant impacts to the native environment.	10

1. Describe Pathways and Biological Groups

Pathways for cargo and personnel movements from ports of origin to Barrow Island were described, including types and quantities of materials (or personnel); layout of facilities used to receive, pack and ship consignments; steps and equipment used in the process of handling cargoes (or personnel); and a description of transport vessels (marine vessels, aircraft, trucks). Pathways currently under consideration are listed in Box 12-7 and additional pathways will be added to this list as they are identified. In the first instance, these pathways were described without the benefit of any quarantine barriers to allow the workshop participants to identify infection scenarios and consider possible preventive measures without prejudicial attention to existing quarantine barriers already implemented for Barrow Island.

A second activity is to identify broad biological groups which may 'infect' cargoes, transport vessels or personnel handled on the subject pathway. The list of biological groups is presented in Box 12-8. Advice was sought from the QEP to identify recognised ecologists and conservation specialists who have significant expertise in these biological groups.

Box 12-7:
List of Potential Introduction Pathways for Construction and Operation

Pathways Being Assessed to Manage the Likelihood of Introductions

- Personnel and accompanying luggage
- Personal tools consigned for transport
- Skid equipment, accommodation units
- Pre-fabricated modules
- Food and perishables
- Containerised goods
- Sand and aggregate
- Cement
- Plant, including earthmoving equipment and vehicles
- Pipe
- Steel
- Aircraft, including flights from neighbouring islands and petroleum facilities
- Marine vessels, including coastal vessels and international vessels.

Box 12-8:
Biological Groups for Consideration in Hazard Evaluation

Terrestrial groups	Marine groups
Vertebrates (e.g. mammals, birds, reptiles (snakes, geckoes), amphibians, fresh and brackish water fishes)	**Vertebrates** (e.g. fin fish, sea snakes)
Soil-dwelling invertebrates (e.g. arthropods (termites, worms))	**Invertebrates** (e.g. molluscs, crustaceans, coelenterates (hydroids, jellyfish, corals), ascidians (sea squirts), worms, echinoderms (sea urchins, starfish), bryozoans)
Above-ground invertebrates (e.g. ants, terrestrial molluscs)	**Plants** (e.g. algae, sea grasses)
Subterranean fauna (e.g. stygofauna (crustaceans, worms), troglofauna (insects, millipedes))	**Micro-organisms** (e.g. zooplankton, phytoplankton, fungi, dinoflagellates, bacteria)
Plants (vascular plants, non-vascular plants)	
Micro-organisms (e.g. fungi, bacteria, viruses)	

2. Infection Modes and Effects Analysis (IMEA) Pathway Workshops

   Undertake an IMEA workshop involving specialists with expertise in particular biological groups of interest to assess each step of the pathway. Record details of how infections of cargoes, transport vessels and personnel occur, estimate likelihoods of infection and survival at each pathway step. Identify possible quarantine barriers which should be considered to prevent infections and reduce the likelihood of survival.

3. Develop Conceptual Quarantine Barriers

   Conduct feasibility studies and develop requirements for conceptual quarantine barriers which could be considered to reduce risk. Document barriers under consideration which reduce risk to meet standards for acceptable risk.

4. Preliminary Barrier Analysis (PBA) Conceptual Barrier Workshops

   Undertake a PBA of the conceptual barriers described for each pathway. Re-evaluate risk based on the expected performance of the conceptual barrier. Recommend new barriers or improvements to the conceptual design to further reduce risk.

5. Review Risk Estimates and Propose Detailed Barriers

   Perform feasibility analysis and estimate the overall likelihood of introduction for each pathway by combining the likelihood of infection at each pathway step. Document feasibility analysis in Barrier Selection Documents for each pathway. Prepare detailed barrier specifications and designs with assistance from specialist contractors.

6. Quarantine Hazard (QHAZ) Analysis of Detailed Barrier Designs

   Once the design of barriers is advanced to the detailed design stage, but prior to finalising the design for construction and implementation, undertake a QHAZ analysis with specialists to evaluate the design intention of selected barriers. Identify improvements which will make barriers more effective. Ecological experts re-evaluate risk based on expected performance of each barrier. If community risk standards cannot be achieved, verify that all measures recommended by specialists have been considered to reduce risk. Subsequent improvements and management of change will be captured through implementation of the QMS in step 7.

7. Implement Proposed Barriers in the QMS

   Implement quarantine barriers through the QMS where information can be kept up to date and continuously monitored, assessed and improved. Develop plans for implementing a monitoring and assessment regime, including key performance indicators, to evaluate the performance of quarantine barriers.

In general, the risk management strategy gives priority to the following hierarchy of risk reduction measures:

- eliminating the likelihood of introduction
- reducing the likelihood of introduction
- reducing the likelihood of survival
- improving monitoring and detection methods
- improving control and eradication responses to introduction.

The risk assessment process is iterative as shown by the dashed lines in Figure 12-3. The PBA workshops (Step 4) were convened early in the conceptual design of barriers when several options for reducing risk may be under consideration simultaneously.

Similarly, once quarantine barriers are at the detailed design stage, a QHAZ analysis will be undertaken by ecological experts to determine if the proposed barrier will achieve its intended performance (Step 6). Improvements and re-design of barriers will be subject to repeat QHAZ analysis, if necessary, to address standards for acceptable risk and will be implemented through the QMS.

All information generated from the risk assessment process is captured in a Risk Register, in accordance with the guidelines contained in AS/NZS 4360 for risk management (Standards Australia 2004). The purpose of the Risk Register is to enable the Joint Venturers to monitor the implementation and efficacy of quarantine barriers to reduce risk. The Risk Register will also be used as input to the QHAZ workshops, and will be communicated to stakeholders as part of the QHAZ workshop records. The Risk Register, Barrier Selection Documents, key performance indicators and other technical inputs to the management of quarantine risk will ultimately be captured and updated in the QMS.

The methodology for the risk-based assessment is described in detail in the How to Guide for Conducting Risk-based Assessments of Quarantine Hazards on Barrow Island provided in Technical Appendix D2.

12.4.3 Development of Standards for Acceptable Risk

It has been necessary to develop standards for acceptable risk in consultation with technical experts and stakeholders, as there are no precedents for risk standards to protect the conservation values of nature reserves in Australia or elsewhere. A risk-based management approach for quarantine threats is used by regulatory authorities in Australia (Biosecurity Australia 2003; Russell et al. 2003) and overseas (FAO 1996; USDA 2000; NZ Department of Conservation 2003). These existing risk-based management approaches seek to identify hazards and suggest management strategies without attempting to achieve a clearly stated standard for 'acceptable risk' which accounts for stakeholder expectations.

The Joint Venturers have undertaken significant community consultation in developing a set of standards for acceptable risk. As a result of this community involvement, broad agreement of stakeholders has been reached.

Community Expectations for Acceptable Risk

Community involvement in the setting of standards for acceptable risk resulted in a proposition that certain combinations of risk estimates (likelihoods of introduction, survival, detection and eradication could represent risk standards which are acceptable to the community. Introduction is the outcome of infection by non-indigenous species at steps along a pathway. The likelihood of introduction for an entire pathway is a combination of the likelihoods of infection at each pathway step. Definitions of risk estimates are taken from Table 12–1.

Three scenarios were proposed, and are summarised in Figure 12-4. The proposed scenarios were recognised as the key outcomes of community involvement in the process for developing standards for acceptable risk. Each scenario represents a combination of maximum risk scores that community stakeholders believe would represent an acceptably low risk of establishment of species on Barrow Island. The scenarios apply to the residual risk of introducing species on particular pathways where barriers have been applied to manage specific quarantine threats.

The first priority is to reduce the likelihood of introduction (overall likelihood of the infection of cargoes arriving at Barrow Island) to a score of '1', as shown in Scenario 1 (Figure 12-4). In Scenario 1, if the introduction score could be reduced to '1', then the risk would be acceptable if the survival score was '2' or less, and the detection and eradication scores were '3' or less. In combination, such a set of scores would reduce the perceived risk of establishment to an acceptable level.

In the event that the introduction score cannot be reduced to '1', the community expressed the view that higher introduction scores ('3' or less) could be acceptable in combination with lower scores for survival, detection and eradication as shown in Scenarios 2 and 3. In Scenario 2, the survival score would have to be reduced to '1', and in Scenario 3, the detection and eradication scores would have to be reduced to '1'.

It was understood by the community that the scenarios shown in Figure 12-4 are only applicable to terrestrial flora and fauna, which largely constitute the conservation values of Barrow Island and are of primary concern in the risk-based management of quarantine threats. The community recognised that these standards could not be directly applied to marine introductions or to micro-organisms (organisms less than 10 microns in diameter up to about 50 microns in diameter). Figure 12-4 is taken from the community report on acceptable risk standards submitted to the Joint Venturers and to the EPA in September 2004 (Technical Appendix D3).

In the case of marine introductions, the same risk assessment process is to be used to identify threats and prevent introductions on vessels under control of the Joint Venturers, subject to international maritime laws and regulations. However, the marine environment is exposed to non-indigenous species which could arrive in the waters surrounding Barrow Island from any number of sources, translocated from nearby vessel routes and distant ports by regional currents (over hundreds of kilometres). There have been recorded observations of non-indigenous species in the waters surrounding Barrow Island which also have a very wide biogeographical distribution in north-west Australia (Technical Appendix D7). None of these species identified to date are listed as invasive in the National Introduced Marine Pest Information System (NIMPIS); however they have established in the marine

Figure 12-4:
Community Expectations for Acceptable Risk – Three Combinations of Risk Scores

Scenario 1
Community-proposed combination of risk scores, if introduction can be reduced to a score of ‘1’

Introduction	Survival	Detection	Eradication	Score
The introduction is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect early enough to consider eradication strategy.	Virtually certain to eradicate without significant impacts to the native environment.	1
	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection early enough to consider eradication strategy.	Very high likelihood of eradication without significant impacts to the native environment.	2
		High likelihood of detection early enough to consider eradication strategy.	High likelihood of eradication without significant impacts to the native environment.	3

Scenario 1: Community expectation of the combination of acceptable scores to prevent the establishment of species on Barrow Island, if the overall likelihood of introduction can be reduced to a score of ‘1’.

In Scenario 1, the survival score would also have to be ‘2’ or less, and the detection and eradication scores would have to be ‘3’ or less to meet community expectations.

Scenario 2
Community-proposed combination of risk scores, if introduction can be reduced to a score of ‘3’ or less

Introduction	Survival	Detection	Eradication	Score
The introduction is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect early enough to consider eradication strategy.	Virtually certain to eradicate without significant impacts to the native environment.	1
The introduction is remote, unlikely.		Very high likelihood of detection early enough to consider eradication strategy.	Very high likelihood of eradication without significant impacts to the native environment.	2
There is a slight chance of introduction.		High likelihood of detection early enough to consider eradication strategy.	High likelihood of eradication without significant impacts to the native environment.	3

Scenario 2: Community expectation of the combination of acceptable scores to prevent the establishment of species on Barrow Island, if the overall likelihood of introduction can be reduced to a score of ‘3’ or less.

In Scenario 2, the survival score would also have to be reduced to ‘1’, and the detection and eradication scores would have to be ‘3’ or less to meet community expectations.

Figure 12-4: (continued)
Community Expectations for Acceptable Risk – Three Combinations of Risk Scores

Scenario 3 **Community-proposed combination of risk scores, if introduction can be reduced to a score of '3' or less, and survival score reduced to '2' or less**				
Introduction	**Survival**	**Detection**	**Eradication**	**Score**
The introduction is extremely remote, highly unlikely.	The environment is not suitable for survival of any organisms.	Virtually certain to detect early enough to consider eradication strategy.	Virtually certain to eradicate without significant impacts to the native environment.	1
The introduction is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.			2
There is a slight chance of introduction.				3
Scenario 3:	Community expectation of the combination of acceptable scores to prevent the establishment of species on Barrow Island, if the overall likelihood of introduction can be reduced to a score of '3' or less, and the survival score can be reduced to '2' or less. In Scenario 3, the detection and eradication scores would also have to be reduced to '1' to meet community expectations.			

environment and would not be amenable to any eradication efforts without causing damage to the native marine environment. Established species in the marine environment are almost impossible to eradicate in almost all cases, although there are notable exceptions (Carlton 2002; McEnnulty et al. 2001; URS 2003). For marine micro-organisms such as planktonic larvae, dinoflagellates and algae, the prevention of translocation of these types of organisms largely relies on international maritime regulations for ballast water and hull anti-fouling treatments.

The likelihood of introduction, survival, detection and eradication in the marine environment cannot be compared to the community expectations for the standards for acceptable risk as such standards cannot be applied to threats which occur by natural means, or by means not associated with the Gorgon Development. An alternative approach has therefore been applied to the development of standards for the marine environment and is discussed in Section 12.4.3.

The QEP recognised that it would be impossible to prevent the introduction of all non-indigenous species of micro-organisms to Barrow Island given the enormous variety and number of known and unknown micro-organisms that exist. Terrestrial micro-organism quarantine threats therefore cannot be assessed in the same manner as flora and fauna threats, as the likelihood of introduction is almost certain in every case. Efforts to manage micro-organism threats to the conservation values of Barrow Island are therefore best invested in the prevention of potential outbreaks of disease by eliminating or containing pathogen hosts on pathways of exposure, particularly the personnel pathway and the food and perishables pathway.

Implementation of Risk Standards

Terrestrial Flora and Fauna

Based on substantial consultation with technical experts and community stakeholders, the Joint Venturers have developed a set of standards for acceptable quarantine risk to the terrestrial flora and fauna conservation values of Barrow Island (Box 12-9). These standards reflect the view that the highest priority for the prevention of establishment is the prevention of introductions in the risk-based management process. It has been acknowledged in community consultation that prevention of establishment to meet the community expectations for acceptable risk is not always possible.

It was also acknowledged that in those instances the Joint Venturers would demonstrate in a transparent manner that technical experts have been consulted to identify all possible quarantine barriers for consideration, with attention given to quarantine practices currently used elsewhere.

Box 12-9:
Standards for Acceptable Quarantine Risk to the Terrestrial Flora and Fauna Conservation Values of Barrow Island

The Gorgon Joint Venturers will use the risk assessment process to identify and eliminate significant threats of introduction wherever possible, substitute particular cargoes with alternative goods and materials to reduce the severity of threats, and minimise the volumes of cargoes to reduce the likelihood of introduction.

For threats which cannot be entirely eliminated or reduced, the objective of the Joint Venturers is to meet the community expectations for acceptable risk by implementing quarantine barriers to prevent establishment. The focus of these barriers is on the pre-border prevention of introductions from infected cargoes, personnel and vessels, such that the likelihood of introduction is considered extremely remote and highly unlikely (an overall introduction score of ‘1’). Quarantine barriers will also include border protection measures on Barrow Island, and post-border monitoring and eradication strategies to prevent establishment.

Where the community expectations for acceptable risk scores cannot be achieved, the Joint Venturers will demonstrate in a transparent manner that:

- Advice has been sought from specialists (ecological and construction) as to whether there are additional quarantine barriers to be considered which would further reduce the likelihood of introduction.
- Barriers adopted to prevent introductions are of a standard which has considered current quarantine practices found elsewhere; and establishes new benchmarks in relation to the pathways under consideration.
- Plans are developed for implementing a surveillance, monitoring and assessment regime to evaluate the performance of the quarantine barriers.

The standards for acceptable risk presented in Box 12-9 are the starting point for all threats of introduction, although they only strictly apply to the protection of terrestrial flora and fauna conservation values. The application of risk standards for marine organisms and micro-organisms is discussed below.

As an illustration of the application of these risk standards to terrestrial flora and fauna, it was discovered that road base material which was proposed to be sourced from mainland Western Australia would be subject to infection by non-indigenous species. Technical experts cautioned that it was difficult to identify preventive quarantine barriers that would reduce the likelihood of introduction and survival to low levels. It was also recognised that road base could be used across many areas of Barrow Island, potentially exposing a number of areas to the threat of infected material. As a result, the Joint Venturers decided to eliminate the proposed importation of road base in favour of sourcing this material from site preparation works at the proposed location of the gas processing facility on Barrow Island. A potential quarantine threat was eliminated through an alternative engineering solution.

The management of quarantine on priority pathways (Section 12.5) reflects many more examples of solutions which reduce threats wherever possible. Where threats cannot be entirely eliminated, multiple layers of barrier protection can be applied to prevent introductions. Further barrier strategies identified by technical experts have been considered with regard to current quarantine practices found elsewhere.

Notwithstanding the primary objective of preventing pre-border infections of cargoes and personnel, the risk assessment process addresses both border and post-border quarantine threats to prevent establishment of any organisms which might ‘slip through’ quarantine barriers. Analysis of the food and perishables pathway demonstrates how border and post-border quarantine management measures can be applied effectively. This is because food and perishables obviously consist of plant matter and may harbour invertebrate organisms which are acknowledged as difficult to eliminate from food prior to shipment. The likelihood of introduction will be managed at the border with a village kitchen complex which contains many features of a quarantine containment and eradication facility and post-border surveillance.

Once detailed designs for barriers are adopted, a risk assessment workshop of ecological specialists, experienced construction and operational specialists and designers will be convened to consider whether the proposed barriers on a specific pathway can be implemented and will function as intended (Step 6 in Figure 12-3). This step verifies that attention has been given to an effective mix of risk reduction strategies identified during the risk assessment process, which taken together will meet the standards for acceptable risk.

Marine Organisms

In the marine environment, the introduction of marine species throughout the region from shipping and port activities cannot be entirely prevented. Community expectations for acceptable risk, based on terrestrial flora and fauna, were recognised by stakeholders to be problematic for the waters surrounding Barrow Island when non-indigenous species could arrive quite independently of proposed development activities. Expert advice indicated that the risk standards were impractical for the prevention of introducing marine organisms. However, the Joint Venturers have taken steps to mitigate introductions from proposed development activities, prior to arrival of vessels at Barrow Island. The standards for acceptable risk to marine conservation values are presented in Box 12-10.

The Joint Venturers intend to take a 'forward-defence' approach to mitigate potential marine introductions from international ports through vessels calling at Barrow Island or working in the surrounding waters. Prior to accepting marine vessels from international ports, an 'environmental matching' risk assessment will be undertaken to determine if environmental conditions (e.g. temperature, salinity) are compatible for the translocation of species; and to investigate whether there are particular species of concern which are known to be present in ports visited by marine vessels sailing to Barrow Island. In the event that specific threats of translocating known pest species exist, options for ballast water management, sediment management, and cleaning/disinfection of wetted surfaces can be implemented to mitigate the establishment of pest species in the waters surrounding Barrow Island (Hayes and Hewitt 1998).

Box 12-10:
Standards for Acceptable Quarantine Risk to the Marine Conservation Values of Barrow Island

The Gorgon Joint Venturers will use the risk assessment process to identify and eliminate significant threats of introduction wherever possible, substitute particular types of vessels or components of vessels to reduce the severity of threats and minimise the number of shipments to Barrow Island to reduce the likelihood of introduction.

For threats which cannot be entirely eliminated or reduced, the objective of the Joint Venturers is to meet the community expectations for acceptable risk by implementing quarantine barriers to mitigate establishment. The goal of these barriers is to mitigate introductions from infected ballast water and hull surfaces of vessels under the direct control of the Joint Venturers, subject to requirements imposed by domestic and international maritime laws and regulations. Ballast water management regimes and hull anti-fouling coating maintenance practices of vessels not under the direct control of the Joint Venturers will be closely scrutinised to ensure compliance with all applicable regulations and internationally accepted standards. Quarantine barriers will also include border protection measures on Barrow Island and post-border monitoring and eradication strategies to mitigate establishment.

In all cases, the Joint Venturers will demonstrate in a transparent manner that:

- Advice has been sought from specialists (ecologists and marine vessel operators) as to whether there are additional quarantine barriers to be considered which would further reduce the likelihood of introduction.
- Barriers adopted to mitigate introductions are of a standard which has considered current quarantine practices found elsewhere; and establishes new benchmarks in relation to the pathways under consideration.
- Plans are developed for implementing a surveillance, monitoring and assessment regime to evaluate the performance of the quarantine barriers.

For vessels discharging ballast water at Barrow Island, existing ballast water exchange practices required by domestic and international regulations will occur and will be monitored for compliance. However, the vast majority of vessels calling at Barrow Island during the construction period will be unloading cargoes, so will not be discharging ballast water. To mitigate translocation of species from foreign ports during the construction period, inspection of wetted hull surfaces (followed by cleaning/disinfection, and maintenance of anti-fouling paint, if necessary), will be required to verify that threats of introduction are being managed prior to loading of cargoes destined for Barrow Island.

Dredging vessels and associated trailer/hopper vessels will be required to undergo ballast water and sediment management, inspection, cleaning/disinfection and anti-fouling paint maintenance regimes. An alternative approach under consideration for dredge vessels, sourced from outside Australia, is to dry-dock or transport them by heavy lift barge to a port in north-west Australia. This keeps the dredge out of the water for a period of time sufficient to destroy marine organisms, which would be confirmed by a qualified inspector.

The Joint Venturers also support a collaborative baseline survey of the Port of Dampier for introduced marine species, as recommended for all Australian first-ports-of-call by the Joint Standing Committee on Conservation/Standing Committee on Forestry and Aquaculture (SCC/SCFA) National Task Force on the Prevention and Management of Marine Pest Incursions (SCC/SCFA 1999), using established protocols described by Hewitt & Martin (2001). Such a survey of the largest freight tonnage port in Australia would benefit existing industry and port operators at large; and form the basis for a wider responsibility to prevent the introduction of marine species to the region from a variety of potential sources.

Marine quarantine measures are subject to further development within the risk-based assessment and management process, such that activities associated with the proposed Development will not compromise the conservation values of marine waters surrounding Barrow Island.

Micro-organisms

In the case of terrestrial micro-organisms, it is not practical to attempt to prevent all introductions as a wide range of micro-organisms will be routinely carried by personnel and cargoes. It is recognised that the taxonomic identification of the vast majority of micro-organism species is not available. However, information exists on known pathogens that could be associated with specific cargoes, personnel and vessels. It may also be feasible in some cases to identify what species of flora and fauna are particularly vulnerable to specific pathogens.

For terrestrial micro-organisms, the QEP recommended that the Joint Venturers obtain advice on potential threats of disease to living conservation values in the form of desktop studies. Reports of the desktop studies are presented in Technical Appendices D8 and D9, for terrestrial fauna and flora respectively. Terrestrial pathogens and their likely hosts were identified in these studies, such that quarantine management would take these pathogen hosts into account when developing barriers, particularly for the food and perishables and personnel pathways.

The village and kitchen facilities will include hygiene and waste management practices to eliminate or contain potentially harmful pathogens, preventing exposure to flora and fauna on Barrow Island. These precautionary measures will be backed up with response strategies in the event that a disease is detected in the native environment. A number of disease control strategies for animals and humans have been considered in the Australian Veterinary Emergency Plan (Animal Health Australia 2002). Guidance for responding to animal and plant disease is discussed in the Protocols for Generic Incident Management in the Department of Agriculture (Department of Agriculture Western Australia 2003).

The standards for acceptable risk with regard to the threat of introducing terrestrial micro-organisms are presented in Box 12-11.

Box 12-11:
Standards for Acceptable Quarantine Risk with regard to the Threat of Introducing Terrestrial Micro-organisms to Barrow Island

The Joint Venturers will consult with technical experts to review known threats of disease to terrestrial flora and fauna for relevant pathways of exposure. Specialist advice will be used to: eliminate significant threats of introduction wherever possible; and substitute particular cargoes, which may act as hosts for disease, with alternative goods and materials to reduce the severity of threats.

Box 12-11: (continued)
Standards for Acceptable Quarantine Risk with regard to the Threat of Introducing Terrestrial Micro-organisms to Barrow Island

For threats which cannot be entirely eliminated or reduced, the objective of the Joint Venturers is to meet the community expectations for acceptable risk by implementing appropriate hygiene and waste management practices which prevent exposure of flora and fauna to pathogens; and to perform surveillance of the health of personnel and wildlife.

Quarantine barriers will include border protection measures on Barrow Island and post-border monitoring and disease control strategies.

In all cases, the Joint Venturers will demonstrate in a transparent manner that:

- Advice has been sought from specialists as to whether there are additional quarantine barriers to be considered which would further reduce the likelihood and spread of disease.
- Barriers adopted to prevent introductions are of a standard which has considered current quarantine practices found elsewhere.
- Plans are developed for implementing a surveillance, monitoring and assessment regime to evaluate the performance of the quarantine barriers.

In the case of marine micro-organisms, ballast water performance standards under the International Maritime Organisation (IMO) Convention address the disinfection of ballast water. Also anti-fouling paints, used on hulls, mitigate introductions through the elimination of non-indigenous species which might otherwise be hosts for micro-organisms. Marine micro-organism threats may include planktonic larval stages of marine fauna and propagules of marine flora. The standards for acceptable risk with regard to the threat of introducing marine micro-organisms are presented in Box 12-12 and will apply to marine vessels operated in relation to the Development.

Box 12-12:
Standards for Acceptable Quarantine Risk with regard to the Threat of Introducing Marine Micro-organisms to Barrow Island

The Joint Venturers will use the risk assessment process to identify and eliminate significant threats of introduction wherever possible, subject to requirements imposed by domestic and international maritime laws and regulations.

For threats which cannot be entirely eliminated or reduced, the objective of the Joint Venturers is to meet the community expectations for acceptable risk by implementing ballast water management regimes and maintaining hull anti-fouling coatings on vessels calling at Barrow Island which are under the direct control of the Joint Venturers. Ballast water management regimes and hull anti-fouling coating maintenance practices of vessels not under the direct control of the Joint Venturers will be closely scrutinised to ensure compliance with all applicable regulations and internationally accepted standards. Ballast water management will be subject to a high level of compliance monitoring for vessels which load cargoes at Barrow Island (and therefore are likely to discharge ballast water to the surrounding waters).

Quarantine barriers will include border surveillance measures on Barrow Island and post-border monitoring and response strategies.

In all cases, the Joint Venturers will demonstrate in a transparent manner that:

- Advice has been sought from specialists (ecologists and marine vessel operators) as to whether there are additional quarantine barriers to be considered which would further reduce the likelihood of introduction.
- Barriers adopted to mitigate introductions are of a standard which has considered current quarantine practices found elsewhere.
- Plans are developed for implementing a surveillance, monitoring and assessment regime to evaluate the performance of the quarantine barriers.

12.4.4 Identification of Quarantine Threats

The risk-based assessment is an ongoing task to address each unique pathway which might expose Barrow Island to non-indigenous species. To date, 17 risk assessment workshops have been conducted, with information being captured for many of the 13 pathways listed in Box 12-7. Progress on these risk assessment workshops is shown in Table 12-2 for terrestrial quarantine threats and Table 12-3 for marine quarantine threats. These tables show the status of the risk-based assessment process, by reference to the step completed (Figure 12-3). Comprehensive records of each workshop are reported by the workshop facilitator to the Joint Venturers and workshop participants. These records have been made available to the QEP and community stakeholders to maintain a highly transparent assessment.

Micro-organism threats are being identified and managed through a separate process of consultation with specialists in plant and animal disease prevention and control (Section 12.4.3).

Table 12-2:
Status of Risk-based Assessment of Terrestrial Quarantine Threats to Barrow Island

Pathway for terrestrial organisms	Vertebrates	Invertebrates	Plants
Rock aggregate, sand	Step 2 (IMEA)	Step 4 (PBA)	Step 4 (PBA)
Cement			
Pre-fabricated modules		Step 2 (IMEA)	Step 2 (IMEA)
Plant, equipment		Step 2 (IMEA)	Step 2 (IMEA)
Pipe		Step 2 (IMEA)	
Containerised goods		Step 2 (IMEA)	
Steel		Step 2 (IMEA)	
Food and perishables	Step 2 (IMEA)	Step 4 (PBA)	Step 4 (PBA)
Skid equipment		Step 2 (IMEA)	Step 2 (IMEA)
Personal tools consigned for transport			
Personnel, luggage (by air)	Step 2 (IMEA)	Step 4 (PBA)	Step 4 (PBA)
Aircraft			Step 2 (IMEA)
Marine vessels ('topsides')	Step 4 (PBA)		
Legend: One or more IMEA, PBA workshops			

Table 12-3:
Status of the Risk-based Assessment of Marine Quarantine Threats to Barrow Island

Pathway for marine organisms	Vertebrates	Invertebrates	Plants
Barges		Step 4 (PBA)	Step 4 (PBA)
Cargo, container vessel (Australia)		Step 4 (PBA)	Step 4 (PBA)
Heavy lift vessel (Europe, SE Asia)		Step 2 (IMEA)	Step 2 (IMEA)
Marine construction vessels (dredge, lay barge)		Step 4 (PBA)	Step 4 (PBA)
Supply vessels		Step 4 (PBA)	Step 4 (PBA)
Small coastal vessels		Step 4 (PBA)	Step 4 (PBA)
Condensate and crude oil tankers			
LNG Tankers			
Dive equipment, submersibles			
Legend: One or more IMEA, PBA workshops			

12.5 Quarantine Barrier Selection

The Joint Venturers are committed to adopting an array of quarantine barriers that reduce the quarantine risks to an acceptable standard. Quarantine barriers relevant to each pathway have been identified through numerous Risk Assessment Workshops. The process for achieving quarantine barrier implementation has been outlined in the Gorgon Risk-based Quarantine Assessment Method in Section 12.4.2. In accordance with this risk assessment method, all proposed quarantine barriers will proceed through feasibility and QHAZ analyses (Steps 5 and 6) prior to final design and implementation (Step 7). Details of the barrier selection method (Step 5), including feasibility analysis are described below in Section 12.5.1.

Feasibility and QHAZ analyses will be conducted on the barriers as soon as the necessary Front-End Engineering and Design (FEED) information is available. Information relevant to the three pathways described below will be available during the public review period. The Joint Venturers are committed to the risk assessment method and barriers proposed in this Section. These barriers may need to be modified in light of additional information and in order to meet the risk standards.

For the purpose of illustrating the types of quarantine barriers under consideration, the QEP advised that some of the more difficult-to-manage pathways should be given priority in the risk-based barrier selection process. Three priority pathways were considered to present the greatest management challenge for meeting standards for acceptable risk based on the results of risk assessment, expert opinion and community consultation. These three priority pathways are also relevant to early development activities and have progressed furthest through the risk-based assessment method. The three pathways are listed below and discussed in detail in the relevant Sections indicated:

1. Sand and aggregate (Section 12.5.3)
2. Food and perishables (Section 12.5.4)
3. Personnel and accompanying luggage (Section 12.5.5).

These priority pathways are believed to represent the greatest range of threats of introduction of non-indigenous species. Other pathways which may be less difficult to manage will be subject to exactly the same assessment process to develop barriers which will meet the standards for acceptable risk. As such, the QEP have advised that a description of the conceptual quarantine barriers on the three priority pathways will convey the best demonstration of the risk-based management process at the time of submission of this Draft EIS/ERMP. The discussion of the three pathways below includes a description of the key barriers proposed by the Joint Venturers for implementation. The Joint Venturers are of the view that the combination of these barriers will reduce the quarantine risks to an acceptable level. This will be tested as these barriers are taken through Steps 5 and 6 of the risk assessment method.

The Joint Venturers have established an ongoing process of analyses of the proposed barriers; and have committed to publishing Step 5 information for the three priority pathways as a supplementary report to this Draft EIS/ERMP document four weeks prior to the close of the public review period. This report will provide more detailed information and justification on the barriers selected by the Joint Venturers to reduce the quarantine risks. The Joint Venturers will conduct a further Barrow Island Quarantine Community Consultation Meeting subsequent to the release of the supplementary report.

Community consultation already undertaken on the development of barriers included a stakeholder workshop to review and discuss the way in which conceptual barriers will be selected and implemented in the QMS to meet the standards for acceptable risk. The Joint Venturers prepared explanatory 'Design Guides' (which presented barrier specifications at a conceptual level) for community consultation, from which information has been summarised in Conceptual Quarantine Barriers (Technical Appendix D10). The results of the workshop were presented to the wider community consultation group, which facilitated an understanding of the level of detail that will be provided for quarantine barriers. The community consultation resulted in a view that the conceptual quarantine barriers should be subject to independent expert review in future QHAZ workshops (Step 6) for each pathway.

In recognition of the importance of the marine transport pathway, the Joint Venturers have also progressed the marine vessel 'topsides' pathway for terrestrial vertebrates (rodents, reptiles and birds) to Step 4 of the risk-based assessment process.

Each pathway was initially assessed to identify opportunities to eliminate cargoes of raw materials, equipment, supplies and food to the extent possible. Construction activities on Barrow Island that could be undertaken on the mainland are also identified to reduce the size of the workforce on the island. The elimination of high risk cargoes has been possible in several instances as discussed below for the three priority pathways.

For cargoes which cannot be eliminated, substituted for alternative low-risk cargoes, or otherwise minimised, the first priority of quarantine management is to prevent the introduction of non-indigenous species on Barrow Island. As such, risk assessment workshops initially focus on *pre-border* quarantine threats and barriers to assess: the likelihood of the arrival of a non-indigenous species on Barrow Island; and the types of substantial quarantine barriers that should be considered to prevent introductions. Pre-border quarantine management and quarantine barriers on pathways of exposure are not a perfect solution in themselves. Therefore, a QMS is necessary to ensure that border and post-border surveillance and monitoring are implemented; and a response strategy is in place to contain and eradicate any introductions before they establish a 'foothold' on Barrow Island.

An essential element of the Joint Venturers' approach to quarantine management is to establish purpose-built mainland logistics facilities for preparation of cargoes to be shipped to Barrow Island. Mainland logistics facilities will provide central locations to consistently address all of the requirements for quarantine inspection, cleaning, and packaging that will be required. Similarly, a purpose-built facility is proposed to receive cargoes shipped by sea at Barrow Island, which will be designed to address quarantine requirements.

At this early design stage of the Gorgon Development, a large number of conceptual quarantine barriers are under consideration. The entire list of conceptual barriers is provided in Technical Appendix D10.
In many instances a subset or even one of the alternative barriers under consideration at each pathway step will address the standards for acceptable risk. Final quarantine barrier designs and risk reduction measures will be described in detail and evaluated at Step 6 of the risk-based assessment process and ultimately captured and implemented through the QMS.

12.5.1 Quarantine Barrier Selection Method

Selection of quarantine barriers is a four-step process, beginning with the conceptual quarantine barriers suggested in IMEA and PBA workshops (Step 5 of the Gorgon Risk-based Quarantine Assessment Method in Figure 12-3). Any other barriers that might have become evident to the Joint Venturers as a result of further research have been added to this workshop list. The four step barrier selection method is illustrated in Figure 12-5, Steps 5A to 5D.

The first step is to assess the 'feasibility' of each barrier. This is done by separately assessing:

- the practicability of implementing a barrier and having it meet its design intention over its expected lifetime
- the balance of estimated effort against the risk reduction benefits that would be achieved
- the compatibility of barrier implementation with respect to project timelines
- any legal or regulatory constraints.

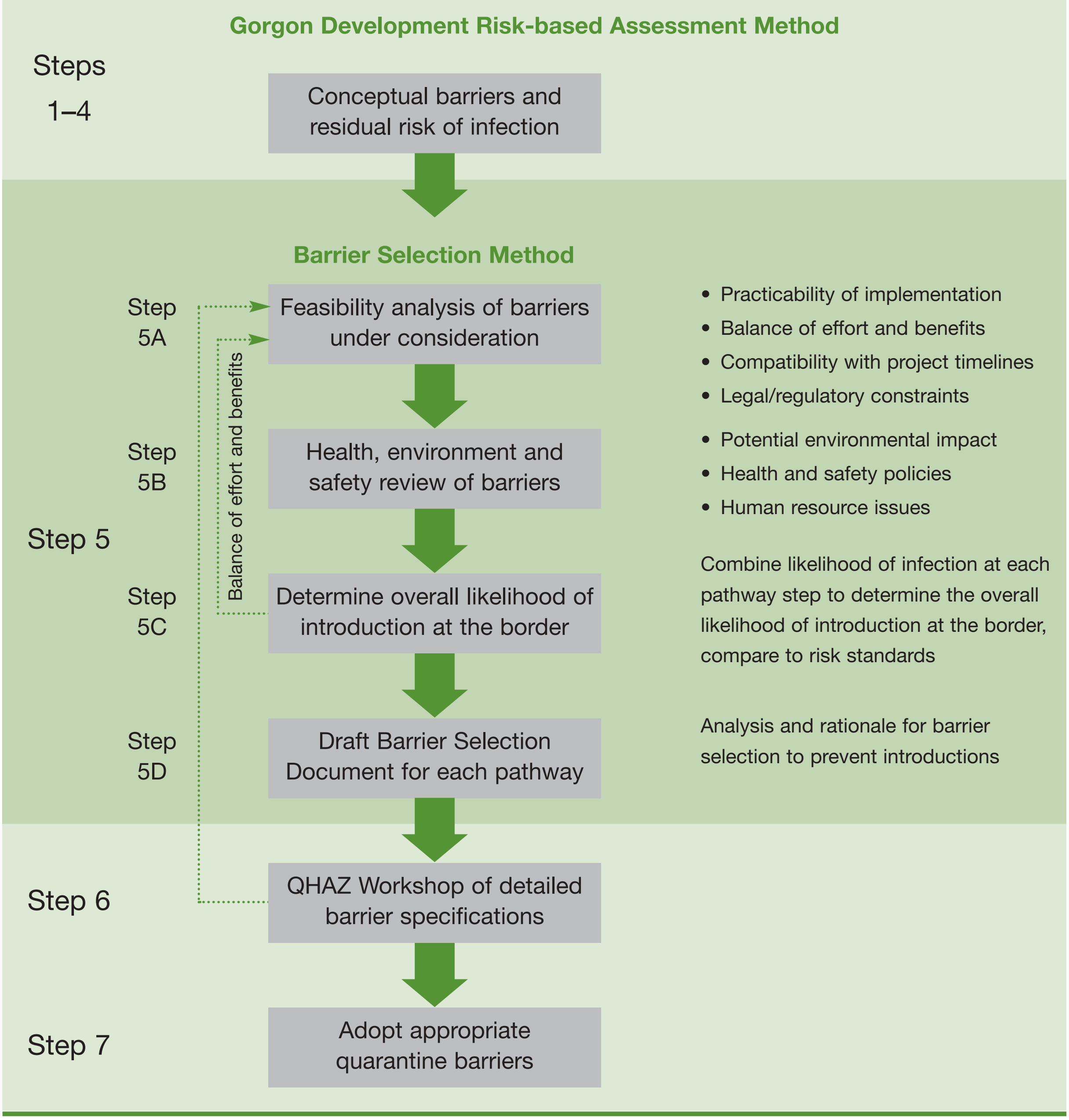
The criteria for making judgments about each of these elements of the feasibility analysis are described in Table 12-4. Each of the feasibility attributes pass, or fail, the broadly stated assessment criteria. If a barrier fails any of the feasibility attributes, the rationale is documented and it is dropped from further consideration. The outcome of the feasibility analysis is a subset of barriers which are considered feasible to implement, subject to meeting standards for acceptable risk.

The second step in the barrier selection process is to assess the soundness of the remaining barriers from a health, environment and safety (HES) and human resources (HR) perspective. The HES-HR review includes:

- consideration of any potential 'collateral' damage that might be caused to the environment
- health and safety policies associated with barrier activities
- any foreseeable roadblocks to implementation which might eventuate from an HR perspective.

The criteria for making judgments about each of these elements of the HES-HR review are described in Table 12-5. Each of the HES-HR attributes pass or fail the

Figure 12-5:
Quarantine Barrier Selection Method



broadly stated assessment criteria. If a barrier fails any of the HES-HR attributes, it may be modified to allow further consideration or excluded from the process. The outcome of the HES-HR review is a subset of barriers which are considered both feasible to implement and consistent with HES-HR policies, subject to meeting standards for acceptable risk.

The third step in the barrier selection process is to review the list of feasible barriers with respect to the quarantine risk assessment outputs from PBA workshops. The effectiveness of each barrier (represented by their likelihood of infection scores) is considered at the point on the pathway at which it would be implemented. Decision rules can be used to develop a residual introduction risk score for the overall pathway, combining the infection scores at each pathway step in a qualitative manner.

An example of the types of decision rules that could be applied is presented in Table 12-6, referring to the infection scores of 1 to 10 defined in Table 12-1. The rationale for decision rules is based on the proposition that multiple barriers along a pathway, each

Table 12-4:
Feasibility Analysis Criteria for Quarantine Barrier Selection

Feasibility Attribute	Acceptance Criteria
Practicability of implementation	The elements of barrier design must be practical to implement under the specific circumstances. Confidence that the design intention can be achieved is necessary for barriers which involve untested technology or are otherwise unprecedented.
Balance of effort and benefits	The effort (resources and costs) of barrier implementation must balance the incremental risk reduction benefits which would be achieved. This judgment is made in the context of implementing the subject barrier in addition to other barriers, which may themselves reduce the likelihood of introduction to a very low level.
Compatibility with project timelines	The development of barriers on a specific pathway must have sufficient implementation time, which is consistent with the project timelines for commencing activities on the pathway.
Legal/regulatory constraints	The elements of quarantine barriers on specific pathways must comply with all legal and regulatory obligations, both within Australia and internationally in the case of pathways which originate overseas.

Table 12-5:
HES-HR Review Criteria for Quarantine Barrier Selection

HES-HR Attribute	Acceptance Criteria
Potential environmental impact	Barrier specifications must comply with Joint Venturers' environmental policy, and not require referral to the government for approval based on their potential to cause adverse environmental consequences. Only localised, short-term and reversible types of potential impacts would be considered acceptable.
Health and safety policies	Barrier activities must comply with Joint Venturers' health and safety policy, and meet the goal of incident and injury free construction and operations. Barriers must be designed to eliminate any predictable adverse consequences to personnel health and safety.
Human resource issues	Barrier specifications and requirements for personnel involvement must not forseeably impact the civil liberties of personnel to an extent that would be clearly objectionable (e.g. personal privacy and the collection of any personal information). Barrier activities must allow for an acceptable quality of life for personnel working in strenuous construction and operations positions for extended periods of time.

of which reduce the risk of infection, must result in a lower overall risk of infection. If it were possible to adopt a quantitative risk assessment process, an analogy would be the calculation of a conditional probability based on the product of individual probabilities. The exact form of the decision rules is not critical to the barrier selection process, only that the rules are applied consistently for all pathways.

Because the consequences associated with the introduction of non-indigenous species to the Barrow Island environment cannot be predicted for all organisms with confidence, the likelihood of introduction has been taken to be the residual quarantine 'risk' at the quarantine border. The residual likelihood of introduction can then be compared with the standards for acceptable risk (Box 12-9). Of these standards, stakeholders expressed the view that the most important objective would be to reduce the residual likelihood of introduction to the lowest level possible (e.g. a likelihood score of '1').

Where the barrier selection process identifies the subset of quarantine barriers which are feasible, consistent with HES-HR policies and meet the standards for acceptable risk, the analysis and rationale is recorded in draft barrier selection documents for each of the pathways. This is the fourth step in the barrier selection process.

Table 12-6:
Proposed Decision Rules for Qualitatively Combining Infection Scores at Each Pathway Step into an Overall Introduction Score

Rule	Method of Combining Infection Scores for an Overall Residual Risk of Introduction
Rule 1	The overall likelihood of introduction score for an entire pathway is less than or equal to the lowest likelihood of infection score for any pathway step, as long as subsequent pathway steps are not vulnerable to threats of re-infection.
Rule 2	If any barrier in a pathway step scores 1, then the pathway score is 1.
Rule 3	If two or more barriers in different pathway steps score 2 (or below), then the pathway score is 1. In general, if two or more barriers in different pathway steps score n (or below), then the pathway score is n-1 (where n represents an infection score from 1 to 10).
Rule 4	If three or more barriers in different pathway steps score 3 (or below), then the pathway score is 1. In general, if three or more barriers in different pathway steps score n (or below), then the pathway score is n-2.
Rule 5	If four or more barriers in different pathway steps score 4 (or below), then the pathway score is 1. In general, if four or more barriers in different pathway steps score n (or below), then the pathway score is n-3.
Rule 6	If five or more barriers in different pathway steps score 5 (or below), then the pathway score is 1. In general, if five or more barriers in different pathway steps score n (or below), then the pathway score is n-4.

In the event that the subset of selected quarantine barriers does not appear to meet the standards for acceptable risk, particularly for the residual introduction risk score, further consideration of barriers previously dropped from consideration will be made. This is an iterative process represented by the dashed line in Figure 12-5, from Step 5C to Step 5A. It is largely a re-assessment of the balance of effort and benefits for quarantine barriers which were previously excluded from further consideration in Step 5A. If the magnitude of the effort to adopt an additional barrier is balanced by an equal magnitude of reduction in the overall likelihood of introduction, then the additional quarantine barrier may be included if it also passes the HES-HR review (Step 5B).

The draft barrier selection is documented; and detailed quarantine barrier specifications for each pathway will be subject to a QHAZ analysis (Step 6 in Figure 12-6).

The Joint Venturers will use the risk assessment process to: eliminate significant threats of introduction wherever possible; substitute particular cargoes with alternative goods and materials to reduce the severity of threats; and minimise the volumes of cargoes to reduce the likelihood of introduction.

In recognition that all threats cannot be entirely eliminated, the objective of the Joint Venturers is to meet the standards for acceptable risk by implementing quarantine barriers to prevent establishment of non-indigenous species on Barrow Island. A precautionary approach has been taken to focus the development of barriers on the pre-border prevention of introductions on pathways involving cargoes, personnel and vessels. Quarantine barriers will also include border protection measures on Barrow Island, and post-border monitoring and eradication strategies to prevent establishment.

12.5.2 Systematic Quarantine Barriers for all Pathways

There are a number of systematic quarantine barriers that are common to all pathways. These system-wide barriers will be applied through the implementation of the QMS. Some examples of the systematic barriers that the Joint Venturers are committed to are:

- inclusion of quarantine requirements in pre-qualification of suppliers and contractors
- inclusion of quarantine requirements in contracts for all contractors and suppliers providing goods and services for Barrow Island
- induction of all personnel (staff, contractors, and suppliers) in quarantine management requirements
- provision of specific quarantine training to personnel in the procurement and logistics supply chain
- inclusion of quarantine responsibilities in the position description for key personnel

- development and support of a strong culture of quarantine awareness in the workforce
- quarantine compliance for all personnel and goods going to Barrow Island will be recorded and tracked
- conduct regular quarantine compliance audits and checks throughout the supply chain.

The following Sections demonstrate the application of pathway-specific quarantine barriers for the three priority pathways.

12.5.3 Management of Quarantine on the Sand and Aggregate Pathway

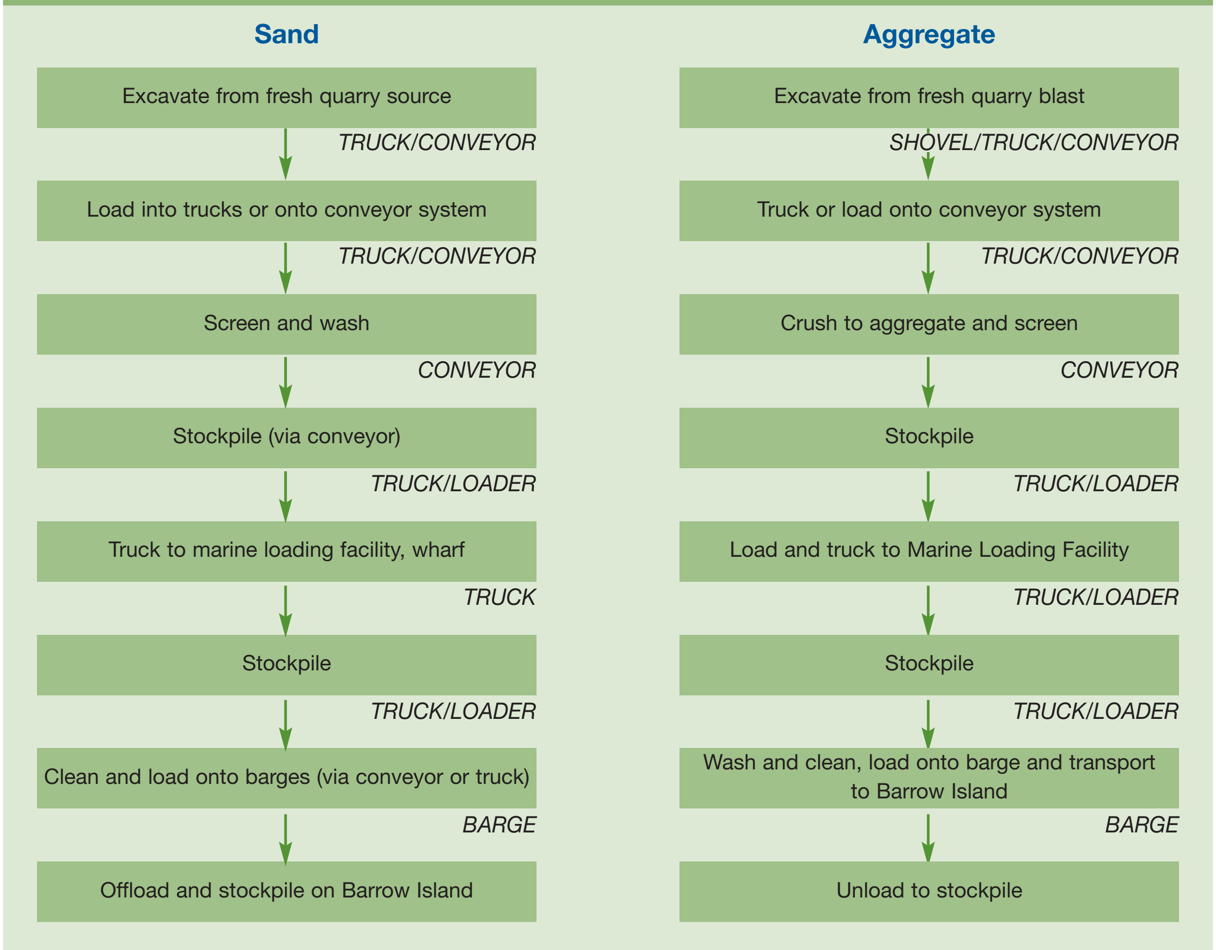
Sand and aggregate will be mined from a quarry, processed and loaded onto barges for transport to Barrow Island for use in construction. Figure 12-6 is an overview of the pathway steps considered in the identification of quarantine threats and barriers.

Based on the results of IMEA pathway and PBA workshops the most significant infection modes were considered to be:

- the storage and handling of topsoil at the quarry site, due to potential cross-infection with quarried sand and aggregate
- the lighting of the lay down area at the port, which would attract vertebrate and invertebrate organisms
- the use of port facilities by other shipping customers and vessels, where exposure to other sources of infection could occur.

Approximately 70 potential quarantine barriers were identified for consideration to manage specific quarantine threats on the sand and aggregate pathway. Workshop participants identified a number of ‘key barriers’ for special consideration, with the opinion that these would significantly reduce the likelihood of introduction. For example, the washing of rock aggregate with heated water prior to loading onto the

Figure 12-6:
Sand and Aggregate Pathway Steps



transport barge was considered a key barrier to reduce the likelihood of infected cargoes. However, washing of fine grained sand may be impractical to effectively remove small organisms and seeds. It may also cause a loss of sand entrained in waste water. Specialists advised that the alternative of dry heat sterilisation could be used to achieve a similarly significant reduction of infections in sand.

The Joint Venturers commit to the following key barriers for the sand and aggregate pathway:

- implement a Quarry Environmental Management Plan
- clean and inspect quarry equipment
- cover material in segregated storage
- sample material to verify compliance
- cover during sea transport.

A key barrier identified in the risk workshops is the heat treatment and water wash of sand and aggregate. The Joint Venturers are continuing to analyse the feasibility and reliability of this barrier. Investigations to date indicate that herbicide/pesticide spray may achieve a greater level of risk reduction and efficacy. The results of this work will be tested in Steps 5 and 6 of the risk assessment method.

In order to meet the risk standards, preferred barriers including key barriers listed above, may need to be modified or further barriers added in light of additional information arising from Steps 5 and 6.

Figure 12-7 illustrates the maximum infection scores, estimated by PBA workshop participants, that apply to all quarantine barriers at each step of the sand and aggregate pathway. In this figure, only a subset of quarantine barriers is listed (at each step) to illustrate the application of some important barriers. Two pathway steps (7 and 8) have the lowest infection scores (maximum 3). In this example, if all the barriers listed in steps 7 and 8 were adopted, decision rule 3 in Table 12-6 could be used to estimate the residual likelihood of introduction for the entire pathway. For example, the maximum infection scores of 3 (slight chance) at steps 7 and 8 would reduce the residual likelihood to a score of 2 (remote, unlikely). The conservative estimate of the residual likelihood of introduction for the entire pathway can therefore be expressed as 'remote, unlikely' which is derived from the residual score of 2.

In the case of the sand and aggregate pathway, it was recognised by technical specialists that, although barriers should be implemented at every step of the pathway, the greatest effort should be made to prevent infection of this cargo at the mainland port facility. Infection modes identified at the port facilities could otherwise compromise efforts to prevent infections earlier in the pathway (e.g. quarry and road transport activities). The infection scores estimated for barriers applied at the mainland port facility (Figure 12-7 step 7) and sea transport (Figure 12-7 step 8) support this objective.

All quarantine barriers currently under consideration and not shown in Figure 12-7 are listed in Conceptual Quarantine Barriers Technical Appendix D10. The Joint Venturers have identified additional or alternative barriers for the barrier selection process, based on consultation with specialist contractors and consultants during early feasibility studies. On the sand and aggregate pathway, some alternative barriers under consideration to further reduce risk by substitution or reduction of potential threats are:

- sourcing sand and aggregate from south-west Australia to reduce the chances of survival of organisms in the semi-arid climate of Barrow Island
- pre-fabricating concrete structures including foundations, paving and protective armour for the MOF and pipelines, thereby reducing the volumes of aggregate, sand and rock armour cargoes that will arrive at Barrow Island
- using marine dredge spoil to offset a portion of the requirement for importation of crushed rock for the marine causeway.

In addition to the above quarantine management options, and as a precautionary measure to address the residual risk of introduction at the border, the Joint Venturers will consult with CALM to undertake a plant eradication program on the proposed gas processing facility construction site and village. The purpose will be to eradicate all plant species in the cleared area of the facility, whether re-establishing plants are native or not. In the unlikely event that an introduced plant species is detected, a rapid response strategy will be mobilised to control the spread of the plant and prevent its establishment in the native environment. Similar efforts will be undertaken to monitor for fauna with baits and traps in the construction and village areas, as part of the overall environmental monitoring and response effort (refer to Sections 12.5.8 and 12.5.9, respectively).

The 'remote, unlikely' estimate of introduction on the sand and aggregate pathway is an example of what can be achieved in the risk-based management of quarantine threats. The interim information provided here demonstrates how the risk of introduction can be mitigated to very low levels. The QHAZ analysis will allow improvements in barrier design to further reduce the likelihood of infection. Further development in the design of post-border monitoring and eradication strategies will provide additional levels of risk reduction and provide confidence that the standards for acceptable risk will be met.

12.5.4 Management of Quarantine on the Food and Perishables Pathway

Food and perishables required for the Development will be sourced from mainland suppliers, consolidated and prepared for shipment at a centralised mainland facility. Containerised food will be transported by truck to a marine loading facility and loaded onto barges for sea shipment to Barrow Island. Once food containers are accepted and unloaded from barges at the Barrow Island MOF, containers will be transported to a purpose-built border kitchen facility, which will be a significant barrier to prevent introductions associated with food and perishables (e.g. seeds, invertebrates). The pathway steps considered in the management of quarantine threats is illustrated in Figure 12-8.

Based on the results of IMEA pathway and PBA workshops the most significant infection modes were considered to be:

- contamination of raw food and perishables with invertebrates (fruit and vegetables, particularly those harvested from below ground and those sourced from overseas)
- invertebrates on transport vehicles and vessels
- waste water and solid waste management on the island.

During IMEA workshops, it was highlighted that the food and perishables pathway would contain non-indigenous species that could not be entirely eliminated by quarantine barriers. Although elimination of non-indigenous species in food and perishables is not possible, it is considered feasible to adopt quarantine barriers to contain these organisms inside packaging through to arrival at the kitchen facility on Barrow Island. The kitchen facility was recognised as the optimum location to install border quarantine barriers and therefore the kitchen design will be of a standard which will function as a physical containment barrier. The conceptual kitchen design includes receiving sealed containers at the kitchen facility and strategies for air management. Solid waste and wastewater management will be integrated into the kitchen facility design and food handling process to prevent waste, which is potentially infected with small organisms, from being released to the native environment, or otherwise exposing native flora and fauna to potential hosts for disease.

The Joint Venturers commissioned the conceptual design of a kitchen facility for Barrow Island, which incorporates barriers recommended by ecological experts and designers with expertise in construction village facilities in Western Australia, as well as Australian health guidelines and food hygiene standards. The conceptual design includes strategies for air management and filtration, zones of quarantine compliance levels, physical and chemical barriers and waste management. The recommendations for pre-border quarantine barriers and the border kitchen facility concept have been the subject of several PBA workshops. Workshop participants and the Joint Venturers identified approximately 52 barriers for consideration to manage specific quarantine threats on the food and perishables pathway. Of these conceptual barriers, most were identified by technical experts as key barriers for special consideration.

The Joint Venturers commit to the following key barriers for the food and perishables pathway:

- manage receipt, screening, consolidation, despatch from a central facility
- pre-process fresh food and vegetables prior to despatch
- select packaging to allow visual inspection
- reduce organic packaging
- inspect, seal and tag shipping containers
- comply with record of food and perishables items prohibited from transport to Barrow Island
- design kitchen facility with internal quarantine zones and barriers to contain and eradicate non-indigenous species
- implement a dedicated food and packaging waste containment and removal program.

In order to meet the risk standards, preferred barriers including key barriers listed above, may need to be modified or further barriers added in light of additional information arising from Steps 5 and 6.

Figure 12-7:
Illustration of Conceptual Quarantine Barriers and Infection Scores on the Sand and Aggregate Pathway

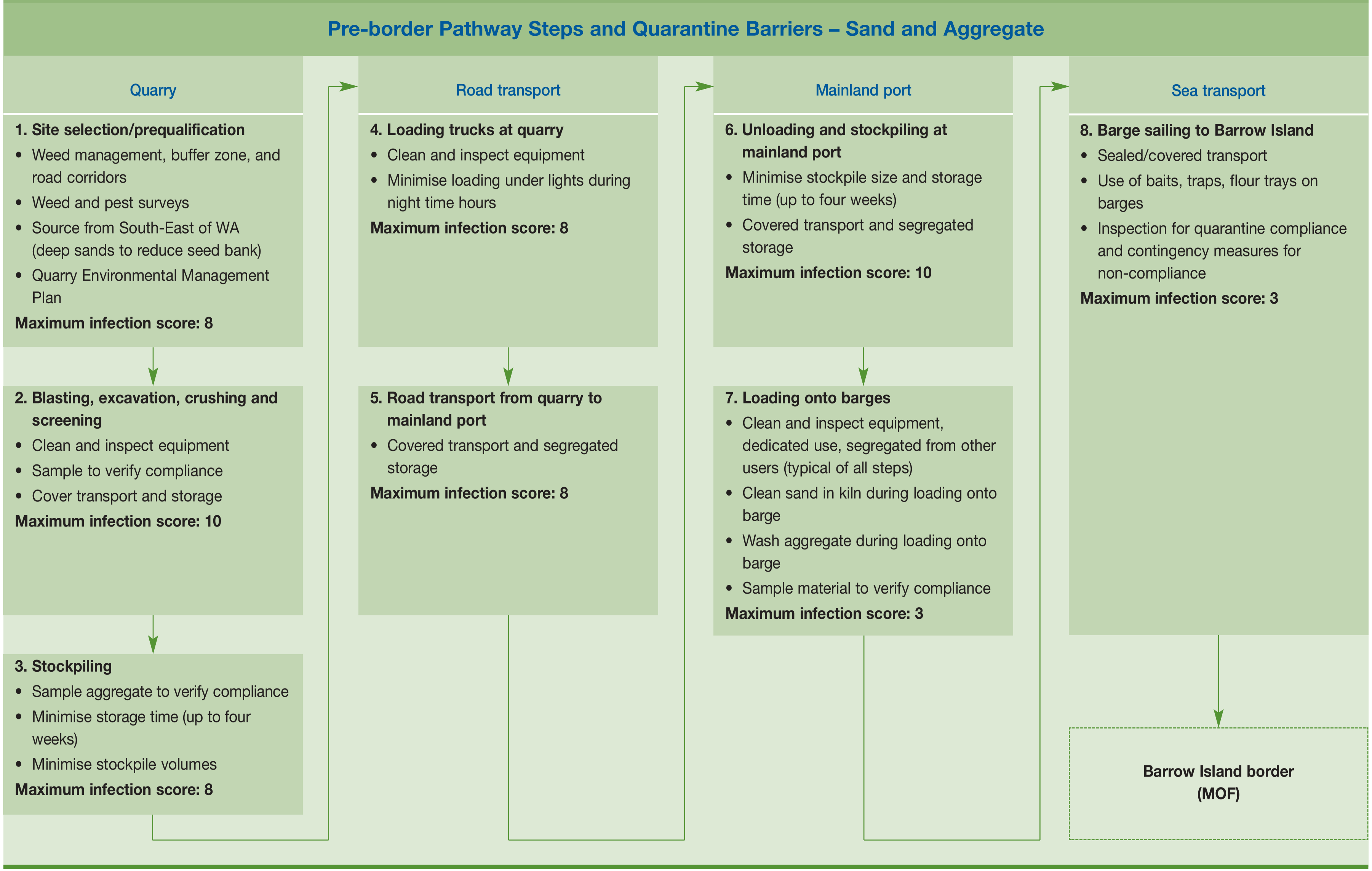


Figure 12-8:
Food and Perishables Pathway Steps

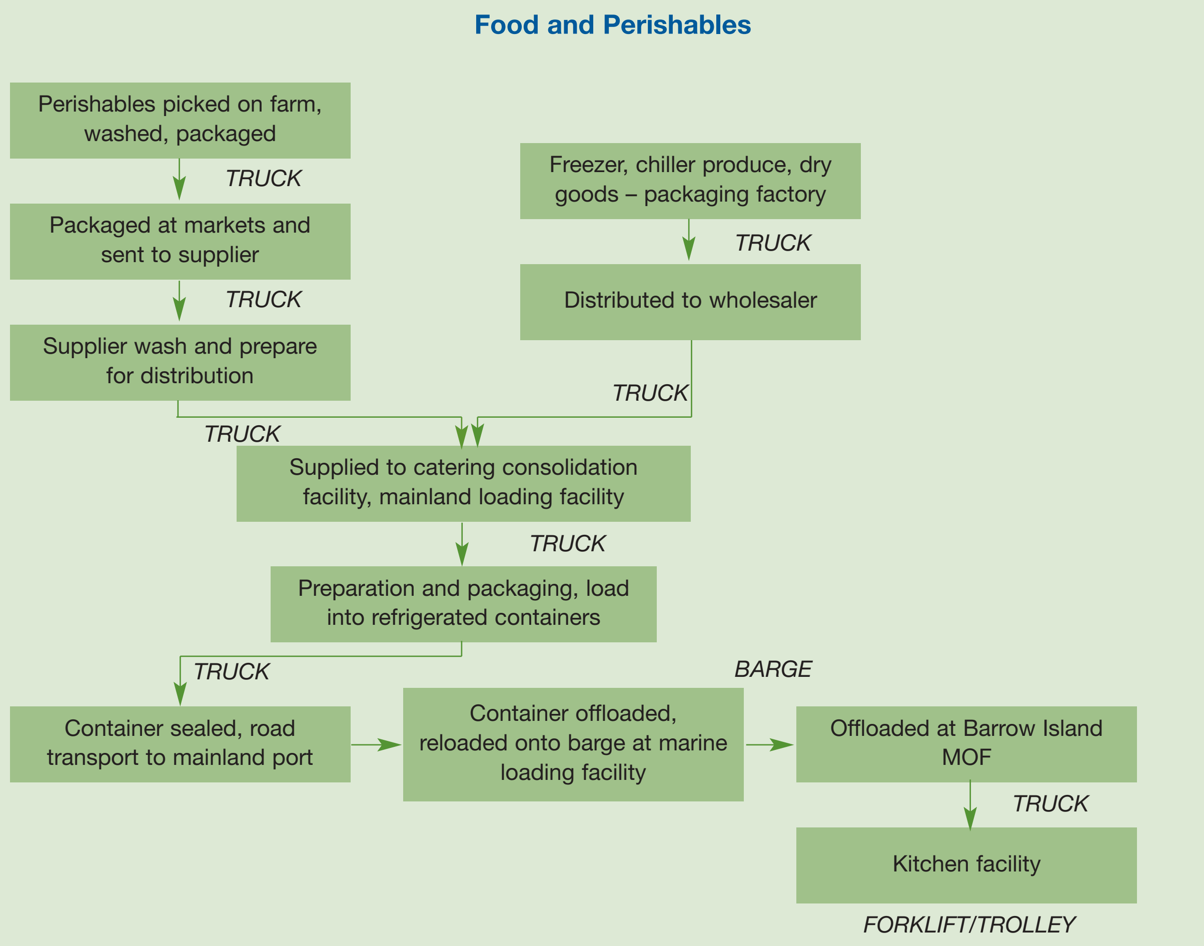


Figure 12-9 and Figure 12-10 demonstrate the application of quarantine barriers, including the key barriers listed above, across the pre-border and border sectors of the food and perishables pathway respectively. The maximum infection scores, estimated by PBA workshop participants, that apply to all quarantine barriers at each pre-border pathway step are shown in Figure 12-9, and to the MOF and kitchen facility border steps in Figure 12-10. In these figures, only a subset of quarantine barriers is listed to illustrate the application of some important barriers.

Reducing the likelihood of infection to low levels relies on the barriers associated with the border kitchen facility, which recorded an infection score of 2 (remote, unlikely) in the PBA workshops. Food and perishables which are contained during transport and processed within the kitchen facility will therefore present a very low likelihood of introduction. Decision rule 1 in Table 12-6 with regard to this pathway step of the border kitchen facility would be applied in this example. The conservative estimate of the residual likelihood of introduction on the entire pathway can therefore be expressed as 'remote, unlikely' which is derived from the residual infection score of 2.

All quarantine barriers currently under consideration for the food and perishable pathway and not shown in Figure 12-9 and Figure 12-10 are listed in Conceptual Quarantine Barriers, Technical Appendix D10.

The 'remote, unlikely' estimate of introduction on the food and perishables pathway is an example of what can be achieved in the risk-based management of quarantine threats. The interim information provided here demonstrates how the risk of introduction can be mitigated to very low levels. Further development of pre-border quarantine barriers, and the design of Barrow Island border protection measures and post-border monitoring and eradication strategies will provide additional levels of risk reduction and provide confidence that the standards for acceptable risk will be met.

Figure 12-9:
Illustration of Conceptual Pre-border Quarantine Barriers on the Food and Perishables Pathway (pathway continued to border in Figure 12-10)

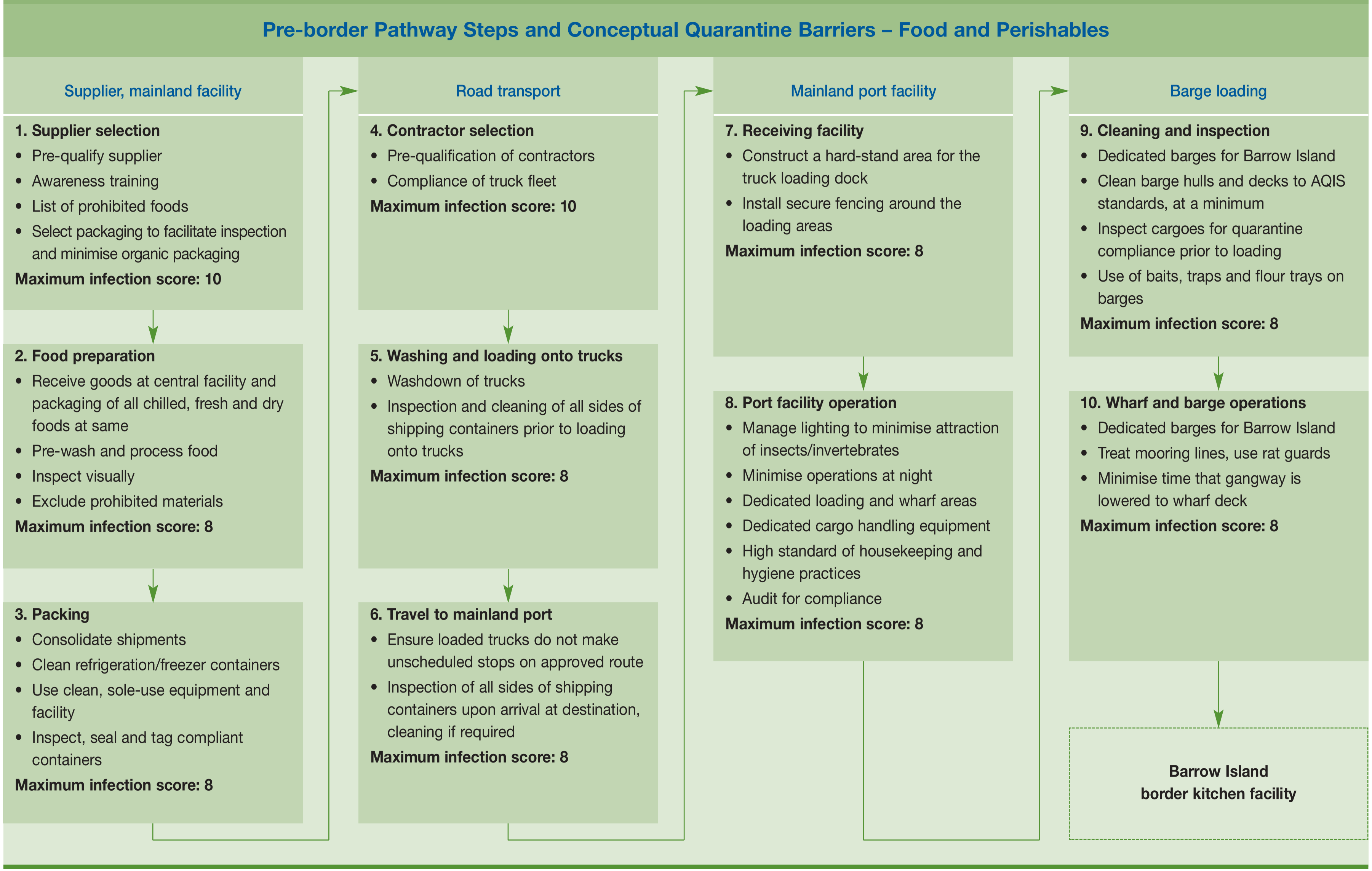


Figure 12-10:
Illustration of Conceptual Border Quarantine Barriers on the Food and Perishables Pathway

Border Pathway Steps and Conceptual Quarantine Barriers – Food and Perishables

Barrow Island MOF/barge loading

1. Offloading of barge at Barrow Island

- Inspect cargo and barge to verify quarantine compliance
- Establish criteria and actions for treating or rejecting non-compliant barges and containers at the MOF

Maximum infection score: 8

Kitchen facility

2. Facility design

- Seal building and truck loading area
- Chill area for receiving food and perishables during unloading of food containers (approximately 12°C to reduce activity of flying insects and other invertebrates)
- Establish quarantine 'zones' within the facility (e.g. storage, packaging, unwrapping, cleaning, waste handling, preparation, cooking and eating)
- Apply negative pressure air filtration systems in high sensitivity zones where food is likely to contain organisms and propagules
- Install barriers at building entry/exit points (e.g. air locks, air curtains, treated mats for shoes)
- Integrate traps in the kitchen design

Food processing

- Process all food to be removed from the facility (e.g. lunches, snacks)
- Wash all fresh vegetables in saline solution, followed by potable water

Disinfection and waste

- Treat inside and outside of kitchen facility with chemicals
- Install electric insect 'zapper' lights at food unloading and food preparation areas
- Use high pressure water to clean floors at the end of each shift
- Routine disinfection and cleaning of facility
- Double-bag waste before removal from facility

Personnel

- Inspect footwear and clothing for seeds, plant and animal matter prior to entry

Maximum infection score: 2

Solid waste management

3. Food at work sites

- Provide mobile food supply and waste storage for crews working outside the gas plant construction area (e.g. pipeline construction, drilling)
- Provide dedicated, secure waste storage and rapid turnaround to mainland disposal site

Solid waste disposal

- Incinerate kitchen wastes at the end of each meal period
- Minimise waste storage

Sewage, wastewater management

4. Grey-water

- Separate shower, basin, and laundry wastewater (grey water) from toilet and kitchen waste water, for re-use

Sanitation at work sites

- Provide mobile toilets for crews working outside the gas plant construction site

Contingencies for accidental spills

- Contain spills on construction sites with dry absorbent materials
- Establish sewage spill containment and response procedures

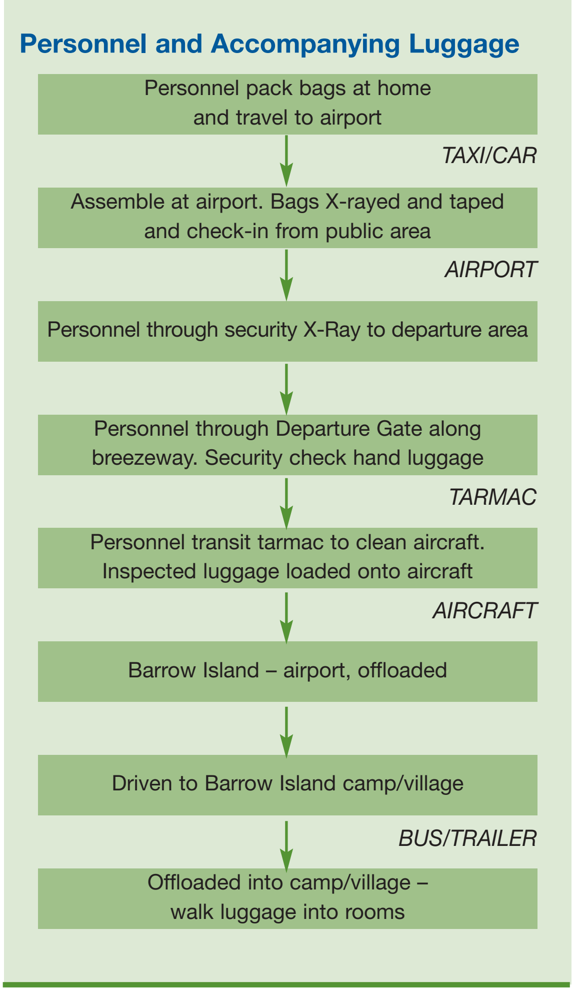
Waste treatment, disposal

- Contain spills on construction sites with dry absorbent materials
- Establish sewage spill containment and response procedures

12.5.5 Management of Quarantine on the Personnel and Accompanying Luggage Pathway

A rostered work force will be employed to construct and operate the proposed gas processing facility and associated infrastructure on Barrow Island. Personnel will be accommodated on the island in a purpose-built village near the proposed gas processing facility and flown to and from the island on scheduled commercial aircraft from mainland airports. An outline of the pathway steps is presented in Figure 12-11.

Figure 12-11:
Personnel and Accompanying Luggage Pathway Steps



Based on the results of IMEA pathway and PBA workshops the most significant infection modes were considered to be:

- the activities of personnel packing their personal luggage and potential infection of clothing
- the potential for personnel hosting ticks, that will not be detected and removed prior to travel
- the difficulty of using existing x-ray and cursory quarantine inspections of personnel and air cargo to detect infected persons or goods for a full range of invertebrates.

The Joint Venturers commit to the following barriers for the personnel and accompanying luggage pathway:

- pre-employment agreements, including awareness training and inductions to appreciate quarantine risks and barriers which carry personal responsibilities
- inspection of all luggage via x-ray or visually by trained inspectors
- declaration of quarantine compliance for personal luggage
- cleaning of aircraft to meet quarantine standards
- shipment of toolboxes and work cargoes not accepted as checked luggage and processed through mainland logistics base
- transit passengers, luggage and freight contained in secure area at Barrow Island airport
- management plan for flights departing from locations other than Perth
- verification of personnel, luggage and freight on arrival.

In order to meet the risk standards, preferred barriers including those listed above, may need to be modified or further barriers added in light of additional information arising from Steps 5 and 6.

Figure 12-12 and Figure 12-13 demonstrate the application of a selected array of quarantine barriers, including some of the barriers listed above, across the personnel and accompanying luggage pathway.

All quarantine barriers currently under consideration for the personnel and accompanying luggage pathway and not shown in Figure 12-12 and Figure 12-13 are listed in Technical Appendix D10.

The airport and the village will function as border quarantine facilities. Precautionary measures will be taken in the village area to clear the area of vegetation and maintain a plant eradication program as recommended by specialists. Baiting and trapping of fauna in the village will likewise be undertaken. Chemical treatment of accommodation units and other village structures will be used to prevent the colonisation of any ‘cosmopolitan’ organisms (e.g. small invertebrates, cockroaches) which are associated with human activities, but are not considered likely to survive in the natural environment.

Figure 12-12 illustrates the maximum infection scores, estimated by PBA workshop participants, that apply to quarantine barriers at each pathway step relevant to personnel. In this figure, only a subset of quarantine barriers is listed to illustrate the application of some important barriers. Step 2 has a maximum infection score of 3 (slight chance) with regard to supplied work clothing, although the likelihood of infection is higher for personal clothing unless barriers are applied to address this threat. Three pathway steps (6, 7 and 8) have a maximum infection score of 3 (slight chance) for personnel travelling to Barrow Island. If air crews are subject to the same requirements as passengers travelling to Barrow Island, then the likelihood of infection should be the same in both cases. It should also be noted that barriers in step 1 of the pathway also serve to further reduce the likelihood of infections, with a maximum score of 5 (occasional infections).

In this example, if all the barriers listed in pathway steps 6, 7 and 8 were adopted, decision rule 4 in Table 12-6 could be used to estimate the residual likelihood of introduction. The maximum scores of 3 on these pathway steps would reduce the residual likelihood score to 1 (extremely remote, highly unlikely). The conservative estimate of the residual likelihood of introduction for the entire personnel pathway can therefore be expressed as 'extremely remote, highly unlikely' which is derived from the residual infection score of 1.

Figure 12-13 illustrates the maximum infection scores estimated by PBA workshop participants for the application of all quarantine barriers at each pathway step relevant to accompanying luggage. In this figure, only a subset of quarantine barriers is listed to illustrate the application of some important barriers. Three pathway steps (5, 6 and 7) have maximum infection scores of 3 for checked luggage transported to Barrow Island. Using the same decision rules, the conservative estimate of the residual likelihood of introduction for the entire luggage pathway can be expressed as 'extremely remote, highly unlikely'.

The 'extremely remote, highly unlikely' estimate of introduction on the personnel and accompanying luggage pathway is an example of what can be achieved in the risk-based management of quarantine threats. The interim information provided here demonstrates the feasibility of meeting the standards for acceptable risk.

12.5.6 Management of Quarantine on the Marine Vessels Pathway

Regional currents, tidal currents, winds and coastal shipping provide a ready mechanism for the distribution of marine species over a very large area of north-west Australia. It is reasonable to expect that marine organisms that are already established within waters affected by the Leeuwin Current could reach Barrow Island. There is substantial exposure of Barrow Island to introduced marine species from sources independent of the existing oilfield activities on the island. The increase in the number of vessel movements associated with construction of the proposed Gorgon Development is an additional threat of exposure to introduced organisms.

The risk-based assessment process has been undertaken to Step 4 for many of the types of marine vessels that could translocate organisms from one port to another via ballast water, sediment or hull fouling (Table 12-3). Marine ecologists and marine logistics specialists have participated in workshops to suggest appropriate barriers to prevent introductions. The key barriers for vessels calling at Barrow Island will be:

- inspection and cleaning/disinfection of vessel components that could harbour marine organisms (e.g. wetted surfaces, sea chests, sea water circulation systems)
- maintenance and application of anti-fouling paint on vessel hulls
- adoption of ballast water exchange standards and ballast water performance standards which will be required by the International Maritime Organisation (IMO) Convention for the Control and Management of Ships' Ballast Water and Sediments (February 2004)
- use of dedicated coastal vessels (barges, tugs and workboats) to facilitate control and monitoring activities to the greatest extent possible during construction.

