Technical Appendix A

Framework Environmental Management Plan

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Gorgon Development

Appendix A1: Framework Environmental Management Plan

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1.0 INTRODUCTION

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. Chapter 16 of the Draft EIS/ERMP outlines the key elements of the proposed Gorgon Health, Environment and Safety 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 the Draft EIS/ERMP and will be documented via an integrated series of documents; the first step of which is this Framework Environmental Management Plan (the Framework EMP), as represented in Figure 1.

Figure 1: Phases of EMP Development

This 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). A matrix of activities and components is provided in Attachment 1.

The core of this Framework EMP is the set of environmental protection and management measures to avoid, reduce or mitigate impacts (refer to Section 3).

This document 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of the Draft EIS/ERMP by the public and regulatory agencies, the Framework EMP will be used as a basis for, and be superseded by, the detailed EMP series. These Plans will in turn be used as the basis for the Contractors' Environmental Management Implementation Procedures (EMIPs), as outlined below.

The Joint Venturers will adopt management measures outlined in this Framework EMP to avoid or mitigate environmental impacts. 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 the stated environmental objectives and outcomes will be developed. The Joint Venturers are confident that the Gorgon HES Management System and the Environmental Management Plans and procedures will provide an effective approach for protecting the conservation values of Barrow Island and the proposed Development area.

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 and onshore feed gas pipeline construction). 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 for 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 (including this Appendix) 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 2).

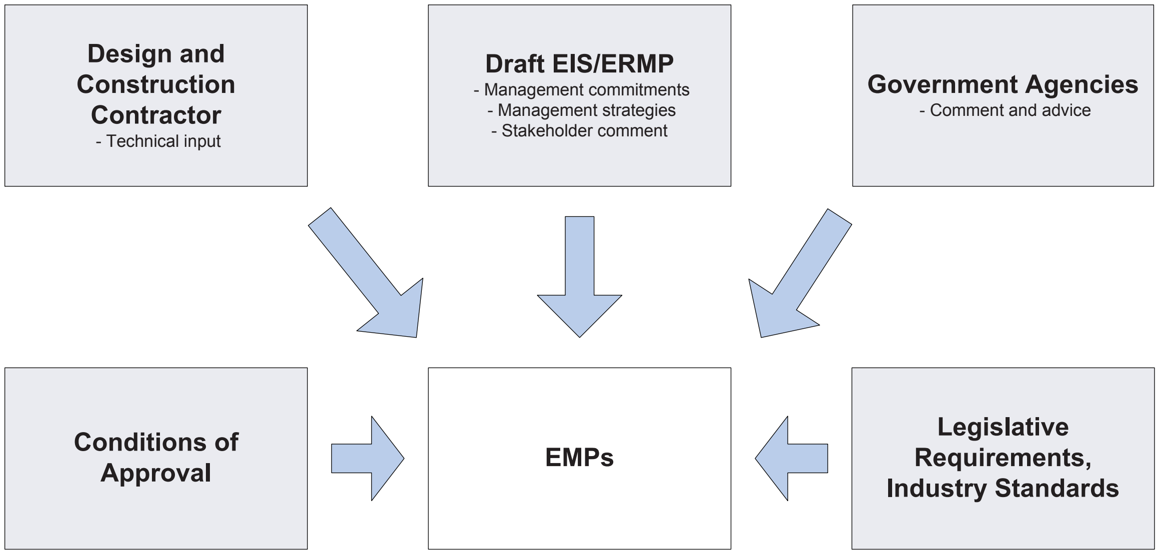

Figure 2: Inputs to Detailed EMPs

Detailed EMPs will cover all Development components. An indicative breakdown of the detailed EMPs is listed in Table 1. The final structure will be determined during the detailed design phase in conjunction with the design and construction contractor, to the satisfaction of the EPA and DEH.

Table 1: Detailed EMP Series

EMP	Title of Detailed EMP Document
1	Upstream Field Infrastructure (Manifolds and Flowlines)
2	Offshore Feed Gas Pipeline
3	Onshore Feed Gas Pipeline
4	Gas Processing Facility, Camp & Associated Infrastructure
5	Port Facilities (Materials Offloading and LNG Jetty)
6	Dredging and Dredge Spoil Disposal
7	Drilling (Offshore)
8	CO2 Injection System (Pipeline and Wells)
9	Domestic Gas Pipeline & Associated Infrastructure
10	Greenhouse Gases
11	Optical Fibre Cable
12	Mainland Supply Base
13	Quarantine Management
14	Waste Management
15	Spill Contingency and Response
16	Cultural Heritage Management

Contractor EMIPs

Environmental Management Implementation Procedures (EMIPs) will be prepared by the design and construction contractors. The EMIPs will be internal project documents that 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.

1.1 Environmental Objectives

This Framework EMP and the subsequent detailed EMP series and contractor EMIPs aim to achieve the environmental, social and economic objectives presented in Chapters 10 to 15 of the Draft EIS/ERMP. These objectives are collated in Boxes 1 and 2.

Box 1: Environmental 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 EPBC Act listed threatened and migratory species • To protect Declared Rare and Priority Flora, consistent with the provisions of the *Wildlife Conservation Act 1950*
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
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

Environmental Factor	Management Objective
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 2: 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

1.2 Staff Resourcing, Competence, Organisation and Reporting Structure

Adequate staffing resources will be committed to prepare and implement the detailed EMPs and monitor and audit the effectiveness of the environmental management and protection procedures. The Gorgon Development Team and the contractors will develop and hire personnel with clearly defined responsibilities and authority levels. Personnel with responsibilities for specific environmental practices will have both the necessary education and training to ensure effective implementation of the work.

A simple and functional organisation and reporting structure will be established that reflects the hierarchy of responsibility for environmental management. This will be documented in the detailed EMPs.

1.3 Induction and Training

All Gorgon Development and contractor personnel will attend a Development orientation and induction presentation prior to commencing work on the site. All orientation and induction will contain HES requirements relevant to the specific development component or activity.

The purpose of the inductions is to ensure that all personnel understand their environmental responsibilities and are fully aware of the management and protection measures required to reduce the potential impact on the environment in the Development area prior to the commencement of construction, commissioning and operations. As part of the induction process, the environmental sensitivities of the Barrow Island and surrounding areas will be described, the environmental aims and objectives explained, and the measures in place to achieve those aims and objectives, will be outlined.

Personnel with environmental-specific responsibilities will have appropriate qualifications and experience and will be adequately trained to ensure effective implementation of the work they have been assigned.

Compliance with HES requirements will be a condition of employment and requirements will be incorporated into job specifications. For contractors, compliance with the detailed EMPs will be part of the contractor selection process and a condition of contracts.

1.4 Continuous Improvement and Adaptive Management

The Gorgon Joint Venturers have adopted an environmental management 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 identifies the continuous improvement process as:

- identifying areas of opportunity for the improvement of the environmental management system which leads to improved environmental performance
- determining the root causes of non-conformities or deficiencies
- developing and implementing a plan or corrective and preventative action to address root causes
- verifying the effectiveness of the corrective and preventative actions
- documenting any changes in management measures resulting from process improvement
- making comparisons with objectives, goals and targets.

Through the process of staff training, site inductions, monitoring, auditing, corrective actions and the inclusion of any new environmental management procedures and initiatives, the detailed EMPs and Contractors' EMIPs will be periodically reviewed and improved to ensure stated performance objectives and standards are achieved. The flexibility of incorporating new information into this process will allow the Gorgon Development to adapt and best achieve world-class environmental performance.

1.5 Management of Change

The Gorgon Joint Venturers have an established and documented Management of Change procedure. This procedure will be applied to the Development concept and engineering design. It will also be applied to the proposed environmental management measures and detailed procedures, to ensure due consideration of all relevant issues. Such changes may arise from modification to the design as well as from the results of additional environmental surveys and monitoring. As part of this process, alternative environmental management strategies will need to achieve the stated environmental objectives and outcomes.

Any changes to management measures which result in a change to the assessed environmental impact will be referred to DEH and the EPA. Any changes which require a change in a condition of approval will be assessed by DEH and the EPA before being considered by the relevant Ministers.

2.0 DEVELOPMENT COMPONENTS AND ACTIVITIES

Chapter 6 of the Draft EIS/ERMP details the major components that comprise the Gorgon Development and describes the construction activities required to install these components. These are listed in Table 2, and a matrix is presented in Attachment 1.

Each activity presents a range of potential environmental hazards. Section 3 of this Framework EMP outlines proposed management measures to avoid, reduce or rehabilitate potential impacts associated with each activity. The measures are structured by activity or stressor, and are presented in this format to facilitate review as part of the environmental impact assessment process. The measures will be incorporated into the detailed EMPs which, as outlined in Table 1, will generally be structured by Development component. That is, Section 3 does not explicitly provide management measures for pipeline construction (for example), but for the conduct of pipeline personnel, earthworks, waste management etc.; all of which will be included in the Onshore Feed Gas Pipeline EMP.

Table 2: Development Components and Activities

Development Components	Construction Activities
• Wells • Field infrastructure (manifolds, flowlines) • Feed gas pipeline • Gas processing facility • Construction Village • Port facilities (MOF, barge landing, jetty, shipping channel, turning basin) • Condensate load-out • Optical fibre cable • Domestic gas pipeline and associated infrastructure • Power and water facilities • Access roads • Airport modifications • CO_2 Injection system (pipeline, wells, monitoring) • Mainland supply base	• General conduct of personnel • Drilling • Subsea installation • Pipelaying • Horizontal directional drilling • Piling • Traffic and access management • Earthworks (clearing and grading) • Blasting (noise and vibration) • Air and dust generation • Lighting • Material import (quarantine management) • Dredging and dredge spoil disposal • Waste management • Spill contingency and response • Shipping and navigation • Rock dumping/placement • Facility testing • Clean-up and rehabilitation • Incident management

3.0 ENVIRONMENTAL PROTECTION AND MANAGEMENT MEASURES

3.1 General Conduct of Development Personnel

The following measures shall apply to all construction personnel. They are primarily focussed on Barrow Island based Development components but shall be applied to all relevant workforces:

- Only authorised personnel shall be allowed on the work site.
- Development personnel shall not bring firearms or pets onto or adjacent to the site.
- Construction personnel shall confine their activities and equipment to approved and designated work site areas.
- Recreation shall be restricted to designated areas at selected times (e.g. workforce access to beaches shall be controlled).
- In accordance with CALM Act regulations, Development personnel shall not collect shells (dead or alive).
- Fishing or recreational boating shall be prohibited during the construction phase of the Development.
- Recreational facilities shall be provided within the construction village to limit requirement for recreational activity outside of the construction village.
- Wildlife (including marine fauna) shall not be fed, or harassed, and shall not be unnecessarily injured or killed.
- Vehicle speeds shall be restricted to a maximum of 60 km/hr in daylight and 40 km/hr at night.
- Personnel shall manage general rubbish in accordance with Section 3.15.
- To minimise the risk of fires due to smoking, designated work areas shall have facilities to receive cigarette butts. Matches shall be banned.
- Personnel shall be required to minimise interference with existing Barrow Island Lease operations (i.e. no parking or blocking access, marking and avoiding production flowlines, waterlines and powerlines).
- Job Hazard Analysis (JHAs) shall be prepared with appropriately trained personnel and equipment to undertake identified task(s).
- ‘Tailgate meetings’ shall be regularly scheduled with work crews, where current or specific environmental, health and safety issues shall be discussed.

3.2 Drilling

The following management measures will be applied to drilling offshore and onshore wells, as appropriate. Separate detailed EMPs will be prepared prior to regulatory approval for the respective drilling programs. Measures to be applied to Horizontal directional drilling (HDD) are outlined in 1.0.

- Legislative requirements (including MARPOL requirements) for ballast water, discharge criteria, garbage, harmful substances and sewage management) shall be met. Biodegradable detergents shall be used onboard.
- Offshore discharge (>12 NM from land) of treated sewage shall be conducted in accordance with Commonwealth *P(SL)A* clause 222 and *MARPOL 73/78.*
- Drilling rigs and support vessels shall meet regulatory requirements for quarantine clearance where the rig or vessels are sourced from outside Australian waters (to prevent potential introduction or translocation of undesirable species and diseases in ballast water or marine surfaces).

- Drilling rigs shall have adequate safety systems such as blowout preventers, alarms and automated shutdown devices in accordance with regulatory and industry standards, and for which adequate maintenance and testing programs are in place.
- Spill Contingency Plans (SCP) shall be developed for potential spill scenarios. Offshore hydrocarbon spill response shall be in accordance with the Gorgon Development SCP approved by the DoIR. The contractor's SCP shall bridge to the operator's Plan to ensure an effective, integrated response to any hydrocarbon spill.
- All rig and support vessel navigation crews shall be qualified under the Flag State and International regulations and duly certified to perform their duties.
- Prior to the start of any operations, agreement shall be reached with the Harbour Master and Pilots/Vessel Masters on procedures and communications (VHF channel, Barrow Island/Gorgon dedicated channels, etc.) to be used on the Development.
- A 'Notice to Mariners' shall be prepared and posted to provide advance notification of the rig's planned location to the local fishing industry, the public and other affected parties.
- Radio watch on shipping traffic and fishing vessel movements shall be undertaken.
- The Australian Maritime Safety Authority (AMSA) shall be notified of the rig's location (and anchor distances).
- Sensitive marine fauna activities (e.g. nesting, migration) shall be considered when planning drilling, piling and dredging plans and operations.
- A marine mammal observation program shall be developed prior to the commencement of drilling activities.
- Specific navigation routes and flight paths and operating procedures shall be developed for supply vessels and helicopters that minimise impact on wildlife.
- Onshore and Offshore rigs shall have safe operating procedures in place which meet regulatory and industry standards (including chemicals and waste management aspects, etc.).
- Drilling rigs shall have efficient solids control and mud recirculation systems which maximise recycling of drilling fluids.
- Drilling rigs shall have adequate on-board comminution, containment, drainage and monitoring systems to prevent overboard discharges of unauthorised effluents (eg. hydrocarbon or chemical contaminated effluents, whole food scraps and sewage, etc.).
- Specialised drilling methods shall be undertaken to avoid impacts to highly valued resources (eg. directional drilling, etc.).
- Special drilling methods shall be undertaken to minimise total discharges to sea (eg. Step-out wells, directional drill).
- Low toxicity, water-based drilling fluid formulations shall be used as far as practicable.
- Oil-based mud formulations shall not be used. Where required fluid properties cannot be achieved using a water-based drilling fluid, a synthetic fluid which is of low toxicity, biodegradable and non-accumulative shall be used.
- A marine safety zone shall be in place for the proposed Development (500 m radius around surface and sub-surface equipment and structures such as pipelines and jetties). This safety zone shall be gazetted under Section 119 of the Commonwealth *P(SL)A*, and will appear on Australian navigation charts.

3.3 Subsea Installation

The upstream subsea equipment (i.e. located over the Gorgon field) includes subsea trees, manifolds, flowlines and associated equipment. Management measures associated with the installation of the Gorgon pipelines are outlined Section 3.4.

The following environmental protection measures will be undertaken:

- Selection of foundation type, location and installation method will consider environmental aspects.
- Equipment will be tested onshore as much as possible to minimise offshore work activities.
- Legislative requirements (including MARPOL), for ballast water, discharge criteria, garbage, harmful substances and sewage management shall be met. Biodegradable detergents shall be used onboard.
- Offshore discharge (>12 NM from land) of treated sewage shall be conducted in accordance with Commonwealth *P(SL)A* clause 222 and *MARPOL 73/78.*
- Installation vessels and support vessels shall meet regulatory requirements for quarantine clearance where the vessels are sourced from outside (or relocated within) Australian waters (to prevent potential introduction or translocation of undesirable species and diseases in ballast water or marine surfaces).
- Installation vessels and support vessels shall have adequate safety systems such as alarms and automated shutdown devices in accordance with regulatory and industry standards, and for which adequate maintenance and testing programs are in place.
- Oil Spill Contingency Plans (OSCP) shall be developed for potential spill scenarios. Offshore hydrocarbon spill response shall be in accordance with the Gorgon Development OSCP approved by the DoIR. The contractor's OSCP shall 'bridge' to the Joint Venturers' to ensure an effective, integrated response to any spill.
- All installation vessel and support vessel navigation crews shall be qualified under the Flag State and International regulations and duly certified to perform their duties.
- Prior to the start of any operations, agreement shall be reached with the Harbour Master and Pilots/Vessel Masters on procedures and communications (VHF channel, Barrow Island/Gorgon dedicated channels, etc.) to be used on the Development.
- A 'Notice to Mariners' shall be prepared and posted to provide advance notification of the installation vessel's planned location to the local fishing industry, the public and other affected parties.
- Radio watch on shipping traffic and fishing vessel movements shall be undertaken.
- The Australian Maritime Safety Authority (AMSA) shall be notified of the installation vessel's location.
- Sensitive marine fauna activities (e.g. nesting, migration) shall be considered when planning installation activities.
- A marine mammal observation program shall be developed prior to the commencement of installation activities.
- Operating procedures shall be developed for supply vessels and helicopters to reduce impact on wildlife.
- Installation vessels and support vessels shall have safe operating procedures in place which meet regulatory and industry standards (including chemicals and waste management aspects, etc.).
- Installation vessels and support vessels shall have adequate on-board comminution, containment, drainage and monitoring systems to prevent overboard discharges of unauthorised effluents (eg. hydrocarbon or chemical contaminated effluents, whole food scraps and sewage, etc.).

- A marine safety zone shall be in place for the proposed Development (500 m radius around surface and sub-surface equipment and structures such as flowlines, manifolds, wellheads, etc). This marine safety zone shall be gazetted under Section 119 of the Commonwealth *P(SL)A*, and will appear on Australian navigation charts.

3.4 Pipelaying

Environmental protection measures to be undertaken as part of the pipelaying activities are outlined below. Measures proposed to manage rock dumping/placement associated with pipeline construction are outlined in Section 3.5; while measures to manage construction of the shore crossing are outlined in Section 3.6. Activities associated with construction of the onshore section dealt with under a number of sections: primarily general conduct (3.1); traffic and access (3.8); earthworks (3.9); blasting (3.10), dust generation (3.11), material import (3.13) and waste management (3.15). These issues will be brought together in a detailed EMP for the onshore feed gas pipeline.

- Selection of pipeline route, installation method and stabilisation technique will include environmental aspects. Stabilisation technique is mainly driven by met-ocean conditions at the site.
- Pipelines shall be separated by sufficient distance such that future pipelines can be installed safely.
- Where anchors are required, anchor management plans will be developed to ensure minimum impact on seabed features from anchors and potential anchor chain scour.
- Legislative requirements, such as MARPOL requirements, for ballast water, discharge criteria, garbage, harmful substances and sewage management shall be met. Biodegradable detergents shall be used onboard.
- Offshore discharge (>12 NM from land) of treated sewage shall be conducted in accordance with Commonwealth *P(SL)A* clause 222 and *MARPOL 73/78.*
- Pipelay barge and support vessels shall meet regulatory requirements for quarantine clearance where the vessels are sourced from outside (or relocated within) Australian waters (to prevent potential introduction or translocation of undesirable species and diseases in ballast water or marine surfaces).
- Further Marine Cultural Heritage survey work shall be conducted during the detailed engineering phase, as input to detailed EMP.
- Pipelay barge and support vessels shall have adequate safety systems such as alarms and automated shutdown devices in accordance with regulatory and industry standards, and for which adequate maintenance and testing programs are in place.
- Spill Contingency Plans shall be developed for potential spill scenarios. Offshore hydrocarbon spill response shall be in accordance with the Gorgon Development Spill Contingency Plan (SCP) approved by the DoIR. The contractor's SCP shall 'bridge' to the Joint Venturers' to ensure an effective, integrated response to any spill.
- All pipelay barge and support vessel navigation crews shall be qualified under the Flag State and International regulations and duly certified to perform their duties.
- Prior to the start of any operations, agreement shall be reached with the Harbour Master and Pilots/Vessel Masters on procedures and communications (VHF channel, Barrow Island/Gorgon dedicated channels, etc.) to be used on the Development.
- A 'Notice to Mariners' shall be prepared and posted to provide advance notification of the installation vessel's planned location to the local fishing industry, the public and other affected parties.

- Radio watch on shipping traffic and fishing vessel movements shall be undertaken.
- The Australian Maritime Safety Authority (AMSA) shall be notified of the pipelay barge's location.
- Sensitive marine fauna activities (e.g. nesting, migration) shall be considered when planning pipelaying activities.
- A marine mammal observation program shall be developed prior to the commencement of pipelaying activities.
- Operating procedures shall be developed for supply vessels and helicopters to reduce impact on wildlife.
- Pipelay barge and support vessels shall have safe operating procedures in place which meet regulatory and industry standards (including chemicals and waste management aspects, etc.).
- Pipelay barge and support vessels shall have adequate on-board comminution, containment, drainage and monitoring systems to prevent overboard discharges of unauthorised effluents (eg. hydrocarbon or chemical contaminated effluents, whole food scraps and sewage, etc.).
- Pipeline hydrotesting is addressed in Section 3.17.
- A marine safety zone shall be in place for the proposed Development (500 m either side of the pipeline corridor. This marine safety zone shall be gazetted under Section 119 of the Commonwealth *P(SL)A*, and will appear on Australian navigation charts.

3.5 Rock Dumping/Placement

The following environmental management and protection measures are proposed for rock dumping/placement activities associated with pipeline stabilisation and construction of the MOF:

- A suitably scaled map of the rock dumping/placement site (the relevant sector from an AusMap), including a clear grid reference, showing bathymetric contours, the boundaries of the site and distance from land shall be prepared. Particular reference shall be made to specific marine zoning which may have a bearing on the rock dumping/placement.
- The method(s) to be used in positioning the dumping vessel shall be identified.
- Details of the sea-bed topography, sediment characteristics, and biological characteristics (including life-cycle and timing sensitivities of cetaceans, turtles, dugongs, etc), and history of the area shall be described in the detailed EMP.
- The disposal techniques (i.e. side-cast, chute or flexible fall-pipe) and procedures shall be identified along with the size distribution and type of rock to be dumped.
- The anticipated schedule, vessel(s) and other relevant information shall be identified.

3.6 Horizontal Directional Drilling

Horizontal directional drilling (HDD) techniques may be used to install short, but critical sections of the Onshore Feed Gas Pipeline, and possibly the Optical Fibre Cable and the Domestic Gas Pipeline. The following measures shall be undertaken to minimise potential environmental impacts associated with the construction of these sites:

- The clearing or footprint of the HDD site shall be minimised to the extent practical.
- The site shall be graded and levelled and designed to allow drainage of uncontaminated areas and collection of water in those areas subject to potential contamination (see Earthworks, Section 3.9).
- Access shall be managed in accordance with Section 3.8.

- Noise, air, light and dust emissions shall be in accordance with Sections 3.10, 3.11, and 3.12, respectively.
- Waste, spills and leaks shall be handled in accordance with Sections 3.15 and 3.19.

3.7 Piling

3.7.1 Offshore Piling Construction and Installation

As offshore pile driving involves similar vessels, and equipment to some of the other Development's marine components (i.e. offshore drilling, subsea installation, pipelaying and dredging), many of the same environmental management and protection procedures will be undertaken, including:

- Pre-construction surveys shall be designed to investigate marine habitats and species use (particularly flatback turtles) in the area to identify and map sensitivities, important habitats, population and distribution and potentially sensitive life-cycle timing.
- Jetty pilings shall be located to reduce impact to important and sensitive marine habitats.
- Sensitive marine fauna activities (e.g. nesting, migration) shall be considered when planning drilling, piling and dredging plans and operations.
- Vessels and support equipment and anchors shall be located to avoid areas of conservation significance where practicable.
- No un-authorised pile driving shall occur.
- The construction workforce, construction and supply vessels shall be restricted to designated areas. Recreational fishing, diving, spear-fishing, fossicking, surfing, or boating shall be prohibited.
- A marine mammal observation program shall be developed prior to the commencement of activities
- Further Marine Cultural Heritage survey work shall be conducted during the detailed engineering phase, as input to detailed EMP.
- Sensitive turtle breeding, nesting and hatchling periods shall be factored into the jetty construction schedule to the extent practical.
- Sediment plumes shall be modelled to provide input to jetty piling design and detailed EMP.
- Moorings shall be established for support vessels to minimise anchoring requirements. Anchoring sites and locations shall be selected that reduce impacts on fauna.
- Light levels and turtle hatchling behaviour shall be monitored for the period November to March.
- The performance and availability of vessels, plant and equipment capable of undertaking the work proposed shall be reviewed and analysed. This includes comparison with the physical constraints of the site and/or equipment (i.e. potential restriction of certain equipment due to shallow waters or sea states).
- Drawings and plans showing sufficient detail to allow accurate field identification (i.e. appropriate scale, bathymetric and met-ocean information, GPS and Lat/Long coordinates, pile locations, etc) shall be prepared.
- All pipeline and other marine and navigational infrastructure will be located, verified and marked prior to construction activities. Survey and identification procedures (i.e. system of buoys, flagging, navigational lighting, signage, etc.) will be used. Work specifications will clearly define equipment limitations and procedures for working in the vicinity or crossing these facilities.

- A 'Notice to Mariners' shall be prepared and posted to identify the location, timing, and any new navigational aids or details related to the construction and installation of the jetty and berthing dock.
- All navigation in Barrow Island Port shall be performed under Port Regulations.
- All vessel navigation crews shall be qualified under the Flag State and International regulations and shall be duly certified to perform their duties.
- Prior to the start of any operations, agreement shall be reached with the Harbour Master, Vessel Masters and Pilots on procedures and communications (VHF channel, Barrow Island/Gorgon dedicated channels, etc.) to be used within the Development area. Specified communication channels will be established and available for all marine traffic.

3.7.2 Onshore Piling or Plinth Construction and Installation

Onshore piling or plinths will be required on Barrow Island for above ground feed gas pipelines, auxiliary lines, CO_2 injection pipeline and water lines. Activities associated with construction of the onshore plinths are dealt with under a number of sections, primarily: general conduct (3.1); traffic and access (3.8); earthworks (3.9); blasting (3.10), dust generation (3.11), material import (3.13) and waste management (3.15). These issues will be brought together in the detailed EMPs for the relevant development component.

3.8 Traffic and Access Management

Access to Development areas for equipment and workers is required for the construction and operation of the Development. For the majority of the Development, including the pipelines, access will be along existing roads and seismic lines. Because of the size and amount of construction equipment used in construction, upgrading of existing access in particular areas will be required.

The following environmental protection measures shall apply to vehicle and equipment access:

- Relevant Lessees and regulatory authorities shall be consulted regarding the use and upgrading of existing roads and seismic tracks, and the selection, location, and development of new access routes.
- Existing roads, seismic tracks, and other previously disturbed areas, shall be used in preference to creating new access.
- Where new access tracks are required, important ecological features such as bettong warrens, listed vegetation species and cultural heritage sites shall be avoided.
- Where new permanent access roads are required, topsoil shall be removed prior to new road surface preparation and either stockpiled in windrows adjacent to temporary access for re-spreading during reclamation or stockpiled for possible use at other locations where permanent access will remain.
- Vehicle speeds shall be restricted to a maximum of 60 km/hr in daylight and 40 km/hr at night, and shall be restricted to minimise potential wildlife collisions and dust.
- Dust suppression measures shall be used on road and construction sites where required.
- New access shall, where practical, avoid crossing waterways.
- Drainage channel crossings shall be designed and constructed in a manner that minimises sediment release (e.g., erosion berms, silt fences and sediment basins), does not prevent water flows and is capable of accommodating locally significant rainfall events.

- Where vehicles and equipment are required to cross existing utilities (e.g., waterlines, flowlines, power and communication cables etc.) protective measures such as ramps, signage and flagging shall be used to identify and protect these facilities.
- Vehicles shall remain on designated access roads and within the defined Development construction area and associated work/staging sites unless otherwise authorised. This shall be supported by workforce education, signs, boundary markers and fences.
- Vehicle parking shall be restricted to designated areas unless otherwise authorised.
- Following completion of construction, access not required for the operation or maintenance shall be closed and rehabilitated.
- Surface drainage patterns intercepted by access not required for the Development's operation or maintenance shall be rehabilitated as soon as practicable.

3.9 Earthworks – Site Clearing and Grading

The following environmental management measures shall apply to earthworks associated with any Development component (such as construction of the onshore pipeline, drill pads, the gas processing facility, accommodation and utilities):

- Further vegetation and cultural heritage surveys shall be conducted during detailed design phase, as input to detailed EMPs.
- An experienced and trained Site Environmental Officer with access to specialist biologist(s) will be employed to inspect construction areas prior to any site clearing.
- Un-authorised clearing shall not be permitted.
- The area of exposed soils shall be limited to that required for safe construction and operation.
- All planned land disturbance shall be clearly designated, with areas to be cleared surveyed and pegged in the field in accordance with design plans and in advance of any clearing activities.
- All pipeline and other underground and above-ground facilities including gas, water, sewer, and communication systems will be located, verified and marked prior to construction activities.
- Drainage channel crossings shall be designed and constructed in a manner that minimises sediment release (e.g. installation of erosion berms, silt fences and retention/settling basins), does not prevent water flow and is capable of accommodating locally significant rainfall events.
- Where necessary, retention/settling basins will be located in previously disturbed areas and will be constructed to intercept, settle and then redirect uncontaminated site drainage to the nearest drainage zone (within the same catchment/basin).
- Erosion and drainage control devices shall be installed where required and maintained on drainage lines to control surface run-off and minimise soil loss from the working areas.
- Storm/cyclone events could potentially breach retention/settling basins. Basins shall be engineered and constructed to allow for storm events without erosion or damage.
- Nearshore construction activities will be scheduled to minimise overlap with key breeding periods for sensitive protected fauna (e.g. turtles) where practicable.
- Sensitive vegetation communities and habitats in proximity to working areas shall be clearly marked and access to these areas will be prohibited, unless otherwise approved.

- On sites to be cleared or graded, vegetation shall be removed, mulched and either stored for later rehabilitation or directly placed on disturbed areas to reduce erosion and to encourage native seed propagation.
- Stockpiled vegetation shall be segregated from work areas.
- No burning of vegetation during site clearing shall occur unless otherwise approved.
- Topsoil, where present, shall be stripped prior to land grading. Stripping will be to a depth of colour change, dependent on local soil profiles.
- Topsoil shall be stored in a windrow or stockpile which shall be discernibly separate from any other graded or excavated materials. Topsoil shall not be contaminated with anything that might impair its plant-support capacity (e.g. aggregate, cement, concrete, fuels, litter, oils, domestic and industrial waste).
- Cleared vegetation, topsoil or subsurface material shall not be stored in drainage channels.
- Flagging or temporary fencing shall be used to clearly delineate sensitive ‘no go’ areas such as important vegetation, fauna habitat or areas of cultural heritage significance. Features marked in this manner shall not be disturbed. Flagging and temporary fencing shall be removed at the completion of construction.
- Construction pads and lay down areas shall be compacted to limit the potential infiltration of treated grey water to the subsurface environment.
- Hardstand runoff shall be contained within a settling/holding basin and shall only be discharged to natural drainage if it meets agreed water quality standards.
- Potential sources of ignition shall be identified through the Job Hazard Analysis process. A hot work permitting system will be used to minimise risk of fire from Development activities.
- Soil and surface stability shall be maintained at all times; cut and fill excavation will be shaped to maintain slope stability and temporary erosion control berms, drains and sediment barriers shall be installed as necessary and maintained until final construction clean-up is completed.
- Grading, drill and blast techniques will be adopted which reduce dust, noise and vibration effects (see Section 3.10).
- Mufflers and other appropriate noise suppressants will be used on heavy equipment where practicable.

3.10 Blasting (Noise and Vibration)

In rock terrain where the use of conventional excavation or ripping equipment alone is not feasible, it will be necessary to undertake controlled blasting. The following environmental management measures shall apply to all activities that involve blasting (and the generation of associated noise and vibration):

- Blasting procedures shall be conducted in compliance with Development specifications and relevant legislation.
- The handling, storage and use of explosives shall be in accordance with legislation and Industry Standards.
- Blasting activities shall be conducted in a manner that reduces the amount of clearing, grading and soil disturbance required.
- Drill and blast techniques shall be planned and adopted that reduce dust, noise and vibration effects (i.e. using smaller, more frequent blasts, as opposed to less frequent, larger blasts; using sequential, staggered, or time-delayed charges or shaped charges to minimise cumulative effects of the explosions).
- Equipment used to undertake grading and excavation work shall be appropriately sized.
- Mufflers and other appropriate noise suppressants shall be used on heavy equipment where practicable.

- Blasting mats shall be used where required.
- Blasting shall be scheduled to avoid sensitive lifecycle periods of wildlife species (e.g., breeding, nesting, migration) where practical.
- Blasting shall be scheduled for daylight hours only to avoid activity peaks for nocturnal mammals (dusk to dawn).
- Continuous soft start and repetitious warning shots (air guns) shall be used prior to blasting in the marine environment use.
- A marine mammal observation program shall be developed prior to the commencement of activities.
- Vessel speed and access shall be strictly controlled.
- Consideration of physical removal of turtles using controlled trawling methods if efforts such as warning shots are not satisfactory and turtles are not clearing the blast area.
- Blasting activities shall be suspended turtle breeding season if individuals cannot be satisfactorily removed from the area and blasting results in mortality.
- Blast rock shall be reused where suitable and practicable (for erosion control rip-rap at drainages, water discharge areas, access control or potential wildlife habitat creation etc).
- All blasting refuse, such as containers, cartridges, caps and wire shall be recovered for disposal in accordance with the approved Waste Management Plan.

3.11 Air and Dust Emissions

The following environmental management and protection measures shall apply to construction activities that have the potential to result in gaseous or dust emissions to atmosphere:

- Industry standards shall be adopted for refuelling, transfer and storage of fuels and chemicals (e.g. level indication, overflow protection, containment, bunding, appropriate drainage systems and hardstand areas) to reduce fugitive emissions.
- Any hydrocarbon or volatile chemical spill shall be cleaned up as soon as possible.
- Vehicle speeds shall be restricted to a maximum of 60 km/hr in daylight and 40 km/hr at night.
- Buses shall be used to minimise the number of vehicle movements.
- Off-road or off-site vehicle use will be prohibited without prior approval.
- Unpaved surfaces shall be stabilised to reduce dust generation. Dust suppression measures, such as use of water carts and sprinklers on exposed soils and roadways, shall be implemented. Dust suppression shall be managed to ensure that measures do not result in erosion or significant runoff. Treated grey water shall not be used for dust suppression on exposed karst formations
- Fire (and related emissions) shall be prevented and managed in accordance with Section 3.19.
- An approved dust monitoring program shall be established.
- Construction vehicles and equipment shall be regularly maintained to ensure efficient operation and appropriate emissions standards.
- Australian standard low-sulphur diesel shall be used as the vehicle and equipment fuel source.
- Modular construction techniques shall be employed to the extent practical to reduce net diesel emissions from construction machinery.
- Alternatives to ozone depleting substances shall be selected wherever practicable. Contractors shall be required to advise of the use of ozone depleting substances and develop management plans to avoid release.

3.12 Lighting

The following management measures shall be adopted to reduce potential effects of construction lighting on sea turtles and other important marine fauna:

- Outdoor light level shall be reduced by the application of a range of strategies including: using low-pressure sodium vapour lights; reducing wattage in sensitive areas; using focused lighting units to concentrate light; shielding light sources; using artificial or natural screens; recessing sources; lowering mountings; using timers; or motion sensors.
- Night time construction activities in the near shore areas shall be minimised to the extent practical.
- Areas of construction shall be lit only when personnel are present or equipment is operating.
- Where practicable, vessel and barge loading and unloading shall be conducted during daylight hours. Where this is not practicable, lighting shall be reduced to safe levels.
- Lights shall be located such light emissions will be blocked by process vessels, equipment or structures, where practicable.
- Where colour definition or safety is not critical, light types shall be selected that are least disruptive to sea turtles (such as shielded or recessed lighting with long wavelengths).
- Construction lighting on the MOF causeway and LNG jetty shall be mounted low, shielded and focused towards the travelled pathway to reduce light spill.
- Lights shall be directed away from large plant and equipment to reduce glow effects.
- Lighting on construction vessels working at night during January to April (turtle nesting season) shall be shielded and directed onto work areas, long wavelength and switched off when not in use, to minimise attraction of hatchlings
- Matt paints and colours such as greys or shades of brown/olive shall be used to minimise the effect of reflective surfaces, paints or coatings which would contribute to glow.
- Window blinds shall be installed and used to eliminate spill from internal lighting.
- Commissioning flaring shall be reduced to the extent practical.
- A light audit shall be conducted during the turtle breeding, nesting and hatching periods (November to April) to assess illumination at the turtle beaches and light spill into marine areas.

Survey and monitoring strategies that will be adopted are to:

- 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
- 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 Department of Environment (DoE), and submitted for approval as part of the detailed EMP for the Development.

3.13 Dredging and Dredge Spoil Disposal

The following management measures shall apply to dredging and spoil disposal activities:

- Routes for the feed gas pipeline, domestic gas pipeline and optical fibre cable shall be selected to avoid areas of sensitive benthic primary producers.
- Final MOF access channel alignment shall be selected to reduce the volume of dredging across the nearshore limestone reef platform.
  Facilities on the east coast of Barrow Island shall be designed to reduce indirect impacts to benthic primary producers.
- A solid fill causeway and open pile jetty shall be designed to reduce interruption to local hydrodynamics and sedimentation patterns.
- Jetty pylons shall be located to avoid impacts to corals.
- Dredge spoil ground location shall be selected to avoid adverse impacts to macrophytes and corals.
  An anchor management plan shall be developed for each operation to avoid unnecessary anchor set and anchor chain scour in areas of corals and macroalgae. Anchor chains shall be managed to reduce contact with the seabed.
- An adaptive management strategy shall be developed and implemented for dredging operations that is based on three management zones, determined on the basis of predicted environmental impact (refer to Box 1).

Box 1: Management Zones

Zone 1 – (Zone of High Impact): Area where high coral mortality may result directly from dredging or construction, burial by dredge spoil, or indirectly from smothering by sediment and/or deterioration in water quality.
Zone 2 – (Zone of Moderate Impact): Area where some coral mortality may result indirectly due to deterioration in water quality and/or an increase in sedimentation rates.
Zone 3 – (Visible plume): Area that may experience marginal increases in turbidity, but not to the extent that corals, or other components of the benthos, are likely to suffer any measurable impacts.
(Refer to Draft EIS/ERMP Chapter 11).

- Adaptive management actions shall be triggered by the results of a comprehensive monitoring program used to investigate water quality, sedimentation and coral health. Monitoring methods shall include use of satellite imagery, aerial survey, and field sampling.
- Fortnightly sedimentation and coral health monitoring shall be conducted in Zone 1 and Zone 2; and as required in Zone 3 and reference sites.
- Prior to finalisation of the monitoring program, additional geophysical, metocean, bathymetric and biological surveys shall be conducted to enhance the knowledge and understanding of the marine environment of the Development area.
- The monitoring and adaptive management plan will be refined, in consultation with the Commonwealth and Western Australian regulatory agencies.
- Monitoring results shall be assessed against alert trigger levels and a tiered management response implemented as follows:

Tier 1 Management Actions

- The initial trigger for management shall be based on water quality (total suspended solids (TSS)) and sedimentation data collected in Zone 2 and 3, respectively (refer to Table 3).
- Should monitoring show that TSS or sedimentation rates at monitoring sites in Zone 2 or Zone 3 have increased above the trigger levels, the following series of management measures shall be progressively implemented :
    - The Gorgon Dredging Site Manager shall be advised immediately.
    - Tidal, wave, and wind forecasts shall be checked and verified to predict the likely duration of the event(s) that caused the Trigger Level exceedance.
    - Management options shall be reviewed available in the event that the monitoring results progresses to the Coral Health Trigger Level.
    - Compliance with the contractor's approved work practices shall be verified.
    - The dredging contractor shall adjust work practices as required.
    - Dredge contractor shall be advised of the need to temporarily halt operations should the exceedance continue.
    - TSS and sedimentation monitoring shall 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 shall be undertaken within 14 days of the exceedance.
    - Tier 1 management shall cease if within 18 days following the exceedance if:
        - TSS and sedimentation rates in Zone 2 and Zone 3 are each less than the criteria; and
        - Coral mortality in Zone 3 is below detectible limits and in Zone 2 is consistent with predicted partial mortality.

Table 3: Alert Trigger Levels

Zone	Water Quality Parameter	Trigger Level (Concentration)	Time (Consecutive Days)
Zone 2	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.
Zone 3	TSS	The five-day running median of TSS at monitoring sites within the visible plume zone 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 visible plume zone 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.

Tier 2 Management Actions

- Should coral health exceed threshold (trigger) values in Zones 2 or Zone 3 (refer to Table 4) the following management measures shall be implemented:
  - The influence of seasonal factors, storm activity and run-off events shall be assessed and considered prior to any response.
  - Additional monitoring (frequency and location) and testing will be conducted to verify coral health results are a consequence of dredging operations.
  - The dredging and disposal sequence shall be modified to reduce potential impact.
  - The hours of continuous dredging shall be reduced until water quality and sediment loading return to acceptable levels at the affected location(s).
  - Approval of the relevant regulatory agency shall be sought to modify the dredging and/or spoil disposal operations to allow works to continue.

Table 4: Coral Health Threshold Level

Zone	Threshold Level (Coral Mortality)
Zone 2	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.
Zone 3	Low level 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.

Tier 3 Management Actions

- Should coral health exceed Coral Health Limit Levels (refer to Table 5), the following management measures shall be implemented:
  - The influence of seasonal factors, storm activity and run-off events shall be assessed and considered prior to any response.
  - Dredging and disposal activities shall be suspended.
  - Dredging and disposal activities shall only recommence when it can be demonstrated to the satisfaction of the Minister for the Environment, upon advice from the EPA that:
    - Any new activity would not contribute to further net mortality of corals at any site(s) at which the limit level had been exceeded.
    - The ambient environmental conditions at any site(s) at which the limit level had been exceeded are such as to not prevent recovery.

Table 5: Coral Health Limit Level

Zone	Limit Level (Coral Mortality)
Zone 2	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.

Zone	Limit Level (Coral Mortality)
Zone 3	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.

3.14 Quarantine Management

The following quarantine management measures shall apply to all activities that have the potential to introduce non-indigenous species to Barrow Island and the surrounding waters:

- A risk-based approach shall be adopted to quarantine management. This approach will focus on pre-border prevention of the introduction of non-indigenous species, with post-border contingencies for detection and eradication.
- A Quarantine Management System (QMS) shall be designed specifically for the Gorgon Development and will align with AS/NZS ISO 14001.
- Information developed, as necessary, for the QMS shall be integrated into existing business support systems to the extent possible; and additional tools shall be developed to capture information specifically related to quarantine barriers and risk management.
- Quarantine requirements shall be included in pre-qualification of suppliers and contractors. Only contractors and suppliers that have demonstrated a willingness to meet or exceed the Development quarantine standards shall be engaged.
- Quarantine requirements shall be included in contracts for all contractors and suppliers providing goods and services for Barrow Island.
- All relevant personnel shall be inducted regarding quarantine management requirements.
- Specific quarantine training shall be provided to personnel in the procurement and logistics supply chain.
- Quarantine responsibilities shall be included in the position description for key personnel.
- A strong culture of quarantine awareness shall be developed and promoted in the workforce.
- Any quarantine emergency shall be responded to quickly and effectively, utilising the expertise of nominated specialists and relevant government agencies.
- A monitoring program to determine the effectiveness of the implemented quarantine barriers shall be reviewed by flora and fauna specialists, and incorporated into the QMS.
- Quarantine compliance for all personnel and goods going to Barrow Island shall be recorded and tracked.
- The Gorgon Joint Venturers shall work closely with CALM to ensure that there is an ongoing examination and audit of the QMS, and regular quarantine compliance audits and checks shall be conducted throughout the supply chain.
- The quarantine management process shall include stakeholder engagement and reporting.

<u>Management of Quarantine on Priority Pathways</u>

Eleven pathways have been identified for the transfer of vessels, cargoes, and personnel to Barrow Island. Of these, three specific pathways (namely sand and aggregate, food and perishables and personnel and accompanying luggage) present the highest risk of transfer of non-indigenous species to Barrow Island and are therefore considered priority pathways for assessment of quarantine risk. A pool of measures (or barriers) to prevent the introduction of non-indigenous species has been identified, and from this, via the risk assessment workshop process, the following conceptual barriers have been identified. These barriers are subject to further scrutiny and design modification prior to implementation via a Hazard Operability (HAZOP) analysis (refer to Chapter 12 of the Draft EIS/ERMP). Prior to construction quarantine barriers will be selected for all pathways via this process.

The following quarantine barriers shall be adopted for the **sand and aggregate** pathway:

- A Quarry Environmental Management Plan shall be implemented
- Quarry equipment shall be cleaned and inspected.
- Quarry material shall be covered in segregated storage.
- Quarry material shall be sampled to verify compliance.
- Material shall be covered during sea transport.
- Additional quarantine barriers will be implemented subject to the completion of the barrier selection process.

The following quarantine barriers shall be adopted 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.
- Additional quarantine barriers will be implemented subject to the completion of the barrier selection process.

The following barriers shall be adopted 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
- all luggage is inspected 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
- 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.
- Additional quarantine barriers will be implemented subject to the completion of the barrier selection process.

3.15 Waste Management

The following waste management measures shall apply to all construction activities:

- Wastes shall be managed in accordance with the principles of: eliminate, reduce, reuse, recycle/recover, treat and dispose of wastes in an environmentally responsible manner.
- MSDS information on hazardous materials shall be reviewed to identify opportunities to substitute them with a less hazardous or non hazardous replacement.
- Waste management shall be included in the Job Hazard Analysis process.
- To minimise packaging wastes, supply materials shall be purchased in bulk wherever practicable.
- Wastes shall be identified, classified and segregated into specified areas to facilitate recycling.
- Unused materials shall be returned to suppliers wherever practicable.
- Chemical and other consumable suppliers shall be required to receive containers for refilling rather than for waste disposal.
- Specific waste management procedures shall be developed for each waste stream (solid, liquid and hazardous) and identified in the detailed Waste Management Plan. Emergency response and spill contingency planning measures shall be implemented in accordance with Section 3.19.
- The handling of non-destructive test media shall be in accordance with industry and regulatory requirements.

<u>Onshore</u>

In addition to the above general measures, the following waste management measures shall be adopted for onshore construction activities:

- Construction wastes not re-used or recycled shall be collected at designated sites, initially stored and appropriately contained on location taking into consideration fire, safety, worker health, and pest and odour control. In general, solid wastes generated during construction and operations shall either be incinerated or returned to the mainland for re-use, recycling or disposal in approved facilities.
- General rubbish such as food wrapping, garbage, and sanitary waste, shall be confined to the work site and collected daily for appropriate disposal at an approved location.
- Construction rubbish shall be collected for disposal at an approved location. Rubbish shall not be disposed of in any excavation or trench.
- Liquid wastes, redundant chemicals and batteries shall be disposed of on the mainland by a licensed waste disposal contractor.
- Liquid wastes from construction will generally be treated and then disposed into deep injection wells. Exceptions include use of treated grey water for dust suppression and disposal of chemicals and hydrocarbon at approved sites on the mainland.
- Except for emergency situations, vehicles and other equipment shall be maintained and washed at a designated maintenance yard. The maintenance facility shall accommodate a concrete or other impervious surface which shall drain to a sump. Water and potential wastes and contaminants collected in the sump shall be pumped to a separator where it shall be regularly removed by a waste contractor. Waste hydrocarbon shall be stored in labelled drums or tanks for disposal by a waste Contactor.
- Portable toilet facilities shall be located at convenient sites where workers shall have access.
- All holding basins shall be cleaned and maintained regularly.

- Segregated waste storage areas and containers shall be located away from drainages and low-lying areas. Containers shall be appropriately labelled. The area shall be graded to drain away from the storage areas to a settling basin and sump which can be emptied, as required.
- Contaminated soil shall be stored in a dedicated bin or on a designated impervious surface for removal to the mainland for bioremediation or landfill.
- Use of disposable food and drink containers shall be avoided, where practicable. The use of plastic bags shall be avoided except for containing food or putrescible wastes.
- Installation and use of a compactor/crusher for certain solid waste and recycle streams (i.e. aluminium, timber, and paper) shall be considered.
- Installation of an incinerator (possibly with heat recovery) shall be considered.
- Potentially contaminated runoff shall be contained within a holding basin and shall be discharged once cleared of any potential contaminants. Potentially contaminated hardstand water shall be captured in a holding basin, where an Oil in Water (OIW) separator system shall recover the hydrocarbon, and the water reinjected into existing or purpose constructed disposal wells.
- Potable water shall only be used where such quality is required (that is alternative water sources shall be used for drilling water, construction, dust suppression, and toilet flushing, etc.)
- Flow meters shall be installed on water sources and discharges to enable targets for reduction to be set and monitored. Sampling facilities shall be designed into on discharges.

<u>Offshore</u>

- Drilling rigs, pipeline lay-barges, tankers, rock dumping vessels and other supply and support vessels shall have efficient and fully operational oil/water separators in bilges.
- Ballast water shall be exchanged beyond the 12 nautical mile limit by an approved method, and shall not be discharged in port.
- The Ballast Water Decision Support System shall be used to provide vessels with a risk assessment of ballast water.
- No waste will be disposed overboard within 12 nautical miles.
- Beyond 12 nautical miles comminuted sewage and food wastes, drilling cuttings, drilling fluids and uncontaminated deck wash-down wastes shall be disposed overboard in accordance with regulatory requirements and project-specific approval conditions.
- On vessels operating less than 12 nm from land, sewage and grey water shall be stored in tanks for disposal to an approved shore-based treatment system.
- Food wastes shall 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 Commonwealth *Petroleum (Submerged Lands) Act 1967*, and the *International Convention for the Prevention of Pollution from Ships (MARPOL)* regulations.
- Deck drainage water shall be directed overboard if clean, or to a sump and oil/water separator if it contains traces of hydrocarbon. Contaminated drainage from decks and work areas shall be collected and processed to remove hydrocarbons.
- The discharge of surfactants, dispersants and detergents shall be minimised. Detergents or dispersants used for wash-down shall be biodegradable and phosphate free. The use of detergents shall be managed to reduce the opportunity for entry to the oily water separation system, as they adversely affect separation.
- Waste oil shall be stored in labelled drums or tanks for disposal.

- The recirculation of drilling fluids shall be optimised to minimise total discharges.
- Drilling cuttings and fluid discharges shall be monitored to ensure compliant oil concentrations.
- Discharges from essential operations such as grouting of the conductor and surface casing strings (eg. cement mixture circulation, surplus cement fluid and powder, etc.) shall be minimised.
- Discharges from drilling rigs shall be staged (eg. disposal of excess fluid at end of well) where necessary to achieve optimum dispersal.
- Where small amounts of oil additives (eg. spotting pills) are added to drilling fluid on a one-off basis, the Designated Authority shall be consulted on disposal.
- Non-incinerable domestic wastes shall be collected and compacted for onshore disposal. Detailed documentation and manifests shall be kept. Onshore receiving and disposal measures shall meet local government requirements. Waste containers will be closed to prevent loss overboard.

3.16 Shipping and Navigation

The following environmental management and protection measures shall be adopted to reduce the risk of damage to life, property and the environment that could be caused by vessel collision, grounding, equipment failure, fire, or refuelling incident:

- All relevant marine personnel shall be appropriately trained in navigation and communication procedures. All vessel navigation crews shall be qualified under the Flag State and International regulations. Crews shall be duly certified to perform their duties.
- All navigation within the Barrow Island Port boundary shall be performed under Port Regulations, current Notices to Mariners and the *International Regulations for Preventing Collisions at Sea (1972)* and amendments.
- Prior to the start of any operations, agreement shall be reached with the Harbour Master, Vessel Masters and Pilots on procedures and communications to be used within the Development area. Specified communication channels will be established and available for all marine traffic.
- All operations shall be conducted in accordance with Australian and International Conventions and regulations, particularly the *International Regulations for Preventing Collisions at Sea (1972)*, *International Convention for the Safety of Life at Sea (SOLA*S) 19*74, Marine Act 1982* (WA)*, Shipping and Pilotage Act 1967* (WA) and *Marine Navigation Aids Act 1973* (WA).
- An Oil Spill Contingency Plan (OSCP), consistent with Australian Marine Safety Association (AMSA) and MARPOL requirements, shall be prepared and approved prior to commencing marine construction or shipping activity.
- Communication shall be maintained with vessels wishing to transit the Development area, especially those areas being constructed.
- Marine and meteorologic conditions shall be forecast, monitored and communicated to construction vessels.
- Vessel and equipment location and movement shall be recorded and made available to all vessels working in the Development area.
- All pipeline and other marine and navigational infrastructure shall be located, verified and marked prior to construction activities. Survey and identification procedures (i.e. system of buoys, flagging, navigational lighting, signage, etc.) shall be used. Work specifications shall clearly define equipment limitations and procedures for working in the vicinity or crossing these facilities.
- A 'Notice to Mariners' shall be prepared and posted identifying the location, timing, and any new navigational aids or details related to the dredging and dredge spoil disposal works, drilling activity and submarine pipeline and communication infrastructure.

- Vessel speed restrictions shall be established and enforced in accordance with Barrow Island Port Authority. Should any pilot or vessel master request additional sea space to perform required manoeuvres because of size, draught or safety, the dredge or trailer hopper barge shall be moved to a safe location. Follow AMSA/Auscoast warnings; with navigational standards and procedures.
- Permanent moorings shall be installed where practicable, to minimise need for anchoring.
- All incidents, including near misses, shall be reported and recorded in accordance with regulatory and corporate Chevron guidelines.
- Whale, dolphin, dugong and sea turtle sightings will be recorded, collated and reported to HES Manager. This shall be forwarded to CALM, the WA Museum and Department of the Environment and Heritage Marine Species Section. Whale (and dolphin) observations shall be recorded on the standard cetacean sighting form.
- All towed equipment shall be labelled in the event of loss during the construction program.
- In the event of a cyclone, all marine vessels, dredging and spoil disposal operations shall be suspended and made safe in accordance with the Gorgon Development's emergency procedures.

3.17 Facility Testing

The following environmental management and protection measures shall be adopted:

- Prior to testing, the contractor shall prepare a hydrostatic testing plan which as a minimum shall include:
  - the location and detailed description of the water source
  - the volume of water required and the extraction rate
  - the anticipated quality of the source water (including chemistry and total suspended solids)
  - the equipment and infrastructure required for the testing
  - the location and detailed description of the receiving environment into which the effluent shall be discharged
  - a description and the concentration of any biocides, oxygen scavengers, rust inhibitors or other materials to be added to the test water
  - methods proposed to prevent erosion or any other biophysical impacts at the point of water discharge if test water is not discharged to injection wells.
- Where practicable piping, vessels and fabrication plant sections shall be pre-tested before shipping to Barrow Island.
- The potential impacts to subterranean fauna shall be reduced by locating withdrawal wells away from known; significant habitat areas; maintaining adequate withdrawal rates and water levels, and; screening uptake water.
- Where feasible, test water shall be reused for a series of test sections.
- Water quality monitoring shall include the results of sampling prior to use, and again prior to discharge.
- Generally, used test water shall be injected into existing or purpose drilled disposal wells. Offshore disposal may considered depending on the scheduling of activities and technical requirement regarding hydrotest water quality. If marine discharge is to be considered, test water shall meet ANZECC/ARMCANZ (2002) water quality standards after dilution at discharge point and test water shall be discharged into high exchange areas offshore where practical.
- The handling of non-destructive test media shall be in accordance with industry and regulatory requirements.

3.18 Clean-up and Rehabilitation

The following environmental management measures will be adopted for the clean-up and rehabilitation of disturbed work sites (e.g. pipeline rights of way, drill pads, temporary or abandoned access roads, make-up or fabrications sites which will no longer be required, etc):

- The period of time between initial disturbance and clean-up of work areas shall be minimised to prevent degradation and loss of exposed soils.
- Clean-up operations shall keep pace with construction.
- The construction area shall be left with stable contours, following clean-up
- Surface drainage shall be re-established.
- Compacted soils shall be ripped or scarified.
- Benched surfaces immediately above potentially erodible or unstable terrain shall be contoured so as to avoid overloading slopes or concentrating surface runoff.
- Where there are steep disturbed slopes, the surface shall be crossed with adequately-spaced angled water bars (diversion terraces) to intercept and disperse runoff. Surface erosion control measures such as water diversion terraces shall be installed at appropriate intervals on all sloping ground to divert surface water quickly away from the disturbed area.
- Other drainage, erosion, and sediment control measures (e.g. geotextile matting, filter fencing, and retention/settling basins) shall be removed as required once stability is achieved.
- Unauthorised access to rehabilitated pipeline rights-of-way shall be prohibited
- Flagging used to identify sensitive environmental features (e.g. natural and cultural heritage), temporary fencing, survey stakes, etc., shall be removed and disposed of at the completion of construction.
- Access roads shall be rehabilitated where no longer required for operations.
- After the completion of re-contouring and erosion control works, any topsoil salvaged and stored earlier shall be spread evenly, over the areas from which it was removed.
- Native plant species shall be used to maintain biodiversity, reduce opportunity for weed establishment, and maintain wildlife habitat.
- Vegetation and indigenous seed salvaged during clearing operations shall be used with the objective of establishing plant communities similar to pre-construction conditions.
- Rehabilitation measures shall actively promote the regeneration of native groundcover and shrubs.
- Where appropriate, habitat structural elements such as rock groupings and vegetation shall be placed at the outer edges of the pipeline rights-of-way and other construction areas to enhance wildlife use of the area while not impeding operation and maintenance requirements.

3.19 Contingency Planning and Emergency Response

The following measures relate to all construction activities that have the potential to result in an unplanned environmental incident or emergency. Incidents of particular note are hydrocarbon or chemical spills, fire, wildlife injury, discovery of cultural heritage material and extreme weather conditions.

General

- All relevant personnel shall be trained in environmental incident response and reporting.

- Response measures shall be consistent with legislation, regulations, and conditions of the Development Approval.
- Contingency response planning shall conform to the Gorgon Development's overall Emergency Response Plan.
- A list of emergency response contact names and numbers shall be kept on-site at all times.

Hydrocarbons and Chemical Spills

- A complete inventory of chemicals shall be maintained.
- Wherever practicable non-hazardous (or less hazardous) materials shall be selected.
- Oil and chemical-use areas shall be appropriately contained.
- Fuel and chemical storage, handling and distribution systems, and areas where vehicles, plant and machinery are stored shall be regularly inspected to identify, repair and respond to leaks.
- Regular maintenance of dredges, drilling rigs, barges, supply vessels, plant and equipment shall be conducted to reduce the chance for equipment failure, spills and leaks. Maintenance logs shall be kept for all major vessels, plant and equipment.
- Fuel storage tanks, handling areas, drainage and bunding systems shall be inspected and maintained with particular emphasis on condition and performance of foundations and supports, serviceability of fittings, vents, valves and lines and condition of welds, surface corrosion and paintwork.
- A scheduled and systematic inspection for general leaks and spills shall be undertaken on all marine vessels, plant and equipment.
- Marine and shoreline sites that are potentially susceptible to contamination shall be monitored to detect potential impact from hydrocarbon or chemical leaks and spills.
- Records of liquids received, stored and dispensed shall be maintained and reconciled. Where any discrepancy in records indicates that leakage may be occurring, the facilities shall be subjected to investigation.
- All port authority and pollution prevention regulations shall be adhered to when delivering product from supply vessel to drilling rig, lay barge, dredgers and support vessels.
- Safe fuel transfer procedures shall be adopted.
- Refuelling of marine vessels shall only be conducted under suitable sea-state and visibility conditions.
- Dry break couplings and floating hoses shall be used where appropriate.
- Tanks and machinery shall be equipped with measurement and overflow protection (e.g. flow and level meters, relief valves, overflow protection valves and emergency shut off).
- Refuelling activities shall be visually monitored.
- An Oil Spill Contingency Plan (OSCP) shall be developed to address all credible spill scenarios, and must be approved by relevant regulatory agency prior to undertaking the construction activity to which it relates.
- Sufficient and appropriate equipment, materials and resources shall be available to respond to a spill incident.
- Absorbent materials shall be available on equipment to handle small hydrocarbon or liquid chemical leaks or spills. Spill kits shall be provided where spills are possible.
- Upon finding a spill or leak, the person on-site shall report the incident supervisory/management personnel.

- Any spillage shall be cleaned up immediately and the materials used in the clean up shall be disposed of safely. Affected areas shall be monitored to determine effectiveness of remediation.
- Hydrocarbon spills shall be reported to the DoIR in compliance with *P(SL)A (Management of Environment) Regulations 1999* (WA) and other relevant regulatory authorities in accordance with the approved OSCP.

Fire

The following measures shall be undertaken to minimise the likelihood of fire occurring, and quickly deal with potential effects if fire does occur:

- A list of available equipment and manpower to be employed on the Development including an organisation chart identifying personnel, contact numbers and responsibilities on the job site, shall be prepared.
- Fire control measures to be taken by each crew (i.e. welding, fuel transportation and handling, equipment servicing, etc) and for the work proposed, shall be clearly documented and communicated.
- All earthmoving equipment shall be fitted with spark arrestors or similar devices.
- Each vehicle shall be outfitted with a fire extinguisher.
- Fires associated with recreational BBQs shall be prohibited.
- Appropriate fire fighting equipment shall be stored at all suitable work sites in accordance with relevant regulations.
- Fire fighting equipment shall be inspected and well maintained.
- Flammable material shall be cleared from around potential fire ignition sources.
- When not in use machinery and vehicles shall be parked in areas free of flammable material and vegetation (e.g. not parked over shrubs, tall grass or cleared vegetation residue).

In the event that a fire is ignited the following shall be undertaken:

- On-site personnel shall immediately report the fire to the Development component Site Manager.
- Gorgon Joint Venturers and the contractor shall carry out initial fire suppression and take all reasonable steps to extinguish a fire that spreads beyond an area authorised or intended for burning.
- The Gorgon Joint Venturers and the contractor shall mobilise heavy equipment, man power, and water trucks as necessary for fire suppression.
- All fires observed shall be reported immediately to the Barrow Island Operations (Dial 9001) and to CALM.

Archaeology and Cultural Heritage Resource Discovery

The following measures shall be undertaken to ensure appropriate management of cultural heritage:

- All areas likely to be disturbed shall be assessed for cultural heritage by a qualified archaeologist with appropriate input from Indigenous community representatives.
- All personnel and contractors on site shall be advised that it is an offence under legislation to interfere with a site or collect artefacts.
- Site clearing works shall be monitored by suitably qualified personnel to ensure only designated areas are disturbed.
- Monitoring activities shall seek to identify potential for new discovered cultural heritage material uncovered during site clearing.

If an archaeological or cultural heritage site or artefacts are discovered during construction, the following site management measures shall be undertaken:

- All work shall cease at the location and an archaeologist shall be notified.
- The Development component Site Manager, contractor supervisor, and the Gorgon HES Manager shall be notified immediately.
- All reasonable efforts to protect the site or artefacts shall be made. For example, buffer zones shall be established or temporary barriers (i.e. stakes and appropriate flagging) shall be erected.
- No material shall be further disturbed or removed without appropriate authorisation.
- Construction workers and operational personnel shall comply with the instructions of the archaeologist. Construction may continue at an agreed distance away from the site.
- At the same time as other individuals and agencies are contacted, the archaeologist or cultural heritage monitor shall notify Indigenous people of the discovery, the steps which have been taken and make appropriate arrangement for nominated Indigenous people to attend the site, if not already present.
- Indigenous people shall be consulted regarding the management of the material once indigenous origin has been determined.
- No further work at the locations sahll be undertaken until all parties have been consulted and agreement has been reached.

If Indigenous sites cannot be avoided then:

- An application should be made under Section 18 of the *Aboriginal Heritage Act 1972* (WA) to disturb the required sites.
- A detailed recording of the site(s) shall be undertaken by qualified archaeologists.
- If the potential for sub-surface cultural material is identified the site will be test-excavated to determine this potential. A Section 16 permit (*Aboriginal Heritage Act 1972*) will need to be obtained from the DIA to conduct this work.
- Indigenous people will be consulted regarding the proposed site disturbance.

Should human remains be discovered, the following legislation will apply:

- *Coroners Act 1996* (WA) – all human remains
- *Aboriginal Heritage Act 1972* (WA) – (Indigenous burials)
- Commonwealth *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* – (Indigenous burials).

On discovery of skeletal material:

- All work shall cease at the location and the archaeologist and cultural heritage monitor shall be notified, if not already present at the location.
- The Development component Site Manager, contractor supervisor, and the Gorgon HES Manager shall be notified.
- All reasonable efforts to protect the remains shall be made. The material shall not be removed or disturbed further but buffer zones or temporary barriers may be appropriate.
- Construction workers and operational personnel shall comply with the instructions of the archaeologist. Construction may continue at an agreed distance away from the site.
- All personnel and contractors on site should be advised that it is an offence under the *Coroners Act 1996* (WA) and the relevant heritage legislation to interfere with the remains.
- Under Section 17 of the *Coroners Act 1996* (WA) the local Police/Coroners office will be notified. Direction in the first instance should be taken from the Police. However, given the potential significance of any burials, an archaeologist/physical anthropologist with demonstrable experience in excavating Indigenous and

historical burials should supervise the removal of the human remains, as the skills required for this form of excavation are likely beyond that of police forensic teams.

- If human remains are suspected to be Indigenous then the Registrar of Aboriginal Sites at the Department of Indigenous Affairs (DIA) will be informed. In addition the Federal Minister for Indigenous Affairs Office needs to be informed.
- At the same time as other individuals and agencies are contacted, the archaeologist or cultural heritage monitor shall notify Indigenous people of the discovery, the steps which have been taken and make appropriate arrangement for nominated Indigenous people to attend the site, if not already present.
- Indigenous people shall be consulted regarding the management of the material once indigenous origin has been determined.
- No further work at the locations shall be undertaken until all parties have been consulted and agreement has been reached.
- The location of the burial shall be recorded in sufficient detail for its future protection.
- In consultation with the Police/Coroner and DIA staff steps will be taken to identify the skeletal material. A physical anthropologist shall need to be engaged to complete this task on site.

Wildlife Incidents

The following environmental protection measures shall be adopted to avoid, mitigate or respond to incidents that result in impacts to wildlife:

- Development personnel shall not be permitted to intentionally harass or harm wildlife on or near the worksite, or along access routes to the worksite.
- Vehicles and equipment shall be operated in accordance with Section 3.8.
- All work-site personnel shall be inducted regarding the proper response to wildlife encounters (including unexpected encounters).
- Vehicle collisions with wildlife on the worksite or access routes shall be reported to the Site Environmental Officer.
- The appropriate care and handling of injured animals will be identified in a plan prepared in consultation with CALM.
- The Site Environmental Officer shall maintain a record of all reportable wildlife incidents and non-compliance.

Weather and Climatic Events

The following environmental protection measures shall be adopted to avoid or mitigate impacts associated with high intensity cyclonic rainstorms that have the potential to result in flooding and erosion:

- During high-risk season(s), a reserve of suitable material and equipment shall be located on-site to mitigate potential erosion and sedimentation due to heavy rainfall events.
- Drainage channel crossings shall be designed and constructed in a manner that minimises sediment release (e.g. erosion berms, silt fences and retention/settling basins), does not prevent or unnecessarily restrict water flows and is capable of accommodating locally significant rainfall events.
- Installed retention/settling basins shall be cleaned and maintained regularly.
- Construction site drainage shall be regularly reviewed for the potential to temporarily diverting storm water away from area and materials susceptible to erosion.

4.0 ENVIRONMENTAL INSPECTION AND MONITORING

The environmental inspection and monitoring program will record compliance with required environmental management procedures and shall be used to evaluate the effectiveness of the environmental protection, mitigation, contingency planning, emergency response and rehabilitation measures.

4.1 Environmental Inspection

The Gorgon Development will be subject to a comprehensive inspection program. In accordance with standard industry practice, construction activities (such as clear and grade, blasting, welding, testing, etc), will undergo quality assurance inspections by dedicated technical inspectors. As part of the inspection program, appropriately qualified, trained and experienced Site Environmental Officers, will have an inspection role. These personnel will work with specialist environmental inspectors (such as marine monitors, quarantine inspectors and archaeologists). The inspection program (covering environmental, health, safety, trade, and utility inspections) will be coordinated by Construction Manager.

4.2 Environmental Monitoring

Environmental monitoring will be undertaken at a wide variety of locations and times to qualitatively and quantitatively evaluate the success of environmental management and protection procedures, including, but not limited to: rehabilitation, waste minimisation and management procedures, the effectiveness of fauna protection, access to existing Barrow Island Lease assets, erosion control and other control measures.

The programs will aid in the early identification of potential environmental issues and will fulfil the due diligence requirements of the Joint Venturers to document effective environmental performance, as well as any shortcomings during the construction period. In particular, the monitoring programs will aim to:

- identify environmental changes and, specifically, identify those changes resulting from the Development construction
- survey topics that are specified in permits, licenses, and approvals
- determine actual versus predicted change
- review and improve upon the EMPs.
- 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 conducted by appropriately qualified personnel. These programs will be periodically reviewed and modified to assure continued appropriateness. Records of all monitoring activities will be retained to facilitate the audit program.

The programs will investigate a range of construction issues including:

- the volume and composition of waste discharges
- the volume and composition of air emissions, including greenhouse gas emissions
- dredging effects
- the rate, extent and success of rehabilitation

- the detection, control and eradication of potentially introduced animals, plants and diseases
- presence and abundance of rare fauna
- protection of sites of cultural and historical significance.

5.0 AUDITING

5.1 Compliance Auditing

Compliance auditing shall be undertaken throughout the design, construction, operations and decommissioning phases of the Gorgon Development. An audit program will be developed in consultation with the Environmental Audit Branch of the Department of Environmental Protection and the Commonwealth Department of Environment and Heritage. This program will define the scope and timing of audits. Generally, audits will assess compliance with regulatory requirements, licence conditions and matters covered in the detailed EMPs and the EMS.

The audit methodology shall be based on objective evidence that will generally comprise review of documented environmental records, direct observations of activities and interviews with relevant personnel.

6.0 REPORTING

6.1 General

Information management will be a key aspect of the successful execution of the design, construction and operations phases of the Development. Numerous environmental reports and audits shall be required to record details such as the progress of work, monitoring of key physical and environmental factors, incidents, complaints and their status and resolution, compliance and performance. Reporting procedures will be consistent with regulatory (notably those under the Barrow Island Act), and as agreed with the EPA and DEH.

The proposed major reports, as well as the individual roles and responsibilities for reporting are outlined in
.

Table 6: – Key Reporting Requirements and Responsibilities

Report	Prepared by	Submitted to	Content
Daily Environmental Report	Gorgon Site Environmental Officer	Development component Site Manager and Gorgon HES Manager	Daily log of activities. Daily general discussion and communication with job site inspectors and contractors. Identification of specific issues and potential incidents. Forward planning and scheduling

Report	Prepared by	Submitted to	Content
Weekly Environmental Report	Gorgon Site Environmental Officer	Development component Site Manager and Gorgon HES Manager	On-going compliance activities, priority actions, review of completed and scheduled construction activities. Summary of incidents and reporting (as required).
Environmental Incident Report (as required)	Gorgon Site Environmental Officer and other Specialist Consultants	Development component Site Manager, Gorgon HES Manager, and Barrow Island Coordination Council and DoE for waste discharges	Issues, practices or incidents which may impact the environment. Actions taken to avoid, mitigate, investigate and respond to the incident, procedures for evaluation, follow-up of the success of actions taken and closure of actions.
Monthly Environmental Monitoring Report	Gorgon HES Manager	Gorgon Development Management, Barrow Island Coordination Council	Summary of monitoring data along with assessment of progress against EMPs. Report on staffing and compliance issues. Summary of compliance auditing reports. Requirements for EMP or procedure, reporting or communications adjustments. Record of any significant incidents and follow-up.
Quarterly Environmental Monitoring Report	Barrow Island Coordination Council, Gorgon HES Manager	Gorgon Development Management, EPA, DoIR and DEH	Summary of feedback compliance monitoring, issue management, actions and activities taken to respond to environmental issues. Scheduling and environmental performance review.
Six-monthly Progress Report	Barrow Island Coordination Council, Gorgon HES Manager and Gorgon Development Stakeholder Communications Manager	Gorgon Development Manager, EPA, DoIR, DEH and public stakeholders	Summary and update of Development progress, compliance monitoring and results, complaint and environmental incident reporting and follow-up. Overall performance evaluation and compliance with EMP/EMS objectives.
Internal Development Environmental Audit	Gorgon Site Environmental Officer, Specialist Consultants	Gorgon HES Manager, Gorgon Development Management	Assessment of progress against EMP including non-compliance and corrective action reports where required.

6.2 Non-Conformance, Incident and Corrective Action Reporting

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 shall 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 shall include management responsibilities for addressing, tracking and close-out of incident investigations, audits, inspections and monitoring programs.

Chevron Australia has a robust and proven incident management and investigation process. The Gorgon Development shall review, revise, document and adopt this process where appropriate.

This process shall 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 learnt
- procedures for follow-up and closure of actions.

Attachment 1

Matrix of Development Components and Activities

Development Component	Development Activities																		
	General Conduct	Drilling	Subsea Installation	Pipelaying	Rock Dumping/ Placement	Horizontal Directional Drilling	Piling	Traffic and Access	Earthworks	Blasting	Air and Dust Emissions	Lighting	Dredging and Spoil Disposal	Quarantine Management	Waste Management	Shipping and Navigation	Facility Testing	Clean-up and Rehabilitation	Contingency Planning and Emergency Response
Wells	✓	✓	✓								✓	✓		✓	✓	✓	✓		✓
Upstream Field Infrastructure (Manifolds and Flowlines)	✓		✓	✓							✓	✓		✓	✓	✓	✓		✓
Feed Gas Pipeline (Offshore and Onshore)	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Port Facilities (MOF and LNG Jetty)	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
MOF and LNG Channel and Turning Basin	✓		✓		✓					✓	✓	✓	✓	✓	✓	✓			✓
Condensate Load-out	✓		✓	✓	✓			✓	✓		✓	✓		✓	✓	✓	✓		✓
Optical Fibre Cable	✓		✓		✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓	✓
Domestic Gas Pipeline & Infrastructure	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Gas Processing Facility, Camp & Infrastructure	✓			✓				✓	✓	✓	✓	✓		✓	✓		✓	✓	✓
Power and Water Facilities	✓	✓		✓				✓	✓	✓	✓	✓		✓	✓			✓	✓
Access Roads	✓							✓	✓	✓	✓	✓		✓	✓			✓	✓
Airport	✓							✓	✓	✓	✓	✓		✓	✓			✓	✓
CO2 Injection System (Pipeline and Wells)	✓	✓		✓				✓	✓	✓	✓	✓		✓	✓		✓	✓	✓
Mainland Supply Base	✓			✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓

Technical Appendix B1

Air Quality Assessment

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SINCLAIR KNIGHT MERZ

SKM

The Gorgon Gas Development

AIR QUALITY ASSESSMENT

TECHNICAL APPENDIX B1

Prepared for

Chevron Texaco Australia Pty Ltd

The Gorgon Gas Development

AIR QUALITY ASSESSMENT

Prepared for

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Contents

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1 Executive Summary

The Gorgon Venture proposes to develop the Gorgon gas fields. The Gorgon gas development proposal includes establishing a gas processing facility within a limited area of Barrow Island. Currently, two LNG trains are proposed, each with a production capacity of 5 Mtpa.

Atmospheric emissions from the LNG plant will vary depending on the operating and tanker loading conditions. These include normal plant operations, ship loading and non-routine operations such as plant start up, plant shutdown and emergency venting of the CO_2 gas stream.

Two different atmospheric dispersion models were used to assess the impacts. DISPMOD modelled near-field dispersion of combustion products, while TAPM was used to evaluate regional impacts in the form of photochemical smog and the local deposition of combustion products.

Results indicate that the proposed facility will increase NO_2 concentrations but these will remain well below the relevant NEPM standard of 120ppb across the island. From a regional perspective, although current industrial emissions on the Burrup Peninsula may give rise to relatively hight peak concentrations on rare occasions, the proposed LNG facility makes negligible impact on these peaks.

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2 Introduction

The proposed gas processing plant will be located at Town Point on the central-east coast of Barrow Island. The development of the gas processing facility would occur in different phases based on market demand. This has been assumed to be achieved via the construction of one LNG train with a nominal capacity of five million tonnes per annum and a second similar capacity train as soon as there is sufficient market demand (anticipated to be within a few years of the first train).

During operation of the LNG plant, atmospheric emissions of greenhouse gases and other combustion products will occur. Ozone depleting substances may also be released. These air emissions 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 encountered from several kilometres to several hundred kilometres of the source. Potential regional impacts could be related to gases such as volatile organic compounds (VOCs) and NO_x that react at ground level or sea level to form ozone. Ground-level ozone does not replace the ozone depleted in the stratosphere, but remains in the stratosphere where it can contribute to health problems. Local effects are related to health effects, e.g. due to an increase in exposure within the LNG plant.

The Gorgon Venture is proposing to employ the latest production technology, resulting in reduced emissions over similar LNG facilities currently operating in Australia. Use of the latest technology has eliminated all emission sources except combustion of clean-burning natural gas. The principal emission from the plant will be NO_x. Consequently, an assessment of the likely impact on downwind nitrogen dioxide concentrations and potential photochemical smog has been conducted.

This report presents an estimate of the emissions from the LNG plant based on preliminary design information, and an assessment of the impact using atmospheric dispersion modelling. All combustion sources are assumed to have stack heights and emission velocities sufficient to prevent building wake effects. This requirement will be included in all relevant design specifications.

The report is divided into three sections as follows:

- Section 3 describes the likely emissions from the facility;
- Section 4 presents the relevant air quality criteria;
- Section 5 presents the atmospheric dispersion modelling results.

As requested by the Department of Environment, the modelling study predicts concentrations from existing sources in the area and the contribution from the proposal. Regional impacts are also addressed. Non-routine operating conditions are also considered, including start-ups, emergency flaring and venting due to failure of CO_2 re-injection system.

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3 Emissions to Atmosphere

A full description of the gas processing facility is provided in the EIS/ERMP. Only a summary is presented in this document.

The gas processing facility would separate gas and condensate (light oil) received from the Gorgon gas fields. After separation from the gas, the condensate will be stabilised prior to shipping to market. The gas component of the stream will then be treated to remove carbon dioxide (CO_2), hydrogen sulphide (H_2S), trace amounts of mercury (Hg) and water vapour. At this point the gas can be either liquefied for export as LNG, compressed and exported as domestic gas or utilised as feed gas other gas processing facilities.

Atmospheric emissions from the LNG plant will vary depending on the operating and tanker loading conditions. These include normal plant operations, ship loading and non-routine operations such as plant start up, plant shutdown and emergency venting of the CO_2 gas stream. It is expected however that normal conditions will predominate for the great majority of the time and will occur in excess of 92% of the time. For 30% of this time, plant operations will be accompanied by the loading of product onto LNG tankers. It is anticipated that the level of production may be reduced for 4 to 5 days per year, with another 22 days where the plant is shutdown for maintenance. Emergency operations may occur for up to 10 times per year. A shutdown will result in less than 1 hour of peak flaring, while start-up will be of approximately 6 hours duration.

3.1 Emissions from Normal Operation of LNG Plant

Combustion Products

The principal emissions from the LNG process arise from combustion of natural gas. The most significant products of gas combustion include: carbon dioxide (CO_2), oxides of nitrogen (NO_x) and carbon monoxide (CO) and unburnt hydrocarbons (VOCs). There may also be traces of particulate and sulphur dioxide (SO_2) but such emissions are generally considered negligible due to the firing of very low sulphur content natural gas in a controlled environment. NO_x will be the predominant pollutant.

Combustion sources from the 10 Mtpa LNG plant include:

- Power generation: 3 x Frame 9 gas turbines with dry low NO_x burners.
- Gas compressors: 4 x Frame 7 gas turbines with dry low NO_x burners powering direct drives with heat recovery steam generator to produce steam for steam drives.
- Package boilers: 2 x boilers raising the equivalent of 150 MW of steam.

Emissions of nitrogen dioxides would be minimised by the use of low-NO_x burners in all gas turbines. Emissions of sulphur oxides are expected to be low, as 75% of fuel gas would be sourced from treated "end-flash" gas that has negligible sulphur content. Initial sulphur levels in the raw feed gas would also be very low. Any hydrogen sulphide in the raw feed gas would be removed along with CO_2 in the "acid gas" removal process and re-injected into saline reservoirs 2000 m below Barrow Island. There would be no continuous hydrocarbon vents or emissions.

Table 3-1 lists the emissions produced from combustion during normal operation of the 10 mtpa LNG plant. The model input files presented in Appendix A give details of chimney heights and exhaust conditions.

Table 3-1 Combustion Emissions during Normal Operations

Source	Emissions			
	NO_X		Particulate	
	(kg/hr)	(tpa)	(kg/hr)	(tpa)
Frame 9 gas turbines	190	1700	12	105
Frame 7 gas turbines	240	2100	10	80
Boilers	70	630	7	56
Total	**500**	**4430**	**29**	**241**

Non-combustion Products

Major sources of potential fugitive emissions include volatilisation from storage and loading of products, compressor seals and component leaks (e.g., valves, flanges and pumps). The use of latest engineering practices has significantly reduced the level of fugitive emissions from gas plants. Historically, compressor seals have been a significant source of fugitive emissions from gas processing facilities. The proposed Gorgon gas development would utilise dry compressor seals that virtually eliminate fugitive emissions from this source. Vapour recovery on storage and loading facilities would be utilised where practicable. Selection of equipment would include consideration of the potential for fugitive emissions.

Typically almost all of the emissions from an LNG plant occur from the CO_2 removal process. The Gorgon Joint Venture has implemented several strategies to virtually eliminate BTEX emissions from the gas development. Gorgon has approached this issue in three ways:

- Re-injection of CO_2 and associated traces of BTEX and H_2S
- Use of a MDEA solvent to minimise the removal of BTEX from the gas stream
- Hydrocarbons from the CO_2 waste stream are recovered and sent back into the process or used as fuel gas.

Under normal operations there will be no emissions due to the CO_2 removal process. The only other potential source of BTEX from the facility is from the regeneration of MEG and TEG. In both these cases a similar regeneration process is used with the BTEX rich flash gases being recovered back to the process.

The proposal will include two 135 000 m^3 LNG storage tanks. The tanks will include both a double containment system and a vapour recovery system. Any LNG boil off gas will be captured and returned to the LNG plant as fuel gas for the turbines.

There will also be two 35 000 m^3 condensate storage tanks, which will have internal floating roofs to minimise fugitive emissions.

There will a vapour recovery system installed for the loading of LNG tankers. As with the storage tanks, any LNG boil off gas will be captured and returned to the LNG plant as fuel gas for the turbines. It is proposed to load condensate through the existing WA Oil tanker loading facility. This facility does not have a vapour recovery system, so there will be minor emissions of VOCs.

3.2 Emissions from Non-Routine Operation of LNG Plant

To minimise the risk to personnel and the plant in the event of process upsets, flaring will be used as a safety measure to release gases from high pressure vessels rather than venting. Gas processing facility flare systems collect and dispose of hydrocarbons released during start-up, shutdown, upset and emergency conditions. Where practicable and without compromising the safety of the plant and personnel, all significant continuous flaring or venting sources will be eliminated.

Emissions from flaring will occur due to emergencies, process upsets, plant start-up and plant shutdown. The design will incorporate a high efficiency flare to minimise the portion of unburnt hydrocarbon to as low as reasonably practicable. The height of the flare will depend on the final facility layout and flare structure location, but is expected to be approximately 120 m.

It is expected that the LNG plant will be shut down for sufficient time to require a cold start on up to ten occasions per year. Each start up will be of approximately 6 hours duration, during which time scrub overheads, which represent 30% of the normal flow rate of a single train, will be directed to the dry gas flare. Maximum emissions from the flare include up to 420 kg/hr of particulate matter and 25 kg/hr of oxides of nitrogen. Peak emissions are unlikely to remain at the full maximum for the full duration of the start-up process.

During a cold start power will be supplied by a 5 MW diesel generator, which could 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.

Shutdowns of the LNG plant could take several forms. They could be required for a planned maintenance program, in which case there will be the opportunity to minimise emissions. Alternatively, there could be an emergency shutdown of both trains, requiring release of the total plant inventory of LNG, feed gas etc. In either case, gases will be released via both wet and dry flares. It is anticipated that such emergency situations will occur less than ten times per year and be of less than one hour peak flaring. The total design capacity of the two flares is 4200 t/hr and this will represent a worst case event. Maximum emissions from the two flares include up to 2500 kg/hr of particulate matter and 160 kg/hr of oxides of nitrogen.

It is proposed to re-inject reservoir carbon dioxide into saline reservoirs beneath Barrow Island. Emergencies may occur, for example failure of the CO_2 compressor unit, whereby the re-injection system is not available. In this event, it will be necessary to vent CO_2 from both trains to the atmosphere. As H_2S is also present in the feed gas, it will be released with the CO_2. It is estimated that approximately 100 kg/hr of uncombusted H_2S will be vented with the CO_2. The LNG plant will continue to operate normally whilst venting of the CO_2 and H_2S occurs. Therefore, the emissions of these two gases will be the same as for that described for "normal operations".

Table 3-2 gives a summary of emissions resulting from non-routine operation of the LNG plant.

Table 3-2 Emissions from Non-routine Operation of LNG Plant.

Operating Scenario	Emissions			
	NO_x (kg/hr)	H_2S (kg/hr)	SO_2 (kg/hr)	Particulate (kg/hr)
Shutdown Emissions are for worst case, emergency shut down of both trains	160	0	0	2 500
Start-Up For both trains	378	0	3.6	440
Failure of CO_2 Re-Injection System	500	100	< 1	29

3.3 Existing Emission Sources

Local Emissions

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 flare and crude oil storage and transport.

The Central Power Station which consists of 2 x 2.5 MW gas turbines fuelled by low pressure gas supply, is currently the main source of power generation for Barrow Island. Products of combustion are the most significant emissions from the turbines, with oxides of nitrogen being the predominant pollutant.

A summary of current atmospheric emissions is presented in Table 3-3.

Table 3-3 Current Annual Atmospheric Emissions from Barrow Island (from Barrow Island Annual Environmental Report, 2003).

Source Description	SO_x (tonne)	NO_x (tonne)	VOC (tonne)	CO (tonne)
Diesel Engines	3	-	-	-
Barrow Island Power Station	-	927	23	736
Barrow Island Well field Operations	-	638	19	582
Crude oil transport and storage	-	-	33	-
Flare	26	31	246	169
Flashing	-	-	18	-
Venting	-	-	502	-
Fugitive Emissions	-	-	544	-
Total	**29**	**1 596**	**1 385**	**1 487**

Regional Emissions

At the time of writing, the existing industrial activities that emit significant quantities of related contaminants to the proposed LNG plant include:

- The Woodside onshore gas treatment facility on the Burrup Peninsula including the domestic gas plant, LNG and LPG facilities;
- Hamersley Iron's power station at Parker Point near Dampier.

Woodside is also currently constructing Train 4 for their existing facility.

Table 3-4 lists emissions from these sources and compares them with the proposed LNG plant under normal operations.

Table 3-4 Regional Industry Emissions as modelled.

Source	Emissions (kg/hr)	
	NO_x as NO_2	VOC
Dampier Power Station	76	0
Woodside Facilities (with Trains 4 and 5)	911	4 752

As part of the assessment of regional photochemical reactions, it is necessary to also account for both biogenic and area source emissions from the general area. A recent study of the Pilbara region undertaken by CSIRO Atmospheric Research and the

Department of Environmental Protection (CSIRO, DEP 2001) has evaluated these emissions with respect to determining appropriate dispersion models for the region. The relevant data input files for TAPM used were provided by the CSIRO.

4 Air Quality Criteria

Within Western Australia, the Environmental Protection Authority (EPA) assesses any new project in terms of emissions at stack and the resultant ambient ground level concentrations.

4.1 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 assessments 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.

The EPA has developed a guidance statement for oxides of nitrogen emissions from gas turbines, with limits for emissions following the AEC/NHMRC National Guidelines (EPA, 2000). These limits are 0.07 g/m^3 (STP, dry and 15% O_2) for gaseous fuels" and 0.15 g/m^3 for "other fuels". The Guidance Statement goes on to say that modern natural gas-fired systems, employing NO_x control technology can be expected to achieve lower emissions than 0.07 g/m^3.

4.2 Ambient Air Quality Standards

For ambient ground level concentrations, the EPA does not have state-wide standards. For these, the EPA requires that pollutants meet the National Environmental Protection Measure (NEPM) standards (NEPC, 1998) as listed below in Table 4-1. These specify a maximum concentration and the goal that is to be achieved within 10 years.

Table 4-1 Relevant Environmental Protection Measures – Standards and Goals.

Pollutant	Averaging Period	Maximum Concentration	Goals within 10 years Maximum allowable exceedences
Nitrogen Dioxide	1 hour 1 year	0.12 ppm (246 $\mu m/m^3$) 0.03 ppm (62 $\mu m/m^3$)	1 day per year
Photochemical oxidants (as ozone)	1 hour 4 hours	0.10 ppm (214 $\mu m/m^3$) 0.08 ppm (171 $\mu m/m^3$)	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 $\mu g/m^3$	5 days a year

These NEPM standards and goals have not been implemented in legislation throughout the state as yet, the DoE intend to implement them through the development of a state-wide Environmental Protection Policy (EPA, 1999b). Throughout Western Australia, these standards apply outside industrial areas and residence free buffer areas around industrial estates" (EPA, 1999b, pp3).

For other pollutants, the DoE tends to reference the lowest standards that are in use throughout Australia. For this plant, the only other pollutant of concern is hydrogen sulphide. For this project the Victorian State Environmental Protection Policy (Victorian Government Gazette, 2001) design ground level concentration of 470 $\mu g/m^3$ (0.32 ppm) for a 3-minute average has been adopted. This concentration corresponds to the toxicity level, it is likely that odour from the gas will be detected at a much lower concentration.

These standards apply outside industrial areas and residence-free buffer areas around industrial estates. With no formally defined industrial buffer zone applied to Barrow Island, we have elected to apply the NEPM at the nearest permanent residence, namely the current ChevronTexaco accommodation facility.

5 Atmospheric Dispersion Modelling

5.1 Important Dispersion Processes

For pollutants released in near coastal environments the following four dispersion processes are considered important:

- Dispersion under convective conditions when the buoyant plumes can be mixed to ground level within a short distance of the stacks;
- The influence of the sea breeze with the creation of the Thermal Internal Boundary layer (TIBL) where onshore winds can lead to complex vertical dispersion. For onshore flows during the day time, the relatively cooler, stable onshore air will be warmed by the heated land surface. As such, a region of unstable convective turbulence (the TIBL) will grow with distance downwind. For tall stacks sited at the coast or very buoyant plumes, the plumes will rise above the TIBL and initially be relatively concentrated, not having had an opportunity to disperse. Further inland when the TIBL has grown to the height of these plumes, the plumes will then undergo rapid vertical mixing resulting in relatively high ground level concentrations. Alternatively plumes from short stacks and/or low buoyancy plumes will remain trapped beneath the TIBL resulting in higher ground level concentrations than would otherwise occur;
- The influence of the buildings and structures around facilities that may lead to increased dispersion and reduced plume rise from the stacks; and
- The presence of terrain features like hills and ridges in the surrounding area can impact on dispersion and be subject to elevated concentrations.

To assess all four processes, two models CALPUFF and TAPM are available. CALPUFF (Californian Puff model) performs well under convective conditions, allows for puffs to drift in light winds or to be recirculated and can cover both local and regional scales. However, CALPUFF has not been used in this study due to the long run times and the complexities involved in establishing a suitable meteorological file. TAPM is a 3-dimensional prognostic model that predicts both meteorology and dispersion of air pollutants including the chemical transformations involved in the production of ozone (EPA, 2004). TAPM is limited by the resolution of the grid and it is recommended that alternative models be used to predict near source ground level concentrations. TAPM has been used in this assessment to model:

- Regional impacts (ozone);
- Determine dry deposition rates; and
- Determine if building wakes will increase dispersion and reduce plume rise from the stacks.

To predict local air quality impacts from existing and future industries in this study, DISPMOD, the Western Australian Department of Environmental Protection (WA DEP) dispersion model was used. DISPMOD was specifically developed to model dispersion in coastal regions and under convective conditions.

5.2 DISPMOD

DISPMOD is primarily suitable for near field predictions, particularly for non-reactive gases and is the recommended model for predictions within 2 to 3 km of a source. In general, it appears that this model is likely to over-predict concentrations but it has limitations in areas where fumigation of recirculated emissions are involved, or where area sources contribute to background emissions. DISPMOD was used for this project to predict concentrations of NO_x, SO_2, H_2S and particulates for the proposed plant over a 5.5 by 8.5-km receptor grid.

The model used the following parameters:

- Dispersion in the layer above the TIBL governed by plume self generated turbulence;
- Account for wind shear in the new PDF model;
- Numerical model to predict TIBL heights;
- Convective plume trapping cases to be modelled using the PDF approach; and
- Coastal file developed from the 1:100,000 Barrow Island topographical map.

TAPM ver2.5 (The Air Pollution Model) was used to obtain both the hourly surface meteorological file and the upper air potential temperature lapse rate file required by DISPMOD. TAPM is a prognostic three-dimensional model designed by CSIRO that can used to predict meteorological and air pollution parameters on an hourly basis (Physick *et al* 2001). The meteorological parameters predicted by the model have been compared to actual readings recorded during the Kwinana Coastal Fumigation study (Hurley *et al* 2000) and the Pilbara air quality study (Physick *et al* 2001). It was found that the model predicts near-surface parameters very well while the upper parameters were also well predicted. An observed file containing hourly wind speed and direction for the year 2003 from the Bureau of Meteorology station at the Barrow Island airstrip was used to 'force' the model.

The model was setup with the following parameters:

- Grid centre at 21°47'S and 115°27.5'E (339700E 7699950N);
- 30 km, 10 km, 3 km and 1 km grids nested at 21 x 21 x 20; and
- Elevation changed to agree with the 1:100,000 Barrow Island topographical map.

Maximum nitrogen dioxide concentrations were estimated from the DISPMOD simulations by assuming the following relationship for all parts of the grid:

$$NO_2 = 0.3NO_x + 14.39 \quad \text{for } NO_x \geq 20.56\ \mu g/m^3$$

$$NO_2 = NO_x \quad \text{for } NO_x < 20.56\ \mu g/m^3$$

This is based on monitoring data from Dampier, which shows the ratio of NO_2 to NOx to generally remain well below 0.3.

DISPMOD was used to model both normal and non-routine operations.

Appendix A gives examples of DISPMOD input files. All combustion sources are assumed to have stack heights and emission velocities sufficient to prevent building wake effects.

5.3 TAPM

Atmospheric Deposition on the Surrounding Environment
The deposition of atmospheric pollutants can occur through two mechanisms, these being wet and dry deposition. Wet deposition describes the deposition of acidic pollutants through rainfall, and is commonly referred at as "acid rain". Dry deposition refers to the fall-out of gases and particulates on the ground surface without any interaction with water. Dry deposition tends to occur close to the source of pollution, depending upon prevailing weather conditions, and dominates in dry climates (EPA, 2001). Dry deposition is expected to be the dominant mechanism on Barrow Island by which atmospheric pollutants are deposited on terrestrial and aquatic environments.

It is important to note that there are large uncertainties with the predicted deposition values predicted by TAPM. This uncertainty is present in all models that predict deposition due to the large uncertainty in the water, soil and vegetation surface resistances used. Extensive programs using both measurements and model calibration are necessary to reduce this uncertainty, and this will only reduce the uncertainty in that particular study area (Hurley et al, 2003). The deposition values presented in this report can only be considered 'indicative' of what may occur until measurements can be conducted to validate the model.

Regional Impacts
The impact of the operation of the LNG plant on regional air quality was investigated using TAPM to model photochemistry. The model was run using both existing sources and existing plus future on both Barrow Island and the Burrup Peninsula.

For this purpose, the model simulation was set up with the following parameters:

- Grid centre at 21°47'S and 115°27.5'E (339700E 7699950N);
- 30 km and 10 km grids nested at 31 x 31 x 20; and
- Biogenic and gridded inventory files obtained from the CSIRO (Hurley et al, 2003 and SKM 2003).

The existing sources on the Burrup Peninsula consisted of the Woodside Onshore Treatment plant and the Hamersley Iron power station adjacent to Dampier. The stack parameters and emission values were obtained from Hurley et al (2003). The stack parameters for the existing sources on Barrow Island were not available, therefore the stack parameters were taken as identical to a similar plant at the Woodside plant. NO_x and VOC emissions were obtained from the Barrow Island Annual Environmental Report 2003 (ChevronTexaco Australia Pty Ltd, 2003).

The stack and emission parameters for the future sources on the Burrup were also obtained from Hurley et al (2003) with the exception that Methanex, Dampier Nitrogen and GTL were not included as these projects are unlikely to proceed. The future sources on Barrow Island are identical to that used in the DISPMOD modelling for normal operations with the inclusion of a Rsmog emission rate of 0.4 g/s. Using a Rsmog of this rate is considered an over-estimate as the process is using the latest production technology that should reduce fugitive emissions of volatile organic compounds.

The stack and emission parameters are presented in Appendix A.

The same NO_x emissions data was used as for the DISPMOD normal operations run with a NO/NO_x ratio of 0.9 for all sources.

Part of a sample list file for TAPM is presented in Appendix A.

5.4 Modelling Results

Local Ground Level Concentration

Normal Operations

Figures 5-1 and 5-2 present the local distribution of the maximum NO_2 concentrations (ppm) for normal operations predicted using DISPMOD. The maximum 1-hour NO_2 concentration predicted over the entire grid is 0.06 ppm, compared to the NEPM value of 0.12 ppm. Similarly, the predicted maximum annual concentration of NO_2 is 0.003 ppm, which is approximately 10 times less than the NEPM value of 0.03 ppm. Maximum annual averages occur to the north east of the proposed LNG plant, reflecting the dominant south westerly winds.

Figure 5-3 presents the maximum predicted 24-hour PM10 concentrations ($\mu g/m^3$) for normal operations. The maximum predicted value of 3 $\mu g/m^3$ is approximately 6% of the corresponding NEPM value of 50 $\mu g/m^3$.

A summary of the maximum concentrations of the various pollutants for routine operations is presented in Table 5-1.

Non-Routine Operations

As described in Section 3-2, under non-routine operations, emissions from the flare and diesel generator will be much greater than under normal operations and potentially may lead to higher ground level concentrations. Dispersion modelling was conducted to predict the maximum concentrations of the various emissions resulting from the three non-routine operating scenarios; shutdown, start-up and failure of the CO_2 re-injection system. The modelling considered worst case emissions whereby both trains were considered to in operating in the non-routine mode.

Maximum predicted 1-hour concentrations of NO_2 resulting from a cold start of both trains of the LNG plant are presented in Figure 5-4. Maximum concentrations are predicted to be well below the corresponding NEPM standards. The only other emissions released during a cold start are small quantities of SO_2 (less than 5 g/s) and particulate matter. As expected the dispersion modelling predicted that the ground level concentrations of both emissions are well below the NEPM standards.

The only emissions due to an emergency flaring during shutdown are oxides of nitrogen and particulate matter. Maximum 1-hour concentrations of NO_2 resulting from an emergency shutdown of the LNG plant are presented in Figure 5-5. The maximum value of 0.049 μg/m^3 is less than 50% of the relevant NEPM standard. The predicted maximum 1-hour concentration of particulate during an emergency shutdown assuming that the flaring occurred at the worst case meteorological conditions is 4561 μg/m^3. This equates to a 24-hour average of approximately 200 μg/m^3. The maximum concentration occurs within the boundary of the plant. The peak concentrations decrease rapidly with distance from the plant, such that at the current ChevronTexaco accommodation camp 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.

Maximum predicted 1-hour concentrations of NO_2 occurring during a failure of CO_2 re-injection system are the same as those presented in Figure 5-1. . The maximum 3-minute concentrations of H_2S generated by flaring due to failure of CO_2 re-injection system are presented in Figure 5-6. The maximum value of 113 μg/m^3 is less than a quarter of the Victorian EPA design ground level concentration of 470 μg/m^3.

A summary of the maximum concentrations of the various pollutants for non-routine operations is presented in Table 5.1.

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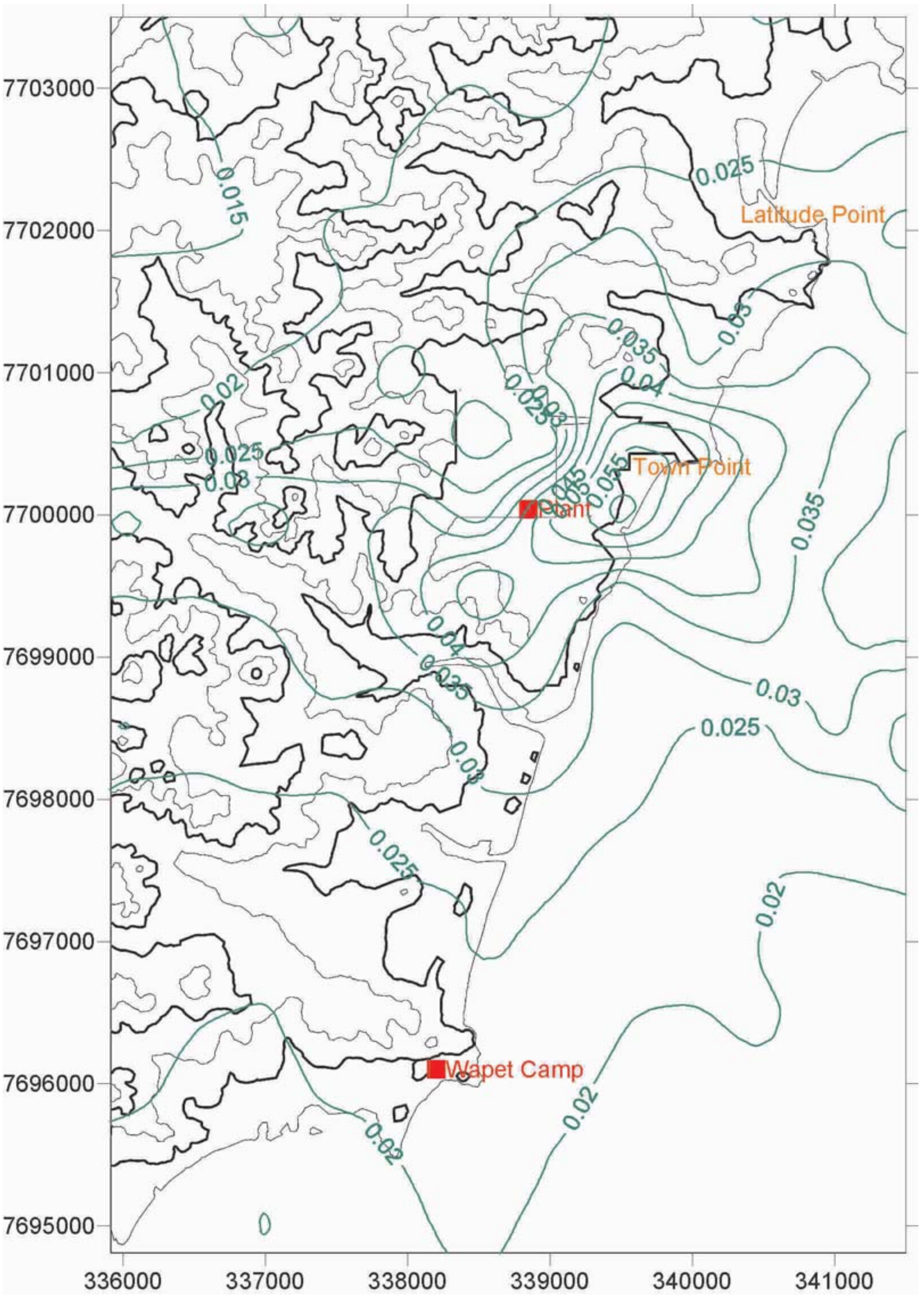

Figure 5-1 Maximum predicted 1-hour NO_2 concentrations (ppm) for proposed LNG plant under normal operation

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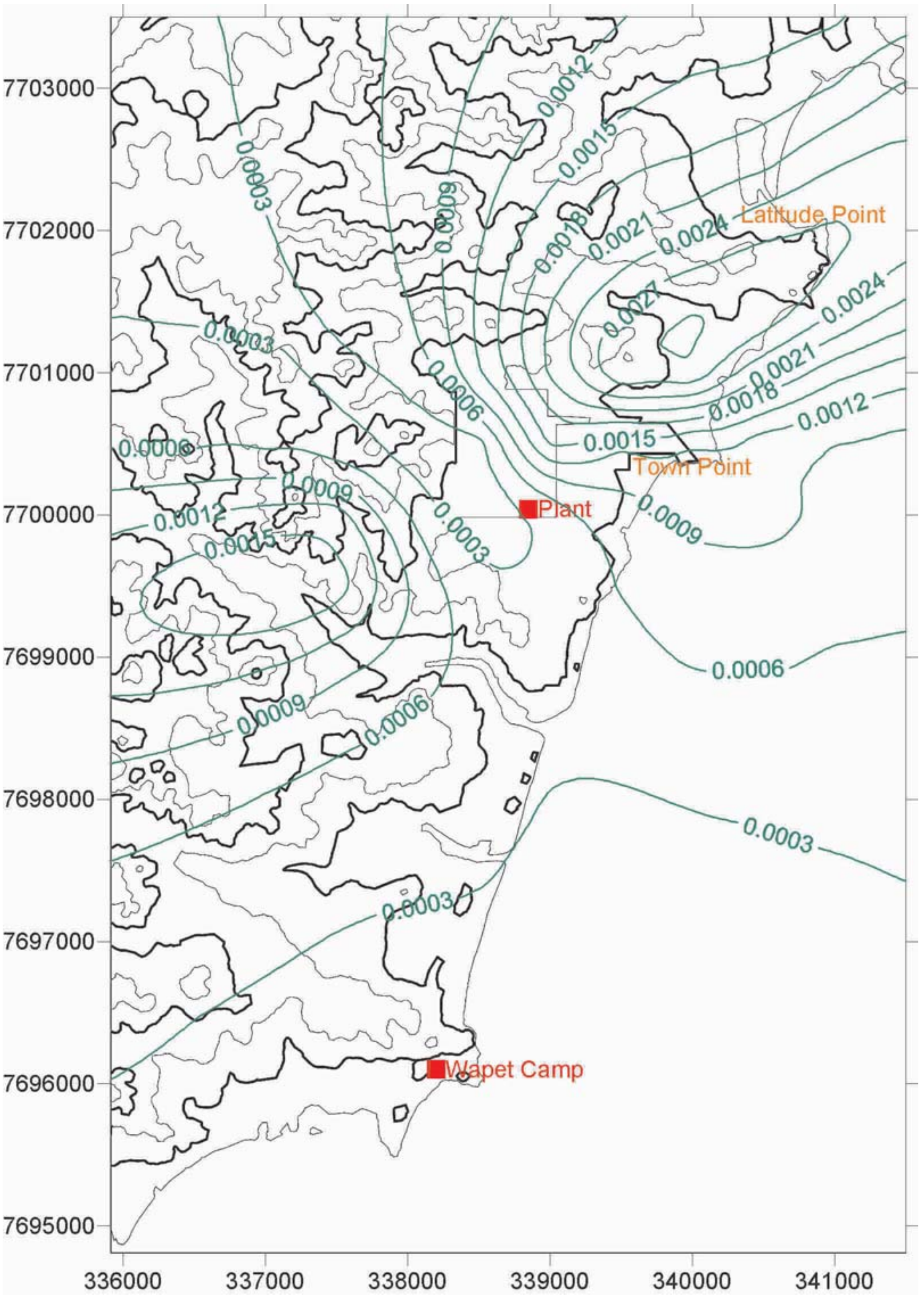

Figure 5-2 Maximum predicted annual NO_2 concentrations (ppm) for proposed LNG plant under normal operation

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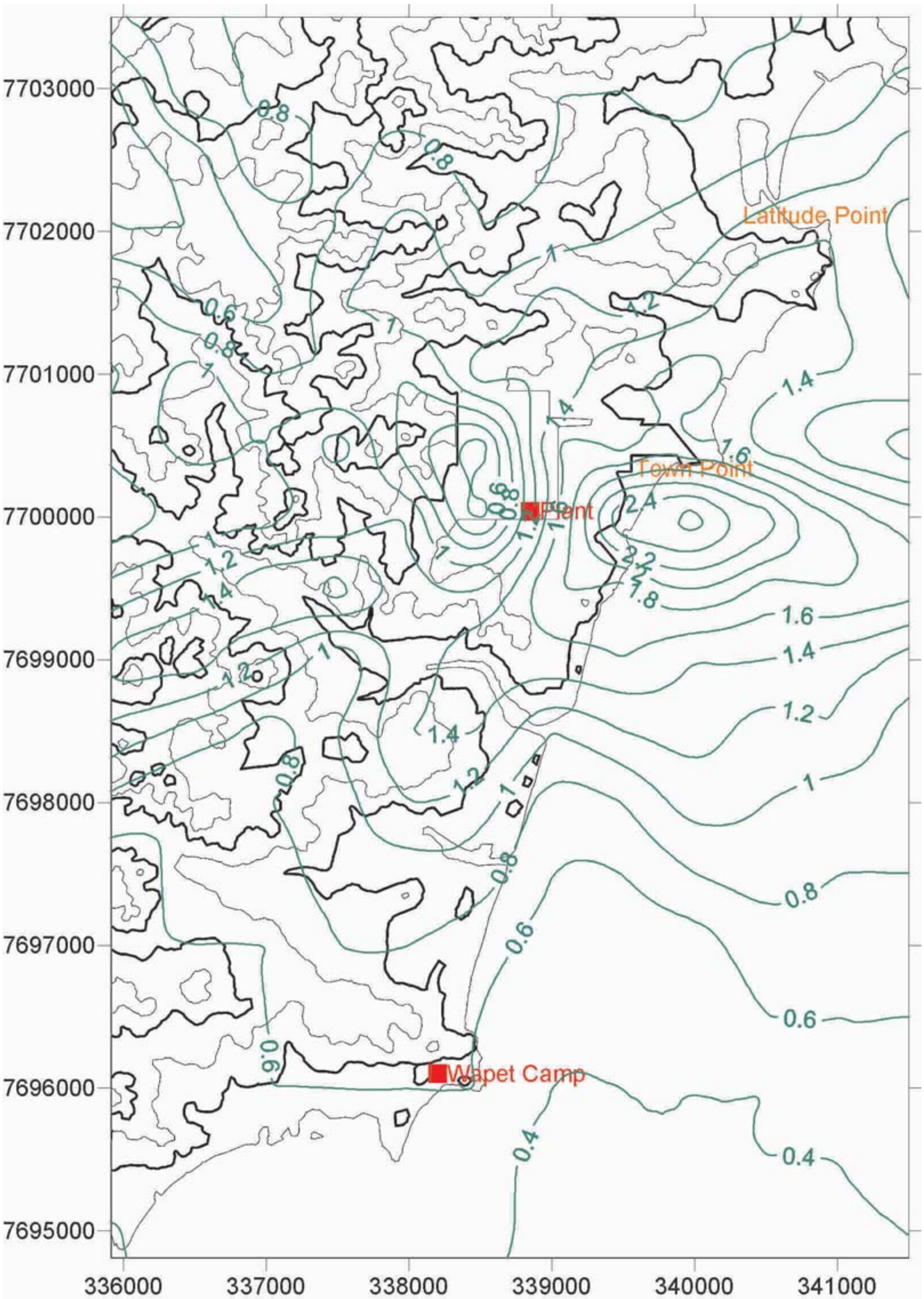

Figure 5-3 Maximum predicted 24-hour PM10 concentrations (μg/m^3) for proposed LNG plant under normal operation

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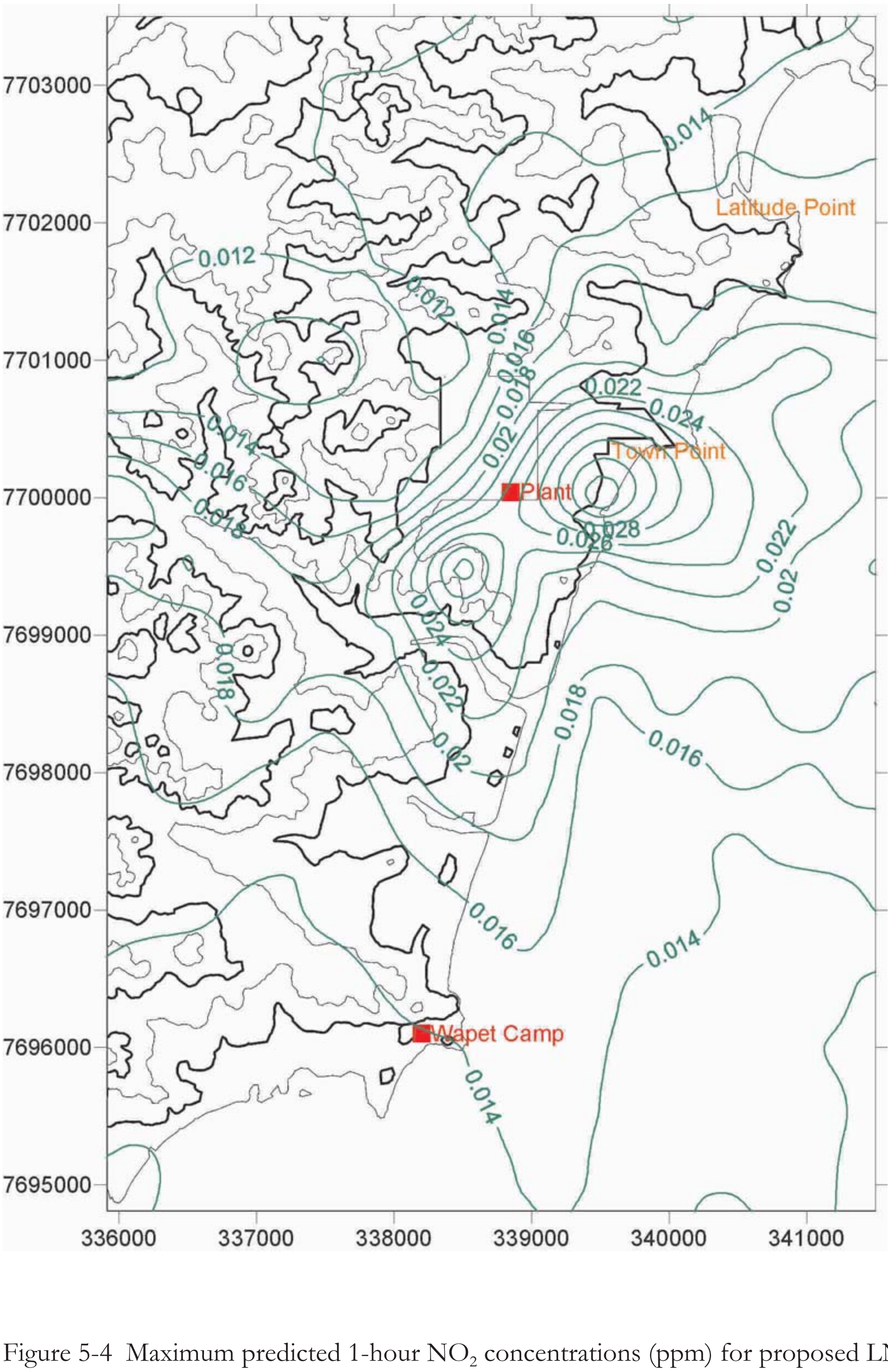

Figure 5-4 Maximum predicted 1-hour NO_2 concentrations (ppm) for proposed LNG plant under a cold start-up

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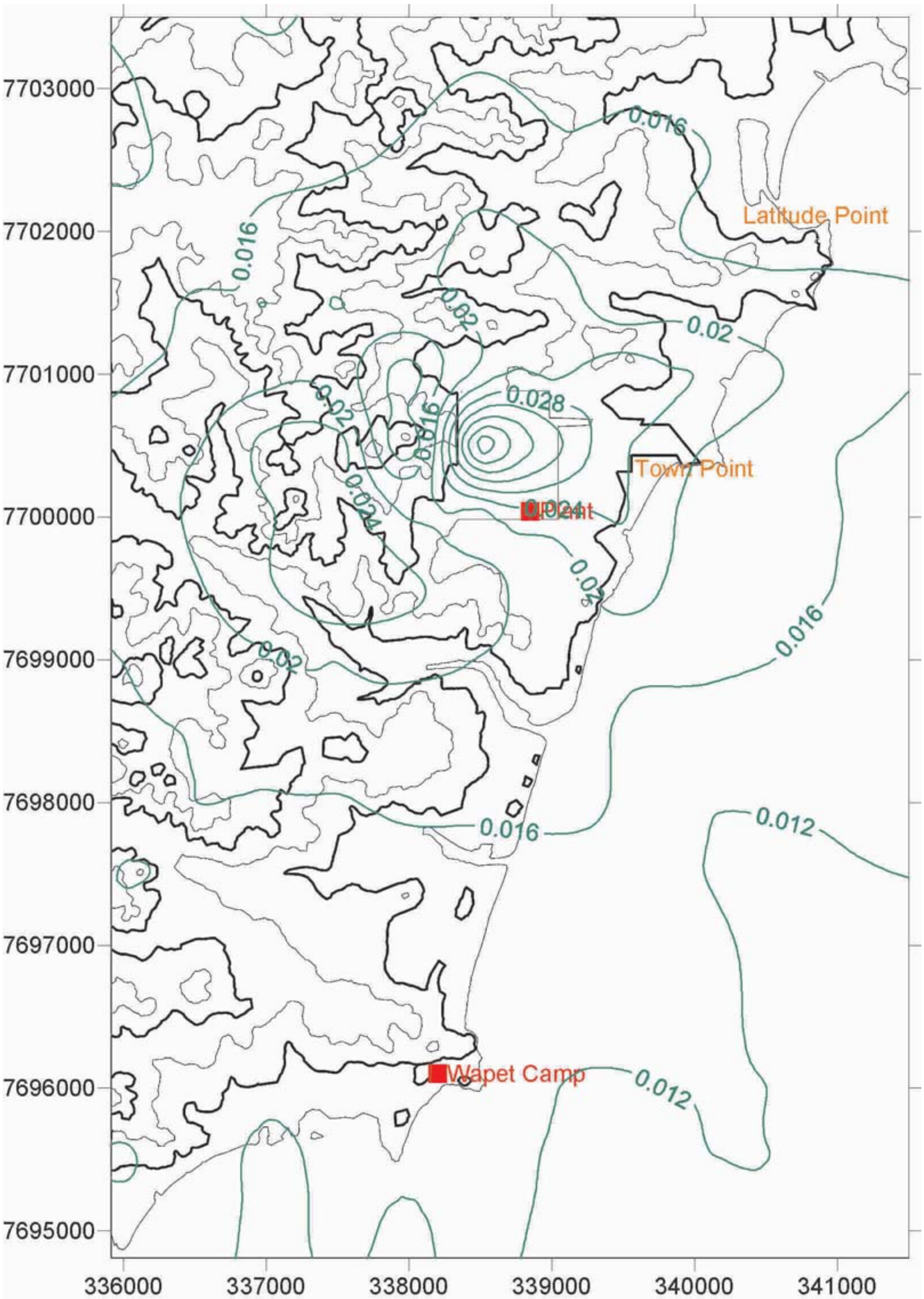

Figure 5-5 Maximum predicted 1-hour NO_2 concentrations (ppm) for proposed LNG plant resulting from an emergency shut-down

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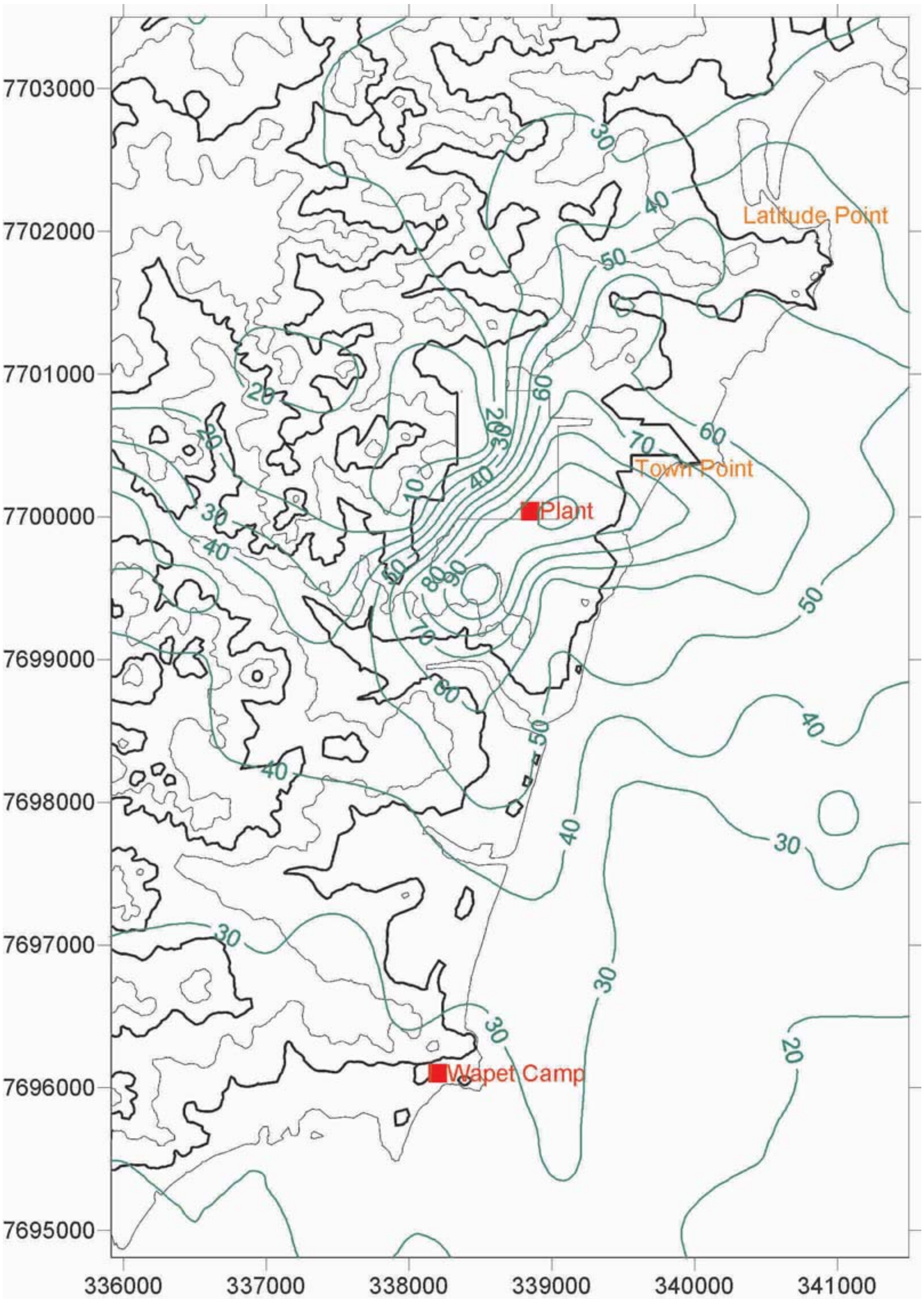

Figure 5-6 Maximum predicted 3-minute H_2S concentrations ($\mu g/m^3$) for proposed LNG plant generated by flaring due to failure of CO_2 re-injection system

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Table 5-1 Maximum ambient concentrations with low NO_x Burners for various Operating Scenarios.

Operating Scenario	**NO_x**		**NO_2**		**PM_{10}**	**H_2S**		**SO_2**	
	1-hour (ppm)	Annual (ppm)	1-hour (ppm)	Annual (ppm)	24-hour ($\mu g/m^3$)	3 minute ($\mu g/m^3$)	1-hour ($\mu g/m^3$)	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
Shutdown	0.212	N/A	0.049	N/A	330	N/A	N/A	N/A	N/A
Failure of CO_2 Re-injection system	0.293	N/A	0.064	N/A	3	113	62	N/A	N/A

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A summary of the maximum concentrations of the various pollutants for non-routine operations is presented in Table 5-1.

5.5 TAPM

Local Deposition Rates

The total dry deposition to the ground (vegetation, soil/rock and any water bodies) of NO_2 from TAPM are presented in Figure 5-7. The highest NO_2 deposition rates occur over water. This is considered to be primarily due to the deposition to vegetation being dependent on daylight and the photosynthesis process and that TAPM uses a moderately high solubility factor for NO_2; the maximum deposition rates are around 180 000 $\mu g/m^3$ (1.8 kg/ha/year).

Comparison to the WHO (2000) critical load for N deposition of 15-20 kg/ha/year for dry heathland, indicates that the deposition over land of between 0.2 to 1.8 kgNO_2/ha/year (0.06 to 0.55kgN/ha/year) is relatively insignificant (0.4-3.6% of the criteria).

Regional Impacts

Photochemical smog forms when pollutants such as nitrogen oxides and reactive organic compounds react together under the influence of sunlight and high temperature. The principal component of smog is ozone and consequently it is used to define smog levels. Ozone near the ground (as distinct from the "ozone layer" that occurs tens of kilometres up in the atmosphere) occurs typically in the range of 15 to 35 ppb and at such concentrations is a colourless gas. Ozone is a strong oxidant which reduces pulmonary function and can damage vegetation and susceptible materials at higher levels.

Figure 5-8 presents the peak TAPM predictions for existing sources. The 1-hour maximum concentrations of ozone are slightly higher than those predicted by the CSIRO in their Burrup modelling (0.087 ppm to 0.081 ppm). This is thought to be mainly due to the inclusion of emissions from Barrow Island. These emissions were based solely on information supplied by (WA Oil) and consisted only of total annual emissions of VOC and NO_x.

The maximum 1-hour concentrations of ozone (ppm) predicted for future operations are presented in Figure 5-9. The modelling considered emissions from the current WA Oil operations on Barrow Island, regional emissions (e.g. industrial plants currently in operation or under construction on the Burrup Peninsula) and the proposed Gorgon LNG plant.

With the inclusion of emissions from the proposed LNG facility, the maximum 1-hour ozone concentration (anywhere on the grid) increased slightly from 0.087 ppm to 0.092 ppm. There is little change over the existing scenario, apart from an increase in maximum ozone concentration to the south west of Barrow Island. The concentrations predicted for the Burrup Peninsula and Dampier/Karratha region exhibit very little, if any, change.

The maximum peak 1-hour ozone concentrations on the grid are predicted to be below the NEPM standard of 0.10 ppm. Thus, while the current and proposed emissions on the Burrup Peninsula may give rise to relatively high peak concentrations on rare occasions, the proposed LNG facility makes little impact on these peaks.

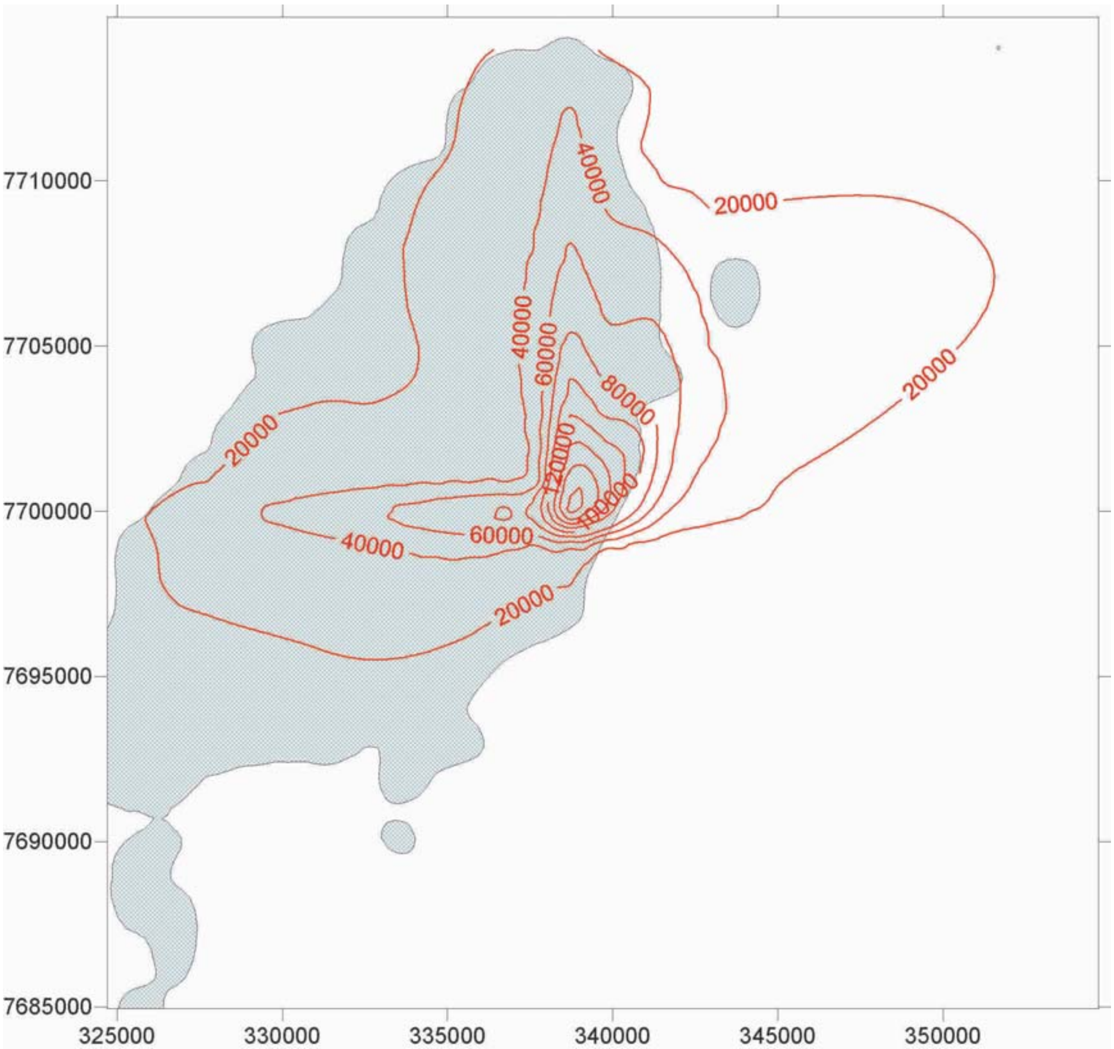

Figure 5-7 Annual dry NO_x deposition ($\mu g/m^2/yr$) for proposed LNG plant

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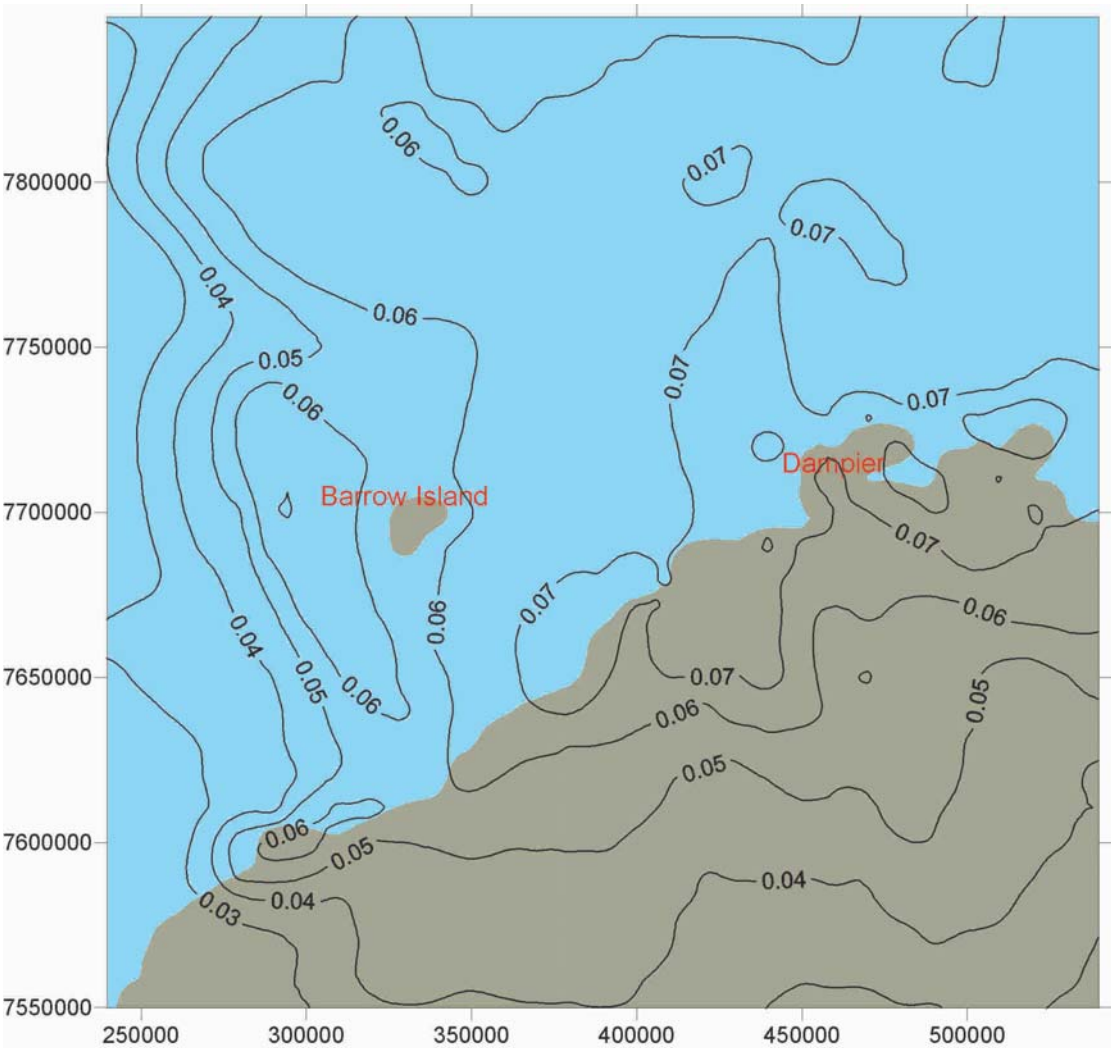

Figure 5-8 Maximum 1-hour ozone predictions using TAPM for existing emissions

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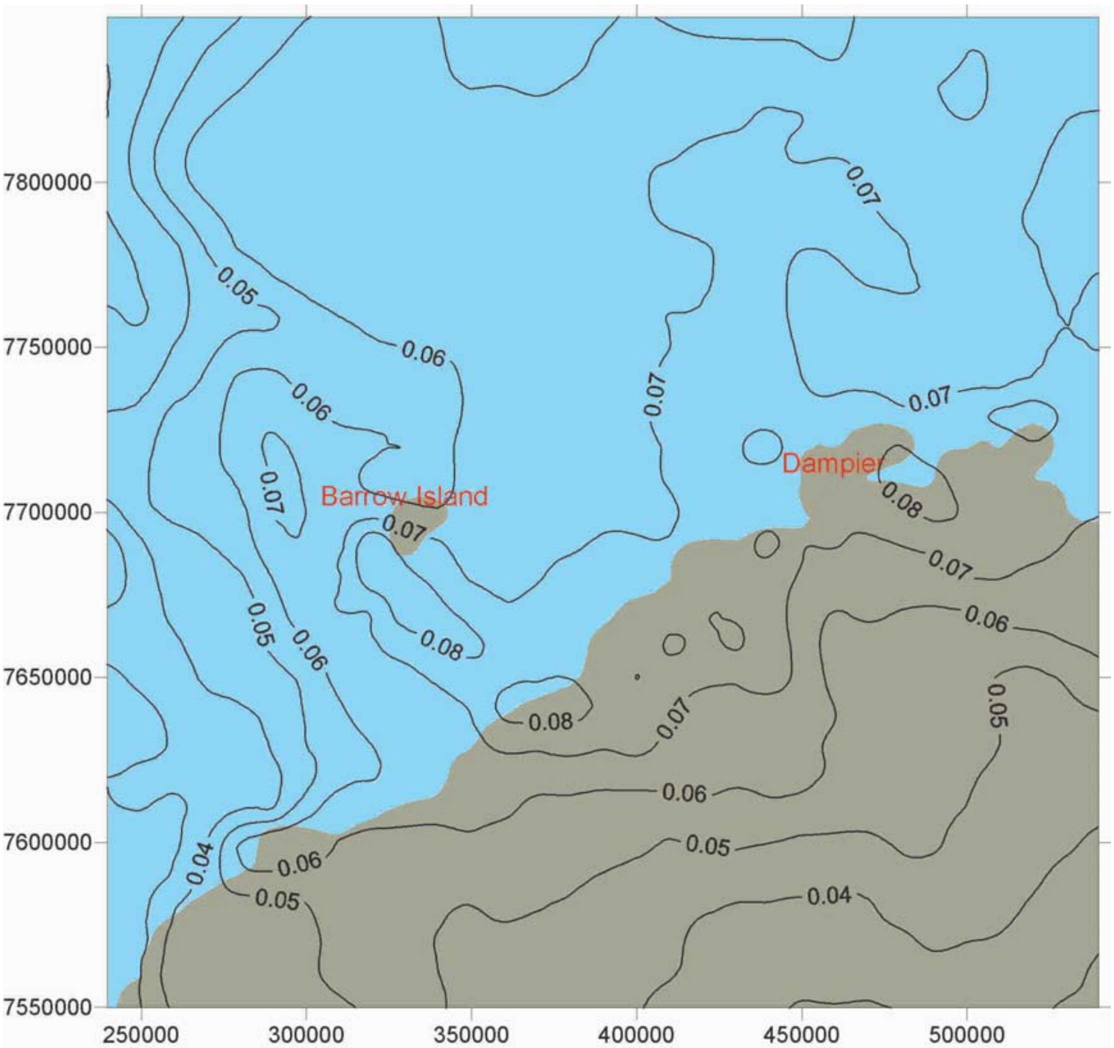

Figure 5-9 Maximum 1-hour ozone predictions using TAPM for existing and proposed LNG emissions

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Appendix A Model Input Files

Existing Sources

Source	Location		Height	Radius	EF	Velocity	Temperature	PM10	NOx	SO2	Rsmog
	(Easting)	(Northing)	(m)	(m)		(m/s)	(K)	(g/s)	(g/s)	(g/s)	(g/s)
Woodside											
GT4001	476910	7722765	40	1.98	2.7	20.2	777	0	13.5	0.2	0
GT4002	476910	7722800	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4003	476910	7722810	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4004	476910	7722845	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4005	476910	7722855	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4006	476910	7722890	40	1.98	2.7	20.2	777	0	13.46	0.24	0
1KT1410	476540	7722965	40	1.94	2.1	23.9	790	0	15.8	0.3	0
1KT1420	476590	7722965	40	1.94	2.1	23.9	790	0	15.6	0.27	0
1KT1430	476610	7722965	40	1.87	2.1	25.8	790	0	15.3	0.27	0
1KT1440	476660	7722965	40	1.87	2.1	26.3	806	0	15.5	0.27	0.4
1KT1450	476510	7722960	40	1.36	2.1	21.2	784	0	9.4	0.1	0
2KT1410	476540	7722845	40	1.94	2.1	23.9	790	0	15.8	0.3	0
2KT1420	476590	7722845	40	1.94	2.1	23.9	790	0	15.6	0.27	0
2KT1430	476610	7722845	40	1.87	2.1	25.8	790	0	15.3	0.27	0
2KT1440	476660	7722845	40	1.87	2.1	26.3	806	0	15.5	0.27	0.4
2KT1450	476510	7722840	40	1.36	2.1	21.2	784	0	9.4	0.1	0
3KT1410	476540	7722610	40	1.94	2.1	23.9	790	0	15.8	0.3	0
3KT1420	476590	7722610	40	1.94	2.1	23.9	790	0	15.6	0.27	0
3KT1430	476610	7722610	40	1.87	2.1	25.8	790	0	15.3	0.27	0
3KT1440	476660	7722610	40	1.87	2.1	26.3	806	0	15.5	0.27	0.4
3KT1450	476510	7722605	40	1.36	2.1	21.2	784	0	9.4	0.1	0
1F2001	477152	7722915	33	0.73	1.7	6	700	0	0.3	0	0
2F2001	477152	7722905	33	0.73	1.7	6	700	0	0.3	0.01	0
3F2001	477152	7722895	33	0.73	1.7	6	700	0	0.3	0.01	0
4F2001	476968	7722880	33	0.73	1.7	6	700	0	0.3	0.01	0
5F2001	476968	7722870	33	0.73	1.7	6	700	0	0.3	0.01	0
1KT2420	477035	7722698	24	1	2.5	40.7	816	0	9.4	0.1	0
1KT2430	477050	7722698	24	1.45	2.5	30.6	620	0	20.3	0.2	0
2KT2420	477065	7722698	24	1	2.5	40.7	816	0	9.4	0.1	0
2KT2430	477080	7722698	24	1.45	2.5	30.6	620	0	20.3	0.2	0
SealOil	476500	7722500	20	1	1	0	400	0	0	0	0.1
Hamersley											
HAM_stack1	471500	7717000	60	1.3	1	7	393	0	5.7	1	0
HAM_stack2	471500	7717000	60	1.3	1	7	393	0	5.7	1	0
Barrow Island											
BI_GT1	332000	7697000	30	1.98	2.7	20.2	777	0	25.3	0.3	0
BI_GT2	332000	7697045	30	1.98	2.7	20.2	777	0	25.3	0.3	0
BI_OilSeal	331900	7697150	20	1	1	0	400	0	0	0	0.1
BI_Vent	332200	7697200	20	0.73	1.7	6	700	0	0	0	0.1

Future Sources

Source	Location		Height	Radius	EF	Velocity	Temperature	PM10	NOx	SO2	Rsmog
	(Easting)	(Northing)	(m)	(m)		(m/s)	(K)	(g/s)	(g/s)	(g/s)	(g/s)
Woodside											
GT4001	476910	7722765	40	1.98	2.7	20.2	777	0	13.5	0.2	0
GT4002	476910	7722800	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4003	476910	7722810	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4004	476910	7722845	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4005	476910	7722855	40	1.98	2.7	20.2	777	0	13.46	0.24	0
GT4006	476910	7722890	40	1.98	2.7	20.2	777	0	13.46	0.24	0
1KT1410	476540	7722965	40	1.94	2.1	23.9	790	0	15.8	0.3	0
1KT1420	476590	7722965	40	1.94	2.1	23.9	790	0	15.6	0.27	0
1KT1430	476610	7722965	40	1.87	2.1	25.8	790	0	15.3	0.27	0
1KT1440	476660	7722965	40	1.87	2.1	26.3	806	0	15.5	0.27	0.4
1KT1450	476510	7722960	40	1.36	2.1	21.2	784	0	9.4	0.1	0
2KT1410	476540	7722845	40	1.94	2.1	23.9	790	0	15.8	0.3	0
2KT1420	476590	7722845	40	1.94	2.1	23.9	790	0	15.6	0.27	0
2KT1430	476610	7722845	40	1.87	2.1	25.8	790	0	15.3	0.27	0
2KT1440	476660	7722845	40	1.87	2.1	26.3	806	0	15.5	0.27	0.4
2KT1450	476510	7722840	40	1.36	2.1	21.2	784	0	9.4	0.1	0
3KT1410	476540	7722610	40	1.94	2.1	23.9	790	0	15.8	0.3	0
3KT1420	476590	7722610	40	1.94	2.1	23.9	790	0	15.6	0.27	0
3KT1430	476610	7722610	40	1.87	2.1	25.8	790	0	15.3	0.27	0
3KT1440	476660	7722610	40	1.87	2.1	26.3	806	0	15.5	0.3	0.4
3KT1450	476510	7722605	40	1.36	2.1	21.2	784	0	9.4	0.1	0
1F2001	477152	7722915	33	0.73	1.7	6	700	0	0.3	0	0
2F2001	477152	7722905	33	0.73	1.7	6	700	0	0.3	0.01	0
3F2001	477152	7722895	33	0.73	1.7	6	700	0	0.3	0.01	0
4F2001	476968	7722880	33	0.73	1.7	6	700	0	0.3	0.01	0
5F2001	476968	7722870	33	0.73	1.7	6	700	0	0.3	0	0
1KT2420	477035	7722698	24	1	2.5	40.7	816	0	9.4	0.1	0
1KT2430	477050	7722698	24	1.45	2.5	30.6	620	0	20.3	0.2	0
2KT2420	477065	7722698	24	1	2.5	40.7	816	0	9.4	0.1	0
2KT2430	477080	7722698	24	1.45	2.5	30.6	620	0	20.3	0.2	0
SealOil	476500	7722500	20	1	1	0	400	0	0	0	0.1
4KT1430a	476664	7722465	40	1.45	2	28.2	490	0	5	0.3	0
4KT1430b	476664	7722461	40	1.45	2	28.2	490	0	5	0.3	0
4KT1410	476650	7722461	40	3.05	1	23.4	814	0	10.6	0.6	0
1F1251	476933	7722944	40	1.46	1.8	21.3	1373	0	0.8	2.8	0
GT4007	476972	7722702	40	1.65	1.7	23	694	0	3.3	0.2	0
GT4008	476972	7722668	40	1.65	1.7	23	694	0	3.3	0.2	0
GT4009	476972	7722626	40	1.65	1.7	23	694	0	3.3	0.2	0
GT4010	476972	7722592	40	1.65	1.7	23	694	0	3.3	0.2	0
5KT1430a	476664	7722335	40	1.45	2	28.2	490	0	5	0.3	0
5KT1430b	476664	7722331	40	1.45	2	28.2	490	0	5	0.3	0
5KT1410	476560	7722331	40	3.05	1	23.4	814	0	10.6	0.6	0
2F1251	476953	7722944	40	1.46	1.8	21.3	1373	0	0.8	2.8	0
Hamersley											
HAM_stack1	471500	7717000	60	1.3	1	7	393	0	5.7	1	0
HAM_stack2	471500	7717000	60	1.3	1	7	393	0	5.7	1	0
Barrow Island											
BI_GT1	332000	7697000	30	1.98	2.7	20.2	777	0	25.3	0.3	0.01
BI_GT2	332000	7697045	30	1.98	2.7	20.2	777	0	25.3	0.3	0
BI_OilSeal	331900	7697150	20	1	1	0	400	0	0	0	0.1
BI_Vent	332200	7697200	20	0.73	1.7	6	700	0	0	0	0.1
Burrup Fertiliser											
BF1	476915	7718833	36	1.78	1	12.7	413	0.3	15.4	0	0
BF2	477060	7718820	15	0.85	1	5	450	0	1.3	0	0
Gorgon											
G_GTG1	338372	7700255	40	2.25	1	34.5	692	1.1	17.9	0	0
G_GTG2	338418	7700255	40	2.25	1	34.5	692	1.1	17.9	0	0
G_GTG3	338464	7700255	40	2.25	1	34.5	692	1.1	17.9	0	0
G_1-1541_MJ	338850	7700040	40	2.25	1	14.9	423	0.6	16.7	0	0
G_1-1544_MJ	338850	7700040	40	2.25	1	14.9	423	0.6	16.7	0	0.4
G_2-1541_MJ	338850	7700040	40	2.25	1	14.9	423	0.6	16.7	0	0
G_2-1544_MJ	338850	7700040	40	2.25	1	14.9	423	0.6	16.7	0	0
G_4212-MCA	338485	7700135	40	1.1	1	20	448	0.9	10	0	0
G_4212-MCB	338485	7700135	40	1.1	1	20	448	0.9	10	0	0

DISPMOD Files

Input File

```
barrow.ctl
lm_nox.out
y        ! Use self generated turbulence
y        ! use pdf
y        ! Account for wind shear
n        ! Is yearly shear data available?
y        ! use numerical TIBL
50        ! Distance to extend TIBL
y        ! use coast amg coords for TIBL calcs
barrow.coa
y        ! Model convective plume trapping using PDF?
n        ! Account for wind shear in the model within TIBL
n        ! use stability classes
n        ! centreline concentrations
5        ! option for onshore lapse rate , 6 = Pilbara
n        ! apply standard seasonal variation
n        ! use measured sigma theta
n        ! mixing into TIBLS sharper than sgphi
y        ! use greater of direction varaince to calculated variance
n        ! log of events exceeding a certain value
n        ! Ausplume plume penetration
n        ! write all timestep conc to a disk file
chev2003.wml
chev2003.stb
lm_nox.emi
windveer.dat
```

Control File

```
Gorgon_Barrow Island
  332000. 7694000.  500. 20 20 0.2833 -20.6 220.7   90.0  3.0  .083  .047  0.25
 01012003 31122003 0000 2400  6  6 77  1.9  2.3
14 0.00 0350. 0500. 0700. 1000. 0   5000.
  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  2  3  4  5  6  7  8  9 10 11 12 13 14
   0        ! NUMBER OF STACKS THAT ARE NOT BEING USED
4101_MJA      40.0  5.50 338372 7700255 1.00  0. 500
4101_MJB      40.0  5.50 338418 7700255 1.00  0. 500
4101_MJC      40.0  5.50 338464 7700255 1.00  0. 500
1-1541_MJ     40.0  5.50 338850 7700040 1.00  0. 500
1-1544_MJ     40.0  5.50 338785 7700040 1.00  0. 500
1-1541_MJ     40.0  5.50 338850 7700205 1.00  0. 500
1-1544_MJ     40.0  5.50 338785 7700205 1.00  0. 500
4108_MJA      40.0  0.79 338500 7700226 1.00  0. 500
4108_MJB      40.0  0.79 338500 7700238 1.00  0. 500
Pack_Boil1    40.0  2.22 338485 7700135 1.00  0. 500
Pack_Boil2    40.0  2.22 338485 7700145 1.00  0. 500
WetGasFlare  150.0  1.27 338104 7700505 1.00  0. 500
```

```
DryGasFlare   150.0 1.27 338104 7700505 1.00  0. 500
BOGasFlare     40.0 1.27 339165 7700170 1.00  0. 500

1
340000. 7692000.      ! Airport

HM_NOx.dis

TITLE
(A)
XREF,YREF,GINT,NUMX,NUMY,DTSL,ALAT,CSTDIR,ZLSB,SGTHSB,SGPHSB,TIBPEN
(2F9.1,F6.1,2I3,F7.4,3F6.1,3F6.0)
IDS,IMS,IYS,IDF,IMF,IYF,IT1,IT2,IAV,IDATAV,IY1,CSIGON,CSIGOF
(2(1X,3I2),2I5,3I3,2F5.1)
**** NOTE - IAV    = MODEL TIME STEP IN MULTIPLES OF 10 MINUTES (EG. 3 = 30 MIN
                 TIMESTEP.
        - IDATAV = INPUT MET DATA AVERAGING TIME IN MULTIPLES OF 10 MINUTES
                 (EG. 3 = 30 MIN INPUT DATA)
**** NOTE - IAV CANNOT BE LESS THAN IDATAV AND IDATAV MUST BE GREATER THAN 0
NUMSCE,QMIN,ALEV1,ALEV2,ALEV3,ALEV4,I
(I3,F5.1,4F6.0,I2)
**** NOTE - POLPOT MODE IS NOW FOR MULTIPLE SOURCES WITH FIXED EMISSIONS.
READ IN THE NUMBER OF STACKS PER SOURCE GROUP
KSCE(I),I=1,NUMSCE
(22I3)
READ IN THE STACK NUMBERS IN THE ORDER OF USE (.IE SOURCE GROUPING)
(ISTNUM(I),I=1,ISTTOT
READ IN THE NUMBER OF STACKS NOT TO BE USED
NSNTUS
READ IN STACK INFORMATION DATA
C STKHGT - HEIGHT OF STACK
C STKDIA - DIAMETER OF STACK
C STKX   - LATITUDE OF STACK AMG COORDS
C STKY   - LONGITUDE OF STACK AMG COORDS
C TEMSL  - SLOPE OF THE TEMPERATURE LOSS EQUATION FOR STACK
C TEMIN  - INTERCEPT OF THE TEMPERATURE LOSS EQUATION FOR STACK
C TEMSL AND TEMIN ARE USED TO AMKE ALLOWANCE FOR THE TEMPERATURE LOSS OF
C         FLUE GASES IN THE STACK WHEN GAS TEMPERATURES ARE MEASURED AT
C         THE BASE OF THE STACK
C DCOAST - ARRAY DISTANCE (METRES) FROM THE COAST OF EACH SOURCE GROUP
C Q      - SOURCE STRENGTH (KG/S)
C STKVOL - SOURCE VOLUME (M**3/S) AT STACK TEMP (IE. GAS FLOW RATE)
C STKRHO - EMISSION DENSITY (KG/M**3) AT STACK TEMP
C IBUILD - BUILDING EFFECTS FOR THIS SOURCE (1=YES, 0=NO)
C HBSTK  - HEIGHT OF BUILDING
C WBSTK  - WIDTH OF BUILDING
STKHGT(K),STKDIA(K),STKX(K),STKY(K),DCOAST(K),Q(K),STKVOL(K),STKRHO(K),
IBUILD(K),HBSTK(K),WBSTK(K)
(14X,F5.1,F5.2,F7.0,F8.0,F5.2,F4.0,F6.0,3F8.0,I2,2F4.0)
*** NOTE- WITH BUILDING EFFECTS IT IS ASSUMED THAT THE LAST SOURCE IN THE
       SOURCE GROUP HAS THE BUILDING DIMENSIONS. THIS LAST SOURCE ALSO
       CONTAINS THE LOGICAL (IBUILD) WHICH DETERMINE WHETHER BUILDING
       EFFECTS ARE TO BE USED.
```

Emissions File

Gorgon_Barrow Island

Name	Q	V	Rho	Nd	Nh	Int
4101_MJA	.0179	832.0	0.503			0
4101_MJB	.0179	832.0	0.503			0
4101_MJC	.0179	832.0	0.503			0
1-1541_MJ	.0167	353.2	0.835			0
1-1544_MJ	.0167	353.2	0.835			0
1-1541_MJ	.0167	353.2	0.835			0
1-1544_MJ	.0167	353.2	0.835			0
4108_MJA	.0000	000.0	0.000			0
4108_MJB	.0000	000.0	0.000			0
Pack_Boil1	.0100	77.5	0.789			0
Pack_Boil2	.0100	77.5	0.789			0
WetGasFlare	.0000	20.0	0.278			0
DryGasFlare	.0000	20.0	0.278			0
BOGasFlare	.0000	20.0	0.278			0

TAPM List File

```
|----------------------------------------|
| THE AIR POLLUTION MODEL (TAPM V2.5).   |
| Copyright (C) CSIRO Australia.         |
| All Rights Reserved.                   |
|----------------------------------------|

----------------
RUN INFORMATION:
----------------
NUMBER OF GRIDS=  2
GRID CENTRE (longitude,latitude)=( 115.458298 , -20.7833309 )
GRID CENTRE (cx,cy)=( 339700 , 7699950 ) (m)
GRID DIMENSIONS (nx,ny,nz)=( 31 , 31 , 20 )
NUMBER OF VERTICAL LEVELS OUTPUT = 17
DATES (START,END)=( 20030101 , 20030331 )
DATE FROM WHICH OUTPUT BEGINS = 20030104
LOCAL HOUR IS GMT+ 7.69999981
SYNOPTIC WIND SPEED MAXIMUM = 30 (m/s)
SYNOPTIC PRESSURE-GRADIENT SCALING FACTOR = 1.00000000
SYNOPTIC PRESSURE-GRADIENT FILTERING FACTOR = 1.00000000
VARY SYNOPTIC WITH 3-D SPACE AND TIME
INCLUDE VEGETATION
EXCLUDE NON-HYDROSTATIC EFFECTS
EXCLUDE RAIN AND SNOW
INCLUDE PROGNOSTIC EDDY DISSIPATION RATE EQUATION
POLLUTION : CHEMISTRY (APM,NOX,NO2,O3)
EXCLUDE POLLUTANT CROSS-CORRELATION EQUATION
EXCLUDE POLLUTANT VARIANCE EQUATION
POLLUTANT GRID DIMENSIONS (nxf,nyf)=( 29 , 29 )
BACKGROUND APM    = 0.00000000E+00 (ug/m3)
BACKGROUND NOX&NO2= 0.00000000E+00 (ppb)
BACKGROUND O3     = 20.0000000 (ppb)
BACKGROUND Rsmog  = 0.500000000 (ppb)
pH of liquid water= 4.50000000

--------------------------------
START GRID 1 D:\TAPM_run\Chevron\Regional\Chev300
GRID SPACING (delx,dely)=( 30000 , 30000 ) (m)
POLLUTANT GRID SPACING (delxf,delyf)=( 30000 , 30000 ) (m)
NO MET. DATA ASSIMILATION FILE AVAILABLE
NO BUILDING FILE AVAILABLE
NUMBER OF pse SOURCES= 37
NO lse EMISSION FILE AVAILABLE
NO ase EMISSION FILE AVAILABLE
USING gse EMISSIONS AND MIXING THEM OVER FIRST 1 LEVEL(S)
USING bse EMISSIONS AND MIXING THEM OVER FIRST 1 LEVEL(S)
NO whe EMISSION FILE AVAILABLE
NO vpx EMISSION FILE AVAILABLE
NO vdx EMISSION FILE AVAILABLE
NO vlx EMISSION FILE AVAILABLE
NO vpv EMISSION FILE AVAILABLE
```

INITIALISE
LARGE TIMESTEP = 300.000000
METEOROLOGICAL ADVECTION TIMESTEP = 300.000000 (s)
 Deep Soil Moisture Content (kg/kg)= 0.150000006
 Deep Soil & Sea Temperatures (K) = 299.799988 299.799988
POLLUTION ADVECTION TIMESTEP = 300.000000 (s)
pse KEY :
is = Source Number
ls = Source Switch (-1=Off,0=EGM,1=EGM+LPM)
xs,ys = Source Position (m)
hs = Source Height (m)
rs = Source Radius (m)
es = Buoyancy Enhancement Factor
fs_no = Fraction of NOX Emitted as NO
fs_fpm= Fraction of APM Emitted as FPM
INIT_pse

is,	ls,	xs,	ys,	hs,	rs,	es,	fs_no,	fs_fpm
1,	0,	476910.,	7722765.,	40.00,	1.98,	2.70,	0.90,	0.50,
2,	0,	476910.,	7722800.,	40.00,	1.98,	2.70,	0.90,	0.50,
3,	0,	476910.,	7722810.,	40.00,	1.98,	2.70,	0.90,	0.50,
4,	0,	476910.,	7722845.,	40.00,	1.98,	2.70,	0.90,	0.50,
5,	0,	476910.,	7722855.,	40.00,	1.98,	2.70,	0.90,	0.50,
6,	0,	476910.,	7722890.,	40.00,	1.98,	2.70,	0.90,	0.50,
7,	0,	476540.,	7722965.,	40.00,	1.94,	2.10,	0.90,	0.50,
8,	0,	476590.,	7722965.,	40.00,	1.94,	2.10,	0.90,	0.50,
9,	0,	476610.,	7722965.,	40.00,	1.87,	2.10,	0.90,	0.50,
10,	0,	476660.,	7722965.,	40.00,	1.87,	2.10,	0.90,	0.50,
11,	0,	476510.,	7722960.,	40.00,	1.36,	2.10,	0.90,	0.50,
12,	0,	476540.,	7722845.,	40.00,	1.94,	2.10,	0.90,	0.50,
13,	0,	476590.,	7722845.,	40.00,	1.94,	2.10,	0.90,	0.50,
14,	0,	476610.,	7722845.,	40.00,	1.87,	2.10,	0.90,	0.50,
15,	0,	476660.,	7722845.,	40.00,	1.87,	2.10,	0.90,	0.50,
16,	0,	476510.,	7722840.,	40.00,	1.36,	2.10,	0.90,	0.50,
17,	0,	476540.,	7722610.,	40.00,	1.94,	2.10,	0.90,	0.50,
18,	0,	476590.,	7722610.,	40.00,	1.94,	2.10,	0.90,	0.50,
19,	0,	476610.,	7722610.,	40.00,	1.87,	2.10,	0.90,	0.50,
20,	0,	476660.,	7722610.,	40.00,	1.87,	2.10,	0.90,	0.50,
21,	0,	476510.,	7722605.,	40.00,	1.36,	2.10,	0.90,	0.50,
22,	0,	477152.,	7722915.,	33.00,	0.73,	1.70,	0.90,	0.50,
23,	0,	477152.,	7722905.,	33.00,	0.73,	1.70,	0.90,	0.50,
24,	0,	477152.,	7722895.,	33.00,	0.73,	1.70,	0.90,	0.50,
25,	0,	476968.,	7722880.,	33.00,	0.73,	1.70,	0.90,	0.50,
26,	0,	476968.,	7722870.,	33.00,	0.73,	1.70,	0.90,	0.50,
27,	0,	477035.,	7722698.,	24.00,	1.00,	2.50,	0.90,	0.50,
28,	0,	477050.,	7722698.,	24.00,	1.45,	2.50,	0.90,	0.50,
29,	0,	477065.,	7722698.,	24.00,	1.00,	2.50,	0.90,	0.50,
30,	0,	477080.,	7722698.,	24.00,	1.45,	2.50,	0.90,	0.50,
31,	0,	476500.,	7722500.,	20.00,	1.00,	1.00,	0.90,	0.50,
32,	0,	471500.,	7717000.,	60.00,	1.30,	1.00,	0.90,	0.50,
33,	0,	471500.,	7717000.,	60.00,	1.30,	1.00,	0.90,	0.50,
34,	0,	332000.,	7697000.,	30.00,	1.98,	2.70,	0.90,	0.50,
35,	0,	332000.,	7697045.,	30.00,	1.98,	2.70,	0.90,	0.50,
36,	0,	331900.,	7697150.,	20.00,	1.00,	1.00,	0.90,	0.50,
37,	0,	332200.,	7697200.,	20.00,	0.73,	1.70,	0.90,	0.50,

LAGRANGIAN (LPM) MODE IS OFF FOR THIS GRID
IN_pse
IN_gse
IN_bse
DATE=20030101,HOUR= 1.000
IN_pse
REWIND_pse
IN_gse
IN_bse
REWIND_bse
IN_bse
IN_SYNOPTIC
Deep Soil Moisture Content (kg/kg)= 0.150000006
Deep Soil & Sea Temperatures (K) = 299.799988 299.799988

Technical Appendix B2

Noise Impact Assessment

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Noise Impact Assessment for the Gorgon Development Project

Client: Sinclair Knight Merz
Client Contact: Barbara Brown
SVT Contact: Jim McLoughlin
Job No: 03133
Report No: AV/04/03/014

Revision	Prepared	Reviewed	Date	Description
0	Jim McLoughlin		29/3/04	Draft r1
1	Jim McLoughlin	Paul Keswick	29/04/04	Issued for use

Noise Impact Assessment for the Gorgon Development Project

1 Glossary

A-weighting. A frequency weighting applied to sound measurements that approximates the response of the human ear.

Decibel (dB). A logarithmic unit which represents the ratio of a measured quantity (such as sound pressure or sound power) to a defined reference level. (**dB(A**) – A-weighted decibel.)

Sound Power. The total sound energy radiated by a sound source per unit time - measured in Watts.

Sound Power Level (SWL). 10 times the logarithm to the base 10 of the ratio of the sound power to the reference sound power (1 pW) – measured in decibels.

Sound Pressure. The variation in ambient pressure caused by a sound wave - measured in Pascals.

Sound Pressure Level (SPL). 20 times the logarithm to the base 10 of the ratio of the root mean square sound pressure to the reference sound pressure (20 micropascals) – measured in decibels.

L_{Amax}. The maximum A-weighted sound pressure level.

L_{A1}. The A-weighted sound pressure level exceeded for 1 % of the time.

L_{A10}. The A-weighted sound pressure level exceeded for 10 % of the time.

L_{A90}. The A-weighted sound pressure level exceeded for 90 % of the time.

2 Introduction

This report presents the results of a noise impact assessment for the proposed Gorgon Development on Barrow Island. The assessment comprises measurement of ambient noise levels at several locations on the Island and noise level predictions using an acoustic model of the Liquefied Natural Gas Plant (LNG Plant).

Barrow Island is recognised as a Class A Nature Reserve. Consequently, public access to the Island is limited and there are no noise sensitive premises. However, the ChevronTexaco camp is located approximately 3.5 km to the south-south-east of the proposed Gorgon LNG development. Although this camp is not classed as noise sensitive, it is the only existing location on the Island where noise from the proposed development is likely to have any social impact. Therefore, noise level predictions are provided for the camp in addition to noise contours that have been prepared for the area surrounding the LNG Plant.

While the social impacts of noise emission from the LNG Plant are restricted to the existing ChevronTexaco camp, (and to the new camp that forms part of the proposed development), noise emission may affect the activities of local fauna. This report does not consider these effects, but the results may be used as input data for further study in this area.

The acoustic model has also been used to estimate the existing noise emission from the power station at Base Castle on Barrow Island. Noise contours have been prepared to assist in the identification of any existing noise impacts on local fauna.

3 Methods

The noise impact assessment has been conducted using the detailed assessment procedure provided in the Environmental Protection Authority's (EPA) *Guidance for the Assessment of Environmental Factors (in accordance with the Environmental Protection Act 1986) Environmental Noise No.8 Draft June 1998* (Western Australia), (Guidance Note 8).

3.1 Ambient Noise Assessment

Measurements of ambient noise have been carried out at the following four locations on Barrow Island:

- ChevronTexaco camp site
- Proposed LNG Plant site
- T-Tree
- Flacourt Bay.

These locations are shown in Figure 1 in Appendix 1.

Noise levels at each location were logged continuously for two weeks using a sampling period of 15 minutes. The noise level data collected comprises L_{A1}, L_{A10} and L_{A90} noise levels. Wind speed and direction data during the measurement period have been obtained (by SKM) from Barrow Island Airport.

In addition to the above, background noise levels have been determined for each measurement location by extracting from the full data the "L_{90}" of the L_{A90} noise levels for the following periods which correspond to day, evening and night:

- 0700-1900 hours Monday to Saturday
- 1900-2200 hours Monday to Saturday and 0900-2200 hours on Sundays
- 2200-0700 hours Monday to Saturday and 2200-0900 hours Sundays

3.2 Noise Modelling

An acoustic model has been developed using the environmental noise modelling program "ENM", version 3.06, 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 ENM noise modelling program was originally developed by RTA Technology for the Australian Noise Advisory Council. 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 LNG plant and also to predict noise levels at the ChevronTexaco camp site.

The model does not include noise emissions from any sources other than the proposed LNG plant. Pipelines to and from the LNG plant are not included in the noise model since it is not expected that they will emit any significant noise.

3.2.1 Noise Modelling Scenarios

The acoustic model has been used to predict noise levels for the following scenarios:

- Normal LNG plant operation
- Emergency blow-down of LNG plant
- Plant construction.

The model has also been used to estimate noise levels from the existing power station at Base Castle on Barrow Island.

3.2.2 Noise Emission Data

LNG Plant Normal Operation

Sound power levels have been developed for normal operating conditions of the LNG plant assuming that the sound pressure level at 1m from individual equipment items will not exceed 85 dB(A). (This criterion is consistent with occupational noise emission requirements.) The plant equipment included in the noise model has been obtained from the Gorgon Development Equipment List (APCI 2 x 4.9 mmtpa Case) provided by SKM, (Document No. J6962-17-001 Rev 1). The spectral contents of equipment noise emissions have been obtained either from experience gained on similar projects or using empirical methods described in standard acoustic texts. Table 3-1 below provides a summary of the overall sound power levels for the major equipment items included in the acoustic model. A comprehensive listing of all sources including spectral data is provided in Table A1 in Appendix 2.

Table 3-1 Summary of Sound Power Levels for Normal LNG Plant Operation

Equipment Item	Plant Area	Sound Power Level dB(A)	Comments
Air coolers for propane circuit	LNG Trains 1 & 2	116[1]	Includes propane condenser, desuperheater & subcooler.
Air coolers for MR compressor	LNG Trains 1 & 2	112[1]	Includes MR compressor & fuel gas compressor inter & after coolers, and other smaller coolers / condensers
Propane compressor	LNG Trains 1 & 2	114	Includes all package equipment excluding exhaust stack outlet
Propane compressor exhaust stack	LNG Trains 1 & 2	103	
MR Compressor	LNG Trains 1 & 2	114	Includes all package equipment excluding exhaust stack outlet
MR Compressor exhaust stack	LNG Trains 1 & 2	103	

Regeneration gas compressor	LNG Trains 1 & 2	105	
Fuel gas compressor	LNG Trains 1 & 2	105	
LNG expander	LNG Trains 1 & 2	102	
MR Expander	LNG Trains 1 & 2	102	
Lean Amine cooler / Amine regen. reflux cooler	AGRU 1, 2 & 3	111[1]	
Lean Amine pumps	AGRU 1, 2 & 3	105[2]	2 of 3 pumps operating
Lean Amine booster pumps	AGRU 1, 2 & 3	99[2]	2 of 3 pumps operating
CO2 re-injection pumps	CO2 compression	99[2]	2 of 3 pumps operating
CO2 re-injection compressor	CO2 compression	111	
CO2 compressor coolers	CO2 compression	107[1]	
Inlet area air coolers	Inlet	108[1]	Includes LP steam control condenser, LP flash drum vent condenser, condensate product cooler & stabiliser overheads compression cooler
Stabiliser overheads compressor	Inlet	105	
Wellhead injection pumps	Inlet	100[2]	2 of 2 pumps operating
BOG compressor coolers	LNG Storage & Loading	98[1]	
BOG compressor	LNG Storage & Loading	107[2]	2 of 2 compressors operating
LNG Loading pumps	LNG Storage & Loading	106[2]	1 of 8 pumps operating
Condensate Loading pumps	LNG Storage & Loading	100[2]	1 of 2 pumps operating
Power generators	Power generation	109[2]	2 of 2 units operating
Boiler feed water pumps	Utilities	100[2]	2 of 3 pumps operating
Package steam boilers	Utilities	104[2]	2 o 2 units operating
Instrument air compressors	Utilities	102[2]	Includes air drier. 2 of 2 units operating

Notes

1. Overall sound power level calculated assuming a sound power level of 94 dB(A) per fan.

2. Sound power level is for a single item.

The overall sound power level for continuous normal operation of the LNG plant has been calculated to be 126 dB(A).

LNG Plant Emergency Blow-down

During an emergency LNG plant blow-down the over-riding source of noise will be the plant flare. It has been assumed that a sonic flare will be used in this situation and a sound power level of 150 dB(A) has been assigned for the flare.

Plant Construction

Noise associated with construction of the LNG plant will be variable in nature and will depend on the particular activities being undertaken as well as the equipment in operation. For the purposes of this assessment a worst-case cumulative sound power level of 140 dB(A) has been assumed for construction noise sources. This would be equivalent, for example, to the simultaneous operation of 100 items of high powered equipment such as trucks, excavators, loaders, generators, etc, each having an individual sound power level of 120 dB(A).

Power Station at Base Castle

A sound power level of 110 dB(A) has been estimated for the power station at Base Castle based on a description of the facility provided in the "Barrow Island Noise Survey" November 2001, provided by SKM.

3.2.3 Topography

Topographical information for the acoustic model was extracted from 1m ground contours supplied in electronic format by SKM for the area surrounding the LNG Plant. The acoustic model also includes the shielding effects of large buildings and structures at the LNG plant such as electrical sub-stations and storage tanks.

3.2.4 Meteorology

The acoustic model has been used to predict noise levels and produce noise contours for a range of meteorological conditions. In all cases the temperature and relative humidity values used were 15°C and 50% respectively, to represent night time atmospheric conditions as per the default values provided in Guidance Note 8. Wind speeds ranging from calm to 3 m/s have been investigated in each of 8 cardinal directions. The effects of a well developed thermal inversion (2°C/100m) have also been investigated for a range of wind conditions. (The combination of a 3 m/s wind with a 2°C/100m thermal inversion represents the default worst-case conditions for sound propagation as per Guidance Note 8.)

4 Results

4.1 Ambient Noise

Ambient noise levels were recorded between 20 January and 10 February 2004.

Figures 2 to 5 in Appendix 1 present the results of continuous noise monitoring at each of the four locations selected. The figures also show the wind speed during the measurement periods. Winds were predominantly from the west and south west during the noise monitoring. The background noise levels at each location are summarised in Table 4-1 below.

Table 4-1 Background Noise Levels

	"L_{90}" of L_{A90} noise levels – dB(A)		
Location	**0700-1900 hrs Monday to Saturday**	**1900-2200 hrs Monday to Saturday and 0900 – 2200 hrs on Sundays**	**2200-0700 hrs Monday to Saturday and 2200-0900 hrs on Sundays**
Chevron Texaco Camp Site	50.0	50.0	49.5
Proposed LNG Plant Site	30.0	24.5	23.5
T-Tree	30.5*	36.5*	30.5*
Flacourt Bay	40.2	42.0	41.5

* Note that the second week of continuously monitored data at this location contains anomalous results and has therefore been excluded when calculating the L_{90} of L_{A90} noise levels.

Ambient noise at the Chevron Texaco camp site was dominated by noise from the facilities' air conditioners. At all other sites ambient noise showed a pronounced diurnal cycle. This is most probably attributable to bird activity (and/or activities of other fauna), since the locations selected were remote from human activity. Wind generated noise also significantly contributed to the measured noise levels.

4.2 Noise Modelling

4.2.1 LNG Plant Normal Operation

Table 4-2 below presents the predicted noise levels for normal LNG Plant operation at the Chevron Texaco camp site for a range of meteorological conditions.

Table 4-2 Predicted Noise Levels for Normal LNG Plant Operation

		Predicted Noise Level at Chevron Texaco Camp Site – dB(A)			
Temperature Inversion Rate (°C/100m)	**Wind Direction**	**Calm**	**1 m/s Wind**	**2 m/s Wind**	**3 m/s Wind**
0	N/A	29			
0	North		32	33	35
0	North-east		32	33	34
0	East		30	31	31
0	South-east		25	24	24
0	South		25	24	23
0	South-west		25	24	23
0	West		26	25	25
0	North-west		31	32	33
2	N/A	32			
2	North		33	34	36
2	North-east		33	34	35
2	East		32	33	33
2	South-east		31	26	25
2	South		30	25	24
2	South-west		31	25	24
2	West		32	32	32
2	North-west		33	34	35

Predicted noise levels range from 23 dB(A) to 36 dB(A) and the highest noise levels are predicted for northerly wind conditions.

Noise contours have been prepared for calm conditions and for 3 m/s winds both with and without a temperature inversion. The following noise contours are presented in Appendix 3.

Table 4-3 Figure Numbers for Noise Contours

Wind Direction	Wind Speed (m/s)	Temperature Inversion Rate (°C/100m)	Figure Number
Calm	0	0	NC 1
North	3	0	NC 2
North-east	3	0	NC 3
East	3	0	NC 4

South-east	3	0	NC 5
South	3	0	NC 6
South-west	3	0	NC 7
West	3	0	NC 8
North-west	3	0	NC 9
Calm	0	2	NC 10
North	3	2	NC 11
North-east	3	2	NC 12
East	3	2	NC 13
South-east	3	2	NC 14
South	3	2	NC 15
South-west	3	2	NC 16
West	3	2	NC 17
North-west	3	2	NC 18

The 65 dB(A) and 35 dB(A) noise contours have been highlighted in magenta and red respectively. 65 dB(A) L_{A10} is the assigned noise level that applies at an industry – industry boundary. 35 dB(A) L_{A10} is the lowest assigned noise level that can apply at a noise sensitive receiver.

Ranking of Noise Sources

Air coolers are the most significant source of noise received at the Chevron Texaco camp site for all meteorological conditions investigated. This includes the various banks of air coolers in the LNG trains, the Acid Gas Removal Units, inlet area, and CO_2 compression area.

4.2.2 Emergency Blow-Down of LNG Plant

Noise predictions for an emergency blow-down scenario have been undertaken for worst-case sound propagation conditions, i.e. 3 m/s winds combined with at 2°C/100m temperature inversion. Three wind directions have been investigated: north, east, and south. Table 4-4 below presents the predicted noise levels at the Chevron Texaco camp site. Noise contours for the same meteorological conditions are presented in Figures NC19 to NC21 in Appendix C.

Table 4-4 Predicted Noise Levels at Camp Site During Emergency Blow-Down

Wind Direction	Wind Speed (m/s)	Temperature Inversion Rate (°C/100m)	Predicted Noise Level – dB(A)
North	3	2	59
East	3	2	55

South	3	2	47

4.2.3 Plant Construction

Noise predictions for plant construction activities have been undertaken assuming a cumulative source sound power level of 140 dB(A) originating from the proposed site location. The screening effects of buildings and barriers at the site have been excluded from the acoustic model. Noise level predictions and noise contours have been produced for worst-case sound propagation conditions, i.e. 3 m/s winds combined with at 2°C/100m temperature inversion. Three wind directions have been investigated: north, east, and south. Table 4-5 below presents the predicted noise levels at the Chevron Texaco camp site. Noise contours for the same meteorological conditions are presented in Figures NC22 to NC24 in Appendix C.

Table 4-5 Predicted Noise Levels at Camp Site During Construction

Wind Direction	Wind Speed (m/s)	Temperature Inversion Rate (°C/100m)	Predicted Noise Level – dB(A)
North	3	2	44
East	3	2	41
South	3	2	31

4.2.4 Power Station at Base Castle

Noise contours have been prepared for worst-case sound propagation conditions to the north, south, east and west of the power station. The contours are presented in figures NC25 to NC28 in Appendix C.

5 Discussion

5.1 Noise Limits

Barrow Island is recognised as a Class A nature reserve. Consequently, public access to the Island is limited and there are no noise sensitive premises. The Chevron Texaco camp site, located approximately 3.5 km to the south-south-east of the proposed development, is the only existing location on the island where noise is likely to have any social impact. Since this camp services existing industry on the island, it is classed as an industrial premises according to Schedule 1, clauses 7 & 8, of the *Environmental Protection (Noise) Regulations 1997*, (The Regulations.) The assigned noise levels are, therefore, 65 dB(A), 80 dB(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 noise contours presented in Appendix 3 show the area over which noise levels exceed 65 dB(A).)

5.2 Noise Impacts

Noise from the proposed development has the potential to result in social impacts at the Chevron Texaco camp site if it is audible above the prevailing background noise. These impacts are discussed in the following sections. Noise emissions may also have impacts for local fauna. Such impacts are beyond the scope of this study. However, the results of noise predictions presented in this report may be of use to others when assessing impacts on fauna.

5.2.1 Noise from Normal Operation of the LNG Plant

Noise level predictions for normal operation are based on an overall sound power level of 126 dB(A). (See section 3.2.2.)Predicted noise levels for normal operation of the LNG Plant reach a maximum of 36 dB(A) at the Chevron Texaco camp site under worst-case meteorological conditions for sound propagation. This is far below the assigned level of 65 dB(A). Furthermore, the predicted levels are also far below the existing ambient noise level of 50 dB(A) and it is likely, therefore, that noise from the LNG Plant will be inaudible during normal operations.

5.2.2 Noise from Emergency Blow-Downs

Predicted noise levels for flaring associated with an emergency blow down of the LNG Plant reach a maximum of 59 dB(A) at the Chevron Texaco camp site under worst-case meteorological conditions for sound propagation. (It has been assumed that a sonic flare will be used and that the sound power level could reach 150 dB(A).) The predicted levels are below the assigned level of 65 dB(A). However, they can exceed the existing background noise levels at the camp and may, therefore, be audible under some meteorological conditions.

5.2.3 Construction Noise

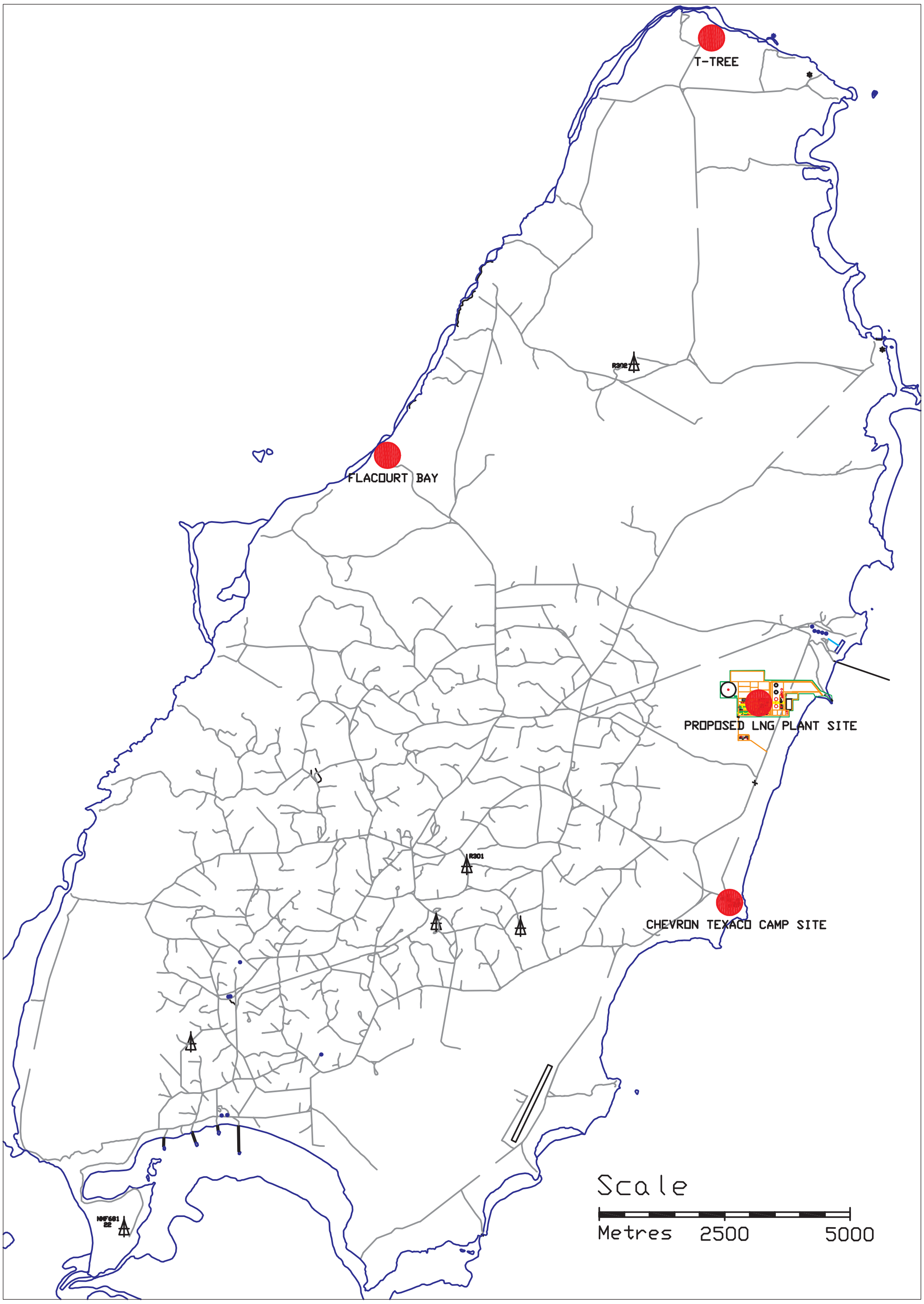
Noise levels from construction will vary depending on the particular activities being undertaken. This assessment has considered a worst-case scenario where the cumulative sound power level for all activities reaches 140 dB(A). The noise levels predicted at the Chevron Texaco camp site reach a maximum of 44 dB(A) for a 3 m/s northerly wind combined with a 2°C/100m temperature inversion. This is less than the existing ambient level of 50 dB(A) and, therefore, construction activities are unlikely to have any noticeable impact at the camp.

5.2.4 Noise & Vibration from Blasting

The *Environmental Protection (Noise) Regulations 1997* specify maximum allowable noise levels resulting from blasting. The most stringent noise level, 90 dB $L_{Linear\ peak}$, applies at any premises outside of the period from 0700 hours to 1800 hours. Considering the distance between the proposed LNG Plant site and the Chevron Texaco Camp site (approximately 3.5 km) it is highly unlikely that airblast levels will reach the 90 dB limit, even for very large blasts.

Without detailed information on the size and type of blasting to be used and the ground composition between the proposed development site and the camp, it is not possible to predict vibration levels at the camp site. However, assuming blast sizes are limited so as prevent any structural damage to the existing oil pipeline terminal to the north of the proposed development, it is unlikely that there will be any impact at the camp site.

6 Appendix 1: Results of Continuous Noise Monitoring



N

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Continous Noise Monitoring Locations

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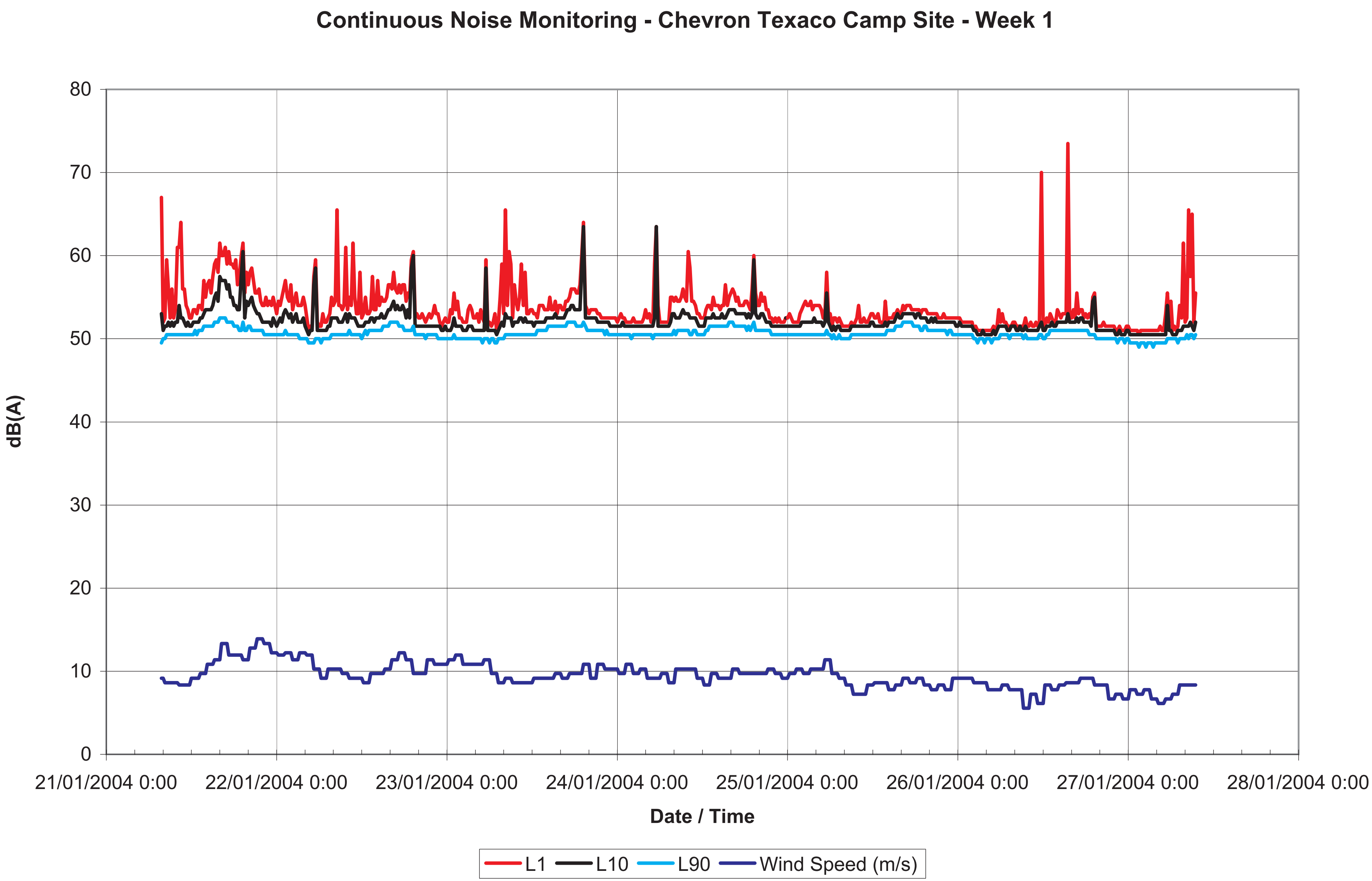
Title:

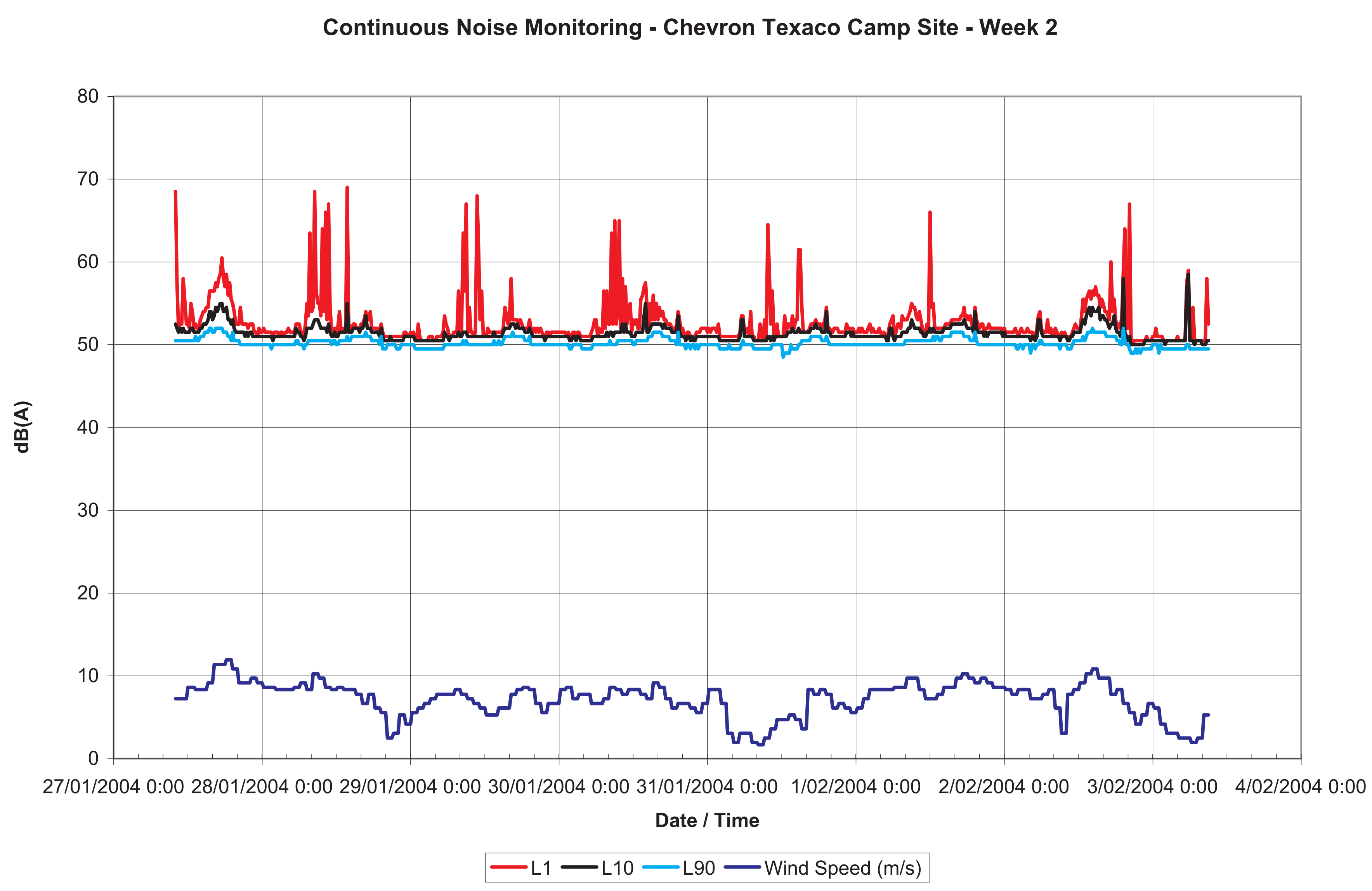
GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	1

Figure 2a



Continuous Noise Monitoring - Chevron Texaco Camp Site - Week 1
dB(A)
80
70
60
50
40
30
20
10
0
21/01/2004 0:00
22/01/2004 0:00
23/01/2004 0:00
24/01/2004 0:00
25/01/2004 0:00
26/01/2004 0:00
27/01/2004 0:00
28/01/2004 0:00
Date / Time
L1
L10
L90
Wind Speed (m/s)


Continuous Noise Monitoring - Chevron Texaco Camp Site - Week 2
dB(A)
80
70
60
50
40
30
20
10
0
27/01/2004 0:00
28/01/2004 0:00
29/01/2004 0:00
30/01/2004 0:00
31/01/2004 0:00
1/02/2004 0:00
2/02/2004 0:00
3/02/2004 0:00
4/02/2004 0:00
Date / Time
L1
L10
L90
Wind Speed (m/s)

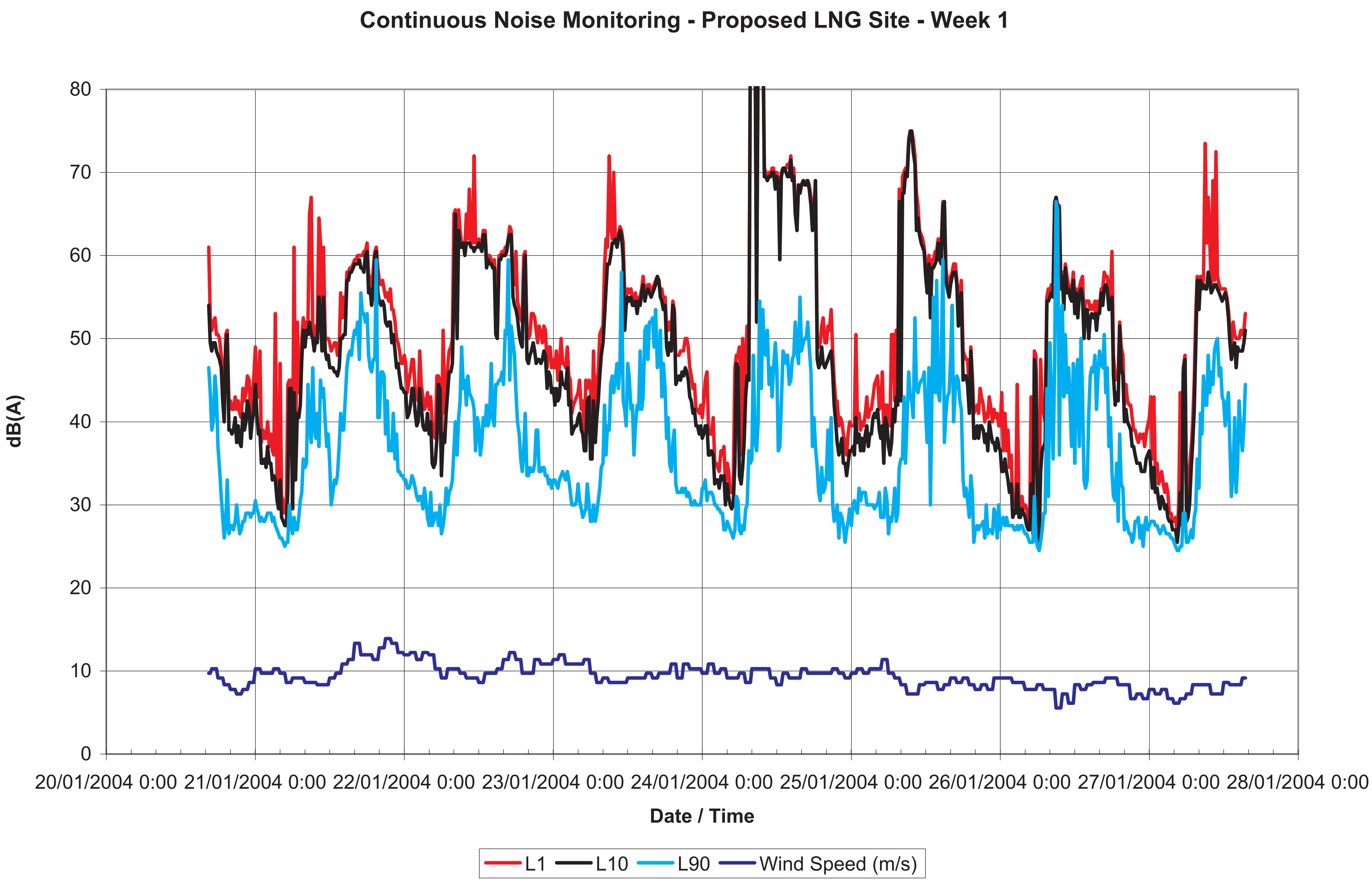
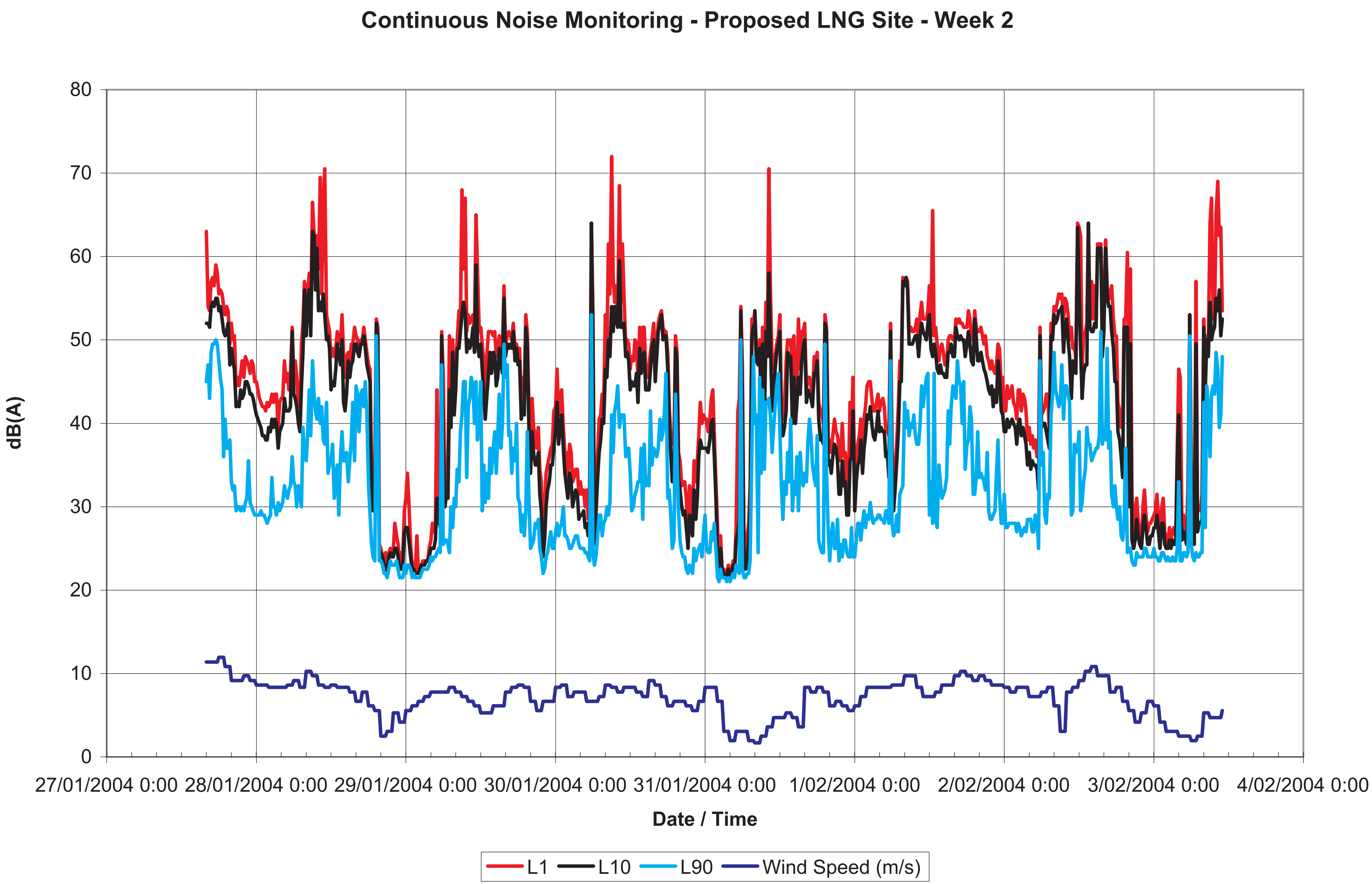

Continuous Noise Monitoring - Proposed LNG Site - Week 1
dB(A)
80
70
60
50
40
30
20
10
0
20/01/2004 0:00
21/01/2004 0:00
22/01/2004 0:00
23/01/2004 0:00
24/01/2004 0:00
25/01/2004 0:00
26/01/2004 0:00
27/01/2004 0:00
28/01/2004 0:00
Date / Time
L1
L10
L90
Wind Speed (m/s)

Figure 3b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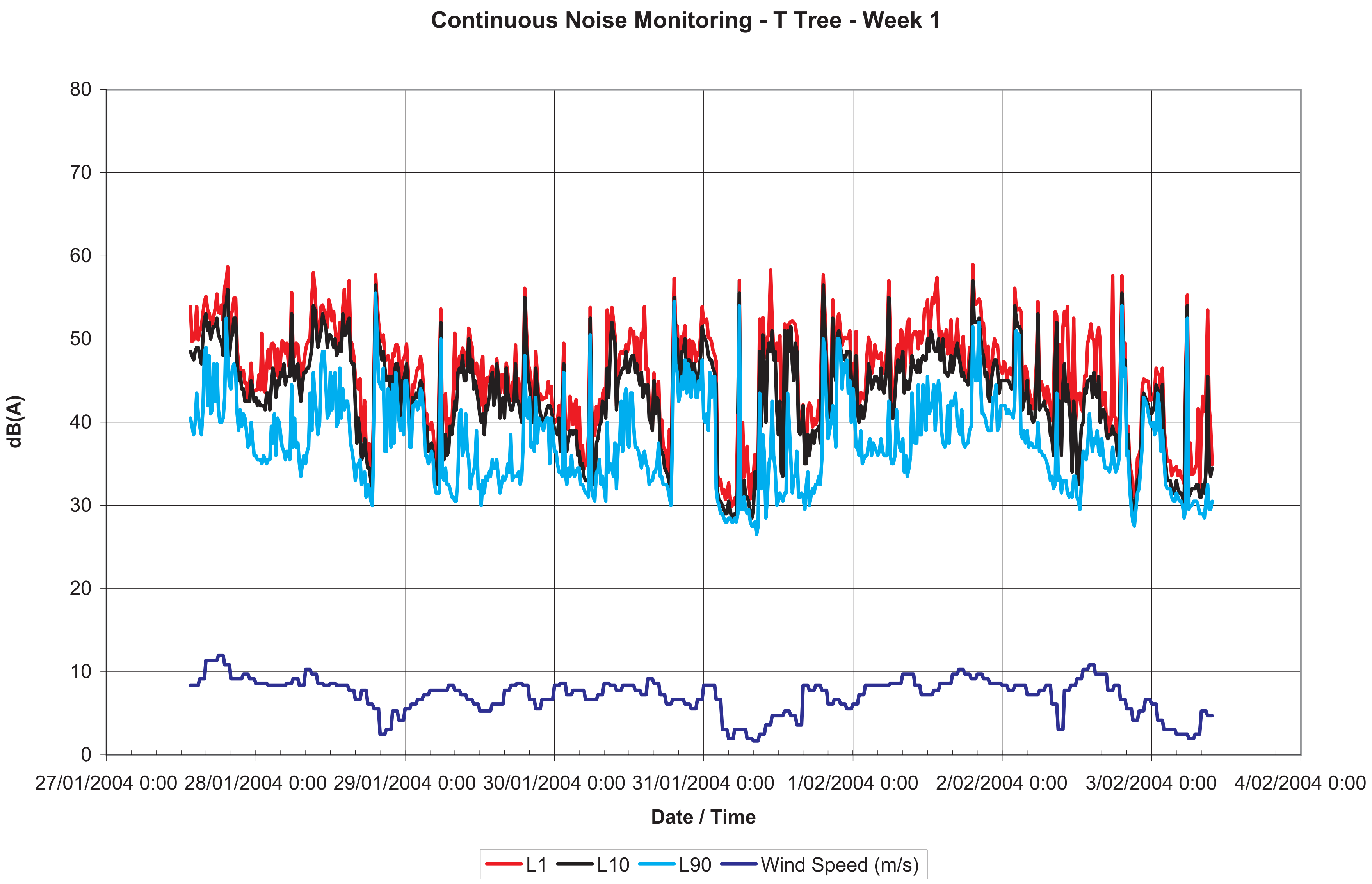
dB(A)
80
70
60
50
40
30
20
10
0
27/01/2004 0:00
28/01/2004 0:00
29/01/2004 0:00
30/01/2004 0:00
31/01/2004 0:00
1/02/2004 0:00
2/02/2004 0:00
3/02/2004 0:00
4/02/2004 0:00
Date / Time
L1
L10
L90
Wind Speed (m/s)

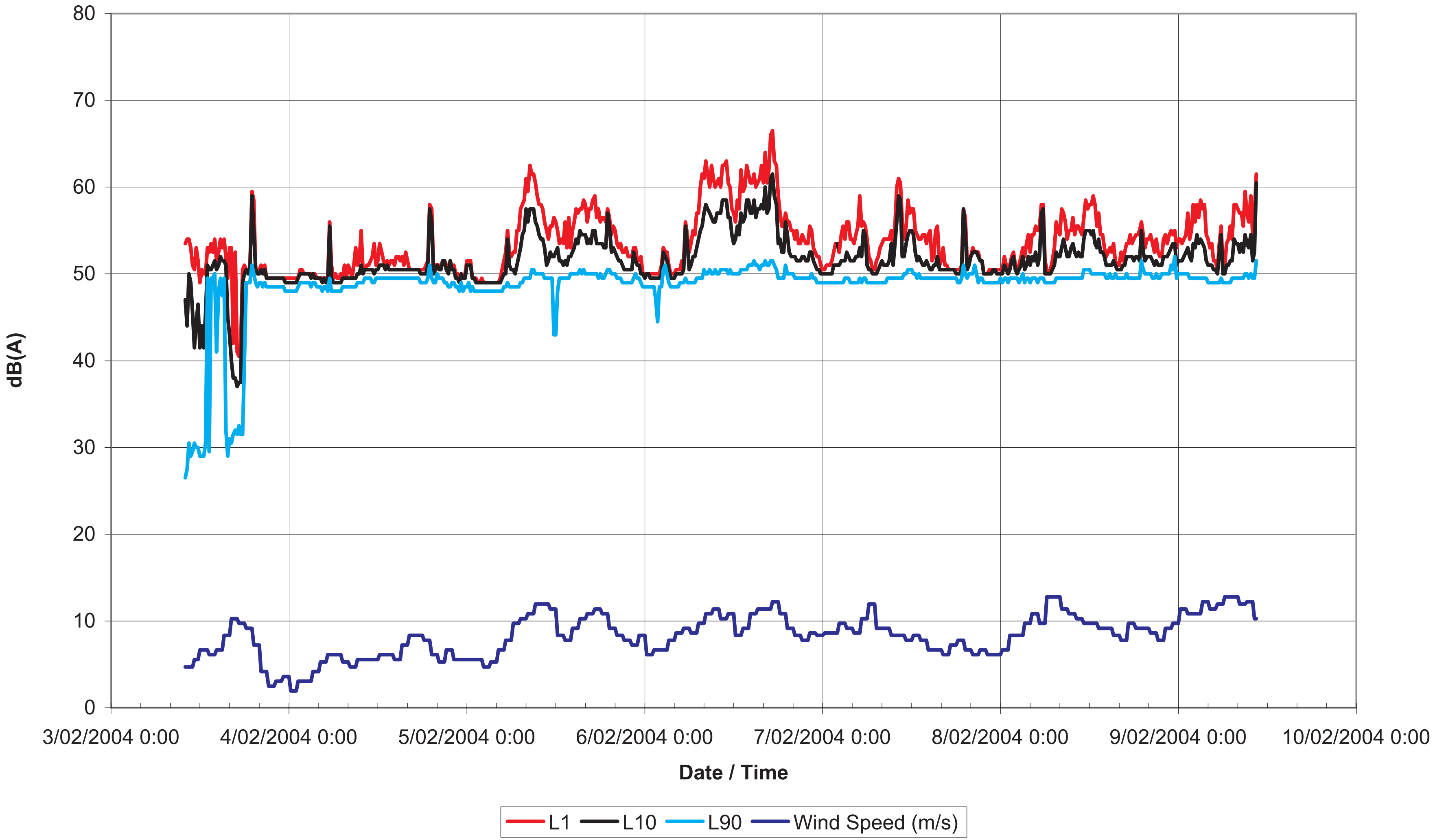
Figure 4a

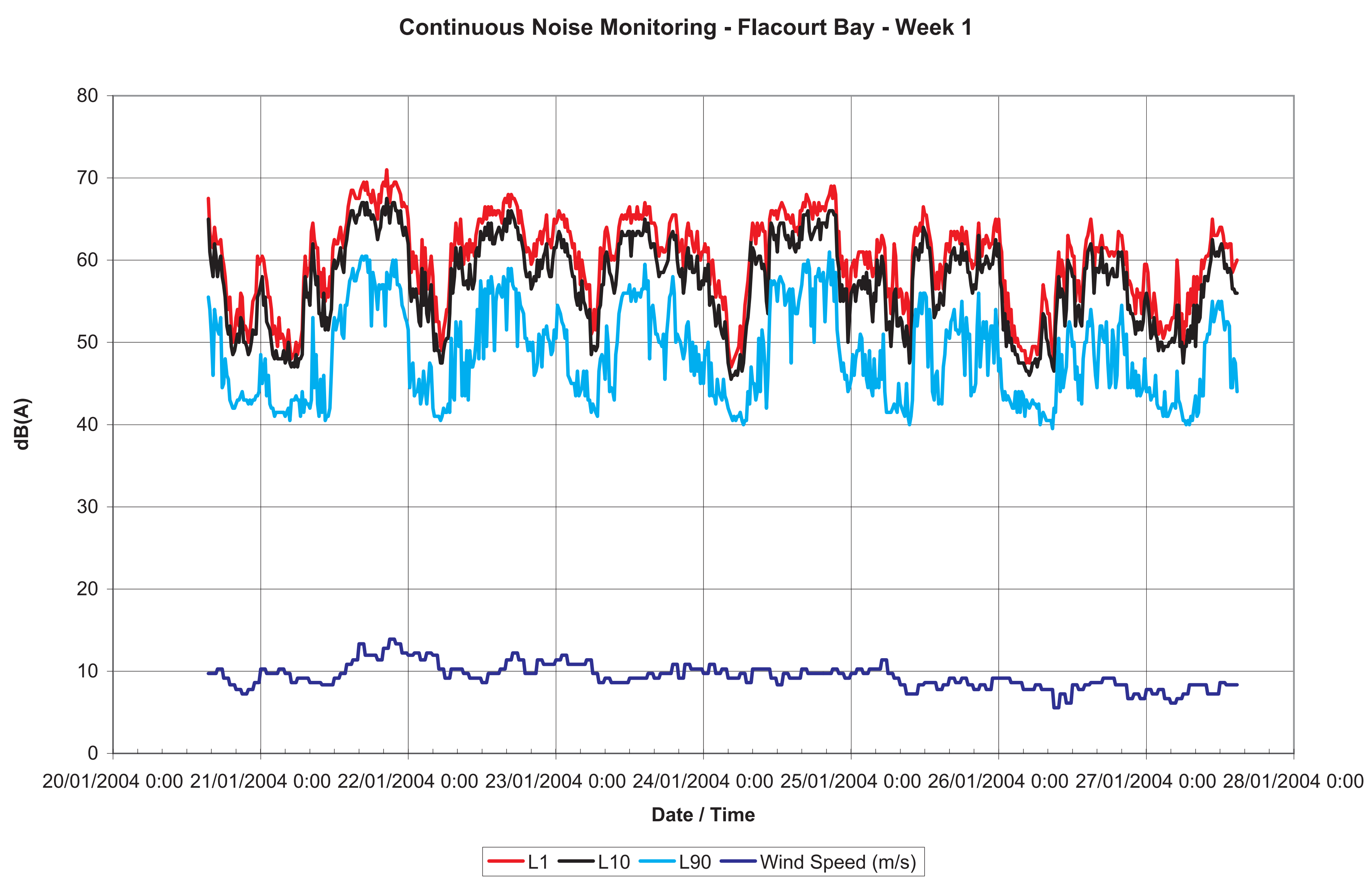


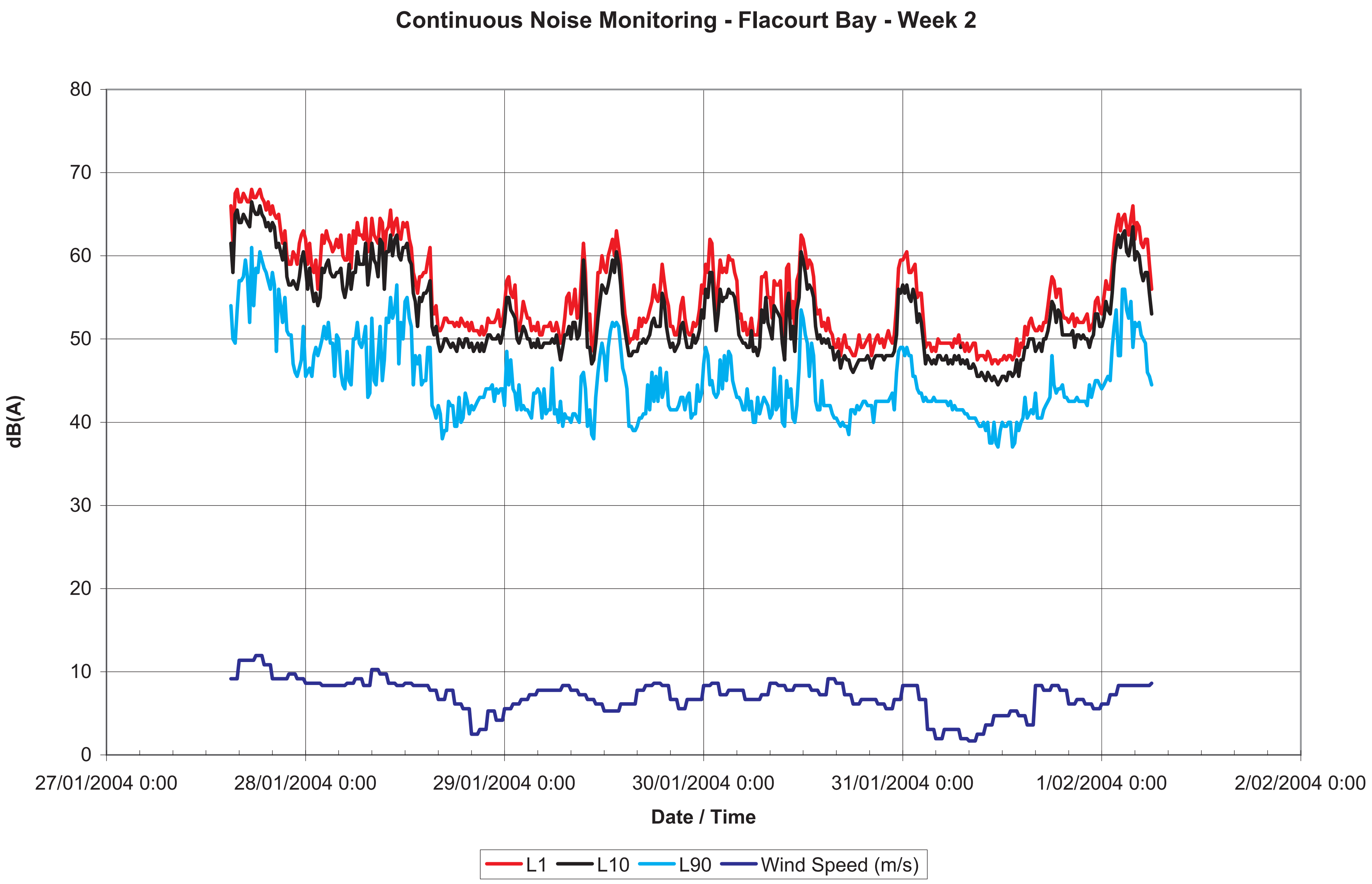
Continuous Noise Monitoring - T Tree - Week 1
dB(A)
80
70
60
50
40
30
20
10
0
27/01/2004 0:00
28/01/2004 0:00
29/01/2004 0:00
30/01/2004 0:00
31/01/2004 0:00
1/02/2004 0:00
2/02/2004 0:00
3/02/2004 0:00
4/02/2004 0:00
Date / Time
L1
L10
L90
Wind Speed (m/s)

Figure 4b

Continuous Noise Monitoring - T Tree - Week 2




Continuous Noise Monitoring - Flacourt Bay - Week 1
dB(A)
80
70
60
50
40
30
20
10
0
20/01/2004 0:00
21/01/2004 0:00
22/01/2004 0:00
23/01/2004 0:00
24/01/2004 0:00
25/01/2004 0:00
26/01/2004 0:00
27/01/2004 0:00
28/01/2004 0:00
Date / Time
L1
L10
L90
Wind Speed (m/s)


Continuous Noise Monitoring - Flacourt Bay - Week 2
dB(A)
80
70
60
50
40
30
20
10
0
27/01/2004 0:00
28/01/2004 0:00
29/01/2004 0:00
30/01/2004 0:00
31/01/2004 0:00
1/02/2004 0:00
2/02/2004 0:00
Date / Time
L1
L10
L90
Wind Speed (m/s)

7 Appendix 2: Octave Band Equipment Sound Power Levels for LNG Plant

Table A1: Sound Power Levels for LNG Plant Equipment

			Octave Band Sound Power Level (SWL) - dB(lin)								Overall SWL	
Description	**Tag No**	**Plant Area**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**A**	**Lin**
Condensate product cooler	1002-MC	Inlet, stabilisation, MEG Regen.	117	114	106	102	102	101	95	85	108	119
Stabiliser overheads compression cooler	1003-MC	Inlet, stabilisation, MEG Regen.	Included in SWL for 1002-MC									
LP steam control condenser	4204-MC	Inlet, stabilisation, MEG Regen.	Included in SWL for 1002-MC									
LP Flash drum vent condenser	4205-MC	Inlet, stabilisation, MEG Regen.	Included in SWL for 1002-MC									
Stabiliser overheads 1st stage compressor	1001-MJ	Inlet, stabilisation, MEG Regen.	88	103	92	90	93	98	95	88	102	105
Stabiliser overheads 2nd stage compressor	1002-MJ	Inlet, stabilisation, MEG Regen.	88	103	92	90	93	98	95	88	102	105
Wellhead Injection pumps	1003-MJ/MJA	Inlet, stabilisation, MEG Regen.	92	94	94	94	94	94	91	84	100	102
Lean Amine cooler	1103-MC	AGRU 1	120	117	109	105	105	104	98	88	111	122
Amine regenerator reflux cooler	1104-MC	AGRU 1	Included in SWL for 1103-MC									
Lean Amine pumps	1101-MJ A/B/C	AGRU 1	97	99	99	99	99	99	96	89	105	107
Lean Amine booster pumps	1102-MJ A/B/C	AGRU 1	91	93	93	93	93	93	90	83	99	101
Lean Amine cooler	1123-MC	AGRU 2	120	117	109	105	105	104	98	88	111	122
Amine regenerator reflux cooler	1124-MC	AGRU 2	Included in SWL for 1123-MC									
Lean Amine pumps	1121-MJ A/B/C	AGRU 2	97	99	99	99	99	99	96	89	105	107
Lean Amine booster pumps	1122-MJ A/B/C	AGRU 2	91	93	93	93	93	93	90	83	99	101
Lean Amine cooler	1143-MC	AGRU 3	120	117	109	105	105	104	98	88	111	122
Amine regenerator reflux cooler	1144-MC	AGRU 3	Included in SWL for 1143-MC									
Lean Amine pumps	1141-MJ A/B/C	AGRU 3	97	99	99	99	99	99	96	89	105	107
Lean Amine booster pumps	1142-MJ A/B/C	AGRU 3	91	93	93	93	93	93	90	83	99	101
Propane compressor desuperheater	1548-MC	Train 1	125	122	114	110	110	109	103	93	116	127
Propane condenser	1549-MC	Train 1	Included in SWL for 1548-MC									
Propane subcooler	1550-MC	Train 1	Included in SWL for 1548-MC									
LP MR compressor intercooler	1541-MC	Train 1	121	118	110	106	106	105	99	89	112	123
MP MR compressor intercooler	1542-MC	Train 1	Included in SWL for 1541-MC									
HP MR compressor aftercooler	1543-MC	Train 1	Included in SWL for 1541-MC									
Fractionation feed cooler	1641-MC	Train 1	Included in SWL for 1541-MC									
Depropaniser condenser	1644-MC	Train 1	Included in SWL for 1541-MC									
Debutaniser condenser	1646-MC	Train 1	Included in SWL for 1541-MC									
Debutaniser bottoms cooler	1648-MC	Train 1	Included in SWL for 1541-MC									
Feed gas air pre-cooler	1241-MC	Train 1	Included in SWL for 1541-MC									
Regeneration gas compressor	1201-MJ	Train 1	96	96	98	98	99	98	98	92	105	106
Fuel gas compressor	1441-MJ	Train 1	106	100	98	98	99	98	99	92	105	109
LNG Expander	1444-MJ	Train 1	103	97	95	95	96	95	96	89	102	106
MR Expander	1445-MJ	Train 1	103	97	95	95	96	95	96	89	102	106
LP MR compressor	1541-MJ	Train 1	108	112	107	105	106	108	105	107	114	117
Gas turbine driver for 1541/1542-MJ	1541-MJ-GT	Train 1	Included in SWL for 1541-MJ									
Helper turbine for 1541/1542-MJ	1541-MJ-T	Train 1	Included in SWL for 1541-MJ									
MP MR compressor	1542-MJ	Train 1	Included in SWL for 1541-MJ									
Exhaust stack for MR compressor	-	Train 1	109	108	89	95	97	96	91	96	103	112
Propane compressor	1544-MJ	Train 1	108	112	107	105	106	108	105	107	114	117

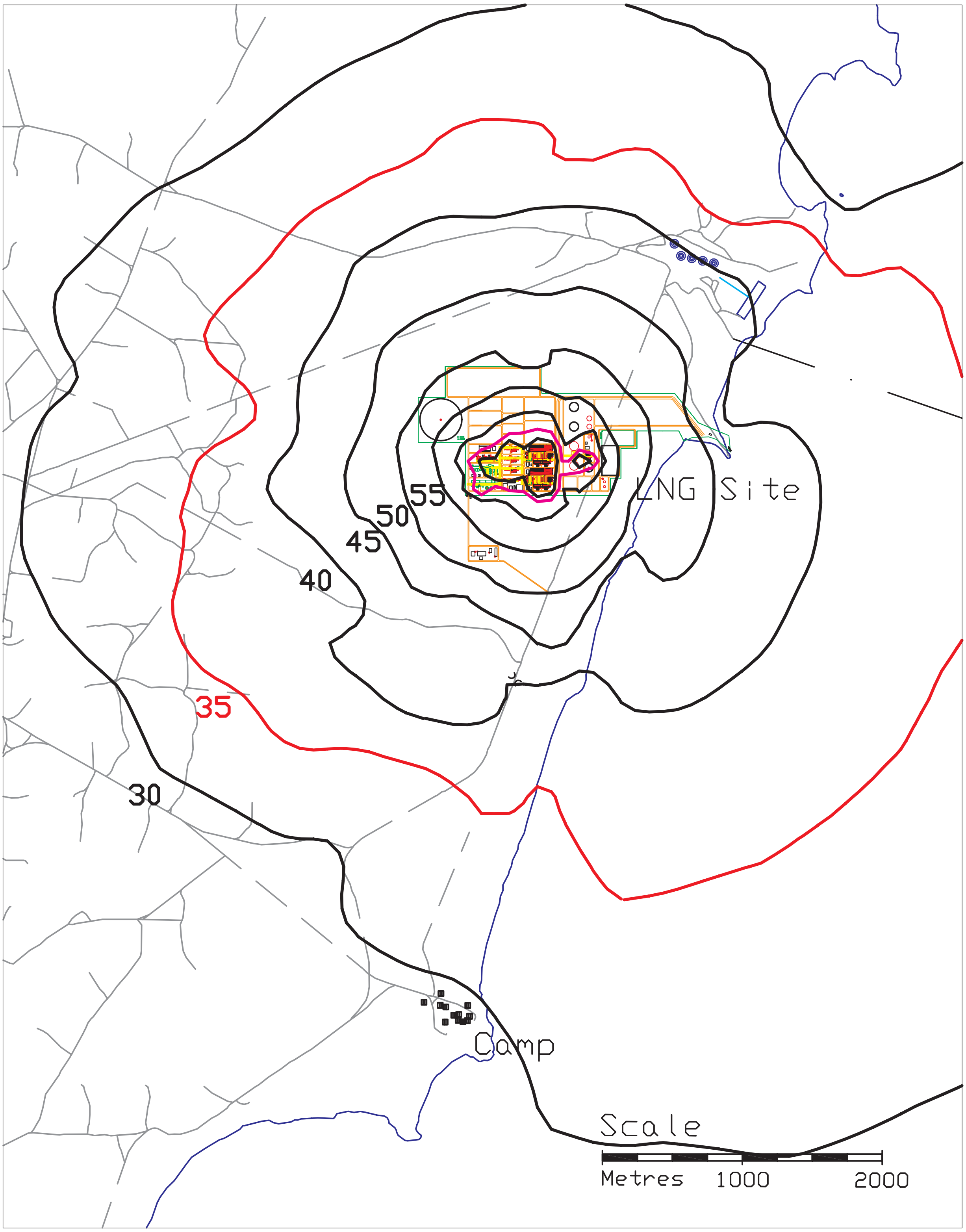
Table A1: Sound Power Levels for LNG Plant Equipment

			Octave Band Sound Power Level (SWL) - dB(lin)								Overall SWL	
Description	**Tag No**	**Plant Area**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**A**	**Lin**
HP MR compressor	1543-MJ	Train 1	Included in SWL for 1544-MJ									
Gas turbine driver for 1543/1543-MJ	1544-MJ-GT	Train 1	Included in SWL for 1544-MJ									
Helper turbine for 1543/1543-MJ	1544-MJ-T	Train 1	Included in SWL for 1544-MJ									
Exhaust stack for Propane compressor	-	Train 1	109	108	89	95	97	96	91	96	103	112
Propane compressor desuperheater	1548-MC	Train 2	125	122	114	110	110	109	103	93	116	127
Propane condenser	1549-MC	Train 2	Included in SWL for 1548-MC									
Propane subcooler	1550-MC	Train 2	Included in SWL for 1548-MC									
LP MR compressor intercooler	1541-MC	Train 2	121	118	110	106	106	105	99	89	112	123
MP MR compressor intercooler	1542-MC	Train 2	Included in SWL for 1541-MC									
HP MR compressor aftercooler	1543-MC	Train 2	Included in SWL for 1541-MC									
Fractionation feed cooler	1641-MC	Train 2	Included in SWL for 1541-MC									
Depropaniser condenser	1644-MC	Train 2	Included in SWL for 1541-MC									
Debutaniser condenser	1646-MC	Train 2	Included in SWL for 1541-MC									
Debutaniser bottoms cooler	1648-MC	Train 2	Included in SWL for 1541-MC									
Feed gas air pre-cooler	1241-MC	Train 2	Included in SWL for 1541-MC									
Regeneration gas compressor	1201-MJ	Train 2	96	96	98	98	99	98	98	92	105	106
Fuel gas compressor	1441-MJ	Train 2	106	100	98	98	99	98	99	92	105	109
LNG Expander	1444-MJ	Train 2	103	97	95	95	96	95	96	89	102	106
MR Expander	1445-MJ	Train 2	103	97	95	95	96	95	96	89	102	106
LP MR compressor	1541-MJ	Train 2	108	112	107	105	106	108	105	107	114	117
Gas turbine driver for 1541/1542-MJ	1541-MJ-GT	Train 2	Included in SWL for 1541-MJ									
Helper turbine for 1541/1542-MJ	1541-MJ-T	Train 2	Included in SWL for 1541-MJ									
MP MR compressor	1542-MJ	Train 2	Included in SWL for 1541-MJ									
Exhaust stack for MR compressor	-	Train 2	109	108	89	95	97	96	91	96	103	112
Propane compressor	1544-MJ	Train 2	108	112	107	105	106	108	105	107	114	117
HP MR compressor	1543-MJ	Train 2	Included in SWL for 1544-MJ									
Gas turbine driver for 1543/1543-MJ	1544-MJ-GT	Train 2	Included in SWL for 1544-MJ									
Helper turbine for 1543/1543-MJ	1544-MJ-T	Train 2	Included in SWL for 1544-MJ									
Exhaust stack for Propane compressor	-	Train 2	109	108	89	95	97	96	91	96	103	112
CO2 reinjection compressor	1701-MJ A/B	CO2 reinjection	105	109	104	102	103	105	102	104	111	114
CO2 reinjection pumps	1702-MJ A/B/C	CO2 reinjection	91	93	93	93	93	93	90	83	99	101
1st stage CO2 compressor dishcarge cooler	1701-MC A/B	CO2 reinjection	116	113	105	101	101	100	94	84	107	118
2nd stage CO2 compressor dishcarge cooler	1702-MC A/B	CO2 reinjection	Included in SWL for 1701-MJ									
3rd stage CO2 compressor dishcarge cooler	1703-MC A/B	CO2 reinjection	Included in SWL for 1701-MJ									
CO2 condenser	1704-MC A/B	CO2 reinjection	Included in SWL for 1701-MJ									
BOG compressor aftercooler	3101-MC	LNG storage & loading	110	107	99	93	91	89	85	75	98	112
BOG recycle compressor intercooler	3102-MC	LNG storage & loading	Included in SWL for 3101-MC									
BOG recycle compressor aftercooler	3103-MC	LNG storage & loading	Included in SWL for 3101-MC									
LNG BOG compressor	3101-MJ	LNG storage & loading	101	101	103	103	104	103	103	97	110	111

Table A1: Sound Power Levels for LNG Plant Equipment

			Octave Band Sound Power Level (SWL) - dB(lin)								Overall SWL	
Description	**Tag No**	**Plant Area**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**A**	**Lin**
LNG BOG recycle compressor	3103-MJ	LNG storage & loading	Included in SWL for 3101-MJ									
LNG loading pumps	3102-MJ A to H	LNG storage & loading	98	100	100	100	100	100	97	90	106	108
Condensate loading pumps	3210-MJ A/B/C	LNG storage & loading	92	94	94	94	94	94	91	84	100	102
Power generators	4101-MJ A/B/C	Power generation	114	107	104	101	101	104	102	100	109	116
Boiler feed water pumps	4202-MJ A/B/C	Utilities	92	94	94	94	94	94	91	84	100	102
Package steam boilers	4212-MC A/B	Utilities	107	106	104	101	98	95	92	89	104	111
Instrument air compressor packages	4302-ML/MLA	Utilities	91	91	90	93	96	96	94	91	102	102
Instrument air driers	4301-ML/MLA	Utilities	Included in SWL for 4302-ML									

8 Appendix 3: Noise Contours



Wind Speed(m/s): 0m/s (Calm)	Thermal Inversion: N/A	RH: 50%	N	Client: Sinclair Knight Merz
Wind Direction: N/A	Temperature: 15 C	Day/Night: Night		

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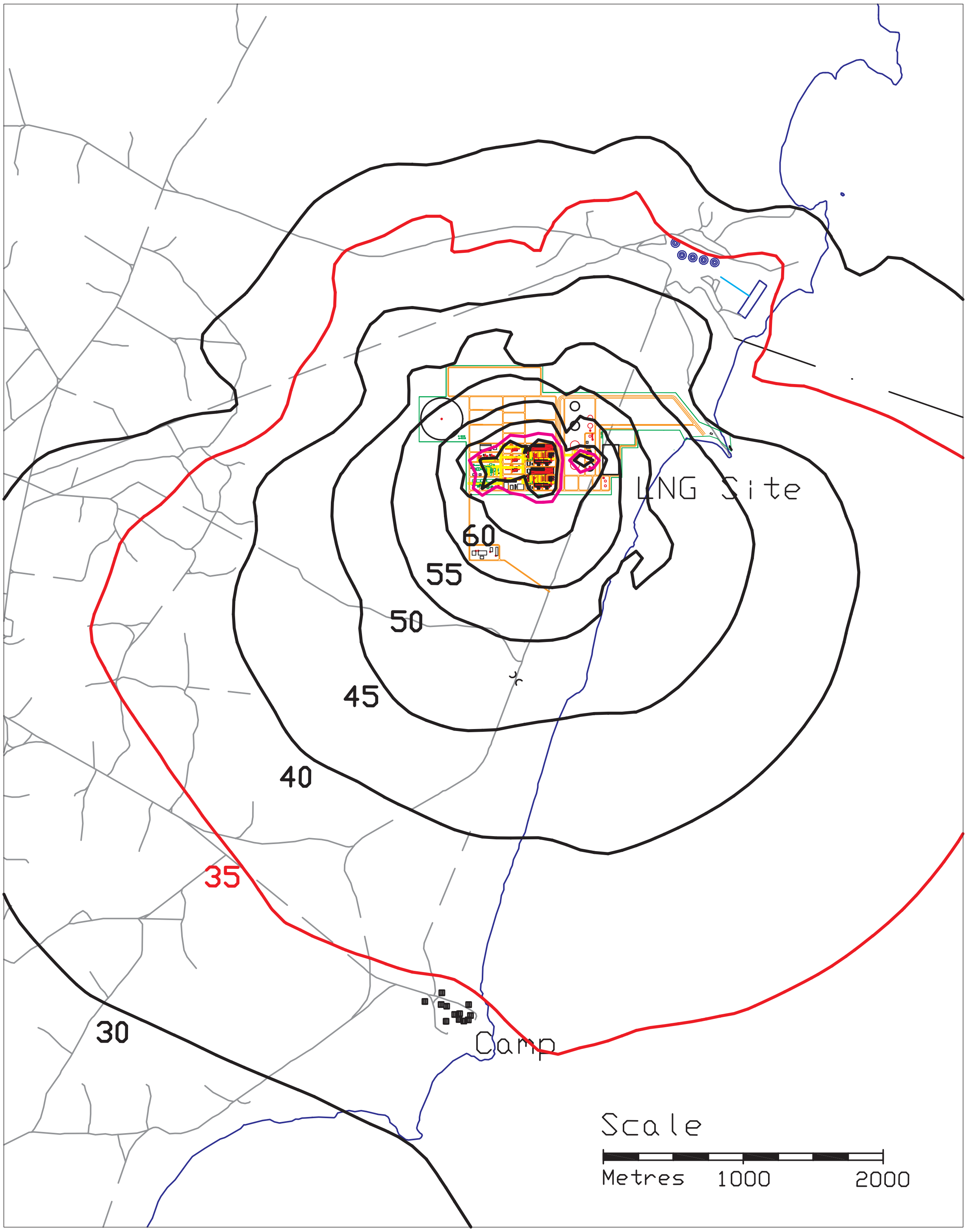
Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC1



Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	N	Client: Sinclair Knight Merz
Wind Direction: North	Temperature: 15 C	Day/Night: Night		

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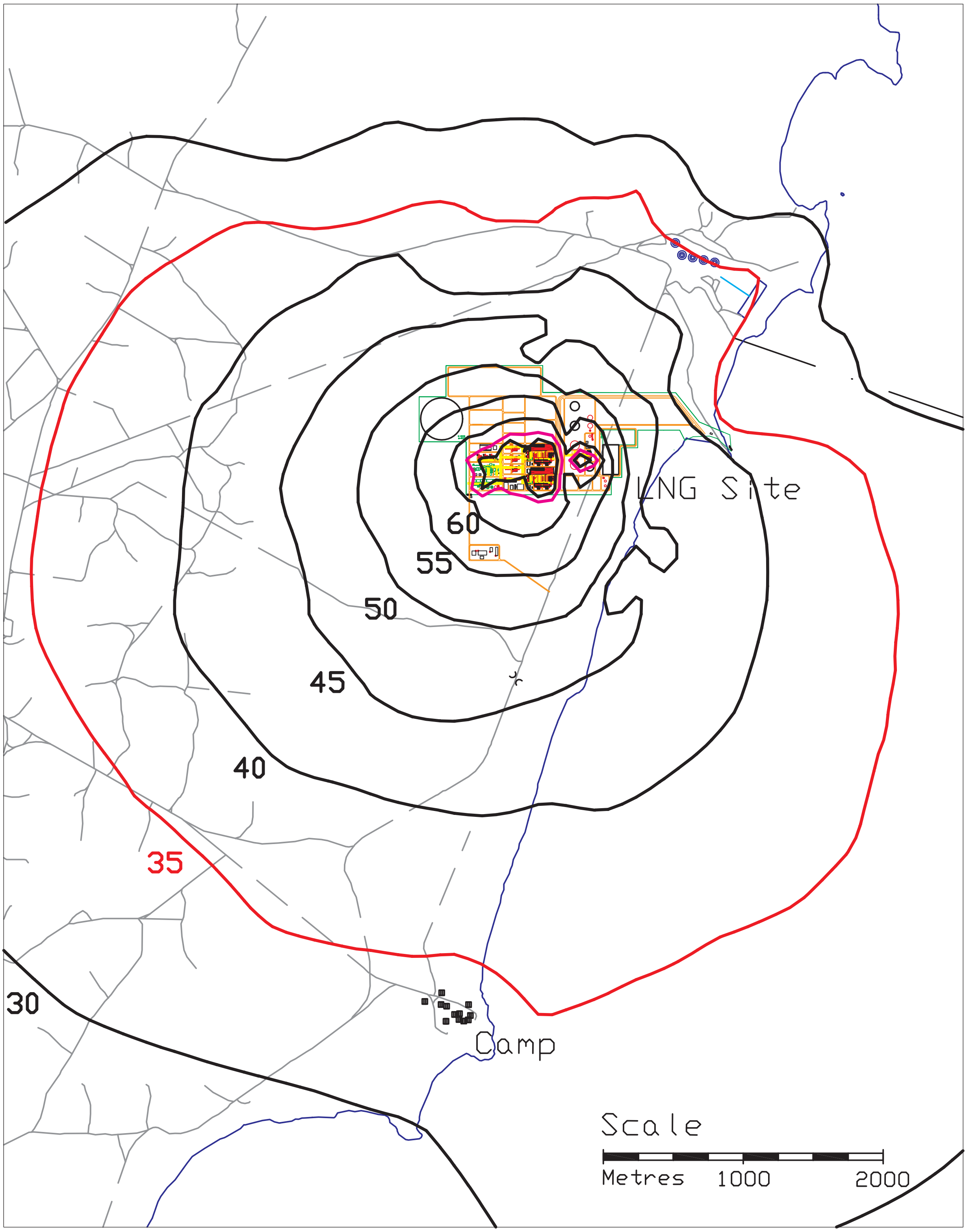
Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC2



Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	N	Client: **Sinclair Knight Merz**
Wind Direction: North East	Temperature: 15 C	Day/Night: Night		

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Comments:
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Title:
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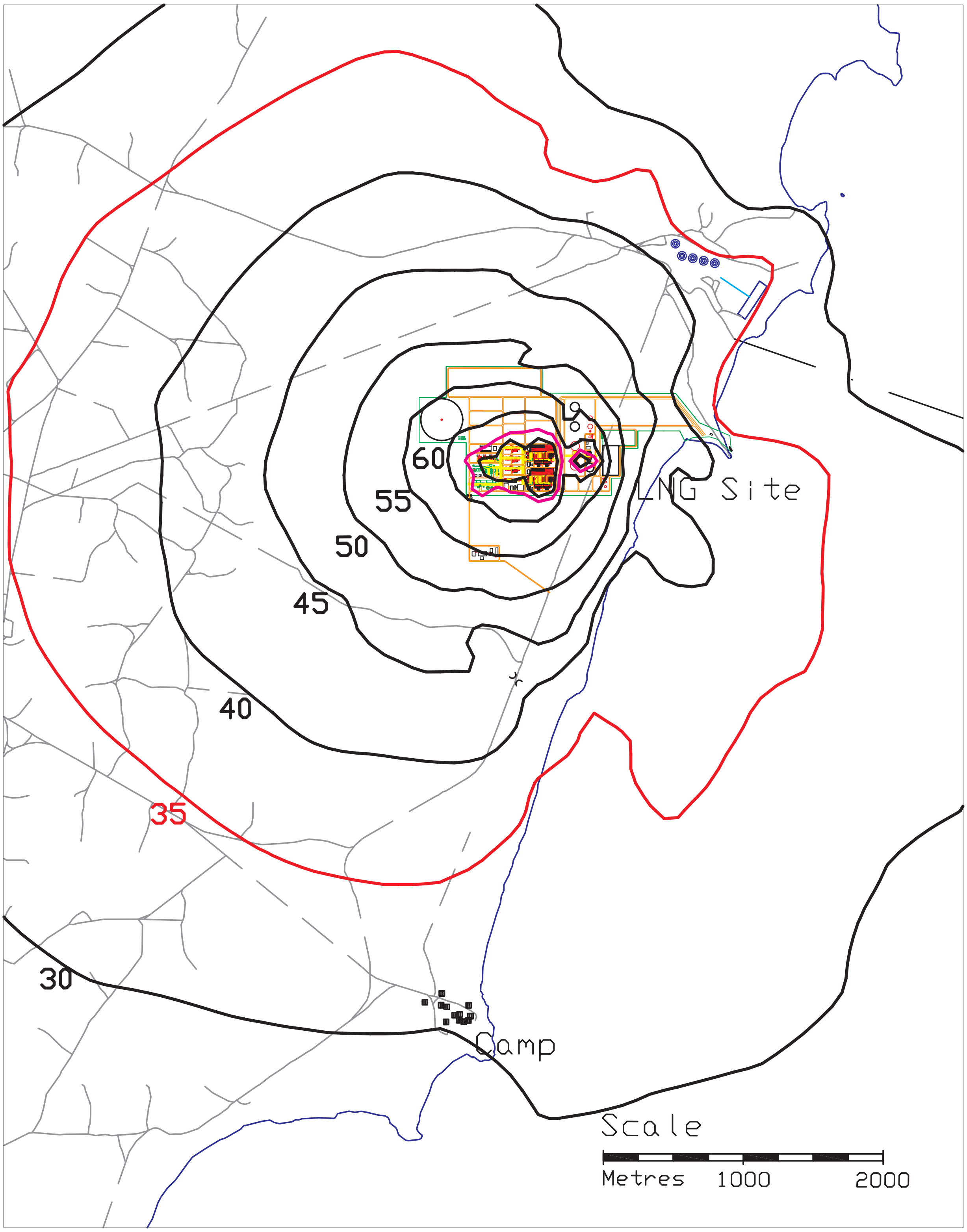
Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC3



Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	Client: Sinclair Knight Merz
Wind Direction: East	Temperature: 15 C	Day/Night: Night	

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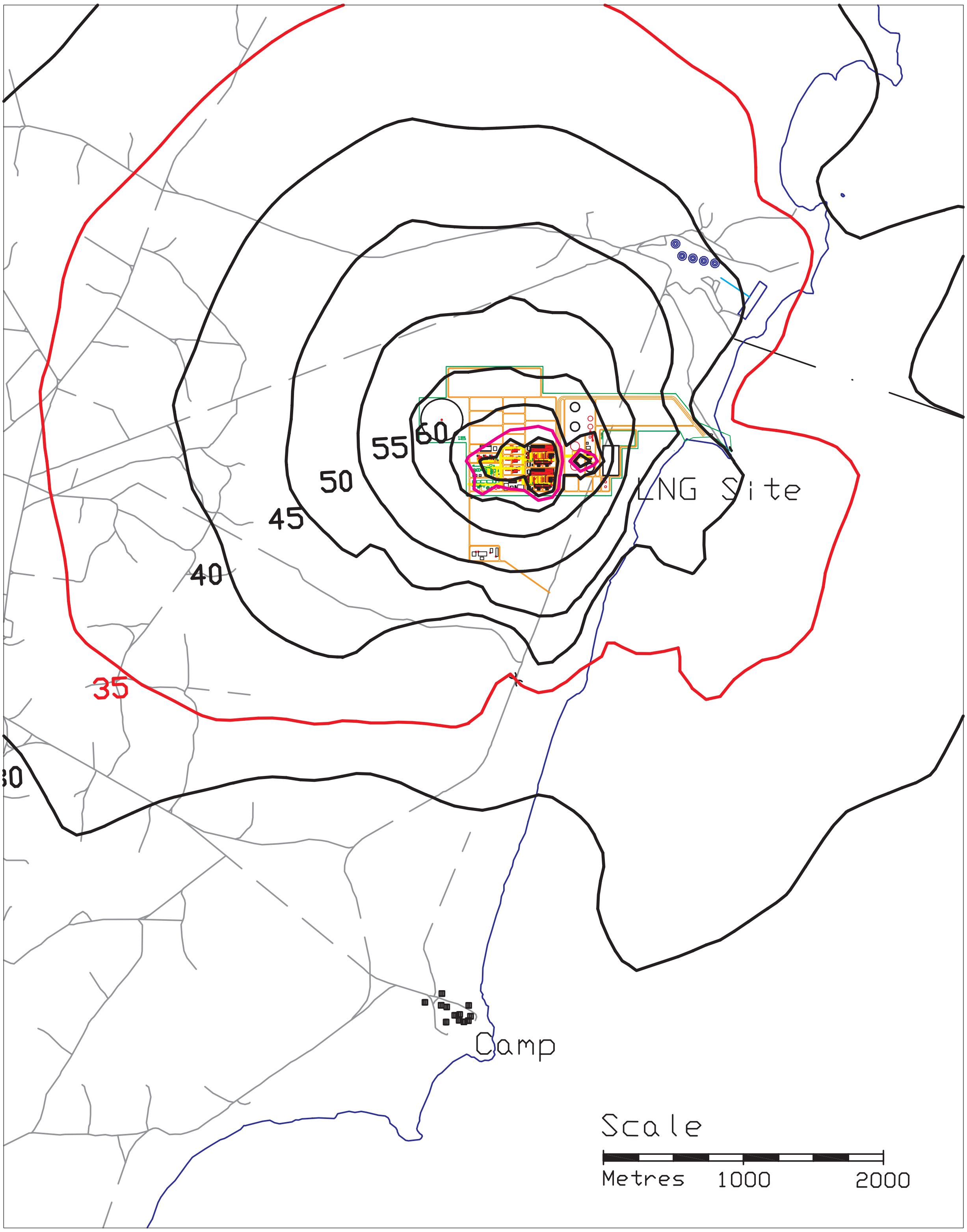
Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC4



Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	Client: **Sinclair Knight Merz**
Wind Direction: South East	Temperature: 15 C	Day/Night: Night	

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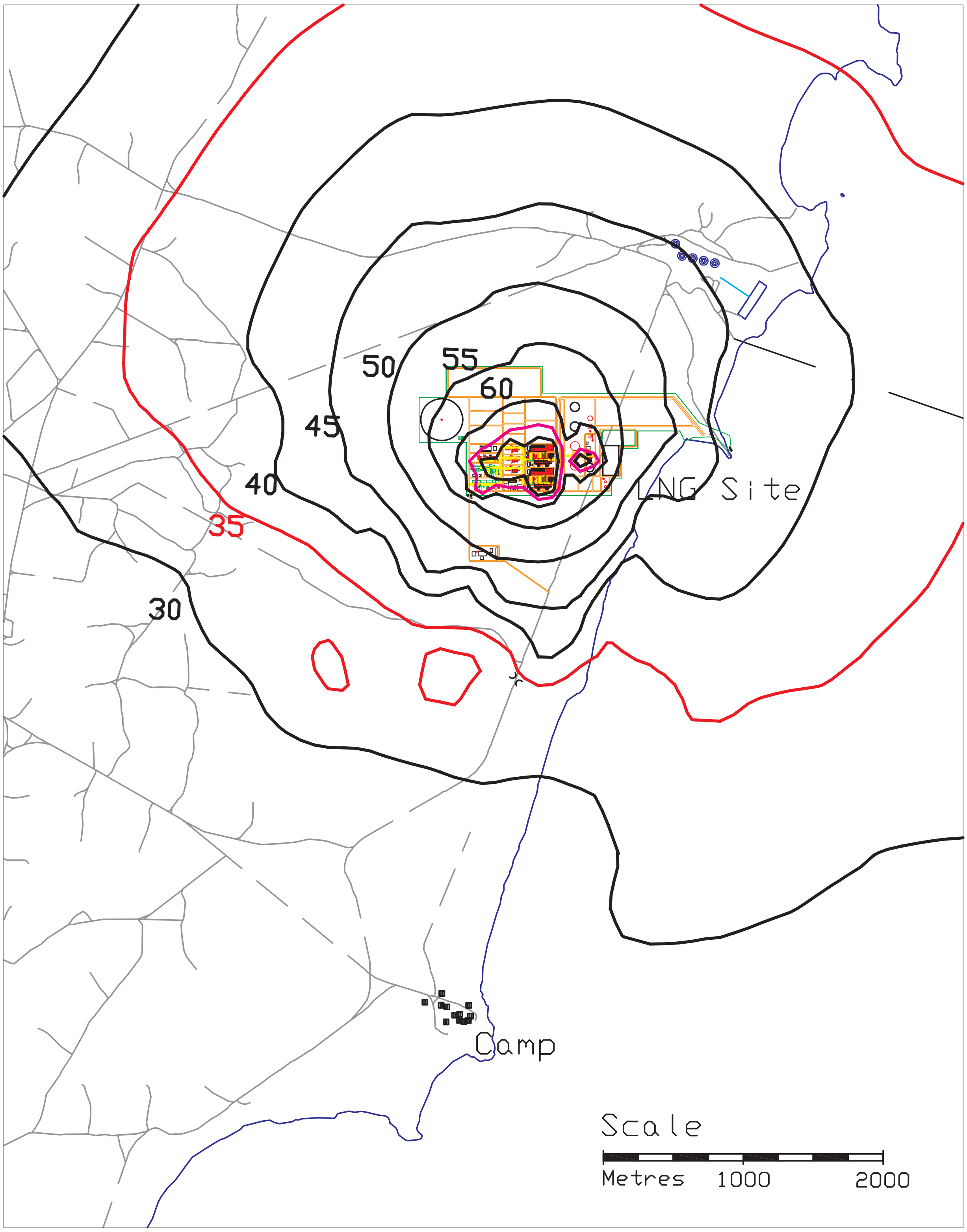
Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC5



Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	N	Client: **Sinclair Knight Merz**
Wind Direction: South	Temperature: 15 C	Day/Night: Night		

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Comments:
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Title:
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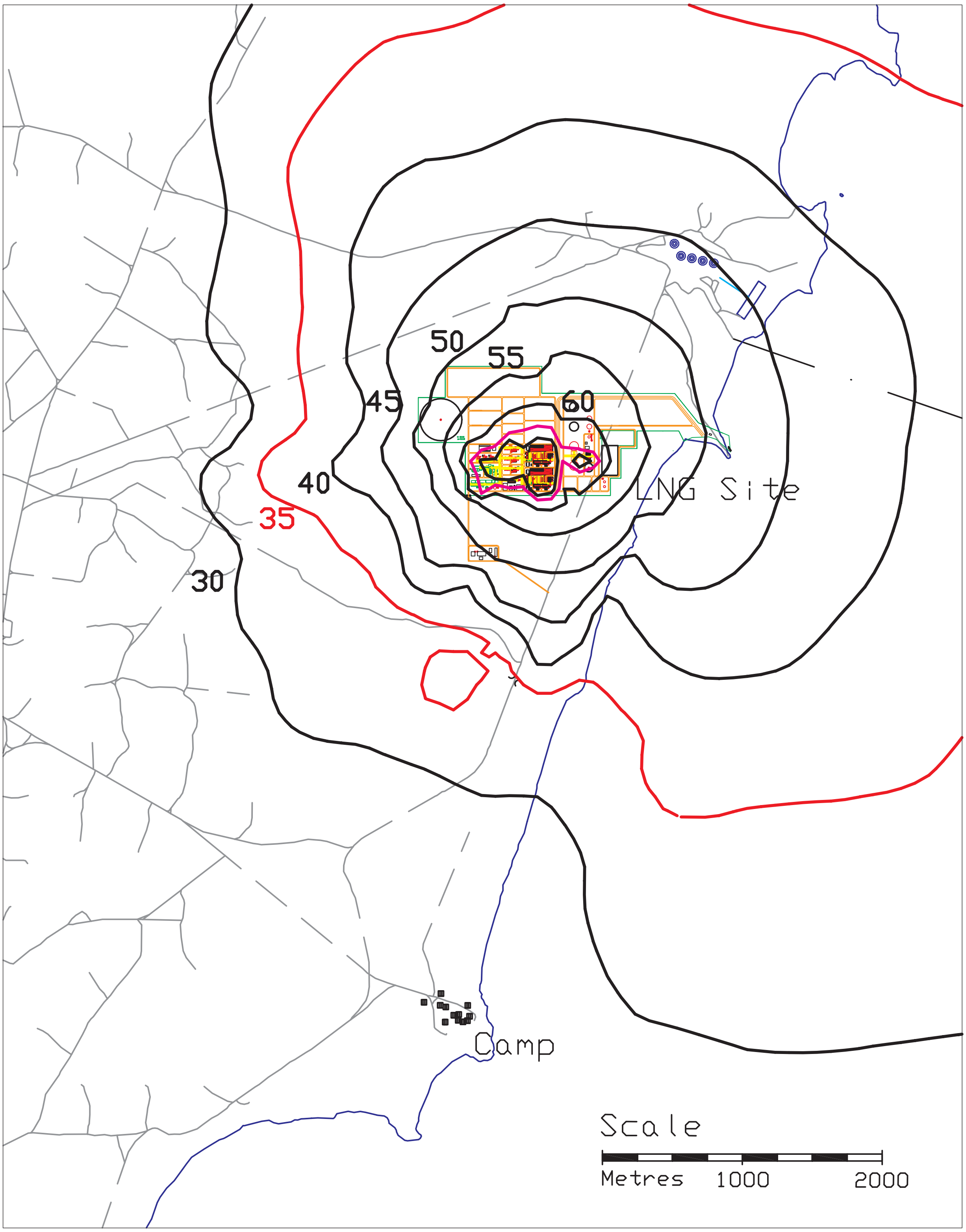
Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC6



Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	Client: **Sinclair Knight Merz**
Wind Direction: South West	Temperature: 15 C	Day/Night: Night	

Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC7

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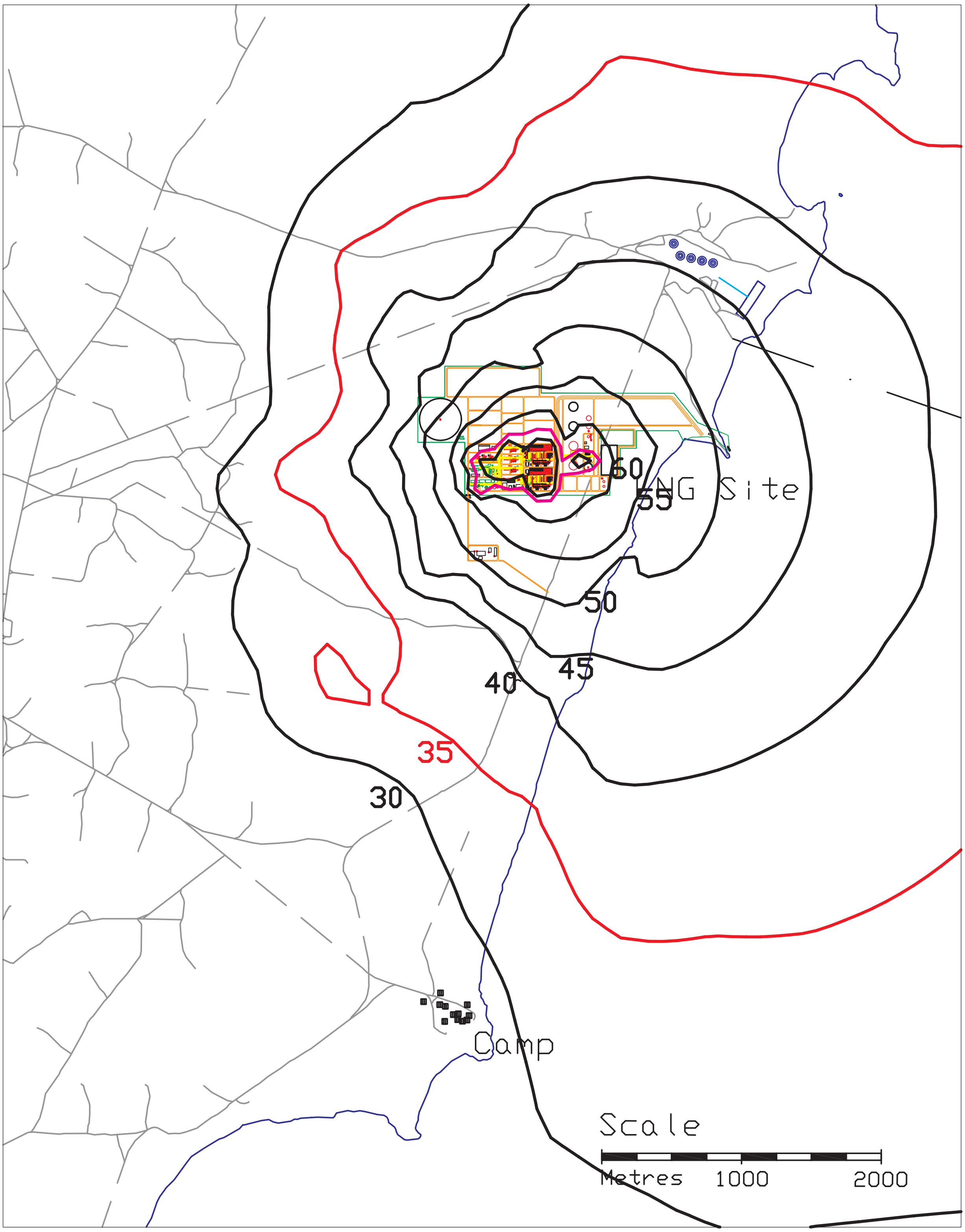

Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	Client: **Sinclair Knight Merz**
Wind Direction: West	Temperature: 15 C	Day/Night: Night	

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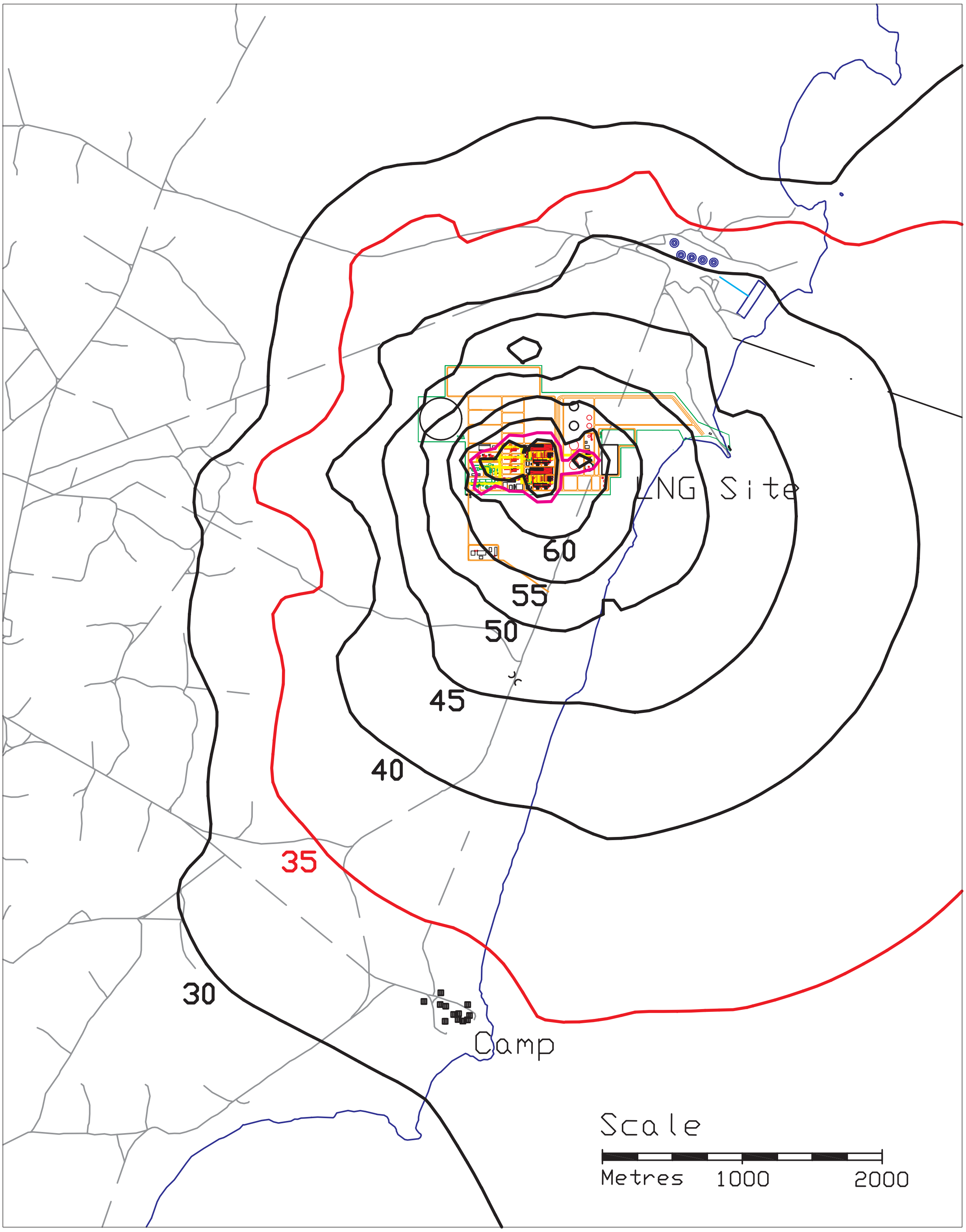
Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC8



Wind Speed(m/s): 3m/s	Thermal Inversion: N/A	RH: 50%	Client: Sinclair Knight Merz
Wind Direction: North West	Temperature: 15 C	Day/Night: Night	

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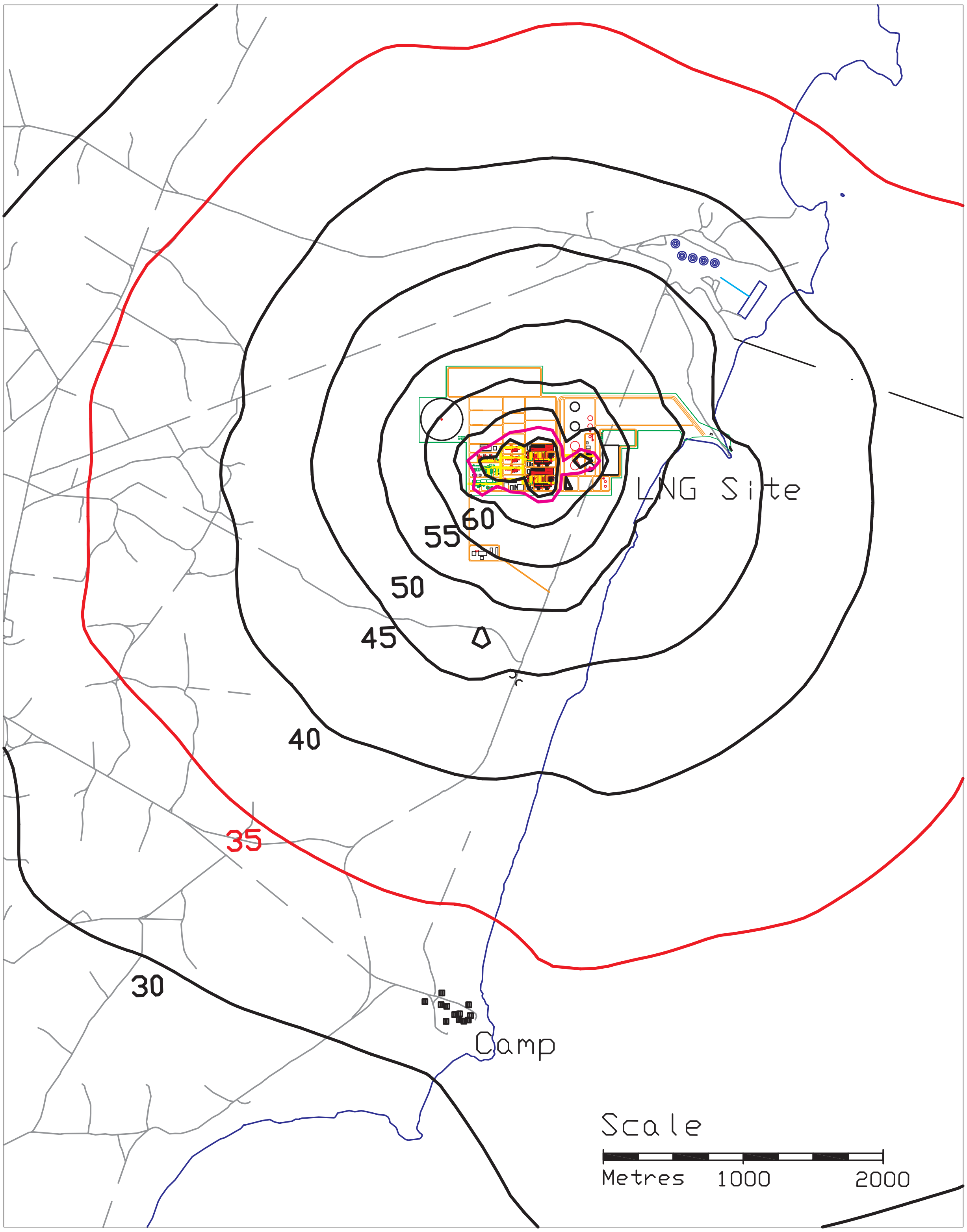
Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC9



Wind Speed(m/s): 0m/s (Calm)	Thermal Inversion: 2C/100m	RH: 50%	N	Client: **Sinclair Knight Merz**
Wind Direction: N/A	Temperature: 15 C	Day/Night: Night		

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Comments:
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Title:
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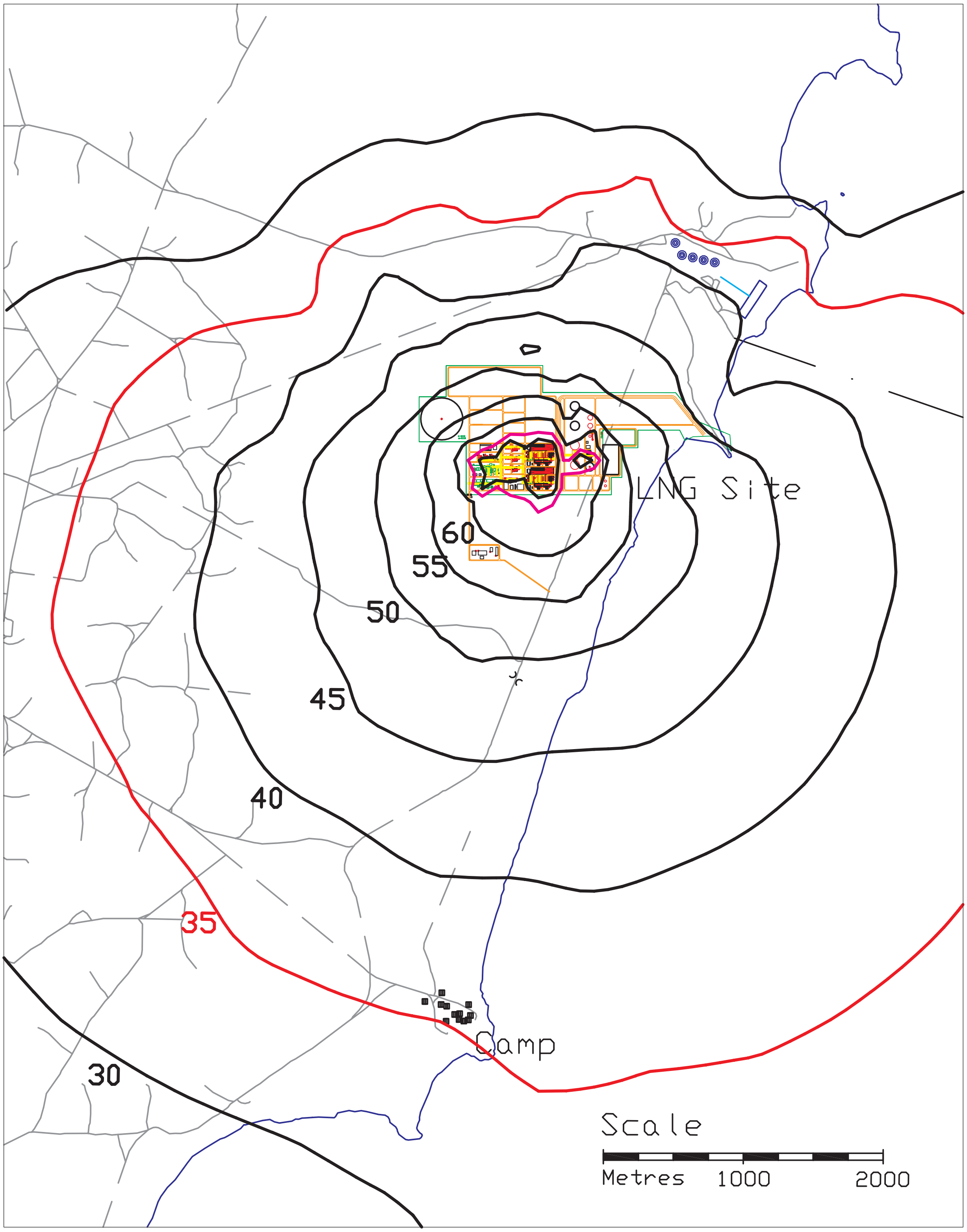
Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC10



Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	N
Wind Direction: North	Temperature: 15 C	Day/Night: Night	

Client: **Sinclair Knight Merz**

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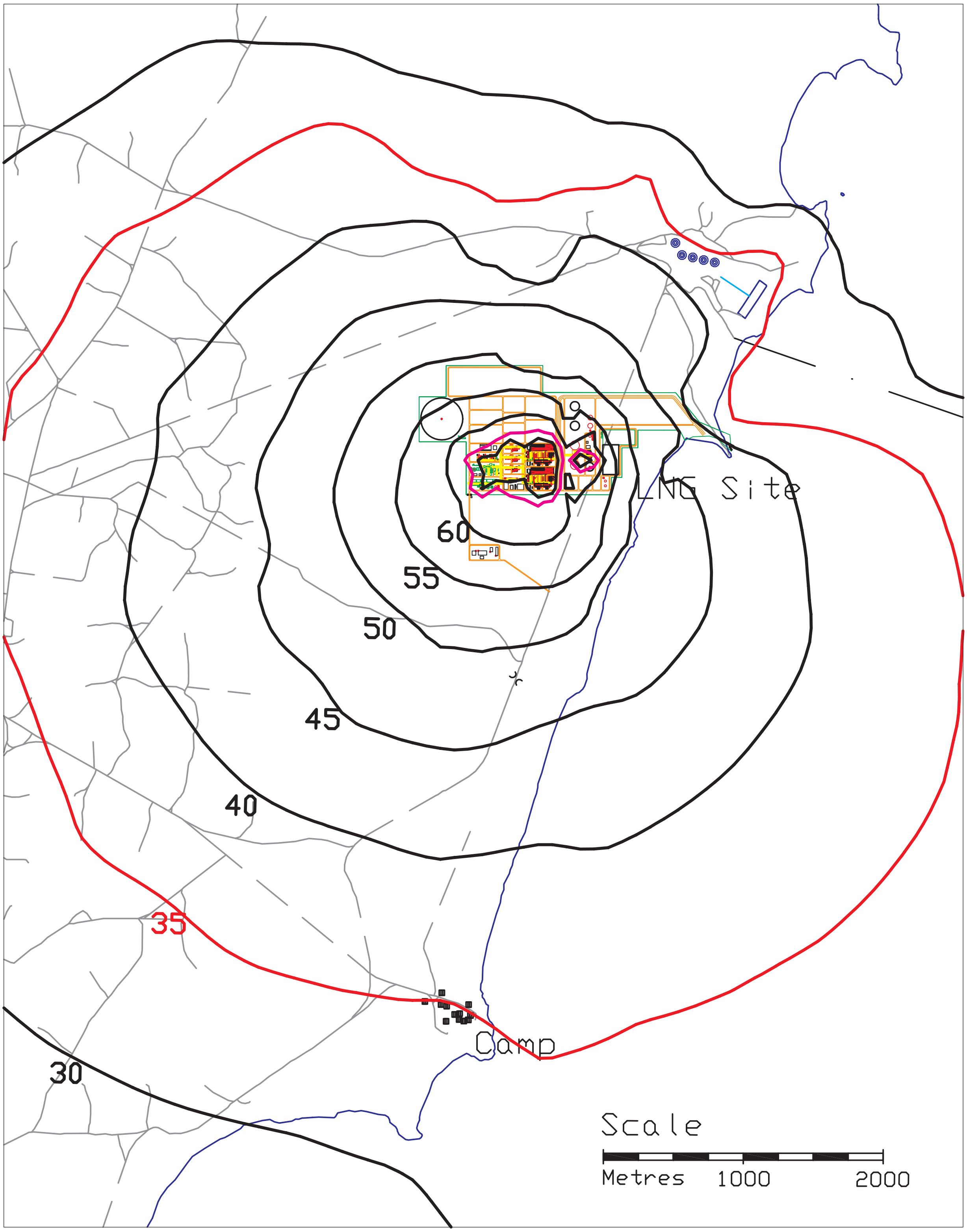
Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC11



Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	Client: Sinclair Knight Merz
Wind Direction: North East	Temperature: 15 C	Day/Night: Night	

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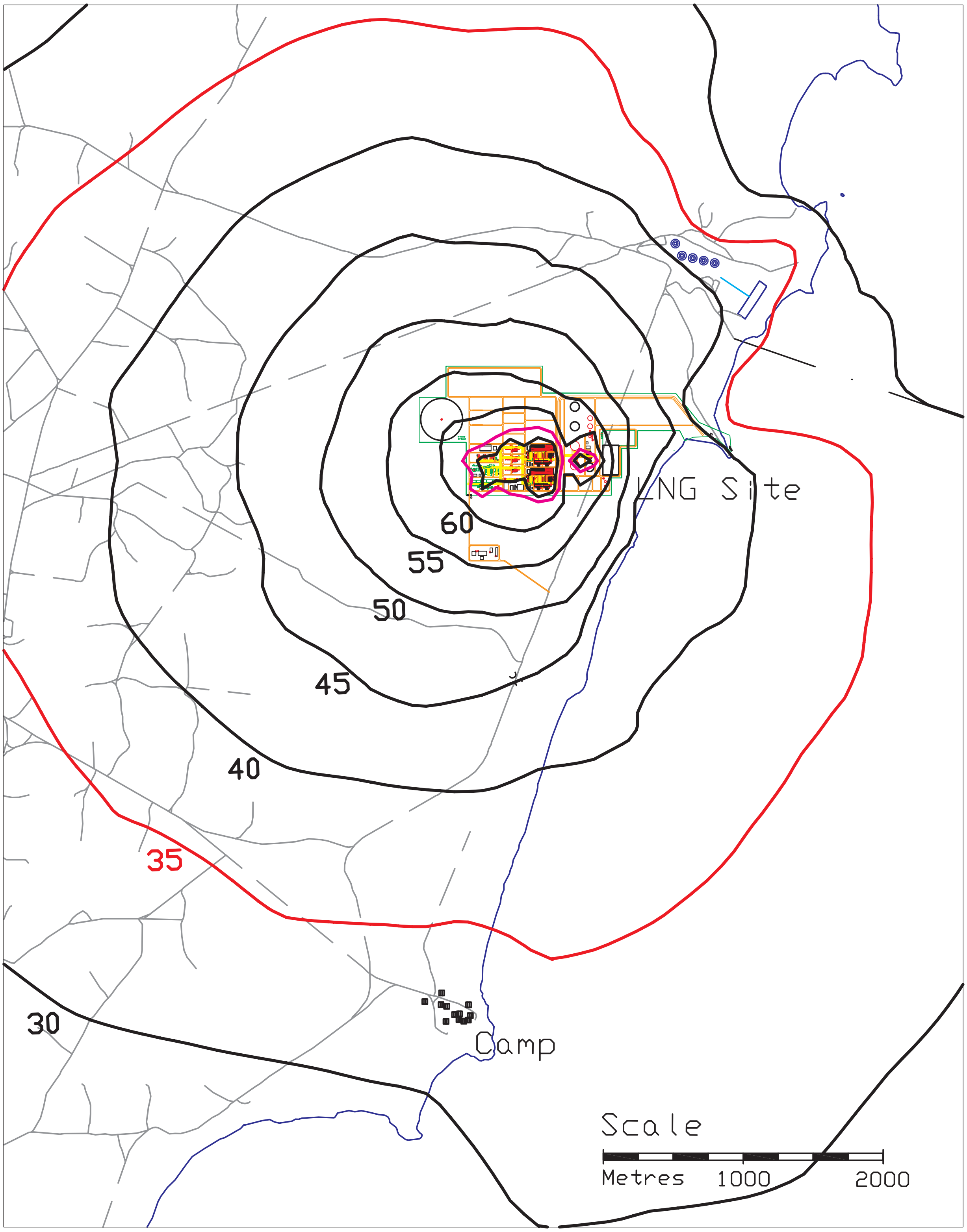
Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC12



Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	N	Client: **Sinclair Knight Merz**
Wind Direction: East	Temperature: 15 C	Day/Night: Night		

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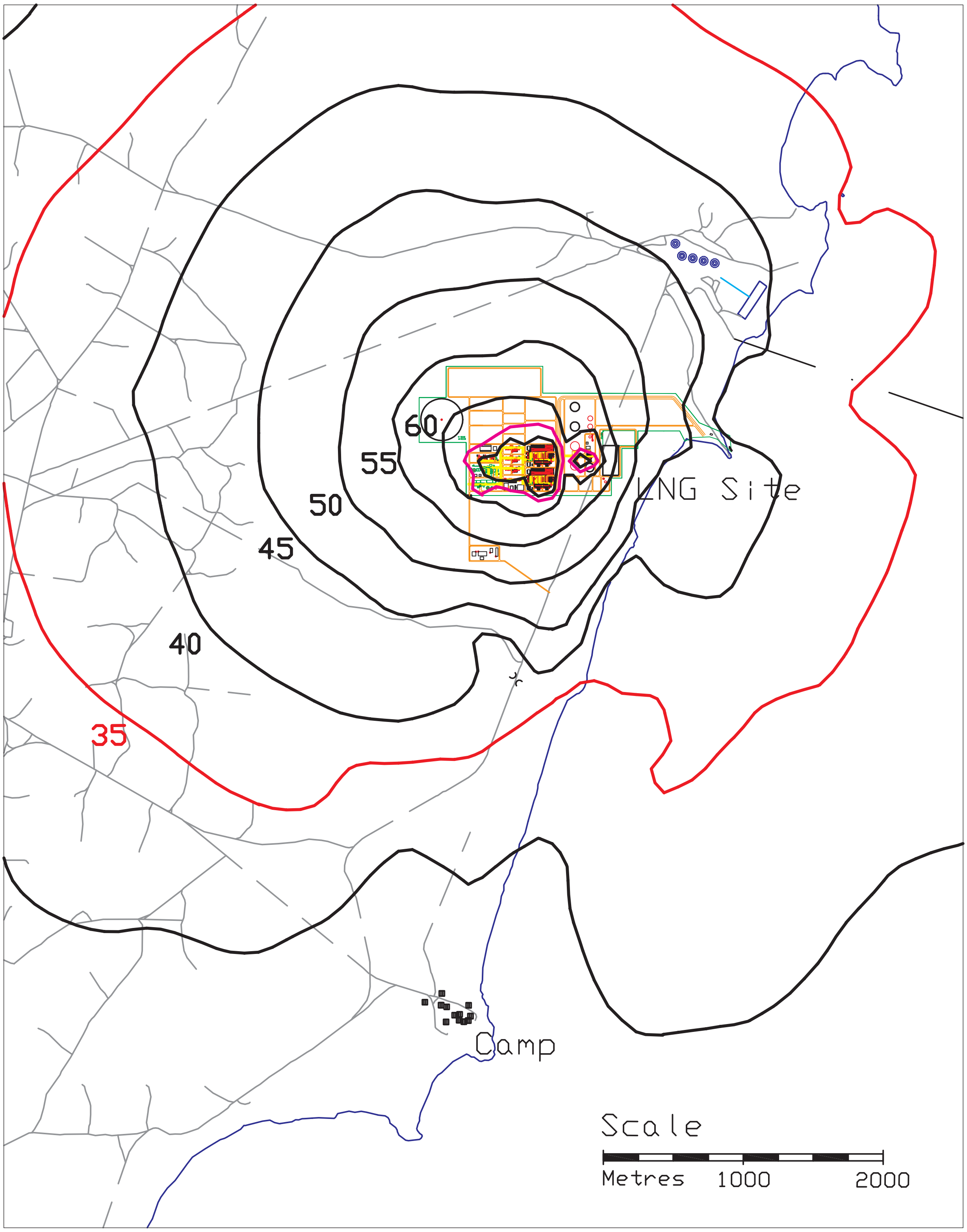
Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC13



Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	N	Client: **Sinclair Knight Merz**
Wind Direction: South East	Temperature: 15 C	Day/Night: Night		

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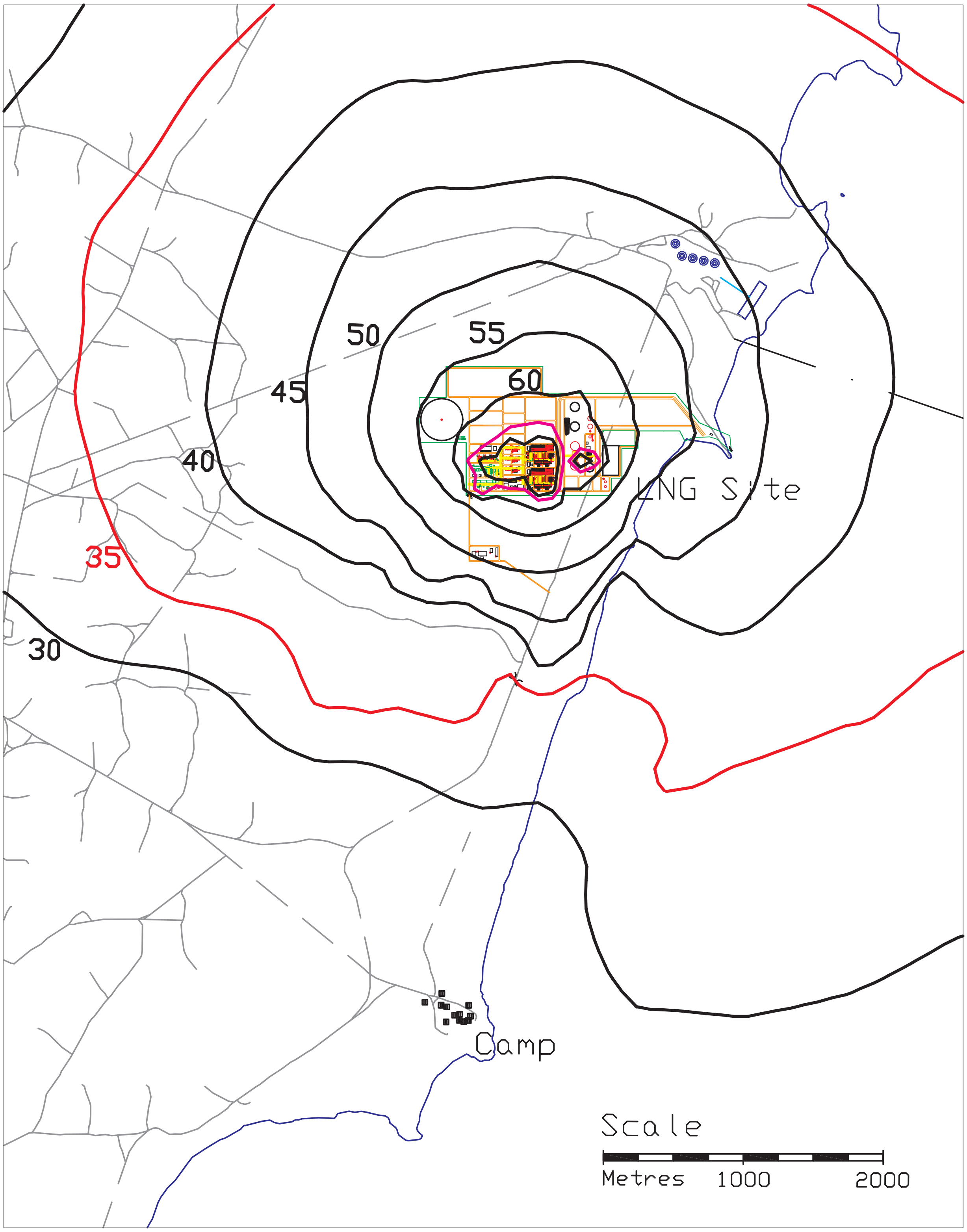
Comments:
Normal Plant Operation

Title:
GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC14



Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	Client: Sinclair Knight Merz
Wind Direction: South	Temperature: 15 C	Day/Night: Night	

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Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
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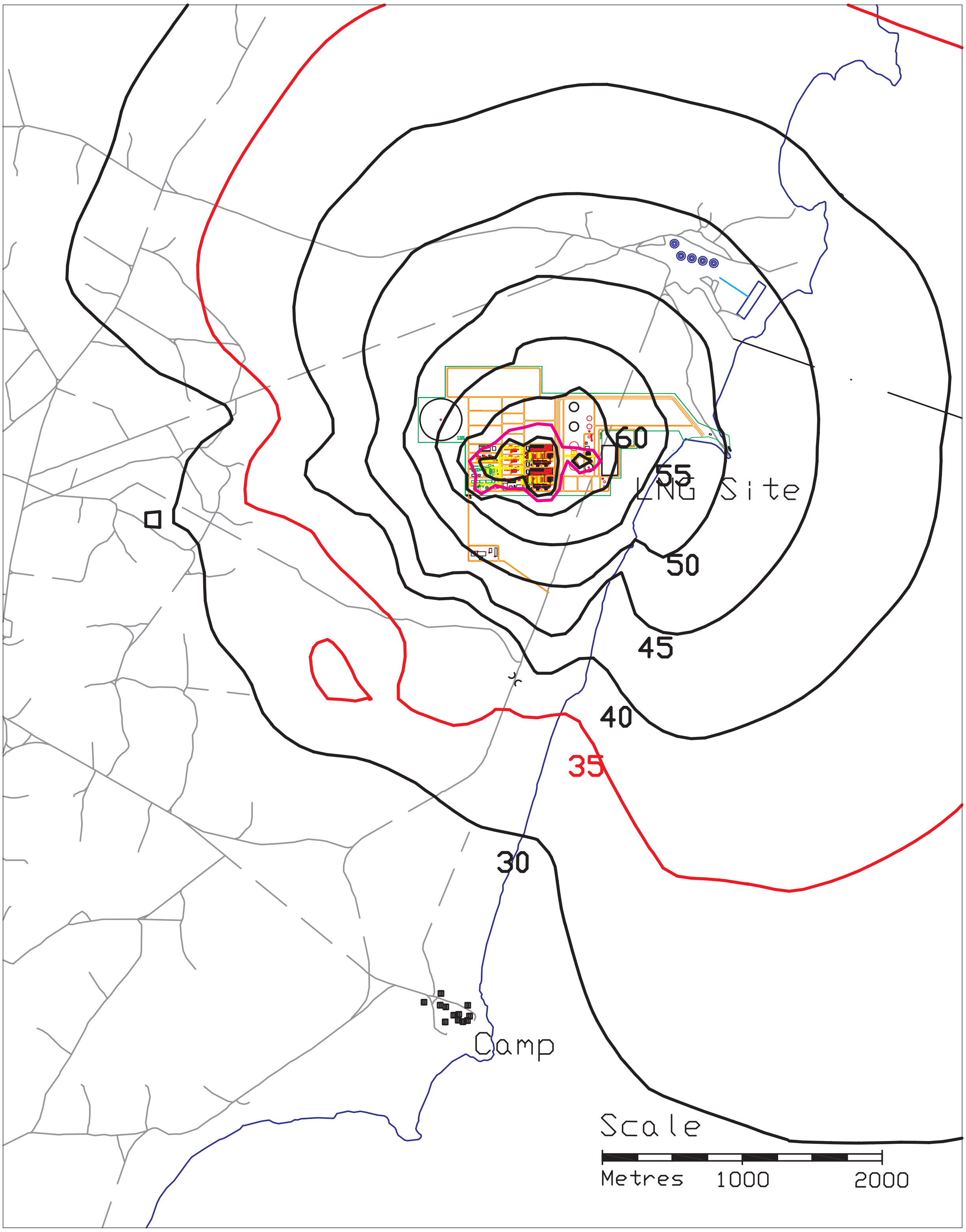

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Wind Direction: South West	Temperature: 15 C	Day/Night: Night	

Client: **Sinclair Knight Merz**

Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC16

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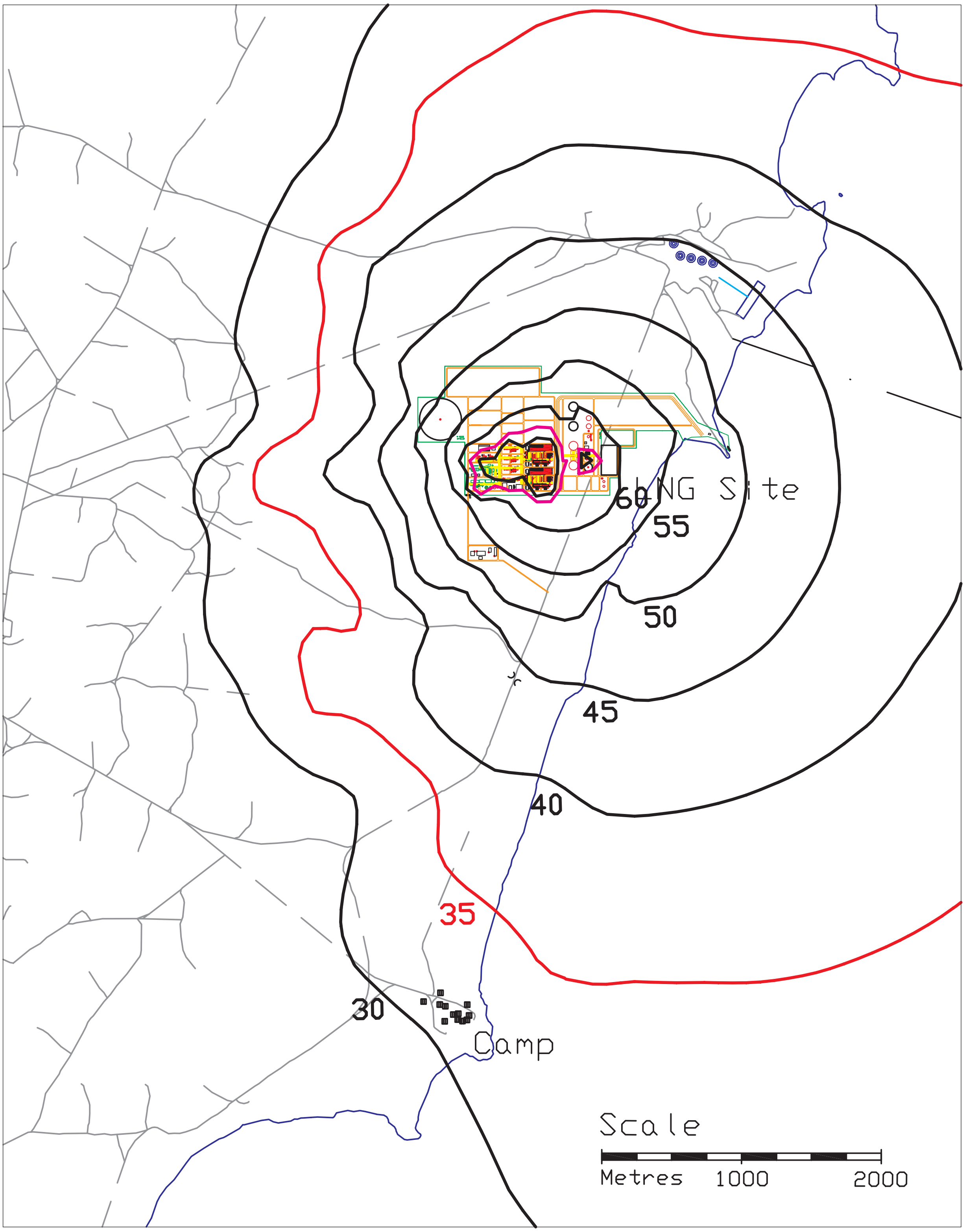

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Wind Direction: West	Temperature: 15 C	Day/Night: Night		

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Comments:
Normal Plant Operation

Title:
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Scale:	Date:	Drawn:	Rev:	Figure No:
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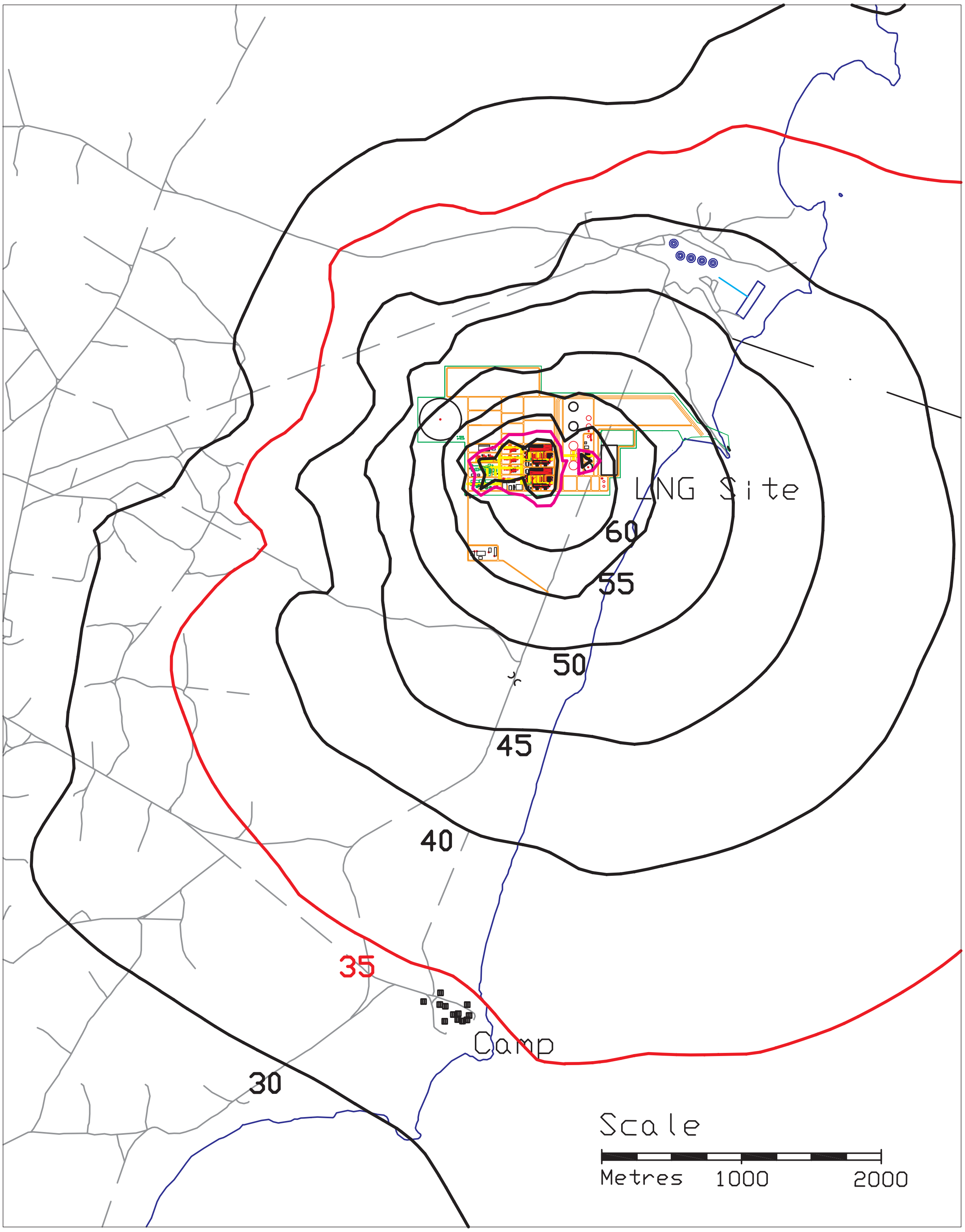

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Wind Direction: North West	Temperature: 15 C	Day/Night: Night		

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Comments: **Normal Plant Operation**

Title: GORGON DEVELOPMENT PROJECT

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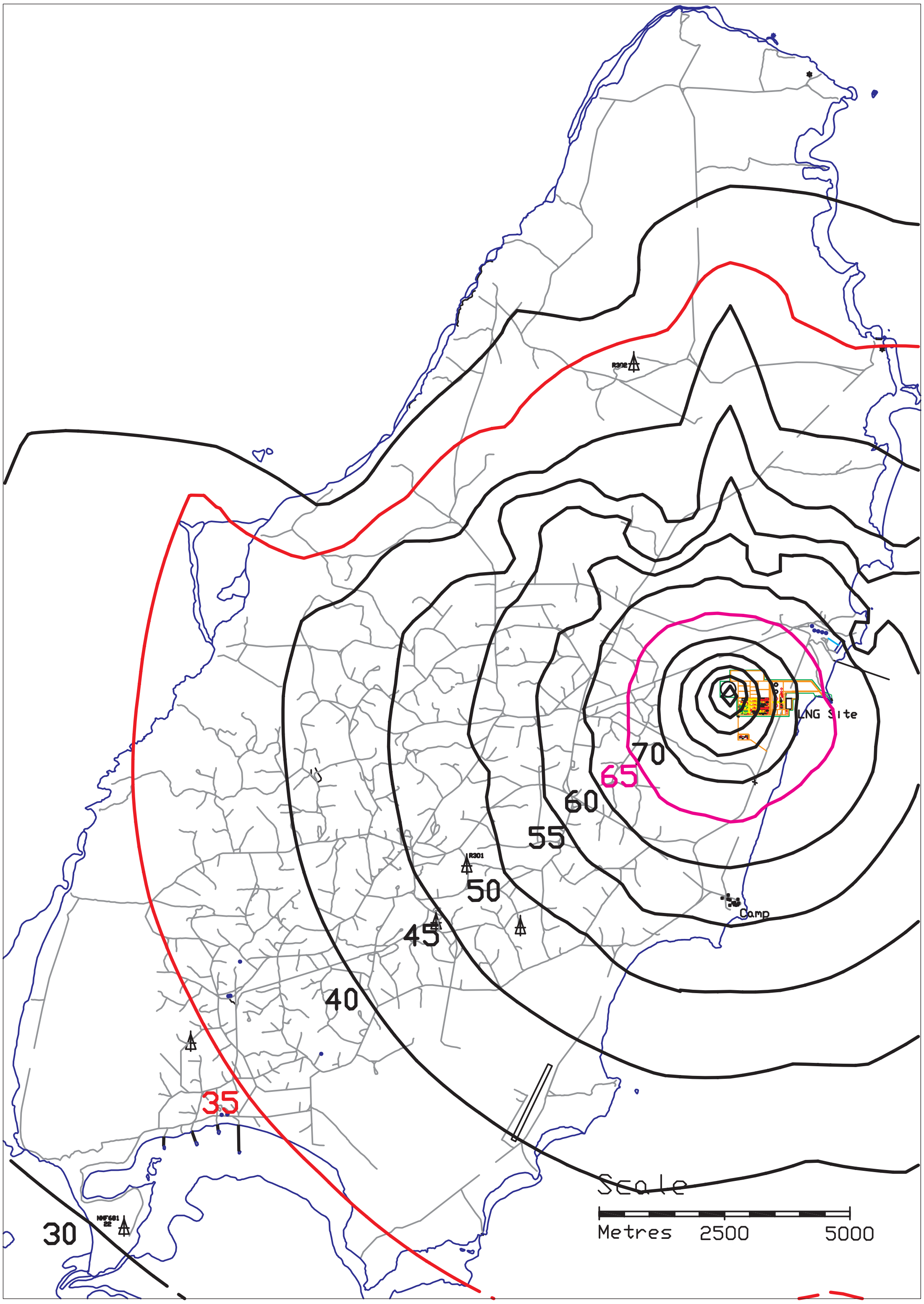

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Wind Direction: North	Temperature: 15 C	Day/Night: Night	

Client: **Sinclair Knight Merz**

Comments: **Emergency Flaring**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC19

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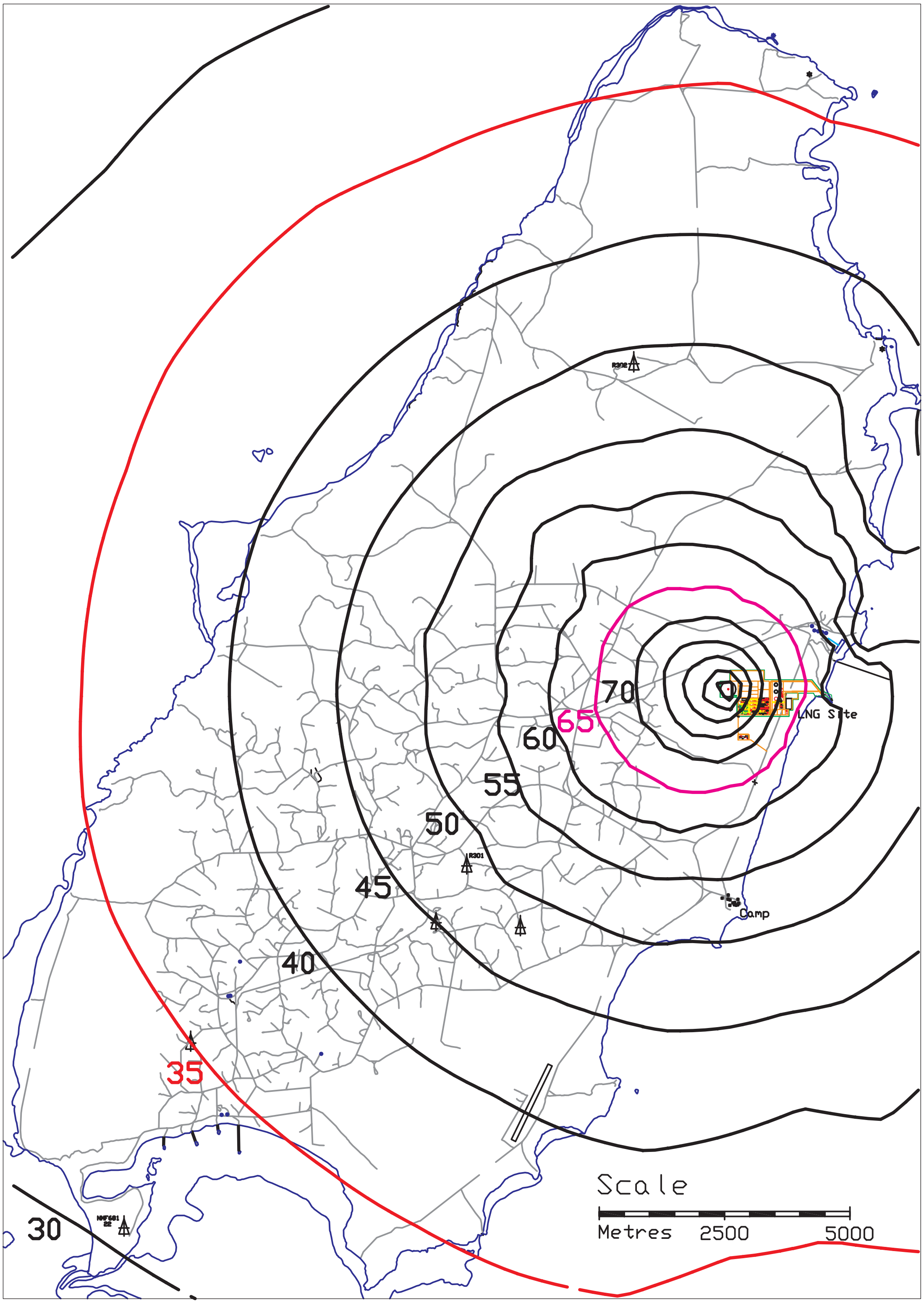

Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	Client: **Sinclair Knight Merz**
Wind Direction: East	Temperature: 15 C	Day/Night: Night	

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Comments:
Emergency Flaring

Title:
GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
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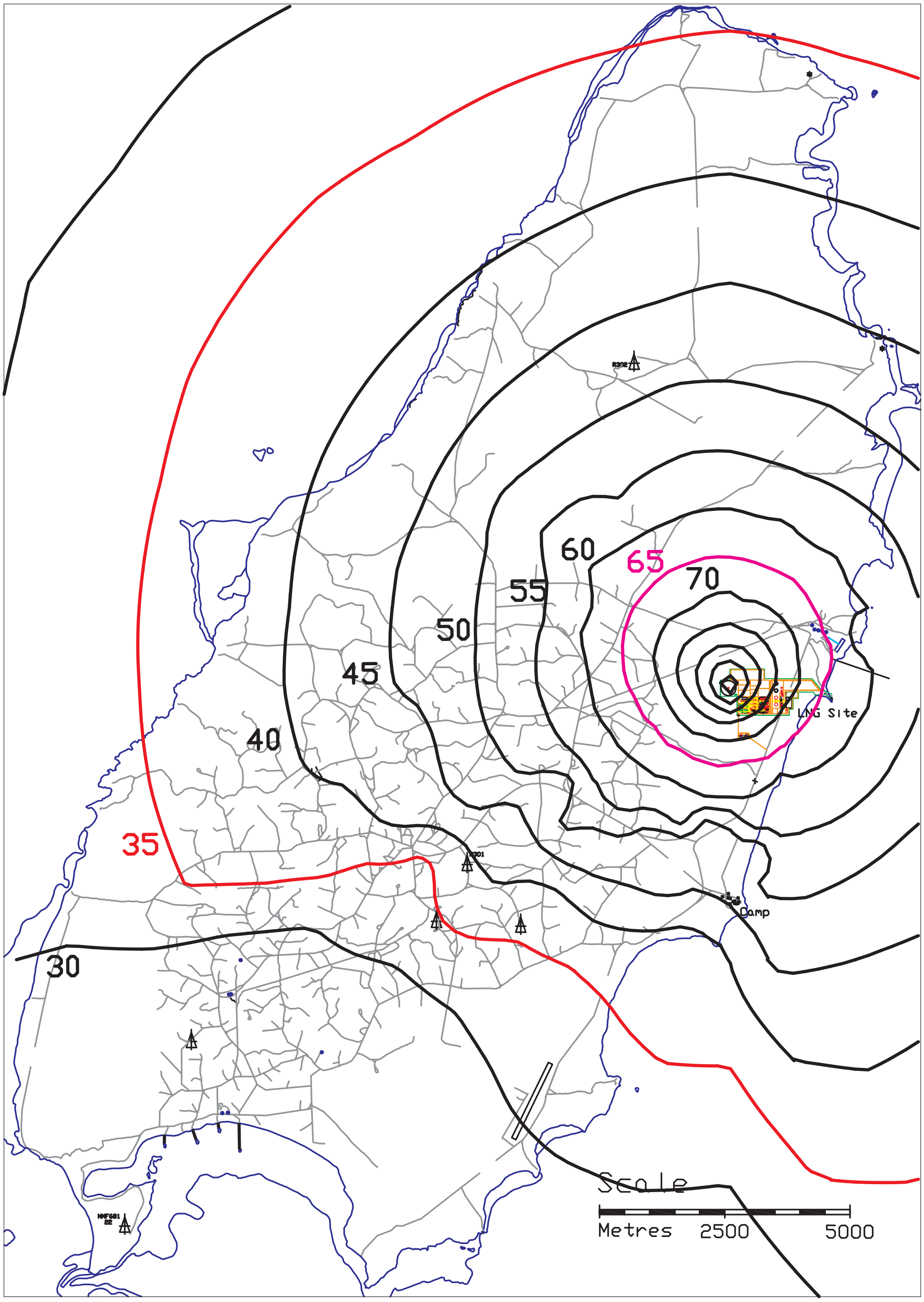

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Wind Direction: South	Temperature: 15 C	Day/Night: Night		

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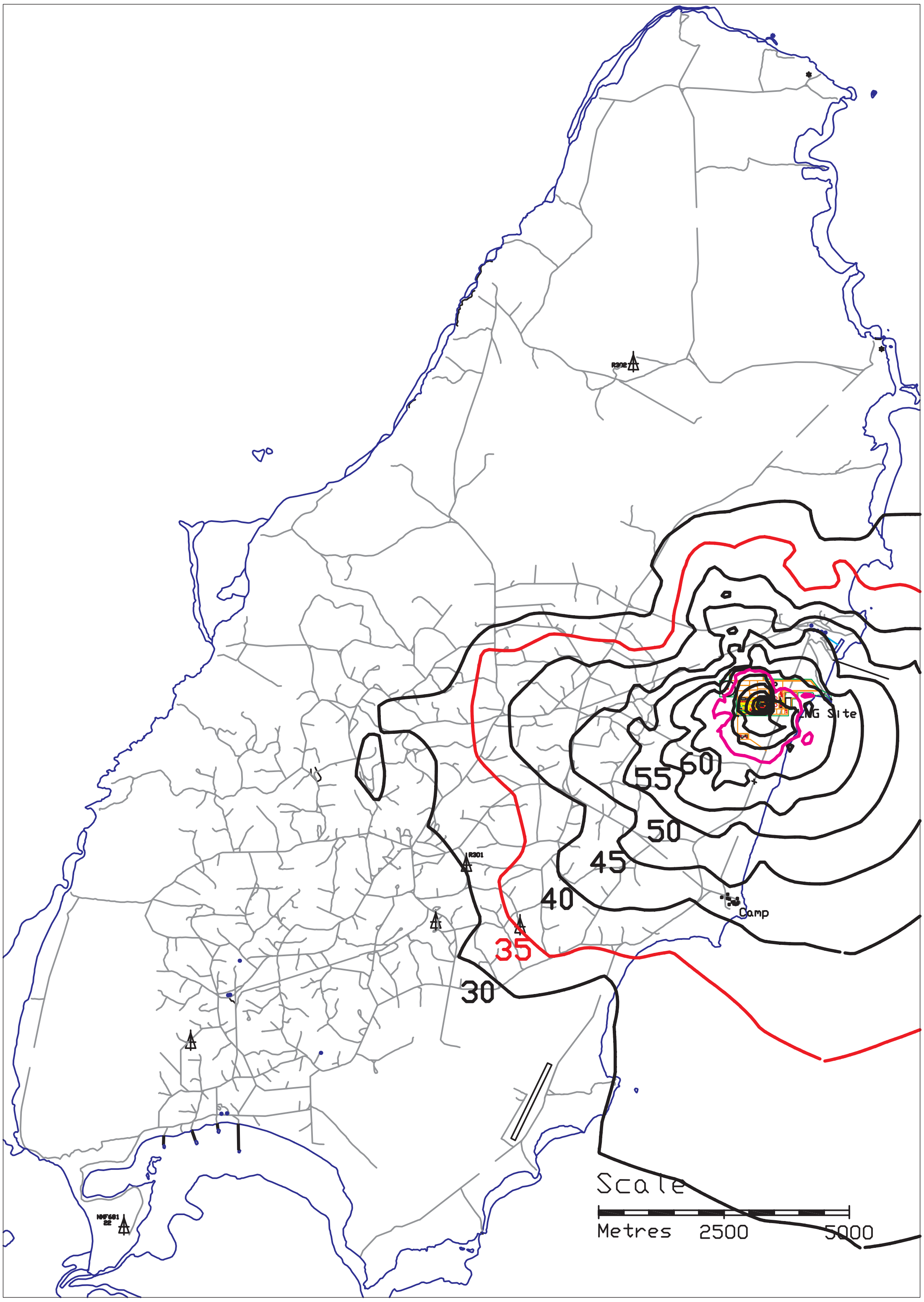
Comments: **Emergency Flaring**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC21



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Wind Direction: North	Temperature: 15 C	Day/Night: Night	

Client: **Sinclair Knight Merz**

Comments: **Construction Noise**

Title: GORGON DEVELOPMENT PROJECT

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Scale:	Date:	Drawn:	Rev:	Figure No:
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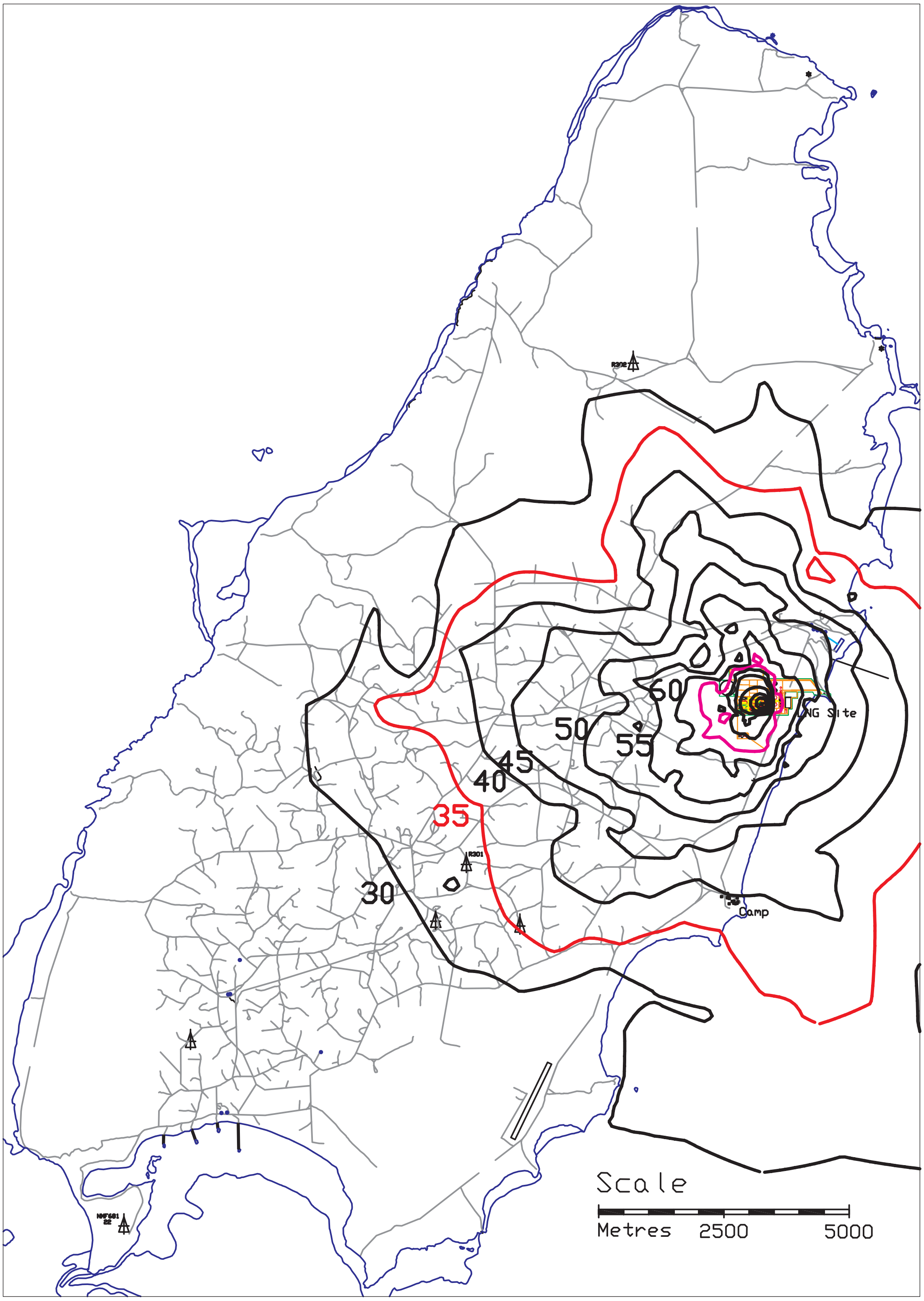

Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%
Wind Direction: East	Temperature: 15 C	Day/Night: Night

N

Client:
Sinclair Knight Merz

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Comments:
Construction Noise

Title:
GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
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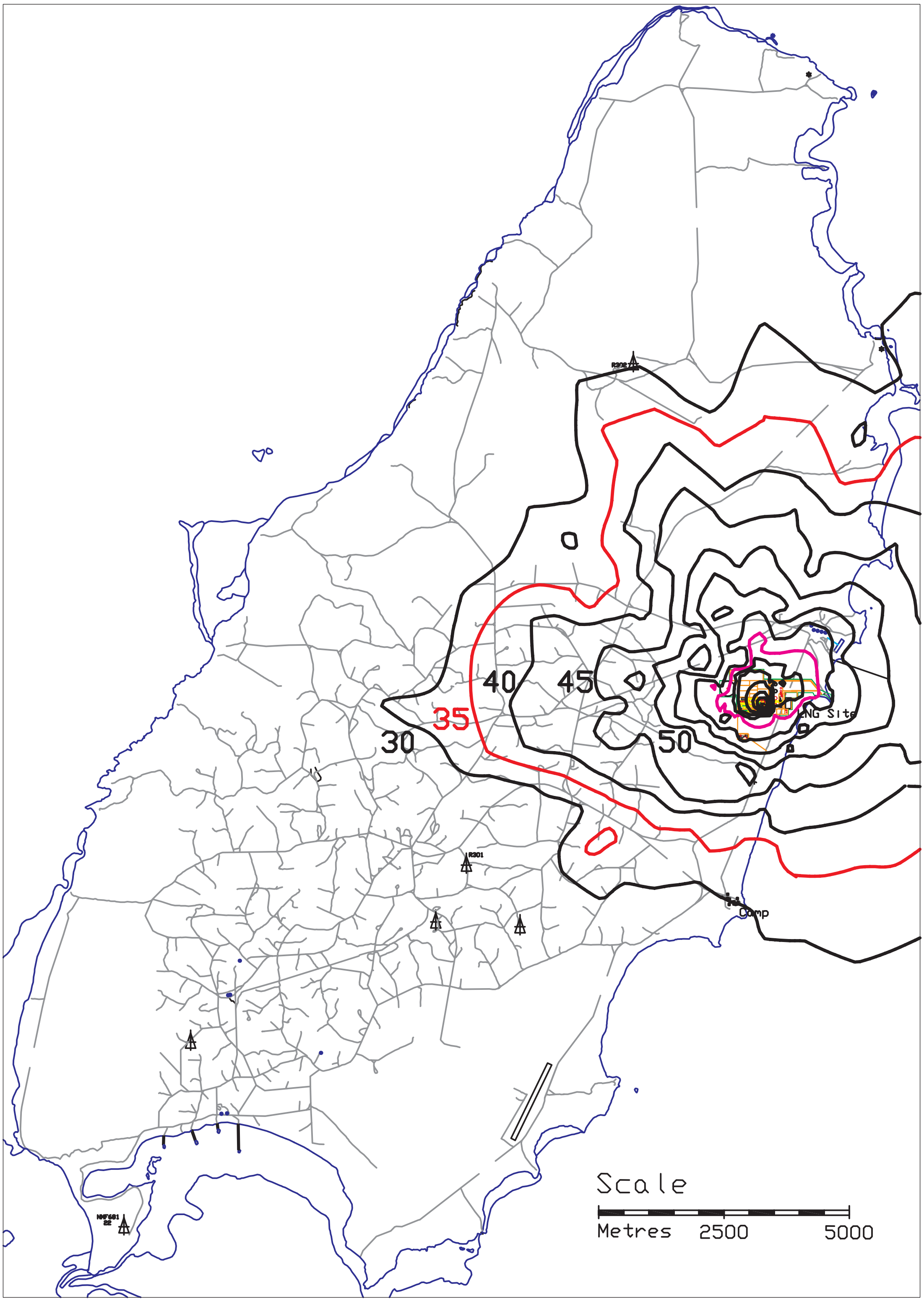

Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	Client: **Sinclair Knight Merz**
Wind Direction: South	Temperature: 15 C	Day/Night: Night	

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Comments:
Construction Noise

Title:
GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
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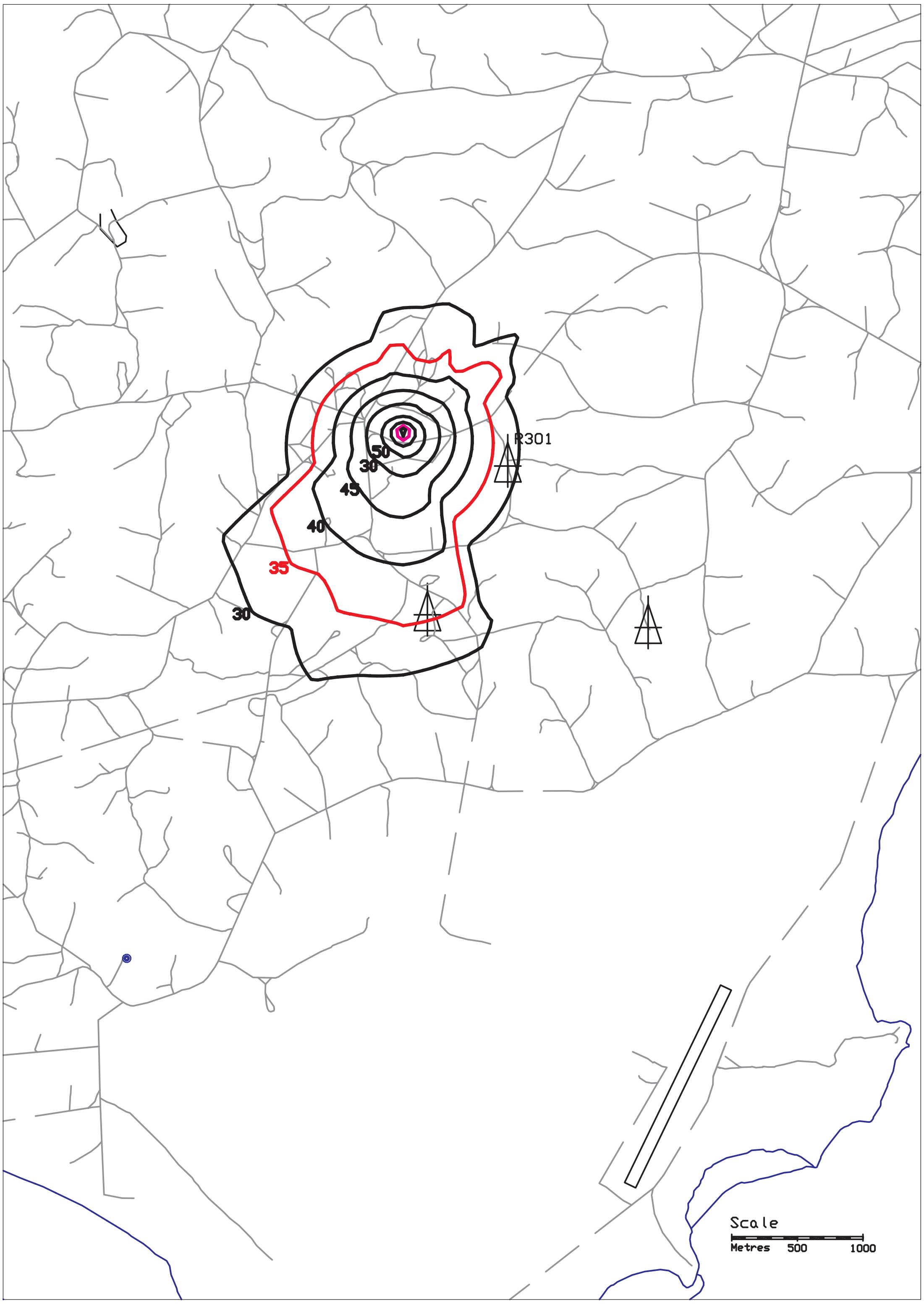

Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	N	Client: **Sinclair Knight Merz**
Wind Direction: North	Temperature: 15 C	Day/Night: Night		

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Comments: **Power Station at Base Castle**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
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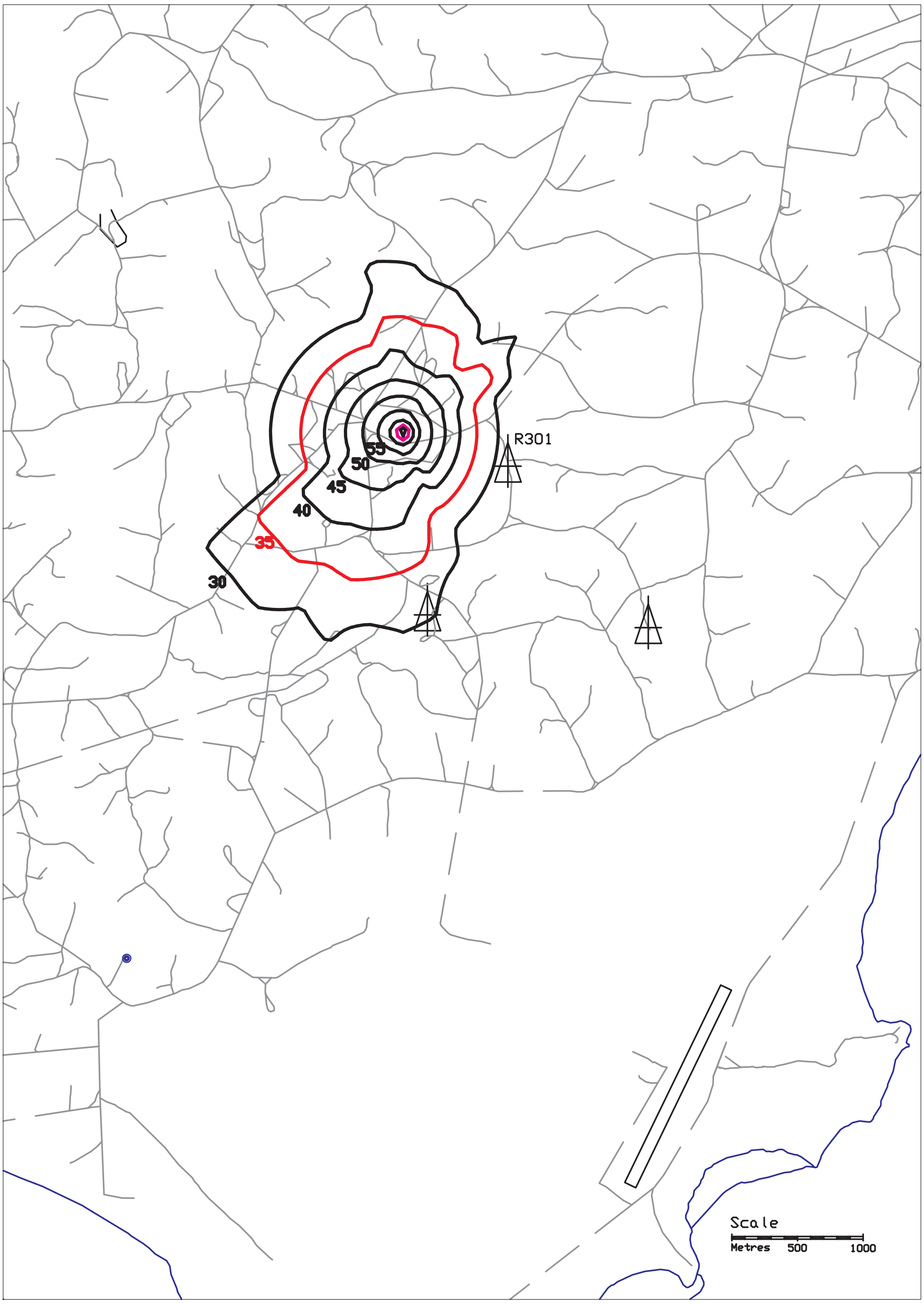

Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	N
Wind Direction: East	Temperature: 15 C	Day/Night: Night	

Client: **Sinclair Knight Merz**

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Comments: **Power Station at Base Castle**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
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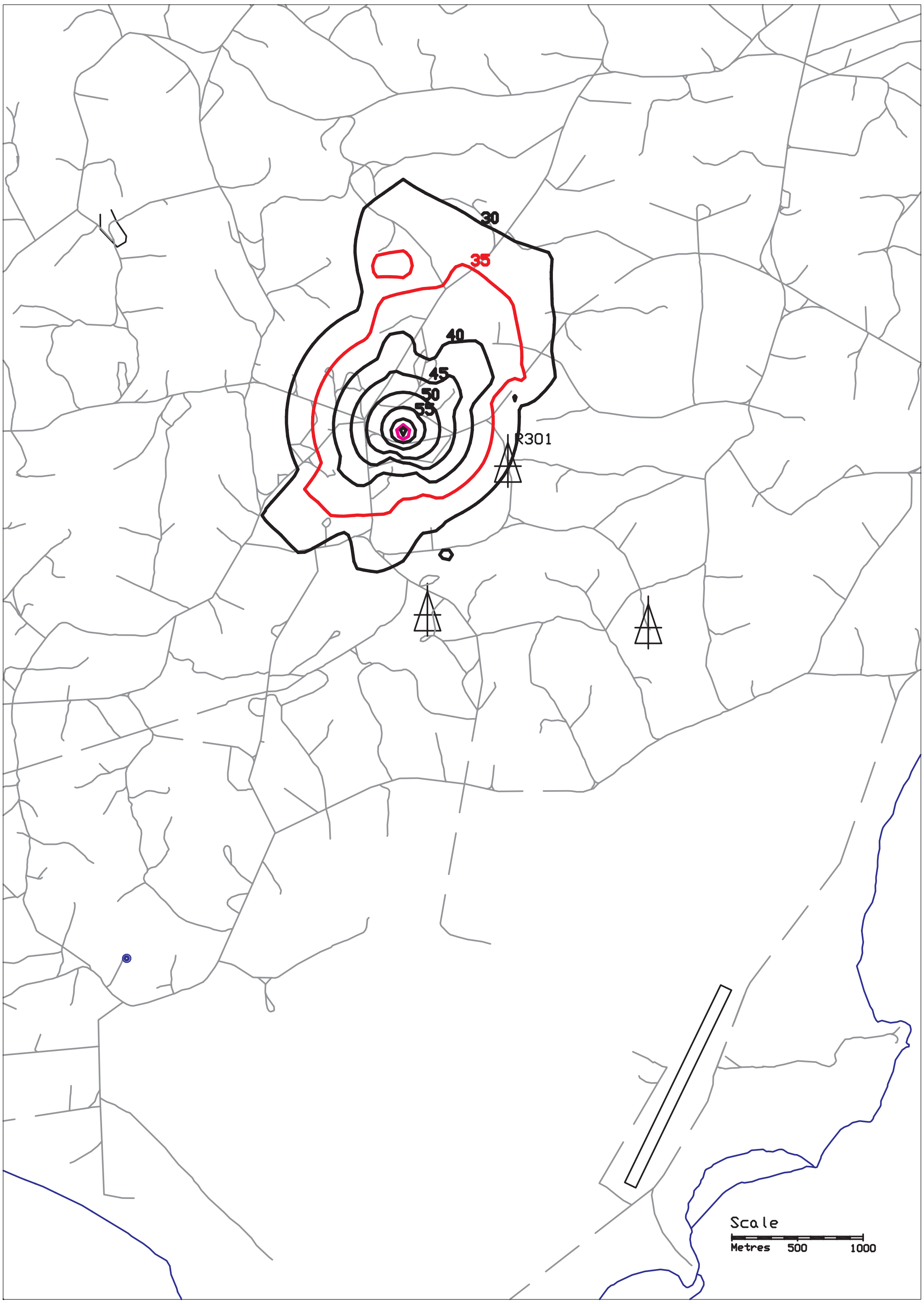

Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	Client: Sinclair Knight Merz
Wind Direction: South	Temperature: 15 C	Day/Night: Night	

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Comments: **Power Station at Base Castle**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
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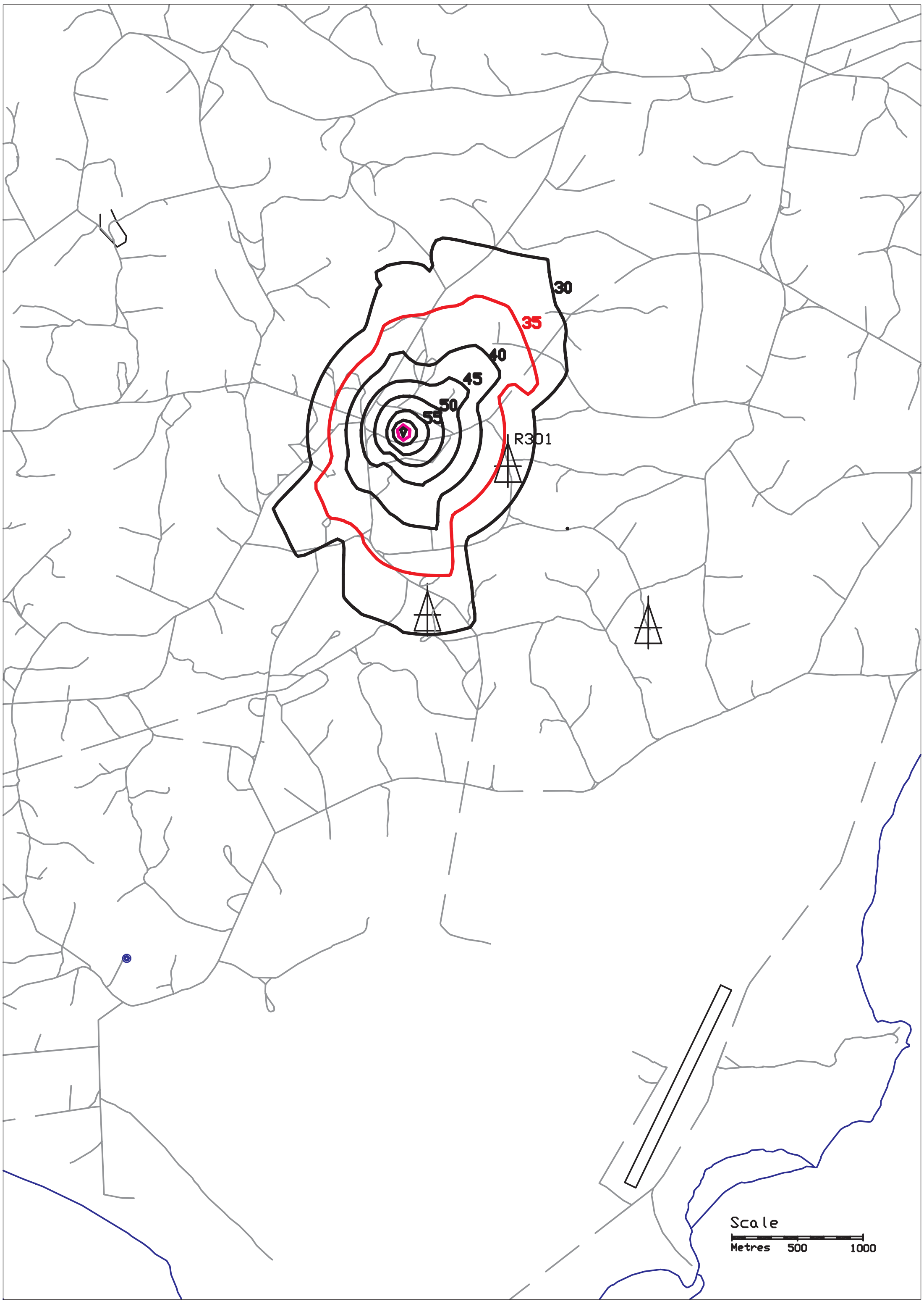

Wind Speed(m/s): 3m/s	Thermal Inversion: 2C/100m	RH: 50%	Client: Sinclair Knight Merz
Wind Direction: West	Temperature: 15 C	Day/Night: Night	

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Comments: **Power Station at Base Castle**

Title: GORGON DEVELOPMENT PROJECT

Scale:	Date:	Drawn:	Rev:	Figure No:
NTS	Mar 2004	JMc	0	NC28

Technical Appendix B3

Modelling of Spills and Discharges

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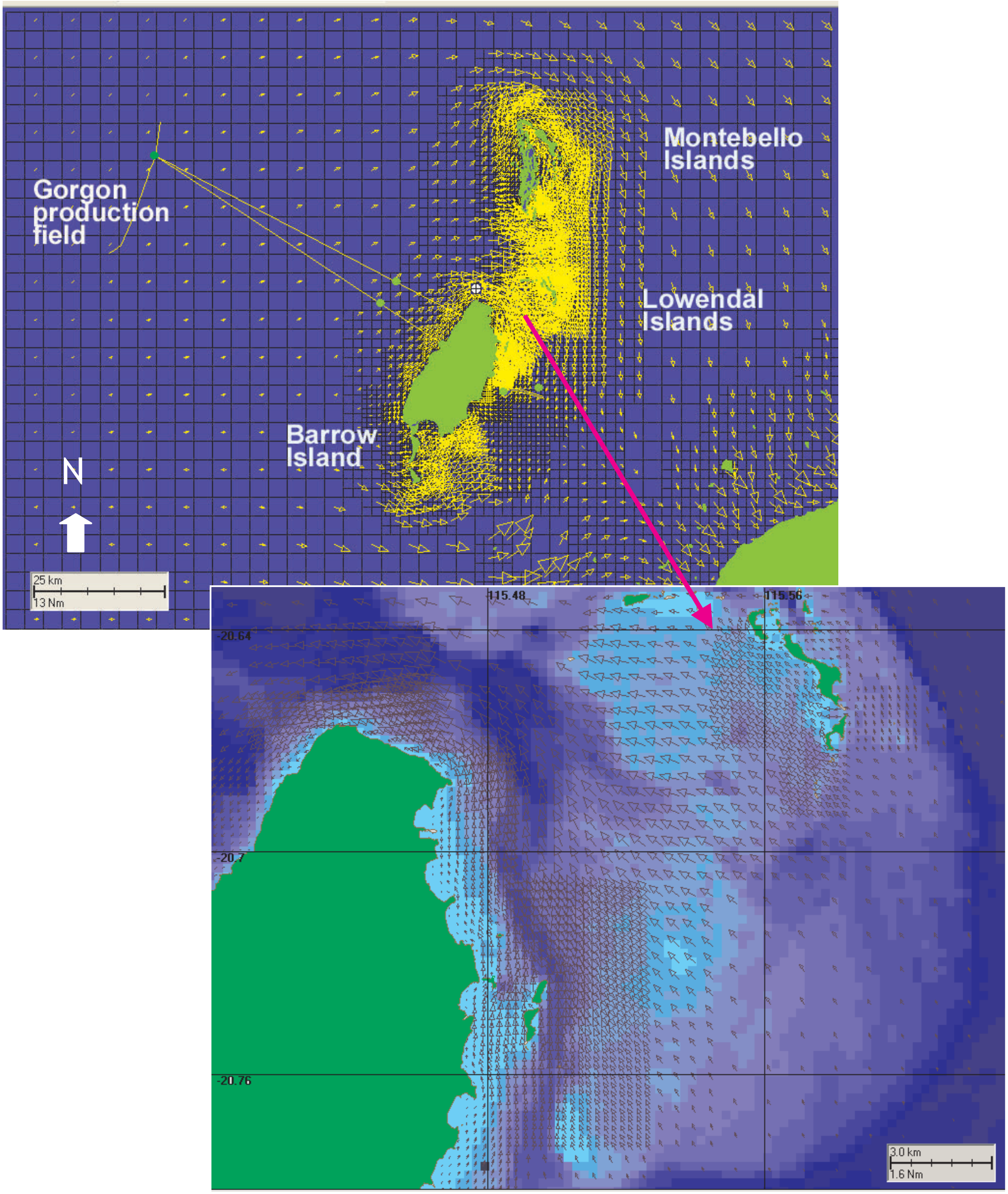
Technical Appendix: Modelling of spills and discharges



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DOCUMENT CONTROL

Document draft	*Originated by*	*Edit & review*	*Authorized for release by*	*Date*
Client version 1	*Scott Langtry*	*Kathy Sheridan*	*Scott Langtry*	*10/5/2004*
Final report after client review, incorporating primary risks		*Ken Berry* *Scott Langtry*	*Scott Langtry*	*9/8/2004*
Final report revised by inclusion of output figures		*Scott Langtry*	*Scott Langtry*	*28/4/2005*

Document name: Spill risk modelling Appendix Rev 3.doc

APASA Project Number: H105

APASA Project Manager: Scott Langtry

Contents

Figures

Tables

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1 Introduction

Risks of environmental harm from hydrocarbon spills are the product of the risk of a spill occurring in the first place and the risk that prevailing environmental forces will transport hydrocarbons into locations occupied by sensitive habitats or biota, at sufficient concentrations to cause harm. Thus, prevention of spills removes the potential for harm to the environment. If a spill does occur, the probability of environmental harm will then vary depending upon the nature of the spill, and whether sensitive life forms lie in the path of the spill. Because the major mechanisms by which oil may induce environmental harm are toxicity, induced by particular constituent components of the oil, and by physical smothering and these processes are affected by weathering and dispersion of the oil, the state of the oil at the time of contact is another important indicator of the potential for harm. Finally, for a full consideration of the potential for environmental harm, it is important to consider risks posed to both intertidal habitats, which are mostly susceptible to surface slicks, and subtidal habitats, which are only susceptible to exposure to oil that entrains or dissolves into the water column.

Asia Pacific ASA (APASA) was commissioned to carry out three-dimensional spill trajectory and fate modelling for various potential spills from the Gorgon Gas Development. The purpose of this modelling was to quantify risks of hydrocarbon contact with sensitive shorelines and submerged habitats from given spill scenarios, if those spills were to occur in the first place. Risks calculated in this process were then combined with estimates for the risk of such scenarios actually occurring (Appendix B4) to provide estimates of the overall risk of oil contact from such scenarios.

This technical appendix provides details of the models, specifications, assumptions and output of the modelling studies. The appendix also provides details of the validation of the hydrodynamic model used to represent water circulation throughout the study area.

2 Hydrodynamic modelling

2.1 The hydrodynamic modelling system

Modelling of hydrodynamic circulation over the region was carried out using the three-dimensional hydrodynamic model, HYDROMAP, (Isaji *et al.* 2001, Zigic *et. al.* 2003). HYDROMAP is a globally re-locatable hydrodynamic model capable of simulating complex circulation patterns due to tidal forcing, wind stress and density differentials. HYDROMAP operates over a spatially-nested, rectangular, grid that may have up to six step-wise changes in resolution in the horizontal plane. This facility allows for the model resolution to step up as land or complex bathymetry is approached. Vertically, the model domain may be subdivided into any number of levels using a polynomial scheme.

The model solves the three-dimensional conservation equations in spherical coordinates for water mass, density, and momentum across all levels of spatial resolution at each time step. A quadratic stress law, based on the local bottom terrain, is used to represent frictional dissipation. Output from the model is a three-dimensional current field that spans all steps in spatial resolution.

2.2 Definition of local inputs

HYDROMAP was set up over a model domain that covered the North West Shelf from North West Cape to Nickol Bay (Figure 1). This domain was subdivided by areas of higher resolution around the Barrow Island, Lowendal Island and Montebello Islands complex and the smaller inshore islands along the mainland coast (Figure 2). The spatial scale of the grid ranged 2,000 m over the open-water areas of the North West Shelf to 250 m around sections of Barrow Island and adjacent islands. Bathymetric data from a number of sources were used to define the three-dimensional shape of the seabed in the domain. High-resolution (20-200 m scale) data supplied by Apache Energy, under agreement with ChevronTexaco, were applied for areas extending from southeast of Barrow Island to the Montebello Islands. Depths of shallow areas that were not covered by these data sets were digitised from bathymetric contours defined by Apache Energy from a composite of bathymetric data measurements (multiple sources). Bathymetric data for deeper areas and for parts of the model domain that had lower spatial resolution were extracted from the Geoscience Australia bathymetric set, which has a spatial resolution of approximately 900m. Spatial interpolation was applied to spread depth data to fill gaps in the available bathymetric data. Details of the bathymetric model generated by this process are shown in Figure 3.

Tidal forcing at the open boundaries of the model was calculated using tidal constituent data from the Topex/Poseidon global tidal set (TPX051), which is calculated from satellite altimeter observations (Egbert *et. al.* 1994). Data for 8 tidal constituents were used (M2, S2, K1, O1, N2, P1, K2, Q1).

Archived wind data were sourced from the automatic meteorological station on Barrow Island (source: BOM & ChevronTexaco). Data were available from this source for an 11 year period spanning 1988-1998. For the purpose of including spatial variation in wind data, predicted wind data for offshore sites were sourced from the output of a numerical atmospheric model (the NCEP/NCAR Model Reanalysis Project), which is operated by the NOAA-CIRES Climate Diagnostics Center in Boulder, Colorado, and made publicly available via their web site (http://www.cdc.noaa.gov). Data were sourced for the same period as the measured data.

Examples of the current vectors produced by the model using the defined depth, tidal and wind data are shown in Figure 4.

2.3 Validation against field measurement

Measured tidal data, as derived tidal constituents, were available for comparison to model predictions for the offshore production area and at Barrow Island tanker terminal, on the eastern side of Barrow Island (Figure 5, Table 1).

Table 1: Location of tidal measurements available for comparison to HYDROMAP predictions

Name	Latitude and Longitude	Source	Duration
Gorgon North	20^0 22.8167" S 114^0 51.7167" E	WNI	24/7/91-7/11/91
Tanker Terminal	20^0 48.8667" S 115^0 33.0667" E	WNI	30/6/82-5/9/82

Measured current velocity and direction data were also available for comparison to predicted currents from four locations within the model domain (Figure 5, Table 2):

These data were collected in support of previous studies and thus varied in the timing of measurement, instrumentation (and associated measurement errors) and measurement depth.

Table 2: Location and depth of current measurements available for comparison to HYDROMAP predictions

Name	Latitude and Longitude	Depth above seabed (m)	Site depth (m)	Source	Duration
Mooring #1	20^0 35.290" S 115^0 37.239" E	1.5 & 10	24	AIMS	24/7/91-7/11/91
Mooring #2	20^0 36.259" S 115^0 37.713" E	1.5	27	AIMS	24/7/91-7/11/91
Location 5	20^0 47.5333" S 115^0 53.1667" E	6.5	12	WNI	20/6/97-31/8/97
Location 2	20^0 21.8333" S 115^0 33.2500" E	110 & 180	200	WNI	7/10/97-31/12/97

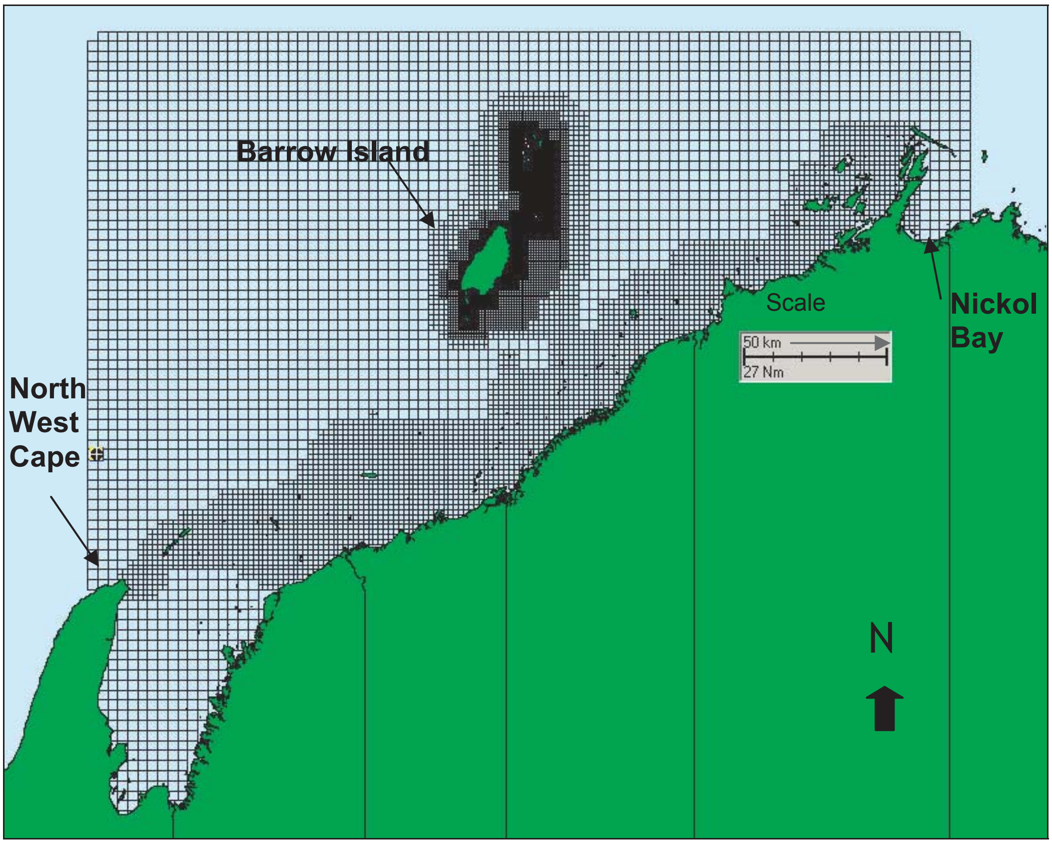


Figure 1: The hydrodynamic model domain showing details of sub-gridding

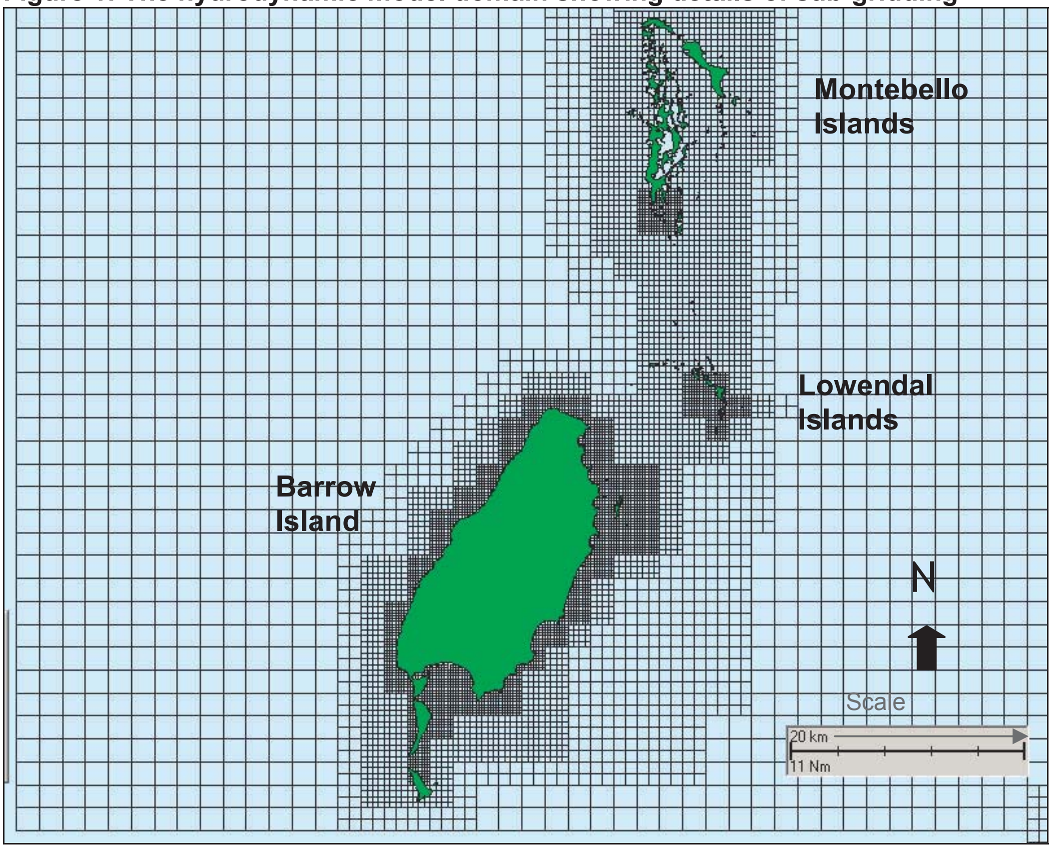


Figure 2: Details of sub-gridding around Barrow Island

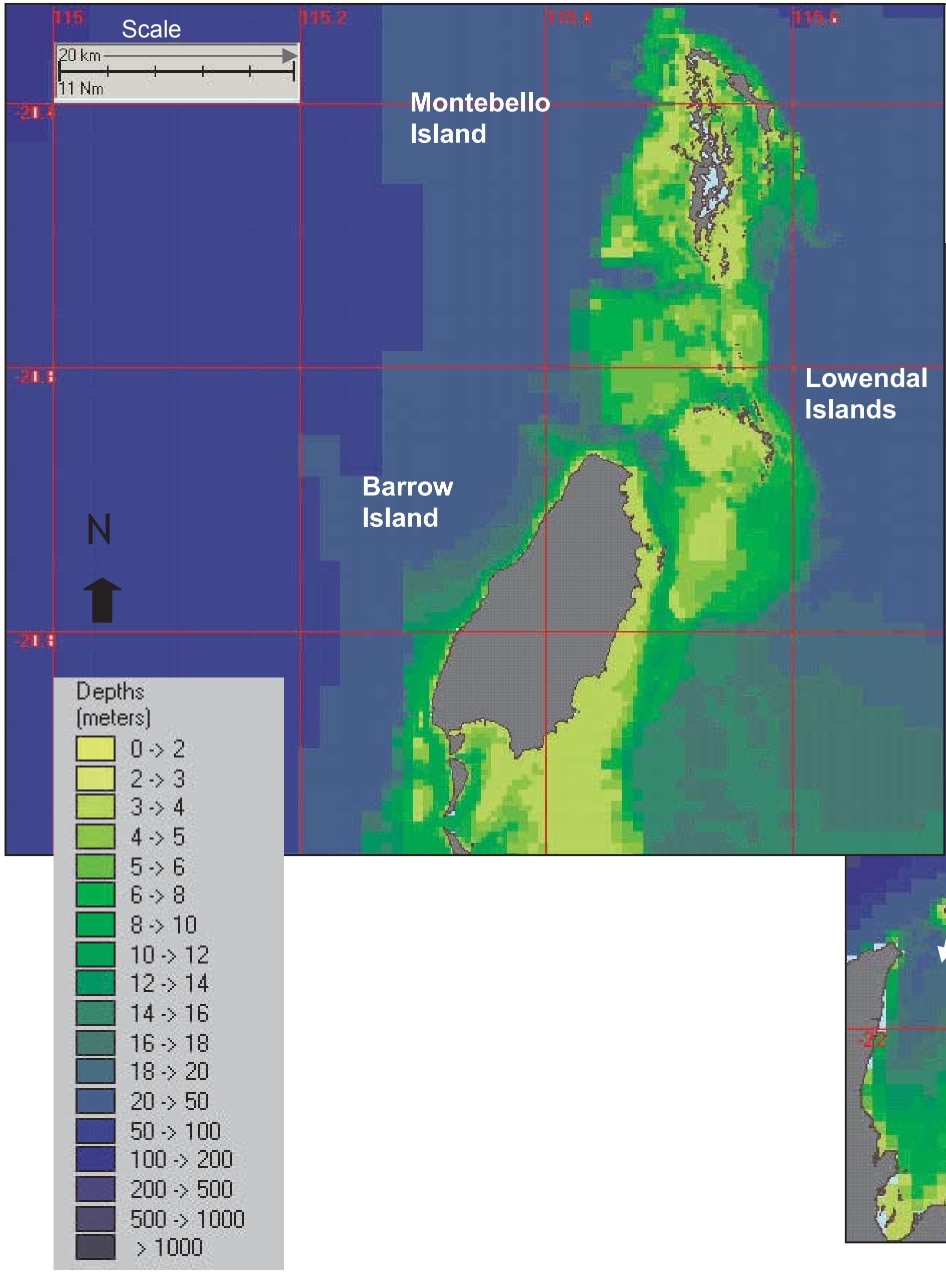
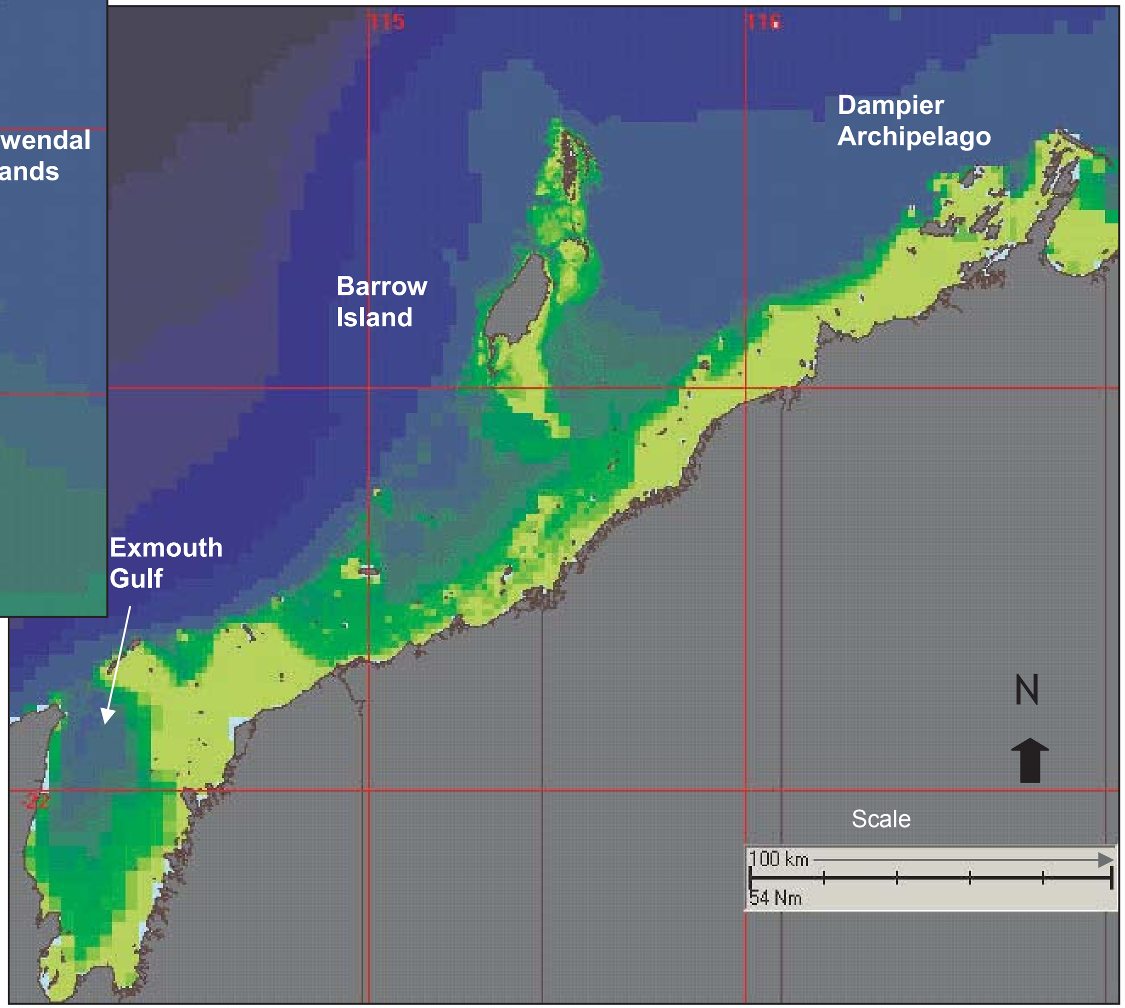


Figure 3: Details of the bathymetry specified within the HYDROMAP grid. The inset (left) shows a zoomed in view of the bathymetry specified around Barrow Island.



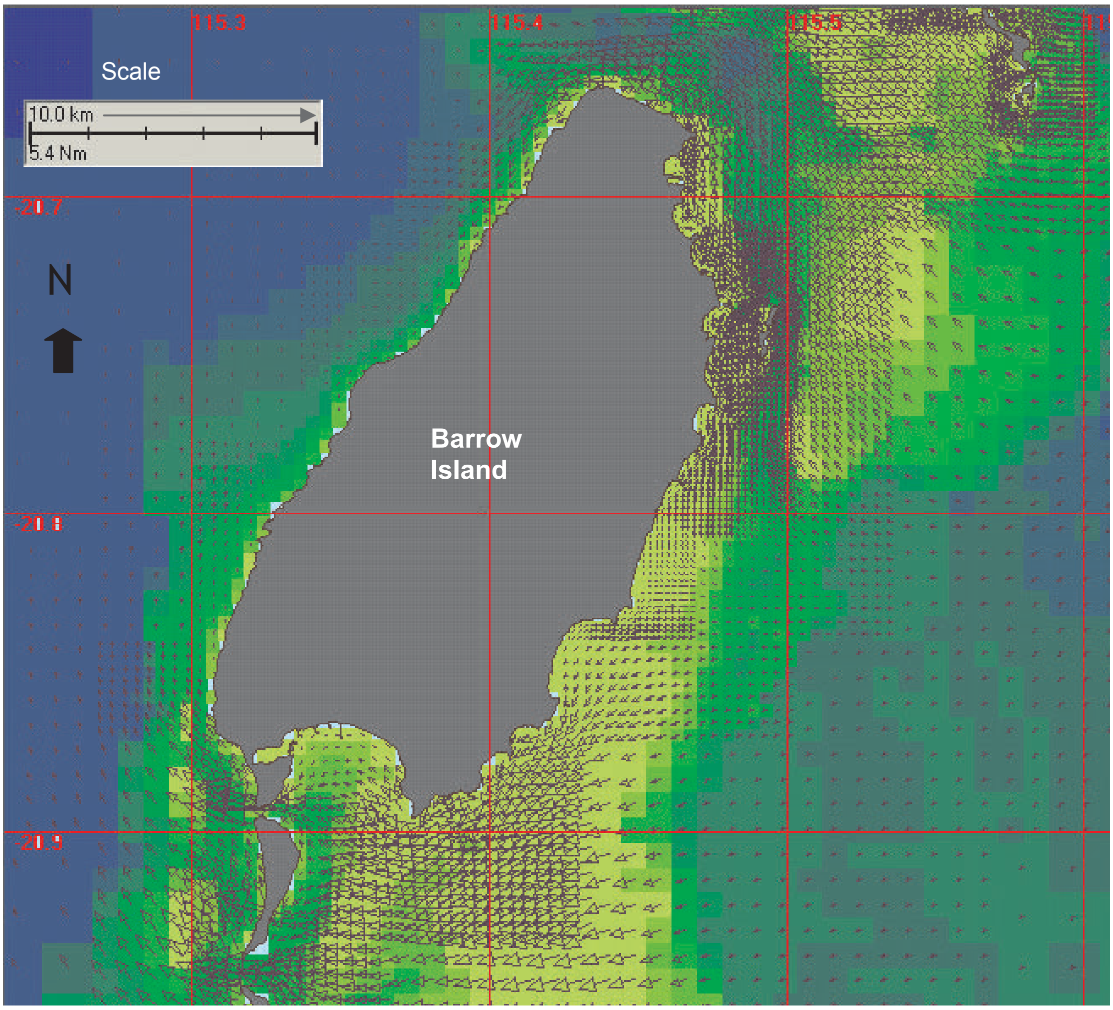


Figure 4: Example current vectors for the area around Barrow Island

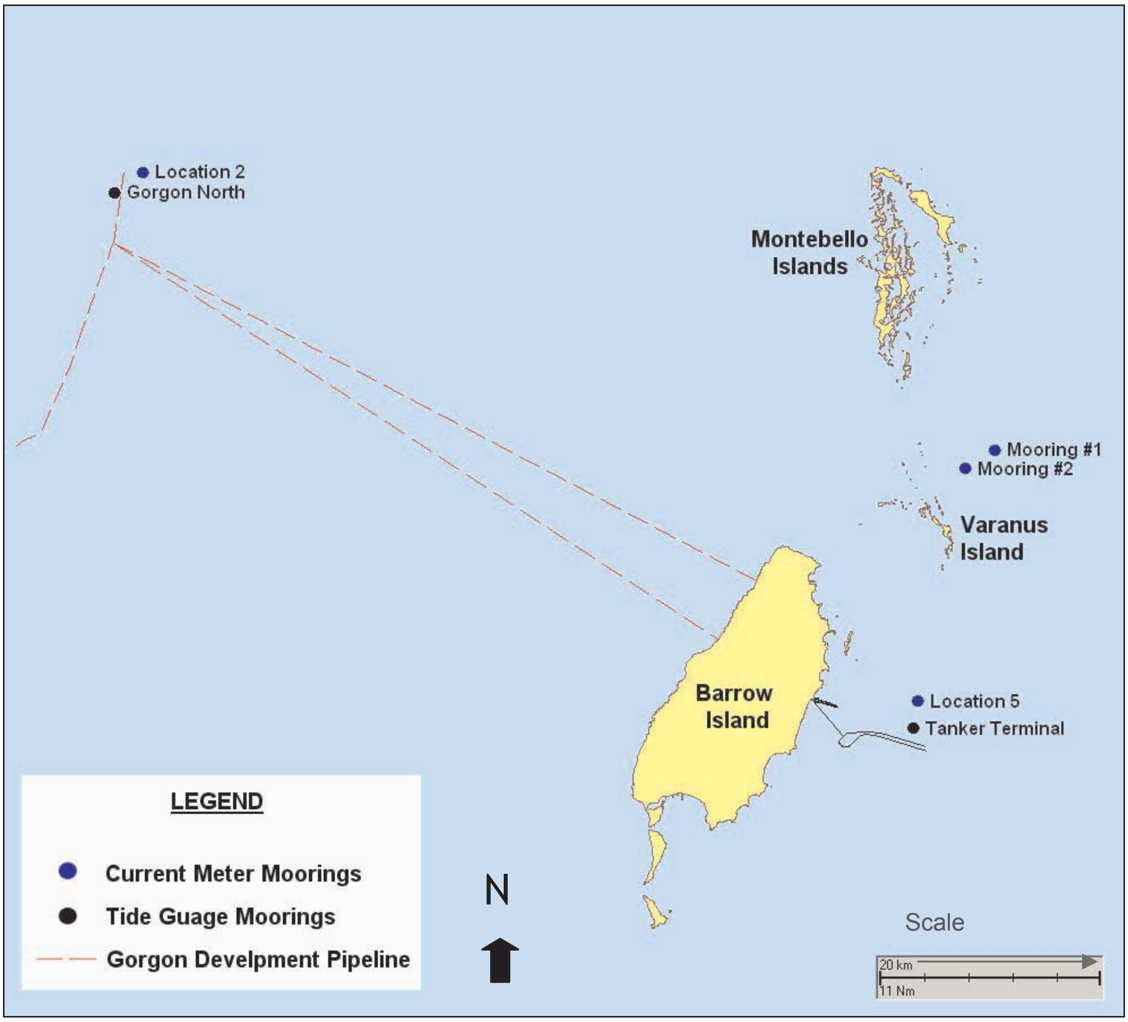


Figure 5: Locations of measurement points for water circulation that were available for validation of the HYDROMAP model predictions.

Comparisons between tidal constituents derived by in-situ measurement and HYDROMAP prediction showed close agreement at both the offshore production area and at the tanker terminal on the eastern side of Barrow Island (Tables 3 & 4), indicating that the tidal data supplied to the boundary of the model was accurate and that the model was accurately predicting the spatial propagation of the tidal waves through the model domain based on the specifications for bathymetric and seabed drag. Plots of the expected tidal elevation over time at these two sites using the measured and predicted tidal constituents showed that the model was closely predicting the magnitude and timing of astronomical tides from the combined effect of the constituents (Figure 6). The close agreement between measured and observed sea-heights at two widely spaced locations demonstrates that the model was performing well in this respect over the wider domain, not just a particular sub-area.

Currents predicted by HYDROMAP due to the combined effects of tides and winds, using wind data observed on Barrow Island, similarly agreed with observations made throughout the model domain, indicating that the model was accurately predicting the direction and magnitude of currents due to the combined influence of winds and tides. As for the tidal elevation comparisons, results demonstrated a good comparison for widely spaced locations. Thus, indicating that the model was suitably accurate throughout the model domain. This was important for oil spill modelling where the spill sources varied widely and spills could drift widely over time.

Working through the points of comparison from east to west, plots of current flows measured at Moorings #1 and # 2 (northeast of the Lowendal Islands) indicated very regular oscillations in direction that follow a diurnal and neap-spring cycle, indicating that currents here are primarily due to tidal forcing, especially for the near-seabed measurements (Figures 7 – 12). Currents predicted by HYDROMAP closely matched the observed currents at this depth in magnitude, direction and timing indicating that the model was correctly applying the tidal elevation data, bathymetry and seabed drag co-efficients to derive the resulting tidal currents. Correlations between observed and predicted currents near seabed at Mooring #1 and #2, were between 85% and 90% in the along-shelf direction and between 91% and 96% in the across-shelf direction.

Currents at mid-depth (at Mooring # 1), where wind-forcing would have more influence, similarly showed good agreement in the magnitude, direction and timing of most periods of current flow, although there were sometimes errors in the magnitude and direction of the currents during the neap-tide period (Figures 13-15), when tidal forces were weakest. These results indicate the errors are due to representation of the wind forcing, possibly due to spatial variation in wind conditions between Barrow Island (the source of the wind data) and the current measurement site over the period of measurement. Despite this, the correlations between observed and predicted currents were 60% in the along-shelf and 72% and in the across-shelf direction.

Table 3: Comparison between measured and predicted tidal constituents for Gorgon North tide gauge.

Tidal constituent	Frequency (cycle/hour)	Measured		Predicted		Deviation	
		Amplitude (m)	Phase (deg)	Amplitude (m)	Phase (deg)	Amplitude (m)	Phase (deg)
Q1	0.03721850	0.0259	250.97	0.0352	255.76	-0.0093	-4.79
O1	0.03873065	0.1358	270.03	0.1223	273.05	0.0135	-3.02
P1	0.04155259	0.2032	287.16	0.1852	303.41	0.0180	-16.02
K1	0.04178075	0.0626	284.33	0.0536	275.29	0.0090	9.04
N2	0.07899925	0.0969	256.53	0.1131	249.30	-0.0162	7.23
M2	0.08051140	0.5212	289.75	0.5132	288.81	0.0080	0.94
S2	0.08333334	0.2904	351.04	0.3101	2.35	-0.0197	11.31
K2	0.08356149	0.0796	350.74	0.0845	358.37	-0.0049	-7.63

Table 4: Comparison between measured and predicted tidal constituents for Barrow Island tanker Terminal tide gauge.

Tidal constituent	Frequency (cycle/hour)	Measured		Predicted		Deviation	
		Amplitude (m)	Phase (deg)	Amplitude (m)	Phase (deg)	Amplitude (m)	Phase (deg)
Q1	0.03721850	0.0304	262.46	0.0421	245.73	-0.0117	16.73
O1	0.03873065	0.1492	277.35	0.1685	240.44	-0.0193	36.91
P1	0.04155259	0.0630	305.73	0.0587	297.51	0.0043	8.22
K1	0.04178075	0.2427	296.52	0.2496	290.22	-0.0069	6.3
N2	0.07899925	0.1759	287.82	0.1582	273.75	0.0177	14.07
M2	0.08051140	1.0004	319.61	0.9799	302.27	0.0205	17.34
S2	0.08333334	0.5976	30.07	0.5229	27.37	0.0747	2.7
K2	0.08356149	0.1493	28.38	0.1653	33.73	-0.016	-5.35

Observed currents at mid-depth level adjacent to the Barrow Island tanker terminal (located at the southern end of the Barrow Island channel) also showed a very strong tidal cycle. The main axis of this tidal flow was NW to SE. Currents predicted by HYDROMAP corresponded very closely in magnitude, direction and timing to the observed currents during periods of spring and neap tides (Figures 15-18) indicating that the model correctly represented tidal and wind forcing in this area. Errors in magnitude of the currents (both underestimates and overestimates) were generally restricted to periods of peak flow speeds and the overall correlation between predicted and observed currents was 87% in the along-shelf direction and 80% in the across-shelf direction.

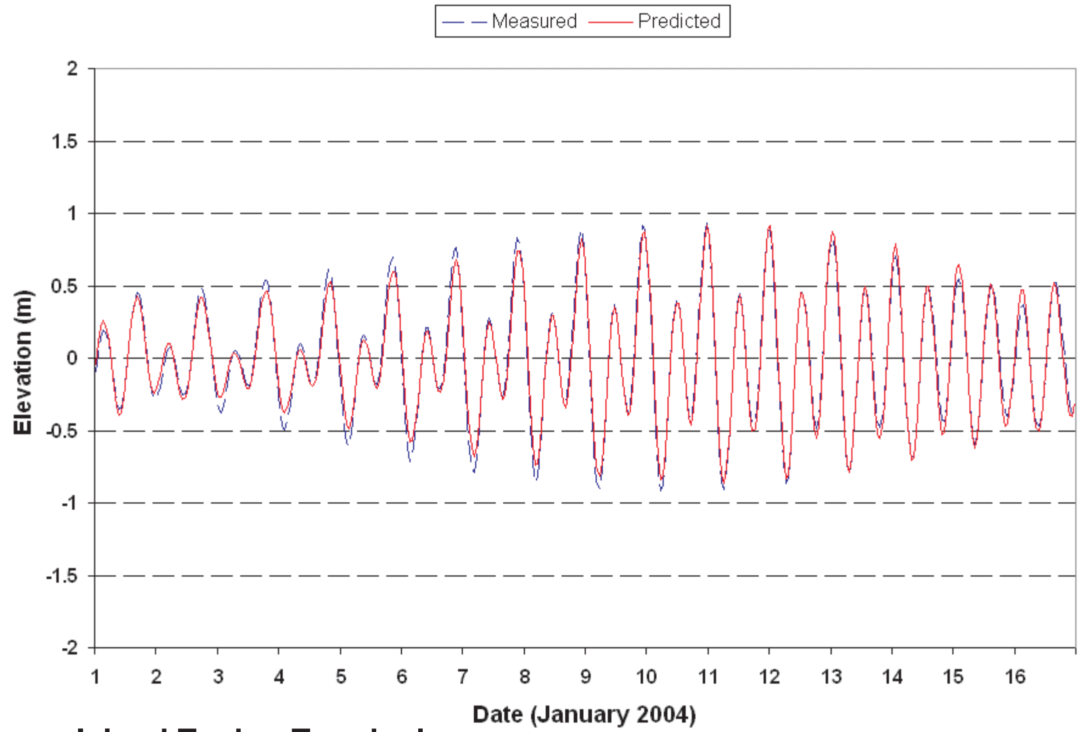
Observed currents over the Gorgon production area (Location 2), which has a depth of ~ 200 m, were more variable than over the shallow water areas surrounding Barrow Island (Figures 19-24), indicating less influence of tidal forcing. Currents predicted by HYDROMAP, using tidal forcing data and winds observed at Barrow Island, showed best agreement with observations made near the surface (~20m depth), with many of the flow episodes correctly represented in magnitude, direction and timing. However, there were a number of cases where flows were not predicted or observed currents showed errors in timing or were in opposing directions to the predicted currents. Currents predicted by HYDROMAP at mid-depth (~ 90 m depth) demonstrated similar overall trends in current directions to the observed currents, although the correlation between observed and predicted currents were low (36% along-shelf;- 43% across-shelf) because the model generally under-predicted short-term fluctuations in the current speeds and directions. These results indicate that forces other than winds and tides have a significant influence on circulation at this depth.

In general, the comparisons of tidal and current data provide confidence that circulation data predicted by the hydrodynamic model will provide a good representation of circulation within the study area. The HYDROMAP validation study indicated that variation in wind conditions from place to place within the model domain could be a significant source of error in the derived circulation patterns, with an increased opportunity for errors with increasing distance from sources of wind data. Similarly, the validation study indicated that temporal variability in winds would have a large influence on spill trajectories.

For these reasons, a spatially-varying wind field that covered a long duration (11 years: January 1988-December 1998) was used as input to the hydrodynamic model to generate data for use in the spill modelling. Wind data spanning this period were obtained for three locations within the hydrodynamic model domain. These included hourly data from Barrow Island and six-hourly data from two offshore locations located east and west of Barrow Island (Figure 25). The former were electronic records from an observation station located near the centre of Barrow Island ("The Castle"; source: ChevronTexaco). The latter were output of a global atmospheric model (the NCEP Model reanalysis program; source: NOAA). These data were used to specify a time-varying three-dimensional wind field for the study area applying distance-weighted spatial interpolation.

HYDROMAP was then used to produce a three-dimensional current field representing circulation for the period of the wind data.

(a) Gorgon North



(b) Barrow Island Tanker Terminal

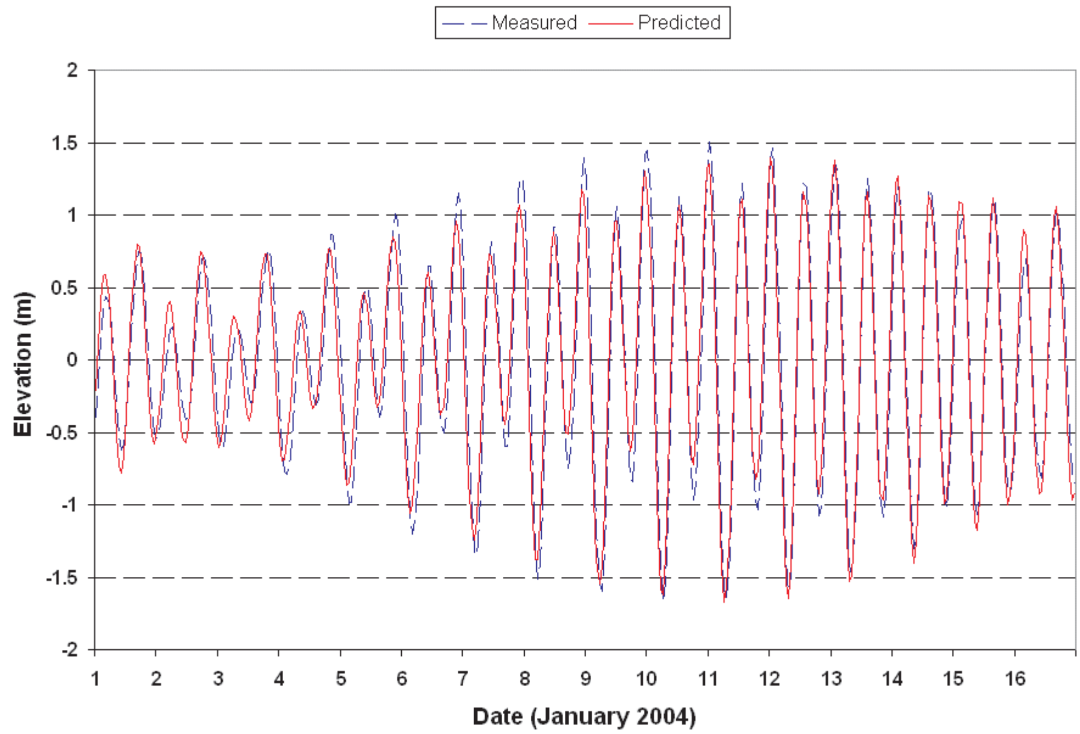


Figure 6: Comparison of tidal elevations predicted by HYDROMAP based on propagation from the model boundaries, and expected from data measured at (a) Gorgon North and (b) Barrow Island Tanker Terminal.

Northeast of Lowendal Islands (Mooring #1) – Near sea-bed

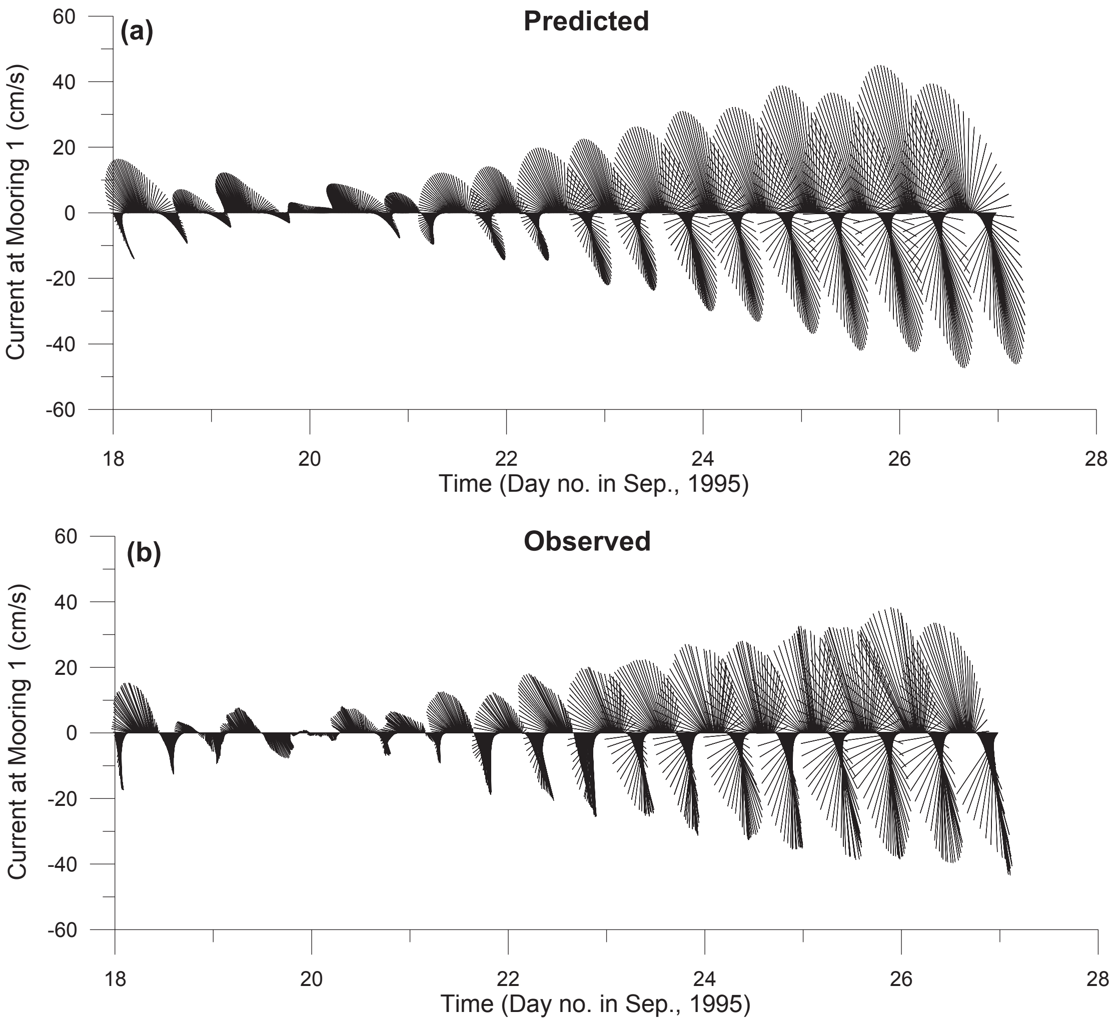
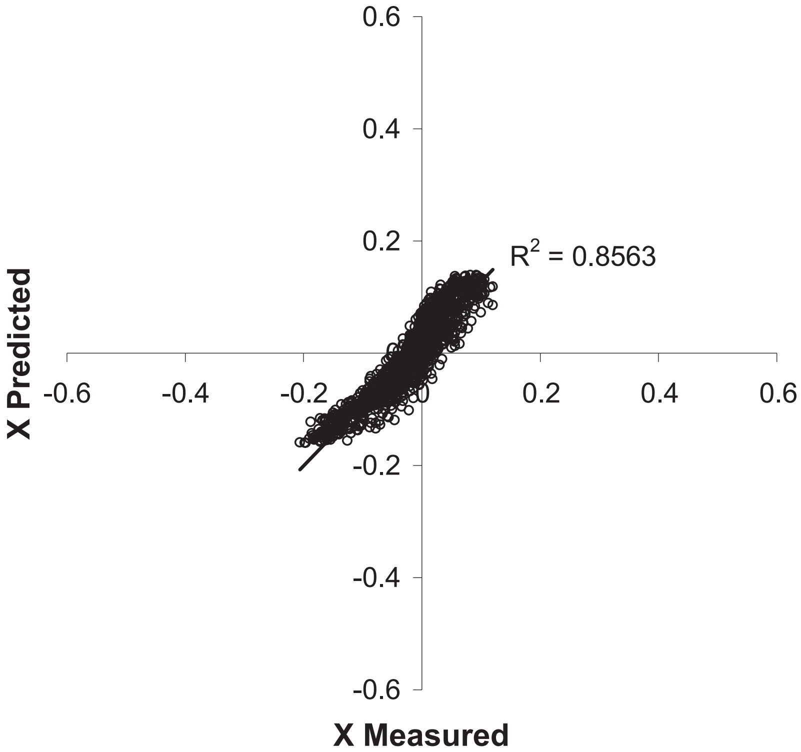


Figure 7: Stick plots comparing the speed and direction of observed and predicted currents near seabed at Mooring #1

Northeast of Lowendal Islands (Mooring #1) – Near sea-bed

(a) East-West velocity



(b) North-South velocity

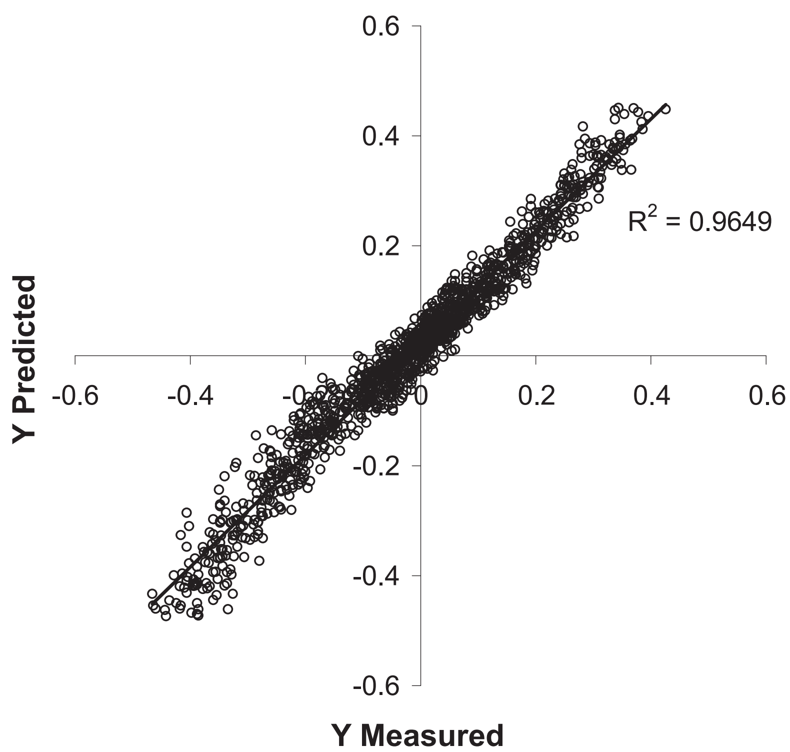
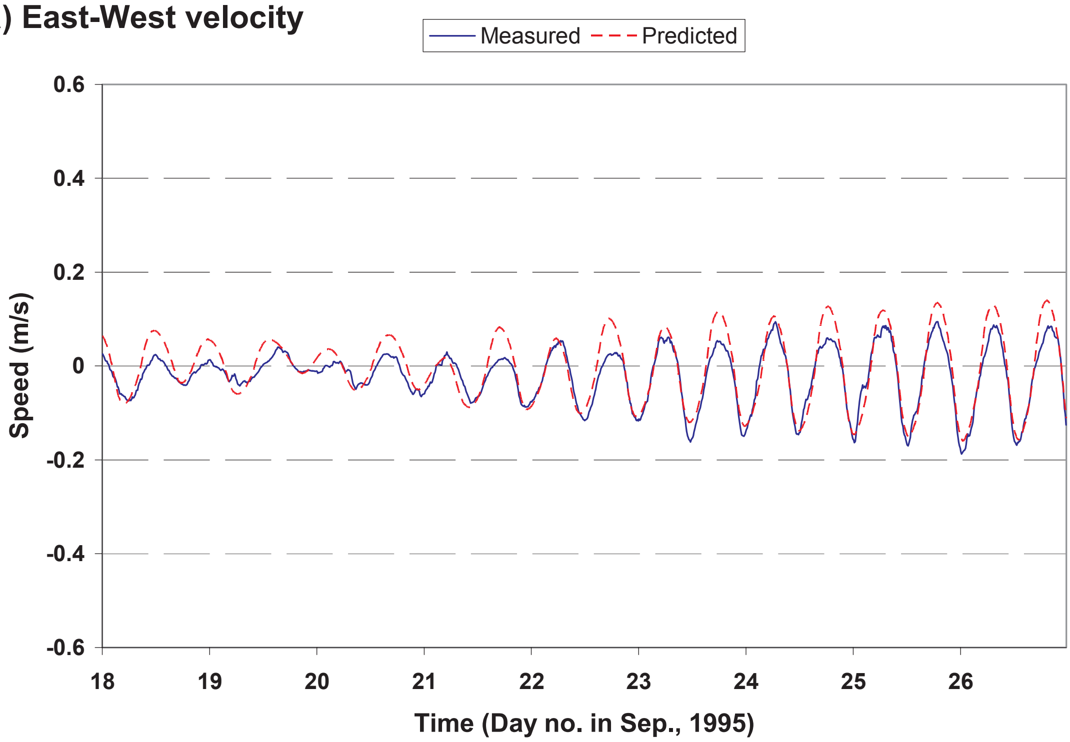


Figure 8: **Scatter plots showing the correlation between measured and predicted seabed currents at Mooring #1 (east of Varanus Island) in the (a) east-west direction and (b) north-south direction. Bold black line shows the correlation line for a perfect fit (R2=1).**

Northeast of Lowendal Islands (Mooring #1) – Near sea-bed

(a) East-West velocity



(b) North-South velocity

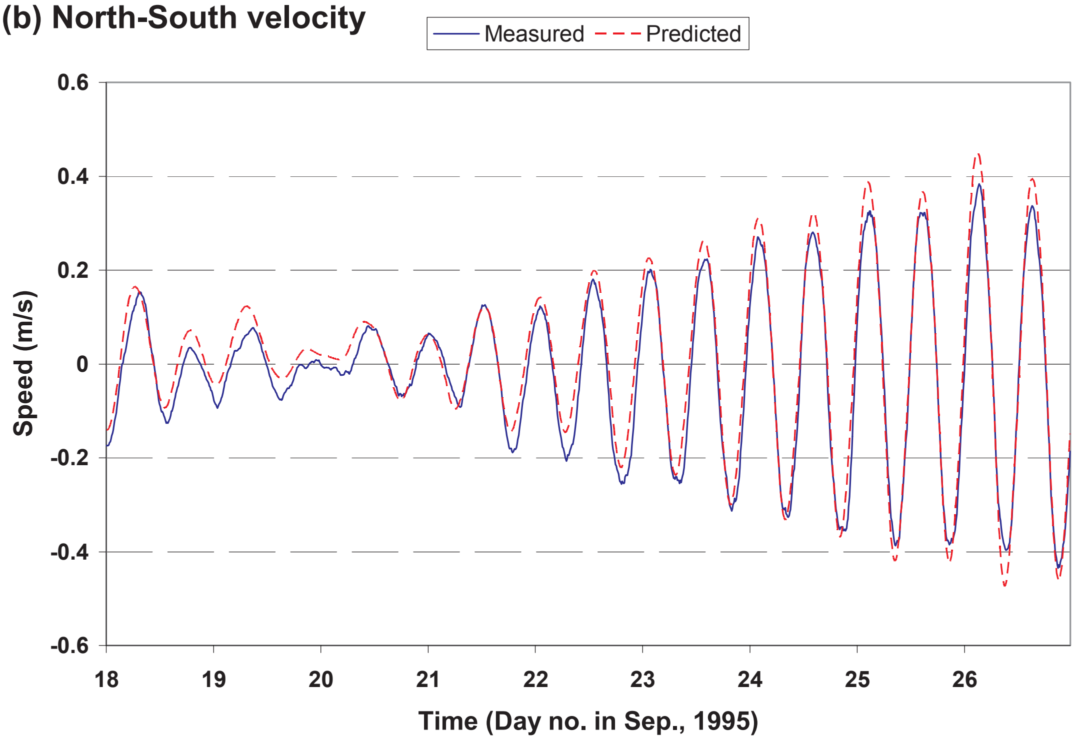


Figure 9: Time-series plot comparing measured and predicted near-seabed currents at Mooring #1 in the (a) east-west direction and (b) north-south direction.

Northeast of Lowendal Islands (Mooring #2) – Near seabed

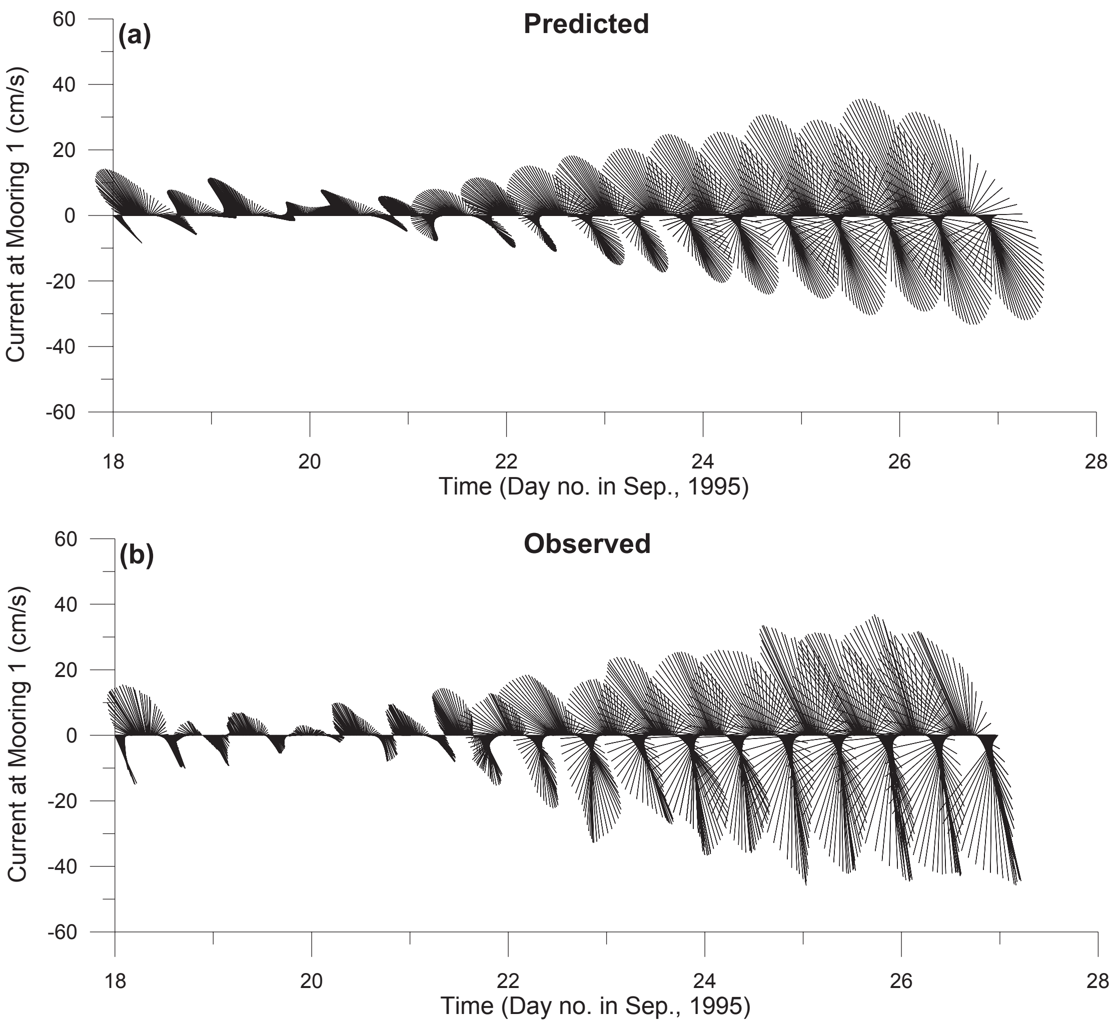


Figure 10: Stick plots comparing the speed and direction of observed and predicted currents near seabed at Mooring #2.

Northeast of Lowendal Islands (Mooring #2) – Near seabed

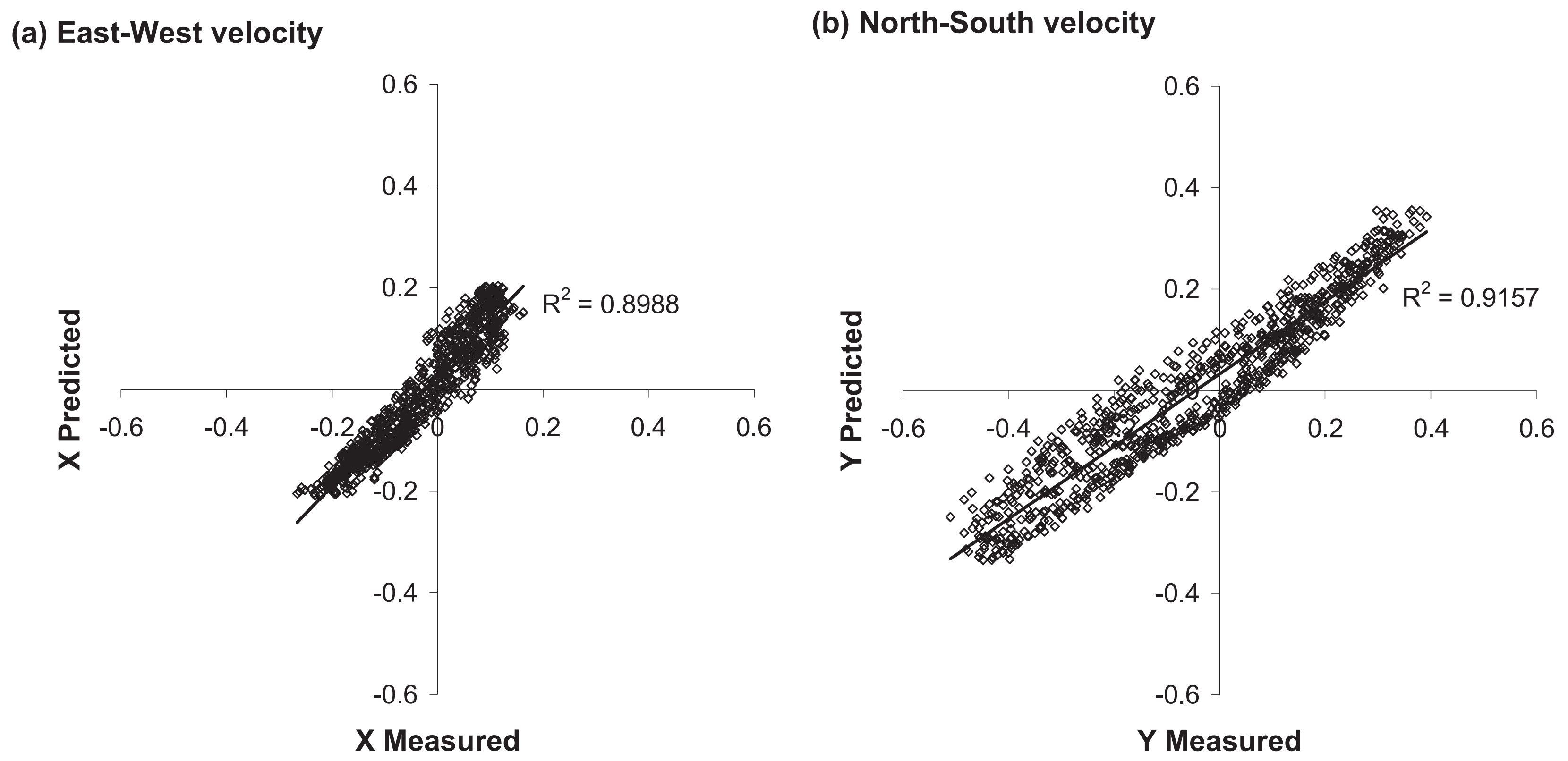
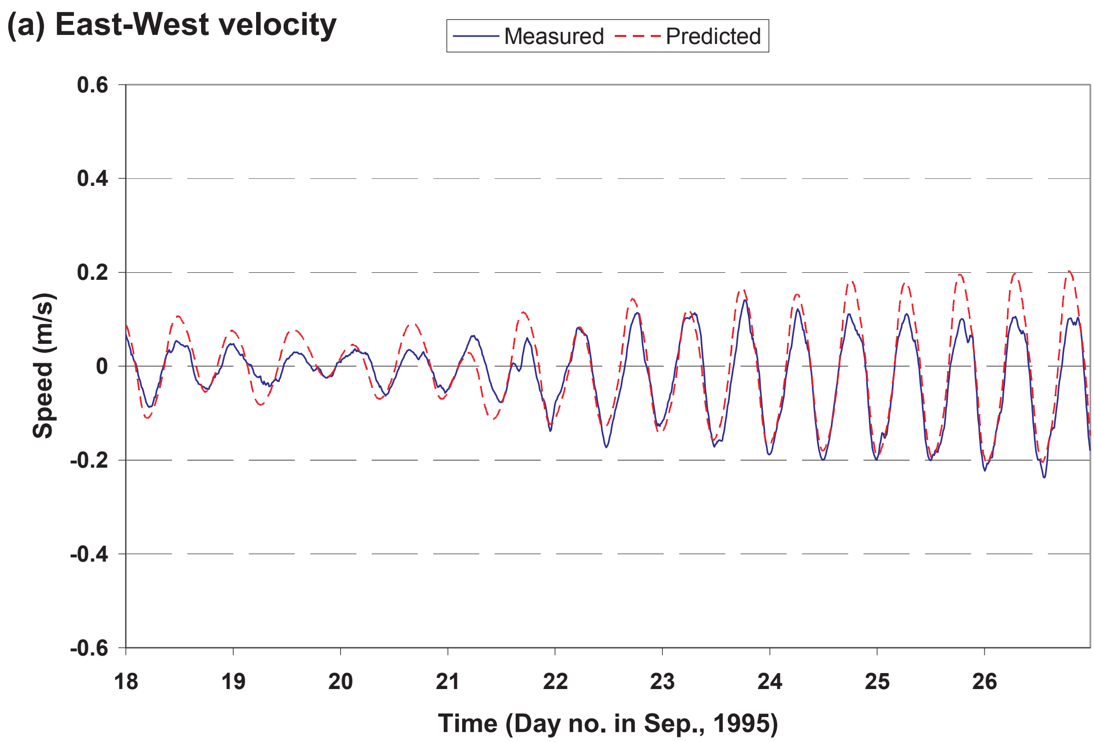


Figure 11: Scatter plots showing the correlation between measured and predicted seabed currents at Mooring #2 in the (a) east-west direction and (b) north-south direction. Bold black line shows the correlation line for a perfect fit (R2=1).

Northeast of Lowendal Islands (Mooring #2) – Near seabed



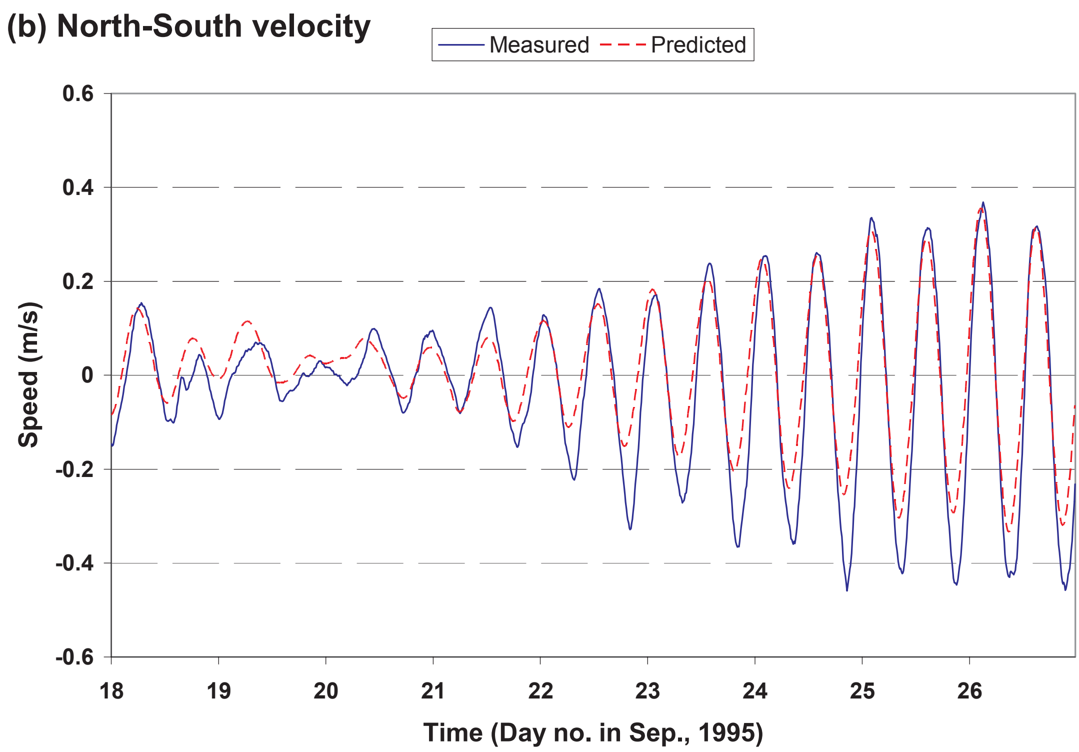


Figure 12: Time-series plot showing the comparison between measured and predicted near-seabed currents at Mooring #2 in the (a) east-west direction and (b) north-south direction.

Northeast of Lowendal Islands (Mooring #1) – Mid-depth

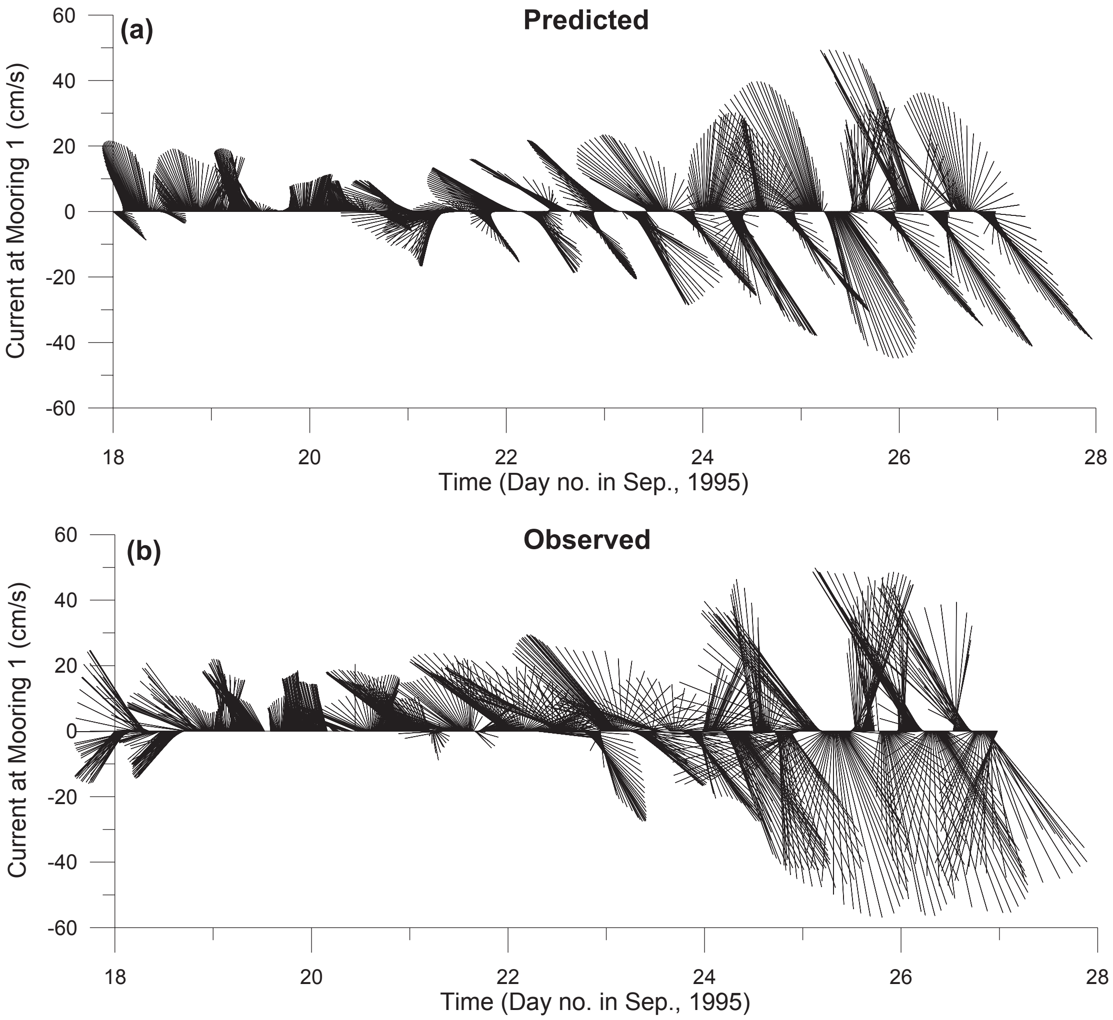


Figure 13: Stick plots comparing the speed and direction of observed and predicted currents mid-depth at Mooring #1.

Northeast of Lowendal Islands (Mooring #1) – Mid-depth

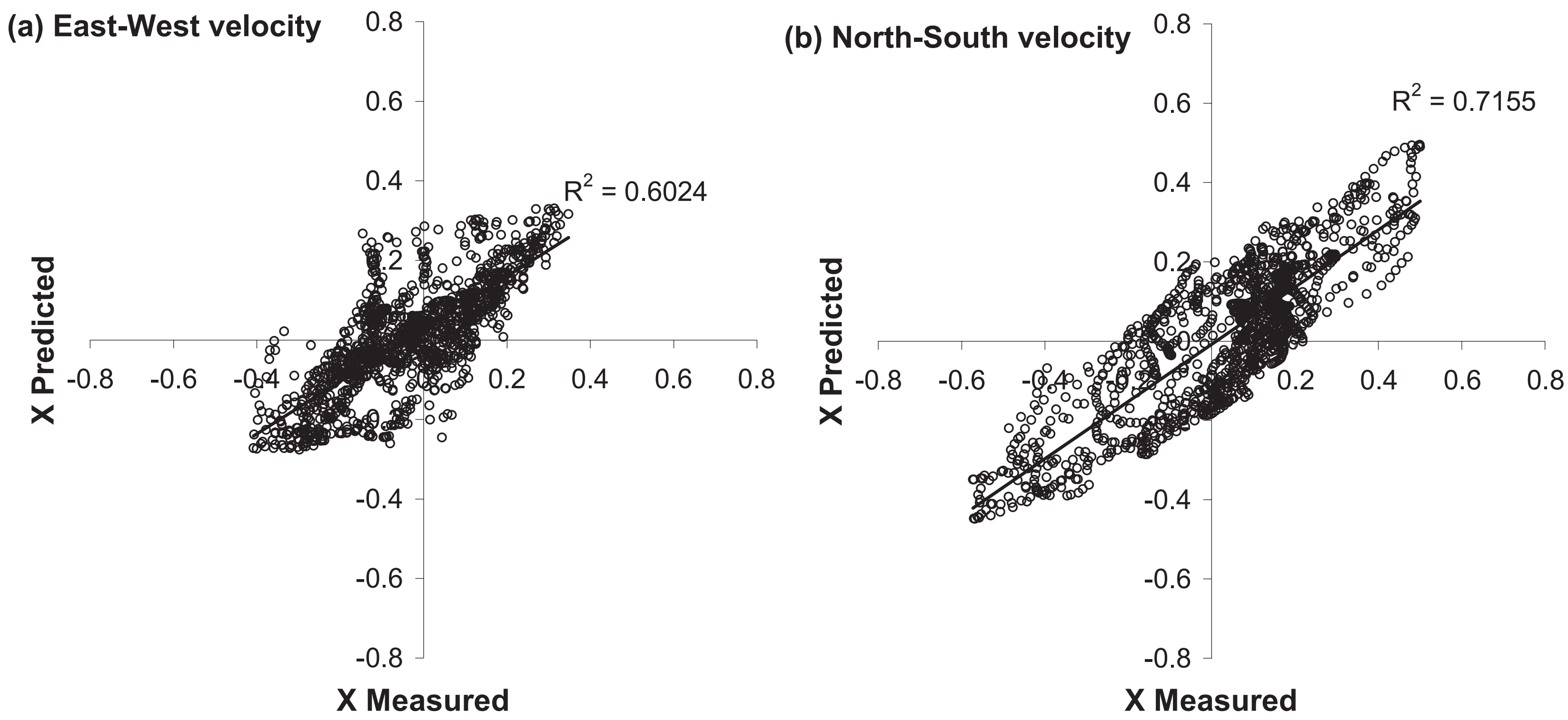
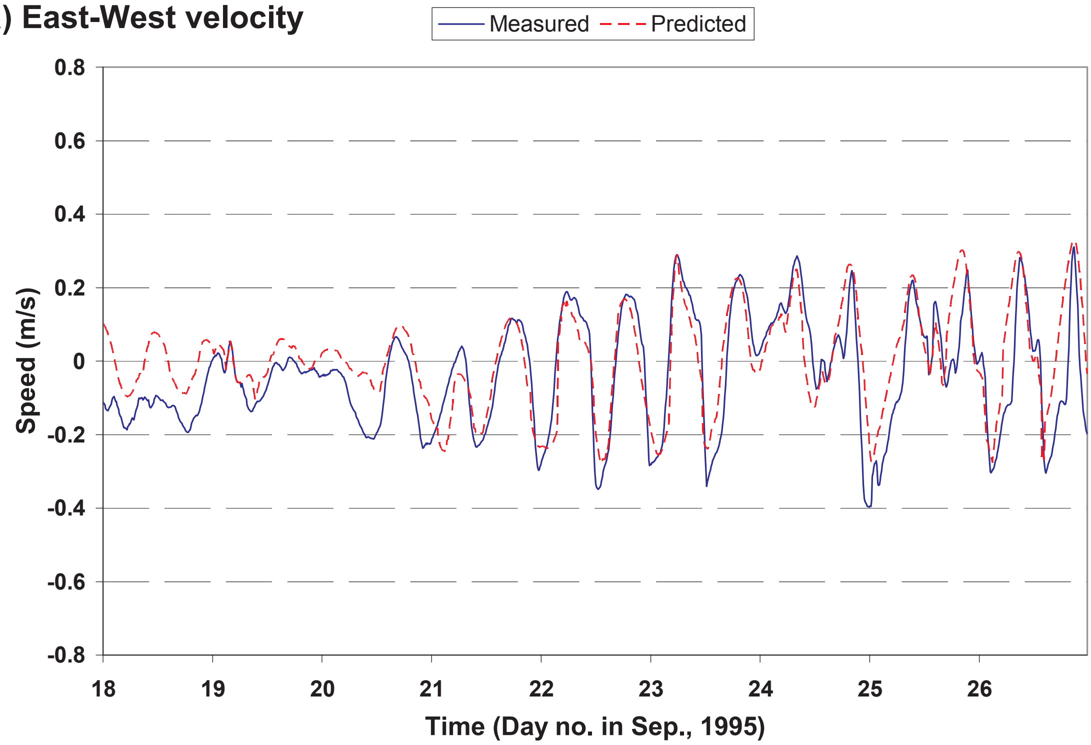


Figure 14: **Scatter plots showing the correlation between measured and predicted mid-depth currents at Mooring #1 in for the (a) east-west direction and (b) north-south direction. Bold black line shows the correlation line for a perfect fit (R2=1).**

Northeast of Lowendal Islands (Mooring #1) – Mid-depth

(a) East-West velocity



(b) North-South velocity

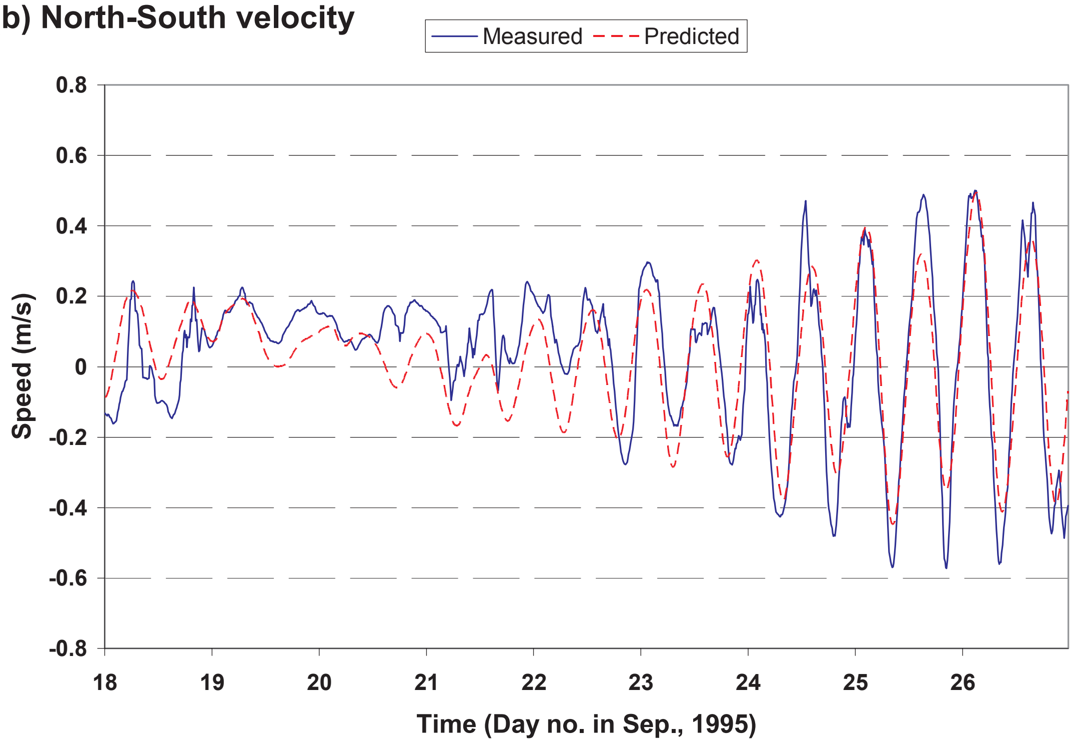


Figure 15: Time-series plot showing the comparison between measured and predicted mid-depth currents at Mooring #1 in the (a) east-west direction and (b) north-south direction.

East of Barrow Island (Location 5) – Mid-depth

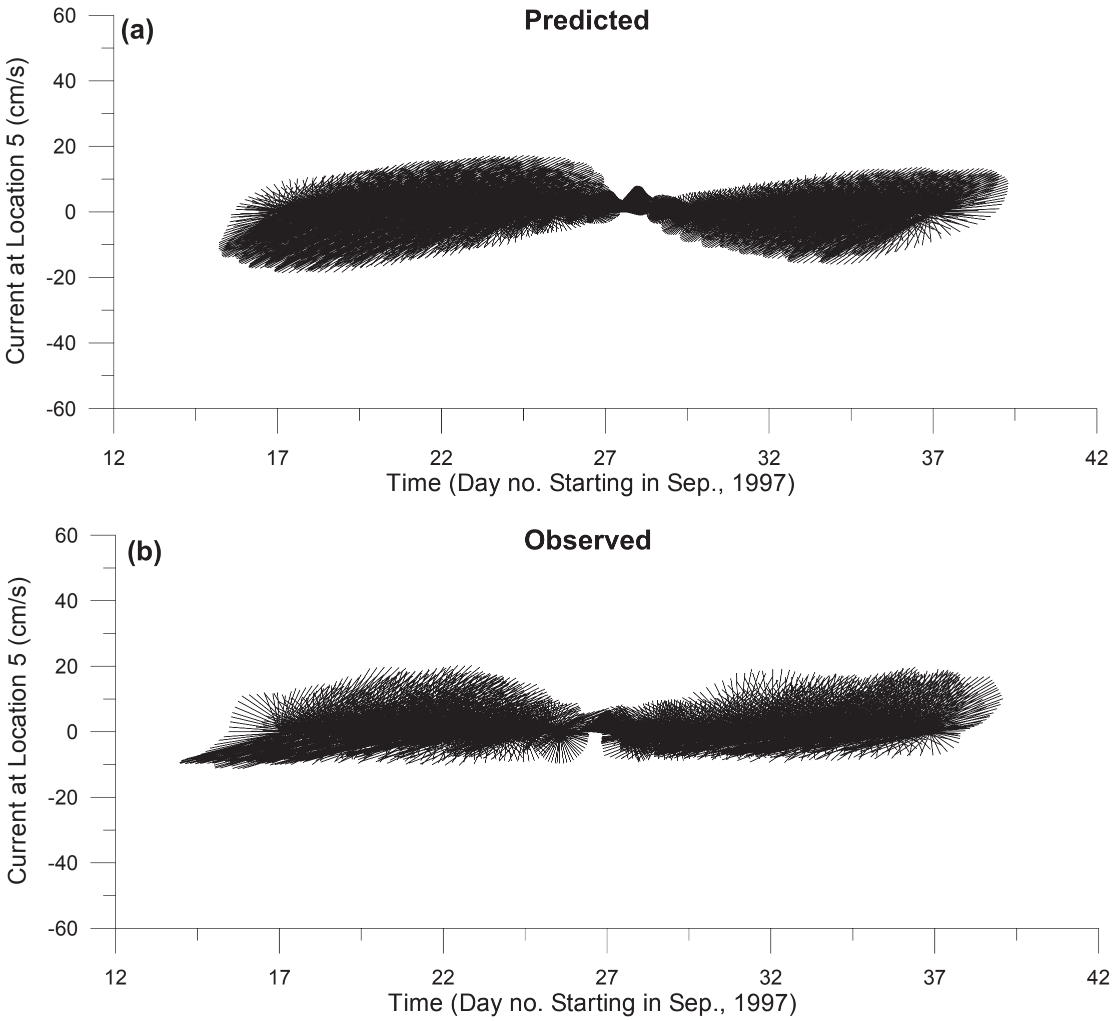


Figure 16: Stick plots comparing the speed and direction of observed and predicted currents mid-depth at Location 5.

East of Barrow Island (Location 5) – Mid-depth

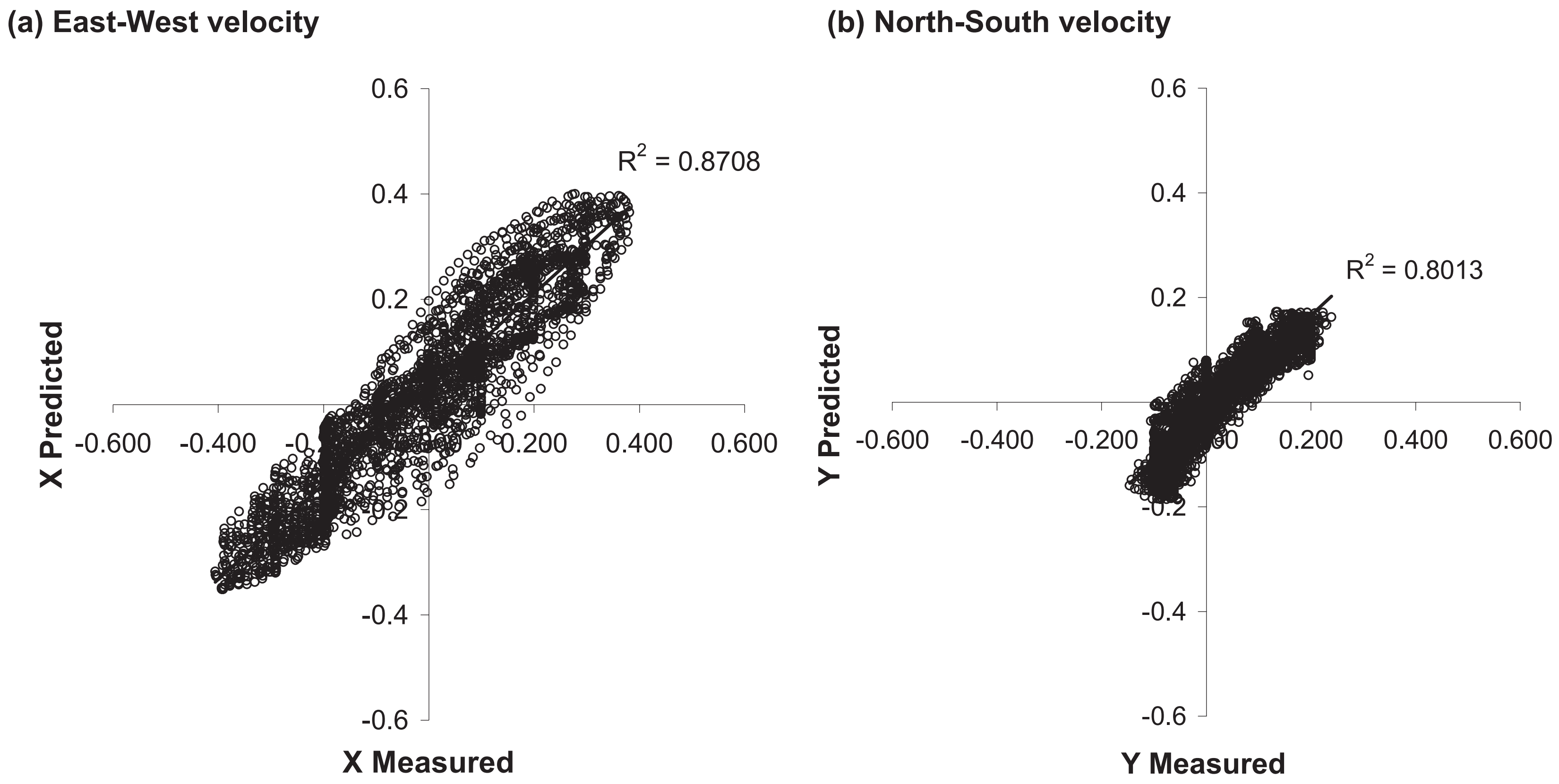
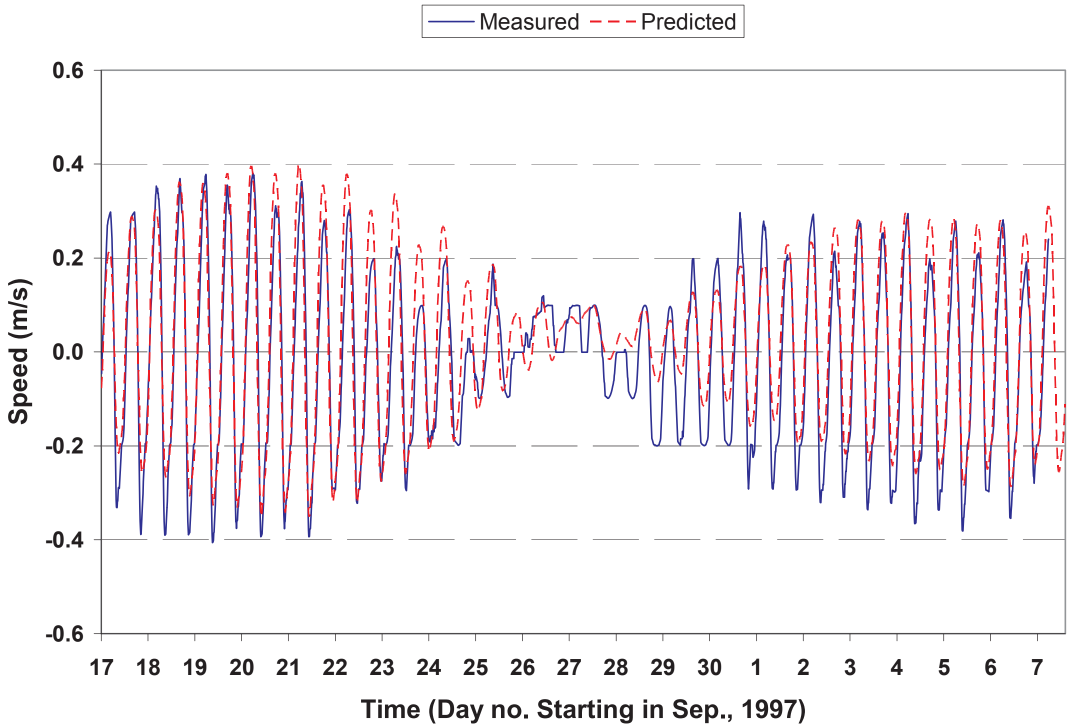


Figure 17: Scatter plots showing the correlation between measured and predicted mid-depth currents at Location 5 in the (a) east-west direction and (b) north-south direction. Bold black line shows the correlation line for a perfect fit (R2=1).

East of Barrow Island (Location 5) – Mid-depth

(a) East-West velocity



(b) North-South velocity

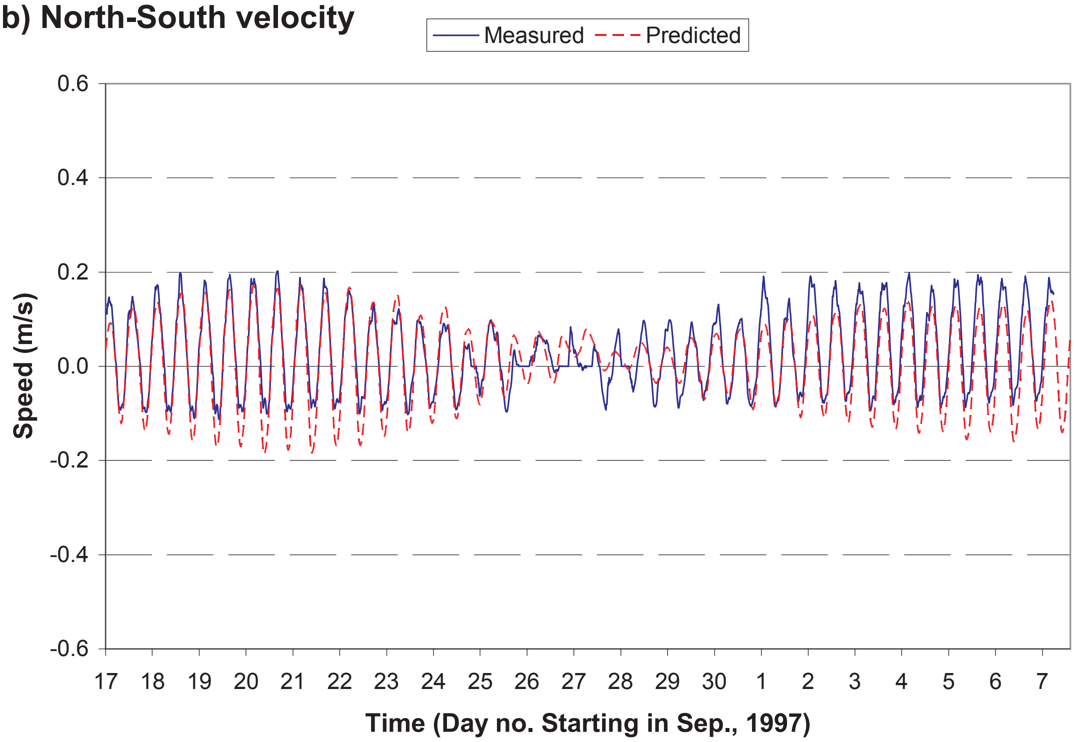


Figure 18: Time-series plots showing the comparison between the measured and predicted mid-depth currents at Location 5 in the (a) east-west direction and (b) north-south direction.

Gorgon North (Location 2) – Near-surface

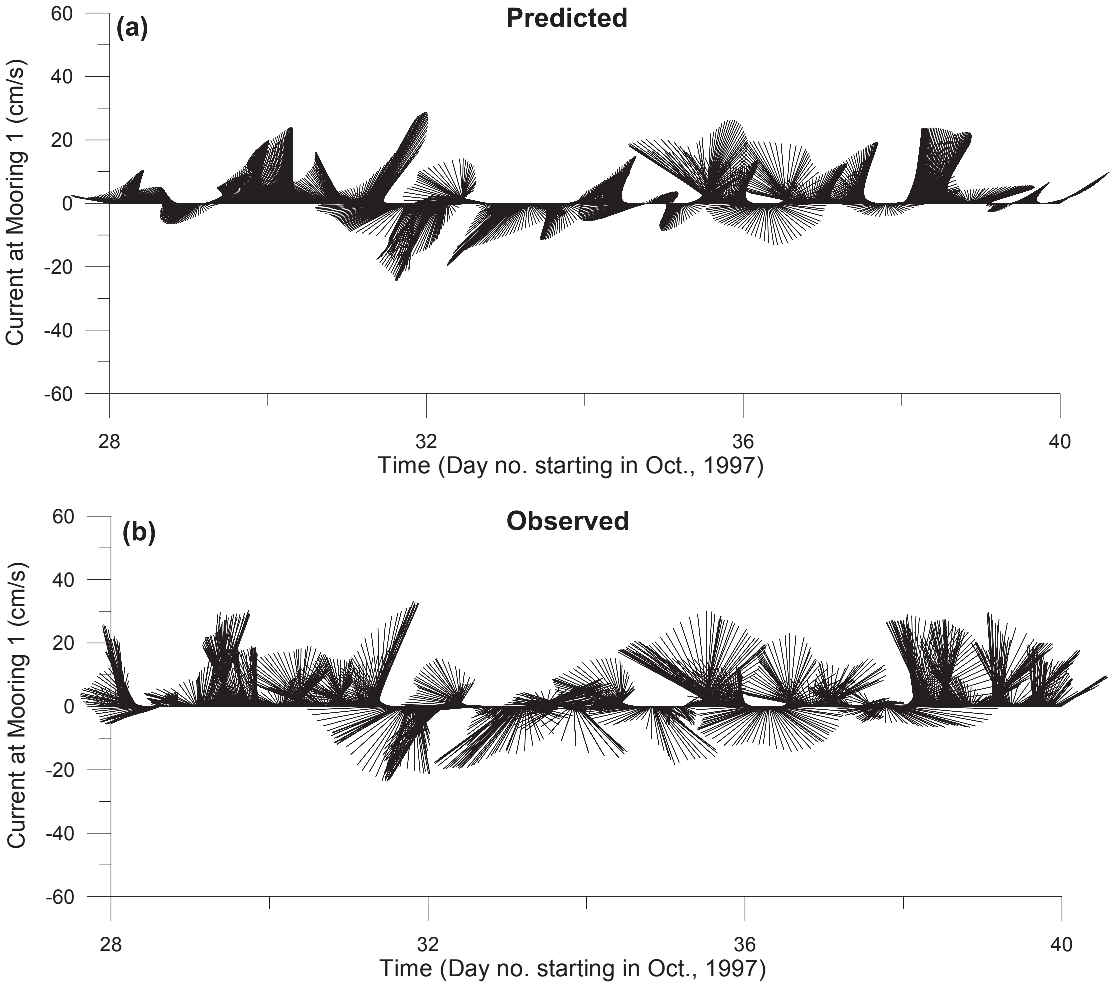
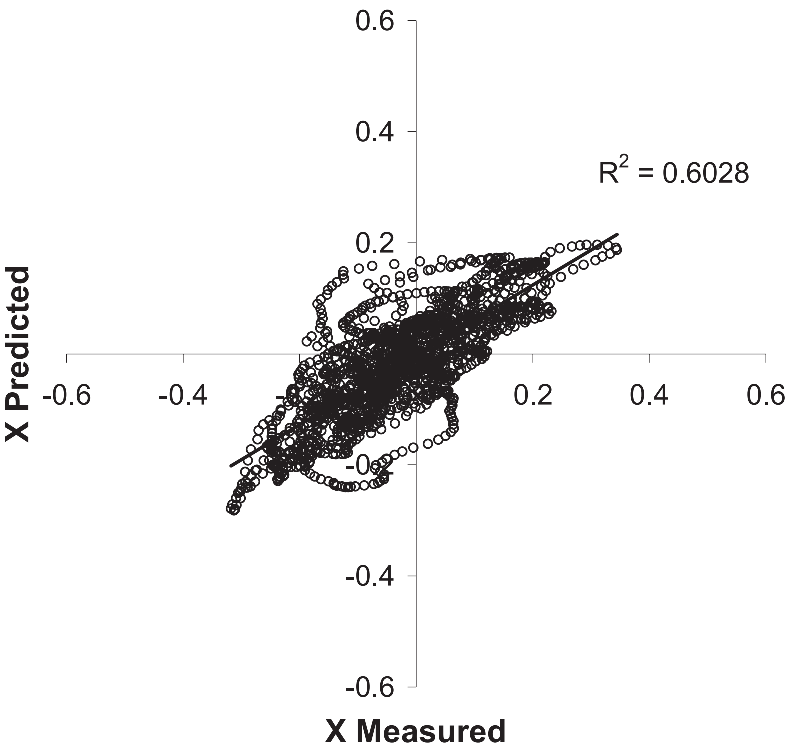


Figure 19: Stick plots comparing the speed and direction of observed and predicted currents near surface at Location 2.

Gorgon North (Location 2) – Near-surface

(a) East-West velocity



(b) North-South velocity

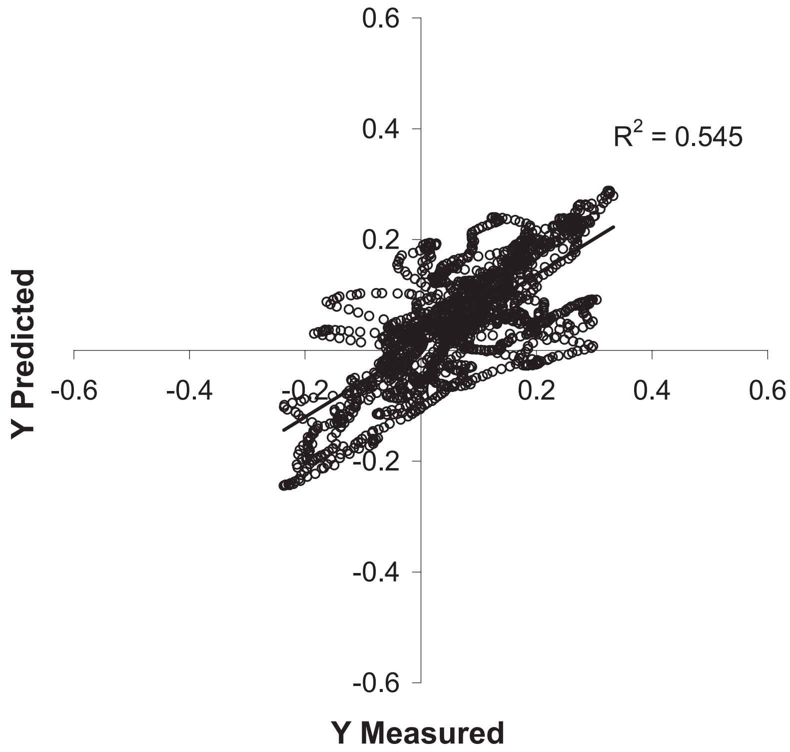


Figure 20: **Scatter plots showing the correlation between measured and predicted near-surface currents at Locations 2 in the (a) east-west direction and (b) north-south direction. Bold black line shows the correlation line for a perfect fit (R2=1).**

Gorgon North (Location 2) – Near-surface

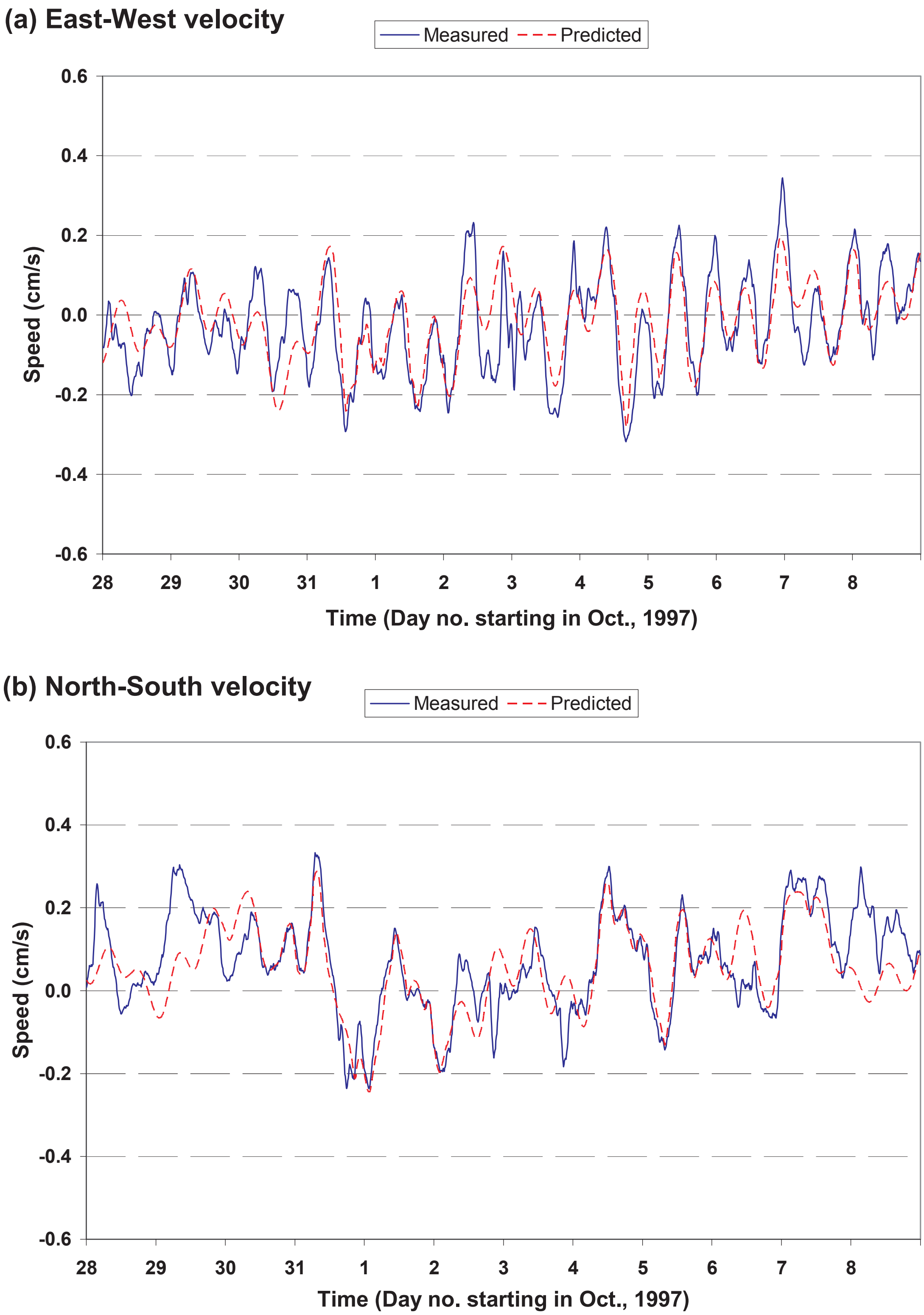


Figure 21: Time-series plots showing the comparison between the measured and predicted near-surface currents at Location 2 in the (a) east-west direction and (b) north-south direction.

Gorgon North (Location 2) – Mid-depth

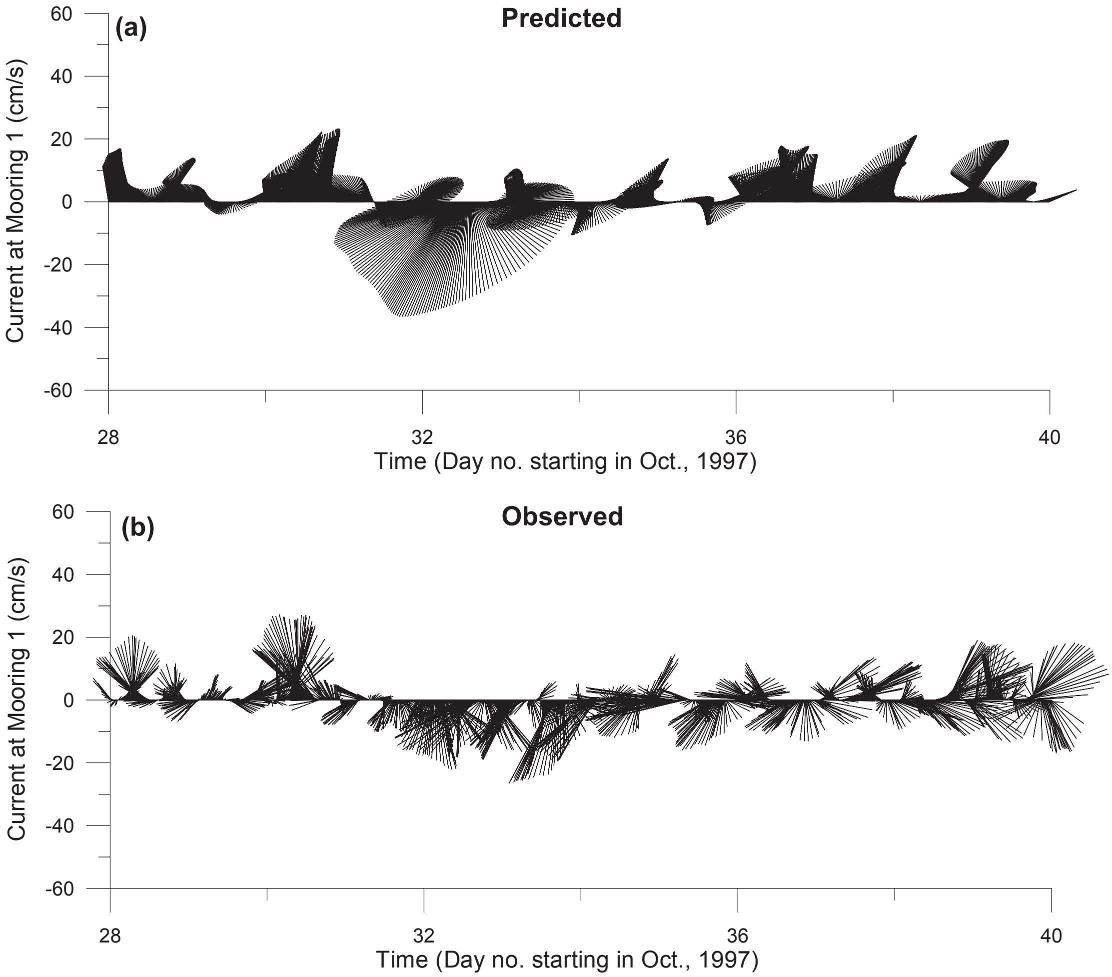
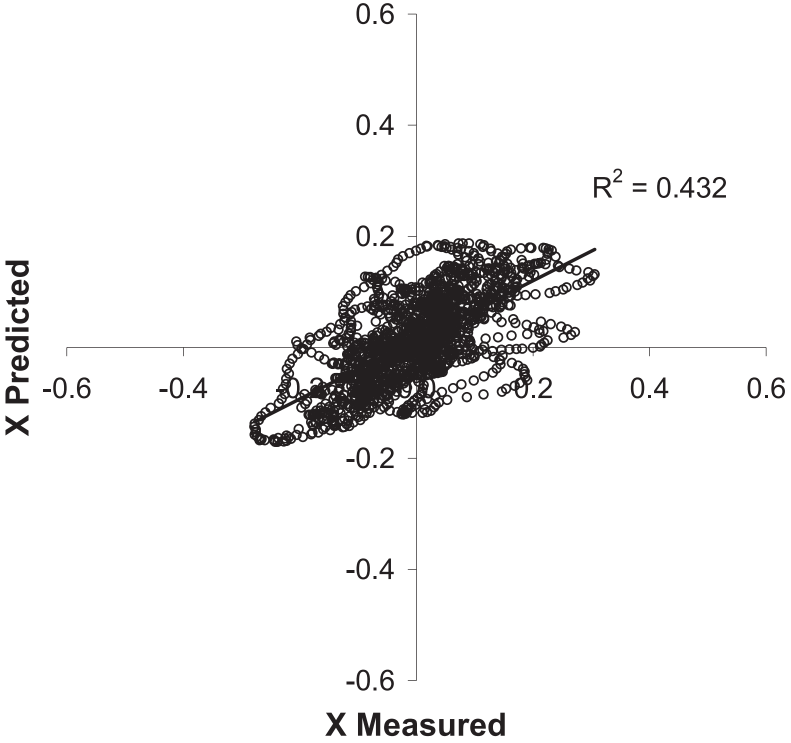


Figure 22: Stick plots comparing the speed and direction of observed and predicted currents mid-depth at Location 2.

Gorgon North (Location 2) – Mid-depth

(a) East-West velocity



(b) North-South velocity

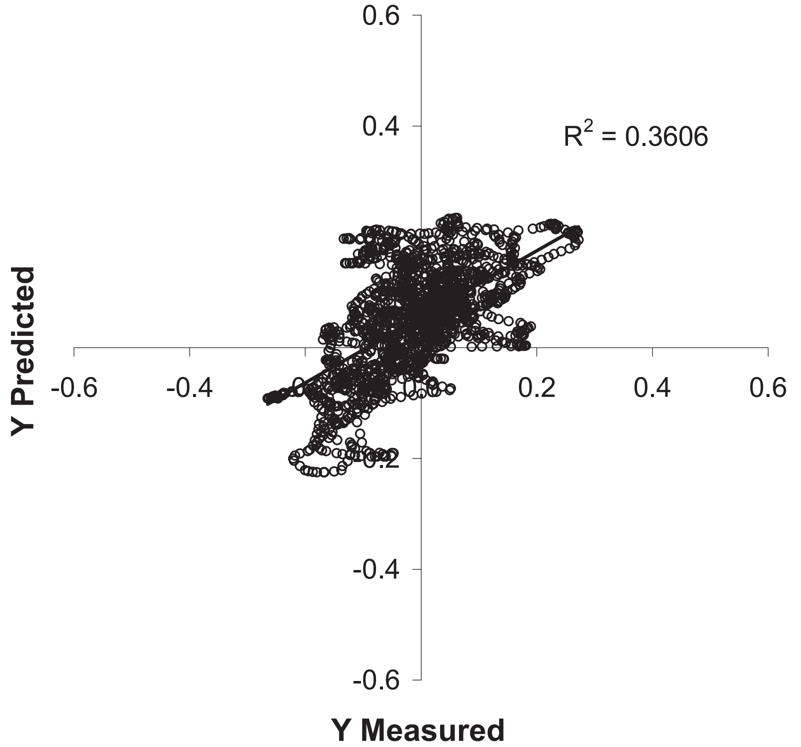


Figure 23: Scatter plots showing the correlation between the measured and predicted mid-depth currents at Location 2 in the (a) east-west direction and (b) north-south direction. Bold black line shows the correlation line for a perfect fit (R2=1).

Gorgon North (Location 2) – Mid-depth

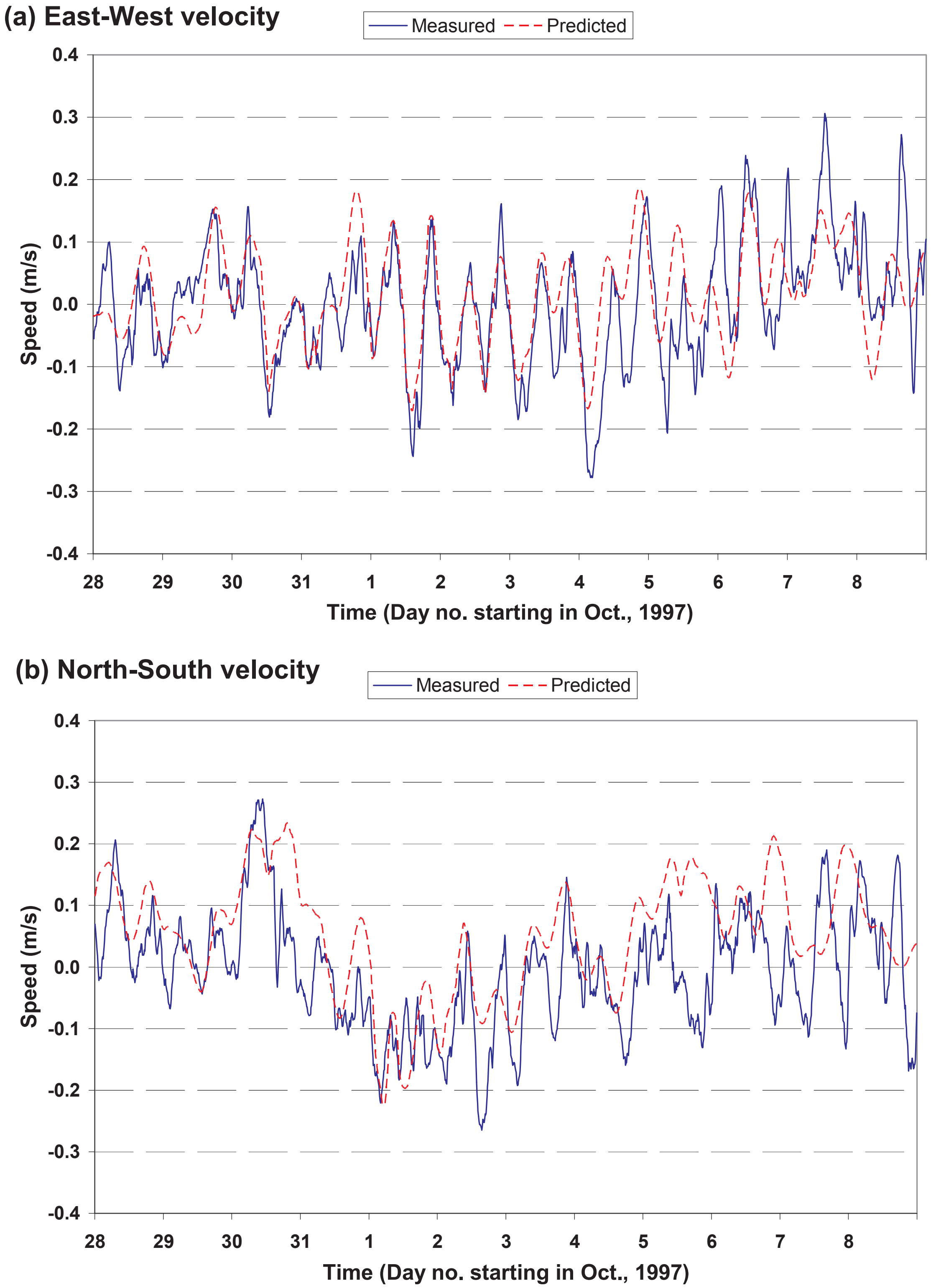


Figure 24: Time-series plots showing the comparison between the measured and predicted mid-depth currents at Location 2 in the (a) east-west direction and (b) north-south direction.

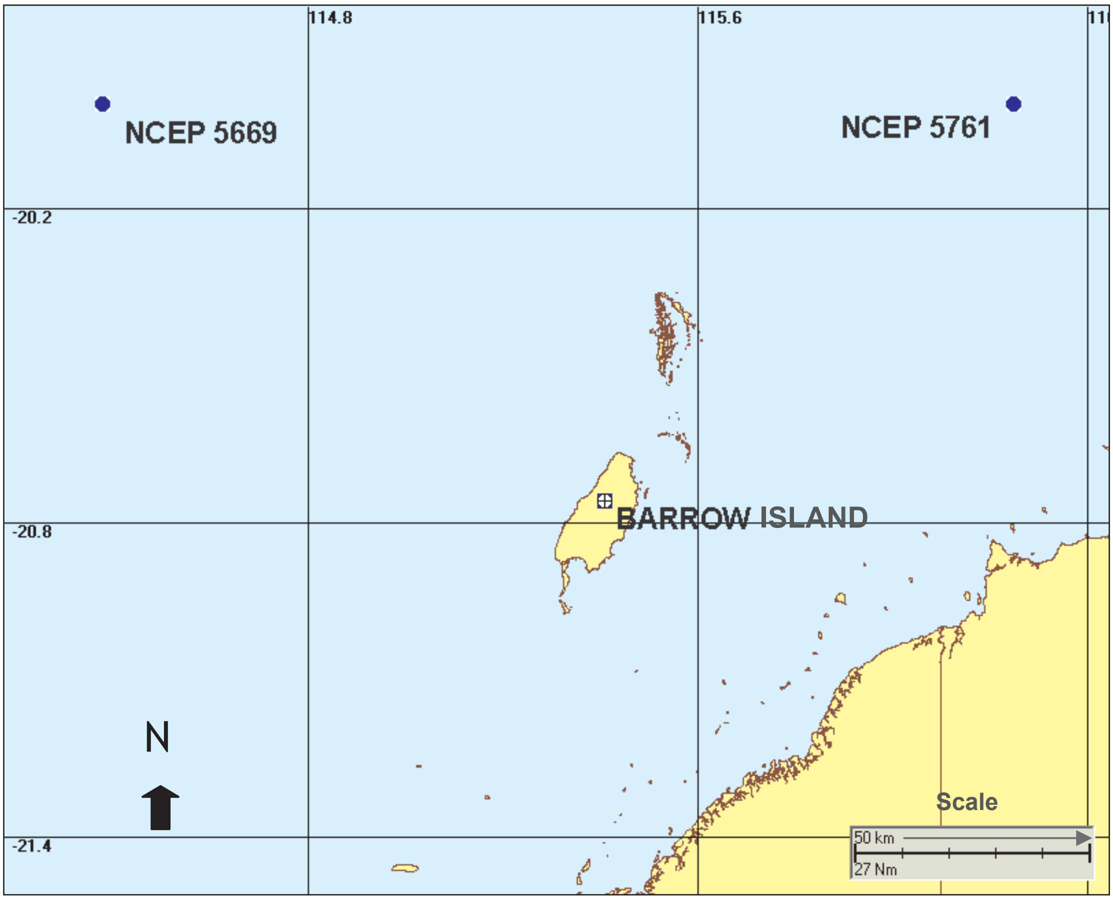


Figure 25: Locations of the wind stations used as a source of long-run wind data (1988-1998). NCEP = output from the NCEP Model Reanalysis Program, NOAA. Barrow Island = output from a fixed anemometer.

Technical Appendix B4

Marine Spill Primary Risk Assessment

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CHEVRONTEXACO AUSTRALIA

GORGON DEVELOPMENT

MARINE SPILL PRIMARY RISK ASSESSMENT

Technical Appendix B4

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REVISION	**:**	**2**
DATE	**:**	**18/08/2004**

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REVISION RECORD

Rev	Date	Description	Prepared	Reviewed	Approved
0	18/06/04	First Draft	S Robertson	K Cheney	K Berry
1	26/07/04	Client Components incorporated	S Robertson	K Cheney	K Berry
2	18/08/04	Typo correction	S Robertson	K Cheney	K Berry
Title		**CHEVRONTEXACO AUSTRALIA, GORGON DEVELOPMENT, Marine Spill Primary Risk Assessment**	**QA Verified**		

CONTENTS

LIST of TABLES

ABBREVIATIONS

APASA	Asia–Pacific Applied Science Associates
DOMGAS	Domestic Gas
EIS/ERMP	Environmental Impact Statement/Environmental Review and Management Programme
ERS	Environmental Risk Solutions Pty Ltd
GV	Gorgon Venture
km	kilometre(s)
kmy	kilometre year
LNG	Liquefied Natural Gas
LOC	Loss of Containment
m	metre(s)
MEG	Monoethylene Glycol
MOF	Materials Offloading Facility
UKCS	United Kingdom Continental Shelf
y	year
/kmy	per kilometre year
/y	per year

1. SUMMARY

The Gorgon Venture (GV), the participants being ChevronTexaco Australia, Texaco Australia, Shell Developments Australia and Mobil Australia Resources Pty Ltd; proposes to construct and operate a number of pipelines and onshore plant as part of the Gorgon Development which is located off North Western Australia.

During the construction and operation phases of the project, there is potential for spills of fluid to the marine environment; the scenarios for which have been identified by others (APASA, 2004, Reference 1). Environmental Risk Solutions Pty Ltd (ERS) has been commissioned to undertake a Primary Risk Assessment for the identified scenarios as part of the Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) for the Gorgon Development.

There are 12 Spill Scenarios that have been identified, two of which relate to the discharge of hydrotest water which is an intended action, and was not considered further. With regards to the spill scenario due to work vessel collision within port approaches, it was concluded that this scenario is very unlikely to occur and result in a marine spill, and was not considered further.

In determining the primary risk for the Spill Scenarios, reference has been made to data that is available in the public domain, the majority of which is based on incident history for North Sea and European operations. The source of the data reflects a location where there are a number of large facilities with associated support infrastructure in terms of pipelines, support vessels, etc. The Gorgon Development is remotely located and although the data is applicable, the results in terms of primary risk represent a conservative approach. Data that is available in the public domain such as the Exploration & Production Forum, and Lloyd's Maritime Information Service has been used to determine the primary risk. Table 1.1 is a summary of the primary risk for the 10 Spill Scenarios.

Table 1-1 Primary Risks Table

Spill Scenario ID	Description	Primary Risk
1	Rupture at Central Manifold	1.5×10^{-4} /y
2	Rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 1	2.81×10^{-5} /kmy
3	Rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 2	2.81×10^{-5} /kmy
4	Rupture of the Feed Pipeline 200m from Barrow Island along proposed Route 1	2.81×10^{-5} /kmy
5	Rupture of Condensate Export Pipeline	1.48×10^{-4} /kmy
6	Refuelling accident during the supply gas pipe-laying	4.1×10^{-2}/y (1)
7	Refuelling or incident or spill of fuel from the port facilities	9.0×10^{-3}/y
8	Work vessel collision within port approaches	ruled out
9	Grounded export tanker	2.34×10^{-5}/y
10	Rupture of the MEG Pipeline	4.32×10^{-5} /kmy

Note: 1 This scenario is applicable for the year during pipe-laying only.

2. INTRODUCTION

2.1 Background

The Gorgon Venture (GV), the participants being ChevronTexaco Australia, Texaco Australia, Shell Developments Australia and Mobil Australia Resources Pty Ltd; proposes to construct and operate a number of pipelines and onshore plant as part of the Gorgon Development which is located off North Western Australia. A gas processing facility (ie a Liquefied Natural Gas (LNG) and Domestic Gas (DOMGAS) plant) located on the central-east coast of Barrow Island would process the gas. The production fluids from the Gorgon Fields will be transported to this plant via a pipeline known as the Feed Gas Pipeline. The liquid hydrocarbon product would then be transported by ship to international markets. Compressed domestic gas would be delivered via a sub-sea pipeline to the Western Australian Mainland for use in the industrial and domestic gas markets.

During the construction and operation phases of the project, there is potential for spills of fluid to the marine environment; the scenarios for which have been identified in work by others (APASA, 2004). Environmental Risk Solutions Pty Ltd (ERS) has been commissioned to undertake a Primary Risk Assessment for the identified scenarios as part of the Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) for the Gorgon Development. This document reports said risk assessment.

2.2 Scope

One of the preliminary phases of the Marine Spill and Discharge Risk Assessment was the undertaking of the identification of spill scenarios as reported in the Marine Spill and Discharge Risk Assessment Report (Reference 1). These are:

Hydrocarbon Spill Scenarios:

1. Rupture at Central Manifold.
2. Rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 1.
3. Rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 2.
4. Rupture of the Feed Pipeline 200m from Barrow Island along proposed Route 1.
5. Rupture of Condensate Export Pipeline.
6. Refuelling accident during the supply gas pipe-laying.
7. Refuelling or incident or spill of fuel from the port facilities.
8. Work vessel collision within port approaches.
9. Grounded export tanker.

Non-hydrocarbon Spill Scenarios:

10. Rupture of the MEG Pipeline.
11. Discharge of hydrotest water from the supply manifold at Production Manifold (M2) at a depth of 200m.
12. Discharge of hydrotest water from the DOMGAS Line on the east coast of Barrow Island supply manifold at Production Manifold (M2) at a depth of 2m.

The likelihood (i.e. the Primary Risk) of each of the above spill scenarios is to be determined. Given that the discharge of hydrotest water (Spill Scenarios 11 and 12 above) is an intended action, then these are not considered further.

3. ANALYSIS

3.1 Overview

In determining the primary risk for the Spill Scenarios, reference has been made to data that is available in the public domain, the majority of which is based on incident history for North Sea and European operations. The source of the data reflects a location where there are a number of large facilities with associated support infrastructure in terms of pipelines, support vessels, etc and where weather conditions are more severe from those. The Gorgon Development is remotely located and although the data is applicable, the results in terms of primary risk represent a conservative approach.

3.2 Pipeline Primary Risk

Of the 10 Spill Scenarios that are identified in Section 2.2, five are due to the rupture of a submarine pipeline; i.e.;

- spill scenario ID No 2 - rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 1;
- spill scenario ID No 3 - rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 2;
- spill scenario ID No 4 - rupture of the Feed Pipeline 200m from Barrow Island along proposed Route 1;
- spill scenario ID No 5 - rupture of Condensate Export Pipeline; and
- spill scenario ID No 10 - rupture of the MEG Pipeline.

A source of submarine pipeline risk data is provided by PARLOC (Oil Industry International Exploration and Production Forum, 1992 (Reference 2)), which is prepared for the United Kingdom's Health and Safety Executive (HSE) and is internationally recognised. PARLOC provides data for flexible and steel pipelines and risers for various sizes and is primarily focussed on pipelines in the North Sea. The frequency data from the North Sea incorporates data from incidents that are due to a very high number of ship movements when compared to the environs of the Gorgon Field and Barrow Island. Therefore, the primary risk data used in this study reflects a very conservative approach. In the absence of other publically available data that is equally regarded, then this data is used for the Gorgon submarine pipelines.

The data is presented in terms of a Loss of Containment (LOC) for pipelines in operation due either to;

- anchor and impact incidents; or
- corrosion and material defects.

In the calculation of frequencies, PARLOC assumes that the number of incidents follows a mathematical binomial distribution known as a Poisson Distribution. The best estimate, as used in this study, repeats this distribution with an upper 95% and lower 5% confidence limits.

With regards to the Condensate Export Pipeline, it is proposed to use the existing Barrow Island Oil Export Line, and therefore in determining the Primary Risk, the upper bound is used. This provides a conservative approach to accommodate the age of the existing pipeline, whilst recognising that, as reported by PARLOC, it is difficult to draw firm conclusions on trends in LOC primary risk with age.

The MEG Pipeline will be one of the lines included in the Umbilical Bundle. PARLOC concludes that the reporting of incidents involving umbilicals is not considered to be comprehensive. Therefore, relevant data is not available pertaining specifically to the MEG Pipeline. Given that this pipeline's route will be parallel to the Feed Pipeline and provided with the same protection mechanisms, then PARLOC's data for this size pipeline is assumed to be applicable.

The PARLOC data provides the distribution of the leak sizes including the scenario for pipeline rupture. For pipelines with a diameter greater than 16 inches, (i.e. the Feed Pipeline, and the Condensate Export Pipeline) the distribution of pipeline ruptures is 1/3 of the total likelihood for all pipeline LOCs for this size pipeline. For the MEG Pipeline, the distribution is 14.7% for pipeline ruptures when compared to the total likelihood for all pipeline LOCs. These distributions are applied to the total likelihoods to provide the primary risk for the rupture spill scenarios. These are listed in Table 3.1.

Table 3-1 Pipeline Primary Risks Table

Spill Scenario ID	Description	Primary Risk (per kmy)
2	Rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 1	2.81×10^{-5}
3	Rupture of the Feed Pipeline 14 km from Barrow Island along proposed Route 2	2.81×10^{-5}
4	Rupture of the Feed Pipeline 200m from Barrow Island along proposed Route 1	2.81×10^{-5}
5	Rupture of Condensate Export Pipeline	1.48×10^{-4}
10	Rupture of the MEG Pipeline	4.32×10^{-5}

3.3 Rupture of Central Manifold

It has been identified that there is potential for a rupture to occur at the Central Manifold which is a sub-sea installation.

The HSE hydrocarbon release database is a comprehensive collection of all significant hydrocarbon releases in the UK offshore sector from 1992 to 1997. The Centre for Marine and Petroleum Technology (Reference 3) reports this database and includes the major event LOC frequencies for installation type (i.e. fixed manned, unattended, sub-sea, semi-sub and jack-up). The reported likelihood of a LOC for a sub-sea installation is 1×10^{-2} per installation year.

The HSE hydrocarbon database includes a distribution of hole sizes and the probability of that hole size. For this scenario, it is assumed that rupture is equivalent to hole sizes greater than 100mm in diameter; the probability of which is 0.015.

Therefore the primary risk for rupture of the Central Manifold is 1.5×10^{-4} per year.

3.4 Refuelling accident during the supply gas pipe-laying

It has been identified that a spill of fuel used by vessels during the pipe-laying construction phase could occur. This spill could occur during the refuelling of the pipe-laying vessels from dedicated barges, with the likely cause being the failure of the transfer hose.

The E & P Forum (Reference 2) provides data from the United Kingdom Continental Shelf (UKCS) offshore loading statistics on Department of Trade and Industry pollution reports over the years 1977 to 1993. This data has been broken down into separate factors for the different components of the loading system. For transfer hoses, the likelihood of a LOC is 4.1×10^{-3} per cargo transfer.

It is assumed that the Feed pipelines will be installed by a single pipe-laying barge over an 8 month period. During that time, the pipe-laying barge will require approximately 10 refuellings. It is anticipated that the pipe-laying will require a supply vessel/tender to support the pipe-laying barge, the refuelling of which will be at Dampier. Therefore to determine the annualised primary risk during the year of construction for the supply gas pipeline, the 10 refuellings for the pipe-laying barge are applicable. The primary risk is 4.1×10^{-2}/y and is only applicable for the period during pipe-laying.

3.5 Refuelling or incident or spill of fuel from the port facilities

This spill source includes the spills that may occur during a transfer of fuel to and from the Material Offloading Facility (MOF) port facilities during the construction phase. The probable spill source includes the fuel pipeline along the wharf and transfer hoses.

The above UKCS statistics published in the E & P Forum (Reference 2) provide data by which the likelihood of a LOC, due to pipeline and transfer hoses, is determined to be 3.0×10^{-3} per cargo transfer.

It is anticipated that the facilities on Barrow Island will be refuelled twice per year. The refuelling of vessels is assumed to occur at Dampier where there is existing infrastructure for both the project's construction and operational phases. During the operational phase, it may be necessary to refuel a vessel, but this is considered to be an infrequent event. Nevertheless, a conservative assumption is made that a total of 3 refuellings will occur per year and the primary risk is determined to be 9.0×10^{-3}/y.

3.6 Work vessel collision within port approaches

During the construction phase of the project, there is potential for work vessels to collide within the port approaches. The construction phase will involve approximately 7 support vessels that will be approximately 20m in size. The approaches to Barrow Island are in a Designated Port Area and are subject to the controls for that area which include low speed and good communications. It is not expected that a collision between vessels will occur given the low number of vessels in the large port area and the port control.

In the unlikely event of a vessel collision, given the low speed, then it is considered that any damage incurred, if any, will be minimal. Therefore it is highly unlikely that fuel tanks (either the vessel's own tanks or tanks used to transport fuel to other vessels) would suffer damage that could result in a spill.

From the anecdotal evidence of the operations at Dampier Port with a larger number of vessel movements, there have been no incidents of vessel collisions resulting in spills to the marine environment between support vessels, and support vessels and ships within the Woodside port approaches. It is therefore concluded that this scenario is very unlikely to occur and result in a marine spill, and will not be considered further.

3.7 Grounded export tanker

It has been identified that a spill could occur during the operational phase of the project as the result of an export condensate tanker or LNG tanker being grounded in the port area. The spill could either originate from the tanker's fuel tanks or the condensate on-board the condensate tanker. The following examines the likelihood of such an event resulting in an LOC of approximately 10 to $100m^3$.

The primary source of ship accidents data is the ship casualty database maintained by Lloyd's Maritime Information Service. The probability of a loss can be obtained by combining the historical data with fleet data as provided by Lloyd's Register, which, covers all self-propelled sea-going merchant vessels over 100 gross tonnes. In its analysis of this data for the period of 1991 to 1995, DNV reported (Reference 4) the frequency in terms of per ship year for a ship grounding and the probability of an oil spill due to grounding.

The data provided segregates the groundings between a powered grounding where the vessel is under-way by its own engines, and a drift grounding where the vessel is drifting without propulsion from its engines. The likelihood of a powered grounding is higher than a drift grounding. This likelihood is used in this study, as the vessels will be under-way during transits to and from the export berth. This represents a conservative approach which is in keeping with good practice. Further levels of conservatism are incorporated into this analysis by;

- the historical data from Lloyd's Maritime Information Service is significantly influenced by the number of incidents involving single hull vessel versus doubled hull vessels. The latter have been in service for a relatively short period when compared to single hull vessels and the benefits of double hull vessels include the reduced likelihood of a LOC to the marine environment being incurred given an incident occurs (i.e. collision, grounding, etc.). Given that in the future, the number of double hull vessel will increase and single hull vessels will decrease as per the requirements of the International Maritime Organisation, then it is expected that the probability of an oil spill occurring due to powered grounding will decrease; and

- the schedule of LNG Tankers is one every 3 days (i.e. 122 vessels per year), and condensate exports are scheduled at one per month (i.e. 12 vessel per year). Therefore the LNG Tankers dominated the analysis. LNG tankers are generally constructed so that the ship's fuel tanks are located at the stern of the vessel. Given that the likelihood of grounding whilst under power is higher than a drift grounding, then in the scenario for grounding whilst under power, it is more likely that other sections of the LNG Tanker will come into contact with a reef than the stern. Therefore, given the location of the ship's fuel tanks, it is considered to be the least likely scenario by which an LOC to the marine environment could occur.

The likelihood of a tanker vessel being grounded whilst under power is 2×10^{-3} per ship year, and the probability of an oil spill occurring due to the grounding whilst under power is 0.2. Therefore the likelihood of an oil spill from grounding whilst under power is 4×10^{-4} per ship year.

This assumes that the vessel is in the port area continually throughout the year. It is therefore necessary to account for the actual proportion of time that a vessel is in transit in the port area so as to reflect the actual level of primary risk due to each vessel. The sum of all scheduled vessel transits within the Barrow Island Port Area as a proportion of the total hours per year, together with the likelihood of an oil spill from grounding whilst under power will determine the annual primary risk of an oil spill from grounded export tankers.