The IMO Convention was adopted in February 2004 and will enter into force 12 months after ratification by 30 states. Once ratified, the Convention will become international law. Ballast water management will be particularly relevant to marine vessels which load cargoes at Barrow Island (and thus discharge ballast water while berthed). Oil tankers loading crude oil from the existing Barrow Island terminal, and LNG and condensate carriers for the Development, represent potential threats of

Figure 12-12:
Illustration of Conceptual Quarantine Barriers on the Personnel Pathway

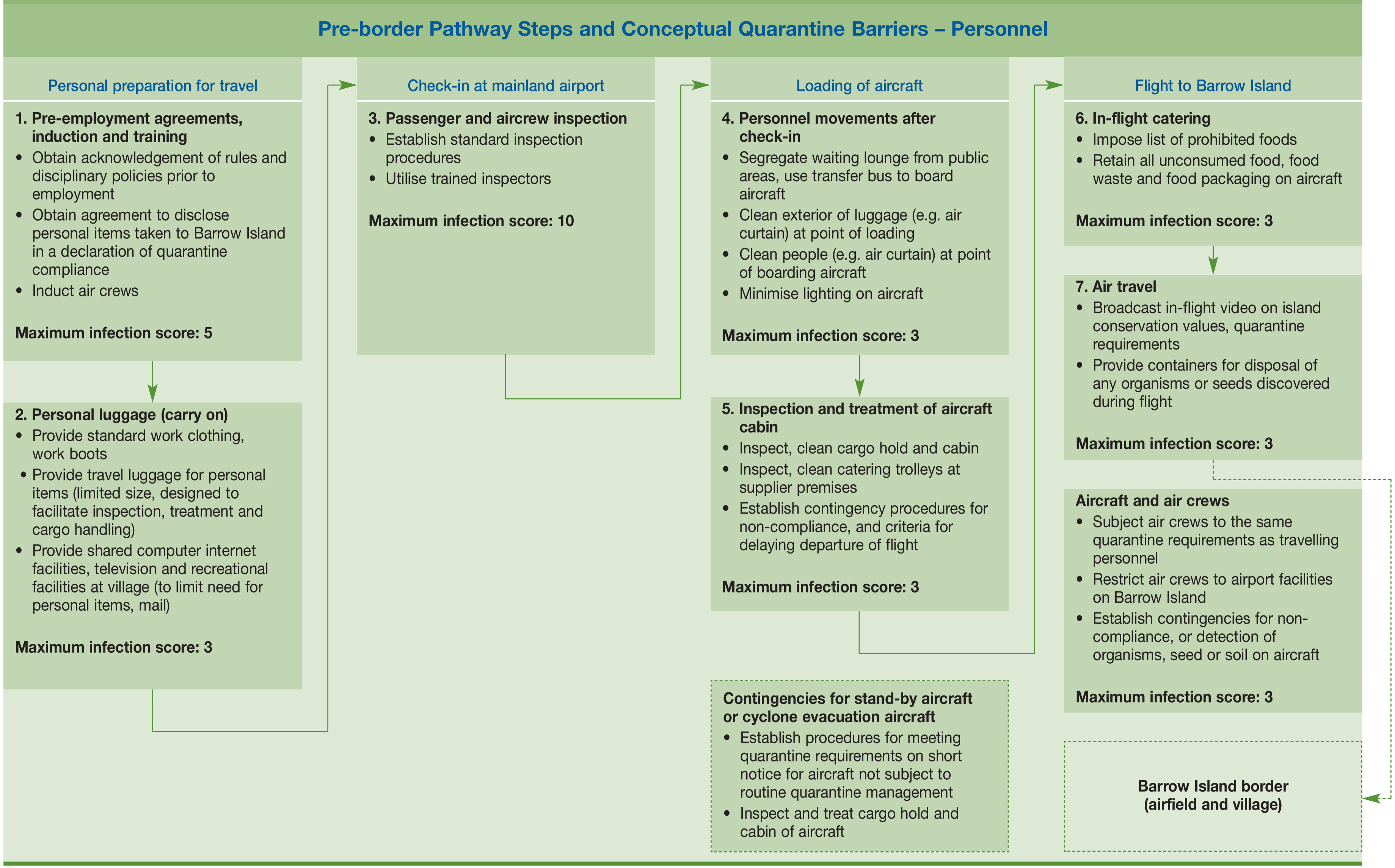
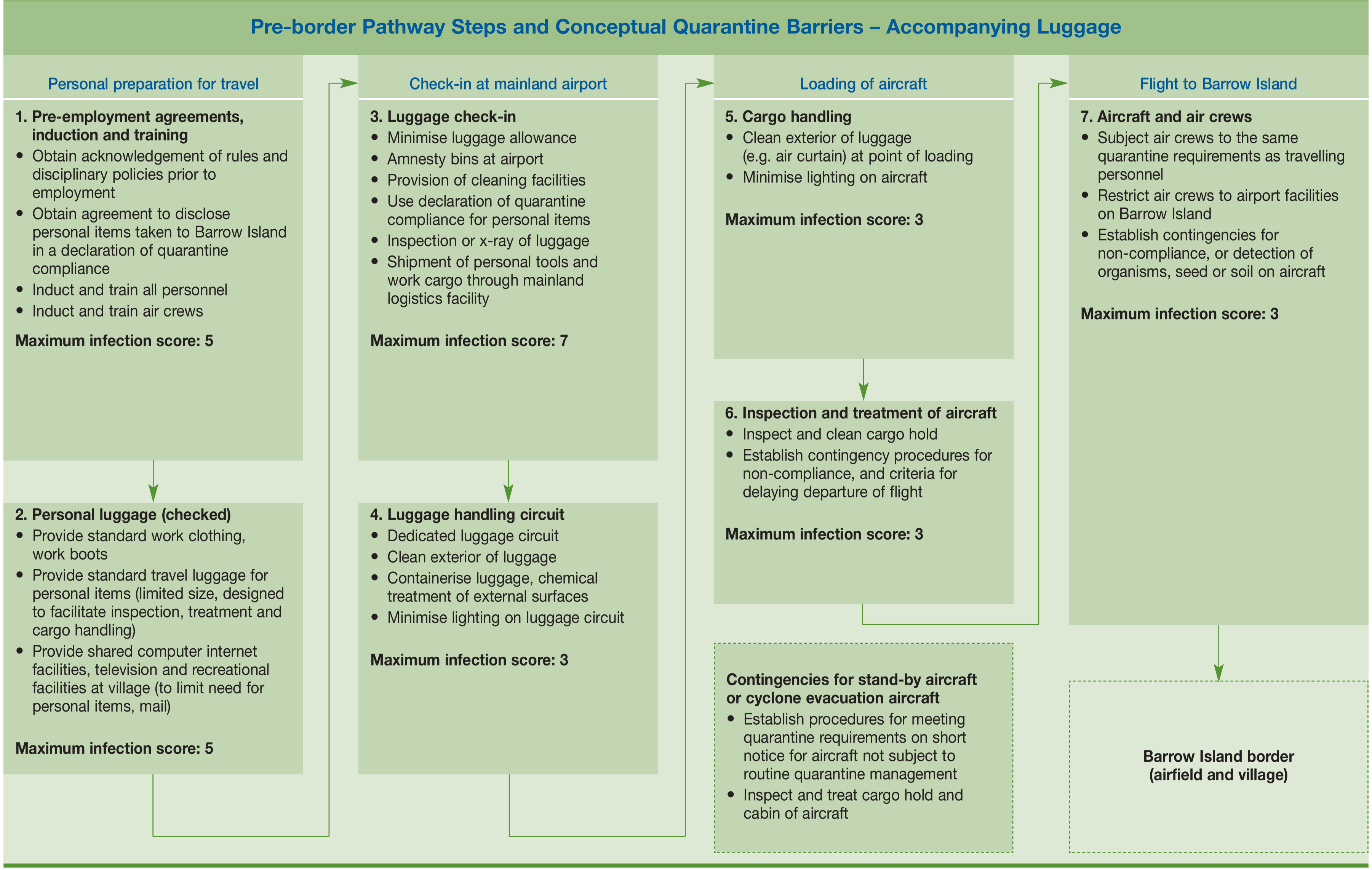


Figure 12-13:
Illustration of Conceptual Quarantine Barriers on the Accompanying Luggage Pathway



introduction from ballast water discharge, and will be subject to the Joint Venturers' standards for acceptable risk (Box 12-10 and Box 12-12).

12.5.7 Management of Quarantine for Rodents on Marine Vessels

An IMEA and PBA workshop was convened to address the specific threat of introducing terrestrial vertebrates on marine vessels calling at Barrow Island. Vessels on domestic routes (coastal barges, tugs and cargo ships) and international routes (cargo ships and heavy lift vessels) were considered. Expertise in rodents (e.g. rats and mice), reptiles (e.g. geckoes, frogs and snakes), and birds has been utilised to identify threats of infection and specific barriers to prevent introductions that might be related to these types of vessels.

For each type of vessel, three pathway steps were considered: vessel moored at the port of departure; loading of cargo at the departure wharf; and sailing from the port of departure to Barrow Island. For domestic coastal barges, tugs, and cargo ships, 25 conceptual quarantine barriers were recommended for consideration, including those summarised in Table 12-7.

Table 12-7:
Summary of Conceptual Quarantine Barriers for Preventing the Introduction of Rodents to Barrow Island from Domestic Marine Vessels

Type of Domestic Vessel	Pathway Step	Suggested Barriers	Infection Score (maximum)
Barge	Vessel moored in port	• Inspection and cleaning of vessels by trained personnel prior to commissioning for Barrow Island service. Removal of habitat materials and foodstuffs (e.g. high pressure water wash, rubbish control).	2
	Loading of cargo	• Perform loading operations in daylight whenever possible (to take advantage of higher temperature).	(not scored)
	Sailing to Barrow Island	• Limit or eliminate situations where the bow door of barges needs to be lowered for loading or unloading. Use crane alternative unless roll-on roll-off is the only alternative.	4
Tug and cargo ship	Vessel moored in port	• Establish permanent bait stations. Monitoring of vessel by trained personnel on a regular schedule.	1
		• Apply baits for a two week period prior to commissioning vessels for Development activities.	1
		• Prohibit vessel crews from having pets on board vessels.	1
		• Vessels to be laid-up on cyclone-proof moorings rather than tied up to shore facilities. Design moorings to prevent rats from being able to use them to climb out of the water and access mooring lines.	2
	Loading of cargo	• Establish rules for packaging and use of sealed containers.	1
		• Establish a quarantine store aboard manned vessels using quarantine standards for domestic stores (e.g. inspection and re-packaging).	1
		• Restrict refuelling to daylight hours.	1
	Sailing to Barrow Island	• Tugs at Barrow Island to take over the tow from mainland tugs. Contingency plan needed for emergency situations involving safety of life at sea.	1
		• Establish rodenticide stations inside holds of vessels.	3
		• Limit or eliminate situations where the bow door of cargo ships needs to be lowered for loading or unloading. Use crane alternative unless roll-on roll-off is the only alternative.	4

A number of conceptual barriers which reduce the likelihood of rodent infection to a low level on the pathway are redundant and offer multiple layers of protection. Therefore, the residual likelihood of introducing rodents on the overall domestic vessel pathway can be potentially reduced to a score of 2 (remote, unlikely) for domestic barges and a score of 1 (extremely remote, highly unlikely) for domestic tugs and cargo ships. Table 12-7 shows that there are a range of alternative barriers which reduce the likelihood of rodent introductions to meet the standards for acceptable risk. Similar advice was obtained from PBA workshop participants with regard to reptiles. Bird species were not considered by experts to be a threat to the conservation values of Barrow Island as a result of domestic vessel voyages (but are considered for international vessel voyages).

For international vessels (foreign cargo ships and heavy lift vessels), the same types of barriers apply for vessels under the direct control (chartered) by the Joint Venturers. It is unlikely that some of the barriers recommended for domestic vessels could be implemented with confidence on vessels which are used to ship mixed cargoes to a variety of ports before and after calling at Barrow Island.

For international vessels, a number of conceptual barriers were suggested and scored for their ability to prevent infections by rodents, as listed in Table 12-8.

The conceptual barriers presented in Table 12-8 rely on vessels being chartered such that they are under the direct control of the Joint Venturers. Otherwise the opinion expressed by specialists was that mixed cargoes on unchartered vessels could achieve similar reductions in the likelihood of infection if they were to unload cargoes for the Development at a mainland port where they can be inspected and treated prior to shipment to Barrow Island.

12.5.8 Monitoring Strategy

To meet the need for effective post-border quarantine protection, monitoring for non-indigenous species will be integrated into the ecological monitoring of wider environmental change associated with the Gorgon Development (refer to Chapter 16 for further details).

Extensive consultation with a diverse range of experts and stakeholders has been undertaken to develop monitoring strategies which will assist in the early detection of introduced terrestrial and marine species. Given the long-term nature of an ecological monitoring effort, a management structure to oversee and guide the design, implementation and interpretation of the proposed monitoring program has been developed (refer to Figure 16-1). This model will incorporate expert advice to develop a scientifically rigorous program which will deliver a high degree of confidence that any incursion will be detected early.

Table 12-8:
Summary of Conceptual Quarantine Barriers for Preventing the Introduction of Rodents to Barrow Island on International Marine Vessels

Type of Int'l Vessel	Pathway Step	Suggested Barriers	Infection Score (maximum)
Cargo ship	Vessel moored in port	Consolidate cargo into single ship loads, and charter vessel to enable implementation of quarantine barriers. Deliver all cargo to a mainland port for inspection and treatment prior to shipment to Barrow Island.	1
	Sailing to Barrow Island	Use specialists to fumigate cargo in holds with chemicals or carbon dioxide (requires chartered vessel).	2
Heavy lift vessel in port	Vessel moored	Temporarily seal and fumigate potential habitat areas within cargo spaces (requires chartered vessel).	1

Terrestrial Monitoring

The task of detecting a non-indigenous species at an early stage of arrival in the native environment, such that effective remedial action can be undertaken, is a difficult sampling problem because of the rarity of the event in time and space (Short 2004). Effective sampling protocols for a wide range of species exist, many of which have been successfully implemented within Australia.

The variability and number of non-indigenous species whose introduction will be prevented through quarantine barriers means that a single monitoring approach is unlikely to be effective or appropriate toward early detection. Monitoring requirements will be tailored to the most effective practices for the broad biological groups considered in the risk-based management of exposure pathways, those being:

- vertebrates
- invertebrates
- plants
- micro-organisms.

The Joint Venturers engaged CSIRO Sustainable Ecosystems to provide advice to guide the development of a monitoring protocol aimed at maximising the detection of incursions of non-indigenous species (Short 2004). Key recommendations of this work include: the stratification of Barrow Island by perceived risk of incursion; systematic sampling within each stratum; and prioritisation of monitoring effort on basis of perceived risk and optimisation of detection probability.

This advice has been discussed with the QEP and communicated to community stakeholders, who understand it represents a highly structured and statistically robust approach. Subsequent development of the practical application of the strategy will involve specialists experienced in the ecology of north-west Australia and Barrow Island, particularly in the fields of exotic plants and invertebrates.

The timing and frequency of the CSIRO monitoring approach recommends utilising expertise to assist in the field identification and analysis of species. Wide area searches in particular are likely to be heavily reliant on accurate, field-based identification.

The requirements for timing of monitoring activities and repetitious sampling will be established in consultation with technical specialists to enable detection of the types of species that could establish in the arid Barrow Island environment. Seasonal monitoring has been suggested with an emphasis on additional post-rainfall or post-cyclonic monitoring.

Further development of the terrestrial monitoring approach is to occur within the ecological monitoring structure outlined in Chapter 16.

Marine Monitoring

The objective of marine monitoring is to detect the arrival of non-indigenous species as early as possible using a range of survey and sampling techniques. Detection is to be investigated with quantitative, statistical sampling techniques which will allow marine ecologists to evaluate the impact to the marine environment. In the unlikely event that Gorgon Development activities are the source of a detected introduction, an appropriate response will be undertaken by the Joint Venturers.

Discussions with relevant specialists of the Western Australian Museum, the University of Western Australia, Murdoch University and Sydney University (amongst others) have indicated the need for a stratified and statistically valid approach to monitoring. Similar to the approach outlined for the initial baseline surveys monitoring will prioritise efforts to identify and detect indicator species which represent the greatest threats to the marine ecology of Barrow Island. Priority will also be given to areas where disturbance has or will occur and is likely to create environments suitable for non-indigenous species to colonise.

Following a baseline survey period, the design of ongoing monitoring should be capable of identifying changes caused by disturbances or invasions. It should also be possible to distinguish these types of changes from natural spatial and temporal variability (McDonald 2004).

It is anticipated that monitoring will involve seasonally repetitive diving programs at specifically targeted sites by specialists trained to identify and sample for listed invasive species (NIMPIS 2002) and other potentially non-indigenous marine organisms. Sites will include those which have experienced historical disturbance, such as the crude oil tanker terminal and beach landing. Monitoring will also be undertaken at sites which will be disturbed as part of the Gorgon Development, prior to the commencement of construction and then also at seasonally repeated intervals thereafter. The Joint Venturers are investigating the potential for using strategically placed artificial substrates in vulnerable areas to act as early warning sites. This would provide a cost efficient way to detect colonisation of non-indigenous species.

The proposed monitoring program provides an opportunity to assess the impacts of cyclones by conducting post-cyclone surveys. Such surveys would adopt the same methods utilised in the baseline surveys and will therefore provide direct comparisons of pre- and post-cyclone benthic communities.

Marine fauna gathered from the monitoring program will be initially curated and sorted at the Western Australian Museum. Identifications will be undertaken at the Museum, or referred to appropriate taxonomic specialists. Representative material of each species will be incorporated into the permanent museum collections and recorded on a database. The Museum will be provided with samples of all species collected in field surveys.

Seagrasses and macroalgae will initially be curated and examined at Murdoch University, with permanent herbarium vouchers (pressed specimens or microscope slides) lodged at the Western Australian Herbarium. Identification of micro-organisms may be undertaken by specialists at the University of Tasmania and other organisations with appropriate expertise.

Further development of marine monitoring approaches and protocols will occur within the Ecological Monitoring Structure outlined in Chapter 16.

12.5.9 Response Strategy

If monitoring activities were to detect the arrival of a non-indigenous species associated with Gorgon Development activities, a rapid response strategy is the preferred approach. The ultimate response to a non-indigenous species can vary from intensive eradication activities and treatments to a ‘do nothing’ approach depending upon the potential adverse effects of an eradication method to the conservation values of Barrow Island and the surrounding marine environment. Although published response strategies generally refer to pest and weed species, a precautionary approach will be taken to treat any non-indigenous species on Barrow Island or surrounding waters as a potentially invasive species that could impact the conservation values of the island.

The Joint Venturers propose to adopt the rapid response strategy developed by McEnnulty et al. (2001), which utilises the resources of Australia’s National Toolbox for the control of invasive marine species (URS 2003), and gives attention to protocols for managing terrestrial pests and weeds by the Western Australian Department of Agriculture (2003). In the case of micro-organism threats, the Australian Animal Health (2002) and Agriculture Fisheries and Forestry (2001) plans will guide the response efforts to any introduced pathogens in the terrestrial or marine environment.

Eradication is among the first treatments mentioned when land managers are confronted by a new weed, pest species, or threat from a newly introduced plant. Eradication is defined as the elimination of the entire population of an alien species, including any resting stages, in the managed area (McNeely et al. 2001).

A major constraint of eradication is the availability of specific control techniques for target pest species which minimise damage to the native environment or non-target species. A risk-based approach is needed to weigh the benefits of eradication with the risks of environmental damage. Such an approach has been developed by McEnnulty et al. (2001) for marine invaders, using the rapid response decision diagram presented in Figure 12-14.

The decision diagram can be applied to both marine and terrestrial introductions and involves consultation with relevant government agencies. At the first step, where the problem will be defined and communicated to government authorities, the source of an introduction should be established to determine if the response will relate to Gorgon Development activities. Otherwise, the range of responses will need to be considered separately by relevant agencies for an introduction which arrives on Barrow Island from sources independent of Gorgon Development activities. In cases where the source of the introduction is unclear, the Joint Venturers will not delay participating in an appropriate response strategy while the source is being investigated.

Factors which can improve the ability to make appropriate response decisions include:

- knowledge of basic ecology and physiology of likely invasive species

- early detection of a potentially invasive pest or weed
- the ability to quarantine the infested area while the response strategy is being considered
- survey capacity to determine whether the suspect pest is restricted to the quarantined area
- a low risk of re-introduction
- pre-existing knowledge of available options for eradicating likely invaders and related taxa
- the tools to eradicate the quarantined population
- ongoing monitoring to modify, amplify or end an eradication campaign.

There is a wealth of resources to draw upon for information on the basic ecology and physiology of likely invaders and related taxa (URS 2003; Department of Agriculture 2003). To prepare for the detection of a non-indigenous species, the Joint Venturers will pre-plan sufficient administrative and funding resources to mobilise specialists most able to contribute to an effective response strategy. In addition to ecological and conservation specialists in Western Australia familiar with the ecology of Barrow Island, there are world-wide resources accessible through organisations such as the International Union for the Conservation of Nature (IUCN) Species Survival Commission's Invasive Species Specialist Group (ISSG). The Joint Venturers will develop a reference list of technical specialists for taxa in each of the broad biological groups, in the event that their expertise is needed to assist decision making and selection of appropriate response strategies, survey techniques and monitoring design on short notice.

The Joint Venturers will consult with conservation specialists with experience in the control and eradication of species. They will also commit to the development of an incident response equipment cache on Barrow Island. Selected personnel will be trained and drilled in the rapid deployment of containment equipment in the event of detection of a non-indigenous species, under the guidance of experienced flora and fauna ecologists who are knowledgeable of the Barrow Island environment.

Terrestrial Response

Application of the rapid response approach and development of a wider reference list of ecological and conservation specialists will improve current capabilities on Barrow Island. To ensure that the spatial extent of any introductions are minimised at the Development site, a precautionary eradication program will be undertaken to prevent the establishment of any plant species, whether native or introduced, as recommended by plant ecologists. This will simplify the response to any non-indigenous species that might attempt to establish in a disturbed environment. It will also significantly improve the likelihood of successful eradication by limiting the infestation area.

Marine Response

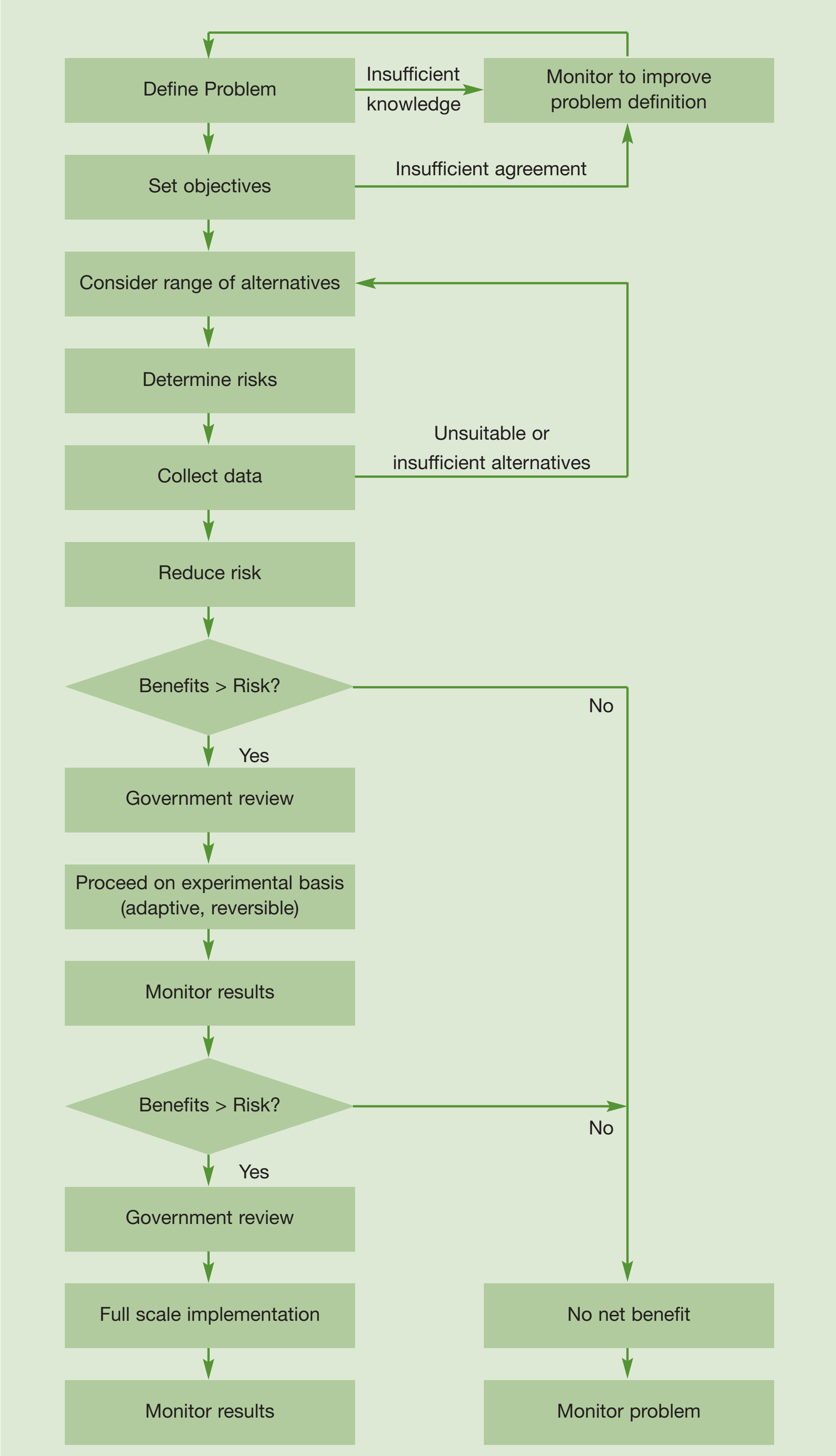
Marine introductions are generally very difficult to eradicate. Containment of an infested area would be virtually impossible for most types of marine organisms.

Successful eradications reported in Australia and elsewhere (URS 2003; McEnnulty 2001) have been generally attributed to early detection and rapid response. Other important factors have been government and community support, ability to isolate or quarantine the area of infestation, ability to track exposed vessels, and a pre-existing legal capacity to undertake response actions on private property.

The application of the rapid response strategy for marine organisms is the best practice for the control and eradication of non-indigenous species. Strategies for control of marine introductions may include a number of technologies depending upon the type of organism involved, lifecycle stage and circumstances of the problem (Carlton 2002; McEnnulty et al. 2003):

- mechanical control (harvesting for some use, or *in situ* destruction)
- chemical control (toxic chemicals ideally targeting only the species to be controlled)
- thermal control (if the target species can be exposed to thermal shock)
- electric current, cathodic protection, ultrasonic vibration and electromagnetic fields (affecting target species on particular substrates)
- radiation (e.g. ultraviolet treatment of water conduits)
- physiological control (species-specific chemical metabolic inhibitor)
- genetic control (alteration of environmental tolerance, reproduction or other processes)
- ecological control by habitat modification (affecting survival of target species or enhancing recovery of native species)
- ecological control by species introduction or enhancement of native species (including host-specific parasites and predators).

Figure 12-14:
Rapid Response Decision Diagram



(Source: McEnnulty et al. 2001).

All of these control methods have been used in response to introductions of various pest species. Each has significant limitations and risks to native organisms in the area where control actions are taken. The rapid response decision diagram and guidance described by McEnnulty et al. (2003) takes the value of the ecological consequences into account when weighing the benefits of particular response strategies with the risks to conservation values.

The Joint Venturers are committed to implementing rapid response capabilities in the event of marine introductions. An investigation of any detected marine introduction will be undertaken by technical specialists as part of the data collection and survey step of the rapid response process. An attempt will be made to identify the source of the non-indigenous species, but this investigation will not delay the involvement of the Joint Venturers in appropriate response actions.

12.6 Quarantine Management System

12.6.1 Introduction

A QMS for the Gorgon Development is being developed based upon the principles of AS/NZS ISO 14001:1996, Environmental Management Systems – Specification with Guidance for Use (ISO 14001). This standard has been chosen because it is a proven method of establishing effective systems for environmental management generally. It also contains all of the elements necessary to manage threats of introduction. There is currently no recognised international standard specifically for quarantine management systems.

The purpose of the QMS is to ensure that there will be consistent application of appropriate quarantine management measures over the lifetime of the proposed Development in order to protect the conservation values of Barrow Island. The role of the QMS is to ensure that quarantine data is kept up to date throughout the life of the Development; and that selected quarantine barriers are consistently and effectively implemented. As new information and technologies become available, continual improvement in quarantine performance will be delivered through the QMS.

The structure of the QMS is illustrated in Figure 12-15. Actions that will be implemented under this system include:

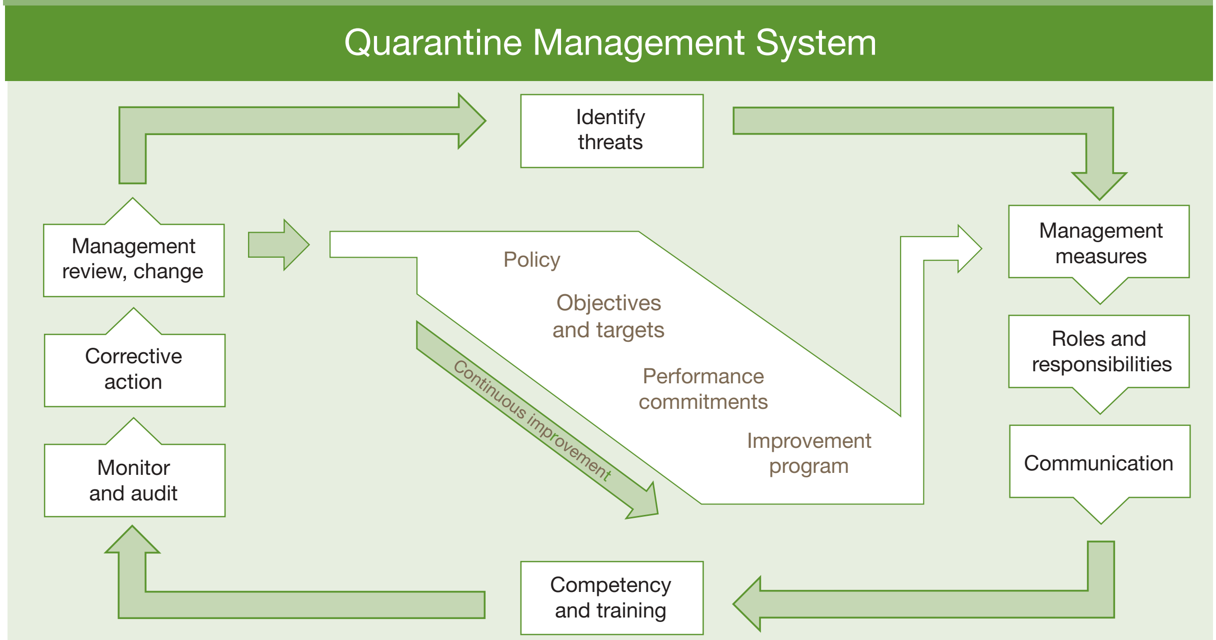
- Establishing policy (Section 12.1.1) for quarantine management and setting the direction for continual improvement of the system. Implement the policy through improvement objectives, targets and action plans.
- Having a management of change process for identifying changes to operational activities or processes that could have an impact on quarantine; and for defining and implementing measures to minimise the quarantine risks associated with these changes.
- Defining the management measures to be implemented to minimise quarantine risks, detailed in quarantine procedures.
- Identifying roles and responsibilities for personnel implementing management measures and ensuring that these responsibilities have been clearly and effectively communicated.
- Ensuring that all personnel are trained and are competent to perform their tasks.
- Conducting measurement and verification to ensure the system represents best practice and demonstrates leadership in quarantine management. Perform monitoring, inspections and auditing to verify that management measures are being properly implemented and that they are effective.
- Engaging in a regime of continuous improvement. In the event that monitoring, inspections or auditing show that improvement is required, the system should be self-correcting. The system should also identify what actions need to be taken to improve performance and reduce risk.

A system is based on how personnel behave. Thus a quarantine-sensitive culture is necessary for the system to work as desired. Everyone involved in the Gorgon Development will be required to understand the importance of quarantine and appreciate that this issue is one that needs to be included in day-to-day decision making.

12.6.2 Elements of the QMS

A description of the elements of the QMS based on the requirements of ISO 14001 is presented in Table 12-9. The elements of the QMS will be subject to change as the result of continuous improvement and information which will be collected during the management of quarantine threats. Experience gained through the application of numerous quarantine barriers will need to be communicated rapidly and widely through the organisation, which will be facilitated within the QMS where information is maintained electronically and

Figure 12-15:
Structure of the Quarantine Management System



accessible to all personnel with quarantine responsibilities. As such, information will be kept up to date and will be consistently applied to all quarantine activities.

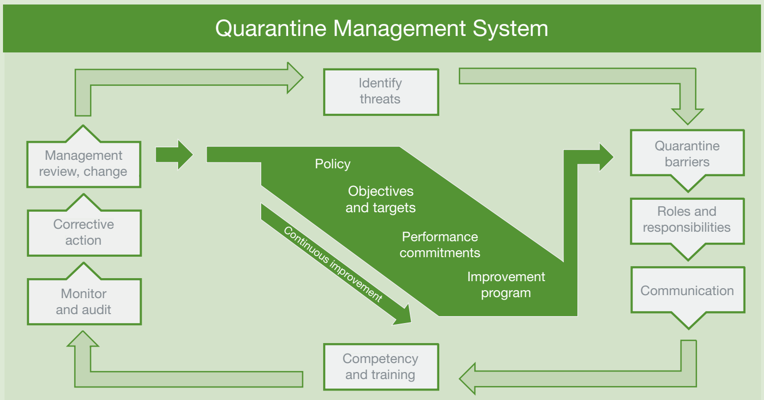
The QMS contains information relevant to:

- all pre-border, border and post-border Gorgon Development activities
- contingencies for quarantine management in emergency situations
- employees, contractors, suppliers, sub-contractors and visitors
- management decision makers
- community stakeholders and government agencies.

12.6.3 System Implementation

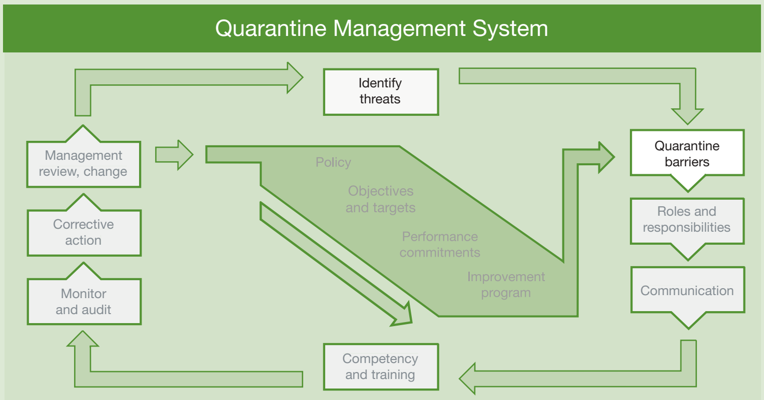
The QMS will be implemented in stages, beginning with the commitments described in this Draft EIS/ERMP, the Quarantine Policy statement and the quarantine barriers selected for the three priority pathways (Section 12.5). Information developed for the QMS will be integrated into existing business support systems to the extent possible. Additional tools will be developed to capture information specifically related to quarantine barriers and risk management.
An implementation schedule is presented in Table 12-10.

Table 12-9:
Elements of the Quarantine Management System



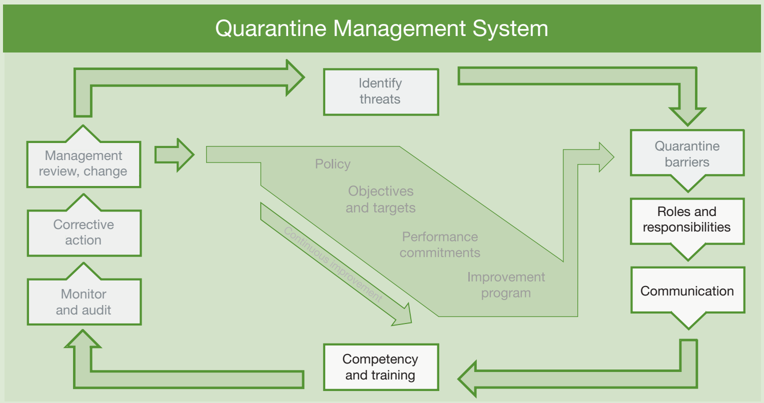
QMS Element (after ISO 14001)	Gorgon Development Actions to Manage Quarantine
Policy	The Joint Venturers have established a policy for quarantine, including commitments to implement the QMS to protect conservation values of Barrow Island, develop and maintain a positive quarantine culture, maintain a system of continuous improvement, and have a transparent process which includes stakeholder engagement and reporting. The Quarantine Policy statement appears in Section 12.1.1.
Objectives and Targets	The Joint Venturers will establish measurable quarantine targets and performance objectives, including key performance indicators for quarantine barriers which will be implemented to manage specific quarantine threats.
Legal Requirements and Obligations	The Quarantine Policy requires that only staff, contractors and suppliers who have demonstrated a willingness to meet or exceed quarantine standards will be engaged. A comprehensive compliance program will be established, including compliance auditing. The Joint Venturers will meet or exceed all legal requirements and demonstrate leadership in quarantine management.

Table 12-9: (continued)
Elements of the Quarantine Management System



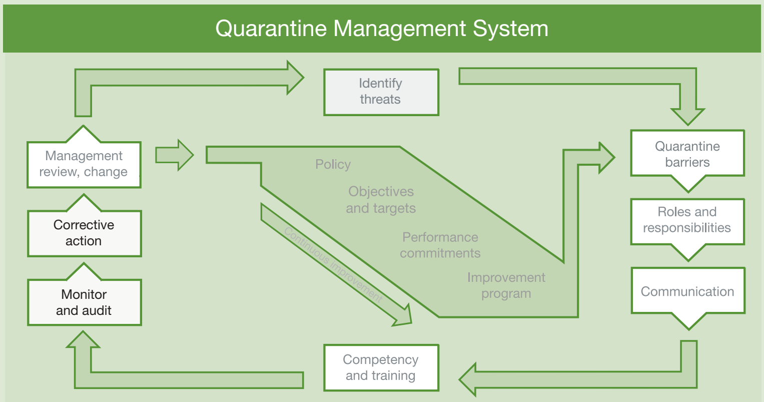
QMS Element (after ISO 14001)	Gorgon Development Actions to Manage Quarantine
Risk Assessment and Risk Management	Threats of introducing species to Barrow Island are being identified through a systematic, consultative risk assessment process involving technical experts. Specific quarantine barriers are under development to manage threats of introduction on exposure pathways. The objective of risk-based management of quarantine threats is to adopt barriers which meet standards for acceptable risk. The risk management process is described in Section 12.4, with details presented for the three priority pathways to demonstrate that quarantine threats can be managed with a high level of confidence (Section 12.5).
Operational Control	The management of quarantine threats will be documented for all pathways, which will include detailed designs and operational procedures. Key performance indicators and compliance regimes will be established for all quarantine barriers.

Table 12-9: (continued)
Elements of the Quarantine Management System



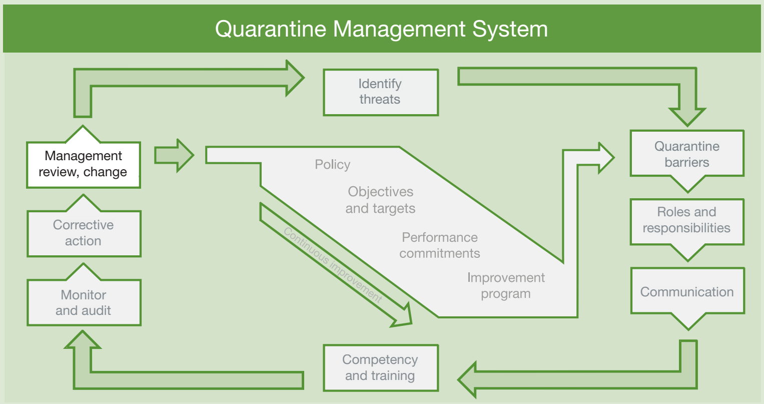
QMS Element (after ISO 14001)	Gorgon Development Actions to Manage Quarantine
Organisational Structure and Responsibility	The responsibility for quarantine management at an organisational level and the roles and responsibilities of specific personnel will be established. The overall responsibility for quarantine performance will rest with the Joint Venturers. Specific responsibilities will be identified for all contractors and suppliers who will be involved in design, procurement, construction, operation and supply of materials and services. The level of authority of personnel will be established for all quarantine activities. Criteria will be established to enable personnel to exercise their authority to direct quarantine actions and to refuse the transfer or acceptance of non-compliant cargoes, personnel and vessels at Barrow Island and surrounding waters (the quarantine 'border'). The responsibility and authority for incident response will be clearly established.
Communication	Quarantine Policy and quarantine awareness will be communicated to all staff, contractors and suppliers. Awareness of quarantine issues will be reinforced with announcements, displays and quarantine messages that emphasise outstanding performance and leadership. Quarantine awareness will also be communicated to community stakeholders, government agencies and visitors to Barrow Island. Management commitment to quarantine standards will be demonstrated through quarantine performance reports, direct involvement in awareness communication and inductions and issues raised with regard to compliance with quarantine standards.
System Documentation and Document Control	Documentation will be maintained in the QMS through the Joint Venturers' information management systems in electronic form to ensure that all information is up to date and consistently applied across the organisation. Guidance and training will be provided to staff, contractors and suppliers to enable an understanding of the elements of the system relevant to quarantine activities and responsibilities. All information, designs and documentation are controlled in the document management system.
Training and Competence	Persons involved in quarantine activities will be trained for any specialised technical tasks (e.g. inspection, application of chemical treatments, maintenance of treatment and handling equipment, etc). Involvement in quarantine barriers which are designed to manage significant quarantine risks will require verification of competency. Refresher training will be required to maintain competence. Persons having responsibility for quarantine performance will also be trained to ensure an understanding of all requirements, and competency will be assessed.

Table 12-9: (continued)
Elements of the Quarantine Management System



QMS Element (after ISO 14001)	Gorgon Development Actions to Manage Quarantine
Records	All records of quarantine activities will be managed electronically in the document control system, including backups and archival for an appropriate period of time.
Monitoring and Measurement	Monitoring of objectives, targets, and key performance indicators will be undertaken for all quarantine barriers and operational controls. Monitoring will include independent measurement and inspection with regard to implementation of barrier designs, compliance with procedures, training and competency of personnel, and surveillance of the environment (Section 12.5.8). Compliance monitoring will be undertaken for consistent application of laws, regulations and adopted standards, seeking to maintain leadership in quarantine management. Business support processes (e.g. human resource management and recruitment, procurement and purchasing, courier and transport services) will be subject to monitoring for compliance with quarantine requirements and awareness. The results of monitoring activities will be presented to management for review. Changes to the system will be identified to improve the performance of management measures and reduce risk.
Non-compliance, Corrective and Preventive Action	A hierarchy of response actions, reporting requirements and investigation processes will be established for non-compliance with procedures, or detecting evidence of infected cargoes, personnel or vessels. Response actions, corrective actions, or preventive measures to be undertaken will depend on the location of the occurrence and the severity of the threat. Any quarantine breach detected at the border (arrival at Barrow Island) will trigger significant corrective actions, including the refusal or isolation and treatment of infected cargoes and vessels, and isolation of infected persons for treatment. Detection of a post-border incursion (in the Barrow Island native environment) will be treated as an emergency incident. Corrective actions will include management responsibilities for addressing, tracking and close-out of incident investigations, audits, inspections and monitoring programs.
Incident Response	A rapid response capability will be established consistent with published models for the control and eradication of introduced pest and weed species. The Joint Venturers will initially respond to the detection of any incursion of a non-indigenous species into the native environment, in consultation with government agencies, whether or not the source of the incursion is known (Section 12.5.9). Rapid response equipment and materials will be cached at Barrow Island. Personnel will be trained to respond to incidents and drills will be conducted. Procedures will be described for incident investigation, reporting and corrective action.

Table 12-9: (continued)
Elements of the Quarantine Management System



QMS Element (after ISO 14001)	Gorgon Development Actions to Manage Quarantine
Management System Audit	Internal and independent audits will be undertaken to ensure that established practices and processes are being implemented in accordance with defined and documented procedures; and that the procedures are effective. Audits will focus on significant risks. All aspects of the management system will be audited on an annual basis during construction and commissioning of the proposed Gorgon Development. Depending on the outcomes of the initial audits, an appropriate schedule for ongoing audits will be established for operations. The Conservation Commission will oversee the inspection of quarantine activities and documentation on Barrow Island. The Commission will have the ability to conduct audits of the management system.
Management Review	The Joint Venturers will assess the adequacy and effectiveness of the management system. Reviews will be based upon monitoring and auditing activities, internal changes (availability of new technology, organisational changes) and external drivers (access to new markets, regulatory requirements). Scheduled reviews will be undertaken to evaluate system performance and to explore opportunities to improve the management of quarantine threats. Management reviews will include legal compliance and results of stakeholder engagement. Quarantine management performance will be formally reported to the Joint Venturers as part of the annual business planning process. The Joint Venturers will develop a public reporting process to inform stakeholders of the status and progress of quarantine management on Barrow Island.

Table 12-10:
Implementation of the Quarantine Management System

Timing	QMS Development Stage
At the time of submission of the Draft EIS/ERMP	• Establish Barrow Island Quarantine Policy. • Demonstrate the use of the risk assessment process and conceptual barriers to protect conservation values for the three priority pathways suggested by the QEP in consultation with community stakeholders. • Commit to the elements of the QMS developed to address the requirements of ISO 14001.
During the Public Review and Government Assessment Process	• Continue pathway risk assessments and identification of suggested quarantine barriers, as input to the barrier selection process (Section 12.5.1). • Produce detailed barrier specifications and designs on pathways related to early construction activities during the front-end engineering design (FEED) phase of the proposed Development. • Undertake independent expert review of detailed barrier specification and design in QHAZ workshops (Section 12.4.2), to validate expected barrier performance. • Establish specific targets and key performance indicators to assess performance of quarantine management for barriers which have reached the detailed specification and design stage. • Develop electronically accessible pathway and barrier documentation for quarantine management and Risk Registers. • Integrate QMS elements in electronic information systems.
Prior to commencement of Gorgon Development: field-based construction activities, including village construction etc.	• Complete pathway risk assessments and identification of quarantine barriers for all relevant pathways, as input to the barrier selection process. • Produce detailed barrier specifications and designs on all pathways related to construction activities, and validation of expected barrier performance to protect conservation values. • Undertake independent expert review of detailed barrier specification and design in QHAZ workshops, to validate expected barrier performance. • Establish specific targets and key performance indicators to assess performance of quarantine management. • Implement electronically accessible pathway and barrier documentation and Risk Registers. • Complete development of all elements of the QMS and integrate in electronic information systems. • Undertake independent audit of the QMS to establish readiness for quarantine management operations.

12.7 Conclusion

The Joint Venturers recognise the unique conservation values of Barrow Island as a Class A Nature Reserve, and have over 40 years of environmental and quarantine expertise as the operator of the Barrow Island oilfield. Notwithstanding this knowledge and experience on Barrow Island, the Joint Venturers are committed to a quarantine management regime of sufficient rigour to continue to protect the conservation values in the construction and operation of the proposed Development. To do this, the Joint Venturers have addressed the EPA's advice to government (EPA 2003) to:

- develop a set of standards for acceptable risk ('risk standards') to the conservation values of Barrow Island
- demonstrate to the EPA, on the advice from the Department of Environment and CALM, that the risk standards can be met with a very high level of confidence.

The Joint Venturers have taken a number of important steps to develop risk standards, involving expert advice and a high level of community consultation over a period of 18 months. The Joint Venturers have:

- Established a Quarantine Expert Panel to provide advice on quarantine management for Barrow Island.
- Appointed an environmental risk specialist to develop the approach to risk management.
- Established working groups of independent specialists, to analyse exposure pathways and provide advice on the range of barriers which could reduce the threat of introductions.
- Accepted specialist advice to adopt a qualitative risk assessment strategy for the protection of conservation values, rather than attempting to quantify 'acceptable risk' for Barrow Island in a manner similar to that undertaken for individual risk in relation to, for example, hazardous industrial plants where risk data are available.
- Produced a framework for qualitatively scoring the likelihood of infection, survival, detection and eradication of non-indigenous species on exposure pathways, utilising the informed judgements of technical experts.
- Established an open and transparent community consultation process.
- Provided information to a community-formed workshop which was established to consider the development of risk standards in detail, and report back to the community meeting.
- Received a report from the community consultation which advised that after three Risk Standards Workshops it was agreed, with a small number of participants abstaining, that the risk of establishment of introduced species was acceptably low if it conforms to the community expectations for acceptable risk established through the workshop process.
- Accepted the community expectations for risk, noting that such expectations could not be applied to micro-organisms and marine organisms in the same way that it relates to terrestrial flora and fauna.

To demonstrate that the risk standards can be met with a very high level of confidence, the Joint Venturers have progressed the analysis of three priority exposure pathways as recommended by experts and the community. The threat analysis of these pathways is complete. Further, a number of quarantine barriers which should be considered to manage the risk of introduction have been identified by experts. A barrier selection process has been developed to determine those barriers that will be adopted to meet the standards for acceptable risk; and special attention has been given to the priority pathways. Proposed barriers for these pathways have been established and described in this Draft EIS/ERMP. Further analyses to Step 5 of the risk assessment method will be undertaken and released as a supplementary report four weeks prior to the close of the public review period.

The Joint Venturers have:

- Established a barrier selection process for considering the ability of quarantine barriers which will be selected for implementation to meet the risk standards.
- Established technical groups to provide advice on both the list of potential introduction pathways and the biological groups requiring consideration for threat analysis.
- Considered risk treatment strategies to address threats of introduction which were advised to be particularly difficult to manage with quarantine barriers.

- Established that pre-border, preventive quarantine barriers will be the primary means of meeting the risk standards, but recognised that both border and post-border quarantine measures will also be essential elements of the Quarantine Management System.
- Examined three priority pathways for early assessment: sand and aggregate; food and perishables; and personnel and accompanying luggage.
- Estimated the residual risk of introduction which can be achieved for the three priority pathways.
- Committed to re-examining all proposed options for reducing risk if the risks for a particular set of barriers on a pathway fall outside the risk standards for terrestrial flora and fauna.
- Established a process to have specialists advise on the strategy and protocols for baseline flora and fauna surveys of Barrow Island and the surrounding waters, as the basis for establishing a monitoring program to scrutinise the effectiveness of the quarantine barriers which are ultimately implemented.
- Committed to working closely with the CALM to ensure that there is an ongoing independent examination of the quarantine controls being applied.
- Committed to establishing a rapid response strategy in the event of an incursion.
- Committed to having expert advisory groups providing advice to the Gorgon Joint Venturers on the overall direction of quarantine management for Barrow Island, and the priorities for ongoing flora and fauna monitoring.

In summary, the Joint Venturers commit to undertake the following:

- Implement the Barrow Island Quarantine Policy (Section 12.1.1).
- Implement a Quarantine Management System (Section 12.6).
- Adopt the risk standards (Section 12.4.3).
- Apply the risk management process to all pathways (Section 12.4.2).
- Undertake flora and fauna surveys for Barrow Island and the surrounding waters, as the basis for determining baseline data which will be used to judge the effectiveness of quarantine barriers.
- Establish expert advisory groups to provide advice to the Joint Venturers on:
  - the direction of quarantine management for Barrow Island
  - flora and fauna ecological surveys
  - a response strategy and implementation of that strategy in the event of an incursion.
- Issuing a supplementary report to the Draft EIS/ERMP document four weeks prior to the close of the public review period. This report will provide additional information and justification on the barriers selected by the Joint Venturers to reduce quarantine risk.
- The Joint Venturers will conduct a further Barrow Island Quarantine Community Consultation Meeting subsequent to the release of the supplementary report.

The Joint Venturers have been guided by the advice of the EPA and have established a set of standards for acceptable risk. They have also provided information to demonstrate that the standards can be met with a very high level of confidence. The development of a Quarantine Management System in accordance with the approach presented in this chapter will deliver new performance benchmarks for quarantine management. It will also provide an unprecedented level of protection for the conservation values of Barrow Island.

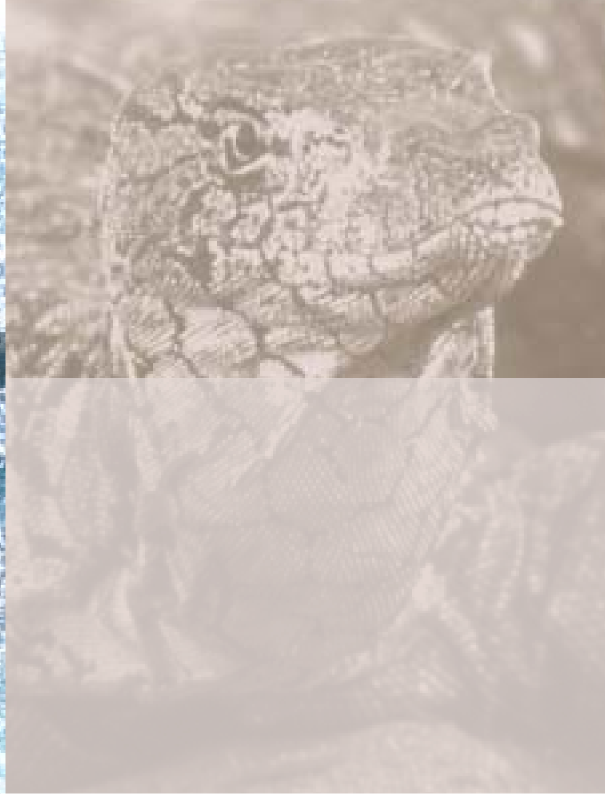
13: Greenhouse Gas Emissions – Risks and Management

Processing of gas from the Greater Gorgon area fields into Liquefied Natural Gas (LNG) will result in greenhouse gas emissions over the full energy lifecycle of the proposed Development. These emissions will be approximately half those that would be generated from the use of alternative hydrocarbon fuels such as coal or fuel oil by the Gorgon Development's potential customers.

Integration of the Gorgon Development Greenhouse Gas Management Strategy into the gas processing facility design has resulted in the adoption of greenhouse efficient practices such as waste heat recovery and the proposal to inject the carbon dioxide (CO_2), contained in the reservoir gas stream, into the Dupuy Formation below Barrow Island. These actions represent a commitment to reduce emissions of greenhouse gases that exceed those of other LNG producers.

A thorough review of potential CO_2 injection locations has been conducted and has determined that the Dupuy Formation, accessed from the eastern side of Barrow Island, is the preferred location for this activity. Extensive monitoring of the injected CO_2 is planned and will assist with the ongoing management of the CO_2 injection operations. The Gorgon Joint Venturers undertake to make information from the monitoring program available to the public.

The proposed injection of reservoir CO_2 will reduce greenhouse gas emissions attributable to the Development (including domestic gas production and the provision of infrastructure support on Barrow Island) by 40% from 6.7 million tonnes per annum of CO_2 equivalent (MTPA CO_2e) to 4.0 MTPA CO_2e. A range of ongoing management actions and longer term performance targets have been established with the objective of further reducing greenhouse gas emissions below those presented in this Draft EIS/ERMP.



Management of CO_2 injection operations will be implemented as documented in the CO_2 Injection Operations Management Plan. This Plan incorporates a range of management responses in the unlikely event that unpredicted migration is detected.

The probability of CO_2 migrating to the surface has been determined to be remote with potential environmental consequences limited to localised impacts on flora and possible detrimental impacts on subterranean fauna. The environmental risks associated with the injection of CO_2 have been assessed and the environmental impact discussed in Chapter 10. The monitoring and reservoir management program will be critical in ensuring that the migrating CO_2 does not reach these environments.

Benchmarking of LNG plant efficiency shows that the Gorgon Development will be amongst the most efficient LNG developments in the world with an estimated greenhouse efficiency of 0.353 tonnes of CO_2e per tonne of LNG. This efficiency includes all emissions related to the production of the natural gas from the offshore fields, the energy required to inject reservoir CO_2 and the assumed volume of reservoir CO_2 vented.

13.1 Introduction

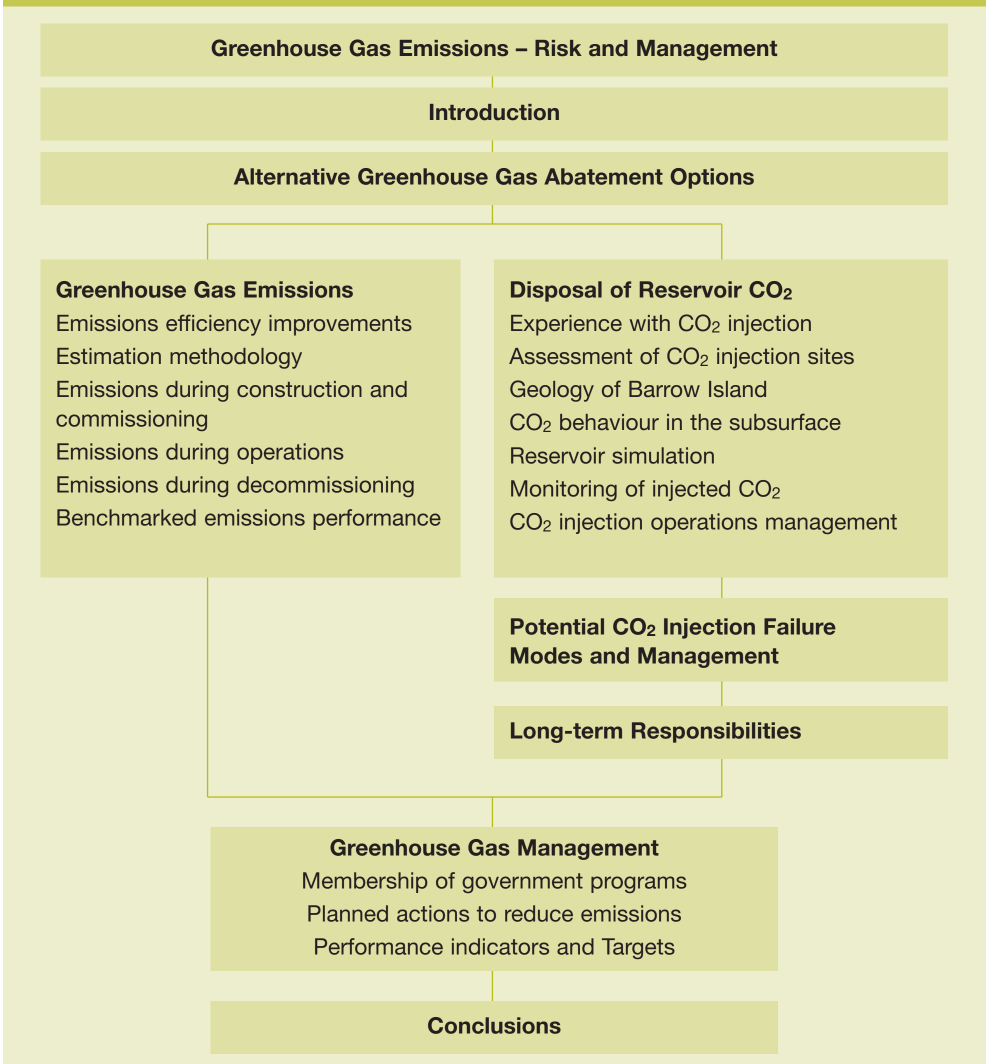
This Chapter is a discussion of the Gorgon Joint Venturers approach to the management of greenhouse gas emissions. Figure 13-1 provides an outline of the content of the chapter.

The two principle areas discussed are: the greenhouse gas emissions from the proposed Development; and the proposal to dispose of reservoir CO_2 by subsurface injection into the Dupuy Formation. The discussion on greenhouse gas emissions includes the sources of greenhouse gas emissions (based on an assumed reference case) and the engineering approaches adopted to minimise these emissions. A comparison of the emissions intensity with other LNG projects is also provided in Section 13.3.6.

The Gorgon Development will be the first project in Australia to significantly reduce greenhouse gas emissions to the atmosphere by the injection of CO_2 underground. This chapter provides information on the selection of the proposed injection site, a summary of the geology of Barrow Island, a description of the predicted behaviour of the injected CO_2 and the plans for ongoing monitoring and management. This is followed by a review of the potential failure modes and effects from injecting CO_2. The Joint Venturers' approach to the management of long-term responsibility, associated with the proposal to inject CO_2, is also discussed.

This Chapter concludes with a review of the Greenhouse Gas Management Plan for the Gorgon Development including the activities planned to be

Figure 13-1:
Overview of Chapter Structure



undertaken to manage the Development's greenhouse gas emissions during the ongoing engineering and design work and through operations. A number of greenhouse emissions performance targets have been developed as part of this management plan to guide ongoing greenhouse gas reduction activities.

13.1.1 Commitment to Greenhouse Gas Management

The Gorgon Joint Venturers recognise and share the concern of the community, industry and government about the potential for global climate change, so have integrated these concerns into their business decisions. This commitment to responsible greenhouse gas emissions management is reflected in the adoption of the Gorgon Gas Development Greenhouse Gas Management Strategy (Figure 13-2). The commitments contained in this strategy have been used to guide the Joint Venturers in their planning for the Development and will continue to provide a framework for future engineering decisions and the ongoing management of greenhouse gas emissions.

The Gorgon Joint Venturers will sell LNG in the global energy market. As outlined in Section 13.1.3 the use of LNG from the Gorgon Development will result in significantly less greenhouse emissions over the full energy lifecycle than alternative energy sources such as coal or fuel oil. In order to realise these reduced life cycle emissions, the Gorgon Joint Venturers must maintain their international competitiveness against these competing energy suppliers. This limits the level of expenditure that can be applied to greenhouse gas reduction and requires expenditure to be targeted to achieve the greatest impact.

The use of best practice thermally efficient plant, with associated reduced greenhouse gas emissions, has been a key consideration in the design selection criterion, for the proposed gas processing facility. Section 13.3.4 provides details on the selection methodology for the LNG liquefaction processes technology and the gas turbine and waste heat recovery systems. These systems are the major drivers of plant greenhouse gas efficiency and the design selection represent currently applied best practice in Australia and internationally. The inherent technical risk and capital cost burden for unproven or 'leading edge' technologies cannot be justified on the basis of relatively minor improvements in greenhouse gas emissions.

The Gorgon Joint Venturers have determined that the subsurface injection of the CO_2 contained in the reservoir gas stream provides an opportunity within the scope of the Gorgon Development to significantly reduce greenhouse gas emissions. To ensure the efficient use of capital resources, CO_2 injection is planned to be implemented using injection equipment sized to handle the expected rate of reservoir CO_2 removed from the incoming gas stream to the gas processing facility. Venting of reservoir CO_2 will be required during commissioning, periods of maintenance and equipment downtime associated with the injection equipment or for reservoir constraints. The requirement to vent reservoir CO_2 during periods of plant downtime, or if reservoir constraints are encountered, was identified in the ESE Review (ChevronTexaco Australia 2003) as essential to maintaining the international competitiveness of the Development. Full redundancy in the CO_2 injection system to eliminate venting as a contingency, cannot be justified given the impact on project financial viability. Further discussion on the assumptions included in the reference case relating to the venting of reservoir CO_2 can be found in Section 13.3.4.

In common with the subsurface uncertainties encountered in the oil and gas industry, there remains an element of cost and technical uncertainty with the CO_2 injection proposal. This uncertainty is associated with the performance of the injection wells and the behaviour of the CO_2 once injected. The Gorgon Joint Venturers have committed to a range of activities, such as the drilling of a data well in the latter part of 2005 (which will be the subject of its own approval) and to an ongoing reservoir monitoring and management program to further reduce and manage these uncertainties. In the unlikely event that the proposed CO_2 injection should prove technically infeasible or cost prohibitive, such as if it is determined that a large number of additional injection wells are required, the Gorgon Joint Venturers will consult with government with the intent of maximising the injection of CO_2 within the commercial constraints of the Gorgon Development.

Studies undertaken by the Gorgon Joint Venturers indicate that risk of failure of CO_2 containment is extremely low. However, if at any time the Joint Venturers consider that the injection of reservoir CO_2 represents an unacceptable risk to the environmental values of Barrow Island, or a safety risk, then CO_2 injection operations would be suspended and the remaining reservoir CO_2 vented to the atmosphere. It is not the Gorgon Joint Venturers intention to ever have to

Figure 13-2:
Gorgon Development Greenhouse Gas Management Strategy

GORGON
AUSTRALIAN GAS

Gorgon Gas Development Greenhouse Gas Management Strategy

The Gorgon Development Greenhouse Gas Management Strategy for a Barrow Island development is to:

- Demonstrate via lifecycle analysis that a Gorgon gas development and LNG export results in a net reduction in global greenhouse gas emissions relative to other fossil fuel alternatives.
- Design the production facilities to incorporate current best practices in thermal efficiency and greenhouse emission control where practicable.
- Develop a project to re-inject the removed reservoir CO_2 into the Barrow Island Dupuy saline reservoir, unless it is technically infeasible or cost-prohibitive. This will involve:
  - Pursuing a stepwise process to: develop a reservoir CO_2 re-injection project, demonstrate technical feasibility, and ensure costs to the project are not excessive.
  - Selling treated gas to meet domestic gas customer requirements and re-inject the removed reservoir CO_2.
  - Commencing re-injection as soon as practicable after the processing facilities commissioning and start-up process.
  - Implementing re-injection of reservoir CO_2 by installing a single train of injection equipment, sized for the full volume of reservoir CO_2.
- Investigate potential synergies with existing Barrow Island operations and implement measures that minimise greenhouse emissions and enable full use of associated gas production where practicable.
- Pursue projects and opportunities which provide net conservation benefits and enhance greenhouse gas removal from the atmosphere.
- Continue existing funding for greenhouse gas related research and development projects such as CRC's and technological research.
- Review options for funding additional value-added research and development or demonstration projects.
- Pursue potential opportunities for external sale or use of separated reservoir CO2 as a chemical feedstock or enhanced oil recovery agent.
- Develop a contingency plan that could provide a partial offset for reservoir CO2 if a sequestration project proves infeasible. Options may include:
  - Maturing alternative re-injection sites that could be developed in the future such as a depleted gas reservoir.
  - Creation of emission reductions or offsets external to the Gorgon gas development.
  - Sequestration opportunities such as forestry.
  - Additional research funding.
- Meet the commitments within the LNG Action Agenda including the revision of the existing Gorgon Greenhouse Challenge Cooperative Agreement.
- Continue to advocate increased use of gas based fuels, in preference to more carbon intensive options, to reduce greenhouse emissions.
- Participate constructively in the development of greenhouse policy at both the State and Commonwealth level.

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suspend CO_2 injection operations. In the unlikely event of unpredicted migration of CO_2 that could reach the surface, the Gorgon Joint Venturers will place the safety of the workforce and the environmental values of Barrow Island above the mitigation of increased atmospheric greenhouse gas emissions.

13.1.2 Impact on National and State Greenhouse Gas Emissions

The estimated annual greenhouse gas emissions (4.0 MTPA CO_2e) from the proposed Development will result in an increase in Australia's annual greenhouse gas emissions of approximately 0.8% and an increase in Western Australia's greenhouse gas emissions of 6.4% relative to their respective greenhouse gas emissions in 1990. However, the use of Gorgon LNG for power generation in Pacific Basin countries will provide the potential to avoid an additional 30 MTPA CO_2e of greenhouse gas emissions that would result from using more carbon intensive fuels.

Table 13-1 presents the greenhouse gas emissions from the proposed Development relative to Australia's 1990 and 2002 baseline emissions. Table 13-2 presents the same information relative to Western Australia's 1990 and 2002 emissions.

Table 13-1:
Predicted Greenhouse Emissions Relative to Australia's 1990 and 2002 Baseline

	Million Tonnes of CO_2e per Annum	**Percentage increase relative to the 1990 Baseline**
Australia's 1990 Baseline Emissions	536.9	–
Australia's 2002 Emissions	541.8	0.9%
Gorgon Development with Injection of Reservoir CO_2	4.0	0.8%

Data sourced from State and Territory Greenhouse Gas Emissions – An Overview (Australian Greenhouse Office 2005).

Table 13-2:
Predicted Greenhouse Emissions Relative to Western Australia's 1990 and 2002 Baseline

	Million Tonnes of CO_2e per Annum	**Percentage increase relative to the 1990 Baseline**
Western Australia's 1990 Baseline Emissions	62.8	–
Western Australia's 2002 Emissions	70.4	12.1%
Gorgon Development with Injection of Reservoir CO_2	4.0	6.4%

Data sourced from State and Territory Greenhouse Gas Emissions – An Overview (Australian Greenhouse Office 2005).

Box 13-1:
LNG as a Transition Fuel

Natural gas and LNG are often referred to as 'transition' fuels in the context of fossil fuel use and greenhouse gas emissions. This is due to the recognition that natural gas has a lower greenhouse gas intensity compared to other fossil fuels. Natural gas and LNG also have many properties that make them suitable fuels for high efficiency, low emission energy conversion devices such as fuel cells.

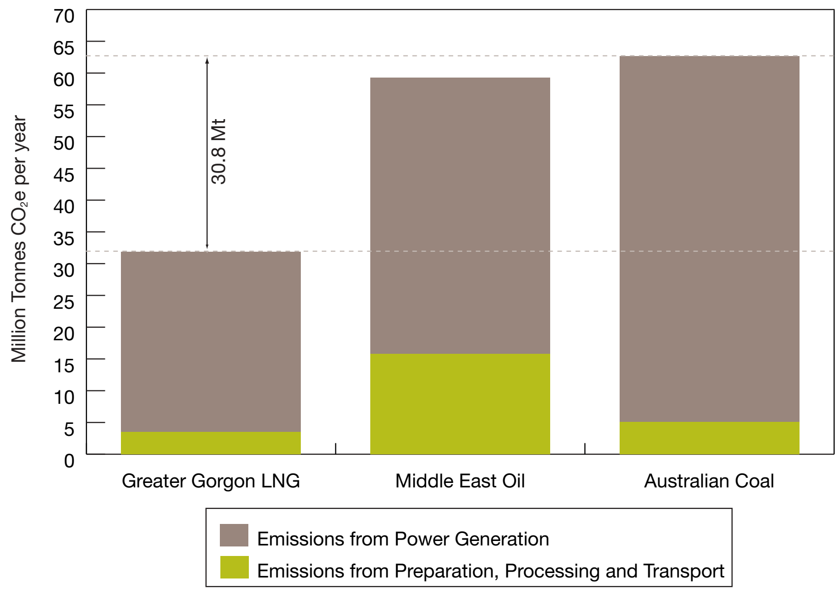
Natural gas is also a likely feedstock for the production of hydrogen, which may replace petroleum as a potential future transport fuel. In particular the combination of producing hydrogen from natural gas and the disposal, by injection into the subsurface of the carbon dioxide produced in the process, would result in a near zero emissions transport fuel. While the production of zero emissions hydrogen is not part of this proposal, the CO_2 injection technology being applied by the Gorgon Joint Venturers may assist in the development of this future fuel.

13.1.3 The Relative Greenhouse Impact of LNG

When used as a primary energy source, LNG has a number of benefits over competing fuels such as coal and oil (Box 13-1). These benefits include lower emissions of sulphur dioxide, particulate matter and greenhouse gas emissions. The quantity of greenhouse gases emitted over the full lifecycle (that is the emissions required to extract, produce and transport LNG) combined with the emissions from the end-user, such as an electricity power plant, is less than the comparable lifecycle emissions for either coal or oil to deliver the same amount of energy. Figure 13-3 demonstrates the relative lifecycle emissions associated with LNG, oil and coal to supply the Asian market in which Gorgon LNG will be competing. This data is based on a study conducted by the CSIRO into the life cycle advantages of LNG over coal and fuel oil (CSIRO 1996).

The Western Australian Greenhouse Strategy (Government of Western Australia 2004) and the LNG Action Agenda (Department of Industry Science and Resources 2000) support the increased use of LNG and natural gas to reduce greenhouse emissions from electrical power generation.

Figure 13-3:
Comparison of Lifecycle Greenhouse Gas Emissions for Gorgon LNG and Alternative Fuels for Electrical Power Generation in Asia



Basis: Over one year 10 Million tonnes of LNG will generate 73 Million MWh of electricity

13.2 Alternative Greenhouse Gas Abatement Options

The Gorgon Joint Venturers commenced a number of studies in 1998 to identify potential greenhouse gas reduction or offset opportunities that could be used to reduce the emissions from any proposed development of the Greater Gorgon gas fields. The options assessed in 1998 included:

- investing in commercial forestry
- assisting in revegetation or land rehabilitation plantings
- facilitating reduced land clearing
- undertaking the disposal of reservoir CO_2 by injection into the subsurface
- assisting other industries to switch fuels (e.g. gas for coal)
- facilitating the use of compressed natural gas (CNG) as vehicle fuel
- providing support for renewable energy technologies (wind, solar, biomass)
- promoting the sale of CO_2 as a feed stock to another company or industry.

As a result of these studies the Gorgon Joint Venturers concluded that the disposal of reservoir CO_2 by injection into the subsurface and investing in commercial forestry were two options that should be further considered to reduce the greenhouse emission impact of the Gorgon Development. As well as continuing the scientific and engineering investigations into the subsurface disposal of CO_2, Chevron Australia funded a trial planting of 65 ha of maritime pine to assess the potential for using plantation derived offsets to reduce the Developments greenhouse gas emissions. While the greenhouse offsets from this planting are small, involvement in the plantation has increased the Gorgon Joint Venturers familiarity and understanding of forestry issues such as carbon rights, costs and plantation management issues.

In parallel with the ongoing CO_2 injection studies, the Gorgon Joint Venturers have continued to review alternative greenhouse offset options to ensure that any proposal to reduce or offset the Development's greenhouse gas emissions will be cost effective. This culminated in an Offset Emissions Study undertaken by specialist consultants in 2004 (ACIL Tasman 2004) which considered:

- Sequestration options
  - commercial plantations
  - revegetation/rehabilitation plantations
  - reduced land clearing
  - mineral CO_2 sequestration
- Market based options
  - Mandatory Renewable Energy Target (MRET)/Renewable Energy Certificates (RECs)
  - New South Wales Greenhouse Abatement Certificates
  - Queensland Gas Electricity Certificates
  - Greenhouse Friendly Program (Australian Greenhouse Office)
- Overseas market based options.

The study concluded that commercial forestry plantations provide a viable mechanism to offset greenhouse gas emissions but may be unable to provide the scale of offsets required by the Gorgon Development. Additional benefits such as increased regional employment opportunities and potential reductions in salinity levels may be realised through plantation offsets; however the scale of commercial plantations required by the Gorgon Development may lead to increased demand for land for forestry plantations which could result in dislocation of communities and downward pressure on timber prices. Other options that were considered that may provide viable greenhouse gas offsets at some time in the future include: salt bush plantations, land clearing reductions, mineral CO_2 sequestration research and development of credit based schemes. A summary of these alternative greenhouse gas offset opportunities is provided in Table 13-3.

Considerable uncertainty is associated with all of the alternative greenhouse gas offset options particularly over the operational time frame of the Gorgon Development. For example, while a current price per tonne CO_2e can be determined for each of the alternative options, there is considerable uncertainty over future prices. In addition, many of the opportunities that have the potential to supply the large volumes of low cost offsets required by the Joint Venturers are not practical as they are derived from programs that have a limited life. That is the programs are only legislated to run until 2012 or 2020. It is not feasible to base a greenhouse gas emissions mitigation strategy for the Gorgon Development upon programs that have a short life span relative to the Gorgon Development, and have technical and price uncertainty as documented in Table 13-3.

Table 13-3:
Summary of Alternative Greenhouse Gas Offset Opportunities

Greenhouse Offset Opportunity	Independent Verification	Current Cost Estimate	Quantity	Risk
Commercial Timber Plantations	Verification is possible. But measurement remains an issue.	NSW Forestry selling CO_2 credits derived from plantations for $10 per tonne.	Around 100 000 ha required for 1 million tonnes CO_2 per year.	Drought, fire, future value of timber sales.
Revegetation/ Rehabilitation Plantations	No formal institutions available at present.	Cost per tonne CO_2 not known at this stage.	Around 77 000 ha required for 1 million tonnes CO_2 per year.	Growth conditions at site, commercial grazing, measurement uncertainty.
Reduced Land Clearing	Potentially more difficult than other sinks.	ABARE estimates cost at less than $1 per tonne for government mandated scheme, costs higher for voluntary scheme.	AGO have estimated up to 25 million tonnes per year in Queensland.	Establishing a base line needs further study. Unknown if government would make credits available.
Mineral Sequestration	Still to be established.	Not known at this time.	Unlikely to provide offsets of the scale required by the Gorgon Development.	Technology needs to be tested. Requires partnering with other industries that are likely to claim credits.
Australians Market Based Mechanisms (e.g. MRET)	Provided in legislation or through agencies such as AGO.	Uncertain, but possibly as low as $5 per tonne for low volumes, potentially much higher for larger volumes.	Potentially 10-20 million tonnes per annum, highly dependent on technology uptake.	Most market-based schemes in Australia have limited life, e.g. 2012 or 2020. Lack of certainty over time frame required for Gorgon.
Overseas Market Based Mechanisms linked to Kyoto (Note: opportunity currently not available to Australian companies)	Verification rules set by legislation consistent with the Kyoto Protocol.	Currently trading at approximately $45 per tonne. Costs post-2012 are very uncertain.	Potentially in the hundreds of millions of tonnes per annum.	Lack of certainty about how these mechanisms will continue to operate, if at all beyond 2012.
Overseas Market Based Mechanisms not linked to Kyoto (e.g. Chicago Climate Exchange)	Verification rules stipulate independent, internationally accredited organisations, but no government backing or verification.	Currently trading at approximately $2.20 per tonne, but trade volumes have been small (thousands of tonnes). Price highly dependent on country of origin energy and greenhouse policy.	Uncertain, but potentially many millions of tonnes per annum.	Success and long term viability of these mechanisms will be heavily dependent on country of origin energy and greenhouse policy.

Based on this analysis, the Gorgon Joint Venturers have elected to reduce the Developments greenhouse gas emission by the disposal of reservoir CO_2 by injection into the Dupuy Formation. The primary driver behind this decision is the higher level of certainty, particularly in the area of cost of abatement that the proposed injection of CO_2 offers over the offset alternatives.

Additional drivers behind the decision to inject CO_2 are:

- preference to reduce emissions rather than looking to offset emissions
- infeasible to meet the full demand for emissions offsets through forestry or revegetation planting with any degree of certainty over long term security or price
- familiarity with the technology and management issues associated with CO_2 injection
- less external factors such as rainfall and climate variation
- ease of greenhouse emissions estimation and reporting.

The proposed subsurface injection of reservoir CO_2 also provides benefits for Australia through the demonstration of CO_2 geosequestration, via access to data on the performance of the project.

13.3 Gorgon Development Greenhouse Gas Emissions

This section is a description of the actions taken during the engineering studies to date to reduce greenhouse gas emissions and the methodology used to estimate the greenhouse gas emissions from the Gorgon Development. It also provides estimates of greenhouse emissions over the life of the proposed Development and compares the resulting greenhouse efficiency of the LNG component of the Development with other recent LNG developments.

The greenhouse gas emissions estimates provided in this section are based on a reference case (details of which are provided in Section 13.3.4) that assumes a high level of emissions where engineering design work or operational procedures are yet to be finalised. Further actions, including longer term performance targets, to reduce emissions below those stated in the reference case are outlined in Section 13.5.

13.3.1 Greenhouse Gas Emissions Efficiency Improvements

Early design concepts for the development of the Gorgon field incorporated a gas processing platform located offshore in proximity to the gas field with a LNG processing facility on the Burrup Peninsula. This design concept formed the basis of the 1998 Greenhouse Challenge Cooperative Agreement between the Gorgon Joint Venturers and the Australian Greenhouse Office (WAPET 1998). The greenhouse gas emissions efficiency improvements identified below compare the current design with that used as the basis of the 1998 Cooperative Agreement.

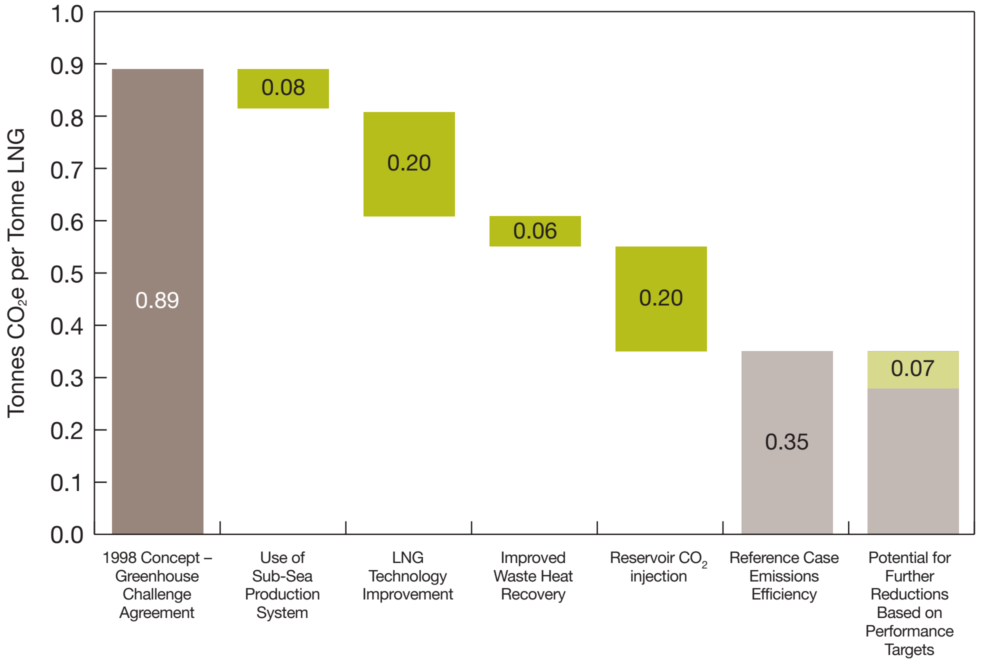
The greenhouse gas efficiency of the Gorgon Development as stated in the 1998 cooperative agreement was 0.89 tonnes of CO_2e emitted to the atmosphere for every tonne of LNG to be produced. Emissions efficiency expressed as tonnes of CO_2e per tonne of LNG has been used in this analysis to account for the different plant capacities between the basis of the Cooperative Challenge Agreement (8 MTPA LNG) and the current development concept (10 MTPA LNG). As the 1998 cooperative agreement did not include gas for domestic consumption, only emissions related to the processing of LNG have been included in this discussion.

Engineering decisions that have resulted in significant improvements in greenhouse gas emissions efficiency compared to the 1998 design case include:

- replacement of the offshore gas processing platform with an all subsea development
- changes in LNG process technology
- improved waste heat recovery on the gas turbines resulting in a significant reduction in the use of supplementary boilers and heaters
- significantly reducing greenhouse gas emissions by the injection of reservoir CO_2 into the subsurface.

The contribution to improved greenhouse gas emissions efficiency from each of these areas is shown graphically in Figure 13-4.

Figure 13-4:
Greenhouse Emissions Efficiency Improvements



The selection of Barrow Island as the preferred site for the development of the gas processing facilities has enabled the use of subsea technology rather than platform-based offshore gas processing. The offshore gas production platform in the 1998 design accounted for approximately 600 000 tonnes of CO_2e emissions per year. By eliminating the offshore gas production platform and utilising a subsea gas production system, the greenhouse gas emissions efficiency of the Gorgon Development has been improved by 0.075 tonnes of CO_2e per tonne of LNG to be produced.

LNG process technology has evolved significantly over the last ten years driven by larger more efficient plants and changes in technology used to remove CO_2 in the inlet gas stream. A range of design areas have been studied for incremental improvements in greenhouse gas emissions efficiency. These include:

- increasing the size of the LNG process trains to the maximum practical
- use of a-MDEA as the CO_2 removal medium in the acid gas plant
- use of dry compressor and hydrocarbon pump seals
- locating a cold recovery exchanger on the overhead gas from the nitrogen removal column.

These technology improvements have resulted in a greenhouse gas emissions efficiency improvement of 0.20 tonnes of CO_2e per tonne of LNG to be produced compared with the 1998 plant design.

The design concept upon which the Greenhouse Challenge Cooperative Agreement was based included the use of direct fired heaters/boilers. These boilers/heaters accounted for approximately 520 000 tonnes of CO_2e emissions per annum. Studies into the better capture and application of waste heat recovered from the process gas turbines has resulted in the restricted use of process heaters to during periods of plant start-up only. Ongoing design work may ultimately lead to the total elimination of boilers and heaters. The improved waste heat recovery in the reference case has resulted in a greenhouse gas emissions efficiency improvement of 0.058 tonnes of CO_2e per tonne LNG to be produced.

The Gorgon Joint Venturers have studied how they might further reduce the greenhouse gas emissions beyond those available through improved plant design such as the subsurface injection of CO_2. Greenhouse gas offsets such as forestry or land rehabilitation planting or purchasing greenhouse credits were also considered. Further discussion on the evaluation of offsets is included in Section 13.2. As a result of these studies the Gorgon Joint Venturers have elected to make a significant reduction in Development emissions by injecting the reservoir CO_2 removed during the gas processing operations into the Dupuy Formation. The reference case assumes that 2.7 MTPA of reservoir CO_2 will be injected into the Dupuy Formation. The reduction in greenhouse emissions by this method has resulted in a greenhouse gas emissions efficiency improvement of 0.20 tonnes of CO_2e per tonne LNG to be produced. Future activities, particularly in the area of developing operational procedures around CO_2 injection, are planned with the objective of increasing the volume of CO_2 injected to 3.2 MTPA.

While not included in the reference case, there is potential for further greenhouse emissions efficiency improvement. Section 13.5 outlines longer term performance targets and management actions to achieve those targets. If these performance targets are met, the resulting greenhouse efficiency will be further improved by approximately 0.066 tonnes of CO_2e per tonne LNG to be produced.

13.3.2 Emissions Estimation Methodology

This section is a description of the methodology used to estimate the greenhouse gas emissions that will result from the Gorgon Development and provides estimates of greenhouse emissions during the construction (including plant commissioning) and operational phases of the Development. As engineering and design work is ongoing not all issues around plant configuration and operations have been finalised. As a result the greenhouse gas emissions estimated during the operational phase are based on a reference case that has assumed a number of high emission (or worst case) design outcomes. The assumptions behind the reference case and the design options still under consideration are outlined in Section 13.3.4.

The emission estimates described throughout this Chapter were compiled based on the American Petroleum Institute's Compendium of Greenhouse Gas Emissions Estimating Methodologies of the Oil and Gas Industry (American Petroleum Institute 2004).

Estimations have been compiled by determining the type and quantity of fuel used and the resulting greenhouse emissions from the use of that fuel. The conversion factors used in determining the estimated greenhouse gas emissions are provided in Table 13-4.

Emissions of methane (CH_4) and nitrous oxide (N_2O) have a higher greenhouse effect than does CO_2. Greenhouse gas emissions are often reported in tonnes of carbon dioxide equivalent or CO_2e. The conversion factors used for CH_4 and N_2O to CO_2e are 21 and 310, respectively. Emissions of these products have been included in the calculation of the CO_2e figures presented in this document.

Once construction activities commence the Joint Venturers will track greenhouse emissions using the SANGEA™ Energy and Emissions Estimating System and report these emissions in accordance with the Gorgon Joint Venturers' obligations under the Greenhouse Challenge Program.

The SANGEA™ system was initially developed by Chevron but has been made freely available through the American Petroleum Institute in order to assist in

Table 13-4:
Greenhouse Emissions Conversion Factors

Fuel Type	Conversion Factor
Industrial diesel fuel	2.8 tonnes CO_2e per thousand litres
Natural Gas – WA Domestic (Full fuel cycle)	60.0 tonnes CO_2e per tera joule
Gorgon Gas Processing Facility Fuel Gas	54.7 tonnes CO_2 per tera joule
	0.004 tonnes CH_4 per tera joule
	0.0014 tonnes N_2O per tera joule
	Total CO_2, CH_4 and N_2O 55.2 tonnes CO_2e per tera joule

establishing uniform emissions estimation standards across the petroleum industry. SANGEA™ is designed to assist petroleum companies with estimating, managing and reporting greenhouse gas (GHG) emissions. It can also be used to track energy consumption and criteria pollutant emissions. Information on the SANGEA™ Emissions Estimating System can be found at http://projects.battelle.org/sangea/home.asp

13.3.3 Emissions During Construction and Commissioning

The Gorgon Joint Venturers estimate that greenhouse gas emissions during the construction and commissioning of the gas processing facility will be between 1.64 and 1.74 million tonnes CO_2e. As many of the construction and commissioning activities remain to be finalised, these emission estimates should be considered provisional. The greenhouse gas emissions from the main construction activities are presented in Table 13-5.

Recent offshore drilling operations conducted by Chevron Australia in the Greater Gorgon area have used diesel at the rate of approximately 34 000 litres per day to fuel the drilling rig and associated support vessels. This equates to approximately 95 tonnes CO_2e per day for a typical offshore drilling operation in the Greater Gorgon area. It is anticipated that between 18 and 25 wells will ultimately be required to develop the Gorgon gas field, with between 5 and 10 wells drilled during the initial field development. Assuming that it takes 65 days to drill each well and install the subsea equipment, the anticipated greenhouse emissions from fuel usage during offshore drilling activities over the life of Development will be between 110 000 and 160 000 tonnes CO_2e. An additional 4000 tonnes of CO_2e per well are estimated to be released from the flaring of natural gas during operations associated with completing the well. These operations generally entail ‘flowing’ the well for less than 24 hours. During this time, the produced gas will be flared.

Table 13-5:
Greenhouse Emissions During Construction and Commissioning

Construction Activity	Estimated Greenhouse Gas Emissions (tonnes CO_2e)
Offshore drilling activities (fuel consumption)	110 000–160 000 (in phases over life of Development)
Offshore drilling activities (well clean up operations)	70 000–100 000 (in phases over life of Development)
Pipe laying operations – Gorgon field to Barrow Island.	25 000
Multiple support vessel	45 000
Electrical power generation on Barrow Island	75 000–95 000
Mobile equipment and vehicle usage on Barrow Island	25 000
Dredging	75 000
LNG process commissioning operations	1 200 000
Pipe laying operations – Domestic gas pipeline	15 000
Total estimated greenhouse gas emissions related to construction and commissioning activities	1.64–1.74 million tonnes
The emissions stated in this table should be considered as order of magnitude estimates.	

A multiple support vessel (MSV) will be used to install the subsea production systems and umbilical control lines. These activities are estimated to take 175 days. Estimated energy consumption on the MSV is 40 MW provided by burning diesel fuel. This will result in 250 tonnes of CO_2e emissions per day or approximately 45 000 tonnes of CO_2e. This estimate includes a reasonable allowance for any support vessels.

Preliminary engineering studies indicate that it will take slightly over 100 days to lay the pipeline from the Gorgon gas field to Barrow Island. Estimated energy consumption on the pipelay barge is 40 MW provided by burning diesel fuel. This will result in 250 tonnes of CO_2e emissions per day or approximately 25 000 tonnes CO_2e over the duration of the pipeline installation works.

Greenhouse gas emissions from construction activities on Barrow Island will be dominated by two sources: emissions from electrical generation, including that to power the construction village for the workforce; and diesel fuel used to operate various plant and equipment on the island. Two energy sources are currently being evaluated for the supply of electrical power during the construction period: either obtaining local supplies of natural gas; or using diesel. If natural gas is chosen then the estimated energy demand is 1.3 petajoules (PJ) whereas if diesel is selected, the anticipated requirement is for 35 million litres. The resulting greenhouse gas emissions over the three to four year construction period are approximately 75 000 tonnes CO_2e for natural gas and 98 000 tonnes CO_2e for diesel. The anticipated diesel fuel usage to power equipment on Barrow Island, such as earth moving transport, welding machines and for the drilling of the CO_2 injection wells and pipeline shore crossing is estimated at 9 million litres. Greenhouse gas emissions from this fuel usage will be approximately 25 000 tonnes CO_2e.

Dredging operations are currently planned using two medium-to-large dredges. Anticipated fuel usage for each dredge is 250 000 litres of diesel per week. Dredging operations are anticipated to run for 12 months consuming a total of 26 million litres of diesel. This equates to 75 000 tonnes of greenhouse gas emissions from dredging operations.

Preliminary engineering studies around the installation of the domestic gas pipeline suggest that this operation will result in approximately half the emissions of the Gorgon field to Barrow Island pipeline. This is a result of a potentially smaller lay barge and anticipated faster installation rate. Anticipated greenhouse gas emissions for this activity are estimated at 15 000 tonnes of CO_2e.

Commissioning activities will involve progressively cooling down the LNG gas processing facility and storage facilities to operational temperature. This process will be conducted progressively over several weeks during which the gas flowing through the plant will be flared. The Gorgon Joint Venturers are investigating options for the recovery of this gas into the gas processing stream but for the purposes of this assessment, it is assumed that this gas will be flared. Further information on the commissioning operations is available in Chapter 6 (Section 6.4). For the purposes of calculating greenhouse gas emissions resulting from commissioning operations it has been assumed that the volume of gas flared will equate to two weeks of average LNG production (385 000 tonnes of LNG or 1 200 000 tonnes CO_2e).

13.3.4 Emissions from Operations

Greenhouse gas emissions during operation of the gas processing facility will be predominantly from combustion sources used to supply energy for LNG and domestic gas production; and to remove CO_2 from the feed gas stream and inject it into the Dupuy Formation. Figure 13-5 shows a schematic of the main sources of greenhouse gas emissions from the proposed Development.

Based on experience with similar gas processing facilities throughout the world, the on-stream availability of the facility during the first year of operation is expected to be lower due to bedding in and minor operational issues associated with bringing such a complex facility on-line. Additionally, the facility is expected to start-up at a low production rate and ramp-up to full production over a period of several years as market demand for the produced LNG and domestic gas increases. Maximum efficiency of the facility will be at the nominal design rate, so during this ramp-up period, the facility will be operating at less than optimum efficiency. As a result the corresponding CO_2e emissions per tonne of LNG will be higher than in the subsequent years of operation. Figure 13-6 shows the expected greenhouse emissions profile over the life of the Development. Note: greenhouse gas emissions related to construction emissions are not shown in this figure. In the following discussion only the emissions during the steady state operation of the facility are discussed.

For the purposes of this Draft EIS/ERMP, a reference case has been developed based on the facility design assumptions outlined in Chapter 6 and incorporates high emissions scenarios where engineering design work is ongoing or where operational uncertainty exists. High emissions scenarios have been assumed in the following areas:

- domestic gas sourced from the Gorgon gas field
- configuration of gas turbines used for electrical power generation
- waste heat recovery configuration
- percentage of reservoir CO_2 vented
- use of fired heaters (linked to use of waste heat recovery on power generations turbines)
- power generation standby gas turbine operated as spinning reserve.

Based on the reference case the estimated annual greenhouse gas emissions from the proposed Development are 4.0 million tonnes of CO_2e (MTPA CO_2e). Table 13-6 documents the estimated emissions from the LNG and domestic gas components of the facility and the estimated emissions resulting in the provision of support infrastructure and logistics to Barrow Island.

Ongoing engineering and design work and the actions contained in the Greenhouse Gas Management Plan (refer Section 13.5.2) may reduce these estimated greenhouse gas emissions by 660 000 MTPA CO_2e.

Figure 13-5:
Main Sources of Greenhouse Gas Emissions from the Proposed Gas Processing Plant

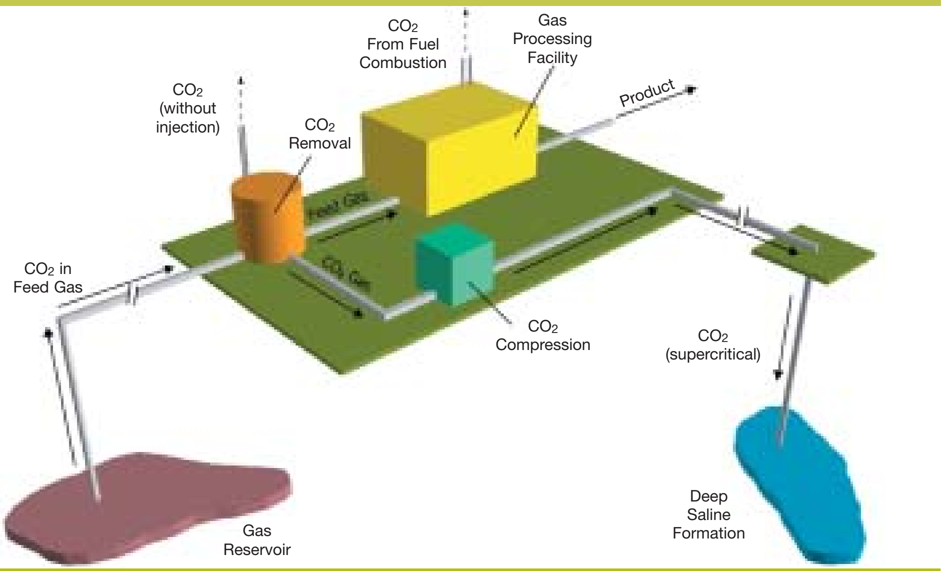
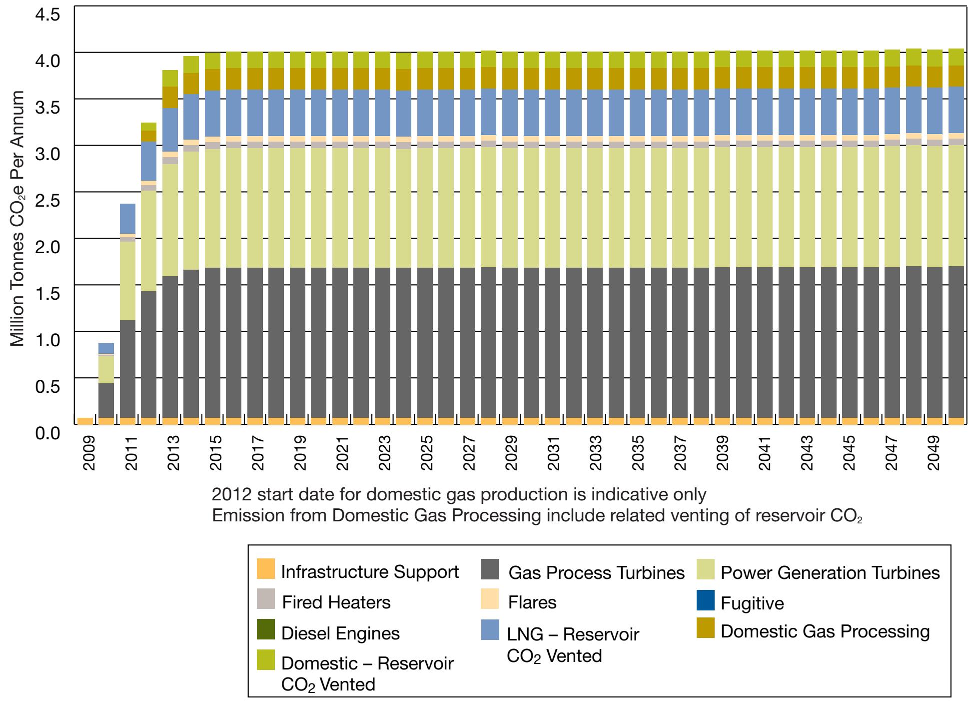


Figure 13-6:
Predicted Greenhouse Gas Emissions from the Proposed Gorgon Development



No perfluorocarbons are planned to be used in the gas processing facilities (therefore will not be emitted). Hydrofluorocarbons will be used in the heating ventilation and air conditioning systems and sulphur hexafluoride will likely be used for electrical switch gear. However, both these uses are for closed systems, so total emissions of these substances will be negligible (<0.01% of the total greenhouse gas emissions on a CO_2e basis) compared to the major emissions sources.

Table 13-6:
Predicted Annual Greenhouse Gas Emissions from the Gorgon Development

Emissions Source	**LNG Processing**	**Domestic Gas Processing**	**Island Infrastructure Support**
	TPA CO_2e	TPA CO_2e	TPA CO_2e
Gas Turbine – Gas Processing Drivers	1 612 000	Nil	Nil
Gas Turbine – Power Generation	1 287 000	200 000	60 000
Fired Heaters	71 000	28 000	Nil
Flare – Events	60 000	Minor	Nil
Flare – Pilots	2 000	Minor	Nil
Fugitive Emissions	Less than 1 000	Less than 1 000	Nil
Transport	Nil	Nil	10 000
Diesel Engines	Less than 300	Minor	Minor
Reservoir CO_2 Vented	500 000	180 000	Minor
Total	**3 534 000**	**409 000**	**70 000**

Reference Case Assumptions:

- LNG production is sourced equally from the Gorgon and Jansz fields.
- Domestic gas production is sourced from the Gorgon Field.
- Based on 8160 hours (340 days) plant operation per year.
- All power generation gas turbines (including spare) are operated at part load, resulting in an additional 65 000 tonnes per year of emissions over case where spare is on cold standby and online turbines are operated at maximum efficiency.
- 20% of reservoir CO_2 (0.68 MTPA) is vented rather than injected into the Dupuy Formation.
- Waste heat recovery is applied to LNG process drive gas turbines and hot oil used as the waste heat recovery medium.

The greenhouse emissions due to reservoir CO_2 venting shown in Table 13-6 are based on a reference scenario that assumes 20% of the reservoir CO_2 is vented rather than injected. The vented reservoir CO_2 has been allocated between LNG and domestic gas production based on the portion of gas from the Gorgon field used in each facility (26.5% to domestic gas and 73.5% to LNG).

The following sections expand on each of the main greenhouse gas emission sources. For the large emission sources, the basis on which the emissions were calculated or the assumptions used in developing the reference case are outlined.

Gas Turbines – Gas Processing Drivers

The gas turbines to be used in the LNG processing facility will represent 40% of the overall greenhouse gas emissions in the reference case. The level of these emissions is dictated by the liquefaction technology and process configuration selected for the Development which is heavily dependant on three interrelated decisions:

- liquefaction process vendor selection
- liquefaction capacity range
- liquefaction compressor driver selection as either direct drive gas turbines or electric drive motors.

During design selection, LNG process vendors were requested to supply process proposals based on three design cases:

- LNG capacity throughput range for each processing train of four to six million tonnes per annum (MTPA) with direct gas turbine refrigerant compressor drive
- LNG capacity throughput range for each processing train of four to six MTPA with electric motor refrigerant compressor drive
- LNG capacity throughput range of seven to nine MTPA with vendor choice of either direct gas turbine drive or electric drive.

The proposals were evaluated using the following criteria:

- safety hazard risk
- technology risk and contingency levels
- availability and reliability
- greenhouse gas emissions
- economics.

The greenhouse gas emissions per unit of LNG production, the risk profile (a combination of safety hazard, technology risk including construction and operational uncertainties and contingency risk) and the capital cost for each option, were similar for each of the high level process configurations considered.

Liquefied natural gas processing design incorporating direct drive gas turbines with an LNG throughput of approximately 5 MTPA represents established best practice in LNG process design. This configuration is similar to that being applied to the North West Shelf Project for the Train 4 expansion and planned Train 5 expansion. This configuration offers the optimum balance between capital cost, greenhouse emissions efficiency and risk profile.

The designs incorporating either electric drive or higher capacity LNG throughput show a potential for improved greenhouse emissions efficiency of approximately 0.03 tonnes CO_2e per tonne LNG, but at an increased risk profile. This reflects the essentially untested nature of these technologies. The Gorgon Joint Venturers have determined that risk profile associated with these unproved options is not compatible with the risk profile required for the Gorgon Development.

Based on this analysis, the Joint Venturers have selected a proven liquefaction process design based on LNG processing trains utilising gas turbine direct drives; and with a nominal LNG throughput of 5 MTPA for each processing train.

The greenhouse gas emissions estimate for the gas processing drivers provided in Table 13-6 have been calculated using the assumptions contained in Table 13-7.

The greenhouse gas emissions reference case developed for this document assumes that the gas turbines in the LNG processing facility include waste heat recovery to increase the recovered energy from combustion of the fuel gas. This waste heat will be used within the gas processing facility for heating duties, such as that required for the regeneration of the CO_2 removal solvent (accelerated MDEA), regeneration of hydrate inhibitor, feed gas preheating and fractionation.

Gas Turbines – Power Generation

Greenhouse gas emissions from the gas turbines used to generate electrical power for the gas processing facility and support infrastructure represent approximately 40% of the overall reference case greenhouse gas emissions.

Engineering options for the configuration of gas turbines for electrical power generation and the capture and use of waste heat throughout the gas processing facility are currently being studied. The timing for the selection of the final configuration falls after the date of the release of this Draft EIS/ERMP for public review. These issues are closely linked with the liquefaction technology selection and the heat load and power requirements of the facility.

The energy intensive need to remove moderate levels of CO_2 from the incoming gas stream from the Gorgon field dictates that the Gorgon Development will have a high demand for process heat. It is estimated that the thermal energy required by the gas processing facility will be approximately 430 MW. In addition, approximately 270 MW of electrical power will be required to be generated.

A range of options for electrical power generation and waste heat recovery have been developed and are being considered by the Gorgon Joint Venturers. These options will be evaluated using the following criteria:

- safety hazard risk
- capital and operating cost
- availability and reliability
- fuel consumption and resulting greenhouse gas emissions
- land area required to be cleared.

The greenhouse gas emissions reference case is based on the assumption that 270 MW of electrical power will be generated by five industrial gas turbines of approximately 85 MW ISO capacity and operated at partial load. Of the power generation options under consideration, this scenario represents a high emissions case.

Table 13-7:
Gas Processing Drivers – Greenhouse Gas Emissions

Gas Turbines – Gas Processing Drivers	
Number/type of gas turbines	4 x 85 MW industrial gas turbines
Assumed mechanical load – operating condition	4 x 79.8 MW = 319.2 MW
Assumed electrical load	Nil
Assumed heat load	4 x 107 MW = 428 MW
Fuel usage at operating conditions	4 x 894.6 = 3578 GJ/h
Operating time	8160 hours (340 days per year)
Greenhouse gas emissions	1 612 000 tonnes/year
Indicated gas turbine capacity is rated capacity at ISO conditions. Actual output will be approximately 6% lower due to operational conditions on Barrow Island.	

Table 13-8:
Power Generation – Greenhouse Gas Emissions

Gas Turbines – Power Generation	
Number/type of gas turbines	5 x 85 MW industrial gas turbines
Assumed mechanical load	Nil
Assumed electrical load – operating conditions	5 x 53.9 MW = 270 MW
Assumed heat load	Nil
Fuel usage at operating conditions	5 x 686.6 = 3433 GJ/h
Operating time	8160 hours (340 days per year)
Greenhouse gas emissions	1 547 000 tonnes/year
Indicated gas turbine capacity is rated capacity at ISO conditions. Actual maximum available output will be approximately 6% lower due to operational conditions on Barrow Island. While electrical load could be met with four turbines, five operating at part load have been selected to provide redundancy in the event of failure of one of the units.	

The greenhouse gas emissions estimates for the reference case electrical power generation gas turbines provided in Table 13-6 have been calculated using the assumptions contained in Table 13-8.

A Power Generation Study has been commissioned with the engineering design contractor to optimise the power generation configuration. The study will include examining installation of waste heat recovery on the power generation turbines in addition to the LNG process gas turbines and the utilisation of different turbine types including the use of aero-derivative gas turbines.

Fired Heaters

The reference case incorporates the use of fired heaters to provide process heat requirements during start-up, when the waste heat recovery units (on the LNG compression gas turbines) have not reached operating temperature. It is anticipated that the fired heaters will only be required when both LNG processing trains have been shut down. It is likely that only one LNG train would be taken offline at any particular time enabling waste heat from the operational train to be used in place of the fired heaters to start the second train.

Shut-down of both LNG processing trains is not anticipated to occur; however in the reference case, it is assumed that the use of fired heaters to provide process heat during a start-up of both LNG trains will be required once per year. The use of fired heaters in the reference case represents less than 2.5% of the Gorgon Developments greenhouse gas emissions.

Flaring of Gases

The gas processing facility will be designed to avoid routine gas flaring or venting. However, a flare is required to ensure the safe operation of the facility. A continuous purge may be required along with pilots to ensure the safe ignition of the flare. Alternatives which do not require the continuous flow of gas to the flare will be examined during the detailed design. The contribution to the Development's total greenhouse gas emissions from flaring is estimated to be less than 2%.

Uncombusted gases, such as natural gas, have a higher greenhouse gas impact when simply vented rather than combusted. All flammable gases will be combusted at the flare.

The most significant periods of flaring will be during the start-up and shut-down of the LNG processing facility. The ability to reduce the volume of gas flared during plant start-up is limited as the flared gas will not meet the specification for LNG sales and may be outside specification for use as fuel. During a shut-down, it will be necessary to ensure the safety of the gas processing facility by depressurising and flaring either the entire inventory of the gas in the facility, or in the section subject to the shut-down. The development of operating procedures for the facility will consider methods for reducing the amount of flared gas during shut-downs to the minimum possible.

Flaring during commissioning will be minimised by appropriate design and control of commissioning procedures.

As a result of the policy to operate the gas processing facility without routine gas flaring, all low pressure hydrocarbon streams in the facility (including those from the various regeneration processes) will be redirected either to the fuel gas system or back into the process. Compressors and other systems in the LNG process will be designed to start-up, operate continuously and shutdown on full recycle to minimise flaring.

In order to undertake inspections of the feed gas pipelines (those linking the offshore fields with the gas processing facility and the domestic gas pipeline), it may be necessary to de-pressure the pipelines during the life of the Development. Should this need arise, then the pipelines will be depressurised in accordance with approved operational plans such that the quantity of gas flared during pipeline depressurisation for inspection work is minimised.

Fugitive Emissions and Venting of Hydrocarbons

As fugitive emissions represent potential safety or environmental hazards, significant engineering work has focused on ensuring such emissions are kept to a very low level. Fugitive emissions are estimated to represent approximately 0.1% of the total greenhouse gas emissions from the proposed Development.

The main sources of fugitive emissions throughout the gas processing facility will be:

- compressor seal losses
- flanges and fittings
- condensate storage tanks
- seals on stems and valves.

Measures taken to reduce greenhouse gas emissions from fugitive sources include: dry gas seals on compressors; maximum practicable use of welded piping; and the specification of high integrity valves (such as blowdown valves and relief valves), pump seals and joining materials.

All low pressure hydrocarbon vapour streams will be redirected back to the gas processing facility rather than being vented to atmosphere.

Transport

The proposed gas processing facility will require logistic support that would not be required if the facility was located on the mainland. This support will consist of aircraft to mobilise personnel and supply vessels to move equipment and supplies to Barrow Island.

Diesel Engines

There will be emissions from diesel powered equipment such as fire pumps and back-up power generation systems. While this equipment will not operate routinely, it will be tested on a regular basis to ensure operational integrity.

Venting of Reservoir Carbon Dioxide

As described in Chapter 6 (Section 6.2.3), it will be necessary to remove CO_2 and minor traces of H_2S from the reservoir gas stream as one of the first steps in gas processing. The volume of reservoir CO_2 will vary over the operational life of the facility due to the natural variability of the CO_2 content within the Gorgon gas field (the gas from the Jansz field contains very little reservoir CO_2). Some areas of the Gorgon gas field have higher CO_2 concentrations than others. On average, it is anticipated that 3.1 MTPA of reservoir CO_2 will be removed from the incoming gas stream. However the CO_2 removal and injection facilities will be designed to handle a maximum rate of 3.4 MTPA. The reference case, on which the greenhouse gas emissions in this document are estimated, is based on the maximum anticipated rate of 3.4 MTPA of reservoir CO_2 being removed from the incoming gas stream.

It is proposed that reservoir CO_2 extracted from the natural gas stream will be injected into the Dupuy Formation utilising injection equipment sized to handle 3.4 MTPA of CO_2. Under routine operations, all reservoir CO_2 removed from the incoming gas stream will be injected. However, venting of the reservoir CO_2 will be required during commissioning, periods of facility or injection system maintenance, unplanned downtime and in the event of unforeseen reservoir or injection well constraints. While it is anticipated that the amount of reservoir CO_2 vented in any particular 12-month period will be significantly less than 200 000 tonnes CO_2e, there is potential for a higher level of venting, particularly in the event of unexpected injection well failure. As a consequence, the reference case for greenhouse gas emissions used in this document is based on 680 000 tonnes (or 20% of the reservoir CO_2, available for injection) will be vented on an annual basis. The 680 000 tonnes represents an allowance of approximately 5% for maintenance and compressor down time plus an allowance of 15% assuming one of the seven injection wells is offline. This represents a worst-case outcome which is likely to be improved upon during the front end engineering and design phase and with the development of operational procedures. Section 13.5 outlines the management measures that are planned to ultimately reduce the percentage of reservoir CO_2 vented to a level below the 20% used in the reference case.

The anticipated volumes of reservoir CO_2 that will be vented along with the volumes anticipated to be injected are identified in Table 13-9. These volumes are expected to decline over time as the facility operation and CO_2 injection are optimised.

The anticipated scenarios that may result in venting of reservoir CO_2 are discussed below.

Venting Due to Maintenance

The combined time when the CO_2 injection facilities are offline for scheduled, or unscheduled, maintenance is anticipated to be less than 30-days per year. This is based on typical maintenance data from the LNG and gas processing industry. The Joint Venturers will minimise the scheduled downtime that results in venting by scheduling the injection facility maintenance to coincide as much as practical with scheduled maintenance of other equipment (within the constraints of LNG and domestic gas production commitments).

Venting Due to Unforeseen Reservoir Constraints

In designing the CO_2 injection system, the number and type of CO_2 injection wells is dependent upon the reservoir properties expected in the Dupuy Formation. The Gorgon Joint Venturers have a high level of understanding of the Dupuy Formation and the anticipated behaviour of the CO_2 once injected into the reservoir but an element of uncertainty remains about the exact nature and performance of the injection wells and the reservoir in proximity to the injection wells.

The Joint Venturers have incorporated the best current understanding of the reservoir and the CO_2 behaviour in the reservoir into estimates of well injectivity. However, it is possible that a particular well might fail to deliver the injectivity expected either at the commencement of injection operations or in the first few years of injection. The failure of a well to deliver the expected injection rates could result from a number of causes. These include intersecting a poorer quality reservoir than expected, plugging of the formation in the area around the well bore, or failure of the hardware within the well bore. All of these situations are encountered in the conventional oil and gas field

Table 13-9:
Volumes of Reservoir CO_2 Anticipated to be Vented and Injected

Percentage of Reservoir CO_2	Year 1	Year 2–5	Year 6+	Long Run Performance Target
Percentage of Reservoir CO_2 injected into the Dupuy Formation	60–90% (2.04–3.06 MTPA)	70–95% (2.38–3.23 MTPA)	80–95% (2.72–3.23 MTPA)	95% (3.23 MTPA)
Vented due to scheduled maintenance and unplanned facilities downtime	5–15% (0.17–0.51 MTPA)	5–10% (0.17–0.34 MTPA)	3–5% (0.10–0.17 MTPA)	3% (0.10 MTPA)
Vented due to unforeseen reservoir constraints (including well injectivity failure)	0–25% (0–0.85 MTPA)	0–20% (0–0.68 MTPA)	0–15% (0–0.51 MTPA)	2% (0.06 MTPA)
As the concentration of CO_2 varies in different parts of the Gorgon field, these figures represent the maximum anticipated rate of 3.4 MTPA of reservoir CO_2. Average rate over life of the Gorgon Development is 3.1 MTPA.				

environment and all can be remedied through working over the well, stimulating the formation, or in extreme cases, drilling a new well. Planning, procurement and implementation of remediation activities for a particular well may take up to 12 months, partially as a result of the remoteness of Barrow Island and the requirement for quarantine management.

It is anticipated that as experience is gained with CO_2 injection into the Dupuy Formation, the ability to predict well and reservoir performance will also improve. Over time, the amount of CO_2 vented, due to well bore or reservoir performance issues is anticipated to decrease.

The Joint Venturers are continuing to undertake a range of activities during the detailed design phase the Development, including drilling a data well. The aim of these activities is to reduce reservoir uncertainty such that the probability of having to vent reservoir CO_2 is minimised.

13.3.5 Greenhouse Gas Emissions during Decommissioning

Estimates of greenhouse gas emissions for the decommissioning of facilities and the rehabilitation of disturbed sites has not been undertaken. A number of the activities such as the removal of the subsea production system or the decommissioning of the facility on Barrow Island will potentially involve similar emissions to their installation, whereas emissions related to the offshore drilling operations and plant commissioning will be substantially reduced. Likely emissions during decommissioning are presented in Table 13-10. These estimates are based on the assumption that offshore pipelines will be left in place following decommissioning.

13.3.6 Benchmarked Greenhouse Gas Emission Performance

Benchmark data for comparing the greenhouse gas emissions efficiency of the proposed Development is not widely published. The data that is available is restricted to the efficiency of LNG processing. The volume of greenhouse gas emissions emitted to the atmosphere for each tonne of LNG produced provides a recognised benchmark by which to assess the greenhouse emissions intensity of an LNG plant. However, the metric is not a direct reflection of the thermal efficiency of the LNG plant as it is influenced by:

- the composition of the incoming gas stream, particularly the concentration of reservoir CO_2 and nitrogen, as well as the level of ethane, propane, butanes and pentanes
- the ambient temperature in which the gas plant operates
- the energy used to inject reservoir CO_2, if it is to be injected
- the degree to which greenhouse gas emissions from supporting infrastructure have been included in the calculation.

The Gorgon Joint Venturers have not been able to benchmark the greenhouse gas efficiency of the domestic gas component of the gas processing facility as comparable data is not widely available in the public domain.

LNG processing efficiency data often does not represent the full suite of greenhouse gas emissions for a particular development as it does not include emissions from the gas production facilities. For example, many LNG developments are supplied with

Table 13-10:
Greenhouse Gas Emissions During Decommissioning

Decommissioning and Rehabilitation Activity	Estimated Greenhouse Gas Emissions (tonnes CO_2e)
Decommissioning of offshore wells (fuel consumption)	75 000–100 000
MSV to remove subsea production system and umbilicals	45 000
Electrical power generation on Barrow Island	75 000–95 000
Mobile equipment and vehicle usage on Barrow Island	25 000
Total estimated greenhouse gas emissions related to decommissioning and rehabilitation activities	**220 000–265 000 tonnes**
The emissions stated in this table should be considered as order of magnitude estimates	

gas produced from offshore gas processing platforms. The greenhouse gas emissions from these platforms are generally not included in the LNG efficiency benchmark.

The ability to estimate greenhouse emissions related to the initial gas production is prevented by many of these gas production facilities having more than one function. For example, in Australia the offshore gas platforms supplying gas to the North West Shelf and Darwin LNG Projects also undertake liquids stripping operations, whereby gas is produced from the field, the liquid hydrocarbons removed and the natural gas re-injected back into the reservoir. The North West Shelf gas platforms also produce a significant volume of gas for use in the domestic gas market.

Where gas is produced using a subsea production system, the LNG processing efficiency represents the efficiency of the overall LNG development as gas production from subsea production systems results in essentially no greenhouse gas emissions. In the following benchmarking discussion only the Gorgon and Snohvit Developments are designed around an all-subsea production system.

In order to make a meaningful comparison of overall greenhouse efficiency, an estimate of likely greenhouse gas emissions associated with gas production from the published benchmarked projects has been made. Previous proposals to develop the Gorgon field incorporated the use of an offshore gas production platform. The annual greenhouse gas emissions associated with this platform were estimated at approximately 600 000 tonnes CO_2e per annum, while supplying enough gas for the production of 8 MTPA LNG (WAPET 1998). This equates to an incremental 0.075 tonnes of CO_2e per tonne of LNG. This incremental emission performance has been applied to the LNG plant benchmarking data except for the Gorgon and Snohvit Developments.

The greenhouse efficiency of the LNG component of the reference case for the Gorgon Development is 0.353 tonnes of CO_2e per tonne LNG. This efficiency includes all emissions related to the production of the natural gas from the offshore fields, the energy required to inject reservoir CO_2 and the volume of reservoir CO_2 vented. As such, it represents the greenhouse efficiency of the overall LNG component of the proposed Development, not just the manufacture of LNG.

The greenhouse efficiency data from the Gorgon Development has been compared with data from the:

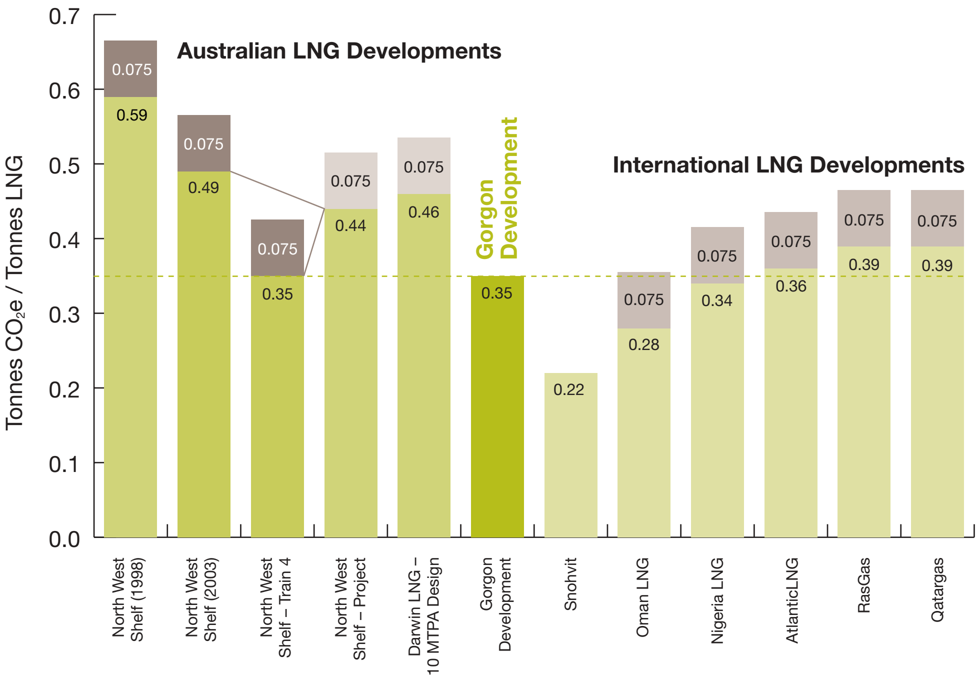
- North West Shelf Project
- Darwin LNG Project (under construction)
- Snohvit – Hammerfest, Norway (under construction)
- Oman LNG – Qalhat, Oman
- Nigeria LNG – Bonny Island, Nigeria
- RasGas – Ras Laffan, Qatar
- Qatargas – Ras Laffan, Qatar
- Atlantic LNG – Point Fortin, Trinidad and Tobago.

Figure 13-7 shows the LNG greenhouse gas emissions efficiency of the Gorgon Development benchmarked against these other LNG projects. The LNG efficiency includes emissions of reservoir CO_2 where these are vented to the atmosphere.

The North West Shelf LNG facility (Woodside 2004) has seen its greenhouse emissions efficiency for LNG production improve from 0.59 to 0.49 tonnes of CO_2e per tonne LNG for the initial three processing trains. This was due to process improvements and de-bottlenecking the process trains once commissioned. The recently commissioned Train 4 expansion and possible Train 5 are reported to have an efficiency of 0.345 tonnes of CO_2e per tonne LNG reflecting efficiency improvements related to the increased size of the process trains. This gives the current North West Shelf LNG processing facility a greenhouse emissions efficiency of 0.44 tonnes of CO_2e per tonne LNG (based on production from Trains 1, 2, 3 and 4). The feed gas supplying the North West Shelf LNG facility includes approximately 2.5% reservoir CO_2 which, once removed from the gas stream, is vented to the atmosphere and is included in the calculation of greenhouse efficiency. The benchmark numbers above exclude greenhouse gas emissions from the offshore gas production platforms required to produce the gas into the LNG processing facility.

ConocoPhillips is currently constructing an LNG facility in Darwin which will process gas from the Bayu-Undan and other gas developments in the Timor Sea. ConocoPhillips estimates that the Darwin LNG facility will have a greenhouse efficiency of 0.46 tonnes of CO_2e per tonne of LNG to be produced (ConocoPhillips 2002). The feed gas supplying the Darwin LNG facility includes approximately 6.0%

Figure 13-7:
Benchmarked Greenhouse Gas Efficiency



reservoir CO_2 which, once removed from the gas stream, will be vented to the atmosphere and is included in the calculation of the Darwin LNG Project's greenhouse efficiency. The greenhouse efficiency numbers stated above exclude the greenhouse gas emissions from the offshore gas processing platform required to produce the gas.

Statoil are currently constructing the Snohvit LNG development near the town of Hammerfest in northern Norway. Snohvit comprises a subsea development of an offshore gas field, LNG manufacturing onshore and the re-injection of CO_2 contained in the reservoir gas. The feed gas supplying the Snohvit development will include approximately 8.0% reservoir CO_2. The data published for Snohvit is based on the assumption that all reservoir CO_2 will be injected into the subsurface.

The Oil and Gas Journal has published benchmark data on five recent greenfield LNG developments: Oman LNG, Nigeria LNG, RasGas, Qatargas and Atlantic LNG (Yost and DiNapoli 2003). These LNG facilities have all been commissioned in the last five years and as such represent current design practice. All were commissioned as greenfield developments rather than as expansions to existing LNG projects. The reservoir CO_2 content in the feed gas supplying these developments is:

- Oman LNG – 1.0 mole %
- Nigeria LNG – 1.8 mole %
- RasGas – 2.3 mole %
- Qatargas – 2.1 mole %
- Atlantic LNG – 0.8 mole %.

The venting of the reservoir CO_2 from these projects is included in the calculation of their greenhouse gas efficiency.

Comparison to the Gorgon Development

This benchmarking analysis shows that the Gorgon Development will be amongst the most greenhouse efficient LNG developments in the world, particularly when emissions related to the initial gas production are considered. Based on this data, only Oman LNG and Snohvit have appreciably better LNG greenhouse gas efficiency. The benchmark data show that the Gorgon Development reference case greenhouse gas emissions are comparable to those from the North West Shelf Train 4 and proposed Train 5 expansion.

In comparison to Oman LNG, the Gorgon Development must remove a greater proportion of reservoir CO_2 from the incoming feed gas. The increased electrical power required to operate the larger Gorgon Development acid gas removal plant is estimated at 10 MW. The increased heat load associated with the larger acid gas removal plant has not been considered in this calculation as it is supplied by the waste heat recovery system.

The reference case greenhouse gas emissions include 500 000 tonnes per year of reservoir CO_2 that is assumed to be vented and 270 000 tonnes of CO_2e per year associated with operating the CO_2 compressors and pumps. If the Gorgon Development had the same gas composition as Oman LNG, the benchmarked greenhouse efficiency for Gorgon would reduce to 0.27 tonnes CO_2e per tonne LNG.

A calculation enabling the Gorgon Development greenhouse emissions benchmark to be compared with Oman LNG is provided in Table 13-11.

The Shohvit LNG development is currently being constructed in the Barents Sea and will potentially be the most greenhouse efficient LNG plant in the world. Shohvit will have less than half (4.1 MTPA LNG) the gas processing capacity of the Gorgon Development but shares a similar approach to the management of greenhouse gases. Both developments are based around a subsea gas production system and both propose to significantly reduce greenhouse gas emissions by the subsurface injection of reservoir CO_2. Data on the Snohvit development is available from www.snohvit.com/STATOILCOM/snohvit.

Snohvit is being constructed using aero-derivates gas turbines for power generation. Unlike the Gorgon Development, no spare electrical generation capacity will be installed, with redundancy being provided by a connection with the local electricity grid. If the Gorgon Development was able to rely upon a local grid connection to provide redundant electrical power, then the power generation turbines could be operated more efficiently saving 65 000 tonnes CO_2e per year.

The climate in which Snohvit will operate is very different from that of the Gorgon Development, as it is located above the artic circle. Average temperatures in the area where Snohvit will operate are approximately 0ºC compared to the design case for the Gorgon Development of 26ºC. This colder ambient temperature results in both the gas turbines and the LNG process working more efficiently. For every one degree reduction in ambient operating temperature LNG process capacity is increased by 0.6%. Assuming the same LNG plant configuration, if the Gorgon Development was operating in a similar climate to Snohvit, annual LNG production would lift from 10 MTPA to 11.56 MTPA. This would improve the benchmarked greenhouse gas efficiency by 0.047 tonne CO_2e per tonne LNG.

While the joint venturers of both the Snohvit and Gorgon Developments plan to inject reservoir CO_2 the reference case for Gorgon Development greenhouse gas emissions efficiency assumes that 500 000 tonnes of reservoir CO_2 will be vented each year. In order to compare the underlying LNG plant efficiency between these developments, the emissions associated with the venting of reservoir CO_2 have been removed.

Table 13-11:
Benchmark Comparison to Oman LNG

	Tonnes CO_2e per tonne LNG
Gorgon Development LNG Benchmark	0.353
Less power to acid gas removal plant	0.006 (10 MW = 127 GJ/h = 58 000 tonnes CO_2e/year)
Less reservoir CO_2 vented	0.05
Less power to run CO_2 compressors	0.027 (47.3 MW = 603 GJ/h = 270 000 tonnes CO_2e/year)
Gorgon Development LNG benchmark, assuming field gas has same CO_2 content as Oman	0.27
Oman LNG benchmarked greenhouse efficiency	0.28
Note: Above calculations do not include the reduction in process heat associated with CO_2 removal from the gas stream. Process heat required for CO_2 removal in the acid gas removal plants is provided from waste heat recovery system. This scenario assumes that less waste heat is recovered.	

A calculation enabling the Gorgon Development greenhouse emissions benchmark to be compared with Snohvit is provided in Table 13-12.

The similarity in greenhouse gas emissions efficiency between the Gorgon Development and North West Shelf Train 4 (and planned Train 5) is testament to the appropriate balance being reached between capital cost, greenhouse emissions efficiency and risk profile as discussed in Section 13.3.4. The liquefaction process adopted by both the Gorgon Development and the North West Shelf Train 4, while deploying particular features from their respective LNG Licensors, is very similar.

As indicated above, the reservoir CO_2 content differs between the Gorgon Development and the North West Shelf Project and this underlies the main variation in the energy configuration (both electrical, heat and mechanical drive) adopted for each project. North West Shelf Train 4 has a relatively small electrical and heat requirement and has selected aero-derivative gas turbines (without waste heat recovery) as the appropriate choice for electrical power generation. The Gorgon Development has a high heat requirement due to both the level of reservoir CO_2 and the use of a subsea gas production system making waste heat recovery a paramount consideration. As a consequence, the Gorgon Joint Venturers have elected to maximise waste heat recovery from industrial type gas turbine generators.

13.4 Disposal of Reservoir Carbon Dioxide by Injection into the Dupuy Formation

The opportunity to reduce greenhouse emissions by the subsurface injection of CO_2 is relatively new; however the technologies to be applied by the Gorgon Joint Venturers are well established in the oil and gas industry and are being used to inject CO_2 in other parts of the world (Box 13-2). In addition there are a number of research programs looking into the application of injection of CO_2 into the subsurface as a means to reduce atmospheric greenhouse gas emissions (Box 13-3).

In order to ensure that the community remains well informed about the performance of the CO_2 injection project, the Gorgon Joint Venturers undertake to make information available to the public with regard to the ongoing monitoring program.

The reference to reservoir CO_2 throughout this Draft EIS/ERMP refers to the gas stream coming from the acid gas removal plant and being available for injection into the Dupuy Formation. This reservoir CO_2 stream will contain impurities such as hydrogen sulphide (200 ppm), methane (typically between 0.2% and 0.5%) and traces of benzene, toluene, etheylbenzene and xylene, together referred to as BTEX (generally less than 0.5 mol%). The level of BTEX in the reservoir CO_2 may be reduced during the detailed design phase. These impurities are expected to behave in much the same way as the CO_2 once injected. For simplicity the reference to reservoir CO_2 includes these other gases.

Table 13-12:
Benchmark Comparison to Snohvit

	Tonnes CO_2e per tonne LNG
Gorgon Development LNG Benchmark	0.353
Less emissions related to stand by power generation	0.0065 (65 000 tonnes CO_2e/year)
Efficiency improvement due to lower ambient operating temperature	0.047 (LNG throughput increased from 10 MTPA to 11.56 MTPA)
Less Gorgon Development reservoir CO_2 vented	0.05
Gorgon Development LNG Benchmark, assuming no standby power generation, no CO_2 venting and operations in cold ambient conditions	0.25
Snohvit benchmarked greenhouse efficiency	0.22

Box 13-2:
Worldwide Experience with Carbon Dioxide Injection

The disposal of reservoir CO_2 by injection into the Dupuy Formation, as proposed by the Gorgon Joint Venturers, will be one of only a few such projects worldwide. However, the concept of injection of fluids into a subsurface formation for enhanced oil recovery, gas storage and acid gas disposal is well accepted throughout the world and has a long history of successful operation.

The Joint Venturers have experience in other parts of the world in operating systems designed to inject mixtures of CO_2 and hydrogen sulphide into subsurface formations. Chevron's Acheson Field in Canada was one of the first to use this technique, referred to as 'acid gas injection', to dispose of hydrogen sulphide and CO_2 separated from a natural gas stream. Prior to this, these gases were vented or flared to the atmosphere. Acid gas injection typically involves compressing the mixed gas, dehydrating the gas and injecting it into a saline formation other than the oil or gas field. Chevron's Canadian subsidiaries have successfully operated four such acid gas injection projects since 1990, with 21 years of cumulative experience. The CO_2 content in the injected gas is up to 88 mol%. Acid gas injection is now commonly undertaken where gas fields have high concentrations of hydrogen sulphide.

The Gorgon Joint Venturers also have extensive experience in the design, construction and successful operation of enhanced oil recovery projects involving injection of substantial volumes of CO_2 into the oil-producing formations. The CO_2 acts to reduce the viscosity of the oil allowing it to flow into the production wells with greater ease.

Chevron's largest current CO_2 injection operation is the Rangely Weber Sand Unit in western Colorado, of the USA. Rangely is the largest oilfield in the US Rocky Mountain area and is the third largest CO_2 enhanced oil recovery operation in the world. Injection of CO_2 for enhanced recovery began in 1986. About three million tonnes of CO_2 per annum are injected into sandstone formations at a depth of about 1800 m. The CO_2 is compressed, dehydrated, then injected using a network of wells. The CO_2 supply for this enhanced oil recovery project is transported to Rangely via a CO_2 pipeline, built and operated by Chevron.

Chevron's North American exploration and production company currently operates six CO_2 injection projects. In addition, Chevron has a working interest in 11 non-operated CO_2 injection projects, two of which are the world's largest – the Seminole Unit and the Denver Unit.

Both Shell and ExxonMobil have experience in the operation of CO_2 injection based on enhanced oil recovery projects.

ExxonMobil is a joint venture partner in Sleipner, a large scale CO_2 injection project currently operating in the Norwegian sector of the North Sea. One million tonnes of CO_2 per annum have been injected at Sleipner since 1996.

Since the publication of the ESE Review (ChevronTexaco Australia 2003) the basis of design has been revised to include the development of the Jansz field (refer to Chapter 1). The reference case used for determining the volumes of reservoir CO_2 in this Draft EIS/ERMP is for the LNG processing trains to be sourced equally from the Gorgon and Jansz gas fields and for domestic gas to be supplied from the Gorgon field. As a consequence of the reduced CO_2 content in the Jansz field, the volume of reservoir CO_2 as a proportion of plant throughput has been reduced resulting in the injection of between 2.7–3.2 million tonnes of reservoir CO_2 per annum. Information on the gas compositions from both the Gorgon and Jansz fields is provided in Chapter 6 (Section 6.1.1).

13.4.1 Assessment of Potential Carbon Dioxide Injection Sites

The Gorgon Joint Venturers have undertaken a number of studies since 1992 to identify a suitable site to dispose of reservoir CO_2 by injection into subsurface formations. The region considered is shown in Figure 13-8.

Sites considered for CO_2 injection included saline reservoirs, depleted oil and gas fields and other formations that satisfy appropriate selection criteria. The Gorgon Joint Venturers' selection criteria include:

- the availability of subsurface data over the site
- the top of the injection target at least 800 m below the surface. At this depth the CO_2 will remain in a

Box 13-3:
Research into Carbon Dioxide Injection

Research is currently being conducted around the world to investigate the viability of subsurface injection of CO_2 to reduce greenhouse gas emissions. The four primary goals of research into CO_2 injection are to:

- lower the cost of injection and ensure reservoir integrity
- demonstrate environmental acceptability
- understand the behaviour of injected CO_2 and gain assurance on its predictability
- develop reliable monitoring and verification technology for CO_2 injection.

The Gorgon Joint Venturers are actively involved in several research and demonstration programs, participation in which has already contributed to the planning of the reservoir CO_2 injection below Barrow Island. These programs are:

- GEODISC
- Cooperative Research Centre of Greenhouse Gas Technologies (CO2CRC)
- CO_2 Capture Project
- Stanford University Global Climate and Energy Project (GCEP)
- Weyburn Project
- GEO-SEQ
- Saline Aquifer CO_2 Storage Project (SACS).

GEODISC was a program undertaken by the Australian Petroleum Cooperative Research Centre and was designed to address key technical, commercial and environmental issues associated with the injection of CO_2 in Australia. A key deliverable of this work was a high level assessment of potential CO_2 injection locations within Australia. The Research Centre has now closed with the work of the GEODISC program being continued and expanded by the CO2CRC. Information on the GEODISC program can be found at www.apcrc.com.au/Programs/geodisc_res.html.

The CO2CRC has continued the work commenced by the GEODISC program with the aim of further developing the CO_2 capture and storage technologies. A key component of the activities of the CO2CRC will be the operation of a number of demonstration CO_2 injection pilot projects. Information on the CO2CRC can be accessed at www.co2crc.com.au. The Gorgon Joint Venturers plan to maximise the transfer of knowledge between the Gorgon Development and the CO2CRC programs to assist in establishing Australia as a leader in CO_2 injection.

The CO_2 Capture Project is a major international collaboration aimed at reducing the cost of capturing CO_2 from combustion sources and developing methods for safely storing the CO_2 underground. Key work activities of the CO_2 Capture Project involve technology development of the injection and monitoring of CO_2 and work on the area of policy development dealing with CO_2 capture and storage. Information on the CO_2 Capture Project can be accessed at www.co2captureproject.com.

The Stanford University Global Energy Project (GCEP) is a long-term collaborative effort of the scientific and engineering community in universities, research institutions and private industry with the purpose of conducting fundamental pre-commercial research and to foster the development of global energy technologies (including CO_2 Capture and Storage) with significantly reduced greenhouse gas emissions. Information on GCEP can be accessed at http://gcep.stanford.edu/.

The Weyburn Project is utilising a major CO_2 enhanced oil recovery project in Canada to assist in understanding the behaviour of the CO_2 in the subsurface and to demonstrate potential monitoring activities. Information on the Weyburn Project can be accessed at www.ieagreen.org.uk/weyburn.htm.

GEO-SEQ is a public-private research and development partnership aiming to deliver the technology and information needed to enable the application of safe and cost effective methods of CO_2 injection. Information on GEO-SEQ can be accessed at esd.lbl.gov/GEOSEQ.

The SACS consortium was established to monitor the injection of CO_2 at the Sleipner gas field in the Norwegian North Sea. Information on the SACS consortium and the Sleipner CO_2 injection project can be accessed at www.ieagreen.org.uk/sacshome.htm.

dense state maximising the storage capacity of the reservoir to contain the CO_2

- a low risk of the CO_2 being able to migrate out of the reservoir
- a reservoir of sufficient permeability to handle the injection rates
- a reservoir of sufficient capacity to accept the volume of CO_2 being injected without build-up of pressure to a point where the integrity of the reservoir seals might be compromised
- close proximity to the CO_2 source to minimise risks related to transportation and energy required to transport the CO_2.

The existence of a well-defined geometric trap and high quality reservoir is not mandatory provided that CO_2 movement through the reservoir will be tortuous enough to ensure that the CO_2 is permanently immobilised before it can migrate to locations where its presence might be undesirable. In the absence of a well-defined geometric trap, a clear migration pathway and understanding of the rate of migration should be demonstrated to allow the ultimate containment of the CO_2 to be predicted.

Within the area of interest 17 sites were initially considered as candidates for CO_2 injection. Seven of these areas were quickly determined to be unsuitable and were eliminated from further consideration. These included:

- Exmouth area
- Barrow Island – Windalia Sandstone Member
- Wandoo area
- Barrow Group offshore
- Montebello Islands
- Burrup Peninsula area
- North Rankin.

These locations were excluded from further consideration due to a combination of reasons including risk to currently producing oil or gas fields, distance from potential gas processing facilities sites, and a lack of suitable CO_2 injection reservoirs.

This preliminary assessment left a total of nine locations to be evaluated in more detail as potential sites for CO_2 injection. Table 13-13 outlines the major advantages and disadvantages for each of this short list of locations and provides comments on their suitability.

The West Tryal Rocks and Gorgon gas fields represent ideal sites to inject reservoir CO_2 due to the presence of proven geometric traps and therefore a low technical risk of unpredicted migration to the surface. However the hydrocarbon in these fields would have to be depleted prior to the sites being available for CO_2 injection.

The Barrow Island Dupuy Formation has a number of attributes that make it a preferred location for

Figure 13-8:
Region of Investigation for CO_2 Disposal Sites

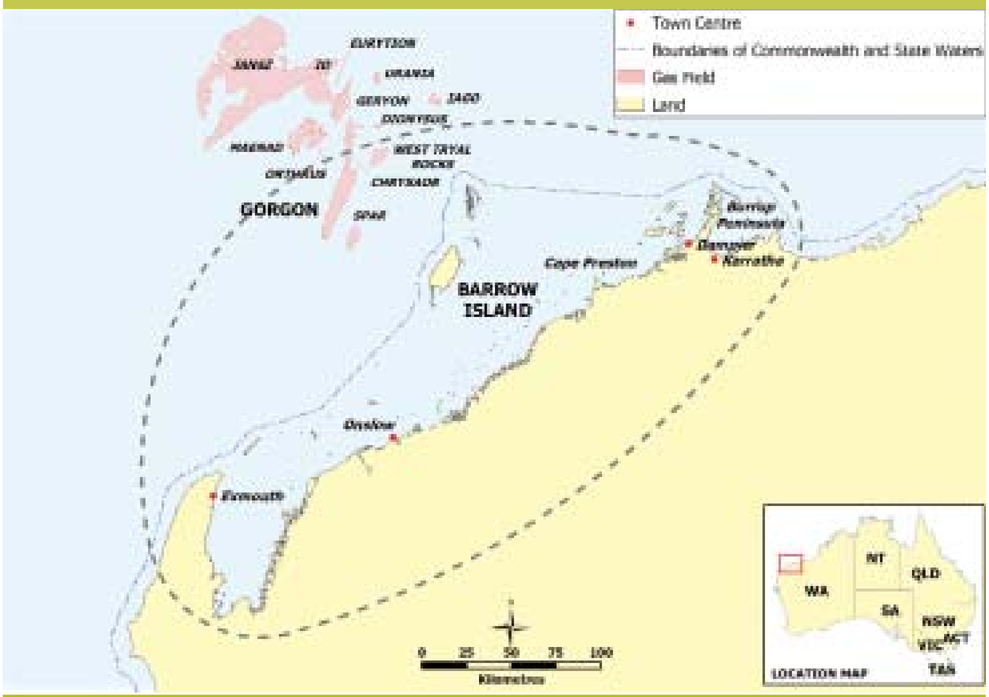


Table 13-13:
Potential CO_2 Injection Locations

Location	Approximate Distance to Plant Site (km)	Capacity to Accept Anticipated CO_2 Volumes	Risk to Potential Hydrocarbon Production	Cost	Comments
West Tryal Rocks	75 km	Yes	Yes (gas)	Very High	Would not be available until the field was depleted.
North Gorgon	75 km	Yes	Yes (gas)	Very High	Would not be available until the field was depleted.
South Gorgon	75 km	Yes	Yes (gas)	Very High	Would not be available until the field was depleted.
Spar	60 km	No	Yes (gas)	Very High	Insufficient capacity.
Barrow Island Dupuy Formation	**2–5 km**	**Yes**	**Minimal**	**Medium**	**Barrow Fault is known to be sealed at the Windalia Sandstone Member (reservoir for Barrow Island oilfield) but could pose a migration path risk if Dupuy formation reservoir pressure increase is excessive.** **Greater depth favours the Dupuy Formation over the shallower Flacourt and Malouet Formations of the Barrow Group.**
Barrow Island, Flacourt and Malouet Formations of the Barrow Group	2–5 km	Yes	Minimal	Medium	Possible targets, though considered less favourable than the Dupuy Formation because shallower and exhibits greater dip northwards. Barrow Fault is known to be sealed at the Windalia Sandstone Member (reservoir for Barrow Island oilfield) but could pose a migration risk if Flacourt or Malouet Formation pressure increase is excessive.
Kennedy Group Sands	45–70 km	Yes	No	Very High	High degree of uncertainty due to limited data. Significant cost to obtain sufficient data. Further data may show that the reservoir is not suitable.
Harriet – Campbell Group of Fields	35 km	No	Yes (oil and gas)	High	Insufficient capacity. Would not be available until the fields were depleted.
Saladin (Thevenard Island)	90 km	No	Yes (oil and gas)	High	Insufficient capacity.

Source: ESE Review (ChevronTexaco Australia 2003)

CO_2 injection and it would be available as soon as production commences from the Gorgon Development. The additional attributes that make the Dupuy Formation the preferred option include:

- the depth of the Dupuy Formation allows the CO_2 to remain in a supercritical phase
- the reservoir properties of the Dupuy Formation provide effective trapping of the injected CO_2
- the structure of the Dupuy Formation provides predictable migration pathways
- there is little potential to jeopardise current or future production of hydrocarbons
- injection wells that penetrate into the Dupuy Formation would allow access to other saline reservoirs (Flacourt and Malouet Formations) as mitigation/upside options
- the Dupuy Formation can be accessed from onshore and close to the source of CO_2, removing the need for subsea wells and offshore platforms and thereby reducing risk and cost
- 2-D and 3-D seismic data and stratigraphic information from 27 wells provide a comprehensive data set on which to base technical studies.

13.4.2 Location of Carbon Dioxide Injection on Barrow Island

The Gorgon Joint Venturers have undertaken a detailed study to identify the optimum location for the injection of CO_2 into the Dupuy Formation. A total of seven different injection scenarios around Barrow Island were evaluated before the preferred location was selected. The alternative injection scenarios evaluated were:

- Central East Coast Onshore
- Central West Coast Onshore
- Northern Onshore
- Western Offshore
- Eastern Offshore
- Northern Offshore
- Combined East and West Central Onshore.

Issues considered in the selection of the preferred location include:

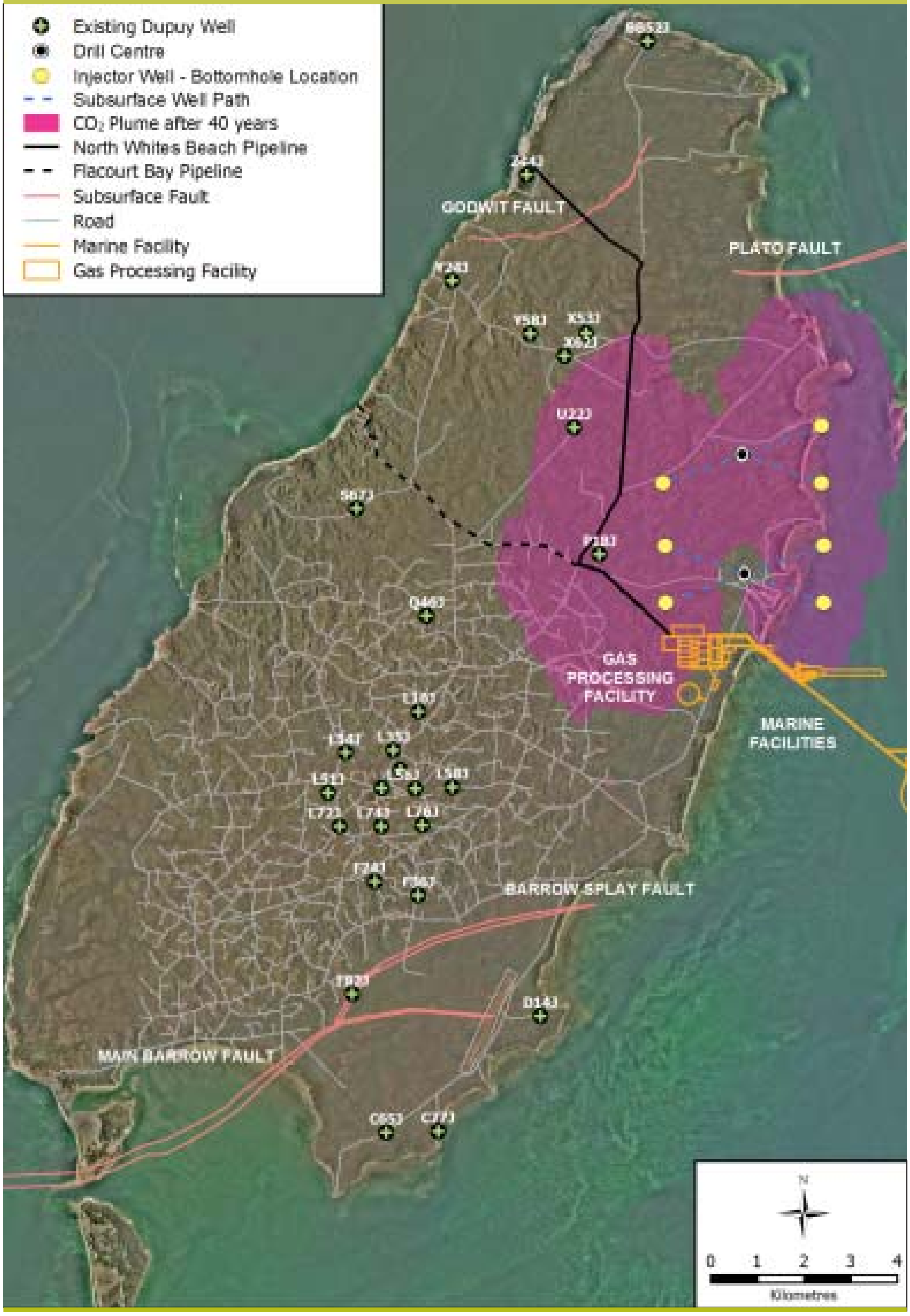
- maximising the distance of the injection wells from the major faults thereby reducing the risk of unpredicted migration
- minimising the area required to be cleared for the facilities on Barrow Island
- ensuring any areas to be cleared are of lower environmental sensitivity when compared to other proposed locations on Barrow Island
- identifying sites where the Dupuy Formation reservoirs is at, or near, its maximum thickness
- minimising the number of existing wells that will be intersected by the migrating CO_2 plume
- a preference for areas of fair to good seismic data quality so as to assist in the monitoring of the CO_2 plume.

The preferred location for CO_2 injection is on the central eastern coast of Barrow Island in the general location of the proposed gas processing facility. This site was selected so as to maximise the migration distance from the major faults while limiting environmental disturbance to areas around the proposed gas processing facility. The number of injection wells will be confirmed following further technical studies during 2005. For this Draft EIS/ERMP it is assumed that seven injection wells will be required. The wells are planned to be directionally drilled from two or three surface locations to minimise the area of land required for the well sites, surface facilities, pipelines and access roads. The CO_2 injection development concept is shown schematically in Figure 13-9. It is likely that an observation well (or wells) will be drilled from each cluster of injection wells to provide a sample point within the area of injection.

Faults which can be mapped from seismic and well data are known areas of disruption to the stratigraphy and therefore represent added risks to the containment capacity of an area. As such, they are areas to be avoided in planning the location of injection wells: firstly, to avoid the physical migration of the CO_2 plume to the fault; and secondly, to minimise the pressure increase within the injection zone at the fault.

The north onshore and western offshore sites were discounted as both provided similar technical risk and both are in areas of higher environmental significance than the preferred location.

Figure 13-9:
CO_2 Injection Development Concept



Box 13-4:
Geological Data

Rock samples can be obtained from surface rock outcrops, from conventional core, side wall cores and drill cuttings and provide information on the subsurface geology. Cores are cylinders of rock cut during the drilling process. Cores generally provide undisturbed samples of the rock and are considered to be the highest quality, direct physical data available. However, cores are expensive to acquire. Additional rock samples are obtained from drill cuttings brought to the surface as the well is being drilled and from sidewall cores which are acquired once drilling has ended.

Wireline logs are recorded in wells and measure the electrical, physical and radioactivity properties of the rocks and their contained fluids. Wireline logs provide only indirect information but when tied carefully to information from drilling samples and core, yield an accurate picture of the rock sequence and provide a convenient graphical basis for comparing well information.

Seismic surveys are usually acquired as either two dimensional (2-D) or three dimensional (3-D) surveys. The result of a 2-D seismic survey is a series of two dimensional displays which show the underground rock structure, much as it can be seen in a road cutting. 3-D seismic is based on a much larger data set which provides a three-dimensional view of the underground structure. Both 2-D and 3-D surveys can be reacquired over time (time lapse seismic) to provide an illustration of how the fluids in the subsurface have migrated. The ability to compare and contrast seismic images over time allows subtle changes in the formation fluids to be detected. These technologies are frequently employed in the oil and gas industry to assist in the management of oil and gas field operations and are likely to be used to assist in monitoring of the CO_2 plume.

Other sites were discounted due to the predicted absence of the lower Dupuy Formation sands, lack of well control and known areas of poor seismic quality. The central west coast location is considered an area which might provide an area for supplementary injection in the event that injectivity proves to be inadequate at the preferred location.

The extent of the CO_2 plume migration at year 1, 5, 40 and 1000, based on the reservoir simulation for the proposed injection scenario is shown in Figure 13-10. The contours on this figure represent the depth of the top of the Dupuy Formation below sea level.

13.4.3 Geology of Barrow Island

The Gorgon Joint Venturers’ understanding of the geology of the Barrow Island area is based on extensive rock samples obtained during drilling, well logs and seismic or other geophysical data collected over more than 40 years of petroleum exploration and production. A description of some of the common methods used to obtain geologic data is contained in Box 13-4.

The geological description outlined in this section summarises the results of oil and gas exploration on and around Barrow Island. Over 900 wells have been drilled on Barrow Island with approximately 700 of these wells being drilled into the oil accumulation in the Windalia Sandstone Member at a depth of around 650 m. Approximately 50 wells have been drilled into the Barrow Group and 27 of those wells have penetrated the full thickness of the Barrow Group and reached the Dupuy Formation or sands within the underlying Dingo Claystone. Figure 13-11 shows the location of these deeper wells on Barrow Island.

Porosity is a measure of the void or pore space between the grains in a rock. Normally these pore spaces contain saline water (formation water) and occasionally oil or gas. It is into these pore spaces that the CO_2 will be injected.

Figure 13-10:
Extent of CO_2 Plume Migration Over 1000 years

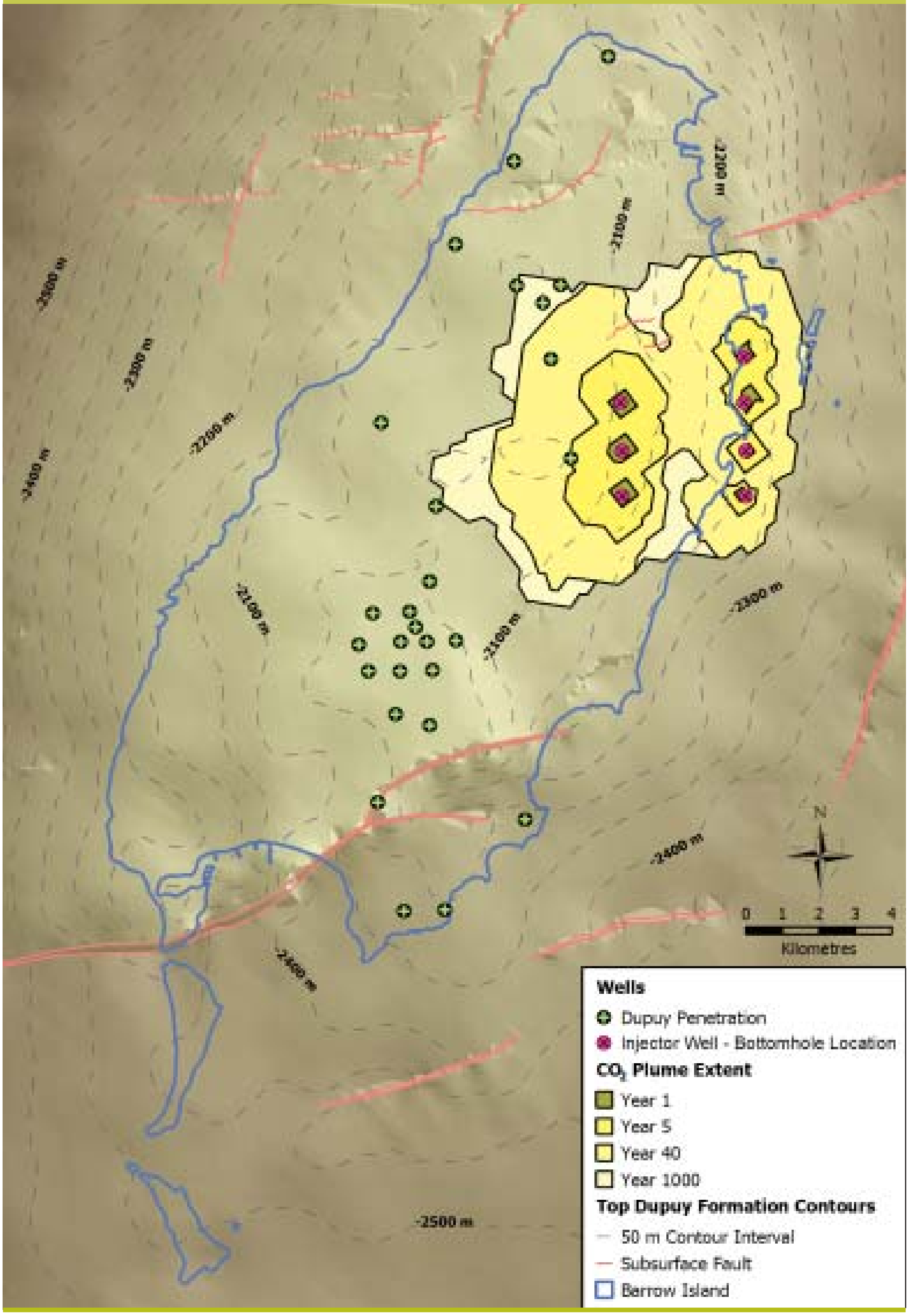


Figure 13-11:
Barrow Island Dupuy Formation Well Control

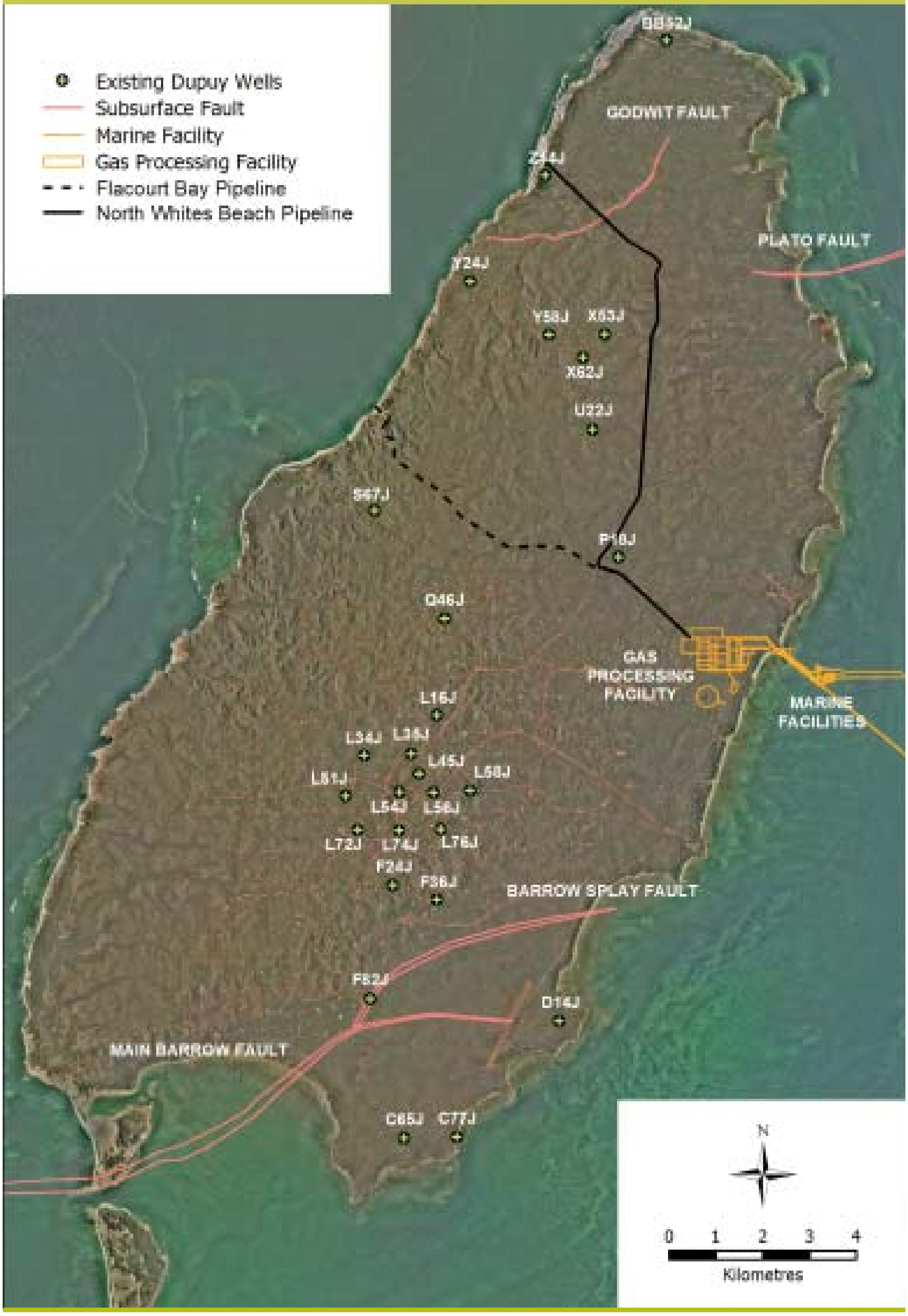


Figure 13-12:
Photo-micrograph Showing Clean Pore Space

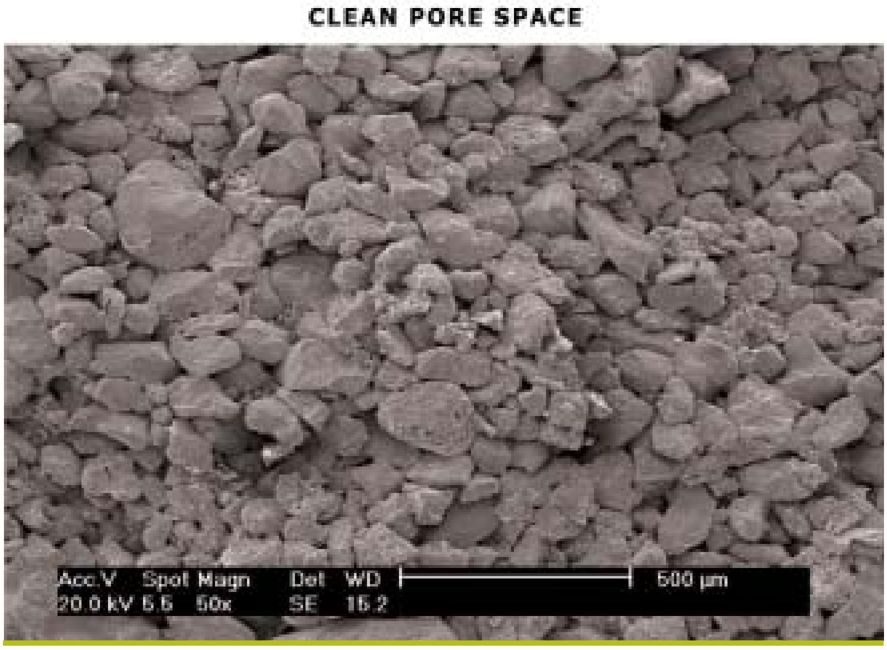
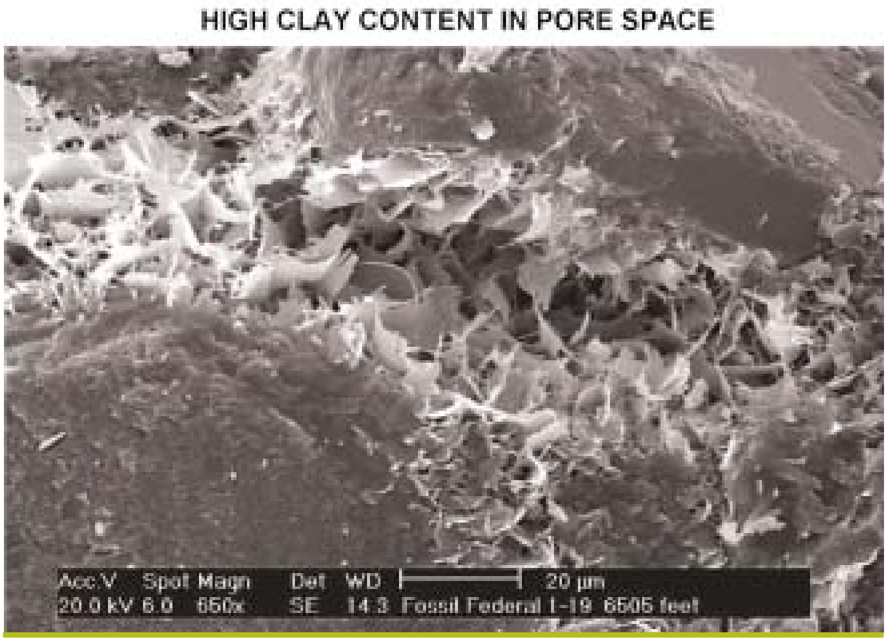


Figure 13-13:
Photo-micrograph Showing High Clay Content in Pore Space



Prior to compaction, sand typically contains over 40% porosity. That is, a one litre container full of clean sand contains room for over 400 ml of water in the pore space. Compaction with burial reduces the amount of porosity. Figure 13-12 shows a clean sandstone in which the pore spaces between the individual grains are sufficiently large and uncluttered (by particles of clay) to allow fluids to enter or exit them easily. Such rocks constitute excellent reservoirs and have high porosity and permeability. The sandstones under Barrow Island in which it is proposed to inject CO_2, are at a depth of over 2000 m with porosities of about 20%.

Permeability is a measure of how easily fluids can move through a formation. Permeability is a function of how individual pore spaces are interconnected, their size and the amount of finer-grained material such as clay in the pore space.

Rocks with a large amount of clay in the pore space (such as shown in Figure 13-13, note the increased magnification compared to Figure 13-12) have low permeability and will act as a type of geological 'barrier' or 'baffle' to the migration of the injected CO_2. The clay within the pore spaces acts to prevent the movement of fluids, including CO_2, through the pores. The role of baffles in the migration of CO_2 is discussed in Section 13.4.4.

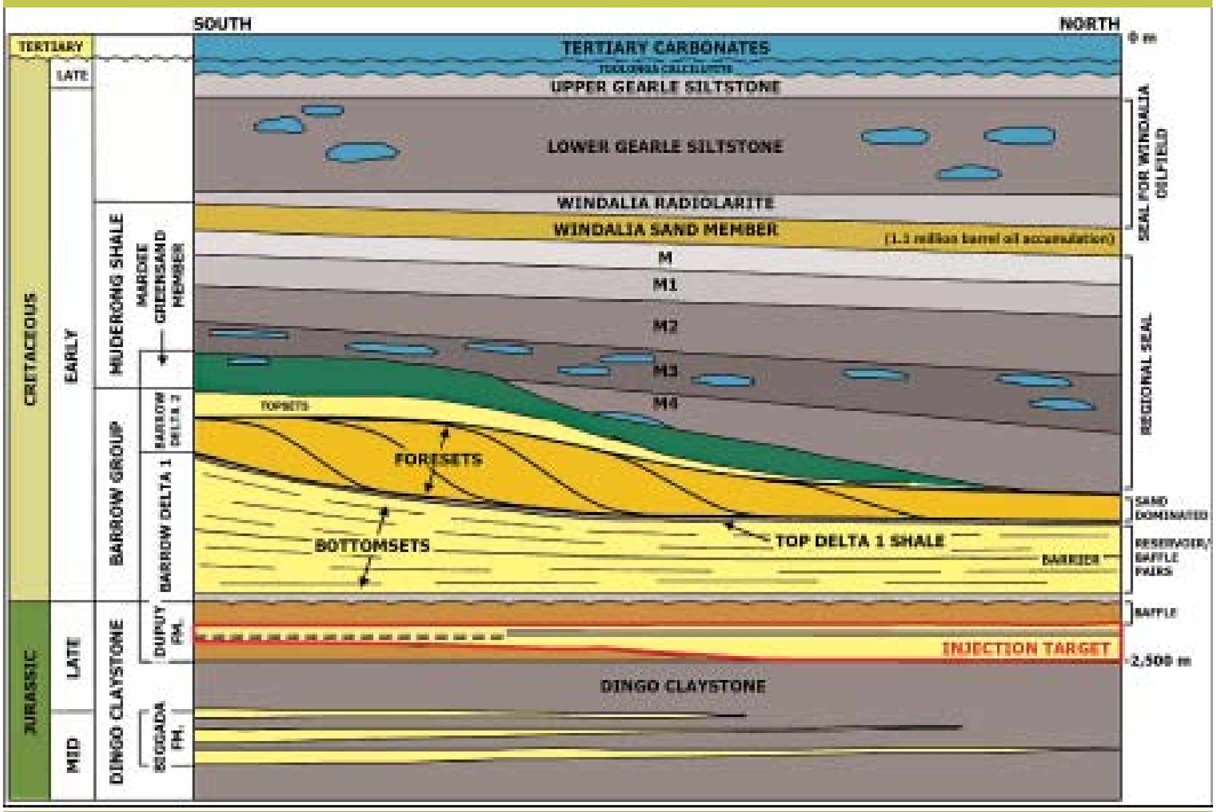
Rocks referred to as shale or claystone consist of individual grains which are so small (virtually water-borne dust) that they are easily transported in water and will be deposited only in a very deep water environment. The fine-grained nature of the rock means that the pore spaces between grains are so small that droplets of migrating fluid are unable to enter the pores easily. When a sufficient thickness of these fine-grained rocks has built up, it can form a seal or barrier which is impermeable to migrating fluids including CO_2.