It is assumed that a condensate tanker will require 1 hour per transit for berthing, and an LNG Tanker will require 2 hours to transit the 8km in the designated channel until it is tied up along-side its station. It is assumed that similar periods of time are required for the outward transit. The schedule of LNG Tankers is one every 3 days (i.e. 122 vessels per year), and condensate exports are scheduled at one per month (i.e. 12 vessel per year). Therefore the total number of hours that vessels are in transit in Barrow Island Port Area per year is 512, which equates to:

$$\frac{512}{365 \times 24} = 0.058 \text{ of a year.}$$

Therefore the primary risk of an oil spill from a grounded export tanker is determined to be $4 \times 10^{-4} \times 0.058 = 2.34 \times 10^{-5}$/y.

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2. The Oil Industry International Exploration & Production Forum; “Risk Assessment Data Directory”; Report No 11.8/250; October, 1996; London.
3. Spouge, S; “A Guide to Quantitative Risk Assessment for Offshore Installations”; CMPT; 1999, Aberdeen.
4. DNV Technica; *“SAFECO, WP III.2, Statistical Analysis of Ship Accidents”*; DNV Technica Report 97-2039; UK; 1997.

Technical Appendix B5

Proposed Gorgon Dredging Simulation Studies

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GLOBAL ENVIRONMENTAL MODELLING SYSTEMS
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ABN 28 061 965 339

CHEVRON

Gorgon Development

Dredging Program Simulation Studies

July 2005

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Disclaimer

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1 Introduction

Global Environmental Modelling Systems (GEMS) has been contracted to carry out simulations of the dredging of the Materials Offload Facility (MOF) and the LNG shipping access channel for the Chevron Gorgon Development at Barrow Island.

The work is being undertaken using two sophisticated numerical computer models:

a) The GEMS 3D Coastal Ocean Model (GCOM3D) to simulate the complex three-dimensional ocean currents surrounding Barrow Island; and
b) The GEMS 3D Dredge Simulation Model (DREDGETRAK) to determine the fate of particles released into the water column during the dredging operations.

1.1 Scope of Work

The Scope of Work for this study has been undertaken in several stages as follows:

Stage 1: Simulations for a "Typical" 15 month Period

---

a) Incorporate the latest bathymetry data and establish bathymetric grids (covering all potential regions of impact) for the hydrodynamic and dredge simulation modelling.

b) Analyse annual meteorology data for the region to choose a "typical" 15 month period.

c) Run GCOM3D for a selected period and compare with ocean currents and tides measured by MetOcean in 2003.

d) Show results of hydrodynamic model verification and discuss methodology with the EPASU.

e) Meet with URS and Baggermans to establish the best estimate of the dredge simulation parameters including:
- Particle distribution curve
- Dredge(s) to be used and proposed hours of operation
- Dredge cutting rate(s)
- All potential sources of turbidity together with rate and duration
- Proposed spoil ground(s)
- Establish the expected maintenance schedules and associated down times.

f) Meet with RPSBBG to establish the required outcomes of dredge simulations (e.g. TSS levels and durations, bottom sedimentation thickness, impact zone criteria)

g) Run GCOM3D for the “typical” 15 month period driven by winds, tides and satellite sensed large scale currents.

h) Run the full dredge scenario for the MOF and the LNG access channel for the “typical” 15 month period.

i) Analyse output from the simulation to provide data for initial impact assessment studies.

j) Derive impact zones, based on model output and RPSBBG exposure criteria, defining regions of full mortality, partial mortality and exposure without mortality.

Stage 2: Sensitivity Studies

a) Analyse annual meteorology data for the region to choose two “atypical” 15 month periods with more or less easterly wind events than the “typical” year.

b) Run GCOM3D for the two “atypical” 15 month periods driven by winds, tides and satellite sensed large scale currents.

c) Run full dredge simulations for three extra dredging scenarios:

- An “atypical” meteorological period containing more easterly wind events.
- An “atypical” meteorological period containing more westerly wind events.
- A “typical” meteorological period with the underkeel clearance (UKC) of the THSD limited to 4 metres to reduce propeller wash.

d) Analyse output from the simulations to determine differences between the “typical” and “atypical” years and the effects of limiting UKC.

e) Derive impact zones based on model output and RPSBBG exposure criteria for the three sensitivity scenarios.

2 GEMS Background Information

GEMS has expertise in the development and application of high-resolution computer models to realistically predict atmospheric and oceanographic conditions for use in riverine, coastal and oceanic settings. The GEMS team is made up of qualified and experienced physical oceanographers, meteorologists, numerical modellers and environmental scientists.

GEMS is a leading developer of numerical models in Australia. It has developed a system of validated environmental models that provide solutions to a variety of environmental, engineering and operational problems. Services provided to the oil and gas exploration industry include:

- Oil Spill Prediction and Risk Modelling under fully representative climatic and oceanographic conditions;
- Real-time, on-call Oil Spill Modelling
- Dredge sediment fate modelling
- Production Formation Water and Pipeline Hydro-test discharge modelling and related risk analysis;
- Wave/Current design criteria modelling for pipelines and off-shore and on-shore facilities;
- Comprehensive tropical cyclone modelling, including winds, waves, currents and storm surge;
- Provision of accurate tidal prediction based on extensive 2D and 3D hydrodynamic ocean modelling.

Through it links with Australia's premier research institution, the Commonwealth Scientific and Industrial Research Organization (CSIRO), GEMS now includes satellite derived ocean elevation and large-scale ocean current data into its modelling suite. This state-of-the-art approach allows more accurate representation of ocean currents to be included in all ocean discharge applications. The methodology was applied successfully as part of a comprehensive Environmental Impact Assessment for the Woodside Enfield Project (and more recently for the BHP Stybarrow and Pyrenees studies) near the Ningaloo Marine Park.

The Australian Maritime Safety Authority (AMSA) has now fully implemented the GEMS atmospheric and oceanographic modelling suite into its Search and Rescue and Oil Spill Response systems. GEMS models provide the basis for on-going, round-the-clock spill response services for Chevron, Woodside, Apache and BHP-Billiton.

GEMS involvement with the oil industry in Australia dates back to its introduction of 3D modelling for oil spill trajectory modelling to the oil industry in the early 1990's. GEMS first undertook a series of tracking-verification exercises for WAPET in 1991. These verification studies demonstrated the need to model the ocean in three dimensions and to model at sufficiently high resolution to explain the flow in complex regions such as Barrow Island.

GEMS pioneered the stochastic approach to risk modelling, whereby the effects of inter-annual variability are treated intrinsically within the modelling program by running a large number of simulations commencing at randomly chosen times over several years.

3 Climate and Meteorology

The climate of the region is effectively dominated by two main seasons.

During the ‘dry’ season from May to October a belt of high pressure known as the sub-tropical ridge forms over the continent and results in semi-persistent easterly flow across the Pilbara. This flow may weaken and strengthen as individual high pressure centres evolve to the south in response to cold frontal activity. The easterly flow is characterised by low moisture content and stable weather conditions.

Warming of the continent following the winter solstice results in a gradual southward migration of the subtropical ridge. This has a two-fold effect by which the general strength of the easterlies weaken and a persistent ‘heat’ trough (area of low pressure) forms along the Pilbara coast. Over the greater Gorgon area, the general flow then trends to be more southwesterly. Closer to the coast diurnal variations in terrestrial temperatures cause local sea-breeze impacts to become important.

This general trend toward more westerly flow results in monsoonal flow across the tropical north. Episodic bursts in monsoonal activity results in increased tropical convection (thunderstorms) and convective clusters can form into discrete low pressure systems and, if conditions are conducive, these can eventually intensify to tropical cyclones.

Generally cyclogenesis occurs well to the north where sea temperatures are warmer; storms may then intensify as they track southwards. The direction of movement of the storms is generally controlled by upper atmospheric ‘steering’ – some storms track to the west under the influence of strong upper easterlies, but others can recurve towards the Pilbara coast. This situation can be conducive to rapid intensification and acceleration of the cyclones toward the Pilbara coast. More recent developments in numerical weather prediction and other forecasting techniques has allowed for more accurate forecasting of such events with longer advisory lead times.

In the past, much of the atmospheric forcing applied in the region has been based on the application of historic, single station (wind) data obtained from the nearest automatic or manual weather station to the site of interest.

This approach is often unsatisfactory since the single station data does not adequately represent the spatial variability of the governing climate conditions. GEMS has already moved to applying spatial and time varying data from numerical weather prediction (NWP) models to force its oceanographic models. The improvement in results based on this approach was verified in satellite tracked drifting buoy exercises carried out for the Woodside Enfield project between Northwest Cape and Barrow Island.

Data from the Bureau of Meteorology’s operational weather forecast model (LAPS - Limited Area Prediction System) is used for this purpose.

Meteorological measurements have been recorded at Barrow Island for many years and provide the ability to examine the behaviour of the local winds. The annual wind rose for Barrow Island, derived from 6 years of data (1999 - 2005), is given in Figure 3.1. These data are disaggregated into quarterly wind roses in Figures 3.2 to 3.5.

Figure 3.6 shows the results of an analysis of the occurrence of easterly or westerly wind events compared with the average during the years 1999 to 2005.

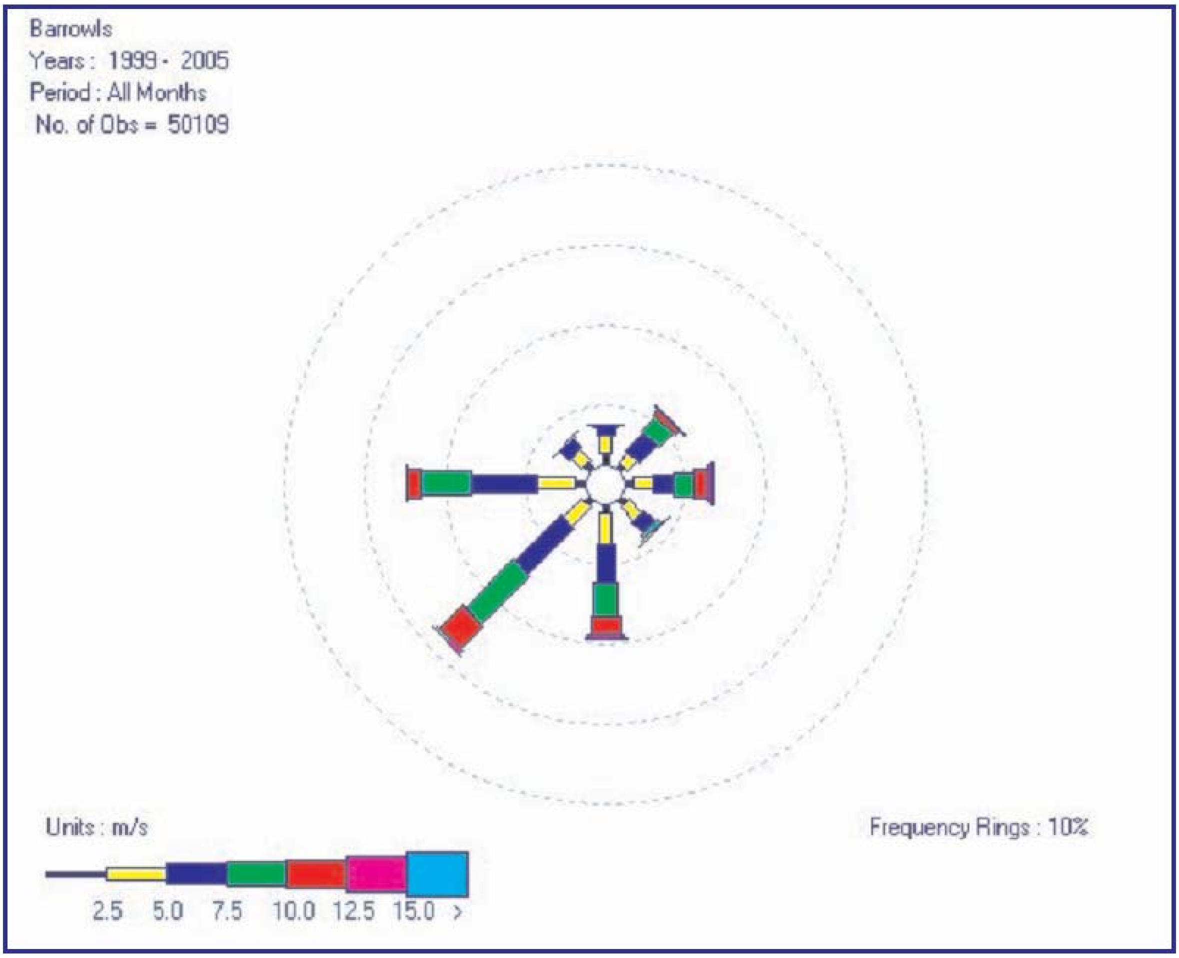

Figure 3.1: Annual wind rose for Barrow Island derived from the years 1999 to 2005.

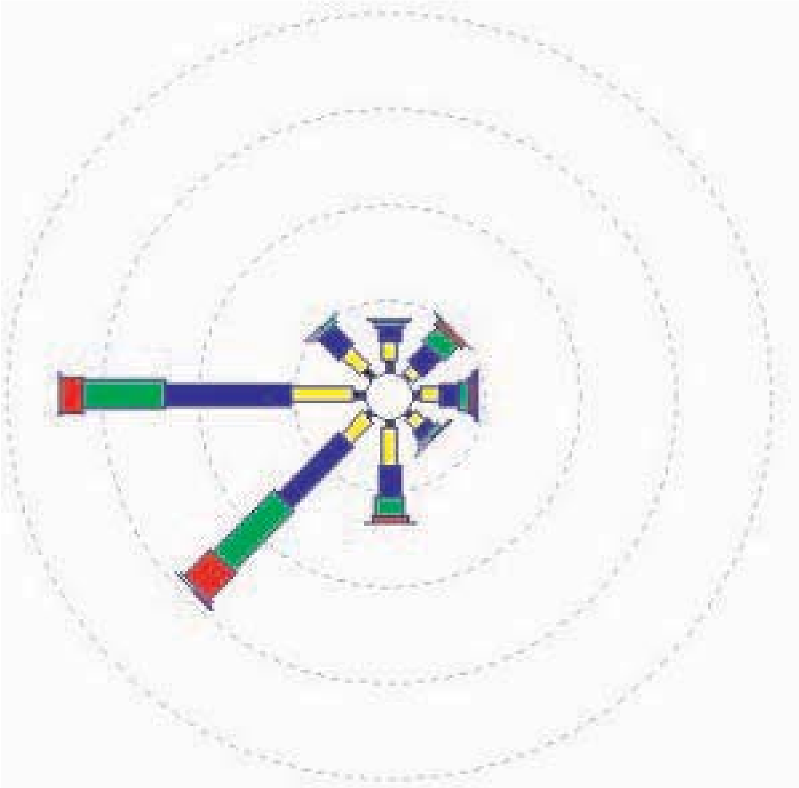

Figure 3.2: Wind rose for Barrow Island for January to March from 1999 to 2005.

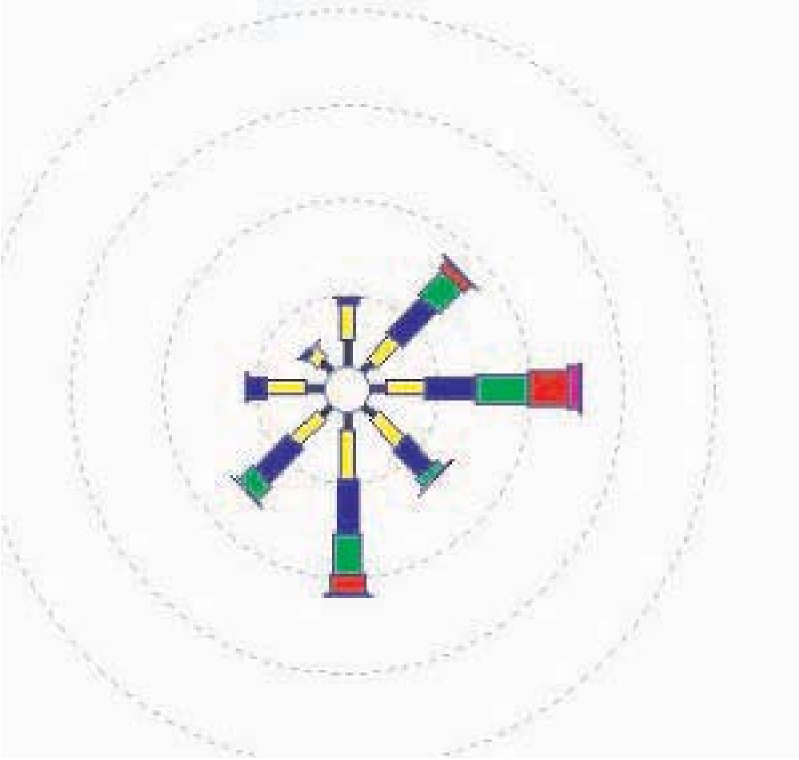

Figure 3.3: Wind rose for Barrow Island for April to June from 1999 to 2005.

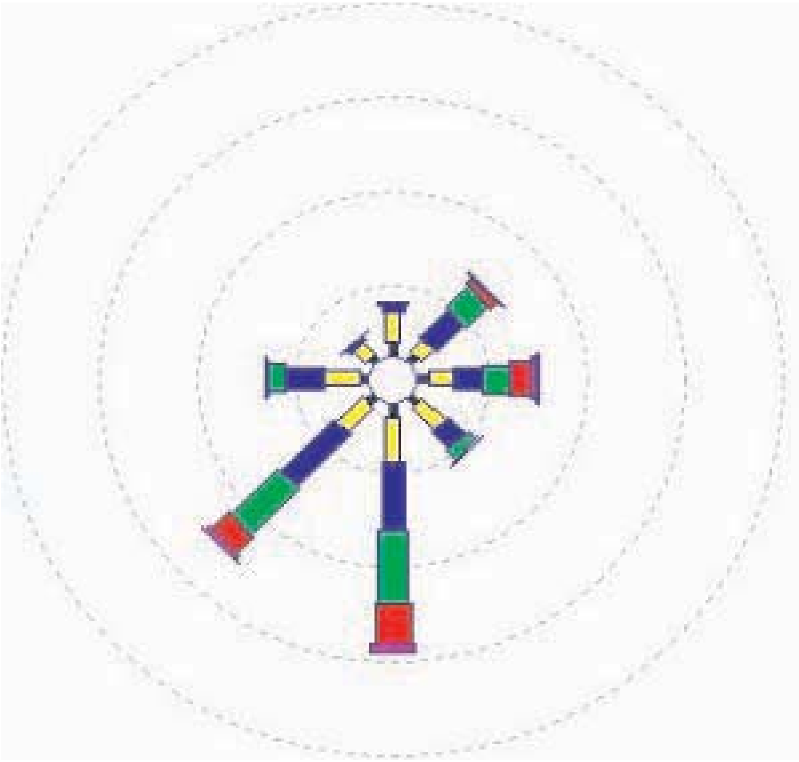

Figure 3.4: Wind rose for Barrow Island for July to August from 1999 to 2005.

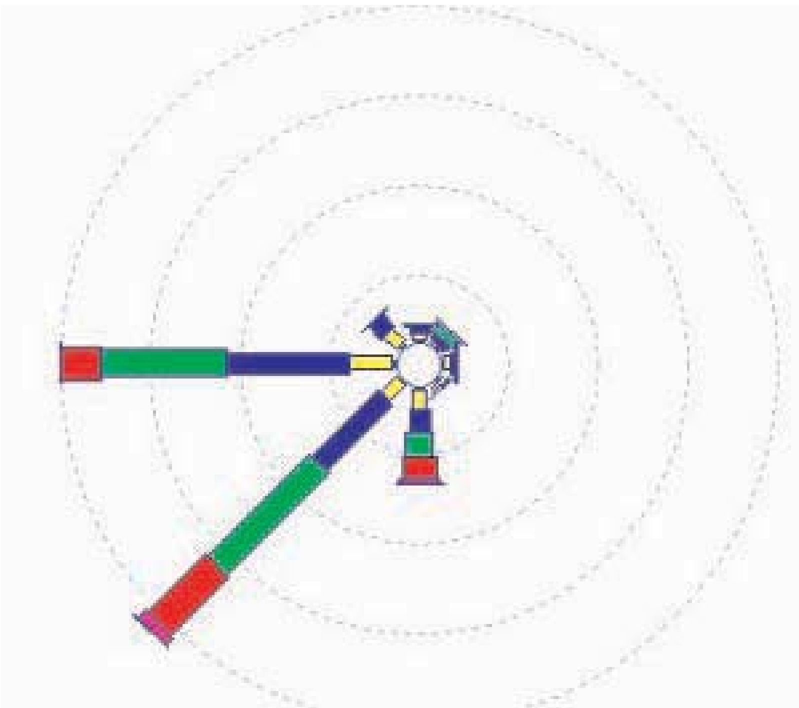

Figure 3.5: Wind rose for Barrow Island for September to December from 1999 to 2005.

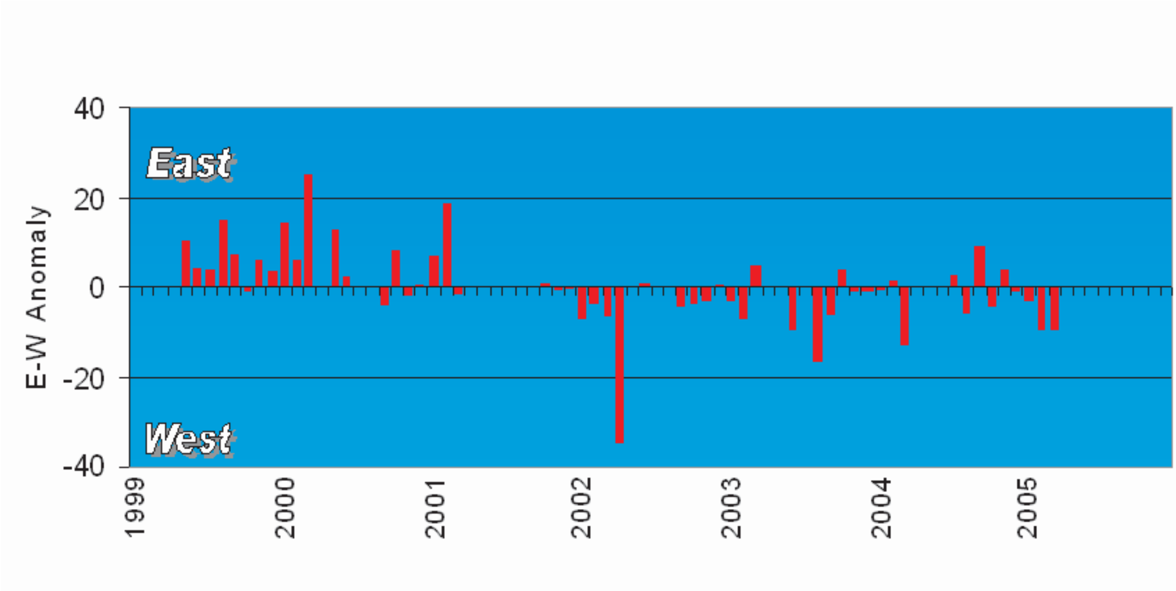

Figure 3.6: Analysis of the occurrence of easterly or westerly wind events compared with the average during the years 1999 to 2005.

4 GCOM3D and DREDGETRAK

4.1 Modelling the Physical Oceanography

The dominant influences on the circulation in the waters surrounding Barrow Island are the local wind and tides. This circulation can be simulated to a high level of accuracy using the GEMS three-dimensional ocean model (GCOM3D).

GCOM3D is a state-of-the-art 3D primitive equation ocean model, which has been developed by GEMS to study and predict ocean currents on or near the continental shelf and in harbours and estuaries anywhere on the globe. GCOM3D includes the non-linear advection terms and is driven by wind stress, atmospheric pressure gradients, astronomical tides, depth and terrain dependent bottom friction and ocean thermal structure (where relevant). For high-resolution studies over small regions GCOM3D can be nested in larger domains and still runs relatively fast on any modern computer (PC or UNIX).

For search and rescue applications and the tracking of buoyant discharges the surface ocean currents from GCOM3D are used. For oil spill modelling, water quality, sediment transport and other marine discharge studies, which often require an understanding of the vertical variation of the currents, the full three-dimensional current field is used.

GCOM3D is the longest serving three-dimensional ocean model in Australia. It was the first 3D ocean model to be used on a consulting job (Geelong Ocean Outfall, 1984) and has since been continuously developed in the research world and since the formation of GEMS in 1993.

GCOM3D has been used by the Australian Maritime Safety Authority in Canberra, as the national ocean forecast model for search and rescue (and oil spill prediction) for the past three years. During this time the model has been used at many locations around the Australian coastline and verified against SAR buoys (surface drifters) with only three cases in three years producing incorrect results. These cases have since been shown to be due to the influence of the East Australian Current, which has now been incorporated.

4.2 Dredge Modelling

Once the physical oceanography has been simulated it is possible to study the movement of discharges into the water column (e.g. sediments, chemicals etc.) or components of the water body itself (flushing rates of harbours, bays etc.).

The GEMS 3D Dredge Simulation Model (DREDGETRAK) is used either for simulating the ambient behaviour of coastal sediments under the influences of waves and currents or the specific fate of particles discharged during a dredging program. This model inputs the physical environmental data from GCOM3D, together with wave data and meteorological data, to simulate the movement and deposition, of suspended particles in the water body across the study area.

DREDGETRAK was used with great success in the Geraldton Port Redevelopment Project where it was extensively verified against in situ data, aerial photographs and satellite images.

In Western Australia it has since been used in Mermaid Sound for both the Dampier Port Authority and the Hammersley Iron port expansion projects and in New Caledonia for the INCO nickel processing plant and port development.

4.3 Model Forcing

Model forcing includes both wind and tides concurrently.

4.3.1 Meteorology

GCOM3D can be driven with gridded atmospheric model output or single station data. For this study wind observations at Barrow Island were used to represent the meteorology of the region. Data was obtained for a 6 year period from 1999 to 2005 and analysed.

Meteorological data for 2001 was chosen for the "typical" year as the wind rose for this year closely represented the long-term wind rose (Figure 3.1). The reason for this choice of time period can be more clearly seen in Figure 3.6 which shows the analysis of east-west anomalies in the six year wind record. This figure also underlines the selection of 2000 to represent the period containing more easterly events and 2002 to represent the period containing more westerly events.

4.3.2 Bathymetry

The bathymetric data sets held by GEMS were updated with bathymetry acquired by Chevron. The GEMS database has been developed from a range of sources including data from Geoscience Australia (formerly AUSLIG) and oil company surveys. Of particular relevance to this project is that the original 3D bathymetric survey of the Gorgon field is included together with the Apache Energy 3D bathymetric survey from south of Barrow Island to the Montebello Islands.

4.3.3 Tides

Tidal forcing was based on data from the GEMS Australian region gridded tidal data base which has been developed with extensive modelling programmes.

The tidal data for this project was enhanced with data from a high resolution tidal modelling project carried out by GEMS for Apache Energy in 1998.

5 Verification OF GCOM3D

Current measurements during August 2003 were available on the eastern side of Barrow Island and were used to compare with GCOM3D current predictions.

To verify GCOM3D a bathymetric grid covering the region in Figure 5.1 was set up at 100 metre resolution. Tidal data for the model boundaries was extracted from the GEMS database and winds from the Bureau of Meteorology were used to force the model.

GCOM3D was run for the month of August, 2003 producing hourly currents at between 5 and 15 levels in the water column (depending on the depth).

Figures 5.1 and 5.2 show examples of the flood and ebb tidal flow in the region respectively. Figures 5.3 and 5.4 show the good agreement obtained between GCOM3D predictions of current speed and direction and the observed data for the full month of August, 2003.

To augment this verification further measurements (including the release of drifters as recommended by the EPASU) are planned for later this year.

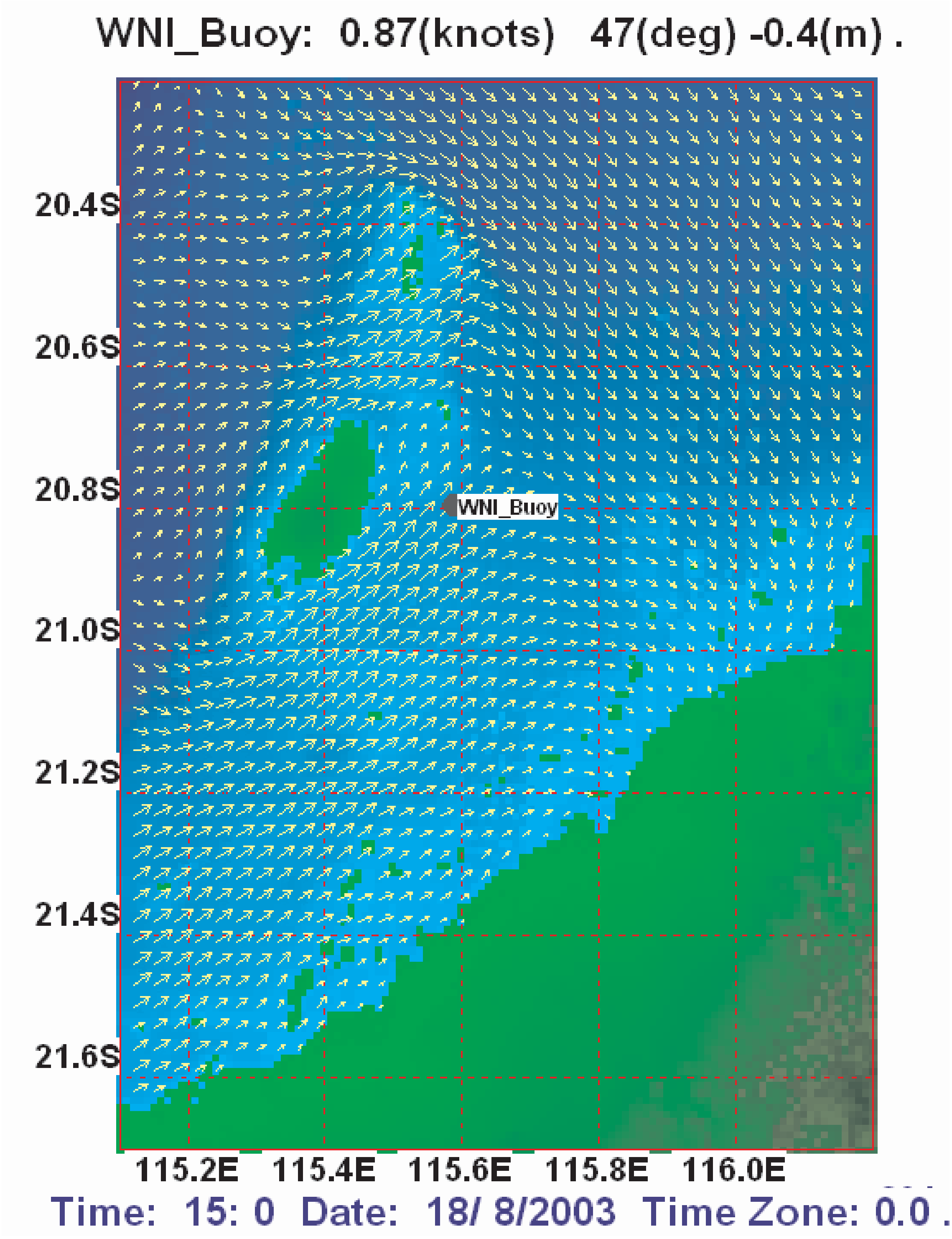

Figure 5.1: Example of the flood tide near Barrow Island predicted by GCOM3D.

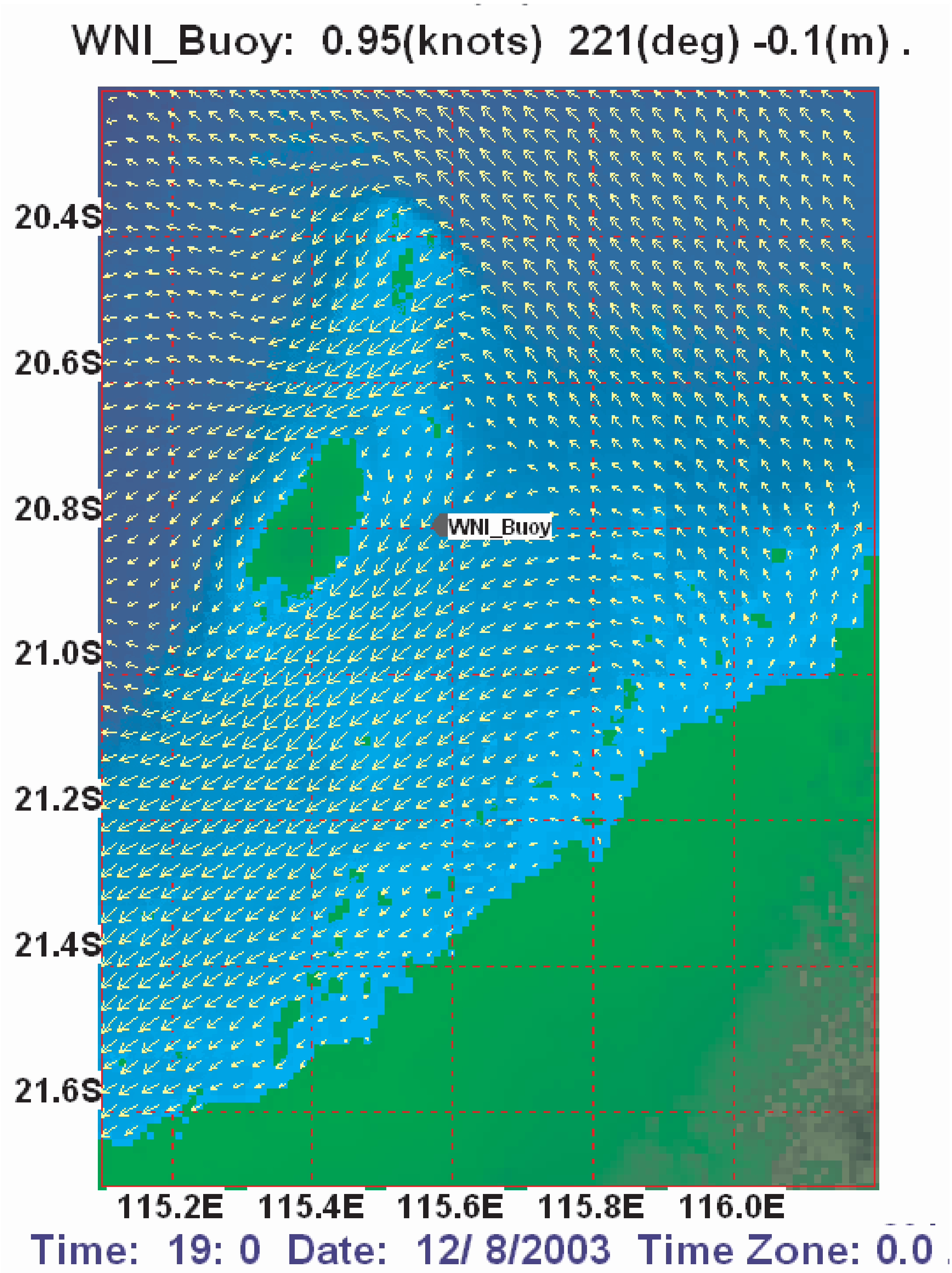

Figure 5.2: Example of the ebb tide near Barrow Island predicted by GCOM3D.

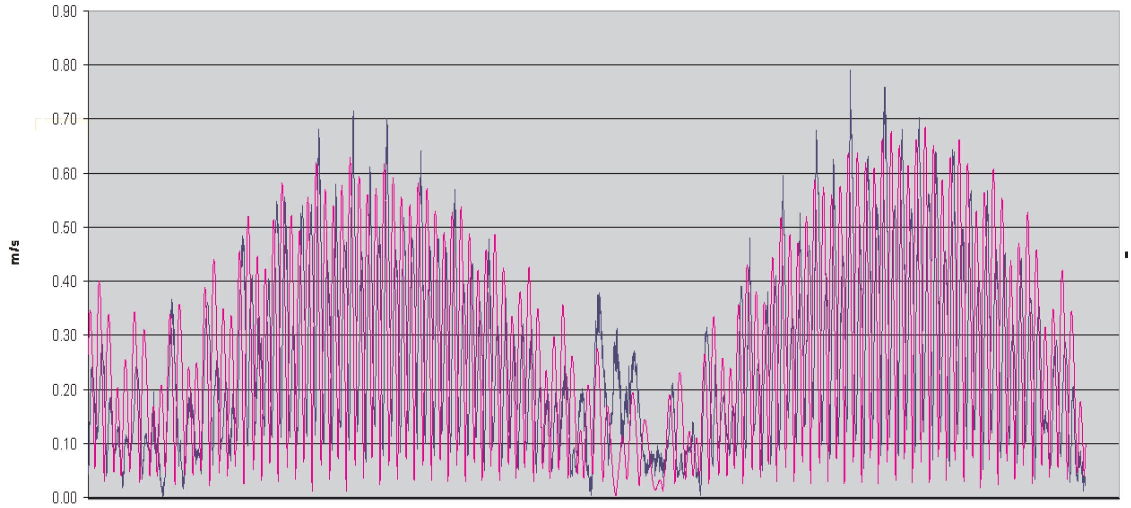

Figure 5.3: Comparison of current speeds measured with the WNI buoy (blue) and GCOM3D predictions (purple).

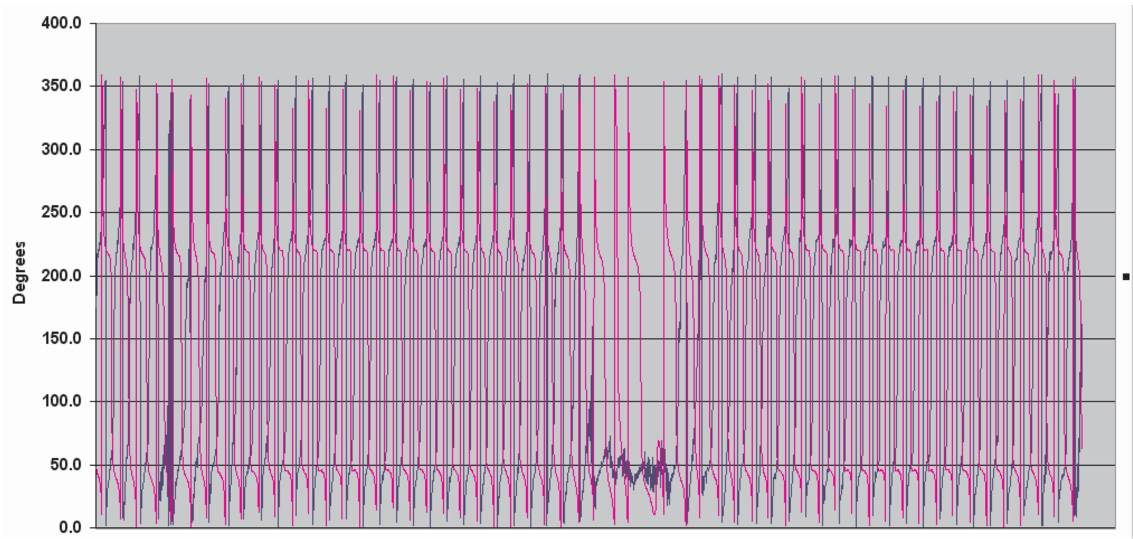

Figure 5.4: Comparison of current directions measured with the WNI buoy (blue) and GCOM3D predictions (purple).

6 Verification of Dredgetrak

The best verification of Dredgetrak available so far was carried out during the Geraldton Port dredging program. The results are described in this section.

6.1 Method

To establish predictions for the verification of the GEMS sediment plume model, a hindcast of the actual dredging program was carried out using the real-time wind, wave and dredge location/performance data. The hindcast was carried out from the commencement of dredging in October, 2002 until December 31, 2002 to generate fine particle loads in Champion Bay for comparison with TSS data collected in late November and December 2002 by the GPA.

The detailed tasks required to achieve these aims were as follows:

- Setup new model domain/bathymetry over a larger area than in previous studies
- Setup the sediment plume model with the new input data
- Process wind, wave and dredge location data from the commencement of dredging to December 31, 2002
- Hindcast ocean currents with the GEMS 3D Ocean Model (GCOM3D) driven by tides and winds from Geraldton Port for the period October 2002 to December 31 2002
- Hindcast turbid plume behaviour with the sediment plume model, driven by currents from GCOM3D, for the period October 2002 to December 31 2002
- Compare model predictions with satellite and aerial photos at four specific times in the prediction period.
- Analyse hindcast data to compare predicted TSS values with measured data in November and December 2002.

6.2 Results

Figure 6.1 shows the model region and the sites chosen for sampling TSS levels in Champion Bay. Figures 6.2 and 6.3 show sample surface currents from GCOM3D during the three month simulation under the influence of southerly and north-easterly winds respectively.

6.2.1 Comparison of Predictions with TSS Measurements

The results of the plume model predictions for TSS are compared with observations taken by the GPA on 7 days in late November and December in Table 1. The observed values shown in Table 1 are an average of all measurements taken in Champion Bay on the particular day. Since TSS measurements can vary significantly with small spatial or temporal changes it was considered to be more valid to compare regional averages rather than try and compare site-specific predictions and measurements.

Table 1 indicates that on December 5 the model exhibits a generally higher suspended sediment load in Champion Bay than recorded. On the other 6 days, however, the agreement is much closer. Given the potential errors in the input data (winds, dredge performance, particle distribution) the overall agreement must be considered to be very good.

6.2.2 Comparison of Model Predictions with Satellite and Aerial Photos

Comparison of model predictions with aerial or satellite photos can be misleading as it is impossible to determine what TSS values are contributing to the turbid plume in the images. Nevertheless a qualitative comparison can be made and such things as the basic path of the plume, denser areas etc. can be compared.

The GPA provided satellite images for November 26 and December 17, 2002 and aerial photos for October 30, December 5 and December 18, 2002. Comparisons are shown for these dates in the following figures:

a) Figures 6.4 and 6.5 compare the satellite image with model predictions on October 30, 2002.

b) Figures 6.6 and 6.7 compare an aerial photo with model predictions on November 26, 2002.

c) Figures 6.8, 6.9 and 6.10 compare aerial and satellite photos with model predictions on December 18, 2002

On the other three days of comparison with satellite and aerial photos the plume is predominantly moving northward and the predictions show similar paths and density patterns to the photos.

6.2.3 Outcomes

The qualitative comparisons with satellite and aerial photographs show similar features and density patterns although, as expected, agreement is by no means exact.

These qualitative results and the good agreement between predicted and measured TSS values on six out of the seven days suggests that the sediment plume model is simulating the sediment loads in Champion Bay very well and can reliably be used to predict the fate of turbidity from the dredging programme.

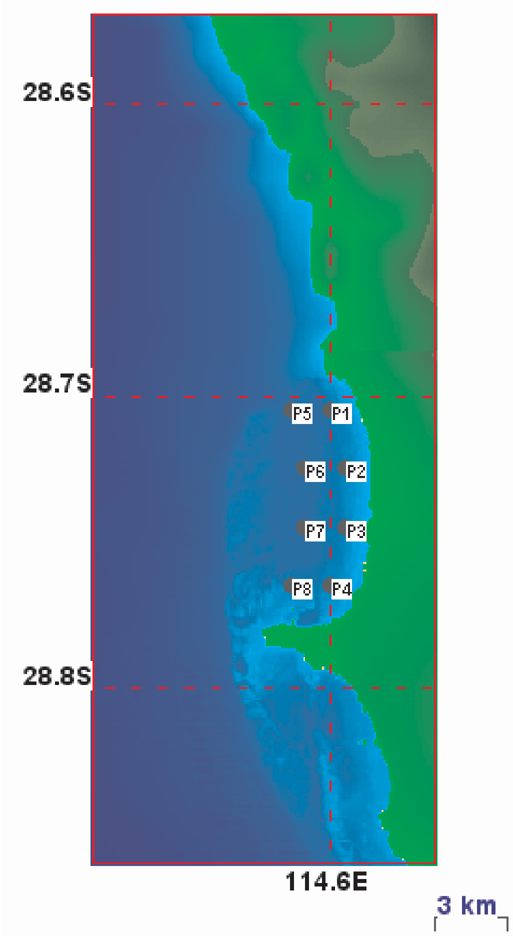

Figure 6.1: Model region showing TSS sites chosen for output in Champion Bay.

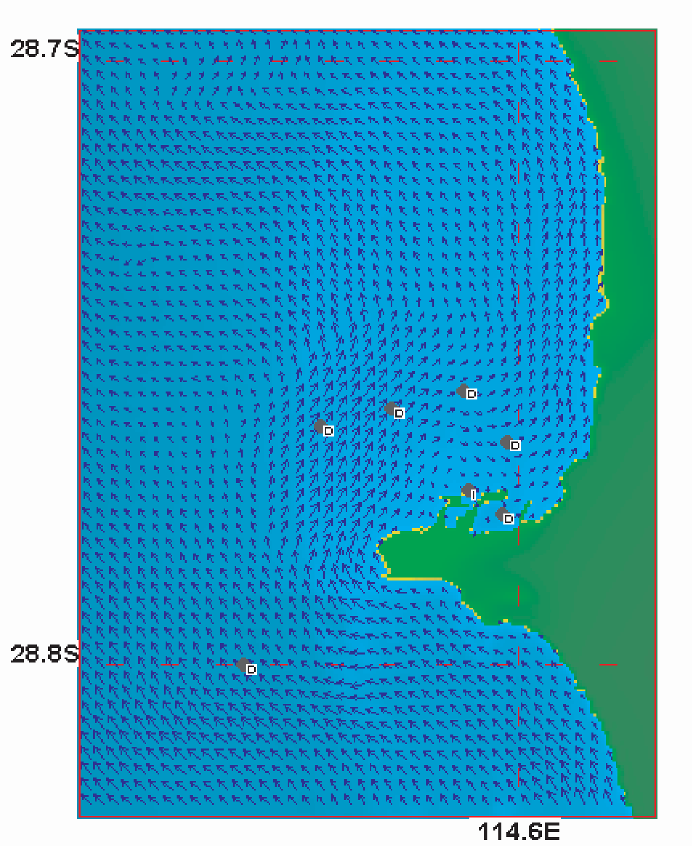

Figure 6.2: Sample surface currents from GCOM3D during southerly winds.

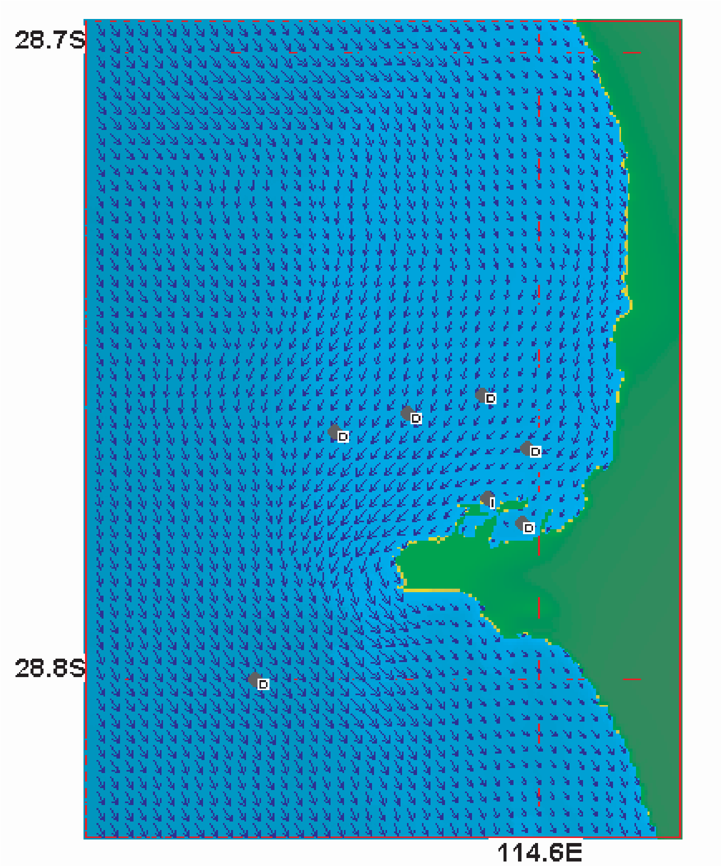

Figure 6.3: Sample surface currents from GCOM3D during north-easterly winds.

Table 1: Comparison of Predicted TSS values (P1-8) with measured values (TL1-21).

Site	TSS (mg/l)							
	Nov-28	Nov-29	Dec-05	Dec-06	Dec-10	Dec-24	Dec-27	Average
P1	5.4	7.3	9.7	6.1	4.9	3.4	1.3	
P2	5.2	3.0	8.8	2.6	3.9	3.5	1.1	
P3	4.9	2.5	6.0	4.6	2.0	3.5	1.0	
P4	4.2	2.2	5.6	3.5	3.0	1.8	0.4	
P5	4.2	5.4	8.7	6.3	4.5	3.3	5.4	
P6	3.6	2.3	8.7	3.4	2.9	2.7	5.0	
P7	2.9	1.6	5.6	4.2	1.7	2.5	5.4	
P8	2.7	1.0	5.5	3.3	1.9	1.0	2.3	
Average	**4.1**	**3.2**	**7.3**	**4.3**	**3.1**	**2.7**	**2.7**	**3.9**
TL1	5.8	1.2	2.6	1.7	4.7	1.2	2.9	
TL2	3.9	2.2	4.0	2.7	4.3	1.3	2.1	
TL3	3.4	3.3	2.9	3.0	1.8	0.9	2.4	
TL4	3.8	14.2	3.6	4.2	4.2	2.0	4.8	
TL5	3.1	1.9	6.0	2.7	2.6	1.6	1.9	
TL6	2.4	2.8	5.2	5.9	3.4	2.2	3.2	
TL7	9.3	2.7	4.5	2.0	2.5	1.4	3.1	
TL8	11.9	2.6	5.1	2.8	2.9	1.1	3.7	
TL9	6.7	2.2	5.0	3.3	1.8	5.1	5.6	
TL10	4.7	-	3.6	3.6	2.6	1.4	1.5	
TL11	-	2.9	3.1	4.4	2.7	1.6	2.1	
TL12	-	2.0	3.0	4.7	4.3	2.0	2.2	
TL13	3.4	2.7	5.4	5.3	2.8	1.2	1.6	
TL14	-	3.7	2.4	4.8	4.2	2.2	2.0	
TL15	-	2.7	2.6	4.5	4.0	4.1	1.8	
TL16	5.0	2.6	3.1	4.4	4.2	1.8	3.9	
TL17	-	2.7	2.8	4.4	3.4	1.3	2.9	
TL18	-	4.2	3.4	3.5	5.2	3.8	3.6	
TL19	-	3.6	2.9	4.1	3.3	2.8	2.3	
TL20	-	5.6	2.7	5.1	5.9	3.1	3.4	
TL21	4.2	4.6	7.2	4.6	3.7	6.1	3.5	
Average	**5.2**	**3.5**	**3.9**	**3.9**	**3.5**	**2.3**	**2.9**	**3.6**

Figure 6.4: Satellite photo of the turbid plume on October 30, 2002

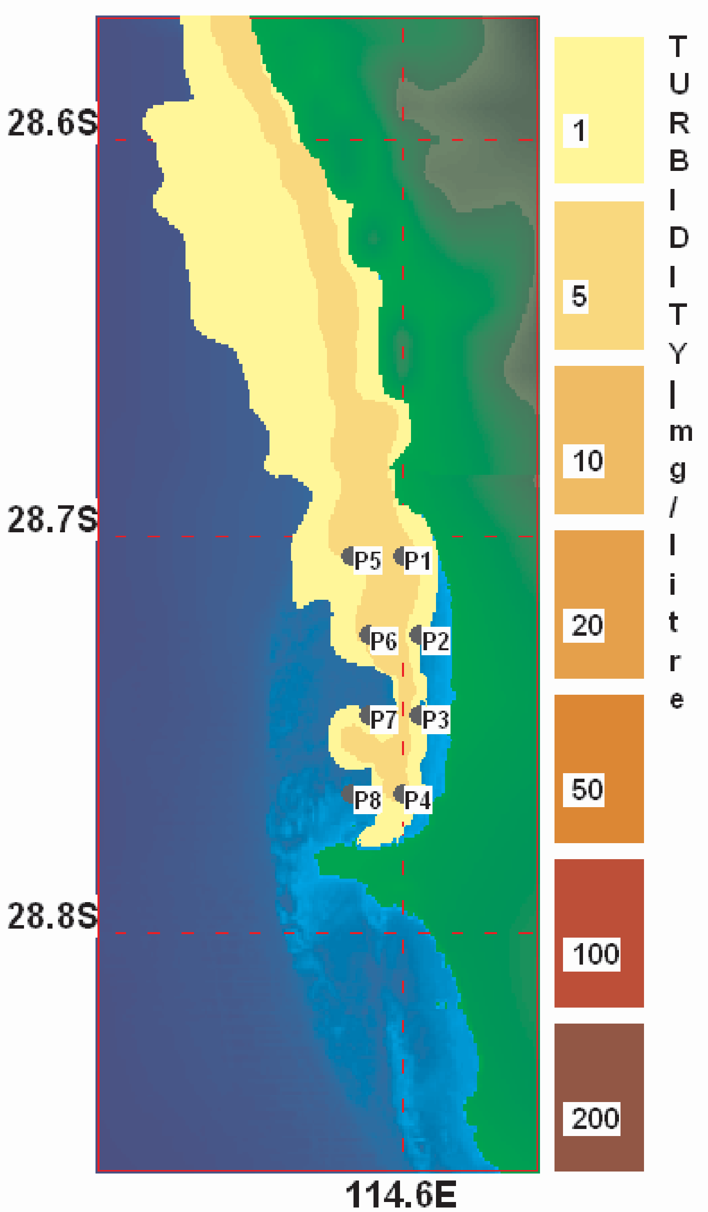

Figure 6.5: Model prediction for the turbid plume on October 30, 2002

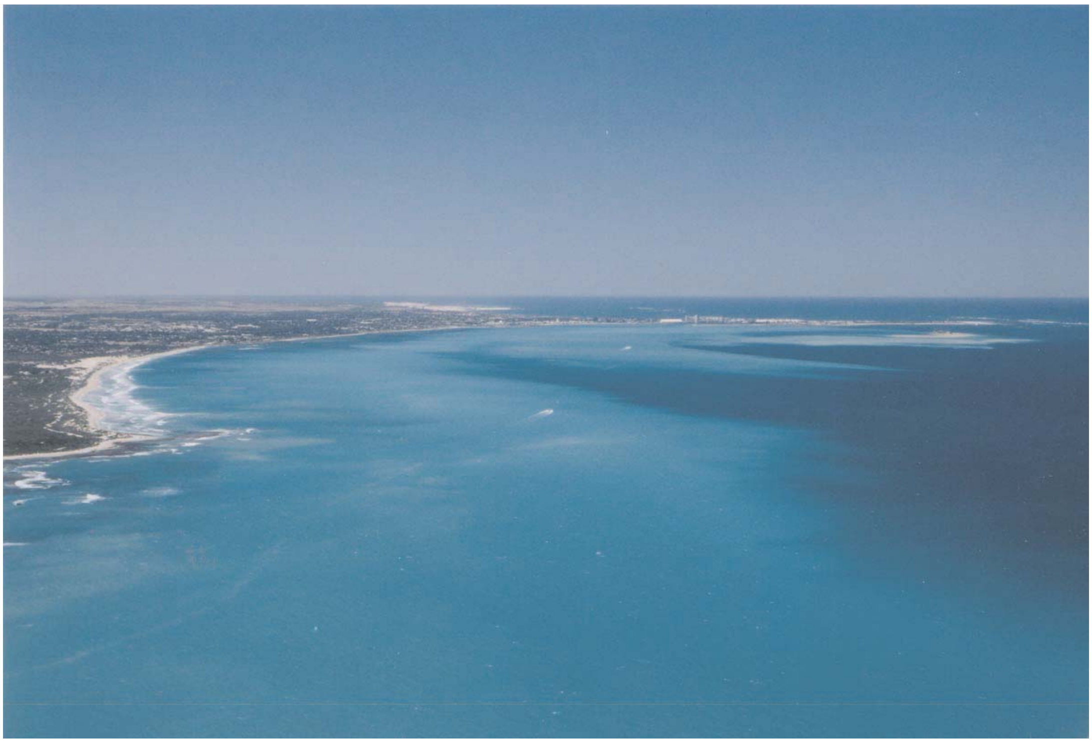

Figure 6.6: Aerial photo of the turbid plume on November 26, 2002

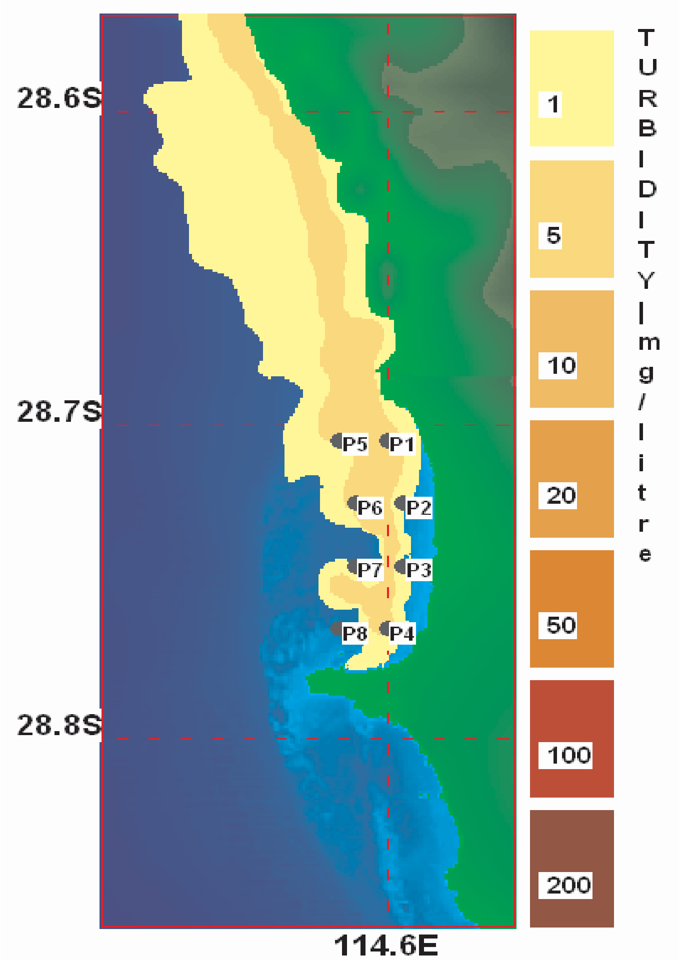

Figure 6.7: Model prediction for the turbid plume on November 26, 2002.

Figure 6.8: Aerial photo of the turbid plume on December 18, 2002

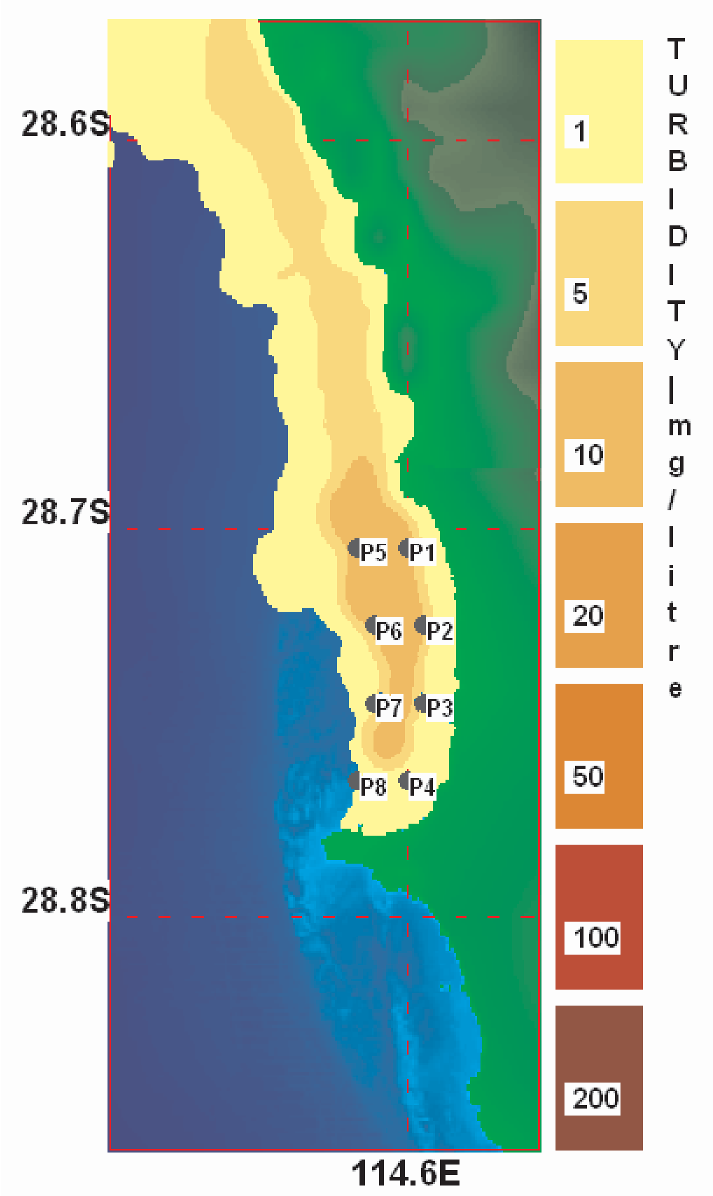

Figure 6.9: Model prediction for the turbid plume on December 18, 2002.

Figure 6.10: Satellite photo of the turbid plume on December 17, 2002.

7 Dredge Program Simulations with DREDGETRAK

The dredge 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 15 months using GCOM3D. Then the total dredge program was simulated over 464 days using DREDGETRAK which simulates the daily behaviour of the dredge(s) based on an estimated dredge log

Modelling relied on the best available meteorology and bathymetric information and included assumptions and details from other recent dredging programs in WA. Where there was uncertainty in model parameters, conservative values were chosen such that the model would tend to overestimate the impact. The modelling started in October (from the proposed dredging schedule) with pauses during coral spawning.

Modelling predicted the hourly distribution of Total Suspended Solids (TSS) and seabed coverage to be developed over the total dredge program (approximately 464 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 or a visible plume or a very small level of sedimentation.

7.1 Dredge Assumptions

For the model simulation of the dredging for the Material Offload Facility (MOF) the following assumptions were made (Box 7.1):

Box 7-1: 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 rock is believed to be harder on average than that encountered at Geraldton.
- The characteristics of the spoil are 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 (or more) weeks weather downtime.
- A mean dredge work rate of 96 hours of dredging per week. (actual 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.

- The dredge will start at outer end of the access channel and gradually work towards the shore creating a 6.5m deep channel (LAT).
- Maintenance will occur as needed. 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.
- It is assumed that 5% of total material cut will be below 75 microns and that the distribution of these particle sizes will be similar to Geraldton.
- It is assumed that 50% of these fines will be released at the cutter head and 50% from the tailwater discharge.

For the simulation of the dredging of the LNG access channel and turning basin on the eastern side of Barrow Island the following assumptions were made (Box 7-2):

Box 7-2: Summary of Assumptions for the LNG Access Channel and Turning Basin

- The total volume to be dredged is estimated to be 7 million m^3.
- Roughly 40% of the total volume in the LNG Access Channel and turning basin is sediment 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 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 TSD (-6 m depth).
- Overflow discharge will be approximately 8 m^3/sec (2 x 4 m^3 /sec dragheads).
- Fines within the sediments may be released.
- When dredging, without any controls on underkeel clearance, 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.
- The sands are coarser than the "rock flour" and the particle size distribution used in this part of the simulation is based on laboratory analyses of field samples taken from Development area.
- The harder material will be removed by a large CSD pumping directly into one of two self propelled hopper barges that will transport the material to the spoil ground.
- CSD dredge behaviour and production rates are anticipated to be similar to the MOF dredging rates described above (effective production of 96 hours/week).
- The duration of CSD dredging is anticipated to be 48 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.

7.2 Simulation 1: The "Base" Case

For the "base" case DREDGETRAK was used to simulate the behaviour of particles released into the water column by the dredges using the dredging program assumptions outlined in the previous section. The dredging was started on October 1, 2000 and finished on January 8, 2002 to cover the period of most average conditions. Turbidity and sedimentation data were stored hourly for each 1 m layer of the water column of the gridded study area.

Sample plots showing predicted TSS plumes during the dredging program are shown in Figures 7.1 and 7.2. These plots provide an insight to the variations that are likely to occur as a result of changes to dredge location, tidal phase and wind strength and direction during the dredging program.

When interpreting the results in Figures 7.1 and 7.2 the following issues should be noted:

- all plots show turbidity levels due to dredging alone, and the colour codes were chosen to distinguish the different concentration ranges. The latter should not be taken as any indication of water coloration or clarity.

- The turbidity levels were derived at each model grid point by scanning the water column from surface to bottom for the grid cell with the highest turbidity rather than averaging over the water column. The results therefore show the highest turbidity levels found across the grid.

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 impact criteria provided by RPSBBG are given in Table 2. These criteria were used to analyse the 464 days of model output to produce exposure zones showing regions affected by turbidity or sedimentation that result in high impact, moderate impact or influence (but no impact) (Figures 7.3 and 7.4).

Closer examination of the results showed that:

a) The dredging of the MOF contributed very little to the impact zones. In other words, although there was turbidity generated during the dredging, the major effects were very localised in the region surrounding the dredging and the bund overflow. Likewise the sedimentation occurred within a small distance from the dredging and did not occur in sufficient quantities elsewhere to violate the impact criteria, or even register as a zone of influence.

b) The region of moderate impact due to sedimentation, extending northward to the Lowendal shelf, is entirely due to material released into the water column by the propeller wash of the THSD. This material is then subject to strong tidal currents and southerly winds for several hours at a time allowing it to move, deposit, resuspend etc. during several tidal cycles to reach the Lowendal Shelf. A further point to note is that the algorithms for generating suspended sediments due to propeller wash in the model are not well proven and may be over-estimating the outcomes.

7.3 Simulation 2: The “Base” Case with UKC Controlled

A second simulation of 464 days of dredging was carried out with the same assumptions/parameters as in Simulation 1 but with UKC controlled to 4 metres.

As before, the coral impact criteria were used to analyse the 464 days of model output to produce exposure zones showing regions affected by turbidity or sedimentation that result high impact, moderate impact or influence (but no impact) (Figures 7.5 and 7.6).

These results showed a significant reduction in the moderate impact zone, particularly in the region extending north towards the Lowendal Shelf.

Note that the sedimentation threshold was different for the base ($2mg/cm^2$) and UKC controlled ($1mg/cm^2$) cases. This explains the differences in the area of influence in Figures 7.3 and 7.5 and gives an insight into the effect of a change in the lower threshold.

7.4 Simulation 3: The “Base” Case with more Easterly Winds

A third simulation of 464 days of dredging was carried out with the same assumptions/parameters as in Simulation 1 but the dredging was started on October 1, 1999 and finished on January 8, 2001 to cover the period containing higher than average easterly wind events.

The overall results from this simulation were similar to the “base” case but with slightly increased flushing during the winter months when the easterlies added to the westward flushing action of the ebb tide around Barrow Island.

7.5 Simulation 4: The "Base" Case with more Westerly Winds

A fourth simulation of 464 days of dredging was carried out with the same assumptions/parameters as in Simulation 1 but the dredging was started on October 1, 2001 and finished on January 8, 2003 to cover the period containing higher than average westerly wind events.

The impact of the greater incidence of westerly winds (reduced level of easterly winds) was evident in slightly higher occurrences of turbidity across the Lowendal Shelf and past Varanus Island. However minimal change in the impact zones resulted.

Table 2: The Coral Impact Zone Criteria Supplied by RPSBBG

Note:

a) Exposure for at least six hours during daylight hours was regarded as satisfying the exposure criteria

b) The minimum TSS level adopted for the zone of influence (zone 3) was 2mg/litre

c) The minimum sedimentation adopted for the zone of influence (zone 3) was 1mg/cm^2

Zone 1: High Impact

Variable	Timeframe	Concentration	Time (consecutive days)
TSS	Short	≥25 mg l^{-1}	5
	Medium	≥10 mg l^{-1}	20
	Long	≥5 mg l^{-1}	80
Sedimentation	Short	≥25 mg cm^{-2} d^{-1}	5
	Medium	≥10 mg cm^{-2} d^{-1}	20
	Long	≥5 mg cm^{-2} d^{-1}	40

Zone 2: Moderate Impact

Variable	Timeframe	Concentration	Time (consecutive days)
TSS	Short	≥25 mg l^{-1}	2
	Medium	≥10 mg l^{-1}	7
	Long	≥5 mg l^{-1}	20
Sedimentation	Short	≥25 mg cm^{-2} d^{-1}	2
	Medium	≥10 mg cm^{-2} d^{-1}	7
	Long	≥5 mg cm^{-2} d^{-1}	20

Zone 3: Visible Plume and Extent of Sedimentation

Variable	Timeframe	**Concentration** (Anything above background, but less than the moderate impact zone)	Time (consecutive days)
TSS	Short	>0 mg l^{-1} <25 mg l^{-1}	2
	Medium	>0 mg l^{-1} <10 mg l^{-1}	7
	Long	>0 mg l^{-1} <5 mg l^{-1}	20
Sedimentation	Short	>0 mg cm^{-2} d^{-1} <25 mg cm^{-2} d^{-1}	2
	Medium	>0 mg cm^{-2} d^{-1} <10 mg cm^{-2} d^{-1}	7
	Long	>0 mg cm^{-2} d^{-1} <5 mg cm^{-2} d^{-1}	20

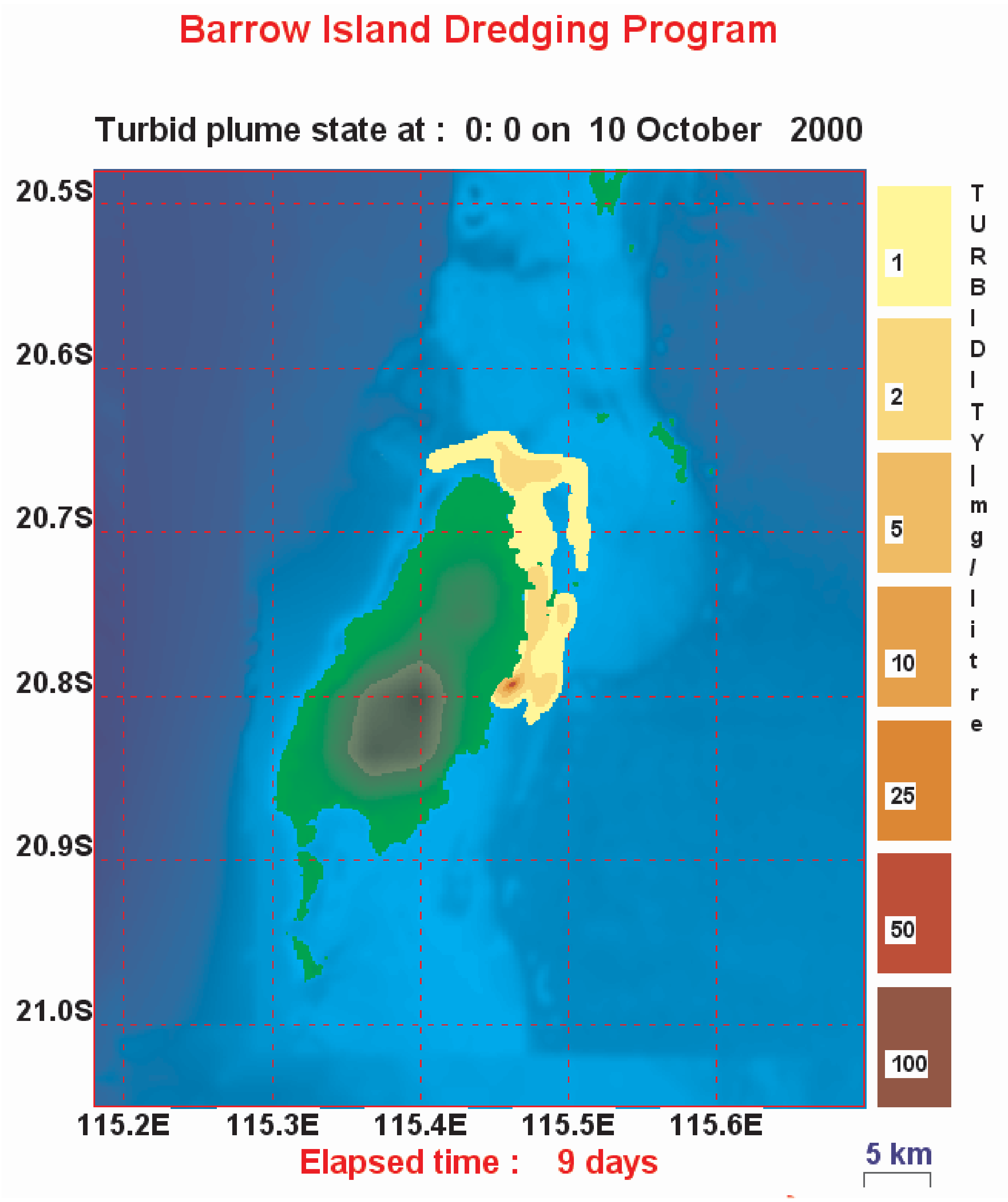

Figure 7.1: Sample TSS plot during dredging of the MOF by the CSD showing the flushing of turbidity around the northern end of Barrow Island.

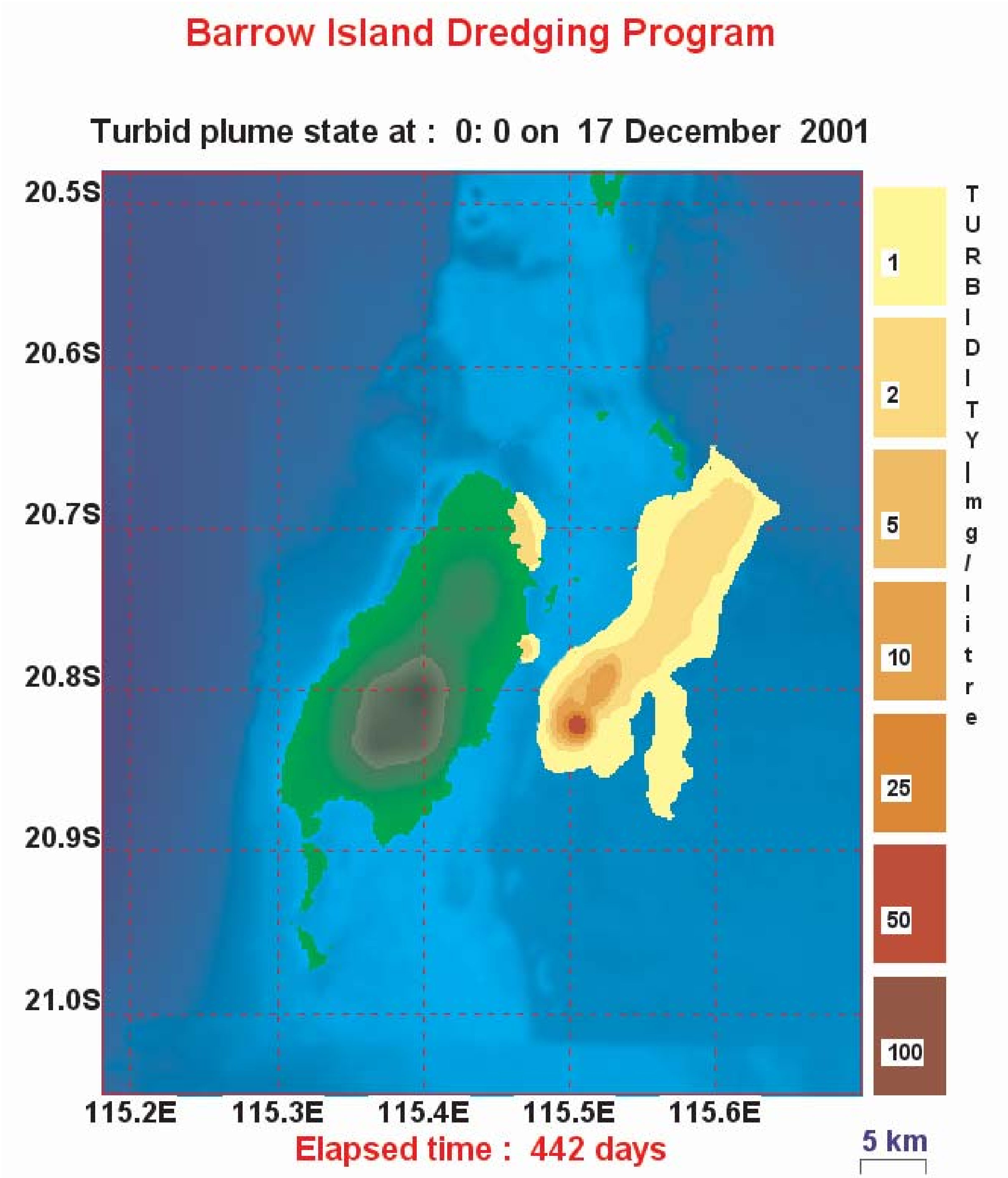

Figure 7.2: Sample TSS plot during dredging of the LNG access channel by the CSD in summer showing the effect of southwesterly winds.

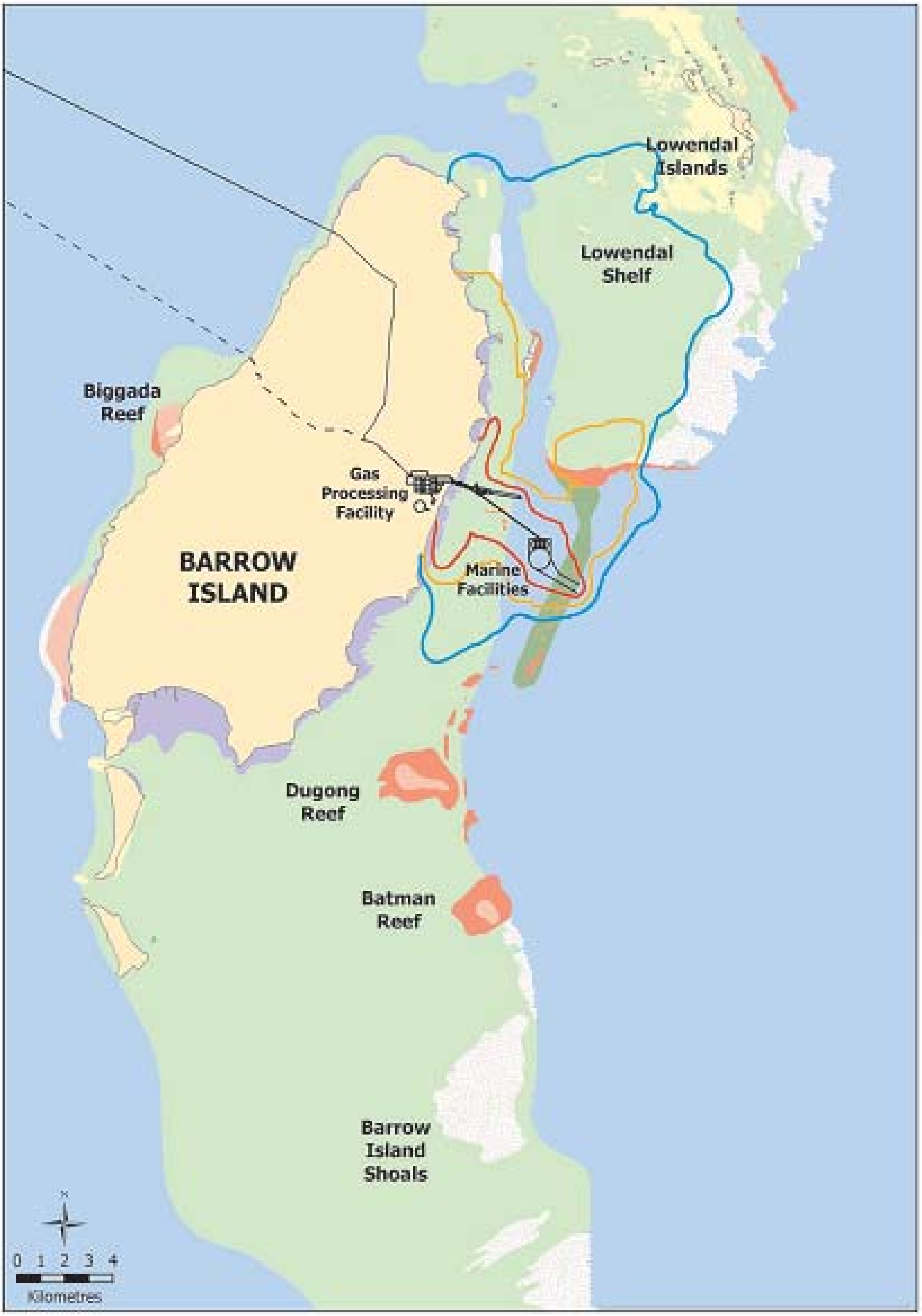

Figure 7.3 Mortality zones derived from sedimentation data for the "Base" case.
Level 1(red) = high impact,
Level 2 (orange) = moderate impact,
Level 3 (blue) = extent of sedimentation (2 mg/cm^2).

Figure 7.4: Mortality zones derived from TSS data for the “Base” case.
Level 1 (red) = high impact,
Level 2 (orange) = moderate impact,
Level 3 (blue) = visible plume (exposure above 2mg/litre).

Figure 7.5 Mortality zones derived from sedimentation data for the "Base" case with the UKC of the THSD controlled to 4 metres.
Level 1(red) = high impact,
Level 2 (orange) = moderate impact,
Level 3 (blue) = extent of sedimentation (1 mg/cm^2).

Figure 7.6 Mortality zones derived from TSS data for the “Base” case with the UKC of the THSD controlled to 4 metres.
Level 1 (red) = high impact,
Level 2 (orange) = moderate impact,
Level 3 (blue) = visible plume (exposure above 2mg/litre)..

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Technical Appendix B6

Quantification of Suspended Sediment Concentrations and Sedimentation Associated with Directional Drilling from the West Coast of Barrow Island

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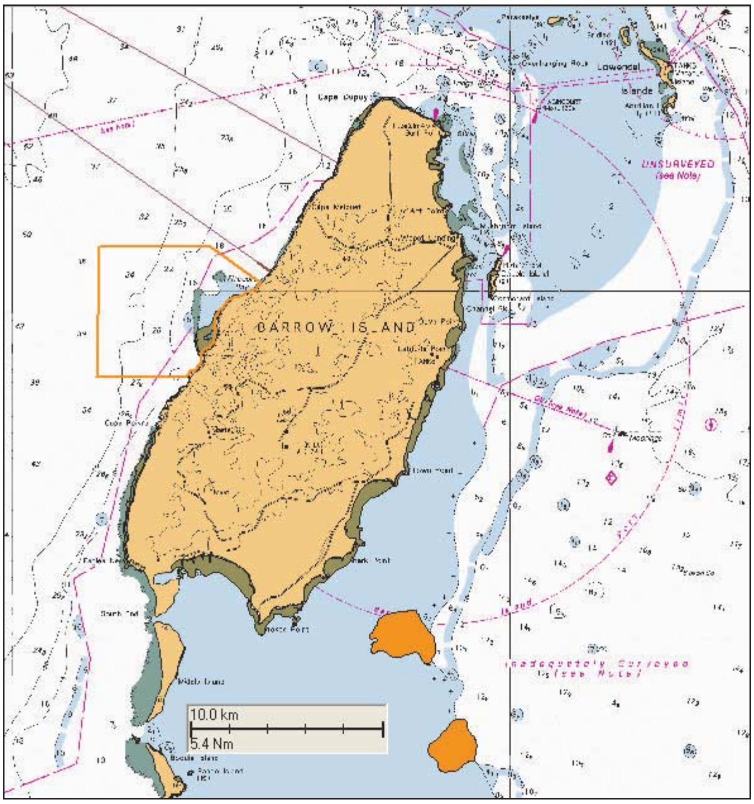
Quantification of Suspended Sediment Concentrations and Sedimentation Associated with Directional Drilling from the West Coast of Barrow Island

Comparison of Outcomes for Two Alternative Drilling Fluids (Bentonite Clay or Biodegradable Polymer) at Two Alternative Discharge Sites (Flacourt Bay or North White's Beach)



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Contents

Figures

Tables

1 Introduction

Chevron is proposing to construct feed gas pipelines and associated umbilicals from the Gorgon field, which is located to the north-west of Barrow Island, to a gas processing facility on the east coast of the island. The pipelines must be securely anchored to the seabed in the shallow waters approaching the island and at the shore crossing. While there are a number of alternative technologies that could be applied to anchoring of the pipeline, these vary in their logistical, environmental, and economic implications. A previous modelling study compared the sedimentation associated with dredging of a trench for burying the pipeline and directional drilling of conduits from the shoreline (APASA 2005a). While this study indicated that dredging would result in higher turbidity and burial of a larger area of seabed than directional drilling, the study raised concerns about the concentrations of bentonite clay that could accumulate on the local seabed if large quantities of this material, which is a weighting/lubricating agent, was discharged into the near-shore waters during directional drilling.

This report provides a further investigation of the outcomes of directional drilling, following development of alternative directional drilling programs, including investigation of alternative drilling fluids. In this study, modelling was undertaken to quantify and compare the sedimentation patterns that would be generated using either:

1. Bentonite clay, or
2. Water soluble polymer.

Two pipeline routes are under consideration. One route would be drilled from Flacourt Bay with the conduit breaking through to the sea approximately 1200m off the coast of Barrow Island. The alternative route would be from North White's Beach, in which case a shorter conduit length (approximately 600 m) would be required.

A common drilling plan was specified in each case, following a program specified by Chevron. This involved drilling multiple conduits as 10 separate drilling operations, each lasting approximately 1 week and with a break between each drilling operation of about 7-10 days. Thus, there would be 10 separate periods of continuous discharge separated by 7-10 days of nil discharge over a period of approximately 6 months. Chevron specified that this drilling would be carried out over June to December, based on other logistical and environmental considerations.

A sediment fates model (DREDGEMAP) was applied to represent the multiple discharges specified in the drilling program. Each simulation was carried out using unique samples of current data simulated for the June to December drilling window using a hydrodynamic circulation model (HYDROMAP). In this way, the modelling accounted for the seasonal and episodic variation in currents affecting the proposed discharge sites.

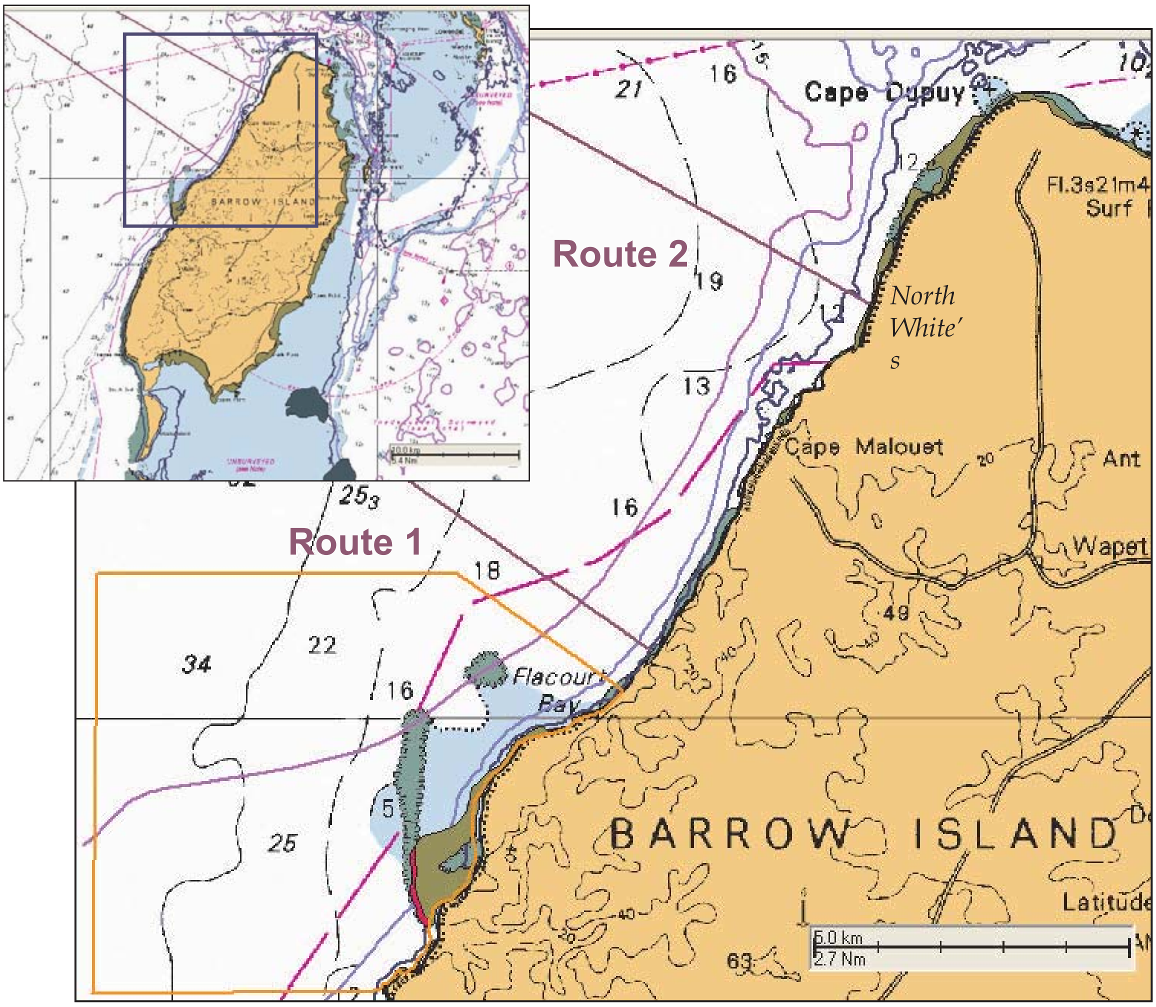

Figure 1: Study area showing the two alternative routes proposed for the Gorgon supply gas pipeline and location of fringing reefs (dark green), high diversity corals (red) and proposed marine park boundary (orange line). Inset shows the wider study area.

2 Hydrodynamic Circulation

Modelling of hydrodynamic circulation over the region was carried out using the three-dimensional hydrodynamic model, HYDROMAP, which has been validated for the study area (APASA 2005b). Full details of the model set-up are described in previous reports (APASA 2005 a, b). In brief, the model was operated in three-dimensional mode over a grid that extended 50 km west and 80 km east of Barrow Island. The grid resolution (i.e. grid size) was varied horizontally to focus upon the waters immediately surrounding Barrow Island. The grid had a horizontal resolution of 248 m along the west coast of Barrow Island. The model produced current data for 7 vertical layers.

The model was applied to predict circulation from wind and tidal effects. Because the drilling program is proposed for June to December, and thus spanning the winter, spring and summer seasons on the North West Shelf, the modelling approach was to apply HYDROMAP to produce a series of simulations, each spanning one week, using samples of archived wind data for these seasons. Care was taken to ensure that the simulations reflected the inter-annual and episodic variation in circulation over this period. This was achieved by randomly selecting weekly samples of wind data from each month spanning June to December. Data were available for this purpose from an 11 year long (1989-1998) record of hourly wind data from Barrow island. The model was then applied to produce week-long samples of circulations using the randomly selected samples of wind data and tidal conditions hind-cast for the corresponding time and date of the wind data.

3 Sediment Discharge Modelling

Sediment discharges associated with the alternative drilling fluids and pipeline routes were simulated using a three-dimensional sedimentation model, DREDGEMAP. This model estimates the transport, sinking and settlement of mixed particle-sized sediments suspended by dredging or discharges to calculate concentrations of suspended solids within the water column and rates of sedimentation to the seabed. Generic details of this model have been described in a previous report (APASA 2005a).

DREDGEMAP was applied to quantify the time-evolving concentrations of suspended sediments and sedimentation patterns generated by four configurations of drilling-fluid type (bentonite clay or water-soluble polymer) and discharge location (Flacourt Bay or North White's Beach).

Chevron defined an average discharge rate of 5.95 $m^3\ hr^{-1}$ (inclusive of fluids and sediments). This rate was used to define the quantity of drilling fluid that would be discharged per drilling operation, taking account of the conduit lengths required at each site (Table 1). Conduits required for Flacourt Bay (1200 m) would be twice the length of those required at North White's Beach (600 m). Thus it was assumed that each discharge would last for 10 days at Flacourt Bay and 5 days at North White's Beach for the same discharge rate. For the case where bentonite clay was added to the drilling fluid, an average dosing rate of 60 kg/m^3 was specified. Thus, based on the average fluid discharge rate, bentonite solids would be discharged at an average rate of 3,571.4 kg/hr. For the case where water-based polymer was used, the drilling fluid was assumed to add no solids to the discharge.

The discharge was assumed to contain cuttings removed from the conduits. Chevron specified that there would be eight conduits required and that these would range in size. There would be a requirement for two each of a 4 inch, 8 inch, 30 inch and 90 inch conduit. These diameters and the conduit lengths required for each site were used to calculate the total volume of cuttings that would be produced at each site. It was assumed that 75% of this volume would be discharged. These estimates yielded an average discharge rate for cuttings of 24.75 m^3/hour, which translates to an average discharge of 66.83 kg/hr based on the density of the principal rock type (Trealla Limestone). These rates were then used to estimate the total mass of sediments that would be discharged for each combination of drilling fluid type and discharge location (Table 1).

DREDGEMAP required specification of the size distribution of solids that would be discharged. Five major size classes were specified, ranging from clay to coarse sand and larger particles. Cuttings were assumed to principally consist of clay to silt-sized particles (85% by mass, Table 2), due to the requirement to cut through the relatively hard Trealla Limestone. Bentonite was assumed to consist of clay sized particles. Table 2 summarises the combined size distributions that were calculated for each discharge type.

DREDGEMAP was used to simulate 10 independent discharges of each combination of discharge type and location (40 simulations in total) using the hydrodynamic data described in Section 2. The model produced estimates for the above-background concentration of suspended sediments (mg l^{-1}) within each depth layer of each grid cell of the model at hourly intervals. These estimates were used to identify locations where instantaneous concentrations were expected to exceed defined thresholds. Because the frequency and duration of exposure are more indicative of the potential for impacts on local biota, outputs were further processed to identify locations where threshold concentrations were exceeded more chronically. Exceedance of a suspended solid concentration of 25 mg l^{-1} at least once per day for five consecutive days was treated as indicative of a high probability of mortality to corals based on a review by RPS-BBG of available information on the impacts of suspended solids on corals.

DREDGEMAP also calculated the total sedimentation (i.e. mass settling onto the seabed, as mg cm^{-2}) and sedimentation rates (mg cm^{-2} d^{-1}) within each grid cell from each period of discharge. Data for total sedimentation from each of the 10 discharges of a particular site and drilling fluid type were further analysed to produce an estimate of the cumulative sedimentation from the full drilling program. For these calculations, it was assumed that sediments did not subsequently resuspended and drift between consecutive discharges. It is noted that estimates for cumulative sedimentation would be conservative (i.e. overestimated) if resuspension and transport of sediments are significant. This would be particularly true for locations that initially receive highest concentrations from the initial discharges. Conversely, results are likely to underestimate the total area that could be affected by low levels of sedimentation due to subsequent resuspension and drift of sediments over longer time frames.

Table 1: Assumed Discharge Rates for Each Discharge Type and Site

	Bentonite		Water-soluble polymer	
Parameter	**North White's Beach (600 m conduits)**	**Flacourt Bay (1200 m conduits)**	**North White's Beach (600 m conduits)**	**Flacourt Bay (1200 m conduits)**
Bentonite Discharge rate (kg/hr)	3571	3571	0	0
Cuttings Discharge rate (kg/hr)	67	67	67	67
Total solids discharge rate (kg/hr)	3638	3638	67	67
Mass per discharge (kg)	436,590	873,181	8,019	16,038
Mass per 10 discharges (T)	4,366	8,732	80	160

Table 2: Assumed Size Distribution of Sediments within Discharges Produced by Drilling with Bentonite or Water-based Polymer

	Bentonite		Water-soluble polymer	
Size class	**Discharge mass rate (kg/hr)**	**% by mass**	**Discharge mass rate (kg/hr)**	**% by mass**
Clay	3591.05	98.7	20.05	30
Fine silt	26.73	0.7	26.73	40
Coarse silt	10.02	0.3	10.02	15
Fine sand	6.68	0.2	6.68	10
Coarse sand or larger	3.34	0.1	3.34	5

4 Results

4.1 Suspended Sediment Concentrations

Simulations indicated that sediments suspended by discharging from the conduits would tend to drift southwards from the Flacourt Bay site and northwards from the North White's Beach site (Figure 2 and 3), reflecting the strong influence of tidal currents on local hydrodynamic flows. Analysis of the vertical and horizontal distributions of discharged material by particle-class indicated that coarser cuttings material will tend to settle locally (< 1 km) to the discharge sites, but clay (contributed by bentonite) and fine silt (generated by rock drilling) would remain suspended in the lower water column for extended periods of time (days). Current speeds are predicted to be too high to allow faster settlement of these fine particles.

If bentonite is discharged from Flacourt Bay, elevated levels (> 1 mg/l above background) of suspended sediments are expected to potentially extend beyond Boodie Island at times. Locations as far south as Middle Island are expected to experience instantaneous concentrations > 25 mg/l. There were relatively minor differences in the potential zone of influence predicted from simulations using currents predicted for June through to December, indicating that the tidal currents predominate. Onshore winds typical of summer tended to result in material drifting closer to the coast compared to winter, when offshore winds are more common. Instantaneous concentrations of bentonite at > 250 mg/l where predicted to occur up to 8 km south of the Flacourt Bay discharge site at any time from winter to summer. Biggada Reef was predicted to experience instantaneous concentrations exceeding 300 mg/l during all simulations of discharge from this site.

Simulations of bentonite discharge from the North White's Beach site indicated that elevated concentrations of bentonite (at up to 150 mg/l) would consistently occur around the North end of Barrow Island. Bentonite particles were predicted to migrate northwards and to become trapped within the strong tidal currents that operate in this area, although some bentonite is also expected to drift southward along the coast under winter conditions. Figure 4 shows predictions for the plume that could be generated by discharge at North White's Beach at hourly steps. Results show that material is likely to be transported clockwise around the northern end of Barrow Island on a flooding tide, but will tend to migrate directly westward on an ebbing tide. Consequently, sediments are not expected to migrate back towards the discharge site. Reversal of the strong tidal flows around the north end of the Barrow Island were also predicted to result in a concentration of the suspended plume at the change of each tide (e.g. see steps C to D in Figure 4).

Analysis of the time-varying concentrations expected over given locations (Figures 5-8) indicated that movement of the plume is likely to result in repeated episodes of relatively short-term exposure, rather than chronic exposure. Typical return periods between exposure to elevated concentrations varied from location to location and with the discharge site. In general, locations along the west coast are expected to have shorter return periods (i.e. more chronic exposure) because tidal migrations are shorter along this coast. In contrast, locations off the north-east coast of Barrow Island are only expected to experience elevated concentrations twice per day at the top of each tide (i.e. at the end of each flood).

Table 3 lists the criteria that were specified by RPS-BBG as indicative of impacts of sedimentation and suspended sediment on corals, based on a review of the available literature. The criteria for suspended sediments relate to impacts through suppression of light levels and thus consider exposure during daylight hours only. Based on these criteria, discharge of bentonite at North White's Beach would be expected to cause total mortality only to corals in the immediate vicinity (within < 200 m) of the discharge. Partial mortality would be expected over a 3 km long strip extending south of the discharge and the zone of influence would extend from approximately 4 km south of the discharge to the north-east corner of Barrow Island (Figure 9).

Table 3: Criteria Used to Judge the Significance of Suspended Sediment Concentrations

Effect	Time frame	Concentration	Rate of occurrence	Consecutive days
Total coral mortality	Short	$\geq$25 mg l^{-1}	> 6 hours per daylight period*	5
Partial coral mortality	Short	$\geq$25 mg l^{-1}	> 6 hours per daylight period*	2
Zone of Influence (no mortality)	Short	$\geq$1 mg l^{-1}	> 1 hour at any time	1

* 6 am to 6 pm

It should be noted that bentonite may cause other impacts beyond reduction of light levels, such as interference with feeding or smothering of polyps, and thus the threshold concentrations and consideration of day-time exposure only may not be appropriate to judge potential impacts on corals. The time-series results showing expected changes in suspended solid concentrations over time (e.g. Figures 6 and 8) would be more appropriate in this case.

Discharge simulations assuming that cuttings are released with a water-based polymer indicated a much reduced zone of potential influence by suspended sediments in comparison to the bentonite case (Figures 10 and 11). Suspended solid concentrations were not expected to exceed 25 mg/l beyond the immediate location of each discharge and concentrations > 1 mg/l suspended sediments were only expected to occur within 2-3 km. Plumes with > 1 mg/l were predicted to only cover an average area of 0.05 km^2 at any given point in time (compared to 5 km^2 with bentonite). Similarly, concentrations of suspended sediments expected over time at any location were two orders of magnitude lower where bentonite was not discharged. This effect is illustrated in Figure 11 for a location on Biggada Reef, given discharge at Flacourt Bay under identical conditions with and without bentonite. Based on the criteria given in Table 3, partial or total coral mortality would not be expected for any location beyond the immediate discharge.

Suspended sediment concentrations quoted here were based on multiple simulations under different conditions and assumed that there were no background concentrations of suspended sediments generated by previous discharges. Tests for overlap between simulations, by running simulations for up to 15 days beyond the end of discharge indicated that some bentonite could still remain suspended within the study area after 7-10 days, but cuttings sediments were not expected to remain suspended for more than five days. These results indicate the potential for compounding of the suspended sediment concentrations for bentonite from one discharge to the next. It should also be noted that modelling assumed that sediments did not resuspend after settling. However, as the west coast of Barrow Island is subject to wave action, there is also the potential for compounding of the suspended sediment loads by fine sediments that have been resuspended by wave action. Studies by Environment Canada indicate that bentonite can be readily resuspended into the benthic layer by wave action, but the material then sinks when waves dissipate (Milligan *et. al*. 1996).

4.2 Sedimentation

Calculation of cumulative sedimentation, based on combining the sedimentation resulting from each of the ten independent discharges for each combination of site and discharge type and assuming that there is no resuspension and redistribution of sediments between each period of discharge, indicated that a significantly larger area of seabed would be impacted if bentonite was used as the drilling fluid (Figure 12 to 15). Bentonite discharged at Flacourt Bay was predicted to settle along the full extent of the Barrow Island coast from Boodie Island to the north-eastern corner of Barrow Island (Figure 12). Concentrations within Flacourt Bay were predicted to exceed 12 kg/m^2 near the discharge and concentrations > 1 kg/m^2 are expected to extend up to 3 km to the north and south of the discharge site. Concentrations > 10 kg/m^2 are predicted to accumulate on Biggada Reef. In contrast, a much reduced sediment pile was predicted for discharge of cuttings with polymer (Figure 13). Concentrations were predicted to peak at approximately 500 g/m^2 around the discharge and at < 150 g/m^2 on Biggada Reef.

Discharge from North White's Beach is expected to result in sedimentation over the tidal channel around the north end of Barrow Island (Figure 14). A more even spread of sediments with lower peak concentrations were predicted for discharge at this site due to the higher current speeds to the north. Peak concentrations were predicted to occur on the reefs and channel edges along the tidal path. Discharge with bentonite was predicted to result in peak concentrations at up to 10 kg/m^2 adjacent to the discharge point and up to 5 kg/m^2 on some of the reefs. In contrast, discharge with polymer is expected to generate peak sedimentation of < 250 g/m^2 at the discharge point and < 100 g/m^2 on reefs along the tidal path (Figure 15).

Results indicate that a continuous layer of sediments would be expected on the seabed within an elliptical area surrounding the discharges. The area was predicted to be considerably larger for bentonite discharge compared to polymer-based discharge. As stated, these results assume no re-suspension of sediments. If resuspension is an important process, then resuspended sediments would be subject to the tidally-dominated currents acting over the study area and thus, over the shorter-term, would be expected to redistribute within the same area of effect predicted for first settlement. Consequently, resuspension is likely to result in a more even distribution of sediments rather than an increase in the field of effect. Thus, results presented here would tend to overestimate the near-field concentrations but under-estimate the far-field concentrations.

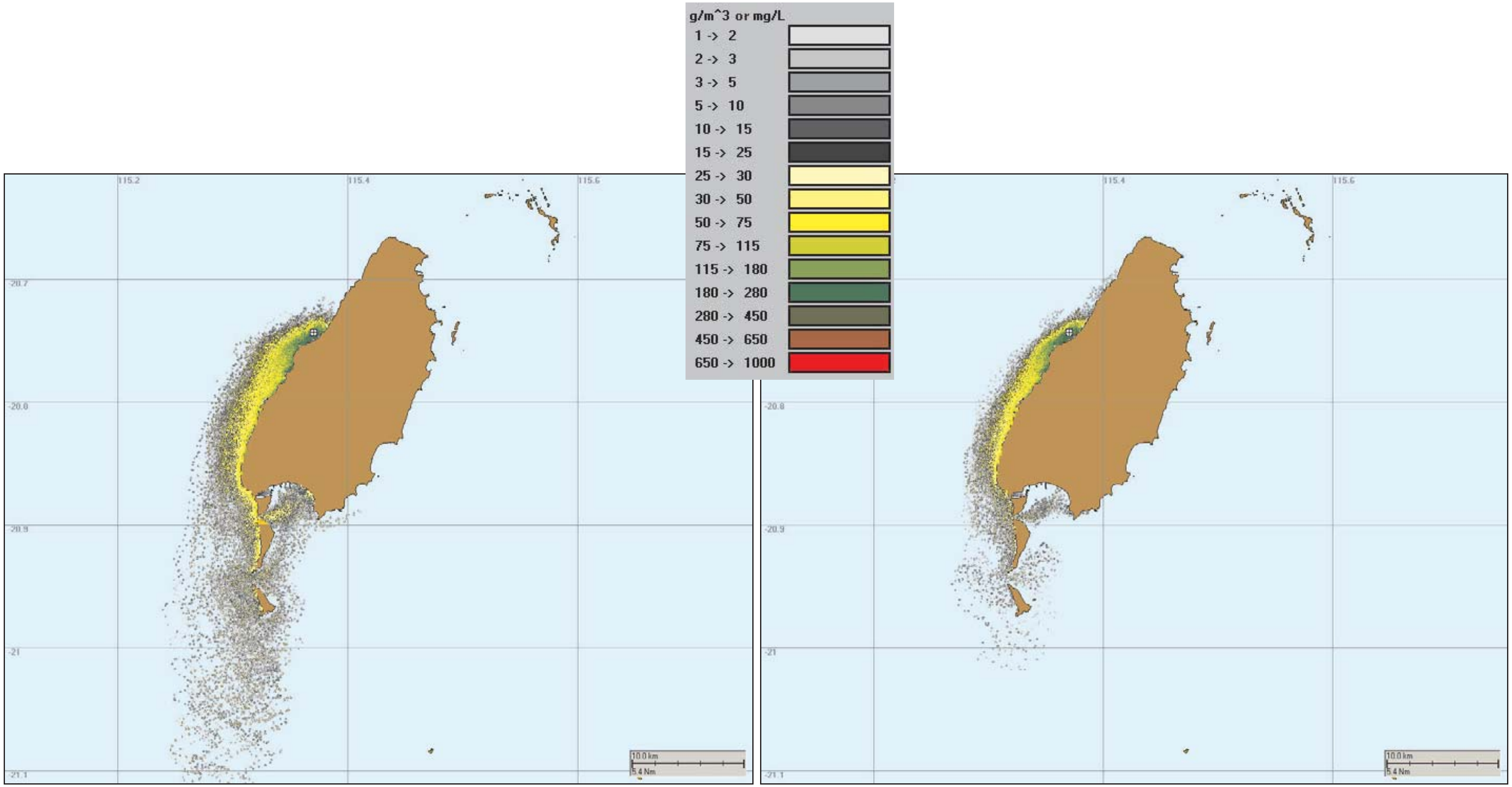

Figure 2: Examples of the zone of influence and maximum instantaneous concentrations of suspended solids predicted for individual locations as a result of discharges of bentonite and cuttings off Flacourt Bay under different environmental conditions. Each figure shows the outcome from 10 days of discharge given a different 10-day sample of currents. Left figure is from June, right figure is from December. Note: the collective areas do not represent the plume at any one point in time (see Figure 4 for clarification).

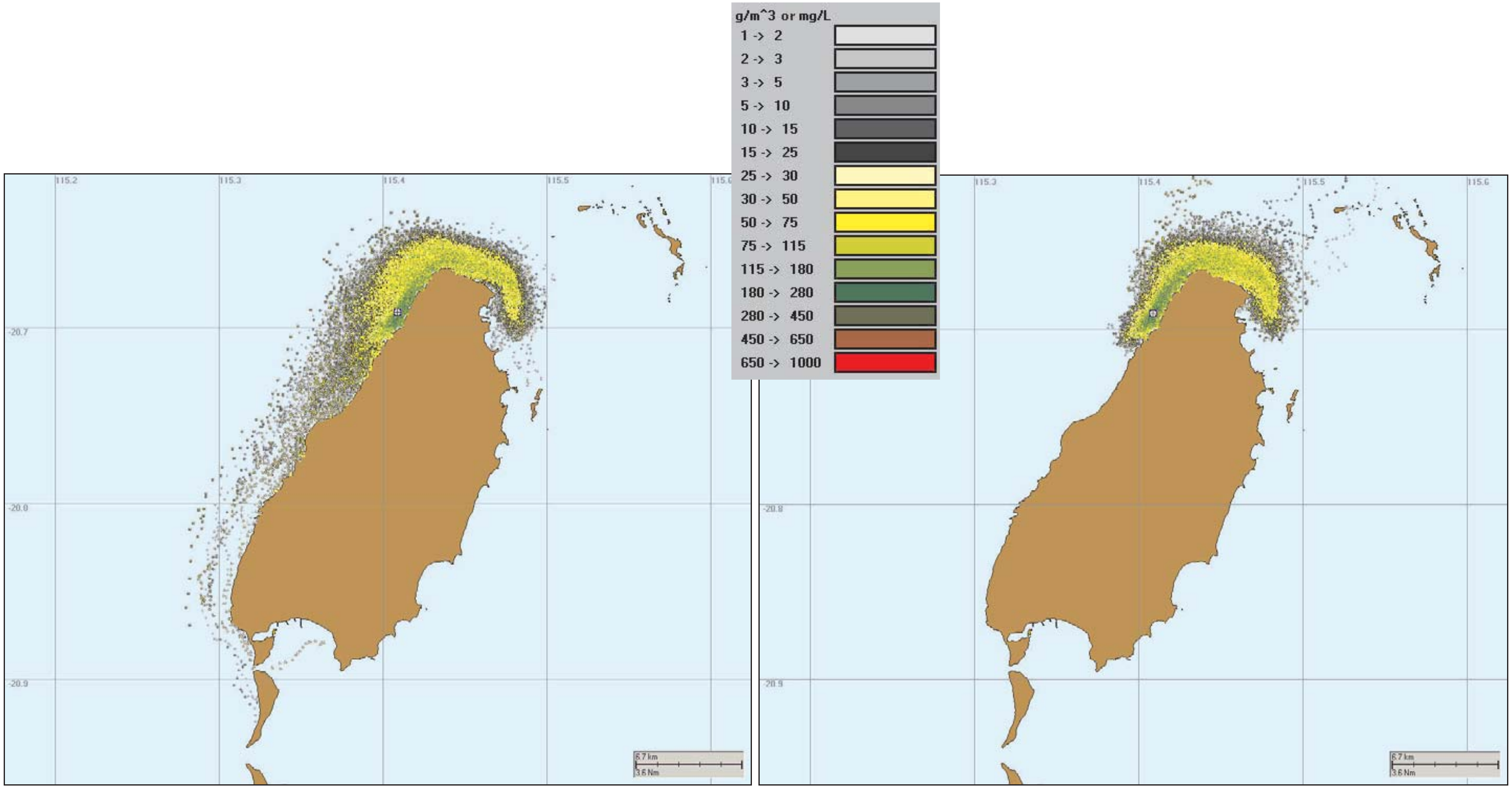

Figure 3: Examples of the zone of influence and maximum instantaneous concentrations of suspended solids predicted for individual locations as a result of discharges of bentonite and cuttings off North White's Beach under different environmental conditions. Each figure shows the outcome from 10 days of discharge given a different 10-day sample of currents. Left figure is from June, right figure is from December. Note: the collective area does not represent the plume at any one point in time (see Figure 4 for clarification).

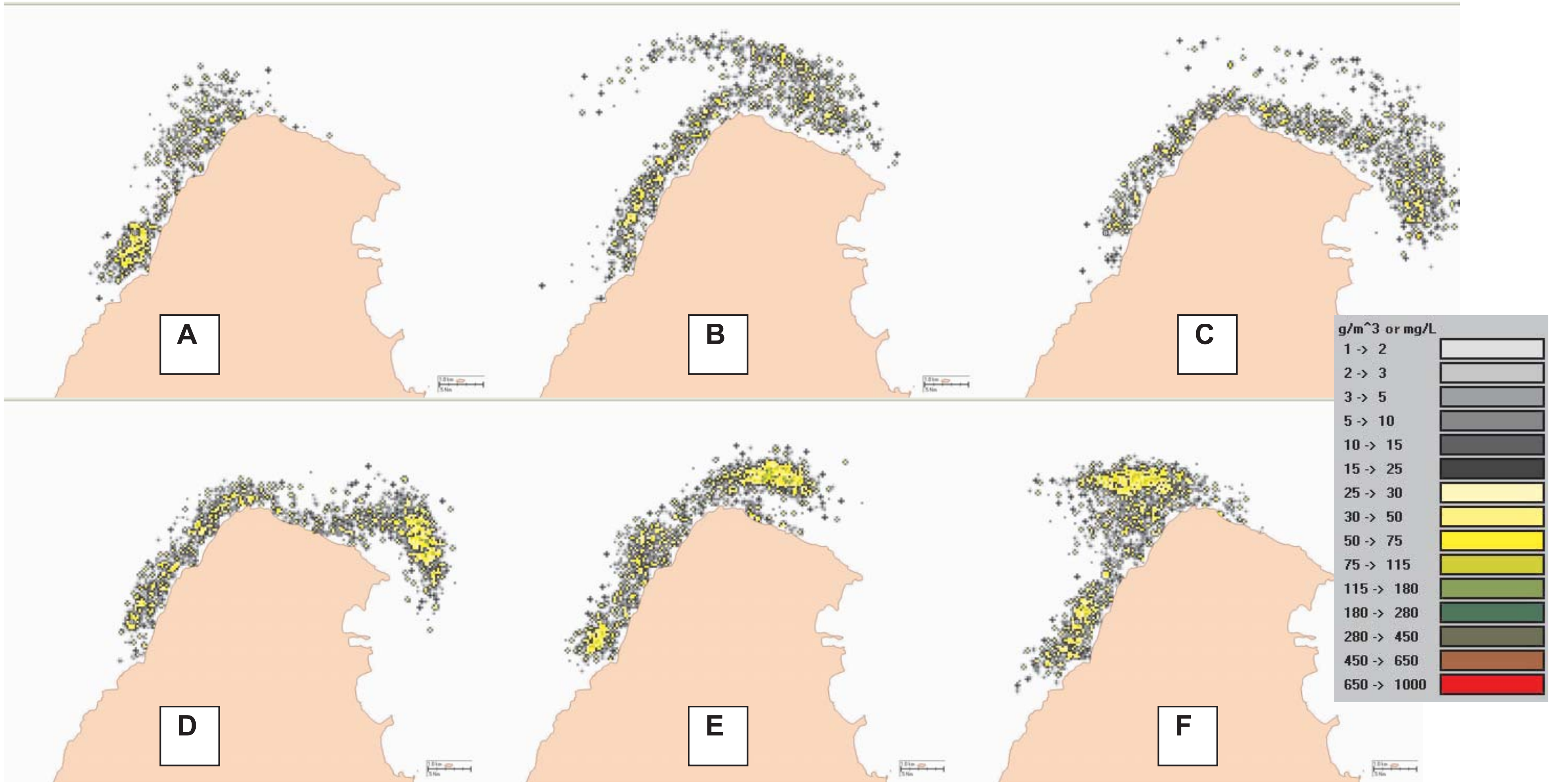

Figure 4: Example of the evolution of a sediment plume expected with changing tidal states during bentonite discharge at North White's Beach. The examples are for one set of conditions. Plumes are shown commencing at the end of one ebb tide and concluding at the end of the next ebb tide. Note that an accumulation of sediments is expected to occur at the turning of the tide.

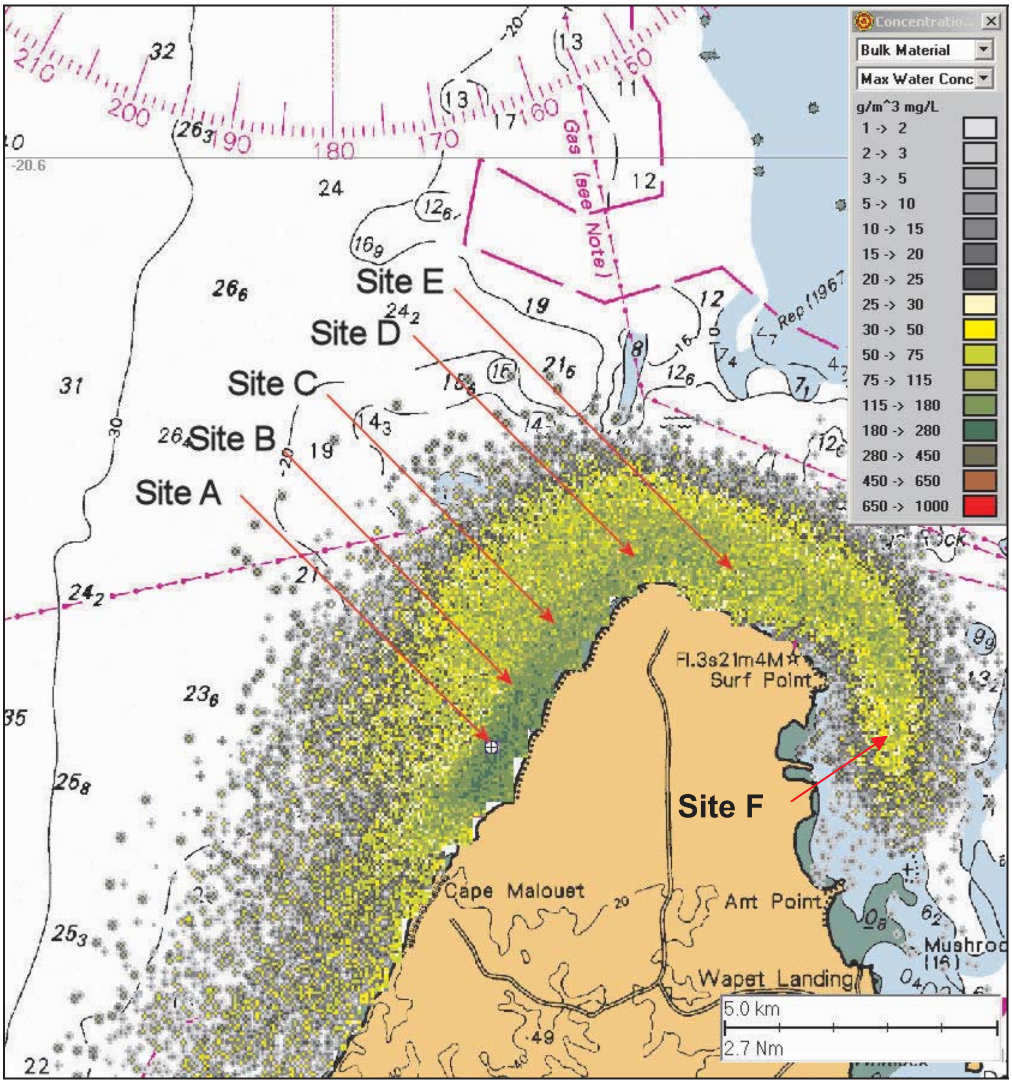

Figure 5: Maximum instantaneous concentrations of suspended solids predicted for locations surrounding the North White's Beach discharge site (shown by the white marker), given a 5 day discharge of bentonite and cuttings (simulation period of 8 days). Site markers relate to details shown in Figure 6.

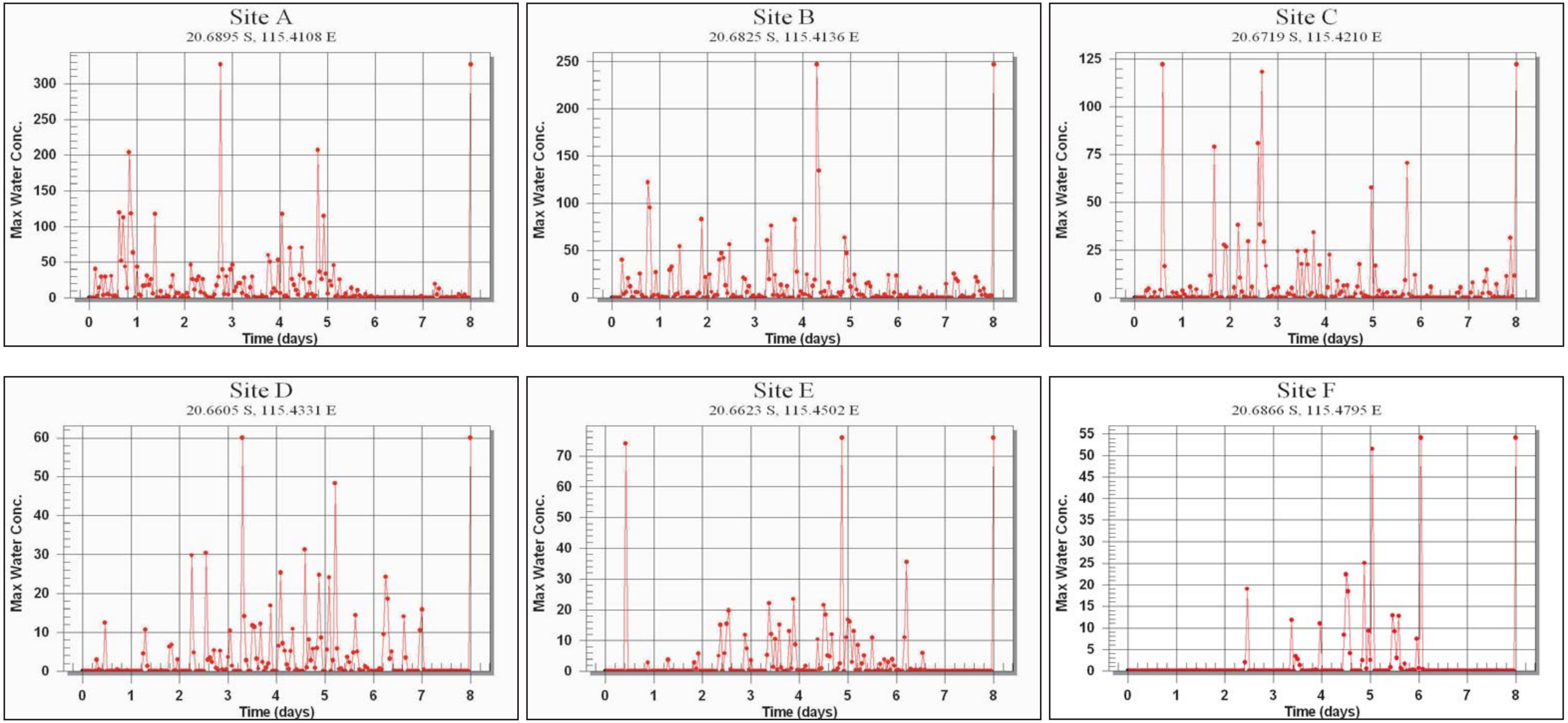

Figure 6: Time-varying concentrations of suspended sediments predicted for locations indicated in Figure. Note (1) the scale of the vertical axis varies among plots to highlight variations at each site (2) the point shown at last time step is the maximum value during the period.

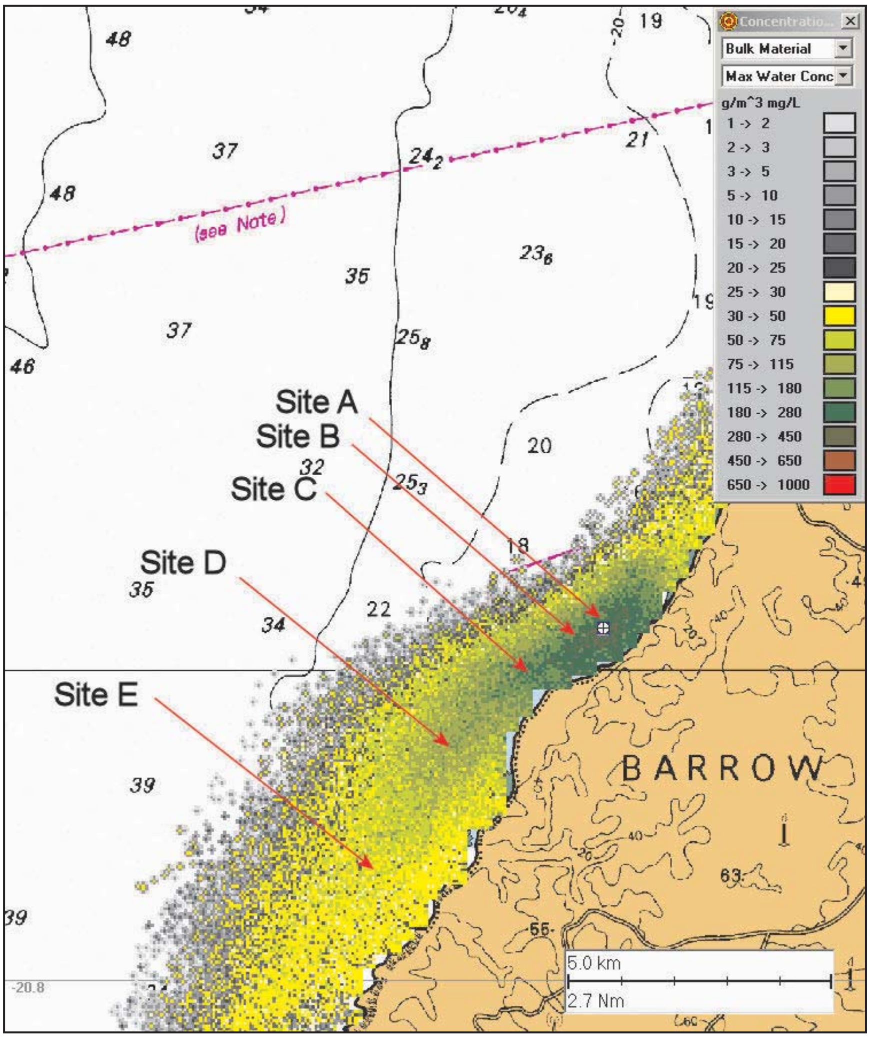

Figure 7: Maximum instantaneous concentrations of suspended solids predicted for locations surrounding the Flacourt Bay discharge site (shown by the white marker), given a 10 day discharge of bentonite and cuttings (simulation period of 8 days). Site markers relate to details shown in Figure 8.

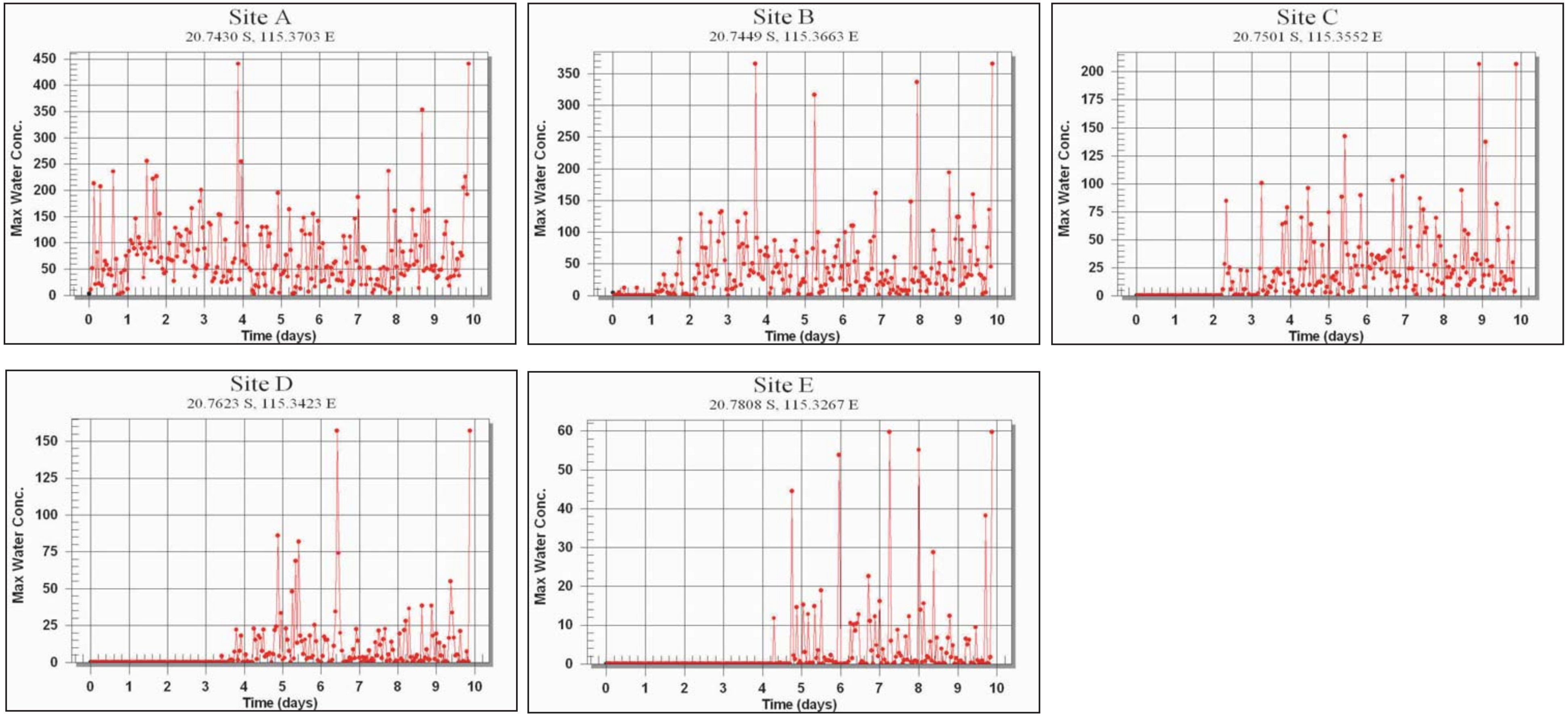

Figure 8: Time-varying concentrations of suspended sediments predicted for locations indicated in Figure. Note (1) the scale of the vertical axis varies among plots to highlight variations at each site (2) the point shown at last time step is the maximum value during the period.

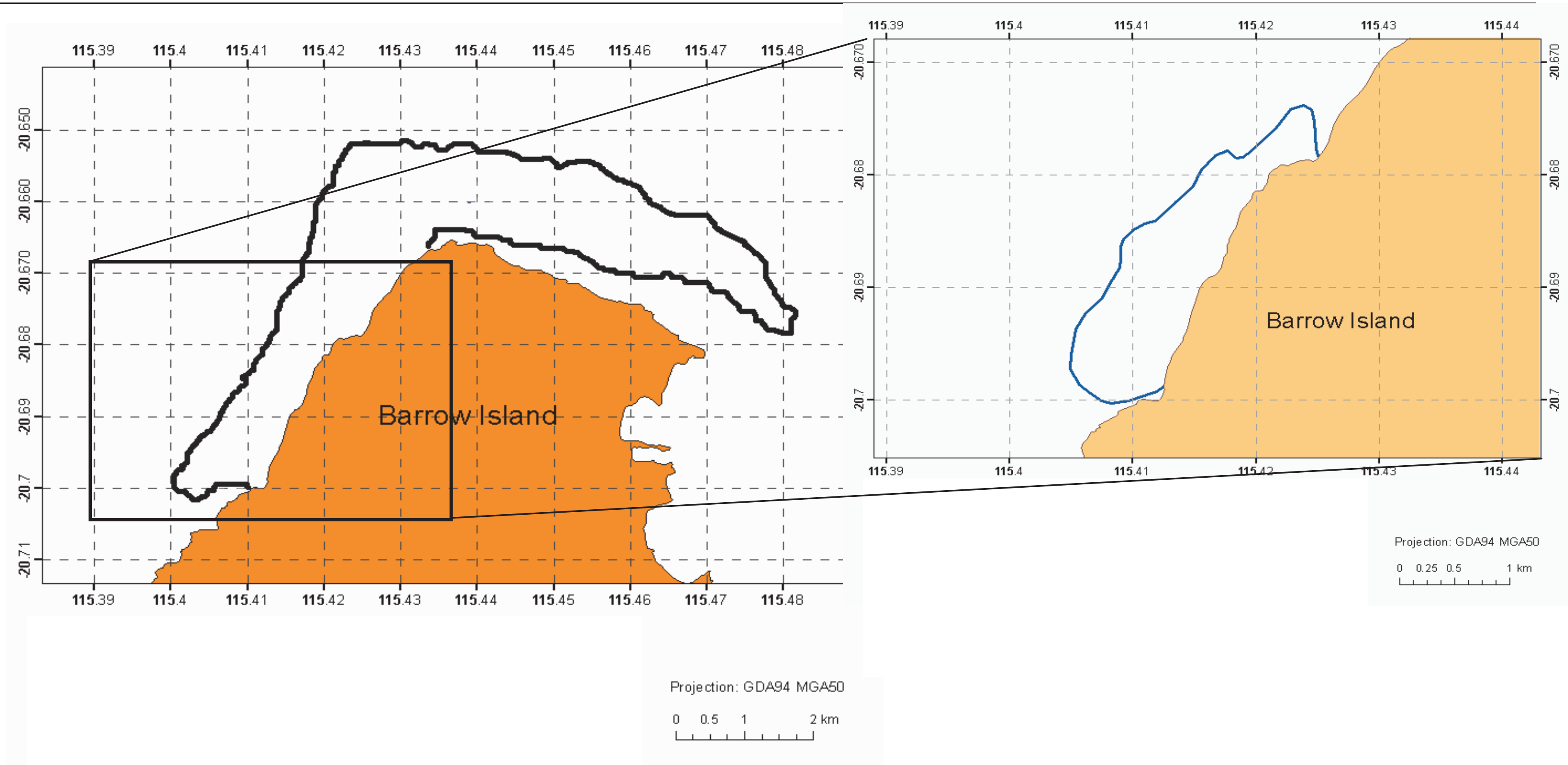

Figure 9: Locations where suspended solid concentrations are expected to exceed 25 mg/l due to bentonite discharge at North White's Beach. The main image shows locations where >25 mg/l are expected for at least 1 hr per day for 5 consecutive days. The inset shows locations where > 25 mg/l are expected for 6+ hours during daylight hours for at least 2 consecutive days.

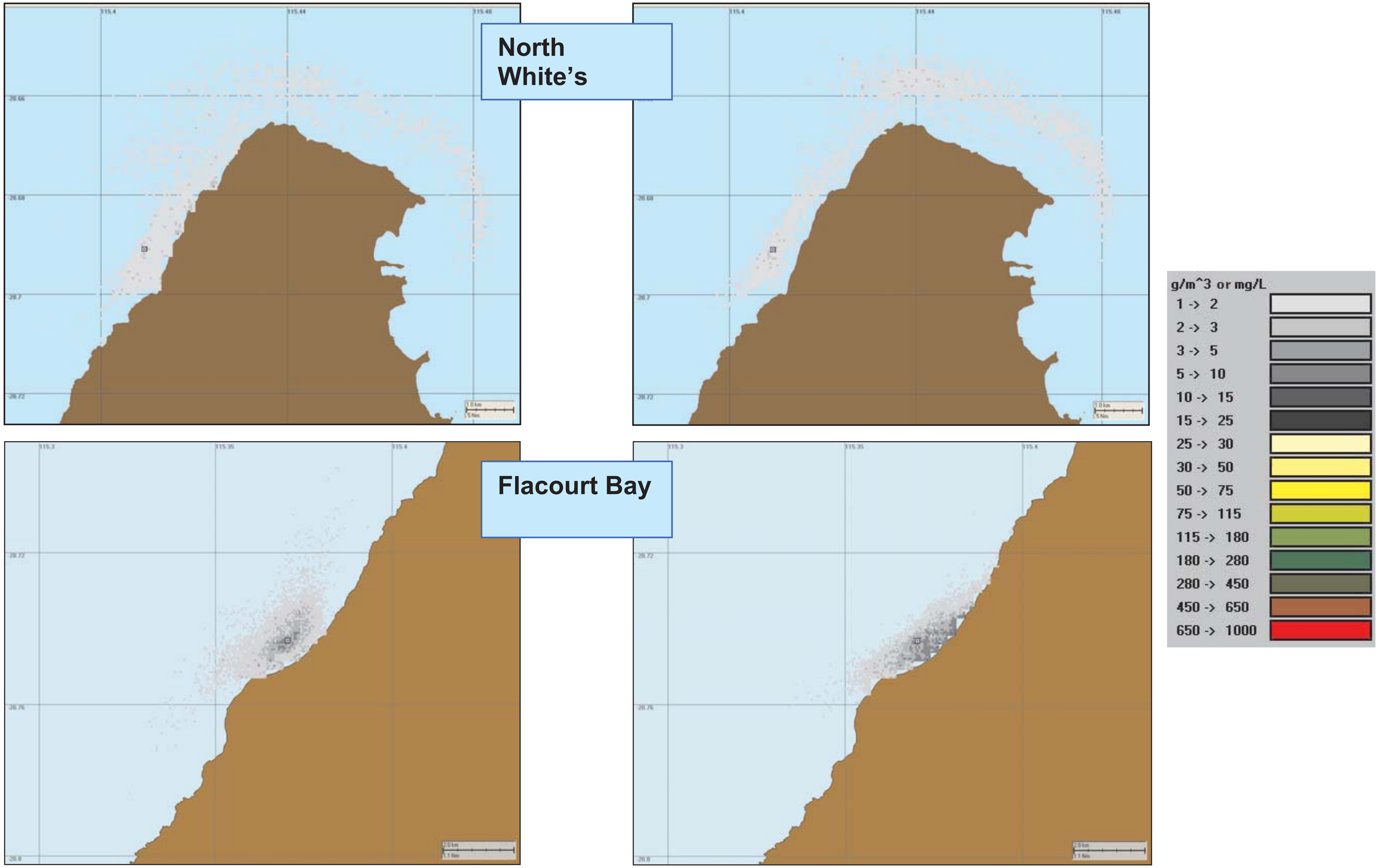

Figure 10: Examples of the maximum instantaneous concentrations of suspended solids predicted from discharges of cuttings with polymer. Each figure shows the outcome from 10 days of discharge given a different 10-day sample of currents. Left figure is from June, right figure is from December. Inset shows the location of the views.

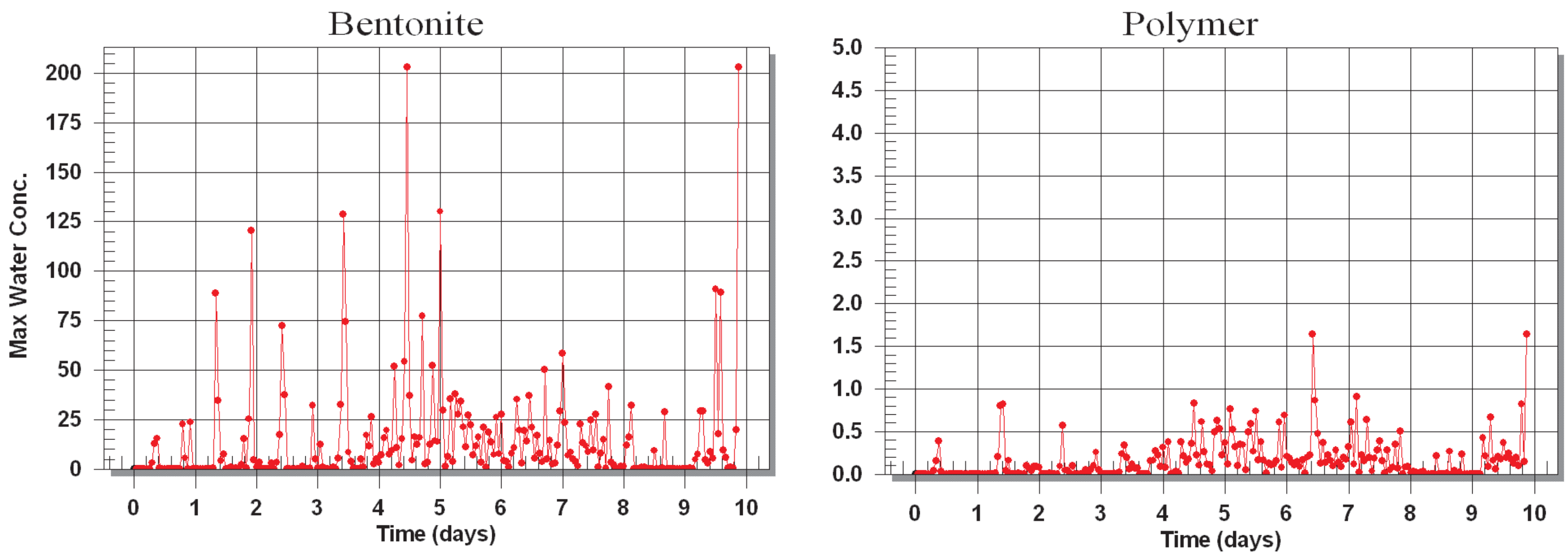

Figure 11: Comparison of the suspended solid concentrations predicted for Biggada Reef for discharge off Flacourt Bay using (a) bentonite clay and (b) water-based polymer. <u>Note that the vertical axes differ between plots.</u>

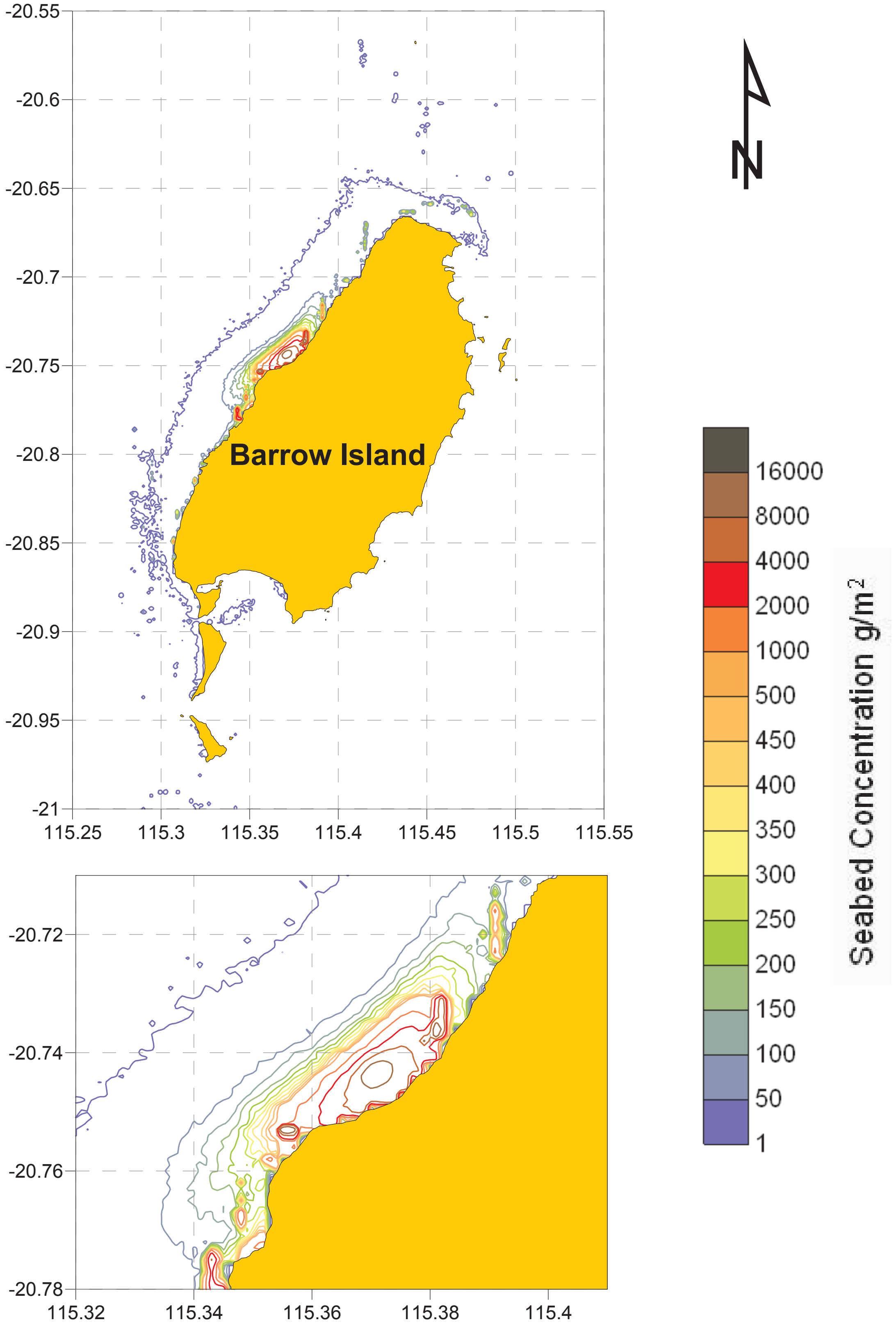

Figure 12: Contour plots showing the cumulative sedimentation predicted for discharge of bentonite and cuttings off Flacourt Bay, assuming no re-distribution of sediments after initial settlement.

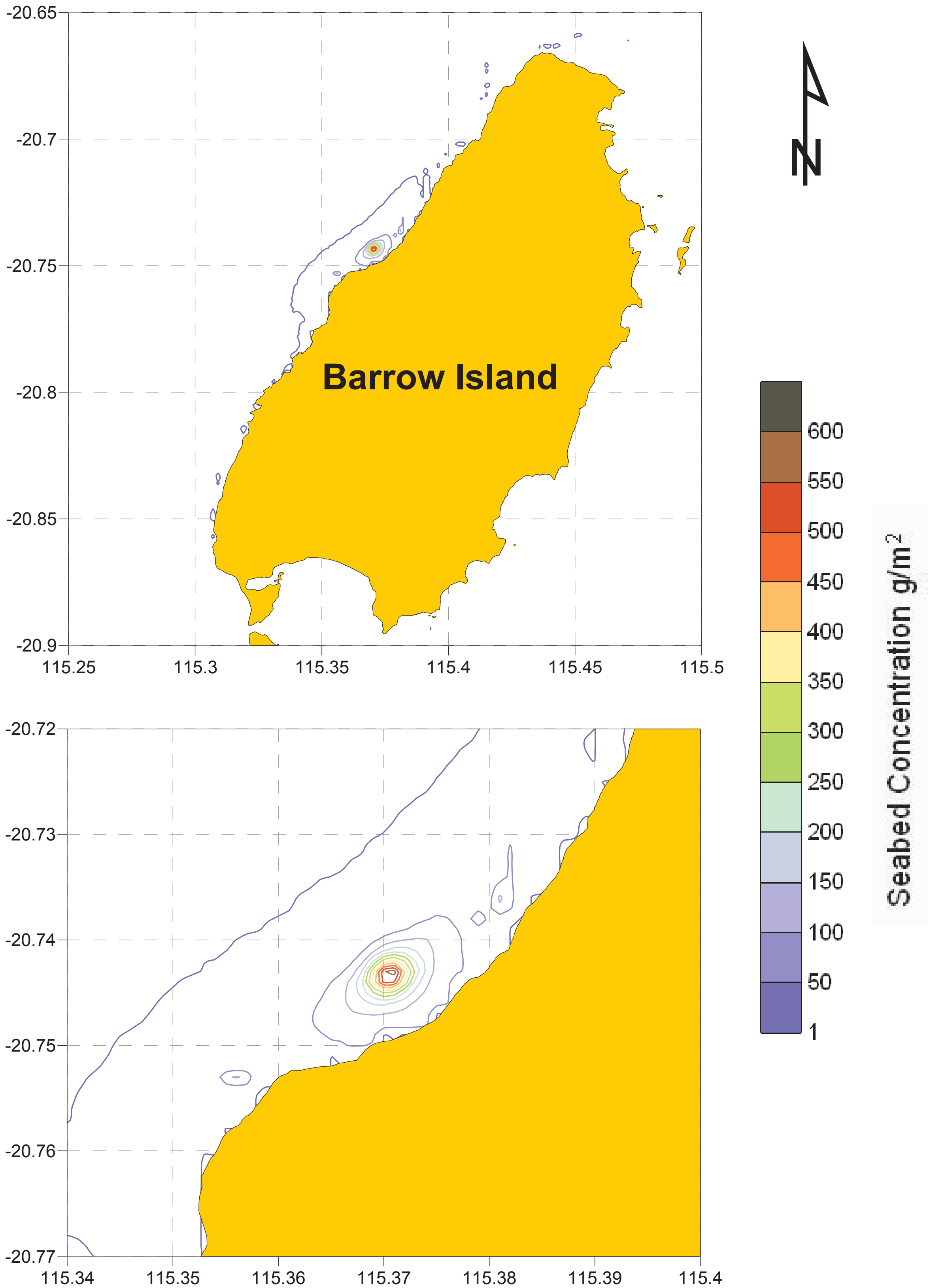

Figure 13: Contour plots showing the cumulative sedimentation predicted for discharge of polymer and cuttings off Flacourt Bay, assuming no re-distribution of sediments after initial settlement.

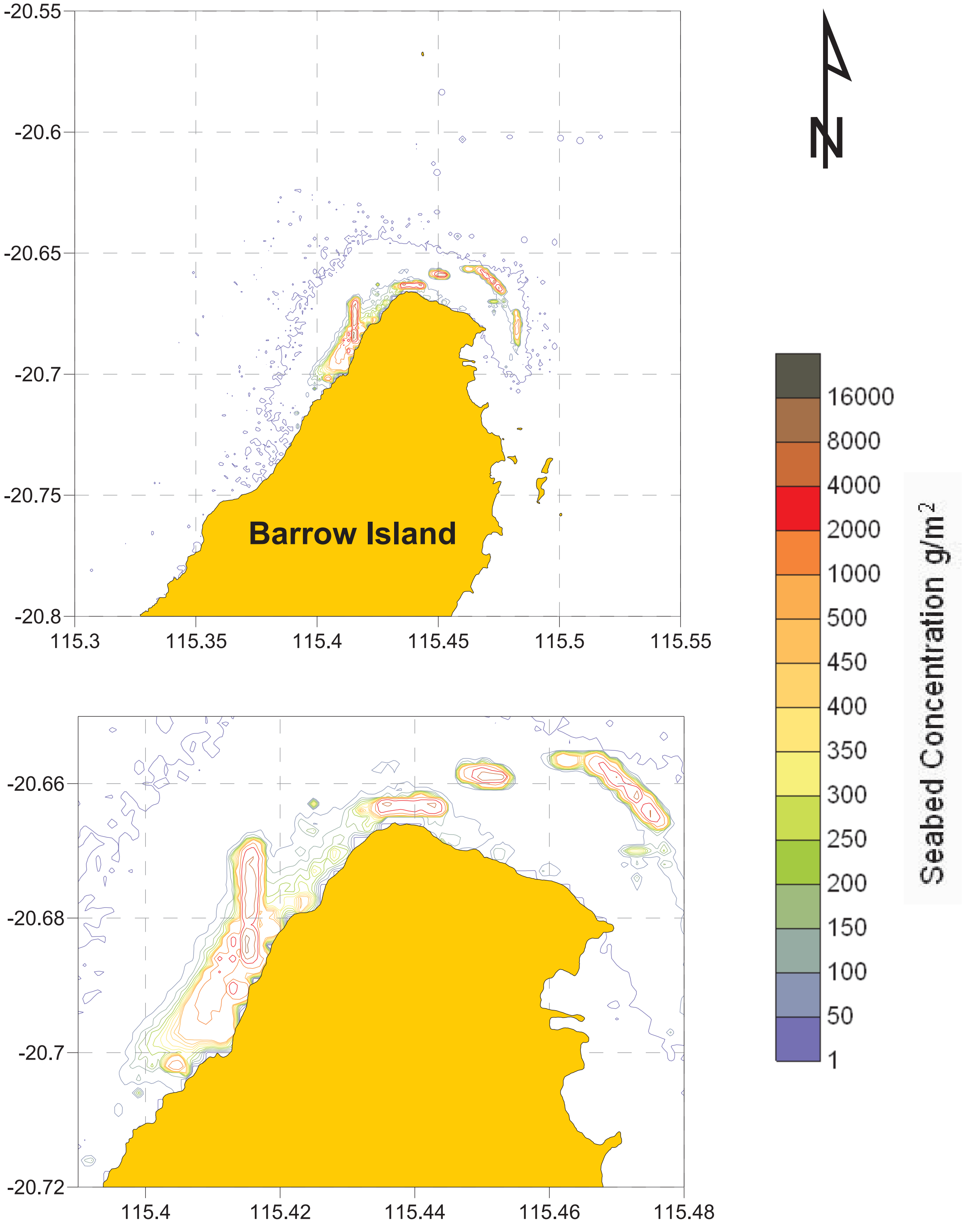

Figure 14: Contour plots showing the cumulative sedimentation predicted for discharge of bentonite and cuttings off North White's Beach, assuming no re-distribution of sediments after initial settlement.

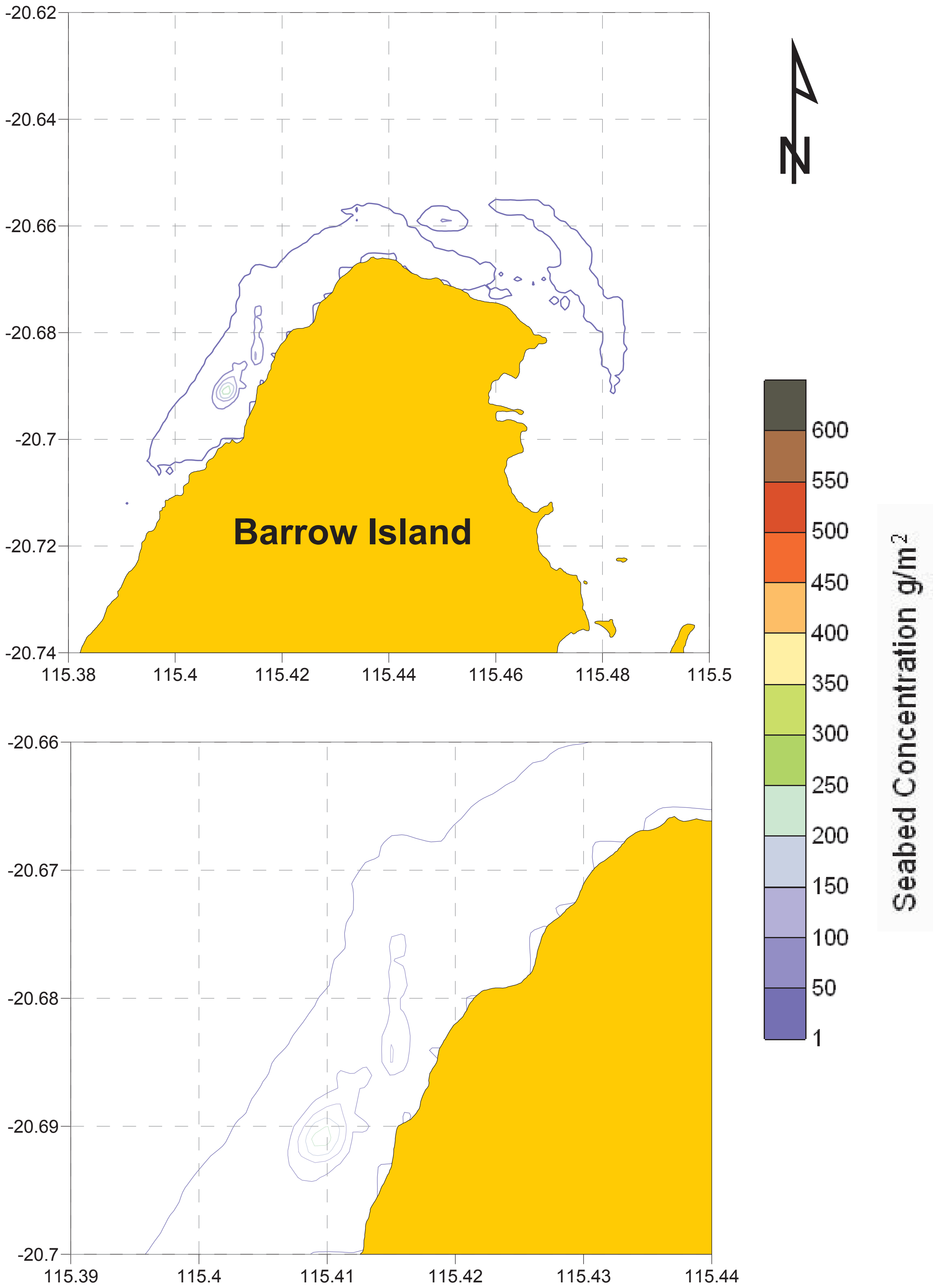

Figure 15: Contour plots showing the cumulative sedimentation predicted for discharge of polymer and cuttings off North White's Beach, assuming no re-distribution of sediments after initial settlement.

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Technical Appendix C1

Flora and Vegetation

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

FLORA AND VEGETATION

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Report No. R03201
April 2005

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Summary

A total of 68 families, 180 genera and 406 vascular plant taxa have been recorded on Barrow Island (Attachment A). The total of 406 vascular plant species, subspecies and varieties constitutes approximately 23 per cent of the flora recorded for the Pilbara region. Fourteen vascular plant species have been introduced to the Island, the majority of which have been recorded in the vicinity of 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 (2003a, 2004a), have been found on Barrow Island. Two Priority species have been collected on Barrow Island: *Helichrysum oligochaetum* (Priority 1) and *Corchorus interstans* ms (Priority 3).

The Priority 1 species *Helichrysum oligochaetum* is known to occur on Barrow Island and was searched for during post cyclonic rain surveys (April and May 2004) to check for potential presence on the proposed development site. *Corchorus interstans* ms (Priority 3) was recorded within the proposed gas processing plant site and the proposed North White's Beach pipeline. *Corchorus interstans* ms is widely distributed on parts of the Island and the mainland and 'has also been observed to regenerate successfully on rehabilitated sites' (Astron Environmental 2002).

No vegetation communities listed under The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* have been recorded or are known to occur on Barrow Island. No threatened ecological community as listed by CALM's Threatened Ecological Database (2003c) has been recorded or is known to occur on Barrow Island.

Barrow Island's vegetation has been previously classified by Buckley (1983) into eight major vegetation units. They were subsequently divided into 34 vegetation types based on major landforms, soil types and species composition by Mattiske (1993b). In recent, more detailed mapping of the vegetation on the proposed development area and associated infrastructure corridors, 83 vegetation communities (Attachment B and Attachment C) were defined and mapped within the proposed gas processing facility and wider study area and the proposed pipeline routes.

Flora and vegetation communities, especially those of particular significance located within the proposed development area, are discussed in this technical appendix to the ERMP for the Gorgon Gas Development.

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1 Introduction

Barrow Island is approximately 70 km off the coast of Western Australia and falls within the Fortescue Botanical District, which itself is a component of the Eremaean Botanical Province (Beard 1980). Climate, landforms and soils determine the distribution of vegetation and plant communities within the Fortescue Botanical District (Beard 1975, Beard 1990).

Barrow Island consists primarily of an undulating limestone plateau (Beard 1975). The southern end of the island is low lying and sandy with Quaternary beach sands and sandy bays. The central part of the island consists of many small limestone ridges and slopes. The northern and eastern sides of the island consist of low cliffs with intervening sandy flats and bays. The western side of the island is more exposed and consists of deeper drainage valleys within the limestone plateau and sandy beaches and narrow near-coastal dune systems.

This report details the findings of a series of vegetation surveys of the proposed gas processing facility and surrounding areas on the eastern side of the island (Figure 2-1) and of three proposed pipeline routes, which extend to the western and northern boundaries of Barrow Island (Figure 3-1 to 5-2), as detailed below:

- the proposed CO_2 reinjection pipeline deviates north from the proposed feed gas pipeline and runs north to Cape Dupuy (Figure 3-1 to 3-6) *this option has since been dropped from Development plan*,
- the proposed feed gas pipeline route runs from a northerly point on the proposed CO_2 reinjection line north-west to North White's Beach (Figure 5-1 and 5-2).
- an alternative feed gas pipeline route runs from the east side of the island close to the 'Terminal Tanks', west to Flacourt Bay (Figure 4-1 to 4-4) ,

The methodology for the above surveys is detailed in Section 2.2. The findings of a preliminary vegetation survey of the proposed pipeline corridor on the mainland on Mardie Station are also discussed in this report.

This appendix is a stand alone document as per EPA Guidance No. 51. A summary of the report is included in the ERMP document.

2 Methods

2.1 Historical Data

A series of vegetation and flora studies have been undertaken on Barrow Island since the 1960's (Butler (1970), Buckley (1983), West Australian Petroleum Pty Ltd (1988), Mattiske and Associates (1993a, 1993b) and Astron (2002)).

Many available species lists from the series of studies undertaken on Barrow Island (Attachment F) were merged and the names checked against those currently accepted by the Western Australian Herbarium using the MAX database and the Department of Conservation and Land Management's (2003b, 2004b) FloraBase and in consultation with other experienced botanists working on the island including Vicki Long, Arthur Weston and Libby Mattiske. Peer review of the species lists for the technical report were undertaken by Vicki Long and review of the technical report was undertaken by Arthur Weston as per EPA Guidance No. 51.

The amalgamated list, including historical synonyms was used by the team to assist in facilitating plant identifications and to identify gaps in existing collections.

While undertaking a review of the amalgamated species list for the island, substantial changes in identifications and in taxonomic nomenclature were noted.

2.2 Field Program

The initial botanical surveys conducted for the proposed Gorgon development areas were undertaken by botanists with significant survey experience, as per EPA Guidance No. 51. The botanical team consisted of a team of eight botanists with vast collective botanical survey experience. Members of the team have been coordinating and participating in botanical surveys in excess of 5 years for most individuals and more than 10 and 30 years botanical survey experience for others. The botanical team contained individuals with significant botanical experience, including significant experience in the Pilbara region. Members of the original survey team were used for all subsequent botanical surveys for the project.

2.2.1 Proposed Gas Processing Facility Site

The wider study area for this study is located on the eastern side of the island, approximately halfway between the northern and southern ends of the island (Figure 2-1). It covers a rectangular area of approximately 1683 ha and is bound on the eastern side by the island's coast. The proposed gas processing facility falls within the eastern side of this area and covers approximately 134 ha.

The field program was designed in consultation with CALM to ensure consistency with other regional studies and databases.

Plots were selected to represent undisturbed vegetation within the proposed development area and surrounding areas. Areas of previous disturbance, for example by seismic lines or clearing, were avoided. The plots were selected on the basis on aerial photography, GIS information and field observations.

In September and October 2003, fifty six 50 m x 50 m plots, each divided into 10 m x 10 m quadrats were established within the proposed gas processing facility site and wider study area. Gaps in representation of vegetation communities within the wider study area were identified through preliminary analysis and a further fifteen plots were established in the area in January 2004. This resulted in a total of seventy two plots.

The data collected in the January 2004 survey were collected in an identical manner to the September and October 2003 surveys, by members of the original field team to ensure continuity in the datasets.

Physical limitations precluded establishing 50 m x 50 m square plots in some communities. In small or linear communities (e.g. coastal, dunes, creeks), the plots consisted of abutting and continuous 10 m x 10 m quadrats within the community boundary, with as many quadrats as possible (up to 25).

The establishment of 10 m x 10 m quadrats allowed comparison with previously established 20 m x 20 m plots on the island (Mattiske 1993b) and with data collected by Trudgen (1989).

Two post-cyclonic rain surveys of the proposed development area were undertaken in April and May 2004, approximately six to eight weeks after Cyclone Monty passed over Barrow Island. Two post-cyclonic rain surveys were undertaken in accordance with EPA Guidance No. 51, in order to complement the initial survey which was undertaken after a long dry period. The first post-cyclonic rain survey focussed primarily on collection of annual grass species and the second on general annual species that may have germinated as a result of the recent rains. The 50 m x 50 m vegetation plots established within the proposed gas processing facility were reassessed as part of the post-cyclonic rain surveys.

In each 10 m x 10 m quadrat the percentage foliage cover was recorded, instead of numbers of individuals, due to difficulties in accurately counting *Triodia* hummocks.

Flora of interest that occurred outside the recording sites was noted during the field surveys.

2.2.2 Proposed Pipeline Routes

A continuous transect, at least twice the width of the proposed pipeline easement, was surveyed for the three proposed pipeline routes:

- the feed gas pipeline from Flacourt Bay to the gas processing facility,
- the alternate feed gas pipeline from North White's Beach to the proposed gas processing facility and,
- the proposed CO_2 reinjection pipeline from the proposed gas processing facility to Cape Dupuy.

The entire length of each of the proposed pipeline routes (Figure 3-1 to Figure 5-2) was surveyed on foot, with either a new site recorded with every change in vegetation or notes taken with reference to the recurrence of a previously observed community.

Percentage foliage cover and height range of each species were recorded and photographs and GPS locations were taken at the Northwest corner at each site.

2.3 Plant Identifications

All plant specimens were processed (pressed and dried) on site and then returned to Perth for identification.

Plant specimens were identified by experienced botanists and all specimens were compared with plant collections at the Western Australian Herbarium. Some plant identifications required further specialist input. *Corchorus* specimens were sent to Dr David Halford at the Queensland Herbarium for identification. *Acacia* specimens were confirmed by Dr Bruce Maslin of the Western Australian Herbarium and specimens of *Chenopodiaceae* were identified by Dr Paul Wilson of the Western Australian Herbarium.

Liaison with the Western Australian Herbarium was undertaken as per EPA Guidance No. 51 and specimens collected as part of the surveys on Barrow Island will be submitted for mounting, and will be included in the Western Australian Herbarium and Karratha regional herbarium collections.

2.4 Data Analyses

The data were loaded into a proprietary SQL-compliant database. All taxon names were corrected against the names in the most recent CALM census.

Basic statistics of the percentage cover observations were calculated using the SYSTAT statistical software package. These included means, ranges and medians. Histograms of each taxon were prepared in order to check statistical distributions of the taxa. Box and whisker plots were produced for each taxon in order to identify any outliers in the data set. These outliers were then rechecked for validity against the field sheets, and corrected as necessary.

PATN software was used to analyse both the data recorded in the vegetation plots within the proposed gas processing facility plant area and a merged data set which included previous survey data. Initial data analyses were undertaken on presence/absence, percentage live foliage cover and total percentage foliage cover, by plot and by individual quadrat.

Hierarchical clustering was undertaken using two principal association measures, Bray and Curtis and Cosine (or Ochiai). Hierarchical fusion clustering was undertaken using a number of strategies. Nearest Neighbour, Furthest Neighbour, Flexible WPGMA (weighted pair group arithmetic averaging), Flexible UPGMA (unweighted pair group arithmetic averaging) using beta = -0.1, UPGMC (unweighted pair group centroid) and WPGMC (weighted pair group centroid) were evaluated.

Dendrograms were produced for each combination of association measure and clustering strategy. A TWINSPAN run was undertaken using the plot data. All of the clustering was undertaken on both plots and quadrats (Q mode). Some R mode clustering was investigated on taxa.

Outputs were then compared and interpreted in relation to other data, notes and aerial photographs.

2.5 Vegetation Mapping

2.5.1 Proposed Gas Processing Facility Development and Wider Study Areas

Vegetation within the proposed gas processing facility development and wider study areas (Figure 2-1) was mapped from detailed observations, aerial photograph interpretation and data from the detailed recording sites.

Vegetation along the proposed pipeline options was mapped from detailed site observations, aerial photograph interpretation and plant specimen collections. Plots were not established along the proposed pipeline routes and therefore statistical and cluster analyses of the proposed pipeline routes were not undertaken for this area of the study.

Barrow Island was classified into eight major vegetation units by Buckley (1983). These were subsequently refined and mapped as 34 vegetation types, based on major landforms, soil type and species composition, by Mattiske and Associates (1993b) (Figure 6-1 to

Figure 6-2). The Mattiske mapping units were based on vegetation components, as follows:

M	Marine — 1 vegetation type
T	Tidal — 2 vegetation types
C	Coastal Complex and Dunes Systems — 7 vegetations types
D	Drainage lines and creeks — 3 vegetation types
F	Flats — 7 vegetation types,
L	Limestone Ridges and Slopes — 10 vegetation types,
S	Clay Pans — 2 vegetation types,
V	Valley Slopes and Escarpment Slopes — 2 vegetation types.

Trudgen's (2002) adaptation of Aplin's (1979) modification of Specht's (1970) vegetation classification system was used in order to allow cover of species with less than two per cent cover to be considered. This system allows for the 'low cover of many strata in the vegetation of more arid areas' (Trudgen 2002). Species with greater than 0.5 percent cover were included in vegetation descriptions for this study.

Vegetation communities were mapped in accordance with EPA Guidance No. 51.Vegetation communities for the proposed gas processing facility and wider study area were described on the basis of the relationships between plots in the cluster analysis, tables of alive and dead species, covers and original field plot community descriptions, and Trudgen's (2002) vegetation classification system. The term 'tall' is substituted for 'high' in vegetation descriptions in this report.

2.6 Limitations

The initial surveys followed a significant period without substantial rains and consequently, the full floral diversity, of annual species in particular, would have been underestimated. Further surveys undertaken after cyclonic rain improved the representation of ephemeral flora. However it is assumed that additional species would be found after several 'good' seasons.

Although plots were established extensively within the proposed gas processing facility area and the wider surrounding study area, it was not logistically possible to establish plots for analysis of vegetation over the whole island. For this reason, analysis was undertaken using data from vegetation plots established in the current survey and that from plots established previously on the island to assist in the assessment of representation of vegetation on the island. Some temporal variation in vegetation would be introduced by using data from different years. This may reduce the accuracy of our assessment of representation of vegetation communities on the island.

3 Flora

3.1 Barrow Island

The Eremaean nature of the flora on Barrow Island is demonstrated by the dominance of families such as Poaceae (grasses), Chenopodiaceae (chenopods), Papilionaceae (peas), Malvaceae and Asteraceae (daisies). The dominant flora, namely *Triodia* and *Acacia*, are typically Eremaean (Mattiske 1997).

The Department of Conservation and Land Management (2004a, 2004b) currently has 1733 records of flora taxa for the Pilbara region, which covers about 178 017 km^2.

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), particularly in coastal areas, and with the Pilbara and Kimberley regions for other flora (Table 3-2).

Trudgen (1989) based the similarities between the vegetation of Cape Range and Barrow Island on the dominance of *Melaleuca* with *Triodia* hummock grasses and the presence of selected species such as *Acanthocarpus verticillatus, Lechenaultia divaricata, Olearia* sp. and *Scaevola crassifolia*. The *Lechenaultia* sp. highlighted by Trudgen (1989) may correspond to an unidentified *Lechenaultia* sp. on Barrow Island (Attachment F).

These floral linkages reflect the diversity of the environments on Barrow Island, as well as the past linkages to the mainland.

A total of 68 families, 180 genera and 406 vascular plant taxa have been recorded on Barrow Island (Attachment A). The flora includes 250 perennial species, 75 annual species and 81 species which are considered to be annual or perennial species (Attachment A and Attachment F). The Barrow Island flora constitutes approximately 23 per cent of the flora records for the Pilbara region. Fourteen vascular plant taxa have been introduced to the island, the majority of which have been recorded in the vicinity of previously disturbed sites.

Table 3-1 (below) summarises the number of vascular plant taxa recorded from the various studies that have been undertaken on Barrow Island, as shown in full in Attachment F.

Table 3-1 – Number of Vascular Plant Taxa on Barrow Island

Data Source	No. of Vascular Plant Taxa
Barrow Island records	201
Western Australian Herbarium ^	199
Karratha Herbarium ^	124
Buckley and Butler ^(Buckley 1980)	215
Lewis and Grierson ^(1989)	56
M.E. Trudgen (1989)	69
Mattiske & Associates (1993a)	76
Mattiske & Associates (1993b)	166
Astron Environmental (2002, 2004)	213
RPS Bowman Bishaw Gorham (2003, 2004)	164
Pilbara Region – CALM Florabase (2004b)	1733
Current Barrow Island Flora Tally	**406**

Note: ^ Many voucher plant specimens were not relocated – totals are an overestimate of potential numbers.

It is estimated that at least 90 per cent of the total vascular plant flora of the island has been documented through these studies. Approximately 20 to 30 per cent of the species on the island would occur only after cyclonic rain or as ephemerals after fires.

Table 3-2 summarises the geographical spread of species recorded on Barrow Island. The table is expanded further in Attachment A.

Table 3-2 – Geographical Affinities of Species and Taxa Recorded on Barrow Island with Other Parts of the Region

Regional Distribution	Number of Species/Taxa
Potentially restricted to Barrow Island (section 3.2)	17
Kimberley	122
Pilbara	193
Cape Range and southern districts	50
Widespread (multiple botanical districts)	115

The flora of Barrow Island is regionally significant because there are species or taxa that:

- appear to be restricted to the island
- represent the southern limit of plants of the Kimberley region
- represent the western limit of plants of the Pilbara region
- represent the northern limit of the plants of Cape Range and southwards.

3.1.1 Rare and Priority Flora

No protected plant taxa listed under Section 179 of the EPBC Act and no Declared Rare Flora species, listed under subsection (2) of Section 23F of the *Wildlife Conservation Act* or listed by CALM (2004a) were located during surveys on Barrow Island.

Two Priority Flora species have been collected on Barrow Island:

- *Helichrysum oligochaetum* (Priority One), and
- *Corchorus interstans* ms (Priority Three).

Helichrysum oligochaetum was recorded on the flats south of the proposed gas processing facility and north of the current ChevronTexaco camp (Mattiske & Associates 1993b). This species is only known from six records at the Western Australian Herbarium and was not found within the proposed gas processing facility footprint or proposed pipeline routes during the initial or post cyclonic rain surveys.

Corchorus interstans ms is represented by only four collections in the Western Australian Herbarium but is widespread on Barrow Island and known to extend into the Pilbara region. It was recorded in 18 of the 24 vegetation communities defined in the wider study area, in eight of the nine communities located within the proposed gas processing facility area, along the Flacourt Bay feedgas pipeline route and on the proposed CO_2 reinjection line (Attachment G and Attachment H). The Herbarium collection will be supplemented by collections from the current study.

Specimens collected on the proposed pipeline routes which were potentially *Corchorus interstans* ms were recently identified as *Corchorus congener*, *Corchorus ?congener, Corchorus walcottii* and *Corchorus* sp. Further collection of *Corchorus* specimens along the proposed pipeline routes would be required to confirm the identification of the *Corchorus* sp. collections and to determine the potential distribution of *Corchorus interstans* ms along these routes.

3.1.2 Restricted Flora

The plant species listed in Table 3-3 are considered to have restricted distributions. They either have a limited distribution on Barrow Island or occur as range extensions from other botanical regions in Western Australia.

Table 3-3 – Restricted Flora on Barrow Island and their Presence in the Gorgon Development Areas

Taxa	Regional Range and Barrow Island Occurrence	Present in Proposed Gorgon Development Area
Acacia cowleana	Appears to extend from Barrow Island to the Kimberley region. Restricted to one small population on the island.	This species was not located in the proposed development areas.
Acacia inaequilatera (dwarf form)	This variant is restricted to the south-west corner of the island and differs from the mainland variant.	This variant was not located in the proposed development areas.

Taxa	Regional Range and Barrow Island Occurrence	Present in Proposed Gorgon Development Area
Acacia synchronicia	Is very restricted on Barrow Island but appears to be widespread in mainland areas.	This species was not located in the proposed development areas, but occurs to the north and northeast of the existing airstrip.
Cassytha capillaris	This creeper extends from Barrow Island to the Kimberley and Pilbara regions.	This species was not located in the proposed development areas.
Cullen patens (formerly known as *Psoralea patens*)	Extends from Barrow Island to the Pilbara and southern areas. This species is relatively restricted on the island.	This species was not located in the proposed development areas.
Dichanthium sericeum subsp. *humilius*	This subspecies extends from Barrow Island to the Kimberley and Pilbara regions.	This subspecies was recorded within the proposed gas processing facility area in recent post-cylonic rain surveys.
Dysphania kalpari	This species is widespread on the mainland, but its distribution on Barrow Island is unknown.	This species was not located in the proposed development areas.
Erythrina vespertilio	This species is restricted on the island to five main populations and localised scattered trees. Although this species is considered to be relatively widespread in the State, on Barrow Island it is very restricted. The main areas were initially defined and mapped as vegetation community F4 (Mattiske and Associates, 1993b).	The species was recently mapped within vegetation community F4a along the proposed CO_2 reinjection pipeline.
Eucalyptus xerothermica ms	This species is restricted to localised patches, three main small populations and a few scattered trees on the island. This species is widespread in the Pilbara region.	This species was not located in the proposed development areas.
Euphorbia sp. A	This species requires further taxonomic investigations.	This species was not located in the proposed development areas.
Ficus opposita var. *aculeata* (formerly recorded as *Ficus opposita* var. *micrantha)*	This species is known from only one location in the south-west section of the island and from three recent collections on the island This species extends in distribution to the Pilbara and Kimberly regions.	This species was not located in the current proposed development areas.
Gossypium australe	This species extends from Barrow Island to the Kimberley and Pilbara regions.	This species was not located in the proposed development areas.
Grevillea pyramidalis subsp. *leucadendron*	Scattered populations of this subspecies occur in the middle of the island, near the central east coast and in the northwest of the island.	This subspecies was recorded in communities L6b, L6c and L6d on the proposed North White's Beach pipeline route and in community L6a, south-east of the proposed camp area.

Taxa	Regional Range and Barrow Island Occurrence	Present in Proposed Gorgon Development Area
Hakea lorea subsp. *lorea*	This subspecies was previously located in scattered populations in the central part of the island and is recognised as being widespread in the Pilbara region. It is now known to occur in a range of vegetation community types on the island.	This subspecies occurs in several communities associated with a range of site conditions from valleys (V1m and V3b) to drainage systems (D1a) and limestone slopes and ridges (L3i, L5a and L6a) within the proposed development area.
Halosarcia indica subsp. *julacea*	This subspecies extends from Barrow Island to the Kimberley. Restricted to tidal flood areas of the island.	This subspecies was not located in the proposed development area.
Hibiscus sturtii var. *platychlamys*	This variety extends from Barrow Island to the Pilbara region. Located on edges of red sandy areas and in gullies on western and northern edges of the island.	This variety was not located in the proposed development area.
Hybanthus aurantiacus	This species extends from Barrow Island to the Kimberley and Pilbara regions. Previously located on a disturbed site on northern section of the island.	This species was located in communities L3a, L5a and V1m in the proposed gas processing facility footprint and wider study area and within plot 15 under the proposed footprint. This species is a relatively short-lived plant, which occurs after favourable seasonal rains.
Isotropis atropurpurea	This species extends from Barrow Island to the Kimberley and Pilbara. Localised occurrence on the island.	This species was not located in the proposed development area.
Mallotus dispersus (formerly recorded as *Mallotus didmochryseus*)	This species is restricted on Barrow Island and extends to the Kimberley.	This species was not located in the proposed development area.
Santalum murrayanum	Restricted to one valley on the island. This species extends from Barrow Island southwards.	This species was not located in the proposed development area.
Sporobolus mitchellii	This species, although restricted in occurrence on Barrow Island, is widespread on the mainland. It has only been recorded in the south-west of the island.	This species was not located in the proposed development area.
Stemodia glabella	This species is relatively widespread on the mainland, but its distribution on Barrow Island is unknown. It extends from Barrow Island to the Kimberley and Pilbara regions.	This species was not located in the proposed development areas. Further investigations are required to clarify the taxonomy of the *Stemodia* species on the island.
Whiteochloa airoides	This species extends from Barrow Island to the Kimberley and Pilbara regions. This species has been recorded on the western coastal area and inland. It appears that this grass may be grazed in some areas and therefore may be more widespread following favourable seasonal conditions for establishment and growth.	This species was located on the proposed feed gas pipeline area.

An additional 17 taxa are potentially restricted to Barrow Island and require further attention in order to confirm their classification, distribution and conservation status (Attachment A). This group includes variants of *Acacia bivenosa* and *Corchorus* sp. and the following:

- *Abutilon* sp. (VL-2706-09)
- *Calandrinia* aff. *remota*
- *Euphorbia* aff. *drummondii* (Boodie Island)
- *Ficus brachypoda* (hairy variant – ex *Ficus platypoda* var. *lachnocaula*)
- *Heliotropium* sp. (VL-2104-19)
- *Isolepis* sp.
- *Lechenaultia* sp. (VL-BW103-13)
- *Marsilea* ?*hirsuta*
- *Ptilotus obovatus* (adherent prostrate from on island)
- *Scaevola* sp. (VL-2104-26)
- *Sida* sp. (VL-2709-14).

Species that tend to be restricted to creek beds and gullies on Barrow Island are of conservation significance, due to the historical loss of this habitat through anthropogenic disturbance. The taxa associated with these habitats include *Abutilon otocarpum, Dysphania kalpari, Euphorbia* sp. A, *Gossypium australe* and *Hibiscus sturtii* var. *platychlamys.*

3.1.3 Introduced Species

Fourteen plant species have been introduced to Barrow Island (Table 3-4).

Table 3-4 – Introduced Species Previously Recorded on Barrow Island

FAMILY	GENUS AND SPECIES
AMARANTHACEAE	*Aerva javanica* (Kapok bush)
ASTERACEAE	*Arctotheca calendula* (Cape weed)
	Conyza sumatrensis (Tall fleabane)
	Pseudognaphalium luteoalbum (Jersey cudweed)
	Sonchus oleraceus (Milk thistle)
CYPERACEAE	*Isolepis marginata* (Coarse club-rush)
MALVACEAE	*Malvastrum americanum* (Spiked Malvastrum)
MYRTACEAE	*Eucalyptus gomphocephala* (native to SW EA – planted)
PASSIFLORACEAE	*Passiflora foetida* var. *hispida* (Wild passionfruit)
POACEAE	*Cenchrus ciliaris* (Buffel grass)
	Cynodon dactylon (Couch grass)
	Setaria verticillata (Whorled pigeon grass)
POLYGONACEAE	*Emex australis* (Doublegee)
SOLANACEAE	*Solanum nigrum* (Blackberry nightshade)

Astron Environmental (2002) notes that *Malvastrum americanum* was rated by CALM in 1999 as being 'moderate' in its potential to invade and endure, and that the weed has become naturalised on the Pilbara mainland.

3.2 Proposed Development Areas

3.2.1 Species of Conservation Significance in Proposed Development Areas

The occurrence of restricted species within the proposed development areas is detailed at Table 3-3 above. The significant species recorded within the proposed development areas are further described below:

Species restricted to specific areas on the island

Erythrina vespertilio occurs within vegetation community F4a on the proposed CO_2 reinjection pipeline (Figure 3-1) and an isolated tree of this species was located near the proposed North White's Beach pipeline.

Grevillea pyramidalis subsp. *leucadendron* occurs within community L6a near the proposed camp site (Figure 2-1) and communities L6b, L6c and L6d along the proposed North White's Beach pipeline (Figure 5-1, Figure 5-2). Scattered populations have been recorded in the centre of Barrow Island (Mattiske and Associates 1993b).

Hakea lorea subsp. *lorea* occurs in several communities associated with a range of site conditions from valleys (V1m and V3b) to drainage systems (D1a) and limestone slopes and ridges (L3i, L5a and L6a) within the proposed gas processing facility area, the proposed feed gas pipeline corridor and the proposed CO_2 reinjection pipeline corridor. Prior to this study it was recorded by Mattiske (1993b) as occurring only in scattered populations in the middle of the island, but has since been recorded in a variety of communities.

Melaleuca cardiophylla occurs in vegetation communities D1a, F8a, L3h, L7a, L7b, V1d, V1k and V1m, of which communities D1a, F8a, V1d, V1k and V1m occur within the proposed gas processing facility footprint (Figure 2-1). This species was recorded within approximately 1583ha of vegetation type L7 (Mattiske and Associates 1993b). This species is now known to be widely distributed on the island, but remains significant due to its ecological function as fauna habitat.

Dichanthium sericeum subsp. *humilius* is an annual grass that was recorded in two locations within the proposed gas processing facility area during the post cyclonic rain surveys. Mattiske and Associates (1993b) also found the species amongst the chenopod fringes of Barrow Island. This subspecies extends from Barrow Island to the Kimberley and Pilbara regions and is expected to be widely distributed on the island, but distribution on the island is unknown.

Hybanthus aurantiacus occurs in vegetation community V1m within the proposed gas processing facility area and in communities L3a, L5a and V1m in the wider study area. This species extends from Barrow Island to the Kimberley and Pilbara regions and is also located on a disturbed site in the northern part of Barrow Island. It is a relatively short-lived species which occurs after favourable seasonal rains. Although some populations will be affected by the proposed gas processing facility, the majority of the populations will not be affected.

Whiteochloa airoides grows on the proposed feedgas pipeline route. This species extends from Barrow Island to the Kimberley and Pilbara regions and has been recorded on the western coastal area and in the centre of the island. It appears that this grass is heavily grazed and therefore is likely to be more widespread following favourable seasonal conditions for establishment and growth.

Several different forms of *Acacia bivenosa* were recorded in the survey of the proposed gas processing facility and wider study areas. Two forms of *Acacia bivenosa* were apparent in the collections — a 'normal' variant and an 'elongate phyllode variant' (Bruce Maslin, Western Australian Herbarium, personal communication). Further assessment of these forms and other *Acacia* species on Barrow Island is anticipated in the future to determine whether they are genetic variants.

Table 3-5 summarises the number of vascular plant taxa and families recorded within the proposed development areas. Attachment G and Attachment H show the taxa recorded in plots within the proposed gas processing facility.

Table 3-5 – Numbers of Plant Taxa and Families Recorded within Proposed Gorgon Development Areas

Proposed Development Area	No. Taxa	No. Families	Dominant Families
Proposed gas processing facility wider study area	115	38	Poaceae (13 taxa), Asteraceae (11 taxa), Tiliaceae (10 taxa), Mimosaceae (6 taxa), Euphorbiaceae (7 taxa) and Papilionaceae (6 taxa)
Proposed gas processing facility footprint (species recorded in six vegetation plots within footprint)	48	26	Euphorbiaceae (7 taxa), Poaceae (5 taxa), Asteraceae (3 taxa), Papilionaceae (4 taxa)
Proposed CO_2 reinjection pipeline	68	30	Poaceae (9 taxa), Asteraceae (4 taxa), Mimosaceae (4 taxa) and Papilionacae (5 taxa)
Proposed feed gas pipeline	60	27	Poaceae (12 taxa), Asteraceae (5 taxa) and Papilionaceae (4 taxa)
Proposed North White's Beach pipeline	67	27	Chenopodiaceae (9 taxa), Poaceae (9 taxa) and Asteraceae (7 taxa)

Table 3-6 shows the numbers of annual and perennial species recorded within vegetation plots in the proposed gas processing facility area, before and after the post-cyclonic rain surveys.

Thirteen additional species were recorded in the proposed gas processing facility and wider study areas. Eleven additional species were recorded on the proposed feed gas pipeline area, 16 additional species were recorded on the proposed CO_2 reinjection pipeline area and 11 additional species were recorded on the proposed North White's Beach pipeline as a result of post-cyclonic rain surveys.

Table 3-6 – Annual and Perennial Species Recorded in Plots within the Proposed Development Area Before and After Post-cyclonic Rains

	Plot 1		Plot 2		Plot 3		Plot 15		Plot 46		Plot 47	
Annual/Perennial	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
A	0	3	1	3	0	0	0	1	0	3	0	2
P	5	7	10	11	13	14	12	16	9	9	9	10
A/P	1	4	1	8	1	2	0	3	0	0	0	0
total	6	14	12	22	14	16	12	18	9	12	9	12
Increase # species after rain	-	8	-	10	-	2	-	6	-	3	-	3
% species increase	-	133.3	-	83.3	-	87.5	-	50	-	33.3	-	33.3

Note: Pre = number of annuals/perennials in initial plot surveys (September/October/ December 2003),
Post = number of annuals/perennials in post rain surveys (April/May 2004)

New Records for Barrow Island

Nine new records or confirmed identities for Barrow Island were added to the list of vascular plant species as a result of the post-cyclonic rain surveys on the island.

These new records and confirmations are described in the following.

Tephrosia clementii has not previously been recorded for Barrow Island and was found in limestone community F5d (Figure 3-1) on the proposed CO_2 pipeline route. This species differs from *Tephrosia rosea* var. *clementii*, which was previously recorded on Barrow Island. The Western Australian Herbarium's current MAX database lists four varieties of *Tephrosia rosea*: var. *clementii*, var. *glabrior*, var. *rosea* and var. *venulosa*. Both *Tephrosia clementii* and *Tephrosia rosea* var. *clementii* names are current.

The recent collections of *Tephrosia clementii* were very small and herbaceous. Only five collections of the species are lodged at the Western Australian Herbarium. The limited collections and knowledge of the distribution of this species suggests that listing by CALM as a Priority species may be considered. Further survey work will be required to determine the distribution of this species on the island.

The Southern Pilbara — Carnarvon Coastal form of *Eriachne flaccida* (Trudgen 2002), was collected from the clay pan community S1a on the proposed CO_2 reinjection pipeline and confirms the identity of the previous collection from the same area. Trudgen (2002) noted that the *Eriachne* specimen from Barrow Island differs from the inland Pilbara material for *Eriachne flaccida* in seven ways. However, it is the same as R. Buckley's collection of the species from Barrow Island and a few coastal specimens from the Carnarvon area.

An unidentified *Isolepis* sp. was found within the proposed gas processing facility footprint after the post-cyclonic rains, in the south-west corner of the proposed footprint, and at two locations outside the proposed footprint. The Barrow Island specimens do not match any known *Isolepis* specimen held in the Western Australian Herbarium (Cate Tauss (pers. comm.)), apart from a specimen recently collected in Perth. There is potential for the species to be a new native species, or a cosmopolitan species of Asian origin. Further investigation of this species is required to resolve its taxonomic and biogeographical affinities.

Tribulus hirsutus was recorded within community F8a in the wider study area (Figure 2-1) and Community F5c on the proposed CO_2 reinjection pipeline. It appears to be a new record for the island. The species has a distribution that extends from the Pilbara to parts of the Kimberley.

Corchorus congener was added to the species list for the island after recent identifications of *Corchorus* specimens by David Halford of the Queensland Herbarium. This species has been recorded near Exmouth but had not been previously recorded on Barrow Island.

Corchorus congener was found within the proposed gas processing facility footprint. Specimens tentatively identified as *Corchorus congener* were also located within the wider study area surrounding the proposed gas processing facility footprint (Figure 2-1) and on the proposed North White's Beach pipeline route. Further survey and collections would be required to determine the distribution of this species on the island.

The other taxa added to the Barrow Island flora list after the recent post-cyclonic rain surveys include *Evolvulus alsinoides* var. *villosicalyx*, *Ptilotus fusiformis* var. *fusiformis* and introduced species *Setaria verticillata*. None of these three records appear to be significant range extensions. However, the collection of a new introduced species (*Setaria verticillata*) near the proposed North White's Beach pipeline corridor warrants further investigation.

Little is known about the non-vascular plant species in the Pilbara region. Fruiting bodies of an unidentified fungus were observed on a termite mound on the proposed CO_2 reinjection pipeline route (Plate 1). No non-vascular plant species were observed within the proposed development area during post-cyclonic rain surveys.

3.2.2 Proposed Gas Processing Facility

Forty eight taxa, from 26 families were recorded from six plots within the proposed facility footprint, after post-cyclonic rain surveys. These totals probably underestimate the number of species within the gas processing facility footprint and represent less than half of the taxa in the area.

No introduced species were recorded in the proposed gas processing facility or the wider study area.

3.2.3 Proposed Pipeline Corridors

Each of the three pipeline routes yielded more than 60 plant taxa (Table 3-5). One introduced species, *Setaria verticillata,* was recorded outside the proposed North White's Beach pipeline in the post-cyclonic rain surveys.

The flora values in these pipeline areas will be assessed further as part of the finalisation of the alignment of the pipelines.

3.2.4 Proposed Mainland Pipeline Corridor

A preliminary flora and vegetation survey of the proposed mainland pipeline route, adjacent to the existing Apache pipeline on Mardie Station south of Karratha, was undertaken in May 2003. Preliminary vegetation assessment of this area, which has coastal mangrove and samphire communities, salt pans and inland terrestrial vegetation communities, is shown in section 4.2.3 of this report and in Appendix J and Chapter 11 of the main report. Further collections and identifications are required to complete a species list for the proposed mainland pipeline survey area.

4 Vegetation

Generally, the vegetation of the near-coastal environments are relatively consistent within the Pilbara region. The typical pattern of vegetation comprises mangroves in tidal areas, *Spinifex longifolius* assemblages on the foredunes, halophytic communities on the saline flats, stunted vegetation on the near-coastal rocky headlands, and hummock grasslands of *Triodia* on the inland areas. The grass species and emergent shrubs and trees in these hummock grasslands reflect local patterns in landforms, soils and moisture availability.

4.1 Vegetation Types of Barrow Island

The 34 vegetation types mapped by Mattiske and Associates (1993b) were further refined to create 83 mapping units after surveys of the proposed development areas (Figures 1-1 to 1-4). The mapping codes for the vegetation communities were linked to previous mapping studies by Mattiske and Associates (1993a) and Astron Environmental (2002).

Additional vegetation communities that were delineated and mapped within and near the proposed development area were the rocky headlands (mapping unit R) and disturbed areas (Dist). Disturbed areas include roads, areas of recent disturbance, seismic lines and areas of historical disturbance where partial regrowth of vegetation had occurred, well pad areas and areas of disturbance around the Terminal Tanks and the old airport (Figure 2-1).

The ground-truthing and high resolution aerial photography used in the current survey facilitated the clarification of some vegetation types and hence there are some discrepancies between the various maps. For example it facilitated the definition of the new vegetation type (F8) on the flats near the proposed gas processing facility footprint.

4.2 Proposed Development Area

4.2.1 Proposed Gas Processing Facility

Figure 2-1 shows the distribution of vegetation communities in the vicinity of the proposed gas processing facility footprint (including proposed plant, camp area and adjoining road).

Table 4-1 shows the areas of the 11 vegetation communities, areas of disturbance and unvegetated rocks which will potentially be impacted by the proposed gas processing facility.

Table 4-1 – Vegetation Communities and Areas Potentially Impacted by the Proposed Gas Processing Facility Footprint

Vegetation Community	Area (ha)
C2a	0.20
C2b	0.002
C5a	0.58
D1a	0.09
Disturbed Areas	0.66
F8a	47.86
L3a	1.34
L3f	6.24
L3i	28.06
L7b	2.20
Rocks (unvegetated)	0.50
V1d	3.15
V1k	10.70
V1m	31.77

The dominant communities within the proposed gas processing facility area as shown in the table above 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.

Vegetation within a wider study area surrounding the proposed gas processing facility footprint was mapped to provide context and guidance for the location of the proposed gas processing facility footprint. The wider study area totals approximately 1483 ha (Figure 2-1). Of this, approximately 64ha has been previously cleared or disturbed for roads, terminal tanks and oil remediation areas. A further 40 ha has been disturbed within the wider study area by the removal of drainage soil material for road works and well sites.

The wider study area contains 26 vegetation communities. Substantial areas of communities such as F8a (*Acacia bivenosa* and *Triodia wiseana* 'flats') occur in the east, with ten undulating limestone slope and ridge communities and eight valley slope communities with minor drainage lines in the west. Small pockets of the limestone community (L6a), dominated by *Grevillea pyramidalis* subsp. ?*leucadendron* and *Triodia angusta,* are located in the south-east of the wider study area (Figure 2-1).

Several major drainage gullies occur within the wider study area and flow towards the east coast of the island. Some of these drainage gullies have been disturbed as a result of 'borrowing' of soil material. The east coast of the island forms the eastern edge of the wider study area and supports four coastal dune vegetation communities and one coastal limestone cliff vegetation community (Figure 2-1).

Data Analyses

Dendrograms (Figure 7-1 to 7-3) were used as a means of checking groupings and the resulting vegetation communities for the proposed gas processing facility and for a comparison of this area with the remainder of Barrow Island.

The results for some of the more distinct vegetation communities reflected sharp boundaries in site conditions, whilst other less-distinct vegetation communities were related and reflected only subtle differences in species composition. In general, there was a reliance on experience of the ecologists in delineating the less-distinctive communities.

In delineating the groups the following trends were observed:

- Although plots established in dune areas were located both on top of dunes and in swales between the dunes, and aerial photography showed the two areas as differing in appearance, several of these plots were linked closely in the output of the analysis. It appears that the composition and percentage cover of species in these differing parts of the dune system were sufficiently similar to allow the grouping of the plots into the same vegetation community.
- Although plot 47 was not linked closely in the dendrogram with the other plots containing *Melaleuca cardiophylla*, it was grouped within *Melaleuca* community V1m as a result of the presence of this dominant species and certain other species, and its topographical position in the landscape.
- Although the *Melaleuca* plots were linked closely in the dendrograms, the plots were divided into upper slope, valley and flats communities.
- Plot 12 was not linked closely to other dune plots as it was a transect that traversed several different coastal communities adjacent to a major creek line.

4.2.2 Proposed Pipeline Corridors

Proposed CO_2 Reinjection Pipeline

The corridor surveyed for the proposed CO_2 reinjection pipeline extends from near the proposed gas processing facility footprint almost to Cape Dupuy at the northern end of the island, and has an approximate width of 60m (Figure 3-1 to 3-6). Of the 70 ha mapped within the pipeline survey area, approximately half of that would be expected to be impacted by the proposed pipeline. Forty three vegetation communities were mapped within the proposed corridor survey area, approximately six hectares of which has been previously disturbed or cleared for roads.

Vegetation along the corridor consists predominantly of 13 'flats' communities, located more commonly in the north of the island, with 11 valley slopes communities and 11 undulating limestone slopes and ridge communities in the southerly extent of the corridor (Figure 3-1 to 3-6). Of the 'flats' communities recorded along this corridor, one community (F4a) is dominated by *Erthyrina vespertilio*, *Triodia wiseana* and *Triodia angusta*. Approximately 0.3 ha of this community is expected to be impacted by the proposed pipeline corridor.

Six drainage communities occur intermittently along this route, of which 1.5 ha of major drainage is likely to be impacted by the proposed corridor. One coastal community was recorded at the northern end of the proposed pipeline corridor. A clay pan community (S1a) was also recorded in this corridor, 0.3 ha of which is likely to be impacted by the proposed corridor.

Proposed Feed Gas Pipeline

The proposed feed gas pipeline corridor extends from near the proposed gas processing facility footprint to Flacourt Bay, on the west coast of the island (Figure 4-1 to 4-4). The area surveyed for this pipeline was approximately 50 m wide. It includes 23 vegetation communities over an area of about 44 ha, of which approximately 22 ha is expected to be impacted by the proposed corridor. Approximately 3.5 ha of this area has been previously disturbed or cleared for roads.

For much of the corridor length, vegetation consists predominantly of seven undulating limestone slope and ridge communities and seven valley slope communities.

The proposed corridor intersects two major and two minor drainage vegetation communities and additional minor drainage lines within the limestone and valley slope communities. Approximately 0.5 ha of major drainage lines are expected to be impacted by the proposed corridor. The undulating limestone communities toward the western end of the proposed corridor drop away steeply to Flacourt Bay, which supports five coastal vegetation communities; C1d, C2e, C5b, C5c and C4e, which are restricted to the small erodible beach dunes and limestone flats (Figure 4-1 to 4-4).

Proposed North White's Beach Pipeline

The proposed North White's Beach pipeline corridor is located in the north of the island. It extends west from the proposed CO_2 reinjection pipeline to the northern end of White's Beach on the west coast of the island (Figure 5-1 to 5-2). The area surveyed for this pipeline is approximately 50 m wide and includes 20 vegetation communities over an area of about 20 ha, of which approximately 10 ha is likely to be impacted by the proposed pipeline. Of this area, less than 0.03 ha has previously been disturbed.

The proposed North White's Beach pipeline corridor contains two valley slope vegetation communities and seven undulating limestone vegetation communities, of which three are dominated by *Grevillea pyramidalis* subsp. ?*leucadendron* over *Triodia epactia* or *Triodia wiseana*. A total of about 3ha of communities containing *Grevillea pyramidalis* subsp. ?*leucadendron* is likely to be impacted by the proposed pipeline. Several of the valley slope and limestone vegetation communities contain minor drainage lines.

The vegetation opens out into two 'flats' communities near the west coast, separated in parts by a small area of limestone vegetation community (L3c) containing scattered herbs and grasses, of which approximately 0.1 ha is likely to be impacted by the proposed pipeline. A third 'flats' community is located further east on the proposed corridor.

The proposed North White's Beach pipeline corridor supports eight coastal vegetation communities, including elevated dunes, swales and flats (Figure 5-1 and 5-2).

4.2.3 Proposed Mainland Pipeline Corridors

The proposed mainland pipeline route is adjacent to an existing Apache pipeline on Mardie Station, south of Karratha. Preliminary vegetation mapping of the proposed pipeline route showed intertidal vegetation in this area, including mangroves consisting of *Avicennia marina* subsp. ?*eucalyptifolia*, *Bruguiera exaristata* and *Rhizophora stylosa*, areas of samphires consisting of a low shrubland of *Halosarcia halocnemoides* subsp. *tenuis, Halosarcia indica* and *Suaeda arbusculoides* and unvegetated tidal flats (Plate 69, Plate 70 and Plate 71).

Preliminary assessment of the inland vegetation along the proposed mainland pipeline route includes communities consisting of the following:

- A Grassland of *Triodia epactia* and ?*Cenchrus* sp. with *Eragrostis dielsii* and *Eragrostis falcata* with occasionally emergent *Acacia farnesiana*, *Acacia trachycarpa, Lawrencia viridigrisea* and *Neobassia astrocarpa* shrubs on raised red earth mounds (Plate 72).
- A Low Open Shrubland including *Acacia* sp. over grassland with *Dicanthium sericeum* subsp. *humilius*, *Eriachne flaccida*, *Aristida holathera* var *holathera* and *Eriachne benthamii* over a Very Open Herbland including *Rhynchosia minima* and *Neptunia dimorphantha* on red earth flats (Plate 73).
- An Open Shrubland to Tall Open Shrubland of *Acacia trachycarpa*, *Acacia ancistrocarpa*, *Acacia elachantha*, *Acacia victoriae* and *Acacia xiphophylla* over a Grassland of *Triodia epactia* and ?*Cenchrus* sp. over mixed herb species on red sandy flats (Plate 74). This community was recorded at the eastern end of the proposed mainland pipeline route, near the existing compressor station.

Confirmation of the identification of the ?*Cenchrus* sp. specimen and other specimens collected in the preliminary survey is likely to indicate the significant presence of introduced species *Cenchrus ciliaris* along this proposed route; Arthur Weston (pers.comm) notes that it is almost certainly this species. Detailed vegetation mapping and Declared Rare and Priority Flora searches should be undertaken prior to finalisation of the route.

4.3 Vegetation Representation on Barrow Island

4.3.1 Dendrogram Outputs

In reviewing the dendrograms the initial letter and first number code were consistent among recent and historical vegetation studies on the island, however, an additional letter was added for the vegetation communities defined for the proposed gas processing facility site as the studies were then undertaken at a more detailed sampling level. Therefore C2 and L3 (Mattiske 1993b) can be compared with C2a and L3a to L3i respectively.

The dendrogram for the sites on the proposed gas processing facility reflected some key groupings (Figure 7-1 to 7-3). For example, the coastal communities C1a, C2a and C5a were delineated in the first of the groupings.

The dendrogram for the sites on the proposed gas processing facility area and the wider island reflects the complexity of the vegetation on Barrow Island. As for the proposed gas processing facility site, some of the groupings reflect overlap with similar vegetation community types, whilst others were grouped with apparently dissimilar community types. In general, although the samples were based on different survey times, some general trends were consistent, for example, the valley (V) and drainage (D) types overlapped in some of the groupings, and the coastal (C) and flat (F) types overlapped or merged due to the species' composition, reflecting similar underlying soil types.

The results for the D2 and V1 communities in Figure 6-1 reflect the concentrated effort of Trudgen in 1989 (sites prefixed by MET) on the vegetation in the valleys and gullies.

4.3.2 Representation of Vegetation Communities

In reviewing the representation of the vegetation communities on the island it is important to recognise the different data sets used. To address the differences between the data sets, the various mappings undertaken to date were related through the vegetation mapping codes in Attachment C. The use of related mapping codes also allowed linkage of similar vegetation descriptions from work undertaken by Astron Environmental (2002) and vegetation descriptions for the current study. Codes for similar units mapped by Astron Environmental in 2002 units were given a prefix 'A' (Attachment C).

4.3.3 Representation of Significant Vegetation Communities

The vegetation communities on the proposed development area were assessed by comparison of the 2003/2004 studies with previous findings on the vegetation of the island (Mattiske and Associates 1993b). The communities and representation are summarised in Attachment C and discussed in the following.

4.4 Significant Vegetation Types

Criterion 2 of the 'Guidelines for applying criteria to assess the level of threat to ecological communities' (Environment Australia 2004) uses a total of 1000 ha as an indicative threshold for identifying terrestrial vegetation communities with small distributions as 'very restricted'.

Based on the combined areas of the vegetation types as defined by Mattiske (1993b) only eight vegetation types defined for Barrow Island cover more than 1000 ha (D2, F1, F5, L1, L3, L7, L9 and V1), with the remaining 26 vegetation types covering less than 1000 ha (M1, T1, T2, C1, C2, C3, C4, C5, C6, C7, D1, D3, F2, F3, F4, F6, F7, L2, L4, L5, L6, L8, L10, S1, S2 and V2). All of the vegetation communities mapped recently in the proposed development area, including F8 and V3, which were not defined and mapped prior to the current survey, cover less than 1000 ha. These communities are well represented on the island and the 1000 ha guideline has not been adopted in the current assessment.

In assessing the representation of vegetation types and vegetation communities, the scale of definition is critical in applying criteria defined by others. At this point, the vegetation mapping by Mattiske and Associates (1993b) as the vegetation type scale, the regional mapping by Beard (1975) and the extensive botanical experience by various authors (Astron, Trudgen and Mattiske) provide a wider context in which to assess the significance of the vegetation on Barrow Island. Therefore, the representation and significance of the vegetation communities in the proposed development area have been assessed against the broader vegetation types that have been defined for Barrow Island.

Comparisons were also made with previous studies on the seismic lines and drainage areas (Mattiske and Associates 1993a; Mattiske Consulting 1997; Trudgen 1989). The significance of these relationships with the environment has been used in the interpretation of representation.

Previous broad-scale mapping on the island undertaken by Mattiske and Associates (1993b) used prefixes to categorise the vegetation assemblages. For example, limestone outcropping ridge and slope community descriptions are grouped as 'L', valley systems as 'V', drainage areas as 'D', coastal communities as 'C' and communities on the extensive sandy flats as 'F' . Astron Environmental (2002) further expanded this coding system to define communities within the broader units, for example C1a. This methodology has been employed for the current study to enable linkage to previous studies.

The representation of the vegetation types within those defined and mapped previously by Mattiske and Associates (1993b), and for the recently mapped proposed development, are reviewed below.

- **'Marine' community (M1 vegetation type)** occurs within localised pockets (covering approximately 24.67 ha) on the fringes of the more protected southern and eastern coastlines (Mattiske and Associates 1993b). On current knowledge of regional communities, this vegetation type is well represented on the mainland. This type was not recorded in the proposed development area.
- **'Tidal' communities (T vegetation types)** occur in very localised pockets (covering approximately 16.6 ha) on the tidal areas scattered around the island (Mattiske and Associates 1993b). These vegetation types have similarities with halophytic communities on the mainland, although further regional comparisons are required. These types were not recorded within the proposed development area.
- **'Coastal' communities (C vegetation types)** occur in very localised pockets (covering approximately 1536.8 ha) on the island. Some have similarities with mainland coastal communities, whilst others appear to differ from those on the mainland. Further regional studies and comparisons with coastal areas in the Pilbara and Cape Range areas are required. Based on recent vegetation community mapping (Figure 2-1 to 5-2) and estimates of vegetation types (Mattiske and Associates 1993b), 0.5 per cent of the combined 'C' types on the island occur within the proposed development area.
- **'Drainage and creekline' communities (D vegetation types)** occur in linear patterns (covering approximately 1137.56 ha) along the floors of broader valley systems. These communities have been widely disturbed by historical activities on Barrow Island and this significance has been highlighted by Trudgen (1989). Based on recent vegetation community mapping (Figure 2-1 to 5-2) and estimates of vegetation types (Mattiske and Associates 1993b), 0.6 per cent of the combined 'D' types on the island may occur within the proposed development area.
- **'Flats' communities (F vegetation types)** occur on broad sandy flats, largely located on the northern, eastern and southern fringes (covering approximately 72.1 ha) of the island. Based on recent vegetation community mapping (Figure 2-1 to 5-2) and estimates of vegetation types (Mattiske and Associates 1993b), 1.8 per cent of the combined 'F' types on the island occur within the proposed development area.
- **'Limestone' communities (L vegetation types)** occur on the shallow limestone ridges and slopes located mainly on the central part of the island (covering

approximately 9444.1 ha). Based on recent vegetation community mapping (Figure 2-1 to 5-2) and estimates of vegetation types (Mattiske and Associates 1993b), 0.9 per cent of the combined 'L' types on the island occur within the proposed development area.

- **'Clay Pan' communities (S1 and S2 vegetation types)** occur on the localised clay plans located on flow lines and flats on the island (covering approximately 193.2 ha). Similar clay pan communities have been recorded by Trudgen and Mattiske in the Pilbara region and are generally associated with significant shifts in the local floristic composition of the communities. Based on recent vegetation community mapping (Figure 2-1 to 5-2) and estimates of vegetation types (Mattiske and Associates 1993b), 0.3 per cent of the combined 'S' types on the island occur within the proposed development area.
- **'Valley slopes and escarpment slopes' communities (vegetation types V1 and V2)** occur on the various slopes of the narrow and broad valley systems. Based on recent vegetation community mapping (Figure 2-1 to 5-2) and estimates of vegetation types (Mattiske and Associates 1993b), 1.2 per cent of the combined 'V' types on the island occur within the proposed development area.

Although several halophytic communities occur south of the proposed North White's Beach pipeline route and will not be impacted by the current proposal, it is important to highlight their presence in the event that a change of pipeline route is considered. Halophytic communities have been identified as one of the restricted communities on the island and should be avoided by proposed developments.

4.4.1 Significant Vegetation Communities

Communities with Restricted Distribution or Threatened or Restricted Species

Beyond the extent of representation of a vegetation community, flora and vegetation may be significant for a variety of reasons, including the presence of rare, threatened or geographically-restricted species or restricted distribution of the community. While there are recognised limitations with respect to representation of vegetation on Barrow Island, the vegetation communities located within the proposed development considered to be of particular significance (Figure 8-1 to 8-4) include the following:

- *Erythrina vespertilio* has a restricted distribution on Barrow Island, and consequently vegetation community F4a, which was recorded on the proposed CO_2 reinjection pipeline in the current survey, is considered to be locally significant. Of this community, 0.6 ha may be impacted by the proposed development. 127.6 ha within five main populations of the broader F4 unit have been mapped previously on Barrow Island (Mattiske and Associates 1993) (Plate 20).
- *Grevillea pyramidalis* ?subsp. *leucadendron* has a patchy and restricted distribution on Barrow Island, and consequently vegetation communities L6a, L6b, L6c and L6d which contain the species *Grevillea pyramidalis* subsp. ?*leucadendron* are considered to be locally significant. Two small areas of community L6a are located south of the proposed gas processing facility, in the south-east part of the wider study area (Plate 49).

  The proposed campsite, to the south of the proposed gas processing facility, was relocated during the design stage to avoid community L6a. Of communities L6b, L6c and L6d, 1.2 ha, 1.5 ha and 0.19 ha respectively are likely to be impacted by the North White's Beach pipeline route (Figure 5-1 to 5-4).

Major Drainage Areas

The proposed feed gas pipeline and proposed CO_2 reinjection pipeline cross several areas of major drainage line which are restricted in distribution as a result of historical 'borrowing' of soil material. Approximately 0.5 ha and 1.5 ha of these communities are likely to be impacted by the proposed feed gas pipeline and proposed CO_2 reinjection lines, respectively (Figure 3-1 to 4-4). A drainage area of 0.092 ha may be affected by the proposed camp site (Plate 10 to 19).

Otherwise Significant Vegetation Communities

Previously mapped vegetation type L7 as defined by Mattiske and Associates (1993b) contains *Melaleuca cardiophylla,* which is significant for supporting the restricted and endemic White-winged fairy-wren (*Malurus leucopterus edouardi*) which is listed as Vulnerable under the Western Australian Wildlife Conservation Act and the EPBC Act. In recent mapping of the wider study area the species was recorded in vegetation communities D1a, F8a, L3h, L7a, L7b, V1d, V1k and V1m, of which five communities; D1a, F8a, V1d, V1k and V1m, totalling 93.57 ha were mapped beneath the proposed gas processing facility footprint (Figure 2-1). A total of 1583.84 ha of vegetation type L7 has been previously mapped for the island (Mattiske and Associates 1993b).

Communities Requiring Further Investigation

A range of communities within the proposed development area are either patchy or very restricted in area and require further investigation to clarify their significance. These communities include:

- A range of coastal communities defined and mapped at the western end of the proposed feed gas pipeline, including communities C1d, C2e, C5b, C5c and C4e, which are restricted to the near-coastal areas. Total areas of 0.13 ha, 0.19 ha, 0.22 ha, 0.07 ha and 0.38 ha respectively, would be affected by the proposed pipeline route. (Plate 2, Plate 7, Plate 8). Only one other small area with strong affinities with these communities has been found.
- The clay pan community S1a (Plate 55) recorded on the proposed CO_2 reinjection pipeline. Of this community, 0.3 ha may be impacted by the proposed pipeline. Community S1a relates to broader scale mapping unit S1 (Mattiske and Associates 1993b) which is represented by 192.3 ha on Barrow Island. This community is significant as it supports a combination of grasses that are restricted to the northern clay pans.
- Limestone community L3c is located on the proposed North White's Beach pipeline (Figure 5-1 and 5-2). Of this community, 0.1 ha is likely to be impacted by the proposed pipeline. This community is very restricted and requires further investigation to determine its wider distribution on the island.
- Communities which contain species that germinated after recent post-cyclonic rains and appear to be restricted. Such communities include limestone communities F5d and F5e on the proposed CO_2 reinjection pipeline. One of these communities is known and another presumed to contain *Tephrosia clementii*, which appears to be

restricted on the island. These limestone communities appear to be restricted in distribution and further work is required to determine their extent.

- Vegetation communities in the proposed CO_2 reinjection well sites areas on Barrow Island and the proposed pipeline corridor on the mainland, the significance of which is to be assessed when the locations have been confirmed.

4.5 Vegetation Condition

Most of the vegetation in the proposed development area is in excellent-to-pristine condition, with little apparent disturbance. Exceptions are along main tracks and seismic lines that run across the proposed gas processing facility site and wider study areas and, to a lesser degree, along the proposed pipeline routes.

Vegetation has regenerated to varying degrees on the seismic lines. Table 4-2 shows the areas of vegetation communities within the proposed gas processing facility and wider study area (Figure 2-1) affected by seismic line disturbance.

Table 4-2 – Areas of Vegetation Communities Affected by Seismic Lines and Roads within the Proposed Gas Processing Facility Footprint and Wider Study Area

Vegetation Community	Area of Pre 1994 Seismic lines (ha)	Area of 1994 Seismic lines (ha)	Area of roads (ha)	Total area (ha)
C1a	0.05	0.11	0.01	0.18
C2a	0.56	0.56	0.26	1.38
C2b	0.24	0.41	0.43	1.08
C2c	0.00	0.01	0.00	0.01
C5a	0.04	0.16	0.49	0.68
D1a	0.87	0.98	3.75	5.60
D1a dist	0.05	0.14	31.43	31.62
Dist	0.23	0.56	27.49	28.28
F8a	1.87	2.58	2.85	7.30
L3a	0.16	0.20	0.20	0.56
L3f	0.58	0.57	0.75	1.90
L3h	0.18	0.29	0.31	0.78
L3i	0.99	1.96	1.20	4.15
L4a	1.53	2.18	1.52	5.23
L5a	0.37	0.28	0.37	1.02
L6a	0.01	0.04	0.02	0.07
L7a	0.02	0.06	0.05	0.12
L7b	1.32	2.30	2.22	5.84
L9a	0.08	0.11	0.08	0.28
R	0.00	0.04	0.55	0.59

Vegetation Community	Area of Pre 1994 Seismic lines (ha)	Area of 1994 Seismic lines (ha)	Area of roads (ha)	Total area (ha)
V1a	0.41	0.84	0.51	1.76
V1c	0.01	0.29	0.11	0.40
V1d	0.05	0.10	0.15	0.31
V1k	0.77	1.57	1.77	4.12
V1m	1.68	2.67	2.55	6.89
V1n	0.13	0.17	0.33	0.64
V3a	0.66	0.47	0.73	1.87
V3b	0.48	1.00	0.59	2.07
Total	13.34	20.65	80.72	**114.14**

5 Discussion and Conclusions

The majority of vegetation communities mapped within the proposed development areas extend well beyond the proposed development area and the areas of the communities are larger outside the proposed corridors and gas processing facility than within these areas.

Some work has been undertaken in accurately determining the extent of significant vegetation communities in the vicinity of the proposed development areas, however the extent of these communities over the island requires further clarification. Consideration should be given to, where possible, avoiding those communities identified as being of particular significance within the proposed development areas.

The F4a *Erythyrina vespertilio* community, F5d and F5e *Scaevola cunninghamii* limestone communities, the L6b, L6c and L6d *Grevillea pyramidalis* communities, S1a Clay pan community and L3c Limestone communities mapped within the proposed development area appear to be restricted in distribution on the island. Five coastal vegetation communities recorded at the western end of the proposed feed gas pipeline at Flacourt Bay (C1d, C2e, C5b, C4e and C5c) appear to be restricted to the near coastal areas at Flacourt Bay. Community C2e occurs just outside the proposed pipeline corridor and any changes to the proposed pipeline routes should take into account these five coastal communities.

The *Grevillea pyramidalis* subsp. ?*leucadendron* communities on the proposed North White's beach pipeline corridor appear to extend well beyond the expected area of impact, however the distribution of these communities over the island appears to be limited.

Limited searching in the vicinity of community L3c on the proposed North White's Beach pipeline route were recently undertaken, however limited knowledge of the extent the community shows that it appears to be locally restricted at this stage. Limited searches have been undertaken on the west coast of the island to find other occurrences of community C5c. This community appears at this stage to be locally restricted.

The species composition of the clay pan communities in the south west of the island differed significantly from the S1a clay pan community on the proposed CO_2 reinjection pipeline. Further investigation is required to determine whether other clay pan areas mapped previously by Mattiske and Associates (1993) differ significantly from the S1a community on the proposed pipeline route.

Impacts on major drainage lines in the vicinity of the proposed development should be minimised, given the historical disturbance of major drainage communities on the island.

Neither of the two Priority species recorded on Barrow Island (*Corchorus interstans* ms or *Helichrysum oligochaetum*) are restricted to the island. *Helichrysum oligochaetum* has not been observed or recorded in surveys of the proposed development areas. Although the proposed development on Barrow Island may impact some of the populations of *Corchorus interstans* ms, this species is widely represented outside the proposed development areas. *Corchorus interstans* ms is abundant in a wide range of environments and is not threatened by the proposed development.

A number of species, though not listed as Rare or Priority, appear to be restricted in distribution on the island and consideration should be given to avoiding these species where possible within the proposed development areas. Of the 23 species considered to be restricted in distribution or poorly known on the island prior to recent post cyclonic rain surveys, 6 species were recorded in recent surveys of the proposed development areas;

Dichanthium sericuem subsp. *humilius*, *Erythrina vespertilio*, *Grevillea pyramidalis* subsp. ?*leucadendron*, *Hakea lorea* subsp. *lorea*, *Hybanthus aurantiacus* and *Whiteochloa airoides*.

Dichanthium sericuem subsp. *humilius* was located within the proposed gas processing facility area in recent post cylonic rain surveys and knowledge of this species on the island is limited.

Grevillea pyramidalis subsp. ?*leucadendron* occurs in communities L6a, L6b, L6c and L6d, of which three communities were recorded on the proposed North White's Beach pipeline route. *Erythrina vespertilio* was recorded within community F4a on the proposed CO_2 reinjection pipeline corridor.

Hakea lorea subsp. *lorea* was recorded in a variety of vegetation communities within the proposed development areas in the current survey, and appears to be more widespread than previously considered.

Hybanthus aurantiacus was recorded within the proposed gas processing facility area and in the wider study area. Although some populations are likely to be affected by the proposed gas processing facility, most populations of this species are not likely to be affected.

Whiteochloa airoides was recorded on the proposed feed gas pipeline corridor and has been found further inland in previous surveys. Further investigation of this species is required to determine its distribution on the island.

Species recorded during recent post cyclonic surveys of the proposed development areas that require further investigation to clarify their distribution on the island include *Tephrosia clementii, Eriachne flaccida* (Southern Pilbara — Carnarvon Coastal Form), *Isolepis* sp. , *Tribulus hirsutus* and *Corchorus congener.*

Eriachne flaccida (Southern Pilbara – Carnarvon Coastal Form) may be restricted to the clay pan community on the proposed CO_2 reinjection pipeline. Further investigation of other clay pan areas on the island are required to clarify the distribution of community S1a on the island.

Due to the limited number of specimens of *Tephrosia clementii* in the Western Australian Herbarium and limited knowledge of its wider distribution, the conservation significance of this species may be revised by CALM.

Seventeen species requiring further identification are potentially restricted on Barrow Island and further studies are required to determine whether these species are restricted to Barrow Island. Of these 17 species, *Isolepis* sp. and *Acacia bivenosa* (elongate phyllode variant) were recorded within the proposed development areas. The *Isolepis* specimen does not appear to match any known *Isolepis* specimen held in the Western Australian Herbarium, apart from a specimen recently collected in Perth. Further collections of *Isolepis* sp. are necessary to enable positive identification.

Two forms of *Acacia bivenosa* occur in the proposed development areas, a 'normal' variant and an 'elongate phyllode' variant. Further studies of *Acacia bivenosa* and variants of it on the island are required to clarify the taxonomic status of this species.

The collection of a new introduced species; *Setaria verticillata* on the island, near the proposed North White's Beach pipeline corridor warrants further investigation.

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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.
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*.

FIGURE 1-1

BARROW ISLAND

VEGETATION LEGEND

Sheet 1 of 4 sheets

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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.
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 *Triodia epactia, 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.

FIGURE 1-2

BARROW ISLAND

VEGETATION LEGEND

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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.
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.

FIGURE 1-3

BARROW ISLAND

VEGETATION LEGEND

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	V1k	Scattered *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.
	Restricted Area	

FIGURE 1-4

BARROW ISLAND

VEGETATION LEGEND

Sheet 4 of 4 sheets

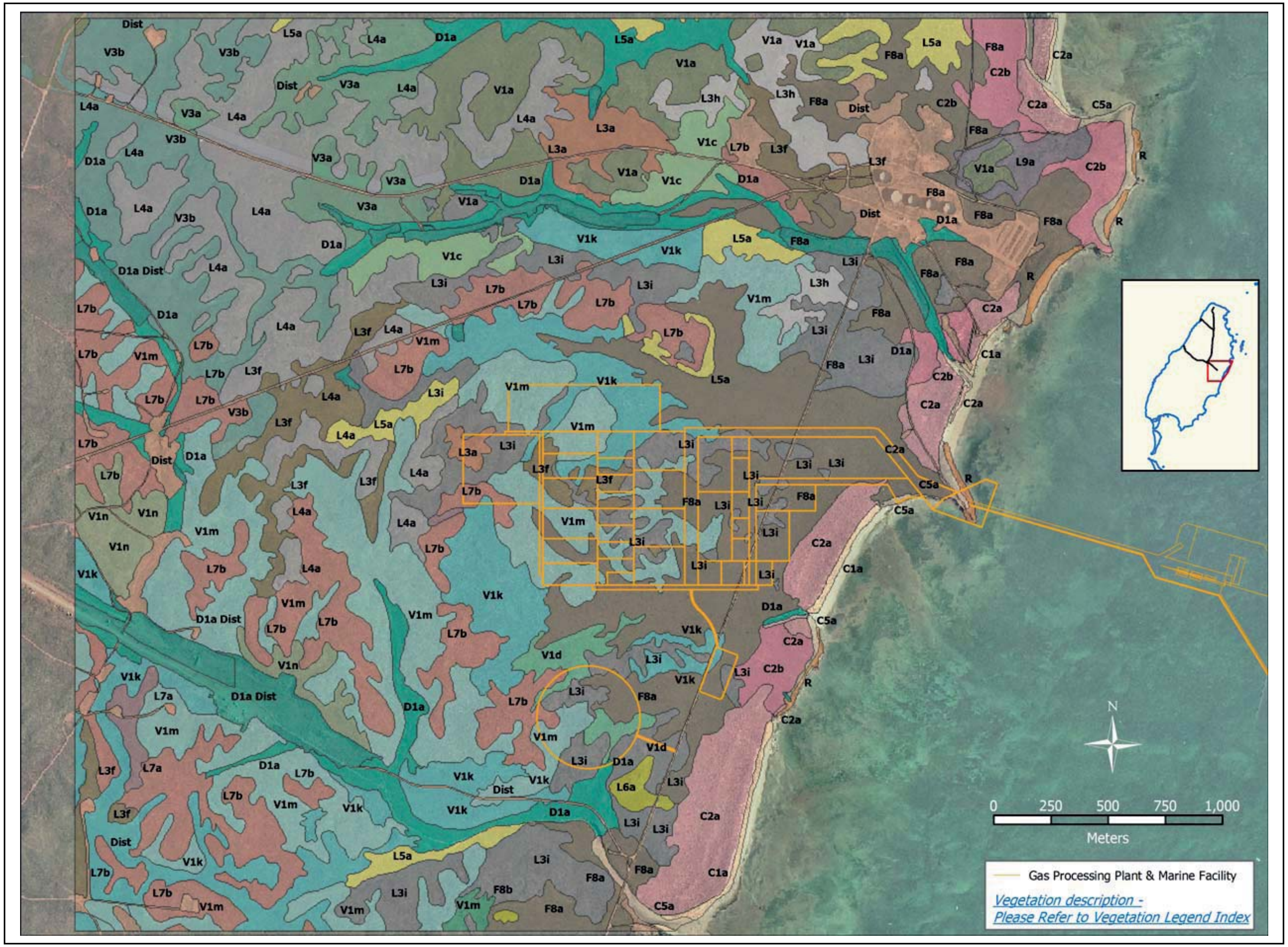
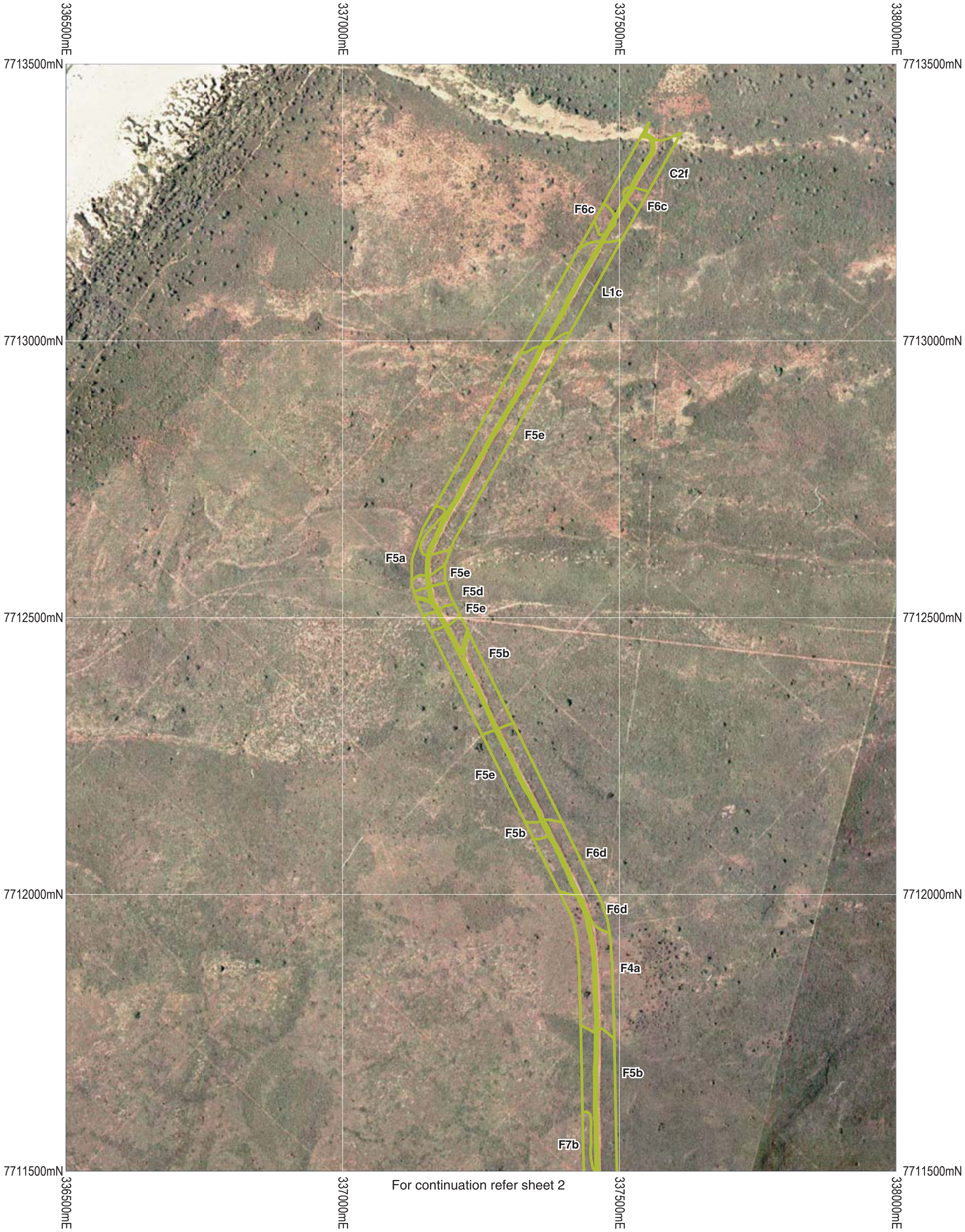
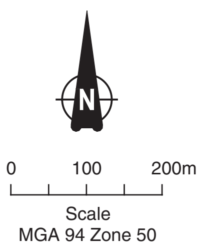
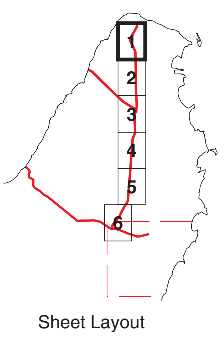


Figure 2-1 – Wider Study Area for Proposed Gas Processing Facility – Vegetation



For continuation refer sheet 2





For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 3-1

BARROW ISLAND

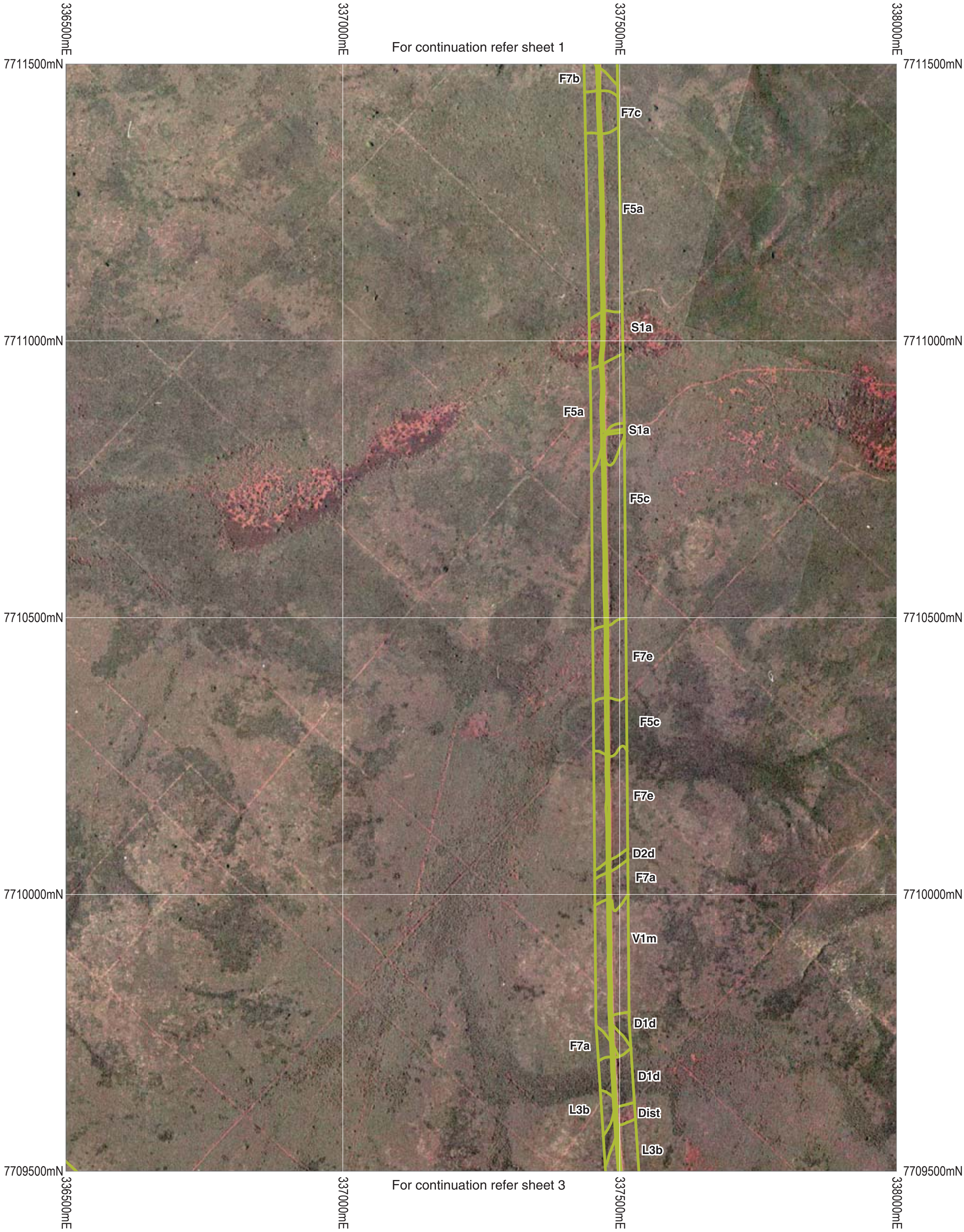
PROPOSED CO_2 REINJECTION PIPELINE

VEGETATION BOUNDARIES

Sheet 1 of 6 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcar1.dgn ~ Rev: C ~ Aug 2004

For continuation refer sheet 1



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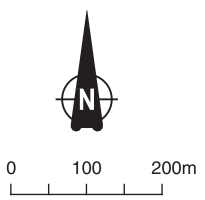
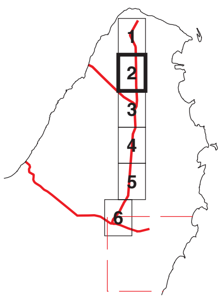


Scale
MGA 94 Zone 50



Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 3-2

BARROW ISLAND

PROPOSED CO_2 REINJECTION PIPELINE

VEGETATION BOUNDARIES

Sheet 2 of 6 sheets

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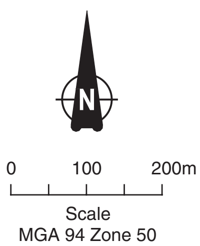

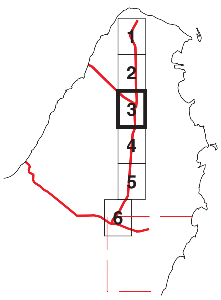

Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 3-3

BARROW ISLAND

PROPOSED CO_2 REINJECTION PIPELINE

VEGETATION BOUNDARIES

Sheet 3 of 6 sheets

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For continuation refer sheet 3

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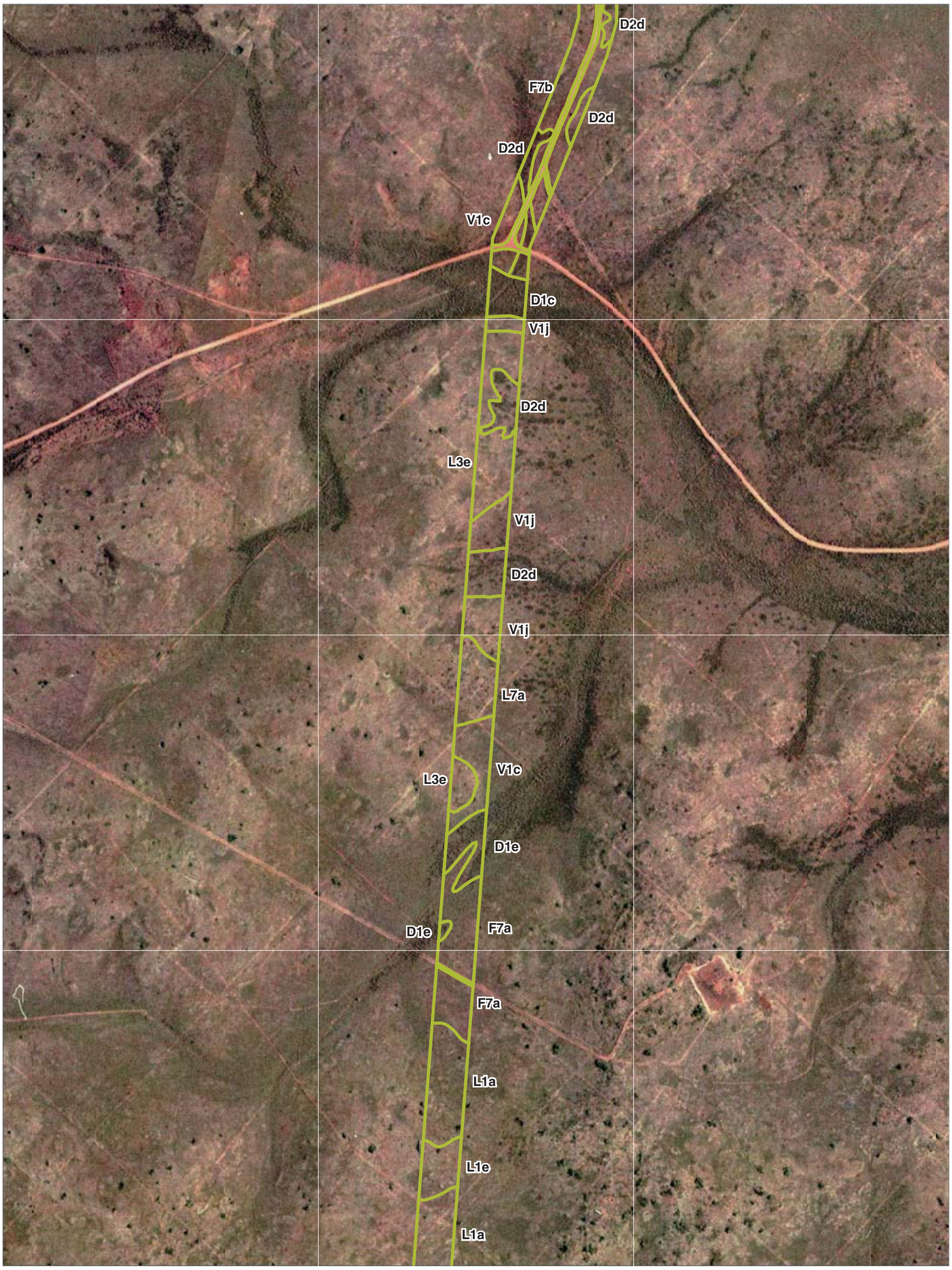

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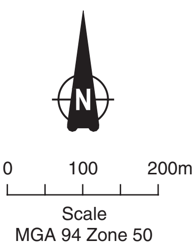

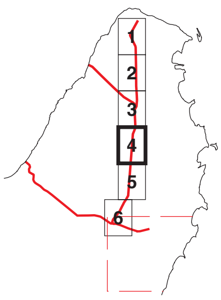

Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 3-4

BARROW ISLAND

PROPOSED CO_2 REINJECTION PIPELINE

VEGETATION BOUNDARIES

Sheet 4 of 6 sheets

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For continuation refer Sheet 4

For continuation refer Sheet 6

N

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Scale
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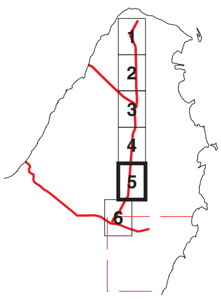

Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 3-5

BARROW ISLAND

PROPOSED CO_2 REINJECTION PIPELINE

VEGETATION BOUNDARIES

Sheet 5 of 6 sheets

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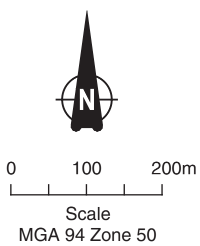
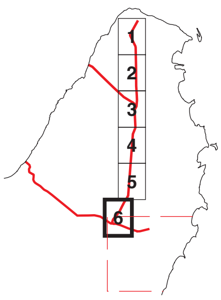
For continuation refer Sheet 5





For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 3-6

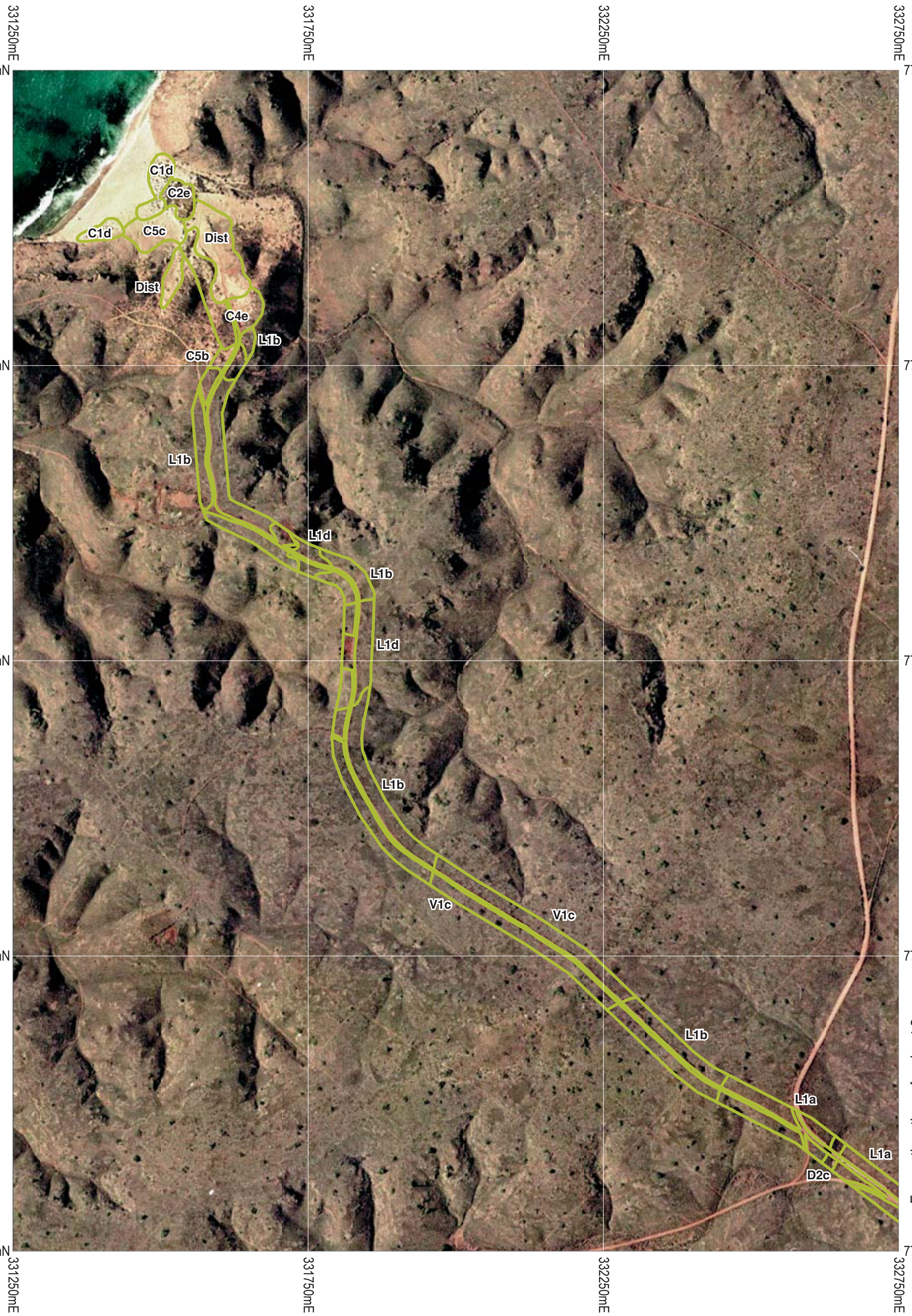
BARROW ISLAND

PROPOSED CO_2 REINJECTION PIPELINE

VEGETATION BOUNDARIES

Sheet 6 of 6 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcar6.dgn ~ Rev: C ~ Aug 2004



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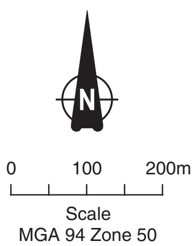
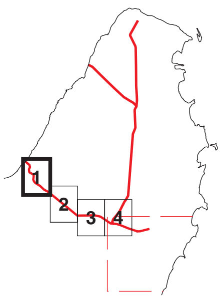




Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 4-1

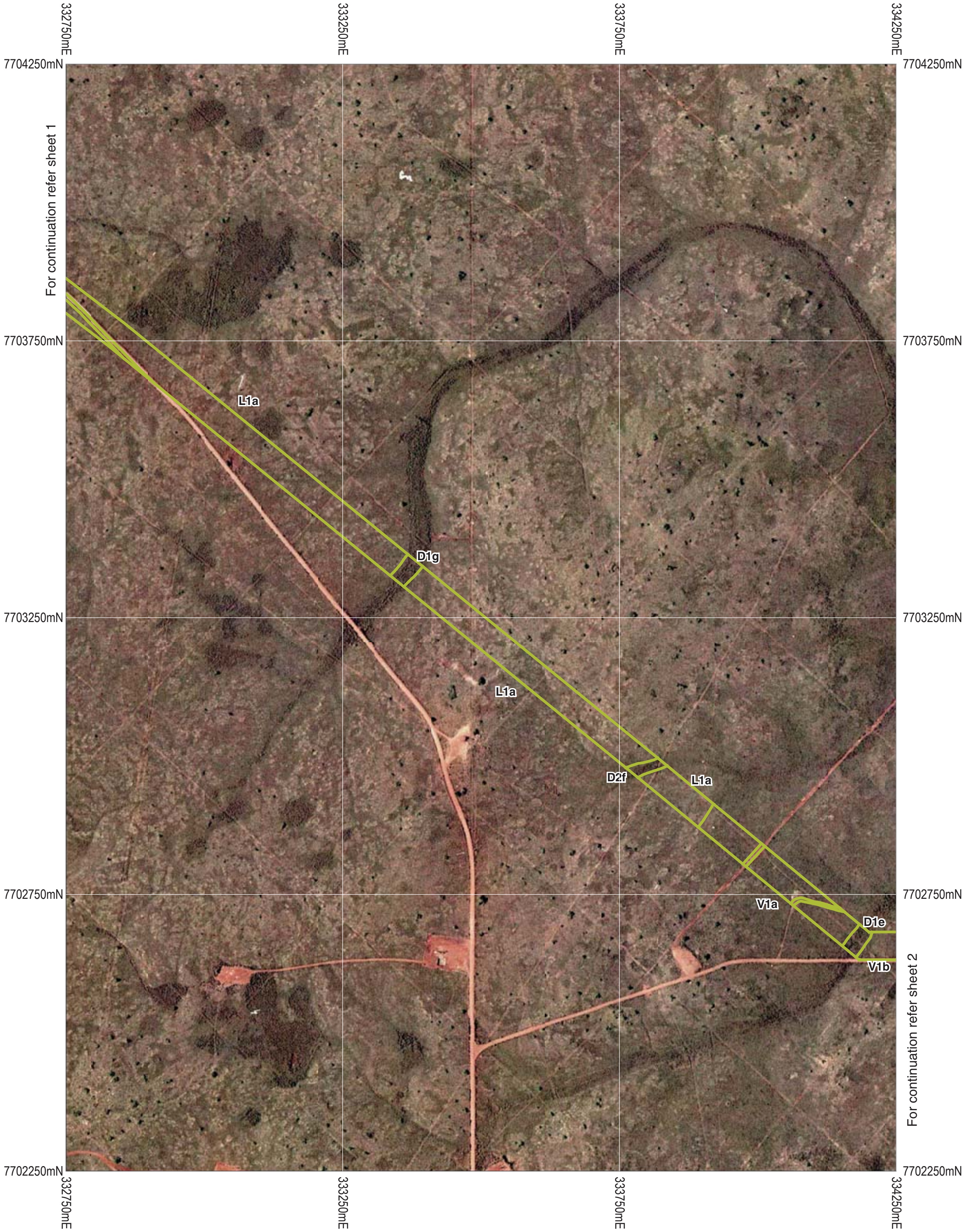
BARROW ISLAND

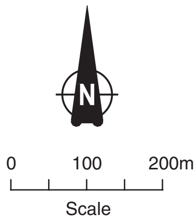
PROPOSED FEED GAS PIPELINE

VEGETATION BOUNDARIES

Sheet 1 of 4 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcaf1.dgn ~ Rev: C ~ Aug 2004





Scale
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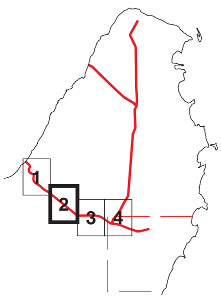


Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 4-2

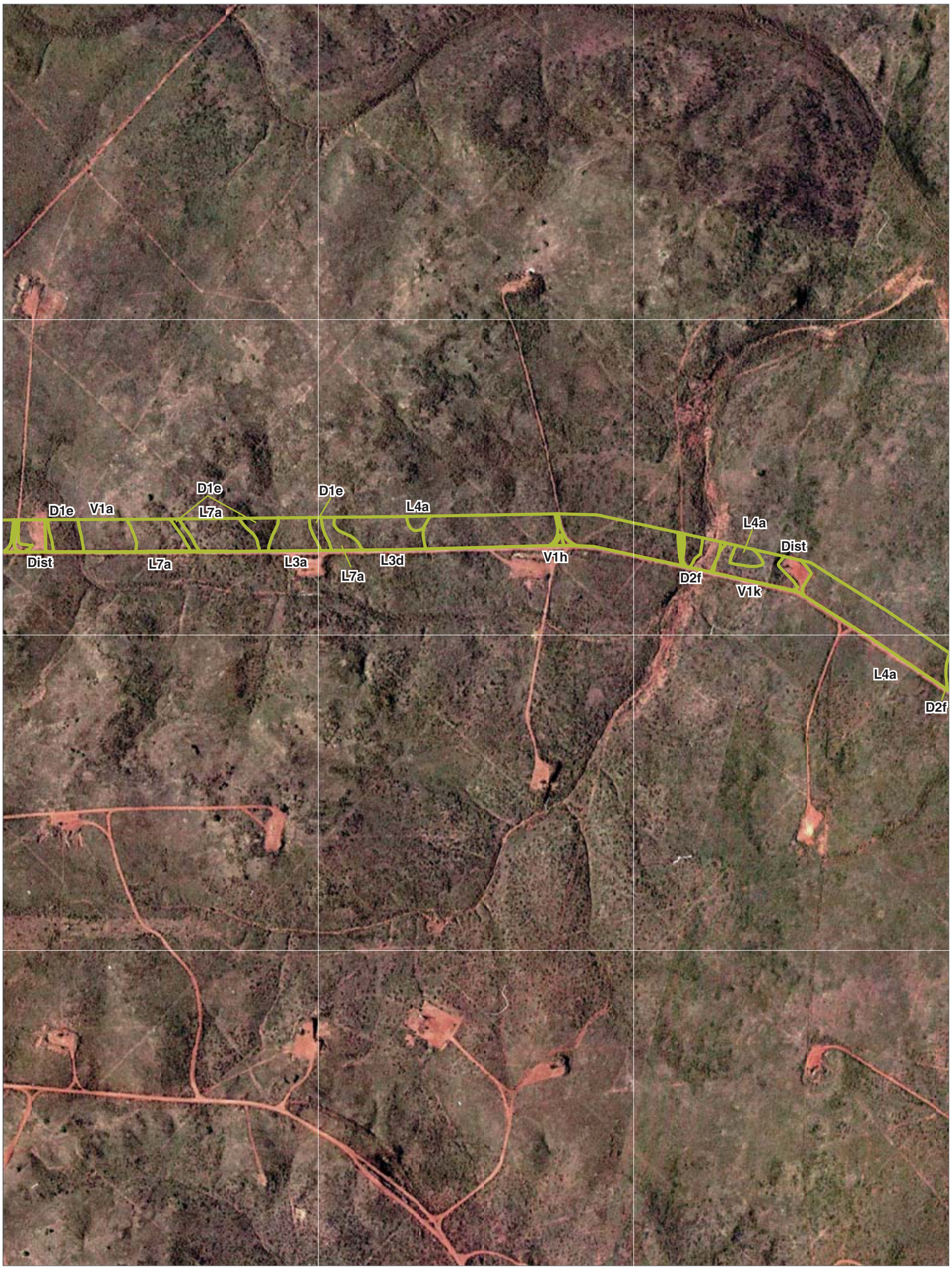
BARROW ISLAND

PROPOSED FEED GAS PIPELINE

VEGETATION BOUNDARIES

Sheet 2 of 4 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcaf2.dgn ~ Rev: C ~ Aug 2004



For continuation refer sheet 2

For continuation refer sheet 4

N

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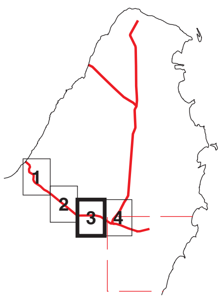
Scale
MGA 94 Zone 50



Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 4-3

BARROW ISLAND

PROPOSED FEED GAS PIPELINE

VEGETATION BOUNDARIES

Sheet 3 of 4 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcaf3.dgn ~ Rev: C ~ Aug 2004

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7703500mN

7703000mN
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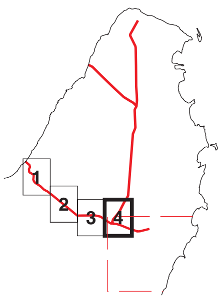
For continuation refer sheet 3

0 100 200m
Scale
MGA 94 Zone 50



Sheet Layout

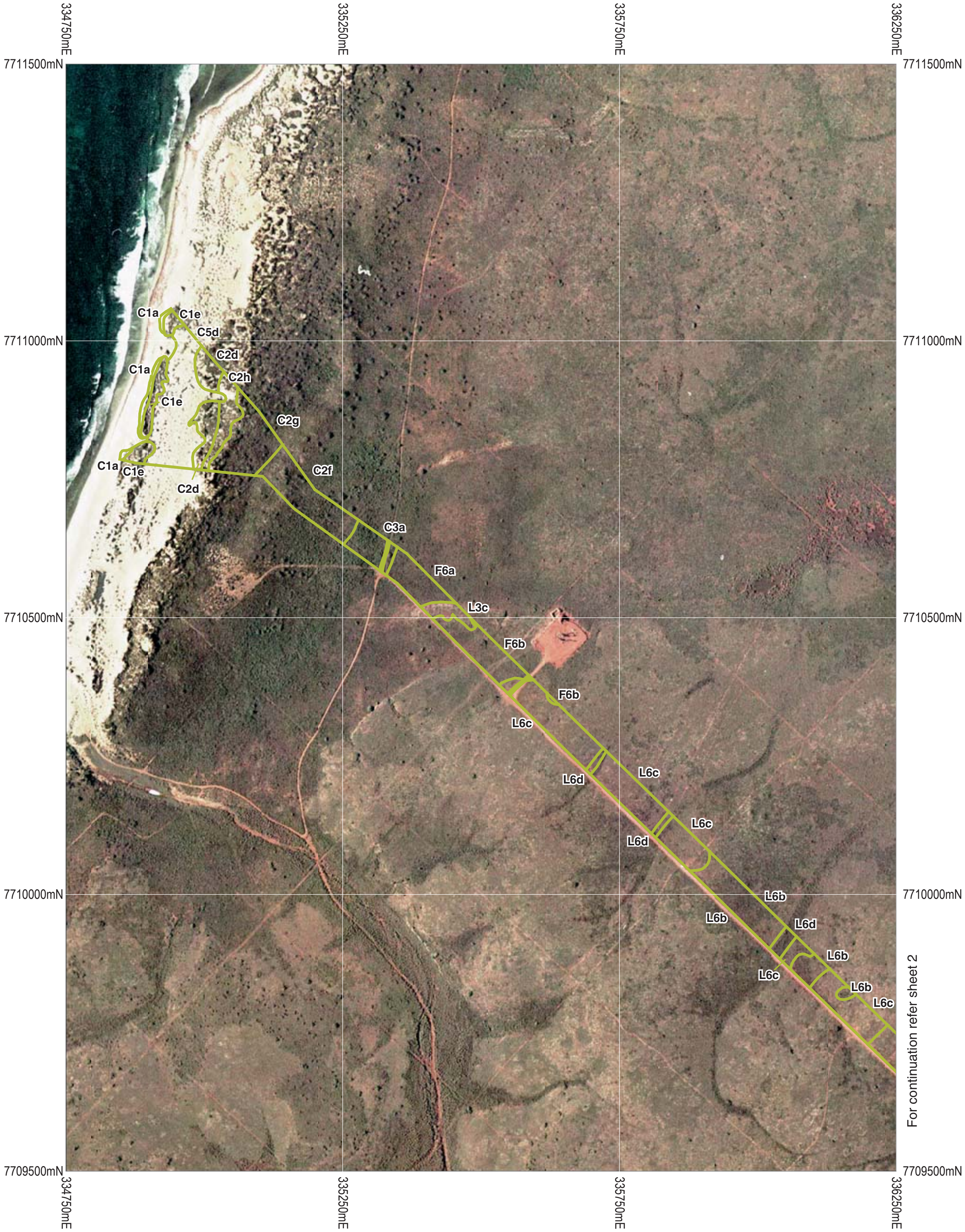
For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

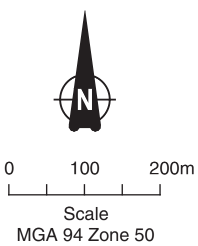
FIGURE 4-4

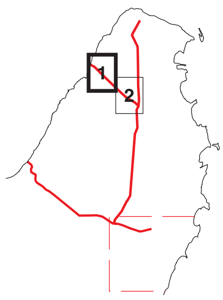
BARROW ISLAND
PROPOSED FEED GAS PIPELINE
VEGETATION

Sheet 4 of 4 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcaf4.dgn ~ Rev: C ~ Aug 2004







Sheet Layout

For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 5-1

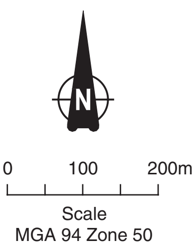
BARROW ISLAND

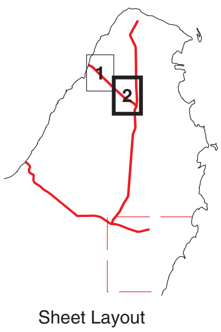
PROPOSED NORTH WHITES BEACH PIPELINE

VEGETATION BOUNDARIES

Sheet 1 of 2 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcaw1.dgn ~ Rev: C ~ Aug 2004





For detailed vegetation legend refer to Vegetation Legend Sheets 1 to 4

FIGURE 5-2

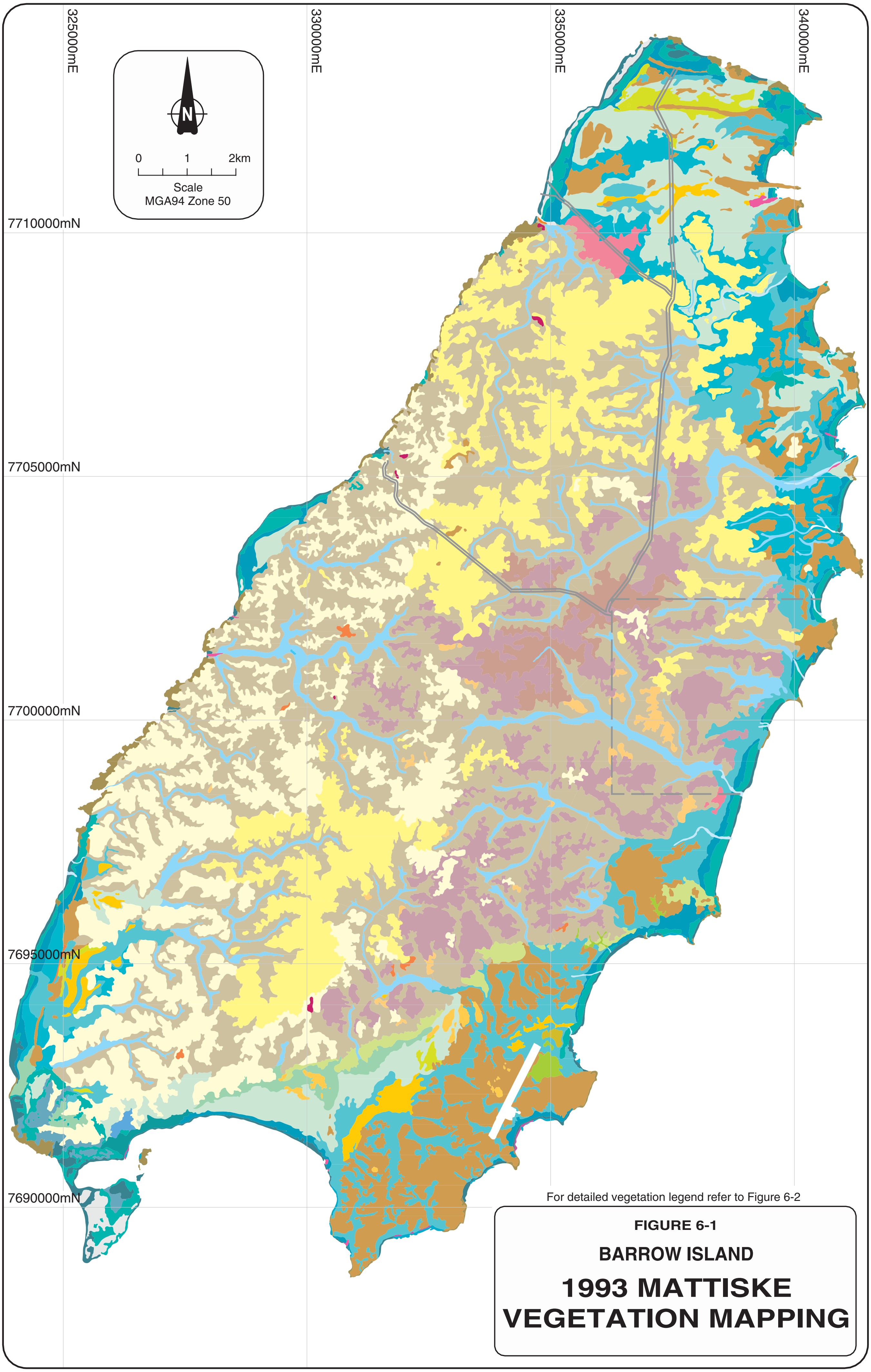
BARROW ISLAND

PROPOSED NORTH WHITES BEACH PIPELINE

VEGETATION BOUNDARIES

Sheet 2 of 2 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vcaw2.dgn ~ Rev: C ~ Aug 2004



For detailed vegetation legend refer to Figure 6-2

FIGURE 6-1

BARROW ISLAND

1993 MATTISKE VEGETATION MAPPING

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Marine

M1 Aquatic Complex supporting stands of *Avicennia marina* and *Ruppia maritima* on the fringes of the Island.

Tidal

T1 Halophytic Complex dominated by *Halosarcia halocnemoides* and *Halosarcia indica* on tidal flats.

T2 Mixed Chenopod and Halophytic Complex with low *Frankenia pauciflora* shrubs on high tide areas usually associated with stands of *Avicennia marina.*

Creek or Seasonal Drainage Lines

D1 Mixed Hummock Grassland of *Triodia angusta* with pockets of dense shrubs along major creek-lines.

D2 Hummock Grassland of *Triodia angusta* along minor creek-lines and drainage lines.

D3 Hummock Grassland of *Triodia angusta* along minor creek-line with emrgent *Santalum murrayanum.*

Coastal Complex and Dune System

C1 Coastal Complex dominated by *Spinifex longifolius* on white fore-dunes; including Coastal Complex of *Ipomoea pes-caprae* ssp. *brasiliensis* and *Spinifex longifolius* on strand line foredunes.

C2 Open Scrub of *Acacia coriacea - Rhagodia preissii* ssp. *obovata - Olearia dampieri* ssp. *dampieri* on elevated dunes on fringes of Island.

C3 Hummock Grassland of *Triodia pungens* with dense shrubs including *Acacia bivenosa* on back-slopes of foredunes.

C4 Mixed Hummock Grassland of *Triodia angusta - Triodia pungens* with dense shrubs including *Acacia bivenosa* on back-slopes of foredunes.

C5 Low Mixed Shrubland of *Frankenia pauciflora* and *Hedyotis crouchiana* on exposed cliff faces around edge of Island.

C6 Hummock Grassland of *Triodia pungens* with dense pockets of *Melaleuca cardiophylla* on sandy valley systems in south-western corner of Island.

C7 Hummock Grassland of *Triodia pungens* with dense pockets of *Olearia dampieri* spp. *dampieri* on sandy soils behind fore-dune in south-western corner of Island.

Clay Pans

S1 Mixed Herbfield and Grassland of *Eragrostis xerophila, Eriachne flaccida* and *Sporobolus virginicus* on clay pans.

S2 Mixed Herbfields with *Streptoglossa bubakii* and *Pterocaulon sphacelatum* on fringes of tidal Halophytic areas and flood channels on clay soils near coast.

Miscellaneous

BS Bare sand

Flats

F1 Hummock Grassland of *Triodia angusta* on red earth flats and drainage lines.

F2 Hummock Grassland of *Triodia angusta* with emergent *Acacia synchronicia* on red earth flat.

F3 Hummock Grassland of *Triodia angusta* with emergent shrubs of *Gossypium robinsonii* on red earth flats.

F4 Hummock Grassland of *Triodia angusta - Triodia* spp. with emergent pockets of *Erythrina verspertilio* on flats.

F5 Mixed Hummock Grassland of *Triodia pungens - Triodia angusta* on fringes of main red earth flats and drainage lines.

F6 Hummock Grassland of *Triodia pungens* on slopes of escarpments on fringes of red earth flats.

F7 Hummock Grassland of *Triodia pungens - Triodia angusta - Triodia wiseana* on slopes of escarpments on fringes of red earth flats.

Limestone Ridges

L1 Hummock Grassland of *Triodia wiseana* with *Ficus platypoda* var. *platypoda* on central limestone ridges.

L2 Hummock Grassland of *Triodia wiseana* with *Ficus virens* var. *virens* on escarpments on west coast and southern edge of limestone ridges.

L3 Hummock Grassland of *Triodia wiseana* with low mixed shrubs, including *Acacia gregorii* on limestone ridges.

L4 Hummock Grassland of *Triodia wiseana* with dense emergent shrubs of *Acacia pyrifolia, Acacia gregorii* and *Petalostylis labicheoides* on limestone ridges.

L5 Hummock Grassland of *Triodia wiseana* with emergent *Hakea suberea* on limestone ridges.

L6 Hummock Grassland of *Triodia wiseana* with emergent *Grevillea pyramidalis* on limestone ridges.

L7 Hummock Grassland of *Triodia wiseana* with dense pockets of *Melaleuca cardiophylla* on limestone ridges.

L8 Hummock Grassland of *Triodia wiseana* with pockets of *Eucalyptus patellaris* on limestone ridges.

L9 Hummock Grassland of *Triodia wiseana - Triodia angusta* with emergent *Sarcostemma viminali* spp. *australe* and *Ficus platypoda* var. *platypoda* on coastal limestone flats and low ridges with localised pockets of *Frankenia pauciflora.*

L10 Hummock Grassland of *Triodia pungens - Triodia augusta* with emergent *Hakea suberea* on exposed small limestone hills on southern coastal area.

Valley Slopes and Escarpment Slopes

V1 Hummock Grassland of *Triodia wiseana* with mixed emergent shrub species on valley slopes.

V2 Hummock Grassland of *Triodia wiseana* with *Pentalepis trichodesmoides* on southern escarpment.

◆ Merchant Site

▲ Mattiske Seismic Site 1993A

▼ Mattiske Vegetation Site 1993B

Trudgen Site

Astron Site

FIGURE 6-2

BARROW ISLAND

1993 MATTISKE VEGETATION LEGEND

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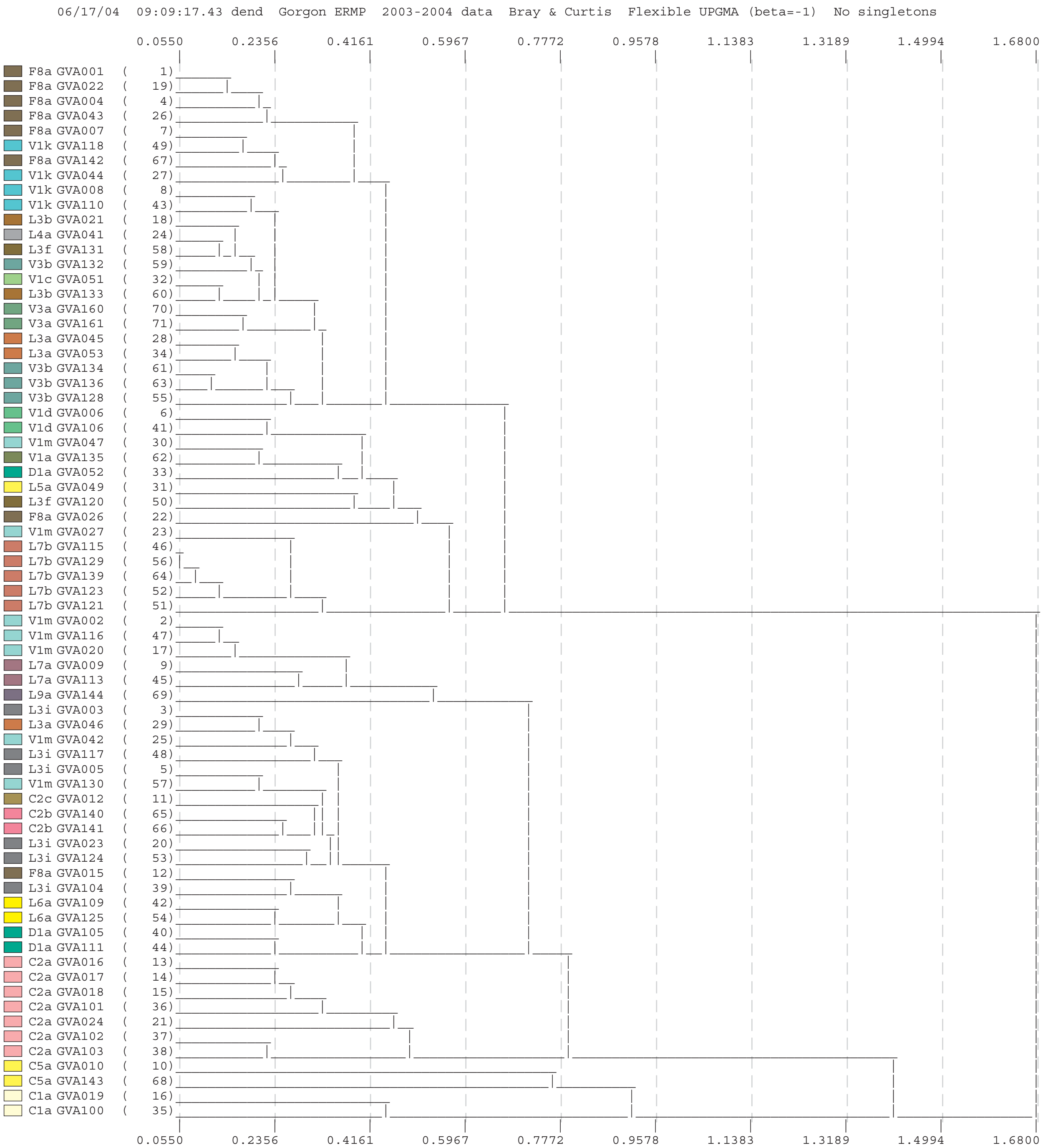


LEGEND

Vegetation Community	Vegetation Plot No.
F8a	GVA001
F8a	GVA022
F8a	GVA004

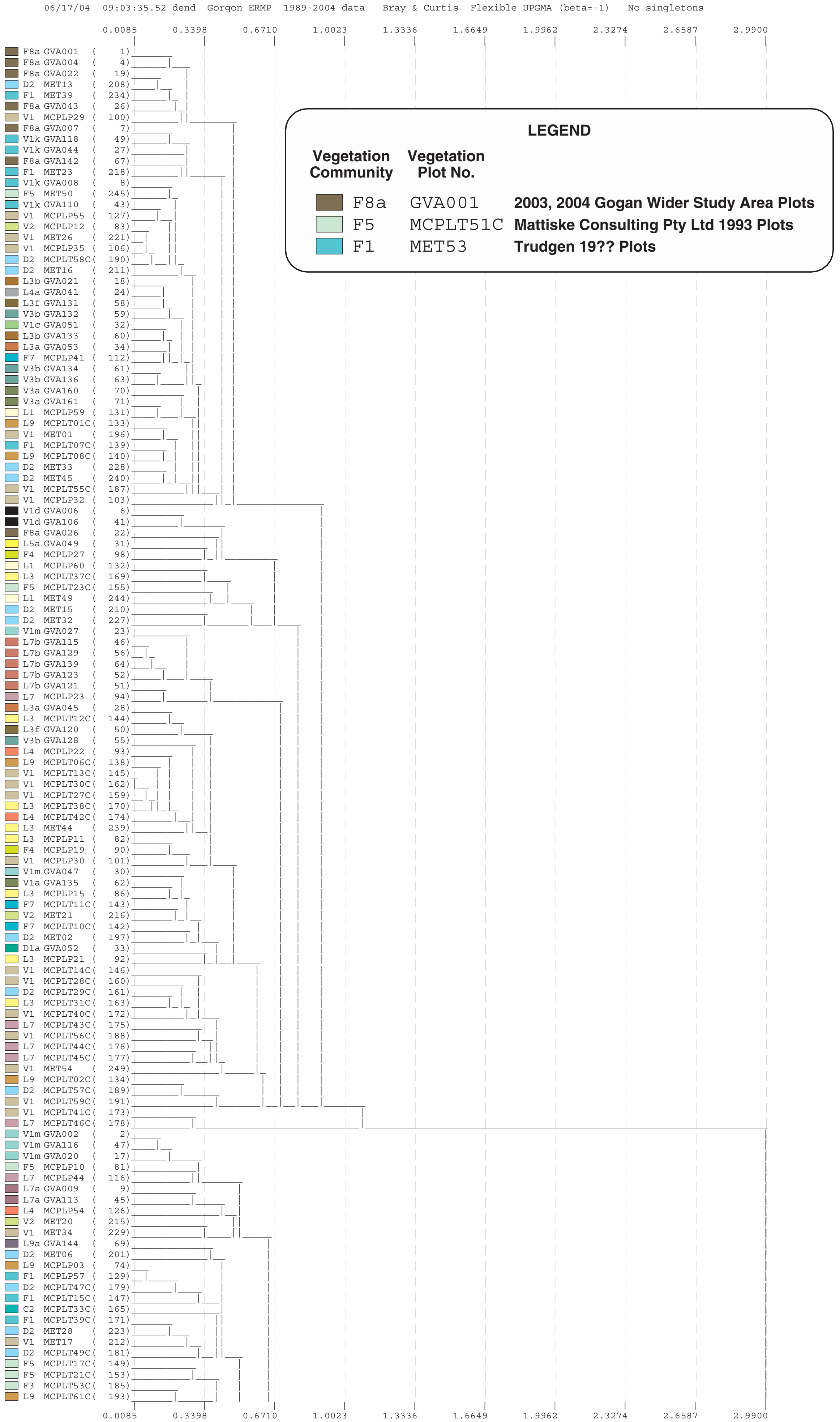
BARROW ISLAND

2003 & 2004 GORGON PROJECT AREA VEGETATION MAPPING

WIDER STUDY AREA FOR PROPOSED GAS PROCESSING FACILITY
BRAY CURTIS DENDROGRAM

Sheet 1 of 1 sheets

FIGURE 7-1



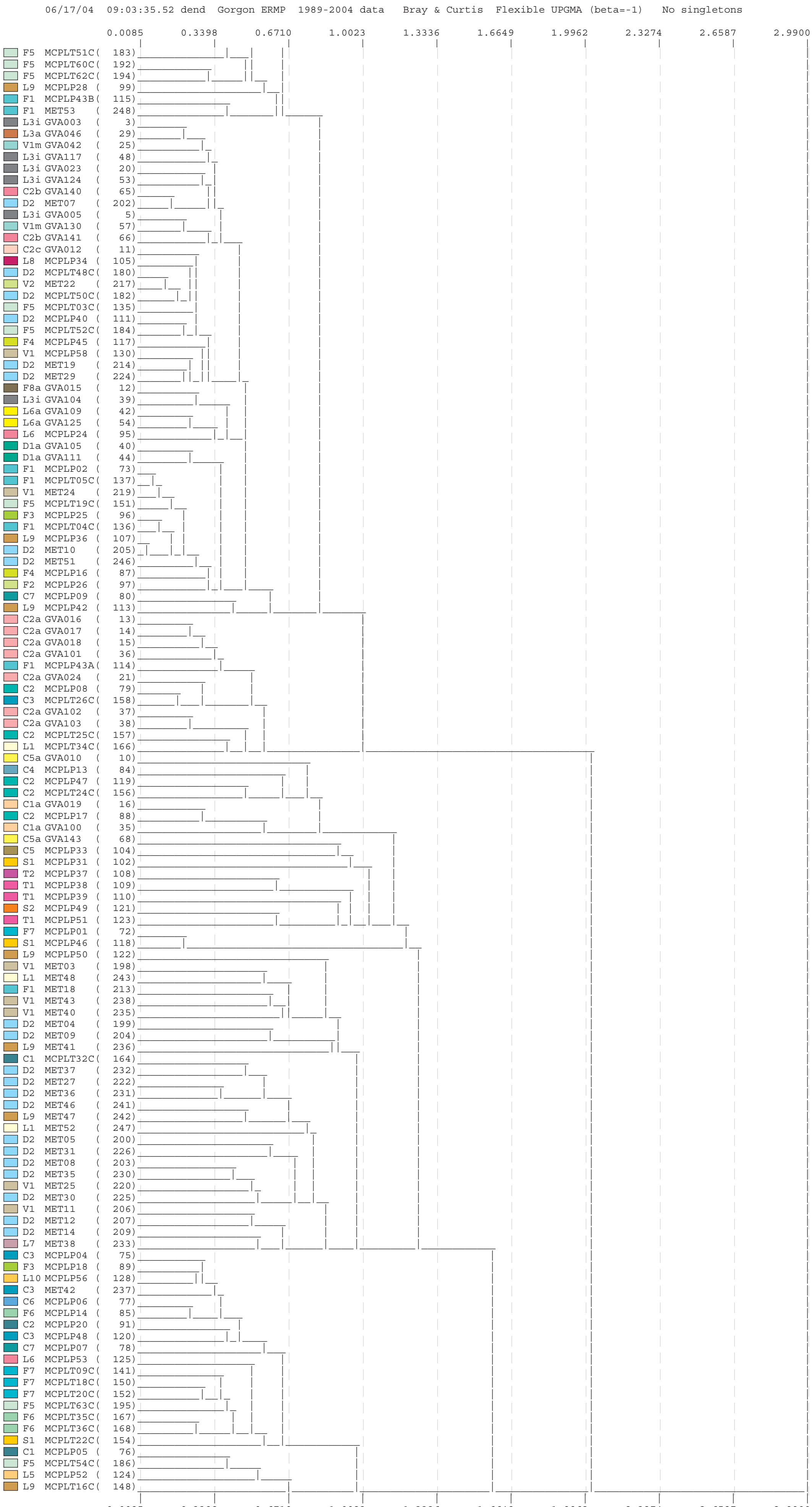
BARROW ISLAND

BRAY CURTIS DENDROGRAM

Historical and Recent Vegetation Plots

Sheet 1 of 2 sheets

FIGURE 7-2



BARROW ISLAND
BRAY CURTIS DENDROGRAM
Historical and Recent Vegetation Plots
Sheet 2 of 2 sheets

FIGURE 7-3

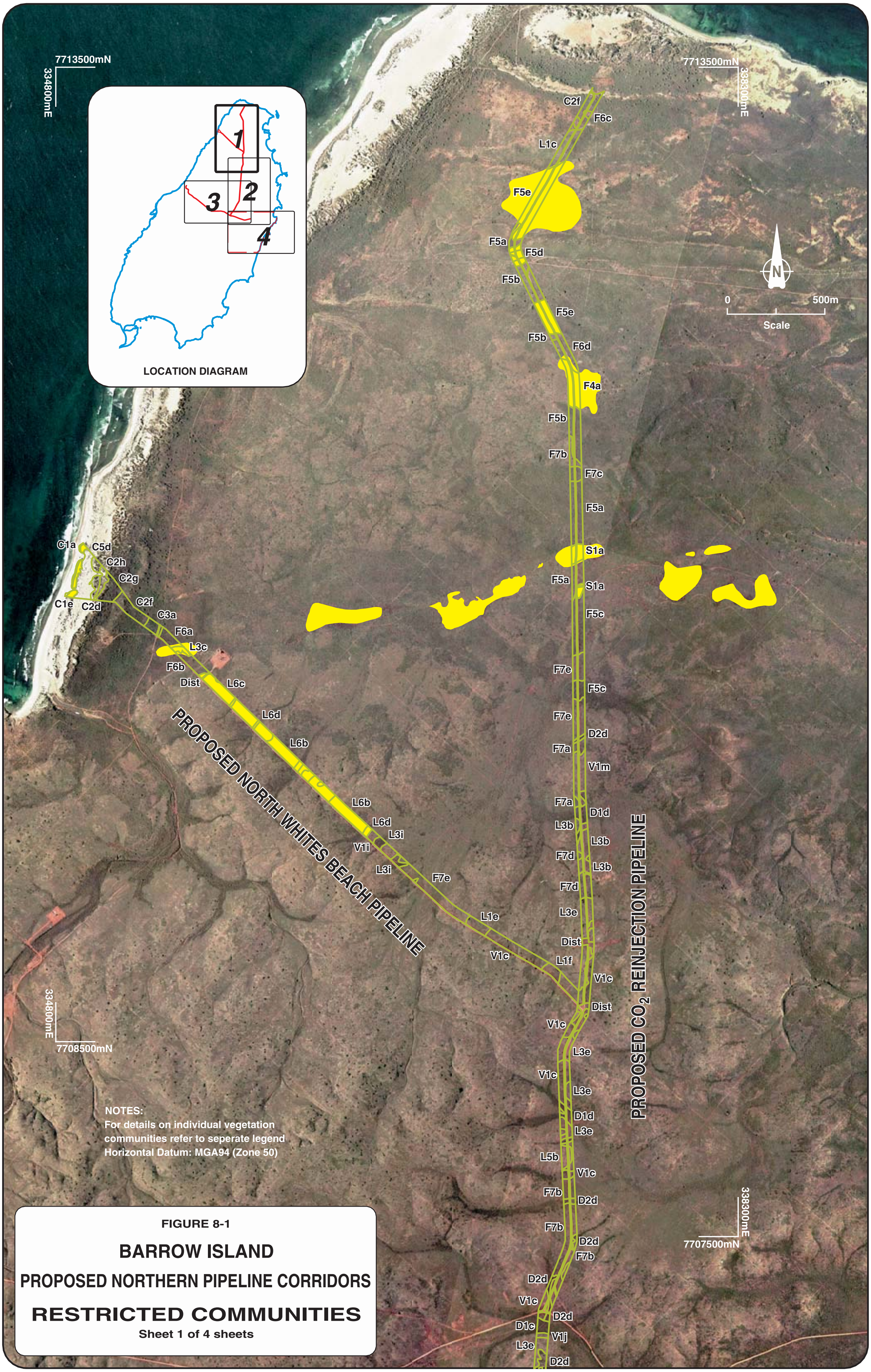


FIGURE 8-1

BARROW ISLAND

PROPOSED NORTHERN PIPELINE CORRIDORS

RESTRICTED COMMUNITIES

Sheet 1 of 4 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vr1.dgn ~ Rev: C ~ Aug 2004

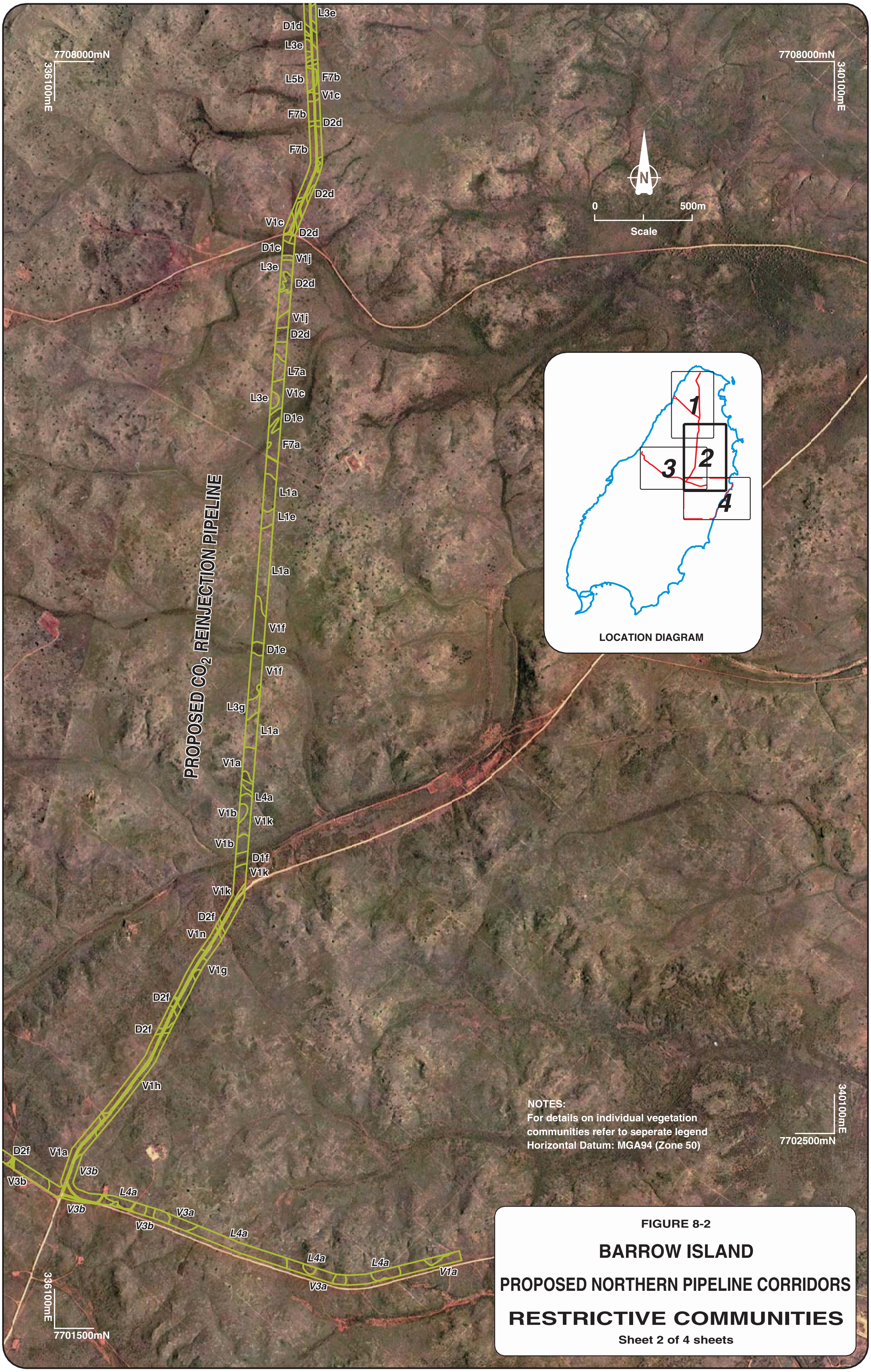


FIGURE 8-2

BARROW ISLAND

PROPOSED NORTHERN PIPELINE CORRIDORS

RESTRICTIVE COMMUNITIES

Sheet 2 of 4 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_tech_vr2.dgn ~ Rev: C ~ Aug 2004

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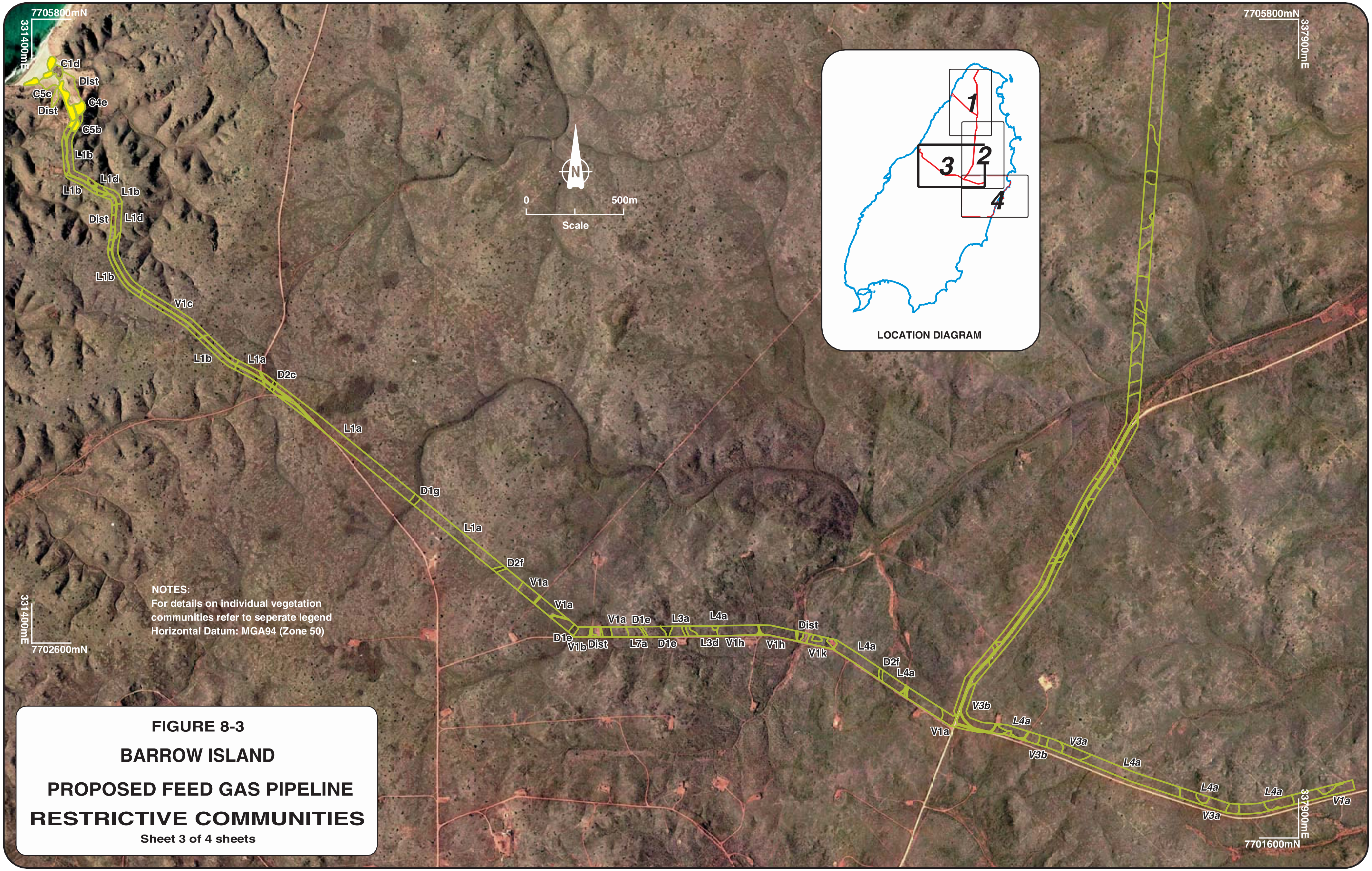


NOTES:
For details on individual vegetation communities refer to seperate legend
Horizontal Datum: MGA94 (Zone 50)

FIGURE 8-3

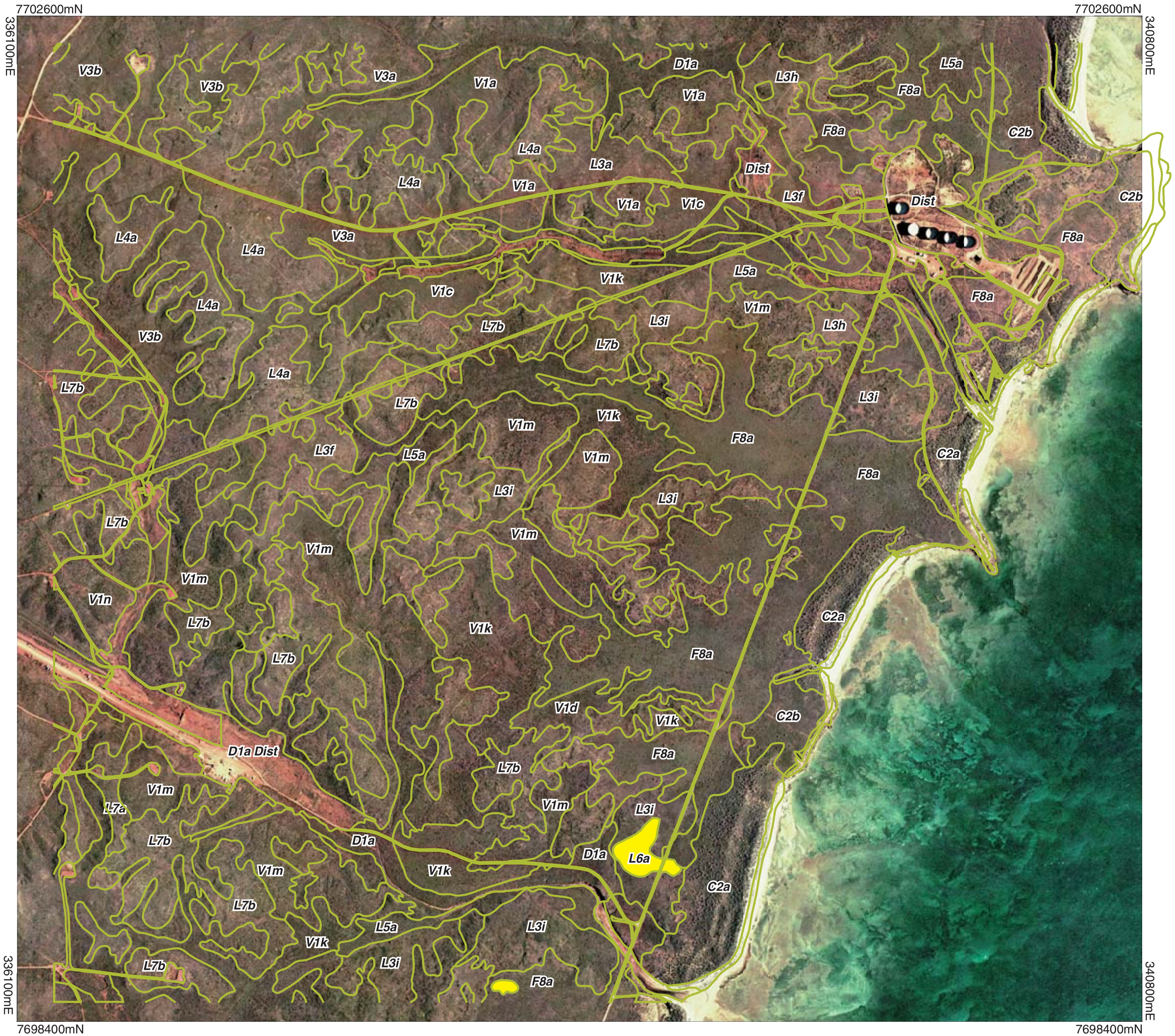
BARROW ISLAND

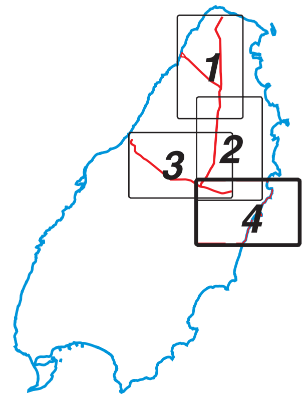
PROPOSED FEED GAS PIPELINE

RESTRICTIVE COMMUNITIES

Sheet 3 of 4 sheets

Drawn: CAD Resources ~ www.cadresources.com.au ~ Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202 ~ A4 ~ CAD Reference: g1032_Tech_vr4.dgn ~ Rev: C ~ Aug 2004





LOCATION DIAGRAM

Notes:
For detailed legend refer figure numbered 8.3.1.1:1 to 8.3.1.1:4
Horizontal Datum: MGA94 (Zone 50)

N

0 500m
Scale

FIGURE 8-4

BARROW ISLAND

WIDER STUDY AREA FOR PROPOSED GAS PROCESSING FACILITY

RESTRICTIVE COMMUNITIES

Sheet 4 of 4 sheets

PLATES

Plate 1 - Non-vascular species observed on proposed CO_2 Reinjection Pipeline

Plate 2 - C1d Community

Community C1d – Low Open Shrubland of *Scaevola cunninghamii*, *Corchorus* sp. and *Heliotropium glanduliferum* over Very Open Grassland of *Spinifex longifolius* over scattered *Cynachum floribundum* creeper on lower slopes at the base of primary sand dunes. Recorded on the proposed feed gas pipeline route.

Plate 3 - C2a Community

Community C2a – Shrubland to Tall Shrubland of *Acacia coriacea* over Low Open Shrubland to Open Shrubland of *Acacia bivenosa* with low scattered *Olearia dampierii* subsp. *dampierii* over Open Hummock Grassland to Hummock Grassland of *Triodia angusta* on dune swales, slopes and ridges.

Plate 4 - C2f Community

Community C2f – Open Shrubland of *Acacia coriacea* over Low Open Shrubland of *Olearia dampierii* subsp. *dampierii* 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 the back of red/brown sandy flats and dunes).

Plate 5 - C2g Community

Community C2g – Shrubland of *Acacia coriacea* over Low Shrubland to Shrubland of *Olearia dampierii* subsp. *dampierii, Stylobasium spathulatum* and *Acacia bivenosa* over Hummock Grassland of *Triodia epactia* over low scattered *Threlkeldia diffusa* herbs in swales between dunes.

Plate 6 - C3a Community

Community C3a – Open Heath of *Acacia bivenosa* over Low Open Shrubland of *Olearia dampierii* subsp. *dampierii* with low scattered *Myoporum montanum* and *Enchylaena tomentosa* var. *tomentosa* over Open Hummock Grassland of *Triodia epactia* on red/brown sandy flats behind dunes

Plate 7 - C4e Community

Community C4e – Open Shrubland if *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 slopes to mid slopes of sandy dunes. Recorded on the proposed gas pipeline route.

Plate 8 - C5c Community

Plate 9 - C5c Community

Community C5c – Very Open Hummock Grassland of Triodia angusta over low scattered *Scaevola cunninghammi*, *Corchorus* sp., *Frankenia pauciflora* var. *pauciflora* and *Heliotropium glanduliferum* scattered herbs and shrubs on lower slopes on limestone. Recorded on the proposed feed gas pipeline route.

Plate 10 - D1a Community

Community D1a – Scattered tall *Acacia coriacea* 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*. It also contains areas of scoured drainage channel in areas of heavy seasonal flow.

Plate 11 - D1c Community

Community D1c – Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* with*Triodia epactia* at edges in major drainage lines.

Plate 12 - D1d Community

Community D1d – Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia epactia* with patchy *Triodia angusta* and *Triodia wiseana* on lower edges of broad drainage flats.

Plate 13 - D1e Community

Community 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.

Plate 14 - D1f Community

Community D1f – Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathalatum* with patchy *Petalostylis labicheoides* over Hummock Grassland to Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* in major drainage lines. This community contains occasional *Hakea lorea* subsp. *lorea* and was recorded on the proposed $C0_2$ reinjection pipeline route.

Plate 15 - D1f Community

Hakea lorea subsp. *lorea* recorded within community D1f on proposed $C0_2$ reinjection pipeline route.

Plate 16 - D1g Community

Community D1g – Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over low scattered *Tephrosia* sp. and *Indigofera monophylla* shrubs in wide drainage lines. Recorded on the proposed feed gas pipeline route.

Plate 17 - D2c Community

Community D2c – Tall scattered *Trichodesma zeylanicum* over Hummock Grassland of *Triodia angusta* with *Triodia wiseana* over low Open Shrubland of *Tephrosia rosea* in disturbed drainage lines.

Plate 18 - D2d Community

Community D2d – Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over low shrubland of *Acacia gregorii* in major creek and drainage lines.

Plate 19 - D2f Community

Community D2f – Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum* with patch *Petalostylis labichioides, 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 occasionally holds *Hakea lorea* subsp. *lorea.*

Plate 20 - F4a Community

Community 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. Recorded on the proposed CO_2 reinjection pipeline route.

Plate 21 - F5a Community

Community F5a – Low Open Shrubland of *Stylobasium spathulatum* with scattered *Pentalepis trichodesmoides* and *Senna glutinosa* ovre Hummock Grassland of *Triodia angusta* with *Triodia epactia* over Low Open Shrubland of *Diplopeltis eriocarpa* on gentle low slopes and flats.

Plate 22 - F5b Community

Community F5b – Scattered Low Trees of *Ficus brachypoda* over scattered low *Pentalepis trichodesmoides, Acacia bivenosa, Corchorus* sp. *Tephrosea rosea* and *Streptoglossa decurrens* over Closed Hummock Grassland of *Triodia epactia* with *Triodia angusta* on flats.

Plate 23 - F5c Community

Community 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.

Plate 24 - F5e Community

Community F5e – Scattered low trees of *Ficus brachypoda* over scattered low shrubs of *Pentalepis trichodesmoides, Scaevola cunninghamii, Acacia bivenosa* and *Diplopeltis eriocarpa* over Open Hummock Grassland of *Triodia angusta* with *Triodia epactia* on limestone flats with shallow pale pink sands.

Plate 25 - F6a Community

Community F6a – Low Open Shrubland of *Acacia bivenosa* and *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on red/brown sandy flats.

Plate 26 - F6b Community

Community F6b – Scattered low trees of *Ficus brachypoda* over Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia epactia* on sandy slopes and flats with occasional limestone outcropping.

Plate 27 - F6d Community

Community F6d – Open Shrubland of *Trichodesma zeylanicum* over low scattered *Pterocaulon sphacelatum* shrubs over Hummock Grassland of *Triodia epactia* on limestone flats with shallow sands.

Plate 28 - F7a Community

Community F7a – Scattered low shrubs of *Pentalepis trichodesmoides* and *Trichodesmoides zeylanicum* over Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and scattered *Acacia gregorii* on limestone slopes.

Plate 29 - F7b Community

Community F7b - Scattered low trees of *Ficus brachypoda* over Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia wiseana* with patches of *Triodia angusta* on sandy flats.

Plate 30 - F7d Community

Community F7d – Scattered shrubs of *Hakea lorea* subsp. *lorea* over low scattered shrubs of *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* over Closed Hummock Grassland of *Triodia epactia* and *Triodia wiseana* on mid-slopes and flats.

Plate 31 - F7e Community

Community F7e – Low Open Shrubland of *Pentalepis trichodesmoides* over scattered low shrubs of *Corchorus* sp. and *Sarcostemma viminale* subsp. *australe* over Himmock Grassland of *Triodia wiseana* on red/brown sandy flats (with pockets of *Eriachne mucronata* on valley floors).

Plate 32 - L1a Community

Community L1a – Scattered low trees of *Ficus brachypoda* and *Pittosporum phylliraeoides* over scattered low shrubs of *Stylobasium spathulatum* and *Petalostylis labichiodes* over Hummock Grassland of *Triodia wiseana* (*Triodia* angusta) with occasional *Cymbopogon ambiguus* and *Tephrosia rosea* on limestone ridges and upper slopes.

Plate 33 - L1b Community

Community L1b - Scattered low trees of *Ficus brachypoda* over scattered low shrubs of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* on limestone slopes and ridges.

Plate 34 - L1c Community

Community L1c Scattered low trees of *Ficus brachypoda* over Low Open Shrubland of *Acacia bivenosa* over Closed Hummock Grassland of *Triodia angusta* (*Triodia epactia, T.wiseana)* on limestone slopes and ridges.

Plate 35 - L1d Community

Community L1d – Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and *Heliotropium glanduliferum* on limestone flats (plateau).

Plate 36 - L1e Community

Community L1e – Scattered low trees of *Ficus brachypoda* and *Pittosporum phylliraeoides* (*Mallotus nesophilus)* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) over scattered low shrubs of *Diplopeltis eriocarpa* on limestone slopes and flats.

Plate 37 - L1f Community

Community L1f – Scattered low trees of *Ficus brachypoda* and *Pittosporum phylliraeoides* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta)* on limestone slopes and ridges.

Plate 38 - L3b Community

Community L3b – Scattered low shrubs of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* (*Triodia epactia*) over scattered low *Acacia gregorii, Diplopeltis eriocarpa* on limestone slopes and ridges.

Plate 39 - L3c Community

Community L3c – Low scattered *Diplopeltis eriocarpa* shrubs with scattered *Cymbopogan ambiguus*, *Triodia epactia* and *Cyperus cunninghamii* subsp. *cunninghamii* herbs and grasses on small exposed limestone flat. Recorded on the proposed alternate North White's Beach pipeline route.

Plate 40 - L3d Community

Community L3d – Scattered low shrubs of *Stylobasium spathulatum, Petalostylis labichioides* over Low Open Shrubland of *Diplopeltis eriocarpa, Acacia gregorii* and *Hannafordia quadrivalvis* subsp. *recurva* over Hummock Grassland of *Triodia angusta* (*Triodia wiseana*) on limestone ridges.

Plate 41 - L3e Community

Community L3e – Scattered low trees of *Ficus brachypoda, Pittosporum phylliraeoides* over scattered low shrubs of *Pentalepis trichodesmoides, Trichodesma zeylanicum* over mixed Hummock Grassland of *Triodia wiseana, T. angusta* and *T. epactia* over scattered low shrubs of *Diplopeltis eriocarpa* on slopes and ridges.

Plate 42 - L3f Community

Community L3f – Scattered low shrubs of *Petalostylis labichioides*, *Indigofera monophylla* over Hummock Grassland of *Triodia wiseana* on limestone ridges and upper slopes.

Plate 43 - L3g Community

Community L3g – Low Open Shrubland of *Stylobasium spathulatum* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) and *Cymbopogon anbiguus* over Low Open Shrubland of *Diplopeltis eriocarpa* on limestone hillslopes.

Plate 44 - L3h Community

Community L3h – Scattered low shrubs of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* over scattered low shrubs of *Diplopeltis eriocarpa* on limestone ridges and flats.

Plate 45 - L3i Community

Community L3i – Low Open Shrubland to Low Shrubland of *Acacia bivenosa* with occasional scattered low shrubs of *Stylobasium spathulatum, Petalostylis labichioides* over Hummock Grassland of *Triodia angusta* (*Triodia wiseana*) on limestone slopes, small rises and flats.

Plate 46 - L4a Community

Community L4a – Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Acacia bivenosa* with scattered *Petalostylis labichioides, Stylobasium spathulatum* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) on limestone ridges and mid-slopes. This unit also contains occasional *Hakea lorea* subsp. *lorea*.

Plate 47 - L5b Community

Plate 48 - L5b Community

Community L5b – Scattered *Hakea lorea* subsp. *lorea* shrubs over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy midslopes. Recorded on proposed $C0_2$ reinjection pipeline route.

Plate 49 - L6a Community

Community L6a – Low Open Shrubland of *Grevillea pyramidalis* subsp. *?leucadendron* and *Acacia bivenosa* over Hummock Grassland of *Triodia angusta* over low scattered *Acacia gregorii*, *Scaevola cunninghamii* and *Heliotropium glanduliferum* shrubs and herbs on limestone midslopes. Recorded south of proposed gas processing facility.

Plate 50 - L6b Community

Community L6b – Scattered low trees of *Ficus brachypoda* over Low Open Shrubland of *Grevillea pyramidalis* ?subsp. *leucadendron* with occasional *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* over closed Hummock Grasssland of *Triodia epactia*, *Triodia wiseana* and *Eriachne* sp. over Low Open Shrubland of *Acacia gregorii* on upper slopes and midslopes of small rises. Recorded on proposed North White's Beach pipeline route.

Plate 51 - L6c Community

Community L6c – Low Open Shrubland of *Pentalepis trichodesmoides* (with *Grevillea pyramidalis* subsp. *leucadendron* in eastern parts) over Hummock Grassland of *Triodia wiseana* (*T. epactia*) over Low Open Shrubland of *Diplopeltis eriocarpa* on rocky mid- to upper slopes with red/brown sands and occasional limestone outcropping.

Plate 52 - L6d Community

Community 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. Recorded on proposed North White's Beach pipeline route.

Plate 53 - L7a Community

Community L7a – Low shrubland of *Melaleuca cardiophylla, Stylobasium spathulatum, Pentalepis trichodesmoides, Trichodesma zeylanicum, Acacia bivenosa* (occasional pockets of *Gossypium robinsonii*) over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) over Low Open Shrubland of *Acacia gregorii* on rocky limestone ridges, slopes and minor gullies.

Plate 54 - L7b Community

Community 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.

Plate 55 - S1a Community

Community S1a – Grassland of *Eriachne flaccida* (Southern Pilbara-Carnarvon Coastal Form) 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). Recorded on the proposed CO_2 reinjection pipeline route.

Plate 56 - V1a Community

Community V1a – Low Open Shrubland of *Acacia bivenosa, Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) over Low Open Shrubland of *Acacia gregorii* on limestone midslopes and occasional small rises.

Plate 57 - V1b Community

Community V1b – Low Open Shrubland of *Acacia bivenosa, Petalostylis labichioides* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) over Low Open Shrubland of *Diplopeltis eriocarpa* on red/brown sandy flats.

Plate 58 - V1c Community

Community V1c – Scattered Low trees of *Ficus brachypoda, Pittosporum phylliraeoides* over scattered low shrubs of *Petalostylis labichioides, Pentalepis trichodesmoides* over Hummock Grassland of *Triodia angusta* (*Triodia wiseana, Triodia epactia*) with occasional *Cymbopogon ambiguus* tussocks, on limestone slopes and ridges or with *Stylobasium spathulatum* at edges on red/brown sandy drainage flats.

Plate 59 - V1d Community

Community V1d – Low Open Shrubland of *Acacia bivenosa* with scattered low shrubs of *Pentalepis trichodesmoides* and occasional *Melaleuca cardiophylla* over Hummock Grassland of *Triodia angusta, T. wiseana* on limestone slopes and low ridges.

Plate 60 - V1f Community

Community V1f – Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* on red/brown sandy flats.

Plate 61 - V1g Community

Community V1g – Scattered tall shrubs of *Acacia pyrifolia* over scattered low shrubs of *Petalostylis labichioides, Acacia bivenosa* and *Acacia gregorii* 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.

Plate 62 - V1h Community

Community V1h – Open Shrubland of *Acacia pyrifolia* over low Open Shrubland of *Stylobasium spathulatum, petalostylis labichioides* and *Acacia bivenosa* over Closed Hummock Grassland of *Triodia wiseana, T. angusta* over low Open Shrubland of *Acacia gregorii* on limestone slopes. This unit may contain occasional *Hakes lorea* subsp. *lorea.*

Plate 63 - V1i Community

Community V1i – Hummock Grassland of *Triodia epactia* (*Triodia wiseana*) over low Open Shrubland of *Acacia gregorii* and *Diplopeltis eriocarpa* on gentle slopes and flats.

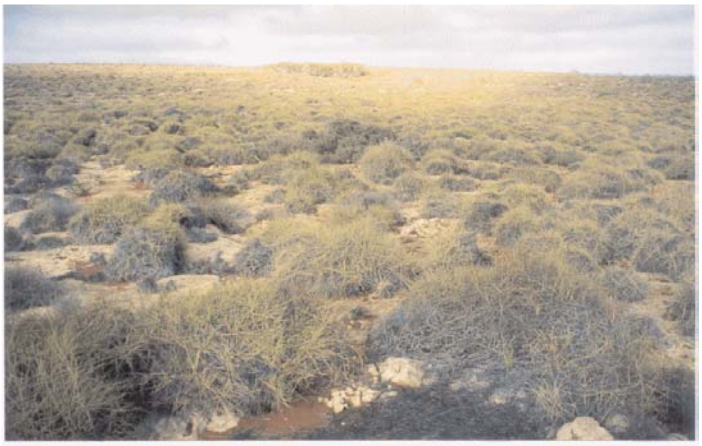


Plate 64 - V1j Community

Community V1j – Scattered low shrubs of *Pentalepis trichodesmoides* over Hummock Grassland *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and scattered *Acacia gregorii* on limestone slopes.

Plate 65 - V1k Community

Community V1k – Scattered shrubs of *Acacia pyrifolia* and occasional *Hakea lorea* subsp. *lorea* over Low Open Shrubland to Shrubland of *Melaleuca cardiophylla* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) over scattered low shrubs of *Acacia gregorii* on limestone hilltops and minor drainage lines.

Plate 66 - V1m Community

Community V1m – Low Open Heath of *Melaleuca cardiophylla* with *Sarcostemma viminale* subsp. *australe* over Hummock Grassland of *Triodia wiseana, T. angusta* on limestone ridges and slopes.

Plate 67 - V3a Community

Community V3a – Scattered low trees of *Ficus brachypoda* over scattered shrubs of *Acacia pyrifolia* over Hummock Grassland of *Triodia wiseana* on limestone slopes and minor drainage lines.

Plate 68 - V3b Community

Community V3b – Scattered shrubs of *Acacia pyrifolia* with occasional *Hakea lorea* subsp. *lorea* over scattered low shrubs to Low Open Shrubland of *Petalostylis labichiodes, Stylobasium spathulatum*, occasional *Acacia bivenosa* and *Acacia gregorii* over Hummock Grassland of *Triodia wiseana* (*Triodia angusta*) on limestone slopes.

Plate 69 - Intertidal Community

Intertidal mangrove vegetation consisting of *Avicennia marina* subsp. ?*eucalyptifolia*, *Bruguiera exaristata* and *Rhizophora stylosa*.

Plate 70 - Intertidal Community

Intertidal vegetation included areas of samphires consisting of a Low Shrubland of *Halosarcia halocnemoides* subsp. *tenuis, Halosarcia indica* and *Suaeda arbusculoides*.