Stratigraphy

Barrow Island sits in the Barrow Sub-basin of the Carnarvon Basin, a major accumulation of sedimentary rocks on the north-west coast of Western Australia. The regional stratigraphy of the Barrow Island area is shown diagrammatically on Figure 13-14.

The sedimentary rocks of the Barrow Sub-basin have predominantly been deposited under water, either in open marine (oceanic) conditions, or in a major delta.

Figure 13-14:
Regional Stratigraphic Section of the Barrow Island Area



They have accumulated to the thickness of at least 8000–10 000 m because of subsidence of the earth's crust under this area. The major rock types preserved in the Barrow Island area are:

- limestone, most notably the so-called Coastal Limestone, which forms a large part of the surface material on Barrow Island
- sandstone, which typically resembles a solidified beach sand
- shale/claystone, the finest grained of the sedimentary rocks, in which individual grains are not discernible to the naked eye
- siltstones, the grain size of which falls midway between those of sands and clays.

The surface rocks on the island are 'Recent' in age (that is, they were formed within the last 100 000 years) while the deepest well on Barrow Island, sampled rocks at over 4000 m which have been dated as Middle Jurassic (160–80 million years old).

The oldest rocks drilled on Barrow Island belong to the Dingo Claystone which is a sequence of claystone and siltstone 4000 to 6000 m thick. The Dingo Claystone is regionally extensive throughout the Barrow Sub-basin and accumulated because of abundant fine-grained sediment supply to an area which subsided steadily throughout the period of sediment accumulation.

The Dupuy Formation overlies the Dingo Claystone and forms a sandy and silty unit 300–500 m thick in the region of Barrow Island. Whereas the Dingo Claystone is present over the entire sub-basin, the Dupuy Formation is a more localised rock body, confined to the sub-basin's eastern flank. By the end of Dingo Claystone deposition, subsidence in the Barrow Island area had slowed and open ocean conditions were established. The Dupuy Formation sandstones are thought to have been deposited as a result of oceanic current activity and sediment gravity flows in which sand originally deposited in shallow water was redeposited further offshore on the continental shelf and possibly the continental slope. The lower Dupuy Formation sandstones have a restricted areal distribution under the island; they are absent in the wells in the south and south-west of the island but thick and well-developed in the wells in the north and north-west. The lower Dupuy Formation sand section consists of finely inter-bedded sands and siltstones. Individual sand bodies within the lower Dupuy Formation appear to have limited lateral extent.

The overlying upper massive sandstone of the Dupuy Formation can be correlated over the entire island; it is shown on logs and in core to be of higher porosity and permeability and is thickly bedded. The Perforans Shale occurs in the upper third of this unit and appears to extend over the northern half of the island. Several other shale/siltstone layers of varying lateral extent are also present. The upper massive sandstone represents shallower water, lower to middle shore face deposit, still within a normal oceanic environment.

The final phase of Dupuy Formation deposition was marked by fine-grained marine deposition with very limited input of sand.

Overlying the Dupuy Formation is the Barrow Group which represents the deposition of a major marine delta. Sediments in the Barrow delta were transported by a large river system which flowed from the south, draining a hinterland now totally removed by erosion. The resulting delta can be seen in wells and on seismic data to have built out from the Onslow area on the coast of Western Australia to Barrow Island. Deltas develop when the supply of sediment from a river system exceeds the capacity of oceanic processes, for example long shore currents, to disperse the sediment.

The geological units within the Barrow Group comprise the:

- basal, pro-delta shale unit
- interbedded sandstones and marine shales of the true bottomsets of the delta
- predominantly sandy foresets which dip to the north
- topsets comprising high permeability sandstone reservoirs.

The Barrow Group is overlain by the Muderong Shale which is between 300 to 500 m thick and 110 to 130 million years old. The Muderong Shale forms the regional seal within the basin; that is, it is sufficiently impervious to the movement of oil and gas to allow the accumulation of commercial deposits of hydrocarbons directly beneath it. Many of the major hydrocarbon accumulations discovered to date in the basin have been sealed by the Muderong Shale. Overlying the Muderong Shale are the Windalia Radiolarite and Gearle Siltstone, which seal the 285 million kilolitre (in place) Windalia oil accumulation. Overlying the Gearle Siltstone is a thick succession of marine carbonates.

Sampling of the formation waters contained in the Barrow Sub-basin in the area below Barrow Island has shown that the major aquifers contain levels of salt that prevent them from being considered as potential groundwater resources. Water in the Dupuy Formation has a salinity of between 4500 and 10 000 ppm sodium chloride (NaCl) equivalents while waters in the Barrow Group have a salinity of between 30 000 and 32 000 ppm NaCl equivalents. There is a lens of relatively fresh water directly below Barrow Island and at the very top of the water table. The limited size of the fresh water lens and its probable importance to stygofauna prevents its commercial exploitation. CO_2 injection operations will be managed to preserve the presence of this fresh water lens.

Structure

The major structural elements in the Barrow Sub-basin are shown in Figure 13-15. The Sub-basin is boarded to the west by the Alpha Arch, to the south-east by the Peedamullah Fault System and to the north by the Dampier Sub-basin.

Barrow Island has been elevated above the surrounding sea floor by the upward flexing of the underlying strata to form an anticline, an elongate dome in which the layers of rock are arched upwards in both the north-south and east-west directions. Figure 13-16 shows a north-west to south-east cross-section through the Barrow Sub-basin.

The presence of this regional structure assists in predicting the migration to CO_2 in the subsurface.

The structure beneath Barrow Island is shown in greater detail on the north-south and north-west south-east cross-sections shown in Figure 13-17 and Figure 13-18.

These cross-sections show the arching of the rock strata under Barrow Island and the location of a number of faults. Faulting occurs when geological strata are broken by tectonic forces greater than the rock strength. The Barrow Fault and the Godwit Fault are the most significant of these and may represent potential fluid migration pathways. The Barrow Fault has had a long history of movement, which is believed to have continued up until recent geological times, based on the observation that the fault is expressed at the surface of the island in a subdued topographic scarp. Movement on the Barrow Fault has resulted in the block on the southern side of the fault being displaced downwards, relative to the northern block. Relative to the Barrow Fault, the Godwit Fault appears to have been active comparatively few times.

The two cross-sections also show the distribution of sandstone within the lower Dupuy Formation. As mentioned above, the upper massive sand unit is uniformly present over the entire island, although it is thinner at the southern end of the island, whereas the lower Dupuy Formation sand is absent in the south and south-west of the island, but is present as a thick accumulation in the north and north-west.

13.4.4 Carbon Dioxide Behaviour in the Subsurface

Phase Behaviour of Carbon Dioxide

For CO_2 to be efficiently disposed in the subsurface, it is preferable for it to be in a supercritical phase so that the volume of the rock occupied by the CO_2 can be minimised. A supercritical fluid is any substance above its critical temperature and pressure. In the supercritical phase, the fluid will possess both gas and liquid like properties. It will have the density of a light liquid and the properties of a gas to allow it to fill the maximum pore space available. Figure 13-19 shows the phase diagram for CO_2 and the temperature and pressure anticipated in the Dupuy Formation. At a depth of approximately 2200 m, the reservoir pressure is 22 MPa and temperature is 100ºC. Under these conditions, CO_2 will have a density of 550 kg/m^3, compared with fresh water with a density of 970 kg/m^3 and normal ocean water with a density of about 1030 kg/m^3. As it is less dense than the waters already contained in the formation, supercritical CO_2 will tend to rise vertically due to buoyancy forces.

Trapping Mechanisms

There are four mechanisms that can trap injected CO_2 within the host reservoir:

- solution trapping
- residual gas trapping
- mineralogical trapping
- large-scale geometric trapping.

The process by which each of these mechanisms works to trap the injected CO_2 is discussed below. The longer the CO_2 remains in the reservoir and the more formation water is contacted the more effective these trapping mechanisms are at immobilising the CO_2 and the higher the proportion of CO_2 trapped.

Figure 13-15:
Barrow Sub-basin Structural Elements

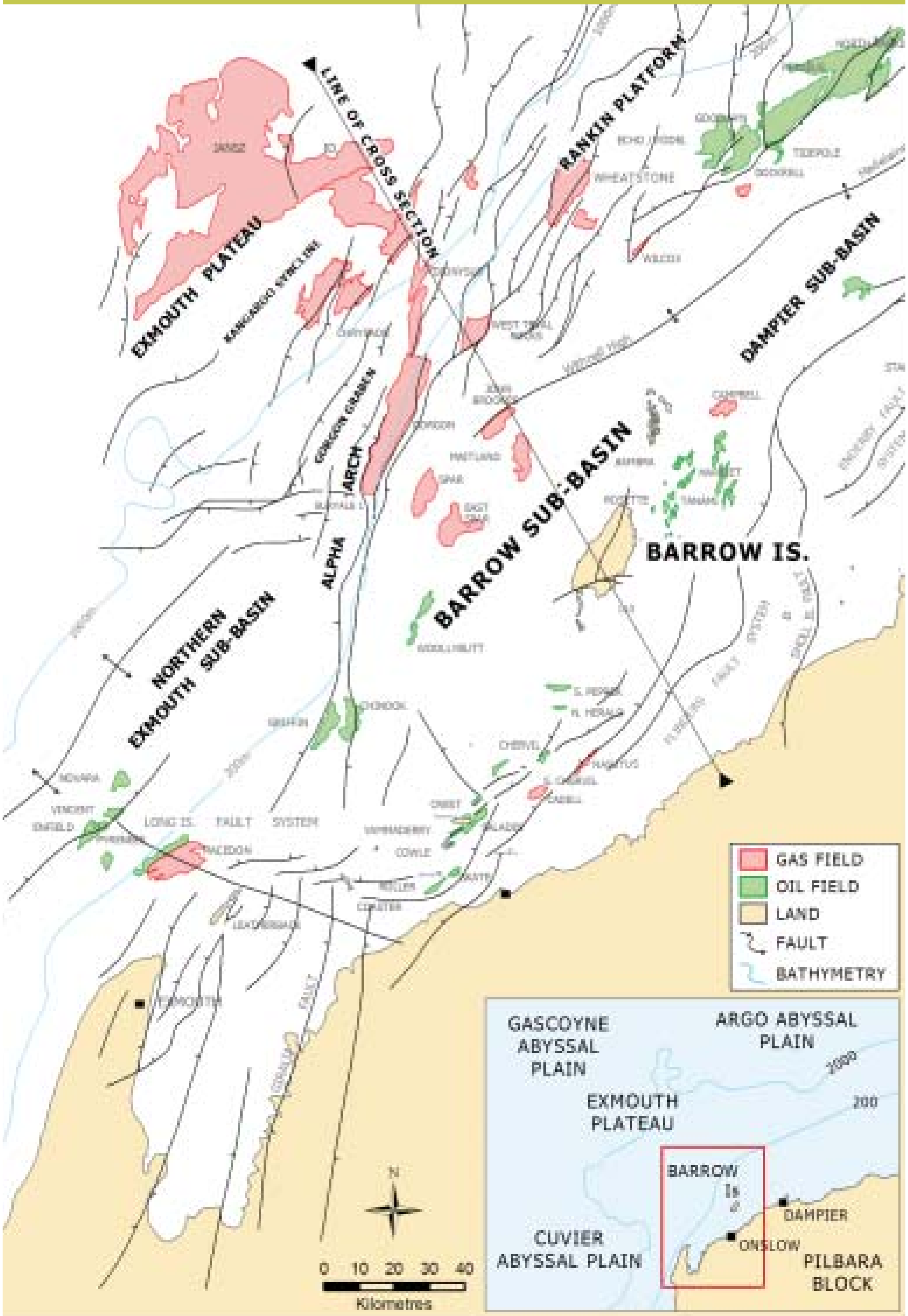


Figure 13-16:
Barrow Sub-basin Regional Cross-Section

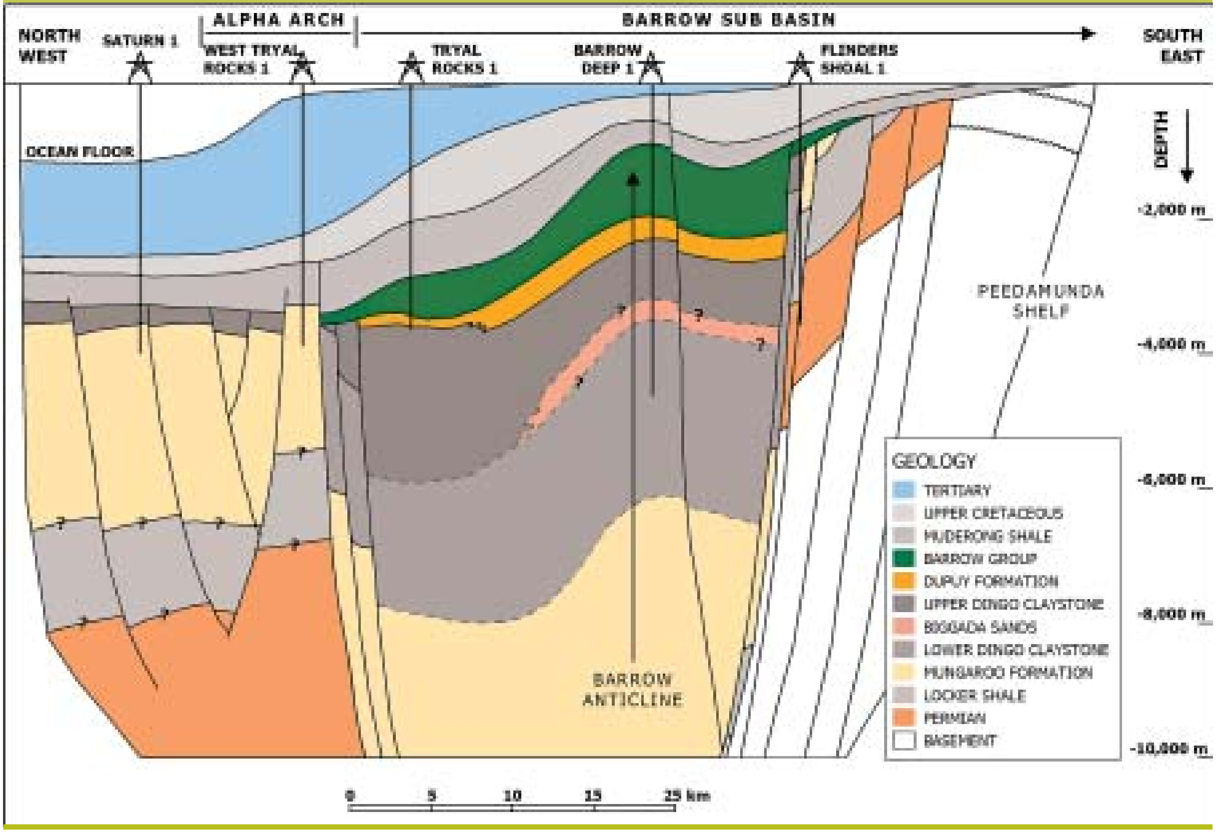


Figure 13-17:
North-South Cross-Section through Barrow Island

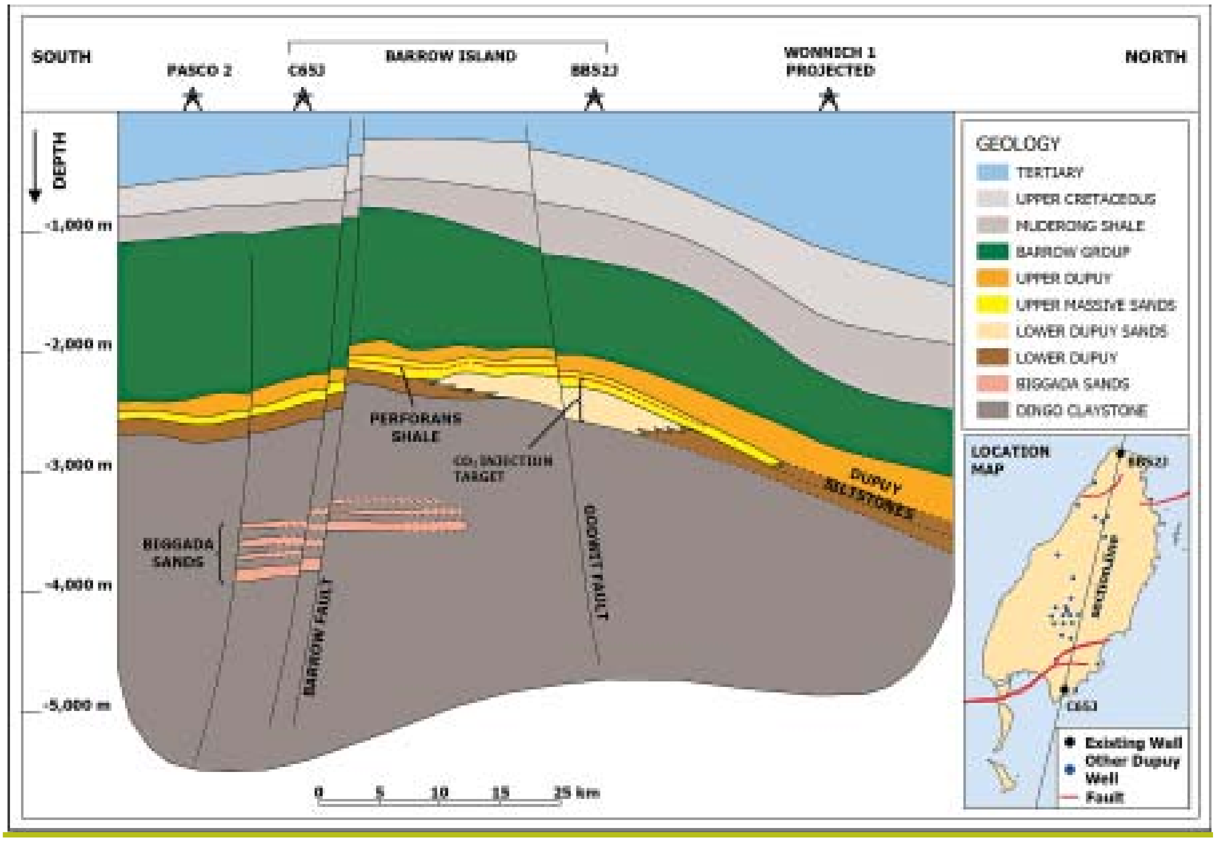


Figure 13-18:
North-West South-East Cross-Section through Barrow Island

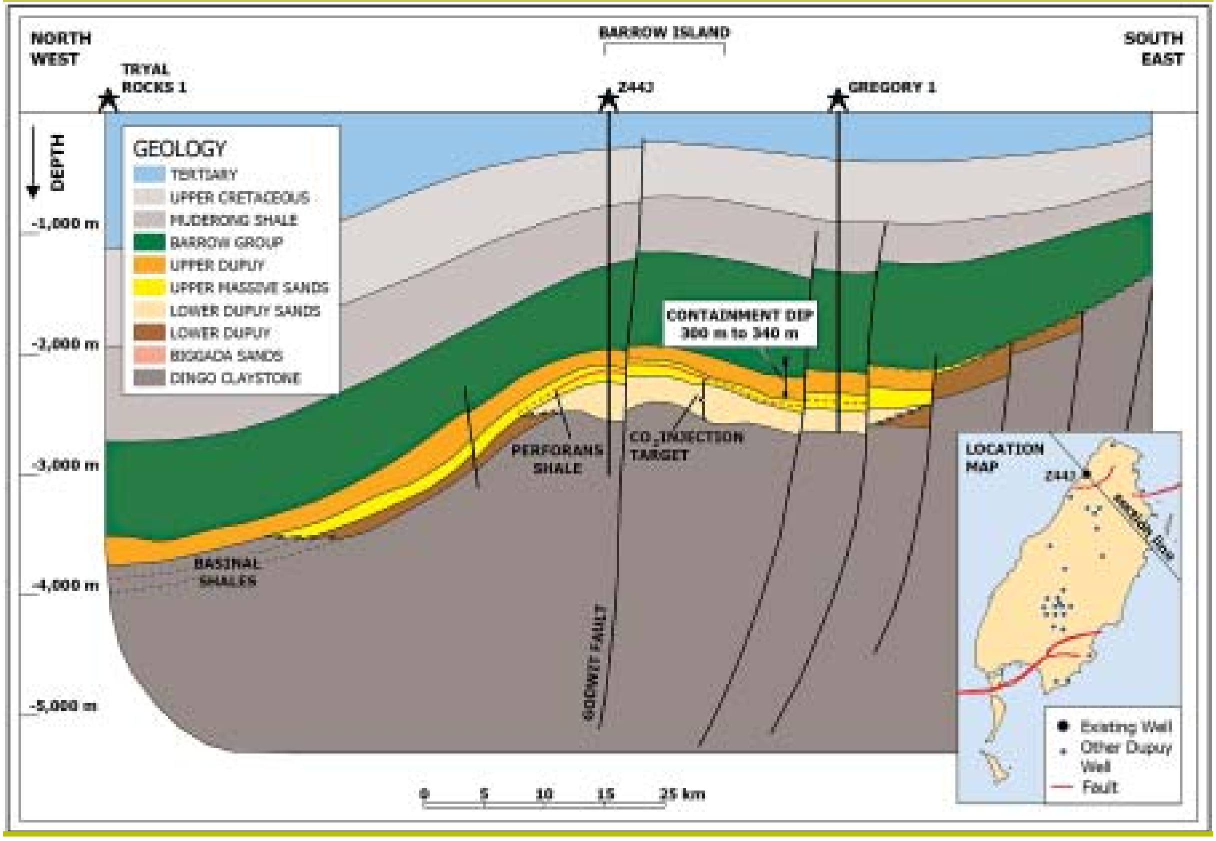
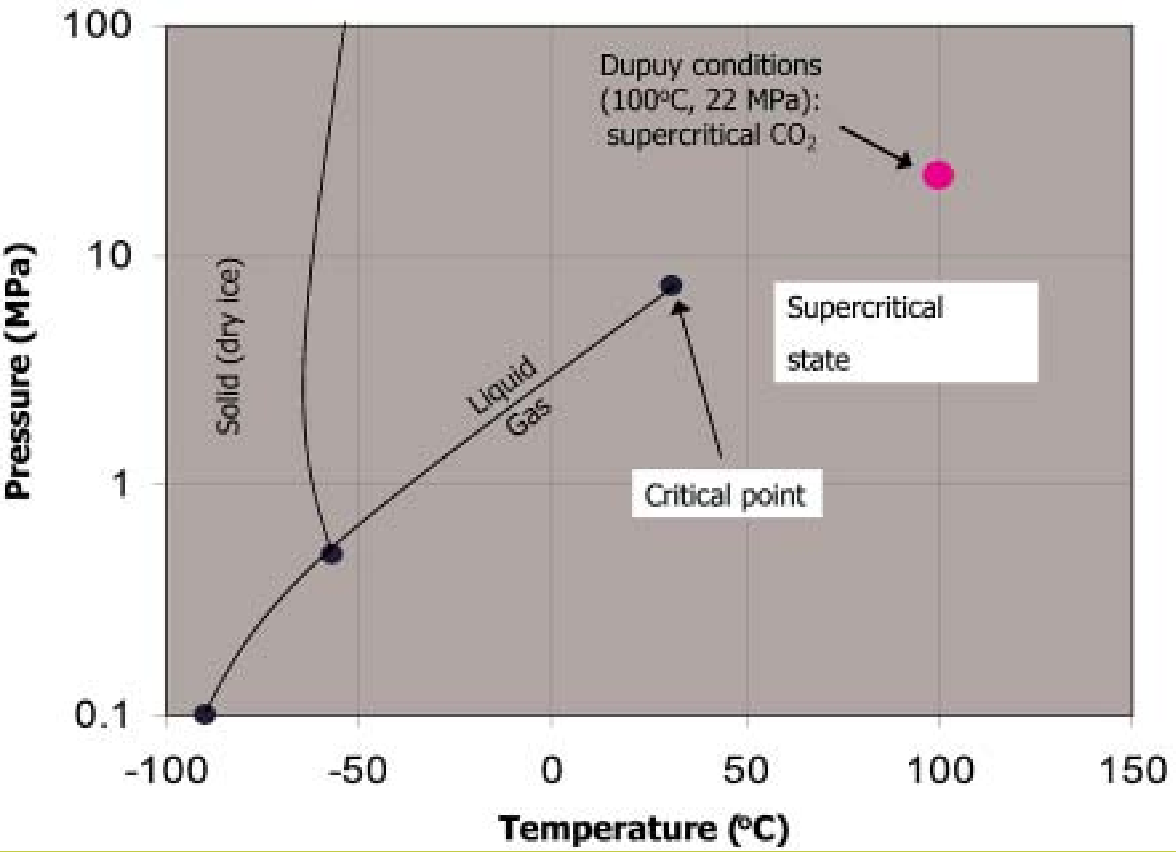


Figure 13-19:
CO_2 Phase Diagram



Solution Trapping

In its natural state the pore space within the formation contains saline water, often referred to as formation water. The migration of CO_2 under either the pressure of injection, or by buoyancy forces following injection will bring the injected CO_2 into contact with this formation water, enabling the CO_2 to dissolve into the water until the water becomes saturated with CO_2.

Figure 13-20 shows typical sandstone within the lower Dupuy Formation prior to the injection of CO_2. A thin layer of formation water is bound to the sand grains and clay platelets by the force of surface tension. The remainder of the pore space is occupied by formation water that is able to migrate through the formation. Figure 13-21 shows the predicted dissolution of the injected CO_2 into the formation water contained in the pore space.

It is anticipated that 10 to 20% of the total CO_2 injected will be trapped in solution during the injection period. Following the injection period, the CO_2 will continue to be trapped as it migrates and contacts unsaturated formation water. The resulting saturated formation water will be slightly denser (1% denser) than the unsaturated water and there will be a tendency for it to sink very slowly through the formation. This mechanism is expected to create convection whereby the dense saturated formation water sinks to the bottom of the formation, displacing unsaturated formation water into the upper parts of the formation. The remaining CO_2 then dissolves in the unsaturated formation water. In the longer term (thousands to hundreds of thousands of years) all of the CO_2 will dissolve in the saline formation waters by this process.

Residual Gas Trapping

During the injection phase, some of the formation water will be displaced by the injected CO_2 with the remainder adhering to the rock minerals due to surface tension. The portion of water that will remain in the pore space is termed the 'residual' or 'irreducible water saturation'. This is a function of the surface tension between the rock minerals and the formation fluids and the size of the pore spaces. The residual saturation around the injection wells is estimated to be between 20% and 40%. That is, between 20% and 40% of the original formation water will remain bound to the rock minerals by surface tension. Some of the injected CO_2 will dissolve in the residual water until that water becomes saturated.

As the CO_2 migrates through the reservoir, small droplets of supercritical CO_2 will also become trapped within the pore spaces by the surface tension between the formation water and the CO_2. This is shown diagrammatically in Figure 13-22. The mechanisms of residual trapping are well understood by the oil and gas industry as this is the primary control on ultimate recovery from oil and gas field operations. The amount of CO_2 trapped by this method is a function of the physical properties of the rock, the formation water and the injected CO_2. It is anticipated that residual gas saturations of approximately 20% will be achieved in the Dupuy Formation. That is, about 20% of the pore space through which the CO_2 has migrated will contain trapped CO_2. If the migration path is long enough, all the CO_2 will become immobilised by residual gas trapping and ultimately by dissolution into the formation water.

Residual gas trapping is a very significant mechanism for immobilising CO_2 and will likely be the dominant trapping mechanism during the first several thousand years following injection. In the longer term the CO_2 trapped by residual gas trapping will dissolve into the formation waters as unsaturated formation water migrates past the trapped CO_2 by the convection process discussed above.

Mineralogical Trapping

As the injected CO_2 dissolves into the formation water, it will produce a weak acid (carbonic acid) which can react with the minerals in the host rock. Some reactions can result in the precipitation of minerals in the formation pore space, which will effectively trap the injected CO_2. The geochemistry of CO_2 in the subsurface is an area of ongoing research but it is generally accepted that the reactions which will permanently trap the CO_2 will occur at very slow rates. The Gorgon Joint Venturers have assumed, for the purpose of reservoir simulation modelling, that this mechanism will not trap a substantive volume of CO_2 during the first 1000 years. However over tens of thousands of years, up to 10% of the injected CO_2 could be trapped by this mechanism in addition to that trapped by the mechanisms described above.

Figure 13-20:
Pre-Injection Distribution of Fluids within the Reservoir

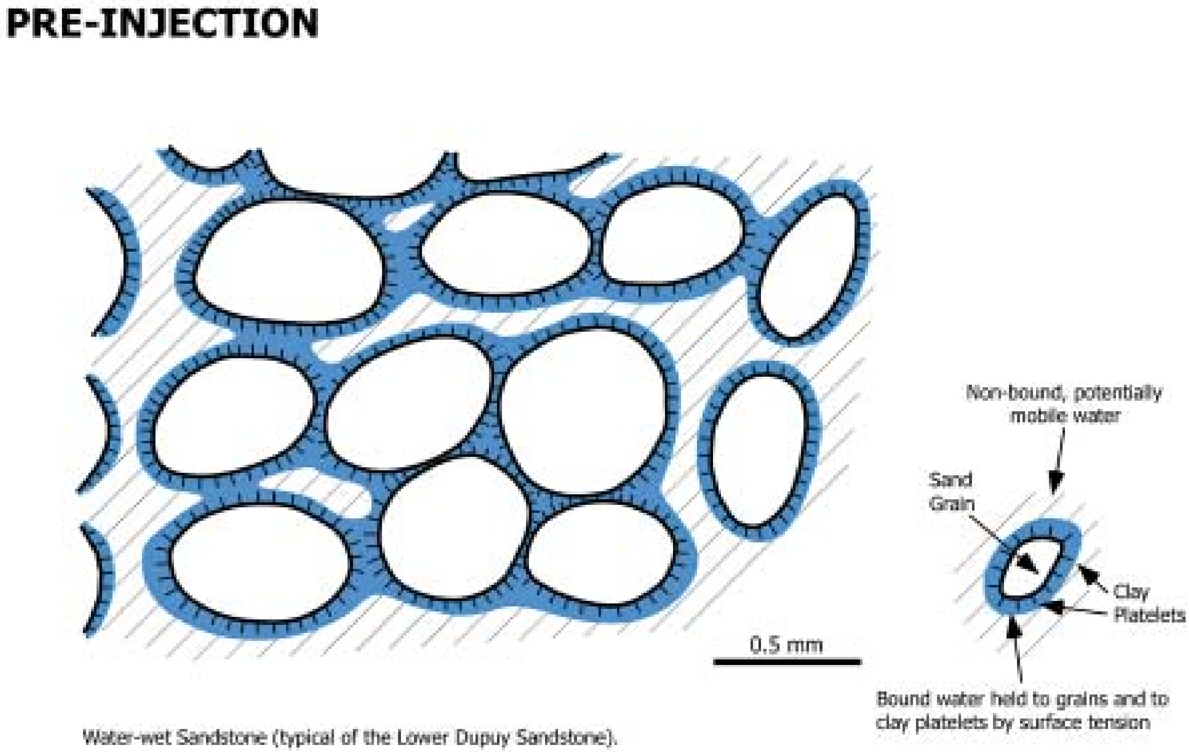


Figure 13-21:
Dissolution of Injected Fluid into the Formation Water

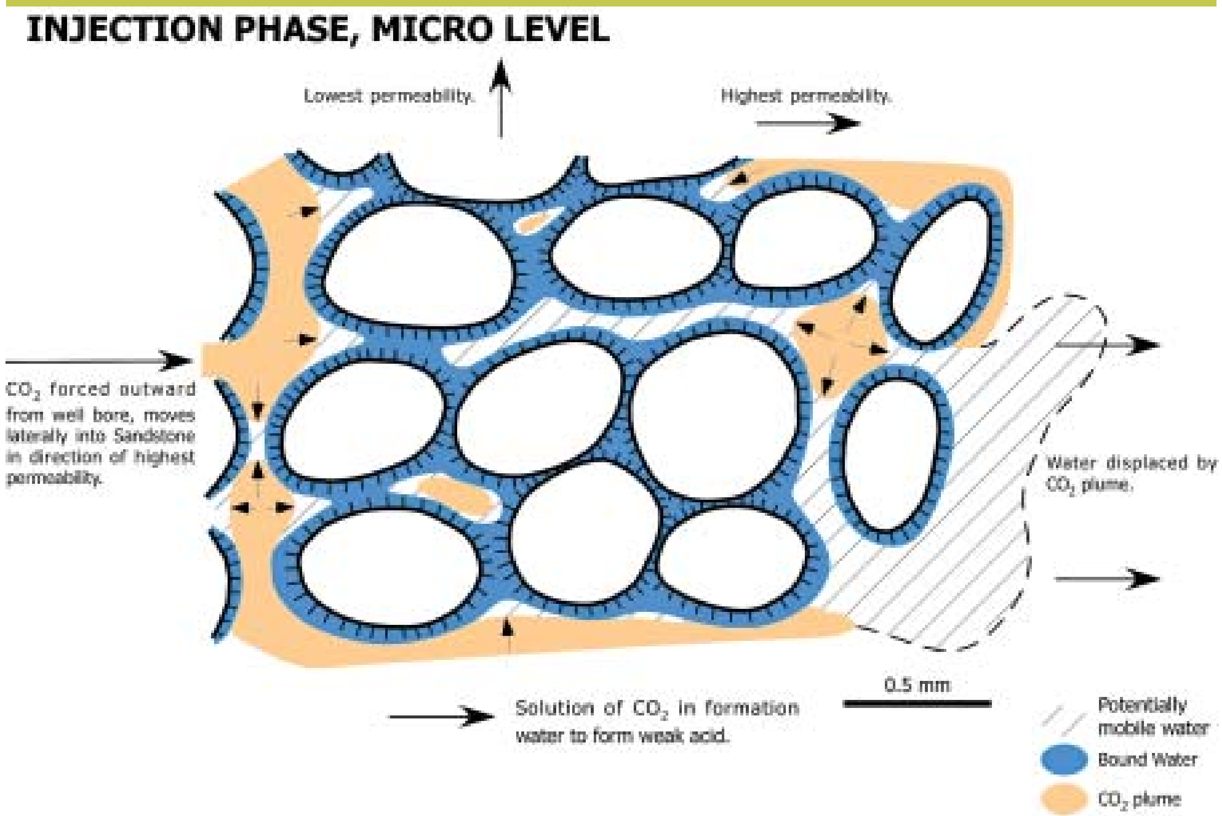
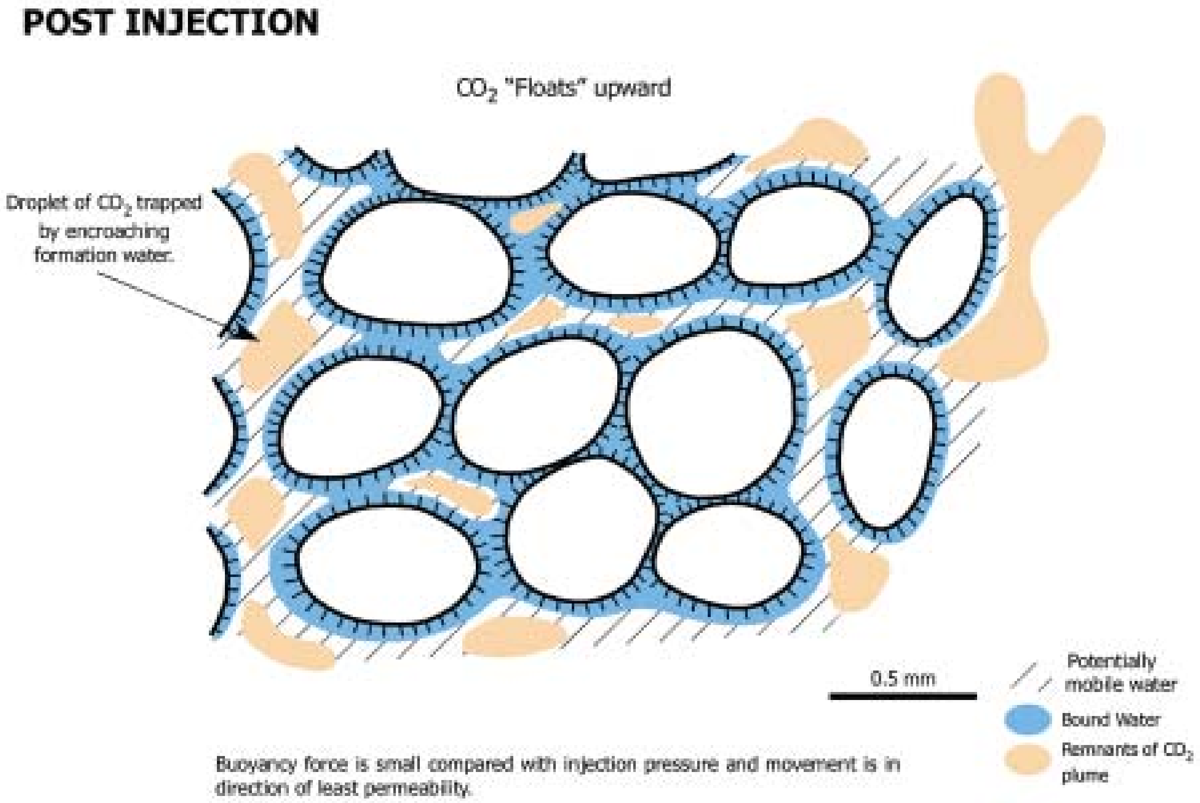


Figure 13-22:
Residual Gas Trapping of CO_2 Droplets



Large-scale Geometric Trapping

As is the case for conventional oil and gas fields, migrating CO_2 will become trapped in conventional underground traps in which an impervious barrier overlies or surrounds a body of permeable rock in all up-dip and lateral directions. The most easily envisaged trap type is a structure in which the shape of the barrier approximates that of an inverted saucer. Mapping from the existing seismic data set indicates that there are few conventional geometric traps at the Dupuy Formation level and those which can be mapped are small. This process is shown diagrammatically in Figure 13-23.

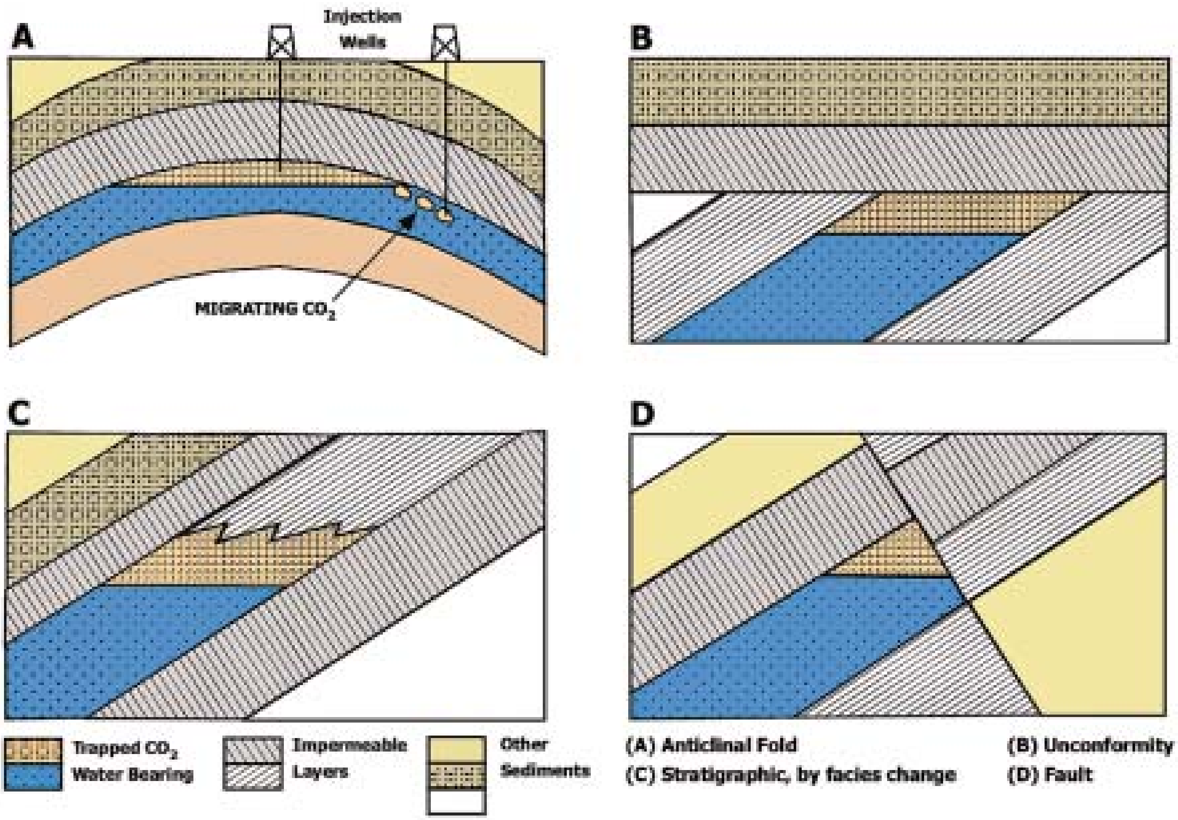
Injectivity/Tortuosity Compromise

Injectivity is a measure of how much CO_2 can be injected as a function of the injection pressure. The higher the 'injectivity', the less injection effort will be required, resulting in savings on injection equipment and injection wells. Tortuosity is a measure of how complex the migration path is through a particular reservoir: the more complex the migration path, the greater the ability for the trapping mechanisms (discussed above) to take effect. While it is not possible to alter the tortuosity of a reservoir, injectivity can be managed through investment in additional equipment, injection wells and well stimulation. Any disposal location represents a compromise between the requirements of having high injectivity and a tortuous migration path.

The Dupuy Formation provides an ideal balance between well injectivity and tortuosity. The Dupuy Formation is a tortuous system with relatively low permeability with many baffles and barriers (the impact of which is discussed below). This is anticipated to result in higher effective trapping rates but at a penalty of increased cost.

One of the major uncertainties with the choice of the Dupuy Formation sandstones as the primary disposal target lies in the injectivity of the sands. Much of the data about injectivity is from cores that are relatively old and subject to degradation. In order to reduce this uncertainty, it is proposed to drill a well to obtain additional data in the second half of 2005.

Figure 13-23:
Geometric Trapping of Injected CO_2



Baffles and Barriers

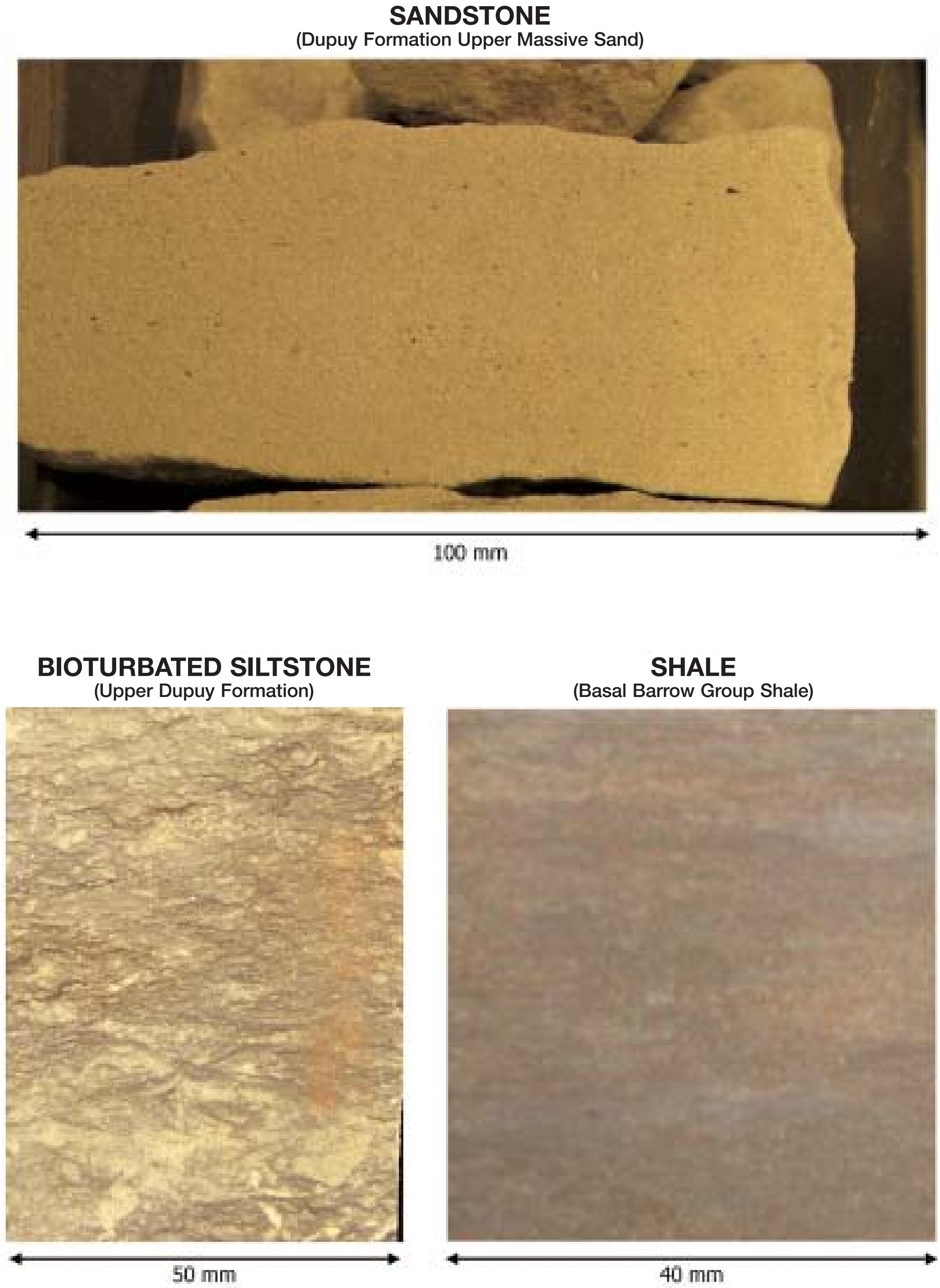
All hydrocarbon seals (the rock over the top of a hydrocarbon accumulation) will allow the very slow migration of hydrocarbon molecules into or, in some cases, through them over millions to hundreds of millions of years. Throughout the world, the hydrocarbon content of seals steadily increases downward to the oil or gas accumulation.
This demonstrates that the more mobile fractions of that accumulation have been able to move very slowly upwards through the seal over time.

The rate of vertical migration is equally important in considering the underground disposal of CO_2 but the difference is that time scales are much shorter: tens of years for the active injection of the CO_2 and perhaps thousands of years to allow for complete immobilisation through dissolution, reaction, residual gas and large scale entrapment. Consequently, fine-grained intervals such as siltstones, which cannot be considered seals in the sense of being able to hold back hydrocarbons over millions of years, can function as effective baffles or barriers in the time scale of a CO_2 injection project. In this Draft EIS/ERMP ‘barriers’ are considered to be layers of rock which have sufficient areal extent to provide a major and predictable block to the upward movement of CO_2 over thousands of years during which the trapping mechanisms, discussed above, will permanently immobilise the CO_2. The term ‘baffle’ is used to describe layers of rock which are very slightly permeable to CO_2 over this time scale and/or lack sufficient predictable areal extent to constitute an identifiable barrier. Baffles impose tortuosity on the migration of the CO_2 plume, increasing the potential for the CO_2 to become trapped prior to reaching the major barriers.

Researchers at the Lawrence Berkley National Laboratory have attempted to quantify the rates at which CO_2 could migrate through a single barrier (Benson 2004). This work indicates that such migration would result in a CO_2 flux rate (a measure of the rate of leakage) of generally less than one micromole/m^2/sec. This compares with a range of naturally occurring ecosystem flux rates of between 2 and 20 micromole/m^2/sec indicating that leakage through a single barrier would be at a rate that would not be detectable against a normal background flux. It should be noted that there are multiple barriers between the proposed CO_2 injection reservoir in the Dupuy Formation and the surface.

Figure 13-24 shows photographs from cores obtained in the Dupuy Formation upper massive sand, the upper Dupuy Formation and the basal Barrow Group. The core from the Dupuy Formation upper massive sand shows very few internal barriers. This will enable the

Figure 13-24:
Cores of the Dupuy Formation Upper Massive Sand, Upper Dupuy Formation and the Basal Barrow Group Shale



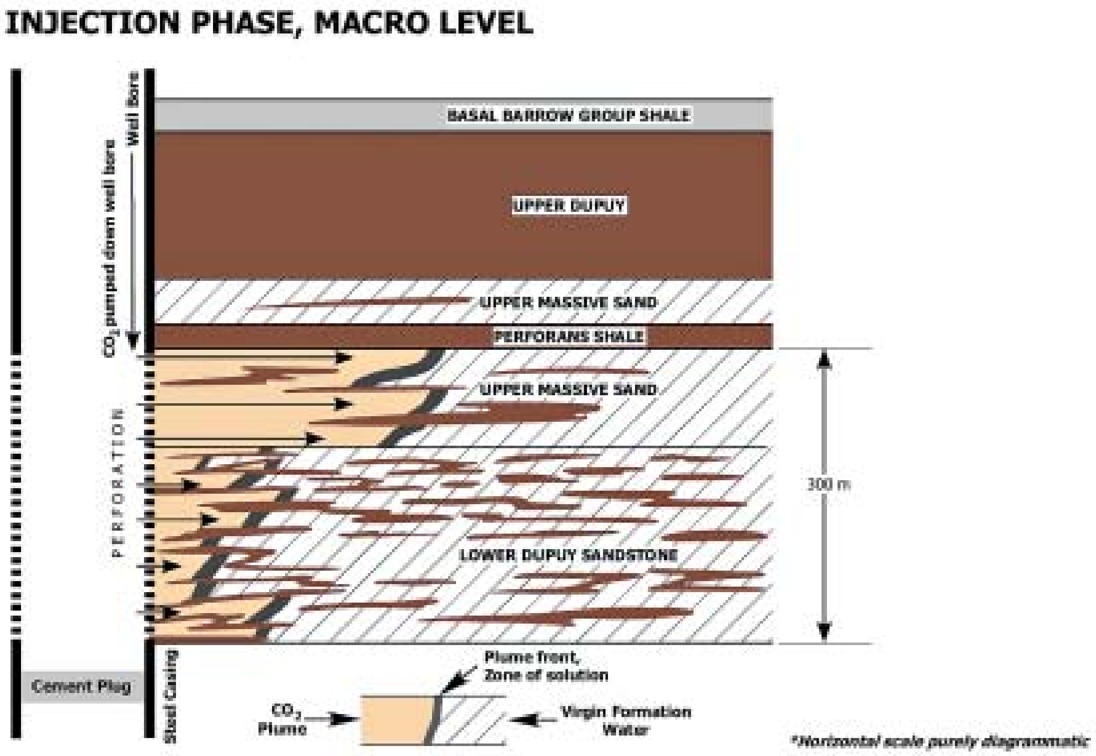
CO_2 to migrate relatively freely through the formation. The core from the upper Dupuy Formation shows low permeability, finely bedded siltstone which has been thoroughly disrupted (bioturbated) as it was being deposited by the action of burrowing organisms such as worms. Although the upper Dupuy Formation is aerially extensive, it can be considered as a baffle to migration of CO_2 because it is slightly permeable to CO_2 migration. The thickness of this unit (approximately 150 m) and the tortuous migration path will significantly reduce the rate of vertical migration and facilitate the trapping of CO_2. The basal Barrow Group shale is a marine shale and represents an effective barrier to vertical migration of CO_2.

The predicted distribution of baffles, barriers and seals in relation to the migration of the CO_2 plume after 40 years of injection is shown diagrammatically in Figure 13-25.

Further evidence for the effectiveness of the basal Barrow Group shale as a barrier to fluid migration is provided by the salinity contrast that exists between the formation waters in the Dupuy Formation and the Barrow Group. Water recovered from the Dupuy Formation has salinities between 4000 and 7000 ppm (total dissolved solids) which is much lower than the water recovered from the overlying lower Barrow Group where salinities range from 16 000 to 20 000 ppm. Waters recovered from sands higher in the Barrow Group have salinities ranging from 30 000 to 35 000 ppm. For reference, sea water has salinities between 30 000 to 35 000 ppm. The existence of this salinity contrast indicates either an effective seal or a very slow rate of formation water diffusion through the base Barrow Group shale. The effectiveness of the basal Barrow Group shale is also reinforced by a pressure differential between the Dupuy Formation and the Barrow Group. These pressure data are interpreted to show limited pressure communication over the 40 years of hydrocarbon production in the Barrow Sub-basin. Both the salinity and the pressure data provide evidence of the effectiveness of the base Barrow Group shale as a barrier to the vertical migration of CO_2.

In the unlikely event that CO_2 migrates through the basal Barrow Group shale into the overlying sands in the Barrow Group, it would migrate through the lower Barrow Group marine shales. These shales have an average thickness of 160 m and provide a further tortuous path and potential for trapping of the CO_2. The ability to correlate these shales over large distances is limited so they are best described as baffles.

Figure 13-25:
Relationship of the CO_2 Plume After 40-Years of Migration and Baffles, Barriers and Seals



The Barrow group is overlain by the Muderong Shale, which has proven sealing capacity, as shown by the 400–700 m columns of natural gas which it traps in the Carnarvon Basin. Any CO_2 which breached the Muderong Shale would then encounter the Windalia Radiolarite and Gearle Siltstone. For any of the injected CO_2 to reach the surface it must first pass through these baffles and barriers while not being trapped by the mechanisms identified earlier.

Operational Phase

When predicting the behaviour of the CO_2 in the subsurface there are two distinct phases to be considered: the operational or injection phase; and the period after injection ceases or the post operational phase.

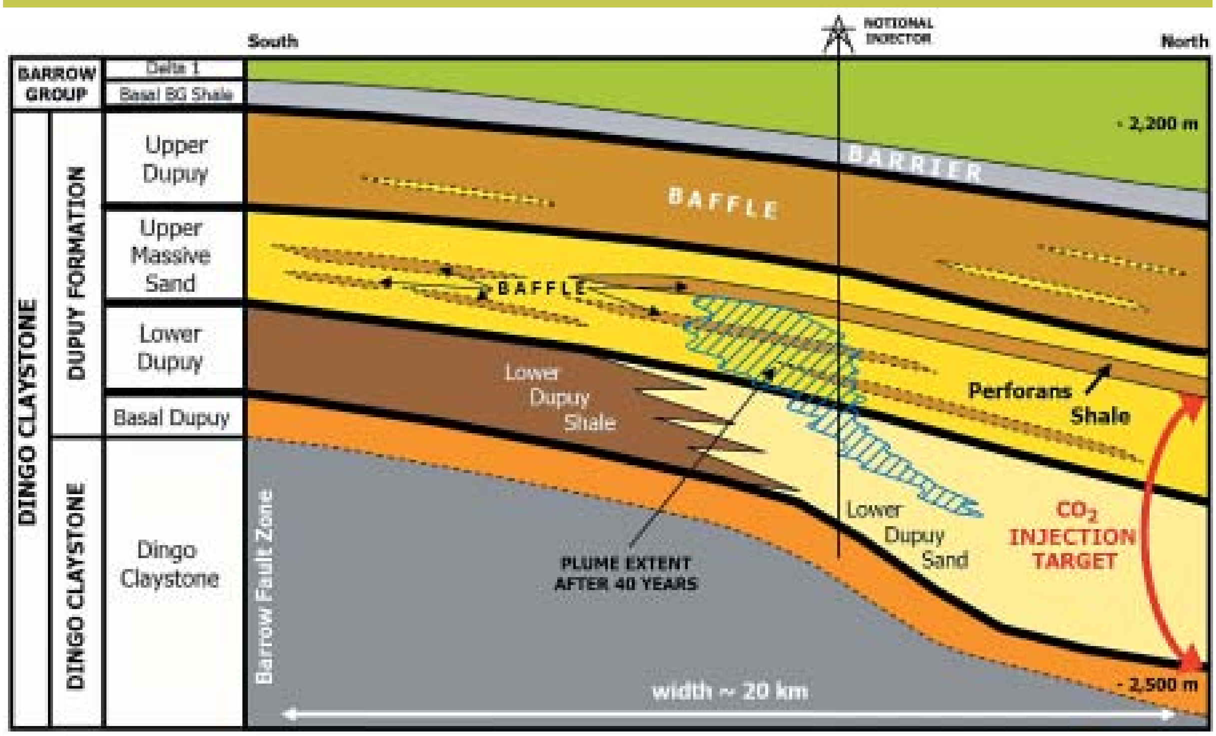
Modelling by the Gorgon Joint Venturers shows that during the operational phase, the CO_2 will initially move out from the well bore as a discrete plume, driven by the injection pressure. This is shown diagrammatically in Figure 13-26. The migration of the CO_2 during the operational phase is a function of the injection pressure and the permeability of the various layers in the reservoir. The CO_2 will migrate more rapidly in the high permeability layers. As the plume moves further away from the injector well, the injection pressure will dissipate and the rate of migration will slow. At this point, the CO_2 plume will migrate under buoyancy forces where the migration path is determined by the dip and heterogeneity of the reservoir. During the injection period, some of the CO_2 will be forced down dip against the force of buoyancy for a lateral distance of up to 2 km.

As the CO_2 migrates during the injection phase a portion of the injected CO_2 will become trapped in the formation by the solution and residual gas trapping mechanism discussed above.

Post Operational Phase

Once injection ceases, the injection pressures will rapidly dissipate and the buoyancy contrast between the CO_2 and the formation water will be the driving force for migration of the remaining CO_2. As a result, the rate of lateral CO_2 migration will dramatically reduce and the CO_2 will tend to migrate upwards with vertical movement being restricted by the baffles and barriers in the system. The rate of migration will be determined by the tortuosity of the formation with a large proportion of the CO_2 plume anticipated to be trapped by residual gas trapping in the low permeability layers in the upper Dupuy Formation. The post injection phase will see that part of the CO_2 plume which has been forced down-dip

Figure 13-26:
Predicted Migration of CO_2 Plume through Layers in the Dupuy Formation During the Operational Phase



under the injection pressure; respond to buoyancy and move back up-dip.

There will be further dissolution of CO_2 in the formation waters during the post operational phase as the migrating CO_2 plume contacts virgin formation water. Potentially an additional 35% of the injected CO_2 will dissolve over the first 1000 years.

Ultimately the CO_2 plume will continue to migrate until it is trapped by the mechanisms discussed earlier.

13.4.5 Reservoir Simulation

The technique used to mathematically model the behaviour of fluids in the subsurface is termed 'reservoir simulation'. Reservoir simulation of oil and gas accumulations has been used for many years to predict the performance of oil and gas fields and provides a powerful tool to assist in management of oil and gas field development. Simulation is now used routinely to assist in the decision to develop a particular field and in the continual management of the field's performance. Regulatory authorities accept reservoir simulation as a key tool in assessing oil and gas field development applications and as a guide to assessing performance in producing the resource once production commences. This tool has been applied to predict the behaviour of CO_2 that is to be injected.

The behaviour of CO_2 in the subsurface is similar to that of oil and gas enabling reservoir simulators developed for the oil and gas industry to be used to predict the behaviour of CO_2. Minor modifications to the oil and gas simulation models have been made in order to accommodate:

- the solubility of CO_2 in aquifer waters
- the density and viscosity of CO_2 in the supercritical state
- the timeframe over which the CO_2 plume dissipates once injection ceases.

The database from which the Dupuy Formation reservoir description has been derived contains seismic coverage and 27 wells which intersect the Dupuy Formation. Core coverage in most of these wells is restricted to the upper part of the Dupuy Formation, but direct measurement of reservoir permeability over the remaining sections has been obtained during well testing. Well testing involves the flowing of formation fluids and the recording of pressures, both while the well is flowing and once the well has been shut-in.

Analysis of these pressures enables the permeability of the tested zone to be calculated. The permeability calculated from intervals that have been tested is within the range of permeability indicated by the core. This data will be supplemented by a data well which is planned to be drilled in 2005. It is planned to core the entire section from the basal Barrow Group through to the base of the lower Dupuy Formation in the data well. This well will be sited in the area of intended injection so that the data gathered will have direct application to the reservoir model.

Reservoir simulations not only predict the movement of the CO_2 plume but also describe the pressure changes occurring within the formation. Pressure changes will be transmitted far more rapidly and more widely than will the CO_2 plume. Care was taken in the modelling process to monitor the pressure increases which might be transmitted to the major faults as a result of a particular injection scenario. This is because faults are seen as potential migration pathways in the various barrier/baffle units above the CO_2 plume.

The reservoir simulation model will be regularly updated with:

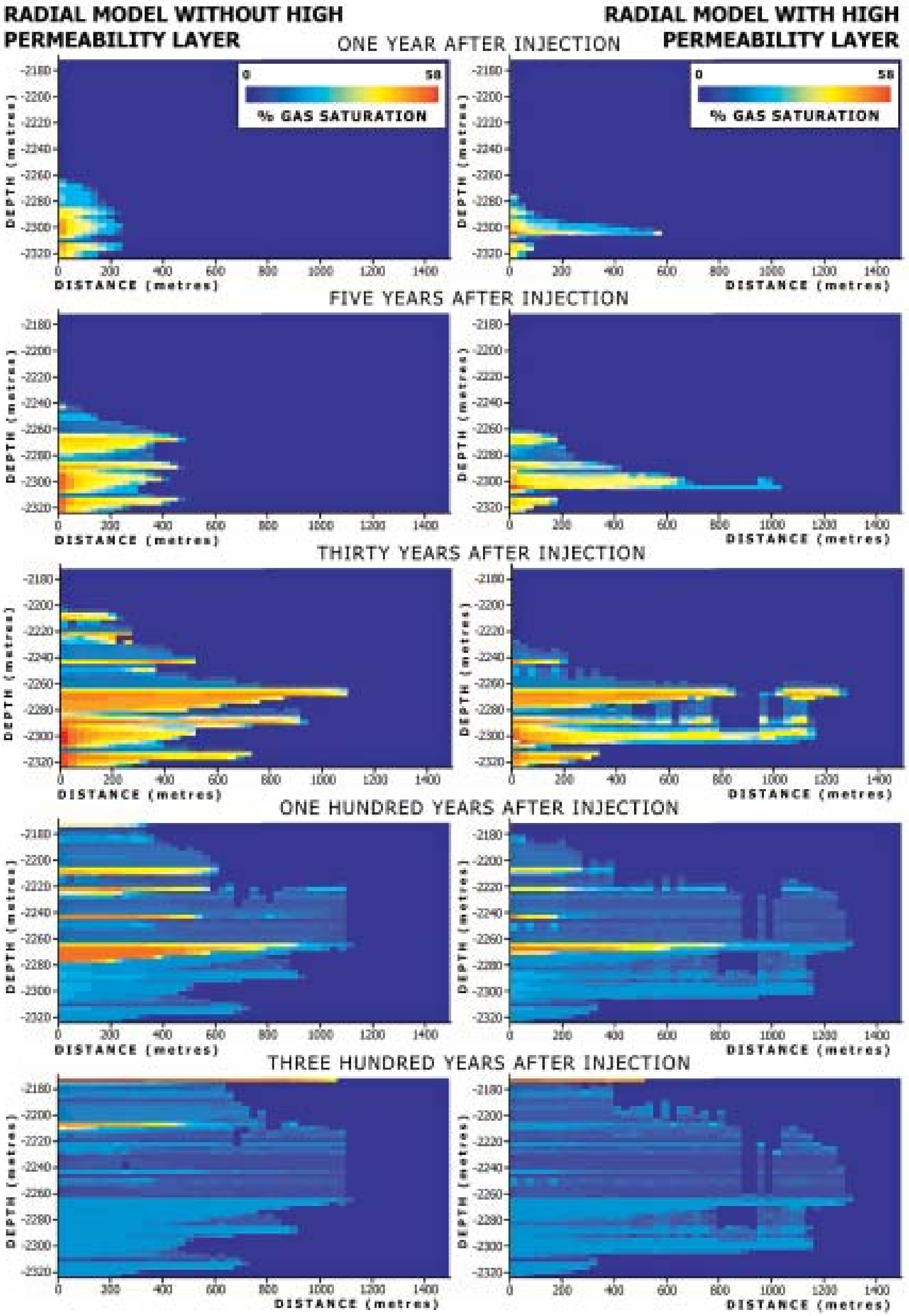
- extensive core data collected from the data well, planned to be drilled in 2005
- data obtained during the drilling of the injection and observation wells
- injection history from the injection wells
- pressure data from the observation wells
- data from the seismic and other monitoring programs.

Updating and validating of reservoir simulation models with data from the monitoring program is a primary activity in the Carbon Dioxide Injection Operations Management Plan. This management plan is discussed further in Section 13.4.8.

Single Injection Well Simulation

Figure 13-27 shows a single well model which highlights the effect of injection into a number of sandstone layers within the Dupuy Formation.
The model predicts a gradual advance of the CO_2 plume dominantly along the higher permeability layers and to a lesser degree, upwards during the injection period. Following injection, the buoyancy effect will be dominant with the CO_2 plume migrating vertically.
A 30-year injection period has been assumed in this particular model.

Figure 13-27:
Single Well Injection Model



The Gorgon Joint Venturers have investigated the possibility that if there was a layer in the Dupuy Formation with anomalously high permeability, it may cause the CO_2 plume to migrate greater distances than indicated by the reservoir simulation. In order to understand this potential impact, a model was run based on the assumption that one of the layers had permeability which was 10 times higher than those anticipated. The output from this model is also shown on the right-hand side of Figure 13-27. The initial impact of the higher than anticipated permeability is significant as the CO_2 plume migrates further along the layers in the reservoir. However by year 30, at the end of the modelled injection phase, the distance the CO_2 plume has migrated is similar to that in the base model. In addition, the behaviour of the CO_2 plume in the following 300 years is similar between the two models with the CO_2 plume only having migrated slightly further in the high permeability case. In this example, the extent of CO_2 migration is relatively insensitive to the presence of an anomalously high permeability layer in the reservoir.

Full Reservoir Simulation

Migration of the Carbon Dioxide Plume

The full reservoir simulation is based on an injection pattern with seven wells at the central east coast area of Barrow Island. The simulation predicts the migration and trapping of the CO_2 plume over a 1000 year period. The simulation is based on injection into the interval below the Perforans Shale for a period of 40 years and provides output in both cross-section form and map view. The production of reservoir CO_2 reduces significantly after 40 years. A typical series of cross-sectional outputs from the simulation are shown in Figure 13-28. Part A of Figure 13-28 shows a map of Barrow Island, the extent of the CO_2 plume and the location of the cross-sectional outputs from the reservoir simulation. Part B of Figure 13-28 shows an expanded cross section of the Dupuy Formation reflected in the cross-sectional outputs from the simulation. The series of six cross-cross sectional outputs in Figure 13-28 show the migration of the CO_2 plume through the Dupuy Formation over the injection period and for the next 1000 years. The cross-sectional outputs represent the Dupuy Formation with the upper boundary being marked by the base Barrow Group Shale over 2000 m below the surface of Barrow Island. During the injection period, the simulation predicts that the CO_2 plume will migrate along the higher permeability layers at a rate determined by the permeability within each layer. Most of the CO_2 will be contained within the higher quality upper massive sandstone below the Perforans Shale, while relatively little CO_2 will be contained in the poorer sands of the lower Dupuy Formation. In the 1000-year period following injection, migration will be dominated by vertical buoyancy forces with the CO_2 plume migrating slowly through the Perforans Shale and into the upper Dupuy Formation. In the 1000 year cross section, the lighter grey colours represent areas where the injected CO_2 has effectively become trapped by the mechanisms described in 13.4.4.

The upper Dupuy Formation is of similarly low permeability to the Perforans Shale, but 10 times the thickness. The model shows that over the 1000-year period, most of the CO_2 plume will become trapped within the Dupuy Formation. The remainder of the injected CO_2 will be prevented from migrating vertically by the basal Barrow Group shale.

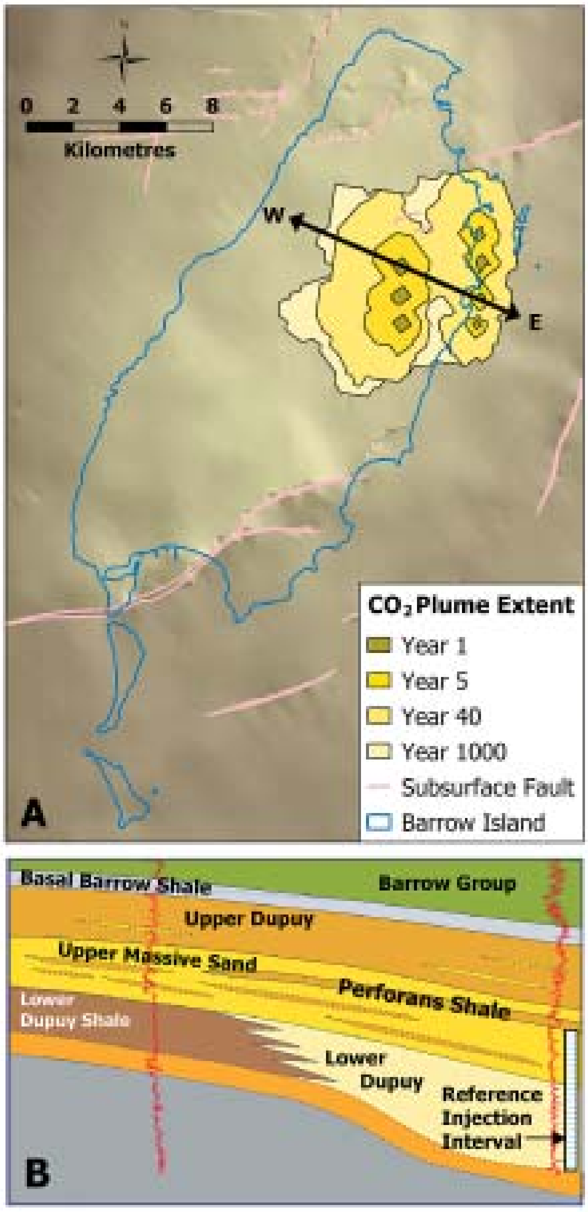
Pressure Field

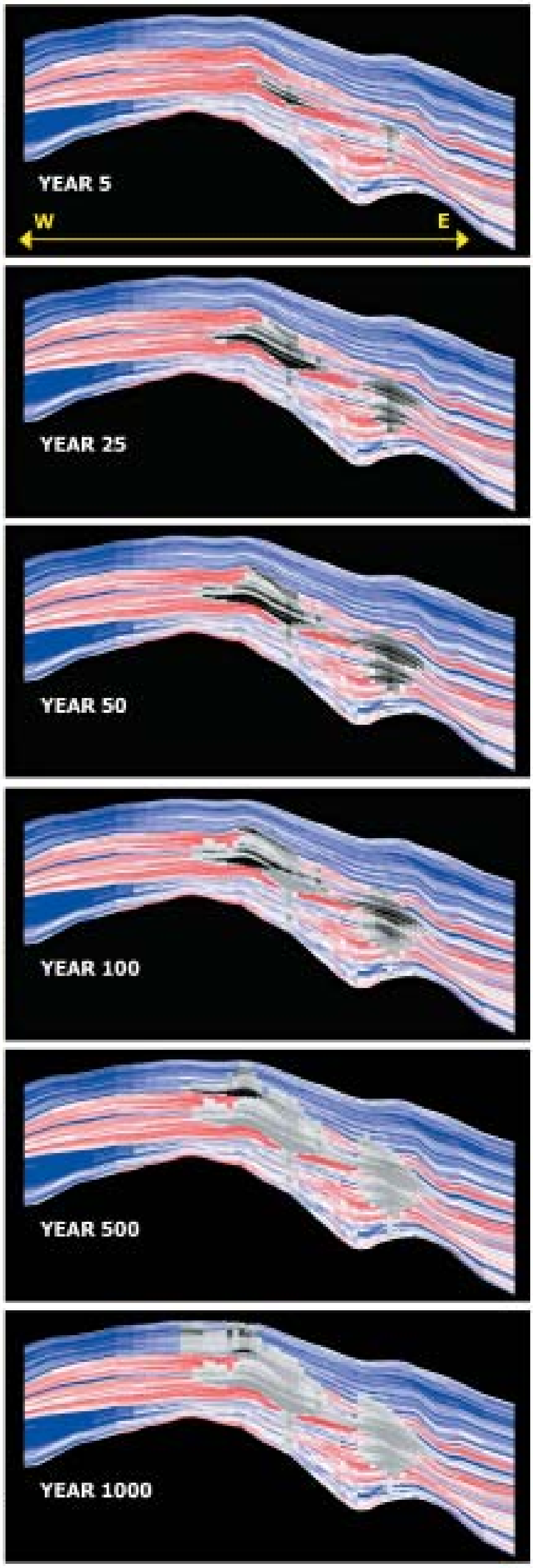
In addition to predicting CO_2 saturation throughout the reservoir, the simulation model predicts pressure increases resulting from the injection process. Understanding reservoir pressure behaviour is a powerful management tool as pressure changes travel faster and further in the reservoir than the injected fluids. This enables pressure readings to be used to monitor the migration of the CO_2 plume in advance of its physical arrival.

Knowledge of the changes to the pressure field attributable to injection is significant for two reasons: excessive pressure increases can cause faults to leak and can fracture seals; and information on the performance of the reservoir can be used to calibrate reservoir simulation models.

Simulation studies have been undertaken to understand the potential increase in pressures within the Dupuy Formation as a result of the planned CO_2 injection. Simulations show the pressure at the main Barrow Fault will reach its peak after approximately 30 years of injection. Ongoing studies will determine an appropriate pressure that could be sustained at the main Barrow Fault. If the pressure at the fault is anticipated to approach this level, the Joint Venturers plan to drill a pressure relief well (or wells) to produce water from the Dupuy Formation and re-inject it into the lower Barrow Group. The pressure-relief well will be sited so that it produces water uncontaminated by the encroaching

Figure 13-28:
Reservoir Simulation Based on the Preferred Injection Scenario and Showing the Extent of the CO_2 Plume Over 1000 Years





The Simulation is of the Dupuy Formation interval only. Top of the simulation interval is marked by the Base Barrow Group Shale.

Red colour intervals represent high permeability layers in the reservoir.

Blue colour intervals represent low permeability layers (baffles) in the reservoir.

Grey shades represent percentage of CO_2 in pore space. Light grey = low percentage, dark grey/black = high percentage.

In the 500 and 1000 year cases, light grey colour represents areas where CO_2 has become trapped.

Dark grey (black) areas represent CO_2 as a separate phase, that will continue to migrate through the reservoir.

CO_2. In the area around Barrow Island, the Barrow Group has been pressure depleted by over 40 years of hydrocarbon production. Injection of Dupuy Formation water into the Barrow Group is not anticipated to result in formation pressures in the Barrow Group that are greater than that present prior to the commencement of hydrocarbon production operations.

Displaced Formation Water

The volume of the pores in the Dupuy Formation into which the CO_2 will be injected is several hundred times larger than the volume of CO_2 to be injected. As the CO_2 is injected, it will partially dissolve in the formation water with the remainder occupying pore spaces which previously contained formation water. As the rock minerals and formation water are only slightly compressible, the reservoir pressure will increase.

Modelling by the Gorgon Joint Venturers indicates that the average pressure in the Dupuy Formation would increase by approximately 1.4 MPa if the Dupuy Formation was totally isolated from the surrounding formations. However total hydraulic isolation of any formation is rare and some movement of formation water between formations is expected. This should limit the overall pressure increase in the Dupuy Formation.

The formation water will move from areas of high pressure to areas of lower pressure along any permeable pathway. It is likely that some of the major faults in the Barrow Sub-basin, such as the Flinders Fault zone or the Barrow Fault, may represent permeable pathways allowing some of the displaced formation water to move into the overlying formations. Since the pressure response travels much further in the reservoir than the CO_2 plume, the formation water will be displaced in areas distant to the injected CO_2.

As discussed earlier, 40 years of hydrocarbon production operations have reduced the pressure in the overlying Barrow Group. Therefore it is reasonable to expect that the displaced formation waters will move preferentially into this formation.

13.4.6 Deviations from Simulation Predictions

Reservoir simulation is a powerful tool for predicting the behaviour of fluids in the subsurface but is restricted by the data available to be input into the models. As a routine part of any reservoir simulation study a sensitivity analysis was undertaken in order to understand the impact of events which might lead to deviations from the model predictions. In understanding the behaviour of the injected CO_2, the Gorgon Joint Venturers determined that the conditions that could lead to deviations from the model predictions are:

- the presence of high permeability layers in the reservoir
- down dip migration
- leakage through existing wells
- faults and fractures.

Each of these conditions, as it relates to the reservoir simulation predictions, are discussed below.

High Permeability Layers

Layers of unexpectedly high permeability may result in more rapid and extensive migration of the CO_2 plume. As discussed in Section 13.4.5, the impact of high permeably layers on the migration of the injected CO_2 is most apparent during the initial injection phase. After approximately 30 years the impact of the high permeability layer on the migration of the CO_2 plume is likely to be low. Additionally, if such a layer were present, it would be readily detected by the performance of the injection wells. If it was determined that the layer was adversely affecting the migration of the CO_2 plume then remediation actions such as those described in section 13.4.8 would be undertaken.

Down Dip Migration

Concern has been raised by oil and gas field operators in the Barrow Sub-basin that the CO_2 plume will migrate ‘down dip’ and possibly affect operations to the east and north of Barrow Island. Down dip migration will occur during the injection or operational phase because the injection pressure will override the vertically upward force of buoyancy. The location of injection wells will be chosen carefully to minimise the possibility of migration into oil and gas fields down dip of Barrow Island. The reservoir simulation shows that the amount of down dip, lateral migration of the CO_2 plume will be limited to about 2 km.

The Gorgon Joint Venturers’ simulation scenarios have shown that down dip migration to the point where it could interfere with these oil and gas field operations is very unlikely. If such migration was detected, then remediation actions such as those discussed in Section 13.4.8 would be taken to redirect the CO_2 plume.

Existing Wells

Experience from CO_2 injection operations (refer to Box 13-2) indicates that existing well bores pose the greatest risk as conduits for upward migration of CO_2. Section 13.4.8 includes information on the proposed management of existing well penetrations.

Faults and Fractures

Fault planes can be conduits for migrating fluids because the rock along the fault plane can be crushed and pore space (and permeability) is created in the process. Sulphur deposits in claypans along the Barrow Fault scarp provide evidence that there has been natural fluid movement up the Barrow Fault and to the surface over the recent geologic past. However, the Barrow Fault currently seals the 285 million kilolitre Windalia oil accumulation, providing a lateral and vertical barrier to fluid migration at that level. Geomechanical data suggests some of the main faults (e.g. the Barrow Fault) may leak vertically at the Dupuy Formation level.

A significant source of potential migration pathways, associated with faulting, lies in the juxtaposition of permeable layers on either side of the fault. For example, it is probable that some movement of aquifer fluid may be occurring across the Barrow Fault from the upper Massive Sand on the northern, up-thrown side of the fault to sands of the basal Barrow Group on the southern, down-thrown side.

Researchers at the Lawrence Berkley National Laboratory (Benson 2004) have attempted to quantify the rates at which CO_2 could leak from a range of simulated faults and fractures. This work concluded that CO_2 flux rates resulting from migration along faults could be of such magnitude that the increased concentrations of CO_2 would have a detrimental impact on flora, but only within the relatively localised area of the fault, possibly impacting an area of between 1000 m^2 and 100 000 m^2.

The Gorgon Joint Venturers' precautionary approach to managing containment risk requires that the CO_2 plume should not impinge on the main faults (e.g. the Barrow Fault) and that migration near these fault zone should be minimised.

There is the possibility that faults and fractures, which are not conduits for fluid movement under the current pressure and formation fluid regime, might allow for fluid migration under the increased pressures which will be created by the injection of CO_2. Geomechanical studies undertaken by the Gorgon Joint Venturers have estimated that the operational reservoir pressures are unlikely to result in fault leakage. During injection, conservative pressure limitations will be employed to avoid possible fault and seal leaks.

13.4.7 Monitoring of Injected Carbon Dioxide

The Gorgon Joint Venturers continue to study the most appropriate techniques to monitor the injected CO_2. It is likely that these activities will evolve as the behaviour of the CO_2 in the subsurface is verified and as existing technologies improve and new technologies become available. The following section outlines the objectives for the CO_2 monitoring program and how these data will be integrated into the ongoing management of the CO_2 injection operations. Section 6.2.5 of Chapter 6 provides information on the type of seismic monitoring activities likely to be undertaken and Section 10.4.1 of Chapter 10 documents a number of environmental performance standards that will be incorporated into the design and operations of the monitoring programs.

Demonstrating the integrity of a CO_2 injection project through monitoring the behaviour of injected CO_2 will be integral to gaining community support for the subsurface injection of CO_2. Key objectives for the monitoring and verification activities therefore include:

- generating clear, comprehensive, timely and accurate information that will be used to effectively and responsibly manage environmental, health, safety and economic risks and to ensure that set performance standards are being met
- determining, to an appropriate level of accuracy, the quality, composition and location of gas captured, injected and stored and the net abatement of emissions. This should include identification and accounting of fugitive emissions
- demonstrating that the residual risk of leakage is acceptably low at the time of site closure.

In order to fulfil these objectives a range of monitoring activities are planned:

- routine observation and recording of injection rates and surface pressures
- health, environment and safety oriented surveillance to detect surface leaks before they can pose a risk to personnel or the environment
- verification via seismic surveys and/or observation wells of the CO_2 plume migration in the subsurface.

Experience from CO_2 injection operations (discussed in Box 13-2) has shown that a combination of observation wells and time-lapse seismic data provides the best possible means to track the progress of migrating CO_2 through the subsurface.

Seismic monitoring of the CO_2 plume in the subsurface will be supplemented by:

- running conventional wireline logging tools in wells to detect CO_2 migration at wells or leakage up the well bore
- conducting geochemical analyses of formation waters recovered from the Dupuy Formation to understand the dissolution of CO_2 and any chemical reactions taking place.

As in any conventional oil or gas field operation, the collection and evaluation of pressure and flow data provides information on the performance of an operation. It is planned to have continuous remote monitoring of pressure and flow data at a number of points from the CO_2 compressors to the injection wells. These data will be primarily used to: verify the volumes of CO_2 injected; to optimise the injection process; and detect leaks in the surface facilities. In addition, the pressure in each monitoring well will be recorded in order to detect any anomalous injection behaviour.

Reservoir modelling by the Gorgon Joint Venturers indicates that the CO_2 plume will have migrated only about 1 km from the injection wells during the first five years. The migration of the plume during this period and prior to the first repeat seismic survey will be assessed on the performance of the injection wells and the pressure response observed in the injection and observation wells.

Surveillance activities to detect surface leakage will comprise CO_2 detection equipment at locations within the compression and pipeline facilities, at each of the injection and observation wells and on any existing wells in the vicinity of the CO_2 plume. These detectors will be used to identify anomalously high levels of CO_2, which may indicate unplanned release of CO_2 from a well or facility.

As discussed in Section 13.4.5, the reservoir simulation model will be refined based on monitoring data in order to provide detailed predictions of the pressure transient caused by injection. Pressure changes in observation wells will provide a means to check the progress of the CO_2 plume in advance of its physical arrival at an observation well. The arrival of the CO_2 plume at an observation well can be detected by conventional well logging methods.

Monitoring activities will be reviewed on a regular basis with the regulatory agencies. Revisions to the injection operations and the monitoring program will be agreed in response to unpredicted migration or improvements in monitoring technology.

13.4.8 Carbon Dioxide Injection Operations Management Plan

Oil and gas field operations are often managed through a Reservoir Management Plan or an Operations Management Plan, which outlines how a field will be developed. The Gorgon Joint Venturers propose to adopt this process to assist in the management of the CO_2 injection operations. The primary objective of the CO_2 Injection Operations Management Plan will be to maximise the volume of reservoir CO_2 injected whilst ensuring that the injection does not pose a health or safety risk to people, an environmental risk to the conservation values of Barrow Island, or a risk to other assets such as oil or gas field operations around Barrow Island. The Plan will outline the following activities:

- routine injection operations
- objectives and nature of monitoring activities
- integration of monitoring data into the current understanding of CO_2 behaviour in the subsurface
- responses to unacceptably high formation pressures
- responses to unpredicted migration
- management of existing well penetrations
- corrosion management of pipelines and wells
- staffing and accountability plan to ensure the objectives outlined under the plan are achieved
- continued support of research into geosequestration and the application of this research into the Gorgon Development
- criteria by which the injection of reservoir CO_2 would be suspended, if it was found that an unacceptable health, safety or environmental risk was present.

The CO_2 Injection Operations Management Plan will be provided to the regulating authorities for their endorsement as part of the formal project proposal applications required under the *Barrow Island Act 2003* and its Schedule 1 (Gorgon Gas Processing and Infrastructure Project Agreement).

Responses to the unpredicted migration of CO_2, the avoidance of unacceptably high formation pressures and ensuring that existing well penetrations are appropriately managed are critical to the overall environmental and safety performance of the CO_2 injection operations. Management actions to ensure effective performance in these areas have been developed and are summarised in the following sections on CO_2 Injection Uncertainty Management, Management of Existing Well Penetrations and Response to Unpredicted Migration or Unacceptably High Pressures.

Carbon Dioxide Injection Uncertainty Management

Appropriately managing uncertainties associated with the subsurface injection of CO_2 is essential to the success of the CO_2 injection project on Barrow Island. Uncertainty management involves the consideration of possible outcomes which lie at or near the extremes of the range predicted by the objective analysis of all of the data and developing strategies to mitigate the downside and capitalize on the upside. In addition, some strictly deterministic 'What if?' scenarios have been framed to explore beyond the limits suggested by objective analysis. The basis of contingency planning is a sound understanding of the limits of accuracy of the input data, and of the models resulting from interpretation of those data.

From the outset, the Gorgon Joint Ventures have taken a rigorously probabilistic approach to uncertainty management, which has ensured that the level of uncertainty relating to each input parameter has been preserved in all outputs. In addition, the importance of each input parameter has been assessed, together with the impact of the current level of uncertainty. Technical work has been focused on reducing the level of uncertainty in the key subsurface areas.

A structured process to manage project uncertainty has been developed to:

- identify all of the subsurface risks
- evaluate the impact of each uncertainty
- generate options for managing the subsurface risks
- develop and implement surveillance plans to identify if any unexpected outcome occurs
- manage unexpected outcomes.

Figure 13-29 illustrates the work flow followed in managing the injection project uncertainties. The first phase in the process is to identify key project parameters and to define a range for each which captures the uncertainty inherent in that parameter. Work is then focused on reducing the level of uncertainty in key technical areas and then plans are developed to mitigate downside outcomes and capitalise on upside outcomes.

The uncertainty management process will be updated regularly as the project matures, particularly as new data becomes available to the project teams.

Potential impact on the project was evaluated in terms of:

- health, safety and environmental issues, including amount of land disturbance
- containment of CO_2 in the subsurface
- monitoring and verification
- injectivity
- capacity
- risk to hydrocarbon or other assets
- cost.

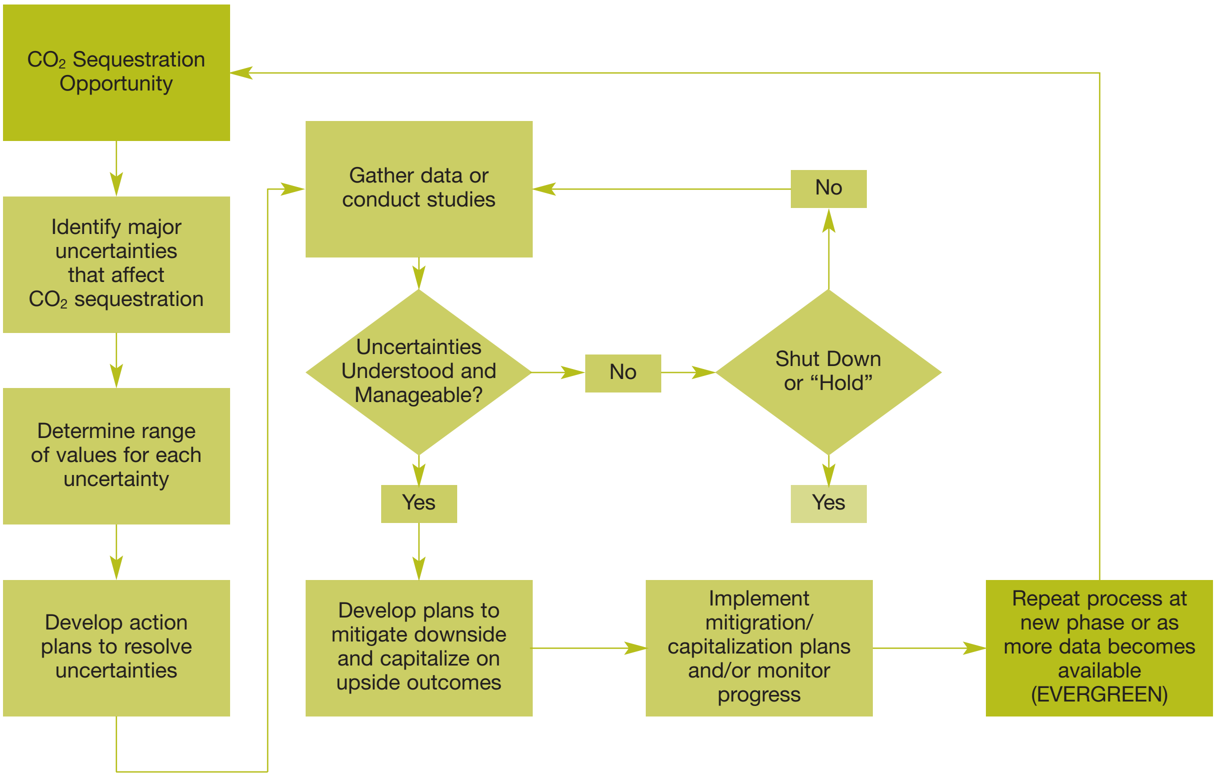
Parameters with the potential to significantly impact one or more of these areas were considered 'high priority' in terms of technical work planing. An objective of work planning is to identify tasks and studies that will reduce the level of uncertainty associated with key project parameters. For example, measurements from formation core samples might be required to reduce the level of uncertainty around formation permeability and CO_2 injectivity.

The process for identifying options to reduce uncertainty involves brainstorming multiple tasks that address high priority parameters. The effectiveness of the tasks in terms of reducing uncertainty, the time required to complete the tasks and notional cost estimates are documented for each, which support a team decision on whether to proceed with the reduction activity or to implement an alternative task. When reduction activities are completed, uncertainties are reassessed and a decision made to determine whether further work is required. When the level of uncertainty is considered manageable, or if a point is reached where the uncertainty cannot be further reduced, mitigation and realisation plans are developed for each uncertainty.

The process of developing mitigation and realisation plans involves:

- identifying indicators or 'signposts' for worse than expected or better than expected project outcomes
- determine the required monitoring technologies that would be required to identify deviations from the expected outcome
- estimating the timeframe in which signposts may become evident

Figure 13-29:
CO_2 Injection Project – Uncertainty Management Work Flow



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- developing mitigation plans for worse than expected outcomes and realisation plans for better than expected project outcomes
- estimating the probability that each mitigation plan will be effective in reducing the impact of the associated worse than expected outcome.

The selection of monitoring technologies is driven by the identification of signposts that signal worst than, or better than expected project outcomes.

Management actions have been designed to mitigate adverse project performance or environmental impacts, if a signpost indicating a worse than expected project outcome is identified. Table 13-14 outlines management actions for the key project uncertainties that may be undertaken in the event a signpost is identified indicating a worse than expected outcome. The table also identifies the monitoring technologies that are likely to be employed and an estimate of the time period over which the signpost may become evident.

Management of Existing Well Penetrations

Experience from CO_2 enhanced oil recovery operations has identified leakage of CO_2 along existing well penetrations as a potential failure mode for CO_2 containment. While the existing wells on Barrow Island are the responsibility of the Barrow Island oil field Joint Venture, the Gorgon Joint Venturers have undertaken a study to determine if the wells likely to be in the vicinity of the migrating CO_2 plume are appropriately completed or decommissioned for service in a CO_2 environment.

There are currently 27 wells on Barrow Island that have either been drilled into the Dupuy Formation or into formations underlying the Dupuy Formation.
The location of each of these wells is shown in Figure 13-11. Each of these wells has been studied by:

- reviewing the current well files and end of well reports
- reviewing the production operations reports to confirm the current status of the well

- undertaking field visits to assess the surface condition of the well
- assessing if the well is suitable for service in a CO_2 environment
- categorising each well as low, moderate or high-risk based on degree of difficulty in undertaking remedial action on the well
- developing a generic plug back and decommissioning plan for each category of well requiring remediation such that the well would then be suitable for service in a CO_2 environment
- developing specific remediation plans including time and cost estimates for each well requiring remediation.

Reservoir simulation studies discussed earlier provide an indication of the CO_2 migration path. During the injection phase, the CO_2 plume will spread several kilometres from the injection wells driven by the force of the injection pressure. Following the injection phase, the CO_2 will migrate more slowly driven by buoyancy in the water filled pore spaces. These simulation studies indicate the approximate timing and order that the existing well penetrations will be exposed to the CO_2 plume. It is anticipated that only two wells will be intersected by the CO_2 plume during the injection phase of operations. An additional four wells will likely be intersected within 1000 years following injection.

During operations, appropriate arrangements will be made with the Barrow Island Joint Venture to ensure that all wells in the path of the migrating CO_2 are assessed and if required, worked over, such that they are fit for service in a CO_2 environment.

The final sequence for undertaking any required remedial actions in the existing well penetrations will be driven by the monitoring and reservoir surveillance activities undertaken during the injection and post-injection phases of the project.

Generic plug and decommissioning plans have been developed for wells that have casing over the Dupuy Formation interval and for those wells that have not been cased (open hole). A key component of these plans is the use of cements that have been developed that are resistant to attack from the mildly acidic formation water that will result from CO_2 injection. Where a well has been completed with casing, the plans call for the milling of the steel casing so that the cement plug can seal against the formation. Schematics of the wells following these generic plug and decommissioning activities are provided in Figure 13-30.

Response to Unpredicted Migration or Unacceptably High Pressures

Unpredicted migration that results in the CO_2 remaining trapped in the subsurface will not result in risk to health, safety or the environment but needs to be understood in order to update and validate the reservoir simulation models. Managing unpredicted migration or unacceptably high reservoir pressures is a key objective of the uncertainty management plan discussed above.

If the monitoring program detects CO_2 migration that potentially could pose a health, safety or environmental risk, or a risk to other assets, a number of activities will be implemented to manage the further migration of the CO_2 plume including:

- drilling new injection wells to direct the injected CO_2 into different parts of the reservoir
- varying the injection rates at individual wells so as to direct the migration of the CO_2 plume
- drilling pressure relief wells ahead of the migrating CO_2 plume
- re-completing injection wells over a larger interval, thereby reducing the volume of CO_2 being injected into each layer of the formation
- upgrading technology where necessary.

If reservoir pressure is increasing more rapidly than expected, such that vertical migration along faults or fractures might occur, then relief wells will be utilised to reduce the pressure in the formation and mitigate the risk of migration along faults of fractures. As discussed earlier, pressure relief wells work by withdrawing water from the Dupuy Formation and placing it in the overlying Barrow Group.

If there are problems with injecting the desired volume of CO_2, or if CO_2 is disproportionately injected into a particular layer, the injection interval in each well will be modified so as to either increase the amount of CO_2 being injected or direct the CO_2 into alternative layers. Ultimately additional wells can be drilled to increase the amount of CO_2 that can be injected or to direct the CO_2 into a different part of the Dupuy Formation.

Highly unlikely events such as migration of CO_2 up an injector well will be detected as anomalous injection behaviour. In such cases, the well would be shut-in, the causes investigated and the well remediated.

If unpredicted migration is identified by the monitoring program the measures outlined above will be implemented. If it is then determined that any further

Table 13-14:
CO_2 Injection Management Actions

Well Injectivity					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
It may be difficult to inject CO_2 at the required rate in the case of a worse than expected geological outcome such as low permeability.	CO_2 cannot be injected at the required rates.	Unexpected bottom hole pressure increase (>6.9 MPa above virgin pressure in 3 months).	Wellhead pressure; down hole pressure gauges; flow rate gauges.	<6 months	Increase/alter monitoring activities to verify cause of bottom hole pressure increase and assess impact/implication and determine if managem.ent action is required. 1) Re-complete injection wells; fracture stimulate. 2) Re-complete and perforate over entire interval if not already done. 3) Change well design for subsequent injection wells (e.g. horizontal). 4) Re-consider bottom hole locations for subsequent injection wells, based on additional knowledge of reservoir heterogeneity acquired from previous drilling. 5) Drill additional injection wells. 6) Complete injectors in another stratigraphic unit as well as the Dupuy Formation (e.g. Malouet 6000 ft Sand) to facilitate injection at the required rate.
	Initially injection rate meets expectations, but overall pore space limited.	Gradual increase in bottom hole pressure at injector wells in excess of expected pressure increase.	Wellhead pressure; down hole pressure gauges; flow rate gauges	10 years	1) Produce water from the Dupuy Formation to offset pressure increase (see Pore Volume and Compartmentalisation).
	CO_2 cannot be injected at the required rates due to chemical reaction with the formation.	Unexpected bottom hole pressure increase (>6.9 MPa in 3 months), and significant change in formation water chemistry near injectors.	Wellhead pressure; down hole pressure gauges; flow rate gauges; fluid samples & geochemical analysis.	0-30 years	1) Work over well and acid stimulate (depending on the specific change in water chemistry e.g. carbonate precipitation around the well bore). 2) Re-complete injection wells; fracture stimulate.

Table 13-14: (continued)
CO_2 Injection Management Actions

Existing Well Failure					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Containment failure via existing well penetrations. Also refer to discussion on management of existing well penetrations. The actions in this table are in addition to the planned assessment and well remediation.	CO_2 migrates into overlying stratigraphy.	Seismic and/or borehole monitoring show CO_2 in stratigraphy above the Dupuy Fm in proximity to existing well penetration(s).	Surface & borehole geophysics.	Ongoing	Increase/alter monitoring activities to verify mode of failure and assess impact/implication and determine if management action is required. Secondary seals in the Malouet Formation may trap CO_2, or residence time in the Malouet Formation may be sufficient for 100% residual gas trapping and dissolution. 1) Remediate leaking wells. 2) Modify injection pattern to drive migration away from 'problem' well penetration(s).
	CO_2 leakage at surface.	Surface monitoring indicates increased levels of CO_2 in proximity to well(s).	Atmospheric and soil gas CO_2 detectors, vegetation surveys, visual inspection of well heads.	Ongoing	1) Remediate leaking well(s); implement appropriate environmental remediation.
	Leakage of displaced formation water into higher stratigraphy via well penetrations.	Fluid sampling indicates Dupuy Formation water in overlying stratigraphy (above Malouet zone of intermediate salinity) and in proximity to existing well penetration(s).	Surface & borehole geophysics (fluid sampling from overlying stratigraphic unit).	0–30 yrs	Increase/alter monitoring activities to verify cause of displaced water and assess impact/implications and determine if management action is required. 1) Remediate leaking wells, particularly if leaking well is along the expected migration path of CO_2 plume.

Table 13-14: (continued)
CO_2 Injection Management Actions

Top Seal Failure					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Containment failure via inadequate top seal. Ability of the sealing lithologies to contain the migrating CO_2.	CO_2 moves into higher levels of the stratigraphy.	Seismic and/or borehole monitoring show CO_2 in stratigraphy above the Dupuy (unrelated to an existing well penetration).	Surface and borehole monitoring.	0–30 years	Increase/alter monitoring activities to verify top seal leakage. Assess impacts/implications and determine if management action is required (secondary seals in the Malouet Formation may trap CO_2, or residence time in the Malouet Formation may be sufficient for 100% residual gas trapping and dissolution). 1) Modify injection pattern to avoid area of top seal leakage. 2) Produce water from Dupuy Formation to lower aquifer pressure and control rate of leakage into overlying stratigraphy.
	Seal integrity compromised due to pressure increase caused by CO_2 injection.	Pressure drop during injection Seismic and/or borehole monitoring show CO_2 in stratigraphy above the Dupuy (unrelated to an existing well penetration).	Wellhead pressure; down hole pressure gauges; flow rate gauges; seismic and borehole monitoring; tilt meter; passive seismic.	0–30 years	Increase/alter monitoring activities to verify pressure increase and top seal leakage. Assess impacts/implications and determine if management action is required (secondary seals in the Malouet Formation may trap CO_2, or residence time in the Malouet Formation may be sufficient for 100% residual gas trapping and dissolution). 1) Modify injection pattern to avoid area of top seal leakage. 2) Lower injection rates/add more injectors to control pore pressure at the base of the seal. 3) Produce water from Dupuy Formation to lower aquifer pressure and control rate of leakage into overlying stratigraphy.

Table 13-14: (continued)
CO_2 Injection Management Actions

Fault Seal Failure					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Containment failure via fault migration.	Faults act as a migration pathway for CO_2 into higher stratigraphy.	Seismic and/or borehole monitoring show CO_2 in stratigraphy above the Dupuy Formation in proximity to fault(s).	Surface and borehole geophysics, fluid sampling, down hole gauges.	Ongoing	Increase/alter monitoring activities to verify fault leakage. Assess impact/implication and determine if management action is required (fault leakage may not result in surface leakage and may be acceptable).
					1) Modify injection pattern to drive migration away from 'problem' fault.
					2) Produce water near the fault to lower pore pressure and control vertical leakage.
	Faults acts as a migration pathway for CO_2 to surface.	Atmospheric CO_2 in proximity of fault expression at surface. Ecological impacts observed as a result of increased levels of CO_2.	Surface monitoring.	Ongoing	1) Modify injection pattern to drive migration away from 'problem' fault.
					2) Use water production well(s) near the fault to lower pore pressure and control fluid leakage up fault.
	Faults are impermeable both laterally and vertically.	Unexpected pressure increase in a part of the Dupuy Formation that is thought to be isolated from the rest (fault bounded).	see Compartmentalisation.		

Table 13-14: (continued)
CO_2 Injection Management Actions

Uncertainty	Worse Than Expected Outcome	Signpost	Reservoir Surveillance	Timing	Management Action
Pore Volume and Distribution					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Reduced pore volume or distribution may limit CO_2 injection.	Insufficient capacity for full volume of CO_2.	Rate of long-term pressure build up greater than expected.	Wellhead pressure; down-hole pressure gauges; flow rate gauges; multi-component seismic for pressure.	10–30 yrs	Increase/alter monitoring activities to verify cause of pressure build and determine that is due to limited pore volume and distribution. Assess impact/implication and determine if management action is required.
					1) Complete injection wells over full Dupuy Formation and higher in stratigraphy (e.g. Malouet 6000' Sand). 2) Produce water from the Dupuy Formation to offset pressure increase. 3) Do not inject the full volume of Gorgon reservoir CO_2.
Permeability and Permeability Heterogeneity					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Permeability and permeability heterogeneity may limit CO_2 injection.	CO_2 cannot be injected at the required rates.	Unexpected bottom hole pressure increase (>6.9 MPa increase in 3 months).	Wellhead pressure; down hole pressure gauges; flow rate gauges.	see Well Injectivity.	
	Unexpected migration of the CO_2 plume.	Seismic and/or borehole monitoring show unexpected CO_2 distribution, possibly related to stratigraphic or depositional geometry which may allow rapid migration (>5 km in 10 yrs; see high permeability layers) related to lower than expected bottom hole pressure (~1.7 MPa vs. expected ~4.8 MPa).	Surface and borehole monitoring (well head pressure/down hole pressure gauges) production logging.	0–10 yrs	Increase/alter monitoring activities to verify cause of unexpected migration. Assess impact/implication and determine if management action is required (other uncertainties that may contribute include: structure, high permeability layers, hydrodynamic flow).
					1) Re-enter well and squeeze off perforations associated with high permeability units. 2) Lower injection rate (drill additional injection wells). 3) Re-locate injection wells.

Table 13-14: (continued)
CO_2 Injection Management Actions

Structure					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Structural uncertainty is primarily a reference to the geometry of the base seal surface, which is likely to be a significant control on CO_2 migration rate and direction.	Migration path not as expected.	Significant volumes of CO_2 move off structure (north, east or west).	Surface and borehole monitoring.	0–30 years	Increase/alter monitoring activities to determine if unexpected migration is caused by structure. Assess impact/implication and determine if management action is required (CO_2 may not move to structural spill point and may not represent a risk). 1) Modify injection pattern to drive migration in desired direction. 2) Use water production wells to deviate course of CO_2 plume.
	Insufficient capacity for full volume of CO_2.	Unexpected pressure increase during injection.	see Pore Volume.		

Compartmentalisation					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Compartmentalisation (vertical & horizontal) may limit CO_2 injection. Either fault or stratigraphic compartmentalisation.	CO_2 can only migrate into an isolated part of the Dupuy Formation.	Unexpected bottom hole pressure increase, pressure transient analysis suggests hydraulically isolated wells.	Surface and borehole monitoring.	0–30 years	Increase/alter monitoring to verify compartmentalisation and assess impact/implication and determine if management action is required. 1) Re-complete and perforate injection wells over entire interval if not already done (Dupuy Formation upper and lower massive sands) 2) Drill additional injection wells outside the compartmentalised area. 3) Produce water from the Dupuy Formation to lower pore pressure in compartmentalised area.

Table 13-14: (continued)
CO_2 Injection Management Actions

High Permeability Layers					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Presence of high permeability layers in reservoir. Thin, high permeability layers within the injection interval may result in rapid lateral migration of CO_2.	CO_2 migrates preferentially along a specific stratigraphic interval or layer (unpredicted rapid migration).	Seismic monitoring and/or borehole monitoring shows CO_2 migrating rapidly in a vertically thin unit (migration of >5 km in 10 yrs).	Surface and borehole monitoring (production logging).	0–30 years	Increase/alter monitoring to verify that unexpected migration is a result of high permeability layers. Assess impact/ implications and determine if management action is required (preferential migration of CO_2 along high permeability layers may not represent a containment risk and are likely to result in less pore pressure build up at the injectors).
					1) Re-enter well and seal off perforations associated with the high permeability layer. 2) Modify injection pattern to allow for high permeability layers. 3) Do not inject the full volume of reservoir CO_2.
		Lower than expected bottom hole pressure (~1.7 MPa vs. expected ~4.8 MPa).	Wellhead pressure; down hole pressure gauges; flow rate gauges.	6–12 months	1) Re-enter well and seal off perforations associated with the high permeability layer. 2) Modify injection pattern to allow for high permeability layers. 3) Do not inject the full volume of reservoir CO_2.
	CO_2 moves off structure as a result of migration along high permeability layer.	Seismic shows CO_2 saturation in a vertically thin unit (~2 km offshore); may also be associated with lower than expected bottom hole pressure (see above).	Offshore seismic; wellhead pressure; down hole pressure gauges; flow rate gauges.	0–30 years	1) Re-enter well and seal off perforations associated with the high permeability layer. 2) Modify injection pattern to allow for high permeability layers. 3) Do not inject the full volume of reservoir CO_2.

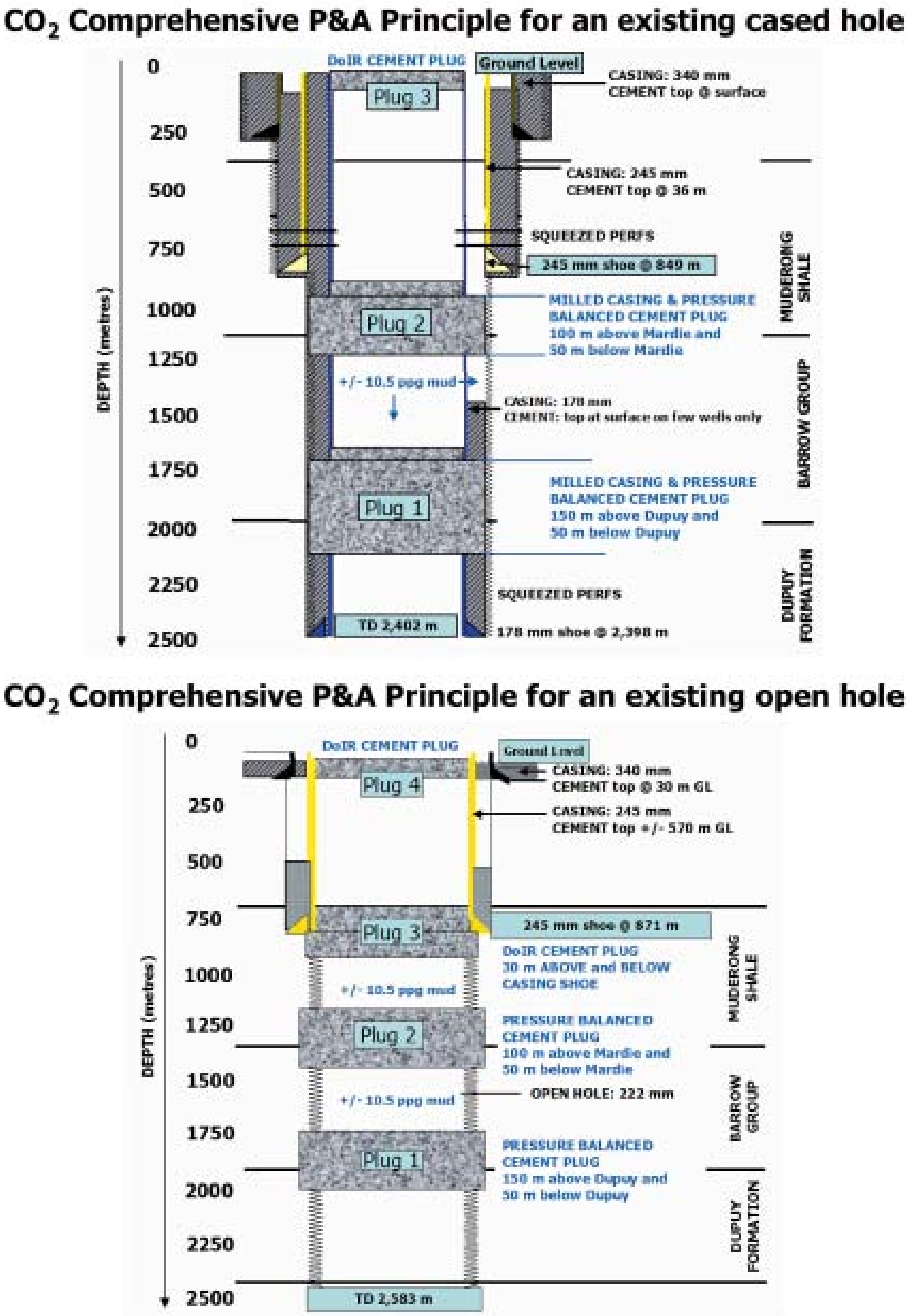
Table 13-14: (continued)
CO_2 Injection Management Actions

Hydrodynamic Gradients					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Unexpected pressure gradients in the formation may alter the CO_2 migration path.	Migration path not as expected.	Significant volumes of CO_2 move off structure (north, east or west). Hydraulic gradient in aquifer the suspected cause.	Surface and borehole monitoring.	0–10 years	Increase/alter monitoring activities to verify that unexpected migration is as a result of hydrodynamic pressure gradients. Assess impacts/implications and determine if management action is required.
					1) Modify injection pattern to allow for hydrodynamic pressure gradient. 2) Use water production wells to alter/offset natural hydraulic flow.
Monitoring					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
Ability to image CO_2.	Subsurface CO_2 is not geophysically (seismically) resolvable.	CO_2 is being injected but cannot be imaged using surface geophysics.	Borehole geophysics.	5–10 years	1) Alter monitoring activities to determine if alternative geophysical methods can be used. Evaluate impact. 2) Alter monitoring strategy to fulfil reservoir surveillance objectives. For example develop an observation well based monitoring strategy.

Table 13-14: (continued)
CO_2 Injection Management Actions

Micro-Seismicity					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
All fluid injection operations (e.g. water flood, gas injection) are associated with micro-seismicity. Objective is to control events to low level.	Excessive micro-seismicity induced as a result of CO_2 injection.	Subsidence and seismicity above background natural level.	Passive seismic/tilt meters.	0–30 years	Increase/alter monitoring activities to verify nature of mirco-seismic events. Assess impact/implications and determine if management action is required. Is micro-seismicity is a result of CO_2 injection and not other operations on or around Barrow Island. 1) Reduce pore pressure, undertake actions identified for reduced pore volume and distribution.
CO_2 injection may result in fracturing or fault reactivation.	Seismicity induced as a result of CO_2 injection.	Passive seismic and tilt meter data suggest significant fracturing/faulting due to CO_2 injection.	Passive seismic/ tilt meters.	0–30 years	Increase/alter monitoring activities to verify nature of mirco-seismic events. Assess impact/implications and determine if management action is required. 1) Reduce pore pressure, undertake actions identified for reduced pore volume and distribution. 2) Modify injection pattern to avoid area of fracturing/faulting.
Residual Hydrocarbon Saturation (Sor)					
Uncertainty	**Worse Than Expected Outcome**	**Signpost**	**Reservoir Surveillance**	**Timing**	**Management Action**
There is some evidence for residual oil saturation in the Dupuy Formation. Residual oil saturations may reduce the relative permeability to CO_2.	Poor injectivity due to reduction in relative permeability to CO_2.	Unexpected bottom hole pressure increase (>6.9 MPa in 3 months).	Wellhead pressure; down hole pressure gauges; flow rate gauges.	0–5 years	Increase/alter monitoring activities to verify cause of pressure increase. Assess impact/implication and determine if management action is required. 1) Undertake actions identified for unexpected pressure increase related to reduced well injectivity.

Figure 13-30:
Well Configuration Following Remedial Action for Carbon Dioxide Service



injection of reservoir CO_2 would result in an unacceptable risk to the personnel or conservation values of Barrow Island, the injection operations will be suspended.

13.4.9 Environmental Impact of Carbon Dioxide Injection Infrastructure

The facilities required for the injection of CO_2 are described in Chapter 6 (Section 6.2.4) and the environmental impact of these facilities has been incorporated into the terrestrial impacts discussed in Chapter 10.

The infrastructure required for the injection project will consist of:

- pipelines to transport the CO_2 from the gas processing facility to the injection wells
- drilling locations for the injection wells
- drilling locations for observation wells
- access roads to service each of these facilities outside the gas processing facility.

Management approaches to minimise the environmental impact of the surface CO_2 injection facilities include:

- submitting Environment Management Plans for the drilling of the injection and monitoring wells
- managing overall surface disturbance in accordance with commitments in the State Agreement
- consolidating the surface location of the injection wells and monitoring wells on a limited number of drill pads using directional drilling technology
- using previously disturbed areas where practicable
- fully integrating the CO_2 removal plant within the gas processing facility to reduce land required for buffer zones.

13.4.10 Potential Failure Modes Related to Carbon Dioxide Injection

The Gorgon Joint Venturers approach to the assessment of environmental risk is documented in Chapter 9 and has been applied in assessing the risks associated with CO_2 injection. The assessment provided here describes the likelihood of possible failure modes relating to CO_2 injection and the possible effects of such failure. The resulting environmental impacts are considered in the discussion on terrestrial impacts in Chapter 10.

Failures in the surface injection facilities or leakage of the injected CO_2 from the subsurface can create potential health, safety and environmental hazards. Hazards caused by the failure of the surface injection facilities are understood by drawing analogies from the operation of CO_2 injection projects and oil and gas operations around the world. Less is known about the risks of leakage from the subsurface as the opportunity to manage greenhouse emissions using subsurface injection has only come about in the last ten years. Consequently the number and variety of projects from which to draw quantitative information is limited. However, analogies can be made with the understanding of the subsurface behaviour of fluids, gases and liquids, drawn from the oil and gas industry.

The environmental impacts and risks associated with CO_2 and its interaction with the atmosphere, soil, water and biota are relatively well understood. Apart from potential climate change impacts, a CO_2 release to the atmosphere poses little environmental hazard provided that it is able to disperse quickly so that localised soil and atmospheric concentrations remain at or near normal levels. A hazard can arise if CO_2, which is denser than air, is allowed to accumulate in low lying, confined or poorly ventilated areas.

The effect of elevated CO_2 levels depends not only on the concentration but also the duration of exposure. The ambient concentration of CO_2 in the atmosphere is currently around 370 ppm or less than 0.004%. For humans, there are no adverse health effects for carbon dioxide concentrations up to 3%. Whilst some discomfort occurs between 3% and 5%, it is only for concentrations above 5% that there are serious, possibly fatal, consequences. At above 25% to 30%, loss of consciousness occurs within several breaths and death occurs quickly thereafter. The National Occupational Health and Safety Commission (NOHSC) have published standards (NOHSC 2005) for human exposure to CO_2. These standards will be adhered to in limiting human exposure to CO_2 resulting from the proposal to inject reservoir CO_2. The NOHSC exposure standards for CO_2 are:

- Time Weighted Average which covers exposure for an eight hour work shift 5000 ppm or 9000 mg/m^3.
- Short Term Exposure Limit which covers exposure for a maximum period of 15 minutes 30 000 ppm or 54 000 mg/m^3. Exposure at Short Term Exposure Limits should not occur more than four times in a work shift.

The Gorgon Joint Venturers have undertaken a study to identify potential risks associated with the proposed injection of CO_2 into the Dupuy Formation. This study commenced with a Failure Mode and Effects Workshop conducted in accordance with the principles and guidelines contained in AS/NZS 4360 for risk management and AS/NZS 3931 for risk analysis of technological systems (Standards Australia 1998 and 2004).

Workshop participants included technical specialists with expertise in CO_2 sequestration, reservoir geology, reservoir engineering and simulation, surface and subsurface engineering and environmental science. Attending the workshop were representatives of the Western Australian Environmental Protection Authority (EPA) Services Unit, the Western Australian Department of Industry and Resources and the CO2CRC. Table 13-15 contains a list of participants at the Failure Modes and Effects Workshop.

The objective of the workshop was to identify credible threats of failure of the proposed injection project, either through a failure in the injection facilities or a failure which might result in the loss of containment in the target reservoirs. A number of risk identification topics were considered to allow detailed assessment of a wide range of 'failure modes' by workshop participants. The risk identification topics were adapted from a risk assessment list of events used by the Australian Petroleum Cooperative Research Centre research program on the Geological Disposal of Carbon Dioxide (Bowden and Rigg 2004). Additional topics were also suggested by participants and discussed in the workshop.

The scope of the workshop was limited to a qualitative estimate of potential likelihood of failure using the definitions documented in Chapter 9, without making judgements of the potential consequences. Where statistical data is available these have also been

Table 13-15:
Failure Modes and Effects Workshop Participants

Name	Organisation/Company Affiliation	Title/Position/Area of Expertise
Technical Specialists		
Roger Bartlett	Chevron Australia	Subsurface Manager – Gorgon Development
Soolim Carney	Chevron Australia/ECOS Consulting	Environmental Advisor
Brian Evans	Curtin University	Professor, Geophysics
Lorna Fitzgerald	Department of Industry and Resources	Senior Project Officer, Office of Major Projects
Craig Gosselink	Chevron Australia	Environmental Engineering Advisor
Gerry McGann	Curtin University	Consulting Geologist
Ian Paton	Department of Industry and Resources	Special Projects Engineer/Development Engineer
Andy Rigg	Cooperative Research Centre for Greenhouse Gas Technologies	Deputy Chief Executive Officer, Storage Program Manager
Robert Root	Chevron Australia	Geoscientist
Richard Sutherland (Observer)	Western Australian Environmental Protection Authority, Services Unit	Environmental Officer
John Torkington	Chevron Australia	Greenhouse Gas Opportunity Manager – Gorgon Development
Facilitator		
Richard Stoklosa	E-Systems/Chevron Australia	Risk Advisor

incorporated into the assessment of likelihood. This was done to capture the circumstances of possible failure in sufficient detail for subsequent analysis of potential human health and ecological consequences by a range of appropriate specialist experts not represented at the workshop.

The identified failure modes associated with the CO_2 injection project have been grouped into four categories:

- leakage from surface injection facilities
- unpredicted CO_2 migration
- reduced well injectivity
- naturally occurring earthquakes.

This discussion on failure modes should be considered in conjunction with the earlier discussion on CO_2 Injection Operations Management which identifies sign posts and describes management actions that can be taken to reduce the risk of failure.

Leakage from Surface Injection Facilities

The potential likelihood of individual failure modes for surface injection facilities identified during this study ranged from unlikely to possible.

The various failure modes that might result in a leakage of CO_2 from the surface injection facilities are:

- mechanical failure of the CO_2 compressors/pumps
- mechanical failure of the CO_2 pipelines
- wellhead leakage, including casing corrosion at ground water level.

Further information on these failure modes including information safeguards or management measures and residual risk is provided in Table 13-16.

Carbon dioxide is transported by pipeline and injected for enhanced oil recovery in the USA, Canada, Turkey and Trinidad and Tobago. Worldwide, approximately 3100 km of CO_2 pipelines exist with a capacity of approximately 45 million tonnes per year of CO_2 (Gale and Davison 2003). Pipeline failures can range from either a pin-hole leak to a major rupture and can be caused by external interference such as unauthorised excavation, construction defects, corrosion or ground movement. The accident record for CO_2 pipelines in the USA shows eight accidents during the period 1968 to 2000 equating to an incident frequency rate of 3×10^{-4} incidents per km per year (Benson et al. 2002). There were no injuries or fatalities associated with these incidents. Statistics of incidents involving natural gas pipelines in the USA between 1986 and 2001 show an incident frequency rate of 2×10^{-4} per km per year (Gale and Davison 2003). Contributing significantly to the failure of these pipelines are external factors such as unauthorised excavation by third parties such as farmers or road construction crews. This factor is eliminated on Barrow Island due to the geographic isolation of the island and the absence of third parties. Consequently a likelihood of 'Unlikely' has been applied to mechanical failure of the CO_2 pipeline.

Wellhead leakage can be caused by construction defects, leaking pipe connections or corrosion. In the majority of well failures the amount of CO_2 release will be limited to less than the volume in the well tubing by the use of emergency shut-down devices. Only failure of the tree and emergency shut-down devices could lead to a blow-out of the injection well where reservoir fluids (CO_2 and formation water) would escape to the surface. Data on hydrocarbon well blow-outs while drilling in the Gulf of Mexico and North Sea between 1980 and 1996 are suggestive of failure rates of 1×10^{-4} per well per year (CMPT 1999).

The oil and gas industry has implemented a range of measures aimed at reducing the incidence of facility failure and the volume of gas released should such failures occur. Measures include material selection and design, the management and monitoring of corrosion rates and regular facilities inspections. Automated systems monitoring and the use of automatic shutdown devices ensure that any unplanned release is restricted to the volume contained in the part of the system that failed. These management systems will be applied to the CO_2 injection infrastructure of the Gorgon Development in order to reduce the potential for failure.

As CO_2 is not flammable, the consequence of an injection facility failure is expected to be less than for a comparable failure of a natural gas system. However CO_2 will tend to form a low lying blanket due to the higher density compared to air, whereas natural gas tends to dissipate into the air (Damen et al. 2003).

Any CO_2 released from these potential failures is anticipated to be at high pressure for the first few minutes before rapidly reducing as the gas within the failed facility escapes. Such a release of high pressure CO_2 represents a significant safety risk to personnel in the immediate vicinity of the failure. Given the limited

Table 13-16:
Potential Failure Modes Resulting in the Release of CO_2 – Facility Leakage (compressor, pipeline, well head)

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
Mechanical failure of CO_2 compressors and pumps resulting in release of CO_2 to the atmosphere. Likelihood: Possible	Design and operate the CO_2 compressors and pumps in accordance with petroleum industry standards. Preventative maintenance program. Apply industry operational experience with CO_2 compressors from North America. Design automatic shut-down and isolation of CO_2 injection equipment to limit release of CO_2 to the volume contained within that part of the facility. Many of the potential failure scenarios would occur within the compressor or pump and would only result in controlled release to atmosphere as equipment was repaired limiting health or environmental impacts. Design CO_2 detection system and alarms. Utilise appropriate personal protective equipment for people working around CO_2 compressors and pumps.	Analogous to existing oil and gas operational risk. Dependent upon nature of failure, there is a potential for release to atmosphere of that volume of CO_2 contained within the compressors and related facilities (several tonnes to several tens of tonnes of CO_2). Many failures would occur within the compressor or pump and would only result in controlled release to atmosphere as equipment was repaired.
Mechanical failure of CO_2 pipeline caused by either below standard operating practice or external factors such as unauthorised excavation resulting in release of CO_2 to the atmosphere. Likelihood: Unlikely	Design and operate CO_2 pipeline in accordance with Australian Standards for petroleum pipelines AS2885. Regular monitoring of pipeline. Apply industry operational experience with CO_2 pipelines from North America. Design automatic shut-down and isolation of pipeline to limit release of CO_2 to volume contained within the pipeline. Pipeline damage by external factors such as unauthorised excavation (which is a significant risk factor for most pipeline operators) are lessened by isolation of Barrow Island, and locating pipeline above ground.	Analogous to existing oil and gas operational risk. Dependent upon nature of failure, there is a potential for release to atmosphere of a moderate volume (several tens of tonnes to several hundred tonnes) of CO_2.
Leakage at the well head caused by worn gaskets, valves or by corrosion resulting in release of CO_2. Failure of well casing at the top of ground water table resulting in release of CO_2 into the near surface. Likelihood: Possible	Implement a wellhead inspection, preventative maintenance program and annular pressure monitoring. Design automatic isolation of wellhead to limit release to volume of CO_2 contained within the wellhead and upper portion of the injection well. Once failure is identified, well will be worked over and leak repaired limiting volume of CO_2 released. Manage ground water level casing corrosion by active cathodic protection. Leakage prevented by multiple casing strings and tubing.	Analogous to existing oil and gas operational risk. Dependent upon nature of failure, there is a potential for release of minor volume (several tonnes to tens of tonnes) of CO_2 to the atmosphere and/or the near surface cave systems. A consequence of well casing leakage at the top of the ground water table is that CO_2 could leak into the near surface cave systems with detrimental impact on the fauna in these systems.

volume of CO_2 that would be released over a very short time, it is not expected that the release would result in a material impact upon the biophysical environment in the vicinity of the release. There is a risk of the released CO_2 accumulating to levels where it represents an asphyxiation risk in low lying areas with poor ventilation. The gas processing facility will be designed to minimise these areas and the potential for high concentrations in low lying and poorly ventilated areas, identified as part of the Developments Safety Management Systems.

A failure of the well casing at the top of the ground water table would not normally result in a release of CO_2 into the near surface cave systems. This is because the CO_2 will be contained within the production tubing. In order for CO_2 to be released into the near surface cave systems, the wells production tubing would also have to fail. The resulting CO_2 release would be of limited volume and would persist until the well could be worked over and the leaks repaired. These types of leaks can be detected readily through annular pressure monitoring in each well.

Unpredicted Carbon Dioxide Migration

Individual failure modes that might result in the unpredicted migration of CO_2 in the subsurface have been divided into three groupings:

- failure of individual baffles and barriers to prevent the CO_2 from migrating vertically
- leakage of CO_2 along faults
- leakage of CO_2 through failures in well penetrations.

Further information on each of these failure modes including information on safeguards or management measures and residual risk is provided in Table 13-17, Table 13-18 and Table 13-19.

The potential likelihood of individual failure modes that could lead to unpredicted migration ranged from remote to likely, however this should not be construed as the potential likelihood of CO_2 escaping to the surface and posing a health, safety or environmental hazard.

Unpredicted migration within the Dupuy Formation into the overlying formations would not constitute a failure of the injection project as the CO_2 will remain trapped in the subsurface rather than being emitted to the atmosphere. Any unpredicted migration will require review and modification of the Gorgon Joint Venturers' reservoir simulation modelling in order to understand why the deviation to model predictions occurred and to predict future migration behaviour. In addition issues such as ensuring the security of existing well penetrations that may be impacted by the CO_2 will be appropriately managed as identified in Section 13.4.8.

Unpredicted migration would represent a failure of the injection project if the CO_2 is able to migrate to the surface (or near surface cave systems) or into the producing oil and gas accumulations around Barrow Island.

Modelling by the Gorgon Joint Venturers indicates that in the event of unplanned migration of CO_2 to the surface, it would most likely occur along one of the larger identified faults (refer Figure 13-11 for the location of the larger faults on Barrow Island). Benson (2004) concluded that flux rates for CO_2 migration along faults could be in the range of 1×10^2 and 1×10^6 micromole/m^2/sec but restricted to areas in close proximity to the fault, possibly impacting an area of between 1000 m^2 and 100 000 m^2. Carbon dioxide migrating to the surface along faults will likely be dispersed by the prevailing winds. The risk to personnel and other fauna from asphyxiation at these flux rates is therefore very low. However, the CO_2 flux rates associated with unpredicted migration along faults would enable the build up of CO_2 concentrations within the soil profile to the point where flora could be detrimentally impacted.

A significant consequence of unpredicted migration along faults or well bores is that CO_2 could migrate into the near surface cave systems. Even at low leakage rates, significant concentrations of CO_2 could accumulate in the air and water contained in these systems. This is anticipated to have a detrimental impact upon the fauna living in that environment.
It should be noted that the cave systems containing these fauna exist close to the surface of the island and are separated from the Dupuy Formation by approximately 2000 m of sandstone, mudstone and shale, comprising numerous reservoirs and baffles and barriers. Further discussion on the impact of elevated CO_2 levels in this environment is provided in Chapter 10 (Section 10.5.6).

Table 13-17:
Potential Failure Modes Resulting in the Unplanned Migration of CO_2 – Failure of Baffles and Barriers

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
Leakage of intra Dupuy Formation baffles such as the Perforans Shale, where injection occurs below these units. Buoyant CO_2 migrating over tens of years (or less) towards the upper Dupuy Formation baffles. Likelihood: Likely	Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow CO_2 migration. Nature of baffle provides tortuous migration path enhancing the ability for the migrating CO_2 to become trapped.	Intra Dupuy Formation seals are likely to behave as flow baffles. Many of these units are unable to be resolved on seismic data due to limited thickness so distribution is uncertain. CO_2 not trapped prior to leaking through the intra Dupuy formation shales will migrate upward towards the upper Dupuy Formation shales. May lead to contamination of oil and gas resources within the upper Dupuy Formation (undiscovered).
Leakage of upper Dupuy Formation baffles. Buoyant CO_2 migrating over tens of years to hundreds of years towards the base Barrow Group shale. Likelihood: Possible	Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow CO_2 migration. Nature of baffle provides tortuous migration path enhancing the ability for the migrating CO_2 to become trapped.	Shales in the upper Dupuy Formation are lithologically similar to those in the intra Dupuy Formation but thicker and more laterally extensive. CO_2 not trapped prior to leaking through the intra Dupuy formation shales will migrate upward towards the base Barrow Group shales. May lead to contamination of oil and gas resources within the upper Dupuy Formation (undiscovered).
If reservoir CO_2 should migrate to the base Barrow Group shale, leakage of base Barrow Group shale barrier. Buoyant CO_2 migrating over tens to hundreds of years into Barrow Group. Likelihood: Likely	Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow CO_2 migration. Nature of barrier provides tortuous migration path enhancing the ability for the migrating CO_2 to become trapped.	Shales at the base of the Barrow Group are 10s of metres thick and can be correlated over the Barrow Island region. There is some uncertainty as the extent of this shale in the area to the east of Barrow Island. Modelling indicates that the rate at which the CO_2 can migrate through shales will be very low (generally less than one micromole/m^2/sec) (Benson 2004). CO_2 not trapped prior to leaking through the base Barrow Group shale becomes trapped in the Barrow Group and below the Muderong Shale. May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered).

Table 13-17: (continued)
Potential Failure Modes Resulting in the Unplanned Migration of CO_2 – Failure of Baffles and Barriers

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
If reservoir CO_2 should migrate to the Muderong Shale, leakage of Muderong Shale barrier. Note: Leakage of the Muderong Shale was not considered during the Failure Modes and Effects Workshop as it was considered remote that the CO_2 would have leaked past the previous three sets of baffles and barriers. Buoyant CO_2 migrating over thousands of years into the Windallia Sandstone Member and the Gearle Siltstone. Likelihood: Remote	Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow CO_2 migration. Nature of barrier provides tortuous migration path enhancing the ability for the migrating CO_2 to become trapped.	The Muderong Shale occurs across the entire Barrow Sub Basin and is the sealing lithology of many (majority) of the hydrocarbon accumulations in the sub basin. Modelling indicates that the rate at which the CO_2 can migrate through shales will be very low (generally less than one micromole/m^2/sec) (Benson 2004). CO_2 not trapped prior to leaking through the Muderong Shale becomes trapped in the overlying Windalia Member and the Geale Siltstone. May lead to contamination of oil and gas resources within the Muderong Shale and Windalia Sandstone Member (both existing and undiscovered).

Table 13-18:
Potential Failure Modes Resulting in the Unplanned Migration or Release of CO_2 – Fault Leakage

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
Leakage along the Barrow Fault. Leakage of CO_2 to higher levels in the stratigraphy. Potential leakage of CO_2 to surface. The location of this fault is shown on Figure 13-11. Likelihood: Remote	Select the injection location such that CO_2 plume is not anticipated to approach the Barrow Fault. Reservoir modelling requires highly pessimistic scenario for CO_2 to migrate in proximity to the fault. For leakage to occur CO_2 would need to migrate to the Barrow Fault then fault would have to act as migration path. Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present.	The Barrow Fault is distant from injection location. Barrow Fault is currently sealing with respect to several hydrocarbon accumulations. Studies indicate that leakage along faults may occur at rates of between 1 x 10^2 and 1 x 10^6 micromole/m^2/sec but over relatively small areas (Benson 2004). Naturally occurring hydrocarbon seeps are geographically limited in area. May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered).

Table 13-18: (continued)
Potential Failure Modes Resulting in the Unplanned Migration or Release of CO_2 – Fault Leakage *(continued)*

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
		CO_2 migration to the surface could result in the localised build up of CO_2 concentrations within the soil profile to the point where flora could be detrimentally impacted. A significant consequence of migration along faults is that CO_2 could migrate into the near surface cave systems with detrimental impact on the fauna in these systems.
If reservoir CO_2 should migrate in proximity to the Godwit and Plato Faults, leakage along the Godwit and Plato Faults. Note these faults do not extend to the surface. Leakage of CO_2 to higher levels in the stratigraphy. Likelihood: Likely	Select the injection location such distant from the Godwit and Plato faults. The CO_2 plume is not anticipated to reach these faults for 1000 years by which time much of the CO_2 will have become trapped. For leakage to occur CO_2 would need to migrate to these faults then the faults would have to act as migration path. Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present.	Plato and Godwit Faults are distant from injection location. May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered). Impacts on surface and neat surface flora and fauna are not anticipated as faults are only identified from seismic and do not extend to the surface.
Leakage along faults or fractures that have not been detected on seismic. This requires the faults to be relatively small. Leakage of CO_2 to higher levels in the stratigraphy. Likelihood: Unlikely	If faults are present they must be small relative to the Barrow, Godwit and Plato Faults as they are not resolvable on seismic. Potential CO_2 flux would also be correspondingly less. Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present.	Potential for fault migration thought to be less than for mapped faults discussed above given smaller nature of the faults. Leakage rates are anticipated to be lower and more localised than for leakage along the Barrow Fault. May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered). CO_2 migration to the surface could result in the localised build up of CO_2 concentrations within the soil profile to the point where flora could be detrimentally impacted. A significant consequence of migration along faults is that CO_2 could migrate into the near surface cave systems with detrimental impact on the fauna in these systems.

Table 13-18: (continued)
Potential Failure Modes Resulting in the Unplanned Migration or Release of CO_2 – Fault Leakage *(continued)*

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
Leakage along offshore faults to north and east of Barrow Island. Leakage of CO_2 to higher levels in the stratigraphy. Likelihood: Possible	Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present. Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that if faults exist they are not fluid conduits at present.	May lead to contamination of oil and gas resources within the Barrow Group in the area of Double Island. (Both existing and undiscovered). Impacts on marine fauna are not anticipated as faults are only identified from seismic and do not extend to the surface.
Leakage along offshore faults to the north and west of Barrow Island. Leakage of CO_2 to higher levels in the stratigraphy. Likelihood: Remote	Select the injection location such that CO_2 plume is not anticipated to approach these faults. Reservoir modelling indicates that it is almost impossible for CO_2 to migrate in proximity to these faults. Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present. Potential for effective dissipation of leaking CO_2 in the marine water column.	May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered).
Operational error resulting in injection at pressure exceeding fracture gradient. Potential to fracture reservoir rock and overlying baffles and barriers leading to unpredicted migration to higher levels in the stratigraphy. Likelihood: Unlikely	The selection of the Dupuy Formation injection target as it has multiple barriers between injection reservoir and surface. Design the compressor operating pressure to remain below fracture pressure of reservoir rock. Develop operational management plans covering high reservoir pressure identified in injection wells. Refer to Section 13.4.8.	Existing hydrostatic pressure is approximately 10.3 MPa less than fracture threshold pressure. Higher than expected pressures in the formation may lead to faults that are currently sealing becoming migration pathways and fracturing of the overlying sealing units allowing CO_2 to migrate vertically into overlying stratigraphy.
Lack of formation capacity to accommodate injected CO_2. If capacity of the reservoir to contain the injected CO_2 is exceeded, CO_2 migration will be more extensive than predicted and ultimately reservoir pressure will increase potentially exceeding fracture gradient. Likelihood: Remote	Develop operational management plans in the event that migration greater than predicted is detected or if high reservoir pressure is identified in observation wells. Refer to Section 13.4.8. Refer above discussion on injection pressure exceeding fracture gradient.	Capacity of the Dupuy Formation has been thoroughly investigated by the Gorgon Joint Venturers and by independent studies commissioned by the Western Australian Government (DoIR). If the formation does not have the capacity to contain the injected volumes of CO_2, this may lead to more extensive CO_2 plume migration or over-pressuring of the formation with associated failure modes.

Table 13-19:
Potential Failure Modes Resulting in the Unplanned Migration or Release of CO_2 – Well Leakage

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
Inappropriate decommissioning of existing wells. Existing well penetrations may act as conduit for leakage of CO_2 to higher levels in the stratigraphy. Potential leakage of CO_2 to surface. Leakage rates could be higher than leakage through faults. Likelihood: Unlikely	Existing decommissioned wells did not contemplate CO_2 injection operations and will require workover to ensure suitability for CO_2 service. Plans to manage well penetrations and ensure they are fit for service have been developed. Refer to Section 13.4.8. If well does ultimately leak then well will be re-entered and leakage stopped.	Condition of wells and potential for leakage is understood and plans in place for remediation prior to CO_2 intersecting well. Limited release (tens to thousands of tonnes) of CO_2 until well re-entered and leakage stopped. May lead to contamination of oil and gas resources (both existing and undiscovered). CO_2 migration to the surface could result in the localised build up of CO_2 concentrations within the soil profile to the point where flora could be detrimentally impacted. A significant consequence of leakage is that CO2 could migrate into the near surface cave systems with detrimental impact on the fauna in these systems.
CO_2 leakage through CO_2 injection or monitoring wells. Conduit for leakage of CO_2 to higher levels in the stratigraphy. Potential leakage of CO_2 to surface. Leakage rates could be higher than leakage through faults. Likelihood: Unlikely	Implement wellhead maintenance program and monitoring of annular pressures. Design CO_2 injection and monitoring wells for CO_2 service. Utilise CO_2 service design from industry experience in enhanced oil recovery and CO_2 injection operations. If well does ultimately leak then well will be re-entered and leakage stopped.	Initial design and decommissioning procedures for CO_2 injection and monitoring wells will accommodate CO_2 service. Limited release (tens to thousands of tonnes) of CO_2 until well re-entered and leakage stopped. May lead to contamination of oil and gas resources (both existing and undiscovered). CO_2 migration to the surface could result in the localised build up of CO_2 concentrations within the soil profile to the point where flora could be detrimentally impacted. A significant consequence of leakage is that CO_2 could migrate into the near surface cave systems with detrimental impact on the fauna in these systems.

Table 13-19: (continued)
Potential Failure Modes Resulting in the Unplanned Migration or Release of CO_2 – Well Leakage

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
CO_2 leakage through future hydrocarbon exploration or development wells. Conduit for leakage of CO_2 to higher levels in the stratigraphy. Potential leakage of CO_2 to surface. Leakage rates could be higher than leakage through faults. Likelihood: Unlikely	Ensure that future hydrocarbon wells will be designed for CO_2 service. Utilise CO_2 service design from industry experience in enhanced oil recovery and CO_2 injection operations. If well does ultimately leak then well will be re-entered and leakage stopped.	Initial design and decommissioning procedures for future exploration and development wells will accommodate CO_2 service. Limited release (tens to thousands of tonnes) of CO_2 until well re-entered and leakage stopped. May lead to contamination of oil and gas resources (both existing and undiscovered). CO_2 migration to the surface could result in the localised build up of CO_2 concentrations within the soil profile to the point where flora could be detrimentally impacted. A significant consequence of leakage is that CO_2 could migrate into the near surface cave systems with detrimental impact on the fauna in these systems.
CO_2 leakage during routine workovers of injection or monitoring wells. Potential leakage of CO_2 to surface. Lowering of partial pressure in well could potentially lead to mineralisation and plugging. Likelihood: Possible	Adhere to three barrier rule during workovers (maintain three barriers to fluid escape at all times) Adopt best practice lessons learned from other enhanced oil recovery and CO_2 injection operations.	Equivalent to failure rates for workovers in the oil and gas industry. Failure is likely to lead to limited release of CO_2 to atmosphere until well can be shut in. Analogies with oil and gas operations indicate that release would be stopped within days or weeks.

Table 13-19: (continued)
Potential Failure Modes Resulting in the Unplanned Migration or Release of CO_2 – Well Leakage

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
CO_2 leakage via water source wells in Barrow Group. Note these wells provide saline water for reverse osmosis plants. Potential leakage of CO_2 to surface. Water supply wells produce CO_2. Likelihood: Unlikely	Existing water source wells do not contemplate CO_2 injection operations and will require decommissioning to ensure suitability for CO_2 service. Manage water source wells in accordance with Existing Well Remediation Plan. Refer to Section 13.4.8. If well does ultimately leak then well will be re-entered and leakage stopped.	Requires CO_2 to have migrated into upper parts of the Barrow Group. Condition of wells and potential for leakage is understood and plans in place for remediation prior to CO_2 intersecting well. May require decommissioning of water source wells and drilling of alternative water source wells away from the CO_2 plume. Limited release (tens to thousands of tonnes) of CO_2 until well re-entered and leakage stopped. May lead to contamination of oil and gas resources (both existing and undiscovered). CO_2 migration to the surface could result in the localised build up of CO_2 concentrations within the soil profile to the point where flora could be detrimentally impacted. A significant consequence of leakage is that CO_2 could migrate into the near surface cave systems with detrimental impact on the fauna in these systems.

Table 13-20:
Potential Failure Modes Resulting in the Unplanned Migration or Release of CO_2 – Reduced Well Injectivity

Description of Potential Failure Mode	Safeguards, Mitigation or Management Measures	Residual Risk
Precipitation of minerals in the formation in close proximity to the injection well bore. Repeated reduction in well/reservoir partial pressure may facilitate mineralisation. Reduced ability to inject CO_2 into well, requires increase in injection pressure to dispose of required volume of CO_2. Increased injection pressure may exceed fracture gradient as discussed above. Likelihood: Unlikely	Studies indicate that mineralisation reactions occur over time periods of thousands of years. Refer to Section 13.4.4 Develop injection well operation plans to minimise reduction in well/formation partial pressure. Develop management plans in the event that high reservoir pressure is identified in injection wells. Refer to Section 13.4.8.	Higher than expected pressures as a result of mineralisation in the injection wells may lead to faults that are currently sealing becoming migration pathways and fracturing of the overlying sealing units allowing CO_2 to migrate vertically into overlying stratigraphy.

In selecting the preferred CO_2 injection site, possible migration of CO_2 along faults and the resulting impact that this might have on cave fauna was considered. The preferred site was selected because it is distant from the large identified faults, enabling the CO_2 to become trapped in the formation prior to reaching these faults. A key objective of the proposed monitoring program is to identify whether unpredicted migration is occurring in order to enable the impact to be assessed and appropriate changes to the injection program made.

Based on this assessment, the Gorgon Joint Venturers have determined that the residual risk of unpredicted migration representing a health, safety or environmental impact is low.

Reduced Well Injectivity

The potential for an injection well to fail as a result of reduced injectivity was assessed at the workshop as unlikely. Reduced well injectivity will most likely be caused by the precipitation of minerals in the target injection formation and in proximity to the injection well, but could also be a result of the movement of clay minerals in the formation. Both these conditions are encountered in oil and gas field operations and can be remedied through redrilling or working over of the well. Further studies are planned to investigate the potential for reduced well injectivity on core obtained from a data well to be drilled in 2005.

The consequences of reduced injectivity are restricted to the economic cost of remedial work to re-establish injection in the well and potentially the need to vent reservoir CO_2 while the particular well is waiting for remediation. The potential for reservoir CO_2 emissions to the atmosphere as a result of a loss of well injectivity and the time taken to restore the well, have been considered in determining the reference case for greenhouse gas emissions used in this document. Refer to Section 13.3.4.

Further information on this failure mode including information on the potential environmental impact, safeguards or management measures and residual risk is provided in Table 13-20.

Naturally Occurring Earthquakes

Horizontal and vertical stresses occur routinely in the subsurface. Where these stresses exceed the strength of the rock, or are sufficient to overcome the frictional resistance along an existing fault plane, movement along a fault will occur. Fault movements through earthquakes redistribute stress in the crust around the earthquake epicentre and consequently affect the future earthquake activity in the region. It is worth noting that faults such as the Barrow Fault, which has displacement of over 500 m, are the result of repeated movements (earthquakes) over geologic time. Faults occurring during a single earthquake are of much lesser magnitude. For example scientists at Geoscience Australia (McCue et al. 2003) have studied the Lake Edgar fault scarp in Tasmania. This fault scarp is 30 km in length with the current day displacement of between 2.5 m and 6.5 m. While there is evidence of repeated movement along the fault scarp, scientists estimate that the earthquake that created the fault scarp was of a magnitude 6.5 to 7.0 on the open ended Richter Scale.

Naturally occurring earthquakes pose a hazard to CO_2 injection where they result in the creation of a new fault or change the properties of an existing fault, such that a fluid migration pathway is created. The risks of CO_2 migration along these faults is comparable to the risk of migration along existing faults discussed above. If fault leakage was to occur as a result of a naturally occurring earthquake, it would enable migration of CO_2 into the next higher level of the stratigraphy: in this case the Barrow Group. The Barrow Group contains an extensive set of baffles and is overlain by regionally significant barriers in the Muderong Shale and Geale Siltstone, providing further opportunities for the CO_2 to become trapped and preventing migration to the surface.

For a naturally occurring earthquake to result in a risk of failure of the CO_2 injection project, the earthquake would have to result in a fault that intersected the CO_2 plume. The fault would then have to be of a size and nature that it allowed the CO_2 to migrate higher in the stratigraphy, and the CO_2 would still need to migrate past the extensive baffles and barriers higher in the stratigraphy.

Leakage from conventional oil and gas fields as a consequence of naturally occurring earthquakes provide an analogy for the risks of CO_2 leakage. No references were found where an earthquake had lead to containment failure and leakage from an existing oil or gas accumulation implying that the risk of containment failure from a naturally occurring earthquake is remote.

Apart from the potential damage to facilities, a naturally occurring earthquake is not likely to pose an additional risk of containment failure for CO_2 injection operations.

Carbon Dioxide Injection Environmental Impact

The identified CO_2 injection failure modes and their potential impact have been considered in assessing the environmental impacts of the project. These are documented in Chapter 10.

13.4.11 Approach to Long-term Responsibilities

In proposing to dispose of reservoir CO_2 by injection into the Dupuy Formation, the Gorgon Joint Venturers recognise that there are community concerns about the management of long-term responsibilities, particularly with respect to the liabilities arising from potential CO_2 leakage from the subsurface. The subsurface injection of CO_2 has many parallels with existing activities such as the decommissioning and rehabilitation of oil and gas fields and mine sites that can provide a basis for how this should be managed. The Joint Venturers believe that existing statutory regulation and the common law provide appropriate mechanisms for managing liabilities associated with CO_2 injection.

Existing approaches to decommissioning oil and gas field operations utilise the concept of site closure to define the point where the owners/operators of the site reach agreement with government on the level of decommissioning and rehabilitation activities. This occurs soon after the oil or gas resources have been depleted. While the concept of site closure can be readily applied to the decommissioning and rehabilitation associated with the surface facilities and wells used for CO_2 injection, the ability to demonstrate that the site is safe from CO_2 leakage may take an additional period. The Gorgon Joint Venturers propose that their day-to-day involvement with the site continue after the cessation of injection operations, into a ‘Post-Injection Phase’. The Post-Injection Phase would end once agreement was reached with government that the closure criteria for the site had been met. The duration of the Post-Injection Phase will depend upon the migration of the CO_2 in the reservoir and the information obtained about the ability to monitor and predict the CO_2 migration. The additional monitoring undertaken during the Post-Injection Phase will be primarily to confirm the understanding developed during the operational phase.

Australian state and federal governments have been considering site closure criteria as part of a set of Draft Regulatory Principles for Carbon Dioxide Geosequestration. These draft principles (Department of Industry and Tourism 2004) propose that site closure should occur once government is satisfied to a high degree of certainty that:

- future land use objectives defined at the time of project approval have been met
- the residual risks of leakage and resulting liabilities are acceptably low
- the ongoing costs associated with the site are acceptably low or are otherwise appropriately managed.

It should be noted that these Draft Regulatory Principles have been put forward for the various federal and state governments to consider. Each government will then decide if and how it will regulate the subsurface disposal of CO_2. There is no obligation on any government to accept these recommendations. The Gorgon Joint Venturers support the use of these criteria to managing and agreeing site closure of the Gorgon CO_2 injection project with government.

At the time of site closure the Gorgon Joint Venturers will prepare a report for government that comprehensively documents the CO_2 injection operations, including monitoring activities and the status of all existing well penetrations in proximity to the CO_2 plume. In addition copies of all documentation and data relating to the CO_2 injection project would be made available to government. This commitment is in addition to the commitment to make data on monitoring activities available to the public throughout the life of the injection project.

Future Land Use Planning

The Draft Regulatory Principles for Carbon Dioxide Geosequestration (Department of Industry and Tourism 2004) propose that future land use objectives need to be defined at the time of development approval. Demonstrating that these future land use objectives can be achieved will become an important site-closure criterion. As a result of their studies, the Gorgon Joint Venturers firmly believe that the proposal to inject CO_2 below Barrow Island will result in the CO_2 becoming effectively trapped in the subsurface. Consequently, the Gorgon Joint Venturers believe that the following land use objectives are consistent with Barrow Island being used as a site for the subsurface disposal of CO_2:

- nature reserve status, with the objective of maintaining the conservation values of Barrow Island
- eco-tourism, both on Barrow Island and in the surrounding waters (the Gorgon Joint Venturers are not advocating eco-tourism on Barrow Island but indicating such a use would be consistent with the site being used for the underground disposal of CO_2)
- marine biodiversity conservation consistent with the proposed Marine Conservation Area around Barrow Island.

Future land use activities will need to be managed after site closure to ensure that they are consistent with the prior use of the site for CO_2 disposal (for example the further exploration and production of hydrocarbons). However, it is envisaged that management of these activities will require only a small increase in resourcing over and above that already required for activities on Barrow Island. By way of illustration, the existing arrangements for the approval of hydrocarbon drilling operations on Barrow Island require the proponents to address a wide range of safety and environmental hazards in planning and undertaking drilling operations. Government only approves such operations once it is satisfied that all the relevant issues have been addressed. In this context the presence of injected CO_2 in the subsurface will be simply another consideration for the proponent to address in designing and planning the drilling operation. Likewise it will be one of many issues for government to consider when assessing and approving drilling operations.

13.5 Greenhouse Gas Management Plan

The Gorgon Joint Venturers have developed a Greenhouse Gas Management Plan as a tool to manage the further reduction in greenhouse gas emissions from the Gorgon Development. The Greenhouse Management Plan documents:

- Gorgon Joint Venturers participation in a range of Government programs aimed at reducing greenhouse gas emissions, including the reporting of greenhouse gas emissions and reduction efforts under those programs
- performance indicators and performance targets for those indicators
- planned actions to be taken by the Gorgon Joint Venturers to minimise greenhouse gas emissions from the Gorgon development with the objective of meeting the set performance targets.

13.5.1 Membership of Government Programs

The Gorgon Joint Venturers will continue to participate in government programs aimed at the voluntary reduction in greenhouse gas emissions. The primary government program aimed at reducing greenhouse gas emissions is the Greenhouse Challenge Plus Program managed by the Department of Environment and Heritage, Australian Greenhouse Office.

Greenhouse Challenge Plus

The Gorgon Joint Venturers have been a member of the Greenhouse Challenge Program since its inception in 1998. The Greenhouse Challenge Program has recently undergone a major review and has been expanded as the Greenhouse Challenge Plus Program.

The existing Greenhouse Challenge Cooperative Agreement between the Gorgon Joint Venturers and the Commonwealth Government covers activities of the proposed Development during the design and approval phase. The decisions taken during this phase of the Development have exceeded the undertakings given by the Gorgon Joint Venturers through the cooperative agreement (refer Section 13.3.1). The Gorgon Joint Venturers commit to updating the existing cooperative agreement in line with the requirements of the Greenhouse Challenge Plus Program prior to the project moving into its operational phase.

The calculation of greenhouse gas emissions in each of the performance indicator categories identified in Section 13.5.3 shall be calculated for each calendar year and reported in accordance with the Gorgon Development Greenhouse Challenge Agreement.

Generator Efficiency Standards

Generator Efficiency Standards (GES) is a program managed by the Australian Greenhouse Office with the objective of encouraging generators of electrical power from fossil fuels to achieve best practice in reducing greenhouse gas emissions. The GES program has recently been incorporated into the Greenhouse Challenge Plus Program.

The program identifies best practice performance targets for thermal efficiency in new power generation plants. For gas fired electrical generation, the established new plant thermal efficiency (sent out) target is 52% of higher heating value (energy in fuel stream in MJ/kg) and assumes that gas fired electrical generation will be via a combined cycle plant.

Energy required in the proposed Gorgon Development gas processing facility comprises direct mechanical drive, electrical generation and process heat. The use of waste heat recovery is driven by process heat requirements during gas processing.

As identified in Section 13.3.4, the total energy required by the Gorgon Development amounts to 1017 MW (319 MW of mechanical load, 270 MW of electrical output and 428 MW of heat load) while the total fuel usage amounts to 7011 GJ/h (1948 MW). Dividing energy load by fuel usage equates to a thermal efficiency of 52%.

Energy Efficiency Assessment

In 2004 the Prime Minister announced as part of the Commonwealth Government's Energy Policy, Securing Australia's Energy Future, that all businesses in Australia using more than 0.5 PJ of energy per year will be required to undertake an energy efficiency opportunity assessment every five years; and to report publicly on the outcomes. Implementation of this policy is due to commence in 2006. Details of how the program will operate are still to be finalised but it was announced as part of the Prime Minister's policy speech that the program will be based on the following components:

- Businesses will have a specified time to complete their assessment and prepare a public report.
- Public reports will be made, where possible, through the Greenhouse Challenge Programs on line reporting system and membership of the Greenhouse Challenge Program would be available to those companies.
- Public reports will need to include details of energy efficiency opportunities as well as information on the energy performance of the business.
- The assessments will need to be conducted in accordance with specified guidelines that will be developed by the government in consultation with industry. The guidelines will be based on a thorough examination of operations, including a systematic analysis of potential systems rather than just an audit of existing plant. Assessments will be more rigorous than current Level 3 audits under Australian Energy Audits Standards.
- Assessments will be verified and assessors accredited.

The Gorgon Joint Venturers will fully comply with the obligations on businesses once this proposed program becomes operational.

13.5.2 Planned Actions to Reduce Greenhouse Gas Emissions

A number of actions are planned by the Gorgon Joint Venturers with the objective of reducing the Development's greenhouse gas emissions below those used as the reference case in this Draft EIS/ERMP and documented in Section 13.3.4. These actions include:

- Undertaking further studies during detailed design and engineering into the electrical generation gas turbine and waste heat recovery configuration.
- Investigating the further integration of the Gorgon Development and the Barrow Island Joint Venture activities on Barrow Island, with the aim of reducing greenhouse gas emissions. For example integration of electrical power systems.
- Undertaking energy optimisation studies during the detailed engineering and design of the development. Energy optimisation is a way to identify, understand, and optimise energy use over the operating lifetime of a project.
- Developing operational and maintenance procedures with the objective of reducing greenhouse gas emissions below those in the reference case and in line with the performance targets listed in Section 13.5.3. Maximising the percentage of reservoir CO_2 injected will be a primary focus in developing these operational and maintenance procedures.
- Once the gas processing facility is operational, undertake Energy Optimisation Studies in line with requirements in Chevron Australia's Operational Excellence Management System (OEMS). An overview of the OEMS is provided in Chapter 16.
- Continue to support research into carbon dioxide capture and storage technology development within Australia and overseas including the potential for provision of data from the Gorgon Development.

13.5.3 Greenhouse Gas Emissions Performance Indicators and Targets

Greenhouse gas emissions from the Gorgon Development will be determined annually for each of the following performance indicators:

- tonnes of CO_2e emitted from LNG processing operations
- tonnes of CO_2e emitted from domestic gas processing operations
- tonnes of CO_2e emitted from logistics and support infrastructure
- tonnes of CO_2e emitted from LNG processing operations per tonne of LNG loaded on ship
- percentage of reservoir CO_2e vented to atmosphere/injected into the subsurface
- tonnes of reservoir CO_2e injected into the subsurface
- incremental emissions of CO_2e resulting from injection of reservoir CO_2.

As the Gorgon Development is in the design phase, the estimated greenhouse gas emissions presented in Section 13.3.4 are based on a reference case which incorporates a number of design assumptions. It is envisaged that as the detailed design progresses and operational procedures are developed, opportunities to further reduce greenhouse gas emissions below those presented in Section 13.3.4 will be realised. Further, the ability to reduce emissions, in particular those related to the venting of reservoir CO_2, should be possible as operational experience is gained with the injection of CO_2. In light of this, a number of key performance targets related to greenhouse gas emissions have been generated as targets for the further reduction in emissions over the first 5–10 years of the operational life of the Development. These key performance targets are presented in Table 13-21.

Table 13-21:
Key Performance Targets for Greenhouse Gas Emissions from the Gorgon Development

Greenhouse Performance Indicator	Value Stated in the Draft EIS/ERMP Based On Reference Case Assumptions	Longer Term Performance Target
Tonnes of CO_2e emitted from LNG processing operations (without contribution from CO_2 venting)	3.03 MTPA CO_2e	5% less or 2.88 MTPA CO_2e
Tonnes of CO_2e emitted from domestic gas processing operations(without contribution from CO_2 venting)	0.23 MTPA CO_2e	5% less or 0.22 MTPA CO_2e
Tonnes of CO_2e emitted from logistics and support infrastructure	0.07 MTPA CO_2e	5% less
Percentage of reservoir CO_2e injected into the subsurface/vented to atmosphere	80% injected/20% vented	> 95% injected/< 5% vented
Tonnes of CO_2e emitted per tonne of LNG loaded on ship (includes contribution from CO_2 venting)	0.353 tonne CO_2e/tonne LNG	0.304 tonne CO_2e/tonne LNG (assumes both plant efficiency and CO_2 venting targets are met)

13.6 Compliance with EPA Guidance Notes

The EPA has issued a number of guidance notes dealing with managing environmental impacts. Two of these guidance notes deal with greenhouse gas emissions and the subsurface disposal of liquid industrial waste. The Gorgon Joint Venturers have complied with the objectives outlined in each of these guidance notes.

13.6.1 Guidance Note No 12: Minimising Greenhouse Gases

EPA Guidance Note No 12 (EPA 2002) provides direction on the minimising of greenhouse gas emissions from significant new or expanding operations. The objective of the EPA is to reduce greenhouse emissions to a level which is as low as practicable by ensuring that emissions from proposed projects are adequately addressed in the planning, design and operations.

The Gorgon Joint Venturers have incorporated energy efficiency and emissions management as key value drivers in designing the proposed Development and intends to restrict its atmospheric greenhouse gas emissions by the injection of reservoir CO_2 into the Dupuy Formation. These actions have delivered the proposed Development with world class benchmarked greenhouse efficiency, when normalised for climate and CO_2 content of reservoir gas, in accordance with the objectives of this guidance note.

13.6.2 Guidance Note No 4: Deep and Shallow Well Injection for Disposal of Industrial Waste

EPA Guidance Note No 4 (EPA 2003) provides guidance on the environmental assessment of deep and shallow well injection of liquid industrial waste into the ground waters of Western Australian by means of Class I, IV or V wells. The objective behind the guidance note is the protection of ground water resources which might be impacted by the subsurface injection of industrial waste. The guidance note outlines the approach that will be used by the EPA during its assessment of such proposals. In particular, the proponent would need to satisfy the EPA that no adverse effects on existing and potential environmental values and beneficial uses of water could occur.

The injection of CO_2 into the subsurface as a means to reduce greenhouse emissions does not appear to have been envisaged at the time this EPA guidance note was drafted (the derivation of the well categories dates to 1994). Consequently the injection of CO_2 does not readily fall within any of the existing well categories discussed in the Guidance Note. In addition, the definitions of industrial waste do not include CO_2. However the Gorgon Joint Venturers consider it appropriate to apply the objectives of the guidance note to the proposed CO_2 injection project on Barrow Island.

The technical studies undertaken by the Gorgon Joint Venturers indicate that there will be a low risk of impact on the environmental values of Barrow Island. Further, as there is no significant ground water resource in the vicinity of Barrow Island, the proposal to inject CO_2 is consistent with this guidance note.

13.7 Conclusions

The Gorgon Joint Venturers' commitment to the responsible management of greenhouse gas emissions is evidenced by the results of benchmarking the anticipated LNG emissions efficiency performance from the Gorgon Development with other LNG facilities. The expected performance of 0.35 tonnes of CO_2e per tonne LNG to be produced (based on the reference case assumptions) exceeds both operating and proposed LNG projects within Australian when greenhouse emissions related to gas production are considered.

As part of the strategy to minimise greenhouse gas emissions, the Gorgon Joint Venturers are proposing to inject the CO_2 contained in the reservoir gas stream. A thorough review of potential CO_2 injection locations has been conducted and has determined that the Dupuy Formation, accessed from the eastern side of Barrow Island, is the preferred location for this activity. Appropriate monitoring of the injected CO_2 is planned to assist with the ongoing management of the CO_2 injection operations. The proposed injection of the reservoir CO_2, will reduce greenhouse gas emissions attributable to the Development (including domestic gas production) from 6.7 million tonnes per annum of CO_2 equivalent (MTPA CO_2e) to 4.0 MTPA CO_2e.

Additional activities to be undertaken with the objective of reducing greenhouse gas emissions from the Gorgon Development include:

- Undertaking further studies into the electrical generation gas turbine and waste heat recovery configuration. Section 13.3.4 documents the options that are being considered.
- Investigating the further integration of the Gorgon Development and the Barrow Island Joint Venture activities on Barrow Island, with the aim of reducing greenhouse gas emissions. For example integration of electrical power systems.
- Undertaking energy optimisation studies during the detailed engineering and design of the development. Energy optimisation is a way to identify, understand, and optimise energy use over the operating lifetime of a project.
- Developing operational and maintenance procedures with objective of reducing greenhouse gas emissions below those in the reference case and in line with the performance targets listed in Section 13.5.3. Maximising the percentage of reservoir CO_2 injected will be a primary focus in developing these operational and maintenance procedures.
- Once the gas processing facility is operational, undertake Energy Optimisation Studies in line with requirements in Chevron Australia's Operational Excellence Management System (OEMS). An overview of the OEMS is provided in Chapter 16.
- Continuing to support research into carbon dioxide capture and storage technology development within Australia and overseas. Potential for provision of data from the Gorgon Development.

The Joint Venturers have developed a series of longer term performance targets with the objective of further reducing greenhouse gas emissions from the proposed Development.

14: Social and Cultural Environment – Effects and Management

The Gorgon Development will be a large and sustainable resource development in a relatively remote area off the Pilbara coast. The Joint Venturers have considerable experience and knowledge associated with large and complicated resource developments world-wide, including a working knowledge of north-western Australia, particularly Barrow Island. This knowledge-base provides a substantial contribution to the identification, understanding and management of potential social impacts and benefits associated with the Gorgon Development.

The major social impacts and benefits identified for the Development include:

- local and regional employment opportunities during planning, construction and operational phases
- specific regional development opportunities
- employment, education and training opportunities due to the Development's proposed staffing levels, construction schedule and Fly-In Fly-Out (FIFO) requirements
- risks to industrial relations with the existing workforce community on Barrow Island due to the influx of a large, temporary construction workforce
- cultural and marine heritage resource issues from possible physical disruption of archaeological and historical sites
- Native Title issues related to the acquisition of pipeline easement(s) for the domestic gas pipeline alignment near shore and onshore to connect with the Dampier to Bunbury natural gas pipeline at Compressor Station 1.

The location of major Development components on Barrow Island means that a relatively small proportion of the infrastructure and facilities will be located on the mainland in the Pilbara or elsewhere within Western Australia. The implications are that physical and social impacts on the mainland related to the Development will be relatively few.

A draft Cultural Heritage Management Plan (CHMP) has been developed to assist in avoiding or minimising potential impacts during the construction and operation of the Gorgon Development. This plan will be refined further in the current phase of Development planning. Consultation with Aboriginal groups will continue throughout the Development phases and good-faith negotiations will be undertaken should an easement for the domestic gas pipeline be required.

A number of plans to identify and enhance the social opportunities are being developed. The Gorgon Development has an Australian Industry Participation Policy (AIPP) outlining the approach to local content and procurement. This Policy specifies a commitment to provide full, fair and reasonable opportunity for Australian industry to supply goods and services to the Development. In accordance with the *Barrow Island Act 2003,* a Social Impact Management Plan (SIMP) is being developed in close consultation with Western Australian government agencies to enhance social opportunities. The SIMP is being prepared during the proposal stage of the Development and will be subject to Ministerial approval, but is separate from the EIS/ERMP process. At the local level, the Joint Venturers will continue to work through community groups in the region to ensure potential impacts are identified, managed and activities in the region are coordinated.

14.1 Introduction

The standards, methodology, and assessment of social, health and safety, cultural, aesthetic and tenure impacts of the Gorgon Development are described in this chapter. Methods and procedures to avoid or minimise potential negative impacts or to enhance and develop the positive opportunities and benefits through appropriate proposed management measures are discussed.

Priority has been given to the development of management strategies for medium to high impact or risk activities (identified prior to the implementation of planned safeguards). Management plans and policy, including a Development-specific Social Impact Management Plan (SIMP), an Australian Industry Participation Policy (AIPP), and a Cultural Heritage Management Plan (CHMP) will be developed and implemented as part of the Gorgon Development. The CHMP will form part of the Gorgon Development environmental management system as one of a suite of management plans proposed for the current phase of the Development (refer Chapter 16). Further definition and details of the social and cultural impacts and management strategy planned for the Gorgon Development are outlined below and in the technical appendices accompanying this Draft EIS/ERMP.

14.1.1 Standards for Social Impact Assessment

Currently there are no specified regulatory assessment frameworks for social impact assessment in use in Western Australia. The established operational guidelines currently being used internationally are largely based on adopting those developed by the World Bank (World Bank Operational Policy 4.01 Environmental Assessment, January 1999) as a minimum. These guidelines are supported by the International Finance Corporation (IFC) and are reflected in the Equator Principles (www.equator-principles.com). The Joint Venturers operate globally and will follow world-best practice for social impact assessment, which involves adherence to the World Bank guidelines. The guidelines are consistently used for major resource development projects around the world and have been used as a framework for the Gorgon Development.