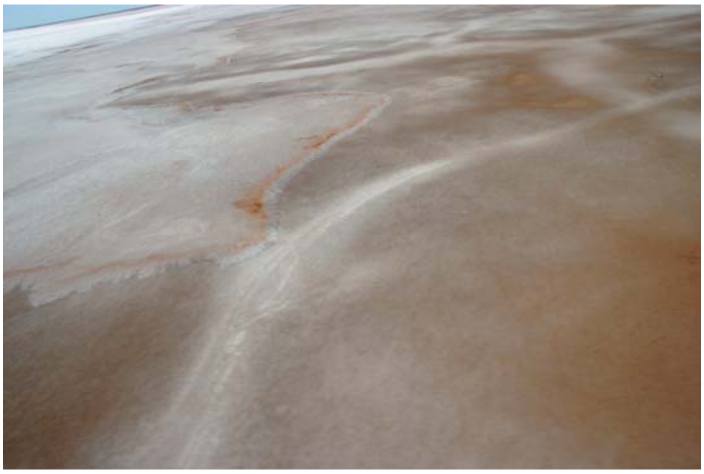


Plate 71 – Unvegetated Tidal Flats

Unvegetated tidal flats.

Plate 72 – Pipeline Vegetation

A Grassland of *Triodia epactia* and ?*Cenchrus* sp. with *Eragrostis dielsii* and *Eragrostis falcata* with occasionally emergent *Acacia farnesiana*, *Acacia trachycarpa, Lawrencia viridigrisea* and *Neobassia astrocarpa* shrubs on raised red earth mounds.

Plate 73 – Pipeline Vegetation

A Low Open Shrubland including *Acacia* sp. over Grassland including *Dicanthium sericeum* subsp. *humilius*, *Eriachne flaccida*, *Aristida holathera* var *holathera* and *Eriachne dimorpantha* over a Very Open Herbland including *Rhynchosia minima* and *Neptunia dimorpantha* on red earth flats.

Plate 74 – Pipeline Vegetation

An Open Shrubland to Tall Open Shrubland of *Acacia trachycarpa*, *Acacia ancistrocarpa*, *Acacia elachantha*, *Acacia victioriae* and *Acacia xiphophylla* over a Grassland of *Triodia epactia* and ?*Cenchrus* sp. over mixed herb species on red sandy flats. This community was recorded at the eastern end of the proposed mainland pipeline site, near the existing compressor station

ATTACHMENT A: LIST OF VASCULAR PLANT SPECIES RECORDED ON BARROW ISLAND

NB: A = Annual, P = Perennial, # = Western Australian Herbarium collections, * denotes introduced (weed) species, SCC = State Conservation Code, FCC = Federal Conservation Code, R = restricted taxon or taxon requiring more investigation on Barrow Island, B-K = Barrow Island to the Kimberly, B-P = Barrow Island to the Pilbara, B-S = Barrow Island to the south, W = widespread, 03/04 = recorded in current survey

Family	03/04	A/P	Life Form		Species	SCC	FCC	Distribution R	B-K	B-P	B-S	W
MARSILEACEAE		P	fern	#	*Marsilea ?hirsuta*			+				+
POTAMOGETONACEAE		P	herb	#	*Ruppia maritima*					+	+	
CYMODOCEACEAE		P	herb	#	*Halodule uninervis*							+
POACEAE		A/P	grass		*Aristida contorta*							+
		A/P	grass		*Aristida holathera*							+
		A/P	grass	#	*Aristida holathera* var. *holathera*							+
		P	grass	#	*Bothriochloa bladhii*				+	+		
		A/P	grass		*Brachyachne* sp.							
		P	grass	*	*Cenchrus ciliaris*							+
		P	grass	#	*Chrysopogon fallax*				+	+		
	+	P	grass		*Cymbopogon ambiguus*							+
		P	grass	#	*Cymbopogon bombycinus*				+	+		
		P	grass	#	*Cymbopogon procerus*				+	+		
		P	grass		*Cymbopogon* sp.							
		P	grass	# *	*Cynodon dactylon*							+
		A	grass	#	*Dactyloctenium radulans*							+
		A	grass	#	*Dichanthium sericeum* subsp. *humilius*				+	+		
		A	grass	#	*Dichanthium sericeum* subsp. *sericeum*							+
		A/P	grass	#	*Digitaria ctenantha*				+	+		
		A/P	grass		*Enneapogon caerulescens*					+	+	

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
POACEAE		A/P	grass		*Enneapogon caerulescens* var. *caerulescens*					+	+	
		A/P	grass	#	*Enneapogon caerulescens* var. *occidentalis*					+		
		A/P	grass	#	*Enneapogon oblongus*				+	+		
		A/P	grass	#	*Enneapogon polyphyllus*							+
		A/P	grass		*Enneapogon* sp.							
		A	grass	#	*Eragrostis cumingii*				+	+		
	+	A/P	grass		*Eragrostis dielsii*							+
		P	grass	#	*Eragrostis falcata*							+
		P	grass	#	*Eragrostis xerophila*							+
		A/P	grass		*Eragrostis* sp.							
		P	grass	#	*Eriachne benthamii*							+
	+	P	grass	#	*Eriachne flaccida*					+	+	
	+	P	grass		*Eriachne flaccida* (Southern Pilbara - Carnarvon Coastal Form)					+		
	+	P	grass	#	*Eriachne mucronata*							+
		P	grass		*Eriachne* sp.							+
		P	grass		*Eulalia aurea*							
		A	grass	#	*Iseilema dolichotrichum*				+	+		
		A	grass		*Paspalidium clementii*					+	+	
	+	A	grass	#	*Paspalidium tabulatum*					+		
		A/P	grass		*Paspalidium* sp.							
		A	grass	#	*Setaria dielsii*							+
	+	A	grass	*	*Setaria verticillata*							+
		P	grass	#	*Sorghum plumosum*				+	+		

ATTACHMENT A: LIST OF VASCULAR PLANT SPECIES RECORDED ON BARROW ISLAND

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
POACEAE	+	P	grass		*Spinifex longifolius*							+
		A	grass	#	*Sporobolus australasicus*				+	+		
		P	grass	#	*Sporobolus mitchellii*							+
		P	grass		*Sporobolus virginicus*							+
		P	grass	#	*Themeda triandra*							+
	+	P	grass	#	*Triodia angusta*					+		
		P	grass	#	*Triodia epactia*				+	+		
	+	P	grass	#	*Triodia wiseana*				+	+		
		P	grass	#	*Triraphis mollis*							+
		A/P	grass	#	*Whiteochloa airoides*				+	+		
	+	A/P	grass	#	*Yakirra australiensis*				+	+		
		A/P	grass		Poaceae sp.							
		A/P	grass		Poaceae sp. 1							
		A/P	grass		Poaceae sp. 2							
		A/P	grass		Poaceae sp. 3 (Tussock grass)							
CYPERACEAE	+	A	sedge	#	*Bulbostylis barbata*							+
		P	sedge	#	*Cyperus bifax*							+
	+	P	sedge	#	*Cyperus cunninghamii*							+
		P	sedge	#	*Cyperus cunninghamii* subsp. *cunninghamii*				+	+		
		A	sedge	#	*Cyperus iria*							+
		A	sedge	#	*Cyperus squarrosus*							+
		P	sedge	#	*Fimbristylis dichotoma*							+

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Family	03/04	A/P	Life Form			Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
CYPERACEAE		A	sedge	#		*Fimbristylis schultzii*				+			
		A	sedge	#	*	*Isolepis marginata*						+	
	+	A	sedge			*Isolepis* sp.			?+				
		A	sedge			*Lipocarpha microcephala*							
		A	sedge	#		*Schoenoplectus dissachanthus*							+
COMMELINACEAE		A/P	herb	#		*Commelina ciliata*				+			
		A/P	herb	#		*Commelina ensifolia*							+
DASYPOGONACEAE	+	P	herb	#		*Acanthocarpus verticillatus*					+		
ANTHERICAEAE		P	herb/shrub	#		*Corynotheca flexuosissima*					+		
MORACEAE		P	shrub/tree	#		*Ficus brachypoda*							+
		P	shrub/tree	#		*Ficus brachypoda* (hairy variant)			+				
		P	shrub/tree	#		*Ficus opposita* var. *aculeata*				+	+		
		P	tree	#		*Ficus virens* var. *virens*				+	+		
		P	shrub/tree			*Ficus* sp.							
PROTEACEAE		P	shrub/tree	#		*Grevillea pyramidalis*							+
	?	P	shrub/tree	#		*Grevillea pyramidalis* subsp. *leucadendron*				+	+		
	+	P	shrub/tree			*Hakea lorea* subsp. *lorea*							+

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution			
									B-K	B-P	B-S	W
SANTALACEAE		P	shrub/tree	#	*Santalum murrayanum*						+	
LORANTHACEAE		P	shrub/tree		Loranthaceae sp.							
POLYGONACEAE		A	herb	*	*Emex australis*							+
CHENOPODIACEAE		P	shrub	#	*Atriplex isatidea*					+	+	
		P	herb	#	*Atriplex semilunaris*					+	+	
		A	herb		*Chenopodium* aff. *cristatum*							+
		A	herb		*Chenopodium melanocarpum* forma *leucocarpum*					+	+	
		A/P	herb	#	*Chenopodium pumilio*						+	
		A	herb	#	*Dysphania kalpari*					+	+	
		A	herb		*Dysphania plantaginella*							+
		A	herb	#	*Dysphania rhadinostachya*							+
		A	herb	#	*Dysphania rhadinostachya* subsp. *inflata*							+
	+	A	herb		*Dysphania rhadinostachya* subsp. *rhadinostachya*							+
		P	shrub		*Enchylaena tomentosa* var. *tomentosa*							+
		P	shrub	#	*Eremophea spinosa*					+	+	
		P	shrub		*Halosarcia halocnemoides*							+
		P	shrub	#	*Halosarcia halocnemoides* subsp. *tenuis*							+
		P	shrub		*Halosarcia indica*							+
		P	shrub	#	*Halosarcia indica* subsp. *leiostachya*							+
		P	herb/shrub		*Halosarcia* sp.							

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
CHENOPODIACEAE		P	shrub		*Neobassia astrocarpa*				+	+		
		P	shrub	#	*Rhagodia eremaea*							+
		P	shrub		*Rhagodia latifolia* subsp. *latifolia*						+	
		P	shrub	#	*Rhagodia latifolia* var. ?*recta*						+	
		P	shrub		*Rhagodia preissii* subsp. *obovata*					+	+	
	+	A	herb		*Salsola tragus*							+
		P	herb	#	*Sclerolaena convexula*					+	+	
		P	herb		*Sclerolaena uniflora*					+	+	
		P	herb	#	*Threlkeldia diffusa*							+
AMARANTHACEAE		A	herb	#	*Alternanthera nodiflora*							+
		A/P	herb/shrub		*Alternanthera* sp.							
		A	herb	#	*Amaranthus mitchellii*				+	+		
	+	A	herb		*Amaranthus pallidiflorus*				+	+		
		A/P	herb/shrub		*Amaranthus* sp. Barrow Island D200(R. Buckley 6884)							
		A	herb		*Amaranthus* sp.							
		A	herb	#	*Gomphrena sordida*					+		
		P	herb	#	*Hemichroa diandra*							+
	+	P	herb/shrub	#	*Ptilotus clementii*				+	+		
		A	herb	#	*Ptilotus exaltatus*							+
		A	herb	#	*Ptilotus exaltatus* var. *exaltatus*							+
		A/P	herb	#	*Ptilotus fusiformis*				+	+		
	+	A/P	herb		*Ptilotus fusiformis* var. *fusiformis*				+	+		

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
AMARANTHACEAE	+	A	herb		*Ptilotus gomphrenoides* var. *gomphrenoides*							+
		P	shrub		*Ptilotus obovatus* (adherent prostrate form on island)			+				+
	+	P	shrub		*Ptilotus obovatus* var. *obovatus*							+
		A/P	herb		*Ptilotus villosiflorus*					+	+	
NYCTAGINACEAE		P	herb/shrub	#	*Boerhavia burbidgeana*				+	+		
		A/P	herb	#	*Boerhavia coccinea*							+
	+	P	herb	#	*Boerhavia gardneri*				+	+		
		A/P	herb	#	*Boerhavia* aff. *repleta*					+		
		P	herb	#	*Boerhavia schomburgkiana*							+
		P	herb		*Boerhavia* sp.							+
		P	shrub		*Commicarpus australis*							+
GYROSTEMONACEAE	+	P	shrub/tree	#	*Codonocarpus cotinifolius*							+
AIZIOACEAE		P	herb		*Sesuvium portulacastrum*							+
PORTULACACEAE		A	herb		*Calandrinia balonensis*							+
	+	A	herb	#	*Calandrinia polyandra*					+	+	
		A	herb	#	*Calandrinia* aff. *polyandra*					+	+	
		A	herb		*Calandrinia* ?aff. *remota*			+				
		A	herb		*Calandrinia* sp.							
		A	herb	#	*Portulaca australis*							

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									Distribution			
Family	**03/04**	**A/P**	**Life Form**		**Species**	**SCC**	**FCC**	**R**	**B-K**	**B-P**	**B-S**	**W**
PORTULACACEAE		A/P	herb		*Portulaca intraterranea*					+		
		A	herb	#	*Portulaca oleracea*							+
		A	herb	#	*Portulaca pilosa*							+
		A	herb		*Portulaca pilosa* (Boodie Island)					+		
CARYOPHYLLACEAE	+	P	herb	#	*Polycarpaea longiflora*				+	+		
MENISPERMACEAE		P	climber	#	*Tinospora smilacina*				+	+		
LAURACEAE		P	climber	#	*Cassytha capillaris*				+	+		
CAPPARACEAE		P	shrub/climber	#	*Capparis lasiantha*				+	+		
		P	shrub	#	*Capparis spinosa*							+
	+	P	shrub	#	*Capparis spinosa* var. *nummularia*							+
		P	shrub/tree	#	*Capparis umbonata*				+	+		
	+	A/P	herb	#	*Cleome viscosa*							+
BRASSICACEAE		P	shrub	#	*Lepidium platypetalum*					+	+	
PITTOSPORACEAE	+	P	shrub/tree		*Pittosporum phylliraeoides*					+	+	
SURIANACEAE	+	P	shrub		*Stylobasium spathulatum*							+

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
MIMOSACEAE	+	P	shrub		*Acacia bivenosa*				+			
		P	shrub		*Acacia bivenosa* (elongate phyllode form)			+				
		P	shrub		*Acacia bivenosa* (Airlie Island variant)			+				
		P	shrub		*Acacia bivenosa* (semiprostrate form)			+				
		P	shrub/tree		*Acacia coriacea*				+	+		
	+	P	shrub/tree		*Acacia coriacea* subsp. *coriacea*				+	+		
		P	shrub/tree	#	*Acacia coriacea* subsp. *pendens*				+			
		P	shrub/tree	#	*Acacia cowleana*				+			
		P	shrub/tree		*Acacia grasbyi*					+	+	
	+	P	shrub	#	*Acacia gregorii*				+			
		P	shrub/tree	#	*Acacia inaequilatera*				+			
	+	P	shrub	#	*Acacia pyrifolia*				+	+		
		P	shrub/tree	#	*Acacia synchronicia*							+
CAESALPINACEAE	+	P	shrub	#	*Petalostylis labicheoides*					+	+	
		P	shrub	#	*Senna artemisioides*							+
		P	shrub	#	*Senna artemisioides* subsp. *oligophylla*							+
		P	shrub	#	*Senna glutinosa* subsp. *glutinosa*				+	+		
	+	P	shrub	#	*Senna glutinosa* subsp. *pruinosa*				+	+		
	?	P	shrub	#	*Senna notabilis*				+	+		
		P	shrub	#	*Senna planitiicola*				+		+	
		P	shrub	#	*Senna venusta*				+	+		

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									Distribution			
Family	**03/04**	**A/P**	**Life Form**		**Species**	**SCC**	**FCC**	**R**	**B-K**	**B-P**	**B-S**	**W**
PAPILIONACEAE		P	climber	#	*Canavalia rosea*				+	+		
		P	shrub	#	*Crotalaria cunninghamii*				+	+		
		A/P	herb/shrub	#	*Crotalaria medicaginea*				+	+		
		P	shrub	#	*Crotalaria novae-hollandiae*				+	+		
		P	shrub	#	*Cullen lachnostachys*					+		
		P	shrub	#	*Cullen leucanthum*							+
		P	herb	#	*Cullen pallidum*					+		
		P	herb	#	*Cullen* aff. *pallidum*					+		
		A/P	herb	#	*Cullen patens*					+	+	
	+	P	herb/shrub	#	*Cullen pustulatum*				+	+		
		P	tree	#	*Erythrina vespertilio*							+
		P	herb/shrub	#	*Indigofera boviperda*					+	+	
		A/P	herb	#	*Indigofera colutea*							+
		A/P	herb	#	*Indigofera linifolia*				+	+		
		P	herb	#	*Indigofera linnaei*				+	+		
	+	P	shrub	#	*Indigofera monophylla*				+	+		
		A/P	herb	#	*Indigofera trita*				+	+		
		A/P	herb/shrub		*Indigofera* sp.							
		P	shrub	#	*Isotropis atropurpurea*				+	+		
		A/P	herb	#	*Lotus australis*							+
		A	herb		*Lotus cruentus*					+	+	
	+	P	climber	#	*Rhynchosia minima*				+	+		
		A/P	herb/shrub	#	*Sesbania cannabina*				+	+		

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								Distribution			
Family	**03/04**	**A/P**	**Life Form**		**Species**	**SCC**	**FCC**	**R**	**B-K**	**B-P**	**B-S**	**W**
PAPILIONACEAE		A	herb	#	*Swainsona formosa*					+	+	
		A/P	herb	#	*Swainsona kingii*							+
		P	herb	#	*Swainsona pterostylis*					+	+	
	+	A	herb		*Tephrosia clementii*					+		
		P	shrub	#	*Tephrosia rosea*				+	+		
	+	P	shrub	#	*Tephrosia rosea* var. *clementii*				+	+		
		P	shrub	#	*Tephrosia rosea* var. *glabrior* (ms)				+	+		
		A/P	herb/shrub		*Tephrosia* sp.							
		A/P	herb/shrub/tree		Papilionaceae sp.							
ZYGOPHYLLACEAE		P	herb	#	*Tribulus cistoides*				+	+		
		P	herb		*Tribulus hirsutus*				+	+		
		P	herb	#	*Tribulus occidentalis*							+
	+	A	herb	#	*Tribulus terrestris*							+
POLYGALACEAE		A	herb	#	*Polygala isingii*					+	+	
EUPHORBIACEAE	+	P	shrub	#	*Adriana tomentosa* var. *tomentosa*				+	+		
	+	A/P	herb	#	*Euphorbia australis*							+
	+	A/P	herb/shrub	#	*Euphorbia coghlanii*				+	+		
	+	P	herb		*Euphorbia drummondii* subsp. *drummondii*							+
		P	herb		*Euphorbia* aff. *drummondii* (Boodie Island)			+				
	+	A	herb	#	*Euphorbia myrtoides*							+

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EUPHORBIACEAE		A/P	herb/shrub		*Euphorbia tannensis* subsp. *eremophila*							+
		A/P	herb/shrub/tree		*Euphorbia* sp.							
		A/P	herb/shrub/tree		*Euphorbia* sp. A				+			
		P	shrub/tree	#	*Flueggea virosa* subsp. *melanthesiodes*				+	+		
		P	shrub/tree		*Mallotus dispersus*				+			
	+	P	shrub/tree	#	*Mallotus nesophilus*				+	+		
	+	A/P	herb/shrub	#	*Phyllanthus maderaspatensis*					+	+	
STACKHOUSIACEAE	?	A/P	herb		*Stackhousia muricata*					+	+	
SAPINDACEAE		P	shrub/tree		*Alectryon oleifolius* subsp. *oleifolius*					+		
	+	P	shrub	#	*Diplopeltis eriocarpa*					+		
		P	shrub	#	*Diplopeltis intermedia* var. *?intermedia*					+	+	
		P	shrub		*Diplopeltis* sp.							
	+	P	shrub	#	*Dodonaea lanceolata*							+
		P	shrub	#	*Dodonaea lanceolata* var. *lanceolata*				+	+		
RHAMNACEAE		P	tree	#	*Ventilago viminalis*				+	+		
TILIACEAE	+	P	shrub	#	*Corchorus congener*					+		
	+	P	shrub	#	*Corchorus ?congener*					+		
	+	P	shrub	#	*Corchorus interstans* (ms)	P3				+		
		A	herb	#	*Corchorus tridens*				+	+		
		P	shrub	#	*Corchorus walcottii*				+	+		
		P	shrub		*Corchorus ?walcottii*							+

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
TILIACEAE		A/P	herb/shrub		*Corchorus* sp.			+				
		A/P	herb/shrub		*Corchorus* sp. Barrow 1			+				
		A/P	herb/shrub		*Corchorus* sp. Barrow 2			+				
	?	P	shrub	#	*Triumfetta appendiculata*					+		
		P	shrub		*Triumfetta* aff. *appendiculata*					+		
		P	shrub		*Triumfetta chaetocarpa*					+		
	+	P	shrub	#	*Triumfetta clementii*					+		
	?	P	shrub	#	*Triumfetta maconochieana*					+		
		P	shrub	#	*Triumfetta ramosa*					+		
		P	shrub	#	*Triumfetta* aff. *ramosa*					+		
		A/P	herb/shrub		*Triumfetta* sp.							
MALVACEAE	?	P	herb/shrub		*Abutilon cunninghamii*				+			
		P	shrub	#	*Abutilon indicum* var. *australiense*				+			
		P	shrub	#	*Abutilon leucopetalum*				+	+		
		P	shrub	#	*Abutilon otocarpum*				+	+		
		A/P	herb/shrub		*Abutilon* sp.(VL-2706-09)			+				
		A/P	herb/shrub		*Abutilon* sp.							
		P	shrub	#	*Gossypium australe*				+	+		
	+	P	shrub	#	*Gossypium robinsonii*				+	+		
		A/P	herb	#	*Herissantia crispa*				+			
		P	shrub	#	*Hibiscus burtonii*					+		
		P	herb/shrub	#	*Hibiscus coatesii*				+	+		

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NB: A = Annual, P = Perennial, # = Western Australian Herbarium collections, * denotes introduced (weed) species, SCC = State Conservation Code, FCC = Federal Conservation Code, R = restricted taxon or taxon requiring more investigation on Barrow Island, B-K = Barrow Island to the Kimberly, B-P = Barrow Island to the Pilbara, B-S = Barrow Island to the south, W = widespread, 03/04 = recorded in current survey

Family	03/04	A/P	Life Form			Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
MALVACEAE		P	shrub	#		*Hibiscus sturtii*							+
		P	shrub	#		*Hibiscus sturtii* var. *campylochlamys*				+	+		
		P	shrub	#		*Hibiscus sturtii* var. *platychlamys*					+		
		A/P	herb/shrub			*Hibiscus* sp. (EM12013)							
		A/P	herb/shrub			*Hibiscus* sp. (VL-2706-41)							
		P	shrub	#		*Lawrencia viridigrisea*							+
		P	herb/shrub	#	*	*Malvastrum americanum*							+
		P	shrub	#		*Sida calyxhymenia*					+	+	
		P	shrub	#		*Sida clementii*					+		
		P	shrub	#		*Sida echinocarpa*					+		
		P	herb/shrub			*Sida fibulifera*							+
		P	herb	#		*Sida spodochroma*				+	+		
		A/P	herb/shrub			*Sida* sp. (VL-2709-14)			+				
		A/P	herb/shrub			*Sida* sp. EM12018							
		A/P	herb/shrub			*Sida* sp. EM20301B							
		A/P	herb/shrub			*Sida* sp.							
STERCULIACEAE	?	P	shrub			*Hannafordia quadrivalvis*					+	+	
	+	P	shrub			*Hannafordia quadrivalvis* subsp. *recurva*							
		P	shrub			*Keraudrenia* sp.							
		P	herb/shrub	#		*Melhania oblongifolia*				+	+		
		P	herb/shrub	#		*Waltheria indica*				+	+		

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Family	03/04	A/P	Life Form			Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
ELATINACEAE		A	herb	#		*Bergia pedicellaris*				+	+		
FRANKENIACEAE		P	shrub	#		*Frankenia ambita*				+	+		
	+	P	shrub			*Frankenia pauciflora* var. *pauciflora*							
		P	shrub			*Frankenia* sp.							
VIOLACEAE	+	P	shrub	#		*Hybanthus aurantiacus*				+	+		
PASSIFLORACEAE		P	climber	#	*	*Passiflora foetida* var. *hispida*				+	+		
LYTHRACEAE		A	herb	#		*Ammannia multiflora*				+	+		
RHIZOPHORACEAE		P	tree/shrub	#		*Rhizophora stylosa*				+	+		
MYRTACEAE		P	tree	#		*Eucalyptus camaldulensis*							+
		P	mallee	#		*Eucalyptus gamophylla*					+		
		P	tree	#	*	*Eucalyptus gomphocephala*						+	
		P	tree	#		*Eucalyptus torquata*						+	
		P	tree	#		*Eucalyptus xerothermica* (ms)					+		
	+	P	shrub	#		*Melaleuca cardiophylla*					+	+	
HALORAGACEAE	+	A	herb			*Haloragis gossei*							+

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									Distribution			
Family	**03/04**	**A/P**	**Life Form**		**Species**	**SCC**	**FCC**	**R**	**B-K**	**B-P**	**B-S**	**W**
PRIMULACEAE		P	herb	#	*Samolus repens*							+
PLUMBAGINACEAE		P	herb	#	*Muellerolimon salicorniaceum*							+
		P	shrub	#	*Plumbago zeylanica*				+	+		
OLEACEAE	+	P	climber/shrub		*Jasminum calcarium*							+
		P	climber/shrub	#	*Jasminum didymum*				+	+		
		P	climber/shrub	#	*Jasminum didymum* subsp. *lineare*				+	+		
GENTIACEAE		A	herb		*Centaurium spicatum*							+
ASCLEPIADACEAE	+	P	shrub	#	*Cynanchum floribundum*							+
		P	climber/shrub		*Marsdenia* sp.							
	+	P	shrub		*Sarcostemma viminale* subsp. *australe*							+
		P	climber	#	*Tylophora cinerascens*				+	+		
		P	climber	#	*Tylophora flexuosa*				+	+		
CONVOLVULACEAE	+	P	herb		*Bonamia media* var. *villosa*							
		P	herb		*Convolvulus* sp. (RB7250)							
		P	herb	#	*Evolvulus alsinoides*							+
	?	P	herb	#	*Evolvulus alsinoides* var. *decumbens*							+
	+	P	herb		*Evolvulus alsinoides* var. *villosicalyx*				+	+		
		P	herb	#	*Ipomoea pes-caprae* subsp. *brasiliensis*				+	+		

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									Distribution			
Family	**03/04**	**A/P**	**Life Form**		**Species**	**SCC**	**FCC**	**R**	**B-K**	**B-P**	**B-S**	**W**
CONVOLVULACEAE	+	P	herb	#	*Polymeria ambigua*							+
		P	herb		*Polymeria* sp.							
CUSCUTACEAE		A	herb/climber	#	*Cuscuta australis*						+	
BORAGINACEAE		P	shrub/tree	#	*Cordia subcordata* (Boodie Island)				+	+		
		P	shrub/tree		*Ehretia saligna*							
		A	herb	#	*Heliotropium conocarpum*					+	+	
		A/P	herb	#	*Heliotropium crispatum*					+		
		A	herb	#	*Heliotropium cunninghamii*					+		
	+	P	herb/shrub	#	*Heliotropium glanduliferum*					+		
		A/P	herb	#	*Heliotropium inexplicitum*					+		
		A/P	herb	#	*Heliotropium ovalifolium*				+	+		
		A/P	herb/shrub		*Heliotropium* sp.							
		A/P	herb/shrub		*Heliotropium* sp. (perennial shrub) VL-2104-19, VL-2709-24			+				
		A/P	herb/shrub		*Heliotropium* sp. (RB6866)							
		A/P	herb/shrub		*Heliotropium* sp. (RB7037)							
	+	A/P	herb/shrub		*Trichodesma zeylanicum* var. *zeylanicum*							
AVICENNIACEAE		P	shrub/tree	#	*Avicennia marina* subsp. *marina*					+	+	
LAMIACEAE		P	shrub/tree	#	*Clerodendrum tomentosum* var. *lanceolatum*				+	+		

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									Distribution			
Family	**03/04**	**A/P**	**Life Form**		**Species**	**SCC**	**FCC**	**R**	**B-K**	**B-P**	**B-S**	**W**
SOLANACEAE		P	shrub	#	*Duboisia hopwoodii*							+
		A/P	herb	#	*Nicotiana benthamiana*				+	+		
	+	A/P	herb	#	*Nicotiana occidentalis* subsp. *occidentalis*					+		
		A/P	herb/shrub		*Nicotiania* sp.							
	+	A/P	herb	#	*Solanum cleistogamum*					+	+	
	+	P	shrub	#	*Solanum diversiflorum*				+	+		
		P	herb	#	*Solanum esuriale*							+
	+	P	shrub		*Solanum lasiophyllum*							+
		P	herb/shrub	*	*Solanum nigrum*							+
		A/P	herb/shrub		*Solanum* sp.							
SCROPHULARIACEAE		A	herb	#	*Mimulus gracilis*					+		
		P	herb	#	*Stemodia glabella*				+	+		
		P	herb	#	*Stemodia grossa*							+
BIGNONIACEAE		P	shrub/tree	#	*Dolichandrone heterophylla*				+	+		
PEDALIACEAE		A	herb	# ?	*Josephinia eugeniae*							+
ACANTHACEAE		P	herb/shrub	#	*Dicladanthera forrestii*					+		
		P	herb/shrub		*Dicladanthera* sp. (RB6863)							
		P	herb/shrub	#	*Dipteracanthus australasicus*					+		
		P	herb/shrub	#	*Dipteracanthus australasicus* subsp. *corynothecus*					+		

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Family	03/04	A/P	Life Form		Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
MYOPORACEAE		P	shrub	#	*Eremophila forrestii* subsp. *forrestii* (ms)					+	+	
		P	shrub		*Eremophila* sp.							
	+	P	shrub		*Myoporum montanum*							
RUBIACEAE	+	A	herb	#	*Oldenlandia crouchiana*				+	+		
		A	herb	#	*Oldenlandia galioides*				+	+		
		A/P	herb	#	*Synaptantha tillaeacea* var. *tillaeacea*							+
CUCURBITACEAE		P	herb/climber	#	*Mukia maderaspatana*							+
CAMPANULACEAE		A/P	herb		*Wahlenbergia* sp.							
GOODENIACEAE		A	herb	#	*Goodenia microptera*				+	+		
		A	herb		*Goodenia* sp.							
		P	shrub	#	*Lechenaultia* sp. VL-BW103-13			+				
		P	herb	#	*Scaevola* cf. *aemula*						+	
		P	shrub	#	*Scaevola amblyanthera* var. *amblyanthera*				+	+		
		P	shrub	#	*Scaevola amblyanthera* var. *centralis*							+
		P	shrub		*Scaevola ?anchusifolia*							
		P	shrub		*Scaevola crassifolia*							+
	+	P	herb/shrub	#	*Scaevola cunninghamii*					+		
		P	shrub	#	*Scaevola sericophylla*					+	+	
	+	P	shrub	#	*Scaevola spinescens*							+

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Family	03/04	A/P	Life Form			Species	SCC	FCC	R	Distribution B-K	B-P	B-S	W
GOODENIACEAE		P	herb/shrub			*Scaevola* sp.VL-2104-26			+				
		P	herb/shrub			*Scaevola* sp.							
ASTERACEAE		A	herb	#	*	*Arctotheca calendula*						+	
		A	herb	#		*Centipeda minima*				+	+		
		A	herb		*	*Conyza sumatrensis*							+
		A	herb	#		*Flaveria australasica*				+	+		
		A	herb	#		*Helichrysum oligochaetum*	P1				+		
		P	herb	#		*Launaea sarmentosa*				+	+		
	+	P	shrub	#		*Olearia dampieri* subsp. *dampieri* (ms)					+	+	
	+	P	herb/shrub	#		*Pentalepis trichodesmoides*				+	+		
	+	P	herb/shrub	#		*Pluchea dentex*					+	+	
		P	shrub			*Pluchea dunlopii*					+		
		P	shrub			*Pluchea ferdinandi-muelleri*				+	+		
	+	P	herb/shrub	#		*Pluchea rubelliflora*							+
		P	herb/shrub	#		*Pluchea tetranthera*				+	+		
		P	herb/shrub			*Pluchea* sp.							
		A	herb		*	*Pseudognaphalium luteoalbum*							+
	+	P	herb/shrub	#		*Pterocaulon sphacelatum*				+	+		
	+	P	herb/shrub	#		*Pterocaulon sphaeranthoides*				+	+		
		A	herb		*	*Sonchus oleraceus*							+
		A	herb	#		*Streptoglossa adscendens*					+		
	+	P	herb	#		*Streptoglossa bubakii*				+	+		

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								Distribution			
Family	**03/04**	**A/P**	**Life Form**		**Species**	**SCC**	**FCC**	**R**	**B-K**	**B-P**	**B-S**	**W**
ASTERACEAE	+	P	herb/shrub	#	*Streptoglossa decurrens*				+	+		
		P	herb/shrub	#	*Streptoglossa macrocephala*				+	+		
		A	herb	#	*Vittadinia arida*					+		
	+	A	herb	#	*Vittadinia hispidula* var. *setosa*					+		
		A	herb	#	*Vittadinia obovata*				+	+		
		A/P	herb/shrub		*Vittadinia* sp.							
		A/P	herb/shrub		Asteraceae sp.							
		A/P	herb/shrub		Asteraceae sp. 2							

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ATTACHMENT D: FIELD DATA COLLECTION SHEETS

Gorgon Gas Development on Barrow Island
VEGETATION SURVEY-2003/2004

Site:			**Date:**		**Initials:**	
Plot No:			**Film:**		**Photo:**	
GPS Datum:			**Accuracy:**		**Topo:** RI BR US MS	**Litter cover:** %
Peg #:	1	2	3	4	F LS VF MIC MAC	**Litter type:** Logs
mE:					**Outcrop:** Few Mod Num	Twigs Lvs
mN:					Lmst Lat Gran Dol Sndst	**Bare ground:** %
Soil Type: SLG SL SG CL G C L P S					**Aspect:** N NW W SW	**Age since fire:** yrs
Soil colour:					S SE E NE N/A	**Disturbance:** Hi Med Lo

Observations: ……………………………………………………………………………………………………

Community Type:	**Vegetation Condition:**

Vegetation Description: ……………………………………………………………………………………
……
……

Plot Location:……………………………… ……………………………………………………………………

Sketch of Quadrat Layout:

Bearing ……

…..

NW NE

1	6	11	16	21
2	7	12	17	22
3	8	13	18	23
4	9	14	19	24
5	10	15	20	25

SW SE

ATTACHMENT D: FIELD DATA COLLECTION SHEETS

Gorgon Gas Development on Barrow Island - Vegetation Survey

Key: **Habit: C** = climber, **P** = prostrate, **T** = tufted, **R** = rhizomatous, other - specify

RS = Reproductive stage: B = bud, **Fl** = flower, **Fr** = fruit, **N** = nut, **N/A** = none of the above

Form: DH = dwarf herb, **WH** = woody herb, **S** = shrub, **T** = single trunk tree, **M** = mallee tree

Col = Reproductive stage colour eg. flower colour

Site:	Plot No:					Quadrat __		Quadrat __		Quadrat __		Quadrat __		Quadrat __	
Date:	Initials:	Ht (cm)	Habit	Form	RS / Co	%A	%D	%A	%D	%A	%D	%A	%D	%A	%D
Coll No.	Species														

Attachment E: Aplin's (1979) modification of Specht's (1970) vegetation classification by Trudgen (2002)

Life Form and Height	Projective Foliage Cover of tallest stratum as %	Description of tallest stratum
Trees over 30 metres	70-100 30-70 10-30 2-10 under 2	High closed forest High open Forest High woodland High open woodland Scattered tall trees
Trees 10-30 metres	70-100 30-70 10-30 2-10 under 2	Closed forest Open forest Woodland Open Woodland Scattered trees
Trees under 10 metres	70-100 30-70 10-30 2-10 under 2	Low closed forest Low open forest Low woodland Low open woodland Scattered low trees
Shrubs over 2 metres	70-100 30-70 10-30 2-10 under 2	Closed scrub Open scrub High shrubland High open shrubland Scattered tall shrubs
Shrubs 1-2 metres	70-100 30-70 10-30 2-10 under 2	Closed heath Open heath Shrubland Open shrubland Scattered shrubs
Shrubs under 1 metre	70-100 30-70 10-30 2-10 under 2	Low closed heath Low open heath Low shrubland Low open shrubland Low scattered shrubs
Herbs/Sedges/Grasses	70-100 30-70 10-30 2-10 under 2	Closed herb, sedge, grassland Herb, sedge, grassland Open herb, sedge, grassland Very open herb, sedge, grassland Scattered herb, sedges, grasses

Note: 'Tall' substituted for 'High' in vegetation descriptions used for the proposed Gorgon development areas survey 2003, 2004

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ATTACHMENT F: AMALGAMATED VASCULAR PLANT SPECIES LIST, BARROW ISLAND

# indicates species updated after post cyclonic rain surveys, + indicates species located in initial vegetation surveys

PGPF: proposed Gas Processing Facility and Wider Study Area, PNW: proposed North Whites Beach Pipeline

PFG: proposed Feed Gas Pipeline, PCO: proposed $C0_2$ Reinjection Pipeline

F: Family, G: Genera, S: Species; T: taxa, I: Introduced Species

Fam No	FAMILY	Species	Barrow Island	PGPF	PFG	PCO	PNW	F	G	S	T	I	New Taxa	PL	P1	P3	2004 Astron	Astron	Barrow	Perth	Karratha	Buckley Butler	Aust. Herb.No.	Lewis Grierson	rudge	1993a	1993b	Mattiske 1994	1995	1996	1999	BARROW ield Herbariur
13	MARSILEACEAE	*Marsilea ?hirsuta.*	+					1	1	1	1						+	+	HB53			+										
13		*(= Marsilea sp.)*																														
23	POTAMOGETONACEA	*Ruppia maritima*	+					1	1	1	1							+	HB152				RB6869,RB6972									
23C	CYMODOCEACEAE	*Halodule uninervis*	+					1	1	1	1							+														
31	POACEAE	*Aristida contorta*	+					1	1	1	1						+	+	12/75x2	RB6910		RB6910	RB6910									
31		*Aristida holathera*	+							1	1							+	+			+			+						+	
31		*Aristida holathera* var. *holathera*	+		#						1						+	+		DWG1554												
31		*Bothriochloa bladhii*	+						1	1	1							+	RB6895	RB6895		RB6895	RB6895									
31		*Brachyachne* sp.	+						1	1	1							+													+	
31		* *Cenchrus ciliaris*	+						1	1	1	1					+	+	MRW122	MRW122	W122, 047	+										+
31		*Chrysopogon fallax*	+						1	1	1						+	+	HB202	DWG1559		+										
31																			BI175													
31		*Cymbopogon ambiguus*	+	+	+	+	+		1	1	1						+	+	+	HB27			RB6760,RB6947			EM1200	M20227					+
31		*(=Cymbopogon ?ambiguus)*																														
31		*Cymbopogon bombycinus*	+							1	1						+	+	+			+					EM20313					
31		*Cymbopogon procerus*	+							1	1						+	+	MRW092	MRW092	RW092, 047	RB6947	46,RB6947,RB6760									
31		*Cymbopogon* sp.	+							1	1							+	+					+								
31		* *Cynodon dactylon*	+						1	1	1	1					+	+	6798, MRW	MRW123	RW123, 047	B6740,RB679	40,RB6741,RB6749									+
31																							RB6798,RB6848									
31		*Dactyloctenium radulans*	+						1	1	1						+	+	RB7217	B199,RB7128		RB7128	RB7128						NEC20575			
31		*Dichanthium sericeum* subsp. *humilius*	+	#					1	1	1						+	+	MRW192	MRW192	MRW192						EM20403				+	+
31		*Dichanthium sericeum* subsp. *sericeum*	+								1																				+	
31		*(=Dichanthium affine)*																	HB110	36705,RB6714		RB6714	B6705,RB6714		+		DET11034		NEC20563			
31																													NEC20532			
31																																
31		*Digitaria ctenantha*	+						1	1	1						+	+	RB7040										NEC20576			
31		*Enneapogon caerulescens*	+						1	1	1						+		+			+					EM20366		NEC2053	+		
31		*Enneapogon caerulescens* var. *caerulescens*	+								1							+	+	RB6891	RB6891	RB6891										
31																																
31		*Enneapogon caerulescens* var. *occidentalis*	+								1							+	+	RB6801			RB6801									
31		*Enneapogon oblongus*	+							1	1						+	+	RB7226	HB, RB6968		RB7226	RB6800				EM20225					
31																				RB6801,RB6800			RB6968				EM20300					
31																				RB7225,DWG1555			RB7225									
31		*Enneapogon polyphyllus*	+							1	1							+	RB7242	RB7230		RB7242	B7230,RB7242									
31		*Enneapogon* sp.	+							1	1							+	+						+							
31																															+	
31		*Eragrostis cumingii*	+	#					1	1	1						+	+	RB7244	RB7269		+	RB6725				EM20375		NEC20528			
31		*(= Eragrostis basedowii)*																		DWG1528							EM20397		NEC20615			
31																											EM20413					
31		*Eragrostis dielsii*	+	+						1	1						+	+									EM20404		NEC20530			
31																													NEC20505			
31																															+	
31		*Eragrostis falcata*	+							1	1						+	+	HB187	MRW193	MRW193	RB7058	B7056,RB7057									+
31																			RB7262	IB44,RB7261		RB7261	B7031,RB7261									
31																			MRW193	RB7056			RB7262		+							
31																				RB7057												
31		*Eragrostis xerophila*	+							1	1							+	MRW090	MRW090	MRW090						DET11000		NEC20561			+
31																					04777											
31																															+	
31		*Eragrostis* sp.	+							1	1								+					+								
31		*Eriachne benthamii*	+						1	1	1							+											NEC20571			
31		*Eriachne flaccida*	+	+		+				1	1						+	+	MRW152	RB6737	MRW199	RB6737	B6737,RB6810				DET11039		NEC20535		+	+
31																			HB54	MRW199							EM20426					

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Fam No	FAMILY	Species	Barrow Island	PGPF	PFG	PCO	PNW	F	G	S	T	I	New Taxa	PL	P1	P3	2004 Astron	Astron	Barrow	Perth	Karratha	Buckley Butler	Aust. Herb.No.	Lewis Grierson	'rudge	Mattiske 1993a	1993b	1994	1995	1996	1999	BARROW 'ield Herbariur
31																			MRW199	RB6810												
31		*(=Eriachne ?flaccida)*																														
31		*Eriachne flaccida* (Southern Pilbara - Carnarvon Cc	#			#				1	1																					
31		*Eriachne mucronata*	+	+	+	#	+			1	1	1					+	+	B6925,HB1:	DWG1552		+			+	+	EM20316		NEC20508		+	
31																											DET11016					
31																											EM20319					
31																											EM20371					
31																											EM20464					
31		*Eriachne* sp.	+		+		+			1	1																					
31		*Eulalia aurea*	+			#			1	1	1						+	+	RB6674	HB76	MRW091	+					EM20380					+
31		*(= Eulalia fulva)*																	MRW091	MRW091	04826						EM20415					
31		*Iseilema dolichotrichum*	+						1	1	1						+	+	+	DWG1515						+			NEC20577			
31		*(= Iseilema eremaeum)*																														
31		*Paspalidium clementii*	+			#			1	1	1						+	+	+			+										
31		*(= Paspalidium gracile)*																														
31		*Paspalidium tabulatum*	+	+	#		#			1	1						+	+	RB6912	RB6768	MRW115	RB6737	:B6677,RB6764		+	+	EM20249		NEC20506		+	+
31																			RB6788	MRW115	04478	RB6768	R6912,RB7028				EM20314		NEC20569			
31																			MRW115	RB6764		RB6788					EM20374					
31																				RB6912		RB6912					EM20378					
31																											EM20385					
31		*Paspalidium sp.*	+							1	1																				+	
31		*Setaria dielsii*	+						1	1	1						+	+	RB6963	B186,RB6963		RB6963	:B6963,RB6964									
31		*(= Setaria carnei)*																	HB186	36964,RB7019		RB7753	:B7019,RB7020									
31		*(=*Setaria verticillata)*																		RB7021,RB7023			RB7021,RB7023									
31																				RB7024,RB7113			RB7024,RB7113									
31																				RB7020												
31		* *Setaria verticillata*	#				#		1	1	1																					
31		*Sorghum plumosum*	+						1	1	1						+	+	HB77	36716,RB6808		RB6716	92,RB6808,RB7149									
31		*Spinifex longifolius*	+	+	+		+		1	1	1						+	+	HB23	RB6822	RW088, 047	RB6822	:B6822,RB682	+		+	+				+	+
31																			MRW088	MRW088	IRW089,04780											
31																			MRW089	MRW089												
31																				RB6823												
31																				DWG1560												
31		*Sporobolus australasicus*	+	#					1	1	1						+	+	HB182	B6704,HB182		RB6704	:B6794,RB6699			+	EM20405		NEC20524			
31																				DWG1527												
31		*Sporobolus mitchellii*	+							1	1							+	+								EM20424		NEC20536			
31		*Sporobolus virginicus*	+		#		+			1	1						+	+	6693, MRW	IB69,RB711	IRW100, 047	RB6648	6667,RB6708	+			EM20220				+	+
31																			HB	MRW100		RB6693	RB7115									
31		*Themeda triandra*	+						1	1	1							+	+			+										
		(=Themeda australis)	+														+															
31		*Triodia angusta*	+	+	+	+	+		1	1	1						+	+	HB145	IB23,RB674	MRW070	RB6838	:B6708,RB674	+	+	EM50063	EM20265					+
31																			RB6838	MRW070	MRW101		RB6791			EM12045						
31																			RB6839	MRW101						EM12044						
31																			MRW070	DWG1561						DET5000						
31																			MRW101	RB6971												
31																															+	
31		*Triodia epactia*	+		+	+	+			1	1						+	+	HB25	HB167		+		+	+	43	EM20266		NEC20522		+	
31		*(= Triodia pungens)*																	HB167							EM1204	EM20290					
31																																
31		*Triodia wiseana*	+	+	+	+	+			1	1						+	+	HB168	RB6909	MRW079	RB6909	RB6757	+	+	+	+		+		+	+
31																			MRW079	MRW079						EM12041			NEC20522			
31																				DWG1563						DET5001						
31																				HB168												
31																				HB171												
31		*Triraphis mollis*	+						1	1	1						+	+	RB7082	RB6892		RB6892	92,RB7067,RB7089						NEC20581			
31																			HB185	RB7067		RB7082	RB7254									

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31																				HB72												
31		*Whiteochloa airoides*	+		+				1	1	1						+	+	+								DET11008				+	
31																											EM20419					
31		*Yakirra australiensis*	+	+					1	1	1						+	+	HB154	HB154									NEC20518			
31		(= *Panicum decompositum*)																	RB7158			RB7158							NEC20570			
31		(= *Panicum australiense*)																											NEC20501			
31		Poaceae sp.	+	+					1	1	1							+	MRW139							+						
31																			MRW145													
31																															+	
31		Poaceae sp. 1	+						1	1	1							+	+						+							
31		Poaceae sp. 2	+						1	1	1							+	+						+							
31		Poaceae sp. 3 (Tussock grass)	+						1	1	1							+	+						+							
32	CYPERACEAE	*Bulbostylis barbata*	+	+				1	1	1	1						+	+	RB7203	HB147		RB7203	RB7203				EM20228		NEC20580			
32																				DWG1530									NEC20572			
32																													NEC20526			
32																													NEC20605			
32																													NEC20534			
32		*Cyperus bifax*	+						1	1	1							+											NEC20604			
32		*Cyperus cunninghamii*	+							1	1																				+	+
32		*Cyperus cunninghamii* subsp. *cunninghamii*	+	+		+	+				1						+	+	RB6627	HB122	MRW078	B6605,RB662	27,RB6651,RB6858		+	+	DET11022		+		+	
32		(= *Mariscus sp.*)																	RB6767	DWG1513	04783		RB6943				EM20226					
32																			RB6651	MRW078							EM20302					
32																			MRW078	RB6858							EM20328					
32																				HB6/64							EM20376					
32																											EM20468					
32		*Cyperus iria*	+							1	1							+											NEC20595			
32		*Cyperus squarrosus*	+							1	1						+	+				RB6737	RB6737						NEC20586			
32																													NEC20602			
32																													NEC20609			
32																													NEC20537			
32		*Fimbristylis dichotoma*	+						1	1	1						+	+											NEC20573			
32		*Fimbristylis schultzii*	+							1	1						+	+	+	HB43		+		+		+					+	
32	*	*Isolepis marginata*	+						1	1	1	1						+	+			+										
32		*Isolepis* sp.	#	#						1	1																					
32		(= *Scirpus marginatus*)																														
32		*Lipocarpha microcephala*	+	+					1	1	1																					
32		*Schoenoplectus dissachanthus*	+						1	1	1							+	HB55			+										
32		(= *Scirpus dissachanthus*)																														
47	COMMELINACEAE	*Commelina ciliata*	+					1	1	1	1							+	+			+										
47		*Commelina ensifolia*	+							1	1							+	HB197	DWG1214		+										
47																			BI202													
54C	DASYPOGONACEAE	*Acanthocarpus verticillatus*	+	+				1	1	1	1						+	+	HB169	B136,RB67	B6784, 0478	RB6784	RB6784	+	+	+	EM2025				+	
54C		(+ *Acanthocarpus preissii*)																	MRW163								EM20361					
54C		(= *Acanthocarpus robustus*)																		MRW163	SVL1083											
54C		(= *Acanthocarpus sp.*)																		MRW119	MRW163											
54C																					MRW119											
54C																																
54F	ANTHERICACEAE	*Corynotheca flexuosissima*	+					1	1	1	1						+	+	RB7202	RB7222		RB7202	B7202,RB7222									
54F		(+ *Corynotheca micrantha*)																		RB7202												
87	MORACEAE	*Ficus brachypoda*	+	+	+	+	+	1	1	1	1						+															
87		(= *Ficus platypoda*)																+	RB6776	RB6621	04785	RB6621	RB7022	+			EM20202				+	+

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87		*(= Ficus leucophea)*																	HB	HB							EM20337					
87		*(= Ficus platypoda* var. *minor)*																	MRW072	MRW072	MRW072						EM20373					
		Ficus brachypoda hairy variant (ex.*Ficus platypoda* va	+								1						+															
87		*Ficus opposita* var. *aculeata*	+							1	1						+	+	RB6802			RB6802	RB6802					DET1101	EC207(	+		
87		*Ficus virens* var. *virens*	+							1	1						+	+	MRW200	MRW200	MRW200	RB6776	RB6776				EM2042	+				+
87		*Ficus* sp.	+							1	1							+	+				RB6616									
90	PROTEACEAE	*Grevillea pyramidalis*	+					1	1	1	1						+	+	+			+					+				+	
90		*Grevillea pyramidalis* subsp. *?leucadendron*	+	+			+				1							+														
90		*Hakea lorea* subsp. *lorea*	+	+	+	+			1	1	1						+															
90		*(= Hakea lorea)*																+	MRW111	MRW111	RW111, 047	+		+			EM20255				+	+
92	SANTALACEAE	*Santalum murrayanum*	+					1	1	1	1						+	+	RB6864	RB6864		RB6864	RB6864				EM2048	+				+
92		*(= Santalum lanceolatum)*																	MRW204													
97	LORANTHACEAE	Loranthaceae sp.	+					1	1	1	1						+	+	+			+										
103	POLYGONACEAE *	*Emex australis*	+					1	1	1	1	1					+															
105	CHENOPODIACEAE	*Atriplex isatidea*	+				+	1	1	1	1						+	+	MRW146	RB6686	6862,RB6742		RB6742				DET110	+				+
105		*Atriplex semilunaris*	+							1	1						+	+	HB193	B7044,HB1	RB7077	77	RB7044,RB7078,RB7080									
105																				RB7078,RB7080												
105		*Chenopodium* aff. *cristatum*	+	+					1	1	1		1																			
105		*Chenopodium melanocarpum* forma *leucocarpum*	+							1	1						+	+	HB100,HB4	G1283,RB6840		RB6769	24,RB6752,RB6827,							+	+	
105		*(= Chenopodium carinatum)*																		RB6827,RB6752			RB6840									
105		*Chenopodium pumilio*	+							1	1							+	RB6624	MRW057	MRW057											
105		*Dysphania kalpari*	+						1	1	1						+	+	MRW178								EM20275				+	+
105																											EM20377					
105																											EM20412					
105																											EM20474					
105		*Dysphania plantaginella*	+							1	1						+	+	RB6706	RB6706		RB6706	B6706,RB6685				EM20206		NEC20558			
105																				DWG1285							EM20473					
105																											EM20479					
105		*Dysphania rhadinostachya*	+							1	1						+		RB6721	HB59		RB6721	RB6753			+	EM20406			+	+	
105		*(= Chenopodium rhadinostachyum)*																									EM20418					
105		*(= Dysphania inflata)*																		DWG1549												
105		*Dysphania rhadinostachya* subsp. *inflata*	+								1							+														
105		*Dysphania rhadinostachya* subsp. *rhadinostachya*	+	+	+						1		1																			
105		*Enchylaena tomentosa* var. *tomentosa*	+				+		1	1	1						+	+														
105		*(= Enchylaena tomentosa)*																	RB7234	RB6960	MRW188	RB6960	B6960,RB7042				EM20299					+
105		*(= Enchylaena micrantha)*																	MRW188	RB7042		RB7234										
105																				MRW188												
105		*Eremophea spinosa*	+				+		1	1	1						+	+	HB142	B1, MRW1	MRW164	RB6783	11,RB6750,RB6770				DET110	+			+	
105		*(= Sclerolaena spinosa)*																		HB142,RB6770			RB6775,RB6777,RB6779				EM20218b					
105																				RB6775,RB6779			RB6871,RB7224,RB7268									
105																				RB6871,RB7224												
105																				RB7224,RB7268												
105																				DWG1274,DWG1275												
105	CHENOPODIACEAE	*Halosarcia halocnemoides*	+					1	1	1	1																				+	
105		*Halosarcia halocnemoides* subsp. *tenuis*	+				+				1						+	+	MRW160	HB70,HB26	RB6780	RB6780	RB6772				EM20219				+	+
105		*(= Arthrocnemum halocnemoides)*																		RB6772	MRW160						EM20230					
105																				MRW160							EM20394					
105																											DET11046					
105		*Halosarcia indica*	+				+			1	1							+	HB								DET11048				+	+
105		*(= Arthrocnemum leiostachyum)*																														

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Fam			Barrow	PGPF	PFG	PCO	PNW						New				2004					Buckley	Aust.	Lewis				Mattiske				BARROW
No	FAMILY	Species	Island					F	G	S	T	I	Taxa	PL	P1	P3	Astron	Astron	Barrow	Perth	Karratha	Butler	Herb.No.	Grierson	'rudge	1993a	1993b	1994	1995	1996	1999	'ield Herbariur
105		(=*Halosarcia indica* subsp. *julacea*)	+															+	MRW165	MRW165	MRW165						EM20231				+	
105																											EM20243					
105																											EM20393					
105		(=*Halosarcia ?indica*)	+																MRW158													
105		*Halosarcia indica* subsp. *leiostachya*	+								1						+	+	20	RB6773		RB6781	RB6773									
105																			21													
105		*Halosarcia* sp.	+							1	1							+						+								
105		*Neobassia astrocarpa*	+				+		1	1	1						+	+	RB6740	26/7	HB71/22	RB6740	:B6722,RB674	+			DET11047				+	+
105		(= *Bassia astrocarpa*)																	BI161	DWG1234	MRW099		RB6873				EM20232					
105		(= *Neobassia sp.*)																	MRW099	MRW099	04787						EM20392					
105																				RB6722												
105																				RB6873												
105		*Rhagodia eremaea*	+						1	1	1							+	HB14													
105		*Rhagodia latifolia* subsp. *latifolia*	+							1	1						+	+	+							EM12025					+	
105		*Rhagodia latifolia* subsp. *?recta*	+								1							+	+							EM5002						
105																										EM12026						
105		*Rhagodia preissii* subsp. *obovata*	+				+			1	1						+	+	RB7104	IB18,RB681	MRW142	RB7104	:B6819,RB683	+			DET11020				+	+
105		(= *Rhagodia obovata*)																	BI60	326/2,RB6830			RB7037,RB7091				EM20207					
105		(= *Rhagodia baccata*)																	MRW142	33285,RB7091			RB7096,RB7097									
105		(= *Rhagodia dioica*)																		DWG1284,RB7096			RB7103,RB7104									
105																				MRW142,RB7097												
105																				RB7103,RB7104												
105		*Salsola tragus*	+	+			+		1	1	1						+	+	HB32	MRW054	MRW054	+				+	+		NEC20613		+	+
105																			MRW054	SVL1075	VL1075, 03876											
105		*Sclerolaena convexula*	+						1	1	1						+	+	MRW164			+										+
105		(= *Bassia convexula*)																														
105		*Sclerolaena uniflora*	+							1	1						+	+	MRW159	MRW159	MRW159	+										+
105		*Threlkeldia diffusa*	+				+		1	1	1						+	+	RB6954	HB,RB6743	HB65	RB6954	:B6743,RB687	+		EM1202	ET11021				+	+
105																			MRW143	MRW143	MRW143		RB7018,RB6954				DET11045					
105																				RB6954												
105																				RB7018												
106	AMARANTHACEAE	*Alternanthera nodiflora*	+					1	1	1	1						+	+														
106		*Alternanthera* sp.	+							1	1								+			+										
106																				RB6836,RB6961		RB6836,RB6961										
106		*Amaranthus mitchellii*	+	#					1	1	1							+													+	
106		*Amaranthus pallidiflorus*	+	+			#			1	1						+	+	+	RB6821	RB6821	RB6683					EM20277		NEC20541			
106		(= *Amaranthus viridis*)																											NEC20549			
106		*Amaranthus* sp. Barrow Island D200(R. Buckley 6	+							1	1							+														
106		*Amaranthus* sp.	+							1	1								RB6961	36962,RB6884		RB6962,RB6884										
106		*Gomphrena sordida*	+						1	1	1						+	+	RB7029	RB7030		RB7029	RB7030	+								
106																						RB7030	RB7125									
106		*Hemichroa diandra*	+						1	1	1						+	+	HB	BI,HB158		+										
106																				DWG1236(1964)												
106		*Ptilotus clementii*	+	+		#			1	1	1						+	+	MRW108	MRW185	MRW108	RB6682	:B6861,RB6945				DET11043					+
106																			MRW185	MRW108	MRW185						EM20264					
106																					04788						EM20266					
106		*Ptilotus exaltatus*	+							1	1								RB7006	HB188	MRW009	RB7006	:B7004,RB7032									+
106																			MRW009	MRW009												
106		*Ptilotus exaltatus* var. *exaltatus*	+								1						+	+														
106		*Ptilotus fusiformis*	+							1	1						+	+														
106		*Ptilotus fusiformis* var. *fusiformis*	#	#		?#					1																					
106		(*Ptilotus fusiformis ?* var.)																	HB105			+										
106		*Ptilotus gomphrenoides* subsp. *gomphrenoides*	+	+						1	1						+															
106		*Ptilotus obovatus*^^	+							1	1						+	+	RB6715	RB6804	MRW007	RB6804	:B6606,RB663	+		+	EM20286			+	+	+
106		(^^abherent prostrate form on island)																	HB85	RB6876	MRW201	RB6715	:B6697,RB6715				EM20430					

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Fam			Barrow	PGPF	PFG	PCO	PNW						New				2004					Buckley	Aust.	Lewis				Mattiske				BARROW
No	FAMILY	Species	Island					F	G	S	T	I	Taxa	PL	P1	P3	Astron	Astron	Barrow	Perth	Karratha	Butler	Herb.No.	Grierson	Trudge	1993a	1993b	1994	1995	1996	1999	ield Herbariur
106																			MRW007	MRW007	03877		RB6876,RB6890				EM20431					
106																			MRW201	MRW201			RB6876,RB6890									
106		*Ptilotus obovatus* subsp. *obovatus*	+	+	+	+	+				1																					
106		*Ptilotus villosiflorus*	+							1	1						+	+	RB6735	HB67		RB6735	RB6735				EM20260				+	+
106																			MRW130								EM20291					
107	NYCTAGINACEAE	*Boerhavia burbidgeana*	+		#			1	1	1	1							+	+													
107		(= *Boerhavia diffusa*)																														
107		(=?*Boerhavia repleta*)																		RB7059		RB6601	·25,RB6880,RB7059									
107		*Boerhavia coccinea*	+							1	1							+	HB90	HB90												
107		*Boerhavia gardneri*	+	+	#	#				1	1						+	+	MRW189	MRW189	MRW189				+		DET11007		NEC20603		+	+
107																											EM20306					
107																											EM20333					
107																											EM20410					
107																											EM20486					
107		*Boerhavia* aff. *repleta*	+							1	1																				+	
107		(=*Boerhavia ?repleta*)	+															+	+	RB7251						+	EM20295					
		Boerhavia schomburgkiana	+							1	1						+	+														
107		(*Boerhavia ?schomburgkiana*)																	+	RB6601									NEC20525			
107																													NEC20557			
107		*Boerhavia* sp.	+							1	1							+	HB10					+							+	
107		*Commicarpus australis*	+				#		1	1	1						+	+	HB31	MRW172	MRW172	+	·45,RB6650,RB7011		+		DET11026				+	
107		(= *Boerhavia chinensis*)																		HB31							EM20209					
107		(= *Boerhavia repandra*)																		RB6880,RB7011							EM20267					
108	GYROSTEMONACEAE	*Codonocarpus cotinifolius*	+	+		+		1	1	1	1						+	+	HB132	RB6941	MRW140	RB6941	RB6941				EM20315					+
108																			MRW140	MRW140												
110	AIZOACEAE	*Sesuvium portulacastrum*	+					1	1	1	1						+	+	HB170	B170,RB69	MRW157	RB6965	RB6965				EM20351					
110																			MRW157	MRW157												
111	PORTULACACEAE	*Calandrinia balonensis*	+					1	1	1	1							+	+			+										
111		*Calandrinia polyandra*	+	+						1	1						+	+	+											96/42 TF	+	
111		(= *Calandrinia ?polyandra*)																	RB6815	RB6746		RB6746,RB6815	RB6746,RB6815			+	EM2023					
111																			HB86								EM20390					
111		*Calandrinia* sp. aff. *polyandra*	+								1																				+	
111		*Calandrinia* ?aff. *remota*	+	+						1	1		1																			
111		*Calandrinia* sp.	+							1	1							+	MRW011		05404											
111		*Portulaca australis*	+						1	1	1							+	+			+										
111		*Portulaca intraterranea*	+							1	1						+	+	RB7207	RB7107		RB7107	:B7095,RB7106									
111																						RB7207	:B7107,RB7208									
111		*Portulaca oleracea*	+							1	1							+	+			+										
111		*Portulaca pilosa*	+							1	1							+	RB7053	RB7255		RB7053	:B7052,RB7088									
111		*Portulaca pilosa (Boodie Island)*	+							1	1						+					RB7255	:B7112,RB7225									
113	CARYOPHYLLACEAE	*Polycarpaea longiflora*	+	+	#	+	+	1	1	1	1							+	HB108	MRW085	MRW085		RB6631,RB6663				EM20293		NEC20578		+	+
113																			MRW085	DWG1253	04789											
113																																
122	MENISPERMACEAE	*Tinospora smilacina*	+				+	1	1	1	1						+	+	RB6859	HB91			RB6859				DET1101	DET1100			+	
122																											EM20326					
122																											EM20483					
131	LAURACEAE	*Cassytha capillaris*	+					1	1	1	1						+	+	MRW180								EM20241					+

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137A	CAPPARACEAE	*Capparis lasiantha*	+					1	1	1	1						+	+	RB7155	RB7155		RB7155	RB7155									
137A		(= *Capparis sp.(RB7155)*)																														
137A		*Capparis spinosa*	+							1	1																				+	
137A		*Capparis spinosa* var. *nummularia*	+	+	+						1						+	+	HB11	HB20	RW015, 03878		RB6798				DET11017				+	+
137A		(= *Capparis spinosa*)																	MRW015	MRW015	SVL1069						EM20467					
137A		*Capparis umbonata*	+							1	1						+	+	IRW202A+B									DET1101				
137A		*Cleome viscosa*	+	+		#			1	1	1						+	+	RB6700	HB140	MRW109	RB6700	RB6700	+	+	+	EM20274				+	+
137A																			MRW109	MRW109	04790						EM20398					
137A																				DWG1286,RB6700							EM20476					
138	BRASSICACEAE	*Lepidium platypetalum*	+					1	1	1	1						+	+	RB7141			RB7139	39,RB7140,RB7141									
152	PITTOSPORACEAE	*Pittosporum phylliraeoides*	+	+	+	+	+	1	1	1	1						+	+	HB17	RB6860	MRW073	RB6860	B6865,RB688	+			EM20257				+	+
152																			HB58	RW073,RB6	04791		RB6894,RB7154				EM20331					
152																			MRW073	7154,DWG1227												
152																				CLAY & YARDAV												
160	SURIANACEAE	*Stylobasium spathulatum*	+	+	+	+	+	1	1	1	1							+	RB6703	IB,SVL108	MRW116	RB6703	RB6753	+	+	+	EM20265				+	+
160																			MRW116	MRW116	SVL1081											
163	MIMOSACEAE	*Acacia bivenosa*	+	+	+	+	+	1	1	1	1						+	+	RB7210	HB50	MRW055	RB7210	B6790,RB721	+	+	+	EM2028	+				+
163		*Acacia bivenosa* (elongate phyllode form)	+	+							1																					
163		*Acacia bivenosa* (intermediate form)	+	+							1																					
		Acacia bivenosa (Airlie Island variant)	+								1						+															
		Acacia bivenosa (semiprostrate form)	+								1						+															
163		*Acacia coriacea*	+							1	1								HB21	HB8	MRW102		RB6680	+	+	+	EM20208					+
163		*Acacia coriacea* subsp. *coriacea*	+	+		+	+				1						+	+		HB												
163		*Acacia coriacea* subsp. *pendens*	+								1						+	+		RB7246			RB7246									
163		*Acacia cowleana*	+							1	1						+	+	MRW195								EM20411					+
163		*Acacia grasbyi*	+							1	1							+	RB6696	HB	HB	RB6696	RB6696									
163		*Acacia gregorii*	+	+	+	+	+			1	1						+	+	MRW084	MRW084	MRW084		RB6655	+		+	EM20312					+
163		*Acacia inaequilatera*	+							1	1						+	+									EM20240		NEC20700			
163		*Acacia pyrifolia*	+	+	+	+				1	1						+	+	HB	SMITH131	MRW058		RB6939	+	+	+	EM20349			+		+
163		*Acacia synchronicia*	+							1	1						+	+	HB	MRW127	MRW127	RB6952	B6951,RB6952				EM20400					+
164	CAESALPINIACEAE	*Petalostylis labicheoides*	+	+	+	+		1	1	1	1						+	+	RB6791	B119,RB67.	MRW016	RB6791	RB6759	+	+	+	EM20311				+	+
164																			MRW016	MRW016	03882											
164																				JSB3275												
164		*Senna artemisioides*	+						1	1	1																				+	
164		(= *Bassia uniflora*)																														
164		*Senna artemisioides* subsp. *oligophylla*	+								1						+	+	6635,MRW(	MRW053	RW053, 047	+					+				+	+
164		(= *Cassia oligophylla*)																	MRW094	MRW094	RW094, 03883											
164		*Senna glutinosa* subsp. *glutinosa*	+		+	+				1	1						+	+	MRW162	MRW162	MRW162				+	+	DET11051				+	+
164		(= *Cassia glutinosa*)																									EM20318					
164		*Senna glutinosa* subsp. *pruinosa*	+	+							1						+	+	MRW161	RB6937		RB6635	35,RB6640,RB6661				DET11031					
164		(= *Cassia pruinosa*)																	HB159			RB6937					EM20317					
164																											DET11050					
164		*Senna notabilis*	+	+		+				1	1						+	+	RB6658	IB63,RB693	MRW056	RB6658	B6658,RB6931		+	+	EM20307				+	
164		(= *Cassia notabilis*)																	MRW056	MRW056	03881						EM20365					+
164		(= ? *Senna notabilis*)																														
164		*Senna planitiicola*	+							1	1						+	+	MRW138							+	DET11003		+			+
164																			MRW182								EM20245					
164																											EM20414					
164		*Senna venusta*	+							1	1						+	+	+			+										
164		(= *Cassia venusta*)																														

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165	PAPILIONACEAE	*Canavalia rosea*	+					1	1	1	1						+	+	HB149	RB6879			RB6879									
165		*(= Canavalia maritima)*																														
165		*Crotalaria cunninghamii*	+						1	1	1						+	+												+		
165		*Crotalaria medicaginea*	+							1	1						+	+	RB7258	RB7258		RB7258	RB7258				EM20298					
165		*(= Crotalaria trifoliastrum)*																									EM20402					
165		*Crotalaria novae-hollandiae*	+							1	1						+	+	MRW126	MRW126	MRW126	+										+
165		*Cullen lachnostachys*	+						1	1	1						+	+	HB127	RB6970	HB, 048802	RB6760	:B6754,RB6762				EM20292					+
165		*(= Psoralea lachnostachys)*																	MRW124	MRW124	MRW124											
165		*Cullen leucanthum*	+		+					1	1						+	+													+	+
165		*(= Psoralea leucantha)*																	RB6736	HB117	03884	RB6736	:B6642,RB673	+	+	+	EM20384		+			
165																			HB6/12	MRW005	SVL1070											
165																			MRW005	SVL1070	MRW005											
165		*Cullen pallidum*	+							1	1														+		EM20381					
165		*(= Psoralea sp.(aff. patens Carr 4603/Beauglehole 4838))*																														
165		*(= Psoralea patens)*																														
165		*Cullen* aff. *pallidum*	+								1							+	+											+		
165		*Cullen patens*	+							1	1						+	+														
165		*Cullen pustulatum*	+	+		+	+			1	1						+	+													+	
165		*Erythrina vespertilio*	+			+	+		1	1	1						+	+	HB161	HB161		+		+		+	+			+	+	
165																			HB27													
165		*Indigofera boviperda*	+			+			1	1	1						+	+	HB121	MRW105	MRW105	+					DET11015				+	+
165		*(?= Indigofera georgei)*																	MRW105	MRW177	MRW177						EM20236					
165																			MRW177		04801						EM20262A					
165																											EM20370					
165																											EM20389					
165		*(= Indigofera ?boviperda)*																														
165		*Indigofera colutea*	+							1	1						+	+	6814, MRW	36814,RB7256		RB6814	86,RB6814,RB7256				EM20238		NEC20616			+
165		*(= Indigofera viscosa)*																									EM20285		NEC20579			
165		*Indigofera linifolia*	+							1	1						+	+	RB7013	IB75,RB7233		RB7013	:B7014,RB7233									
165																				RB7014												
165		*Indigofera linnaei*	+							1	1						+	+	+			+			+		EM20262B		NEC20592		+	
165		*(= Indigofera enneaphylla)*																														
165		*Indigofera monophylla*	+	+	+	+	+			1	1						+	+	RB118	RB6877	MRW125	RB6877	02,RB6612,RB6629		+	EM1201:	EM20248				+	+
165																			HB10	HB203	MRW183		RB6639,RB6787				EM20342					
165																			MRW125	RB6787	04800											
165																			MRW183	MRW183												
165																				MRW125												
165		*Indigofera trita*	+							1	1						+	+	HB198	37036,RB7060		RB7036	36,RB7060,RB6914				EM20253					
165		*Indigofera* sp.	+							1	1							+	+							+						
165		*(Indigofera sp. (RB6723) (not received))*																+	+	RB6914			RB6723									
165		*Isotropis atropurpurea*	+							1	1						+	+	MRW150								DET11037					+
165																											EM20252					
165																											EM20334					
165		*Lotus australis*	+						1	1	1							+	RB6881	RB6881		RB6881	RB6881									
165		*Lotus cruentus*	+							1	1							+														
165		*Rhynchosia minima*	+	+	#		#		1	1	1						+															
165		*(= Rhynchosia ?minima)*																														
165		*(= Rhynchosia cf. minima)*																+	RB7151	RB6825	MRW144	RB6889	:B6660,RB6825		+	+	EM2027(		+			+
165		*Sesbania cannabina*	+	+					1	1	1						+	+	+	DWG1325		+										
165		*Swainsona formosa*	+						1	1	1						+	+	HB172		04792	+										
165		*(= Clianthus formosus)*																														
165		*Swainsona kingii*	+							1	1						+	+	RB7086	HB155		RB7086	85,RB7086,RB7087									
165		*Swainsona pterostylis*	+							1	1							+	HB1	RB6656		RB6656	49,RB6665,RB6671									
165		*Tephrosia clementii*	#			#			1	1	1																					
165		*Tephrosia rosea*	+	#	+	+				1	1								MRW097	MRW097	MRW097										+	+

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165																			MRW186		04808											
165		*Tephrosia rosea* var. *clementii*	+	+	+		+				1						+	+	RB6818	JFC352		RB6818	5818,RB6721	+	+	+	EM20341				+	
165																				JSB3274			RB6789				EM20347					
165																				CLAY & YADAV							EM20484					
165																				RB6789							DET11030					
165		*Tephrosia rosea* var. *glabrior* ms	+								1						+	+	HB62	HB	MRW148	RB6668	B6668,RB6955				DET11033					+
165																			RB6668	DWG1288							EM20201					
165																				MRW148							EM20269					
165																				RB6955							EM20458					
165		*Tephrosia* sp.	+							1	1							+	+							+					+	
165		Papilionaceae sp.	+	+					1	1	1																				+	
173	ZYGOPHYLLACEAE	*Tribulus cistoides*	+					1	1	1	1							+														
173		*Tribulus hirsutus*	#	#		#				1	1																					
173		*Tribulus occidentalis*	+							1	1						+	+	+			+										
173		*Tribulus terrestris*	+							1	1							+	MRW117	MRW117	RW117, 04804		RB7064,RB7065,RB7066									+
183	POLYGALACEAE	*Polygala isingii*	+					1	1	1	1						+															
		(*Polygala* aff. *isingii*)																+											NEC20567			
183																													NEC20608			
183																													NEC20520			
185	EUPHORBIACEAE	*Adriana tomentosa* var. *tomentosa*	+	+	+	+	+	1	1	1	1						+	+														
185		(= *Adriana tomentosa*)																	RB6763	HB8	MRW076	RB6763	RB6763	+		+	EM20321				+	+
185																			MRW076	MRW076	SVL1078						EM20364					
185																					04805						EM20460					
185		*Euphorbia australis*	+	+		+			1	1	1						+	+	RB6756	HB42	HB30/L4	RB6756	31,RB6831,RB6833				EM20237		NEC20503		+	
185		(= *Euphorbia australis* var. *vaccaria*)									1							+									EM20269		NEC20559			
185		(= *Chamaesyce australis*)																									EM20272					
185																											EM20360					
185																											EM20363					
185																											EM20368					
185																																
185		*Euphorbia coghlanii*	+	+		#				1	1						+	+	RB7092	RB7083	RB6794	RB6688	B6688,RB6826		+		DET11019		NEC20500		+	
185		(= *Chamaesyce atoto*)																	RB6688	RB6688	RB6903	RB6903	B7092,RB7094				EM20239		NEC20514			
185																				DWG1330		RB7092	RB7116						NEC20562			
185		*Euphorbia drummondii* subsp. *drummondii*	+	+	+		+			1	1						+	+	HB16	RB6923	HB		RB6923,RB7159,RB6956									
185		(= *Chamaesyce atoto*)																		RB6956												
185		(= ? *Euphorbia drummondii* subsp. *drummondii*)																		RB7148												
185																				RB7159												
		Euphorbia aff. drummondii (Boodie Island)	+							1	1						+															
185		*Euphorbia myrtoides*	+	+						1	1							+	+	RB6901		RB6688	32,RB6690,RB7062		+						+	
185		(= *Chamaesyce myrtoides*)																		RB6902		RB7083	B7081,RB7083									
185		(= *Euphorbia alsiniflora*)																		RB6904		RB7093	01,RB6902,RB6904									
185		*Euphorbia tannensis* subsp. *eremophila*	+	#						1	1						+	+	RB7002	RB7001	MRW045	RB7001	5837,RB7001	+	+	+	DET11013		NEC20512			
185		(+ *Euphorbia boopthona*)																	HB	MRW045		RB7002	B7002,RB7003				EM20267					
185		(= *Euphorbia eremophila*)																					RB7005,RB7012				EM20276					
185																							RB7098,RB7099				EM20472					
185		*Euphorbia* sp.	+							1	1							+														
185		*Euphorbia* sp.A.	+							1	1							+	+				RB7111				EM20482		NEC20548		+	
185																													NEC20510			
185																													NEC20516			
185		*Flueggea virosa* subsp. *melanthesiodes*	+						1	1	1						+	+	+						+					+	+	
185		(= *Flueggea virosa*)																														
185		*Mallotus dispersus*	+						1	1	1						+	+	+								EM20261					
185		(=*Mallotus didmochryseus*)																									EM20327					

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Fam No	FAMILY	Species	Barrow Island	PGPF	PFG	PCO	PNW	F	G	S	T	I	New Taxa	PL	P1	P3	2004 Astron	Astron	Barrow	Perth	Karratha	Buckley Butler	Aust. Herb.No.	Lewis Grierson	Trudgen	Mattiske 1993a	1993b	1994	1995	1996	1999	BARROW Field Herbarium
185		*Mallotus nesophilus*	+	+	+		+			1	1						+	+	HB?	IB80, RB68:	:B6897, 0540	RB6897	:B6857,RB6897				EM20200					+
185																			MRW082	MRW082	MRW082						EM20429					
185		*Phyllanthus maderaspatensis*	+	+					1	1	1						+	+	RB6899	·201,DWG1524		RB6899	·99,RB6900,RB6905		+	+	EM2046		IEC20554			
185																			RB7241	36898,RB6900		RB7241	·06,RB6935,RB7241						IEC20511			
185																				RB6935,RB7241												
185		(=*Phyllanthus* sp.)																+														
202	STACKHOUSIACEAE	*Stackhousia muricata*	+	+				1	1	1	1						+	+	HB28	RB6659	MRW107	RB6659	RB6730				EM20284				+	+
202		(= *Stackhousia elata*)																	MRW107	MRW107	04806						EM20462					
202		(= *Stackhousia ?muricata*)																														
207	SAPINDACEAE	*Alectryon oleifolius* subsp. *oleifolius*	+					1	1	1	1						+	+	HB28	RB6866	RB6862	RB6862	:B6862,RB6866				EM2047	+				
207		(= *Heterodendrum oleaefolium*)																														
207		(= *Atalaya hemiglauca*)																														
207		*Diplopeltis eriocarpa*	+	+	+	+	+		1	1	1						+	+	HB19	MRW003	MRW003		RB6744	+	+	EM1200	EM20218					+
207		(= *Diplopeltis ?eriocarpa*)																	MRW003	HB19	03885						EM20325					
207																				RB6744												
207																				DWG1293												
207																																
207		*Diplopeltis intermedia* var. *?intermedia*	+							1	1							+	+							+	EM20217				+	
207		*Diplopeltis* sp.	+	+						1	1																					
207		*Dodonaea lanceolata*	+						1	1	1							+													+	
207		*Dodonaea lanceolata* var. *lanceolata*	+	+							1						+	+	RB6613	MRW075	MRW075	RB6613	RB6613	+	+	EM1203	EM20330				+	+
207																			HB82	JSB3278	04807											
207																			MRW075	DWG1237												
215	RHAMNACEAE	*Ventilago viminalis*	+					1	1	1	1						+	+														
220	TILIACEAE	*Corhorus congener*	#	#																												
220		*Corhorus ?congener*	#	#			#																									
220		*Corchorus interstans* ms (P3)	+	+			+	1	1	1	1					1	+	+	RB6938			RB6938										
220		(= *Corchorus sidoides*)																					RB6732									
220		(=*Corchorus* aff. sp. Barrow 2)																	MRW149							EM1201	DET11032				+	
220		(=*Corchorus aff. sidoides*)																									DET11055					
220		(= *Corchorus ?interstans*)																														
220		*Corchorus tridens*	+							1	1						+	+											NEC20539			
220		*Corchorus walcottii*	+		#	#	#			1	1						+	+	HB116	HB	MRW081	RB6638	:B6647,RB6734			+	EM20459				+	
220																				JSB3279											+	
220																				DWG1520												
220																				CLAY & YARDAV												
220		(= *Corchorus walcottii*)																	L-3	MRW081	05406						EM20475					
220																			MRW081								EM20281					
220		(= *Corchorus ?walcottii*)	+	+																												
220		(=*Corchorus walcottii* s.l.)	+	+																												
220		(=*Corchorus* sp. Barrow)	+															+	+										NEC2055	+		
220		*Corchorus* sp.	+	+		+				1	1								+	36732,RB6751			RB6870	+	+							
220		*Corchorus* aff. sp. Barrow 1	+							1	1								RB6638	HB11	HB37	RB7132	RB7132				EM20224			+		+
220		(= *Corchorus parviflorus*)															+	+		MRW187	MRW187						EM20271					
220																				RB6623			RB6623				EM20279				+	
220																				RB6793			RB6793				EM20296					
220																											EM20362					
220		*Corchorus* sp. Barrow 2	+							1	1							+														
220		*Triumfetta appendiculata*	+						1	1	1						+														+	
220		*Triumfetta* aff. *appendiculata*	+	+							1		1																			
220		*Triumfetta chaetocarpa*	+				+			1	1																					

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Fam			Barrow	PGPF	PFG	PCO	PNW						New				2004					Buckley	Aust.	Lewis					Mattiske			BARROW
No	FAMILY	Species	Island					F	G	S	T	I	Taxa	PL	P1	P3	Astron	Astron	Barrow	Perth	Karratha	Butler	Herb.No.	Grierson	'rudge	1993a	1993b	1994	1995	1996	1999	'ield Herbariur
220		*Triumfetta clementii*	+	+		#	+			1	1						+	+	RB6672	RB6807	MRW133	RB6807	RB6672		+		EM20263		NEC20533		+	+
220		(= *Triumfetta leptacantha*)																	MRW133	MRW133							EM20353					
220																				DWG1564							EM11006					
220		(= *Triumfetta ?clementii*)																														
220		*Triumfetta maconochieana*	+	+	+					1	1						+		MRW151	MRW151	MRW151	RB6882	97,RB6868,RB6882				EM2025	DET110	NEC20555			
220																			HB31													
220																											EM20336				+	
220		(= *Triumfetta ?maconochieana*)																														
220		(= *Triumfetta* sp. Rudall subsp. Woodstock)	+															+														
220		*Triumfetta ramosa*	+			+				1	1						+	+	HB46	HB46			RB6669				DET11023				+	+
220		(= *Triumfetta appendiculata*)																	MRW147	DWG1538							EM20309					
220		*Triumfetta* aff. *ramosa*	+								1								+	MRW147	MRW147					EM12019						
220		(= *Triumfetta* aff. *appendiculata*)																													+	
220		*Triumfetta* sp.	+	+	+					1	1																					
221	MALVACEAE	*Abutilon cunninghamii*	+	#			#	1	1	1	1						+	+	RB7033	HB45	RB6813	RB6681	:B6681,RB6686				DET11014		NEC20509		+	
221		(+ *Abutilon fraseri?*)																	RB6681	MRW096	MRW096	RB6813	:B6813,RB6817				EM20112					
221		(= *Abutilon exonemum*)																	MRW096			RB7033	:B6924,RB7009				EM20114					
221																							RB7033				EM20268					
221																											EM20289					
221																											EM20301					
221																											EM20352					
221		*Abutilon indicum* var. *australiense*	+							1	1							+														
221		*Abutilon leucopetalum*	+							1	1						+	+	:7232,MRW	MRW128	MRW128	RB7232	RB7231			+						+
221		*Abutilon otocarpum*	+	+						1	1						+	+	+								EM20454					
		Abutilon sp. (VL-2706-09)	+							1	1						+															
221		*Abutilon* sp.	+			+				1	1							+	+						+	+	+				+	
221																			MRW055	MRW055	03879						EM20372				+	
221																				JSB3276												
221																				JSB3284												
221																				DWG1321												
221																			MRW102	MRW102	SVL1084						EM20451				+	
221																				SVL1084	04793											
221																				AAB053	04795										+	
221																				DWG1311												
221																			RB6939	MRW058	MRW176										+	
221																			MRW058	MRW176	03880											
221																				DWG1297												
221																				JSB3272												
221																			MRW127	RB6952	04798										+	
221																				RB6951												
221		*Gossypium australe*	+						1	1	1						+	+	+						+						+	
221		(= *Notoxylinon australe*)																													+	
221		*Gossypium robinsonii*	+	+						1	1						+	+	HB97	RB6940	MRW012	6940	6940	+	+		EM20357					+
221																			MRW012	MRW012	03886						EM20452					
221																				HB97												
221																				CLAY & YARDAV												
221		*Herissantia crispa*	+						1	1	1							+	+			+									+	
221		(= *Abutilon crispum*)																														
221		(= *Abutilon herissantia*)																														
221		*Hibiscus burtonii*	+						1	1	1							+	+							+						
221		*Hibiscus coatesii*	+			#				1	1						+	+	+							47	EM20322					
221		*Hibiscus sturtii*	+			+				1	1																				+	
221		*Hibiscus sturtii* var. *campylochlamys*	+								1						+	+	HB165			+			+	+					+	
221		*Hibiscus sturtii* var. *platychlamys*	+								1						+	+	+							EM1204	EM20288		NEC20513			
221																											EM20303					

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221																											EM20355					
221																											EM20368					
221		*Hibiscus* sp. (VL-2706-41)	+							1	1						+															
221		*Hibiscus* sp. (EM12013)	+							1	1							+	+							EM12013						
221		*Lawrencia viridigrisea*	+						1	1	1						+	+	RB7137	RB7147		RB7137	B7135,RB7136									
221																						RB1747	B7137,RB7147									
221																																
221		* *Malvastrum americanum*	+						1	1	1	1					+	+	RB6709	HB61	MRW120	RB6709	07,RB6609,RB6610		+		DET11002		+		+	+
221		(=**Malvastrum spicatum*)																	MRW120	MRW120	04808		RB6709,RB6959				EM20367					
221																											EM20455					
221		*Sida calyxhymenia*	+						1	1	1							+	RB7236			RB7236	RB7235									
221		*Sida clementii*	+							1	1							+	+						+							
221		*Sida echinocarpa*	+							1	1						+	+	RB6853	HB194		RB6853	RB6853				EM20281					+
221																			MRW187								EM20461					
221		*Sida fibulifera*	+				#			1	1						+	+	RB6701	HB7	MRW110	RB6701	RB6710	+	+	+	EM20310		NEC20523			
221		(= *Sida* aff. *fibulifera*)																	HB101	HB166							EM20350		NEC20566		+	
221																			MRW110	MRW110							EM20369					
221																											EM20386					
221																											EM20407					
221																											EM20422					
221		*Sida spodochroma*	+							1	1								HB	RB6875		RB6875	B7245,RB7143								+	
221		(= *Hibiscus spodochroma*)																+														
221		(= *Sida corrugata*)															+	+														
221		*Sida* sp. (VL-2709-14)	+							1	1						+															
221		*Sida* sp. EM12018	+							1	1							+	+							EM12018						
221		*Sida* sp. EM20301B	+							1	1							+	+								EM20301B					
221		*Sida* sp.	+			+				1	1																					
223	STERCULIACEAE	*Hannafordia quadrivalvis*	+	+	+	+		1	1	1	1						+	+	RB6619	B6626,HB1	MRW141	RB6619	B6619,RB662	+	+	EM1201	DET11019					+
223		(= *Hannafordia ?quadrivalvis*)																	MRW141	MRW141		RB6626	RB6632				EM20234					
223																											EM20323					
223																											EM20469					
223		*Hannafordia quadrivalvis* subsp. *recurva*	+	+			+				1																					
223		*Keraudrenia* sp.	+						1	1	1						+	+	+			+									+	
223		*Melhania oblongifolia*	+						1	1	1						+	+	RB7133	IB92,RB660	HB146K	RB7133	04,RB7073,RB7074									
223		(= *Melhania incana*)																	RB7134	B195,RB7075		RB7134	75,RB7114,RB7120									
223																				RB7121,RB7126		RB7157	21,RB7126,RB7133									
223																				RB7157,RB7263			RB7134,RB7157,RB7263									
223		*Waltheria indica*	+						1	1	1						+	+	HB34	HB34	HB75	+		+		EM1201	DET11028					
223																																
223																				RB6882,RB6868							EM20387				+	
235	ELATINACEAE	*Bergia pedicellaris*	+					1	1	1	1																		NEC20614			
236	FRANKENIACEAE	*Frankenia ambita*	+					1	1	1	1							+	MRW013	MRW013	MRW013											
236		*Frankenia pauciflora* var. *pauciflora*	+	+	+		+			1	1						+															
236		(= *Frankenia pauciflora*)																+	RB6733	HB6	HB	RB6733	B6729,RB673	+	+	+	EM20379					+
236																			HB			RB7060	B6949,RB6950									
236																							RB7069									
236																																
236		*Frankenia* sp.								1	1																				+	
243	VIOLACEAE	*Hybanthus aurantiacus*	+	+	+			1	1	1	1						+	+	+								DET11032		NEC20574		+	
248	PASSIFLORACEAE	* *Passiflora foetida* var. *hispida*	+					1	1	1	1							+														
248		(=*Passiflora foetida*)																+	HB			+										

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No	FAMILY	Species	Island					F	G	S	T	I	Taxa	PL	P1	P3	Astron	Astron	Barrow	Perth	Karratha	Butler	Herb.No.	Grierson	rudge	1993a	1993b	1994	1995	1996	1999	ield Herbariur
265	LYRTHRACEAE	*Ammannia multiflora*	+					1	1	1	1						+	+		RB6742	RB6742								NEC20538		+	
265																				MRW146	MRW146								NEC20593			
265		*(= Cryptostemma calendula)*																														
269	RHIZOPHORACEAE	*Rhizophora stylosa*	+					1	1	1	1							+	L-6			+										
273	MYRTACEAE	^ *Eucalyptus camaldulensis*	+					1	1	1	1			1			+	+	+			+										
273		^ *Eucalyptus gamophylla*	+							1	1			1			+	+														
273		* *Eucalyptus gomphocephala*	+							1	1			1			+	+	+			+					EM20434					
273		^ *Eucalyptus torquata*	+							1	1			1			+	+	+			+										
273		*Eucalyptus xerothermica* (ms)	+							1	1						+	+	HB79	MRW093	MRW093	+					EM2025	DET110			+	
273		*(^=Eucalyptus patellaris)*																	MRW093	MRW156	MRW156											
273																			MRW156	SVL1068	04809											
273		*Melaleuca cardiophylla*	+	+	+	+			1	1	1						+	+	HB133	HB139	:B6922, 0388	RB6922	RB6922	+	+	EM1203:	+					+
273																			MRW018	MRW018	MRW018											
276	HALORAGACEAE	*Haloragis gossei*	+	+		+		1	1	1	1						+	+	MRW113	MRW113	MRW113	6712	67126749		+		EM20273			+	+	+
276																					04810						EM20282					
276																											EM20383					
276																																
293	PRIMULACEAE	*Samolus repens*	+					1	1	1	1						+	+	RB7259			RB6933	:B6913,RB6933								+	
293																			RB6933			RB7259	:B7259,RB7260									
294	PLUMBAGINACEAE	*Muellerolimon salicorniaceum*	+				+	1	1	1	1						+	+	HB	RB7035	HB	RB6778	B6676,6778,70	+			EM20229					
294		*(= Limonium salicorniaceum)*																				RB7035	RB7035								+	
294		*Plumbago zeylanica*	+						1	1	1						+	+	RB6620	HB	MRW083	RB6620	:B6620,RB6644				EM20259		+			+
294																			MRW083	MRW083	04811						EM20409					
294																			HB200													
301	OLEACEAE	*Jasminum calcarium*	+	+		+		1	1	1	1						+	+	RB6739	HB141	MRW008	RB6739	39,RB6828,RI	+	+		DET11012					
301		*(=Jasminum ?calcarium)*																	MRW008	MRW008	03889						DET11042					
301		*(Not Jasminum calcareum -MAX)*																									EM20329					
301																											EM20354					
301		*Jasminum didymum*	+							1	1							+	RB7145	HB		RB7145	:B7144,RB7146									
301		(= *Jasminum* sp.)																														
301		*Jasminum didymum* subsp. *lineare*	+								1																					
303	GENTIANACEAE	*Centaurium spicatum*	+					1	1	1	1						+	+	RB6695	RB6719	MRW196	:B6695,RB671	:B6695,RB6719				EM20417				+	
303		*(= *Centaurium erythraea)*																	MRW196	MRW196							EM20423					
305	ASCLEPIADACEAE	*Cynanchum floribundum*	+	+	+	+	+	1	1	1	1						+	+	HB24	HB24	RB6654	RB6654	RB6662	+			EM20205					
305		(= *Gymnema* sp.)																	7-12	RB6654	MRW010						EM20268				+	
305																			MRW010	DWG1243	03390						EM20339					
305																				MRW010												
305		*Marsdenia* sp.	+							1	1							+														
305		*Sarcostemma viminale* subsp. *australe*	+	+	+	+	+		1	1	1						+	+	MRW095	:138,DWG1	04812											
305		*(= Sarcostemma australe)*																	HB138	MRW095	MRW095		RB6782	+	+		+				+	
305		*Tylophora cinerascens*	+						1	1	1								RB6969			RB6969	:B6967,RB6969								+	+
305		*(= Marsdenia cinerascens)*																+														
305		*Tylophora flexuosa*	+							1	1							+														
307	CONVOLVULACEAE	*Bonamia media* var. *villosa*	+	+				1	1	1	1		1				+															
307		*Convolvulus* sp. (RB7250)	+						1	1	1							+	+				RB7250									
307		*Evolvulus alsinoides*	+						1	1	1																					

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Fam No	FAMILY	Species	Barrow Island	PGPF	PFG	PCO	PNW	F	G	S	T	I	New Taxa	PL	P1	P3	2004 Astron	Astron	Barrow	Perth	Karratha	Buckley Butler	Aust. Herb.No.	Lewis Grierson	rudge	1993a	1993b	Mattiske 1994	1995	1996	1999	BARROW ield Herbariur
307		*Evolvulus alsinoides* var. *decumbens*	+	+							1						+	+														
307		(= *Evolvulus alsinoides* ?var. *decumbens*)																	RB7237			RB7237	RB7238		+		EM20433		NEC20583		+	
307																											DET11024					
307		(= *Evolvulus ?alsinoides* var. *decumbens*)																														
307		*Evolvulus alsinoides* var. *villosicalyx*	#			#					1																					
307		*Ipomoea pes-caprae* subsp. *brasiliensis*	+						1	1	1						+	+	HB148								EM20701					
307		*Polymeria ambigua*	+	+	+	+			1	1	1						+	+	HB83	HB83		+					EM20242					+
307		(+ *Bonamia media*)																	MRW134					+		+	EM20308				+	
307		(+ *Bonamia pannosa*)																	RB6916,RB6932			RB6916	B6603,RB6664				EM20348					
307		(+ *Bonamia rosea*)																				RB6917	RB6673				EM20421					
307		(+ *Polymeria calycina*)																				RB6932										
307																						RB6936										
307		(=*Polymeria ?ambigua*)																+	+								ET11024					
307		*Polymeria* sp.	+							1	1							+	+						+							
307A	CUSCUTACEAE	*Cuscuta australis*	+					1	1	1	1						+	+	RB7102	RB7050	MRW155	B7050,RB710	50,RB7051,RB7102									
307A		(= *Cassytha australis*)																		MRW155												
307A		(+ *Cassytha filiformis*)																														
307A		(= *Cuscuta* sp.)																														
310	BORAGINACEAE	*Cordia subcordata* (Boodie Island)	+					1	1	1	1						+	+					RB7221								+	
310		*Ehretia saligna*	+						1	1	1						+															
310		*Heliotropium conocarpum*	+						1	1	1							+	+			+										
310		*Heliotropium crispatum*	+				#			1	1						+	+	MRW1004	MRW004	MRW004	+					EM20271		NEC20542			+
310		(= *Heliotropium ramosissimum*)																			03391								NEC20560		+	
310		(= *Heliotropium undulatum*)																	RB6850	HBL5	RB6867	RB6850	B6637,RB6689						NEC20515			
310																						RB6867	RB6755		+							
310		*Heliotropium cunninghamii*	+							1	1						+	+	+	HB		+									+	
310		*Heliotropium glanduliferum*	+	+	+	+	+			1	1							+														
310		*Heliotropium inexplicitum*	+							1	1							+														
310		*Heliotropium ovalifolium*	+							1	1						+	+	RB6792	RB6611	HB3, 04813	RB6611	B6618,RB667	+		EM12010	ET20204					+
310																			MRW077	MRW077	MRW077	RB6792	B6771,RB6792									
310		*Heliotropium* sp.	+							1	1																				+	
310		*Heliotropium* sp. (perennial shrub) VL-2104-19, V	+							1	1						+	+	+						+						+	
310		*Heliotropium* sp. (RB6866)	+							1	1							+	+				RB6866									
310		*Heliotropium* sp. (RB7037)	+							1	1							+	+			RB7037	B7037,RB7090									
310		*Trichodesma zeylanicum* var. *zeylanicum*	+	+	+	+	+		1	1	1						+															
310		(=*Trichodesma zeylanicum*)																+	HB48	L-7	RW001, 03892		RB6774	+	+	+	M20382					+
310																			MRW001	MRW001	SVL1087											
310		(=?*Trichodesma zeylanicum*)																														
312	AVICENNIACEAE	*Avicennia marina* subsp. *marina*	+				+	1	1	1	1						+	+	MRW098	MRW098	RW098, 048	+					EM20391				+	+
313	LAMIACEAE	*Clerodendrum tomentosum* var. *lanceolatum*	+	#				1	1	1	1						+	+	RB6928	HB98	MRW086	RB6928	15,RB6628,RB6643				EM2033	+				+
313																			MRW086	MRW086	04814		RB6928,RB7220				EM20450					
313																											EM20261					
315	SOLANACEAE	*Duboisia hopwoodii*	+					1	1	1	1						+	+	+			+									+	
315		*Nicotiana benthamiana*	+						1	1	1						+	+	RB6856	HB88		RB6856	56,RB6942,RB7267				EM20465					+
315																			HB22, MRW207													
315		*Nicotiana occidentalis* subsp. *occidentalis*	+	+						1	1						+	+	RB6696	MRW104	MRW104	RB6696	14,RB6691,RB6702				EM20264				+	+
315																			MRW104		04816		RB6812,RB6915				EM20278					
315		*Nicotiana* sp.	+							1	1																					
315		*Solanum cleistogamum*	+	+			+		1	1	1						+	+	HB126	RB6687		RB6687	6720,RB7227	+	+	+	M20115				+	+
315		(= *Solanum horridum*)																	HB12-1966	DWG1544		RB7228	B7239,RB7243								+	
315		(= *Solanum quadriloculatum*)																	MRW137				RB7228									

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315			*Solanum diversiflorum*	+	+		+				1	1						+	+	HB4	HB99	:B6633, 0481	RB6633	.33,RB6636,RB6713		+	EM1200	EM20203					+
315																				MRW114	MRW114	MRW114		RB6718				EM20280					
315			*Solanum esuriale*	+							1	1						+	+	RB7156			RB7156	:B7138,RB7160								+	
315			*Solanum lasiophyllum*	+	+	+	+	+			1	1						+	+	HB39	RB6738	VL1071, 048	RB6738	RB6738	+	+	+	EM2028	DET110	+		+	+
315			(= *Solanum phlomoides)*																	HB6-1964	MRW074	MRW074						EM20408				+	
315																				MRW074		SVL1072											
315		*	*Solanum nigrum*	+							1	1	1					+	+	MRW112	MRW112	05407	+										+
315			*Solanum* sp.	+							1	1							+	RB7228													
316	SCROPHULARIACEAE		*Mimulus gracilis*	+					1	1	1	1							+	MRW197			+					EM20416		NEC20599			+
316			*Stemodia glabella*	+						1	1	1						+	+	MRW181								DET11005					
316			*(= Morgania glabra)*																	RB6727	HB177		RB6727	:B6727,RB6809				EM20247				+	
316																												EM20480					
316			*Stemodia grossa*	+							1	1						+	+	+			+										
317	BIGNONIACEAE		*Dolichandrone heterophylla*	+					1	1	1	1						+	+	+			+						KK20703				
318	PEDALIACEAE	?	*Josephinia eugeniae*	+					1	1	1	1							+	+							EM12028						
325	ACANTHACEAE		*Dicladanthera forrestii*	+					1	1	1	1						+	+	RB7130	RB7142		RB7129,RB713	:B7129,RB7130									
325																							RB7142	RB7131									
325			*Dicladanthera* sp. (RB6863)	+							1	1							+	RB6863			RB6863	RB6863									
325			*Dipteracanthus australasicus*	+						1	1	1							+														
325			*Dipteracanthus australasicus* subsp. *corynothecus*	+								1						+	+	6885, MRW	HB84	RB6907	B6885,RB690	.85,RB7007,RB7008		+	+	EM20228		NEC20550			+
325			*(= Ruellia primulacea)*																	HB125	HB6/1964	MRW103		RB7045,RB7046,RB7047								+	
325			*(= Brunoniella australis)*																		MRW103	MRW174		RB7072,RB7048									
325																					MRW174												
326	MYOPORACEAE		*Eremophila forrestii* subsp. *forrestii* ms	+					1	1	1	1						+	+														
326			(= *Eremophila leucophylla)*																	MRW080	MRW080	MRW080				+		EM20356				+	
326			(= *Eremophila forrestii)*																			04819											+
326			*Eremophila* sp.	+							1	1																				+	
326			*Myoporum montanum*	+	+	+		+		1	1	1						+	+	RB6929	HB	MRW071	RB6929	RB6641	+	+	+	DET11004					
326			(= *Myoporum acuminatum)*																	MRW071	HB13	SVL1077											+
326																					MRW071	04820											
326			(= *Myoporum* sp.)																														
331	RUBIACEAE		*Oldenlandia crouchiana*	+	+		#		1	1	1	1						+	+	MRW103	DWG1302	04795	+			+		DET11040		NEC20545		+	+
331																				HB66, MRW154		05408						EM20453					
331																				HB174													
331			*Oldenlandia galioides*	+			+				1	1							+											NEC20607			
331			(=*Oldenlandia ?galioides)*	+																													
331																																	
331			*Synaptantha tillaeacea* var. *tillaeacea*	+						1	1	1						+	+														
331			(= *Synaptantha tillaeacea)*																	HB192	RB7229		RB6874	.74,RB7027,RB7061				DET11010		NEC20543		+	
331																				HB112	HB192		RB7229	:B7079,RB7229				EM20471		NEC20587			
337	CUCURBITACEAE		*Mukia maderaspatana*	+					1	1	1	1						+	+	HB179	HB157	MRW087		RB6918			+	+		NEC20529		+	+
337																				MRW087	MRW136	MRW136											
337																				MRW136	MRW087	04821											
339	CAMPANULACEAE		*Wahlenbergia* sp.	+					1	1	1	1							+	RB6766			RB6766	:B6766,RB6816									
341	GOODENIACEAE		*Goodenia microptera*	+		#	+		1	1	1	1						+	+	RB7054	)6785,RB6896		RB6896	85,RB6896,RB6921				EM20481					

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341																				RB7055			RB7054									
341		*Goodenia* sp.	+							1	1							+	HB164													
341		*Lechenaultia* sp. VL-BWI03-13	+						1	1	1						+															
341		(= Goodeniaceae sp.)																														
341		(=?*Lechenaultia divaricata* - not current name)																	MRW131			+										
341		*Scaevola* cf. *aemula*	+						1	1	1							+	+	RB6888			RB6888									
341		*Scaevola amblyanthera* var. *amblyanthera*	+		+					1	1							+														
341		*Scaevola amblyanthera* var. *centralis*	+		#						1						+	+	HB120	IB163,HB12	RB6617	RB6622	B6617,RB6622				EM20244		NEC20556			+
341		(= *Scaevola decipiens)*																	HB6	DWG1240	MRW121						EM20340					
341																			MRW121	MRW121	04822						EM20420					
341		*Scaevola ?anchusifolia*	+			+				1	1																					
341		*Scaevola crassifolia*	+							1	1						+	+	RB7107	HB144		RB7100	B7100,RB7101									
341		(= *Scaevola nitida)*																	RB7101	RB7100												
341																				RB7101												
341		*Scaevola cunninghamii*	+	+	+	+	+			1	1							+	HB8-12	RB6785	MRW106	RB6608	B6646,RB665	+		+	DET11009					+
341		(= *Scaevola ?collaris)*																	HB13	HB3	04823	RB6653	66,RB6785,RB6842				EM20210				+	
341		(= *Scaevola glandulifera)*																	RB6921	RB6653		RB6666					EM20294					
341		(= *Scaevola globulifera)*																	RB6842	DWG1511							EM20470					
341																			HB14	MRW106												
341																			MRW106	DWG1268												
341																				RB6646												
341																				RB6666												
341																				HB13,HB14												
341		*Scaevola sericophylla*	+	+						1	1							+												+	+	
341		*Scaevola spinescens*	+	+						1	1						+	+	RB6678	RB7026	MRW175	RB6675	6675,RB6678	+			DET11029					+
341																			HB74	RB6675		RB7015	B7063,RB7223				EM20235					
341																			MRW175	MRW175			RB7026				EM20320					
341																				RB7063												
341																				RB7223												
341		*Scaevola* sp.VL-2104-26	+							1	1						+															
341		*Scaevola* sp.	+	+						1	1							+				+				+			NEC20596			
345	ASTERACEAE	* *Arctotheca calendula*	+					1	1	1	1	1						+	+			+										
345		*Centipeda minima*	+						1	1	1						+	+	HB57	36805,RB6726		RB6805	05,RB6726,RB6765				EM20396		+			+
345																			MRW194								EM20425					
345		* *Conyza sumatrensis*	+						1	1	1	1					+															
		(= * *Conyza albida)*																														
345		*Flaveria australasica*	+						1	1	1						+	+	RB7068	HB190		RB7068	RB6657	+			+					
345		*Helichrysum oligochaetum* (P1)	+						1	1	1				1			+												+	+	
345		*Launaea sarmentosa*	+						1	1	1							+	RB7117			RB7117	B7118,RB7123								+	
345		*Olearia dampieri* subsp. *dampieri* ms	+	+	+		+		1	1	1						+	+	HB6	MRW014	MRW014	RB6843	B6820,RB685	+		+	EM20263					+
345		(= *Olearia axillaris)*																	MRW014	26/1	SVL1082											
345		(= *Olearia revoluta)*																		MRW032	MRW032											
345																				HB6	03894											
345																				SVL1082												
345																				DWG1277												
345																				RB6820,RB6855												
345		*Pentalepis trichodesmoides*	+	+	+	+	+		1	1	1						+	+	RB6745	HB2,RB674	MRW017	RB6745	RB6745	+	+	EM1200	EM20305				+	+
345		(= *Chrysogonum trichodesmoides)*																	MRW017	Y & YARD	03893											
345																			HB12	DWG1255												
345																				MRW017												
345		*Pluchea dentex*	+	+						1	1						+	+	RB6854	HB123		RB6911	RB6911		+		EM20332				+	
345																				RB6911							EM20478					
345		*Pluchea dunlopii*	+			+				1	1																					
345		*Pluchea ferdinandi-muelleri*	+		+					1	1																					
345		*Pluchea rubelliflora*	+	+			+		1	1	1						+	+	RB6953	B2/12,HB272		RB6854	B6854,RB7206				DET110	K20704			+	+

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345																			HB26	36854,RB6958							EM20223					
345																			MRW153								EM20456					
345		*Pluchea tetranthera*	+							1	1						+	+	RB6852	IB25,RB6852		RB6852	RB6852			EM1202	EM2022	+				
345																				HB85		RB6953	RB6953				EM20358					
345																						RB6958	RB6958				EM20399					
345																											EM20457					
345		(= *Pluchea tetranthera var. ?tetranthera)*																													+	
345		*Pluchea* sp.	+							1	1							+	MRW057	MRW057	MRW057										+	
345																			MRW135		03875											
345		* *Pseudognaphalium luteoalbum*	+						1	1	1	1						+	HB175			+					EM20427					
345		(= *Gnaphalium luteo-album)*																	HB			RB6652										
345		(= *Gnaphalium* sp.)																	RB6652													
345		(= *Gnaphalium pseudognaphalium)*																	MRW198													
345		*Pterocaulon sphacelatum*	+	+	+	+			1	1	1						+	+	HB124	HB124			HB6796		+	+	DET11053					+
345																			HB5/12	RB6796							EM20222					
345																			MRW173								EM20246					
345		*Pterocaulon sphaeranthoides*	+	+			+			1	1						+		MRW002	HB47	SVL1086	+					DET11052				+	+
345		(=*Pterocaulon ?sphaeranthoides)*																		HB12-1966	MRW002						EM20113					
345																				SVL1086	03895						EM20270					
345																				CLAY & YARDAV												
345																				MRW002												
345																				DWG1251												
345		* *Sonchus oleraceus*	+	+					1	1	1	1					+	+	MRW205								EM20463				+	+
345		*Streptoglossa adscendens*	+				+		1	1	1						+	+	RB7205	RB7205		RB7205	:B7204,RB7205				DET11001					
345		(= *Pterigeron adscendens)*																									EM20359					
345		*Streptoglossa bubakii*	+	+			+			1	1						+	+	HB94	IB4-12,HB9	MRW006	RB6698	:B6684,RB669	+	+		+				+	+
345		(= *Pterigeron bubakii)*																	MRW006	₹W006,RB6	03896		RB6717									
345		(= *Streptoglossa ?liatroides)*																		RB6717											+	
345		(=*Streptoglossa ?bubakii)*																	RB6698	HB9-74			RB6957									
345		*Streptoglossa decurrens*	+	+	+	+				1	1						+	+	HB64	RB7257	SVL1088	+	7257		+		DET11035					+
345		(= *Pterigeron decurrens)*																	MRW191	AY & YADAV							EM20388					
345																				SVL1088							EM20432					
345		*Streptoglossa macrocephala*	+				#			1	1						+	+	HB115	HB115							DET11030				+	
345		(= *Pterigeron macrocephala)*																														
345		*Vittadinia arida*	+		#				1	1	1						+	+		HB87												
345		*Vittadinia hispidula* var. *setosa*	+	+						1	1							+	RB6786	MRW118	MRW118	RB6786	RB6786				DET11018					+
345		(=*Vittadinia hispidula)*															+		MRW118	RB6786							EM20258					
345				+															MRW190								EM20401					
345		*Vittadinia obovata*	+							1	1						+	+	HB114	HB114												
345																				Site L29-RB1974												
345		*Vittadinia* sp.	+							1	1							+	MRW208			+										
345		Asteraceae sp.	+						1	1	1							+								+						
345		Asteraceae sp. 2	+						1	1	1							+								+						

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ATTACHMENT G: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive Percentage Foliage Cover data)

No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25	50	95	160	50	100
Species — **Vegetation Community**	**C1a**	**C2a**	**C2b**	**C2c**	**C5a**	**D1a**	**F8a**	**L3a**	**L3f**	**L3h**	**L3i**	**L4a**	**L5a**	**L6a**	**L7a**	**L7b**	**L9a**	**V1a**	**V1c**	**V1d**	**V1k**	**V1m**	**V3a**	**V3b**
Abutilon ?cunninghamii			x								x													
Acacia bivenosa	x	x	x	x		x	x	x		x	x	x	x	x	x			x		x	x	x		x
Acacia bivenosa (elongate phyllode form)		x	x	x			x	x			x	x		x				x		x	x	x		
Acacia coriacea subsp. *coriacea*	x	x	x	x		x	x				x						x			x	x	x		
Acacia gregorii						x	x	x	x		x		x	x	x	x		x	x	x	x	x		x
Acacia pyrifolia												x				x					x		x	x
Acanthocarpus verticillatus		x	x	x		x	x				x			x										
Adriana tomentosa	x	x																						
Adriana tomentosa var. *tomentosa*		x		x			x							x						x		x		
Amaranthus pallidiflorus		x			x						x													
Boerhavia gardneri													x											
Bonamia media var. *villosa*											x								x					
Bulbostylis barbata																	x				x	x		
Calandrinia ?aff. *remota*											x									x	x			
Calandrinia polyandra																	x							
Capparis spinosa var. *nummularia*					x												x							
Chenopodium aff. *cristatum*		x																						
Chenopodium sp.		x																						
Cleome ?viscosa		x															x							
Codonocarpus cotinifolius											x			x						x				
Corchorus ?walcottii																						x		
Corchorus interstans			x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	
Corchorus sp.		x	x			x	x			x	x		x	x	x				x	x	x	x		x
Corchorus sp. (seedling)													x											
Corchorus walcottii																						x		
Corchorus walcottii s.l.						x	x													x	x			
Cullen pustulatum						x	x																	
Cymbopogon ambiguus					x				x				x				x						x	x

ATTACHMENT G: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive Percentage Foliage Cover data)

No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25	50	95	160	50	100
Species / **Vegetation Community**	**C1a**	**C2a**	**C2b**	**C2c**	**C5a**	**D1a**	**F8a**	**L3a**	**L3f**	**L3h**	**L3i**	**L4a**	**L5a**	**L6a**	**L7a**	**L7b**	**L9a**	**V1a**	**V1c**	**V1d**	**V1k**	**V1m**	**V3a**	**V3b**
Cynanchum floribundum						x	x	x					x	x			x					x		
Cyperus cunninghamii subsp. *cunninghamii*					x												x							
Diplopeltis eriocarpa			x	x		x	x		x	x	x					x		x		x	x	x		
Diplopeltis sp.		x									x													
Dodonaea lanceolata var. *lanceolata*						x					x													
Dysphania rhadinostachya subsp. *rhadinostachya*																					x			
Eragrostis dielsii					x																	x		
Eriachne flaccida																				x				
Eriachne mucronata								x			x		x					x						
Euphorbia australis		x																			x			
Euphorbia coghlanii														x										
Euphorbia drummondii subsp. *drummondii*					x						x			x		x						x		
Euphorbia myrtoides	x	x																						
Evolvulus ?alsinoides var. *decumbens*																x								
Ficus brachypoda											x						x						x	
Frankenia pauciflora var. *pauciflora*					x																			
Gossypium robinsonii															x									
Grevillea pyramidalis ?subsp. *leucadendron*														x										
Hakea lorea subsp. *lorea*						x					x		x	x								x		x
Haloragis gossei			x			x	x				x		x	x		x					x	x		
Hannafordia quadrivalvis subsp. *recurva*						x	x	x			x		x	x		x		x		x	x	x		
Heliotropium glanduliferum		x		x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x		x
Hybanthus aurantiacus								x					x									x		
Indigofera monophylla			x		x	x	x	x	x	x	x		x	x	x		x		x	x	x	x	x	x
Jasminum calcarium						x				x														
Lipocarpha microcephala																					x			
Mallotus nesophilus																							x	
Melaleuca cardiophylla						x	x			x					x	x				x	x	x		

ATTACHMENT G: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive Percentage Foliage Cover data)

No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25	50	95	160	50	100
Species / **Vegetation Community**	**C1a**	**C2a**	**C2b**	**C2c**	**C5a**	**D1a**	**F8a**	**L3a**	**L3f**	**L3h**	**L3i**	**L4a**	**L5a**	**L6a**	**L7a**	**L7b**	**L9a**	**V1a**	**V1c**	**V1d**	**V1k**	**V1m**	**V3a**	**V3b**
Myoporum montanum	x	x			x	x	x				x			x			x			x				
Nicotiana occidentalis subsp. *occidentalis*		x					x				x													
Oldenlandia crouchiana					x											x	x					x		
Olearia dampieri subsp. *dampieri*	x	x	x	x	x		x																	
Paspalidium tabulatum					x								x			x				x		x	x	
Pentalepis trichodesmoides			x			x	x	x	x	x		x		x			x		x	x	x	x	x	
Petalostylis labicheoides						x		x	x	x	x	x	x		x			x	x		x	x	x	x
Phyllanthus maderaspatensis													x	x			x						x	
Pittosporum phylliraeoides						x											x						x	x
Pluchea dentex					x								x		x									
Pluchea rubelliflora					x																			
Poaceae sp.											x		x				x				x			
Polycarpaea longiflora			x		x						x						x					x		
Polymeria ambigua			x					x		x												x		x
Pterocaulon sp.	x	x									x		x											
Pterocaulon sphacelatum		x	x		x		x			x	x		x		x		x				x	x		
Pterocaulon sphaeranthoides	x	x									x		x	x			x						x	x
Ptilotus clementii											x													
Ptilotus gomphrenoides var. *gomphrenoides*	x																							
Ptilotus obovatus var. *obovatus*											x													
Rhynchosia minima			x			x	x														x			
Salsola tragus	x																							
Sarcostemma viminale subsp. *australe*		x	x		x		x				x						x						x	
Scaevola cunninghamii					x	x					x			x						x				
Scaevola sp.											x													
Scaevola spinescens		x									x													
Senna glutinosa subsp. *pruinosa*									x															
Senna notabilis																				x		x		

ATTACHMENT G: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive Percentage Foliage Cover data)

Species / No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25	50	95	160	50	100
Species / Vegetation Community	C1a	C2a	C2b	C2c	C5a	D1a	F8a	L3a	L3f	L3h	L3i	L4a	L5a	L6a	L7a	L7b	L9a	V1a	V1c	V1d	V1k	V1m	V3a	V3b
Solanum cleistogamum			x		x												x						x	
Solanum diversiflorum							x				x			x										
Solanum lasiophyllum	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x			x	x		x
Spinifex longifolius	x	x																						
Stackhousia ?muricata										x														
Streptoglossa bubakii						x			x	x	x				x									
Streptoglossa decurrens			x		x		x	x		x				x		x	x			x		x	x	
Streptoglossa sp.										x												x		
Stylobasium spathulatum	x	x	x	x		x	x	x			x				x						x	x		x
Tephrosia rosea var. *clementii*							x	x	x			x			x						x	x		x
Tephrosia sp.																					x			
Trichodesma zeylanicum var. *zeylanicum*		x	x	x		x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x	x
Triodia angusta	x	x	x	x	x	x	x	x		x	x			x	x	x	x	x	x	x	x	x		x
Triodia wiseana		x	x			x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x
Triumfetta ?maconochieana								x																
Triumfetta aff. appendiculata						x														x	x			
Triumfetta clementii			x														x							
Triumfetta sp.																x								
Vittadinia hispidula var. *setosa*											x													
Yakirra australiensis																	x				x			

ATTACHMENT H: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive and Dead Percentage Foliage Cover data)

No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25Q	50	95	160	50	100
Species / **Vegetation Community**	**C1a**	**C2a**	**C2b**	**C2c**	**C5a**	**D1a**	**F8a**	**L3a**	**L3f**	**L3h**	**L3i**	**L4a**	**L5a**	**L6a**	**L7a**	**L7b**	**L9a**	**V1a**	**V1c**	**V1d**	**V1k**	**V1m**	**V3a**	**V3b**
Abutilon ?cunninghamii			x								x	x												
Acacia bivenosa	x	x	x	x		x	x	x		x	x	x	x	x	x			x		x	x	x		x
Acacia bivenosa (elongate phyllode form)		x	x	x			x	x			x			x				x		x	x	x		
Acacia coriacea subsp. *coriacea*	x	x	x	x		x	x				x						x			x	x	x		
Acacia gregorii						x	x	x	x		x	x	x	x	x	x		x	x	x	x	x		x
Acacia pyrifolia											x					x					x		x	x
Acanthocarpus verticillatus		x	x	x		x	x				x			x										
Adriana tomentosa	x	x																						
Adriana tomentosa var. *tomentosa*		x		x			x							x						x		x		
Amaranthus pallidiflorus		x			x						x													
Boerhavia gardneri													x											
Bonamia media var. *villosa*											x								x					
Bulbostylis barbata																	x				x	x		
Calandrinia ?aff. *remota*											x									x	x			
Calandrinia polyandra																	x							
Capparis spinosa var. *nummularia*					x												x							
Chenopodium aff. *cristatum*		x																						
Chenopodium sp.		x																						
Cleome ?viscosa		x															x							
Codonocarpus cotinifolius											x			x						x				
Corchorus ?walcottii												x										x		
Corchorus interstans			x	x	x	x	x	x	x	x	x		x	x	x		x		x	x	x	x	x	
Corchorus sp.		x	x			x	x			x	x		x	x	x				x	x	x	x		x
Corchorus sp. (seedling)													x											
Corchorus walcottii																						x		
Corchorus walcottii s.l.						x	x													x	x			
Cullen pustulatum						x	x																	
Cymbopogon ambiguus					x				x				x				x						x	x
Cynanchum floribundum						x	x	x					x	x			x					x		
Cyperus cunninghamii subsp. *cunninghamii*					x												x							
Diplopeltis eriocarpa			x	x		x	x		x	x	x					x		x		x	x	x		
Diplopeltis sp.		x									x													

ATTACHMENT H: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive and Dead Percentage Foliage Cover data)

No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25Q	50	95	160	50	100
Species / **Vegetation Community**	**C1a**	**C2a**	**C2b**	**C2c**	**C5a**	**D1a**	**F8a**	**L3a**	**L3f**	**L3h**	**L3i**	**L4a**	**L5a**	**L6a**	**L7a**	**L7b**	**L9a**	**V1a**	**V1c**	**V1d**	**V1k**	**V1m**	**V3a**	**V3b**
Dodonaea lanceolata var. *lanceolata*						x					x													
Dysphania rhadinostachya subsp. *rhadinostachya*																					x			
Eragrostis dielsii					x																	x		
Eriachne flaccida																				x				
Eriachne mucronata								x			x		x					x						
Euphorbia australis		x																			x			
Euphorbia coghlanii														x										
Euphorbia drummondii subsp. *drummondii*					x						x			x		x						x		
Euphorbia myrtoides	x	x																						
Evolvulus ?alsinoides var. *decumbens*																x								
Ficus brachypoda											x						x						x	
Frankenia pauciflora var. *pauciflora*					x																			
Gossypium robinsonii															x									
Grevillea pyramidalis ?subsp. *leucadendron*														x										
Hakea lorea subsp. *lorea*						x					x		x	x								x		x
Haloragis gossei			x			x	x				x		x	x		x					x	x		
Hannafordia quadrivalvis subsp. *recurva*						x	x	x			x		x	x		x		x		x	x	x		
Heliotropium glanduliferum		x		x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x		x
Hybanthus aurantiacus								x					x									x		
Indigofera monophylla			x		x	x	x	x	x	x	x		x	x	x		x		x	x	x	x	x	x
Jasminum calcarium						x				x														
Lipocarpha microcephala																					x			
Mallotus nesophilus																							x	
Melaleuca cardiophylla						x	x			x					x	x				x	x	x		
Myoporum montanum	x	x			x	x	x				x			x			x			x				
Nicotiana occidentalis subsp. *occidentalis*		x					x				x													
Oldenlandia crouchiana					x											x	x					x		
Olearia dampieri subsp. *dampieri*	x	x	x	x	x		x							x										
Paspalidium tabulatum					x							x	x			x				x		x	x	
Pentalepis trichodesmoides			x			x	x	x	x	x	x	x		x			x		x	x	x	x	x	
Petalostylis labicheoides						x		x	x	x	x		x		x			x	x		x	x	x	x
Phyllanthus maderaspatensis													x	x			x						x	

ATTACHMENT H: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive and Dead Percentage Foliage Cover data)

No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25Q	50	95	160	50	100
Species / **Vegetation Community**	**C1a**	**C2a**	**C2b**	**C2c**	**C5a**	**D1a**	**F8a**	**L3a**	**L3f**	**L3h**	**L3i**	**L4a**	**L5a**	**L6a**	**L7a**	**L7b**	**L9a**	**V1a**	**V1c**	**V1d**	**V1k**	**V1m**	**V3a**	**V3b**
Pittosporum phylliraeoides						x											x						x	x
Pluchea dentex					x								x		x									
Pluchea rubelliflora					x																			
Poaceae sp.											x		x				x				x			
Polycarpaea longiflora			x		x						x						x					x		
Polymeria ambigua			x					x		x												x		x
Pterocaulon sp.	x	x									x		x											
Pterocaulon sphacelatum		x	x		x		x			x	x		x		x		x				x	x		
Pterocaulon sphaeranthoides	x	x									x		x	x			x						x	x
Ptilotus clementii											x													
Ptilotus gomphrenoides var. *gomphrenoides*	x																							
Ptilotus obovatus var. *obovatus*											x													
Rhynchosia minima			x			x	x														x			
Salsola tragus	x																							
Sarcostemma viminale subsp. *australe*		x	x		x		x				x						x						x	
Scaevola cunninghamii					x	x					x			x						x				
Scaevola sp.											x			x										
Scaevola spinescens		x									x													
Senna glutinosa subsp. *pruinosa*									x															
Senna notabilis																				x		x		
Solanum cleistogamum		x	x		x								x				x						x	
Solanum diversiflorum							x				x			x										
Solanum lasiophyllum	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x			x	x		x
Spinifex longifolius	x	x																						
Stackhousia ?muricata										x														
Streptoglossa bubakii						x			x	x	x				x									
Streptoglossa decurrens			x		x		x	x		x			x	x		x	x			x		x	x	
Streptoglossa sp.										x												x		
Stylobasium spathulatum	x	x	x	x		x	x	x			x	x	x		x						x	x		x
Tephrosia rosea var. *clementii*							x	x	x		x				x						x	x		x
Tephrosia sp.												x									x			
Trichodesma zeylanicum var. *zeylanicum*		x	x	x		x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x

ATTACHMENT H: VASCULAR PLANT SPECIES IN VEGETATION COMMUNITIES WITHIN PROPOSED GAS PROCESSING FACILITY SURVEY AREA

(Presence/absence data based on Alive and Dead Percentage Foliage Cover data)

No. Quadrats	50	175	50	14	35	70	200	75	50	50	150	25	25	50	40	116	25	25	25Q	50	95	160	50	100
Species / **Vegetation Community**	**C1a**	**C2a**	**C2b**	**C2c**	**C5a**	**D1a**	**F8a**	**L3a**	**L3f**	**L3h**	**L3i**	**L4a**	**L5a**	**L6a**	**L7a**	**L7b**	**L9a**	**V1a**	**V1c**	**V1d**	**V1k**	**V1m**	**V3a**	**V3b**
Triodia angusta	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x
Triodia wiseana		x	x			x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
Triumfetta ?maconochieana								x					x											
Triumfetta aff. appendiculata						x														x	x			
Triumfetta clementii			x														x							
Triumfetta sp.																x								
Vittadinia hispidula var. *setosa*											x													
Yakirra australiensis										x							x				x			

ATTACHMENT I: VASCULAR PLANT SPECIES RECORDED IN PROPOSED GORGON DEVELOPMENT AREAS, BARROW ISLAND 2003, 2004

+ indicates species recorded in initial surveys of proposed Gorgon development area
# indicates species updated after post cyclonic rain surveys
PGPF: Proposed Gas Processing Facility and Wider Study Area, PNW: Proposed North Whites Beach Pipeline
PFG: Proposed Feed Gas Pipeline, PCO: Proposed C0$_2$ Reinjection Pipeline

Fam No	FAMILY	Species	Barrow Island	PGPF	PFG	PCO	PNW
31	POACEAE	*Aristida holathera* var. *holathera*	+		#		
31		*Cymbopogon ambiguus*	+	+	+	+	+
31		*Dichanthium sericeum* subsp. *humilius*	+	#			
31		*Eragrostis cumingii*	+	#			
31		*Eragrostis dielsii*	+	+			
31		*Eriachne flaccida*	+	+		+	
31		*Eriachne flaccida* (Southern Pilbara - Carr	#			#	
31		*Eriachne mucronata*	+	+	+	#	+
31		*Eriachne* sp.	+		+		+
31		*Eulalia aurea*	+			#	
31		*Paspalidium clementii*	+			#	
31		*Paspalidium tabulatum*	+	+	#		
31		Poaceae sp.	+	+			
31		* *Setaria verticillata*	#		#		
31		*Spinifex longifolius*	+	+	+		+
31		*Sporobolus australasicus*	+	#			
31		*Sporobolus virginicus*	+		#		+
31		*Triodia epactia*	+		+	+	+
31		*Triodia angusta*	+	+	+	+	+
31		*Triodia wiseana*	+	+	+	+	+
31		*Whiteochloa airoides*	+		+		
31		*Yakirra australiensis*	+	+			
32	CYPERACEAE	*Bulbostylis barbata*	+	+			
32		*Cyperus cunninghamii* subsp. *cunninghamii*	+	+		+	+
32		*Isolepis* sp.	+	#			
32		*Lipocarpha microcephala*	+	+			
54C	DASYPOGONACEAE	*Acanthocarpus verticillatus*	+	+			
87	MORACEAE	*Ficus brachypoda*	+	+	+	+	+
90	PROTEACEAE	*Grevillea pyramidalis*	+				
90		*Grevillea pyramidalis* subsp. ?*leucadendron*	+	+			+
90		*Hakea lorea* subsp. *lorea*	+	+	+	+	
105	CHENOPODIACEAE	*Atriplex isatidea*	+				+
105		*Chenopodium* aff. *cristatum*	+	+			
105		*Dysphania rhadinostachya* subsp. *rhadinosta*	+	+	+		
105		*Enchylaena tomentosa* var. *tomentosa*	+				+
105		*Eremophea spinosa*	+				+
105		*Halosarcia halocnemoides* subsp. *tenuis*	+				+
105		*Halosarcia indica*	+				+

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Fam No	FAMILY	Species	Barrow Island	PGPF	PFG	PCO	PNW
105	CHENOPODIACEAE	*Neobassia astrocarpa*	+				+
105		*Rhagodia preissii* subsp. *obovata*	+				+
105		*Salsola tragus*	+	+			+
105		*Threlkeldia diffusa*	+				+
106	AMARANTHACEAE	*Amaranthus mitchellii*	+	#			
106		*Amaranthus pallidiflorus*	+	+			#
106		*Ptilotus clementii*	+	+			
106		*Ptilotus fusiformis* var. *fusiformis*	#			?#	
106		*Ptilotus gomphrenoides* subsp. *gomphrenoides*	+	+			
106		*Ptilotus obovatus* subsp. *obovatus*	+	+	+	+	+
107	NYCTAGINACEAE	*Boerhavia burbidgeana*	+		#		
107		*Boerhavia gardneri*	+	+		#	
107		*Commicarpus australis*	+				#
108	GYROSTEMONACEAE	*Codonocarpus cotinifolius*	+	+		+	
111	PORTULACACEAE	*Calandrinia* ?aff. *remota*	+	+			
111		*Calandrinia polyandra*	+	+			
113	CARYOPHYLLACEAE	*Polycarpaea longiflora*	+	+		+	+
122	MENISPERMACEAE	*Tinospora smilacina*	+				+
137A	CAPPARACEAE	*Capparis spinosa* var. *nummularia*	+	+	+		
137A		*Cleome viscosa*	+	+		#	
152	PITTOSPORACEAE	*Pittosporum phylliraeoides*	+	+	+	+	+
160	SURIANACEAE	*Stylobasium spathulatum*	+	+	+	+	+
163	MIMOSACEAE	*Acacia bivenosa*	+	+	+	+	+
163		*Acacia bivenosa* (elongate phyllode form)	+	+			
163		*Acacia bivenosa* (intermediate form)	+	+			
163		*Acacia coriacea* subsp. *coriacea*	+	+		+	+
163		*Acacia gregorii*	+	+	+	+	+
163		*Acacia pyrifolia*	+	+	+	+	

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164	CAESALPINIACEAE	*Petalostylis labicheoides*	+	+	+	+	
164		*Senna glutinosa* subsp. *glutinosa*	+		+	+	
164		*Senna glutinosa* subsp. *pruinosa*	+	+			
164		*Senna notabilis*	+	+		+	
165	PAPILIONACEAE	*Cullen leucanthum*	+		+		
165		*Cullen pustulatum*	+	+		+	+
165		*Erythrina vespertilio*	+			+	+
165		*Indigofera boviperda*	+			+	
165		*Indigofera monophylla*	+	+	+	+	+
165		Papilionaceae sp.	+	+			
165		*Rhynchosia minima*	+	+	#		#
165		*Sesbania cannabina*	+	+			
165		*Tephrosia clementii*	#			#	
165		*Tephrosia rosea*	+	#	+	+	
165		*Tephrosia rosea* var. *clementii*	+	+	+		+
173	ZYGOPHYLLACEAE	*Tribulus hirsutus*	#	#		#	
185	EUPHORBIACEAE	*Adriana tomentosa* var. *tomentosa*	+	+	+	+	+
185		*Euphorbia australis*	+	+		+	
185		*Euphorbia coghlanii*	+	+		#	
185		*Euphorbia drummondii* subsp. *drummondii*	+	+	+		+
185		*Euphorbia myrtoides*	+	+			
185		*Euphorbia tannensis* subsp. *eremophila*	+	#			
185		*Mallotus nesophilus*	+	+	+		+
185		*Phyllanthus maderaspatensis*	+	+			
202	STACKHOUSIACEAE	*Stackhousia muricata*	+	+			
207	SAPINDACEAE	*Diplopeltis eriocarpa*	+	+	+	+	+
207		*Diplopeltis* sp.	+	+			
207		*Dodonaea lanceolata* var. *lanceolata*	+	+			
220	TILIACEAE	*Corhorus congener*	+				
220		*Corchorus interstans* ms (P3)	+	+			+
220		*Corchorus* sp.	+	+		+	
220		*Corchorus walcottii* s.l.	+	+			
220		*Corchorus ?walcottii*	+	+			
220		*Triumfetta* aff. *appendiculata*	+	+			
220		*Triumfetta chaetocarpa*	+				+
220		*Triumfetta clementii*	+	+		#	+
220		*Triumfetta maconochieana*	+	+	+		
220		*Triumfetta ramosa*	+			+	
220		*Triumfetta* sp.	+	+	+		

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221	MALVACEAE	*Abutilon cunninghamii*	+	#			#
221		*Abutilon otocarpum*	+	+			
221		*Abutilon* sp.	+			+	
221		*Gossypium robinsonii*	+	+			
221		*Hibiscus coatesii*	+			#	
221		*Hibiscus sturtii*	+			+	
221		*Sida fibulifera*	+				#
221		*Sida* sp.	+			+	
223	STERCULIACEAE	*Hannafordia quadrivalvis*	+	+	+	+	
223		*Hannafordia quadrivalvis* subsp. *recurva*	+	+			+
236		*Frankenia pauciflora* var. *pauciflora*	+	+	+		+
243	VIOLACEAE	*Hybanthus aurantiacus*	+	+	+		
273	MYRTACEAE	*Melaleuca cardiophylla*	+	+	+	+	
276	HALORAGACEAE	*Haloragis gossei*	+	+		+	
294	PLUMBAGINACEAE	*Muellerolimon salicorniaceum*	+				+
301	OLEACEAE	*Jasminum calcarium*	+	+		+	
305	ASCLEPIADACEAE	*Cynanchum floribundum*	+	+	+	+	+
305		*Sarcostemma viminale* subsp. *australe*	+	+	+	+	+
307	CONVOLVULACEAE	*Bonamia media* var. *villosa*	+	+			
307		*Evolvulus alsinoides* var. *decumbens*	+	+			
307		*Evolvulus alsinoides* var. *villosicalyx*	#			#	
307		*Polymeria ambigua*	+	+	+	+	
310		*Heliotropium crispatum*	+				#
310		*Heliotropium glanduliferum*	+	+	+	+	+
310		*Trichodesma zeylanicum* var. *zeylanicum*	+	+	+	+	+
312	AVICENNIACEAE	*Avicennia marina* subsp. *marina*	+				+
313	LAMIACEAE	*Clerodendrum tomentosum* var. *lanceolatum*	+	#			
315	SOLANACEAE	*Nicotiana occidentalis* subsp. *occidentalis*	+	+			
315		*Solanum cleistogamum*	+	+			+
315		*Solanum diversiflorum*	+	+		+	
315		*Solanum lasiophyllum*	+	+	+	+	+

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Fam No	FAMILY	Species	Barrow Island	PGPF	PFG	PCO	PNW
326	MYOPORACEAE	*Myoporum montanum*	+	+	+		+
331	RUBIACEAE	*Oldenlandia crouchiana*	+	+		#	
331		*Oldenlandia galioides*	+			+	
341	GOODENIACEAE	*Goodenia microptera*	+		#	+	
341		*Scaevola ?anchusifolia*	+			+	
341		*Scaevola amblyanthera* var. *amblyanthera*	+		+		
341		*Scaevola amblyanthera* var. *centralis*	+		#		
341		*Scaevola cunninghamii*	+	+	+	+	+
341		*Scaevola sericophylla*	+	+			
341		*Scaevola* sp.	+	+			
341		*Scaevola spinescens*	+	+			
345	ASTERACEAE	*Olearia dampieri* subsp. *dampieri* ms	+	+	+		+
345		*Pentalepis trichodesmoides*	+	+	+	+	+
345		*Pluchea dentex*	+	+			
345		*Pluchea dunlopii*	+			+	
345		*Pluchea ferdinandi-muelleri*	+		+		
345		*Pluchea rubelliflora*	+	+			+
345		*Pterocaulon sphacelatum*	+	+	+	+	
345		*Pterocaulon sphaeranthoides*	+	+			+
345		* *Sonchus oleraceus*	+	+			
345		*Streptoglossa adscendens*	+				+
345		*Streptoglossa bubakii*	+	+			+
345		*Streptoglossa decurrens*	+	+	+	+	
345		*Streptoglossa macrocephala*	+				#
345		*Vittadinia arida*	+		#		
345		*Vittadinia hispidula* var. *setosa*	+	+			

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ATTACHMENT B: VEGETATION COMMUNITY DESCRIPTIONS FOR PROPOSED PIPELINE ROUTES AND PROPOSED GAS PROCESSING FACILITY AND WIDER STUDY AREA 2003, 2004

Note: GPW - recorded in proposed gas processing facility area and wider study area
NW - recorded on North Whites Beach Pipeline route
GF - recorded on proposed feed gas pipeline
C0 - recorded on proposed $C0_2$ reinjection pipeline

Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Pipeline
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 foredunes.	NW/GPW
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.	GF
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.	NW
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.	GPW
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.	GPW
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.	GPW
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.	NW
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.	GF
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).	NW/C0
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.	NW
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.	NW
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.	NW

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Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Pipeline
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.	GF
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.	GPW
C5b	Scattered low *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).	GF
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.	GF
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.	NW
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.	GPW
D1c	Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* with *Triodia epactia* at edges in major drainage lines.	C0
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.	C0
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.	GF/C0
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.*	C0
D1g	Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over low scattered *Tephrosia rosea* and *Indigofera monophylla* shrubs in wide drainage lines.	GF
D2c	Tall scattered *Trichodesma zeylanicum* shrubs over Hummock Grassland of *Triodia angusta* with *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* in disturbed drainage lines.	GF
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.	C0
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.*	C0/GF

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Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Pipeline
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.	C0
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.	C0
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.	C0
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.	C0
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.	C0
F5e	Low scattered *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.	C0
F6a	Low Open Shrubland of *Acacia bivenosa* and *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on red/brown sandy flats.	NW
F6b	Low scattered *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.	NW
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.	C0
F6d	Open Shrubland of *Trichodesma zeylanicum* over low scattered *Pterocaulon sphacelatum* shrubs over Hummock Grassland of *Triodia epactia* on limestone flats with shallow sands.	C0
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.	C0
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.	C0
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.	C0
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.	C0
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 *Ericahne mucronata* on valley floors).	NW/C0

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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.	GPW
F8b	Scattered *Hakea lorea* subsp. *lorea* tall 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.	GPW
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.	C0
L1b	Scattered low *Ficus brachypoda* trees over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on limestone slopes and ridges.	GF
L1c	Low scattered *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.	C0
L1d	Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and *Heliotropium glanduliferum* on limestone flats (plateau).	GF
L1e	Low scattered *Ficus brachypoda* and *Pittosporum phylliraeoides* trees (with *Mallotus nesophilus*) over Hummock Grassland of *Triodia wiseana* with patchy *Triodia angusta* over low scattered *Diploteplis eriocarpa* shrubs on limestone slopes and flats.	NW
L1f	Low scattered *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over Hummock Grassland of *Triodia wiseana* and patchy *Triodia angusta* on limestone slopes and ridges.	NW
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.	GF/GPW
L3b	Scattered low *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.	C0/NW
L3c	Scattered low *Diplopeltis eriocarpa* shrubs with scattered *Triodia epactia*, *Cymbopogon ambiguus* and *Cyperus cunninghamii* subsp. *cunninghamii* herbs and grasses on small exposed limestone flats.	NW
L3d	Scattered low S*tylobasium 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.	GF
L3e	Low scattered *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.	C0
L3f	Low scattered *Petalostylis labicheoides* and *Indigofera monophylla* shrubs over Hummock Grassland of *Triodia wiseana* on limestone ridges and upper slopes.	GPW
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.	C0
L3h	Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* over low scattered *Diplopeltis eriocarpa* shrubs on limestone ridges and flats.	GPW

ATTACHMENT B: VEGETATION COMMUNITY DESCRIPTIONS FOR PROPOSED PIPELINE ROUTES AND PROPOSED GAS PROCESSING FACILITY AND WIDER STUDY AREA 2003, 2004

Note: GPW - recorded in proposed gas processing facility area and wider study area
NW - recorded on North Whites Beach Pipeline route
GF - recorded on proposed feed gas pipeline
C0 - recorded on proposed $C0_2$ reinjection pipeline

Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Pipeline
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.	GPW
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.*	C0/GF/GPW
L5a	Scattered *Hakea lorea* subsp. *lorea* tall 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.	GPW
L5b	Scattered *Hakea lorea* subsp. *lorea* shrubs over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy midslopes.	C0
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.	GPW
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* and *Triodia wiseana* and *Eriachne* sp. over Low Open Shrubland of *Acacia gregorii* on upper slopes and midslopes of small rises.	NW
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.	NW
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.	NW
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.*	GF/C0/GPW
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.	GPW
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.	GPW
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).	C0
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.	GPW/GF

ATTACHMENT B: VEGETATION COMMUNITY DESCRIPTIONS FOR PROPOSED PIPELINE ROUTES AND PROPOSED GAS PROCESSING FACILITY AND WIDER STUDY AREA 2003, 2004

Note: GPW - recorded in proposed gas processing facility area and wider study area
NW - recorded on North Whites Beach Pipeline route
GF - recorded on proposed feed gas pipeline
C0 - recorded on proposed $C0_2$ reinjection pipeline

Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Pipeline
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.	C0/W
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.	NW/GF/C0/GPW
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.*	GPW
V1f	Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* on red/brown sandy flats.	C0
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.	C0/GF
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.*	GF/C0
V1i	Hummock Grassland of *Triodia epactia* with occasional *Triodia wiseana* over Low Open Shrubland *Acacia gregorii* with *Diplopeltis eriocarpa* on gentle slopes and flats.	NW
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.	C0
V1k	Scattered *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.	C0/GF/GPW
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.	GF/GPW
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.	GPW
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.	GF/GPW
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.	GPW/GF/C0

Attachment C: Comparison of Vegetation Mapping Units and Area of Representation on Barrow Island

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
Marine	**M1**	Aquatic Complex supporting stands of *Avicennia marina* and *Ruppia maritima* on the fringes of the island.			Total of Mattiske mapping unit 24.67ha		-	-	-	-		
Tidal	**T1**	Halophytic Complex dominated by *Halosarcia halocnemoides* and *Halosarcia indica* on tidal flats.			Total of Mattiske mapping unit 12.21ha		-	-	-	-		
	T2	Mixed Chenopod and Halophytic Complex with low *Frankenia pauciflora* shrubs on high tide areas usually associated with stands of *Avicennia marina*			Total of Mattiske mapping unit 4.39ha		-	-	-	-		
Coastal Complex and Dune System	**C1**	Coastal Complex dominated by *Spinifex longifolius* on white foredunes; including Coastal Complex of *Ipomoea pes-caprae* subsp. *brasiliensis* and *Spinifex longifolius*.			Total of Mattiske mapping unit 253.78ha	Total of Subunits (below) = 5.61ha (2.2%)	-	-	-	Total of Subunits (below) = 0.58ha (0.23%)		
			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 foredunes.		5.61	-	-	-	0.12	**AC1a**	Open Grassland of *Spinifex longifolius* (10-30%) on the seaward facing foredunes.

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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.		-	-	Outside corridor	-	-		
			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.		-	-	-	-	0.46		
	C2	Open Scrub of *Acacia coriacea* - *Rhagodia preissii* subsp. *obovata* - *Olearia dampieri* subsp. *dampieri* on elevated dunes on fringes of island.			Total of Mattiske mapping unit 535.31ha	Total of Subunits (below) = 84.78ha (15.8%)	Total of Subunits (below) = 0.20ha (0.04%)	-	Total of Subunits (below) = 0.97ha (0.18%)	Total of Subunits (below) = 3.18ha (0.59%)		
			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.		53.46	0.2	-	-	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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.		31.04	0.00	-	-	-	**AC2b**	Tall Shrubland (10-30%; >2m) of *Acacia coriacea* over Shrubland (10-30%; 11.5m) of *Acacia bivenosa* with *Olearia damperi* subsp. *dampieri* over Low Shrubland (10-15%; <1m) of *Acanthocarpus verticillatus* over Hummock Grassland (30-70%) of *Triodia angusta* on hind dunes.
			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.		0.28	-	-	-	-		
			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.		-	-	-	-	0.64		
			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.		-	-	Outside corridor	-	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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).		-	-	-	0.97	1.09		
			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.		-	-	-	-	1.02		
			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.		-	-	-	-	0.43	**AC2a**	Shrubland (30-40%; 12 m) of *Acacia coriacea* over Low Shrubland of *Rhagodia preissii* subsp. *obovata* over Grassland (30-50%) of mixed *Eulalia aurea, Spinifex longifolius* on landward side of foredunes.
	C3	Hummock Grassland of *Triodia epactia* with dense shrubs including *Acacia bivenosa* on back-slopes of foredunes.			Total of Mattiske mapping unit 413.87ha	-	-	-	-	Total of Subunits (below) = 0.44ha (0.11%)		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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.		-	-	-	-	0.44		
	C4	Mixed Hummock Grassland of *Triodia angusta- Triodia epactia* with dense shrubs including *Acacia bivenosa* on back-slopes of foredunes.			Total of Mattiske mapping unit 73.73ha	-	-	Total of Subunits (below) = 0.025ha (0.03%)	-	-		
			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.		-	-	0.025	-	-		
	C5	Low Mixed Shrubland of *Frankenia pauciflora* and *Hedyotis crouchiana* on exposed cliff faces around edge of island.			Total of Mattiske mapping unit 207.81ha	Total of Subunits (below) = 8.92ha (4.3%)	Total of Subunits (below) = 0.58ha (0.28%)	Total of Subunits (below) = 0.22ha (0.11%)	-	Total of Subunits (below) = 1.76ha (0.85%)		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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.		8.92	0.58	-	-	-		
			C5b	Scattered low *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).		-	-	0.22	-	-		
			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.		-	-	Outside corridor	-	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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.		-	-	-	-	1.76		
	C6	Hummock Grassland of *Triodia epactia* with dense pockets of *Melaleuca cardiophylla* on sandy valley systems in south-western corner of island.			Total of Mattiske mapping unit 14.18ha	-	-	-	-	-		
	C7	Hummock Grassland of *Triodia epactia* with dense pockets of *Olearia dampieri* subsp. *dampieri* on sandy soils behind fore dune in south-western corner of island.			Total of Mattiske mapping unit 38.16ha	-	-	-	-	-		
Major Creek or Wide Drainage Lines	**D1**	Mixed Hummock Grassland of *Triodia angusta* with pockets of dense shrubs along major creek-lines and wide drainage lines.			Total of Mattiske mapping unit 34.97ha	Total of Subunits (below) = 64.92ha (further 39.87ha disturbed)	Total of Subunits (below) = 0.09ha	Total of Subunits (below) = 0.92ha	Total of Subunits (below) = 2.74ha	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
	D1		**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.		64.92 (further 39.87ha disturbed)	0.09	-	-	-	**AD1g**	Scattered to Open (<22%)tall shrubs of *Hakea lorea* over tall Dense Hummock Grassland (70-100%) of *Triodia angusta* sometimes with scattered (<2%) *Pentalepis trichodesmoides, Acacia bivenosa.*
			D1c	Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* with *Triodia epactia* at edges in major drainage lines.		-	-	-	0.41	-		
			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.		-	-	-	1.04	-		

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			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.		-	-	0.75	0.9	-		
			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*.		-	-	-	0.39	-		
			D1g	Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over low scattered *Tephrosia rosea* and *Indigofera monophylla* shrubs in wide drainage lines.		-	-	0.17	-	-		
Minor Creeks or Narrow Drainage Lines	**D2**	Hummock Grassland of *Triodia angusta* along minor creek lines and narrow drainage lines.			Total of Mattiske mapping unit 1101.94ha	-	-	Total of Subunits (below) = 0.50ha (0.05%)	Total of Subunits (below) = 2.41ha (0.22%)	-		

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			D2c	Tall scattered *Trichodesma zeylanicum* shrubs over Hummock Grassland of *Triodia angusta* with *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* in disturbed drainage lines.		-	-	0.09	-	-		
			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.		-	-	-	1.8	-		
			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.*		-	-	0.41	0.61	-		
Minor Creekline	**D3**	Hummock Grassland of *Triodia angusta* along minor creek-line with emergent *Santalum murrayanum.*			Total of Mattiske mapping unit 0.65ha	-	-	-	-	-		

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Flats	**F1**	Hummock Grassland of *Triodia angusta* on red earth flats and drainage lines.			Total of Mattiske mapping unit 1558.85ha	-	-	-	-	-		
	F2	Hummock Grassland of *Triodia angusta* with emergent *Acacia synchronicia* on red earth flat.			Total of Mattiske mapping unit 9.02ha	-	-	-	-	-		
	F3	Hummock Grassland of *Triodia angusta* with emergent shrubs of *Gossypium robinsonii* on red earth flats.			Total of Mattiske mapping unit 36.85ha	-	-	-	-	-		
	F4	Hummock Grassland of *Triodia angusta* - *Triodia* spp. with emergent pockets of *Erythrina vespertilio* on flats.			Total of Mattiske mapping unit 127.6ha	-	-	-	Total of Subunit (below) = 1.2ha (0.94%)	-		
			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.		-	-	-	1.2	-		
	F5	Mixed Hummock Grassland of *Triodia epactia* - *Triodia angusta* on fringes of main red earth flats and drainage lines.			Total of Mattiske mapping unit 1350.13ha	-	-	-	Total of Subunit (below) = 11.47ha (0.87%)	-		

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			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.		-	-	-	2.91	-		
			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.		-	-	-	2.55	-		
			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.		-	-	-	2.18	-		
			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.		-	-	-	0.24	-		

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			F5e	Low scattered *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.		-	-	-	3.59	-		
	F6	Hummock Grassland of *Triodia epactia* on slopes of escarpments on fringes of red earth flats.			Total of Mattiske mapping unit 157.51ha	-	-	-	Total of Subunit (below) = 1.15ha (0.73%)	Total of Subunit (below) = 1.34ha (0.85%)		
			F6a	Low Open Shrubland of *Acacia bivenosa* and *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on red/brown sandy flats.		-	-	-	-	0.56		
			F6b	Low scattered *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.		-	-	-	-	0.78		
			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.		-	-	-	0.23	-		

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			F6d	Open Shrubland of *Trichodesma zeylanicum* over low scattered *Pterocaulon sphacelatum* shrubs over Hummock Grassland of *Triodia epactia* on limestone flats with shallow sands.		-	-	-	0.92	-		
	F7	Hummock Grassland of *Triodia epactia - Triodia angusta - Triodia wiseana* on slopes of escarpments on fringes of red earth flats.			Total of Mattiske mapping unit 786.02ha	-	-	-	Total of Subunit (below) = 8.44ha (1.07%)	Total of Subunit (below) = 2.21ha (0.28%)		
			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.		-	-	-	1.9	-		
			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.		-	-	-	3.5	-		
			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.		-	-	-	0.4	-		

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			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.		-	-	-	0.81	-		
			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).		-	-	-	1.83	2.21		
	F8	Not separated as distinct "F" community in Mattiske (1993) - differs in dominance of different *Triodia*			Total of Mattiske mapping unit 0ha	Total of Subunits (below) = 184.25ha	Total of Subunits (below) = 47.86	-	-	-		
			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.		181.87	47.86	-	-	-		

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			F8b	Scattered *Hakea lorea* subsp. *lorea* tall 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.		2.38	-	-	-	-		
Limestone Ridges	**L1**	Hummock Grassland of *Triodia wiseana* with *Ficus brachypoda* on central limestone ridges.			Total of Mattiske mapping unit 2728.29ha	-	-	Total of Subunits (below) = 14.04ha (0.51%)	Total of Subunits (below) = 6.13ha (0.22%)	Total of Subunits (below) = 1.10ha (0.04%)		
			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.		-	-	8.41	4.47	-	**AL1a**	Low Open Woodland (10-20% <5m) of *Ficus brachypoda* over Mixed Shrubland of *Acacia bivenosa, Stylobasium spathulatum* over Dwarf Shrubland (10-20%: 0.5m) of *Solanum lasiophyllum, Corchorus interstans* over mixed Hummock Grassland (30-70%) of *Triodia angusta* and *Triodia wiseana* on limestone ridges.
			L1b	Scattered low *Ficus brachypoda* trees over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on limestone slopes and ridges.		-	-	4.71	0.0002	-		

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			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.		-	-	-	1.16	-		
			L1d	Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and *Heliotropium glanduliferum* on limestone flats (plateau).		-	-	0.92	-	-		
			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.		-	-	-	0.5	0.61	**AL1b**	Dwarf Shrubland (10-30%; 0.5m) of *Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana*. Very scattered *Ficus brachypoda* on limestone hillslopes.
			L1f	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over Hummock Grassland of *Triodia wiseana* and patchy *Triodia angusta* on limestone slopes and ridges.		-	-	-	-	0.49		
	L2	Hummock Grassland of *Triodia wiseana* with *Ficus virens* var. *virens* on escarpments on west coast and southern edge of limestone ridges.			Total of Mattiske mapping unit 19.64ha	-	-	-	-	-		

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	L3	Hummock Grassland of *Triodia wiseana* with low mixed shrubs, including *Acacia gregorii* on limestone ridges.			Total of Mattiske mapping unit 2782.99ha	Total of Subunits (below) = 198.67ha (7.14%)	Total of Subunits (below) = 35.64ha (1.24%)	Total of Subunits (below) = 0.92ha (0.03%)	Total of Subunits (below) = 6.91ha (0.25%)	Total of Subunits (below) = 0.72ha (0.03%)		
			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.		15.73	1.34	0.33	-	-	**AL3a**	Open Shrubland (2-10%; 1m) of *Petalostylis labicheoides, Stylobasium spathulatum* over Dwarf Shrubland (10-20% <0.5m) of *Acacia gregorii* over Hummock Grassland (30-70%) of mixed *Triodia wiseana* and *Triodia angusta*. There are scattered (<2%) *Hakea lorea* on limestone hillslopes.
			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.		-	-	-	1.12	-		
			L3c	Low scattered *Diplopeltis eriocarpa* shrubs with scattered *Cymbopogon ambiguus* and *Cyperus cunninghamii* subsp. *cunninghamii* herbs and grasses on small exposed limestone flats.		-	-	-	-	0.22		

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			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.		-	-	0.59	-	-		
			L3e	Low scattered *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.		-	-	-	5.17	-		
			L3f	Low scattered *Petalostylis labicheoides* and *Indigofera monophylla* shrubs over Hummock Grassland of *Triodia wiseana* on limestone ridges and upper slopes.		42.9	6.24	-	-	-		
			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.		-	-	-	0.62	-		

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			L3h	Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* over low scattered *Diplopeltis eriocarpa* shrubs on limestone ridges and flats.		23.54	-	-	-	-		
			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.		116.5	28.06	-	-	0.5		
	L4	Hummock Grassland of *Triodia wiseana* with dense emergent shrubs of *Acacia pyrifolia, Acacia gregorii* and *Petalostylis labicheoides* on limestone ridges.			Total of Mattiske mapping unit 322.73ha	Total of Subunit (below) = 127.11ha (39.39%)	-	Total of Subunit (below) = 7.47ha (2.31%)	Total of Subunit (below) = 0.38ha (0.12%)	-		
			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.*		127.11	-	7.47	0.38	-		
	L5	Hummock Grassland of *Triodia wiseana* with emergent *Hakea lorea* subsp. *lorea* on limestone ridges.			Total of Mattiske mapping unit 106.54ha	Total of Subunit (below) = 29.12ha (27.33%)	-	-	Total of Subunit (below) = 0.56ha (1.92%)	-		

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			L5a	Scattered tall *Hakea lorea* subsp. *lorea* tall 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.		29.12	-	-	-	-	**AL5a**	Low shrubland (10-30%; 1m) of *Acacia bivenosa* over Hummock Grassland (30-70%) of *Triodia wiseana*. There are scattered Hakea lorea on limestone hillslopes.
			L5b	Scattered *Hakea lorea* subsp. *lorea* shrubs over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy midslopes.		-	-	-	0.56	-		
	L6	Hummock Grassland of *Triodia wiseana* with emergent *Grevillea pyramidalis* on limestone ridges.			Total of Mattiske mapping unit 93.67ha	Total of Subunit (below) = 2.68ha (2.86%)	-	-	-	Total of Subunit (below) = 5.85ha (6.25%)		
			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.		2.68	-	-	-	-		

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			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* and *Triodia wiseana* and *Eriachne* sp. over Low Open Shrubland of *Acacia gregorii* on upper slopes and midslopes of small rises.		-	-	-	-	2.4		
			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.		-	-	-	-	3.07		
			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.		-	-	-	-	0.38		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
	L7	Hummock Grassland of *Triodia wiseana* with dense pockets of *Melaleuca cardiophylla* on limestone ridges.			Total of Mattiske mapping unit 1583.84ha	Total of Subunit (below) = 143.97ha (9.09%)	Total of Subunit (below) = 2.20ha (0.14%)	Total of Subunit (below) = 1.06ha (0.07%)	Total of Subunit (below) = 0.70ha (0.04%)	-		
			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.*		4.92	-	1.06	0.7	-	**AL7a**	Low Shrubland (10-30%; 0.51m) of *Melaleuca cardiophylla* with *Acacia gregorii* (occasional prostrate *Acacia bivenosa)* over Hummock Grassland (30-70%) of *Triodia wiseana* on limestone hillslopes.
			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.		139.05	2.20	-	-	-	**AL7c**	Shrubland (10-30%; 12m) of *Melaleuca cardiophylla, Petalostylis labicheoides* over Dwarf Shrubland (10-30%, 00.5m) of *Acacia gregorii* with *Diplopeltis eriocarpa* over Hummock Grassland (30-70%) of *Triodia wiseana* on limestone hillslopes.
	L8	Hummock Grassland of *Triodia wiseana* with pockets of *Eucalyptus xerothermica* on limestone ridges.			Total of Mattiske mapping unit 8.85ha	-	-	-	-	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
	L9	Hummock Grassland of *Triodia wiseana - Triodia angusta* with emergent *Sarcostemma viminale* subsp. *australe* and *Ficus brachypoda* on coastal limestone flats and low ridges with localised pockets of *Frankenia pauciflora*.			Total of Mattiske mapping unit 1749.96ha	Total of Subunit (below) = 8.37ha (0.48%)	-	-	-	-		
			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.		8.37	-	-	-	-	**AL9a**	Low Woodland (10-30% <5m) *Ficus brachypoda* over Very Open (2-10%; <1m) of Low Shrubland of *Sarcostemma viminale* subsp. *australe* over Hummock Grassland (30-40%) of *Triodia wiseana* on coastal limestone hillslopes and plateaus.
	L10	Hummock Grassland of *Triodia epactia - Triodia angusta* with emergent *Hakea lorea* subsp. *lorea* on exposed small limestone hills on southern coastal area.			Total of Mattiske mapping unit 47.57ha	-	-	-	-	-		
Rocky Headlands	**R**	No equivalent mapped by Mattiske (1993)			Total of Mattiske mapping unit 0ha							
			R			Total of Subunit = 4.7ha	Total of Subunit = 0.5ha	-	-	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
Clay Pans	**S1**	Mixed Herbfield and Grassland of *Eragrostis xerophila, Eriachne flaccida* and *Sporobolus virginicus* on clay pans.			Total of Mattiske mapping unit 192.3ha	-	-	-	Total of Subunit (below) = 0.66ha (0.34%)	-		
			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).		-	-	-	0.66	-		
	S2	Mixed Herbfields with *Streptoglossa bubakii* and *Pterocaulon sphacelatum* on fringes of tidal Halophytic areas and flood channels on clay soils near coast.			Total of Mattiske mapping unit 0.91ha	-	-	-	-	-		
Valley Slopes and Escarpment Slopes	**V1**	Hummock Grassland of *Triodia wiseana* with mixed emergent shrub species on valley slopes.			Total of Mattiske mapping unit 6805.74ha	Total of Subunit (below) = 410.83ha (6.04%)	Total of Subunit (below) = 46.61ha (0.68%)	Total of Subunit (below) = 8.73ha (0.13%)	Total of Subunit (below) = 19.70ha (0.29%)	Total of Subunit (below) = 3.04ha (0.04%)		
			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.		54.4	-	3.88	2.43	-	**AV1a**	Open Low Shrubland (2-10% <1m) of mixed *Petalostylis labicheoides, Acacia bivenosa* over Hummock Grassland (30-70%) of *Triodia wiseana* on valley slopes.