The social impact assessment methodology in this chapter incorporates the normal steps in social impact assessment with outcomes presented in a risk-based framework. While this approach is consistent with the environmental assessment, it is important to understand that for environmental factors, risks generally imply negative consequences. Social and economic impacts can be positive and/or negative, both of which should be, and are, considered in this assessment. The assessment approach has been adjusted to identify both positive and negative impacts.

14.1.2 Risk-Based Assessment Approach

A social and economic impact assessment normally follows the broad approach outlined in Section 14.1.1, and is generally aligned with the World Bank and IFC guidelines (where they are applicable). However due to the scale and complexity of the Gorgon Development, the Joint Venturers have adopted a risk-based assessment approach (refer to Chapter 9). This requires that the normal steps in a Social and Economic Impact Assessment (SEIA) be modified to achieve risk-based assessment outcomes. An SEIA would normally refer to:

- scoping including the development of a Stakeholder Consultation Plan
- profiling of the socio-economic environment
- identifying and predicting impacts
- assessing impact significance (taking into account quantification of impacts and consultation with stakeholders)
- identifying mitigation measures to address impacts.

The risk-based assessment follows these broad steps, but has been adjusted to assess their significance with a focus on risks and benefits. The key steps include:

- identifying relevant social and economic factors (ChevronTexaco Australia 2003; ChevronTexaco Australia 2004)
- screening of social and economic factors, and potential receptors, to identify the potential impacts in each stage of the Development
- assessing impacts to determine the level of risk and/or benefit (significance) associated with social and economic consequences
- identifying mitigation measures to minimise negative and enhance positive consequences.

Stakeholder consultation has been, and will continue to be, an important part of the impact assessment process and development of detailed management strategies (Chapter 5).

The overall approach to the risk-based assessment and risk matrices is described in Chapter 9. The risk-based assessment allows for a detailed consideration of individual impacts. General comments on the expected overall positive and negative impacts of the Development are provided in the conclusion to this chapter.

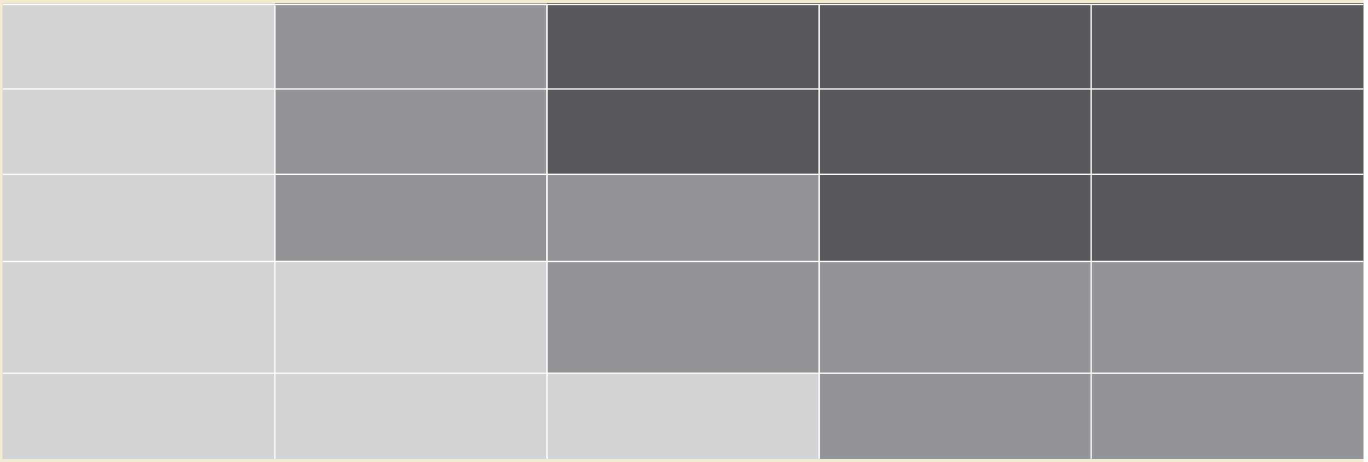
Risk Matrix

The risk matrix, definitions and criteria used for the SEIA are presented in Figure 14-1.

Figure 14-1:
Risk Matrix for Social and Economic Impact Assessment

Risk Categorisation – Socio-economic

Likelihood	
Almost certain – very likely to occur prior to or during construction	HIGH
Occasional – likely to occur within the life of the Development	
Seldom – may reasonably occur within the life of the Development or has occurred at a similar facility	
Unlikely – not likely to occur with current practices and procedures but has occurred elsewhere	
Remote – highly unlikely and unheard of in industry but theoretically possible	LOW



LOW — **Impact/Consequence** — HIGH

	Incidental	Minor	Serious	Major	Severe
Socio-economic	Local, small-scale, easily reversible change on social and economic characteristics, infrastructure and/or values of Shires of Roebourne and Ashburton or Barrow Island. Community can easily adapt or cope with change.	Short-term, recoverable or positive changes to social and economic characteristics, infrastructure and/or values of the Pilbara region or Barrow Island. Community has significant capacity to adapt and cope with or promote change.	Medium-term, recoverable or positive changes to social and economic characteristics, infrastructure and/or values of the Pilbara region or Barrow Island. Community has some capacity to adapt and cope with or promote change.	Long-term, but recoverable or positive changes to social and economic characteristics, infrastructure and/or values of Western Australia, the Pilbara region or Barrow Island. Limited capacity within community to adapt and cope with or promote change.	Irreversible, change to social and economic characteristics, infrastructure and/or values of Western Australia, the Pilbara region or Barrow Island. No capacity of community to adapt and cope with change.
Health	Impacts limited to surrounding locality.	No impact at state, national or international level.	Limited impact at state level. No impact nationally or internationally.	Significant impact at state level. Limited impact at national level. No impact at international level.	Significant impact at state and national levels. Impacts recognised at international level.
	Low level, short-term inconvenience or symptoms. No measurable physical effects. No medical treatment.	Objective but reversible. Disability/impairment and/or medical treatment injuries requiring hospitalisation.	Moderate irreversible disability or impairment (<30%) to one or more persons.	Single fatality or severe irreversible disability or impairment (>30%) to one or more persons.	Short- or long-term health effects leading to multiple fatalities or significant irreversible human health effects to > 50 persons.

14.2 Social Factors Requiring Assessment

From a social and economic perspective, the proposed Gorgon Development has the potential to result in impacts at local, regional, state, federal and international levels. Potential benefits and impacts range from very minor, incidental effects to long-term and widely felt effects. An initial scoping of factors likely to require assessment was conducted as part of the Scoping Document for the proposal (ChevronTexaco Australia 2004). Prior to undertaking a detailed risk assessment, the various factors requiring assessment and the potential receptors were identified through the social impact assessment research and a consultation process. Potential benefits and impacts have been identified, with the likelihood of an impact occurring at each stage of the Development (planning, construction, operation and decommissioning) being noted.

The social factors requiring assessment include:

- government policy and plans
- local communities
- livelihood and lifestyle
- land and sea use and tenure
- Native Title claim areas
- landscape and aesthetic values
- workforce and public health and safety
- cultural heritage
- social infrastructure
- community development.

14.3 Government Policy and Plans

There are a wide range of social and economic plans designed to provide policy and guidance to local, regional, state and federal governments. The Gorgon Development will have implications for a number of these plans which are discussed in more detail below.

14.3.1 Local Policy and Plans

The Shire of Ashburton Town Planning Scheme No. 7 was gazetted in late 2004 and Barrow Island is included within the Shire of Ashburton. The regulations and building codes referred to in the Scheme would normally apply to building and development approvals on the island. The applicability of the Scheme to the Gorgon Development is currently being determined. Due to its designation as a Class A Nature Reserve, the planning of development on Barrow Island is also a state government issue, pursuant to the *Land Administration Act 1997.*

At the local level, Town Planning Schemes and Structure Plans also provide guidance for development on the near and onshore areas of the Australian mainland. The Onslow Structure Plan (Western Australian Planning Commission 2003) and Karratha Area Development Strategy (Western Australian Planning Commission 1998) designate areas for use for industrial development including downstream processing and support for offshore industries. The Joint Venturers are investigating an area for the location of a supply base in the Dampier area, possibly near King Bay (refer to Chapter 6) as well as in the Fremantle/Jervis Bay area. The Joint Venturers will adhere to the requirements of relevant town planning schemes and other local government policy where these apply to the King Bay area and the proposed mainland pipeline route. Exact requirements will be determined during the current design phase.

Consultation with representatives of both the Ashburton and Roebourne Shires indicates that they would prefer the Development to be located on the mainland in their respective areas. The Roebourne Shire would like the Development to be in the Maitland area to provide the impetus for significant social and economic development opportunities both in the shire and the Pilbara generally.

14.3.2 Regional – Policy and Plans

The key regional plans for the Pilbara are the Pilbara Land Use Strategy and the Pilbara Regional Priority Plan. The former presents a strategic 25-year plan for the Pilbara and identifies broad objectives for land use and development. The Pilbara Regional Priority Plan is recent (October 2003) and has a number of key objectives. Table 14-1 is a summary of the relevant plan objectives and describes the implications of the Development on these objectives.

Table 14-1:
Implications of the Proposed Gorgon Development on the Pilbara Regional Priority Plan

Components of the Priority Plan (Socio-Economic)	Implications of Gorgon Development
Delivery of improved secondary and tertiary education.	Gas processing facility construction and operation workforce located on Barrow Island. No improvements to secondary or tertiary education facilities envisaged as a result of the Development. If a new supply base is required it could generate local employment during construction (130–140 jobs) and operation (12–30 jobs). Some of this employment will be for skilled labour and will generate oil and gas industry training opportunities. Mainland construction workforce is likely to be drawn from existing population and elsewhere. During construction, personnel from outside the region are likely to be accommodated in a temporary facility and the majority are unlikely to be accompanied by families. Operations workforce for the supply base will be located in the local community and may create some additional demand for educational facilities but 12–30 households (maximum: not all operations employees will have children and/or educational requirements) is not likely to be significant.
Focused regional health services.	The workforce for a new supply base, should it be required, would likely access local, general health facilities. If this was in the Dampier and Karratha region, preliminary consultation has indicated that general health facilities in the region would require some improvement and therefore this small workforce (and potential families) may increase pressure on these facilities. This is perceived by some as being advantageous if it results in additional services being provided to the region. Much greater impact from the large and unsustainable influx of temporary construction workers would be felt in the local community if a mainland site had been suitable for the Development. The proposed Development will contribute to the further development of emergency response and health services in the region.
Sustainable and viable funding of local government including application of rating to resource projects.	The State Agreement *(Barrow Island Act 2003)* for the Gorgon Development provides the Shire of Ashburton with the opportunity to apply rates for the gas processing facility on Barrow Island. Formulae for calculating these rates and quantum of dollars has yet to be determined, but will levied on a 'non-discriminatory' basis. This will provide a minor benefit from the Development.
Provision of enabling infrastructure in order to meet the needs of the community and industry prepared to invest in the region.	Existing infrastructure is likely to be adequate for Gorgon Development requirements and no implications will be created by the Development.
Land use planning and timely land release.	Industrial land is available in the region. While the majority of the Development will be located on Barrow Island, if a new supply base is required, there currently exists some available land in the King Bay area. Industrial land is also available in Onslow and Perth should other locations be considered for the supply base.

Table 14-1: (continued)
Implications of the Proposed Gorgon Development on the Pilbara Regional Priority Plan

Components of the Priority Plan (Socio-Economic)	Implications of Gorgon Development
Relevant indigenous employment initiatives to increase indigenous employment participation rates by providing educational and training pathways.	The Gorgon Development will include indigenous employment and training activities. Commitment to these activities is included in the Gorgon Development's Australian Industry Participation Policy. Specific details will be developed and included in the SIMP.
Law and order in the community with aim of reducing crime and increasing presence of law and order officers.	Majority of the workforce will be located on Barrow Island reducing the potential incidence of crime associated with construction workforce on local communities in Karratha and Dampier. Supply base construction workforce will be relatively small and is not likely to create significant impacts on local law and order capacity.
Emergency/security awareness and preparation to ensure cyclone preparedness.	The Joint Venturers will manage its own cyclone preparedness for Barrow Island but will liaise and inform the local Fire and Emergency Services Authority (FESA) of Western Australia. No additional requirements for FESA to manage.
Attraction and retention of government staff through housing improvements and career development opportunities.	The Gorgon Development will generate the requirement for full-time Conservation and Land Management (CALM) officers during construction (four officers on a 2-on 2-off shift) and operation (two officers on a 1-on, 1-off shift). Decision as to where these officers will be located rests with CALM *(Barrow Island Act 2003)* (refer to Chapter 2).
Impact of FIFO on social amenity and reduced economic potential of local businesses requires better understanding by state government.	The Joint Venturers will adopt a FIFO regime from Perth for construction and operation workforce for the gas processing facility. This will continue the FIFO trend in the region and contradicts some state, Pilbara Development Commission and local government policies. It should be noted that this workforce would be FIFO regardless of a Perth or Karratha origin, given the proposed Development location on Barrow Island. Consultation indicates that FIFO is a significant issue of concern for many local and regional stakeholders. However social and economic impacts associated with this issue were a subject of the ESE Review process (ChevronTexaco Australia 2003), with government and the Joint Venturers concluding that the Development should be sited on Barrow Island. Supply base workforce will comprise a mix of local and potentially some FIFO depending on where skilled labour force resides. Details of employment sourcing will be determined during the current phase of design.
Requirement for integrated heritage and natural resource management to overcome piecemeal approach taken by industry to date.	The Joint Venturers have undertaken preliminary heritage surveys and consultation in accordance with relevant federal and state legislation. A draft Cultural Heritage Management Plan has been prepared for the Development. Continued stakeholder engagement is part of the SIMP.

14.3.3 State – Policy and Plans

The key state legislation, policies and plans that have implications for the social impact issues are the *Barrow Island Act 2003,* which includes the Gorgon Gas Processing and Infrastructure Agreement (State Agreement), Western Australian Sustainability Strategy (http://www.sustainability.dpc.wa.gov.au/docs/Strategy.htm), and the State Planning Strategy and Regional Development Policy (http://www.dlgrd.wa.gov.au/rdpmain.html).

The *Barrow Island Act 2003* provides a legal framework for the Development and the requirement for an SIMP is contained in the State Agreement which is a schedule to the Act. The SIMP will be developed in consultation with, and to the satisfaction of, the Western Australian Government. The Act has a number of requirements in relation to the use of local labour, professional services, materials, employment and training. The Joint Venturers have developed an AIPP for the Development to 'provide full, fair and reasonable opportunity for Australian industry to supply goods and services to the project' (refer to Chapter 8).

The State Sustainability Strategy is very broad but identifies relevant priority action areas including:

- regional development
- indigenous peoples' development
- sustainable communities
- sustainable use of resources.

The decision to locate the gas processing facility on Barrow Island has limited the opportunities for significant new employment opportunities in the region, indirect regional development and indigenous peoples' development. There will be opportunities for local employment, procurement and supply of goods and services at a reduced level, but it was recognised and highlighted in the ESE Review and Response to Submissions that the main benefits from the Development will be economic, because it will be one of the largest single contributors to government revenues once in full production.

As outlined in Chapter 3, Barrow Island is the only commercially viable location for the Gorgon Development. While the location of the gas processing facility on Barrow Island will result in less direct social benefits than if it were located on the mainland, this should be set against the Development not proceeding at all.

The State Planning Strategy identifies a number of actions for the Pilbara. The extent to which the Gorgon Development contributes to these is shown in Table 14-2.

Table 14-2:
Implications of the Gorgon Development for the Western Australian State Planning Strategy

Components of the Strategy (Socio-Economic)	Implications of Gorgon Development
Minimise the impact of FIFO resource development projects.	The Barrow Island location for the Development requires a FIFO workforce for the gas processing facility. Currently there is not an adequate or sustainable labour pool in the Pilbara region to satisfy the manpower requirement of the Gorgon Development and other large-scale resource projects planned for the area. A mainland supply base will have a smaller construction and operational manpower requirement and will likely use a mix of local and FIFO personnel.
Address the need for social services and facilities.	The Joint Venturers will supply sustainable and well-paying jobs for employees assigned to the Development. The Joint Venturers will substantially contribute to the national and Western Australian revenues, a portion of which will be available for social services and facilities in the region.

Table 14-2 (continued):
Implications of the Gorgon Development for the Western Australian State Planning Strategy

Components of the Strategy (Socio-Economic)	Implications of Gorgon Development
Increase the level of resource royalty income to the region.	The Gorgon Development will contribute significant royalty payments. Decision-making regarding distribution/expenditure of royalties is made by the federal government. The Joint Venturers acknowledge the significant concerns of regional stakeholders on the issue of resource revenue sharing particularly between the federal and state governments. The Joint Venturers will be making full contribution to royalties, but it is a matter for the governments as to the way these funds will be distributed.
Coordination of government agencies to minimise delays in resource developments and associated infrastructure needs.	A coordinated federal and state environmental approval process is well advanced for the Development (refer to Chapter 4).
Detailed planning for population growth and urban centres.	The Joint Venturers will provide employment forecasts and requirements to assist the Western Australian Government plan for growth.
Greater emphasis on local recruitment and training of the workforce.	The Joint Venturers have an Australian Industry Participation Policy that outlines approach to local content and procurement, and the SIMP will outline training and recruitment opportunities. Further Development details will be identified in the current phase of design and in Engineering, Procurement and Construction Management contracts prior to finalisation.
Provide strategic transport linkages within and to the Pilbara region.	The Gorgon Development will require additional flights and servicing to Barrow Island both during the construction and operation of the Development. Air and marine supply services will be negotiated with existing suppliers and, where necessary, new linkages will be developed.
Improve industrial and domestic access to water supplies.	The vast majority of the Gorgon Development will be situated on Barrow Island where an independent water supply and treatment system will be installed. Upgrading or developing a marine supply base on the mainland will put very little pressure on existing domestic and industrial supplies.
Ensure infrastructure provision is the focus of government agencies.	The location of the Development on Barrow Island will significantly reduce any pressure being placed on the state's infrastructure development or improvement. Significantly higher infrastructure costs to the state would have been required if the Development were situated on the mainland.
Improve town amenity.	The Gorgon Development situated on Barrow Island will have the least impact on town amenity concerns and issues.
Protect sensitive environmental and heritage areas.	The gas processing facility will be located on a Class A Nature Reserve. Environmental implications are discussed in this Draft EIS/ERMP (refer to Chapters 10–13). Cultural heritage has been identified on Barrow Island and the mainland, and these issues are discussed in Section 14.8. It is noted that the Gorgon Development is subject to a rigorous environmental approvals process at both the state and federal levels (this EIS/ERMP process), and Schedule 1 (Gorgon Gas Processing and Infrastructure Project Agreement) of the *Barrow Island Act 2003* requires a contribution of $40 million (indexed) to fund Net Conservation Benefits.

14.3.4 Federal – Policy and Plans

The Commonwealth Government of Australia advocates stronger regions around Australia (http://www.rbda.gov.au/action_plan/index.htm). An Action Plan for implementation of the Policy was developed in 2003. The Action Plan promotes investment in the regions, improved government co-ordination of Commonwealth funding expenditure, review of the current Zonal Tax Rebate Scheme, identification of skills shortages, leadership programs for young people, and development of the regional infrastructure bond market to overcome under-investment in regional infrastructure projects.

The implications for the Gorgon Development are the positive and potentially negative impacts to the government initiatives of regional development, employment, education and training. Specific details will be addressed in the SIMP. Many stakeholders suggested that the Gorgon Development could have additional benefit to the local and regional government agencies by assisting them in their federal government discussions and negotiations relating to the distribution of resource royalties.

14.3.5 Summary of Major Benefits and Risks to Government Policy and Plans

The potential socio-economic impacts (risks and benefits) of the Gorgon Development to the various federal government policy and plans are summarised in Table 14.3. They include:

- Perceived reduction in potential opportunities for industrial development in the Pilbara region as a consequence of developing a gas processing facility on Barrow Island.
- Use of a FIFO workforce with potential loss of opportunities for local personnel and social impacts of FIFO on the workforce.
- Shire of Ashburton will be able to rate the Development based on its location on Barrow Island, thus providing the opportunity for a direct revenue stream from the Development to one local authority (high benefit).
- Opportunities for increasing participation of local indigenous workforce by supplementing education and training pathways (high benefit).
- Transfer of knowledge and technology associated with different aspects of the proposed Development to Western Australia and the region (benefit).

Table 14-3:
Key Benefits and Risks to Government Policy and Plans

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/ Target	Measurement Strategies	Residual Benefit/Risk
Facility to be located on Barrow Island.	Perceived reduction of opportunities for regional development.	• Construct and operate supply base in the Pilbara Region. • Construct a domestic gas pipeline as per commitment under State Agreement. • Fulfil AIP Policy and State Agreement commitment to local employment and content. • Outline detailed initiatives for local supply, procurement/ content, employment and training in the SIMP and consult with stakeholders on development of this aspect of the Plan.	• Local, regional and State employment created. • Training opportunities for Pilbara region created. • Local procurement in accordance with SIMP.	• Report on local and regional employment, procurement and development opportunities through the AIPP, State Agreement and/or SIMP.	Likelihood – almost certain Consequence – minor Risk – not applicable
Use of FIFO regime from Perth.	Disruption to routine family life.	• Adopt industry guidelines on work and rotation schedules for FIFO developments. • Allow appropriate communication facilities for workers. • Modify procedures to reduce negative social impacts on workers and families.	• Workforce health and safety within acceptable levels.	• Monitor social impacts on workforce and families during construction and operation. • Report on social impacts in SIMP or other reporting requirement.	**Construction** Likelihood – almost certain Consequence – minor Risk – not applicable **Operations** Likelihood – occasional Consequence – minor Risk – not applicable

Table 14-3: (continued)
Key Benefits and Risks to Government Policy and Plans

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/ Target	Measurement Strategies	Residual Benefit/Risk
Payment of rates to Shire of Ashburton for use of, and development on, land on Barrow Island. Payment of rates to Shire of Roebourne for use of, and development on, land in King Bay area (dependent on whether this site is owned by the Joint Venturers or leased from an existing owner).	Revenue stream for local authorities.	• Consult with Shire on appropriate level of rates and other revenue sharing opportunities. • Pay rates during construction and operation.	• Pay rates in accordance with agreement.	• Good corporate relationship with Shire. • Report on rates structure and payment schedule in SIMP or other reporting requirement.	**Construction** Likelihood – almost certain Consequence – minor Benefit – high **Operations** Likelihood – occasional Consequence – serious Benefit – high
Indigenous education and training initiatives.	Improved Indigenous education, employment and training opportunities in the Pilbara.	• Develop education, training and employment opportunities for Indigenous people in AIPP.	• Opportunities for indigenous employment and training provided.	• Report on local and regional education, training, employment, supply, procurement and development opportunities through the AIPP and/or SIMP.	**Construction** Likelihood – almost certain Consequence – serious Benefit – high **Operations** Likelihood – occasional Consequence – serious Benefit – high

14.4 Local Communities

14.4.1 Population

The Gorgon Development will result in some minor population changes in the Pilbara and Western Australia. The most significant changes would occur in Dampier/Karratha area should the Development require the construction of a supply base. Table 14-4 is a summary of the anticipated population change information.

14.4.2 Social Infrastructure and Regional/ Local Services

Population change can have direct impacts on social infrastructure such as health, welfare, emergency response, transport and other services. The significant majority of the Development workforce will be located on Barrow Island and will generate limited demand for social infrastructure in the Pilbara region and Perth. This situation would be substantially different if the Development were located on the mainland as demand impacts on social infrastructure would be increased.

The size of the construction workforce on Barrow Island will require management and coordination to minimise the impact on the existing operations. The Joint Venturers have substantial world-wide experience in the planning and construction of large and complicated resource projects and the issues associated with staffing, recruitment and management. The interaction of the Gorgon Development workforce with the existing enterprises on the island, which is also managed by Chevron Australia, will be addressed through continued workplace consultation.

In the Pilbara, the construction workforce of 130–140 workers for a potential new supply base may generate a short-term (40-month) demand for the services described above. Some of these workers may already be present in the Pilbara labour force and therefore do not represent an increase in demand. Some may be employed on a FIFO arrangement and will have limited demand for social infrastructure. The exact details of workforce origins will be determined during the current design phase. The results will be outlined in the SIMP submitted by the Joint Venturers prior to construction.

The towns of Dampier and Karratha currently have approximately 500 vacant rental properties. There is currently sufficient capacity to cater for the full 140 workers in rental accommodation. Should other projects come on-stream at the same time as the Gorgon Development, the demand will increase and this may create the potential for a shortage of accommodation for these workers. Table 1-3 in Chapter 1 is a summary of all the planned and proposed resources projects in the Pilbara and the approximate project cost and timing.

The construction workforce for Barrow Island represents a small proportion of the overall population of Perth. Any increase in population as a result of sourcing skilled labour from outside Western Australia is not likely to result in a significant demand for social infrastructure and services in Perth.

Table 14-4:
Population Change Associated with the Gorgon Development

Location	Existing Population	Direct Development Employment: Construction (Peak)	Direct Development Employment: Operation	Increase (%)
Barrow Island	150*	3300	300	100–2200%
Perth	1 339 993	Unknown	Unknown	Unknown but less than .00002%
Onshore Pilbara (total)	15 761	130–140	12–30	Construction – 0.8%
Dampier and Karratha	12 284	130–140	12–30	Construction – 1.13%
Dampier	1492	130–140	12–30	Construction – 9.4%
*Note: all population is FIFO. No full-time residents on Barrow Island				
Source: *http://www.abs.gov.au/Ausstats/abs@.nsf/0/d6c18bf1a2f09e4eca256e8a0077abe7?OpenDocument#POPULATION*				

14.4.3 Summary of Major Benefits and Risks for Local Communities

The consequences for local communities of the Development are summarised in Table 14-5, along with proposed management strategies.

The majority of the Gorgon Development will be on Barrow Island and surrounding waters and there will be no major or serious impacts for local communities in the Pilbara region. Minor impacts will be short-term, and only associated with the construction of a marine supply base, should it be required. During operation, the population increase (if any) will be insignificant, and will have no major or serious impact on the local communities or social infrastructure. The residual risk for local communities is low.

This outcome would be quite different if the Gorgon Development was to be located on the mainland. Locating the Development on the mainland would likely result in major or serious consequences for local communities and social infrastructure at least for the short-term.

14.5 Livelihoods and Lifestyle

14.5.1 Changes to Lifestyle

Major resource projects are a key element of the national economic and social fabric of Australia, Western Australia and in particular the Pilbara region. Western Australia is one of the most productive and diversified mineral and petroleum regions in the world. It hosts 480 commercial mineral projects, embracing 770 operating mine sites (open pit, underground mines and quarries) plus 143 processing plants and some 50 different minerals in commercial production (DoIR 2003). These projects have contributed significantly to the social, economic and culture in the region. In 1999/00, the region's total mining and petroleum industry production was valued at $11.7 billion, 55.1% of the value of the state's total mineral and petroleum production. This is an increase from 50.1% in 1998/99. The Pilbara's economy is based principally on iron ore, petroleum, gold and solar salt, with petroleum products now contributing around 65% of the region's mineral and petroleum wealth.

Future development will be based on the expansion of these industries and value-adding to these commodities.

Woodside's Phase 4 LNG expansion and the familiarity of the regional population with resource projects, and the significant number of major projects occurring or planned (e.g. the establishment of three heavy industry parks, two located in the Shire of Roebourne and one in Port Hedland are being planned to encourage downstream processing of the region's mineral resources), means it is unlikely that the Gorgon Development will create any significant change to this way of life. It represents a continuation of the type of economic activity that is common to the region.

Stakeholders have indicated their concerns about the potential impacts associated with FIFO regimes on regional development including:

- impacts on local amenity as a result of transient workforces which reduce demand and incentives for creating attractive and vibrant communities
- loss of opportunities for local businesses to supply major projects because the FIFO regime makes it more cost-effective to transport goods with employees. This further reduces opportunities for local expenditures (direct and indirect), increased levels of disposable income and creation of new jobs.

The Joint Venturers will work closely with the Commonwealth and Western Australian governments to develop programs to enhance business development in regional areas, facilitate the participation of regional businesses in the Development, enhance communication with business and contractors, and adopt procurement policies that provide opportunities for regional businesses. The location of the Development on Barrow Island will require a FIFO workforce. More details of the workforce source, characteristic and composition will be compiled during the current phase of design and included in the AIPP and SIMP reporting and plans. The social impact of FIFO on workers and their families has not been researched in detail for this specific Development. However some of the potential impacts, as noted by Lambert (2001), include:

Table 14-5:
Key Benefits and Risks to Local Communities

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/ Target	Measurement Strategies	Residual Benefit/Risk
Construction of gas processing facility and associated infrastructure. Operation of gas processing facility. Operation of mainland supply base.	Employment of peak construction workforce of 3300 on Barrow Island. Employment of up to 30 at mainland supply base. Increased business development opportunities. Potential migration into Western Australia. Employment of 300 on Barrow Island during operations.	• Include commitment to maximise local content and employment opportunities in AIPP. • Identify further detailed manpower and service requirements during the current phase of design. • Document detailed initiatives for local procurement/content, employment and training in the SIMP. • Consult/liaise with local government and other stakeholders.	• 10% of total workforce sourced from region.	• Report on local and regional employment, procurement and development opportunities through the AIPP and/or SIMP.	**Construction** Likelihood – almost certain Consequence – minor Benefit – high **Operation** Likelihood – occasional Consequence – serious Benefit – high

- Periodic time away from the family home by the worker results in requirement for spouse to maintain family and friendship networks and run household single-handedly.
- Spouse remaining at home often has to act as a 'single' parent and difficulties can emerge when the worker returns home 'off-shift'.
- Potential for increases in substance abuse as a result of isolation, stress or lack of recreational opportunities.
- Potential for increased instances of family violence, family breakdowns and/or divorce, parenting problems and reduced community involvement.

As stated earlier, it is unlikely the Gorgon Development will change the way of life for a construction workforce which historically is engaged in FIFO employment in the resources sector. While there may be potential impacts or specific Gorgon Development issues it is expected that these differences will be managed through employee relations, employment sourcing and workforce health and safety systems. Some of these issues include: employment opportunities of the existing workforce; the staffing levels during construction and operations; the work schedules during construction and operation; recreation facilities and future access to Barrow Island.

14.5.2 Changes to Sources of Income

The major sources of income associated with the Gorgon Development for communities in the Pilbara region and Western Australia include:

- direct employment on Barrow Island (benefits may accrue to local, regional, other Western Australian, Australian or international employees depending on skill requirements and availability)
- direct employment during construction and operation if a regional onshore supply base is constructed in the Dampier or King Bay area
- business income from providing goods and services to the Development (may be local, regional, state, national or international)
- indirect income associated with 'multiplier effects' of the Development.

Most of the sources of income are similar to existing sources available in the region or in Western Australia. Therefore the source of income is not likely to change; however the opportunities to access additional income associated with Development employment and procurement will increase at all levels.

The most significant opportunities for the Pilbara region will be derived from the employment and procurement that would be required to service a potentially new supply base in the Dampier or King Bay area.

Potential economic impacts of the Development are discussed further in Chapter 15.

14.5.3 Opportunities for Development

The Gorgon Development will generate additional opportunities for development in the region and at a state level. These include:

- potential construction and operation of a supply base in the Dampier/King Bay region, potentially generating increased demand for associated services such as earthworks, transport and logistics services, waste management services and provision of consumables
- operation of a supply base in the Perth region at a location such as the Australian Marine Complex in Henderson. This may also generate demand for additional services such as those described above.

14.5.4 Employment

Employment opportunities associated with the Development have been described above and in detail in Chapter 8. In summary, the majority (greater than 80%) of employment for construction and operation is likely to be sourced from Perth with approximately 10% of the total workforce for the Development expected to be sourced from the region. Lower levels of employment will be generated by the regional supply base.

14.5.5 Summary of Benefits and Risks to Livelihoods and Lifestyle

The Gorgon Development will generally create positive benefits to the livelihoods and lifestyles for the Pilbara community in terms of employment and local business opportunities. The potential benefits and risks are summarised in Table 14-4 and Table 14-5. These tables also contain strategies aimed at enhancing these benefits and managing the risks. The residual benefit is high during construction and high during operation. The residual risks associated with the FIFO workforce, the families of these workforces, and for regional development are high during pre-construction, construction and operation.

14.6 Land and Sea Use and Tenure

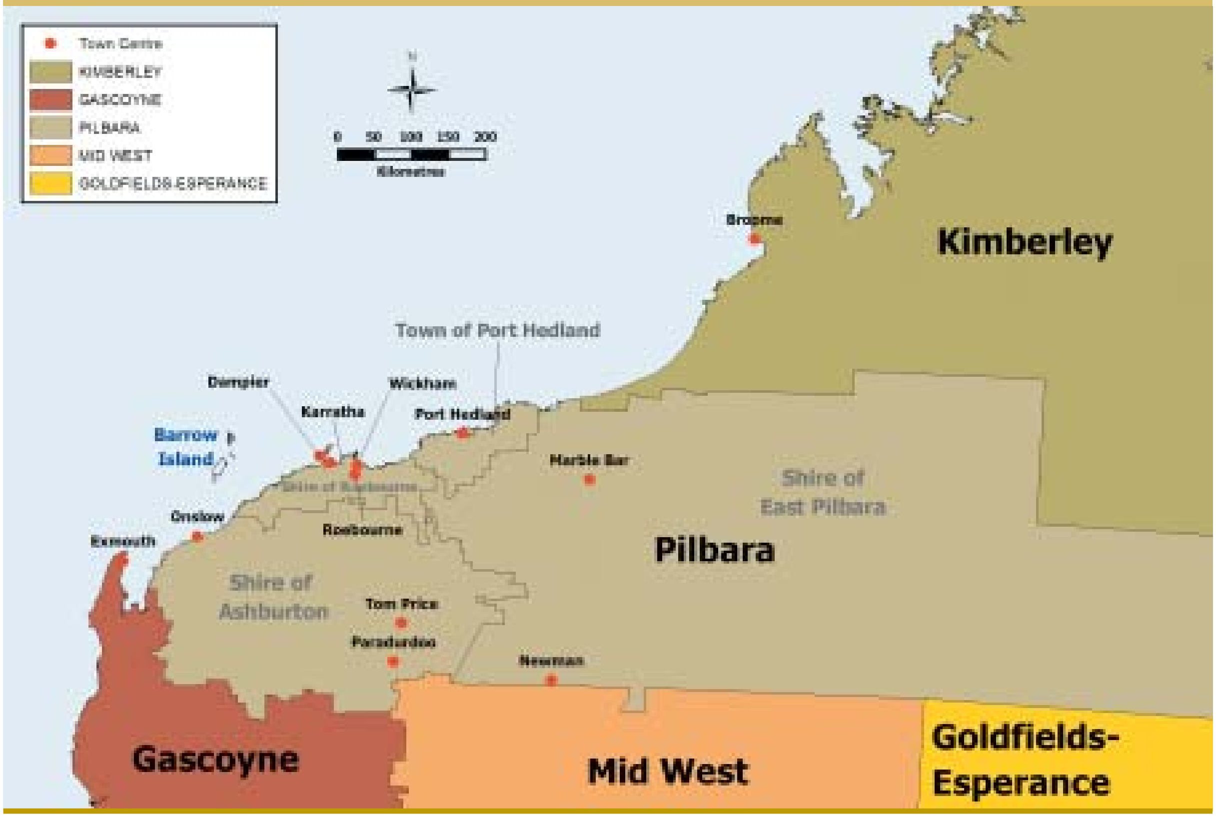
14.6.1 Environmental and Conservation Uses of Barrow Island

The use of 300 ha of Barrow Island, a Class A Nature Reserve, for industrial development is considered unacceptable by some stakeholders. The Gorgon Development will not change the Class A Nature Reserve designation and tenure of Barrow Island will remain with the state. Although this 300 ha represents less than 1.3% of Barrow Island, the use of the island for this purpose means that there will be a slight decrease in the use of the island for environmental and conservation purposes. As a counterpoint to this, the *Barrow Island Act 2003* provides for full-time residence for CALM officers for the duration of the Development. This, when combined with the presence of a well-educated (all employees will be thoroughly inducted) and dedicated workforce will make Barrow Island one of the most secure and best supervised remote conservation reserves in the world. Environmental and conservation consequences and residual risk are discussed in Chapters 10–13 of this Draft EIS/ERMP and the Technical Appendices.

14.6.2 Existing Oil Operations on Barrow Island

The existing oil operations on Barrow Island will not be physically impacted by the Development in a substantial manner since most of the infrastructure (pipelines) and gas processing is proposed to be located north and east of the existing oil field; and is not competing for similar hydrocarbon resources. It is expected that there will be synergies between the oil operations and the proposed Gorgon Development including shared use of facilities, worker accommodation, power and water supplies, and opportunities to reduce oil field flaring.

Figure 14-2:
Local Government Authority Boundaries and Towns in the Pilbara Region



14.6.3 Mardie Station Pastoral Lease

Should the domestic gas pipeline tie-in with the existing Bunbury to Dampier pipeline at Compressor Station 1, an easement over Crown lands located on the Australian mainland will be required. The pipeline will be located on a rural pastoral lease area. Currently this Crown land is part of the Mardie Station, an extensive pastoral lease which fronts unallocated crown land extending along the Western Australian coastline between the towns of Karratha and Onslow (refer to Figure 14-2). The lease holder runs cattle on the approximately 220 000 ha station, with numbers varying depending on the type of season and weather. Stock muster occurs annually anywhere between April and November. The pipeline will be buried and will not impact movement of cattle or vehicles on the property. The pipeline will be installed at a safe depth below access roads. Any fencing temporarily removed during construction will be replaced in like or better condition. The lease holder has not indicated that any fencing will be impacted by current alignment of pipeline (Mike Thompson, Mardie Station Owner, pers. comm. 2004).

14.6.4 Sea Use

The water surrounding Barrow Island is part of the area covered by the Montebello–Barrow Islands marine conservation reserves (CALM 2004). The majority of the conservation area is zoned as a Marine Management Area which is recognised for both commercial and conservation values. The Barrow Island Marine Park and Bandicoot Bay conservation area (benthic fauna/seabird protection) will provide additional protection for Biggada Reef and Bandicoot Bay (Figure 8-22). The Marine Park is comprised of Sanctuary Zone that encompasses the Biggada Reef coral assemblages and the surrounding limestone reef.

A large area off the east coast of Barrow Island is currently a designated port. The Barrow Island port was created under the *Shipping and Pilotage Act 1967* and vested under the *Marine and Harbours Act 1981* in the Minister for Transport.

The waters off the Pilbara Coast are used extensively for oil and gas development with the entire proposed Development area covered by leases/licences granted under the *Petroleum (Submerged Lands) Act 1967* (Figure 14-3). The stretch of water between the island and the mainland contains management areas and leases for other purposes, such as: commercial fisheries zones, Native Title Claim areas (near-shore) and a mangrove management zone.

The Gorgon Development will not change the boundaries or underlying designation of the management areas or zones and the potential impact is considered low.

There are shipping channels and shipping activity in the area for the subsea pipelines that will need to be monitored, particularly during construction. There is also a range of shipping activities occurring in the waters around Barrow Island, including over 1000 crude oil tanker shipments from the Barrow Island Port facility and seismic and exploration activities over 40 years. In the future there will be shipping to export LNG and condensate from Barrow Island.

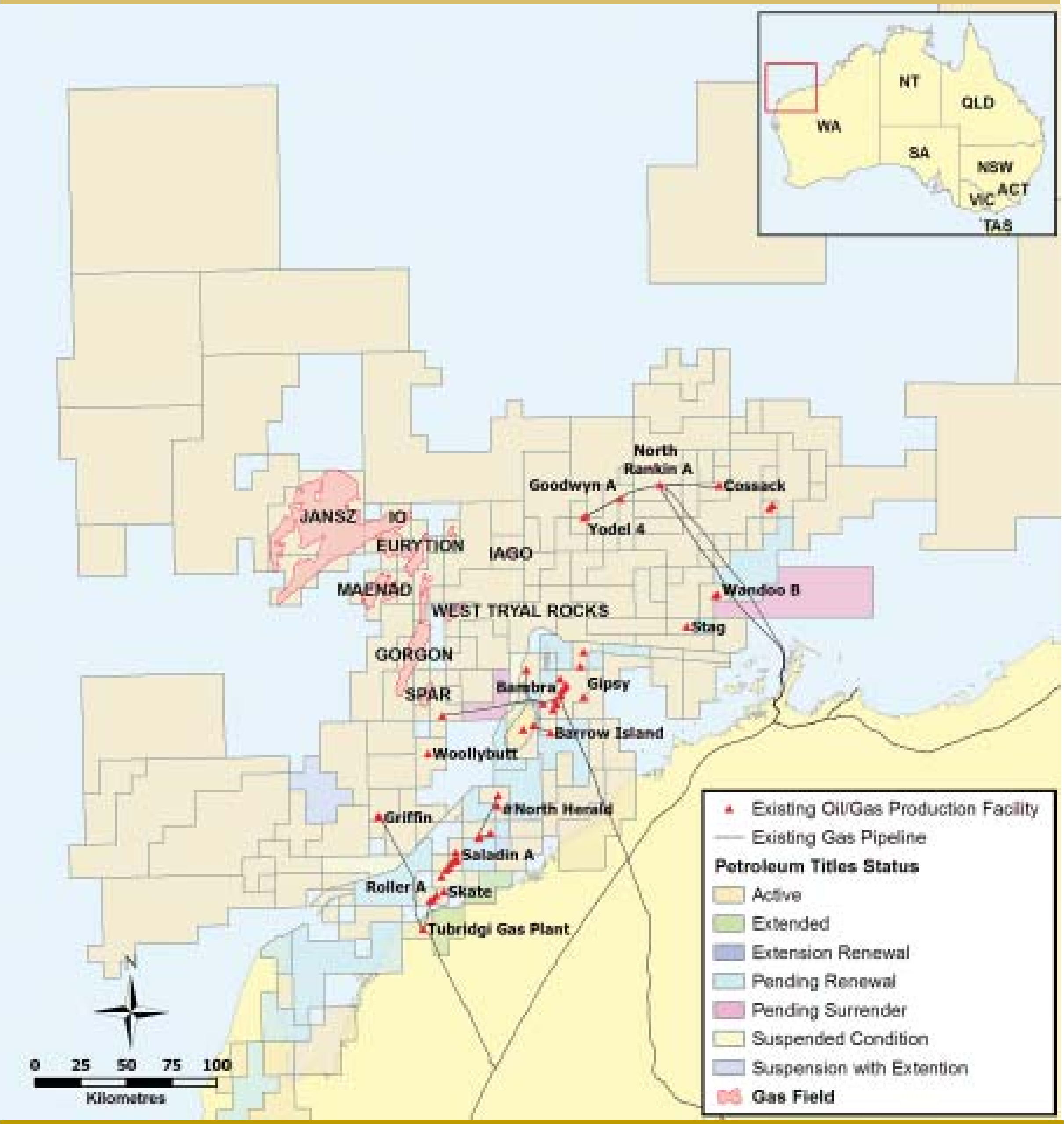
Commercial Fishing

Trawling for both fin fish and prawns occurs in the area between Onslow and Karratha, including Barrow Island. In addition, trap fishing also occurs between Barrow Island and the Greater Gorgon gas fields. Generally, boats engaged in these activities are small, can manoeuvre easily and are not affected by petroleum activities. Prawning is by far the dominant activity. Licensed boats require at least 1–2 nautical miles to perform a trawl.

The existing Apache Energy export pipelines currently transect the Area 3 prawning area. Cables, cable areas, pipelines and pipeline areas are shown on marine charts. Submarine pipelines are also shown in the chart legend and are usually denoted by the words ‘Pipe’, or ‘Pipeline’, or, in respect of those transporting natural gas, ‘Gas Pipeline’ with an additional cautionary note. These pipelines are protected under the Commonwealth *Submarine Cables and Pipeline Protection Act 1963.* Trawling vessels are not permitted to trawl over a pipeline. However, the trawling patterns obtained through 2003 data indicate that trawl activity is high in the vicinity of the pipeline (Fisheries Department, Karratha, pers. comm.). This could indicate that prawn stocks are high in this location or merely that boats use the boundary created by the pipeline alignment as a turn-around point.

Pearling activities in the vicinity of Barrow Island have generally been confined to Ronsard Island which is not currently in operation. Pearling activity is currently undertaken in the Montebello Islands, north of the Development area.

Figure 14-3:
Petroleum Lease and Permit Area – Barrow Island Area



Consultation with commercial fishermen has occurred, and discussions have not identified any unusual or unique impacts associated with the construction and operation of an additional subsea pipeline.

Recreational Fishing

Recreational fishing is popular in the Pilbara. Discussions with the Fisheries Department in Karratha indicates that pipelines are generally viewed as being beneficial to recreational fishers as they create additional habitat for marine species targeted by this group.

Access to and around the waters off Barrow Island will be incrementally limited by the Development; however this does not represent a significant change to the current activities which is currently restricted offshore seismic activity, oil and gas drilling, pipeline and infrastructure development, and represents only a minor potential impact.

Existing Industrial/Port Related Activities

There are a range of existing operations in the King Bay area including the Dampier Port Authority, Mermaid Marine and the Woodside Supply Base. These operations currently provide support to shipping and major resource projects in the region.

The Gorgon Development supply base would increase the level of activity in this area, creating opportunities for flow-on employment and business. During construction, there would be a significant volume of trucks entering the site (section 14.10.2) and this may cause traffic conflict, and wear and tear on road infrastructure.

14.6.5 Summary of Residual Risk to Land and Sea Tenure

The consequences for land and sea use and tenure of the Development, and proposed management strategies are summarised in Table 14-6. The residual risks are:

- low for tenure arrangements on Barrow Island during construction and operations
- low during the construction and commissioning of the domestic gas pipeline to shore, changing to medium during operations
- low during the construction, commissioning and operation of the onshore pipeline and optical fibre line
- low for the transportation of goods to and from a proposed Dampier/King Bay or Perth supply base.

Table 14-6:
Key Benefits and Risks to Land Use and Tenure

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Grant of lease for gas processing facility. Grant of Pipeline Licences.	No change to Class A Nature Reserve designation.	• Issue lease in accordance with legislative requirements.	• Legislation complied with.	• Lease agreements and Licences.	Likelihood – almost certain Consequence – incidental Risk – low
Installation of industrial infrastructure (Barrow Island).	Loss of area used for conservation purposes.	• Restrict area available for use of in the *Barrow Island Act 2003* and Schedule 1. • Specify boundaries of facilities on Barrow Island. • Precede any site clearing for construction with land surveys to ensure area requirements are met.	• Only those areas required for construction or operational facilities cleared.	• Implement environmental monitoring and reporting procedures in accordance with Development's EMS (Chapter 16).	Likelihood – almost certain Consequence – incidental Risk – low
Changed sea use due to construction and operation of: • port facilities • domestic gas pipeline (offshore) • optical fibre cable.	Restricted access during construction. Creation of habitat for fishing (recreational). Creation of additional barrier and exclusion area to trawl and prawn fishing operations.	• Continue ongoing liaison/communication with Fisheries Department and commercial operators to ensure awareness of construction planning, activities and location of the new marine facilities, pipeline and ship navigation. • Inform Mariners of any changes or navigational constraints due to construction and operating conditions. • Make appropriate changes to navigational charts and Fishing Management boundaries. • Introduce new navigation aids, additional monitoring of shipping and fishing activities.	• Negligible impact on commercial fisheries. • Additional recreational fishing opportunities created.	• Commercial and recreational fishing activity in the vicinity of Gorgon Development.	**Construction** Likelihood – almost certain Consequence – incidental Risk – low **Operations** Likelihood – seldom, Consequence – incidental Risk – low

Table 14-6: (continued)
Key Benefits and Risks to Land Use and Tenure

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Construction and operation of the domestic gas pipeline (onshore).	Acquisition of land required for easement from pastoral lease. Increased area of restriction adjacent to existing pipelines.	• Consult with Mardie Station Owner(s). • Negotiate and compensate for the pipeline easement. • Develop an access agreement for monitoring and maintenance activity and pipeline security.	• No significant interruptions to Mardie Station activities.	Annual notice to Crown Licensee regarding planned access activities. Cooperative work arrangement regarding Crown issues such as land rehabilitation, weed control, public access, and safety.	**Construction** Likelihood – almost certain Consequence – incidental Risk – low **Operations** Likelihood – seldom Consequence – incidental Risk – low
Operation of the marine supply base.	Increased truck traffic. Damage to roads. Increased safety hazards to other road users.	• Liaise and communicate with Shire of Roebourne and Karratha Police to manage truck activities and times of activity. • Comply with Zoning and development plans. • Conduct traffic impact assessment and prepare traffic management plans prior to construction.	• No fatalities or significant interruptions associated with Development-related traffic.	Implement monitoring and reporting procedures in accordance with Development's EMS (Chapter 16).	Likelihood – almost certain Consequence – incidental Risk – low

14.7 Native Title

As noted in Chapter 8, there are no Native Title claims over Barrow Island or to the north-west of Barrow Island over the Gorgon or Greater Gorgon gas fields. There are currently three registered Native Title claims that may overlap the proposed domestic gas pipeline route option and onshore seas approach to the mainland. These are large claim areas (13 940, 20 240 and 15 759 km^2 respectively). As shown in Figure 14-4 the Wong-goo-tt-oo Native Title claim (NNTT number: WC98/40) appears to be east and north of the proposed domestic near shore and onshore gas pipeline area; however the large-scale mapping of the claim area is very general and may be subject to interpretation. The near shore and onshore segment of the proposed optical fibre communication cable also crosses an area under Native Title Claim (Thalanyji). The Rights and Interests claimed by the groups are quite broad, but they recognise that they are not to the exclusion of other rights and interests validly created by the Commonwealth or the State of Western Australia, or accorded under international law.

The Joint Venturers intend to engage in appropriate, good-faith negotiations with the indigenous communities. Constructive and inclusive dialogue will maximise the potential for positive impacts and resolve any potential issues. Native Title issues will be resolved in accordance with relevant policy and legislation. The consultation taken to date is outlined in Chapter 5 of this document.

The potential impacts and proposed management strategies on Native Title issues for the Development are summarised in Table 14-7. The residual risk is considered to be high.

Figure 14-4:
Native Title Boundaries in the Pilbara Region

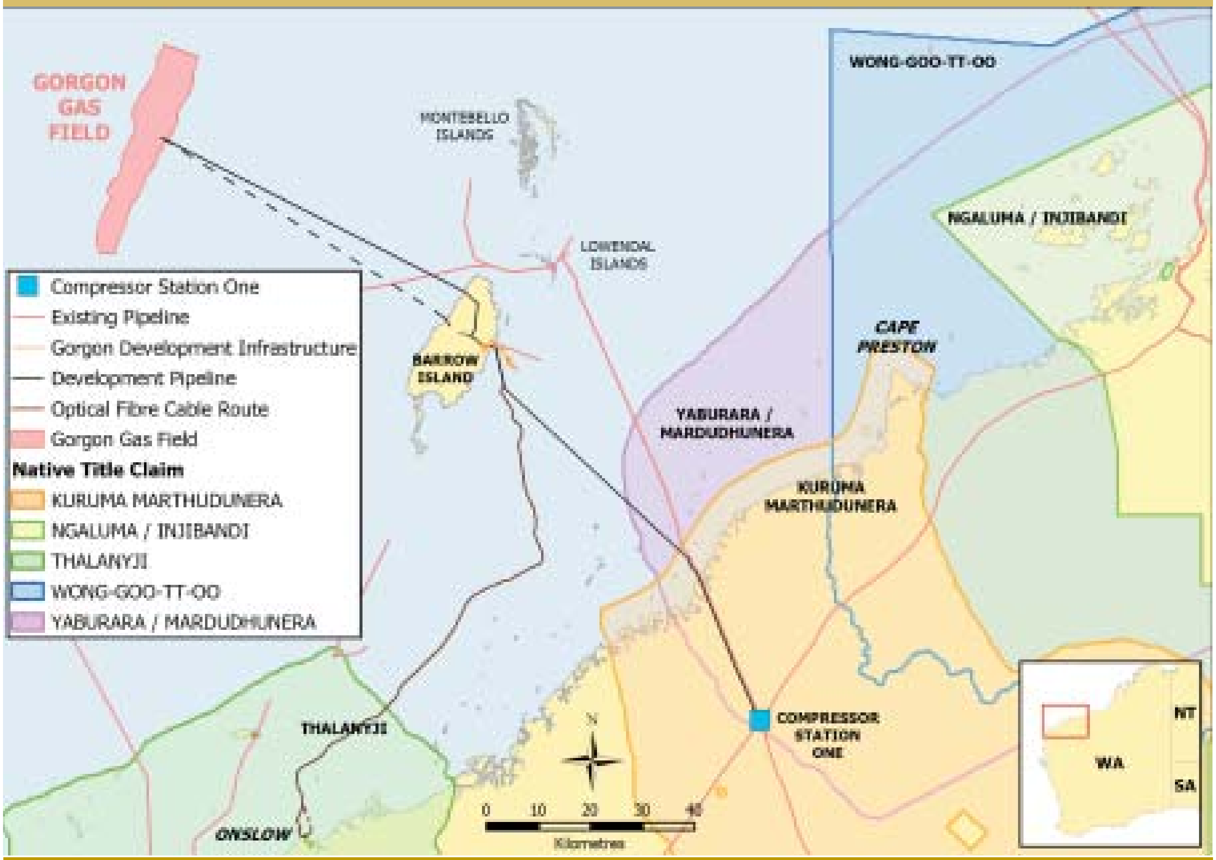


Table 14-7:
Key Benefits and Risks to Native Title Claims

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Construction and operation of the domestic gas pipeline and optical fibre cable.	Potential diminution of native title rights. Potential Development delay if agreement cannot be reached between the parties.	• Identify Native Title Claimants. • Assess potential impact of pipeline and optical fibre cable to Native Title rights and title. • Undertake good-faith consultation and negotiations with indigenous Native Title claimants in accordance with legislative requirements.	• Agreement reached with Native Title Claimants to permit construction and operation of pipeline and optical fibre cable within Claim area(s).	• Report on Native Title negotiations and outcomes as part of SIMP monitoring.	**Pre-Construction** Likelihood – occasional Consequence – serious Risk – high

14.8 Cultural Heritage

14.8.1 Indigenous Anthropology

There are three indigenous groups with a known interest in the region of the domestic gas pipeline route and Barrow Island. Initial discussions with these groups has been undertaken, with the people associated with the Yabbarara/Mardudhunera, Kurama Marthudunera and Thalanyji indigenous groups expressing an interest in being consulted regarding indigenous heritage issues on Barrow Island and the mainland.

At the current time, no ethnographic surveys have been undertaken on Barrow Island or the onshore domestic gas pipeline alignment. However, from earlier work conducted by Apache Energy and their predecessor Hadson Energy Resources Corporation, two ethnographic sites associated with Peters Creek are known to be located adjacent to the Apache Energy export pipeline on the mainland, in the general vicinity of the proposed domestic gas pipeline route. A further detailed survey would confirm whether these sites or other potential sites may be affected and this will be undertaken prior to commencement of construction.

Proposed management strategies are aimed at involving indigenous people in the identification and management of cultural heritage prior to construction on Barrow Island and the mainland. Management strategies are listed in Table 14-8 and outlined in detail in the draft Cultural Heritage Management Plan (CHMP) included in Technical Appendix E1. Further detailed review of this Plan will be undertaken during this phase of the Development when more detailed design information is available to provide a basis for assessment. This will include additional archaeological and ethnographic surveys, involving indigenous people.

14.8.2 Indigenous Archaeology

Barrow Island

Previous archaeological assessment on Barrow Island was undertaken by Quartermaine Consultants (1994; 1997). Further archaeological survey work was undertaken for this Draft EIS/ERMP (refer to Technical Appendix E1). Only two of the 13 registered indigenous sites on Barrow Island were identified as being close to any part of the Gorgon Development. Both were scatter sites: 887 (FS05) and 888 (FS06), and both were located in proximity to an earlier alignment of the reservoir carbon dioxide injection pipeline (CO_2 pipeline) and the proposed injection wells. With the revised location of the CO_2 pipeline and the proposed injection wells, there will be no risk of potentially impacting these sites.

Prior to construction, all proposed ground disturbance areas (including the seabed) will be surveyed for indigenous, historical and maritime cultural heritage evidence. Emphasis will be on areas of high site potential such as clay pans, shore lines, freshwater and drainage areas. Construction activities proximal to any identified cultural sites will be monitored as well as in areas of high potential. Construction, operation, and decommissioning activities will be managed in accordance with the final CHMP.

Although no known sites will be impacted, if new sites are discovered during construction which cannot be avoided by the Joint Venturers, suitable recording work will be undertaken and permits to disturb obtained.

Mainland

A survey for indigenous sites was undertaken for the earlier Apache Energy/Hadson pipeline projects. Six archaeological sites were identified in the general area of these pipelines, but none were disturbed during the construction of these facilities. As one option for the proposed domestic gas pipeline parallels these earlier pipelines, there remains some potential risk that one or more of these sites may be impacted (Figure 14-5). If this option is selected, and once the route is finalised, an archaeological survey of the proposed disturbance area will be undertaken. Any new sites identified will be avoided where practical. Where avoidance is not possible, the site will only be disturbed in accordance with clearance procedures specified in the Western Australian *Aboriginal Heritage Act 1972* and reflected in the CHMP. Similarly, the short section of near-shore and onshore optical fibre communication cable alignment will also be inspected for potential indigenous sites. However the disturbed (urban) nature of the Onslow area and the alignment of the cable within or along roadways will reduce the likelihood of potentially impacting archaeological sites.

Management strategies are included in Table 14-8 and will be detailed in the CHMP. The residual risk for indigenous heritage is low in the pre-construction and decommissioning stage through to high during the construction stage if appropriate survey, inspection, monitoring, recording and reporting measures are not fully undertaken. Additional archaeological and ethnographic surveys of the proposed Development area will be undertaken as part of the detailed design process. This will provide the opportunity for both surveys to be undertaken simultaneously and efficiently.

Figure 14-5:
Archaeological Sites along the Existing Apache Energy Export Pipeline Route

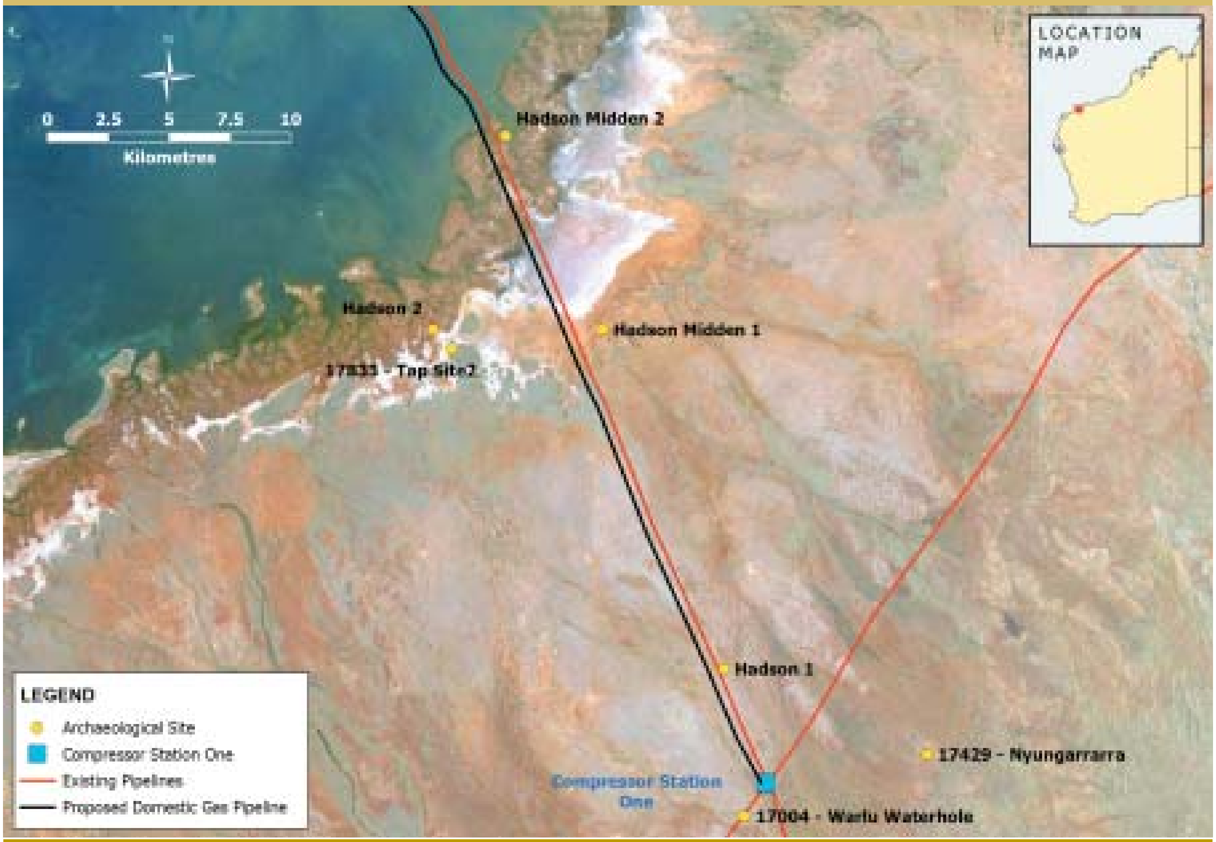


Table 14-8:
Key Benefits and Risks to Indigenous Anthropology and Archaeology

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Surface disturbing activities. **Pre-construction** Site selection and design. **Construction** Clearing, earthworks and drilling. **Operations** Vehicle movement. Maintenance earthworks. **Decommissioning** Dismantling/removal of facility and rehabilitation and associated activities.	Damage to anthropological or archaeological sites. Non-compliance with *Aboriginal Heritage Act 1972* requirements.	• Identify potential additional archaeological and ethnographic sites within the Development area by undertaking additional surveys in consultation with the relevant Indigenous communities. • Minimise amount of land disturbed for facilities. • Survey all proposed area of ground disturbance prior to construction. Emphasis will be on areas of higher sensitivity. • Monitor construction activities in areas of high potential for surface and sub-surface cultural material. • Manage construction, operation, and decommissioning activities in accordance with the final CHMP.	• No impact to indigenous heritage sites. • Where sites cannot be avoided, sites only disturbed in accordance with procedures specified in CHMP.	• Implement cultural heritage monitoring and reporting procedures in accordance with Development's EMS and CHMP (Chapter 16).	**Pre-construction** Likelihood – unlikely Consequence – minor Risk – low **Construction** Likelihood – occasional Consequence – serious Risk – high **Operations** Likelihood – seldom Consequence – minor Risk – medium **Decommissioning** Likelihood – unlikely Consequence – minor Risk – low

14.8.3 Historical and Maritime Heritage – Terrestrial

Barrow Island

If the alternative shore crossing at Flacourt Bay is selected, one known historical site (a glass artefact scatter) may be impacted by the proposed Development. There is the potential for additional sites to be identified, particularly in the coastal zone of Barrow Island which may include subsurface cultural material buried by cyclone and dune aggradation. A more detailed survey will be undertaken following finalisation of the footprint and well in advance of any surface disturbance or construction.

Proposed management strategies are identified in Table 14-9. The residual risk for terrestrial, historical and maritime heritage on Barrow Island varies from low during pre-construction, operations, and decommissioning to medium during construction.

Mainland

There is one known site that may be impacted by the Development (the remains of a reported shipwreck close to the Apache pipeline, located below the high water mark) and the potential exists for others to be present. Until the location for the domestic gas pipeline and the optical fibre communication cable are finalised, it is not possible to confirm the extent of impacts.

Proposed management strategies to reduce potential impacts and risks are listed in Table 14-9. The residual risk for terrestrial, historical and maritime heritage on the mainland is low to medium with the greatest risk occurring during construction.

14.8.4 Maritime Heritage – Subsea

No shipwreck sites have been identified or recorded in the immediate area of the proposed Gorgon Development. Review of underwater video surveillance, side-scan sonar and bathymetry surveys of the general pipeline routes, the pipeline shore approaches, Materials Offloading Facility (MOF) and LNG shipping channel and turning basin have not produced any evidence of maritime heritage sites. To further reduce the possibility of impacting a shipwreck or heritage site, detailed marine surveys will be reviewed by a marine heritage archaeologist/historian at the time the pipeline and optical fibre routes and disturbance areas are being finalised. Due to the flexible nature of pipelines and the optical fibre cable, it is likely that minor re-alignment can be made to avoid areas of known or suspected heritage value.

Management strategies are listed in Table 14-9. Without further detailed studies the residual risk for maritime heritage on the mainland is low to medium with the greatest risk occurring during construction.

14.8.5 Summary of Heritage Impacts and Management Response

Preliminary site survey work undertaken in the fields of indigenous archaeology and anthropology, historical and maritime heritage (terrestrial and underwater), has indicated that there are relatively few known sites on Barrow Island and the mainland that may be impacted by the proposed Development. Research and consultation does indicate that it is possible that other sites may exist. However until the Development footprint is finalised, it is not possible to evaluate the extent to which sites or cultural heritage areas may be impacted. It is proposed to undertake further investigations in consultation with relevant stakeholders prior to the completion of the current design phase to ensure any known or identified sites can be avoided or impacts minimised and managed.

The following management objectives and strategies have been identified for the proposed Development. These are outlined in the draft CHMP in Technical Appendix E1, and include:

- Consulting with indigenous communities to identify potential archaeological and ethnographic sites within/adjacent to the proposed Development during detailed design and well in advance of construction.
- Conducting detailed surveys (pedestrian transects and/or acoustic or video imaging) well in advance of construction to locate, record and avoid identified sites where possible; and where it is not possible:
  - make formal applications to disturb the site(s) to the appropriate authority
  - make test excavations if required
  - make detailed recording of site(s)
  - collect and store site information pursuant to legislation
- Engaging cultural heritage officer(s) to implement an appropriate cultural heritage induction for supervisors and workers involved with ground/seabed disturbance activities, identify, monitor and protect known sites during construction, and manage potential subsurface material identified during construction.

14.8.6 Summary of Risk

The consequences for cultural heritage are summarised in Table 14-8 and Table 14-9. Overall residual risk for cultural heritage will be low during pre-construction, medium during construction, low during operations, and low during decommissioning.

14.9 Landscape and Aesthetics

14.9.1 Overview

A visual assessment of the proposed Gorgon Development was undertaken to evaluate the degree to which its components (subsea wells, pipelines, gas processing facility and marine infrastructure) would change the ‘seen’ or visual amenity of the existing landscape. The evaluation commenced at a very broad scale to gain an understanding of the landscape setting and then focussed in greater detail on the position of the components and their relationship within their immediate setting. Through a qualitative and quantitative assessment, the values were then considered for the periods during and immediately after construction, and then operation. Overall, as expected, the visual impact is limited due to the lack of human receptors (almost exclusively the construction and operational workforce) on and around Barrow Island due to the remote location of the Development.

14.9.2 Visual Absorption Capability and Assessment of Visual Amenity

Visual absorption capability is a measure of the relative ability of a landscape character type to absorb visual change. A landscape with a high absorptive capability is able to absorb more visual change than one with a low capability. For example, an existing industrial site in an urban setting with large vessels, gantries, towers, roads and powerlines would have greater ability to absorb the visual impacts of a proposed new industrial plant than the placement of a similar facility on a rural or undeveloped agricultural area or Nature Reserve.

Table 14-9:
Key Benefits and Risks to Historical and Maritime Heritage – Terrestrial and Underwater

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Surface disturbing activities: **Pre-construction** Site selection and design. **Construction** Clearing, earthworks and drilling. **Operations** Vehicle movement. Maintenance earthworks. **Decommissioning** Dismantling/removal of facility and rehabilitation and associated activities.	Damage to historical sites. Non-compliance with *Maritime Archaeology Act 1973* and /or *Historic Shipwrecks Act 1976* requirements.	• Survey areas of proposed ground disturbance (including the seabed) for historical and maritime cultural heritage. • Minimise the amount of land disturbed for facilities. • Monitor construction activities in areas of higher sensitivity. • Manage construction, operations and decommissioning activities in accordance with the final CHMP.	• No impact to maritime heritage sites. • Where sites cannot be avoided, sites only disturbed in accordance with procedures specified in CHMP.	• Implement cultural heritage monitoring and reporting procedures in accordance with Development's EMS and CHMP (Chapter 16).	**Pre-construction** Likelihood – unlikely Consequence – minor Risk – low **Construction and commissioning** Likelihood – unlikely Consequence – serious Risk – medium **Operations** Likelihood – unlikely Consequence – minor Risk – low **Decommissioning** Likelihood – unlikely Consequence – minor Risk – low

Offshore

The subsea gathering system will be located approximately 200 km from the Australian mainland. Drilling of the wells will be a temporary activity, in line with much of the existing oil and gas development occurring offshore. Completion of the wells will be subsea and all infrastructure will be located on the sea floor. Because none of the wells, manifolds or pipelines will be seen, there will be no impact on the visual absorption capability of the offshore setting and the impact on visual amenity is considered nil.

Barrow Island

The visual absorption capability is influenced by terrain and landscape. On Barrow Island there are five landscape character units:

- West Coastal Complex
- East Coastal Complex
- Valley Slopes and Escarpments
- Limestone Ridges
- Creek or Seasonal Drainage Lines.

Within each of these units, change resulting from the proposed infrastructure can be accommodated to varying degrees without significantly altering the setting. The visual absorption capabilities of the identified Barrow Island landscape units are listed in Table 14-10.

Because Barrow Island has few trees, and is mostly low elevation scrub and *Triodia* species, the overall ability to absorb visual change is considered low. While Barrow Island has the status of a Class A Nature Reserve, it cannot be considered visually or naturally pristine. Existing man-made built elements exist within this environment due to the existing and historical oil extractive industry. Oil infrastructure, tanks, pipe and transmission lines are visually present within the proximity of the proposed development. Moreover, due to the lack of human receptors on remote Barrow Island, the potential to impact visual amenity is perceived as low to very low.

Mardie Station (Domestic Gas Pipeline)

With the exception of a block valve and some marker and cathodic protection posts, the domestic gas pipeline will be located underground, in close proximity to the existing buried Apache Energy export pipeline. Because the pipeline infrastructure will not be visible, regard will be given to the construction easement in particular, the clearance of vegetation and disturbance of the ground surface. Long-term visual effects will be negligible, as rehabilitation and construction management will be carried out in an effective manner. An access track, of similar scale to a farm track, will remain for access by four wheel drive vehicles during operation. Therefore visual absorption capability is not considered a limiting factor. Combined with this is a lack of human receptors within close proximity of the proposed pipeline (currently bisecting the middle of the 220 000 ha stock grazing station). Consequently the potential impact on visual amenity is considered as low to very low.

14.9.3 Visual Effect

The visual effect of the Development is the degree of contrast occurring between the proposed works and the existing visual setting.

Offshore

The offshore wells and infrastructure (all subsea) will not be visible from the ocean's surface or from land.

Table 14-10:
Visual Absorptive Capability of Landscape Units in the Proposed Barrow Island Development Area

Landscape Character Units	Visual Absorption Capability
West Coast Complex	Low
East Coast Complex	Moderate
Valley Slopes and Escarpments	Low to Moderate
Limestone Ridges	Low
Creek or Seasonal Drainage lines	Moderate

Barrow Island – Pipeline(s)

The degree of visual effect involved with the feed gas pipeline and CO_2 pipeline, will generally be associated with how the landscape absorbs an elevated linear form within a natural setting. This has the greatest visual impact when the pipeline corridor departs from an established road easement which also has linear components.

The pipeline corridor will not be obviously visible from anywhere except the road and the few vantage points along the alignment. This line will be most visible in the upland 'Limestone Ridges' landscape unit. Pipeline infrastructure may also be visible when vegetation is sparse in the shared road corridor, or when the pipeline route intersects with the road.

Consideration will be given to location, alignment and construction, in particular the vegetation clearing and grading the ground surface. Long-term visual effects will be negligible, as the pipelines will be located close to the ground surface and follow existing contours and grades. The visual effect will be consistent with the existing elevated oil flow lines that feed the terminal tanks at Town Point, Barrow Island. The feed gas pipeline will be slightly larger in diameter (900 mm) and sit 750 mm off the ground surface. Appropriate restoration will further reduce the visual effect.

Barrow Island – Gas Processing Facility

The gas processing facility will be a large industrial complex, with some similarities to the existing oil and gas development facilities both on Barrow Island and other adjacent islands (Varanus and Thevenard). The visual effect of the gas processing facility and temporary construction village will depend on the viewer's position on Barrow Island. The visual impact of the proposed gas processing facility will be moderate to substantial for views within 5 km of the central eastern section of Barrow Island. Within the 5 km viewing area the gas processing facility will be in stark contrast to the low vegetated nature of the landscape.

Although the Development area as a whole will be approximately 300 ha the gas processing facility is not constructed or viewed as a single mass, but as a mixture of steel structural elements of varying size, width and height.

In general it is planned that the Development be sited in a low-lying area to assist minimising visual impact within the surrounding landscape.

The port facilities will consist of a larger MOF approximately 1 km in length and a lighter structured offshore ship gas loading jetty of approximately 3 km in length. While these facilities will protrude for a substantial distance from the eastern coast, these forms will tend to blend into the seascape due to their low lying and light structured nature.

Appropriate measures will be taken to neutralise the colouring of these port facilities to blend with the seascape while night lighting will be minimal and will not have a high visual impact in this coastal area. The anticipated impacts from key viewing locations are summarised in Table 14-11.

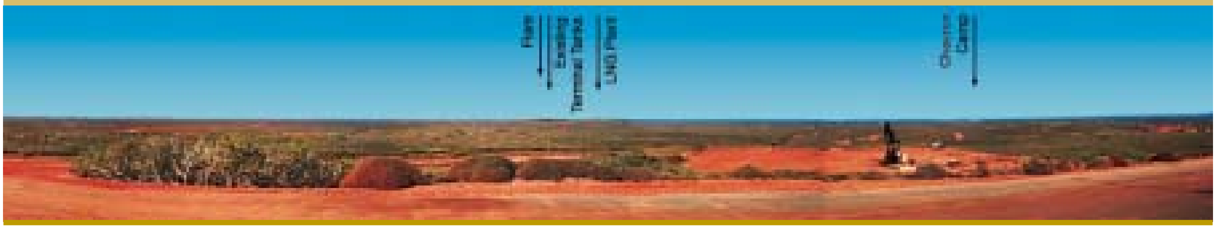
If the gas processing facility is viewed beyond the surrounding ridgeline, the visual effect will range from slight to negligible. This is due to the topography screening, the softening of distance, and the

Table 14-11:
Indicative Areas of Visual Impact

Viewing Location		Impact*
View 1	Chevron Camp	Moderate
View 2	Town Point	Substantial to Severe
View 3	Communication Tower	Negligible
View 4	Ocean View at 5 km	Moderate to Substantial
View 5	Road Junction, Old Airport	Substantial
View 6	Current Airport	Negligible to None
View 7	Ridgeline West of Terminal Tanks	Substantial

**Criteria definitions in Methodology Appendices A 1.5 in Technical Appendix: E2 Visual Assessment*

Plate 14-1:
Viewing Simulation of the 'Constructed' Gas Processing Facility from Communication Tower



integration of gas processing facility mass with the undulating terrain. Plate 14-1 shows a simulation of the constructed gas processing facility viewed from the communication tower site, the highest vantage point in the central uplands. This modelling exercise incorporates the true, scaled vessel and facility dimensions and design layout at the elevation planned for the gas processing facility.

Where the gas processing facility and construction village are visible within the drainage line flat or upon the nearby surrounding ridgeline (within the 5 km viewshed), the visual effect will be moderate to substantial as the structure contrasts with the immediate landscape (refer to Plate 14-2). This simulation does not include the MOF or LNG jetty which would also be moderate to substantial due to the contrast of these structures with the marine landscape.

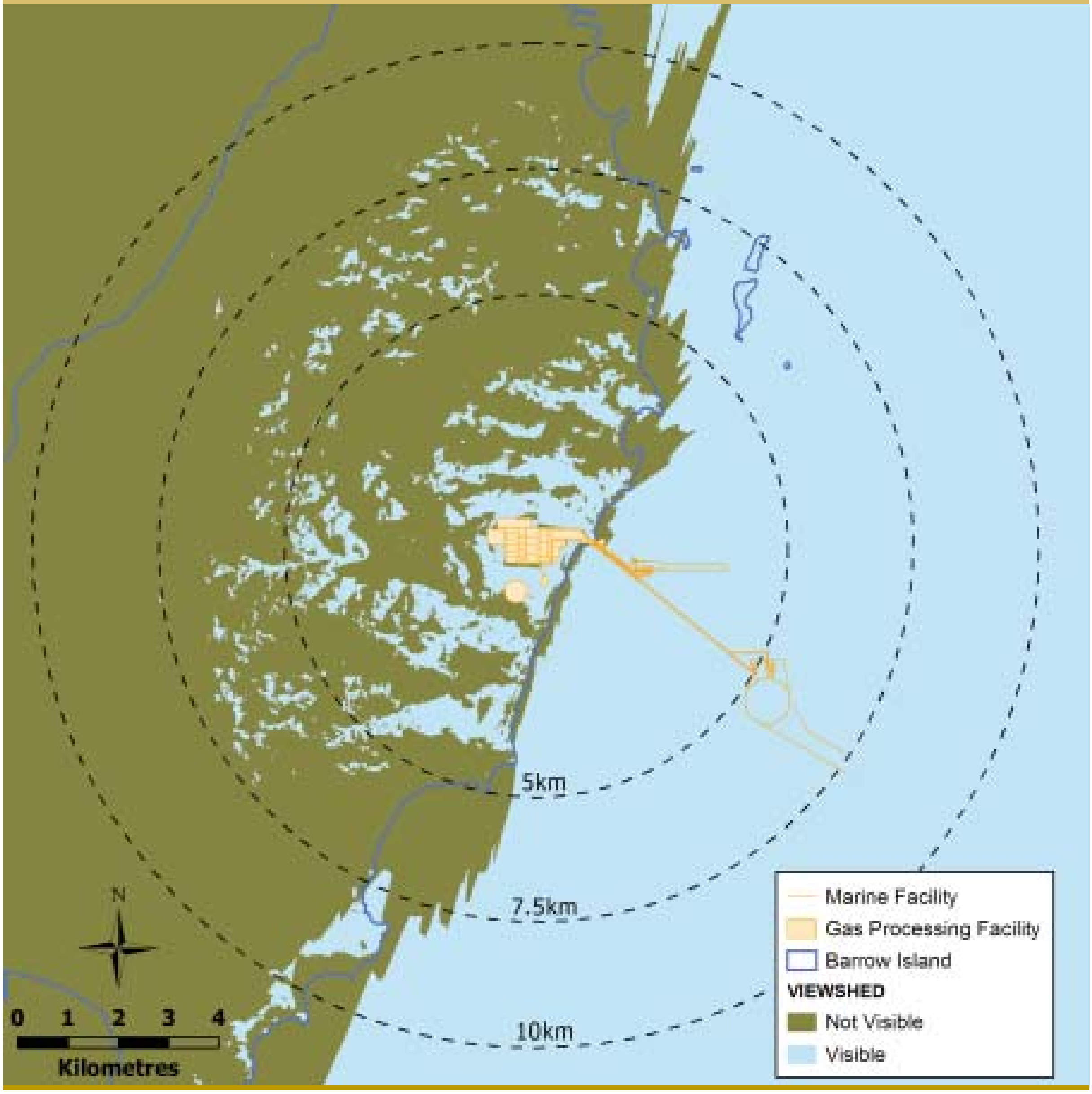
The viewshed analysis in Figure 14-6 shows the locations where the proposed gas processing facility will be visible. The flare height will be approximately 150 m tall. Its thin structure contrasts with the gas processing facility structure resulting in a much reduced visual impact. The concentric rings on the figure are to assist the reader in scaling distances.

The gas processing facility will be visible from within the central eastern area of Barrow Island and offshore while approaching the centre of Barrow Island from the east. Visibility of the facility from the central upland area of Barrow Island will be negligible with views mostly screened by the undulating topography and intervening ridgelines.

Given the arid conditions and the lack of substantial, high-growing indigenous vegetation on Barrow Island, there is limited ability to screen the gas processing facility with vegetation. Further, because Barrow Island is a Class A Nature Reserve, there is no scope to import different vegetation onto the island to use for screening. Consequently, the level of visual impact is not expected to change over time with vegetation growth.

Plate 14-2:
Viewing Simulation Looking North on Ridgeline from Camp (approximately 4 km from gas processing facility site)

Figure 14-6:
Visibility of the Gorgon Gas Processing Facility



Mardie Station (Domestic Gas Pipeline)

Once operational, the domestic gas pipeline will be located underground, but is likely to result in either the creation of a new easement or widening of the existing easement. The clearing required to create the easement and construct the pipeline will be evident during and after construction. The proposed alignment for the domestic gas pipeline does not cross any roads or highways but interconnects with the Dampier to Bunbury pipeline at compressor station 1. Consequently the potential visual receptors are very limited. Over time the visual effects of clearing and surface disturbance will blend in with the surrounding landscape. Marker posts and corrosion test leads (approximately 1.5 m in height) will provide identification of the pipeline location and are designed to keep both the pipeline and the public safe. A minor four wheel drive access track will remain.

14.9.4 Mitigation of Visual Impact

Barrow Island

Barrow Island is a Class A Nature Reserve and the entire ecosystem, including the landscape and visual amenity, is considered sensitive. The existing visual landscape has already been modified to a certain extent by the existing oil field development and operations on the island, including: large tanks for product storage; above-ground pipelines and power cables; roads; an airport; accommodation and office facilities; communication and power facilities; a barge landing and wharfage; plus a pipeline load-out facility and tanker mooring structures.

Given the relative scarcity of vegetation of any physical stature due to the environmental conditions, amelioration methods that rely on topographic shaping or the growth of vegetation to hide the presence of the gas processing facility will not be available and would be considered inappropriate for the size of the proposed Development. Therefore, where practicable during the detailed engineering and design phase, the Joint Venturers will aim to use existing infrastructure (roads) and the location of similar structures (the existing large tankage located immediately to the north of the gas processing facility) to minimise visual disturbance and optimise visual blending and screening.

In general it is planned to locate the Development in low-lying areas to minimise visual impact within the surrounding landscape.

The visual effect of the pipeline easement and benching works around the gas processing facility will depend upon the degree to which it is cleared and the contrast occurring between disturbed areas and the surrounding natural ground surface. This will result from observable differences in the colour of the backfilled material or a change in texture and size of the naturally occurring soil or rock on the ground.

The dominant colour of the weathered and oxidised surface rock is a light (sun bleached) cream to pink colour. However, when the rock is fractured or the surface disturbed the colours become deeper and the underlying rust red-ochre earth becomes dominant (refer to Plate 14-1). Therefore to reduce the visual impact, where practical, different soil profiles will be stored separately and replaced in the same location, while excavated rock of contrasting colour and texture will be covered or reburied where practicable. Storing surface soils separately and replacing them last will also assist in reducing the soil colour and texture contrasts. In addition, consideration will be given to the use of colours similar to the natural environment during detailed engineering and design. Efforts will also be made to reduce the visual impact of pipework clutter as part of the detailed engineering where practical.

In the harsh environment on Barrow Island, vegetation rehabilitation can be assisted by minimising the area of disturbance and by storing and stockpiling surface soils separately, and placing them over disturbed areas. To expedite reclamation success, revegetation will commence immediately following reinstatement, using direct topsoil placement that matches that of the particular location rather than the broader area wherever possible. Collecting organic matter and propagating plant material from the gas processing facility site prior to clearing and site-levelling work will allow stocks of appropriate revegetation species to be grown. Additional impact mitigation and rehabilitation methods are outlined in Technical Appendix E2.

Mardie Station (Domestic Gas Pipeline)

The landscape of Mardie Station has already been altered by stock grazing, fires, and construction of roads, fence-lines and pipelines. There is evidence of introduced vegetation requiring control efforts, particularly creosote bush (Mike Thomson, Mardie Station owner, pers. comm.). To reduce the visual impact of construction, the construction easement will be rehabilitated.

14.9.5 Summary of Risk

The potential visual amenity and aesthetic impacts of the Development and recommended management strategies are summarised in Table 14-12. The residual risks during construction are medium and during operation low. The medium risk is derived from the fact that landscape values will definitely be impacted by the proposed Development. Overall, however the number of receptors is very low and the impact is of low consequence. Following decommissioning the site at Barrow Island will be rehabilitated and some of the landscape values can be returned.

Table 14-12:
Key Risks to Visual Amenity and Aesthetics

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Installation of infrastructure.	Reduction in landscape and/or aesthetic values of Barrow Island and mainland (where domestic gas pipeline comes ashore).	• Evaluate environmental, engineering and economic potential to undertake directional drilling to minimise damage to the foreshore. • Undertake rehabilitation of works sites and access roads with vegetation rehabilitation, sand, soils and rock profile to match existing. • Carefully manage topsoil storage, handling and replacement at disturbed sites. • Align onshore feed gas pipeline easement to take advantage of topography with screening from vantage point views when climbing escarpment within the valleys. • Where possible, align onshore feed gas pipeline easement with roads and other existing industrial infrastructure. • Review colour schemes that will blend processing facility and other facilities into the surrounding landscape.	• Visual impacts associated with the Development are minimised.	• Photographic recording of construction and physical completion.	**Construction** Likelihood – frequent Consequence – incidental Risk – medium **Operation** Likelihood – occasional Consequence – incidental Risk – low

14.10 Workforce and Public Health and Safety

Protection of the workforce health and safety during both construction and operations is important to the Joint Venturers. Utilising expert personnel and the Chevron Operational Excellence Management System (OEMS), the potential health and safety hazards and risks to Development personnel will be identified and assessed, then the subject of substantial planning, organisation and procedural/facility development.

Hazard and Operability (HAZOP) studies will be conducted for Development components. Hazard and risk workshops will be held with a wide range of professionals in relation to the construction, commissioning and operation phases of the Development facilities to:

- identify all hazards and risks
- assess those hazards and risks identified
- develop controls to manage these hazards and risks.

14.10.1 Occupational Health – Gorgon Development Workforce

Occupational Health and Safety systems have been established by Chevron Australia and will address the relevant legislative requirements for health and safety. These systems will address Development contractors.

Key differences for the Gorgon Development compared to other, similar onshore projects in Western Australia will be: the quarantine restrictions that will apply to the workforce on Barrow Island and those working at the supply bases; and the reduction in access to surrounding areas because of Barrow Island's conservation classification. The construction workforce on Barrow Island will be restricted to particular areas including the camp facility and the job site. That is, they will not have unrestricted access to the island. While some restrictions are currently in place for the existing oil operations, a different set of conditions will need to be applied to the much larger workforce.

The remote location of the Development site and the restrictions on activity has the potential to reduce opportunities for recreation. These are proposed to be managed through a variety of programs and activities including health and safety planning, provision of recreation facilities within the construction village and managed access to areas outside of the village. The Joint Venturers intend to continue to sponsor programs (i.e. conservation) on Barrow Island that will allow the workforce some additional access to the area. Similar types of restrictions on access and activities are standard practice in National and Marine Park settings and Nature Reserves where significant flora and/or fauna are present.

14.10.2 Public Health and Safety

The location of the majority of the Development on Barrow Island minimises the potential for the workforce to interact with the public. With the distance and location separation between workers, the majority of the Gorgon Development and the general public, there will be very few public health and safety impacts.

Construction

One area where the Gorgon Development and the general public may be in close proximity is if a marine supply base were to be constructed in the Dampier/King Bay area. This is an industrial/commercial setting, and the Development will result in a relatively small increase in the onshore construction workforce. The presence of additional workers in a relatively small community may put temporary incremental pressure on the public health facilities and the social environment. This impact would be substantially greater if the Gorgon Development were located on the mainland and not on Barrow Island.

Due to the size of the proposed Development and the importance of the marine supply base as a staging area, there will be significant traffic movements (particularly heavy vehicles and their cargoes). This will range from 40 to 150 movements per day for a period of approximately 30–40 months. Construction materials will be imported through a combination of facilities at the Port of Dampier, local (i.e. aggregate), and road freight from Perth and surrounds. Additional traffic movements will increase the potential risk of traffic accidents. This traffic risk is not expected to be difficult to manage using proven journey management processes and road transport contractor selection. Consultation with the local police during the development of the journey management procedures and practices has proven effective in reducing potential traffic risks. In addition, a system of traffic controls will be developed that ensures that heavy vehicles are held at a central point. The holding point will allow the vehicles to be held at times of high local road use and appropriately spaced for travel into towns or residential areas. The recent North West Shelf Venture 'Train Four' project, for example, was of a similar size and traffic was managed very well utilising similar control measures as those planned for the Gorgon Development.

The Perth supply base will potentially be located within the existing Australian Marine Complex (AMC) area which is Australia's largest shipbuilding, marine engineering and fabrication centre that has been designed to manage public access and safety.

Onshore Domestic Gas Pipeline

The domestic gas pipeline is proposed to be located on a rural pastoral lease area. Potential risks to the public are minimal because public access to this area is restricted (grazing lease) and population density in this location is extremely low (< 1 km^2), with the nearest residence greater than 10 km from the pipeline. This will reduce the potential for any public health and safety impacts associated with an accident during construction or pipeline leak or explosion during operation.

The domestic gas pipeline will be constructed adjacent to two existing export gas pipelines operated by Apache Energy and will tie-in with the existing Dampier to Bunbury pipeline at Compressor Station 1. These pipelines are located within well defined pipeline easements and are identified by pipeline markers. The exact location of these facilities will be marked and all construction will be supervised, inspected, tested and protected in accordance with Australian pipeline standards and codes.

14.10.3 Summary of Risk

The consequences and management strategies for health and safety of the workforce and public on the Development are summarised in Table 14-13 and Table 14-14. The level of residual risk is medium overall.

Table 14-13:
Key Benefits and Risks to Workforce Health and Safety

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Plant or equipment failure. Cyclone or other natural disaster. Development standards not maintained. Ineffective contract management.	Major on-site emergency. Pressure on emergency and medical facilities on Barrow Island and in Karratha. Personnel injury or fatality (see Section 14.11).	• Prepare an Emergency Management Plan that includes an integrated safety and emergency response system. The plan will reference assistance requirements and procedures from FESA and other authorities. • Train emergency response crews. • Locate senior medical personnel on Barrow Island throughout construction phase. • Conduct regular (weekly) formal inspections of the Development site by company safety professionals. • Implement emergency evacuation procedures for injured personnel off Barrow Island to suitable medical facility. • Include health and safety obligations and provisions in contracts. • Review preparedness of medical and rescue services in Karratha and supplementing of existing facilities, if required.	• No fatalities. • No lost-time injuries.	• Audits of HES management systems (procedures, equipment and resources).	**Construction** Likelihood – seldom Consequence – serious Risk – medium **Operation** Likelihood – seldom Consequence – serious Risk – medium
Security breach on site or at supply bases.	Development delays, loss of property or personnel injury.	• Apply appropriate security measures to ensure that personnel are properly screened prior to employment and access to facilities is well managed.	• No security breaches.	• Security audits.	Likelihood – seldom Consequence – serious Risk – medium

Table 14-13: (continued)
Key Benefits and Risks to Workforce Health and Safety

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Construction workforce restricted to construction site and village areas.	Worker stress. Reduced standards of health.	• Provide appropriate recreational opportunities within the village. • Provide facilities for physical exercise. • Develop programs and activities to improve health. • Manage access to areas outside of the village where potential environmental impacts can be avoided, minimised or managed. • Provide access to counselling (on and off Barrow Island) if required.	• No incidents related to workforce stress resulting from isolation.	• Workforce surveys. • Health monitoring programs.	Likelihood – seldom Consequence – minor Risk – medium

Table 14-14:
Key Benefits and Risks to Public Health and Safety

Activities/ Causes	Potential Socio-Economic Impact/Consequences	Management Measures	Outcome/Target	Measurement Strategies	Residual Benefit/Risk
Anti-social behaviour of mainland workforce associated with alcohol/drug consumption and abuse. Fights, gambling and prostitution.	Reduced social standards. Reduced public safety. Tainted company reputation.	• Adopt appropriate security screening of personnel prior to employment. • Establish protocols and guidelines for acceptable behaviour of workforce. • Apply strict Fitness for Work policies and procedures. • Provide access to counselling. • Provide recreational facilities.	• No anti-social behaviour reported as being associated with Development personnel.	• Liaise with local authorities to obtain feedback regarding any issues. • Monitor personnel behaviour and report via the SIMP process.	**Operation** Likelihood – seldom Consequence – incidental Risk – low
Transport of materials, goods and personnel on local roads. Use of heavy vehicles.	Traffic accidents, injury to public, damage to public and private property.	• Evaluate traffic flow and volume patterns, assessment of capacity of existing roads. • Implement journey management for all delivery trucks developed in consultation with local authorities. • Monitor oversized loads. • Provide public safety, awareness and signage during construction.	• No fatalities or significant interruptions associated with project-related traffic.	• Audit journey management procedures. • Encourage local police to participate in the audits and suggest improvements. • Encourage local police to make attend mainland facilities and make speed and vehicle checks.	**Construction** Likelihood – occasional Consequence – incidental Risk – low
Conflict between Development and public/commercial marine activities.	Accidents involving private and/or commercial fishing and boating vessels.	• Adopt exclusion areas for high traffic zones and provision of Development security personnel in marine areas. • Provide appropriate information to commercial fishing operators and the public regarding exclusion zones and Development activities.	• No conflict incidents resulting in accidents or loss of income.	• Review accidents and incidents in Development marine area. • Liaise with relevant authorities regarding marine activities.	**Operation** Likelihood – unlikely Consequence – serious Risk – medium

14.11 Public Risk Assessment

This section is a review of the level of offsite risk to human life that could result from the Gorgon Development. It is recognised that the assessment is undertaken at an early stage of Development design; therefore a conservative approach has been adopted. The assessment focused on the primary risk of failure/release frequencies associated with a major plant and associated equipment. All onshore plant failure-case frequencies were multiplied by a factor of five (5) to address the contribution of minor plant and equipment to the failure frequencies, and to ensure that a conservative representation of the level of offsite risk was determined.

The current phase of design will further identify and refine potential risks and threats, such as the security of the Development from natural (e.g. cyclone, lightning) and anthropomorphic threats (e.g. terrorism). This work will focus on and specify appropriate plant, equipment, procedures and controls that will be necessary to reduce the risks to the public and the workforce to as low as reasonably practical.

The methodology used in this assessment is outlined in Technical Appendix E3 and follows an approach consistent with the NSW Department of Planning's Hazardous Industry Planning Advisory Paper No.6 (1997) and in Standards Australia (AS/NZS4360-1999). The level of risk to the public is compared to criteria provided by Standards Australia (AS2885.1, 1997) and the Western Australian Environmental Protection Authority's Public Risk Criteria (EPA 2000).

A Quantitative Risk Assessment (QRA) was also undertaken for all major pipelines associated with the Development. The modelling tools used in the QRA ('TNO Effects 4' and 'Riskcurves') are internationally recognised by industry and government authorities, including Western Australia's Department of Industry and Resources. Results showing individual risk contours are compared to the EPA's Public Risk Criteria.

The applicable individual risk criterion, one in a million per year (1×10^{-6}/y), is not exceeded by any of the pipeline routes. The residential areas on Barrow Island are deemed to be the proposed construction village (due to personnel potentially being housed in this village during commissioning and facility start-up) and the existing Chevron camp. Neither of these facilities will be affected by individual risk levels greater than one in a million per year due to the pipelines or the gas processing facility (storage vessels).

Physical and procedural controls incorporated into pipeline design, construction and operation will comply or exceed the controls criteria provided by AS 2885.1 (1997). Therefore, further analysis as per AS2885.1 is not warranted.

14.11.1 Pipelines

Two methodologies were used in undertaking the pipelines risk assessment: AS2885.1 and QRA.
The AS2885.1 risk assessment was undertaken for:

- feed gas pipeline – both Flacourt Bay and North White's Beach route options
- LNG export pipeline for both the jetty and cryogenic options
- condensate export pipeline
- domestic gas pipeline.

The level of risk to the public for the all of the Gorgon Development facilities was determined to be acceptable given the surrounding land use and the number of physical and procedural controls incorporated into the pipeline's design, construction and operation complying or exceeding the controls criteria as provided by AS2885.1.

Compliance with this Australian Standard requires that risk from each identified threat be as low as reasonably practicable through all stages of design, construction, operation and decommissioning.

The QRA methodology was applied to all hydrocarbon pipelines with individual risk transects for each pipeline provided in Figure 14-7 to Figure 14-11.

Figure 14-7:
Feed Gas Pipeline – Risk Transect

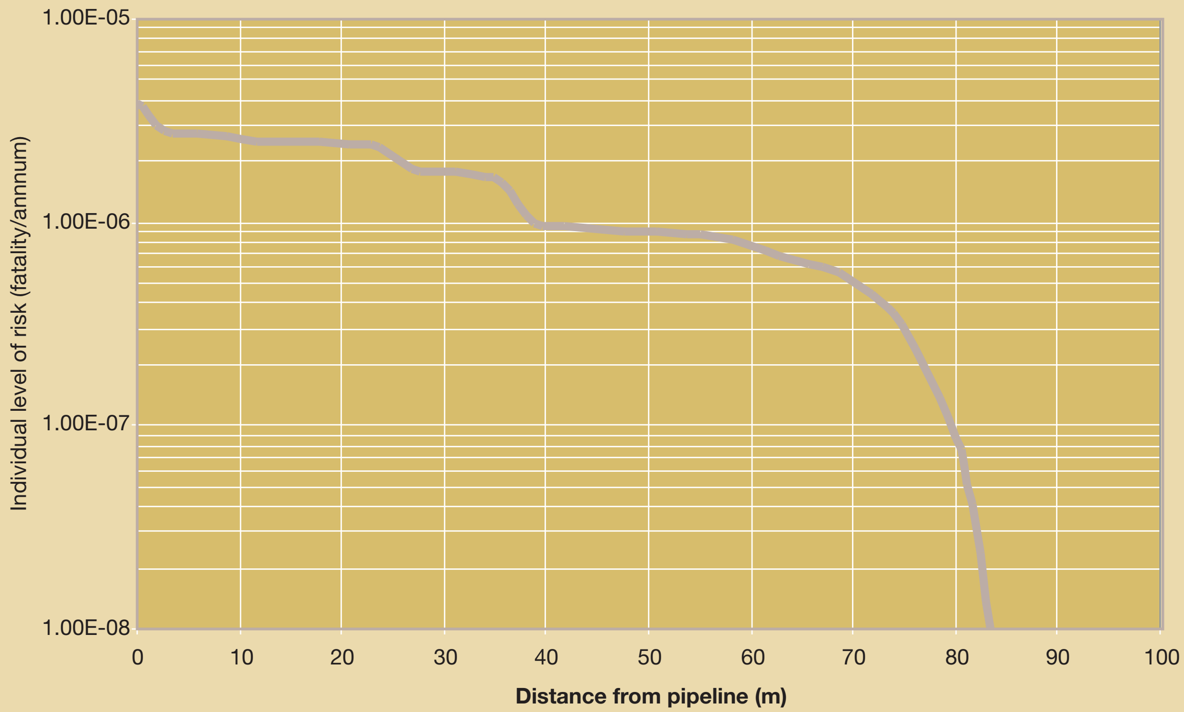


Figure 14-8:
LNG Export Pipeline – Risk Transect

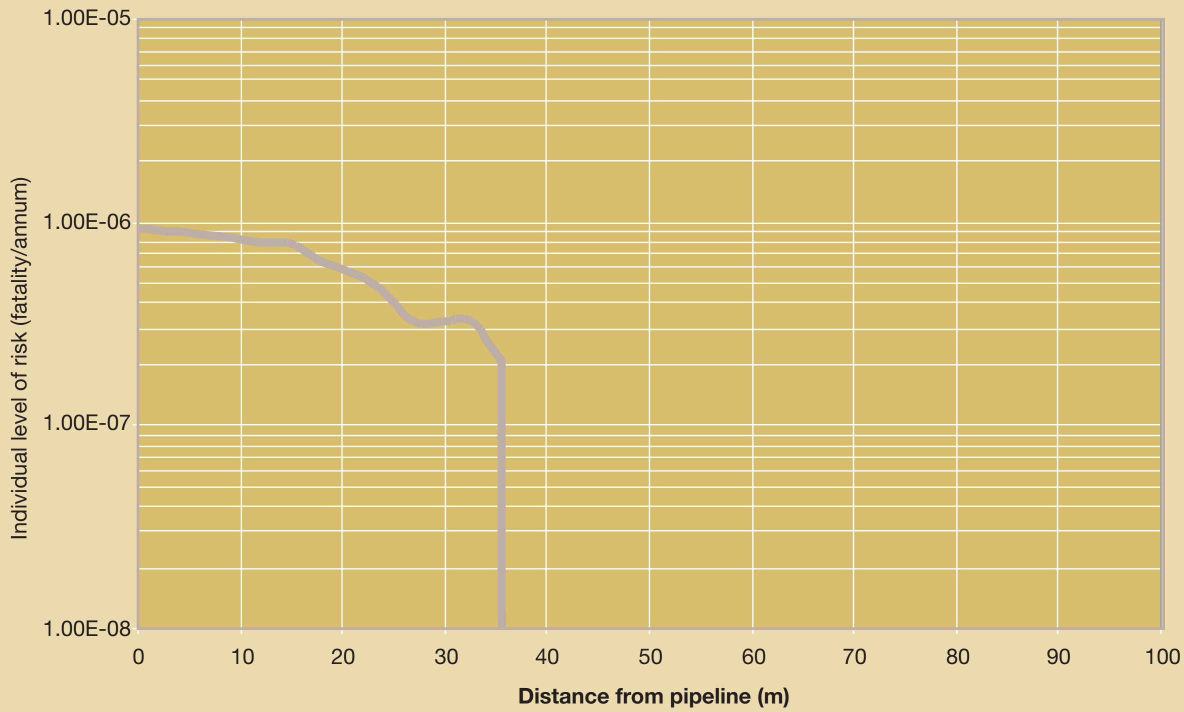


Figure 14-9:
Condensate Pipeline – Risk Transect

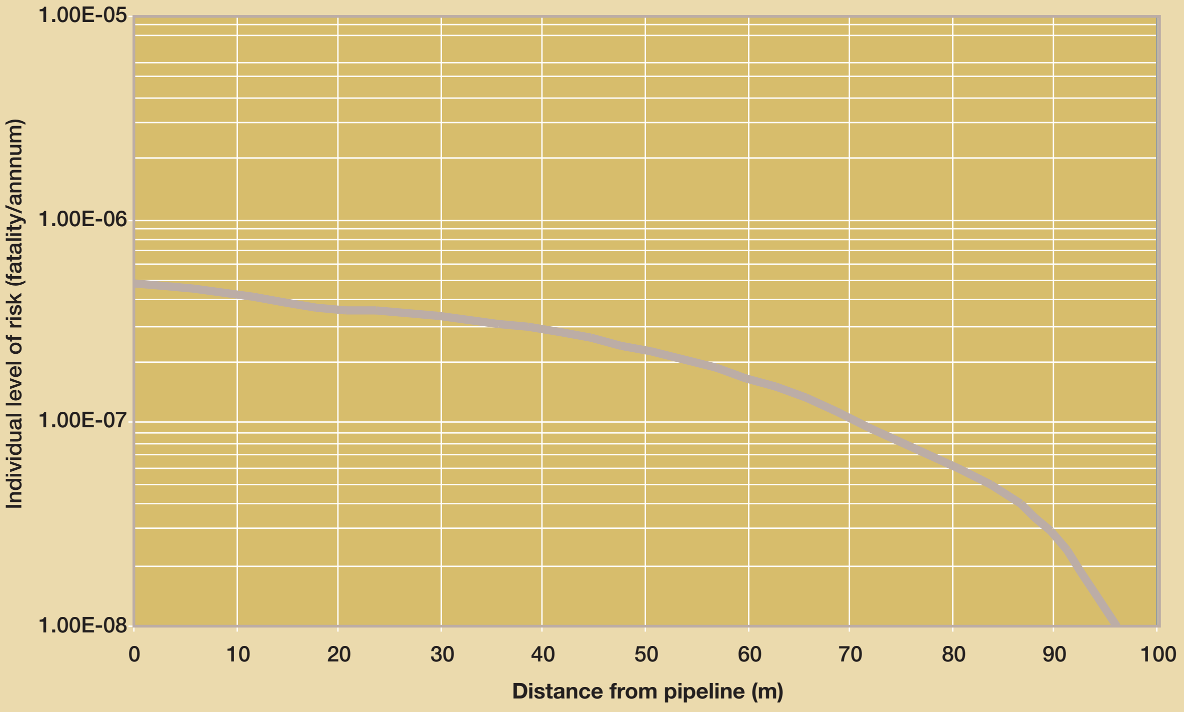
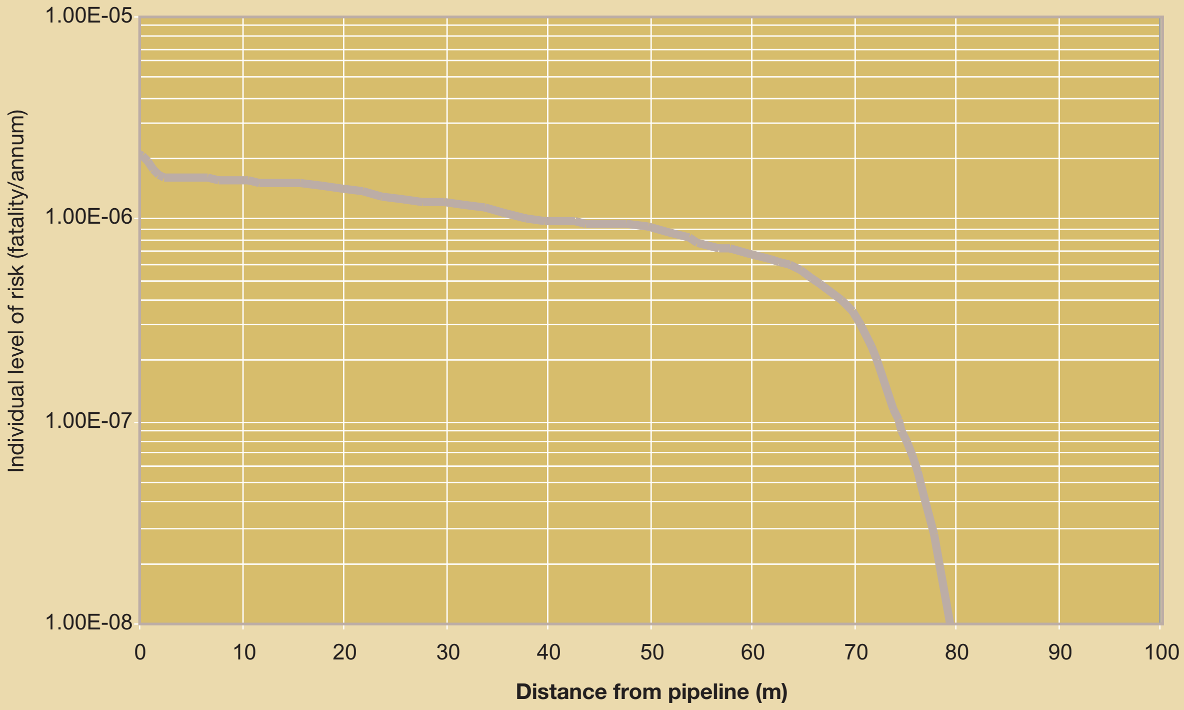


Figure 14-10:
Domestic Gas Pipeline – Risk Transect



The level of individual risk (fatality) is approximately 4 x 10^{-6}/y (per annum) at the centreline for the feed gas pipeline and decreases to 1 x 10^{-6}/y (per annum) over a distance of 40 m either side of the feed gas pipeline route (Figure 14-7). The EPA's individual fatality risk criterion for residential areas is 1 x 10^{-6}/y (per annum). As neither of the feed gas pipeline route options (Flacourt Bay or North White's Beach) pass within 40 m of a residential area (i.e. the construction village or existing Chevron camp), compliance is achieved. These results are indicative for additional feed gas pipelines and both route options (Flacourt Bay and North White's Beach) given that the pipeline's primary content, methane, is modelled as a potential jet fire.

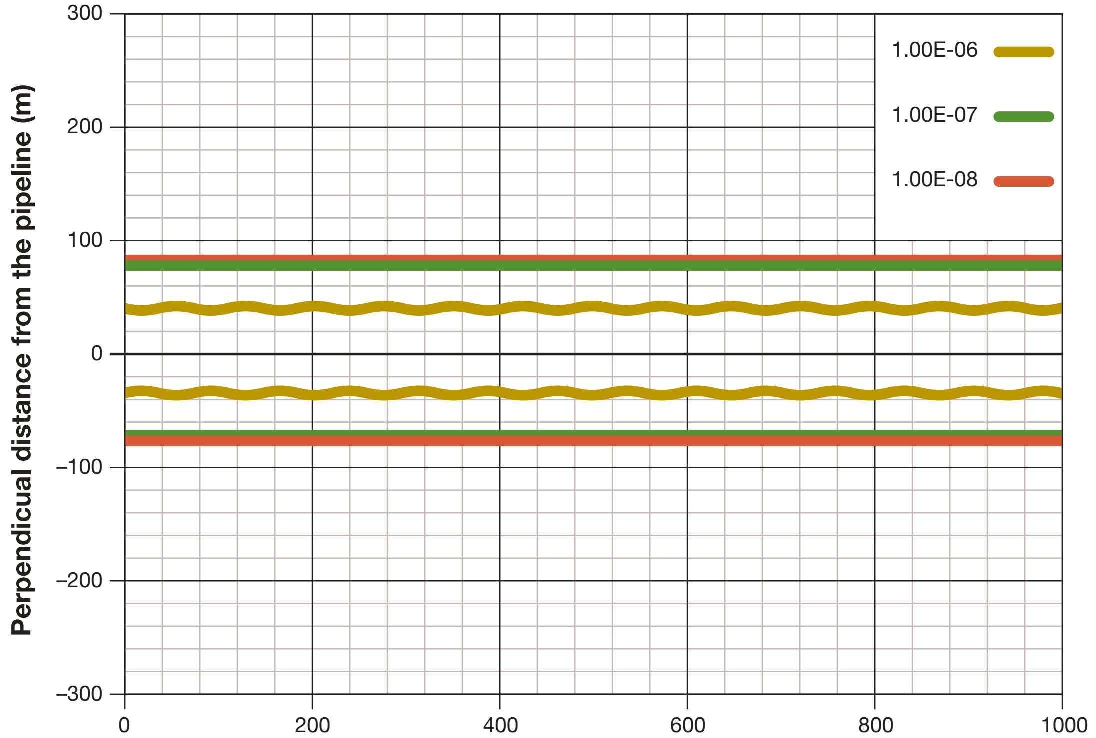
The level of individual risk is approximately 1 x 10^{-6}/y (per annum) at the centreline for the LNG Export route and decreases to 2 x 10^{-7}/y (per annum) over a distance of approximately 40 m either side of the pipeline (Figure 14-8). This level of risk is less than the EPA individual fatality risk criteria and therefore compliance is achieved. These results reflect modelling as methane for jet fires for the jetty option.

The level of individual risk is approximately 4 x 10^{-7}/y (per annum) at the centreline for the Condensate Export Pipeline and decreases to 1 x 10^{-8}/y (per annum) over a distance of approximately 100 m either side of the pipeline (Figure 14-9). This level of risk is less than the EPA individual fatality risk criteria and therefore compliance is achieved. These results are indicative that the material modelled is condensate as pool fires.

The level of individual risk is approximately 2 x 10^{-6}/y (per annum) at the centreline for the domestic gas pipeline and decreases to 1 x 10^{-6}/y (per annum) over a distance of approximately 40 m either side of the pipeline (Figure 14-10). The EPA's individual fatality risk criterion for residential areas is 1 x 10^{-6}/y (per annum). As both route options for the domestic gas pipeline (dedicated line to the mainland and to tie-in to Apache Energy system) do not pass within 40 m of a residential area (i.e. the construction village, the existing Chevron camp or any residential structure on the mainland), compliance is achieved. These results are indicative given that the material modelled is methane as jet fires.

Figure 14-11 is an illustration of the iso-risk contours for a typical 1 km section of the domestic gas pipeline. The black line in the centre of the graph represents the centreline of the pipeline. The yellow line represents the EPA individual fatality risk criteria of 1 x 10^{-6}/y (per annum) and is attained at a distance of

Figure 14-11:
Domestic Gas Pipeline – Iso-Risk Contours



approximately 40 m either side of the pipeline. The orange line, at a distance of approximately 80 m either side of the pipeline is at the iso-risk level of x 10^{-8}/y (per annum) and has been included to provide the reader with an understanding how quickly the risk is reduced with increased distance from the pipeline.

The applicable risk criteria, 1 x 10^{-6}/y (per annum) as published by the EPA (1994), is the level of individual risk for a residential area. This risk level is not exceeded by any of the pipeline routes. The applicable residential areas on Barrow Island are deemed to be the Gorgon Development construction village (due to personnel being housed in this camp during commissioning and plant start-up) and the existing Chevron camp. Both of these ‘residential’ areas are well outside of the 1 x 10^{-6}/y (per annum) individual risk contours for all of the pipelines.

14.11.2 Gas Processing Facility

The results of the risk assessment for the gas processing facility are provided in Addendum E of Technical Appendix E3. The fatality risk contour of 1 x 10^{-6}/y (per annum) extends approximately 150 m outside the gas processing facility’s southern boundary (or approximately 400 m from the centre of the propane storage vessel) (Figure 14-12). This iso-contour does not encroach on any residential area, including the area proposed for the construction village (the contour being approximately 250 m from the construction village boundary, or about 750 m from the propane storage vessel). The major risk contributors were identified as propane and ethane storage vessels (BLEVEs) and jet fires from process equipment. Therefore, compliance with the EPA Criteria for residential areas will be achieved.

Figure 14-12:
Iso-Risk Contour Map – Gorgon Gas Processing Facility

14.12 Conclusions

Both positive benefits and negative social risks will be created by the Gorgon Development. The Development will generally benefit the livelihoods and lifestyles for the Pilbara community in terms of employment and local business opportunities. The level of benefits will be more clearly defined and quantified during later Development phases. At the current level of planning, the positive consequences will be enhanced through appropriate management measures, including the Joint Venturers':

- commitment to provide full, fair and reasonable opportunity for Australian industry to supply goods and services to the Development through the Australian Industry Participation Policy
- initiatives for local procurement/content, employment and training which will be outlined in the SIMP in consultation with major construction contractors and stakeholder groups
- continued consultation/liaison with local government and others through community groups in the region.

There is a strong linkage between the social and economic benefits of the proposed Development. It has been identified that the most significant benefits will be economic with the details addressed in Chapter 15. In particular, the substantial input into the Australian economy through increased taxation revenues, direct spending, opportunity for local government rating, increased security of supply and availability of natural gas, employment and training initiatives, incremental improvement in the capacity of the economy and the labour force to absorb major oil and gas projects and opportunities for increased participation by indigenous people will be the major Development benefits.

The major adverse social risks identified for the Development may apply to:

- cultural heritage (low to potentially high risk depending on the Development phase)
- Native Title (high – but only for the domestic pipeline option to the mainland and a segment of optical fibre communication cable)
- workforce and family through implementation of FIFO regime (high).

Medium social risks apply to:

- visual amenity
- general health and safety of the workforce on Barrow Island.

Low social risks are associated with:

- population change and the demand for social infrastructure
- changes to land tenure
- changes to sea use
- transportation associated with the location of a potential supply base in the Dampier/King Bay area
- public risk.

The result of the pipeline and gas processing facility risk modelling predicts that the level of individual risk to public health in areas potentially classified as residential (construction village) will be below the one in a million per year (1 x 10^{-6}/y) EPA risk criteria. As this construction village may be used in the future to house personnel working on facility additions or maintenance, it is deemed to be a residential area for planning purposes. For pipelines, residential development would need to be within 40 m of the operating pipeline to be at risk. Planned alignment of all pipelines is well outside of the 40 m zone. For the gas processing facility, the residential development would need to be within 400 m of the major refrigerant storage vessels (propane and ethane storage). Currently the nearest residential area, the construction village, is located approximately 750 m from these vessels.

15: Economic Environment – Effects and Benefits

The economic benefits resulting from the Gorgon Development will have national, state and regional dimensions. The Gorgon Development will contribute substantial, positive economic benefits to Australia and Western Australia, derived from the combination of: export income the Development produces; tax and royalty revenue paid by the Joint Venturers; increased supply and competition in the domestic gas market; businesses and individuals employed; and the amount of money spent in the local economy.

Using two independent economic models, AE-MACRO and MMRF-GREEN, a number of major benefits to Australia and Western Australia's economies were identified. At the national level, some of the key benefits will include: some $17 billion in revenue from company tax and Petroleum Resources Rent Tax (PRRT); an increase in Gross Domestic Product (GDP) of approximately $3.6 billion by 2030 (depending on model and scenario used); and an increase of exports in excess of $2 billion per year (at today's prices) during operation. At the state level, Western Australia's economic welfare is expected to improve by approximately $4 billion, which is one-sixth of the total Australian economic welfare. Western Australia will also benefit from significant improvements to business investment and Gross State Product (GSP).

In response to increased revenues and economic growth, governments may increase expenditures, and reduce the average personal income tax rate to keep the ratio of public debt to GDP from falling. In turn, such income tax reductions would stimulate further economic growth. This general growth will provide flow-on benefits for business, employment and government revenues. Western Australia and the Pilbara region will benefit from increased demand for goods and services that will further stimulate business development and employment opportunities. The Gorgon Development is predicted to generate and sustain over 6000 jobs on average through the decades of operation, with 1700 generated in Western Australia.

Currently the regional economy of the Pilbara is not large enough to provide all of the labour, goods and services that will be required by the proposed Development. With increased labour and service demand, there is a risk that regional prices for goods and services will increase. This impact may be compounded by the influence of other large resource project activity scheduled for the area. Both economic models examined the potential for crowding-out investment opportunity and predicted that the Gorgon Development will have limited impact on this opportunity.


15.1 Introduction

This chapter is a description of the potential economic impacts of the Gorgon Development at national, state and regional levels.

The economic impact of the Gorgon Development was assessed using macro-economic modelling by Chevron Australia in 2003 in the Environmental, Social and Economic (ESE) Review (ChevronTexaco Australia 2003) and by modelling undertaken on behalf of the Government of Western Australia (The Allen Consulting Group 2003). These earlier economic modelling studies have been reviewed and assessed by an independent consultant. The model assumptions and results are summarised in this chapter of the Draft EIS/ERMP. Details of the modelling studies are in Technical Appendix F1. For a description of the existing regional, state, and economic setting for the Development refer to Chapter 8.

A number of other economic impacts were identified, on a qualitative basis, during these assessments and are also outlined in this chapter.

15.2 Economic Analysis

15.2.1 Assumptions

The national and state economic impacts of the Gorgon Development have been assessed using two independent macro-economic models of the Australian economy: AE-MACRO and MMRF-GREEN.

AE-MACRO is a dynamic model developed in 1992 by Access Economics (Access Economics 2002). Results from the AE-MACRO modelling studies have been published previously in Chapter 11 and Appendix K of the ESE Review (ChevronTexaco Australia 2003).

MMRF-GREEN is operated by the Centre of Policy Studies at Monash University, and is based on the same economic principles as AE-MACRO (Allen Consulting Group 2003).

In addition to running different Development scenarios, the economic models were based on the following important assumptions:

- tax revenues from the Development are used to reduce overall income taxes to maintain the budget balance
- there is no assistance or tax concessions by federal, state, or local governments
- Australian and international economies develop along steady, long-term economic paths
- the Gorgon Development is wholly foreign-owned, and entirely financed by equity. All cash surpluses are distributed as dividends
- the export price of the hypothetical gas-based resource Development grows by 2% annually in US Dollar terms. Prices of condensate are constant in inflation-adjusted terms, while the price of LNG experiences real price declines.

The results from the AE-MACRO work undertaken for the ESE Review by Chevron Australia most closely reflect the development scenario that forms the basis of this Draft EIS/ERMP: two trains of LNG and 300 TJ/day of domestic gas production. Therefore, the AE-MACRO model is generally referred to in this chapter. The MMRF-GREEN outcomes are discussed in detail in Technical Appendix F1 and the Allen Consulting Group Report (2003). Differences between the development scenario used for the modelling and the current concept include a later start-up date for the proposed Development and a higher estimate for direct employment. These will have the effect of shifting the impacts in time and increasing the benefits derived from direct employment, respectively.

15.2.2 National and State Economic Growth

It is estimated that the Gorgon Development will make a major contribution to Australian and Western Australian economic growth by:

- contributing some $11 billion of investment expenditure (at current prices) between now and the mid-2020s (note: approximately $6 billion will be spent in the initial construction phase of the Development with the rest being additional capital to fully utlilise the Gorgon gas field, for example drilling and future compression facilities) (refer to Figure 15-1)
- generating net exports averaging in excess of $2 billion annually (at current prices) over the period from 2012 to 2030
- permanently adding around 6000 direct and indirect jobs to national employment, 1700 of which will be in Western Australia (refer to Figure 15-2)
- contributing company tax and PRRT payments totalling $17 billion (at today's prices) over the life of the Development. In net present value terms, this amounts to $7 billion at a 5% real discount rate.

The best measures of the overall impact of the Development on economic welfare as predicted by the modelling are the increases in:

- annual flows of private consumption and public sector final expenditures that it allows
- public and private sector wealth at the end of the simulation period.

As modelled, in net present value terms, the benefit is mainly to the private sector. At a real discount rate of 5%, the Development will improve Australian economic welfare by an estimated $24 billion (net present value in 2002).

Figure 15-1:
Gorgon Development – Contribution to National GDP and Western Australian GSP (Net Present Value in 2002)

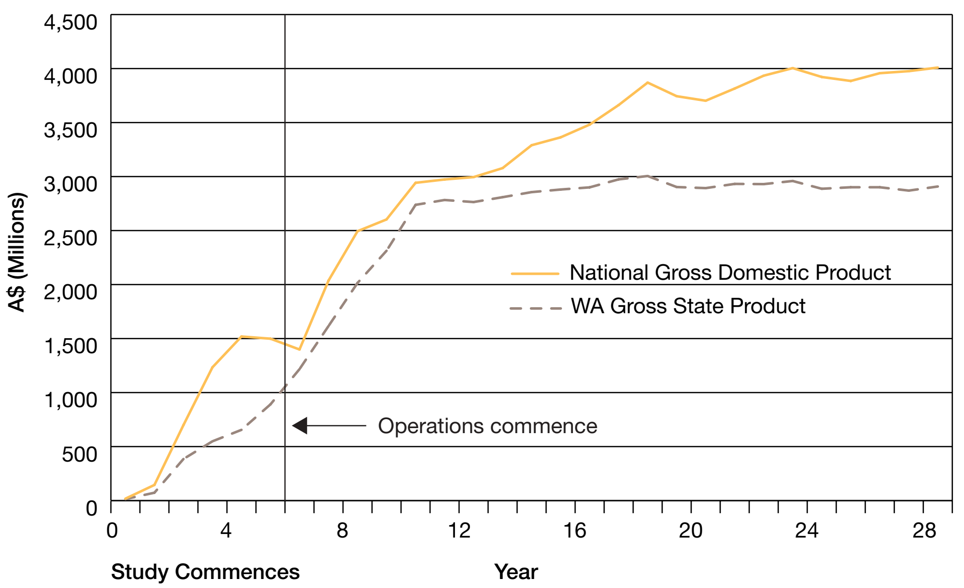
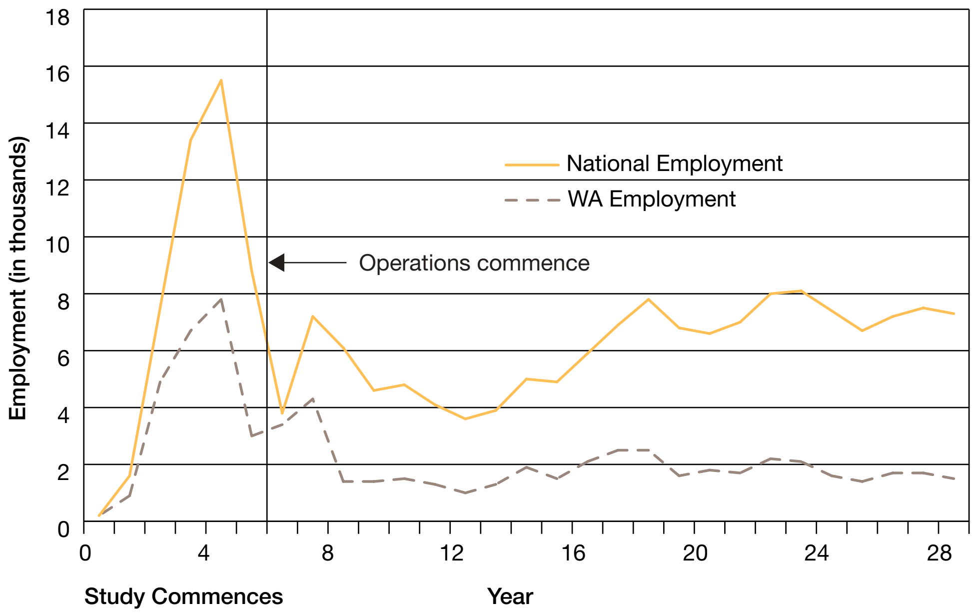


Figure 15-2:
Gorgon Development – Contribution to National and Western Australian Employment



15.2.3 Regional Development

The Pilbara region will benefit significantly from this Development. The extent of those benefits will be a function of:

- goods and services required for the construction and maintenance of the Development that is sourced from the region
- the workforce sourced from the region
- the workforce sourced from outside of the region, but who may choose to relocate to the region.

It is estimated that approximately 10% of the construction and operational workforce could be sourced from the Pilbara region. This workforce will create flow-on economic benefits through spending in the region.

The biggest economic impact will come from the goods and services required for the Development that are purchased in the region. At present, the Pilbara region has insufficient capacity to manufacture suitable plant and equipment and to supply major construction services to support the Gorgon Development. It is expected that most of these requirements will be met by companies located outside the region. In the first instance, supplies will be sourced from Perth. Failing that, then from other parts of Australia, or if needed, from international suppliers. However, there are potential opportunities for Pilbara-based companies to supply a share of these goods and services. These could include general logistics provision, site development, provision of elements of ship-berthing facilities, project buildings, construction materials and services, aggregate and pre-cast concrete, erection and maintenance of the construction village, and supply of general services.

During the operation phase of the Development, supply base and general logistical activities will add to the economic and social welfare of the Pilbara region. These activities will add to the general level of activity in the region and allow further capacity building in local businesses.

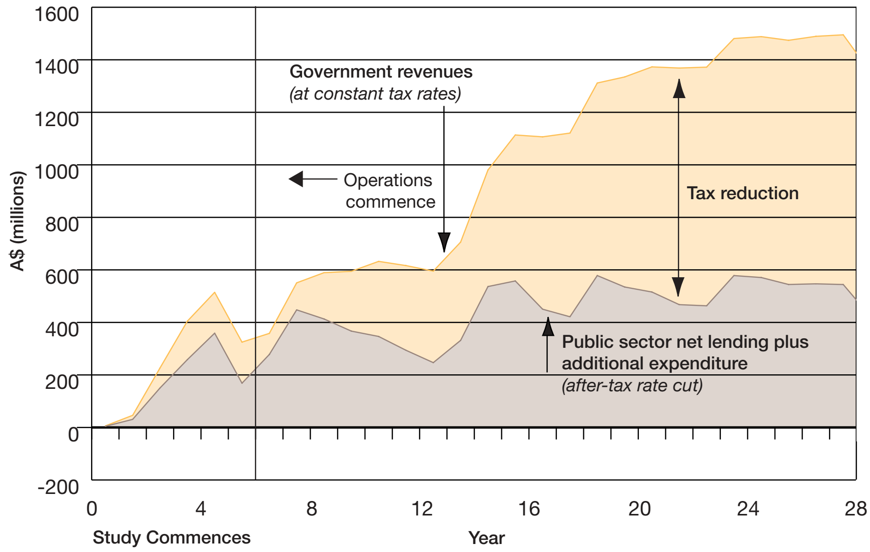
15.2.4 Government Revenue

Specialist studies conducted by Access Economics for the ESE Review (Access Economics 2002) indicate that the Gorgon Development will add substantial revenue to public sector finances, particularly at the Commonwealth level.

In response to these increased revenues and economic growth, governments may increase expenditures, and reduce the average personal income tax rate to keep the ratio of public debt to GDP from falling too rapidly. These income tax reductions, in turn, will stimulate further growth.

The impact on government revenues, with and without the income tax reduction is illustrated in Figure 15-3. The shaded portion of the chart shows the dollar value of the income tax reduction that the public sector is able to provide (rather than accumulating higher budget surpluses).

Figure 15-3:
Government Revenue Associated with the Gorgon Development



The Commonwealth will receive company tax and PRRT payments from the Development's investors. Commonwealth tax receipts will also benefit from the overall increase in economic activity. Expenditures will also rise in an expanding economy. The predicted total of PRRT and company tax payments from the Joint Venturers to the Commonwealth is $17 billion in nominal terms ($7 billion expressed as a net present value at a 5% real discount rate).

This additional economic activity will generate a further $2 billion (net present value at 5% discount rate) in revenue for the Commonwealth. The net present value of the overall Commonwealth budget gain is estimated at over $9 billion.

The Gorgon Development will have modest direct impacts on Western Australian public sector finances. The main impact on revenue will be the additional payroll tax generated from employment associated with the Development. On the expenditure side, it is assumed that there will be no Western Australian Government subsidies. There is also no requirement for Development-specific investment in infrastructure by state authorities.

Indirect effects may be more substantial. The AE-MACRO modelling predicts that the Development will increase both revenues and expenditures. As production rates stabilise, the Development's national economic impacts will flow through in the form of higher consumption expenditure and Goods and Services Tax (GST) revenues.

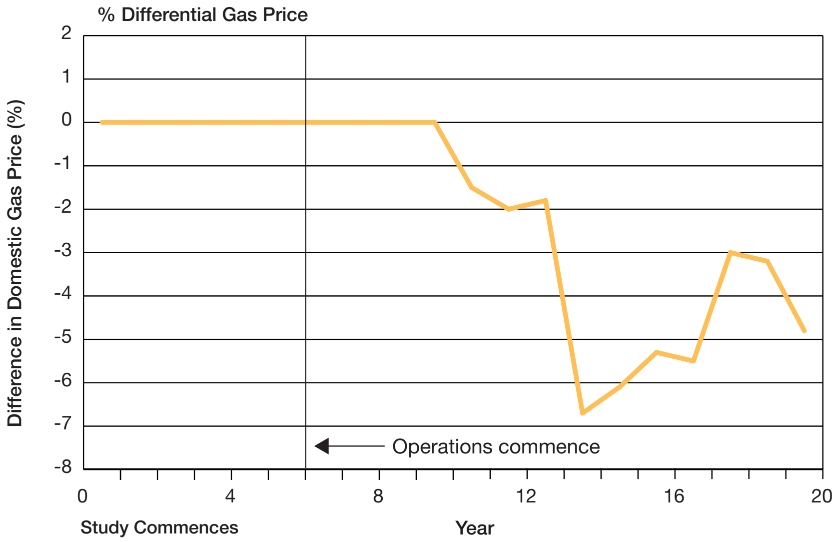
15.3 Impacts on the Domestic Gas Market

The Western Australian gas market may benefit greatly from the addition of another major gas supply to meet a continuing growth in demand. The sources of natural gas supply to Western Australian customers with and without the Gorgon gas field was modelled as part of the economic analysis conducted for the ESE Review. This modelling predicted a supply gap caused partly by the decline in existing production and by an increase in demand which could be filled by the Gorgon Development. This demand-gap is comprised of potential new industrial and domestic gas projects, such as minerals processing projects (refer to Chapter 1 for a list of potential projects). Industrial growth in Western Australia, such as in mineral processing or gas-to-liquids conversion, could be stifled or delayed without the introduction of gas from the Gorgon gas field.

The contribution of the Gorgon Development to enhancing gas market competition will have important implications for the continued international competitiveness of the Western Australian economy. The additional availability of gas in Western Australia will bring benefits to customers from the downward pressure on delivered gas prices.

Modelling conducted for the Joint Venturers predicted that the increased competition associated with the introduction of a major new gas supply may reduce delivered gas prices to domestic gas consumers on a state-wide basis by 2–7% over a 10-year period, compared to pricing without an additional major gas supplier (refer to Figure 15-4).

Figure 15-4:
Predicted Impact of Gorgon Development on Domestic Gas Prices



These predicted price reductions are particularly significant for industrial development in the South-West and Goldfields regions, where there is great potential for expansion in minerals processing and energy-intensive metal production. For example:

- in the South-West, more competitive gas supplies could stimulate further expansion of alumina and titanium pigment production
- gas-fired electricity generation (both stand-alone and co-generation), together with the introduction of a fully competitive electricity market, will contribute to achieving electricity prices which are competitive for energy-intensive processing such as aluminium smelting
- further development of laterite nickel processing and other industries in the Goldfields–Esperance region will be enhanced.

15.4 Local Content

Over the life of the Gorgon Development, the Joint Venturers are expected to invest over $11 billion in upstream gas field development, LNG value-added manufacturing plant and domestic gas infrastructure. Operating expenditure over the same period of time is estimated to be over $5 billion. This could act as a substantial economic catalyst to the Pilbara region.

For both the investment and operating phases of the Development, opportunities are expected for Australian and local suppliers to deliver a significant proportion of the labour, goods and services required. The Joint Venturers' Australian Industry Participation Policy is outlined and discussed in Chapters 2, 8 and 14.

In addition to the opportunities flowing to businesses and workers directly involved with the Development, there will be benefits to other businesses and workers throughout the economy. While the Gorgon Development will mostly benefit directly related activities, there will also be significant benefits for other manufacturing and service industries.

15.5 Capacity Building

The Gorgon Development presents many capacity building opportunities with significant flow-on effects to the Western Australian economy.

15.5.1 Technology and Skills Transfer

Proven and currently applied best practices will be employed throughout the Gorgon Development. These include:

- research and development of the first CO_2 injection facility in Australia with, most likely, the highest injection capacity in the world
- development of one of the largest subsea gas field installations in the world

- the possibility of the installation of one of the largest corrosion-resistant alloy, subsea gas pipelines in the world
- development of a world-class terrestrial and marine quarantine management and control system.

Opportunities will arise for transfer of some of these technologies to other industry participants. Where technologies are proprietary, contractors will gain experience in their application. The capacities of contractors and the skills of their employees could be enhanced as a result of working on the Development. These capacities and skills can be applied to other projects in Australia and other countries.

Australia is currently creating world-class research results in the utilisation of CO_2 injection technology through the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) (refer to Chapter 13). The Development could provide an important critical mass in Western Australia to stimulate research and development in other areas such as petroleum production, health and safety, gas processing technologies, subsea technology and environmental management.

15.5.2 Development of a Petroleum Service Hub

Exploration and development of the petroleum industry in north-western Australia has stimulated strong growth in the petroleum service sector of Western Australia, which parallels the growth in the mining services sector. The petroleum service sector supplies a wide range of services including: exploration, engineering, equipment, training, education, environment, economic, community relations, and legal.

Service firms have developed the capacity to not only compete with foreign companies for work in Australia, but also to win work increasingly throughout the Asia–Pacific region. As a result, Western Australia is developing a reputation as a regional petroleum service hub.

15.6 Expansion of the Development

Development of the Gorgon gas field presents the opportunity to deliver the economic, strategic and social benefits identified in this document. In addition, the Development could lead to further exploration and development of other regional gas resource identified in the area, extending and expanding these economic benefits. It is estimated that the volume of gas in the region is sufficient to support additional LNG trains and/or large scale natural gas developments and industries in the future. Although the economic effects of this future expansion have not been modelled in detail, there are market advantages and considerable economic, strategic and environmental benefits. Competitive economic and market factors will determine the pace and extent of any such future developments.

15.7 Conclusion

Economic modelling studies show that the Gorgon Development will generate substantial, positive economic benefits for Australia and Western Australia. These benefits will be driven by export income generated by the Development, the amount of money spent in the local economy, and the taxes and royalties paid by the Joint Venturers, and associated businesses and individuals. It is expected that the Gorgon Development will contribute approximately $11 billion in investment expenditure at today's prices and pay $17 billion in taxes and royalties over the life of the Development. The Development will stimulate 6000 direct and indirect jobs nationally, of which 1700 will be in the Western Australian workforce. It is estimated that approximately 10% of the construction and operational workforce could be sourced from the Pilbara region. This workforce will create flow-on economic benefits through spending in the region.

The Gorgon Development may provide the impetus for the expansion of existing services and industries and attract a number of new ones. It will help underpin the development of new technologies and skills, for example in disposal of CO_2 by injection and subsea technology, thereby creating regional capacity for future growth.

Development of the Gorgon gas field could lead to further development of other regional gas resources identified in the area, extending and expanding the benefits of the initial Development.

16: Environmental Management Framework

The Gorgon Joint Venturers are committed to conducting activities associated with the proposed Gorgon Development in an environmentally responsible manner; and intend to implement best practice environmental management as part of a program of continuous improvement. This will be achieved by addressing issues systematically, consistent with internationally accepted standards and the Chevron Operational Excellence Management System.

An important element of this systematic approach is the development of detailed environmental management procedures to guide construction, commissioning, operation and emergency response activities. These procedures will incorporate the proposed environmental management safeguards outlined in this Draft EIS/ERMP and will be documented in an integrated series of Environmental Management Plans EMPs. These Plans will be developed progressively though three related stages: A Framework EMP (Technical Appendix A1); the detailed EMP series; and Environmental Management Implementation Procedures to be developed by the engineering and construction contractor.

This chapter outlines the key elements of the proposed Environmental Management System and Environmental Management Plans and discusses the process through which they will be developed, implemented and maintained.

16.1 Introduction

The environmental impact assessment presented in this Draft EIS/ERMP has led to the development of numerous environmental management and mitigation measures covering all aspects of the Gorgon Development. As planning and design for the Development proceeds, these measures will be refined and supplemented with greater detail, technical input and practical application that is not available at this early stage of the Development. To ensure all appropriate measures are captured and implemented a robust management system is required. The purpose of the Environmental Management System (EMS) is to ensure that there is consistent application of appropriate management measures over the life of the Gorgon Development in order to protect the conservation values of Barrow Island and the Development area.

In this regard, the Joint Venturers propose to adopt an approach that is consistent with the recognised international standard AS/NZS ISO 14001:2004, Environmental Management Systems – Specification with Guidance for Use (ISO 14001). This standard has been selected because it is a proven method of establishing effective systems for environmental management generally, and contains all of the elements necessary to manage threats to the important conservation values of the Development area. It is also consistent with Chevron's Operational Excellence Management System (refer to Box 16-1).

The use of an environmental management framework, consisting of an ISO 14001-consistent management system and comprehensive series of Environmental Management Plans (EMPs), is a well-established practice that has been adopted in major resource projects throughout the world for over a decade. The key components of an EMS and EMPs, which are described later in this chapter, are now widely accepted and have been proven to achieve a high level of environmental performance. The EMS will apply to all Development activities. The Quarantine Management System, described in Chapter 12, is a subset of this. The Joint Venturers are confident that the development of the EMS and EMPs will provide effective methods for protecting the conservation values of Barrow Island and the proposed Development area.

Box 16-1:
Chevron Operational Management System

Operational Excellence is the systematic management of safety, health, environment, reliability and efficiency to achieve world-class performance. It is a common process applied to Chevron's operations around the globe in order to:

- achieve an injury-free work place
- eliminate spills and environmental incidents, and identify and mitigate key environmental risks
- promote a healthy workplace and mitigate significant health risks
- operate incident-free with industry leading asset reliability
- maximise the efficient use of resources and assets.

The Operational Excellence Management System consists of three parts:

Leadership Accountability
Leadership is the single largest factor for success in Operational Excellence. Leaders establish the vision and set objectives that challenge the organisation to achieve world-class results. They direct the Management System Process, setting priorities and monitoring progress on plans that focus on the highest impact items. Leaders visibly demonstrate their commitment through personal engagement with the workforce and showing a concern and caring for the health and safety of every individual.

Management System Process
A systematic approach used to drive progress toward world-class performance. The management system process is linked to the business planning process, and begins with defining a vision of success and setting objectives. Gaps between current performance and these objectives are identified during the assessment phase, then plans are developed to close the gaps, the plan is implemented and a review of the plan implementation and performance is completed.

Operational Excellence Expectations
Corporate expectations for Operational Excellence are detailed under 13 elements (listed below). The expectations are met through processes and programs put in place by local management. Many expectations are supported by corporate standards and Operational Excellence processes.

The 13 elements are:

- **Security of personnel and assets**: Provide a secure environment in which business operations may be successfully conducted.
- **Facility design and construction**: Design and construct facilities to prevent injury, illness and incidents and to operate reliably, efficiently and in an environmentally sound manner.
- **Safe operations**: Operate and maintain facilities to prevent injuries, illness and incidents.
- **Management of change**: Manage both permanent and temporary changes to prevent incidents.
- **Reliability and efficiency**: Operate and maintain facilities to sustain mechanical integrity and prevent incidents. Maximise efficiency of operations and conserve natural resources.
- **Third party services**: Systematically address and manage contractor conformance to Operational Excellence.
- **Environmental stewardship**: Strive to continually improve performance and reduce impacts from operations.
- **Product stewardship**: Manage potential risks of products throughout the product's life-cycles.
- **Incident investigation**: Investigate and identify root causes of incidents to reduce or eliminate systemic causes to prevent future incidents.
- **Community awareness and outreach**: Reach out to the community and engage in open dialogue to build trust.
- **Emergency management**: Prevention is the first priority, but be prepared for an emergency and mitigate any incident quickly and effectively.
- **Compliance assurance**: Verify conformance with company policy and government regulations. Ensure that employees and contractors understand their safety, health and environmental responsibilities.
- **Legislative and regulatory advocacy**: Work ethically and constructively to influence proposed laws and regulations, and debate on emerging issues.

16.2 Key Elements of the Environmental Management System

The elements of the proposed management system are based on the requirements of ISO 14001 and will be adapted to meet the specific requirements of the Gorgon Development.

16.2.1 Policy

As Chevron Australia is the operator of the Gorgon Development, established policy (Policy 530 Protecting People and the Environment), will be adopted as a key element of the management system (General Appendix A of this document).

16.2.2 Objectives and Targets

The Policy will be supported by a comprehensive set of environmental objectives and the Gorgon Development sustainability principles (Chapter 1). Where relevant, targets for measuring performance and the achievement of stated objectives will be established. Specific objectives for each environmental factor are outlined in the risk assessment tables in Chapters 10 to 13, respectively and collated in Box 16-2. Specific objectives for each social and economic factor are collated in Box 16-3.

Box 16-2:
Gorgon Development Environmental Management Objectives

Environmental Factor	Management Objective
Flora and Vegetation Communities	• To maintain the abundance, diversity, geographic distribution and productivity of flora through the avoidance or management of adverse impacts and improvement in knowledge. • To protect *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)-listed threatened and migratory species. • To protect Declared Rare and Priority Flora, consistent with the provisions of the *Wildlife Conservation Act 1950* (WA).
Terrestrial Fauna	• To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act-listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the *Wildlife Conservation Act 1950*.
Subterranean Fauna	• To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna, consistent with the provisions of the *Wildlife Conservation Act 1950.*
Soil and Landform	• To maintain the integrity, ecological functions and environmental values of soil and landform.
Foreshore	• To maintain the integrity and stability of beaches.
Water (Surface or Ground)	• To maintain the quantity and quality of water so that existing and potential environmental values, including ecosystem function, are protected. • To minimise the potential for erosion due to stormwater flow.
Marine Fauna	• To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities. • To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. • To protect EPBC Act listed threatened and migratory species. • To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*
Marine Flora (mangroves, corals, seagrasses and algae)	• To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.
Benthic Habitats Intertidal Zone	• To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones. • To protect EPBC Act listed threatened and migratory species.

Box 16-2: (continued)
Gorgon Development Environmental Management Objectives

Environmental Factor	Management Objective
Air Quality	• To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.
Greenhouse Gas Emissions	• To minimise greenhouse gas emissions to levels as low as practicable on an ongoing basis and consider offsets to further reduce cumulative emissions.
Ozone Depleting Substances	• To minimise emissions of ozone depleting substances to levels as low as practicable on an ongoing basis.
Noise and Vibration	• To avoid adverse noise and vibration impacts to fauna. • To ensure that noise impacts emanating from the proposed plant comply with statutory requirements specified in the Environmental Protection (Noise) Regulations 1997.
Light	• To avoid or manage potential impacts from light overspill and comply with acceptable standards.
Liquid and Solid Waste Disposal	• To ensure that liquid and solid wastes do not adversely affect groundwater or surface water quality or lead to soil contamination.
Leaks and Spills	• To ensure hydrocarbons and other chemicals are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.

Box 16-3:
Gorgon Development Social and Economic Management Objectives

Social and Economic Factor	Social and Economic Management Objective
Local Communities	• To maximise social enhancement opportunities dependant on the Development while minimising and mitigating adverse impacts.
Cultural Heritage	• To avoid or minimise impacts to Aboriginal and non-Indigenous cultural heritage sites. • To ensure that the proposal complies with the requirements of the *Aboriginal Heritage Act 1972.* • To ensure that the proposal complies with the requirements of the *Heritage of Western Australia Act 1990.* • To ensure that the proposal complies with the requirements of the *Historic Shipwrecks Act 1976.*
Native Title	• To ensure that the proposal complies with the requirements of the *Native Title Act 1993.*
Workforce and Public Health and Safety	• To ensure that the risk to the workforce and public is as low as reasonably practicable.
Economic Development	• To maximise the contribution to economic development of the region, state and nation.
Community Development	• To maximise the contribution to community development.

16.2.3 Leadership and Commitment

The Joint Venturers are committed to conducting activities in an environmentally responsible manner and will ensure that adequate resources are assigned to implement and monitor an effective EMS. The visible commitment of senior management will demonstrate the importance of sound environmental management to employees, contractors, government and the community.

16.2.4 Organisation Structure and Responsibility

The EMS will clearly define the organisation for the overall management of activities and operations. The responsibilities and authorities for environmental management and control will principally occur through the standard Chevron Australia line-management functions which comprise the:

- Australasia Strategic Business Unit (ASBU) – The ASBU Executive Team, which includes the ASBU Managing Director, holds ultimate responsibility for ensuring that the Gorgon Development achieves its environmental objectives.
- Gorgon Area Gas Asset – The Gorgon Area General Manager is accountable to the ASBU Managing Director for the environmental performance of all development activities in the Gorgon Area.
- Gorgon Development Team – Specific functions of the Development Team include promoting and championing environmental responsibilities amongst the Development participants and ensuring that all contractors, sub-contractors and suppliers fulfil their environmental obligations.
- Gorgon Development Health, Environmental and Safety Team (HES Team) – This team of environmental and technical advisors is led by the Gorgon HES Manager. The HES Team's principal role is to provide expert advice, facilitate specialist studies, and further develop the EMS. The HES Team is also responsible for developing strategies, standards and implementation plans and monitoring performance against EMPs.

All personnel associated with the Gorgon Development are responsible for delivering HES performance. This explicitly includes the Gorgon Team, contractors, sub-contractors and suppliers.

16.2.5 Operational Control

Potential impacts on the conservation values of Barrow Island and the proposed Development area have been identified through a systematic risk assessment process involving specialist ecologists, environmental managers and engineering and construction personnel, as documented throughout this Draft EIS/ERMP. The objective of risk-based management is to adopt management strategies to reduce risks to an acceptable level; for example, reduction of light spill to turtles as outlined in Chapter 11.

A comprehensive series of EMPs will document procedures for the management of potential impacts on conservation values (refer to Section 16.3). The EMS will incorporate a documented program for implementation and maintenance of the system. Detailed procedures will support these processes. Adequate budgets and resources will be provided to enable effective system implementation; and employees and contractors will be required to comply with relevant aspects of the EMPs.

16.2.6 Documentation and Reporting

All elements of the EMS will be documented. In particular, all procedures for implementation and maintenance of the system will be recorded in an integrated and structured manner. Chevron Australia has a comprehensive document control system in place which will be utilised for the Gorgon Development.

A system of internal reporting (on-site and through to senior management) and external reporting (to government and other stakeholders) will be clearly documented. Of particular note, the Joint Venturers will develop a public reporting process to inform stakeholders of the status and progress of key environmental issues such as biodiversity protection, quarantine management and CO_2 injection.

16.2.7 Training, Awareness and Competence

The Joint Venturers will establish and maintain procedures for inducting and training all employees and contractors with regard to their environmental management responsibilities whilst working on the Gorgon Development.

Comprehensive training and induction programs will be developed which will address both administrative and technical environmental management procedures. These programs will be developed and implemented prior to the commencement of construction and operation phases. The programs will be tailored to meet the specific requirements of various roles that employees and contractors undertake for the proposed Development.

Induction programs will include, but are not limited to:

- conservation values of Barrow Island
- relevant legislation and government guidelines
- EMS and EMPs
- quarantine management
- industry codes of practice.

Training programs will include:

- environmental management requirements for various construction and operation activities
- training related to specific tasks
- general environmental awareness.

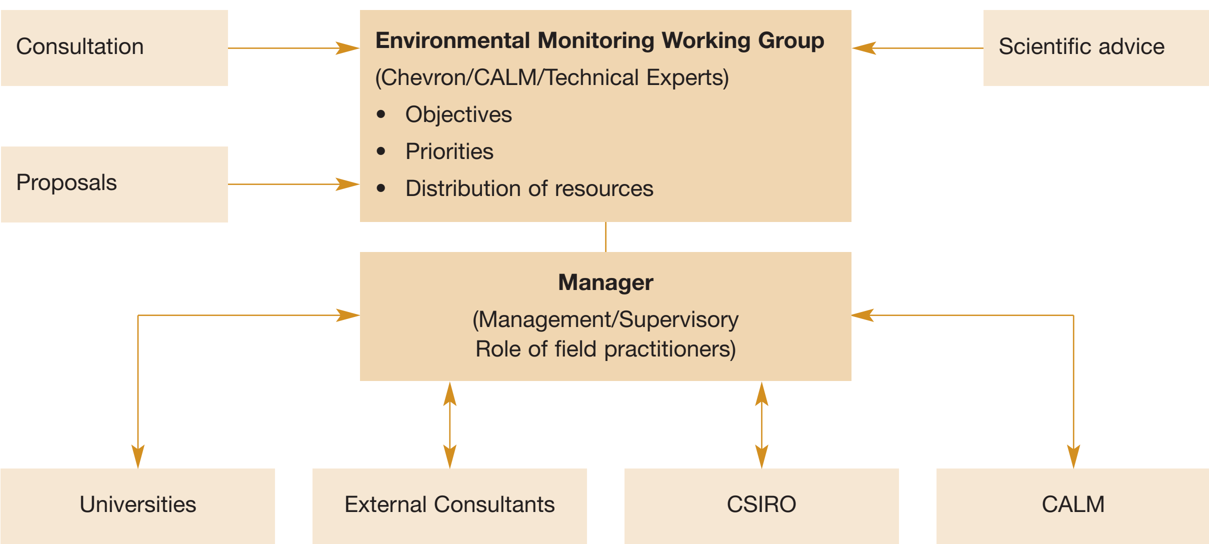
16.2.8 Monitoring

Environmental monitoring is an integral part of Development construction and operations. Detailed monitoring programs will be developed, in consultation with the Barrow Island Coordination Council (BICC), the Department of Environment (DoE), the Department for Conservation and Land Management (CALM) and the Conservation Commission of Western Australia (Conservation Commission), to address construction and operational activities which have the potential to adversely impact the environment. The Joint Venturers have developed a management structure to oversee and guide the design, implementation and interpretation of the proposed monitoring program (Figure 16-1). This model will draw on expert advice to develop a scientifically rigorous program to deliver the necessary confidence that monitoring will be effective.

The monitoring programs will be used to guide the management of environmental impacts. In particular, the programs will aid in the early identification of potential environmental issues and allow the effectiveness of management strategies to be evaluated and amended, if required. The programs will fulfil the due diligence requirements of the Joint Venturers to document effective environmental performance and to address any shortcomings. Specifically, the monitoring programs will aim to:

- detect environmental change and, specifically, identify those changes resulting from the Development

Figure 16-1:
Environmental Monitoring Structure



- determine actual versus predicted change
- contribute to the assessment of the effectiveness of environmental management procedures (including those related to quarantine risks)
- provide data for the assessment of adherence to EMPs and licence conditions.

Monitoring programs will be systematic, scientifically rigorous, statistically valid and conducted by appropriately qualified personnel. These programs will be periodically reviewed and modified to assure continued appropriateness. Such reviews will consider the required frequency and duration of monitoring and evaluate the ongoing need for individual programs. Records of all monitoring activities will be retained to facilitate the audit program (Section 16.2.9).

The programs will investigate a range of issues including:

- the volume and composition of waste discharges
- the volume and composition of air emissions, including greenhouse gas emissions
- ground level concentrations of critical pollutants
- noise emissions
- dredging effects
- the rate, extent and success of rehabilitation
- the control of potentially introduced animals, plants and diseases
- presence and abundance of rare fauna
- protection of sites of cultural significance.

The results of monitoring activities will be presented to senior management within the Joint Venturer companies for review.

16.2.9 Auditing

A detailed environmental audit program will be developed in consultation with the Environmental Audit Branch of DoE. This program will define the scope and timing of audits.

Audits will be conducted to:

- assess compliance with regulatory requirements, licence conditions, specific EMPs and the EMS
- evaluate the extent to which environmental objectives of the Development are being met.

Internal audits will be conducted by company personnel as part of the Gorgon Development Team's system of self-regulation. Audits will also be conducted periodically by specialist personnel from the Joint Venturers. Operations personnel will be involved in the planning and conduct of audits.

The Conservation Commission has a statutory function to assess and audit the implementation of management plans for nature reserves. The Joint Venturers will consult the Commission regarding the development and implementation of the internal audit program.

16.2.10 Non-Conformance and Corrective Action

Where monitoring and/or audits indicate that performance does not conform to environmental management requirements, or further improvement in performance standards is necessary, corrective action will be required. Investigation and corrective action procedures will be established to:

- determine the cause of non-conformance
- identify and implement corrective action
- initiate preventative actions
- apply controls to ensure that preventative actions are effective
- record any changes in written procedure resulting from the corrective action.

Corrective actions will include management responsibilities for addressing, tracking and close-out of incident investigations, audits, inspections and monitoring programs.

16.2.11 Emergency Preparedness and Response

The Joint Venturers will further develop and maintain the existing emergency response plan which clearly outlines how emergencies will be managed. Emergency response procedures will address stressors identified from site-specific risk and impact assessments. Procedures will be developed to ensure that emergency response teams are available, that employees and contractors are well versed in emergency response procedures and that documented plans and procedures are established and maintained. Emergency response procedures will be further developed and implemented through BICC.

16.2.12 Incident Reporting

Chevron Australia has a robust and proven incident management and investigation process. The Gorgon Development will revise and document this process where appropriate. This process will include:

- management roles and responsibilities in incident investigation
- root-cause analysis for significant events and near misses
- periodic evaluation of incident cause trends to determine where improvements in systems, processes, practices or procedures are warranted
- procedures for sharing of relevant lessons learned
- procedures for follow-up and closure of actions.

Copies of incident reports will be provided to regulatory agencies in accordance with statutory requirements.

16.2.13 System Review

The Joint Venturers will assess the adequacy and effectiveness of the management system annually during construction and the first few years of operation. Reviews will be based upon monitoring and auditing activities, internal changes (availability of new technology, organisational changes), and external drivers (access to new markets, regulatory requirements). These scheduled reviews will be undertaken to evaluate system performance and to explore opportunities to improve environmental performance and the protection of conservation values.

As part of this review, the policy, objectives, organisational structure, resource allocation, personnel responsibilities, procedures, training and document control will be considered. The review will recommend improvements and will outline a program and responsibilities for implementation.

16.3 Environmental Management Plans

Environmental Management Plans will form the cornerstone of the Gorgon Joint Venturers' EMS as they will document actions and responsibilities for protection of the conservation values of the Development area. The Plans will be developed in three related phases:

- Framework EMP
- detailed EMP series
- Contractors' Environmental Management Implementation Procedures (EMIPs) (Figure 16-2).

Environmental Management Plans will be developed and implemented such that the procedures adopted do not present any new stressors or result in impacts not foreshadowed in this Draft EIS/ERMP.

16.3.1 Framework EMP

The Framework EMP has been prepared as part of this Draft EIS/ERMP and is presented as Technical Appendix A1. The Framework EMP has two main purposes: to assist the reader by collating proposed management strategies in a more traditional format; and to simplify the production of the detailed EMP series during the current phase of design.

Due to the size and complexity of the Gorgon Development, potential environmental impacts and management strategies have been presented throughout this Draft EIS/ERMP by factor (e.g. terrestrial vegetation or marine mammals) rather than by activity (e.g. earthworks or dredging). This has enabled conclusions to be more easily drawn regarding potential impacts from the overall Development on a particular environmental factor, but makes it more difficult to consider the implications of a specific activity on the broader environment.

Figure 16-2:
Phases of EMP Development

FRAMEWORK EMP (Appendix A1 of the Draft EIS/ERMP) → **DETAILED EMP SERIES (Approved prior to activity execution)** → **CONTRACTORS' EMIPs (Finalised prior to activity execution)**

The Framework EMP has been prepared by the Gorgon Joint Venturers for consideration by regulatory agencies and the public as part of the environmental impact assessment and approval process. The Framework EMP has a specific lifespan in its current form and, following public comment, it will be used as a basis for, and superseded by, the detailed EMP series.

16.3.2 Detailed EMP Series

Environmental Management Plans are 'implementation documents', simple and focussed, and containing practical procedures for application in the field.
To be relevant and effective, the detailed EMP series will be developed in conjunction with the design and construction contractor and in consultation with regulatory agencies. At the time of preparation of this Draft EIS/ERMP, design and construction planning was at the conceptual level and as such, it is too early to prepare detailed and effective EMPs.

The detailed EMP series will be used to direct site-specific management actions to protect the conservation values of Barrow Island and the Development area. These EMPs will outline strategies to achieve the environmental objectives outlined in this Draft EIS/ERMP (refer to Box 16-2). The detailed EMP series will be prepared for each phase of Development to address normal operations, unplanned incidents and emergency situations and will include the environmental management strategies and procedures committed to throughout this document, particularly those in the risk assessment tables of Chapters 10 to 15.

Structure of the EMP Series

The structure of the EMP series has been developed to ensure that the series is comprehensive, but that individual Plans are focussed and succinct. In deciding on the composition of the EMP series, three main issues were considered. Firstly, management measures will be required for the construction, commissioning, operations and decommissioning phases of the

Table 16-1:
Issues to Address in the Detailed EMP Series

Development Component	Activity or Stressor	Factor
• Wells • Subsea manifolds • Flowlines • Feed gas pipeline • Materials offloading facility • Causeway • Jetty • Barge landing • Loading facility (including channel and turning basin) • Condensate loadout • Optical fibre cable • Domestic gas pipeline • Gas processing facility • Village • Power and water • Roads • Airport • CO_2 pipeline • CO_2 injection wells • CO_2 monitoring • Mainland supply base	• Drilling • Subsea installation • Pipe laying • Shipping • Material import • Piling • Rock dumping • Dredging and spoil disposal • Product loading and export • Earthworks • Vegetation clearing • Blasting • Horizontal directional drilling • Traffic and transport • Rehabilitation • Air emissions • Greenhouse gas emissions • Waste (liquid, solid, heat/cold) • Lighting • Noise emissions and vibration • Spills • Fire • Workforce presence • Quarantine	• Marine flora and fauna • Pelagic and benthic habitats • Intertidal zones • Coastal processes • Terrestrial flora and fauna • Subterranean fauna • Soil and landform • Foreshore • Drainage and water resources • Social/community • Land tenure • Land use • Cultural heritage • Workforce

Development. Thus, each phase will involve a different set of activities, schedules, potential environmental stressors and workforces. Secondly, the Development will cover an extensive geographical area and include open oceanic waters west of Barrow Island, shallow state waters between the Island and the mainland, specific areas on Barrow Island, and the mainland (including Mardie Station and the areas to be used as supply bases). Finally, EMPs need to address each Development component; each activity or stressor and all environmental factors (refer to Table 16-1).

As a result, a series of EMPs will be produced for the construction phase (as listed below). Due to the nature of the proposed construction works, these will largely be component-based, but will address all relevant activities, stressors and environmental factors.

Development Component-Based EMPs:

- Gas Processing Facility, Camp and Infrastructure
- Port Facilities (MOF and LNG Jetty)
- Upstream Field Infrastructure (Manifolds and Flowlines)
- Feed Gas Pipeline (Offshore)
- Feed Gas Pipeline (Onshore)
- CO_2 Injection System (Pipeline and Wells)
- Pioneer Construction Village
- Optical Fibre Cable
- Domestic Gas Pipeline and Associated Infrastructure
- Mainland Supply Base.

Activity or Stressor-Based EMPs:

- Waste Management
- Spill Contingency and Response
- Drilling (Offshore)
- Dredging and Dredge Spoil Disposal
- Quarantine Management
- Greenhouse Gas Management.

Factor-Based EMP:

- Cultural Heritage.

Similarly, during operations a series of EMPs will outline procedures needed to manage environmental risks during everyday operations and maintenance activities, as well as emergency and contingency plans in case of unplanned events. These EMPs will be fewer than for construction reflecting the smaller number of work groups. Currently, the following Operations EMPs are anticipated:

- Upstream Field Infrastructure Operations
- Pipeline Operations
- Gas Processing Facility and Utilities Operations
- Marine Terminal Operations
- Mainland Supply Base Operations
- Spill Contingency and Response
- Waste Management
- Quarantine Management
- Greenhouse Gas Management.

A single Decommissioning Plan is most likely, with sections dealing with each of the Development components.

A range of related plans are required by legislation (or regulation). Plans such as Environment Plans required under the *Petroleum (Submerged Lands) Act 1967* will form part of the EMP series. Other plans, such as Reservoir Management Plans and Emergency Response Plans required under the P(SL) Act and the Social Impact Management Plan required under the Barrow Island State Agreement, will be prepared and approved via separate processes, as their primary purpose is not to direct environmental management.

Structure and Content of Individual EMPs

Environmental Management Plans will be prepared in a consistent style and format and the nature of the content will be uniform. The aim will be to produce documents that provide clear guidance and serve as a valuable reference for the relevant workforce group.

The key component of each EMP will be a set of detailed strategies to avoid, mitigate or minimise impacts of tasks or actions. Context for the procedures will be provided by introductory sections regarding environmental factors, objectives and performance criteria. Environmental Management Plans will also be used to inform the workforce of the monitoring, auditing, reporting and corrective action processes, although in general these ‘system’ aspects will be

Table 16-2:
EMP Structure and Content

EMP Component	Content
Development Activity/Issue	The construction or operation activity to be managed (e.g. vegetation clearing at gas processing facility site).
Relevant Environmental Factor/s	Environmental factor/s that may potentially be affected by construction or operation activity to be managed (e.g. flora, fauna and cultural heritage).
Environmental Objective/s	The environmental management objective/s that relates to the environmental factor/s potentially affected by proposed construction or operation activity.
Performance Criteria	Measurable performance criteria for construction and operation activities.
Implementation Strategy	Detailed strategies to avoid, mitigate or minimise impacts of tasks or actions that will be implemented to achieve performance criteria.
Monitoring	Monitoring requirements to measure performance (i.e. specified indicators of change).
Auditing	Auditing requirements to demonstrate implementation of agreed construction and operation environmental management strategies and compliance with agreed performance criteria.
Reporting	Format, timing, and responsibility for reporting and auditing of monitoring results.
Corrective Action/s	Action required when performance requirements are not met and person(s) responsible for undertaking the corrective action.
Review	Process and timing for review and update of the EMPs.

managed by environmental specialists or supervisory personnel from the proponent or contractor teams. A summary of the key content and structure of the proposed EMPs is provided in Table 16-2.

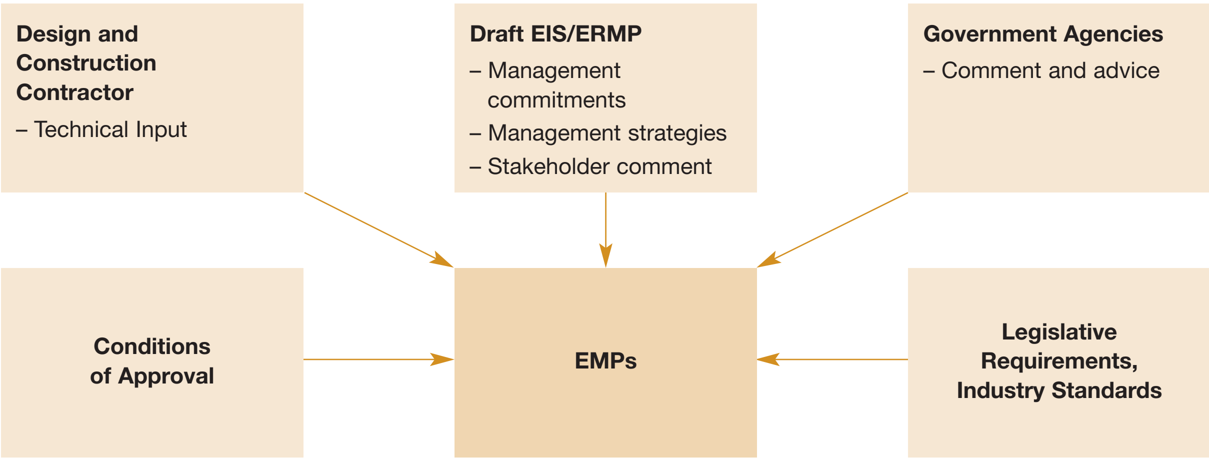
EMP Development and Approval Process

Environmental Management Plans will be developed and documented through a systematic and consultative process to address environmental factors and risks identified during the environmental impact assessment. The Plans will be prepared by the Joint Venturers with technical input from a variety of sources including the design and construction contractor, comment from relevant regulatory agencies and conditions of approval (Figure 16-3). The Conservation Commission of Western Australia will be consulted during the preparation of the detailed EMPs, as will relevant state and Commonwealth regulatory agencies.

Detailed EMPs for activities to be conducted in areas under state jurisdiction will be prepared to the satisfaction of the Western Australian Environmental Protection Authority (EPA). Plans for activities conducted in Commonwealth waters (such as drilling and pipeline construction), or under Commonwealth legislative control (such as dredge disposal) will be approved in accordance with regulatory requirements.

Detailed EMPs for construction will be prepared progressively in the lead-up to the specific activity taking place. That is, some detailed EMPs, such as those for preparation of the Gas Processing Facility site, will need to be prepared in draft form prior to Ministerial approval of the Gorgon Development, as the activities will need to commence shortly after approval. Detailed EMPs for other activities, such as drilling or construction of the domestic gas pipeline, will not need to be prepared until after this time, as the activity may not occur for 12 months or more, and will be more meaningful when a greater level of engineering detail is available.

Figure 16-3:
Inputs to EMPs



Operations EMPs will be developed during the late construction phase; similarly, the Decommissioning EMP will be prepared at an appropriate stage during operations.

Following approval, EMPs will be made available to the public via the Gorgon Development website.

EMPs will be reviewed and periodically updated to reflect knowledge gained during the course of detailed design, early construction or operational activities. Changes to EMPs will be developed and implemented in consultation with relevant authorities to the satisfaction of the EPA.