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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.		-	-	0.44	0.83	-		
			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.		21.42	-	1.79	3.63	2.39		
			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*.		9.4	3.15	-	-	-		
			V1f	Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* on red/brown sandy flats.		-	-	-	2.43	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			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.		-	-	-	1.79	-		
			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.*		-	-	2.02	2.91	-		
			V1i	Hummock Grassland of *Triodia epactia* with occasional *Triodia wiseana* over Low Open Shrubland *Acacia gregorii* with *Diplopeltis eriocarpa* on gentle slopes and flats.		-	-	-	-	0.65		
			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.		-	-	-	1.05	-		

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
			V1k	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.		115.04	10.70	0.6	2.66	-		
			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.		190.71	32.77	-	1.28	-		
			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.		19.86	-	-	0.69	-	**AL7d**	Scattered (<2%) to Open (25%) Tall Shrubland of *Hakea lorea* over Low Shrubland (10-30% ; 1m) of *Melaleuca cardiophylla, Acacia bivenosa* over Mixed Hummock Grassland (30-70%) sometimes Dense (90%) of *Triodia wiseana, Triodia angusta* on limestone hillslopes but frequently also on red earth flats.

	Mattiske Unit	Community Description for Barrow Island (Mattiske 1993)	Mapping Code	Community Description for Proposed Plant Area and Pipeline Corridors (2003, 2004)	Area (ha) on Barrow Island (Mattiske 1993)	Area (ha) on Proposed GPF Wider Study Area	Area (ha) on Proposed GPF Area	Area (ha) on Feed Gas Pipeline	Area (ha) on CO_2 Injection Pipeline	Area on North White's Beach Pipeline	Astron (2002) code - 'A' prefix added to original code	Community Description for Barrow Island (Astron 2002) (units presented are closest match to 2003/2004 communities)
	V2	Hummock Grassland of *Triodia wiseana* with *Pentalepis trichodesmoides* on southern escarpment.			Total of Mattiske mapping unit 144.6ha	-	-	-	-	-		
	V3				Total of Mattiske mapping unit 0ha	Total of Subunits (below) = 105.54ha	-	Total of Subunits (below) = 4.71ha	Total of Subunits (below) = 0.59ha	-		
			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.		37.19	-	2.44	-	-		
			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.		68.35	-	2.27	0.59	-		
	Dist	Disturbed Areas	**Dist**	Disturbed or cleared areas.	Not Available	39.87	0.65	2.68	5.87	0.05		

GPF: Gas Processing Facility

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Technical Appendix C2

Mammals and Reptiles

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

MAMMALS AND REPTILES

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April 2005

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1 Introduction

The Gorgon Venture proposes to develop a gas processing facility at Town Point on the east coast of Barrow Island with associated gas feed pipelines running across the Island from a shore crossing at either North White's Beach or Flacourt Bay. The proposed Development area includes vegetated and unvegetated habitats used by mammals and reptiles. Direct loss of some of these habitats during construction of the gas processing facility and pipelines is likely to affect local fauna.

Formal assessment of the impacts of the proposed Development requires information on the significance of the impacted areas to terrestrial fauna. Forty three reptile species, one frog species, thirteen resident land mammal species and two vagrant mammal species are known from Barrow Island (Attachment 1 and 2). The Barrow Island populations of some of these species are of regional significance because they are secure populations of species that are under threat on the mainland. Long isolation from the mainland has also led to genetic divergence of the Island populations from the mainland populations giving the Island taxa higher conservation significance. While specially protected mammal and reptile species are known to occur on Barrow Island and there is a good species inventory for the Island, quantitative data on the distribution and abundance of the fauna around the Island are scarce.

Harry Butler conducted early surveys to establish an understanding of the vertebrate fauna on Barrow Island, for example Butler (1970). The Department of Conservation and Land Management (CALM) has studied terrestrial vertebrates on the Island during annual trapping and spotlighting surveys for at least the last six years. CALM established a mammal monitoring program for Barrow Island that involves five grids of traps in representative areas around the Island. Population estimates for the key mammal species on the Island have been derived from the work by CALM and by Short et al. (1988). The Western Australian Museum (WAM) has collected on the Island and has been provided with specimens from the Island from other studies.

Literature reviews and further field surveys were conducted on behalf of the Gorgon Venture for the earlier Environmental, Social and Economic (ESE) Review of the Gorgon Development proposal (Bamford 2002). The ESE Review process identified gaps in existing knowledge concerning the distribution and diversity of terrestrial fauna, especially reptiles, in potential impact areas in relation to other areas.

Bamford Consulting Ecologists and Biota Environmental Sciences were engaged to redress this lack of information by surveying mammals and herpetofauna in the proposed Development area in 2003/2004.

The main aims of the current study of the vertebrate fauna of Barrow Island were taxonomic and ecological as described below:

- To assess the reptile and mammal species diversity in the vicinity of the proposed Development area and to augment existing WAM collections for the area (taxonomic).
- To determine the abundance of vertebrates in different landforms/vegetated habitats within the potential impact area (ecological).

Seasonal variation in catchability, detectability and population size necessitate sampling over several seasons to gain a representative sample of the biodiversity of the area. This report presents the findings of trapping surveys in November-December 2003, October

2004 and targeted herpetofauna sampling in August–September 2004. This report assesses the importance of the proposed Development sites in relation to other areas of Barrow Island for terrestrial vertebrate fauna, based on the results of these surveys and previous work by CALM.

2 Methods

The two aims of the study demanded different survey techniques. Trapping grids were set up to survey the abundance of vertebrate fauna in different vegetation and landform habitats. Targeted sampling of habitats known to be important for herpetofauna in other areas was employed to gain an inventory for the area.

2.1 Survey Methodology and Limitations

Survey methodology was consistent with the Guidance for the Assessment of Environmental Factors No. 56 - Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004).

The survey teams were led by Dr Mike Bamford, Dr Mike Craig, Dr Roy Teale and Greg Harold; professionals experienced in small vertebrate surveys and ecology in the Pilbara.

While the survey design and methodology closely matched CALM's trapping program on Barrow Island, there are limitations in these methods for censusing larger reptiles. Pitfall traps were augmented with opportunistic hand foraging and targeted trapping techniques for reptiles. Funnel trapping was not employed to catch larger reptiles, such as pygopodid lizards and snakes, due to concerns that captured animals would be more vulnerable to predation by mammals and perenties prior to traps being cleared.

Trapping grid surveys were conducted in spring of 2003 and 2004 to match the annual sampling periodicity followed by CALM. Surveying at other times of the year may detect other species, especially of reptiles, not recorded during the spring surveys. Changes in abundance and population recruitment rates may also be estimated by sampling at different times of the year.

2.2 Ecological Surveys

Trapping grids replicating the grid layout established by CALM during annual sampling carried out on Barrow Island since 1998 (Burbidge et al. 1998, 2003) were established in the proposed gas processing facility area. CALM currently monitors Barrow Island's mammal and reptile fauna from five grids set out around the Island. Bamford Consulting and RPS Bowman Bishaw Gorham established a further six grids in the vicinity of the proposed Development area. This allowed results collected in the proposed Development area to be compared with CALM data from similar habitats elsewhere on the Island and to determine the importance of different vegetation and landform types in the area for fauna.

Boodie (*Bettongia lesueur*) warrens are of special conservation significance as they persist for many years and boodies rely upon warrens for daytime shelter. An area of approximately 658 ha of the area surrounding proposed infrastructure locations near Town Point was surveyed in an attempt to locate all warrens in the vicinity of the proposed gas processing facility (Figure 2-1). The route of the gas pipeline from North White's Beach to the Gorgon gas processing facility area was also surveyed (approximately 550 ha) for boodie warrens in sectors where this did not follow existing roads. The Flacourt Bay alternative pipeline route was surveyed and found to be clear of boodie warrens during the ESE Review studies (Bamford 2002).

2.2.1 Trapping Grids

Reptiles and mammals were trapped from 25 November to 2 December 2003, and from 16–25 October 2004. The trapping grid layout replicated that used by CALM as part of its long-term monitoring on the Island, with each trapping site containing 25 pitfalls (40 cm deep by 15 cm diameter PVC pipe, assisted with a six metre drift fence), 25 Elliott traps and 25 cage traps. These were deployed at 20 m spacing in a five by five regular grid. Six such layouts were established in the six main vegetation types within the proposed Development area. Some of these vegetation types were also represented in CALM's monitoring program and therefore the sampling in these sites was replicated. Each trapping grid was opened over four consecutive nights for sampling. CALM sampled its trap grids over four nights during 21–29 October 2003 and CALM's trap grids were sampled concurrently with the grids in the Gorgon Development area in October 2004.

Table 2-1 describes each trapping site in the Gorgon Development area and lists the CALM site in similar vegetation where applicable. The trapping grids are shown in Figure 2-1.

Table 2-1 - Locations and Vegetation Descriptions of Reptile and Mammal Trapping Sites in the Proposed Development Area

Trapping Grid	Location (WGS84)	Vegetated habitat	CALM grid analogue
Site 1	339285E 7700715N	Acacia bivenosa shrubland over *Triodia wiseana* on red loam	Similar to CALM Site Landing at 340765E, 7706890N
Site 2	339257E 7700980N	*Melaleuca* shrubland over *Triodia wiseana* on limestone slopes	Similar to CALM Site M21 at 334140E, 698560N
Site 3	339010E 7699320N	*Acacia coriacea* shrubland over *Triodia angusta* on red sandy-loam behind secondary dune	Similar to CALM Site John Wayne Country
Site 4	339885E 7700545N	*Triodia angusta* with scattered *Acacia coriacea* on shallow pale red sand over limestone near coast	No similar CALM site
Site 5	339555E 7700225N	Coastal dune complex, from *Spinifex longifolius* on white sand foredunes to *Acacia coriacea* shrubland over *Triodia angusta* on red sand of secondary dunes and swales	Some similarities to CALM Site John Wayne Country and CALM site Bandicoot Bay. Bandicoot Bay used for comparisons
Site 6	338415E 7701855N	*Triodia wiseana* on hilltop; soil consisting of fragmented limestone and red loam	Similar to CALM Site S62 at 329490E, 7703402N

The location given is for the north-west corner of each grid. Also indicated are CALM trapping sites in similar vegetation types

All specimens caught in the trapping survey were measured, weighed and marked. Reptile snout to vent and total lengths were measured. Reptiles were marked by toe-clipping, with a single clip being taken in most cases so that specimens could be recognised as recaptures during the survey. For mammals, crown, pes and external gonad dimensions were measured, while notes were made on reproductive condition and the presence of pouch young for females. Small mammals were individually marked with an ear punch and larger mammals (boodie, brush-tailed possum, golden bandicoot and spectacled hare-wallaby) had a Passive Identification Tag (PIT) inserted under the skin between the shoulder blades by F. Donaldson or M. Bamford under licence from CALM. Marking allowed assessment of recapture rates.

2.2.2 Boodie Warren Transect Surveys

Boodie warrens have been recorded in the Development area during previous surveys (Bamford 2002). Observations made during operation of the existing oil facilities have also been made available. Nevertheless, a systematic approach of intensive walked transects was required to confirm the status of known warrens and to locate other boodie warrens within the proposed Development area.

Boodie warren transects were spaced 50 m apart and aligned east to west. The area covered by the boodie transects is the Mammal Survey Outline shown in Figure 2-1. Details of the boodie transects, including coordinates of the ends of each transect, are presented in Attachment 3. Hand-held GPS units were used to ensure that surveyors stayed on track and observers moved away from their transect only to investigate interesting features such as possible warrens or dense vegetation. Boodie warren transects were progressively surveyed from October to December 2003 until the entire survey area had been covered. The total length of boodie warren transects was 131 km.

When warrens were located, their position (WGS84; zone 50) was recorded and the approximate number of entrances and significant features such as vegetation and soil type were noted. In addition to warrens, areas of limestone solution pipes that were clearly being used for shelter by mammals or reptiles were noted, with the number of holes also being recorded, as were locations of active foraging by mammals (indicated by concentrations of diggings). The locations of hare-wallabies and incidental observations of landbirds were also recorded. Landbirds are described in Technical Appendix C3.

The pipeline route from North White's Beach to the proposed gas processing facility was surveyed for boodie warrens during 9-10 February 2004. Sections surveyed were from North White's Beach at 334871E, 7710932N to 337503E, 7708662N, with emphasis on the westernmost portion of this section where the route passes through undisturbed vegetation and from 337306E, 7707122N to 337044E, 7703717N. This latter section passes entirely through undisturbed vegetation and is also a potential route for the CO_2 reinjection pipeline.

2.3 Taxonomic Inventory Surveys

To supplement the systematic herpetofauna trapping in the grids described above, in November 2003 and August-September 2004 Biota Environmental Sciences used opportunistic hand foraging and other targeted techniques throughout the Development area to augment the inventory of herpetofauna from the area. The survey methods included visual searches, raking leaf litter, excavating burrows, lifting rocks and head-torching. In addition, three transects of up to 50 medium sized Elliott traps were installed. The aim of the survey was to collect species that do not readily enter pit traps and to search for previously unrecorded species.

Discussions with WAM indicated that whilst previous collecting had been thorough, there was little tissue to support molecular studies examining the taxonomic status of the Barrow Island populations. It was therefore decided that five specimens of each sex for each species should be collected. All specimens were curated in the field under ethics approval granted under the WAM application to the CALM Animal Ethics Committee, which covers Mr Roy Teale as a Research Associate with WAM. Collecting was undertaken under licences granted to Mr Roy Teale and Mr Greg Harold.

The herpetofauna survey was conducted between the 18 and 25 November 2003. Hand foraging and raking was completed during the morning between 6:30 am and 11:30 am and again late in the afternoon through to dusk. This was supplemented by road-spotting and head-torching activities at night.

Specimens were euthanased using Nembutal® which was injected into the heart region or for small reptiles by placing a few drops into the mouth of the animal. Liver samples were taken from a small incision made just below the rib cage. Liver samples were placed into labelled cryovials and deposited into a Dewar flask containing liquid nitrogen. The animal was subsequently labelled with the voucher number provided by WAM and placed into the freezer. Prior to removing a liver sample the animal was weighed, sexed and the snout-vent and tail-vent were measured. Upon completion of the survey all specimens and associated tissue samples were lodged with WAM.

For those specimens where the total species capture had exceeded 10 individuals or five from any one sex (where this could be accurately determined), a small (1–1.5 cm) length of tail was removed and placed in 100% ethanol. These samples were also lodged with WAM for future DNA analysis.

All data for specimens from which tissue was collected were provided to WAM for inclusion in FaunaBase.

For those species where the above program did not yield sufficient numbers for molecular studies, additional specimens were obtained from the ecological trapping grids. This document summarises data associated with the specimens vouchered with WAM as well as additional records from animals captured and subsequently released.

Further to sampling in November 2003, additional opportunistic sampling was conducted at the end of winter between 25 August and 1 September 2004. The work involved hand foraging and raking during the day as the cooler temperatures enabled the reptiles to remain active throughout the daylight hours. Little nocturnal work was completed because cool temperatures and strong winds precluded any significant reptile activity at night time.

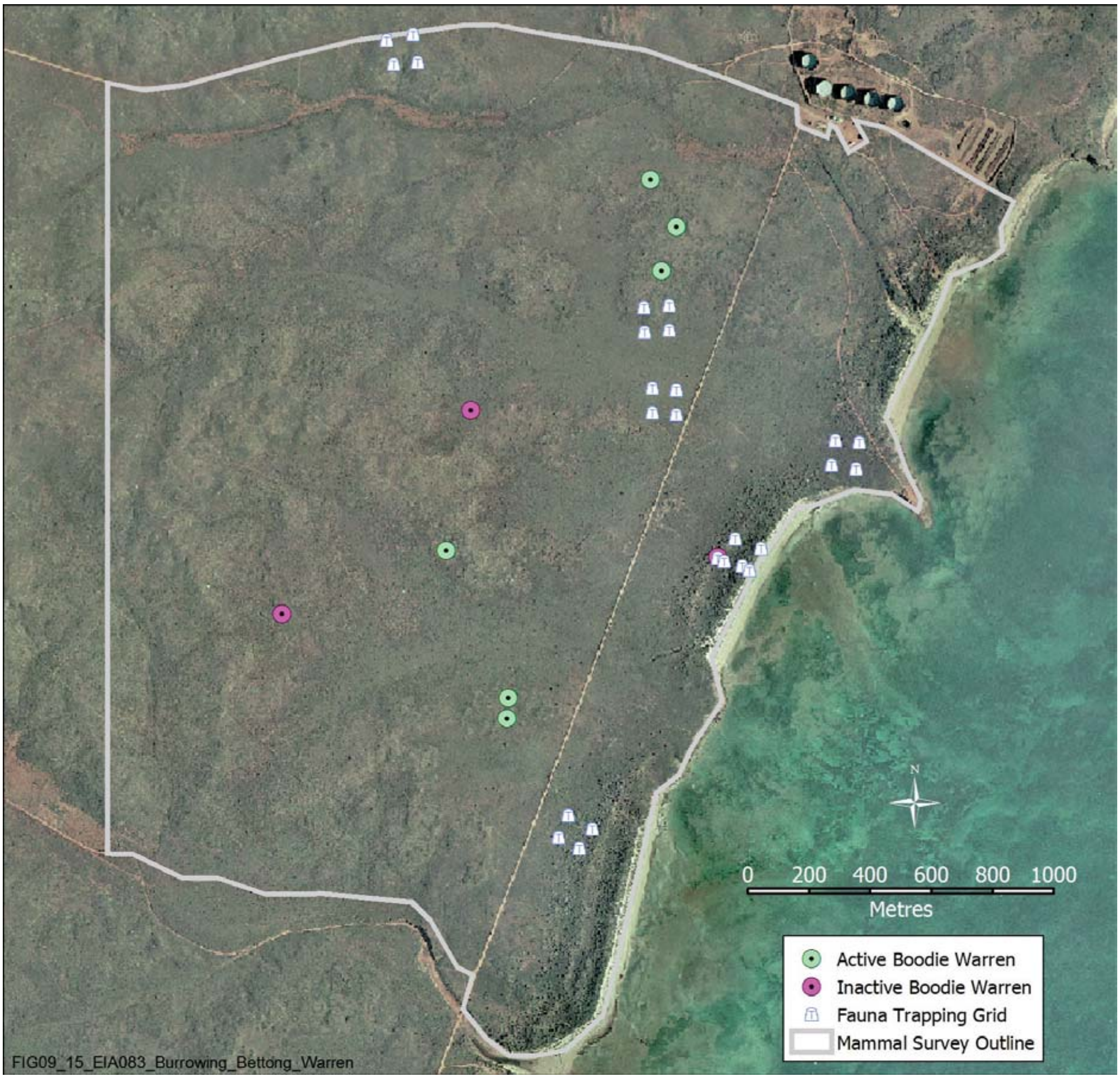

Figure 2-1 - Fauna Trapping Grids, Boodie Warrens and Boodie Transect Survey Area

3 Results

3.1 Trapping Survey and Opportunistic Observations

3.1.1 Reptiles

The number of each species of reptile caught in the six trapping grids in 2003 and 2004 is presented in Table 3-1 and Table 3-2 respectively. Trapping results are presented in Attachment 4. The species list for terrestrial reptiles known from Barrow Island is presented in Attachment 2.

In November-December 2003, a total of 295 individual reptiles representing six families and 18 species were caught in the traps. A further seven species were observed in the trapping area, but were not captured in the pitfalls. In October 2004, a total of 248 individual reptiles representing five families and 17 species were caught in the traps. These numbers are similar to those recorded in the 2003 survey.

In the 2003 and 2004 surveys combined, a total of six families and 22 species were caught in traps. This tally represents slightly more than half the reptile species known from Barrow Island. In addition to the species trapped, the Perentie (*Varanus giganteus*) was observed on major tracks and beaches throughout the study area and on rocks and in open grassland at Town Point, while three snake species (the Mulga Snake *Pseudechis australis*, Stimson's Python *Antaresia stimsoni* and a blind snake *Ramphotyphlops grypus*), were observed within or close to the Development area. The blind snake represented an addition to the reptile fauna known from Barrow Island.

Table 3-1 - Reptiles Caught in Six Trapping Grids on the Proposed Development Area, November-December 2003

Species	Grid						Total
	1	2	3	4	5	6	
Gekkonidae							
Heteronotia binoei	1	3	0	0	2	2	8
Pygopodidae							
Delma borea	0	0	0	1	0	0	1
Delma nasuta	2	0	0	0	0	1	3
Lialis burtonis	0	0	0	0	2	0	2
Agamidae							
Pogona minor	0	0	0	0	3	0	3
Varanidae							
Varanus acanthurus	0	1	0	0	0	0	1
Scincidae							
Carlia triacantha	0	1	0	0	0	0	1
Ctenotus grandis	5	4	5	1	1	0	16
Ctenotus pantherinus	1	0	1	0	1	0	3
Ctenotus saxatilis	1	2	0	1	1	1	6
Cyclodomorphus melanops	1	0	1	1	0	0	3
Lerista bipes	3	17	70	37	51	0	178
Lerista muelleri	6	5	8	9	7	5	40
Menetia greyii	8	5	0	0	2	6	21
Morethia ruficauda	0	0	1	0	0	0	1
Notoscincus ornatus	1	6	0	0	0	0	7
Proablepharus reginae	0	0	0	0	1	0	1
Typhlopidae							
Ramphotyphlops ammodytes	0	1	0	0	0	0	1
Number of species	10	10	6	6	10	5	18
Number of specimens	29	45	86	50	71	15	295

Table 3-2 - Reptiles Caught in Six Trapping Grids on the Proposed Development Area, October 2004

Species	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Total
Gekkonidae							
Heteronotia binoei	2					5	7
Strophurus jeanae			1	1			2
Pygopodidae							
Delma borea	1						1
Agamidae							
Ctenophorus caudicinctus						1	1
Pogona minor					1		1
Varanidae							
Varanus acanthurus		2					2
Scincidae							
Ctenotus grandis	6	12	7	7	2		34
Ctenotus pantherinus	1	2			1	1	5
Ctenotus saxatilis	2	7			1	2	12
Cyclodomorphus melanops	2		1	3		2	8
Glaphyromorphus isolepis					1		1
Lerista bipes	3	14	33	26	43		119
Lerista muelleri	2	4	2	4	3	1	16
Menetia greyii	3	4	2		1	1	11
Morethia ruficauda		3	1	2			6
Notoscincus ornatus	2	4	2		1		9
Proablepharus reginae		2		1		2	5
Number of species	10	10	8	7	9	8	17
Number of specimens	24	54	49	44	54	15	240

The abundances of most of the reptile species were so low within each habitat type that little can be concluded regarding their habitat associations. However, for the more abundant skinks, the following patterns were evident:

- *Lerista bipes* - very abundant in coastal or near-coastal sites with sandy or sandy-loam soils.
- *Lerista muelleri* - widespread across all sites.
- *Menetia greyii* - absent from the coastal sites with sandy soils.
- *Notoscincus ornatus* - practically restricted to *Melaleuca* shrubland and spinifex on shallow soil with a lot of exposed limestone.

Burbidge et al. (2003) indicate the sites at which they trapped each of the 14 reptile species collected from the CALM grids. Two of these species were not recorded in the Gorgon trapping grids, but are expected to occur in the area. The skink *Lerista elegans* was caught only at CALM's Bandicoot Bay site and the gecko *Strophurus jeanae* was caught at the Bandicoot Bay, John Wayne and M21 sites. The habitats surrounding these CALM trapping sites are also represented in the Gorgon trapping sites, although the Bandicoot Bay site has more extensive white sands than are present at the most similar site in the proposed Development area (Site 5 - Table 2-1).

3.1.2 Mammals

The abundances of mammals caught in the six trapping grids in November-December 2003 and October 2004 are presented in Table 3-3 and Table 3-4 respectively. A complete list of mammals known from Barrow Island is presented in Attachment 1. Mammal trapping results are presented in Attachment 5.

A total of 202 individual mammals representing six families and eight species were caught in November-December 2003. In October 2004, 288 individual mammals of six families and six species were caught. Overall, all of the terrestrial mammals of Barrow Island were caught in the Town Point grids with the exception of the bats, the euro (*Macropus robustus isabellinus*), the black-flanked rock-wallaby (*Petrogale lateralis*) and the rakali or water-rat (*Hydromys chrysogaster*).

The euro was present at all sites and was seen most regularly along the coast where rocks and gorges provide shade. It appeared that about 10 animals occurred across the proposed Development area.

The rock-wallaby was absent from the Town Point area as the habitat was not suitable and all previous records of the species are from the west coast. Rock wallabies were observed in the cliffs at Flacourt Bay on the west coast of the Island.

The rakali was recorded along the coast near Town Point where tracks were seen and one specimen was trapped in an opportunistically placed cage trap. Rakali were observed foraging at night along the high tide line on the beach between Town Point and the ChevronTexaco camp (Fitzpatrick, J. and Vitenbergs, A. 2004. Personal communications). Tracks on beaches indicate that the rakali occurs right around Barrow Island, particularly where rocky and sandy shorelines alternate.

Table 3-3 - Mammals Caught in Six Trapping Grids on the Proposed Development Area, November-December 2003

Species	Grid						Total
	1	2	3	4	5	6	
Dasyuridae							
Pseudantechinus sp.	0	0	1	0	0	1	2
Planigale sp.	0	1	0	1	1	0	3
Peramelidae							
Isoodon auratus barrowensis	27	20	18	29	21	21	136
Phalangeridae							
Trichosurus vulpecula	2	9	8	8	8	2	37
Potoroidae							
Bettongia lesueur	2	2	3	3	0	0	10
Macropodidae							
Lagorchestes conspicillatus	1	5	1	0	1	1	9
Muridae							
Pseudomys nanus ferculinus	1	1	0	0	1	0	3
Zyzomys argurus	0	0	1	1	0	0	2
Number of species	5	6	6	5	5	4	8
Number of specimens	33	38	32	42	32	25	202

Table 3-4 - Mammals Caught in Six Trapping Grids on the Proposed Development Area, October 2004

Species	Grid						Total
	1	2	3	4	5	6	
Dasyuridae							
Planigale sp.	0	0	0	0	1	0	1
Peramelidae							
Isoodon auratus barrowensis	30	32	44	20	35	29	190
Phalangeridae							
Trichosurus vulpecula	9	5	4	6	10	5	39
Potoroidae							
Bettongia lesueur	1	0	9	2	5	1	18
Macropodidae							
Lagorchestes conspicillatus	1	5	3	0	9	8	26
Muridae							
Pseudomys nanus ferculinus	1	0	0	7	6	0	14
Number of species	5	3	4	4	6	4	6
Number of specimens	42	42	60	35	66	43	288

Pseudantechinus sp., *Planigale* sp., *Pseudomys nanus ferculinus* and *Zyzomys argurus* were caught too infrequently for any conclusions to be drawn as to their habitat associations. *Zyzomys argurus* (the common rock-rat) is commonly associated with rocky substrates, but the two captures of this species were in sandy areas, although at one site there was coastal limestone nearby. These four species are also infrequently caught in CALM's trapping program, with trap success of <10 per cent each year (1998–2004). In 2003, only eight *Pseudomys nanus ferculinus*, six *Planigale* sp., one *Pseudantechinus* sp. and one *Zyzomys argurus* were caught from four sites in the CALM program (Burbidge et al. 2003). In 2004, only five *P. nanus ferculinus* and two *Planigale* sp. were caught from two sites in the CALM programme (Table 3-7).

Golden bandicoots and northern brushtailed possums were well represented throughout the Gorgon Development area. The golden bandicoot was abundant at all sites and there was no significant difference in the number of individuals between the six sites in 2003 (χ^2 = 4.105, df = 5). However, in 2004 there was a significant difference in the number of individual golden bandicoots between the six sites (χ^2 = 12.303, df = 5), and the abundance of golden bandicoots across the sites was significantly different between the 2003 and the 2004 surveys (χ^2 = 11.638, df = 5). The brush-tailed possum was evenly distributed across all sites in both 2003 (χ^2 = 8.53, df = 5) and 2004 (χ^2 = 4.537, df = 5), and their abundance did not vary significantly between 2003 and 2004 (χ^2 = 8.678, df = 5).

In 2003, boodies were absent from grids five and six and only two or three specimens were caught at each of the remaining sites. In 2004, boodies were recorded in slightly higher numbers, across all sites except grid two. Captures of the spectacled hare-wallabies in 2003 were generally low; the highest catch was five individuals in grid two, but in 2004, catches were generally higher, with the highest catch of nine individuals in grid five.

Opportunistic observations of hare-wallabies during landbird transects over the 2003/2004 summer indicated that these animals favour areas of tall *Triodia* grassland.

3.1.3 Comparison with CALM Trapping Data

The abundances of mammals caught in the CALM monitoring program are compared with their abundances in the proposed Gorgon Development in Table 3-5, Table 3-6 and Table 3-7.

In 2003, the abundances of all species tended to be lower in the six Gorgon grids than in the five CALM grids, despite the sampling effort being 20 % higher in the Gorgon grids (Table 3-5). However, in 2004 the abundances of spectacled hare-wallabies and *P. nanus ferculinus* were higher in the Gorgon grids than in the CALM grids.

Table 3-5 - Total Mammal Abundances from Annual Trapping by CALM (Five grids, 1998-2004) and Sampling in the Proposed Development Area (Six grids, 2003-2004)

Species	CALM 1998	CALM 2000	CALM 2003	Gorgon 2003	CALM 2004	Gorgon 2004
Pseudantechinus sp.	4	2	1	2	0	0
Planigale sp.	6	9	6	3	2	1
Isoodon auratus barrowensis	163	147	166	136	191	190
Trichosurus vulpecula	41	48	60	37	73	39
Bettongia lesueur	30	26	22	10	21	18
Lagorchestes conspicillatus	13	8	11	9	18	26
Pseudomys nanus ferculinus	14	15	8	3	5	14
Zyzomys argurus	1	4	1	2	0	0

The numbers of each mammal species caught in five (of the six) Gorgon trapping grids that most closely resemble the five CALM trapping grids, are presented with the numbers caught in the analogous CALM trapping grids in Table 3-6 (2003) and Table 3-7 (2004).

In 2003 catches of golden bandicoots on Gorgon trapping grids one and two (G1, G2) were very similar to catches in the analogous CALM sites (CALM Landing, CALM M21) and catches in Gorgon grids three, five and six were about half those of CALM sites in similar habitats (Table 3-6). In 2004, catches of golden bandicoots were similar between each of the Gorgon sites and their analogous CALM sites (Table 3-7). However, the differences between the catches of golden bandicoots on the Gorgon sites and the analogous CALM sites were not statistically different in either 2003 (χ^2 = 5.792, df = 4) or 2004 (χ^2 = 2.793, df = 4).

Catches of brushtailed possums and boodies were inconsistent between most pairs of grids (Table 3-6 and Table 3-7). The most extreme differences were between the low numbers of brushtailed possums on Gorgon grid six (2 in 2003 and 5 in 2004) compared with the high numbers caught on CALM grid S62 (21 in 2003 and 25 in 2004). These two grids were established in low *Triodia* on limestone ridges, but S62 was close to a cliff line, which probably provided shelter for possums, with no such shelter available near grid six. The differences in the abundance of brushtailed possums between the Gorgon grids and the analogous CALM grids were significant in both 2003 (χ^2 = 19.374, df = 4) and 2004 (χ^2 = 16.475, df = 4).

Table 3-6 - Comparison of Numbers of Individuals Caught on Grids in the Proposed Development Area with Numbers Caught on Analogous CALM grids in 2003

Species	Gorgon G1	CALM Landing	Gorgon G2	CALM M21	Gorgon G3	CALM JW	Gorgon G5	CALM BB	Gorgon G6	CALM S62
Pseudantechinus sp.	0	0	0	0	1	0	0	0	1	1
Planigale sp.	0	1	1	4	0	0	1	0	0	1
Golden bandicoot *Isoodon auratus barrowensis*	27	28	20	22	18	40	21	39	21	37
Brushtailed possum *Trichosurus vulpecula*	2	14	9	10	8	12	8	3	2	21
Boodie *Bettongia lesueur*	2	10	2	2	3	0	0	7	0	3
Spectacled hare-wallaby *Lagorchestes conspicillatus*	1	2	5	2	1	2	1	5	1	0
Djoori (common rock-rat) *Zyzomys argurus*	0	0	0	9	1	0	0	0	0	1
Barrow Island chestnut mouse *Pseudomys nanus ferculinus*	0	1	0	1		0	0	6	0	0

Table 3-7 - Comparison of Numbers of Individuals Caught on Grids in the Proposed Development Area with Numbers Caught on Analogous CALM grids in 2004

Species	Gorgon G1	CALM Landing	Gorgon G2	CALM M21	Gorgon G3	CALM JW	Gorgon G5	CALM BB	Gorgon G6	CALM S62
Planigale sp.	0	0	0	0	0	1	1	1	0	0
Golden bandicoot *Isoodon auratus barrowensis*	30	44	32	30	44	41	35	39	29	37
Brushtailed possum *Trichosurus vulpecula*	9	16	5	8	4	20	10	4	5	25
Boodie *Bettongia lesueur*	1	6	0	3	9	4	5	6	1	2
Spectacled hare-wallaby *Lagorchestes conspicillatus*	1	1	5	2	3	4	9	11	8	0
Barrow Island chestnut mouse *Pseudomys nanus ferculinus*	1	0	0	0	0	2	6	3	0	0

3.2 Boodie Warrens within the Study Area

There are nine boodie warrens in the proposed Development area, of which six were being actively used (Table 3-8), probably by boodies. Three additional locations where boodie warrens had been reported previously were visited, but no warrens could be found in the general area. Raw data from boodie transects, including coordinates of each transect, are presented in Attachment 3.

In addition, there were 11 locations where solution pipes in limestone provided shelter for animals and appeared to be in use (Table 3-9).

Table 3-8 - Locations, Sizes and Status of Boodie Warrens in the Proposed Development Area (between Terminal Tanks and Airport Road)

Easting	Northing	Number of entrances	Status
339279	7701400	6	Active
338813	7699703	5	Active
338809	7699637	10-20	Active
339314	7701103	11	Active
339364	7701247	3	Active
338611	7700187	20-30	Active
339499	7700165	4	Inactive
338691	7700645	9	Inactive
338072	7699979	0	Inactive

Table 3-9 - Locations, Sizes and Status of Solution Pipe Habitats Being Used for Shelter by Mammals or Reptiles in the Gorgon Wider Study Area

Easting	Northing	Number of entrances	Status
339490	7701210	3	Active
339571	7701211	4	Active
339792	7701034	2	Active
339717	7701037	10	Active
339717	7701037	10	Active
339731	7700866	4	Active
339539	7701064	TBD	unknown
339268	7701002	2	Active
378064	7700814	3	Active
338366	7700553	TBD	unknown
338768	7699202	TBD	unknown

No boodie warrens were found along the alternative pipeline route from Flacourt Bay or along the pipeline route from North White's Beach (Bamford 2002).

During surveys of boodie transects, 33 spectacled hare-wallabies were observed. If a transect width of ten metres along the 131 km of boodie transects is assumed, a search area of 131 ha is indicated, giving a population density of 0.25 hare-wallabies/ha.

3.3 Taxonomic Herpetofauna Survey

An annotated list of the reptile species collected from the proposed Development area and from other parts of Barrow Island during the 2003 taxonomic survey is presented in Attachment 6. The list also describes the voucher specimens collected, their curation and the taxonomic significance of the collections. The annotated list of the species collected during the 2004 survey is presented in Attachment 7. Attachment 8 contains a list of reptile specimens donated to WAM. Figure 3-1 displays the distribution of reptile species caught during the 2004 taxonomic study.

In total, the targeted herpetofauna surveys yielded 24 species of reptile. This compares to the 43 species known from Barrow Island (excluding sea-snakes and marine turtles) (Attachment 2). Additions to the Island's known species list are *Varanus brevicauda* trapped near Surf Point in the late 1990s (Bamford, M. 2004. Personal communication) and observed at Obe's Beach in January 2004 (Pendoley, K. & Vitenbergs, A. 2004. Personal communication) and *Ramphotyphlops grypus* collected from Latitude Point in September 2004.

Some of the species collected are poorly represented in the WAM collection and specimens were collected and curated for donation to WAM. The paucity of specimens is largely due to lack of collecting on Barrow Island, however, some species may be uncommon. For example, *Carla triacantha* was represented by only from three specimens in the WAM Barrow Island collection, from Flacourt Bay and Town Point. They are known from the inter-dunal vegetation near Town Point (Smith 1976).

Four *Ctenotus pantherinus acripes* individuals were caught or observed during the 2003 survey, and seven were caught over a wide area in the 2004 survey (Figure 3-1). This species is of conservation significance on Barrow Island because it is believed to be an endemic race, genetically and geographically separated from the nearest mainland populations in Northern Territory and Queensland. Butler (1970) caught the species on the west coast of Barrow Island. Additionally, seven *Ctenotus pantherinus acripes* were trapped over the two surveys in five of the six trapping grids (G1, G2, G3, G5, G6), suggesting a wide distribution on Barrow Island.

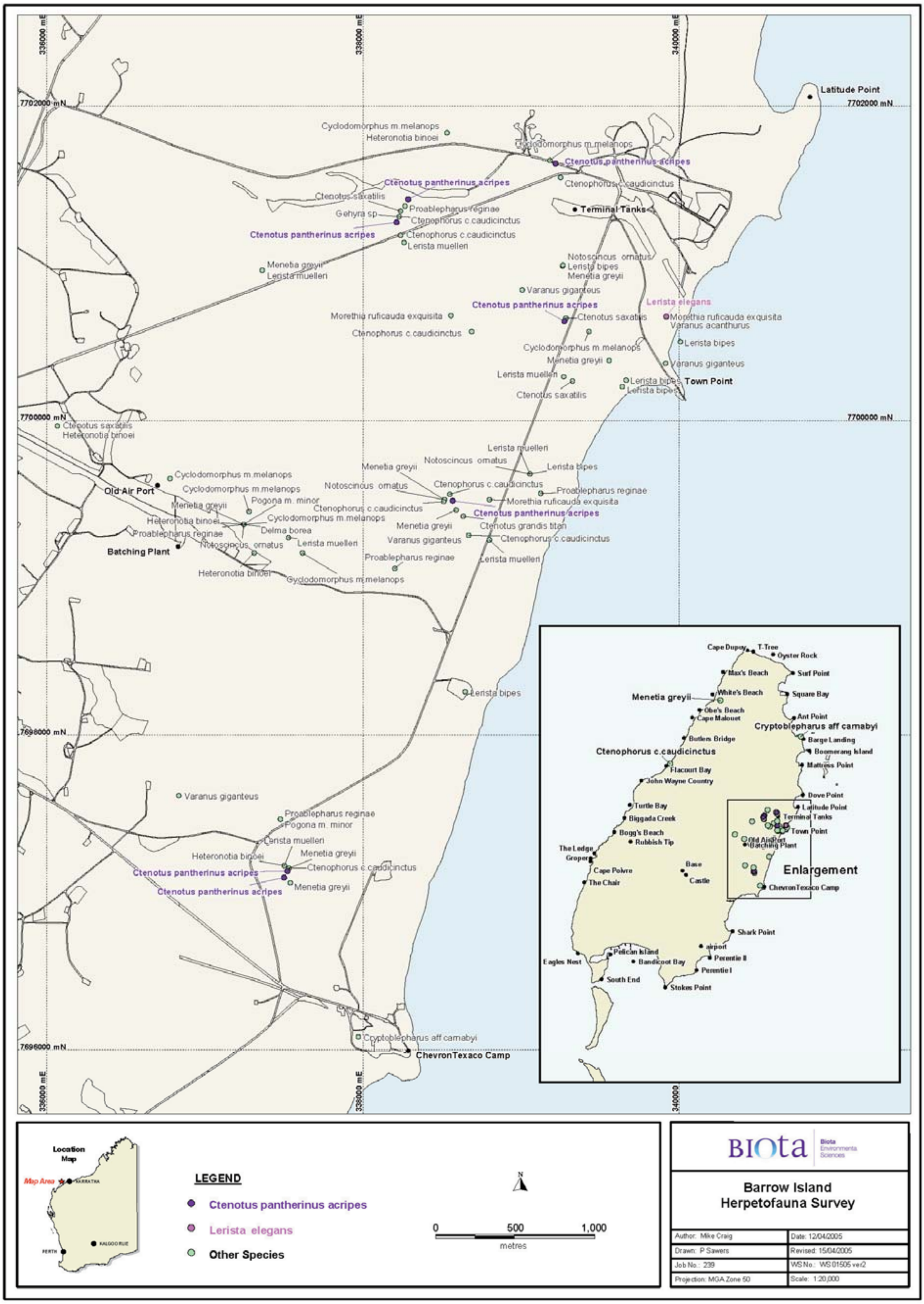

Figure 3-1 - Species Distribution of Herpetofauna Surveyed in August-September 2004

4 Discussion

4.1 Reptiles

Reptile activity on Barrow Island appeared to be low compared with some mainland sites at which the authors have worked (Teale, R. & Harold, G. 2004. Personal observations). Of the 43 reptile species known to occur on Barrow Island, 27 of these species have been identified in vicinity of the proposed Gorgon Development area through trapping, observation and opportunistic surveying.

None of the herpetofauna are geographically restricted to the proposed Development area, with all species occurring in other parts of Barrow Island. The reptile assemblage in the Gorgon trapping grids was similar to the CALM trapping grids in similar parts of the island. The existing information indicates that there are no habitats within the proposed Development area that could sustain higher than usual concentrations of any reptile species and no reptile species are restricted to the proposed Development area.

Some strong patterns in habitat association emerged for the more abundant species in the proposed Development area. Burrowing skinks such as *Lerista bipes* were closely associated with sandy soils and at Town Point and adjacent areas are probably restricted to the coastal dune system. Other skinks were associated with hard substrates. For example, *Menetia greyii*, appeared absent from sandy soils and *Notoscincus ornatus* was associated with *Melaleuca* over *Triodia* on limestone. All of these habitats are widespread within and outside the study area.

The most species-rich areas were on grid five, where the habitat was a complex of shrubs and *Triodia* on coastal primary and secondary dunes, grid one, where the vegetation was largely low *Triodia* in loam soil and grid two, which supported *Melaleuca* and *Triodia* on limestone. The most species-poor site and the site where fewest specimens were caught (grid six) was low *Triodia* in rocky soil, high in the landscape. In contrast, grids three and four, with only six species each, had high numbers of captures.

With the exception of *Ramphotyphlops longissimus*, none of the recorded herpetofauna is confined to Barrow Island. All other taxa are represented elsewhere in Western Australia or, in the case of *Ctenotus pantherinus acripes*, the Northern Territory and Queensland (Horner 1991; Wilson & Swan 2003). However, the taxonomic status of *Ctenotus pantherinus acripes* and many other reptiles on Barrow Island is uncertain. Genetic studies are required to elucidate patterns of relationship and genetic divergence of the isolated Island populations from the mainland populations. *Ctenotus pantherinus acripes* was recorded to the north and south of the proposed gas processing facility which, combined with Butler's records from the west coast, indicate that the species is widespread outside of the proposed Development area.

A number of reptile taxa are confined to Western Australian islands, including *Ramphotyphlops longissimus*, *Ramphotyphlops yampiensis*, *Aprasia rostrata*, *Ctenotus lancelini*, *Egernia pulchra longicauda*, *Lerista praefrontalis*. Island populations are recognised as important repositories for biodiversity, harbouring endemic taxa and genetic novelties, such as dwarfism. Molecular studies based on existing tissue collections have been crucial in resolving taxonomic anomalies within Western Australian taxa (e.g. the *Lerista muelleri* complex, *Delma borea* complex, *Egernia stokesii* complex). Reptile populations on Barrow Island are likely to show unique genetic characteristics as a result of their relatively long isolation.

No molecular (DNA) studies have been undertaken for Barrow Island populations due to the paucity of suitable material for genetic analysis. The current study is critical in improving the collection of tissue in WAM for future genetic studies. Prior to this work, tissue samples were available from only 23 of the 923 specimens and from just 10 of the 43 species lodged with WAM (source Western Australian Museum Fauna Database).

The implications of this lack of knowledge on the true biodiversity of the Island's herpetofauna are that all Island populations must be assumed to be unique genetic races and their conservation significance assessed accordingly.

4.2 Mammals

All of the resident mammal species known from Barrow Island, except the bats and the black-flanked rock-wallaby, occur in the vicinity of the proposed gas processing facility. All of these species are expected to occur in the vicinity of the proposed feed gas pipeline also, but no boodie warrens occur along the pipeline route. Unidentified bats have been observed along Airport Creek to the south of Town Point.

Mammal species richness and abundance on the Gorgon trapping grids varied between November-December 2003 and October 2004. This probably reflects the inter-annual variation in mammal distribution and catchability. For example, grid four showed the highest mammal abundances of the six grids in 2003 and the lowest in 2004. The high limestone with low *Triodia* grassland (grid 6) had the lowest mammal species richness and abundances in 2003, but not in 2004. The presence and abundance of mammals across the remaining sites were similar in 2003, but grid two (*Melaleuca* over *Triodia* on limestone) was species rich and had high captures of the spectacled hare-wallaby. This was not expected as the hare-wallaby was usually observed in dense *Triodia* near the coast and in valleys, but may indicate that the species forages in more open *Melaleuca* and *Triodia* habitats at night. In 2004, however, grid two had the lowest species richness, and the highest captures of hare-wallabies were on grids five and six.

Abundance of mammals tended to be lower in the Gorgon trapping sites than in the CALM sites within similar vegetated habitats even though the two surveys took place only a few weeks or days apart. Read et al. (1988) noted this sort of variability in the results of trapping based on grid layouts, probably because the grids are influenced by the surrounding habitats for animals with large home-ranges. Mammals may have been attracted to the baited traps from other habitats. For example, Gorgon grid 6 was in similar vegetation to CALM's grid S62, but the CALM site was close to a low cliff line that probably provided shelter for brushtailed possums and other mammals that were more abundant on S62 than on Gorgon grid six.

The greatest proportional difference between the CALM survey results and the current survey results was for boodies. This probably reflects the proximity of some of the CALM grids to active boodie warrens and the low abundances of boodies in the vicinity of the proposed gas processing facility.

The surveys suggest similar levels of abundance in the proposed Development area to other parts of Barrow Island. There are no unusual features within the proposed Development area that suggest unusual concentrations of any mammal species may be present. The only areas within the proposed Development area with a relatively depauperate mammal fauna were the highest points in the landscape where there was low, sparse *Triodia* and rocky ground.

The significance of the mammal populations with respect to the rest of Barrow Island can be assessed by comparison of the proportion of Barrow Island population that occurs in the proposed Development area. Burbidge et al. (2003) reviewed population estimates for mammals on Barrow Island and present a range of estimates based on different calculation methods or data sources. Other recent estimates, for example McKenzie et al. (1995) and those based on spotlighting, vary greatly.

The golden bandicoot population on Barrow Island probably ranges from 60 000–80 000 (McKenzie et al. 1995). Population estimates based on spotlighting data fall within the range 1679–3679 (Burbidge et al. 2003), but the authors stress these values should be treated with caution and suggest that the Island population is in the tens of thousands. This species is widespread and abundant throughout its range on Barrow Island.

Available estimates of the Island population of the brushtailed possum are based only on spotlighting data (Burbidge et al. 2003) and range from 650–1468. Thirty seven and thirty-nine were caught within the Gorgon Development area in 2003 and 2004 respectively. Island population estimates for the spectacled hare-wallaby are 8600 (Short et al. 1988.) and estimates based on spotlighting range from 828 to 1661 (Burbidge et al. 2003). Density estimates from the current study suggest a population of 75 individuals in the 300 ha Gorgon Development area. This equates to an Island population of approximately 5800 if the density in the Gorgon Development area is representative of densities across the whole Island.

Euros were not trapped or systematically recorded, but were regularly seen within the proposed Development area. Island population estimates for euros range from 1500 (Short et al. 1988) to 528-914 (Burbidge et al. 2003). Most euro sightings in the proposed Development area were along the coastline where cliffs and gorges provided shelter. It was estimated that ten euros were present across the Gorgon Development area. Euros are widespread across the Island in areas where there is sufficient shade.

The size of the boodie population on Barrow Island, based on spotlighting surveys, is 2884 (Burbidge et al. 2003). However, Burbidge et al. (2003) consider that such estimates should be treated with caution. The distribution of boodies is clumped because of their dependence upon warrens, and boodie numbers in the proposed Gorgon Development area can be estimated from a count of the number of warrens and warren entrances. There are six active warrens with a combined total of about 60 entrances (the number of entrances in some warrens is uncertain) within the mammal survey area (Figure 2-1). There are generally about half as many boodies present as entrances (Donaldson, F. 2004. Personal communication), suggesting approximately 30 boodies in the 658 ha sampling area at the Gorgon Development location. In trapping carried out in March 2004, 14 boodies were trapped on warrens in the Gorgon Development area. The single active warren in the gas facility footprint has 20–30 entrances, suggesting 10–15 boodie inhabitants. However, trapping at this warren (20 traps over 4 nights) caught only three boodies over two years (Donaldson, F. 2004. Personal communication).

Unlike the more mobile mammal fauna, boodies are dependent on their warrens and are expected to have limited ability to disperse into surrounding areas. Their use of surrounding areas for foraging is unknown however they appear to have home ranges of several kilometres (Donaldson, F. 2004 Personal communication). F. Donaldson is currently completing a PhD study to investigate habitat usage by boodies; however, the results of this study will not be available for several years.

Although three of the boodie warrens located were inactive, it is possible that usage of warrens by boodies varies seasonally and annually and that any existing warren may be used at some time in the future. For example, the warrens at 339499 E, 7700165 N and 338691 E, 7700645 N were active in spring 2003 but had been inactive for some weeks or months when examined in March 2004. Unlike other warrens, both were in loam soil rather than excavated beneath limestone.

5 Conclusion

The study area encompassing the proposed gas processing facility and associated infrastructure does not appear to have any intrinsic value to mammals or herpetofauna above that of adjacent and surrounding habitats.

Surveys for the proposed Gorgon Development have revealed a high diversity of mammal and reptile fauna within the proposed Development area. The initial survey in November-December 2003 indicated that all of the mammals on the Island, except the bats and the black-flanked rock-wallaby, occur near Town Point. Over half of Barrow Island's herpetofauna are known to occur in the proposed Development area. More are expected to be found in ongoing surveys.

Comparison of the capture rates within the proposed Development area with those in CALM's trapping grids distributed around the Island, suggest that mammal densities are lower in the study area than in other parts of the Island.

The habitats in which the mammals and reptiles were found are widespread across Barrow Island and well-represented in places unlikely to be affected by Development. The populations of most mammals are believed to be stable, although there is concern that the rock-wallaby population, while probably stable, may be suffering from genetic depression. Rock wallabies occur in the vicinity of the alternative shore crossing at Flacourt Bay, but not at any other proposed Development site. Reptile population sizes could not be assessed but their known distribution and habitat associations indicate that they are well represented in areas outside the Development area.

Ongoing sampling of herpetofauna populations in and around the proposed Development area will yield a valuable scientific resource for genetic determination of the true levels of endemism of Barrow Island's fauna.

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Attachment 1 - Mammal Species Recorded from Barrow Island, Based Upon Western Australian Museum Records and WAPET (1991), Excluding Marine Species

Species recorded within the proposed Development area in August 2002 or during the 2003/2004 field surveys are indicated (+). The conservation status of species under the WA Wildlife Conservation Act, Federal EPBC Act and CALM priority list is indicated. Introduced species considered to be absent from the main Island have been excluded.

Species	Observed	Conservation status
Dasyuridae		
Planigale sp.	+	
Pseudantechinus sp.	+	
Phalangeridae (possums)		
Northern brush-tailed possum *Trichosurus vulpecula arnhemensis*	+	
Peramelidae (bandicoots)		
Barrow Island golden bandicoot *Isoodon auratus barrowensis*	+	Vulnerable
Potoroidae (potoroos and bettongs)		
Barrow Island boodie *Bettongia lesueur* (Barrow Island race)	+	Vulnerable
Macropodidae (kangaroos and wallabies)		
Barrow Island spectacled hare-wallaby *Lagorchestes conspicillatus conspicillatus*	+	Vulnerable
Barrow Island euro *Macropus robustus isabellinus*	+	Vulnerable
Black-flanked rock-wallaby *Petrogale lateralis*	+	Vulnerable
Pteropodidae (fruit bats or flying-foxes)		
Black flying-fox *Pteropus alecto*		(vagrant)
Emballonuridae (sheathtail bats)		
Common sheathtail bat *Taphozous georgianus*	+	
Mollosidae (mastiff bats)		
White-striped bat *Tadarida (Nyctinomus) australis*		(vagrant)
Vespertilionidae (vesper bats)		
Vespadelus (Eptesicus) finlaysoni	+	
Muridae (rats and mice)		
Rakali or water-rat *Hydromys chrysogaster*	+	Priority 4
Barrow Island chestnut mouse or moolboo *Pseudomys nanus ferculinus*	+	Vulnerable
Djoorri or common rock-rat *Zyzomys argurus*	+	

Attachment 2 - Reptile Species Recorded from Barrow Island (Source: Butler 1970, Smith 1976; Western Australian Museum FaunaBase)(Maryan, B. 2004. Personal communication.)

Family Agamidae
*Ctenophorus c. caudicinctus**
Lophognathus gilberti
*Pogona minor**
Family Pygopodidae
*Delma borea**
*Delma nasuta**
Delma tincta
*Lialis burtonis**
*Pygopus nigriceps**
Family Gekkonidae
Diplodactylus stenodactylus
Gehyra Pilbara
*Gehyra variegata**
*Heteronotia binoei**
*Strophurus jeanae**
Family Scincidae
*Carlia triacantha**
*Cryptoblepharus carnabyi**
Ctenotus duricola
*Ctenotus grandis**
Ctenotus hanloni
*Ctenotus pantherinus acripes**
*Ctenotus saxatilis**
Ctenotus serventyi
*Cyclodomorphus melanops**
Eremiascincus richardsonii
Glaphyromorphus isolepis
*Lerista bipes**
*Lerista elegans**
*Lerista muelleri**
*Menetia greyii**
Morethia lineoocellata
*Morethia ruficauda**
*Notoscincus ornatus**
*Proablepharus reginae**
Family Typhlopidae
*Ramphotyphlops ammodytes**
Ramphotyphlops longissimus
Ramphotyphlops grypus
Family Varanidae
*Varanus acanthurus**
Varanus brevicauda
*Varanus giganteus**
Family Boidae
*Antaresia stimsoni**
Family Elapidae
Brachyurophis approximans
Demansia rufescens
Furina ornata
*Pseudechis australis**

* known to occur in the Gorgon Development area

Attachment 3 - Location of Boodie Warrens, Hare Wallaby Sightings and Solution Pipes on the East-West Transects on the Proposed Development Area.

Note: Most transects were divided into three sections, and each section was not necessarily completed on the same day

A: West of about 338000E B: Between 338000E and road C: East of road

	Transect Coordinates		Survey Date			Survey Time			Boodie warrens			Hare Wallaby sightings		Solution pipes	
	Start	Finish	A	B	C	A	B	C	Coordinates	# entrances	Active/ Inactive	Coordinates	#	Coordinates	#
1	338297E 7701850N	339124E 7701850	-	14/12	-	-	1040-1100	-							
2	338066E 7701800	339316E 7701800N	-	14/12	-	-	1010-1035	-							
3	337864E 7701750N	339467E 7701750N	16/12	14/12	-	0815-0820	0930-1005	-							
4	337500E 7701700N	339600E 7701700N	16/12	14/12	-	0755-0810	0820-0920	-							
5	337500E 7701650N	339736E 7701650N	16/12	14/12	-	0745-0755	0720-0810	-				338707E 7701645N	1		
6	337500E 7701600N	339752E 7701599N	16/12	14/12	-	0730-0740	0630-0715	-				339031E 7701607N	1		
7	337500E 7701550N	340100E 7701550N	16/12	01/10	04/10	0720-0730	1015-1120	0630-0650							
8	337500E 7701500N	340151E 7701500N	16/12	02/03	04/03	0705-0720	0630-0730	0625 0640							
9	337500E 7701450N	340233E 7701450N	16/12	02/10	04/10	0655-0705	0620-0725	0650-0705	339279E 7701400N	6	active				
10	337500E 7701400N	340307E 7701400N	16/12	02/10	04/10	0645-0655	0730-0815	0645-0700							
11	337500E	340453E	16/12	02/10	04/10	0630-	0725-	0710-							

	Transect Coordinates		Survey Date			Survey Time			Boodie warrens			Hare Wallaby sightings		Solution pipes	
	Start	Finish	A	B	C	A	B	C	Coordinates	# entrances	Active/ Inactive	Coordinates	#	Coordinates	#
	7701350N	7701350N				0640	0815	0730							
12	337500E 7701300N	339649E 7701300N	16/12	02/10	04/10	0620-0630	0820-0920					337499E 7701312N	1		
13	337500E 7701250N	340416E 7701250N	16/12	02/10	02/10	0610-0615	0820-0920	1055-1120	339364E 7701247	3	unknown	340395E 7701249N	1		
14	337500E 7701200N	340392E 7701200N	16/12	02/10	02/10	0550-0605	0925- 1030					339985E 7701115N	2	339490E 7701210N	3
														339571E 7701211N	4
15	337500E 7701150N	340299E 7701150N	15/12	02/10	02/10	1035-1045	0925- 1055								
16	337471E 7701100N	340243E 7701100N	15/12	05/10	04/10	1035-1050	1320-1430	0705-0725							
17	337500E 7701050N	340226E 7701050N	15/12	05/10	04/10	1035-1045		0740-0805						339792E 7701034N	2
														339717E 7701037N	10
														339717E 7701037N	10
														339539E 7701064N	?
18	337500E 7701000N	340227E 7701000N	15/12	05/10	04/10	1015-1025	1325-1425	0735-0800						339268E 7701002N	2
19	337495E 7700950N	340145E 7700950N	15/12	05/10	04/10	1020-1030	1435-1525	0815-0840							
20	337500E	340145E	15/12	05/10	04/10	1015-	1435-	0805-							

	Transect Coordinates		Survey Date			Survey Time			Boodie warrens			Hare Wallaby sightings		Solution pipes	
	Start	Finish	A	B	C	A	B	C	Coordinates	# entrances	Active/ Inactive	Coordinates	#	Coordinates	#
	7700900N	7700900N				1030	1525	0835							
21	337500E 7700850N	340136E 7700850N	15/12	05/10	04/10	1000-1011		0845-0915				337809E 7700852N	1		
												339983E 7700855N	1		
22	337495E 7700800N	340118E 7700800N	15/12	05/10	04/10	1005-1015	1535-1620	0840-0915				339829E 7700801N	1	378064E 7700814N	3
23	337500E 7700750N	340050E 7700750N	15/12	05/10	04/10	1000-1010	1535-1620	0920-0940				339817E 7700743N	1		
24	337500E 7700700N	340057E 7700700N	15/12	05/10	04/10	0950-0955		0920-0940							
25	337495E 7700650N	340032E 7700650N	15/12	05/10	04/10	0955-1000	1635-1730	0950-1015	338691E 7700645N	9	unknown	338706E 7700652N	1		
26	337500E 7700600N	340056E 7700600N	15/12	05/10	04/10	0945-0955	1630-1725	0945-1010							
27	337500E 7700550N	340040E 7700550	15/12	05/10	04/10	0935-0945		1025-1045						338366E7700 553N	?
28	337496E 7700500N	340076E 7700500N	15/12	12/12	04/10	0940-0950	1000-1045	1020-1045				339442E 7700497N	1		
29	337500E 7700450N	340082E 7700450N	15/12	12/12	04/10	09350-0945	1050-1135	1050-1115							
30	337500E 7700400N	340137E 7700400N	15/12	12/12	04/10	0920-0930	1350-1435	1050-1120				339621E 7700401N	1		
												337732E 7700402N	1		
31	337482E	339775E	15/12	12/12	05/10	0925-	1435-	0925-				337741E	1		

	Transect Coordinates		Survey Date			Survey Time			Boodie warrens			Hare Wallaby sightings		Solution pipes	
	Start	Finish	A	B	C	A	B	C	Coordinates	# entrances	Active/ Inactive	Coordinates	#	Coordinates	#
	7700350N	7700350N				0935	1505	0940				7700332N			
32	337500E 7700300N	339715E 7700300N	15/12	12/12	05/10	0920-0930	1505-1550	0920-0940							
33	337500E 7700250N	339677E 7700250N	15/12	12/12	05/12	0905-0915	1530-1605		338611E 7700187N	20-30	unknown				
34	337484E 7700200N	339628E 7700200N	15/12	12/12	05/10	0910-0920	1615-1640	0950-1005				339402E 7700203N	1		
35	337500E 7700150N	339625E 7700150N	15/12	12/12	05/10	0905-0915	1645-1520	0945-1000							
36	337490E 7700100N	339576E 7700100N	15/12	13/12	05/10	0850-0905	0630-0710					339145E 7700094N	1		
												339348E 7700110N	1		
37	337500E 7700050N	339541E 7700050N	15/12	13/12	05/10	0850-0900	0630-0715	1020-1040				338978E 7700055N	1		
38	337500E 7700000N	339535E 7700000N	15/12	13/12	05/10	0845-0855	0630-0715		338072E 7699979N		unknown	338969E 7700000N	1		
												339323E 7700046N	1		
												339331E 7700044N	1		
39	337500E 7699950N	339506E 7699950N	15/12	13/12	05/10	0825-0840	0720-0750					338648E 7699946N	1		
												339329E 7699964N	1		

	Transect Coordinates		Survey Date			Survey Time			Boodie warrens			Hare Wallaby sightings		Solution pipes	
	Start	Finish	A	B	C	A	B	C	Coordinates	# entrances	Active/ Inactive	Coordinates	#	Coordinates	#
40	337500E 7699900N	339485E 7699900N	15/12	13/12	05/10	0815-0825	0720-0755	1045-1110							
41	337500E 7699850N	339483E 7699850N	15/12	13/12	05/10	0750-0800	0720-0755	1110-1125							
42	337500E 7699800N	339479E 7699800N	15/12	13/12	05/10	07350 0750	0800-0830	1110-1125							
43	337500E 7699750N	339500E 7699750N	15/12	13/12	14/12	0720-0730	0800-0835	0625-0640				339373E 7699744N	1		
44	337500E 7699700N	339500E 7699700N	15/12	13/12	14/12	0710-0720	0800-0835	0625-0640	338813E 7699703N	5	not active	338614E 7699702N	1		
45	337500E 7699650N	339447E 7699650N	15/12	13/12	14/12	0655-0705	0840-0900	0645-0700	338809E 7699637N	10-20	unknown	338075E 7699448N	1		
46	337500E 7699600N	339425E 7699600N	15/12	13/12	14/12	0640-0650	0840-0905	0645-0700							
47	337500E 7699550N	339410E 7699550N	15/12	13/12	14/12	0625-0640	0840-0905	0705-0720							
48	337500E 7699500N	339393E 7699500N	14/12	13/12	14/12	1655-1710	0915-0945	0705-0720							
49	337494E 7699450N	339366E 7699450N	14/12	13/12	14/12	1700-1715	0950-1015	0730-0745							
50	337500E 7699400N	339282E 7699400N	14/12	13/12	14/12	1655-1710	1020-1045	0730-0745				338904E 7699397N	1		
												338507E 7699411N	1		
51	337500E 7699350N	339283E 7699350N	14/12	13/12	14/12	1640-1655	1050-1115	0750-0805							

	Transect Coordinates		Survey Date			Survey Time			Boodie warrens			Hare Wallaby sightings		Solution pipes	
	Start	Finish	A	B	C	A	B	C	Coordinates	# entrances	Active/ Inactive	Coordinates	#	Coordinates	#
52	337498E 7699300N	339246E 7699300N	14/12	13/12	14/12	1640-1655	1415-1435	0750-0805							
53	337500E 7699250N	339258E 7699250N	14/12	13/12	14/12	1635-1650	1435-1455	0805-0820							
54	337500E 7699200N	339241E 7699200N	14/12	13/13	14/12	1620-1635	1500-1520	0805-0820						338768E 7699202N	?
55	337685E 7699150N	339238E 7699150N	14/12	13/12	14/12	1620-1630	1525-1555	0825-0840				338544E 7699152N	1		
56	337925E 7699100N	339228E 7699100N	14/12	13/12	14/12	1620-1625	1555-1635	0825-0840							
57	338000E 7699050N	339218E 7699050N	-	13/12	14/12	-	1640-1700	0845-0900							
58	338557E 7699000N	339189E 7699000N	-	16/12	14/12	-	0800-0810	0845-0900							
59	338575E 7698950N	339201E 7698950N	-	16/12	16/12	-	0810-0815	0800-0810							
60	338604E 7698900N	339168E 7698900N	-	16/12	16/12	-	0815-0820	0810-0825							
61	338625E 7698850N	339160E 7698850N	-	16/12	16/12	-	0820-0825	0830-0845							
62	338698E 7698800N	339139E 7698800N	-	-	16/12	-	-	0828-0840							
63	338680E 7698750N	339134E 7698750N	-	-	16/12	-	-	0845-0900				338745E 7698749N	1		
64	338671E 7698700N	339117E 7698700N	-	-	16/12	-	-	0843-0855							

	Transect Coordinates		Survey Date			Survey Time			Boodie warrens			Hare Wallaby sightings		Solution pipes	
	Start	Finish	A	B	C	A	B	C	Coordinates	# entrances	Active/ Inactive	Coordinates	#	Coordinates	#
65	338698E 7698650N	339045E 7698650N	-	-	16/12	-	-	0850-0857				338796E 7698632N	1		
66	338725E 7698600N	338998E 7698609N	-	-	16/12	-	-	0900-0905				338774E 7698607N	1		

Attachment 4 - Details of Reptile Captures on the Six Grids in the Gorgon Development Area, November-December 2003 and October 2004

Number is the individual mark (toe-clipping) given to some species. Cryo number and Museum number are for specimens collected and preserved for taxonomic studies.

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
01/12/03	AM	1	E13	*Ctenotus grandis*	7		115	272	32.1	Y	F	BIMB043	
01/12/03	AM	1	P18	*Ctenotus saxatilis*	3		100	239	20.2	Y	F	BIMB033	
01/12/03	AM	1	P25	*Lerista bipes*			50	93		N			R154171
01/12/03	AM	2	P25	*Ctenotus grandis*	6		117	265	33.3	Y		BIMB042	
01/12/03	AM	2	P18	*Heteronotia binoei*	4		37	85		Y			
01/12/03	AM	2	P11	*Lerista bipes*			51	90		N			R154172
01/12/03	AM	2	P12	*Lerista bipes*			53	104		N			
01/12/03	AM	2	P18	*Lerista bipes*			46	86		N			
01/12/03	AM	2	P23	*Lerista bipes*			49	95		N			
01/12/03	AM	2	P25	*Menetia greyii*			23	61		N	M		
01/12/03	AM	2	P13	*Notoscincus ornatus*	3		39	84		N			
01/12/03	PM	6	P16	*Lerista muelleri*			35	76		N			
02/12/03	AM	6	E09	*Ctenotus saxatilis*	1		98	226	15.4	Y	F	BIMB045	
02/12/03	AM	6	P08	*Delma nasuta*			80	294	5.0	N	F		
25/11/03	PM	4	P10	*Lerista bipes*			50	55		Y			
25/11/03	PM	4	P24	*Lerista bipes*			30	49		N			
25/11/03	PM	4	P25	*Lerista muelleri*			32	52		B			R154167
25/11/03	PM	5	P01	*Lerista muelleri*			33	80		N			
25/11/03	PM	5	P21	*Pogona minor*	1		39	103				BIMB001	
25/11/03	PM	5	P23	*Pogona minor*			105	288	33.0				

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
26/11/03	AM	4	P13	*Delma borea*			79	325		N			R154148
26/11/03	AM	4	P02	*Lerista bipes*			51	95	0.7	N			
26/11/03	AM	4	P02	*Lerista bipes*			54	90	0.9	Y			
26/11/03	PM	4	P04	*Lerista bipes*			56	92	0.9	Y			
26/11/03	PM	4	P10	*Lerista bipes*			42	76	0.4	N			
26/11/03	AM	4	P14	*Lerista bipes*			54	85	0.8	Y			
26/11/03	PM	4	P16	*Lerista bipes*			52	98		N		BIMB007	
26/11/03	AM	4	P17	*Lerista bipes*			54	100	0.9	N			
26/11/03	AM	4	P21	*Lerista bipes*			50	77	0.6	Y			
26/11/03	AM	4	P21	*Lerista bipes*			57	101	0.6	N			
26/11/03	PM	4	P24	*Lerista bipes*			54	87	0.8	N			
26/11/03	AM	4	P25	*Lerista bipes*			53	82	0.6	Y			
26/11/03	AM	4	P02	*Lerista muelleri*			22	45	0.1	N			
26/11/03	PM	4	P02	*Lerista muelleri*			35	70	0.3	N		BIMB009	
26/11/03	PM	4	P14	*Lerista muelleri*			35	86	0.5	B		BIMB008	
26/11/03	PM	4	P14	*Lerista muelleri*			20	40		N			
26/11/03	PM	4	P23	*Lerista muelleri*			33	66	0.4	Y		BIMB006	
26/11/03	AM	5	P25	*Heteronotia binoei*	1		40	98	1.7	N		BIMB002	
26/11/03	AM	5	P01	*Lerista bipes*			51	96	0.7	N			
26/11/03	AM	5	P01	*Lerista bipes*			55	96	0.8	N			
26/11/03	AM	5	P01	*Lerista bipes*			51	96	0.7	N			
26/11/03	AM	5	P04	*Lerista bipes*			52	82	0.7	Y			
26/11/03	AM	5	P04	*Lerista bipes*			51	93	0.6	N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
26/11/03	AM	5	P05	*Lerista bipes*			49	90	0.7	N			
26/11/03	AM	5	P06	*Lerista bipes*			52	95	0.7	N			
26/11/03	AM	5	P06	*Lerista bipes*			52	85	0.7	Y			
26/11/03	AM	5	P07	*Lerista bipes*			55	89	1.0	Y			
26/11/03	AM	5	P13	*Lerista bipes*			55	98	0.8	N			
26/11/03	AM	5	P13	*Lerista bipes*			49	95	0.6	N			
26/11/03	AM	5	P14	*Lerista bipes*			53	101	0.7	N			
26/11/03	AM	5	P14	*Lerista bipes*			53	95	0.7	N			
26/11/03	AM	5	P15	*Lerista bipes*			55	92	0.8	N			
26/11/03	AM	5	P15	*Lerista bipes*			57	96	0.9	Y			
26/11/03	AM	5	P18	*Lerista bipes*			54	99	0.7	N			
26/11/03	PM	5	P04	*Lerista muelleri*			35	65				BIMB003	
26/11/03	PM	5	P08	*Lerista muelleri*			32	67	0.4	N		BIMB004	
26/11/03	AM	5	P03	*Lialis burtonis*			165	320	12.5	N			
26/11/03	PM	5	P20	*Lialis burtonis*			170	380	9.0	N			
26/11/03	AM	5	P09	*Menetia greyii*			?	?					
26/11/03	PM	5	P18	*Proablepharus reginae*	1		32	96				BIMB005	
27/11/03	PM	1	P13	*Delma nasuta*			96	335		N		BIMB030	
27/11/03	PM	1	P11	*Lerista muelleri*			37	78		N			
27/11/03	PM	1	P21	*Lerista muelleri*			34	77		Y			
27/11/03	PM	1	P24	*Lerista muelleri*			36	88		N			
27/11/03	PM	1	P24	*Lerista muelleri*			37	47		B			R154162
27/11/03	PM	1	P01	*Menetia greyii*	2		25	59		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
27/11/03	PM	1	P16	*Menetia greyii*	1		24	43		Y			
27/11/03	PM	1	P21	*Menetia greyii*	12		27	55		N			
27/11/03	PM	2	P02	*Carlia triacantha*			?	?					
27/11/03	PM	2	P03	*Lerista muelleri*			36	83		N			
27/11/03	PM	2	P09	*Lerista muelleri*			36	64		Y		BIMB029	
27/11/03	PM	2	P17	*Lerista muelleri*			37	85		N			
27/11/03	PM	2	P03	*Ramphotyphlops ammodytes*			?	?					
27/11/03	PM	2	P12	*Varanus acanthurus*	1		127	322	27.0		F	BIMB013	
27/11/03	AM	3	P01	*Lerista bipes*			55	105	1.0	N			
27/11/03	AM	3	P02	*Lerista bipes*			53	91	0.7	Y			
27/11/03	AM	3	P04	*Lerista bipes*			52	97	0.8	N			
27/11/03	AM	3	P05	*Lerista bipes*			52	91	0.8	Y			
27/11/03	AM	3	P05	*Lerista bipes*			56	98	1.0	Y			
27/11/03	AM	3	P05	*Lerista bipes*			48	90	0.5	N			
27/11/03	AM	3	P08	*Lerista bipes*			52	95	0.8	N			
27/11/03	AM	3	P08	*Lerista bipes*			56	95	0.7	N			
27/11/03	AM	3	P08	*Lerista bipes*			55	101	0.8	N			
27/11/03	AM	3	P11	*Lerista bipes*			52	82	0.6	Y			
27/11/03	AM	3	P11	*Lerista bipes*			54	81	0.7	Y			
27/11/03	AM	3	P12	*Lerista bipes*			50	84	0.5	N			
27/11/03	AM	3	P13	*Lerista bipes*			55	100	0.9	N			
27/11/03	AM	3	P14	*Lerista bipes*			47	85	0.5	N			
27/11/03	AM	3	P15	*Lerista bipes*			53	85	0.8	Y			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
27/11/03	AM	3	P15	*Lerista bipes*			45	80	0.4	N			
27/11/03	AM	3	P20	*Lerista bipes*			55	91	0.9	Y			
27/11/03	AM	3	P21	*Lerista bipes*			55	100	0.7	N			
27/11/03	AM	3	P23	*Lerista bipes*			52	86	0.7	N			
27/11/03	AM	3	P24	*Lerista bipes*			57	107	0.9	N			
27/11/03	AM	3	P24	*Lerista bipes*			47	80	0.6	N			
27/11/03	PM	3	P12	*Lerista muelleri*			35	88		N			R154166
27/11/03	PM	3	P17	*Lerista muelleri*			37	85		N			
27/11/03	AM	4	E03	*Ctenotus grandis*	1		80	228	11.0	N			
27/11/03	PM	4	P12	*Cyclodomorphus melanops*			143	239	22.0	Y			R154152
27/11/03	AM	4	P02	*Lerista bipes*			53	77	0.8	Y			
27/11/03	AM	4	P03	*Lerista bipes*			42	51	0.7	B		BIMB011	
27/11/03	AM	4	P06	*Lerista bipes*			50	96	0.7	N			
27/11/03	AM	4	P12	*Lerista bipes*			56	92	0.9	Y			
27/11/03	AM	4	P13	*Lerista bipes*			56	100	0.8	N			
27/11/03	AM	4	P15	*Lerista bipes*			53	96	0.8	N			
27/11/03	AM	4	P20	*Lerista bipes*			52	98	0.8	N			
27/11/03	AM	4	P21	*Lerista bipes*			50	88	0.6	N		BIMB010	
27/11/03	AM	4	P24	*Lerista bipes*			57	100	1.0	N			
27/11/03	AM	4	P25	*Lerista bipes*			57	91	0.8	Y			
27/11/03	AM	4	P03	*Lerista muelleri*			35	84	0.6	N			
27/11/03	AM	5	P02	*Lerista bipes*			55	86	0.6	Y			
27/11/03	AM	5	P03	*Lerista bipes*			55	100	0.8	N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
27/11/03	AM	5	P06	*Lerista bipes*			55	95		B			
27/11/03	AM	5	P06	*Lerista bipes*			50	87	0.7	N			
27/11/03	AM	5	P07	*Lerista bipes*			52	82	0.7	Y			
27/11/03	AM	5	P07	*Lerista bipes*			53	88	0.7	Y			
27/11/03	AM	5	P08	*Lerista bipes*			57	75	0.6	Y			
27/11/03	AM	5	P08	*Lerista bipes*			53	80	0.5	Y			
27/11/03	AM	5	P08	*Lerista bipes*			50	86	0.8	N			
27/11/03	AM	5	P12	*Lerista bipes*			55	90	0.8	Y			
27/11/03	AM	5	P13	*Lerista bipes*			55	95	0.7	Y			
27/11/03	AM	5	P14	*Lerista bipes*			58	102	1.0	Y			
27/11/03	AM	5	P14	*Lerista bipes*			51	95	0.7	N			
27/11/03	AM	5	P16	*Lerista bipes*			53	96	0.8	N			
27/11/03	PM	5	P04	*Lerista muelleri*			34	68		Y			R154164
27/11/03	PM	5	P05	*Lerista muelleri*			35	84		N			R154165
27/11/03	AM	5	P15	*Pogona minor*	2		80	240	15.0			BIMB012	
28/11/03	PM	1	P03	*Ctenotus grandis*			110	221	26.7	Y		BIMB031	
28/11/03	AM	1	P15	*Ctenotus grandis*			109	296	28.9	N	F	BIMB017	
28/11/03	AM	1	P18	*Ctenotus grandis*			114	235	22.2	Y		BIMB016	
28/11/03	PM	1	P07	*Cyclodomorphus melanops*			113	223	16.0	N			R154160
28/11/03	PM	1	P15	*Delma nasuta*			110	288	9.5	Y			R154170
28/11/03	AM	1	P11	*Heteronotia binoei*			40	87		N			
28/11/03	PM	1	P10	*Lerista muelleri*			32	69		N	F		R154163
28/11/03	PM	1	P10	*Menetia greyii*			23	53		N			R154169

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
28/11/03	PM	1	P21	*Menetia greyii*			23	27		B			R154161
28/11/03	AM	1	P22	*Menetia greyii*	3		26	54		N			
28/11/03	AM	2	P02	*Ctenotus grandis*	3		116	252	27.1	Y	F	BIMB018	
28/11/03	AM	2	P25	*Ctenotus grandis*	4		91	212	12.7	Y		BIMB019	
28/11/03	AM	2	P03	*Ctenotus saxatilis*			88	238		Y	F		R154150
28/11/03	AM	2	P12	*Heteronotia binoei*	2		39	99		Y			
28/11/03	AM	2	P20	*Lerista bipes*			44	84		N			
28/11/03	AM	2	P22	*Lerista bipes*			59	97		Y			
28/11/03	PM	2	P25	*Lerista muelleri*			32	76		N		BIMB028	
28/11/03	AM	2	P13	*Menetia greyii*			23	47		N			R154153
28/11/03	PM	2	P13	*Menetia greyii*	8		21	43		Y			
28/11/03	AM	2	P20	*Menetia greyii*	3.4		28	62		N			
28/11/03	PM	2	P20	*Menetia greyii*	9		24	39		Y			
28/11/03	AM	2	P22	*Notoscincus ornatus*			35	83		Y	F		R154147
28/11/03	AM	2	P22	*Notoscincus ornatus*	1		35	94		N			
28/11/03	PM	2	P24	*Notoscincus ornatus*			33	64		Y			R154159
28/11/03	PM	2	P24	*Notoscincus ornatus*			?	?					
28/11/03	PM	3	P02	*Ctenotus grandis*	2		126	307	32.3	N	F	BIMB035	
28/11/03	PM	3	P16	*Ctenotus grandis*			113	311	39.9	N		BIMB034	
28/11/03	AM	3	P23	*Ctenotus grandis*	1		112	262		N	F	BIMB015	
28/11/03	AM	3	P06	*Lerista bipes*		R	53	93		N			
28/11/03	AM	3	P25	*Lerista bipes*		R	55	96		Y			
28/11/03	AM	3	P03	*Lerista bipes*			58	94		Y			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
28/11/03	AM	3	P03	*Lerista bipes*			52	100		N			
28/11/03	AM	3	P03	*Lerista bipes*			55	88		Y			
28/11/03	AM	3	P04	*Lerista bipes*			52	60		B		BIMB014	
28/11/03	AM	3	P04	*Lerista bipes*			55	101		N			
28/11/03	AM	3	P05	*Lerista bipes*			42	76		N			
28/11/03	AM	3	P09	*Lerista bipes*			53	100		N			
28/11/03	AM	3	P09	*Lerista bipes*			36	60		N			
28/11/03	AM	3	P10	*Lerista bipes*			56	95		Y			
28/11/03	AM	3	P10	*Lerista bipes*			52	89		Y			
28/11/03	AM	3	P11	*Lerista bipes*			55	90		N			
28/11/03	AM	3	P12	*Lerista bipes*			54	99		N			
28/11/03	AM	3	P13	*Lerista bipes*			54	99		N			
28/11/03	AM	3	P13	*Lerista bipes*			49	97		N			
28/11/03	AM	3	P14	*Lerista bipes*			47	86		Y			
28/11/03	AM	3	P16	*Lerista bipes*			54	105		N			
28/11/03	AM	3	P17	*Lerista bipes*			57	102		N			
28/11/03	AM	3	P17	*Lerista bipes*			50	92		N			
28/11/03	AM	3	P19	*Lerista bipes*			57	104		N			
28/11/03	AM	3	P19	*Lerista bipes*			54	101		N			
28/11/03	AM	3	P19	*Lerista bipes*			47	79		N			
28/11/03	AM	3	P20	*Lerista bipes*			54	103		N			
28/11/03	AM	3	P20	*Lerista bipes*			?	?					
28/11/03	AM	3	P21	*Lerista bipes*			54	101		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
28/11/03	AM	3	P21	*Lerista bipes*			55	94		Y			
28/11/03	AM	3	P21	*Lerista bipes*			53	97		N			
28/11/03	AM	3	P25	*Lerista bipes*			56	94		Y			
28/11/03	PM	3	P06	*Lerista muelleri*			38	69		N			
28/11/03	AM	4	E19	*Ctenotus saxatilis*	1		110	250	31.3	Y		BIMB022	
28/11/03	AM	4	P09	*Lerista bipes*			55	103					
28/11/03	AM	4	P09	*Lerista bipes*			42	76					
28/11/03	AM	4	P10	*Lerista bipes*			55	92					
28/11/03	AM	4	P17	*Lerista bipes*			50	92		Y			
28/11/03	AM	4	P17	*Lerista bipes*			54	97		Y			
28/11/03	AM	4	P19	*Lerista bipes*			54	89		Y			
28/11/03	AM	4	P20	*Lerista bipes*			55	84		Y			
28/11/03	AM	4	P21	*Lerista bipes*			57	64		B		BIMB021	
28/11/03	AM	4	P21	*Lerista bipes*			56	99		N			
28/11/03	AM	4	P23	*Lerista bipes*			55	64		B		BIMB020	
28/11/03	PM	4	P03	*Lerista muelleri*			38	82		N			
28/11/03	AM	4	P08	*Lerista muelleri*			35	85					
28/11/03	AM	5	P06	*Ctenotus pantherinus*			45	75		N			R154151
28/11/03	AM	5	P02	*Ctenotus saxatilis*			120	340		N	F		R154149
28/11/03	AM	5	P15	*Heteronotia binoei*	2		38	92		N			
28/11/03	AM	5	P01	*Lerista bipes*			53	88		Y			
28/11/03	AM	5	P03	*Lerista bipes*			52	58		B			
28/11/03	AM	5	P05	*Lerista bipes*			42	75		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
28/11/03	AM	5	P07	*Lerista bipes*			51	61		B		BIMB024	
28/11/03	AM	5	P07	*Lerista bipes*			51	95					
28/11/03	AM	5	P08	*Lerista bipes*			58	109		N			
28/11/03	AM	5	P10	*Lerista bipes*			53	100		N			
28/11/03	AM	5	P10	*Lerista bipes*			51	96		N			
28/11/03	AM	5	P14	*Lerista bipes*			53	97		N			
28/11/03	AM	5	P15	*Lerista bipes*			48	53		B		BIMB023	
28/11/03	PM	5	P17	*Lerista bipes*			56	94		Y			
28/11/03	AM	5	P18	*Lerista bipes*			52	99		N			
28/11/03	AM	5	P19	*Lerista bipes*			55	97		N			
28/11/03	AM	5	P20	*Lerista bipes*			51	99		N			
28/11/03	AM	5	P20	*Lerista bipes*			58	107		N			
28/11/03	AM	5	P25	*Lerista bipes*			53	96		N			
28/11/03	AM	5	P25	*Lerista bipes*			53	88		N			
28/11/03	PM	5	P14	*Lerista muelleri*			19	43		N			
28/11/03	PM	5	P20	*Lerista muelleri*			36	92		N			
28/11/03	PM	6	P14	*Lerista muelleri*			35	81		N			
28/11/03	PM	6	P17	*Lerista muelleri*			36	45		Y			
29/11/03	PM	1	P22	*Ctenotus grandis*	3		81	216	10.4	N	F	BIMB040	
29/11/03	PM	1	P04	*Ctenotus pantherinus*			98	234	21.9	N	F		
29/11/03	AM	1	P24	*Lerista bipes*			52	96		N			
29/11/03	AM	1	P20	*Menetia greyii*	10		23	39		Y			
29/11/03	AM	1	P05	*Notoscincus ornatus*			35	88		N			R154155

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
29/11/03	AM	2	P25	*Ctenotus grandis*	5		95	215	24.0	Y		BIMB027	
29/11/03	AM	2	P08	*Ctenotus saxatilis*	2		92	244	26.0	Y	F	BIMB025	
29/11/03	AM	2	P07	*Lerista bipes*			49	93					
29/11/03	AM	2	P14	*Lerista bipes*			50	82		Y			
29/11/03	AM	2	P16	*Lerista bipes*			?	?					
29/11/03	AM	2	P20	*Lerista bipes*			50	99		N			
29/11/03	AM	2	P24	*Lerista bipes*			55	96		N			
29/11/03	AM	2	P14	*Lerista muelleri*		R	?	?					
29/11/03	AM	3	P12	*Ctenotus grandis*	3		127	321	32.8	N	F	BIMB038	
29/11/03	AM	3	P20	*Ctenotus grandis*	4		121	234	32.9	Y	F	BIMB039	
29/11/03	AM	3	P19	*Cyclodomorphus melanops*			104	186	22.0	Y			R154154
29/11/03	AM	3	P01	*Lerista bipes*		R	57	109		N			
29/11/03	AM	3	P02	*Lerista bipes*			52	86		N			
29/11/03	AM	3	P04	*Lerista bipes*			54	72		Y		BIMB037	
29/11/03	AM	3	P04	*Lerista bipes*			52	88		N			
29/11/03	AM	3	P04	*Lerista bipes*			39	70		N			
29/11/03	AM	3	P06	*Lerista bipes*			35	59		N			
29/11/03	AM	3	P08	*Lerista bipes*			60	109		N			
29/11/03	AM	3	P10	*Lerista bipes*			58	94		N			
29/11/03	AM	3	P10	*Lerista bipes*			46	72		Y			
29/11/03	AM	3	P15	*Lerista bipes*			53	100		N			
29/11/03	AM	3	P15	*Lerista bipes*			45	87		N			
29/11/03	AM	3	P16	*Lerista bipes*			51	97		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
29/11/03	AM	3	P16	*Lerista bipes*			58	110		N			
29/11/03	AM	3	P17	*Lerista bipes*			54	85		Y			
29/11/03	PM	3	P01	*Lerista muelleri*			32	79		N			
29/11/03	PM	3	P08	*Lerista muelleri*			34	64		Y			
29/11/03	PM	3	P20	*Lerista muelleri*			40	72		Y			
29/11/03	AM	4	P12	*Lerista bipes*			57	104		N			
29/11/03	AM	4	P14	*Lerista bipes*			54	99		N			
29/11/03	AM	4	P16	*Lerista bipes*			55	102		N			
29/11/03	AM	4	P24	*Lerista bipes*			53	97		N			
29/11/03	AM	5	P03	*Lerista bipes*			52	98		N		BIMB036	
29/11/03	AM	5	P13	*Lerista bipes*			53	96		N			
29/11/03	AM	5	P14	*Lerista bipes*			57	107		N			
29/11/03	AM	5	P20	*Lerista bipes*			44	80		N			
29/11/03	AM	5	P03	*Menetia greyii*			25	52			M		R154158
29/11/03	AM	6	P15	*Heteronotia binoei*	2		43	108		N		BIMB044	
29/11/03	AM	6	P23	*Heteronotia binoei*	1		42	76		Y	M		
29/11/03	AM	6	P03	*Menetia greyii*			19	39		N			R154156
29/11/03	AM	6	P09	*Menetia greyii*			24	54		N			R154157
29/11/03	AM	6	P15	*Menetia greyii*			20	39		Y			
29/11/03	AM	6	P23	*Menetia greyii*	1		24	52		N			
30/11/03	AM	1	P24	*Lerista bipes*			52	82		Y			
30/11/03	PM	1	P05	*Lerista muelleri*			20	43		N			
30/11/03	AM	1	P22	*Menetia greyii*	11		24	57		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
30/11/03	PM	2	P07	*Heteronotia binoei*	3		44	100		N			
30/11/03	PM	2	P09	*Lerista bipes*			54	80		Y			
30/11/03	AM	2	P12	*Lerista bipes*			53	81		Y			
30/11/03	AM	2	P14	*Lerista bipes*			54	94		Y			
30/11/03	AM	2	P16	*Lerista bipes*			51	88		N			
30/11/03	PM	2	P19	*Lerista bipes*			54	92		Y			
30/11/03	PM	2	P21	*Lerista bipes*			56	71		B			
30/11/03	PM	2	P07	*Lerista muelleri*			39	74		Y			
30/11/03	AM	2	P17	*Notoscincus ornatus*	2		36	91		N			
30/11/03	AM	3	P05	*Ctenotus pantherinus*			31	77					R154168
30/11/03	AM	3	P02	*Lerista bipes*			52	84		Y			
30/11/03	AM	3	P02	*Lerista bipes*			55	90		Y			
30/11/03	AM	3	P03	*Lerista bipes*			57	103		N			
30/11/03	AM	3	P04	*Lerista bipes*			53	97		N			
30/11/03	AM	3	P05	*Lerista bipes*			52	99		N			
30/11/03	AM	3	P06	*Lerista bipes*			56	79		B		BIMB041	
30/11/03	AM	3	P07	*Lerista bipes*			57	83		Y			
30/11/03	AM	3	P08	*Lerista bipes*			59	92		N			
30/11/03	AM	3	P17	*Lerista bipes*			54	96		Y			
30/11/03	PM	3	P10	*Lerista muelleri*			34	81		N			
30/11/03	PM	3	P21	*Lerista muelleri*			?	?					
30/11/03	PM	3	P15	*Morethia ruficauda*			36	43		B		BIMB032	R154174
30/11/03	PM	6	P16	*Lerista muelleri*			21	46		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
30/11/03	PM	6	P17	*Lerista muelleri*			35	78		N			
30/11/03	AM	6	P11	*Menetia greyii*	3		25	56		N			
30/11/03	PM	6	P19	*Menetia greyii*			22	55		N			
01/12/03	AM	1	E13	*Ctenotus grandis*	7		115	272	32.1	Y	F	BIMB043	
01/12/03	AM	1	P18	*Ctenotus saxatilis*	3		100	239	20.2	Y	F	BIMB033	
01/12/03	AM	1	P25	*Lerista bipes*			50	93		N			R154171
01/12/03	AM	2	P25	*Ctenotus grandis*	6		117	265	33.3	Y		BIMB042	
01/12/03	AM	2	P18	*Heteronotia binoei*	4		37	85		Y			
01/12/03	AM	2	P11	*Lerista bipes*			51	90		N			R154172
01/12/03	AM	2	P12	*Lerista bipes*			53	104		N			
01/12/03	AM	2	P18	*Lerista bipes*			46	86		N			
01/12/03	AM	2	P23	*Lerista bipes*			49	95		N			
01/12/03	AM	2	P25	*Menetia greyii*			23	61		N	M		
01/12/03	AM	2	P13	*Notoscincus ornatus*	3		39	84		N			
01/12/03	PM	6	P16	*Lerista muelleri*			35	76		N			
02/12/03	AM	6	E09	*Ctenotus saxatilis*	1		98	226	15.4	Y	F	BIMB045	
02/12/03	AM	6	P08	*Delma nasuta*			80	294	5.0	N	F		
25/11/03	PM	4	P10	*Lerista bipes*			50	55		Y			
25/11/03	PM	4	P24	*Lerista bipes*			30	49		N			
25/11/03	PM	4	P25	*Lerista muelleri*			32	52		B			R154167
25/11/03	PM	5	P01	*Lerista muelleri*			33	80		N			
25/11/03	PM	5	P21	*Pogona minor*	1		39	103				BIMB001	
25/11/03	PM	5	P23	*Pogona minor*			105	288	33.0				

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
26/11/03	AM	4	P13	*Delma borea*			79	325		N			R154148
26/11/03	AM	4	P02	*Lerista bipes*			51	95	0.7	N			
26/11/03	AM	4	P02	*Lerista bipes*			54	90	0.9	Y			
26/11/03	PM	4	P04	*Lerista bipes*			56	92	0.9	Y			
26/11/03	PM	4	P10	*Lerista bipes*			42	76	0.4	N			
26/11/03	AM	4	P14	*Lerista bipes*			54	85	0.8	Y			
26/11/03	PM	4	P16	*Lerista bipes*			52	98		N		BIMB007	
26/11/03	AM	4	P17	*Lerista bipes*			54	100	0.9	N			
26/11/03	AM	4	P21	*Lerista bipes*			50	77	0.6	Y			
26/11/03	AM	4	P21	*Lerista bipes*			57	101	0.6	N			
26/11/03	PM	4	P24	*Lerista bipes*			54	87	0.8	N			
26/11/03	AM	4	P25	*Lerista bipes*			53	82	0.6	Y			
26/11/03	AM	4	P02	*Lerista muelleri*			22	45	0.1	N			
26/11/03	PM	4	P02	*Lerista muelleri*			35	70	0.3	N		BIMB009	
26/11/03	PM	4	P14	*Lerista muelleri*			35	86	0.5	B		BIMB008	
26/11/03	PM	4	P14	*Lerista muelleri*			20	40		N			
26/11/03	PM	4	P23	*Lerista muelleri*			33	66	0.4	Y		BIMB006	
26/11/03	AM	5	P25	*Heteronotia binoei*	1		40	98	1.7	N		BIMB002	
26/11/03	AM	5	P01	*Lerista bipes*			51	96	0.7	N			
26/11/03	AM	5	P01	*Lerista bipes*			55	96	0.8	N			
26/11/03	AM	5	P01	*Lerista bipes*			51	96	0.7	N			
26/11/03	AM	5	P04	*Lerista bipes*			52	82	0.7	Y			
26/11/03	AM	5	P04	*Lerista bipes*			51	93	0.6	N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
26/11/03	AM	5	P05	*Lerista bipes*			49	90	0.7	N			
26/11/03	AM	5	P06	*Lerista bipes*			52	95	0.7	N			
26/11/03	AM	5	P06	*Lerista bipes*			52	85	0.7	Y			
26/11/03	AM	5	P07	*Lerista bipes*			55	89	1.0	Y			
26/11/03	AM	5	P13	*Lerista bipes*			55	98	0.8	N			
26/11/03	AM	5	P13	*Lerista bipes*			49	95	0.6	N			
26/11/03	AM	5	P14	*Lerista bipes*			53	101	0.7	N			
26/11/03	AM	5	P14	*Lerista bipes*			53	95	0.7	N			
26/11/03	AM	5	P15	*Lerista bipes*			55	92	0.8	N			
26/11/03	AM	5	P15	*Lerista bipes*			57	96	0.9	Y			
26/11/03	AM	5	P18	*Lerista bipes*			54	99	0.7	N			
26/11/03	PM	5	P04	*Lerista muelleri*			35	65				BIMB003	
30/11/03	AM	3	P04	*Lerista bipes*			53	97		N			
30/11/03	AM	3	P05	*Lerista bipes*			52	99		N			
30/11/03	AM	3	P06	*Lerista bipes*			56	79		B		BIMB041	
30/11/03	AM	3	P07	*Lerista bipes*			57	83		Y			
30/11/03	AM	3	P08	*Lerista bipes*			59	92		N			
30/11/03	AM	3	P17	*Lerista bipes*			54	96		Y			
30/11/03	PM	3	P10	*Lerista muelleri*			34	81		N			
30/11/03	PM	3	P21	*Lerista muelleri*			?	?					
30/11/03	PM	3	P15	*Morethia ruficauda*			36	43		B		BIMB032	R154174
30/11/03	PM	6	P16	*Lerista muelleri*			21	46		N			
30/11/03	PM	6	P17	*Lerista muelleri*			35	78		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
30/11/03	AM	6	P11	*Menetia greyii*	3		25	56		N			
30/11/03	PM	6	P19	*Menetia greyii*			22	55		N			
16/10/04	AM	3	P6	*Ctenotus grandis*	6		115	285	37	?			
16/10/04	PM	3	P9	*Ctenotus grandis*	7		125	325		N			
16/10/04	AM	3	P15	*Cyclodomorphus melanops*	6		78	158		N			
16/10/04	AM	3	P22	*Diplodactylus jeanae*	NA								
16/10/04	AM	3	P14	*Lerista bipes*	tc		56	100		N			
16/10/04	AM	3	P18	*Lerista bipes*	tc		56	101		N			
16/10/04	AM	3	P18	*Lerista bipes*	tc		NA						
16/10/04	AM	3	P20	*Lerista bipes*	tc		53	100		N			
16/10/04	AM	3	P22	*Lerista bipes*	tc		53	92		N			
16/10/04	AM	4	E4	*Ctenotus grandis*	1	Y							
16/10/04	PM	4	P12	*Ctenotus grandis*	6		75	220		N			
16/10/04	PM	4	P9	*Cyclodomorphus melanops*	6		89	152		Y			
16/10/04	PM	4	P7	*Cyclodomorphus melanops*	7		106	192		N			
16/10/04	PM	4	P21	*Lerista bipes*	tc		51			D			
16/10/04	PM	4	P1	*Lerista muelleri*	tc		32	71		N			
16/10/04	AM	5	P11	*Lerista bipes*	tc		52	85		Y			
16/10/04	AM	5	P3	*Lerista bipes*	tc		54	95		N			
16/10/04	AM	5	P10	*Lerista bipes*	tc		56	95		N			
16/10/04	AM	5	P6	*Lerista bipes*	tc		54	102		N			
16/10/04	AM	5	P12	*Lerista bipes*	tc		52	100		N			
16/10/04	AM	5	P14	*Lerista bipes*	tc		52	92		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
16/10/04	AM	5	P15	*Lerista bipes*	tc		54	100		N			
16/10/04	AM	5	P10	*Lerista bipes*	tc		53	100		N			
16/10/04	AM	5	P16	*Lerista bipes*	tc		55	80		Y			
16/10/04	AM	5	P16	*Lerista bipes*	tc		55	88		Y			
16/10/04	AM	5	P16	*Lerista bipes*	tc		53	92		Y			
16/10/04	AM	5	P17	*Lerista bipes*	tc		52	95		N			
16/10/04	AM	5	P20	*Lerista bipes*	tc		50			D			
16/10/04	AM	5	P9	*Pogona minor*	5		78	228		N			
17/10/04	PM	1	P2	*Menetia greyii*	NA	NA							
17/10/04	PM	1	P7	*Notoscincus ornatus*	-		31	87		N			
17/10/04	PM	3	P21	*Ctenotus grandis*	NA		116	335		N			
17/10/04	PM	3	P7	*Ctenotus grandis*	10		110	260		Y			
17/10/04	AM	3	P23	*Ctenotus grandis*	7		85	239	13.5	N			
17/10/04	PM	3	P8	*Lerista bipes*	tc		36	66		N			
17/10/04	PM	3	P19	*Lerista bipes*	tc	Y - 04	52	86		N			
17/10/04	PM	3	P6	*Lerista bipes*	tc	Y - 04	53	90		N			
17/10/04	AM	3	P14	*Lerista bipes*	tc	Y?	53	98		N			
17/10/04	AM	3	P14	*Lerista bipes*	tc		48	91		Y			
17/10/04	AM	3	P17	*Lerista bipes*	tc		54	91		N			
17/10/04	PM	3	P3	*Lerista bipes*	tc		54	92		N			
17/10/04	PM	3	P5	*Lerista bipes*	tc		53	95		N			
17/10/04	PM	3	P6	*Menetia sp.*	NA		24			D			
17/10/04	PM	3	P12	*Morethia ruficauda*	6		32	76		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
17/10/04	AM	3	P14	*Notoscincus ornatus*	1		31	84		N			
17/10/04	AM	4	E4	*Ctenotus grandis*	40		115	310		N			
17/10/04	PM	4	P9	*Ctenotus grandis*	7		114	275		N			
17/10/04	PM	4	P20	*Ctenotus grandis*	8		113	320		N			
17/10/04	AM	4	P18	*Diplodactylus jeanae*	NA		41	81					
17/10/04	AM	4	P1	*Lerista bipes*	tc								
17/10/04	AM	4	P9	*Lerista bipes*	tc		55	98		N			
17/10/04	AM	4	P16	*Lerista bipes*	tc		46	80		N			
17/10/04	PM	4	P21	*Lerista bipes*	tc		41	90		N			
17/10/04	AM	4	P11	*Morethia ruficauda*	10		33	60		Y			
17/10/04	PM	4	P6	*Proablepharus reginae*	6		38	100		N			
17/10/04	AM	5	P8	*Lerista bipes*	tc		52	95		N			
17/10/04	AM	5	P14	*Lerista bipes*	tc		55	100		N			
17/10/04	AM	5	P21	*Lerista bipes*	tc		51	95		N			
17/10/04	AM	5	P22	*Lerista bipes*	tc		52	80		D			
17/10/04	AM	5	P25	*Lerista bipes*	tc		50	70		D			
17/10/04	AM	5	P25	*Lerista bipes*	tc		55	85		Y			
17/10/04	AM	5	P25	*Lerista bipes*	tc		52	95					
17/10/04	PM	5	P25	*Lerista muelleri*	tc		33	70		N			
17/10/04	AM	6	P15	*Ctenotus saxatilis*	-		86	241	20	N			
17/10/04	PM	6	P24	*Cyclodomorphus melanops*	21		95	195		N			
17/10/04	AM	6	E1	*Cyclodomorphus melanops*	20		95	152	17.5	Y			
17/10/04	AM	6	P20	*Heteronotia binoei*	NA	NA	40			D			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
17/10/04	AM	6	P16	*Heteronotia binoei*	NA	NA	35	90		N			
17/10/04	PM	6	P22	*Proablepharus reginae*	6		24	75		N			
18/10/04	AM	1	E15	*Ctenotus grandis*	-	-							
18/10/04	PM	1	C1	*Ctenotus grandis*	6		118	336		N			
18/10/04	PM	1	P7	*Cyclodomorphus melanops*	6		91	196		N			
18/10/04	AM	1	P23	*Heteronotia binoei*	NA	NA	44	105		N			
18/10/04	AM	2	P2	*Ctenotus grandis*	6		102	246	31	Y			
18/10/04	AM	2	E2	*Ctenotus grandis*	7		113	305	40	N			
18/10/04	AM	2	E8	*Ctenotus grandis*	8		80	226		N			
18/10/04	AM	2	E19	*Ctenotus grandis*	9		109	274	33	N			
18/10/04	AM	2	P23	*Ctenotus grandis*	-	-							
18/10/04	AM	2	E23	*Ctenotus grandis*	10		110	283	31	N			
18/10/04	AM	2	P21	*Ctenotus grandis*	11		110	269	36	Y			
18/10/04	AM	2	E6	*Ctenotus saxatilis*	6		95	258	19	N			
18/10/04	AM	2	E13	*Ctenotus saxatilis*	7		19	267	19	N			
18/10/04	AM	2	P8	*Lerista bipes*	tc		58	94		N			
18/10/04	AM	2	P15	*Lerista bipes*	tc		51	93		N			
18/10/04	AM	2	P9	*Menetia greyii*	NA	NA	24	65		N			
18/10/04	AM	2	P16	*Menetia greyii*	NA	NA	30	65		N			
18/10/04	AM	2	P12	*Morethia ruficauda*	-	-							
18/10/04	PM	2	P10	*Morethia ruficauda*	-	-							
18/10/04	PM	2	P24	*Morethia ruficauda*	1								
18/10/04	AM	2	P14	*Notoscincus ornatus*	NA	NA	31	78		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
18/10/04	AM	3	E9	*Ctenotus grandis*	7	Y	125	325		N			
18/10/04	AM	3	P10	*Lerista bipes*	tc		54	90		N			
18/10/04	AM	3	P8	*Lerista bipes*	tc		52	98		N			
18/10/04	AM	3	P13	*Lerista bipes*	tc		54	95		N			
18/10/04	AM	3	P15	*Lerista bipes*	tc								
18/10/04	AM	3	P19	*Lerista bipes*	tc		54	94		N			
18/10/04	AM	3	P17	*Lerista bipes*	tc		58	90		Y			
18/10/04	AM	3	P17	*Lerista bipes*	tc		53	90		N			
18/10/04	AM	3	P17	*Lerista bipes*	tc		50	95		N			
18/10/04	AM	3	P16	*Lerista bipes*	tc		53	95		N			
18/10/04	AM	3	P16	*Lerista bipes*	tc	Y - 04	50	65		D			
18/10/04	AM	3	P23	*Lerista bipes*	tc		55	89		N			
18/10/04	PM	4	P14	*Ctenotus grandis*	8		110	250		N			
18/10/04	AM	4	P7	*Cyclodomorphus melanops*	8		85	125		D			
18/10/04	AM	4	P1	*Lerista bipes*	tc		55	90		N			
18/10/04	PM	5	P18	*Ctenotus grandis*	-		113	295		N			
18/10/04	AM	5	P17	*Ctenotus pantherinus*	6		98	245		N			
18/10/04	AM	5	P12	*Lerista bipes*	tc		55	90		N			
18/10/04	AM	5	P24	*Lerista bipes*	tc		50	92		N			
18/10/04	AM	6	P24	*Heteronotia binoei*	NA	NA							
18/10/04	PM	6	P13	*Lerista muelleri*	-	-							
19/10/04	AM	1	P8	*Ctenotus grandis*	7	R							
19/10/04	AM	1	P22	*Ctenotus grandis*	8		104	240		Y			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
19/10/04	PM	1	P4	*Delma orea*	-								
19/10/04	PM	1	P1	*Lerista bipes*	-								
19/10/04	AM	1	P23	*Menetia greyii*	-		24	65		N			
19/10/04	AM	2	P10	*Ctenotus grandis*	-		82	199	14	Y			
19/10/04	AM	2	P21	*Ctenotus grandis*	80		113	330	42	N			
19/10/04	PM	2	P3	*Ctenotus grandis*	9		112	305		N			
19/10/04	AM	2	E6	*Ctenotus saxatilis*	8		89	248	19	Y			
19/10/04	AM	2	E23	*Ctenotus saxatilis*	9		90	254	21	N			
19/10/04	AM	2	P6	*Lerista bipes*									
19/10/04	AM	2	P6	*Lerista bipes*	tc		52	92		N			
19/10/04	AM	2	P6	*Lerista bipes*	tc		53	77		Y			
19/10/04	AM	2	P6	*Lerista bipes*	tc		55	92		Y			
19/10/04	AM	2	P23	*Lerista bipes*									
19/10/04	AM	2	P23	*Lerista bipes*	tc		51	68		Y			
19/10/04	AM	2	P22	*Lerista bipes*	tc		54	60		Y			
19/10/04	AM	2	P22	*Lerista bipes*	tc		54	82		N			
19/10/04	PM	2	P25	*Lerista muelleri*	tc		34	75		Y			
19/10/04	AM	2	P6	*Menetia greyii*	NA	NA	23	62		N			
19/10/04	AM	2	P9	*Notoscincus ornatus*	-		32	39		Y			
19/10/04	AM	2	P24	*Notoscincus ornatus*	-		32	60		Y			
19/10/04	PM	2	P13	*Notoscincus ornatus*	-		33	90		N			
19/10/04	AM	3	P13	*Ctenotus grandis*	10	Y - 04	115	265		N			
19/10/04	AM	3	P16	*Ctenotus grandis*	16		78	225		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
19/10/04	AM	3	E21	*Ctenotus grandis*	17		120	280		N			
19/10/04	AM	3	P1	*Lerista bipes*	tc		54	95		N			
19/10/04	AM	3	P8	*Lerista bipes*	tc		56	65		D			
19/10/04	AM	3	P7	*Lerista bipes*	tc		43	73		N			
19/10/04	AM	3	P7	*Lerista bipes*	tc		57	90		Y			
19/10/04	AM	3	P7	*Lerista bipes*	tc		52	98		N			
19/10/04	AM	3	P7	*Lerista bipes*	tc		52	80		Y			
19/10/04	AM	3	P7	*Lerista bipes*	tc		54	72		D			
19/10/04	AM	3	P6	*Lerista bipes*	-								
19/10/04	AM	3	P14	*Lerista bipes*	tc		52	95		N			
19/10/04	AM	3	P15	*Lerista bipes*	tc		52	92		N			
19/10/04	AM	3	P23	*Lerista bipes*	tc		52	95		N			
19/10/04	AM	3	P23	*Lerista bipes*	tc		52	90		N			
19/10/04	AM	3	P23	*Lerista bipes*	tc		56	90		Y			
19/10/04	AM	3	P4	*Lerista muelleri*	tc		33	40		D			
19/10/04	AM	3	P7	*Lerista muelleri*	-								
19/10/04	AM	3	P7	*Menetia sp.*	tc		26	60		N			
19/10/04	AM	3	P17	*Notoscincus ornatus*	6		32	41		D			
19/10/04	PM	4	P1	*Ctenotus grandis*	-								
19/10/04	AM	4	P1	*Lerista bipes*	tc		52	65		D			
19/10/04	AM	4	P9	*Lerista bipes*	tc		53	96		N			
19/10/04	AM	4	P8	*Lerista bipes*	tc		52	87		Y			
19/10/04	AM	4	P6	*Lerista bipes*	tc		53	90		N			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
19/10/04	AM	4	P11	*Lerista bipes*	tc		32	60		N			
19/10/04	AM	4	P11	*Lerista bipes*	tc	Y - 03	52	90		N			
19/10/04	AM	4	P17	*Lerista bipes*	tc		54	80		D			
19/10/04	AM	4	P12	*Lerista bipes*	tc								
19/10/04	AM	4	P16	*Lerista bipes*	tc								
19/10/04	AM	4	P21	*Lerista bipes*	tc		52	80		Y			
19/10/04	AM	4	P21	*Lerista bipes*	tc		58	90		Y			
19/10/04	AM	4	P21	*Lerista bipes*	tc		56	99		Y			
19/10/04	AM	4	P21	*Lerista bipes*	tc		55	90		Y			
19/10/04	AM	4	P22	*Lerista bipes*	tc		48	92		N			
19/10/04	AM	4	P22	*Lerista bipes*	tc		38	60		N			
19/10/04	AM	4	P24	*Lerista bipes*	tc		57	95		N			
19/10/04	AM	4	P25	*Lerista bipes*	tc		55	90		N			
19/10/04	PM	4	P6	*Lerista bipes*	tc		56	72		D			
19/10/04	PM	4	P7	*Lerista bipes*	tc		56	105		N			
19/10/04	PM	4	P8	*Lerista bipes*	tc		58	82		Y			
19/10/04	AM	4	P25	*Lerista muelleri*	tc		33	75		N			
19/10/04	PM	4	P4	*Lerista muelleri*	-								
19/10/04	PM	4	P20	*Lerista muelleri*	-								
19/10/04	AM	4	P7	*Morethia ruficauda*	-								
19/10/04	AM	5	E16	*Ctenotus grandis*	1	R - 03	115	330		N			
19/10/04	AM	5	P25	*Ctenotus saxatilis*	2 & 3		102	240		Y			
19/10/04	AM	5	P1	*Glaphyromorphus isolepis*	1		46	90		D			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
19/10/04	AM	5	P7	*Lerista bipes*	tc		56	90		Y			
19/10/04	AM	5	P11	*Lerista bipes*	tc		35	50		D			
19/10/04	AM	5	P11	*Lerista bipes*	tc		57	90		N			
19/10/04	AM	5	P11	*Lerista bipes*	tc		55	104		N			
19/10/04	AM	5	P11	*Lerista bipes*	tc		38	55		Y			
19/10/04	AM	5	P12	*Lerista bipes*	tc		55	100		N			
19/10/04	AM	5	P13	*Lerista bipes*	tc	R - 04	50	75		N			
19/10/04	AM	5	P15	*Lerista bipes*	tc	R - 03	54	70		D			
19/10/04	AM	5	P16	*Lerista bipes*	tc		53	95		N			
19/10/04	AM	5	P17	*Lerista bipes*	tc		33	58		N			
19/10/04	AM	5	P19	*Lerista bipes*	tc		55	95		N			
19/10/04	AM	5	P19	*Lerista bipes*	tc		39	75		N			
19/10/04	AM	5	P20	*Lerista bipes*	tc		52	93		N			
19/10/04	AM	5	P23	*Lerista bipes*	tc		32	57		N			
19/10/04	AM	5	P21	*Lerista bipes*	tc		50	92		N			
19/10/04	PM	5	P6	*Lerista bipes*	tc		52	80		Y			
19/10/04	PM	5	P6	*Lerista bipes*	tc		54	96		N			
19/10/04	PM	5	P4	*Lerista bipes*	tc		52	80		Y			
19/10/04	PM	5	P4	*Lerista bipes*	tc		56	101		N			
19/10/04	PM	5	P4	*Lerista bipes*	tc		51	70		Y			
19/10/04	PM	5	P4	*Lerista bipes*	tc		55	100		N			
19/10/04	PM	5	P15	*Lerista bipes*	tc		54	60		D			
19/10/04	PM	5	P3	*Lerista muelleri*	-								

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
19/10/04	PM	5	P4	*Lerista muelleri*	-								
19/10/04	PM	5	P4	*Menetia sp.*	-								
19/10/04	PM	5	P4	*Notoscincus ornatus*	1		32	90		N			
19/10/04	AM	6	P13	*Ctenotus saxatilis*	3		53	152		N			
19/10/04	AM	6	P10	*Heteronotia binoei*	NA	NA	35	84		N			
19/10/04	AM	6	P20	*Heteronotia binoei*	NA	NA	38	99		N			
19/10/04	PM	6	P18	*Menetia sp.*	10		35	60		N			
19/10/04	PM	6	P11	*Proablepharus reginae*	10		30	55		D			
20/10/04	AM	1	E18	*Ctenotus grandis*	9		106	269	35	N			
20/10/04	AM	1	P21	*Ctenotus pantherinus*	6		87	231	19	N			
20/10/04	AM	1	P4	*Ctenotus saxatilis*									
20/10/04	AM	1	E15	*Ctenotus saxatilis*	6		95	239	21.5	N			
20/10/04	PM	1	P17	*Heteronotia binoei*	-								
20/10/04	AM	1	P1	*Lerista bipes*	tc	R	50	54		Y			
20/10/04	AM	1	P1	*Lerista bipes*	tc		52	81		N			
20/10/04	AM	1	P2	*Lerista bipes*	tc		54	82		N			
20/10/04	AM	1	P6	*Menetia greyii*									
20/10/04	AM	2	E22	*Ctenotus grandis*	-								
20/10/04	AM	2	E4	*Ctenotus grandis*	12		110	250		Y			
20/10/04	AM	2	P15	*Ctenotus pantherinus*	6		90	235		N			
20/10/04	AM	2	P5	*Ctenotus pantherinus*	-		93	248		N			
20/10/04	AM	2	E3	*Ctenotus saxatilis*	7		95	240		Y			
20/10/04	AM	2	E5	*Ctenotus saxatilis*	90		95	245		Y			

Date	Time	Grid	Trap	Species	Number	Rec	SVL	Total	Weight	Regrown tail	Sex	Cryo Number	Museum number
20/10/04	AM	2	P17	*Lerista bipes*	tc		58	87		Y			
20/10/04	AM	2	P17	*Lerista bipes*	tc		45	63		N			
20/10/04	AM	2	P17	*Lerista bipes*	tc		55	97		N			
20/10/04	AM	2	P7	*Lerista bipes*	tc		52	92		N			
20/10/04	AM	2	P21	*Lerista muelleri*	-		37	88		N			
20/10/04	AM	2	P7	*Lerista muelleri*	tc		35	75		N			
20/10/04	AM	2	P21	*Proablepharus reginae*	-		27	41		D			
20/10/04	AM	2	P17	*Proablepharus reginae*	-								
20/10/04	AM	2	P2	*Varanus acanthurus*	-		140	360		N			
20/10/04	AM	2	P2	*Varanus acanthurus*	-		130	355		N			
20/10/04	AM	6	P18	*Ctenophorus caudicinctus*	6		53	141		N			
20/10/04	AM	6	P22	*Ctenotus pantherinus*	1		80	176		N			
21/10/04	PM	1	P6	*Ctenotus grandis*	9		115	288		N			
21/10/04	PM	1	P4	*Cyclodomorphus melanops*	-								
21/10/04	PM	1	P11	*Lerista muelleri*	tc		32	68		N			
21/10/04	PM	1	P23	*Lerista muelleri*	-								
21/10/04	PM	1	P11	*Notoscincus ornatus*	1		32	94		N			
21/10/04	AM	2	E2	*Ctenotus saxatilis*	10		89	248		N			
21/10/04	AM	2	P16	*Lerista muelleri*	tc		32	78		N			
21/10/04	AM	2	P22	*Menetia sp.*	-		24	55		N			

Attachment 5 - Details of Mammal Captures on the Six Grids in the Proposed Development Area, November-December 2003 and October 2004

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
01/12/03	AM	1	C17	*Bettongia lesueur*	630	982009101139931	AS1417	R						
01/12/03	AM	1	C16	*Isoodon auratus barrowensis*	210	240213		C	60.3				F	Virginal
01/12/03	AM	1	E17	*Isoodon auratus barrowensis*	230	258738		C						
01/12/03	AM	1	E09	*Isoodon auratus barrowensis*	220	982009100613438		R						
01/12/03	AM	1	C04	*Isoodon auratus barrowensis*	250	982009100621275		R						
01/12/03	AM	1	C24	*Isoodon auratus barrowensis*	220	982009100664874		R						
01/12/03	AM	1	C13	*Isoodon auratus barrowensis*	300	982009100671145		R						
01/12/03	AM	1	C02	*Isoodon auratus barrowensis*	225	982009100681581		R						regressed
01/12/03	AM	1	C21	*Isoodon auratus barrowensis*	260	982009100690840		R						
01/12/03	AM	1	E14	*Isoodon auratus barrowensis*	290	982009100713545		R						with young
01/12/03	AM	1	E15	*Isoodon auratus barrowensis*	220	982009101221296			61.5	15.2	20.8		M	
01/12/03	AM	1	C14	*Isoodon auratus barrowensis*	270	982009101238585		R						young still present
01/12/03	AM	1	C05	*Isoodon auratus barrowensis*	220	982009101241806		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
01/12/03	AM	1	C22	*Isoodon auratus barrowensis*	300	982009101242881		N						
01/12/03	AM	1	E10	*Isoodon auratus barrowensis*	240	982009101244635		R						
01/12/03	AM	1	E22	*Isoodon auratus barrowensis*	285	982009101261108			65.1				F	Regressed
01/12/03	AM	1	C18	*Isoodon auratus barrowensis*	220	982009101359509			62.7				F	1x20mm
01/12/03	AM	1	E03	*Isoodon auratus barrowensis*		982009101453040		R						with young
01/12/03	AM	1	C15	*Lagorchestes conspicillatus*		No PIT			94.2				F	1x150mm
01/12/03	AM	1	C20	*Trichosurus vulpecula*	1075	982009101216118	AS1311		76.8				F	216118
01/12/03	AM	2	C25	*Isoodon auratus barrowensis*	250	982009100618982		R						
01/12/03	AM	2	E15	*Isoodon auratus barrowensis*	255	982009100660088		R						
01/12/03	AM	2	E12	*Isoodon auratus barrowensis*	225	982009100677956		R						
01/12/03	AM	2	C17	*Isoodon auratus barrowensis*	315	982009100683037		R						
01/12/03	AM	2	E21	*Isoodon auratus barrowensis*	170	982009100702357		R						
01/12/03	AM	2	E3	*Isoodon auratus barrowensis*		982009100708906		R						
01/12/03	AM	2	C23	*Isoodon auratus barrowensis*	250	982009101224743		R						
01/12/03	AM	2	E16	*Isoodon auratus barrowensis*	270	982009101351583		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
01/12/03	AM	2	E2	*Isoodon auratus barrowensis*	245	982009101351996		R						
01/12/03	AM	2	C5	*Isoodon auratus barrowensis*	270	982009101445505		R						
01/12/03	AM	2	C10	*Isoodon auratus barrowensis*	250	982009101455058		R						
01/12/03	AM	2	C10	*Lagorchestes conspicillatus*	4500	982009101244427			99	20.7	24.7		M	
01/12/03	AM	2	E20	*Pseudomys nanus ferculinus*										
01/12/03	AM	2	C12	*Trichosurus vulpecula*	550	239680	AS1305	C						
01/12/03	AM	2	E22	*Trichosurus vulpecula*	525	982009101220124	AS1312		71				F	Virginal
01/12/03	AM	2	C21	*Trichosurus vulpecula*	1000	982009101446496		R						
01/12/03	AM	2	C13	*Trichosurus vulpecula*	1200	No PIT	AS1313		80.1				F	1x40mm
01/12/03	AM	2	C11	*Trichosurus vulpecula*	1300	No PIT	AS1314		85.3	25.1	28.6		M	
01/12/03	AM	6	C21	*Isoodon auratus barrowensis*	140	451740		C						
01/12/03	AM	6	C5	*Isoodon auratus barrowensis*	200	982009101236881		R						
01/12/03	AM	6	E2	*Isoodon auratus barrowensis*	180	982009101241467		R						
01/12/03	AM	6	E21	*Isoodon auratus barrowensis*	160	982009101244207		R						
01/12/03	AM	6	E4	*Isoodon auratus barrowensis*	200	982009101263830			62.3	13.7	19.8		M	
01/12/03	AM	6	C11	*Isoodon auratus barrowensis*	270	982009101357885		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
01/12/03	AM	6	E11	*Isoodon auratus barrowensis*	240	982009101447290		R						
01/12/03	AM	6	C17	*Isoodon auratus barrowensis*	200	982009101448585			65.3	15.8	21.2		M	
01/12/03	AM	6	C12	*Isoodon auratus barrowensis*	170	982009101450647		R						
01/12/03	AM	6	E7	*Isoodon auratus barrowensis*	230	982009101453358		R						
02/12/03	AM	6	C11	*Isoodon auratus barrowensis*	235	982009101447290		R						
02/12/03	AM	6	C5	*Isoodon auratus barrowensis*	175	982009101451260		R						
02/12/03	AM	6	E4	*Isoodon auratus barrowensis*	230	982009101453358		R						
02/12/03	AM	6	C12	*Isoodon auratus barrowensis*	260	No PIT			67.4	15.3	22.1		M	
02/12/03	AM	6	C16	*Isoodon auratus barrowensis*	210	No PIT			62.6	13.7	18.3		M	
02/12/03	AM	6	E2	*Isoodon auratus barrowensis*	260	No PIT			65.7	15.6	21.3		M	
02/12/03	AM	6	C21	*Trichosurus vulpecula*	1150	No PIT			76.1	24.4	29.4		M	
02/12/03	AM	6	C6	*Trichosurus vulpecula*	900	No PIT			69.9	15.2	15.8		M	
26/11/03	AM	4	C07	*Bettongia lesueur*	850	982009101221058			71.9			82	F	reg
26/11/03	AM	4	C22	*Bettongia lesueur*	770	982009101245090			65.6	18.1	21.7	85	M	
26/11/03	AM	4	C01	*Isoodon auratus barrowensis*	270	982009101217247			62.75			40.28	F	2x15mm
26/11/03	AM	4	C21	*Isoodon auratus barrowensis*	300	982009101223852			65.93			43.45	F	1x35mm

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
26/11/03	AM	4	C06	*Isoodon auratus barrowensis*	290	982009101242467			63.81			42.68	F	regressed
26/11/03	AM	4	E07	*Isoodon auratus barrowensis*	230	982009101245369			61.44	12.44	19.73	40.78	M	
26/11/03	AM	4	E16	*Isoodon auratus barrowensis*	300	982009101259441			64.57			41.99	F	1x64.2mm F
26/11/03	AM	4	E15	*Isoodon auratus barrowensis*	280	982009101261450			67.26			42.75	F	1xlac
26/11/03	AM	4	C06	*Isoodon auratus barrowensis*	330	982009101262267			66.71	13.56	21.18	43.18	M	
26/11/03	AM	4	E06	*Isoodon auratus barrowensis*	290	982009101264699			62.5			39.7	F	2x35mm
26/11/03	AM	4	E20	*Isoodon auratus barrowensis*	270	982009101356742			67.22			37.85	F	1x40mm
26/11/03	AM	4	C05	*Isoodon auratus barrowensis*	210	982009101360729			59.5			35.7	F	v
26/11/03	AM	4	E01	*Isoodon auratus barrowensis*	240	982009101446012			62.41	17.89	19.64	41.02	M	
26/11/03	AM	4	E24	*Isoodon auratus barrowensis*	210	982009101451826			39.09			41.67	F	virginal
26/11/03	AM	4	C02	*Trichosurus vulpecula*	1100	982009101222180			75.62			50.15	F	reg
26/11/03	AM	4	C19	*Trichosurus vulpecula*	1350	982009101239433			82.83	26.01	31.16	46.85	M	
26/11/03	AM	4	C11	*Trichosurus vulpecula*	1250	982009101357271			78.2	24.7	33.6	49	M	
26/11/03	AM	4	E21	*Zyzomys argurus*	52		1		37.2		13.5	21	M	
26/11/03	AM	5	E11	*Isoodon auratus barrowensis*	295	982009101222158			66.95			41.88	F	Yng 2x20mm
26/11/03	AM	5	E04	*Isoodon auratus barrowensis*	300	982009101241642			66.63			42.75	F	10mm

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
26/11/03	AM	5	S01	*Isoodon auratus barrowensis*	300	982009101246696			74.52	13.64	20.37	43.1	M	
26/11/03	AM	5	C25	*Isoodon auratus barrowensis*	260	982009101261583			64.44			42.18	F	Yng x2 20x20mm
26/11/03	AM	5	C15	*Isoodon auratus barrowensis*	200	982009101264875			61.26	14.08	19.35	41	M	
26/11/03	AM	5	E10	*Isoodon auratus barrowensis*	250	982009101267637			63.55	13.43	20.72	41.74	M	
26/11/03	AM	5	E03	*Isoodon auratus barrowensis*	200	982009101352703			65.27			37.34	FV	
26/11/03	AM	5	E05	*Isoodon auratus barrowensis*	270	982009101354739			68.98			39.76	F	Young 30mm
26/11/03	AM	5	C11	*Isoodon auratus barrowensis*	270	982009101355888			66.25			39.63	F	Yng 50mm M
26/11/03	AM	5	E25	*Isoodon auratus barrowensis*	310	982009101454810			70.48	12.2	18.85	46.44	M	
26/11/03	AM	5	C22	*Isoodon auratus barrowensis*		No PIT								
26/11/03	AM	5	P20	*Planigale* sp.	11		1		21.20			9.50	F	lactating
26/11/03	AM	5	C21	*Trichosurus vulpecula*	850	982009101220200			76.01			48.05	F	lactating
26/11/03	AM	5	C21	*Trichosurus vulpecula*	950	982009101244679			74.10			44.83	F	
26/11/03	AM	5	C16	*Trichosurus vulpecula*	340	982009101245301			66.72			42.57	M	
26/11/03	AM	5	C21	*Trichosurus vulpecula*	410	982009101262197			66.70	12.91		42.24	M	
26/11/03	AM	5	C19	*Trichosurus vulpecula*	450	982009101449263			64.76	9.85	15.25	34.58	M	
27/11/03	AM	3	E04	*Isoodon auratus barrowensis*	290	982009101220313			70.35				F	Young 30mm

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
27/11/03	AM	3	C16	*Isoodon auratus barrowensis*	270	982009101222352			73.70	13.80	18.40		M	
27/11/03	AM	3	C01	*Isoodon auratus barrowensis*	210	982009101243662			63.46	13.40	19.50		M	
27/11/03	AM	3	C23	*Isoodon auratus barrowensis*	265	982009101257730			67.90				F	Young 60mm
27/11/03	AM	3	C25	*Isoodon auratus barrowensis*	200	982009101355127			64.20				FV	
27/11/03	AM	3	E21	*Isoodon auratus barrowensis*	275	982009101356856			73.20	16.60	22.80		M	
27/11/03	AM	3	C18	*Isoodon auratus barrowensis*	235	982009101452045			69.70				FV	
27/11/03	AM	3	E19	*Pseudantechinus* sp.	17		1		32.80				F	
27/11/03	AM	3	C17	*Trichosurus vulpecula*	1300	982009101453702			82.00	19.40	28.80		M	
27/11/03	AM	4	E02	*Isoodon auratus barrowensis*	280	982009101242467		R					F	
27/11/03	AM	4	E22	*Isoodon auratus barrowensis*	190	982009101261225			60.20	6.30	7.90		M	
27/11/03	AM	4	E23	*Isoodon auratus barrowensis*	300	982009101261450		R					F	
27/11/03	AM	4	E01	*Isoodon auratus barrowensis*	220	982009101262623			67.10	15.90	22.60		M	
27/11/03	AM	4	E16	*Isoodon auratus barrowensis*	275	982009101264699		R						
27/11/03	AM	4	C01	*Isoodon auratus barrowensis*	300	982009101357113			64.80				F	Young 50mm x1
27/11/03	AM	4	E25	*Isoodon auratus barrowensis*	220	982009101360729		R					FV	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
27/11/03	AM	4	E21	*Isoodon auratus barrowensis*	190	982009101451826		R						
27/11/03	AM	4	C14	*Trichosurus vulpecula*	1300	982009101239433		R					M	
27/11/03	AM	4	C16	*Trichosurus vulpecula*	950	982009101262018			73.60				F	Furred young 90mm
27/11/03	AM	4	C21	*Trichosurus vulpecula*	1400	982009101357271		R					M	
27/11/03	AM	5	E04	*Isoodon auratus barrowensis*	240	982009100609711			66.50				F	
27/11/03	AM	5	E03	*Isoodon auratus barrowensis*	230	982009101244635			65.80				F	
27/11/03	AM	5	E21	*Isoodon auratus barrowensis*	270	982009101246696		R					M	
27/11/03	AM	5	E05	*Isoodon auratus barrowensis*	235	982009101257692			63.80				F	
27/11/03	AM	5	C18	*Isoodon auratus barrowensis*	250	982009101258127			65.10				F	Yng 2x 15mm
27/11/03	AM	5	E23	*Isoodon auratus barrowensis*	250	982009101261583		R					F	
27/11/03	AM	5	C15	*Isoodon auratus barrowensis*	170	982009101264875		R					M	
27/11/03	AM	5	E17	*Isoodon auratus barrowensis*	210	982009101264928			61.50				FV	
27/11/03	AM	5	E16	*Isoodon auratus barrowensis*	260	982009101355888		R					F	
27/11/03	AM	5	C24	*Lagorchestes conspicillatus*	4000	982009101224936			96.00				F	Yng 70mmx10mm
27/11/03	AM	5	C12	*Trichosurus vulpecula*	1000	982009101244679		R					F	
27/11/03	AM	5	C20	*Trichosurus vulpecula*	1150	982009101265419			79.60	21.60	29.30		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
27/11/03	AM	5	C23	*Trichosurus vulpecula*	1050	No PIT			75.10				F	
28/11/03	AM	1	C02	*Isoodon auratus barrowensis*	240	982009100613438			63.70	15.20	22.90		M	
28/11/03	AM	1	C05	*Isoodon auratus barrowensis*	260	982009100621275			68.20	15.00	22.20		M	
28/11/03	AM	1	C20	*Isoodon auratus barrowensis*	240	982009100664874			66.00				F	
28/11/03	AM	1	E20	*Isoodon auratus barrowensis*	240	982009100671145			65.80				F	Yng 65mm x 1
28/11/03	AM	1	C04	*Isoodon auratus barrowensis*	240	982009100681581			66.90				F	
28/11/03	AM	1	E21	*Isoodon auratus barrowensis*	255	982009100690840			66.30	14.90	18.00		M	
28/11/03	AM	1	E22	*Isoodon auratus barrowensis*	280	982009100713545			68.10				F	Yng 65mmx1 female
28/11/03	AM	2	C21	*Bettongia lesueur*	800	982009100985920	AS1973	C	75.40	16.20	19.90	83.9	M	
28/11/03	AM	2	C14	*Isoodon auratus barrowensis*	240	982009100613872			68.60				F	
28/11/03	AM	2	E17	*Isoodon auratus barrowensis*	265	982009100618982			65.50	16.50	22.10		M	
28/11/03	AM	2	C22	*Isoodon auratus barrowensis*	250	982009100660088			65.10				F	
28/11/03	AM	2	C09	*Isoodon auratus barrowensis*	230	982009100677956			67.60	14.10	21.30		M	
28/11/03	AM	2	C10	*Isoodon auratus barrowensis*	300	982009100683037			66.60				F	Young 60mm
28/11/03	AM	2	E03	*Isoodon auratus barrowensis*	250	982009100689973			65.10				F	Young 2x15mm

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
28/11/03	AM	2	C23	*Isoodon auratus barrowensis*	235	982009100693687			63.20				F	
28/11/03	AM	2	E11	*Isoodon auratus barrowensis*	210	982009100702357			60.90				FV	
28/11/03	AM	2	C04	*Isoodon auratus barrowensis*	280	982009100708906			65.60				F	Young 60mm
28/11/03	AM	2	E21	*Isoodon auratus barrowensis*	330	982009100819380			70.50	16.40	23.40		M	
28/11/03	AM	2	E23	*Isoodon auratus barrowensis*	240	982009101455058			63.60				F	2x 20mm
28/11/03	AM	2	C03	*Lagorchestes conspicillatus*	4500	982009101245091			96.10	19.20	24.30		M	
28/11/03	AM	2	C25	*Trichosurus vulpecula*	1450	982009101265683			79.90	26.30	29.70		M	
28/11/03	AM	2	C12	*Trichosurus vulpecula*	1050	982009101446496			78.50				F	90mm
28/11/03	AM	3	C07	*Isoodon auratus barrowensis*	320	982009100699086			70.40	15.50	23.30		M	
28/11/03	AM	3	E11	*Isoodon auratus barrowensis*	295	982009100701643			65.70				F	2 x15mm
28/11/03	AM	3	C13	*Isoodon auratus barrowensis*	180	982009100817306			64.8	11.7	16.2		M	
28/11/03	AM	3	E08	*Isoodon auratus barrowensis*	290	982009101220313		R					F	present
28/11/03	AM	3	E20	*Isoodon auratus barrowensis*	210	982009101243662		R					M	
28/11/03	AM	3	E07	*Isoodon auratus barrowensis*	180	982009101355127		R						
28/11/03	AM	3	C12	*Isoodon auratus barrowensis*	275	982009101356856		R					M	
28/11/03	AM	3	C16	*Trichosurus vulpecula*	1300	982009100692633			78.70	23.20			M	1x15mm

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
28/11/03	AM	3	C06	*Trichosurus vulpecula*	1250	982009100813198			85.10				M	
28/11/03	AM	3	C20	*Trichosurus vulpecula*	1300	982009101453702		R					M	1x15mm
28/11/03	AM	4	C11	*Bettongia lesueur*		982009101221058		R					F	
28/11/03	AM	4	C21	*Isoodon auratus barrowensis*	250	982009101217247		R					F	
28/11/03	AM	4	E05	*Isoodon auratus barrowensis*	190	982009101245369		R					M	
28/11/03	AM	4	C25	*Isoodon auratus barrowensis*	280	982009101259441		R					F	
28/11/03	AM	4	E03	*Isoodon auratus barrowensis*	330	982009101262267		R					M	
28/11/03	AM	4	E21	*Isoodon auratus barrowensis*	280	982009101264699		R					F	
28/11/03	AM	4	C16	*Isoodon auratus barrowensis*	290	982009101357113		R					F	
28/11/03	AM	4	C23	*Isoodon auratus barrowensis*	200	982009101360729		R					F	
28/11/03	AM	4	C06	*Isoodon auratus barrowensis*	180	982009101361694			61.40				FV	
28/11/03	AM	4	C03	*Isoodon auratus barrowensis*	220	982009101446012		R					M	
28/11/03	AM	4	P05	*Planigale sp.*	5.8		4		21.7			13.9	F	
28/11/03	AM	4	C12	*Trichosurus vulpecula*	1300	982009101239433		R					M	
28/11/03	AM	4	C01	*Trichosurus vulpecula*	1450	982009101357271		R					M	
28/11/03	AM	5	E10	*Isoodon auratus barrowensis*	230	982009101221505			58.40				FV	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
28/11/03	AM	5	E03	*Isoodon auratus barrowensis*	250	982009101222158		R					F	
28/11/03	AM	5	E12	*Isoodon auratus barrowensis*	240	982009101244635		R						
28/11/03	AM	5	C10	*Isoodon auratus barrowensis*	225	982009101257692		R						
28/11/03	AM	5	C01	*Isoodon auratus barrowensis*	250	982009101258127		R					F	
28/11/03	AM	5	E20	*Isoodon auratus barrowensis*	190	982009101264875		R					M	
28/11/03	AM	5	C22	*Isoodon auratus barrowensis*	190	982009101264928		R						
28/11/03	AM	5	C15	*Isoodon auratus barrowensis*	230	982009101267637		R					M	
28/11/03	AM	5	C02	*Isoodon auratus barrowensis*		982009101355888		R						
28/11/03	AM	5	E13	*Isoodon auratus barrowensis*	315	982009101454810		R					M	
28/11/03	AM	5	C25	*Pseudomys nanus ferculinus*	55								M	
28/11/03	AM	5	C16	*Trichosurus vulpecula*	900	982009101244679		R					F	
28/11/03	AM	5	E11	*Trichosurus vulpecula*	320	982009101245301		R					M	
28/11/03	AM	5	C18	*Trichosurus vulpecula*	1150	982009101265419		R					M	
29/11/03	AM	1	C21	*Bettongia lesueur*	650	982009101139931	AS1417		72.30					
29/11/03	AM	1	E11	*Isoodon auratus barrowensis*	250	982009100621275		R						
29/11/03	AM	1	E19	*Isoodon auratus barrowensis*	240	982009100664874		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
29/11/03	AM	1	C17	*Isoodon auratus barrowensis*	245	982009100681581		R						
29/11/03	AM	1	E22	*Isoodon auratus barrowensis*	260	982009100690840		R						
29/11/03	AM	1	E18	*Isoodon auratus barrowensis*	300	982009100713545		R						
29/11/03	AM	1	E21	*Isoodon auratus barrowensis*	230	982009101241806			64.9				F	regressed
29/11/03	AM	1	E23	*Isoodon auratus barrowensis*	260	982009101258734			65.6	12.5	22.8		M	
29/11/03	AM	1	E16	*Isoodon auratus barrowensis*	305	982009101266038			70				F	1x60mm young
29/11/03	AM	1	C25	*Isoodon auratus barrowensis*	320	982009101267297			71.9	15.3	21			
29/11/03	AM	2	C06	*Bettongia lesueur*	700	982009101168071	AS1416		66.3	16.9	18.3		M	
29/11/03	AM	2	E10	*Isoodon auratus barrowensis*	210	982009100613872		R						
29/11/03	AM	2	C23	*Isoodon auratus barrowensis*	270	982009100618982		R						
29/11/03	AM	2	C21	*Isoodon auratus barrowensis*	250	982009100660088		R						
29/11/03	AM	2	E21	*Isoodon auratus barrowensis*	220	982009100677956		R						
29/11/03	AM	2	E16	*Isoodon auratus barrowensis*	260	982009100689973		R						
29/11/03	AM	2	E09	*Isoodon auratus barrowensis*	340	982009100819380		R						
29/11/03	AM	2	C10	*Isoodon auratus barrowensis*	260	982009101258412			65.1				F	1x50mm young

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
29/11/03	AM	2	C05	*Isoodon auratus barrowensis*	240	982009101351996			64.8	15.1	21.7		M	
29/11/03	AM	2	E04	*Isoodon auratus barrowensis*	280	982009101445505			66.4				F	1X lactating
29/11/03	AM	2	E14	*Isoodon auratus barrowensis*	110	982009101447147			53				F	virginal
29/11/03	AM	2	E20	*Isoodon auratus barrowensis*	260	982009101455058		R						
29/11/03	AM	2	C12	*Lagorchestes conspicillatus*	4500	982009101225961			103.6				F	1X100mm young
29/11/03	AM	2	C03	*Lagorchestes conspicillatus*	5500	982009101452816								
29/11/03	AM	2	P16	*Planigale* sp.	9		1						M	
29/11/03	AM	2	C21	*Trichosurus vulpecula*	500	982009101239680	AS1305	R	62.7				F	Virginal
29/11/03	AM	2	C08	*Trichosurus vulpecula*	1200	982009101260761	AS1306		80.5	22.7	31		M	
29/11/03	AM	2	C19	*Trichosurus vulpecula*	1000	982009101446496		R						
29/11/03	AM	3	C09	*Bettongia lesueur*	750	982009101353434	AS1440		69.3				F	regressed
29/11/03	AM	3	C02	*Isoodon auratus barrowensis*	295	982009100699086		R					M	
29/11/03	AM	3	E09	*Isoodon auratus barrowensis*	280	982009101219142			66				F	regressed
29/11/03	AM	3	C02	*Isoodon auratus barrowensis*	275	982009101220313		R					F	
29/11/03	AM	3	C06	*Isoodon auratus barrowensis*	280	982009101222352		R						
29/11/03	AM	3	C18	*Isoodon auratus barrowensis*	255	982009101241645			64.7				F	regressed

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
29/11/03	AM	3	C08	*Isoodon auratus barrowensis*	230	982009101243662		R						
29/11/03	AM	3	E25	*Isoodon auratus barrowensis*	320	982009101261312			64.2				F	1x10mm
29/11/03	AM	3	C03	*Isoodon auratus barrowensis*	170	982009101355127		R						
29/11/03	AM	3	E07	*Isoodon auratus barrowensis*	255	982009101357653			63.4				F	2x15mm
29/11/03	AM	3	C13	*Lagorchestes conspicillatus*		982009101449376			99.5				F	1x110mm
29/11/03	AM	3	C16	*Trichosurus vulpecula*	1250	982009100692633		R						
29/11/03	AM	3	C20	*Trichosurus vulpecula*	1000	982009101361303	AS1307		78	22.8	26.1		M	
29/11/03	AM	4	C01	*Isoodon auratus barrowensis*	280	982009101221870			70				M	
29/11/03	AM	4	C06	*Isoodon auratus barrowensis*	270	982009101222068			67.6				F	1x10mm
29/11/03	AM	4	C16	*Isoodon auratus barrowensis*	310	982009101223852		R						
29/11/03	AM	4	C11	*Isoodon auratus barrowensis*	320	982009101242881			68.2				F	
29/11/03	AM	4	E04	*Isoodon auratus barrowensis*	225	982009101245369		R						
29/11/03	AM	4	E23	*Isoodon auratus barrowensis*	290	982009101259441		R						
29/11/03	AM	4	E12	*Isoodon auratus barrowensis*	300	982009101261450		R						
29/11/03	AM	4	C08	*Isoodon auratus barrowensis*	270	982009101263196			66.8				F	1x60mm

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
29/11/03	AM	4	C21	*Isoodon auratus barrowensis*	285	982009101357113		R						
29/11/03	AM	4	E20	*Isoodon auratus barrowensis*	200	982009101360729		R						
29/11/03	AM	4	C09	*Trichosurus vulpecula*	1450	982009101239443		C						
29/11/03	AM	4	C23	*Trichosurus vulpecula*	1050	982009101222180		R						
29/11/03	AM	4	C17	*Trichosurus vulpecula*	1000	982009101262018		R						
29/11/03	AM	5	C04	*Isoodon auratus barrowensis*	300	982009101241642		R						
29/11/03	AM	5	C01	*Isoodon auratus barrowensis*	285	982009101246696		R						
29/11/03	AM	5	E05	*Isoodon auratus barrowensis*	230	982009101257692		R						
29/11/03	AM	5	E02	*Isoodon auratus barrowensis*	250	982009101258127		R						
29/11/03	AM	5	C10	*Isoodon auratus barrowensis*	260	982009101261087			70.6				F	2x25mm
29/11/03	AM	5	E03	*Isoodon auratus barrowensis*	240	982009101266837			66				F	1x70mm
29/11/03	AM	5	E09	*Isoodon auratus barrowensis*	225	982009101267637		R						
29/11/03	AM	5	C14	*Isoodon auratus barrowensis*	250	982009101354739		R						
29/11/03	AM	5	E10	*Isoodon auratus barrowensis*	250	982009101355080			64.6				F	
29/11/03	AM	5	E18	*Isoodon auratus barrowensis*	325	982009101454810		R	69.9					

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
29/11/03	AM	5	C15	*Isoodon auratus barrowensis*	310	No PIT			69				F	
29/11/03	AM	5	C08	*Lagorchestes conspicillatus*		982009101224936		R						
29/11/03	AM	5	C03	*Trichosurus vulpecula*	950	982009101244679		R						
29/11/03	AM	5	C12	*Trichosurus vulpecula*	320	982009101245301		R						
29/11/03	AM	5	C20	*Trichosurus vulpecula*	1100	982009101265419		R						
29/11/03	AM	6	C02	*Isoodon auratus barrowensis*	200	982009101236881			66.1	16.3	21.7		M	
29/11/03	AM	6	E23	*Isoodon auratus barrowensis*	210	982009101237480			65.1	15.6	22.3		M	
29/11/03	AM	6	E06	*Isoodon auratus barrowensis*	180	982009101244207			61				F	2x10mm
29/11/03	AM	6	E24	*Isoodon auratus barrowensis*	280	982009101261234			63.5				F	1x70mm
29/11/03	AM	6	C12	*Isoodon auratus barrowensis*	260	982009101357885			66.6	18.3	22.7		M	
29/11/03	AM	6	C11	*Isoodon auratus barrowensis*	250	982009101447290			64.3	13.9	19.9		M	
29/11/03	AM	6	E02	*Isoodon auratus barrowensis*	180	982009101450647			62.2				F	1x20mm
29/11/03	AM	6	E07	*Isoodon auratus barrowensis*	160	982009101450647		R	62.5				FV	
29/11/03	AM	6	E05	*Isoodon auratus barrowensis*	240	982009101453358			69.9	16.1	20.9		M	
29/11/03	AM	6	P24	*Pseudantechinus roryi*	26		10		33.5				F	6x
30/11/03	AM	1	C19	*Bettongia lesueur*		982009101139931	AS1417	R						
30/11/03	AM	1	C20	*Bettongia lesueur*	850	982009100985920	AS1973	N					M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
30/11/03	AM	1	E19	*Isoodon auratus barrowensis*	240	982009100613438		R						
30/11/03	AM	1	C21	*Isoodon auratus barrowensis*	230	982009100664874		R						
30/11/03	AM	1	E24	*Isoodon auratus barrowensis*	305	982009100713545		R						
30/11/03	AM	1	C17	*Isoodon auratus barrowensis*	220	982009101218191			60.8				F	1x10mm
30/11/03	AM	1	C24	*Isoodon auratus barrowensis*	260	982009101237149			68.6				F	1x20mm
30/11/03	AM	1	C02	*Isoodon auratus barrowensis*	250	982009101238585			60				F	1x60mm
30/11/03	AM	1	C15	*Isoodon auratus barrowensis*	340	982009101243648			66.8				F	1x70mm
30/11/03	AM	1	E20	*Isoodon auratus barrowensis*	245	982009101244635		N						
30/11/03	AM	1	E11	*Isoodon auratus barrowensis*	270	982009101258412		N						
30/11/03	AM	1	E17	*Isoodon auratus barrowensis*	300	982009101259959			67.6				F	1x75mm
30/11/03	AM	1	E21	*Isoodon auratus barrowensis*	290	982009101266038		R					F	x1
30/11/03	AM	1	C25	*Isoodon auratus barrowensis*	325	982009101267297		R					M	
30/11/03	AM	1	E05	*Isoodon auratus barrowensis*	280	982009101357359			66.1				F	1x70mm
30/11/03	AM	1	E18	*Isoodon auratus barrowensis*	280	982009101359995			64.5				F	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
30/11/03	AM	1	E15	*Isoodon auratus barrowensis*	270	982009101453040			65.8				F	2x50mm
30/11/03	AM	1	C22	*Pseudomys nanus*	53		1		34.1				F	
30/11/03	AM	1	C05	*Trichosurus vulpecula*	1000	982009101237580	AS1309		75.4				F	
30/11/03	AM	2	E20	*Isoodon auratus barrowensis*	225	982009100613872		R						
30/11/03	AM	2	C21	*Isoodon auratus barrowensis*	255	982009100618982		R						
30/11/03	AM	2	E24	*Isoodon auratus barrowensis*	245	982009100660088		R						
30/11/03	AM	2	C18	*Isoodon auratus barrowensis*	225	982009100677956		R						
30/11/03	AM	2	E12	*Isoodon auratus barrowensis*	265	982009100689973		R						
30/11/03	AM	2	E21	*Isoodon auratus barrowensis*	240	982009100693687		R						
30/11/03	AM	2	E03	*Isoodon auratus barrowensis*	180	982009100702357		R						
30/11/03	AM	2	E02	*Isoodon auratus barrowensis*	290	982009100708906		R					F	
30/11/03	AM	2	E17	*Isoodon auratus barrowensis*	315	982009100819380		R						
30/11/03	AM	2	C12	*Isoodon auratus barrowensis*	270	982009101224743			67				F	
30/11/03	AM	2	C01	*Isoodon auratus barrowensis*	210	982009101245501			61.7	14.9	21.9		M	
30/11/03	AM	2	E05	*Isoodon auratus barrowensis*	290	982009101351583			67.5	16.6	23.2		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
30/11/03	AM	2	C25	*Isoodon auratus barrowensis*	245	982009101455058		R						
30/11/03	AM	2	C06	*Lagorchestes conspicillatus*	4500	982009101355704			99.2				F	1x70mm
30/11/03	AM	2	C16	*Trichosurus vulpecula*	1150	982009101260761	AS1306	R						
30/11/03	AM	2	C11	*Trichosurus vulpecula*	1200	982009101354895	AS1310		74.1				F	
30/11/03	AM	2	C20	*Trichosurus vulpecula*	1100	982009101446496		R						
30/11/03	AM	3	C23	*Bettongia lesueur*	875	982009101237492			76.6	18.6	19.6		M	
30/11/03	AM	3	C05	*Bettongia lesueur*	950	982009101354867	AS1441		74.6				F	1x20mm
30/11/03	AM	3	C01	*Isoodon auratus barrowensis*	280	982009100699086		R						
30/11/03	AM	3	E17	*Isoodon auratus barrowensis*	280	982009101218854			65.3	14.2	22.1		M	
30/11/03	AM	3	C07	*Isoodon auratus barrowensis*	260	982009101220313		R						
30/11/03	AM	3	C06	*Isoodon auratus barrowensis*	195	982009101238985			61.3	12.4	21.1		M	
30/11/03	AM	3	E10	*Isoodon auratus barrowensis*	235	982009101243662		R					M	
30/11/03	AM	3	E20	*Isoodon auratus barrowensis*	195	982009101245099			66				F	2x20mm
30/11/03	AM	3	E21	*Isoodon auratus barrowensis*	280	982009101257730		R						
30/11/03	AM	3	C12	*Isoodon auratus barrowensis*	215	982009101352830			59.7				F	
30/11/03	AM	3	C16	*Isoodon auratus barrowensis*	260	982009101356856		R					M	
30/11/03	AM	3	C25	*Trichosurus vulpecula*	1200	982009101261220	AS1308		83.4	28.2	29.8		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
30/11/03	AM	3	C02	*Trichosurus vulpecula*	1050	982009101361303	AS1307	R						
30/11/03	AM	3	C20	*Trichosurus vulpecula*	1300	No PIT	Ear punch						M	
30/11/03	AM	3	C08	*Zyzomys argurus*	53.1				37				F	
30/11/03	AM	6	C13	*Isoodon auratus barrowensis*	160	451740		R						
30/11/03	AM	6	E07	*Isoodon auratus barrowensis*	190	982009101236881		R						
30/11/03	AM	6	E18	*Isoodon auratus barrowensis*	215	982009101241467			64.1	16.7	23.8		M	
30/11/03	AM	6	E16	*Isoodon auratus barrowensis*	180	982009101244207		R						
30/11/03	AM	6	E11	*Isoodon auratus barrowensis*	250	982009101261234		R					F	Expelled 1x70mm M
30/11/03	AM	6	E23	*Isoodon auratus barrowensis*	200	982009101352288			62.3	13.5	21.8		M	
30/11/03	AM	6	C12	*Isoodon auratus barrowensis*	240	982009101355689			67.6				F	
30/11/03	AM	6	C05	*Isoodon auratus barrowensis*	180	982009101450647		R						
30/11/03	AM	6	C07	*Isoodon auratus barrowensis*	185	982009101451260			62.9				FV	
30/11/03	AM	6	C02	*Isoodon auratus barrowensis*	225	982009101453358		R						
30/11/03	AM	6	C10	*Lagorchestes conspicillatus*		982009101259860			96.8	21.2	23.2		M	
16/10/04	AM	3	C5	*Bettongia lesueur*	820	982F0091 - 01549647			73.8		19		M	
16/10/04	AM	3	C16	*Isoodon auratus barrowensis*	220	982F0091 - 01326492			56.5		20		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
16/10/04	AM	3	E19	*Isoodon auratus barrowensis*	320	982F0091 - 01352830		R					F	PY
16/10/04	AM	3	C4	*Isoodon auratus barrowensis*	250	982F0091 - 01357653		R	64.5				F	NPY
16/10/04	AM	3	C12	*Isoodon auratus barrowensis*	440	982F0091 - 01373856			67		20		M	
16/10/04	AM	3	C15	*Isoodon auratus barrowensis*	245	982F0091 - 01452045		R	65				F	NPY
16/10/04	AM	3	E24	*Isoodon auratus barrowensis*	255	982F0091 - 01547921			63				F	NPY
16/10/04	AM	3	E5	*Isoodon auratus barrowensis*	220	982F0091 - 01658924			64				F	NPY
16/10/04	AM	3	C25	*Isoodon auratus barrowensis*	320	982F0091 - 01659656			72		24		M	
16/10/04	AM	3	E25	*Isoodon auratus barrowensis*	340	982F0091 - 01667298			65		22		M	
16/10/04	AM	3	C19	*Lagorchestes conspicillatus*	2500	982F0091 - 01547863			84		22		M	
16/10/04	AM	3	C24	*Trichosurus vulpecula*	1400	982F0091 - 01670060			77		36		M	
16/10/04	AM	4	C13	*Bettongia lesueur*	690	982F0091 - 01166621		R	64		18		M	
16/10/04	AM	4	E12	*Isoodon auratus barrowensis*	350	982F0091 - 01259441		R					F	PY
16/10/04	AM	4	E8	*Isoodon auratus barrowensis*	345	982F0091 - 01261225		R	70		23		M	
16/10/04	AM	4	E17	*Isoodon auratus barrowensis*	354	982F0091 - 01261450		R	65				F	NPY
16/10/04	AM	4	E25	*Isoodon auratus barrowensis*	365	982F0091 - 01360729		R						2+ PY dropped