16.3.3 Contractor Environmental Management Implementation Procedures

A series of Environmental Management and Implementation Procedures (EMIPs) will be prepared by the engineering and construction contractor. These internal project documents will build on the environmental protection measures contained in the Framework EMP and the detailed EMPs approved by agencies. In particular, they will provide site specific plans and identify individual responsibilities. The EMIPs will need to be approved by the Gorgon Development Team prior to the relevant work commencing.

16.4 Conclusion

The Joint Venturers are committed to protecting the conservation values of the Development area during the construction, operation and decommissioning of the Gorgon Development. To assist in meeting this commitment a comprehensive EMS will be developed that is consistent with recognised international standards and Chevron's Operational Excellence Management System. As part of this process an integrated series of Environmental Management Plans will be developed progressively through three related stages: a Framework EMP (Technical Appendix A1); the detailed EMP series; and the Contractors' Environmental Management Implementation Procedures.

Adequate resources will be committed to implement and monitor an effective EMS with clearly defined responsibilities and authorities. The Joint Venturers are confident that thoughtful implementation and strict adherence to the EMS, EMPs and Contractors' EMIPs by the Gorgon Development Team and its contractors, subcontractors and suppliers will protect the conservation values of Barrow Island and the proposed Development area for current and future generations.

17: Conclusion

17.1 Introduction

This Draft EIS/ERMP is the primary source of information for the public and regulatory decision-makers in their assessment of the potential environmental impacts of the proposed Gorgon Development.

During the course of preparing this Draft EIS/ERMP, the Gorgon Joint Venturers have considered and evaluated the environmental, social and economic issues that may arise from the proposed Gorgon Development using a rigorous risk-based assessment approach. These issues are relevant to the *Environmental Protection Act 1996* (WA), the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) and the *Environment Protection (Sea Dumping) Act 1981* (Commonwealth) and were identified in the Guidelines for an Environmental Impact Statement and Environmental Scoping Document for an Environmental Review and Management Programme (the Scoping Document) (ChevronTexaco Australia 2004).

The major ecological issues investigated during the environmental assessment process were:

- biodiversity and conservation values of Barrow Island and its surrounding waters
- quarantine management
- disposal of reservoir CO_2 by injection into the Dupuy Formation.

As demonstrated throughout this Draft EIS/ERMP, particularly in Chapters 10–15, a number of environmental and socio-economic factors were assessed in accordance with the Scoping Document. The critical factors for assessment were identified in consultation with stakeholders during the Environmental, Social and Economic Review (ESE Review) process that preceded this environmental impact assessment. The overall approach to the environmental assessment involved identifying impacts requiring assessment; developing strategies to avoid, mitigate and/or manage impacts; and assessing the significance of any residual impacts.

The Gorgon Joint Venturers are committed to adopting specific management measures that will protect the conservation values of Barrow Island and the Development area. The management measures, which are described throughout the Draft EIS/ERMP, particularly in Chapters 10–14, will reduce to acceptable levels the environmental risks associated with the Gorgon Development. To assist regulatory agencies, stakeholders and other interested readers, a consolidated list of commitments is provided in General Appendix B. In addition to those specific commitments, the design, construction and operation of the Gorgon Development will be guided by ten principles of conduct as outlined in Table 17-1. These principles relate to the outcomes of the Gorgon Joint Venturers' assessment, as well as the requirements and objectives for managing the environmental and socio-economic factors associated with the proposed Development.

Table 17-1:
Principles of Conduct for Management of the Gorgon Development

Legislative Compliance	The Gorgon Joint Venturers will design, construct and operate the Gorgon Development in a manner that complies with all relevant legislation.
Sustainable Development	The Gorgon Joint Venturers will design, construct and operate the Gorgon Development in a manner that is consistent with its ten Sustainability Principles.
Footprint Compliance	The Gorgon Joint Venturers will design, construct and operate the Gorgon Development in a manner that complies with the *Barrow Island Act 2003,* under which no more than 300 ha of uncleared land is available to this or any future gas processing developments on Barrow Island.
Biodiversity Protection	The Gorgon Joint Venturers will design, construct and operate the Gorgon Development in a manner that maintains ecological structure and function, protects biological diversity and the integrity of populations of listed species.
Quarantine Management	The Gorgon Joint Venturers will adopt a comprehensive quarantine management system to reduce the risks to the conservation values of Barrow Island and surrounding waters to acceptable levels.
Greenhouse Gas Management	The Gorgon Joint Venturers will adopt currently applied best practice greenhouse efficiency measures in the design, construction and operation of the Gorgon Development and will inject reservoir CO_2 into the Dupuy Formation below Barrow Island unless it is technically infeasible or cost-prohibitive.
Cultural Heritage Management	The Gorgon Joint Venturers will design, construct and operate the Gorgon Development in a manner that recognises and manages sites of cultural importance.
Management System Implementation	The Gorgon Joint Ventures will implement an Environmental Management System that is consistent with internationally accepted standards and incorporates best practice environmental management as part of a program of continuous improvement. Specific environmental management measures will be documented in an integrated series of Environmental Management Plans developed during the current phase of design in consultation with regulatory agencies.

Table 17-1: (continued)
Principles of Conduct for Management of the Gorgon Development

Stakeholder Engagement	The Gorgon Joint Venturers will seek the views of stakeholders and give due consideration to their interests in the design, construction and operation of the Gorgon Development.
Transparency	The Gorgon Joint Venturers will make the results of environmental baseline surveys, environmental assessments and monitoring programs available to government agencies, scientific organisations, academic institutions, industry groups and the public to further the understanding of the ecology of the Development area.

If approval for the proposed Development is granted by the relevant ministers, the Gorgon Joint Venturers will be required to meet a range of commitments and obligations under the State Agreement of the *Barrow Island Act 2003* as outlined in Chapter 2. Additional environmental assessment and management requirements would also apply to the Development under state and federal legislation.

17.1.1 Gorgon Development Sustainability Principles

During the ESE Review process, the Gorgon Joint Venturers established a three-tiered sustainability review process, which covered the fundamental environmental, social and economic considerations required to comprehensively review the sustainability of the proposed Development (ChevronTexaco Australia 2003). The sustainability principles for the proposed Development are outlined in Chapter 1.

There are two key features of this approach to sustainability: firstly, an integrated approach to the wider economic, social, and environmental implications of the proposed Development was taken by considering these factors within a single sustainability framework; and secondly, a long-term rather than short-term view was taken when considering the implications of the proposed Development. Both of these features are reflected in this Draft EIS/ERMP and the Gorgon Joint Venturers' environmental management objectives for the proposed Development (Chapter 16).

The five principles of ecologically sustainable development defined under the EPBC Act are:

- decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations
- if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
- the principle of inter-generational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations
- the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
- improved valuation, pricing and incentive mechanisms should be promoted.

These principles are also captured in the *Environmental Protection Act 1996* (which also incorporates a principle related to waste minimisation).

The Gorgon Joint Venturers believe that the intent of each of these principles is embodied in the Gorgon Development's Sustainability Principles. In particular, there is close alignment with the principles of Future Generations Commitment, Precautionary Principle Application, Social Equity and Community Wellbeing Enhancement and Waste Minimisation. The Gorgon Joint Venturers' approach to sustainability is also in keeping with the Western Australian Government's sustainability foundation and process principles as defined by the Western Australian State Sustainability Strategy (Government of Western Australia 2003).

The Gorgon Joint Venturers are committed to sustainable development and to meeting each of the ten Gorgon Development sustainability principles by integrating them into its policies, practices and procedures. The Gorgon Joint Venturers' progress toward sustainability will be assessed through an annual sustainability reporting process which will utilise the sustainability criteria and measurement statements developed during the ESE Review process to measure the Gorgon Venture's performance against each of the sustainability principles.

17.1.2 Development Area on Barrow Island

If environmental and State Agreement approval for construction of a gas processing facility on Barrow Island is granted, the area allowed for new disturbance will be limited to a total of 300 ha. Of that area, 50 ha have been set aside for petroleum pipeline easements and 150 ha reserved until 31 December 2009 for the Gorgon Joint Venturers. The remaining 100 ha is reserved for other projects to process or use gas from the Title Areas or the Greater Gorgon area. A lease for gas processing would be granted under the *Land Administration Act 1997* for a period of 60 years but this land would remain part of the Class A Nature Reserve. The lease would be subject to local government (Shire of Ashburton) rates.

17.1.3 Emissions Associated with the Proposed Development

Air emissions from the proposed Development will meet or measure below established standards including those of the Western Australian Environmental Protection Authority (EPA) and the National Environmental Protection Measure (NEPM) requirements. Noise emissions from the Development will meet or better standards set for workers and residences. Light emissions were modelled with design and management options to reduce light spill so that appropriate lighting measures can be incorporated into construction practice as well as the detailed design and operating philosophy.

The risk of a hydrocarbon spill from the proposed Development is low as the reservoir gas has a low percentage of liquid hydrocarbons, and robust design and engineering standards and construction and operation management and maintenance will be implemented. Credible scenarios of spills associated with the proposed Development have been modelled and will be used to assist with contingency and response planning.

17.1.4 Ecological Assessment

Under the *Environmental Protection Act 1996* of Western Australia, the Gorgon Joint Venturers were required to assess significant impacts to the environment as a potential result of the proposed Development. Under the Commonwealth EPBC Act, three matters of National Environmental Significance (NES), relevant to the proposed Gorgon Development, were assessed:

- nationally threatened species and ecological communities
- listed migratory species
- Commonwealth marine areas.

As highlighted in the ESE Review (ChevronTexaco 2003), the most critical environmental issues associated with the proposed Gorgon Development are risks to the biodiversity and conservation values of Barrow Island and the surrounding waters; the threat of accidentally introducing non-indigenous species ('quarantine'); and the disposal of reservoir carbon dioxide (CO_2) by injection.

A risk-based approach was applied to identify and assess the most significant risks to Barrow Island's conservation values, following the recommendation of the EPA to develop a set of standards for acceptable risks to the conservation values of Barrow Island and demonstrate that these standards could be met with a high level of confidence. This process was undertaken in accordance with Australian standards for risk management and widely accepted best practice in environmental risk assessment.

17.2 Outcomes of the Environmental Impact Assessment of the Proposed Gorgon Development

The main outcomes of the environmental impact assessment are outlined in the following sections and are structured to mirror that of the preceding chapters.

17.2.1 Terrestrial Risks and Management

A summary of the potential stressors and assessed level of residual risk to terrestrial environmental factors is presented in Table 17-2. The residual risks posed by stressors associated with each phase of the Development were assessed as low to medium for all environmental factors except subterranean fauna. In each of the cases where residual risks were low to medium, the potential consequences to the terrestrial ecology of Barrow Island are unlikely to be long-term and with implementation of proposed management measures, pose an overall acceptable level of risk to the conservation values of Barrow Island and meet the environmental management objectives for the Development.

Preliminary assessment of risks to subterranean fauna from clearing and earthworks, noise and vibration and physical presence of the gas processing facility found residual risk associated with these stressors to be high. However, it is important to note that this level of risk primarily reflects uncertainty in the absence of final sampling data on the diversity and distribution of subterranean fauna in the Development area. Although a conservative risk assessment indicates there to be some high risk stressors to subterranean fauna, it is anticipated that further information from the current sampling program will provide a clearer model of the wider distribution of the subterranean taxa. If their distribution is found to be wider than assumed for the preliminary assessment, it will reduce this risk level.

The ongoing sampling and analysis program of subterranean fauna conducted for this environmental impact assessment is one of the most comprehensive in Australia. The information obtained is making a major contribution to this field of science. Publication of future results of the program will further contribute to this knowledge.

The measures described to manage impacts to terrestrial environmental factors will maintain ecological structure and function, and protect the terrestrial biodiversity and the integrity of populations of listed species that naturally inhabit Barrow Island.

17.2.2 Marine Risks and Management

The residual risks posed by stressors associated with each phase of the Development were assessed as low to medium for all marine environmental factors except for marine fauna where the implementation and effectiveness of management measures for light and dredging will be critical to reducing risks to sea turtles to an acceptable level (Table 17-3). The potential environmental consequences of the Development are unlikely to have long-term implications for the marine environment surrounding Barrow Island or the mainland components of the Development. The overall level of risk to marine conservation values is therefore considered to be acceptable and environmental management objectives for the Development achievable.

The Gorgon Joint Venturers are committed to reducing potential impacts on turtles and have conducted extensive research on understanding the impact of light on turtles. A range of management measures, including a commitment to lighting management strategy that is at the level of world-best practice, will be implemented to avoid or minimise impacts to turtles.

The management measures proposed to manage impacts to marine environmental factors will maintain ecological structure and function, and protect the biodiversity and the integrity of populations of listed species that naturally inhabit the marine environs of the Development area.

The location for disposing of dredge spoil has been selected to avoid significant marine flora and coral communities. The detailed management plan for dredging will require approval by regulatory agencies.

Permanent loss of benthic primary producer habitats are predicted to exceed EPA cumulative loss threshold levels in three of the fourteen management units established in accordance with EPA Guidance Statement No. 29. While these losses exceed the benthic primary producer habitat cumulative loss threshold levels, they do not represent a threat to the ecological integrity of the surrounding benthic primary producer habitat or to the conservation values of the Barrow Island Marine Conservation Area.

Losses of unconfirmed coral habitat in the two Lowendal Islands management units also exceed cumulative loss thresholds; however the majority of the assumed distribution of coral habitat in these management units, as identified by the CALM (2004)

Table 17-2:
Summary of Residual Risk Levels to Terrestrial Environmental Factors

Environmental Factor/Stressor	Residual Risk		
	Construction and Commissioning	Operations	Non-routine
Soil and Landform			
• Clearing and earthworks	M	L	–
• Liquid and solid waste disposal	M	L	–
• Leaks or spills	M	M	–
Surface and Groundwater			
• Clearing and earthworks	M	L	–
• Physical presence	M	M	–
• Liquid and solid waste disposal	M	L	–
• Leaks or spills	M	M	–
Air Quality			
• Atmospheric emissions	L	L	L
• Clearing and earthworks	L	L	–
Flora and Vegetation Communities			
• Clearing and earthworks (restricted flora and vegetation communities)	M	L	–
• Clearing and earthworks (general flora and vegetation communities)	L	L	–
• Fire	M	M	–
• Atmospheric emissions	L	L	L
• Light/shading/heat/cold	L	L	–
• Dust	L	L	–
• Unpredicted CO_2 migration	–	–	L
• Leaks or spills	L	L	–
Terrestrial Fauna			
• Clearing and earthworks	M	L	–
• Physical interaction	M	M	–
• Leaks or spills	L	L	–
• Light or shade	L	L	–
• Atmospheric emissions	L	L	L
• Dust	L	L	–
• Unpredicted CO_2 migration	–	–	L
• Heat and/or cold	L	L	–
• Noise and vibration	L	M	–
• Fire	M	M	–
Subterranean Fauna			
• Clearing and earthworks	H*	L	–
• Physical presence	–	H*	–
• Wastewater discharge	H*	–	–
• Noise and vibration	H*	–	–
• Leaks or spills	M	M	–
• Unpredicted CO_2 migration	–	M	–

** Risk level driven by conservative assumption related to uncertainty of species distribution.*

Table 17-3:
Summary of Residual Risk Levels to Marine Environmental Factors

Environmental Factor/ Stressor	Residual Risk		
	Construction and Commissioning	Operations	Non-routine
Seabed (subtidal and intertidal)			
• Physical disturbance	L – M	L	–
• Physical presence	–	L	–
• Liquid and solid waste disposal	L	L	–
• Leaks or spills (minor <10 m^3)	L	L	–
• Leaks or spills (>10 m^3)	L	L	–
Water Quality			
• Discharges	L	L	–
• Leaks or spills (minor <10 m^3)	L	L	–
• Leaks or spills (>10 m^3)	L	L	–
Foreshore			
• Physical disturbance	M	L	–
• Physical presence	–	L	–
Marine Primary Producers			
• Seabed disturbance	L – M	L	–
• Leaks or spills (minor <10 m^3)	–	–	L – M
• Leaks or spills (>10 m^3)	–	–	L – M
• Physical presence	L	L	–
• Wastewater and other discharges	L	L	–
Marine Fauna			
• Seabed disturbance	M	L	–
• Physical interaction	M	M	–
• Physical presence	–	L	–
• Wastewater discharges	L	L	–
• Light	M – H	M – H	L
• Noise and vibration	M	L	–
• Leaks or spills (minor <10 m^3)	M	M	–
• Leaks or spills (>10 m^3)	M	M	–

marine habitat mapping, has not been confirmed by field surveys. It is anticipated that only a small proportion of the areas affected by persistent turbid plumes represent coral habitat and that these coral communities would fully recover from sedimentation and turbidity impacts.

The Gorgon Joint Venturers will develop and adopt a monitoring and management program designed to restrict the potential effects of HDD, dredging and dredge spoil disposal. The monitoring and management program will be developed in consultation with the Commonwealth and Western Australia state agencies. This will form part of the drilling, dredging and dredge spoil disposal monitoring and management plan for the Development.

17.2.3 Quarantine Risks and Management

The Gorgon Joint Venturers are committed to a quarantine management regime of sufficient rigour to continue to protect conservation values throughout the construction and operation of the proposed Development. To do this, the Gorgon Joint Venturers have addressed the EPA's advice (EPA 2003) to:

- develop a set of standards for acceptable risk ('risk standards')
- demonstrate to the EPA, under advice from the Department of Environment and the Department of Conservation and Land Management (CALM), that the risk standards can be met with a high very level of confidence.

Established risk management practices have been adapted to address potential quarantine threats to the conservation values of Barrow Island. The approach taken is consistent with EPA advice as it has engaged independent technical experts to develop and undertake a risk-based quarantine management process, and has involved the community in a transparent manner in the development of acceptable risk standards. This approach involved establishing an independent Quarantine Expert Panel and a community consultation process.

The Gorgon Joint Venturers have developed a set of standards for acceptable risks to the conservation values of Barrow Island. Compliance to these standards would mean that the risk of establishment of a non-indigenous species would be acceptably low. Development of the risk standards involved expert advice and a significant level of community consultation over a period of 18 months. Standards for acceptable risk for terrestrial flora and fauna have been developed directly from these standards. The risk standards have also been used as a starting point to protect the conservation values of Barrow Island from potential threats of accidental introductions of non-indigenous micro-organisms and marine organisms.

The Gorgon Joint Venturers are committed to the implementation of the Barrow Island Quarantine Policy, the Quarantine Management System and ongoing application of the risk-based approach for assessment and management of quarantine risks. Furthermore, the advice of independent experts will continue to play an integral role in the future development of quarantine management options. This will apply particularly to the development and execution of baseline surveys, longer-term environmental monitoring, and development of eradication strategies. It is intended that Joint Venturer and stakeholder responsibilities and authority for quarantine management will also be formalised through the Barrow Island Coordination Council which will engage key government agencies such as CALM in quarantine management activities.

As a result of the quarantine program over the past 40 years, Barrow Island is the only island in the region free from introduced species such as cats, rabbits, rats and mice. The implementation of the Quarantine Management System will also ensure that quarantine barriers are maintained and that their effectiveness is regularly reviewed and improved. Demonstrations of how barriers will be implemented have been provided for the three priority pathways.

The implementation of a Quarantine Management System, in accordance with the risk-based and consultative approach discussed in Chapter 12, will deliver new performance benchmarks for quarantine management, and provide an unprecedented level of protection for the conservation values of Barrow Island.

17.2.4 Greenhouse Gas Risks and Management

The Gorgon Joint Venturers' commitment to the responsible management of greenhouse gas emissions is evidenced by the results of benchmarking the anticipated LNG emissions efficiency performance from the Gorgon Development with other LNG facilities. There is currently one operating LNG facility in Australia and another under construction. The expected performance of 0.35 tonnes of CO_2e per tonne LNG to be produced (based on the reference case assumptions) exceeds both these facilities when greenhouse emissions related to gas production are considered.

As part of the strategy to minimise greenhouse gas emissions, the Gorgon Joint Venturers are proposing to inject the CO_2 contained in the reservoir gas stream into the Dupuy Formation below Barrow Island. Appropriate monitoring of the injected CO_2 is planned to assist with the ongoing management of the CO_2 injection operations. The proposed injection of the reservoir CO_2 will reduce greenhouse gas emissions attributable to the Development (including domestic gas production) from 6.7 million tonnes per annum of CO_2 equivalent (MTPA CO_2e) to 4.0 MTPA CO_2e.

Additional activities to be undertaken with the objective of reducing greenhouse gas emissions from the Gorgon Development include:

- Undertaking further studies into the electrical generation gas turbine and waste heat recovery configuration.
- Investigating the further integration of the Gorgon Development and the Barrow Island Joint Venture activities on Barrow Island, with the aim of reducing greenhouse gas emissions.
- Undertaking energy optimisation studies during the detailed engineering and design of the Development. Energy optimisation is a way to identify, understand, and optimise energy use over the operating life of a project.
- Developing operational and maintenance procedures with the objective of reducing greenhouse gas emissions below those in the reference case and in line with the performance targets. Maximising the percentage of reservoir CO_2 injected will be a primary focus in developing these operational and maintenance procedures.
- Once the gas processing facility is operational, undertake Energy Optimisation Studies in line with requirements in Chevron Australia's Operational Excellence Management System.
- Continuing to support research into CO_2 capture and storage technology development within Australia and overseas. Potential for provision of data from the Gorgon Development.

The Gorgon Joint Venturers have developed a series of longer term performance targets with the objective of further reducing greenhouse gas emissions from the proposed Development.

17.2.5 Potential Social Benefits and Risks

The Development will generally benefit the livelihoods and lifestyles of the Pilbara community in terms of employment and local business opportunities. At the current level of planning, the positive consequences will be enhanced through a range of management measures, including the Gorgon Joint Venturers':

- commitment to provide full, fair and reasonable opportunity for Australian industry to supply goods and services to the Development through the Australian Industry Participation Policy
- initiatives for local procurement/content, employment and training which will be outlined in the Social Impact Management Plan (SIMP) in consultation with major construction contractors and stakeholder groups
- continued consultation/liaison with local government and others through community groups in the region.

There is a strong linkage between the social and economic benefits of the proposed Development. It has been identified that the most significant benefits will be economic with the details addressed in Chapter 15. The major Development benefits will be the substantial input into the Australian economy through increased taxation revenues, direct spending, opportunity for local government rating, increased security of supply and availability of natural gas, employment and training initiatives, incremental improvement in the capacity of the economy and the labour force to absorb major oil and gas projects and opportunities for increased participation by indigenous people. The Gorgon Joint Venturers aim to work with Australian companies who can assist in building and delivering a world-class competitive and safe Development.

The major adverse social risks identified for the Development apply to:

- cultural heritage (low to potentially high risk depending on the Development phase)

- Native Title (high – but only for the domestic pipeline option to the mainland and a segment of optical fibre communication cable)
- workforce and family through implementation of a fly-in fly-out regime (high).

Medium social risks apply to visual amenity and the general health and safety of the workforce on Barrow Island.

Results from modelling of pipeline and gas processing facility risks indicate that the level of individual risk to public health in areas potentially classified as residential (construction village) will be below the one in a million per year (1×10^{-6}/y) EPA risk criteria. As the construction village may be later used to house personnel working on facility additions or maintenance, it is deemed to be a residential area for planning purposes. For pipelines, residential development would need to be within 40 m of the operating pipeline to be at risk. Planned alignment of all pipelines is well outside of the 40 m zone. For the gas processing facility, the residential development would need to be within 400 m of the major refrigerant storage vessels (propane and ethane storage). Currently the construction village is proposed to be located approximately 750 m from these vessels.

17.2.6 Potential Economic Benefits

Results from economic modelling studies indicate that the Gorgon Development will generate substantial, positive economic benefits for Australia and Western Australia. These benefits will be driven by export income generated by the Development, the amount of money spent in the local economy, and the taxes and royalties paid by the Gorgon Joint Venturers, associated businesses and individuals. It is expected that the Gorgon Development will contribute approximately $11 billion in investment expenditure at today's prices and pay $17 billion in taxes and royalties over the life of the Development. The Development will stimulate 6000 jobs nationally, of which 1700 will be in the Western Australian workforce. It is estimated that more than 10% of the construction and operational workforce could be sourced from the Pilbara region. This workforce will create flow-on economic benefits through spending in the region.

The Gorgon Development will provide the impetus for the expansion of existing services and industries and attract a number of new ones. It will help underpin the development of new technologies and skills, for example in disposal of CO_2 by injection and subsea technology, thereby creating regional capacity for future growth. The proposed Development will also underpin a second major gas supply to the mainland for domestic industry.

Development of the Gorgon gas field could lead to further development of other regional gas resources, extending and expanding the benefits of the initial Development.

17.2.7 Environmental Management System

The Gorgon Joint Venturers are committed to protecting the conservation values of Barrow Island and the Development area during the construction, operation and decommissioning of the Gorgon Development. To assist in meeting this commitment a comprehensive Environmental Management System (EMS) will be developed that is consistent with recognised international standards and Chevron's Operational Excellence Management System. As part of this process an integrated series of Environmental Management Plans (EMPs) will be developed progressively through three related stages: A Framework EMP (Appendix A of this document); the detailed EMP series; and Environmental Management Implementation Procedures to be developed by the engineering and construction contractor.

Adequate resources will be committed to implement and monitor an effective EMS with clearly defined responsibilities and authorities. The Gorgon Joint Venturers are confident that thoughtful implementation and strict adherence to the EMS and EMPs by the Gorgon Development Team and its contractors, subcontractors and suppliers will protect the conservation values of Barrow Island and the proposed Development area for current and future generations.

17.3 Stakeholder Engagement and Way Forward

Comprehensive and effective community consultation, engagement and participation have been, and remain, key elements of the proposed Gorgon Development. Community involvement will continue throughout all stages of the proposed Development and, where relevant, will be incorporated into the Social Impact Management Plan pursuant to the State Agreement.

The Gorgon Joint Venturers will continue to meet with stakeholders, answer questions and seek feedback throughout the environmental approval process. The federal and state government review of this Draft EIS/ERMP document and the 10-week public comment period will provide stakeholders with further opportunity to provide formal input into the environmental approvals process. As part of this approach, additional information on subterranean fauna, quarantine barriers and field verification of the dredge plume model will be published during the public comment period.

As an integral component of their commitment to transparency, the Gorgon Joint Venturers will make the results of environmental baseline surveys, environmental assessments and monitoring programs available to government agencies, scientific organisations, academic institutions, industry groups and the public to further the understanding of the ecology of the proposed Development area.

The Gorgon Joint Venturers recognise that the proposed Development is of national significance and believe that, if the $11 billion proposed Development is granted environmental approval, implementation of the management measures proposed throughout this document will continue to protect the conservation values of Barrow Island, whilst contributing $17 billion to government revenue, creating 6000 jobs across Australia and stimulating significant future regional Development.

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Glossary

Glossary	
Term	**Definition**
Acid gas	A mixture of hydrogen sulphide (H_2S) and carbon dioxide (CO_2).
Aggregate	An essentially inert material of mineral origin having a particle size predominantly greater than 10 mesh. Also a group of two or more individual particles held together by strong forces which are not subject to dispersion by normal mixing or handling.
a-MDEA	A chemical which is commonly used to remove CO_2 and other acid gases from a natural gas stream, especially in Liquefied Natural Gas plants.
Allotrophy	External inputs of organic matter to an ecosystem.
Allozyme	Alternative forms of the same protein coded for by different genes at the same locus.
Annual species (flora)	A plant that completes its life cycle and dies within one year or less.
Aytid	Decapod crustacean belonging to the family Aytidae.
Baffle	Layers of rock which are slightly permeable to CO_2 over the nominated time-scale and/or lack of sufficient predictable areal extent to constitute an identifiable barrier.
Barrel (of oil)	A volume of 159 litres (of oil).
Barriers (CO_2 Injection)	Layers of rock which have sufficient areal extent to provide a major and predictable block to the upward movement of CO_2 over the hundreds to thousands of years.
Barrier (quarantine context)	For the purposes of assessing and managing quarantine risk, any physical, chemical, biological, procedural or administrative process which prevents an alien species from being introduced to a native environment outside of its natural range.
Benthic	Living in or utilising the bank or bed surface of water bodies.
Best Practice	Best practice involves the prevention of environmental impact or, if this is not practicable, minimising the environmental impact through the incorporation of 'Best Practicable Measures'.
Best Practicable Measures	Best Practicable Measures are technological and environmental management procedures which are practicable, having regard to, among other things: local conditions and circumstances, including costs; and to the current state of technical knowledge, including the availability of reliable, proven technology.
Biochemical Oxygen Demand (BOD)	A standardised measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. It is measured as the quantity of dissolved oxygen (mg/l) required during stabilisation of the decomposable organic matter by aerobic biochemical action. Commonly abbreviated as BOD.
Biodiversity	Biodiversity is a term used to describe collectively the variety and variability of nature which encompasses the genetic, species, and ecosystem level of organisation in living systems.
Biota	The sum of all living organisms of an ecosystem, or of a defined area or period.
Bombora	A coral structure that rises to, but does not break, the surface.
Bonn Convention	Framework for the conservation and management of migratory species (including waterfowl and other wetland species) and promotion of measures for their conservation including habitat conservation.
Border (quarantine context)	The point of entry of cargoes, vessels or people on Barrow Island. The 'marine pathway' border is the waters surrounding Barrow Island; the 'air pathway' border is the Barrow Island airport, and for the 'personnel, food and perishables pathway' the border is the village.
Breach (quarantine context)	The failure to undertake all of the requirements of the quarantine management protocol.
BTEX	This is an acronym for benzene, toluene, ethylbenzene, and xylene. This group of volatile organic compounds (VOCs) is found in petroleum hydrocarbons, such as gasoline.
Bulldozer Grubbing	Removal of vegetation stumps and roots.
Bund	An earth, rock or concrete wall constructed to prevent the inflow or outflow of liquids.

Glossary	
Term	**Definition**
Carbon Dioxide Equivalents	A measure used to compare various greenhouse gases based upon their global warming potential.
Chemautotroph	An organism that obtains energy by oxidising inorganic compounds.
Chemolithotroph	An organism that obtains its energy from the oxidation of inorganic compounds.
Choke	A piece of equipment which enables the flow from a well to be controlled at the rate required.
Christmas Tree	Assembly of equipment, including tubing head adapters, valves, tees, crosses, top connectors and chokes attached to the uppermost connection of the tubing head, used to control well production.
Community (Ecological)	A group of species inhabiting a common environment and interacting with one another.
Conservation Values	Natural assets or attributes of an area that are of conservation significance. Key conservation values of Barrow Island include: • unique fauna species and a high level of biodiversity • a suite of native marsupials that once occurred on the mainland but are now threatened or extinct there • an absence of introduced fauna species • potential as a source for controlled re-introductions to other areas • a rich marine environment and its various components (e.g. coral reefs, intertidal flats, marine mammals and turtles) • importance as a staging area for migratory birds • various subterranean fauna components and their affinities and differences to populations on the mainland.
Critically Endangered Species (EPBC Act)	A native species is considered critically endangered if it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with prescribed EPBC Act criteria.
Cryptogenic	A species that is not demonstrably native or introduced. Geographic origin unknown.
Cumulative Effects	Progressive environmental degradation over time resulting from a range of activities/sources in an area or region.
dB(A)	Abbreviation for 'decibel adjusted' or 'A-weighted decibel' – a decibel is a logarithmic unit of sound intensity; (10 times the logarithm of the ratio of the sound intensity to some reference intensity). Noise limits are sometimes qualified with the symbol Leq. Leq is defined as the equivalent continuous sound pressure level, which represents the average of a 24-hour noise history at a location. The Leq is used when it is important to consider variations in noise over time, such as between day and night. The ambient (or existing background) noise level is symbolized by L_{90} or L_{95} (the noise level present 90% or 95% of the time).
Detritus	Accumulated organic debris from dead organisms.
Double Containment Tank	Double containment tanks are designed and constructed so that both the inner- and outer-tank are capable of independently containing the refrigerated liquid. The inner-tank contains the LNG under normal operating conditions. The outer-tank or wall is intended to contain any LNG leakage from the inner-tank and the boil-off gas. Most LNG storage tanks built recently around the world were designed as double- or full-containment tanks.
Drilling Fluid	A fluid circulated through the borehole during drilling and work-over operations to remove rock cuttings made by the drill. Drilling fluid also helps to cool the bit, prevent the sides of the borehole from caving and control flow of rock fluids into the borehole.
Easement	A right held by the proponent to make use of the land of another for the installation and operation of a pipeline. Also referred to as a right of way.
Ecological Risk Assessment	A set of formal scientific methods for estimating the likelihoods and magnitudes of effects on plants, animals and ecosystems of ecological value resulting from the release of chemicals, other human actions or natural incidents.
Ecomorph	Species morphology that fits a specific set of ecological requirements.

Glossary

Term	Definition
Ecosystem	The biotic and abiotic environment within a specified location in space and time.
Electrophoresis	A laboratory technique for separating proteins based on their different mobility through an electrical field.
Endangered Species (EPBC Act)	A native species is considered endangered if it is not critically endangered and it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with prescribed EPBC Act criteria.
Endemic	A species unique to an area; found nowhere else.
Environmental Management	The sum of the day-to-day activities that are designed to mitigate a development's environmental impacts by either avoiding them or reducing them to within 'acceptable limits'.
Epibenthic Fauna	Benthic fauna that live above or amongst the sea floor.
Epifauna	Benthic fauna that live on the surface of the bottom, or floor, of a water body.
Epigean	Terrestrial fauna dwelling in habitats on the ground surface.
Ephemeral	Short-lived species.
Eradication	The elimination of every individual of an introduced species and its progeny from Barrow Island.
Eremaean	A general term used to describe the type of plants (families), soil types and rainfall in the arid zone.
Establishment (quarantine context)	Refers to the process of an introduced non-indigenous species successfully reproducing viable offspring with the likelihood of continued survival.
Evolutionary Significant Units	An Evolutionary Significant Unit is a sub-portion of a species that is defined by substantial reproductive isolation from other con-specific units and represents an important component of the evolutionary legacy of the species.
Exposure (risk assessment context)	The contact or co-occurrence of a stressor with a receptor.
Factor (risk assessment context)	Elements of the physical, biological or social environment.
Fauna	Animals characteristic of a region or special environment.
Flash Gas	A gas that is liberated from solution in oil as a result of increasing the space occupied, increasing the temperature, and/or decreasing the pressure.
Flash Vessel (Gas Flashing)	A conventional oil-and-gas separator operated at low pressure, with the liquid from a higher-pressure vessel being 'flashed' into it. Also known as a flash trap.
Flocculate	A group of aggregates or particles in suspension subject to being broken up by normal shaking and stirring and reforming on standing.
Flora	Plants characteristic of a region or special environment.
Fractionation	A process by which a mixed hydrocarbon stream is separated into its constituent components, e.g. a mixed natural gas stream is split into a methane stream, an ethane stream, a propane stream, a butane stream and a liquid stream containing components which are heavier than butane.
Fugitive Emissions	Substances that escape to air from sources not associated with a specific process e.g. leaks from equipment; dust blown from stockpiles.
Full Containment Tank	Full containment tanks typically feature a primary liquid containment open-top inner-tank and a concrete outer-tank. The outer-tank provides primary vapour containment and secondary liquid containment. In the unlikely event of a leak, the outer-tank contains the liquid and provides controlled release of the vapour.
Gabion	A wire basket filled with stones, or similar material, and used for erosion control purposes.
Gas Processing Facility (Gorgon Development)	Liquefied Natural Gas plant (for export market) and domestic gas plant (for domestic market).
Genetic Diversity	Measure of the total number of genes within a population.

Glossary	
Term	**Definition**
Genus (Plural Genera)	Taxonomic group containing one or more species.
Geotechnical	Relating to the (Gorgon Joint Venturers') engineering study of subsurface soils; involves specialised drilling or sampling for soil analysis and testing.
Gorgon Joint Venturers (Joint Venturers)	Chevron Australia Pty Ltd, Texaco Australia Pty Ltd, Shell Development Australia Pty Ltd, Mobil Australia Resources Company Pty Ltd. Chevron is the operator and proponent of the proposed Gorgon Development on behalf of these companies.
Gorgon Wider Study Area	Study area of approximately 1683 ha surrounding the proposed gas processing facility, administration building, and construction village.
Greenhouse Gas Intensity	A measure of the greenhouse gas emissions emitted in order to produce a unit of product. In this Draft EIS/ERMP, greenhouse intensity is stated as tonnes of carbon dioxide equivalents (CO_2e) per tonne of LNG produced. Note: this metric generally does not include greenhouse gas emissions related to gas production, such as those from offshore gas production platforms.
Gross Domestic Product	The total money value of all final goods and services produced in the national economy of a one-year period.
Ground Level Concentration	Measured or estimated concentrations of a pollutant at ground level, estimated values are derived from pollutant dispersion models.
Groundwater	Underground water contained within a saturated zone or rock.
Habitat	The place or type of site in which an organism occurs naturally.
Habitat Heterogeneity	Diversity of habitats within an area.
Hazard (risk assessment context)	A source of potential harm, or a situation with a potential to cause loss or adverse effect.
HAZOP	A Hazard and Operability Study is a formal process to identify hazards, quantify their impact, and analyse problems associated with a given process.
Heterotrophy	The process where existing organic molecules are used by an organism for its energy needs. All organic constituents in the organism are derived from pre-formed organic molecules.
Hydrate	An ice-like material which is comprised of water and hydrocarbons. It forms at high pressures and low temperatures.
Hydrostatic Testing (or Hydrotesting)	The testing of piping or tubing by filling with water and pressurising to test for integrity.
Ichthyofauna	Fish life of an area.
Incursion (quarantine context)	The discovery on Barrow Island of a live, non-indigenous species.
Infauna	Aquatic animals that live in the bottom sediment of a body of water.
Infection (quarantine context)	The contamination at any step in an exposure pathway of cargoes, vessels or people by non-indigenous species. The likelihood is estimated by independent technical experts in risk assessment workshops.
Insurance	A risk management strategy which is implemented to protect against possible impacts associated with the proposed Development (e.g. translocation).
Intelligent Pig	An electronic device inserted periodically into a pipeline to clean and check its integrity. The term 'intelligent' refers to it containing electronics which can accurately detect, size, and locate corrosion or any other anomalies in pipelines.
Internesting	Interval between individual turtle nesting events when a new clutch of eggs is being formed inside the female.
Intercellular Microalgae	Microscopic algae that live within the cells of other organisms.
Intertidal	The area between the high and low water marks.

Glossary	
Term	**Definition**
Introduced species Note: 'Introduced' has the same meaning herein as 'alien', 'invasive', 'exotic' and 'pest'	Any species of plant, animal or micro-organism not indigenous to Barrow Island and marine environs whose presence there is due to intentional or accidental introduction as a result of human activity. Notes: (i) Includes individuals from genetically-distinct populations of the same species that occur on Barrow Island (see definition of 'species'). (ii) Includes species introduced to Australia as a result of human activity (e.g. buffel grass) that may arrive on Barrow Island by natural means. (iii) Does not include the natural turnover of species between Barrow Island and mainland Australia, where some indigenous species may invade and others become locally extinct.
Introduction (quarantine context)	The arrival of non-indigenous species at Barrow Island via a pathway (e.g. cargo, vessels, personnel). Introduction is an outcome of infection at steps along a pathway.
Joint Risk (spill context)	The overall risk of exposure if a hydrocarbon release occurs and is a product of the 'primary' and 'secondary' risks. It is the likelihood that if a release occurs, it will reach an area of potential significance.
Karst	A region composed of limestone or dolomite and characterised by underground drainage systems, sinkholes and gorges.
L_{90} or L_{A90}	The ambient (or existing background) noise level present 90% of the time.
Lifecycle Assessment	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its functional life.
Likelihood (risk assessment context)	Used as a qualitative description of probability or frequency of occurrence.
Liquid Knockout Stream	A gas stream containing a mist of liquids that can be separated in a vessel to make a gas stream without liquid droplets; and a liquid stream without gas bubbles. This is the liquid stream from such a separation which is common place upstream of fuel gas consumers and compressors which cannot be contaminated with liquid droplets.
Lithophagid	Marine bivalve mollusc which lives attached to solid objects, particularly in the intertidal zone.
Littoral Intertidal	Area periodically inundated and exposed during maximum tidal range.
Locus	The place at which a particular gene resides on DNA or a genetic map.
Macroalgae	Large algae commonly referred to as 'seaweed'.
Macrophyte	Broad-leafed aquatic plants visible to the naked eye. A term used to distinguish larger aquatic plants from microscopic algae.
Mangal	A mangrove forest.
Marine Nature Reserves	Marine Nature Reserves are set aside for the conservation and restoration of the natural environment, the protection care and study of indigenous flora and fauna, and the preservation of any feature of archaeological, historic or scientific interest. Only low-impact recreation may be permitted and this only providing it does not adversely affect ecosystems.
Marine Parks	Marine Parks allow for recreation that is consistent with conservation and restoration of the natural environment, the protection of indigenous flora and fauna and the preservation of any feature of archaeological, historic or scientific interest.
Meiofauna	Fauna in the size range of 50 µm to 500 µm.
Melitid	Amphipod crustacean belonging to the family Melitidae.
Mesocavern	Includes all cavities in rock that are smaller than 20 cm in diameter and larger than 0.1 cm in diameter. Not large enough to be considered a cave.
Migratory Species (EPBC Act)	The entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries (Bonn Convention).
Mitigation Measures	Action(s) taken to minimise or lessen impact of activity on the environment or surrounding communities.

Glossary	
Term	**Definition**
Moribund Organisms	Organisms that have died.
Multiplier Effect	Analysis of national economies often uses 'multipliers' to describe the structural relationships between demand for goods and/or services and the associated impacts on industry output, employment, income and imports. Some industries are more labour intensive than others, just as some produce higher income jobs, others need more imports as inputs to production, and others generate more tax revenue. The same value of demand will have different effects in different industries. The use of multipliers can describe the dynamic nature of relationships between sectors and is used to predict how changes in demand will affect the overall economy, a particular commodity or sector of the economy. Multipliers can be created to show direct or 'first round' effects and indirect or 'second round' effects of increased demand. First round effects show the relationship between demand and the immediate suppliers of that demand. Second round effects include the flow-on effects as those suppliers seek additional inputs to their production in order to service this demand.
National Environment Protection Measure	A legal instrument which sets agreed national objectives for protecting particular aspects of the environment.
Nature Reserves	Nature Reserves are set aside for the conservation and restoration of the natural environment, the protection, care and study of indigenous flora and fauna, and the preservation of any feature of archaeological, historic or scientific interest. Only low-impact recreation may be permitted, and providing that it does not adversely affect ecosystems (Western Australian Department of Conservation and Land Management (CALM)). Class 'A' is used where there is a perceived need for the highest form of protection.
Net Conservation Benefits	Means demonstrable and sustainable additions to, or improvements in, biodiversity conservation values of Western Australia targeting, where possible, the biodiversity conservation values affected or occurring in similar bioregions to Barrow Island.
NO_x	NO_x is the generic term for a group of reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colourless and odourless. However, one common pollutant, nitrogen dioxide (NO_2) along with particles in the air can often be seen as a reddish-brown layer over many urban areas. Nitrogen oxides form when fuel is burned at high temperatures, as in a combustion process. The primary sources of NO_x are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.
Octocorals	Soft corals, sea pens and sea fans. Distinguished by polyps having eight branched tentacles.
Offsets	Actions taken outside the Development area to 'compensate' for environmental impacts within the Development site that relate directly to the conservation values affected by the Development.
Oniscid	Isopod crustacean belonging to the family Oniscideae.
Ozone-Depleting Substance(s) (ODS)	A compound that contributes to stratospheric ozone depletion. ODS include CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride and methyl chloroform. Generally very stable in the troposphere and only degrade under intense ultraviolet light in the stratosphere. When ODS break down, they release chlorine or bromine atoms, which then deplete ozone.
Pathway	A route of exposure which might enable non-indigenous species to be introduced to a native environment outside of their natural range.
Pelagic	Relating to the open water in the upper and middle depths of the sea.
Permeability	Capacity of a material to transmit fluids.
Phaeophytes	Brown seaweed: a marine alga that has chlorophyll masked by brown pigment.
Pig	A tool inserted into a pipeline and carried by the gas flow for cleaning or integrity inspection.
Population	A geographically or socially distinct group of interacting organisms of the same species that occupy a definable area.
Post-border (quarantine context)	Quarantine management activities which occur after cargoes, vessels or people have passed the point of entry to Barrow Island. Post-border activities include monitoring, response and contingencies to detect and eradicate any non-indigenous species that are accidentally introduced to Barrow Island.

Glossary	
Term	**Definition**
Pre-border (quarantine context)	Quarantine activities and barriers which occur prior to the arrival of cargoes, vessels or people at the Barrow Island border. Pre-border quarantine barriers are pathway specific.
Primary Risk (spill context)	The potential of an accidental hydrocarbon release occurring from a pipeline, refuelling accident or a marine vessel collision or grounding.
Priority Flora Species	Priority Species as listed by the Western Australian Department of Conservation and Land Management (CALM).
Protozoan	Single-celled organisms in the Kingdom Protista.
Pupillid Species	Species of snails within the family Pupillidae.
Quarantine Incident	Any event that results in, or has the potential to result in, an incursion.
Quarantine Management System	A set of measures designed to prevent the introduction and/or the establishment of introduced species.
	These measures address the guidelines of ISO 14001 for environmental management systems.
RAMSAR Convention	The Convention on Wetlands of International Importance, especially as Waterfowl Habitat.
Rare Flora	Protected species under the *Wildlife Conservation Act 1950* (WA) that are considered to be in danger of extinction, rare or otherwise in need of special protection.
Receptor (risk assessment context)	An ecological entity exposed to a stressor. For the purposes of assessing and managing quarantine risk, any species, community or habitat which may respond to, or be vulnerable to the introduction of an introduced species.
Reservoir CO_2	Carbon dioxide that occurs naturally within a natural gas reservoir.
Resident (species)	A permanent, non-migratory species.
Residual Risk (risk assessment context)	The remaining level of risk after management/treatment measures have been taken into account.
Reverse Osmosis	Water purified by forcing it, under pressure, through a membrane which is impermeable to impurities (salt).
Risk Analysis	A systematic use of available information to determine how often specified events may occur (likelihood) and the magnitude of their consequences.
Risk	The chance of something happening that will have an impact on objectives. Risk is measured in terms of 'consequence' and 'likelihood'. Consequence refers to the outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain. There may be a range of possible outcomes associated with an event. Likelihood is a qualitative description of probability or frequency.
Risk Assessment	The overall process of risk analysis and risk evaluation.
Risk Identification	The process of determining what can happen, why and how. This definition from AS/NZS 4360 is considered the same as 'hazard identification' in other references.
Risk Management	The culture, processes and structures that are directed towards effective management of potential opportunities and adverse effects.
Samphire Flats	An area of land generally in saline conditions (salt pans or areas near the ocean) that contain succulent species of plants which are adapted to/able to tolerate the saline conditions.
Sand Cay	Low sandy island.
Scleractinian	Stony coral.
Secondary Risk (spill context)	The probability of any released hydrocarbon reaching a shoreline or environmentally sensitive area.
Secure Population	A population of a species that currently is not threatened.
Short Range Endemics	Taxonomic groups of invertebrates with naturally small distributions (less than 10 000 km^2).
Single Containment Tank	Single containment tanks typically feature a primary liquid containment open-top inner-tank, a carbon steel primary vapour containing outer tank and an earthen dike for secondary liquid containment.

Glossary	
Term	**Definition**
Slugcatcher	A vessel or series of pipes designed to collect and separate liquids from gas. It is especially important in pipelines where a wave of liquid could damage downstream equipment; such a wave is also called a slug.
Social Characteristics	Social characteristics are those that reflect the demographic, cultural, health, recreational, heritage, visual and lifestyle values and attributes.
Stabilised	A term often used in relation to condensate, where the lighter components have been removed from the liquid stream such that they do not evaporate.
Stereotropism	See Thigmotropism
Stressor (risk assessment context)	A physical, chemical or biological entity that induces an adverse response.
Stygobites	Obligate groundwater-dwelling fauna.
Stygofauna	Aquatic subterranean fauna that inhabit cavities and interstices (small or narrow spaces) in groundwater-filled karst.
Sublittoral	The area below datum, or below the littoral (intertidal) zone.
Subsea Tree	A subsea system of valves and fittings assembled on the sea bed above the gas well to control the flow of hydrocarbons and other fluids.
Supralittoral	Relating to the part above the littoral zone where sea spray dominates the air and where ocean tides do not normally reach.
Supratidal Zone	The tidal zone that is infrequently inundated.
Sustainable Development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Swale	Linear depression caused by wind erosion.
Taxon/Taxa	Any of the groups into which living organisms are formally classified.
Thalli	Most marine red algae have soft and delicate bodies, or thalli (pl.). A flattened body is referred to as a thallus. Coralline algae have thalli that become strongly calcified and contribute significantly to the growth of coral reefs in tropical seas.
Thigmotactism	The tendency of many small organisms to be attracted to objects.
Thigmotropism	Directional growth in response to the stimulus of direct contact.
Threatened Species (EPBC Act)	A species is considered 'Threatened' if it falls under one of the following categories: extinct, extinct in the wild, critically endangered, endangered, vulnerable, or conservation significant.
Tortuosity (CO_2 injection context)	A measure of how complex the migration path (in this case the migration path for the injected CO_2) is through a particular reservoir: the more complex the migration path, the greater the ability for the CO_2 to become trapped.
Troglofauna	Terrestrial subterranean fauna that inhabit air-filled caves, cavities or interstices in the karst above the watertable.
Umbilical Bundle	In subsea applications, a group of electric cables, hoses, and tubes, either on their own or in combination with each other, cabled together for flexibility and over-sheathed and/or armoured for mechanical strength.
Uncertainty (risk assessment context)	A lack of knowledge arising from changes that are difficult to predict or events whose likelihood and consequences cannot be predicted accurately.
Vagrant (species)	Individuals of a species which, by natural means, move from one geographical region to another outside their usual range, or away from usual migratory routes, and which do not establish a population in the new region.
Vegetation Community	A distinct group of plants that grow in a given area, at a given time.
Vermiform	Worm-type body organisation.
Visual Adsorption Capability	A measure of the relative ability of a landscape character type to absorb visual change.

Glossary

Term	Definition
Voucher Specimen	Any specimen, consisting of an individual animal, or part of an animal, that serves as a basis of study and is retained as a reference.
Vulnerable Species (EPBC Act)	A native species is considered 'Vulnerable' if it is not critically endangered or endangered and it is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with prescribed EPBC Act criteria.
World-class	State-of-the-art processes, facilities or methods of operation.
World Health Organisation	United Nations specialised agency for health established in 1948. WHO's objective, as set out in its Constitution, is the attainment by all peoples of the highest possible level of health. Health is defined in WHO's Constitution as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.
Zooxanthellae	A form of algae that lives symbiotically in the tissue of corals and other animals and provides some of the coral's food supply by photosynthesis.

Unit Conversion Factors

Property	From	To	Multiply By
Mass	kg	lb	2.2046
	Tonne (metric)	UK (ton)	0.9842
Length	m	ft	3.2808
	mm	in	0.03937
Area	m^2	ft^2	10.7639
	mm^2	in^2	0.001550
	hectare	acre	2.4710
Volume	m^3	ft^3	35.3147
	m^3	BBL	6.29
	litre	gal (US)	0.26417
Molar	m^3(st)	nm^3	0.946
	nm^3	scf	37.3
	kg-mole	nm^3	22.4
	kg-mole	scf	836.6
Flow	kg-mole/hr	std ft^3/hr (60ºF, 14.696 psi)	836.6
	m^3/hr	BBL/day	151
	kg/sec	tonne/day	86.4
Force	kN	UK ton force	0.10036
Pressure	kPa	bar	0.010
	bar	psi	14.504
	kPa	psi	0.14504
Energy	kJ	BTU	0.94782
Power	kW	hp	1.3410
Temperature	ºC	ºF	1.8 + 32
Heating Value	MJ/nm^3	BTU/scf	25.4
Time	second	hour	3600
	hour	day	24.0
	day	year	365.25

Acronyms & Abbreviations

AAD	Australian Antarctic Division
ABARE	Australian Bureau of Agriculture and Resource Economics
ABS	Australian Bureau of Statistics
AE	Access Economics
AEC/NHMRC	Australian Environment Council/National Health and Medical Research Council
AGA	Australian Gas Association
AGO	Australian Greenhouse Office
AHD	Australian Height Datum
AIMS	Australian Institute of Marine Science
AIP	Australian Industry Participation
AIPP	Australian Industry Participation Policy
ALARP	As Low As Reasonably Practicable
ALOP	Appropriate Level of Protection
AMC	Australian Marine Complex
a-MDEA	Accelerated-Methyl Diethanolamine
AMEEF	Australian Minerals and Energy Environment Foundation
AMSA	Australian Marine Science Association
AMSA	Australian Maritime Safety Authority
ANZECC/ARMANZ	Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand
APCI	Air Products and Chemicals, Inc.
APCRC	Australian Petroleum Co-operative Research Centre
APIA	Australian Pipeline Industry Association
APPEA	Australian Petroleum Production and Exploration Association
AQIS	Australian Quarantine Inspection Service
AS	Australian Standards
ASBU	Australasia Strategic Business Unit (Chevron Australia)
AS/NZS	Australian/New Zealand Standard
ATSIC	Aboriginal and Torres Strait Islander Commission
AUSLIG	Australian Land Information Group (now called GeoScience Australia)
ABWMAC	Australian Ballast Water Management Advisory Council
$BaSO_4$	Barium Sulphate
bbl	Barrel
BEC	Business Enterprise Centre (Karratha)
BICC	Barrow Island Coordination Council
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOD	Biological Oxygen Demand
BOP	Blow-out Preventer
BP	Before Present (1950)
Bpd	Barrels per day
BPP	Benthic Primary Producer
BPPH	Benthic Primary Producer Habitats
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
BWDSS	Ballast Water Decision Support System
C	Celsius
$CaCO_3$	Calcium Carbonate

CALM	Department of Conservation Land Management (WA)
CAMBA	China Australia Migratory Birds Agreement
CAPEX	Capital Expenditure
CASA	Civil Aviation Safety Authority
CEMP	Construction Environmental Management Plan
CH_4	Methane
CHMP	Cultural Heritage Management Plan
CIEP	Chevron International Exploration and Production
CNG	Compressed Natural Gas
CNOOC	China National Offshore Oil Company
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO2CRC	Cooperative Research Centre for Greenhouse Gas Technologies
CO_2e	Carbon Dioxide Equivalents
COD	Chemical Oxygen Demand
CPDEP	Chevron Project Development and Execution Process
CPI	Consumer Price Index
CPUE	Catch Per Unit Effort
CRA	Corrosion Resistant Alloy
CRIMP	CSIRO Centre for Research on Introduced Marine Pests
CRM	Cultural Resource Management
CS	Carbon Steel
CS1	Compressor Station 1
CSD	Cutter Suction Dredge
CSIRO	Commonwealth Scientific Industrial Research Organisation
CTGG (now CGG)	ChevronTexaco Global Gas (now Chevron Global Gas)
CTOP (now CIEP)	ChevronTexaco Overseas Petroleum
Cwlth	Commonwealth (jurisdiction for legislation)
dB (A)	decibel
dB re μPa	Sound pressure expressed as decibels relative to one micro pascal
DBNGP	Dampier to Bunbury Natural Gas Pipeline
DEH	Department of the Environment and Heritage (Cwlth)
DEP	Department of Environmental Protection (WA) (now DoE – see below)
DIA	Department of Indigenous Affairs (WA)
DLN	Dry, Low NOx (burners)
DMA	Decision Making Authority
DME	Dimethyl/Ether
DNA	Deoxyribonucleic acid
DNV	*Det Norske Veritas*
DoE	Department of Environment (WA)
DoIR	Department of Industry and Resources (WA)
DOMGAS	Domestic gas
DP	Dynamic Positioning
DSDMP	Dredging and Spoil Disposal Management Plan
E	East
EA	Environment Australia
EFDC	Environmental Fluid Dynamics Code

EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EIS/ERMP	Environmental Impact Statement/Environmental Review and Management Programme
EMIP	Environmental Management Implementation Plan
EMP	Environmental Management Plan
EMS	Environmental Management System
ENM	Environmental Noise Model
EP	Environmental Plan
EP Act	*Environmental Protection Act 1986* (WA)
EP(SD) Act	*Environmental Protection (Sea Dumping) Act 1982* (Cwlth)
EPA	Environmental Protection Authority (WA)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
EPCM	Employment Procurement Contract Management
ERMP	Environmental Review and Management Programme
ESE Review	Environmental, Social and Economic Review
ESU	Evolutionary Significant Unit
FAO	Food and Agriculture Organisation
FEED	Front-End Engineering and Design
FESA	Fire and Emergency Services Authority of Western Australia
FIFO	Fly-in Fly-out
FTE	Full Time Equivalent
GCEP	Global Climate and Energy Project
GDP	Gross Domestic Product
GEODISC	Australian Petroleum Co-operative Research Centre Research Program on the Geological Disposal of Carbon Dioxide
GES	Generator Efficiency Standards
GHG	Greenhouse Gas
GIS	Geographic Information System
GJ	Gigajoule
GJV	Gorgon Joint Venturers
GPF	Gas Processing Facility
GPS	Global Positioning System
GRE	Glass Reinforced Epoxy
GSP	Gross State Product
GST	Goods and Services Tax (Australia)
GTL	Gas-to-Liquids
H_2S	Hydrogen sulphide
ha	Hectare
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HDD	Horizontal Directional Drilling
HES	Health, Environment and Safety
HESMS	Health, Environment and Safety Management System
HIR	Hydrate Inhibitor Recovery
hp	Horsepower
HVAC	Heating, Ventilation and Air Conditioning

Hz	Hertz
ICN WA	Industry Capability Network (Western Australia)
IFC	International Finance Corporation
IFO	Incident Free Operations
ILUA	Indigenous Land Use Agreement
IMCRA	Interim Marine and Coastal Regionalisation for Australia
IMEA	Infection Modes and Effects Analysis
IMO	International Maritime Organisation
IR	Industrial Relations
ISO	International Standardisation Organisation
ISRC	Independent Scientific Review Committee
ISSG	Species Survival Commission's Invasive Species Specialist Group
IUCN	International Union for the Conservation of Nature
JAMBA	Japan Australia Migratory Birds Agreement
JHA	Job Hazard Analysis
JP	Justice of the Peace
JT	Joule-Thompson
KDCCI	Karratha and Districts Chamber of Commerce and Industry
kg	Kilogram
kg/m^3	Kilogram per cubic metre
kHz	Kilohertz
km	Kilometre
kPa	Kilopascal
kW	Kilowatt
L	Litre
LEDs	Light Emitting Diode(s)
LGA	Local Government Authority
LNG	Liquefied Natural Gas
LOC	Loss of Containment
LPG	Liquefied Petroleum Gas
m	Metre
m^3	Cubic metre
m^3 (st)/s	Cubic metre per second (at standard conditions of pressure and temperature)
MARPOL	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MCHE	Main Cryogenic Heat Exchanger
MDEA	Methyldiethanolamine
MEG	Mono Ethylene Glycol
MEPA	Mobil Exploration and Producing Australia Pty Ltd
mg/L	Milligrams per litre
M	Earthquake magnitude on the Richter scale
ML	MegaLitre
MLA	Member of Legislative Assembly, Western Australian Parliament
MLC	Member of Legislative Council, Western Australian Parliament
mm	Millimetre
MMscfd	Millions of standard cubic feet per day (gas)

Mm^3	Million metres cubed
MOF	Materials Offloading Facility
Mol %	Molar percent (for a gas equivalent to volume percent)
MOU	Memorandum of Understanding
MP	Member of Parliament
MPa	Megapascal
MPR	Department of Mineral and Petroleum Resources of Western Australia, now the Department of Industry and Resources (DoIR)
MPRSWG	Marine Parks and Reserves Selection Working Group
MRET	Mandatory Renewable Energy Target
ms	manuscript name (when appears after a species name)
MSDS	Material Safety Data Sheets
MSP	Management System Process
MSV	Multiple Support Vessel
MTPA	Million Tonnes per Annum
MW	Mega Watt
N	North
N	Nitrogen Compounds
N/A	Not Applicable
N_2	Nitrogen
N_2O	Nitrous Oxide
NAAQS	National Ambient Air Quality Standards (USEPA)
NaCl	Sodium Chloride
NADF	Non-Aqueous Drilling Fluids
NATPLAN	National Plan to Combat Oil Pollution of the Sea by Oil and Other Noxious and Hazardous Substances
NAWC	North American West Coast
NCB	Net Conservation Benefits
NEPM	National Environment Protection Measurement
NES	National Environmental Significance
NGLs	Natural Gas Liquids
NGO	Non-government Organisation
nm	nanometre
NIMPIS	National Introduced Marine Pest Information System
NIS	Non-Indigenous Species
NOHSC	National Occupational Health and Safety Commission
NOPSA	National Offshore Petroleum Safety Authority
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
NPC	Net Present Cost
NPV	Net Present Value
NSW	New South Wales
NWS	North West Shelf
NWSJV	North West Shelf Joint Venture
O_2	Oxygen
O_3	Ozone
OD	Outside Diameter (pipe)

ODS	Ozone Depleting Substances
OE	Operational Excellence
OEMP	Operational Environmental Management Plan
OEMS	Operational Excellence Management System
OiW	Oil in Water
OPEX	Operating Expenditure
OPMF	Onslow Prawn Managed Fishery
OSCP	Oil Spill Contingency Plan
OSH	Occupational Safety and Health
PBA	Preliminary Barrier Analysis
PDC	Pilbara Development Commission
pH	A measure of acidity (7 is neutral), 1 is very acidic and 13 is very alkaline)
PHA	Preliminary Hazard Analysis
PHE	Preliminary Hazard Evaluation
PJ	Petajoule
PLEM	Pipeline End Manifold
PM10	Particulate Matter (less than 10 microns in diameter)
PNTS	Pilbara Native Title Service
ppb	parts per billion
ppm	parts per million
ppmv	Parts Per Million by Volume
PRPP	Pilbara Regional Priority Plan
PRRT	Petroleum Resource Rent Tax
Psi	Pounds per Square Inch (pressure)
P(SL)A	*Petroleum (Submerged Lands) Act 1967*
Q	Quarter of an Australian Financial Year
QEP	Quarantine Expert Panel
QHAZ	Quarantine Hazard
QMP	Quarantine Management Plan
QMS	Quarantine Management System
QRA	Quarantine Risk Assessment
R&D	Research and Development
RCEP	Royal Commission on Environmental Pollution
RECs	Renewable Energy Certificates
RHIB	Rigid Hull Inflatable Boat
RISC	Resource Investment Strategy Consultants
ROV	Remotely Operated Vehicle
S	South
SACS	Saline Aquifer CO_2 Storage Project
SAP	Sample Analysis Plan
SBM	Single Buoy Mooring
SCC/SCFA	Joint Standing Committee on Conservation/Standing Committee on Fisheries and Aquaculture
SCP	Stakeholder Consultation Program
SCR	Selective Catalytic Reduction
SCSSV	Surface Controlled Subsurface Safety Valve
SEIA	Social and Economic Impact Assessment

SES	Social, Economic and Strategic
SES	State Emergency Service
SI	*Systeme Internationale* (International System of Units)
SIAC	Standing Interagency Committee of Chief Executive Officers
SIMP	Social Impact Management Plan
SO_2	Sulphur Dioxide
SO_x	Sulphur Oxides
SPA	Sales and Purchase Agreement
$SrSO_4$	Strontium Sulphate
SSV	Subsurface Safety Valve
STP	Standard Temperature and Pressure
SWATH	Small Waterplane Area Twin Hull
TAFE	Technical and Further Education
TBC	To Be Confirmed
TBD	To Be Determined
TBT	Tributyltin
Tcf	Trillion cubic feet
TDS	Total Dissolved Solids
TECs	Threatened Ecological Communities
TEG	Triethylene glycol
TJ	Terajoule
Tm^3	Trillion cubic metres
tpa	tonnes per annum
TPS	Town Planning Scheme (Shire of Roebourne)
TSHD	Trailer Suction Hopper Dredges
TSS	Total Suspended Solids
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
USA (the US)	United States of America (the United States)
USDA	US Department of Agriculture
USEPA	United States Environmental Protection Agency
VIP	Value Improving Practice (Chevron)
VOCs	Volatile Organic Compounds
Vol %	Volume percent
VRS	Vendor Registration System (supply-base)
W	West
W	Watt
WA	Western Australia
WAERA	Western Australian Energy Research Alliance
WAM	Western Australian Museum
WAPET	West Australian Petroleum Proprietary Limited
WCED	World Commission on Environment and Development
WHO	World Health Organisation
WSF	Water Soluble Fraction
XOV	Cross Over Value

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General Appendix A

Policy 530 – Protecting People and the Environment

It is the policy of Chevron Corporation to protect the safety and health of people and the environment.

Scope

Consistent with our Corporate values and our goal to be recognized and admired for safety, health, and environmental excellence, we conduct our business worldwide in a socially responsible and ethical manner.

Leadership at all levels will foster a culture for HES excellence by assuring alignment of vision, expectations, and behavior drivers, including accountability. Systematic management of HES matters is required to achieve and sustain excellence in all of our operations.

We will assess and manage risks to our employees, contractors, the public and the environment within the framework of the following principles and expectations:

Safe & Incident-Free Operations – Design, construct, operate, maintain and ultimately decommission our assets to prevent injury, illness and incidents.

Advocacy – Work ethically and constructively to influence proposed laws and regulations, and the debate on emerging issues.

Compliance Assurance – Verify conformity with company policy and government regulations. Ensure that employees and contractors understand their safety, health and environmental responsibilities.

Conservation – Conserve company and natural resources by continually improving our processes and measuring our progress.

Product Stewardship – Manage potential risks of our products with everyone involved throughout the products' life cycles.

Pollution Prevention – Continually improve our processes to minimize pollution and waste.

Property Transfer – Assess and manage our environmental liabilities prior to any property transaction.

Community Outreach – Reach out to the community and engage in open dialogue to build trust.

Emergency Management – Prevention is a first priority, but be prepared for any emergency and mitigate any incident quickly and effectively.

These expectations, and our standard approach to managing them, are further explained in the documentation for the Operational Excellence Management System (OEMS).

General Appendix B

Key Commitments

General			
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
1.1	The Gorgon Joint Venturers will implement an Environmental Management System (EMS), which is consistent with the recognised international standard AS/NZS ISO 14001:2004, Environmental Management Systems – Specification with Guidance for Use (ISO 14001).	Ongoing	
1.2	A series of Environmental Management Plans (EMPs) will be developed and documented through a systematic and consultative process according to an agreed timetable with the EPA and DEH, taking into consideration comments on the Draft EIS/ERMP and recommendations from relevant agencies.	Prior to construction of the relevant Development component	Various DMAs
1.3	The Gorgon Joint Venturers will share the use of key infrastructure and services on Barrow Island, whether a part of the existing Barrow Island operation or developed as part of the Gorgon Development in accordance with the Barrow Island State Agreement.	Ongoing	
1.4	Further environmental surveys will be undertaken prior to the commencement of construction to finalise selection of alternatives or preferred routes and/or locations and the survey results provided to CALM. These environmental surveys will include: • the flora of the proposed optical fibre cable route • flora and fauna in the CO_2 injection seismic monitoring area • vegetation communities containing *Acacia synchronicia* to the north of the existing airstrip • avifauna along the proposed domestic gas pipeline route • the distribution of shorebird habitats near the mainland shore crossings • the inter-nesting or hibernating flatback turtles at Town Point.	Prior to construction of the relevant Development component	CALM
1.5	A detailed Decommissioning Assessment and Plan reflecting industry best practice, including completion criteria, will be prepared and submitted 6 months prior to decommissioning to identify the best overall outcome.	At least 6 months prior to decommissioning	Various DMAs
1.6	Once gas processing operations have ended, the facility will be decommissioned and the equipment removed from site; and the land rehabilitated to a condition which is consistent with the surrounding environment.	Decommissioning	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Clearing & Earthworks

Environmental Management Objective/s:

- To maintain the abundance, diversity, geographic distribution and productivity of flora and fauna through the avoidance or management of adverse impacts and improvement in knowledge.
- To protect EPBC Act listed threatened species, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950*.
- To protect evolutionary significant units, including genetic races on Barrow Island.

Commitment Number	Commitment (Action)	Timing	Advice From*
2.1	Gas processing facilities, associated infrastructure and the CO_2 monitoring grid and injection wells will be located to preferentially use previously disturbed areas and limit the disturbance to that required for safe construction and operation.	During design, construction and operations	CALM, DoIR
2.2	Further survey work during the detailed engineering phase will be undertaken to assist with final alignments of the CO_2 monitoring grid and preparation of Environmental Management Plans, which will be undertaken to the satisfaction of the EPA and DEH.	During design and prior to construction	
2.3	Disturbance to important fauna habitats, listed fauna species, restricted flora and vegetation communities will be avoided where practicable.	During design, construction and operations	CALM
2.4	Significant fauna, such as bettongs, will be translocated from the Development area to alternative locations on Barrow Island in consultation with CALM.	During construction	CALM
2.5	No new quarries or borrow pits outside of the construction site will be created to support the Development on Barrow Island.	Construction and operations	
2.6	Site specific rehabilitation procedures including completion criteria will be developed and implemented in consultation with the relevant authorities for areas that are no longer required for operations or future works.	Prior to rehabilitation	CALM, DoIR
2.7	Rehabilitation of works sites and access roads will be undertaken to a condition consistent with the surrounding landscape.	Ongoing	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Fire & Emergency Response

Environmental Management Objectives:

- To ensure that there is no adverse effect on environment values or the health, welfare and amenity of people and land uses.
- To maintain the abundance, diversity, geographic distribution and productivity of flora and fauna through the avoidance or management of adverse impacts and improvement in knowledge.
- To protect EPBC Act listed threatened species, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950*.
- To protect evolutionary significant units, including genetic races on Barrow Island.

Commitment Number	Commitment (Action)	Timing	Advice From*
3.1	An Emergency Management Plan that includes integrated safety and emergency response systems will be prepared and implemented in consultation with the relevant authorities and neighbouring industry participants.	Prior to construction of the relevant Development component and then ongoing	FESA, CALM and local Shire
3.2	In the event that a fire is started as a result of the Development, then immediate corrective action will be taken to extinguish or contain the fire and its occurrence will be reported to relevant authorities.	Ongoing	CALM
3.3	The Gorgon Joint Venturers will participate in a research program, managed by CALM, on the ecological effects of fire regimes on Barrow Island.	Ongoing	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

CO_2 Injection

Environmental Management Objective:

- To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.

Commitment Number	Commitment (Action)	Timing	Advice From*
4.1	The Gorgon Joint Venturers will significantly reduce Development CO_2 emissions by injecting the reservoir CO_2 removed during the gas processing operations into the Dupuy Formation, provided it is technically feasible and not cost prohibitive.	During operations	DoIR
4.2	In the unlikely event that it should prove technically infeasible or cost prohibitive to inject the proposed volume of CO_2, the Gorgon Joint Venturers will consult with government with the intent of maximising the injection of CO_2 within the commercial constraints of the Gorgon Development.	Ongoing	DoIR
4.3	A CO_2 Injection Operations Management Plan will be prepared with the objective of maximising the volume of reservoir CO_2 injected whilst ensuring that the injection does not pose an unacceptable health, safety or environmental risk.	Prior to commissioning	DoIR
4.4	If at any time the Gorgon Joint Venturers consider that the injection of reservoir CO_2 represents an unacceptable risk to the environmental values of Barrow Island, or a safety risk, then the CO_2 injection operation will be suspended until such time as all risks are addressed.	During operations	DoIR
4.5	Appropriate arrangements will be made with the Barrow Island Joint Venture to ensure that all wells in the path of the migrating CO_2 are assessed and if required, worked over such that they are fit for service in a CO_2 environment.	During operations	DoIR
4.6	A CO_2 Monitoring Program will be prepared, implemented and reviewed in consultation with the relevant authorities.	Prior to commissioning and then ongoing	DoIR

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Atmospheric & Greenhouse Gas Emissions

Environmental Management Objective:

- To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.

Commitment Number	Commitment (Action)	Timing	Advice From*
5.1	The Gorgon Joint Venturers undertake to report on and manage greenhouse gas emissions from the Gorgon Development in accordance with the Gorgon Development Greenhouse Gas Management Plan. This plan includes a series of longer term greenhouse gas emission performance targets to be used to guide the further reduction of greenhouse gas emissions.	During operations	
5.2	The Gorgon Joint Venturers will continue to participate in government programs aimed at the voluntary reduction of greenhouse gas emissions.	Ongoing	
5.3	Energy efficiency studies will be undertaken during the detailed engineering and design of the Development.	During design	
5.4	The Development will be designed based on a 'no routine flaring' policy and will incorporate a high efficiency flare to reduce the portion of uncombusted hydrocarbon and particulates to as low as reasonably practicable (ALARP). A small flare is required to be in continuous service for safety and maintenance purposes.	During design and operation	
5.6	The Development will be designed and operated to reduce venting of process hydrocarbons.	Operations	
5.7	A monitoring program of key emission sources and types will be developed and implemented in agreement with the DoE.	Prior to commissioning and during operations	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Liquid, Solid & Hazardous Waste

Environmental Management Objectives:

- To ensure that liquid and solid wastes do not adversely affect groundwater or surface water quality or lead to soil contamination.
- To ensure that hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.
- To ensure that there is no adverse effect on environment values or the health, welfare and amenity of people and land uses.

Commitment Number	Commitment (Action)	Timing	Advice From*
6.1	A Waste Management Plan will be prepared and implemented for hazardous and non-hazardous wastes in consultation with the DoE and will include systems and details for individual waste streams and their disposal.	Prior to construction of the relevant Development component and then ongoing	Local Shire, DoIR
6.2	The Waste Management Plan will be based on the principles of eliminate, reduce, re-use, recycle, treatment and environmentally responsible disposal.	During design, construction and operations	
6.3	Solid waste will not be disposed of on Barrow Island, with the exception of waste concrete where it may be used by the existing oilfield operation.	Ongoing	CALM
6.4	A Hydrotest Water Management Plan will be prepared and implemented.	During design and commissioning	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Leaks & Spills

Environmental Management Objectives:

- To ensure that hydrocarbons and hazardous materials are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.
- To maintain the ecological functions and environmental values of marine benthic habitats and the subtidal and intertidal zones.
- To maintain the ecological function, abundance, species diversity and geographic distribution of mangrove, coral, seagrass and other benthic primary producer communities and their habitats.
- To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated.
- To protect EPBC Act listed threatened, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*

Commitment Number	Commitment (Action)	Timing	Advice From*
7.1	Spills and leaks will be contained, recorded and affected sites remediated.	During construction and operation	CALM, DoIR & Dept of Transport
7.2	Copies of Material Safety Data Sheets (MSDS) for all chemicals will be held on site and all materials managed (handled, stored and disposed of) accordingly.	Ongoing	
7.3	An Oil & Chemical Spill Contingency Plan (OCSCP) including emergency response measures will be prepared, implemented and reviewed in consultation with the relevant authorities.	Prior to construction of the relevant Development component and then ongoing	CALM, DoIR & Dept of Transport
7.4	Spill recovery and cleanup equipment will be provided and maintained at key marine and terrestrial locations as identified in the agreed OCSCP.	Ongoing	
7.5	Navigational exclusion zones will be created around seabed infrastructure to prevent accidental damage to facilities and local pilots will be used to berth ships.	During construction and operations	AMSA, Dept of Transport
7.6	Installed equipment will be designed and operated to prevent spills and leaks through the provision of in-built safeguards such as relief valves, overflow protection, and automatic and manual shut-down systems.	During design, construction and operations	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Noise & Vibration

Environmental Management Objectives:

- To avoid adverse noise and vibration impacts to fauna.
- To ensure that noise impacts emanating from the proposed gas processing facility comply with statutory requirements specified in the *Environmental Protection (Noise) Regulations 1997.*

Commitment Number	Commitment (Action)	Timing	Advice From*
8.1	An Environmental Management Plan for CO_2 monitoring with seismic will be prepared to the satisfaction of the EPA and implemented.	Prior to commencing seismic surveys	CALM, DoIR
8.2	An Environmental Plan for offshore seismic activities will be prepared to the satisfaction of DoIR and implemented.	Prior to commencing offshore seismic surveys	DoIR
8.3	Blasting will be scheduled for daylight hours to avoid activity peaks of nocturnal mammals.	During construction	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Light & Temperature

Environmental Management Objectives:

- To avoid or manage potential impacts from light overspill and shade and comply with acceptable standards.
- To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities.
- To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated.
- To protect EPBC Act listed threatened, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*

Commitment Number	Commitment (Action)	Timing	Advice From*
9.1	The following key lighting strategies will be employed: • The main gas processing facility shall be designed such that no permanently on-lighting is located within 500 m of turtle nesting beaches. • Use red/yellow/orange type of reduced spectrum light, such as sodium vapour as the primary lighting for the facility. • Use shielded white type lights in areas that require inspection during operator rounds and/or regular maintenance. These lights will be switched off when not required.	During design, construction and operation	CALM
9.2	Lighting levels will be reduced to those required for safe working and security; and, in areas where colour definition is not critical for safety or operational purposes, shielded red or mono-chromatic lights will be utilised.	During design, construction and operation	
9.3	Areas where land fauna may come into contact with extreme or hazardous temperatures, will be fenced or selectively cleared in consultation with the CALM to provide a suitable buffer.	During construction and operation	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Physical Disturbance & Interaction (See also – Clearing & Earthworks)

Environmental Management Objectives:

- To protect EPBC Act listed threatened, migratory species and Threatened Ecological Communities (TECs).
- To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950.*
- To maintain the abundance, species diversity, geographic distribution and ecological functions of marine faunal communities and ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated.
- To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge.
- To protect evolutionary significant units, including genetic races on Barrow Island.

Commitment Number	Commitment (Action)	Timing	Advice From*
10.1	A Dredging and Spoil Disposal Management Plan (DSDMP) will be prepared in consultation with the relevant authorities to the satisfaction of EPA and DEH, and implemented.	Prior to commencement of dredging and then ongoing	Marine and Harbours
10.2	To reduce dredge spoil disposal volumes, material will be assessed for use in the construction of the causeway and the MOF.	During construction	
10.3	Shore crossing activities will be managed to reduce impacts during the peak turtle nesting period.	During construction	CALM
10.4	Shore crossing disturbance areas will be rehabilitated to a condition consistent with the surrounding landscape.	During construction	CALM, DoIR
10.5	A Marine Anchoring Management Plan will be prepared and implemented in consultation with the relevant authorities.	Prior to construction of the relevant Development component and then ongoing	CALM, DoIR and Dept of Transport
10.6	Programs will be established to encourage and foster environmental awareness and conservation with the workforce.	Ongoing	

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Key Commitments

Quarantine

Environmental Management Objective:

- To prevent the introduction and establishment of non-indigenous species to Barrow Island and its surrounding waters.

Commitment Number	Commitment (Action)	Timing	Advice From*
11.1	The Gorgon Joint Venturers will develop the Quarantine Management System in consultation with the relevant authorities to the satisfaction of the EPA and DEH, and implement the system.	Prior to construction and then ongoing	CALM
11.2	The Gorgon Joint Venturers will prepare, implement and periodically review specific quarantine management procedures for all pathways.	Ongoing	
11.3	Monitoring and eradication including incident response and reporting will be undertaken in accordance with the agreed Quarantine Management System.	Ongoing	
11.4	An expert Quarantine Advisory Group will be established to provide advice on quarantine management.	Prior to construction	CALM
11.5	Ballast water management practices will be audited by the Gorgon Joint Venturers to verify conformance with domestic and international regulations.	Ongoing	Dept of Transport
11.6	Targeted flora and fauna surveys will be undertaken to determine baseline data that will be used to judge the effectiveness of quarantine barriers.	Prior to construction	CALM

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Cultural Heritage & Native Title

Management Objectives:

- To ensure the cultural and heritage values on and around Barrow Island are not compromised by the Development.
- To ensure that all works are performed in accordance with the *Aboriginal Heritage Act 1972, Heritage of Western Australia Act 1990 and Maritime Archaeology Act 1973.*

Commitment Number	Commitment (Action)	Timing	Advice From*
12.1	Undertake archaeological and ethnographic surveys within the Development area in consultation with the identified Indigenous communities.	Prior to construction of the relevant Development component	DIA
12.2	Prior to construction all proposed ground disturbance areas (including the seabed) will be reviewed for indigenous, historical and maritime cultural heritage evidence.	Prior to construction of the relevant Development component	DIA, WA Museum, Maritime Museum, Heritage Council
12.3	The Development will be managed in accordance with a Cultural Heritage Management Plan, which will be prepared in consultation with the relevant authorities.	Prior to construction of the relevant Development component and during operations	DIA, WA Museum, Maritime Museum, Heritage Council
12.4	The Joint Venturers will undertake consultation and negotiations with indigenous Native Title claimants in relation to mainland activities such as the domestic gas pipeline and optical fibre cable.	Prior to construction of the relevant Development component	DIA, DoIR and Office of NT
12.5	If cultural heritage sites cannot be avoided, the relevant authorities will be consulted and management measures agreed.	Prior to construction of the relevant Development component	

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Key Commitments

Commitment Number	Commitment (Action)	Timing	Advice From*
Social			
Management Objective: • To ensure that there is no adverse effect on the health, welfare and amenity of the workforce or public.			
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
13.1	A Social Impact Management Plan will be prepared in consultation with relevant stakeholders.	Prior to construction	Key stakeholders
13.2	Where necessary, Traffic Management Plans will be prepared in consultation with the relevant authorities prior to the movement of non-standard construction equipment, machinery or vehicles on public roads.	During construction	MRWA, Police and Local Shires
13.3	Significant navigational changes or constraints due to construction and operating conditions will be communicated to mariners and commercial fishing operators.	During construction and operations	Dept of Transport
Health & Safety			
Management Objective: • To ensure that there is no adverse effect on the health, welfare and amenity of the workforce or public.			
Commitment Number	**Commitment (Action)**	**Timing**	**Advice From***
14.1	Comprehensive Safety Management Systems and Plans will be prepared in consultation with the relevant authorities.	Prior to construction of the relevant Development component	DoIR, WorkSafe, and NOPSA
14.2	Emergency evacuation procedures will be established in consultation with the relevant authorities to remove injured personnel off Barrow Island to suitable medical facility.	Prior to construction of the relevant Development component	FESA and local Shire
14.3	Medical personnel will be located on Barrow Island throughout construction and operations.	Ongoing	
14.4	Regular inspections of the Development by company safety professionals will be conducted throughout construction and operations.	Ongoing	DoIR, WorkSafe, and NOPSA
14.5	Appropriate recreational opportunities and facilities will be provided within the construction village.	During construction	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*

Key Commitments

Auditing, Monitoring & Reporting			
Commitment Number	Commitment (Action)	Timing	Advice From*
15.1	A comprehensive Environmental Monitoring Program will be established, implemented and periodically reviewed in consultation with the relevant authorities and will be used to guide ongoing management and corrective action. Specific localised monitoring activities will be included within the EMPs.	Ongoing	CCWA, CALM, DoIR, WA Museum, DIA, Health WA
15.2	An Environmental Audit Program will be established and implemented in consultation with DoE and DEH to determine whether the Development meets environmental objectives, proponent commitments and requirements of the Development's EMS and EMPs. The program will be used to guide ongoing management and corrective action.	Prior to construction of the relevant Development component and then ongoing	
15.3	A Barrow Island land use register will be established and maintained to track all clearing and rehabilitation activities associated with the Development and included in the Annual Environmental Report to authorities.	Prior to construction and then ongoing	
15.4	The status and progress of key environmental issues with be included in the public Annual Environmental Report.	During construction and operations	

** In addition to DoE and DEH, third parties that have particular expertise and/or statutory responsibility relevant to implementing these commitments are included in the column entitled Advice From.*