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
16/10/04	AM	4	C17	*Isoodon auratus barrowensis*	425	982F0091 - 01446012		R	68		20		M	
16/10/04	AM	4	C9	*Isoodon auratus barrowensis*	305	982F0091 - 01451826		R					F	Large PY
16/10/04	AM	4	E5	*Pseudomys nanus ferculinus*	65		#16		36.1		11		M	Scrotal testes
16/10/04	AM	4	P20	*Pseudomys nanus ferculinus*	12.5		#17		29.7					Juv
16/10/04	AM	4	P23	*Pseudomys nanus ferculinus*	10		#18		24.4				M	Juv
16/10/04	AM	4	E23	*Pseudomys nanus ferculinus*	53	no data								
16/10/04	AM	4	C7	*Trichosurus vulpecula*	1150	982F0091 - 01222180		R	69.4				F	PY
16/10/04	AM	4	C22	*Trichosurus vulpecula*	1370	982F0091 - 01357271	ear tag 304	R	78		28		M	
16/10/04	AM	4	C5	*Trichosurus vulpecula*	1005	982F0091 - 01598396		R	73		21		M	
16/10/04	AM	5	E9	*Isoodon auratus barrowensis*	165		#16		59				F	NPY
16/10/04	AM	5	E22	*Isoodon auratus barrowensis*	95		#17		47		6		M	
16/10/04	AM	5	E12	*Isoodon auratus barrowensis*	280	982F0091 - 01222158		R	65				F	NPY - pouch active
16/10/04	AM	5	E6	*Isoodon auratus barrowensis*	290	982F0091 - 01243648		R	67				F	NPY
16/10/04	AM	5	E22	*Isoodon auratus barrowensis*	365	982F0091 - 01245369		R	66		23		M	
16/10/04	AM	5	E21	*Isoodon auratus barrowensis*	405	982F0091 - 01246696		R	72		22		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
16/10/04	AM	5	C8	*Isoodon auratus barrowensis*	400	982F0091 - 01264875		R	70		24		M	
16/10/04	AM	5	E24	*Isoodon auratus barrowensis*	342	982F0091 - 01381631			60		21		M	
16/10/04	AM	5	E10	*Isoodon auratus barrowensis*	198	982F0091 - 01521525			61		16		M	
16/10/04	AM	5	E11	*Isoodon auratus barrowensis*	310	982F0091 - 01657561			66		23		M	
16/10/04	AM	5	C4	*Lagorchestes conspicillatus*		982F0091 - 01483584			84				F	NPY
16/10/04	AM	5	C20	*Lagorchestes conspicillatus*	2900	982F0091 - 01524714							F	PY
16/10/04	AM	5	E3	*Pseudomys nanus ferculinus*	12.5		#16		26				F	Juv
16/10/04	AM	5	E13	*Pseudomys nanus ferculinus*	53	not marked								
16/10/04	AM	5	C22	*Trichosurus vulpecula*	1400	982F0091 - 01480090			69		27		M	
16/10/04	AM	5	C2	*Trichosurus vulpecula*		982F0091 - 01541399			82.5		26		M	
16/10/04	AM	5	C5	*Trichosurus vulpecula*	1185	982F0091 - 01546680			83		26		M	
17/10/04	AM	3	C19	*Bettongia lesueur*	665	982F0091 - 01060164	AS 1449	R	63		16		M	
17/10/04	AM	3	C15	*Bettongia lesueur*	440	982F0091 - 01166229			58		9		M	
17/10/04	AM	3	C25	*Bettongia lesueur*	790	982F0091 - 01243943		R	65		20		M	
17/10/04	AM	3	C17	*Bettongia lesueur*	761	982F0091 - 01319916			64		21		M	
17/10/04	AM	3	C4	*Isoodon auratus barrowensis*	144		#16		59		6		M	
17/10/04	AM	3	E24	*Isoodon auratus barrowensis*	160		#17		56.5		8		M	
17/10/04	AM	3	E12	*Isoodon auratus barrowensis*	170		#18		57				F	virgin pouch

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
17/10/04	AM	3	C11	*Isoodon auratus barrowensis*	415	982F0091 - 00699086		R	73		22		M	
17/10/04	AM	3	E22	*Isoodon auratus barrowensis*	270	982F0091 - 00701643		R	63				F	lactating
17/10/04	AM	3	E23	*Isoodon auratus barrowensis*	270	982F0091 - 01061756			63		21		M	
17/10/04	AM	3	C9	*Isoodon auratus barrowensis*	250	982F0091 - 01066534			60		20		M	
17/10/04	AM	3	E10	*Isoodon auratus barrowensis*	375	982F0091 - 01193845			69		24		M	
17/10/04	AM	3	E15	*Isoodon auratus barrowensis*	230	982F0091 - 01357653		R	61				F	post-lactating
17/10/04	AM	3	C8	*Isoodon auratus barrowensis*	235	982F0091 - 01452045		R	58				F	post-lactating
17/10/04	AM	3	C5	*Isoodon auratus barrowensis*	253	982F0091 - 01522376			59				F	
17/10/04	AM	3	C23	*Isoodon auratus barrowensis*	310	982F0091 - 01659656		R	65.5		21		M	
17/10/04	AM	3	E25	*Isoodon auratus barrowensis*	350	982F0091 - 01667298		R	68		21		M	
17/10/04	AM	3	E3	*Isoodon auratus barrowensis*	274	982F0091 - 01671400			57				F	Post lactating
17/10/04	AM	3	C7	*Lagorchestes conspicillatus*		not marked - escaped								
17/10/04	AM	4	E21	*Isoodon auratus barrowensis*	200		#18		63				M	
17/10/04	AM	4	E10	*Isoodon auratus barrowensis*	265	982F0091 - 01162211			64		24		M	
17/10/04	AM	4	C11	*Isoodon auratus barrowensis*	335	982F0091 - 01173374			66		21		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
17/10/04	AM	4	C5	*Isoodon auratus barrowensis*	340	982F0091 - 01259441		R	64				F	PY
17/10/04	AM	4	E14	*Isoodon auratus barrowensis*	340	982F0091 - 01261450		R	63				F	NPY - recently used
17/10/04	AM	4	C20	*Isoodon auratus barrowensis*	265	982F0091 - 01264928		R	59				F	PY
17/10/04	AM	4	E15	*Isoodon auratus barrowensis*	355	982F0091 - 01360729		R	64				F	PY
17/10/04	AM	4	E13	*Isoodon auratus barrowensis*	300	982F0091 - 01451826		R	63				F	PY
17/10/04	AM	4	E7	*Pseudomys nanus ferculinus*	40		#20		32				F	NPY - lactating
17/10/04	AM	4	C7	*Trichosurus vulpecula*	635	982F0091 - 01024279			64		15		M	
17/10/04	AM	4	C17	*Trichosurus vulpecula*	1040	982F0091 - 01180577			73				F	PY
17/10/04	AM	4	C10	*Trichosurus vulpecula*	1300	982F0091 - 01357271	ear tag 304	R	79		35		M	
17/10/04	AM	5	C13	*Bettongia lesueur*	865	982F0091 - 01358581		R	67		19		M	
17/10/04	AM	5	E22	*Isoodon auratus barrowensis*	95		#16	R	49		5.5		M	
17/10/04	AM	5	E18	*Isoodon auratus barrowensis*	170		#18		57				F	virgin pouch
17/10/04	AM	5	E12	*Isoodon auratus barrowensis*	195	982F0091 - 01018809			57		15		M	
17/10/04	AM	5	E21	*Isoodon auratus barrowensis*	210	982F0091 - 01154506			59				F	virgin pouch
17/10/04	AM	5	E16	*Isoodon auratus barrowensis*	225	982F0091 - 01175495			65		18		M	
17/10/04	AM	5	E6	*Isoodon auratus barrowensis*	275	982F0091 - 01243648		R	68				F	NPY

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
17/10/04	AM	5	C4	*Isoodon auratus barrowensis*	380	982F0091 - 01246696		R	73		24		M	
17/10/04	AM	5	E24	*Isoodon auratus barrowensis*	315	982F0091 - 01258127		R	66				F	PY
17/10/04	AM	5	C5	*Isoodon auratus barrowensis*	385	982F0091 - 01264875		R	69		22		M	
17/10/04	AM	5	E19	*Isoodon auratus barrowensis*	450	982F0091 - 01267297		R	76		23		M	
17/10/04	AM	5	E1	*Isoodon auratus barrowensis*	395	982F0091 - 01267637		R	70		18		M	
17/10/04	AM	5	E3	*Isoodon auratus barrowensis*	270	982F0091 - 01337805			62.5		37		F	recently used pouch
17/10/04	AM	5	E25	*Isoodon auratus barrowensis*	245	982F0091 - 01352703		R	63				F	NPY - lactating
17/10/04	AM	5	C25	*Isoodon auratus barrowensis*	290	982F0091 - 01354739		R	62.5				F	PY
17/10/04	AM	5	E11	*Isoodon auratus barrowensis*	220	982F0091 - 01355080		R	64				F	NPY
17/10/04	AM	5	E23	*Isoodon auratus barrowensis*	340	982F0091 - 01381631		R	65		23		M	
17/10/04	AM	5	C7	*Lagorchestes conspicillatus*	2400		#1		82				F	NPY - lactating
17/10/04	AM	5	C11	*Lagorchestes conspicillatus*	3100		#3		99				F	Small PY
17/10/04	AM	5	C12	*Lagorchestes conspicillatus*	3000		#5		97		24		M	
17/10/04	AM	5	C14	*Lagorchestes conspicillatus*	3000		#7		94					Small PY
17/10/04	AM	5	C21	*Lagorchestes conspicillatus*	2650		#9		94				F	30mm PY
17/10/04	AM	5	C22	*Lagorchestes conspicillatus*	unmarked									

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
17/10/04	AM	5	E4	*Pseudomys nanus ferculinus*	70		#17		36.2		10		M	
17/10/04	AM	5	C1	*Trichosurus vulpecula*	1320	982F0091 - 01480090		R	72		22		M	
17/10/04	AM	5	C2	*Trichosurus vulpecula*	995	982F0091 - 01541399		R	75		33		M	
17/10/04	AM	5	C15	*Trichosurus vulpecula*		not marked							F	1xhalf grown young
17/10/04	AM	6	C21	*Isoodon auratus barrowensis*	450	982F0091 - 01236881		R	62		25		M	
17/10/04	AM	6	C1	*Isoodon auratus barrowensis*	182	982F0091 - 01327188			97				F	Not lactating
17/10/04	AM	6	C16	*Isoodon auratus barrowensis*	260	982F0091 - 01451260		R	68				F	PY
17/10/04	AM	6	E25	*Isoodon auratus barrowensis*	140?	982F0091 - 01451740		R					F	
17/10/04	AM	6	C24	*Isoodon auratus barrowensis*	320	982F0091 - 01453358		R	63		21		M	Post lactating
17/10/04	AM	6	E21	*Isoodon auratus barrowensis*	296	982F0091 - 01543154			68		23		M	
17/10/04	AM	6	C2	*Lagorchestes conspicillatus*	2500		#16		79		28		M	
17/10/04	AM	6	C10	*Lagorchestes conspicillatus*	2250		#18		91		26		M	
17/10/04	AM	6	C20	*Lagorchestes conspicillatus*	2300		#20		36				F	Large PY
17/10/04	AM	6	C20	*Lagorchestes conspicillatus*	45	N/A - pouch young of #20 - dec.						F		
17/10/04	AM	6	C4	*Trichosurus vulpecula*	1025	982F0091 - 01377159			98		32		M	
18/10/04	AM	1	E3	*Isoodon auratus barrowensis*	275	982F0091 - 00664874		R	65				F	inactive pouch

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	1	E2	*Isoodon auratus barrowensis*	245	982F0091 - 00671145		R	65				F	no pouch young
18/10/04	AM	1	E19	*Isoodon auratus barrowensis*	280	982F0091 - 00681581		R	56.5				F	inactive pouch
18/10/04	AM	1	C8	*Isoodon auratus barrowensis*	380	982F0091 - 00690840		R	71		22		M	
18/10/04	AM	1	C20	*Isoodon auratus barrowensis*	330	982F0091 - 00713545		R	68				F	post lactating
18/10/04	AM	1	C3	*Isoodon auratus barrowensis*	320	982F0091 - 01164936			64.5		21		M	
18/10/04	AM	1	C5	*Isoodon auratus barrowensis*	380	982F0091 - 01221296		R	71		23		M	
18/10/04	AM	1	C13	*Isoodon auratus barrowensis*	260	982F0091 - 01243648		R	65				F	inactive pouch
18/10/04	AM	1	E6	*Isoodon auratus barrowensis*	300	982F0091 - 01244635		R	67				F	inactive pouch
18/10/04	AM	1	E7	*Isoodon auratus barrowensis*	265	982F0091 - 01338730			61		20		M	
18/10/04	AM	1	E5	*Isoodon auratus barrowensis*	310	982F0091 - 01453040		R	59				F	post lactating
18/10/04	AM	1	E8	*Isoodon auratus barrowensis*		not marked								
18/10/04	AM	1	C6	*Lagorchestes conspicillatus*	2950		#24		94		28		M	
18/10/04	AM	1	C17	*Trichosurus vulpecula*	335		#16		59				F	
18/10/04	AM	1	C16	*Trichosurus vulpecula*	1080	982F0091 - 01062845			73				F	pouch young
18/10/04	AM	1	C18	*Trichosurus vulpecula*	1090	982F0091 - 01067100			81				F	lactating
18/10/04	AM	1	C1	*Trichosurus vulpecula*	860	982F0091 - 01237580		R					F	pouch young

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	1	C9	*Trichosurus vulpecula*		not marked								
18/10/04	AM	2	C2	*Isoodon auratus barrowensis*		982F0091 - 00613872		R					F	pouch young
18/10/04	AM	2	C21	*Isoodon auratus barrowensis*	390	982F0091 - 00618982		R	73		25		M	
18/10/04	AM	2	E17	*Isoodon auratus barrowensis*	315	982F0091 - 00660088		R	66				F	post lactating
18/10/04	AM	2	C16	*Isoodon auratus barrowensis*	405	982F0091 - 00677956		R	71		22		M	
18/10/04	AM	2	C23	*Isoodon auratus barrowensis*	350	982F0091 - 00689973		R	60				F	no pouch young
18/10/04	AM	2	E16	*Isoodon auratus barrowensis*	305	982F0091 - 00693687		R	65				F	post lactating
18/10/04	AM	2	C18	*Isoodon auratus barrowensis*	395	982F0091 - 00819380		R	69		24		M	
18/10/04	AM	2	E9	*Isoodon auratus barrowensis*	285	982F0091 - 01034150			66		21		M	
18/10/04	AM	2	E25	*Isoodon auratus barrowensis*	210	982F0091 - 01169022			67		21		M	
18/10/04	AM	2	C17	*Isoodon auratus barrowensis*	480	982F0091 - 01258734		R	75		25		M	
18/10/04	AM	2	C5	*Isoodon auratus barrowensis*	470	982F0091 - 01351996		R	74		24		M	
18/10/04	AM	2	E20	*Isoodon auratus barrowensis*		982F0091 - 01445505		R						large pouch young
18/10/04	AM	2	C3	*Lagorchestes conspicillatus*	2880		#26		98		21		M	
18/10/04	AM	3	C12	*Bettongia lesueur*	900	982F0091 - 01261952		R	66				F	small pouch young

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	3	C5	*Bettongia lesueur*		not marked							F	
18/10/04	AM	3	C25	*Isoodon auratus barrowensis*	300		#32	R	68		20		M	
18/10/04	AM	3	C15	*Isoodon auratus barrowensis*	135		#64		54				F	virgin pouch
18/10/04	AM	3	C8	*Isoodon auratus barrowensis*	420	982F0091 - 00699086		R					M	
18/10/04	AM	3	C11	*Isoodon auratus barrowensis*	325	982F0091 - 01021009			64		22		M	
18/10/04	AM	3	E16	*Isoodon auratus barrowensis*	235	982F0091 - 01038424			61				F	post lactating
18/10/04	AM	3	C9	*Isoodon auratus barrowensis*	275	982F0091 - 01154140			58		21		M	
18/10/04	AM	3	C4	*Isoodon auratus barrowensis*	285	982F0091 - 01219142		R	64.5				F	post lactating
18/10/04	AM	3	E10	*Isoodon auratus barrowensis*	230	982F0091 - 01241645		R	63.5				F	post lactating
18/10/04	AM	3	C19	*Isoodon auratus barrowensis*	300	982F0091 - 01261312		R	62.5				F	post lactating
18/10/04	AM	3	E18	*Isoodon auratus barrowensis*	320	982F0091 - 01352830		R						
18/10/04	AM	3	C7	*Isoodon auratus barrowensis*	320	982F0091 - 01373856		R						
18/10/04	AM	3	C24	*Isoodon auratus barrowensis*	310	982F0091 - 01659656		R					M	
18/10/04	AM	3	C23	*Isoodon auratus barrowensis*	295	not marked			60				F	large pouch young
18/10/04	AM	3	C6	*Trichosurus vulpecula*	1000	982F0091 - 01192067			67				M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	3	C16	*Trichosurus vulpecula*	1320	982F0091 - 01261220		R	74		32		M	
18/10/04	AM	4	C13	*Bettongia lesueur*	700	982F0091 - 01178882			68		15		M	
18/10/04	AM	4	E22	*Isoodon auratus barrowensis*	115		#16		52				F	virgin pouch
18/10/04	AM	4	E25	*Isoodon auratus barrowensis*	205		#18	R						
18/10/04	AM	4	E2	*Isoodon auratus barrowensis*	168		#19		54		7		M	
18/10/04	AM	4	E8	*Isoodon auratus barrowensis*	260	982F0091 - 01162211		R					M	
18/10/04	AM	4	E21	*Isoodon auratus barrowensis*	265	982F0091 - 01162442			56				F	post lactating
18/10/04	AM	4	E18	*Isoodon auratus barrowensis*	345	982F0091 - 01173374							M	
18/10/04	AM	4	E4	*Isoodon auratus barrowensis*	343	982F0091 - 01261450		R					F	
18/10/04	AM	4	E23	*Isoodon auratus barrowensis*	260	982F0091 - 01263196			63				F	post lactating
18/10/04	AM	4	E20	*Isoodon auratus barrowensis*	260	982F0091 - 01264928		R					F	
18/10/04	AM	4	C11	*Isoodon auratus barrowensis*	260	982F0091 - 01337600			65				F	virgin pouch
18/10/04	AM	4	C10	*Isoodon auratus barrowensis*	355	982F0091 - 01360729		R					F	
18/10/04	AM	4	E12	*Isoodon auratus barrowensis*	430	982F0091 - 01446012		R					M	
18/10/04	AM	4	C5	*Isoodon auratus barrowensis*	295	982F0091 - 01451826		R					F	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	4	P17	*Pseudomys nanus ferculinus*			#18	R	24				F	
18/10/04	AM	4	E19	*Pseudomys nanus ferculinus*	55		#3		33.5		12		M	
18/10/04	AM	4	E3	*Pseudomys nanus ferculinus*	35		torn between #2 and #3	28.7				M		
18/10/04	AM	4	C6	*Trichosurus vulpecula*	650	982F0091 - 01024279		R					M	
18/10/04	AM	4	C17	*Trichosurus vulpecula*	1200	982F0091 - 01222180		R					F	
18/10/04	AM	4	C1	*Trichosurus vulpecula*	960	982F0091 - 01262018		R	68.5				F	pouch young
18/10/04	AM	4	C9	*Trichosurus vulpecula*	1400	982F0091 - 01357271		R						
18/10/04	AM	4	C19	*Trichosurus vulpecula*	1100	982F0091 - 01598396		R	67		28		M	
18/10/04	AM	5	C14	*Bettongia lesueur*	860	982F0091 - 01033357			66				M	
18/10/04	AM	5	C8	*Bettongia lesueur*	920	982F0091 - 01358581		R						
18/10/04	AM	5	E4	*Isoodon auratus barrowensis*	165		#20 (could be #18)	R	53.5				F	no pouch young
18/10/04	AM	5	C7	*Isoodon auratus barrowensis*	210		#64		61				F	pouch young
18/10/04	AM	5	E25	*Isoodon auratus barrowensis*	145		#64		53				F	virgin pouch
18/10/04	AM	5	E22	*Isoodon auratus barrowensis*	235	982F0091 - 01222158		R					F	
18/10/04	AM	5	E11	*Isoodon auratus barrowensis*	360	982F0091 - 01245369		R						
18/10/04	AM	5	E8	*Isoodon auratus barrowensis*	425	982F0091 - 01246696		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	5	E3	*Isoodon auratus barrowensis*	380	982F0091 - 01264875		R						
18/10/04	AM	5	C12	*Isoodon auratus barrowensis*	270	982F0091 - 01266837		R	67				F	post lactating
18/10/04	AM	5	C19	*Isoodon auratus barrowensis*	420	982F0091 - 01267297		R	72		20		M	
18/10/04	AM	5	E2	*Isoodon auratus barrowensis*	380	982F0091 - 01267637		R						
18/10/04	AM	5	E12	*Isoodon auratus barrowensis*	270	982F0091 - 01337805		R						
18/10/04	AM	5	E24	*Isoodon auratus barrowensis*	325	982F0091 - 01381631		R					M	
18/10/04	AM	5	C25	*Isoodon auratus barrowensis*	355	982F0091 - 01454810		R	64		20		M	
18/10/04	AM	5	P21	*Planigale* sp.	11.5		#16		24.1		8		M	
18/10/04	AM	5	E7	*Pseudomys nanus ferculinus*	52		#18		32.4				F	post lactating
18/10/04	AM	5	E13	*Pseudomys nanus ferculinus*	50		#19		32.8				M	
18/10/04	AM	5	C15	*Trichosurus vulpecula*	1100	982F0091 - 01060146			75		24		M	
18/10/04	AM	5	C20	*Trichosurus vulpecula*	1200	982F0091 - 01069349			77		31		M	
18/10/04	AM	5	P14	*Trichosurus vulpecula*	260	982F0091 - 01069611			59					
18/10/04	AM	5	C16	*Trichosurus vulpecula*	1280	982F0091 - 01480090		R	77				M	
18/10/04	AM	5	C11	*Trichosurus vulpecula*	1000	982F0091 - 01541399		R						
18/10/04	AM	6	C11	*Bettongia lesueur*	840	982F0091 - 01237987		R	66		22		M	
18/10/04	AM	6	C1	*Isoodon auratus barrowensis*	235		#17		64				F	pouch young

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	6	C16	*Isoodon auratus barrowensis*	190		#18		63		20		M	
18/10/04	AM	6	E11	*Isoodon auratus barrowensis*	330	982F0091 - 01035190			64		21		M	
18/10/04	AM	6	C6	*Isoodon auratus barrowensis*	355	982F0091 - 01059827			70		23		M	
18/10/04	AM	6	C12	*Isoodon auratus barrowensis*	210	982F0091 - 01191384		R	60		21		M	
18/10/04	AM	6	E25	*Isoodon auratus barrowensis*	420	982F0091 - 01236881		R						
18/10/04	AM	6	C5	*Isoodon auratus barrowensis*	350	982F0091 - 01237480		R	69.5		23		M	
18/10/04	AM	6	C19	*Isoodon auratus barrowensis*	395	982F0091 - 01241467		R	66		23		M	
18/10/04	AM	6	E4	*Isoodon auratus barrowensis*	285	982F0091 - 01261234		R					F	pouch young
18/10/04	AM	6	E16	*Isoodon auratus barrowensis*	232	982F0091 - 01327188		R	61				F	no pouch young
18/10/04	AM	6	E6	*Isoodon auratus barrowensis*	310	982F0091 - 01448585		R	69		22		M	
18/10/04	AM	6	E22	*Isoodon auratus barrowensis*	260	982F0091 - 01451260		R						
18/10/04	AM	6	E19	*Isoodon auratus barrowensis*	298	982F0091 - 01451740		R	60					
18/10/04	AM	6	E21	*Isoodon auratus barrowensis*	330	982F0091 - 01453358		R						
18/10/04	AM	6	E23	*Isoodon auratus barrowensis*	315	982F0091 - 01543154		R						
18/10/04	AM	6	C25	*Lagorchestes conspicillatus*	2450		#16	R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
18/10/04	AM	6	C13	*Lagorchestes conspicillatus*	2350		#20	R					F	no pouch young
18/10/04	AM	6	C24	*Lagorchestes conspicillatus*	2150		#22		88				F	small pouch young
18/10/04	AM	6	C4	*Trichosurus vulpecula*	1150	982F0091 - 01332594			81				F	post lactating
18/10/04	AM	6	C21	*Trichosurus vulpecula*	980	982F0091 - 01377159		R						
19/10/04	AM	1	E11	*Isoodon auratus barrowensis*	310		#16						F	pouch young
19/10/04	AM	1	E7	*Isoodon auratus barrowensis*		982F0091 - 00664874		R						
19/10/04	AM	1	C15	*Isoodon auratus barrowensis*		982F0091 - 00681581		R						
19/10/04	AM	1	E6	*Isoodon auratus barrowensis*		982F0091 - 00690840		R						
19/10/04	AM	1	E14	*Isoodon auratus barrowensis*		982F0091 - 00713545		R						
19/10/04	AM	1	C8	*Isoodon auratus barrowensis*	225	982F0091 - 01059617			64				F	post lactating
19/10/04	AM	1	E2	*Isoodon auratus barrowensis*		982F0091 - 01164936		R						
19/10/04	AM	1	C13	*Isoodon auratus barrowensis*	225	982F0091 - 01180492			62		21		M	
19/10/04	AM	1	E5	*Isoodon auratus barrowensis*		982F0091 - 01221296		R						
19/10/04	AM	1	E9	*Isoodon auratus barrowensis*	382	982F0091 - 01241806		R	65				F	
19/10/04	AM	1	C5	*Isoodon auratus barrowensis*		982F0091 - 01244635		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	1	C3	*Isoodon auratus barrowensis*	310	982F0091 - 01333353			70		22		M	
19/10/04	AM	1	E4	*Isoodon auratus barrowensis*		982F0091 - 01453040		R						
19/10/04	AM	1	C21	*Isoodon auratus barrowensis*										
19/10/04	AM	1	C7	*Trichosurus vulpecula*		982F0091 - 01237580		R						
19/10/04	AM	1	C2	*Trichosurus vulpecula*	1040	982F0091 - 01340125			67		21		M	
19/10/04	AM	2	E24	*Isoodon auratus barrowensis*	105		#16		50				F	
19/10/04	AM	2	C21	*Isoodon auratus barrowensis*	325		#16		67.5		21		M	
19/10/04	AM	2	C1	*Isoodon auratus barrowensis*		982F0091 - 00613872		R						
19/10/04	AM	2	E7	*Isoodon auratus barrowensis*		982F0091 - 00660088		R						
19/10/04	AM	2	C3	*Isoodon auratus barrowensis*	228	982F0091 - 01066536			66		21		M	
19/10/04	AM	2	E1	*Isoodon auratus barrowensis*	320	982F0091 - 01266038		R	71.5				F	inactive pouch
19/10/04	AM	2	E4	*Isoodon auratus barrowensis*		982F0091 - 01351996		R						
19/10/04	AM	2	C4	*Isoodon auratus barrowensis*		982F0091 - 01445505		R						
19/10/04	AM	2	C5	*Isoodon auratus barrowensis*		982F0091 - 11034150		R						
19/10/04	AM	2	C11	*Isoodon auratus barrowensis*		982F0091- 00618982		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	2	C16	*Isoodon auratus barrowensis*		982F0091- 00677956		R						
19/10/04	AM	2	C12	*Isoodon auratus barrowensis*		982F0091- 00689973		R						
19/10/04	AM	2	E16	*Isoodon auratus barrowensis*		982F0091- 00693687		R						
19/10/04	AM	2	E15	*Isoodon auratus barrowensis*	335	982F0091- 00702357		R	60				F	2 x PY
19/10/04	AM	2	C23	*Isoodon auratus barrowensis*		982F0091- 00819380		R						
19/10/04	AM	2	E21	*Isoodon auratus barrowensis*	485	982F0091- 01033775			71		23		M	
19/10/04	AM	2	E22	*Isoodon auratus barrowensis*		982F0091- 01037246			70		20		M	
19/10/04	AM	2	E19	*Isoodon auratus barrowensis*	250	982F0091- 01062890			62				F	Pre-lactating
19/10/04	AM	2	E13	*Isoodon auratus barrowensis*		982F0091- 01169022		R						
19/10/04	AM	2	E17	*Isoodon auratus barrowensis*		982F0091- 01258734		R						
19/10/04	AM	2	C15	*Lagorchestes conspicillatus*	2650		#32							lactating
19/10/04	AM	2	C15	*Lagorchestes conspicillatus*	480		#34		66.5				F	
19/10/04	AM	2	C24	*Trichosurus vulpecula*	1340	982F0091- 01220124		R	72				F	>1 PY
19/10/04	AM	2	C25	*Trichosurus vulpecula*	1190	982F0091- 01260761		R	74		26		M	
19/10/04	AM	3	E18	*Bettongia lesueur*	400	982F0091- 01166229		R						
19/10/04	AM	3	C18	*Bettongia lesueur*	750	982F0091- 01319916		R						
19/10/04	AM	3	C17	*Bettongia lesueur*		982F0091- 01353434		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	3	C12	*Bettongia lesueur*	790	982F0091- 01549647		R						
19/10/04	AM	3	C9	*Bettongia lesueur*	940	982F0091- 01668970			69		27		M	
19/10/04	AM	3	C23	*Isoodon auratus barrowensis*			#18	R					F	virgin pouch
19/10/04	AM	3	E3	*Isoodon auratus barrowensis*	185		#65		57.5		8		M	
19/10/04	AM	3	E24	*Isoodon auratus barrowensis*	165		#66		57		8		M	
19/10/04	AM	3	E17	*Isoodon auratus barrowensis*	150		#68							
19/10/04	AM	3	E8	*Isoodon auratus barrowensis*	410	982F0091- 00699086		R						
19/10/04	AM	3	E25	*Isoodon auratus barrowensis*	215	982F0091- 01026853			60				F	small PY
19/10/04	AM	3	E2	*Isoodon auratus barrowensis*	335	982F0091- 01066534		R						
19/10/04	AM	3	C15	*Isoodon auratus barrowensis*	240	982F0091- 01154140		R						
19/10/04	AM	3	E22	*Isoodon auratus barrowensis*	315	982F0091- 01171557			71		20		M	
19/10/04	AM	3	C25	*Isoodon auratus barrowensis*	260	982F0091- 01190500			53.5				F	PY
19/10/04	AM	3	E9	*Isoodon auratus barrowensis*	360	982F0091- 01218854		R	64		25		M	
19/10/04	AM	3	E4	*Isoodon auratus barrowensis*	33	982F0091- 01219142		R					F	NPY
19/10/04	AM	3	C6	*Isoodon auratus barrowensis*	355	982F0091- 01243662		R	60.5		21		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	3	C13	*Isoodon auratus barrowensis*	290	982F0091- 01261312		R						
19/10/04	AM	3	E11	*Isoodon auratus barrowensis*	220	982F0091- 01326492		R						
19/10/04	AM	3	C2	*Isoodon auratus barrowensis*	260	982F0091- 01327437			40.5				F	PY
19/10/04	AM	3	C1	*Isoodon auratus barrowensis*	265	982F0091- 01328303			59.5				F	NPY
19/10/04	AM	3	E6	*Isoodon auratus barrowensis*	255	982F0091- 01355127		R						
19/10/04	AM	3	E15	*Isoodon auratus barrowensis*	240	982F0091- 01357653		R						
19/10/04	AM	3	E7	*Isoodon auratus barrowensis*	295	982F0091- 01373856		R						
19/10/04	AM	3	C19	*Isoodon auratus barrowensis*		982F0091- 01452045		R						
19/10/04	AM	3	E10	*Isoodon auratus barrowensis*	270	982F0091- 01522376		R						
19/10/04	AM	3	E5	*Isoodon auratus barrowensis*	245	982F0091- 01525412			59				F	Post-lactational
19/10/04	AM	3	E20	*Isoodon auratus barrowensis*	285	982F0091- 01547921		R						
19/10/04	AM	3	E1	*Isoodon auratus barrowensis*	225	982F0091- 01656232			61		19		M	
19/10/04	AM	3	E16	*Isoodon auratus barrowensis*	280	982F0091- 01657326			65				F	Post-lactational
19/10/04	AM	3	E12	*Isoodon auratus barrowensis*	230	982F0091- 01657750			56		17		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	3	E19	*Isoodon auratus barrowensis*		982F0091- 01659656		R						
19/10/04	AM	3	E13	*Isoodon auratus barrowensis*	205	982F0091- 01666093			60		22		M	
19/10/04	AM	3	C21	*Lagorchestes conspicillatus*	3200		#1 (big chunk - natural mark)	97					M	
19/10/04	AM	3	C11	*Trichosurus vulpecula*	1170	982F0091- 01261220		R					M	
19/10/04	AM	3	C5	*Trichosurus vulpecula*	990	982F0091- 01540851			74				M	
19/10/04	AM	4	E18	*Isoodon auratus barrowensis*	200		#18	R					M	
19/10/04	AM	4	E8	*Isoodon auratus barrowensis*	250	982F0091- 01162211		R					M	
19/10/04	AM	4	C17	*Isoodon auratus barrowensis*	260	982F0091- 01162442		R					F	
19/10/04	AM	4	E11	*Isoodon auratus barrowensis*	330	982F0091- 01173374		R					M	
19/10/04	AM	4	E3	*Isoodon auratus barrowensis*	360	982F0091- 01259441		R						
19/10/04	AM	4	C9	*Isoodon auratus barrowensis*	355	982F0091- 01261225		R						
19/10/04	AM	4	C20	*Isoodon auratus barrowensis*	325	982F0091- 01261450		R						
19/10/04	AM	4	E24	*Isoodon auratus barrowensis*	230	982F0091- 01263196		R						
19/10/04	AM	4	C24	*Isoodon auratus barrowensis*	260	982F0091- 01264928		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	4	E7	*Isoodon auratus barrowensis*	265	982F0091- 01337600		R					F	
19/10/04	AM	4	E1	*Isoodon auratus barrowensis*	315	982F0091- 01357113		R	64				F	post-lactating
19/10/04	AM	4	C5	*Isoodon auratus barrowensis*	345	982F0091- 01360729		R					F	
19/10/04	AM	4	E6	*Isoodon auratus barrowensis*	260	982F0091- 01361694		R	65				F	2 x very small PY
19/10/04	AM	4	E21	*Isoodon auratus barrowensis*	425	982F0091- 01446012		R					M	
19/10/04	AM	4	E4	*Isoodon auratus barrowensis*	305	982F0091- 01451826		R						
19/10/04	AM	4	C7	*Isoodon auratus barrowensis*	225	982F0091- 01655481			59		9.5		M	
19/10/04	AM	4	E2	*Isoodon auratus barrowensis*	225	982F0091- 01661132			56				F	virgin pouch
19/10/04	AM	4	E24	*Isoodon auratus barrowensis*	285	982F0091- 01662579			60		19		M	
19/10/04	AM	4	C1	*Trichosurus vulpecula*	600	982F0091- 01024279		R						
19/10/04	AM	4	C13	*Trichosurus vulpecula*	920	982F0091- 01180577		R					F	
19/10/04	AM	4	E22	*Trichosurus vulpecula*	1170	982F0091- 01222180		R					F	
19/10/04	AM	4	C11	*Trichosurus vulpecula*	1290	982F0091- 01357271		R					M	
19/10/04	AM	5	C5	*Bettongia lesueur*	630	982F0091- 01060164		R						
19/10/04	AM	5	C4	*Bettongia lesueur*	380	982F0091- 01166621		R						
19/10/04	AM	5	C9	*Bettongia lesueur*	870	982F0091- 01654682			70		24		M	
19/10/04	AM	5	E4	*Isoodon auratus barrowensis*	195		#19		58		9		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	5	E10	*Isoodon auratus barrowensis*	135		#65		49		10		M	
19/10/04	AM	5	C8	*Isoodon auratus barrowensis*	195		#66		54		9		M	
19/10/04	AM	5	E15	*Isoodon auratus barrowensis*	200		#67		56		8		M	
19/10/04	AM	5	E19	*Isoodon auratus barrowensis*	195		#68		59				F	virgin pouch
19/10/04	AM	5	E17	*Isoodon auratus barrowensis*	165		#69		55				F	virgin pouch
19/10/04	AM	5	E7	*Isoodon auratus barrowensis*	210	982F0091- 01018809		R						
19/10/04	AM	5	E8	*Isoodon auratus barrowensis*	220	982F0091- 01175495		R	60		22		M	
19/10/04	AM	5	E25	*Isoodon auratus barrowensis*	280	982F0091- 01221505		R	60				F	small PY
19/10/04	AM	5	E22	*Isoodon auratus barrowensis*	270	982F0091- 01222158		R						
19/10/04	AM	5	C20	*Isoodon auratus barrowensis*	410	982F0091- 01246696		R					M	
19/10/04	AM	5	E23	*Isoodon auratus barrowensis*	310	982F0091- 01258127		R						
19/10/04	AM	5	E11	*Isoodon auratus barrowensis*	265	982F0091- 01266837		R						
19/10/04	AM	5	C22	*Isoodon auratus barrowensis*	430	982F0091- 01267297		R						
19/10/04	AM	5	E3	*Isoodon auratus barrowensis*	370	982F0091- 01267637		R					M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	5	C12	*Isoodon auratus barrowensis*	270	982F0091- 01337805		R						
19/10/04	AM	5	C24	*Isoodon auratus barrowensis*	290	982F0091- 01354739		R						
19/10/04	AM	5	C25	*Isoodon auratus barrowensis*	315	982F0091- 01381631		R						
19/10/04	AM	5	E13	*Isoodon auratus barrowensis*		982F0091- 01541775			63.5				F	Large PY CR=20mm
19/10/04	AM	5	E18	*Isoodon auratus barrowensis*	245	982F0091- 01670154			59		21		M	
19/10/04	AM	5	C7	*Lagorchestes conspicillatus*	2900		#3	R						
19/10/04	AM	5	C6	*Lagorchestes conspicillatus*	2950		#4 (natural mark)	96		25		M		
19/10/04	AM	5	P14	*Pseudomys nanus ferculinus*	35		#16	R					M	
19/10/04	AM	5	E1	*Pseudomys nanus ferculinus*	10.5		#20		26				M	
19/10/04	AM	5	C10	*Trichosurus vulpecula*	1170	982F0091- 01069349		R						
19/10/04	AM	5	C2	*Trichosurus vulpecula*	890	982F0091- 01244679		R	78.5				F	NPY
19/10/04	AM	5	C15	*Trichosurus vulpecula*	990	982F0091- 01380569			79				F	
19/10/04	AM	5	C14	*Trichosurus vulpecula*	1210	982F0091- 01453702		R	75		30		M	
19/10/04	AM	5	C11	*Trichosurus vulpecula*	1250	982F0091- 01480090		R						
19/10/04	AM	6	C1	*Isoodon auratus barrowensis*	255		#16	R						
19/10/04	AM	6	E22	*Isoodon auratus barrowensis*	170		#20		54.5				F	virgin pouch

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	6	E1	*Isoodon auratus barrowensis*		982F0091 - 01035190		R						
19/10/04	AM	6	E19	*Isoodon auratus barrowensis*	345	982F0091 - 01061173			66		17		M	
19/10/04	AM	6	C11	*Isoodon auratus barrowensis*	360	982F0091 - 01164926			69		21		M	
19/10/04	AM	6	C21	*Isoodon auratus barrowensis*	200	982F0091 - 01165279 and #18	R	65						
19/10/04	AM	6	E16	*Isoodon auratus barrowensis*	260	982F0091 - 01188434			70		24		M	
19/10/04	AM	6	C20	*Isoodon auratus barrowensis*		982F0091 - 01191384		R						
19/10/04	AM	6	E21	*Isoodon auratus barrowensis*		982F0091 - 01236881		R						
19/10/04	AM	6	C15	*Isoodon auratus barrowensis*		982F0091 - 01241467		R						
19/10/04	AM	6	E8	*Isoodon auratus barrowensis*		982F0091 - 01261234		R	62					
19/10/04	AM	6	C16	*Isoodon auratus barrowensis*	340	982F0091 - 01341030			70		23		M	
19/10/04	AM	6	E4	*Isoodon auratus barrowensis*	407	982F0091 - 01352288		R	70		23		M	
19/10/04	AM	6	E11	*Isoodon auratus barrowensis*		982F0091 - 01451260		R						
19/10/04	AM	6	E10	*Isoodon auratus barrowensis*		982F0091 - 01453358		R						
19/10/04	AM	6	E23	*Isoodon auratus barrowensis*		982F0091 - 01543154		R						
19/10/04	AM	6	C3	*Lagorchestes conspicillatus*	3050		#28		92		21		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
19/10/04	AM	6	C7	*Trichosurus vulpecula*	1040	982F0091 - 01036036			76		24		M	
19/10/04	AM	6	C6	*Trichosurus vulpecula*	1150	982F0091 - 01332594		R						
20/10/04	AM	1	C7	*Bettongia lesueur*	1870	982F0091- 00985920			10		21		M	
20/10/04	AM	1	C13	*Isoodon auratus barrowensis*	160		#18		58				F	virgin pouch
20/10/04	AM	1	C24	*Isoodon auratus barrowensis*	95		#24		52				F	virgin pouch
20/10/04	AM	1	E7	*Isoodon auratus barrowensis*	280		#32 (natural)	68				F	small pouch young	
20/10/04	AM	1	E1	*Isoodon auratus barrowensis*		982F0091- 00664874		R						
20/10/04	AM	1	C22	*Isoodon auratus barrowensis*		982F0091- 00690840		R						
20/10/04	AM	1	E4	*Isoodon auratus barrowensis*		982F0091- 00713545		R						
20/10/04	AM	1	C25	*Isoodon auratus barrowensis*		982F0091- 01164936		R						
20/10/04	AM	1	C6	*Isoodon auratus barrowensis*	235	982F0091- 01218191			67				F	Post-lactational
20/10/04	AM	1	E3	*Isoodon auratus barrowensis*		982F0091- 01241806		R						
20/10/04	AM	1	C2	*Isoodon auratus barrowensis*		982F0091- 01243648		R						
20/10/04	AM	1	C9	*Isoodon auratus barrowensis*		982F0091- 01333353		R						
20/10/04	AM	1	C8	*Isoodon auratus barrowensis*		982F0091- 01338730		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
20/10/04	AM	1	C14	*Isoodon auratus barrowensis*	315	982F0091- 01357359			71				F	small pouch young
20/10/04	AM	1	C11	*Isoodon auratus barrowensis*	375	982F0091- 01359995			64				F	small pouch young
20/10/04	AM	1	C15	*Isoodon auratus barrowensis*		982F0091- 01453040		R						
20/10/04	AM	1	C5	*Isoodon auratus barrowensis*		982F0091- 01509617		R						
20/10/04	AM	1	C1	*Trichosurus vulpecula*		982F0091- 01062845		R						
20/10/04	AM	1	C3	*Trichosurus vulpecula*		982F0091- 01237580		R						
20/10/04	AM	1	C16	*Trichosurus vulpecula*	1470	982F0091- 01265683			79		31		M	
20/10/04	AM	2	C21	*Isoodon auratus barrowensis*	320		#16	R	63.5				M	
20/10/04	AM	2	E1	*Isoodon auratus barrowensis*		982F0091- 00613872		R						
20/10/04	AM	2	E11	*Isoodon auratus barrowensis*		982F0091- 00618982		R			26		M	
20/10/04	AM	2	C16	*Isoodon auratus barrowensis*	390	982F0091- 00677956		R						
20/10/04	AM	2	E12	*Isoodon auratus barrowensis*	335	982F0091- 00689973		R						
20/10/04	AM	2	E9	*Isoodon auratus barrowensis*		982F0091- 00702357		R						
20/10/04	AM	2	E23	*Isoodon auratus barrowensis*	365	982F0091- 00819380		R						
20/10/04	AM	2	C22	*Isoodon auratus barrowensis*	460	982F0091- 01033775		R						

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
20/10/04	AM	2	E14	*Isoodon auratus barrowensis*	290	982F0091- 01034150		R						
20/10/04	AM	2	C5	*Isoodon auratus barrowensis*	215	982F0091- 01066536		R						
20/10/04	AM	2	E13	*Isoodon auratus barrowensis*	310	982F0091- 01169022		R						
20/10/04	AM	2	C25	*Isoodon auratus barrowensis*	400	982F0091- 01245501		R	62		24		M	
20/10/04	AM	2	C18	*Isoodon auratus barrowensis*	435	982F0091- 01258734		R					M	
20/10/04	AM	2	C1	*Isoodon auratus barrowensis*		982F0091- 01266038		R						
20/10/04	AM	2	C4	*Isoodon auratus barrowensis*	405	982F0091- 01445505		R						large PY
20/10/04	AM	2	C7	*Isoodon auratus barrowensis*	320	982F0091- 01447147		R	67				F	Post-lactational
20/10/04	AM	2	E20	*Isoodon auratus barrowensis*	340	982F0091- 01481092			65.6				F	PY
20/10/04	AM	2	C9	*Lagorchestes conspicillatus*		#18	R							
20/10/04	AM	2	C20	*Lagorchestes conspicillatus*	2250		#32	R						
20/10/04	AM	2	C17	*Trichosurus vulpecula*	250	982F0091- 01220124		R						
20/10/04	AM	2	C24	*Trichosurus vulpecula*	1170	982F0091- 01260761		R						
20/10/04	AM	2	C23	*Trichosurus vulpecula*	1190	982F0091- 01667601			71		27		M	
20/10/04	AM	6	E21	*Isoodon auratus barrowensis*	185		#22		60		17		M	
20/10/04	AM	6	C16	*Isoodon auratus barrowensis*	145		#26		59		13		M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
20/10/04	AM	6	E20	*Isoodon auratus barrowensis*	220	982F0091- 00957324			60		20		M	
20/10/04	AM	6	E22	*Isoodon auratus barrowensis*		982F0091- 01164926		R						
20/10/04	AM	6	E6	*Isoodon auratus barrowensis*	365	982F0091- 01188434		R						
20/10/04	AM	6	C21	*Isoodon auratus barrowensis*		982F0091- 01191384		R						
20/10/04	AM	6	E16	*Isoodon auratus barrowensis*		982F0091- 01236881		R?						
20/10/04	AM	6	C14	*Isoodon auratus barrowensis*	320	982F0091- 01237480		R						
20/10/04	AM	6	C18	*Isoodon auratus barrowensis*		982F0091- 01241467		R?						
20/10/04	AM	6	E8	*Isoodon auratus barrowensis*		982F0091- 01244207		R	64				F	Post-lactational
20/10/04	AM	6	E10	*Isoodon auratus barrowensis*	250	982F0091- 01261234		R						
20/10/04	AM	6	C25	*Isoodon auratus barrowensis*		982F0091- 01327188		R						
20/10/04	AM	6	C5	*Isoodon auratus barrowensis*	390	982F0091- 01352288		R					M	
20/10/04	AM	6	E13	*Isoodon auratus barrowensis*	265	982F0091- 01374608			58				F	Post-lactational
20/10/04	AM	6	C6	*Isoodon auratus barrowensis*	250	982F0091- 01375356			60.5				F	PY
20/10/04	AM	6	E1	*Isoodon auratus barrowensis*	315	982F0091- 01448585		R					M	

Date	Time	Grid	Trap	Species	Wt	PIT#	Ear Clip #	Rec	Crown	GL	GW	Pes	Sex	Young
20/10/04	AM	6	E11	*Isoodon auratus barrowensis*	205	982F0091- 01451260		R						
20/10/04	AM	6	E25	*Isoodon auratus barrowensis*		982F0091- 01451740		R						
20/10/04	AM	6	C19	*Isoodon auratus barrowensis*		982F0091- 01453358		R?						
20/10/04	AM	6	C23	*Isoodon auratus barrowensis*		982F0091- 01543154		R						
20/10/04	AM	6	C20	*Lagorchestes conspicillatus*	3050		#18							
20/10/04	AM	6	C24	*Lagorchestes conspicillatus*	2470		#64 (?? natural)	86		25			M	
20/10/04	AM	6	C4	*Lagorchestes conspicillatus*	2300	unmarked			80		26		M	
20/10/04	AM	6	C1	*Trichosurus vulpecula*			#1		56		10		M	young of 01546382
20/10/04	AM	6	C9	*Trichosurus vulpecula*	1070	982F0091- 01332594		R						
20/10/04	AM	6	C15	*Trichosurus vulpecula*	930	982F0091- 01377159		R						
20/10/04	AM	6	C1	*Trichosurus vulpecula*		982F0091- 01546382			75				F	mother of #1

Attachment 6 - Annotated List of Reptiles Collected From the Proposed Development Area in November 2003

Ctenophorus c. caudicinctus

This species was observed on more occasions than the five vouchered specimens suggest (R154125 – 29) and from most areas visited. Most observations were of individuals amongst *Triodia* on exposed limestone and were typically observed basking on large rocks in the windrows along the major roads or on termitaria. There was variation with respect to colour patterns of the males.

This species is represented in the Western Australian Museum's collection by 75 specimens, including three with associated tissue samples. Collection localities are given as Barrow Island, Double Island, Town Point, Flacourt Bay, Turtle Bay, Surf Point, Cape Malouet. Smith (1976) notes that this species was widespread across the Island whilst Butler (1970) noted it as the 'most prevalent and obvious reptile on the Island.'

Delma borea

Recorded from just two specimens (R154143 and R154148) including a gravid female. A juvenile (R154143, SVL of 36 mm) was raked from beneath spoil on G1 (20° 47.402' 115° 27.364') whilst the gravid female (R154148, SVL of 79mm) was collected from pit trap 13 on G4. The species is represented in the Western Australian Museum's collection by just two specimens, one collected in 1973, with a locality listed as Shark Point and the other collected in 1967, listed as Barrow Island.

The '*borea*' species complex has recently been reviewed by Brad Maryan (Western Australian Museum) using both morphological and molecular analysis, though no tissue from Barrow Island individuals was available at the time of the study. The study suggests that the Barrow Island population is the same species as that from the mainland Pilbara at Mandora.

Delma nasuta

A single gravid female (SVL 100 mm, R154170) was collected from trapping grid 1. This species is represented in the Western Australian Museum's collection by 63 specimens, most of which (n=53) were collected by Smith (1976) during his visit in late October/early November 1973. The remaining individuals were collected prior to 1989, with the majority being collected in the 1970s. Smith also collected gravid females during his October/November survey and noted that specimens predominantly came from '*T. angusta o*n red sands and loams.' Locality records from the Western Australian Museum's collection comprise Barrow Island and Flacourt Bay.

Lialis burtonis

Recorded on two occasions, the first record was of a female collected from the cliff in Airport Creek (R154133) a second female (R154134) was collected from pale dunes vegetated with *Triodia* sp. adjacent to trap point T1.11.

The Western Australian Museum's collection includes 21 specimens, all collected during, or prior to 1977, with the locality given as either Barrow Island or Cape Malouet. Smith (1976) collected 17 specimens from '*T. angusta* whilst Butler (1970) notes that he collected specimens from '*Triodia* tussocks, mostly in dune habitats.'

Gehyra variegata

A single specimen (R154142) was collected from the accommodation block at the main camp. The form collected appears to differ from another specimen collected earlier in the year, that also appears to occur on Cape Range and on Varanus Island.

The taxon is represented by 14 specimens in the Western Australian Museum's collection with localities listed as Barrow Island, Town Point, Boodie Island, Whitlock Cove and Flacourt Bay. Smith (1976) collected his specimens from 'under debris such as timber, iron and old tyres.'

Heteronotia binoei

Eleven specimens that were vouchered (R154100 – R154108, R154114, R154141) were collected during the survey. Most were collected whilst raking beneath leaf litter, but specimens were also collected from the main track through the proposed Development area whilst road-spotting, and from termitaria.

Represented by 51 specimens in the collection from localities including Barrow Island, Town Point and Boodie Island. With the exception of one specimen collected in 1990, the remaining collections were made prior to 1977. Smith (1976) notes that this species was 'particularly common under man-made debris' whilst Butler (1970) recorded this species from 'termitaria, caves, *Triodia* clumps and under old camp rubbish.'

Strophurus jeanae

Single specimen (R154145) collected from under a live *Triodia* hummock. Represented by 15 specimens in the collection with localities given as Town Point and Barrow Island. With the exception of one specimen collected in 1990, all others were collected prior to 1977. Smith (1976) recorded all specimens from '*T. angusta* on siliceous sands and loams.'

Carlia triacantha

Several specimens were observed actively foraging on exposed limestone cap, but none were captured. Known from three specimens in the collection, with localities given as Town Point and Flacourt Bay. This species may be genuinely uncommon on Barrow Island. Smith (1976) only recorded a single individual from a 'well vegetated inter-dune near Town Point.'

Cryptoblepharus carnabyi

Five records including one from dead *Acacia coriacea* on the primary dunes within the proposed gas processing facility footprint area (R154112) and four specimens (R154109 – 11 and R154113) collected from low walls within the main camp. Known from 12 specimens within the Western Australian Museum's collection from localities given as Barrow Island and Town Point. Butler (1970) collected this species from mangrove trunks, rock faces, termitaria and caves, whilst Smith (1976) collected his specimens from similar habitat and the trunk of a eucalypt.

Ctenotus grandis

This species was represented by 18 captures including ten specimens vouchered with the Western Australian Museum (R154081 – 90). All individuals recorded by the authors were captured using medium size Elliott traps. A small section of tail was taken from the remaining eight individuals and stored in 100 % ethanol for future molecular studies.

This species is represented by 11 specimens in the collection, including two from 2001 from which tissue was taken. Locations are given as Barrow Island and Town Point. Both Butler (1970) and Smith (1976) record this species as being collected from sand areas.

Ctenotus pantherinus acripes

Only two specimens were collected, though an additional two were seen actively moving through *Triodia* hummock grass. This taxon is represented by 40 specimens in the collections of the Western Australian Museum, but just one from which tissue was taken. Butler (1970) recorded his specimens from *'Triodia* and *Frankenia* on barren salt eroded limestone outcrops on the west coast.' Smith (1976) noted the primary habitat as 'rocky areas with *Triodia wiseana.'*

According to current taxonomy this sub-species does not occur elsewhere in Western Australia, but is recorded from Northern Territory and Queensland (Horner 1991). There is some question over the validity of the sub-species described for Western Australia (Aplin and Smith, 2001) and genetic studies are required.

Ctenotus saxatilis

This species was recorded on nine occasions with an additional two specimens collected from the trapping grids; all eleven specimens were eventually vouchered (R154091 – 99 and R154149 – 50). The majority of the individuals (n=9) were collected using medium size Elliott traps established along the three transects and came from *Triodia* hummock grassland.

The species is well represented in the Western Australian Museum's collection with 96 specimens, though none are complemented with tissue samples. Localities are given as Barrow Island, South Double Island, South Pascoe Island, Town Point, Flacourt Bay, Surf Point, Cape Dupuy, Double Island, Pelican Point, Ant Point and Bandicoot Bay. Smith (1976) notes that this species is the 'dominant skink on the Island ... found in all habitats'. Butler (1970) indicates that this species occurs in '*Triodia* and coastal *Spinifex* thickets'.

The closely related taxa *Ctenotus saxatilis*, *C. fallens* and *C. ornatus* are currently the subject of a detailed phylogenetic study which will also attempt to resolve species distributions in these very similar looking species. Additional collections from Barrow Island and its close neighbours would provide valuable tissue to help resolve these phylogenies as well as place the Barrow Island population in a regional context.

Cyclodomorphus melanops

Recorded from three specimens during opportunistic collections (R154130 – 32) including one gravid female, supplemented by an additional three specimens (R154152, R154154 and R154160) collected from pit-traps in the trapping grids. The former three were recorded from beneath dead *Triodia* in spoil piles and, in one case, from under *Triodia* on limestone.

Represented by 60 specimens in the Western Australian Museum's collection, including one specimen with tissue. Localities are given as Barrow Island, Cape Dupuy, Town Point and Surf Point. Smith (1976) gives the habitat of this species as '*T. angusta* on consolidated dunes and loamy flats'. He also recorded females with enlarged follicles during October and November.

Lerista bipes

A total of ten individuals were lodged with the Western Australian Museum, comprising eight specimens (R154114 – 22) raked from beneath debris and vegetation and a further two collected from pit traps (R154171 – 72). The collection included three individuals collected from Cape Dupuy. Specimens were raked from white siliceous sand on the primary dunes as well as loamy areas.

Represented by 89 specimens in the Western Australian Museum, including just two with associated tissue samples. Localities are given as Barrow Island, Town Point, Flacourt Bay, Surf Point, WAPET Camp, Bandicoot Bay, Pelican Point and Ant Point. Smith (1976) notes that this species was recorded from 'consolidated dunes and loamy flats'.

Lerista muelleri

Two opportunistic collections (R154139 – 40) were supplemented by six pit-trapped specimens (R154162 – 67). Those collected opportunistically were raked from beneath spoil in Airport Creek and from beneath *Triodia* at Cape Dupuy.

Represented by 42 specimens within the Western Australian Museum's collection with locations given as Barrow Island, Town Point, Flacourt Bay, Bandicoot Bay, Pelican Point and Ant Point. Smith (1976) notes that this species was found from 'consolidated dunes'. He recorded one female with an enlarged follicle during October/November.

A recent review of this species complex yielded in excess of 15 new species and it is appears that the Barrow Island taxon is similar to that on the adjacent Pilbara coast.

Menetia greyii

Nine specimens vouchered with the Western Australian Museum, including seven collected from pit-traps (R154153, R154156 – 58, R154161, R154169, R154173) and two collected opportunistically, including one raked from beneath *Triodia* on a primary dune (R154123) and another from under *Triodia* on limestone (R154144). The collection included one gravid female.

Poorly collected on Barrow Island, with just four specimens in the Western Australian Museum collection, with localities given as Barrow Island and Flacourt Bay. The sparsity of this species on Barrow Island was noted by Smith (1976).

This taxa is known to be a complex of species that displays polyploidy, probable parthenogenesis, sympatry and hybridisation (Aplin and Smith 2001).

Morethia ruficauda exquisita

Just the one specimen vouchered with the Western Australian Museum (R154174) collected from a pit-trap.

Represented by 26 specimens in the Western Australian Museum collection with localities given as Barrow Island, Town Point, Flacourt Bay, Pelican Point and Ant Point. Smith (1976) found this species in all habitats but noted it 'mostly in siliceous foredunes and consolidated dunes.'

Notoscincus ornatus ornatus

Five specimens vouchered with the Western Australian Museum, including three from pit traps (R154147, R154155, R154159), one raked from beneath spoil in Airport Creek (R154137) and another from *Triodia* on exposed limestone near Town Point (R154138).

Represented by 25 specimens in the collection including two specimens with associated tissue samples. Localities include Barrow Island, Town Point, Surf Point and Flacourt Bay. Smith (1976) notes that this species 'can be found in all habitats but is most common in consolidated dunes and loamy flats.'

Proablepharus reginae

Just two specimens vouchered with the Western Australian Museum, both collected opportunistically. The first was raked from beneath spoil in Airport Creek (R154135) and the second was collected near T1.21 in sparse *Acacia coriacea* on red loam.

Thirty-one specimens in the Western Australian Museum's collection with localities given as Barrow Island, Flacourt Bay and Surf Point.

Varanus giganteus

No specimens vouchered but often encountered on the major tracks and at Town Point.

Represented in the Western Australian Museum's collection by eight specimens, all collected prior to 1985. There are no supporting tissue samples. It is envisaged that any road kill specimens will be collected and stored in the chest freezer on site. Any such specimens will provide valuable tissue for any future molecular studies.

Pseudechis australis

A single individual collected whilst road-spotting through the proposed Development area (R154124).

This species is represented by just six specimens in the Western Australian Museum collection, with localities given as Barrow Island and Town Point.

Smith (1976) suggests that the Barrow Island form of this species may exhibit dwarfism given the shorter SVL in these individuals.

Attachment 7 - Annotated List of Reptiles Collected From the Proposed Development Area in August-September 2004

AGAMIDAE

Ctenophorus caudicinctus caudicinctus

This species was recorded on nine occasions at Flacourt Bay, alternative campsites and the Gorgon footprint area. Most records were in Acacia over Triodia on limestone (seven observations) with the remaining two records being in Melaleuca cardiophylla and Triodia on limestone. Smith (1976) notes that this species was "seen all over the island" whilst Butler (1970) noted is as the "most prevalent and obvious reptile on the island."

Pogona minor minor

Recorded from two individuals captured in the alternative campsites and old airport area. One individual was from Triodia angusta valleys and the other was from Triodia on loam. Smith (1976) collected most specimens from "2-3 m up in dead Hakea lorea, or Acacia shrubs". Butler (1970) recorded most specimens from Acacia coriacea along the coast and this was the habitat where most individuals were captured during the trapping program in 2003.

PYGOPODIDAE

Delma borea

Recorded on just one occasion from east of the old airport. The individual was captured in Triodia on loam. Smith (1976) states that the one specimen he obtained was "out of Triodia".

The 'borea' species complex has recently been reviewed by Brad Maryan (Western Australian Museum), using both morphological and molecular anlaysis. His study suggests that the Barrow Island population is the same species as that from the mainland Pilbara at Mandora.

GEKKONIDAE

Gehyra variegata

A single individual was recorded in the Gorgon project area near the pipeline in Melaleuca cardiophylla and Triodia on limestone. This individual apparently belong to a species found on Barrow Island and adjacent parts of the Pilbara mainland, which is different from true variegata (G. Harold, pers. comm.). Smith (1976) collected his specimens from "under debris such as timber, iron and old tyres" and Butler (1970) obtained his specimens from "dead Acacia coriacea, caves and termitaria" although it seems likely that his records include other Gehyra species.

Heteronotia binoei

Five records from the alternative campsites, Gorgon project area and old airport area. Most records from Melaleuca cardiophylla and Triodia on limestone (three records) with one record from Triodia angusta valleys and one record from cleared areas at the old airport. Smith (1976) notes that this species was "particularly common under man-made debris" whilst Butler (1970) recorded this species from "termitaria, caves, Triodia clumps and under old camp rubbish".

SCINCIDAE

Cryptoblepharus carnabyi

Recorded from two individuals. One was collected from a stone wall at the main camp and the other was collected from bare sandstone below a limestone cliff at Barge Landing. Butler (1970) collected this species from "rock faces, mangrove trunks, termitaria and caves", whilst Smith (1976) collected his specimens from "mangroves, a eucalypt trunk, the wall of a building and the face of a sink hole".

This species, as currently recognised, is a species complex containing over a dozen true species. It is not clear how widely distributed the form on Barrow Island is.

Ctenotus grandis titan

Only one capture from Triodia on loam in the alternative campsites. Both Butler (1970) and Smith (1976) record this species as being collected from sand areas.

Ctenotus pantherinus acripes

Seven records from the Gorgon project area and alternative campsites. Most records were from Triodia on loam (five records) with the remaining two records being from Melaleuca cardiophylla and Triodia on limestone. This species was recorded from north of the Gorgon footprint during this survey and Butler (1970) recorded his specimens from "Triodia and Frankenia on barren salt eroded limestone outcrops on the west coast". Smith (1976) noted the primary habitat as "rocky areas with Triodia wiseana". This species is clearly widespread across the island.

According to current taxonomy this sub-species does not occur elsewhere in Western Australia, but is recorded from Northern Territory and Queensland (Horner 1991). There is some question over the validity of the sub-species described for Western Australia (Smith and Aplin 2001) and genetic studies are required.

Ctenotus saxatilis

Five records from White's Beach, old airport area and Gorgon project area. It was recorded in a range of habitats with single records in each of Acacia over Triodia on limestone, Melaleuca cardiophylla and Triodia on limestone, Triodia on loam, disturbed ground and Triodia angusta valleys. Smith (1976) notes that this species is the "dominant skink on the island ….found in all habitats." Butler (1970) indicates that this species occurs in "Triodia and coastal Spinifex thickets."

Cyclodomorphus melanops melanops

Eight records from the old airport and Gorgon project areas. Two records from each of Triodia angusta valleys and regrowth Triodia in rehabilitated areas with single records from each of Melaleuca cardiophylla and Triodia on limestone, Acacia over Triodia on limestone and Triodia on loam. Butler (1970) obtained all his specimens "from Triodia except one found under a limestone slab". Smith (1976) gives the habitat o this species as "T. angusta on consolidated dunes and loamy flats". He also recorded females with enlarged follicles during October and November.

Lerista bipes

Seven records from the Gorgon project area and Airport Creek. Most records were from Acacia coriacea over Triodia on coastal sand (three records) and Triodia on loam (two records) with single records from each of Melaleuca cardiophylla and Triodia on limestone and Acacia over Triodia on limestone. Butler (1970) said that "their tracks are extremely common throughout the island in sandy areas" and Smith (1976) notes that this species was recorded from "consolidated dunes and loamy flats".

Lerista elegans

One record from just north of Town Point, in Acacia coriacea on white beach sand. Not previously recorded in the Gorgon project area. During the 2004 trapping survey, the species was recorded in large numbers from Triodia on white sand in the Bandicoot Bay area and Butler (1970) reports it as being common "on Triodia in sand". Not collected by Smith (1976).

Lerista muelleri

Seven records from the alternative campsites, old airport area and Gorgon project area. Most records from Acacia over Triodia on limestone (five observations), with the remaining two records from Melaleuca cardiophylla and Triodia on limestone. Smith (1976) notes that this species was found "among consolidated dunes" and Butler (1970) recorded one from a "sand dune…..among Acacia and Spinifex".

A recent review of this species complex by Laurie Smith at the WA Museum yielded in excess of 15 new species and it is appears that the Barrow Island taxon is similar to that on the adjacent Pilbara coast.

Menetia greyii

Nine records from White's Beach, alternative campsites, old airport area and Gorgon project area. Most records from Melaleuca cardiophylla and Triodia on limestone (four records), with further records from Triodia on loam (three records), Triodia angusta valleys (one record) and Triodia on the edge of a rehabilitated area (one record). Not recorded by either Butler (1970), or Smith (1976).

This taxa is know to be a complex of species that displays polyploidy, probable parthenogenesis, sympatry and hybridisation (Aplin and Smith 2001).

Morethia ruficauda exquisita

Three records from the Gorgon project area in Melaleuca cardiophylla and Triodia on limestone (two records) and Acacia coriacea on white sand (one record). Smith (1976) found this species in all habitats but noted it "mostly in siliceous foredunes and consolidated dunes" and Butler (1970) found it "on limestone edges of sand dunes".

Notoscincus ornatus ornatus

Four records from the old airport and Gorgon project areas. Two records from Acacia over Triodia on limestone, with single records from each of Triodia angusta valleys and Melaleuca cardiophylla and Triodia on limestone. Not recorded by Butler (1970) but Smith (1976) notes that this species "can be found in all habitats but is most common in consolidated dunes and loamy flats".

Proablepharus reginae

Five records from the alternative campsites, old airport area and Gorgon project area. Three records from Triodia on loam, with single records from each of Triodia angusta valleys and Melaleuca cardiophylla and Triodia on limestone. Butler (1970) recorded the species from "Triodia on sand" whilst Smith (1976) recorded it only from "Triodia angusta on sandy soil" but noted that it was one of the most common lizards on the island.

VARANIDAE

Varanus acanthurus

One record from Acacia coriacea on white sand just north of Town Point. Not recorded by Butler (1970) and Smith (1976) collected three specimens, "two under rubbish, the other out of Triodia".

Varanus giganteus

Four observations from the alternative campsites and Gorgon project area. Two observations in Acacia over Triodia on limestone with one observation from Triodia on loam. Butler (1970) described the species as "wide-ranging over all habitats" and Smith (1976) had 27 sightings "in all habitats".

Attachment 8 - List of Reptile Specimens from Barrow Island Donated to the Western Australian Museum

Reg No.	Genus	Species	Subspecies	Latitude	Longitude	Date
154363	*Antaresia*	*stimsoni*	*stimsoni*	20°49`36"S	115°26`41"E	29/11/2003
154109	*Cryptoblepharus*	*carnabyi*		20°49`36"S	115°26`41"E	22/11/2003
154110	*Cryptoblepharus*	*carnabyi*		20°49`36"S	115°26`41"E	20/11/2003
154111	*Cryptoblepharus*	*carnabyi*		20°49`36"S	115°26`41"E	20/11/2003
154112	*Cryptoblepharus*	*carnabyi*		20°47`18"S	115°27`46"E	20/11/2003
154113	*Cryptoblepharus*	*carnabyi*		20°49`36"S	115°26`41"E	23/11/2003
154125	*Ctenophorus*	*caudicinctus*	*caudicinctus*	20°40`16"S	115°26`13"E	24/11/2003
154126	*Ctenophorus*	*caudicinctus*	*caudicinctus*	20°48`09"S	115°26`53"E	23/11/2003
154127	*Ctenophorus*	*caudicinctus*	*caudicinctus*	20°47`32"S	115°26`18"E	22/11/2003
154128	*Ctenophorus*	*caudicinctus*	*caudicinctus*	20°47`32"S	115°26`18"E	23/11/2003
154129	*Ctenophorus*	*caudicinctus*	*caudicinctus*	20°47`06"S	115°27`42"E	23/11/2003
154081	*Ctenotus*	*grandis*	*titan*	20°47`58"S	115°27`12"E	20/11/2003
154082	*Ctenotus*	*grandis*	*titan*	20°47`58"S	115°27`12"E	20/11/2003
154083	*Ctenotus*	*grandis*	*titan*	20°47`58"S	115°27`12"E	22/11/2003
154084	*Ctenotus*	*grandis*	*titan*	20°47`12"S	115°27`22"E	22/11/2003
154085	*Ctenotus*	*grandis*	*titan*	20°47`12"S	115°27`22"E	21/11/2003
154086	*Ctenotus*	*grandis*	*titan*	20°47`58"S	115°27`12"E	20/11/2003
154087	*Ctenotus*	*grandis*	*titan*	20°47`12"S	115°27`22"E	21/11/2003
154088	*Ctenotus*	*grandis*	*titan*	20°47`58"S	115°27`12"E	21/11/2003
154089	*Ctenotus*	*grandis*	*titan*	20°47`58"S	115°27`12"E	22/11/2003
154090	*Ctenotus*	*grandis*	*titan*	20°47`58"S	115°27`12"E	22/11/2003
154151	*Ctenotus*	*pantherinus*	*acripes*	20°47`29"S	115°27`31"E	28/11/2003
154168	*Ctenotus*	*pantherinus*	*acripes*	20°47`58"S	115°27`12"E	30/11/2003
154389	*Ctenotus*	*pantherinus*	*acripes*	20°47`12"S	115°27`22"E	29/11/2003
154091	*Ctenotus*	*saxatilis*		20°47`58"S	115°27`12"E	22/11/2003
154092	*Ctenotus*	*saxatilis*		20°47`58"S	115°27`12"E	22/11/2003
154093	*Ctenotus*	*saxatilis*		20°47`03"S	115°27`21"E	24/11/2003
154094	*Ctenotus*	*saxatilis*		20°47`03"S	115°27`21"E	24/11/2003
154095	*Ctenotus*	*saxatilis*		20°47`12"S	115°27`22"E	21/11/2003
154096	*Ctenotus*	*saxatilis*		20°47`03"S	115°27`21"E	24/11/2003
154097	*Ctenotus*	*saxatilis*		20°47`58"S	115°27`12"E	20/11/2003
154098	*Ctenotus*	*saxatilis*		20°47`58"S	115°27`12"E	24/11/2003
154099	*Ctenotus*	*saxatilis*		20°47`58"S	115°27`12"E	24/11/2003
154149	*Ctenotus*	*saxatilis*		20°47`29"S	115°27`31"E	28/11/2003

Reg No.	Genus	Species	Subspecies	Latitude	Longitude	Date
154150	*Ctenotus*	*saxatilis*		20°47`03"S	115°27`21"E	28/11/2003
154130	*Cyclodomorphus*	*melanops*	*melanops*	20°48`08"S	115°26`52"E	21/11/2003
154131	*Cyclodomorphus*	*melanops*	*melanops*	20°48`08"S	115°26`52"E	21/11/2003
154132	*Cyclodomorphus*	*melanops*	*melanops*	20°47`06"S	115°27`42"E	19/11/2003
154152	*Cyclodomorphus*	*melanops*	*melanops*	20°47`18"S	115°27`43"E	27/11/2003
154154	*Cyclodomorphus*	*melanops*	*melanops*	20°47`58"S	115°27`12"E	29/11/2003
154160	*Cyclodomorphus*	*melanops*	*melanops*	20°47`12"S	115°27`22"E	28/11/2003
154143	*Delma*	*borea*		20°47`24"S	115°27`21"E	21/11/2003
154148	*Delma*	*borea*		20°47`18"S	115°27`43"E	26/11/2003
154170	*Delma*	*nasuta*		20°47`12"S	115°27`22"E	28/11/2003
154362	*Delma*	*nasuta*		20°46`35"S	115°26`53"E	02/12/2003
154142	*Gehyra*	*variegata*		20°47`06"S	115°27`42"E	22/11/2003
154100	*Heteronotia*	*binoei*		20°49`55"S	115°26`06"E	22/11/2003
154101	*Heteronotia*	*binoei*		20°48`06"S	115°26`54"E	22/11/2003
154102	*Heteronotia*	*binoei*		20°48`08"S	115°26`53"E	21/11/2003
154103	*Heteronotia*	*binoei*		20°47`18"S	115°27`46"E	20/11/2003
154104	*Heteronotia*	*binoei*		20°47`28"S	115°27`12"E	21/11/2003
154105	*Heteronotia*	*binoei*		20°47`16"S	115°27`09"E	22/11/2003
154106	*Heteronotia*	*binoei*		20°47`16"S	115°27`09"E	22/11/2003
154107	*Heteronotia*	*binoei*		20°48`08"S	115°26`53"E	21/11/2003
154108	*Heteronotia*	*binoei*		20°48`08"S	115°26`53"E	21/11/2003
154114	*Heteronotia*	*binoei*		20°48`48"S	115°26`31"E	22/11/2003
154141	*Heteronotia*	*binoei*		20°49`24"S	115°27`18"E	24/11/2003
154115	*Lerista*	*bipes*		20°40`16"S	115°26`13"E	23/11/2003
154116	*Lerista*	*bipes*		20°40`16"S	115°26`13"E	23/11/2003
154117	*Lerista*	*bipes*		20°47`18"S	115°27`47"E	20/11/2003
154118	*Lerista*	*bipes*		20°40`16"S	115°26`13"E	23/11/2003
154119	*Lerista*	*bipes*		20°47`18"S	115°27`46"E	20/11/2003
154120	*Lerista*	*bipes*		20°48`20"S	115°27`03"E	21/11/2003
154121	*Lerista*	*bipes*		20°48`24"S	115°27`01"E	22/11/2003
154122	*Lerista*	*bipes*		20°48`24"S	115°27`01"E	22/11/2003
154171	*Lerista*	*bipes*		20°47`12"S	115°27`22"E	01/12/2003
154172	*Lerista*	*bipes*		20°47`03"S	115°27`21"E	01/12/2003
154139	*Lerista*	*muelleri*		20°48`16"S	115°26`57"E	18/11/2003
154140	*Lerista*	*muelleri*		20°40`15"S	115°26`13"E	23/11/2003
154162	*Lerista*	*muelleri*		20°47`12"S	115°27`22"E	27/11/2003
154163	*Lerista*	*muelleri*		20°47`12"S	115°27`22"E	28/11/2003

Reg No.	Genus	Species	Subspecies	Latitude	Longitude	Date
154164	*Lerista*	*muelleri*		20°47`29"S	115°27`31"E	27/11/2003
154165	*Lerista*	*muelleri*		20°47`29"S	115°27`31"E	27/11/2003
154166	*Lerista*	*muelleri*		20°47`58"S	115°27`12"E	27/11/2003
154167	*Lerista*	*muelleri*		20°47`18"S	115°27`43"E	25/11/2003
154133	*Lialis*	*burtonis*		20°48`08"S	115°26`53"E	20/11/2003
154134	*Lialis*	*burtonis*		20°47`28"S	115°27`27"E	21/11/2003
154123	*Menetia*	*greyii*		20°48`24"S	115°27`01"E	22/11/2003
154144	*Menetia*	*greyii*		20°47`32"S	115°26`18"E	23/11/2003
154153	*Menetia*	*greyii*		20°47`03"S	115°27`21"E	28/11/2003
154156	*Menetia*	*greyii*		20°46`35"S	115°26`53"E	29/11/2003
154157	*Menetia*	*greyii*		20°46`35"S	115°26`53"E	29/11/2003
154158	*Menetia*	*greyii*		20°47`29"S	115°27`31"E	29/11/2003
154161	*Menetia*	*greyii*		20°47`12"S	115°27`22"E	28/11/2003
154169	*Menetia*	*greyii*		20°47`12"S	115°27`22"E	28/11/2003
154173	*Menetia*	*greyii*		20°47`03"S	115°27`21"E	01/12/2003
154174	*Morethia*	*ruficauda*	*exquisita*	20°47`58"S	115°27`12"E	30/11/2003
154137	*Notoscincus*	*ornatus*	*ornatus*	20°48`16"S	115°26`57"E	18/11/2003
154138	*Notoscincus*	*ornatus*	*ornatus*	20°48`00"S	115°28`00"E	22/11/2003
154147	*Notoscincus*	*ornatus*	*ornatus*	20°47`03"S	115°27`21"E	28/11/2003
154155	*Notoscincus*	*ornatus*	*ornatus*	20°47`12"S	115°27`22"E	29/11/2003
154159	*Notoscincus*	*ornatus*	*ornatus*	20°47`03"S	115°27`21"E	28/11/2003
154135	*Proablepharus*	*reginae*		20°48`16"S	115°26`57"E	18/11/2003
154136	*Proablepharus*	*reginae*		20°47`28"S	115°27`27"E	24/11/2003
154124	*Pseudechis*	*australis*		20°48`32"S	115°27`18"E	24/11/2003
154145	*Strophurus*	*jeanae*		20°47`20"S	115°27`17"E	22/11/2003

Attachment 9 - Report on the Findings of the Hepetofauna Survey of the Gorgon Project Area 2004. Report to RPS Bowman Bishaw Gorham by Biota Environmental Sciences, April 2005.

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Report on the findings of the herpetofauna survey of the Gorgon project area 2004

Introduction

The purpose of the herpetofauna work was to sample the Gorgon project area at a different season and, specifically, to search for additional herpetofauna species that may have been present in the Gorgon project area. The aim of the survey was to collect species that do not readily enter pit traps and to search for previously unrecorded species, in particular *Aprasia rostrata* (see below). That new species are still to be recorded for Barrow Island is suggested by the recent (Jan 2004) recording of *Varanus brevicauda* on Obe's Beach.

Methodology

The herpetofauna survey was conducted between the 25th August and 1st September 2004 in comparison to the 18th and 25th November 2003. For the 2004 survey, hand foraging and raking was conducted throughout the day as the cooler temperatures enabled reptiles to remain active throughout the daylight hours. However, little nocturnal work was completed because the low temperatures and strong winds after dark precluded any significant reptile activity at night time (Table 1). A total of 33.4mm of rain had fallen on Barrow between 1st April 2004 and the end of the survey compared to an average from April to August inclusive of 162.7mm. This indicates that the survey was conducted during a very dry period.

Table 1: Climatic variables for Barrow Island for the duration of the 2004 herpetofauna survey (data from Bureau of Meteorology website http://www.bom.gov.au/climate/dwo/IDCJDW6008.shtml)

Date	25/8/04	26/8/04	27/8/04	28/8/04	29/8/04	30/8/04	31/8/04	1/9/04	Average
Maximum	23.8	23.9	23.9	23.5	22.4	22.0	21.3	23.1	23.0
Minimum	19.1	18.6	17.7	18.1	17.7	17.7	13.4	14.7	17.1
Rainfall	0	0	0	0	0	0	0	0	0

For all reptiles hand captured or identified in the field, we recorded (1) date, (2) species, (3) number of individuals, (4) location (northings and eastings in WGS 84) and (5) a habitat description. All collecting was undertaken under licences granted to Mr Greg Harold by the Department of Conservation and Land Management (DCLM).

Results

The targeted herpetofauna survey yielded 19 species of reptile (Table 2). This compares with 18 species captured in the 2003 survey and a total of 42 species known from the island (excluding sea-snakes and marine turtles). All of the 19 species were previously known from the Gorgon project area, except *Lerista elegans*. The location of all individuals captured during the herpetological survey are shown in Figure 1.

Table 2: Reptile species recorded from Barrow Island (Source: Butler 1970, Smith 1976; WA Museum Faunabase, Brad Maryan pers comm.)

Family Agamidae	*Cyclodomorphus melanops melanops**
*Ctenophorus caudicinctus caudicinctus**	*Eremiascincus richardsonii*
Lophognathus gilberti	*Glaphyromorphus isolepis*
*Pogona minor**	*Lerista bipes**
Family Pygopodidae	*Lerista elegans**
*Delma borea**	*Lerista muelleri**
Delma nasuta	*Menetia greyii**
Delma tincta	*Morethia lineoocellata*
Lialis burtonis	*Morethia ruficauda exquisita**
Pygopus nigriceps	*Notoscincus ornatus ornatus**
Family Gekkonidae	*Proablepharus reginae**
Diplodactylus stenodactylus	**Family Typhlopidae**
Gehyra pilbara	*Ramphotyphlops ammodytes*
*Gehyra variegata**	*Ramphotyphlops longissimus*
*Heteronotia binoei**	**Family Varanidae**
Strophurus jeanae	*Varanus acanthurus**
Family Scincidae	*Varanus brevicauda*
Carlia triacantha	*Varanus giganteus**
*Cryptoblepharus carnabyi**	*Family Boidae*
Ctenotus duricola	*Antaresia stimsoni*
*Ctenotus grandis titan**	Family Elapidae
Ctenotus hanloni	*Brachyurophis approximans*
*Ctenotus pantherinus acripes**	*Demansia psammophis reticulata*
*Ctenotus saxatilis**	*Furina ornata*
Ctenotus serventyi	*Pseudechis australis*

* recorded during the 2004 survey

Annotated List

AGAMIDAE

Ctenophorus caudicinctus caudicinctus

This species was recorded on nine occasions at Flacourt Bay, alternative campsites and the Gorgon footprint area. Most records were in *Acacia* over *Triodia* on limestone (seven observations) with the remaining two records being in *Melaleuca cardiophylla* and *Triodia* on limestone. Smith (1976) notes that this species was "*seen all over the island*" whilst Butler (1970) noted is as the "*most prevalent and obvious reptile on the island*."

Pogona minor minor
Recorded from two individuals captured in the alternative campsites and old airport area. One individual was from *Triodia angusta* valleys and the other was from *Triodia* on loam. Smith (1976) collected most specimens from "*2-3 m up in dead Hakea lorea, or Acacia shrubs*". Butler (1970) recorded most specimens from *Acacia coriacea* along the coast and this was the habitat where most individuals were captured during the trapping program in 2003.

PYGOPODIDAE
Delma borea
Recorded on just one occasion from east of the old airport. The individual was captured in *Triodia* on loam. Smith (1976) states that the one specimen he obtained was "out of *Triodia*".
The '*borea'* species complex has recently been reviewed by Brad Maryan (Western Australian Museum), using both morphological and molecular anlaysis. His study suggests that the Barrow Island population is the same species as that from the mainland Pilbara at Mandora.

GEKKONIDAE
Gehyra variegata
A single individual was recorded in the Gorgon project area near the pipeline in *Melaleuca cardiophylla* and *Triodia* on limestone. This individual apparently belong to a species found on Barrow Island and adjacent parts of the Pilbara mainland, which is different from true *variegata* (G. Harold, pers. comm.). Smith (1976) collected his specimens from "*under debris such as timber, iron and old tyres*" and Butler (1970) obtained his specimens from "*dead Acacia coriacea, caves and termitaria*" although it seems likely that his records include other *Gehyra* species.

Heteronotia binoei
Five records from the alternative campsites, Gorgon project area and old airport area. Most records from *Melaleuca cardiophylla* and *Triodia* on limestone (three records) with one record from *Triodia angusta* valleys and one record from cleared areas at the old airport. Smith (1976) notes that this species was "*particularly common under man-made debris*" whilst Butler (1970) recorded this species from "*termitaria, caves, Triodia clumps and under old camp rubbish*".

SCINCIDAE
Cryptoblepharus carnabyi
Recorded from two individuals. One was collected from a stone wall at the main camp and the other was collected from bare sandstone below a limestone cliff at Barge Landing. Butler (1970) collected this species from "*rock faces, mangrove trunks, termitaria and caves*", whilst Smith (1976) collected his specimens from "*mangroves, a eucalypt trunk, the wall of a building and the face of a sink hole*".
This species, as currently recognised, is a species complex containing over a dozen true species. It is not clear how widely distributed the form on Barrow Island is.

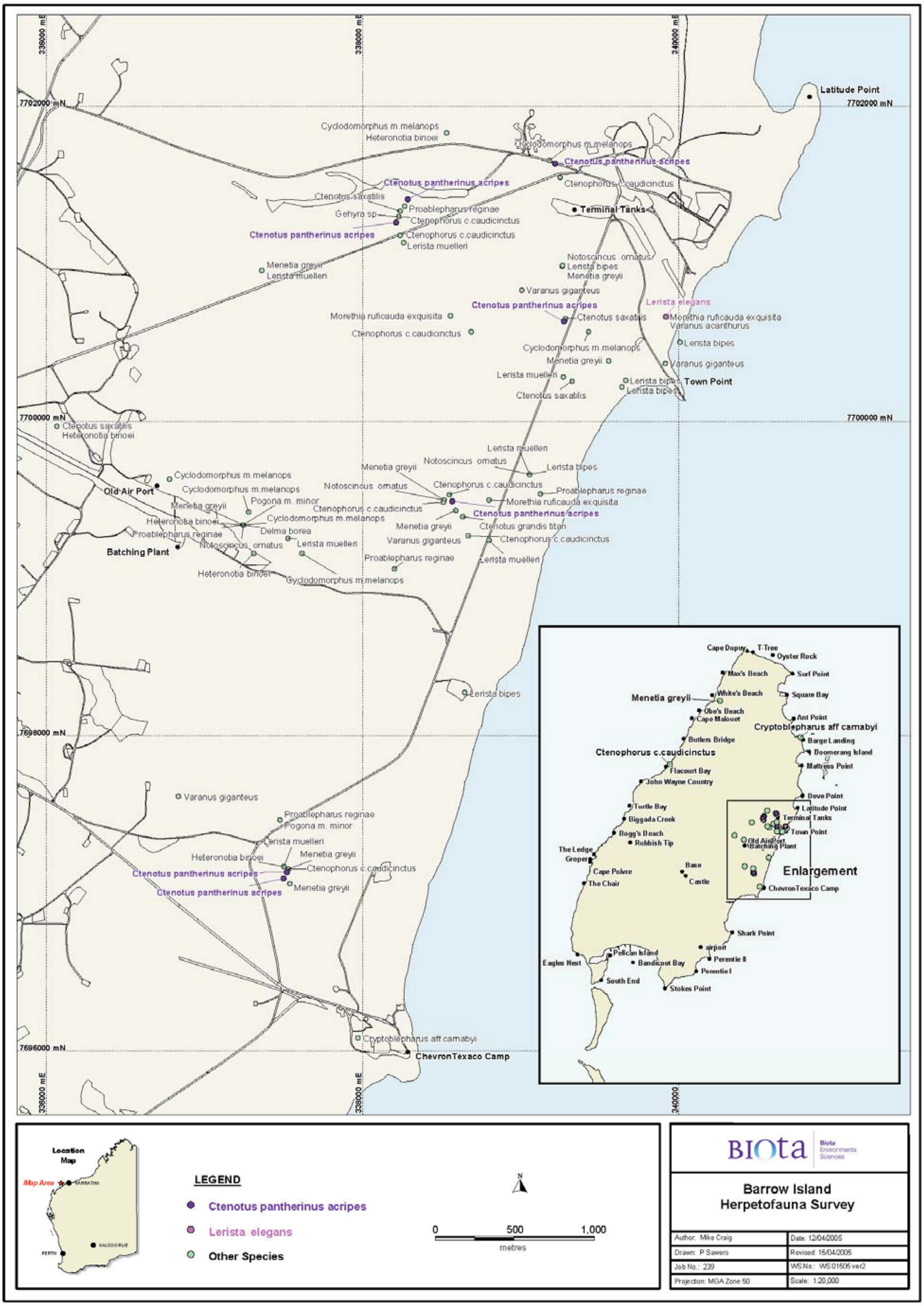

Figure 1. Location of all reptiles captured during the herpetological survey.

Ctenotus grandis titan
Only one capture from *Triodia* on loam in the alternative campsites. Both Butler (1970) and Smith (1976) record this species as being collected from sand areas.

Ctenotus pantherinus acripes
Seven records from the Gorgon project area and alternative campsites. Most records were from *Triodia* on loam (five records) with the remaining two records being from *Melaleuca cardiophylla* and *Triodia* on limestone. This species was recorded from north of the Gorgon footprint during this survey and Butler (1970) recorded his specimens from "*Triodia and Frankenia on barren salt eroded limestone outcrops on the west coast*". Smith (1976) noted the primary habitat as "*rocky areas with Triodia wiseana*". This species is clearly widespread across the island.
According to current taxonomy this sub-species does not occur elsewhere in Western Australia, but is recorded from Northern Territory and Queensland (Horner 1991). There is some question over the validity of the sub-species described for Western Australia (Smith and Aplin 2001) and genetic studies are required.

Ctenotus saxatilis
Five records from White's Beach, old airport area and Gorgon project area. It was recorded in a range of habitats with single records in each of *Acacia* over *Triodia* on limestone, *Melaleuca cardiophylla* and *Triodia* on limestone, *Triodia* on loam, disturbed ground and *Triodia angusta* valleys. Smith (1976) notes that this species is the "*dominant skink on the island ….found in all habitats*." Butler (1970) indicates that this species occurs in "*Triodia and coastal Spinifex thickets*."

Cyclodomorphus melanops melanops
Eight records from the old airport and Gorgon project areas. Two records from each of *Triodia angusta* valleys and regrowth *Triodia* in rehabilitated areas with single records from each of *Melaleuca cardiophylla* and *Triodia* on limestone, *Acacia* over *Triodia* on limestone and *Triodia* on loam. Butler (1970) obtained all his specimens "*from Triodia except one found under a limestone slab*". Smith (1976) gives the habitat o this species as "*T. angusta on consolidated dunes and loamy flats*". He also recorded females with enlarged follicles during October and November.

Lerista bipes
Seven records from the Gorgon project area and Airport Creek. Most records were from *Acacia coriacea* over *Triodia* on coastal sand (three records) and *Triodia* on loam (two records) with single records from each of *Melaleuca cardiophylla* and *Triodia* on limestone and *Acacia* over *Triodia* on limestone. Butler (1970) said that "*their tracks are extremely common throughout the island in sandy areas*" and Smith (1976) notes that this species was recorded from "*consolidated dunes and loamy flats*".

Lerista elegans
One record from just north of Town Point, in *Acacia coriacea* on white beach sand. Not previously recorded in the Gorgon project area. During the 2004 trapping survey, the species was recorded in large numbers from *Triodia* on white sand in the Bandicoot Bay

area and Butler (1970) reports it as being common "*on Triodia in sand*". Not collected by Smith (1976).

Lerista muelleri
Seven records from the alternative campsites, old airport area and Gorgon project area. Most records from *Acacia* over *Triodia* on limestone (five observations), with the remaining two records from *Melaleuca cardiophylla* and *Triodia* on limestone. Smith (1976) notes that this species was found "*among consolidated dunes*" and Butler (1970) recorded one from a "*sand dune…..among Acacia and Spinifex*".
A recent review of this species complex by Laurie Smith at the WA Museum yielded in excess of 15 new species and it is appears that the Barrow Island taxon is similar to that on the adjacent Pilbara coast.

Menetia greyii
Nine records from White's Beach, alternative campsites, old airport area and Gorgon project area. Most records from *Melaleuca cardiophylla* and *Triodia* on limestone (four records), with further records from *Triodia* on loam (three records), *Triodia angusta* valleys (one record) and *Triodia* on the edge of a rehabilitated area (one record). Not recorded by either Butler (1970), or Smith (1976).
This taxa is know to be a complex of species that displays polyploidy, probable parthenogenesis, sympatry and hybridisation (Aplin and Smith 2001).

Morethia ruficauda exquisita
Three records from the Gorgon project area in *Melaleuca cardiophylla* and *Triodia* on limestone (two records) and *Acacia coriacea* on white sand (one record). Smith (1976) found this species in all habitats but noted it "*mostly in siliceous foredunes and consolidated dunes*" and Butler (1970) found it "*on limestone edges of sand dunes*".

Notoscincus ornatus ornatus
Four records from the old airport and Gorgon project areas. Two records from *Acacia* over *Triodia* on limestone, with single records from each of *Triodia* angusta valleys and *Melaleuca cardiophylla* and *Triodia* on limestone. Not recorded by Butler (1970) but Smith (1976) notes that this species "*can be found in all habitats but is most common in consolidated dunes and loamy flats*".

Proablepharus reginae
Five records from the alternative campsites, old airport area and Gorgon project area. Three records from *Triodia* on loam, with single records from each of *Triodia angusta* valleys and *Melaleuca cardiophylla* and *Triodia* on limestone. Butler (1970) recorded the species from "*Triodia on sand*" whilst Smith (1976) recorded it only from "*Triodia angusta on sandy soil*" but noted that it was one of the most common lizards on the island.

VARANIDAE
Varanus acanthurus
One record from *Acacia coriacea* on white sand just north of Town Point. Not recorded by Butler (1970) and Smith (1976) collected three specimens, "*two under rubbish, the other out of Triodia*".

Varanus giganteus
Four observations from the alternative campsites and Gorgon project area. Two observations in *Acacia* over *Triodia* on limestone with one observation from *Triodia* on loam. Butler (1970) described the species as "*wide-ranging over all habitats*" and Smith (1976) had 27 sightings "*in all habitats*".

Discussion

The 2004 herpetofauna survey recorded only one additional species for the Gorgon project area, the skink *Lerista elegans*. This species was recorded north of Town Point on the edge of the Gorgon footprint. However, the species is widespread elsewhere on the island and appears to be particularly common in white sand areas around Bandicoot Bay. In addition, *Ctentous pantherinus acripes* was also recorded to the north of the Gorgon footprint which, combined with Butler's records from the west coast, indicate that the species is widespread outside the Gorgon footprint. None of the species recorded in he Gorgon project area are restricted to that part of the island.

One species that was not recorded during the 2004 survey was the pygopodid *Aprasia rostrata*, even though it was specifically targeted. This species is found on the Montbello Islands and on the Pilbara mainland at Cape Range, so its absence from Barrow Island is surprising. Its apparent absence from the Gorgon project area suggests that searches in the northern part of Barrow Island around Cape Dupuy may be more fruitful. The northern part of the island was separated from the much larger southern part when sea levels were higher a few thousand years ago (W.H. Butler, pers. comm.). As this area is geographically closer to the Montebello Islands, it seems the most likely place for the species to occur, assuming that it is present on Barrow Island.

Another species not recorded by this survey, *Ramphotyphlops longissimus*, is the only reptile species endemic to Barrow Island. However, this species is known from only one pair hauled up from below ground with some well casings (Storr et al. 2002). Based on its morphology, this species appears to spend its entire life in subterranean limestone caves. Thus, there is almost no chance of detecting one during a terrestrial survey such as this one. It is hoped that further stygofauna and troglobitic surveys will reveal more specimens.

A total of 27 reptile species are now known from the Gorgon project area (Table 3). As reptile assemblages can change markedly over time, particularly in arid areas in response to rainfall events, it is unlikely that the reptile list for the Gorgon project area is complete. However, it is likely that any additional species are rare or temporally highly variable in abundance in the project area. Based on the species recorded so far, none are restricted to the Gorgon project area.

Table 2: Reptile species recorded from the Gorgon Project Area

Family Agamidae	*Cyclodomorphus melanops melanops*
Ctenophorus caudicinctus caudicinctus	*Lerista bipes*
Pogona minor	*Lerista elegans*
Family Pygopodidae	*Lerista muelleri*
Delma borea	*Menetia greyii*
Delma nasuta	*Morethia ruficauda exquisita*
Lialis burtonis	*Notoscincus ornatus ornatus*
Pygopus nigriceps	*Proablepharus reginae*
Family Gekkonidae	**Family Typhlopidae**
Gehyra variegata	*Ramphotyphlops ammodytes*
Heteronotia binoei	**Family Varanidae**
Strophurus jeanae	*Varanus acanthurus*
Family Scincidae	*Varanus giganteus*
Carlia triacantha	**Family Boidae**
Cryptoblepharus carnabyi	*Antaresia stimsoni*
Ctenotus grandis titan	**Family Elapidae**
Ctenotus pantherinus acripes	*Pseudechis australis*
Ctenotus saxatilis	

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Horner, P. (1991). Skinks of the Northern Territory. Northern Territory Government Printing Office, Darwin.

Smith, L.A. (1976). The Reptiles of Barrow Island. *Western Australian Naturalist*, **13**: 125-136.

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Appendix 1: A list of the all the reptiles seen or captured during the 2004 herpetofauna survey including location and habitat information.

Family	Species	Number	Northing	Easting	Habitat	Comments
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	1	338238	7701179	*Acacia* over *Triodia* on limestone	
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	1	331192	7705341	*Triodia* on limestone	Limestone headland
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	2	338229	7701297	*Triodia* on limestone	
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	1	338511	7699486	*Triodia* on limestone	
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	1	338549	7699533	*Triodia* on limestone	
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	1	338668	7699272	*Triodia* on limestone	
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	3	339249	7701547	*Triodia* on limestone	
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	1	337532	7697155	*Triodia*/*Melaleuca* on limestone	
AGAMIDAE	*Ctenophorus caudicinctus caudicinctus*	1	338687	7700567	*Triodia*/*Melaleuca* on limestone	
AGAMIDAE	*Pogona minor minor*	1	337246	7699341	*Triodia angusta*	In rehab pit
AGAMIDAE	*Pogona minor minor*	1	337478	7697468	*Triodia* on red loamy sand	
PYGOPODIDAE	*Delma borea*	2	337246	7699341	*Triodia* on red loamy sand	
GEKKONIDAE	*Gehyra variegata*	1	338229	7701297	*Triodia*/*Melaleuca* on limestone	
GEKKONIDAE	*Heteronotia binoei*	9	337246	7699341	*Triodia angusta*	On edge of rehab
GEKKONIDAE	*Heteronotia binoei*	1	338532	7701830	*Triodia* on limestone	
GEKKONIDAE	*Heteronotia binoei*	1	337312	7699160	*Triodia*/*Melaleuca* on limestone	
GEKKONIDAE	*Heteronotia binoei*	1	337503	7697172	*Triodia*/*Melaleuca* on limestone	Dead in pit
GEKKONIDAE	*Heteronotia binoei*	1	336068	7699966	?	Dead in pit trap
SCINCIDAE	*Cryptoblepharus carnabyi*	1	341044	7707397	On bare sandstone below limestone cliff	Dead in pit
SCINCIDAE	*Cryptoblepharus carnabyi*	3	337971	7696084	Stone walls at camp	
SCINCIDAE	*Ctenotus grandis titan*	1	338634	7699393	*Triodia* on red loamy sand	
SCINCIDAE	*Ctenotus pantherinus acripes*	1	337501	7697096	*Acacia* over *Triodia* on limestone	
SCINCIDAE	*Ctenotus pantherinus acripes*	1	337522	7697137	*Acacia* over *Triodia* on loamy sand	
SCINCIDAE	*Ctenotus pantherinus acripes*	1	339273	7700632	*Acacia* over *Triodia* on loamy sand	
SCINCIDAE	*Ctenotus pantherinus acripes*	1	338567	7699491	*Triodia* on red loamy sand	
SCINCIDAE	*Ctenotus pantherinus acripes*	1	339217	7701636	*Triodia* on red loamy sand	
SCINCIDAE	*Ctenotus pantherinus acripes*	1	338213	7701261	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Ctenotus pantherinus acripes*	3	338286	7701408	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Ctenotus saxatilis*	1	339325	7700252	*Acacia* over *Triodia* on limestone	

SCINCIDAE	*Ctenotus saxatilis*	1	334970	7710149	Dead *Triodia* along creek	
SCINCIDAE	*Ctenotus saxatilis*	1	336068	7699966	Scattered herbs on bare hard loam	Dead in pit trap
SCINCIDAE	*Ctenotus saxatilis*	1	339283	7700651	*Triodia* on red loamy sand	
SCINCIDAE	*Ctenotus saxatilis*	1	338238	7701333	*Triodia*/*Melaleuca* on limestone	Dead in pit trap
SCINCIDAE	*Cyclodomorphus melanops melanops*	2	337280	7699424	Sparse *Acacia* over *Triodia* on rehab	
SCINCIDAE	*Cyclodomorphus melanops melanops*	1	337618	7699160	*Triodia angusta*	
SCINCIDAE	*Cyclodomorphus melanops melanops*	1	?	?	*Triodia angusta*	
SCINCIDAE	*Cyclodomorphus melanops melanops*	1	336780	7699632	*Triodia* on edge of rehab	
SCINCIDAE	*Cyclodomorphus melanops melanops*	1	338532	7701830	*Triodia* on limestone	
SCINCIDAE	*Cyclodomorphus melanops melanops*	2	339182	7701655	*Triodia* on red loamy sand	
SCINCIDAE	*Cyclodomorphus melanops melanops*	1	339429	7700567	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Cyclodomorphus melanops melanops*	4	337246	7699341	?	
SCINCIDAE	*Lerista bipes*	1	339640	7700217	*Acacia* coriacea on wet sand dune	
SCINCIDAE	*Lerista bipes*	1	339664	7700258	*Acacia* coriacea on wet sand dune	
SCINCIDAE	*Lerista bipes*	1	338646	7698278	*Acacia* coriacea over *Triodia* on sand	
SCINCIDAE	*Lerista bipes*	1	339056	7699662	*Acacia* over *Triodia* on loamy sand	
SCINCIDAE	*Lerista bipes*	1	340007	7700502	*Acacia* over *Triodia* on loamy sand	
SCINCIDAE	*Lerista bipes*	2	339056	7699662	*Triodia* on limestone	Dead in pit trap
SCINCIDAE	*Lerista bipes*	2	339262	7700983	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Lerista elegans*	1	339918	7700662	*Acacia* coriacea on white beach sand	
SCINCIDAE	*Lerista muelleri*	1	338260	7701133	*Acacia* over *Triodia* on limestone	
SCINCIDAE	*Lerista muelleri*	1	338800	7699243	*Acacia* over *Triodia* on limestone	
SCINCIDAE	*Lerista muelleri*	1	337363	7700956	*Triodia* on limestone	
SCINCIDAE	*Lerista muelleri*	1	339056	7699662	*Triodia* on limestone	Dead in pit trap
SCINCIDAE	*Lerista muelleri*	1	339270	7700280	*Triodia* on limestone	Dead in pit trap
SCINCIDAE	*Lerista muelleri*	2	337503	7697172	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Lerista muelleri*	1	337529	7699257	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Menetia greyii*	1	334970	7710149	Dead *Triodia* along creek	
SCINCIDAE	*Menetia greyii*	1	337541	7697063	*Melaleuca* & *Acacia* over *Triodia* on sandy loam	
SCINCIDAE	*Menetia greyii*	7	337246	7699341	*Triodia* on edge of rehab	
SCINCIDAE	*Menetia greyii*	2	338589	7699433	*Triodia* on red loamy sand	
SCINCIDAE	*Menetia greyii*	1	339556	7700383	*Triodia* on red loamy sand	
SCINCIDAE	*Menetia greyii*	2	337363	7700956	*Triodia*/*Melaleuca* on limestone	

SCINCIDAE	*Menetia greyii*	1	337532	7697155	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Menetia greyii*	1	338516	7699499	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Menetia greyii*	1	339262	7700983	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Morethia ruficauda exquisita*	1	339918	7700662	*Acacia coriacea* on white beach sand	
SCINCIDAE	*Morethia ruficauda exquisita*	1	338556	7700668	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Morethia ruficauda exquisita*	1	338800	7699499	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Notoscincus ornatus ornatus*	1	337246	7699341	*Triodia angusta*	On edge of rehab
SCINCIDAE	*Notoscincus ornatus ornatus*	1	338516	7699499	*Triodia* on limestone	
SCINCIDAE	*Notoscincus ornatus ornatus*	1	339056	7699662	*Triodia* on limestone	Dead in pit
SCINCIDAE	*Notoscincus ornatus ornatus*	1	339264	7700988	*Triodia*/*Melaleuca* on limestone	
SCINCIDAE	*Proablepharus reginae*	1	337478	7697468	*Acacia* over *Triodia* on loamy sand	
SCINCIDAE	*Proablepharus reginae*	1	339124	7699538	*Acacia* over *Triodia* on loamy sand	
SCINCIDAE	*Proablepharus reginae*	1	338202	7699061	*Melaleuca* over *Triodia* on loamy sand	
SCINCIDAE	*Proablepharus reginae*	1	337246	7699341	*Triodia angusta*	On edge of rehab
SCINCIDAE	*Proablepharus reginae*	1	338266	7701364	*Triodia*/*Melaleuca* on limestone	
VARANIDAE	*Varanus acanthurus*	1	339918	7700662	*Acacia coriacea* on white beach sand	Dead
VARANIDAE	*Varanus giganteus*	1	338668	7699272	*Triodia* on limestone	
VARANIDAE	*Varanus giganteus*	1	339914	7700365	*Triodia* on limestone	Town point
VARANIDAE	*Varanus giganteus*	1	336836	7697617	*Triodia* on red loamy sand	
VARANIDAE	*Varanus giganteus*	1	339007	7700831	?	

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Technical Appendix C3

Avifauna

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

AVIFAUNA

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Report No: R03203
April 2005

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1 Introduction

The Gorgon Venture proposes to develop a terrestrial gas processing facility and associated marine infrastructure at Town Point on the east coast of Barrow Island. The proposed development area near Town Point includes littoral and terrestrial habitats used by shorebirds, seabirds and landbirds. Direct loss of some of these habitats and disturbance to surrounding areas is likely to affect local avifauna.

Formal assessment of the impacts of the proposed development requires information on the significance of the impacted areas to avifauna. Protected and migratory species are known to occur on Barrow Island, however, quantitative data on the distribution and abundance of avifauna around the Island are scarce.

Field surveys and literature reviews were conducted on behalf of the Gorgon Venture for the earlier Environmental, Social and Economic (ESE) Review of the proposal (Bamford 2002, Astron Environmental 2002). The ESE Review process identified gaps in existing knowledge concerning the distribution and seasonality of birds in potential impact areas.

Most shorebirds and some other species are listed as migratory and are known to be abundant on the Island (Sedgwick 1978), but it is not clear for which species the Island is of particular importance, nor how the species vary in abundance during the year or across the Island. Previous studies indicated that the Bandicoot Bay area in the south of Barrow Island is the main area of importance for migratory shorebirds (Sedgwick 1978), but little was known of the importance of beaches near Town Point in relation to the rest of the Island.

Bamford Consulting Ecologists were engaged to redress this lack of information, by surveying avifauna in the development area in 2003/2004 and assessing the significance of this area to regional and local populations. This report presents the findings of the current study and provides assessment of the importance of the proposed development area in relation to other areas of Barrow Island for avifauna.

The current study addresses three aspects of the avifauna of Barrow Island:

- littoral avifauna (waterbirds that utilise coastal environments)
- landbirds
- Double Island seabirds

The littoral avifauna surveys aimed to identify the importance of the Town Point area for avifauna and to contribute to an understanding of the importance of Barrow Island for these species.

Landbird surveys were designed to compare the abundance of landbirds in the vicinity of the proposed gas processing facility with abundances in surrounding areas and with data from other studies on Barrow Island. The importance of different habitat and landform types for landbirds was investigated to facilitate estimates of the wider distribution of these birds on the Island.

Double Island, about four kilometres north-east of the project area, is known to support breeding populations of the wedge-tailed shearwater and bridled tern (Astron Environmental 2002). Although some distance from the proposed development area, it was suggested that lights might affect the breeding colony of shearwaters, particularly through mortality of young birds attracted to the proposed development's lights. Preliminary surveys of this colony were carried out in October and November 2003.

2 Methods

2.1 Field Program

Field surveys were undertaken monthly between September 2003 and September 2004. Dates of surveys and activities undertaken during each survey are presented in Table 2-1. Most survey work was undertaken by Dr Mike Bamford and Dr Mike Craig (Bamford Consulting Ecologists). This report presents the results of all surveys, September 2003 to September 2004.

Table 2-1 – Barrow Island Sampling Program, September 2003 to September 2004

Sampling period	Littoral birds	Landbirds	Double Island seabirds
8-12 Sept 2003	*	*	
1-7 Oct 2003	*	*	*
22 Nov – 2 Dec 2003	*	*	*
11-16 Dec 2003	*	*	
9-14 Jan 2004	*	*	
6-11 Feb 2004	*	*	
11-17 March 2004	*	*	
21 – 28 April 2004	*	*	
21 – 24 May 2004	*	*	
18-21 June 2004	*	*	
16-19 July 2004	*	*	
18 –22 August 2004	*	*	
15-19 September 2004	*	*	

2.2 Littoral Avifauna Surveys

Surveys of littoral avifauna involved monthly counts around as much of the Island as possible and detailed observations on the coastline north and south of Town Point. Monthly counts were carried out during high tide periods, usually within two hours of the high tide, when most littoral avifauna were concentrated on beaches and headlands. Surveys were conducted at times when the maximum tide was at least 2.7 m (WAPET Landing datum). Surveys were carried out on foot by experienced observers, who identified birds with binoculars (10 x) and spotting telescopes (20 x to 60 x). Birds were counted individually, where possible, but when large flocks were encountered, standard approaches of estimation were used, such as block counting and using the proportion of each species determined from a detailed count to estimate the number of that species present in a mixed flock.

For the purposes of littoral avifauna counts, Barrow Island was divided into regions and sites, the sites consisting of individual bays, beaches and headlands (Figure 2-1). Within each site, birds were recorded as being either located at a roost, where ten or more birds were concentrated, or outside of roosts. The co-ordinates of each roost (WGS84 datum) were recorded using a hand-held GPS unit. Survey coverage was not the same on each field trip and is summarised in Attachment 1.

Nearly the whole coastline of Barrow Island was surveyed from January to September 2004, most of the coast was surveyed from October to December 2003 and over half the coastline was surveyed in September 2003 (Attachment 1). To facilitate comparison of island-wide abundance between months, abundances at sites that were not surveyed were estimated for September to December 2003.

Population estimates for the whole island for September to December 2003 were derived by adding the abundances of birds at surveyed sites to the estimated abundance of birds at unsurveyed sites. Abundances of birds at unsurveyed sites was estimated from the proportional distribution of birds around the island in surveys from January to March 2004, when numbers were high and virtually all the island was counted.

The proportion of the island-wide total abundance of birds that was present at each of the beaches surveyed in January to March 2004 was used to scale up island-wide abundances for September to December 2003. This assumes that the proportion of birds using various sites was constant between September and December 2003 and between January and March 2004.

Littoral avifauna foraging in intertidal habitats in the vicinity of Town Point were counted at low tide. Waterbirds were counted on Terminal Beach (between Town Point and the pipeline to the north) and on Bivalve Beach (between Town Point and the first rocky point to the south). All birds within this area were counted using a spotting scope and classified as either within 200 m of Town Point or 200 m to 400 m from Town Point.

2.2.1 Double Island Seabird Surveys

Double Island is known to support breeding colonies of the wedge-tailed shearwater and bridled tern, and was visited in October and November 2003. Both islands were surveyed in October, but only the South Island was revisited in November because it supported the most accessible breeding areas for shearwaters. During the visits, observations were made on activity in some burrows and estimates were made of numbers of burrows present in the main breeding areas.

2.2.2 Landbird Surveys

Landbirds were surveyed along six transects in the vicinity of the proposed gas processing facility (Figure 2-2). Each transect was one kilometre long and sampled twice (once by each observer) during each monthly survey. All surveys occurred between 0600 and 0800 hours, when landbirds are most active and their densities can be most accurately estimated. The start and finish coordinates of each transect are shown in Table 2-2.

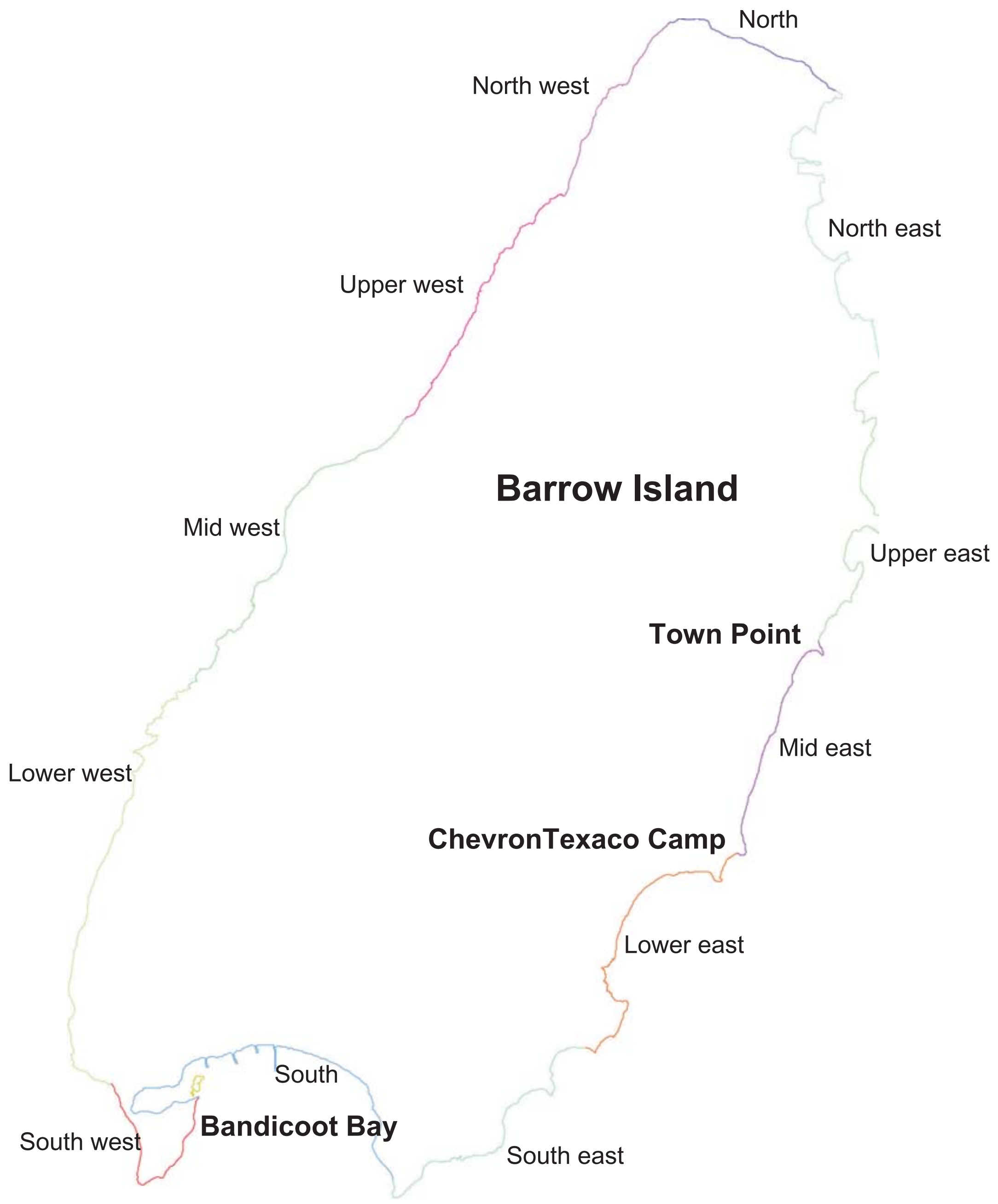

Figure 2-1 - Littoral Avifauna Survey Regions Around Barrow Island

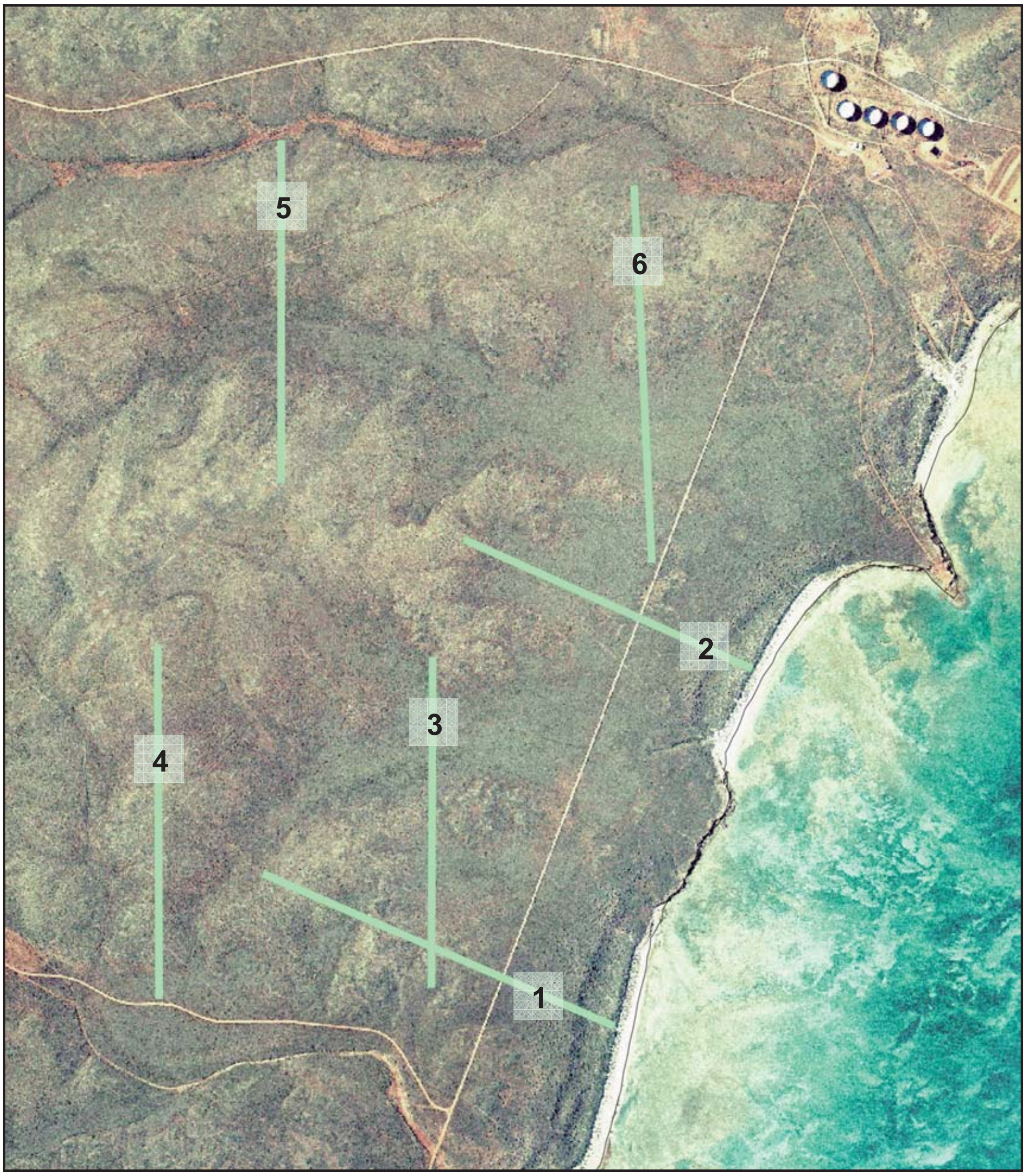

Figure 2-2 - Landbird Survey Transects

Table 2-2 - Landbird Transects within the Proposed Development Area - Co-ordinates: WGS84 (GDA94) Datum, Zone 50

Transect No.	Start	Finish
1	339170E, 7699045N	338156E, 7699495N
2	339527E, 7700100N	338748E, 7700460N
3	338645E, 7700115N	338645E, 7699155N
4	337855E, 7699146N	337850E, 7700149N
5	338210E, 7700618N	338210E, 7701615N
6	339234E, 7701482N	339283E, 7700387N

Surveys along the landbird transects involved walking slowly along each transect, recording landbirds within 25 m either side and beyond 25 m of each transect. Only records from within 25 m of each transect were used for the calculation of density estimates. The locations where birds within 25 m were first observed were recorded with a handheld GPS unit. Birds were identified and counted and some observations were made, such as the presence of male white-winged fairy- wrens in breeding plumage.

Each transect was 50 m wide and one kilometre long and therefore covered an area of five hectares. Within each transect, bird counts were related to vegetation type by recording the principle type of vegetation in 100 m units along each transect. The number of 100 m units in which each of the six main vegetation types was represented is presented in Table 2-3.

Details of landbird surveys conducted in October 2004 can be found in Attachment 5.

Table 2-3 - Vegetation Types on the Landbird Transects. F = Number of 100 m Units in Total Dominated by Each Vegetation Type

Vegetation code	Vegetation type	F
1	*Acacia coriacea* over *Triodia angusta* on coastal red, sandy dunes	4
2	*Acacia bivenosa* over mixed *Triodia* spp. on red sandy-loam plain	17
3	*Melaleuca* over mixed *Triodia* spp. on shallow soils of limestone rises and ridges	26
4	*Triodia angusta* forming dense stands with or without emergent shrubs in red sandy-loam valleys	2
5	*Triodia wiseana* occasionally with shrubs <1 percent cover on shallow soils of limestone ridges	3
6	Low *Acacia bivenosa* over mixed *Triodia* spp. on shallow soils of limestone slopes	8

3 Results

3.1 Littoral Avifauna

3.1.1 Barrow Island Total Counts

Monthly and maximum counts of each littoral avifauna species on Barrow Island are presented in Attachment 2.

A minimum of 32 119 littoral avifauna were counted on Barrow Island during the period September 2003 to September 2004. The highest monthly count of all birds was 20 428 in September 2004. Monthly counts of some species qualify Barrow Island as an internationally-significant migratory shorebird site, under the Ramsar Convention for supporting >1 % of a species' population in the East Asian-Australasian Flyway. Population estimates for migratory shorebirds in the East Asian-Australasia Flyway have been calculated by Bamford *et al.* (in press) and have been calculated for non-migratory shorebirds and terns by Wetlands International (2002).

Barrow Island is a regionally significant site for grey-tailed tattlers (6.6 % of known population), ruddy turnstones (5.5 % of known population), red-necked stints (2.4 % of known population) and fairy terns (8.3 % of known population).

In addition, counts of sanderlings, greater sand plovers and lesser sand plovers during southward migration period (September to November), met the staging criterion (0.25 % of a species' population) of the Ramsar Convention. Counts of roseate terns over adjacent waters in August 2002 (Astron Environmental 2002) and of bridled terns around Double Island in November 2003, may also be significant for these species. Population estimates for common terns in the north-west of Australia are uncertain and therefore the significance of over 1708 common terns in November 2003 is unknown. The maximum count of the sooty oystercatchers (83) represents 1.1 % of the known population of the distinctive northern race (*ophthalmicus*) of the species (Wetlands International 2002).

The total counts from January to March are based on surveys covering nearly all of the shoreline of Barrow Island, whereas coverage varied from September to December (see Attachment 1). Total Island-wide estimates based on the subset of sites surveyed in September, based on the sites surveyed between January and March and extrapolated to all sites (total) are presented in Figure 3-1. Total littoral avifauna abundances around Barrow Island increased during the southward migration in September to November 2003, dropped slightly in December and then peaked again in January to March 2004. Total island-wide abundances decreased following the northward migration and remained low between April and August 2004. The southward migration in 2005 appeared to start earlier than previously, with the highest total abundances counted in September 2004.

Monthly counts of the most abundant species are presented in Figure 3-2, Figure 3-3 and Figure 3-4 , to examine monthly patterns for the main species. Several of the most abundant species are migrants that showed a peak during southward migration and during the non-breeding season. These included the red-necked stint (Figure 3-3), and greater and lesser sand plovers (Figure 3-4). The common tern (Figure 3-3) contributed significantly to the overall spring peak while the silver gull and fairy tern (Figure 3-2) contributed to the summer non-breeding season peak. In contrast, grey-tailed tattler and ruddy turnstone abundances (Figure 3-3) displayed little variation during the spring-summer period (September 2003 to March 2004). Numbers of the bar-tailed godwit were constant over the non-breeding period but peaked slightly during the northward migration in March 2004 (Figure 3-2).

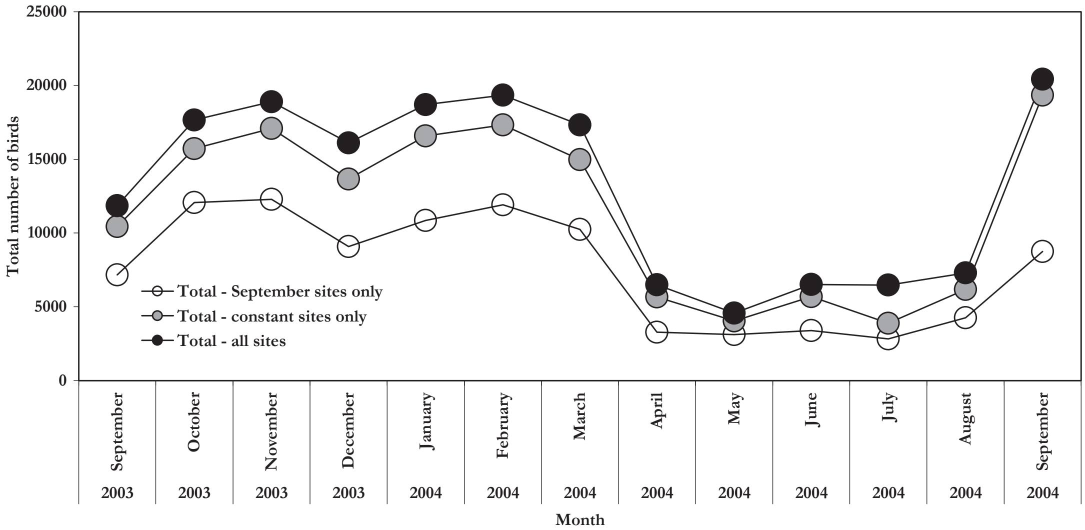

Figure 3-1 - Total Numbers of Waterbirds from September 2003 to September 2004. September 2003 to December 2003 Counts are Estimates

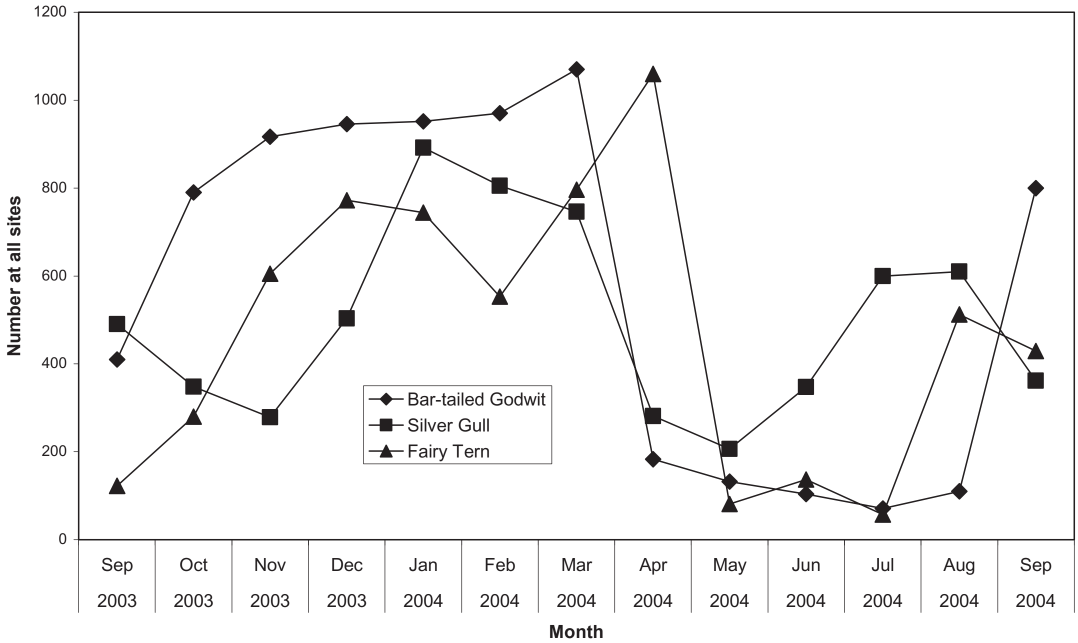

Figure 3-2 - Total Numbers of Bar-tailed Godwits, Silver Gulls and Fairy Terns from September 2003 to September 2004. September 2003 to December 2003 Counts are Estimates

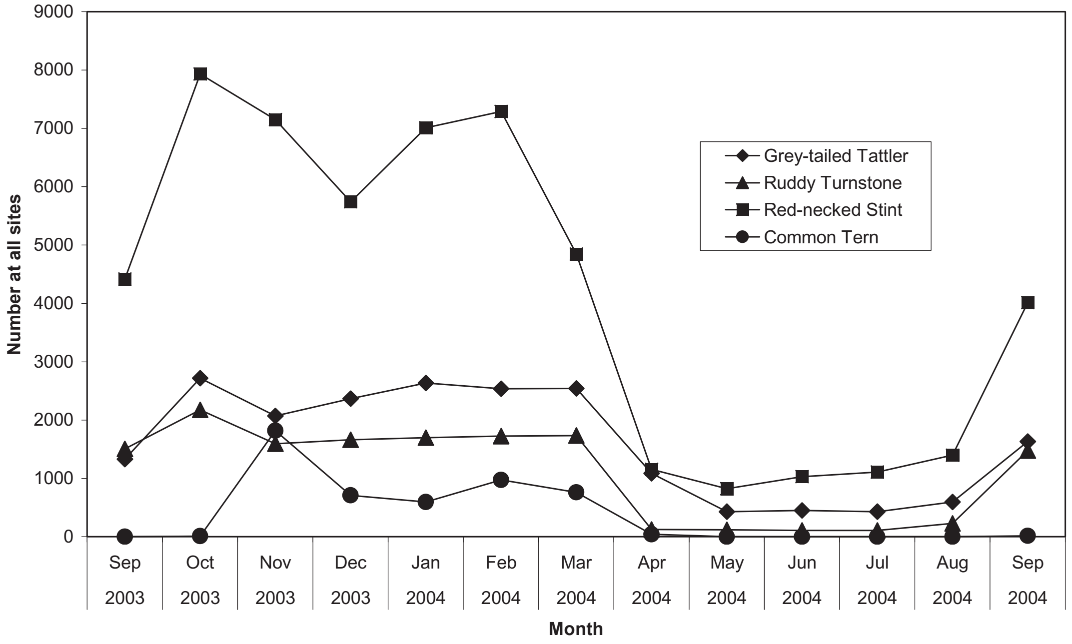

Figure 3-3 - Total Numbers of Grey-tailed Tattlers, Ruddy Turnstones, Red-necked Stints and Common Terns from September 2003 to September 2004. September 2003 to December 2003 Counts are Estimates

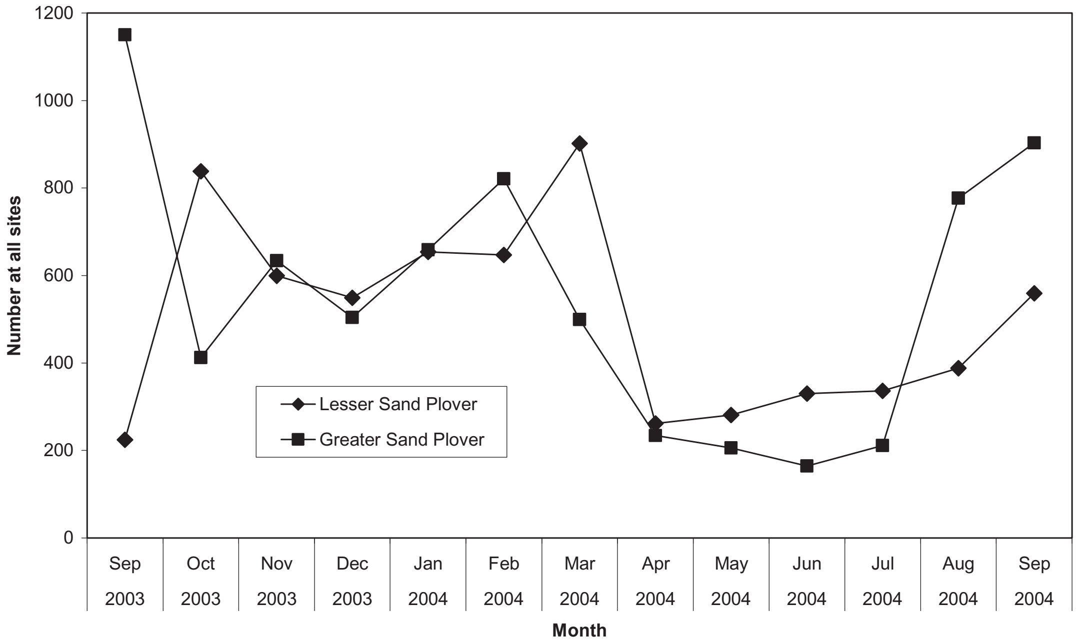

Figure 3-4 - Total Numbers of Lesser Sand Plovers and Greater Sand Plovers from September 2003 to September 2004. September 2003 to December 2003 Counts are Estimates

3.1.2 Distribution of Littoral Avifauna on Barrow Island

The abundances of all littoral avifauna pooled, and of the most abundant species in different sections of the shoreline around Barrow Island, are presented in Figure 3-5 to Figure 3-14. All of the monthly count data for various sections of the Barrow Island shoreline (regions) for all species pooled and for the most abundant species are presented in Attachment 3.

Littoral avifauna in general were concentrated in the south-east and south of Barrow Island (Figure 3-5) along beaches from the existing camp to the Bandicoot Bay area. This pattern was common to the majority of the most abundant species (Figure 3-6 to Figure 3-12). Silver gulls were more evenly distributed around the Island (Figure 3-13). Grey-tailed tattlers were also abundant in the North-East (Figure 3-7). Among less commonly observed species, the sanderling was recorded mainly in the South-West region but most other species were concentrated in the Lower East, South-East and/or South. There was little evidence of seasonal variation in distribution amongst regions of the Barrow Island shoreline.

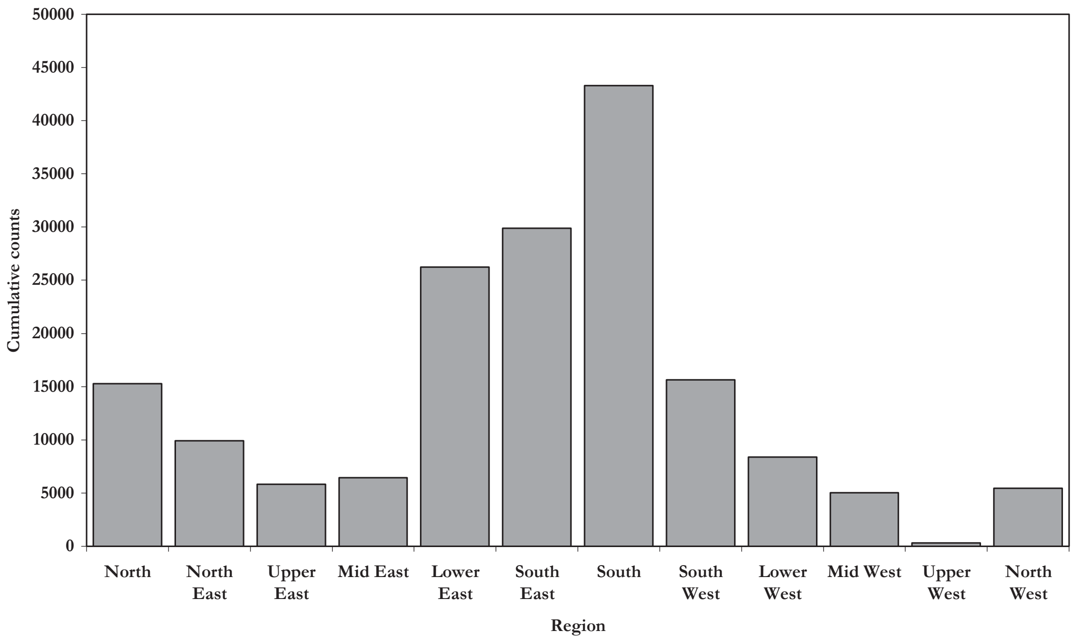

Figure 3-5 - Regional Distribution of all Waterbird Species Pooled from all Surveys, September 2003 to September 2004. Counts include Estimated Values for September to December 2003

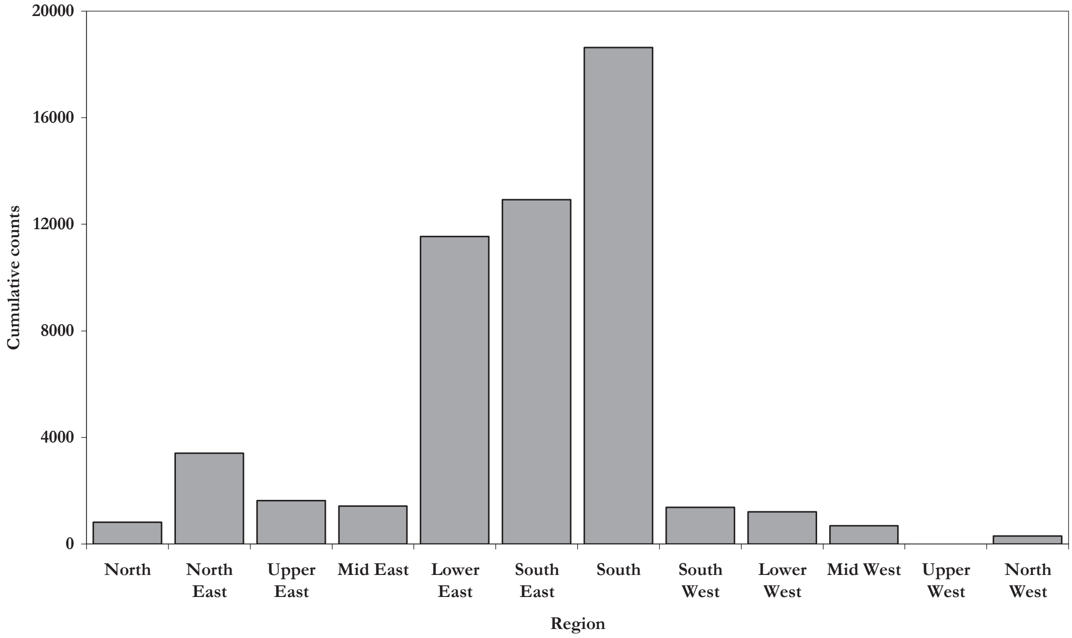

Figure 3-6 - The Regional Distribution of Red-Necked Stints on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

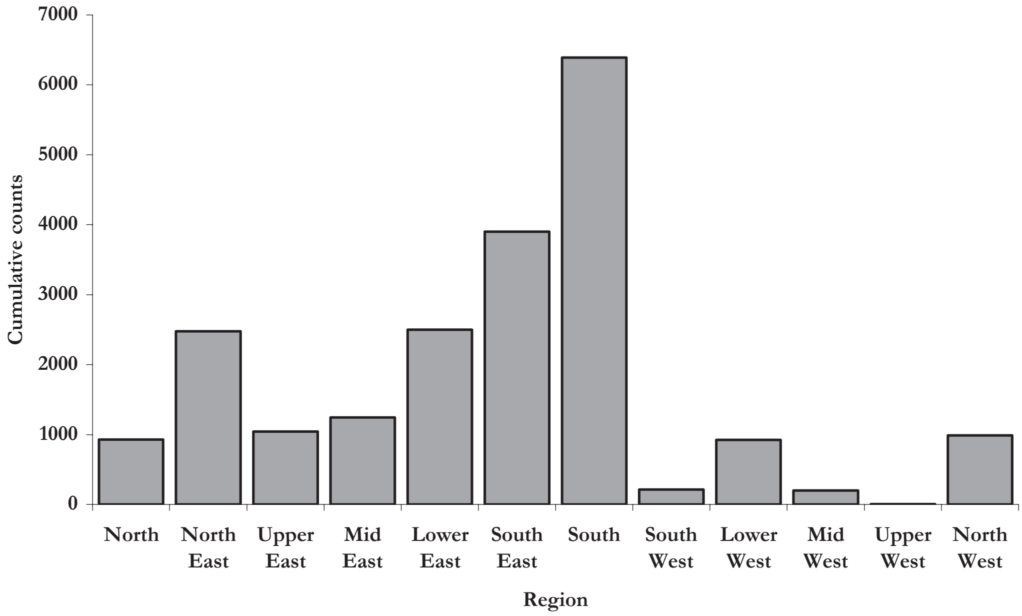

Figure 3-7 - The Regional Distribution of Grey-Tailed Tattlers on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

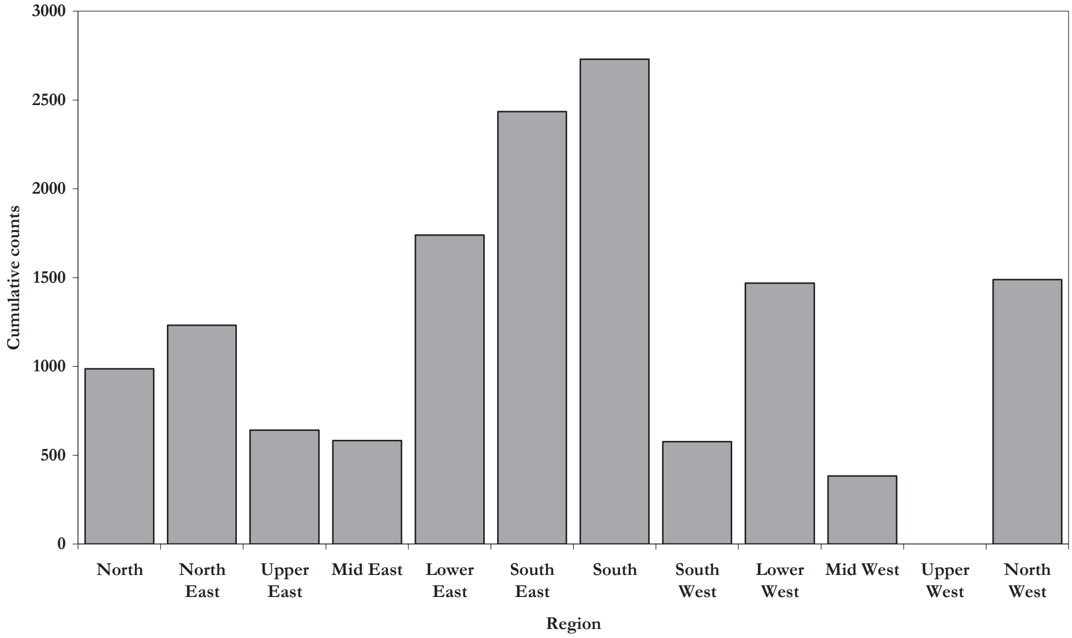

Figure 3-8 - The Regional Distribution of Ruddy Turnstones on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

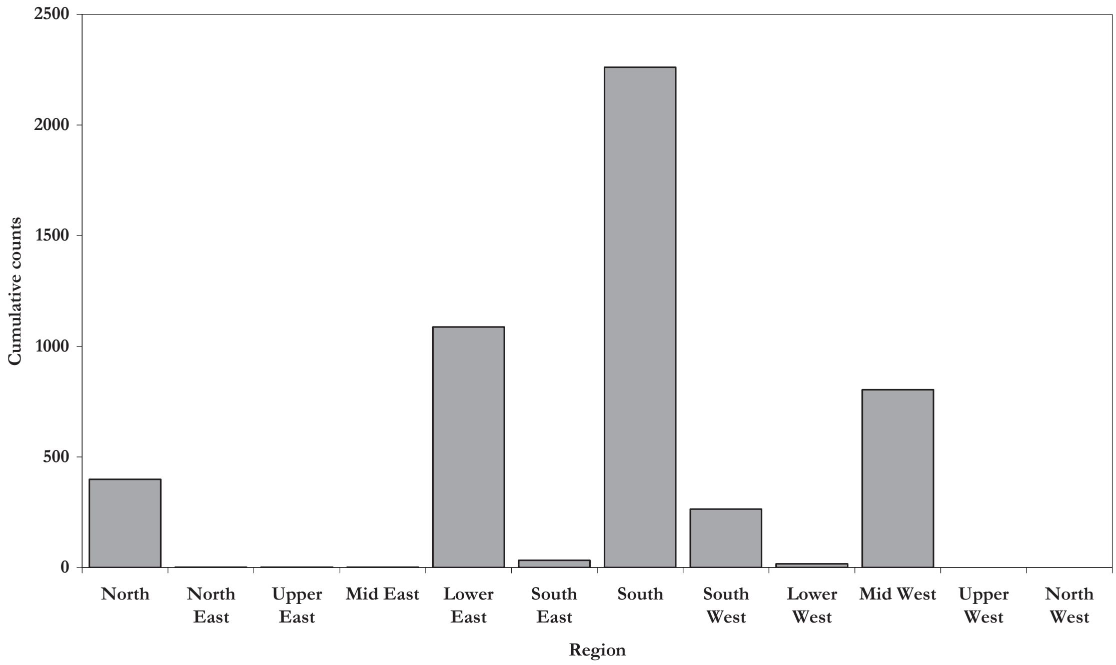

Figure 3-9 - The Regional Distribution of Common Terns on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

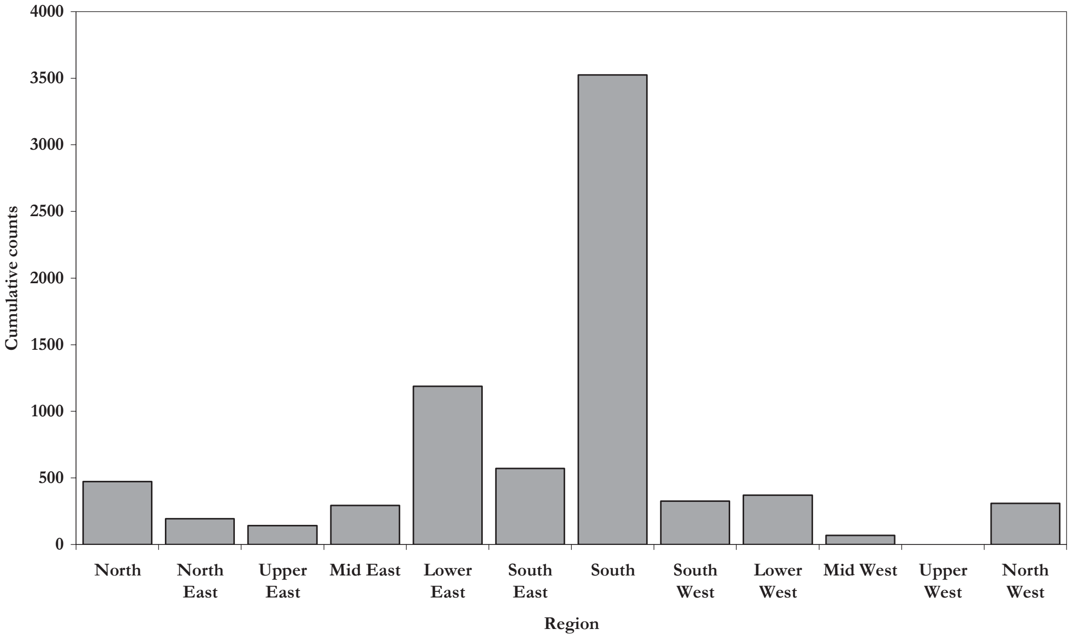

Figure 3-10 - The Regional Distribution of Bar-Tailed Godwits on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

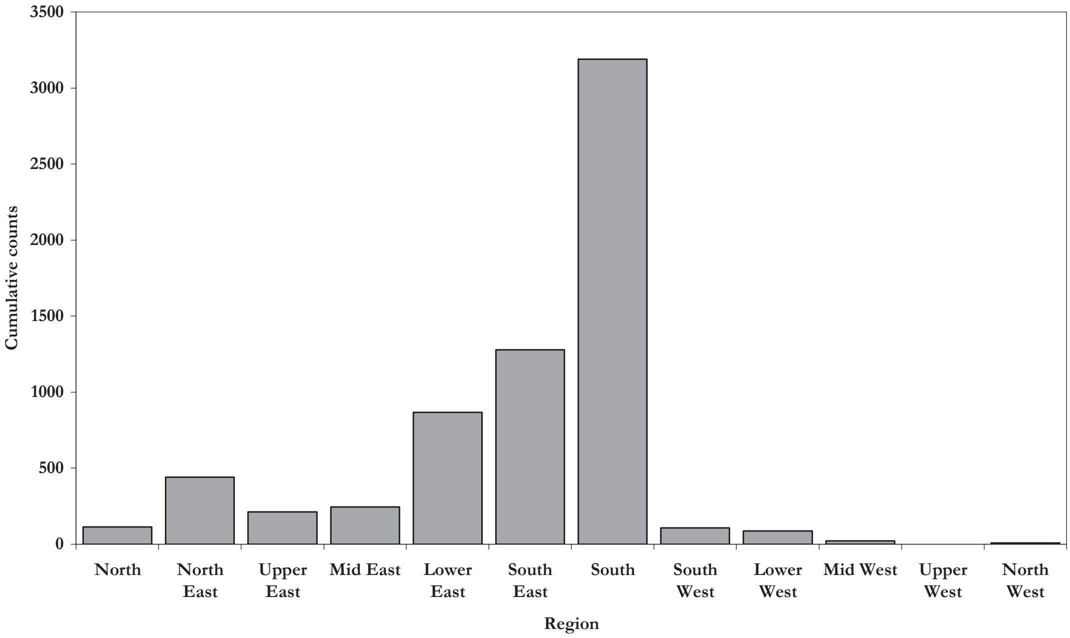

Figure 3-11 - The Regional Distribution of Lesser Sand Plovers on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

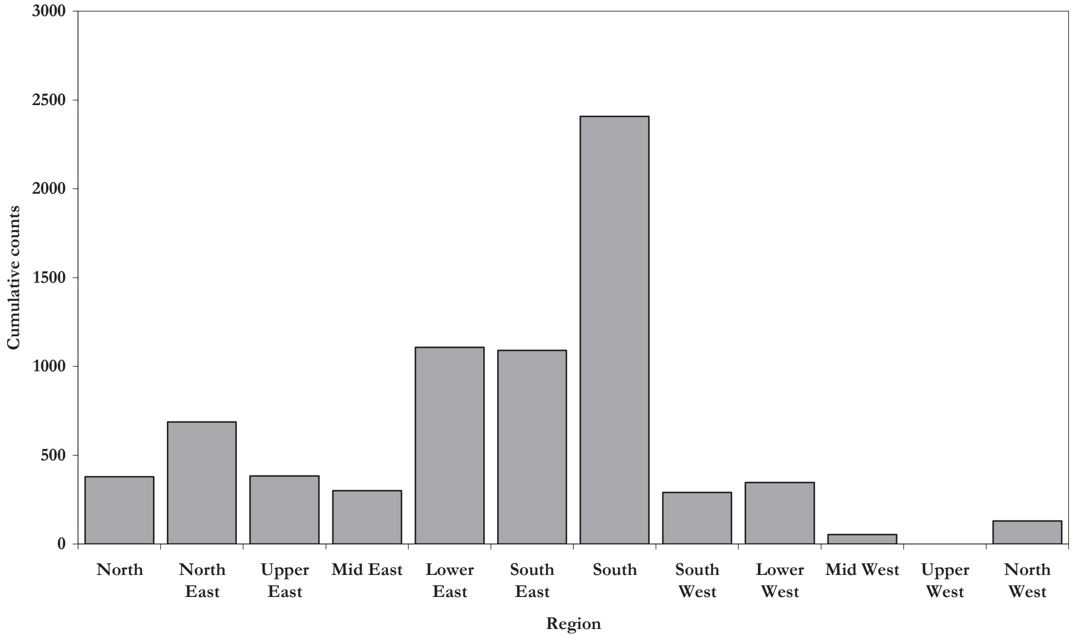

Figure 3-12 -The Regional Distribution of Greater Sand Plovers on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

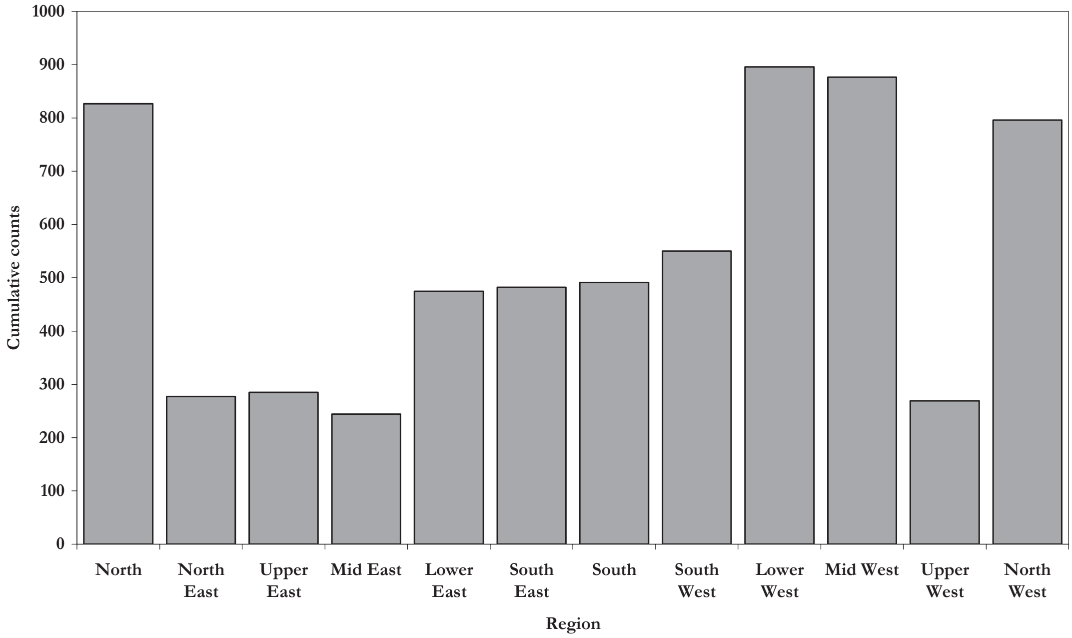

Figure 3-13 - The Regional Distribution of Silver Gulls on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

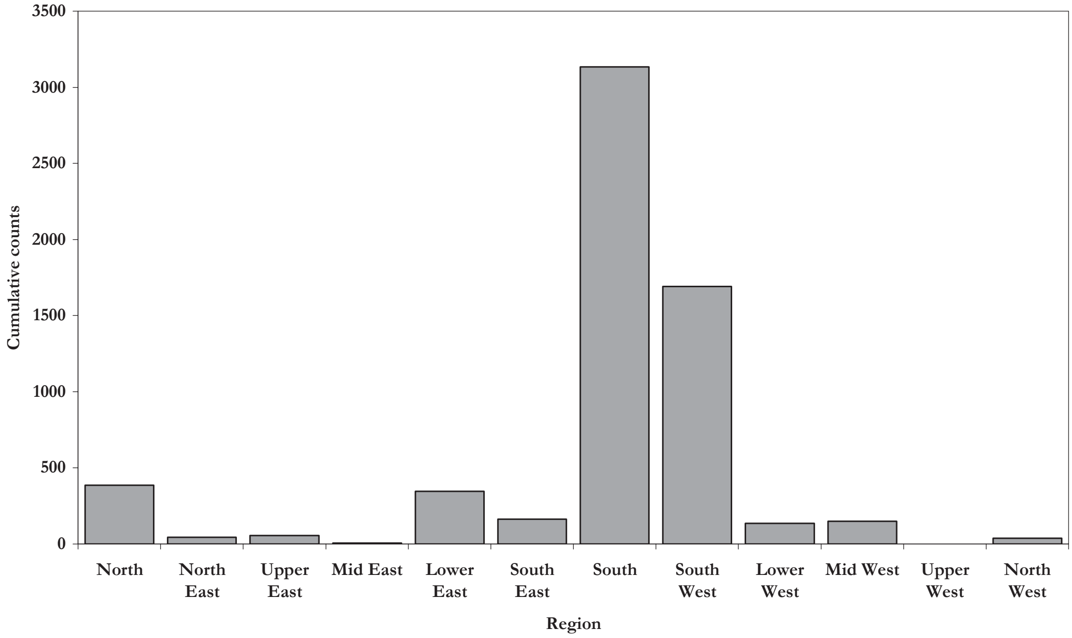

Figure 3-14 - The Regional Distribution of Fairy Terns on Barrow Island for all Months Combined. Counts include Estimated Values for September to December 2003

3.1.3 Littoral Avifauna of the Town Point Area

The distribution of littoral avifauna roost sites along the east coast shoreline adjacent to the proposed development at Town Point is presented in Figure 3-15.

At high tide, small numbers of cormorants, eastern reef egrets, silver gulls and oystercatchers roost on the rocks at Town Point. Favoured roost sites on the adjacent shoreline were consistently used between months. Data collected between April and September 2004 further supported these observations. Sooty oystercatchers successfully nested on the rocky cliff top at Town Point during spring 2003 and 2004. Other nests of this species were observed at Cape Dupuy on the north coast of Barrow Island.

The proposed Development at Town Point lies between the upper east and mid east regions that span approximately 11 km of the shoreline that was visited by 7.1 % of all littoral avifauna during the surveys. For the most abundant species, the percentage of island-wide records from the Town Point area (upper east and mid east regions) is presented in Table 3-1.

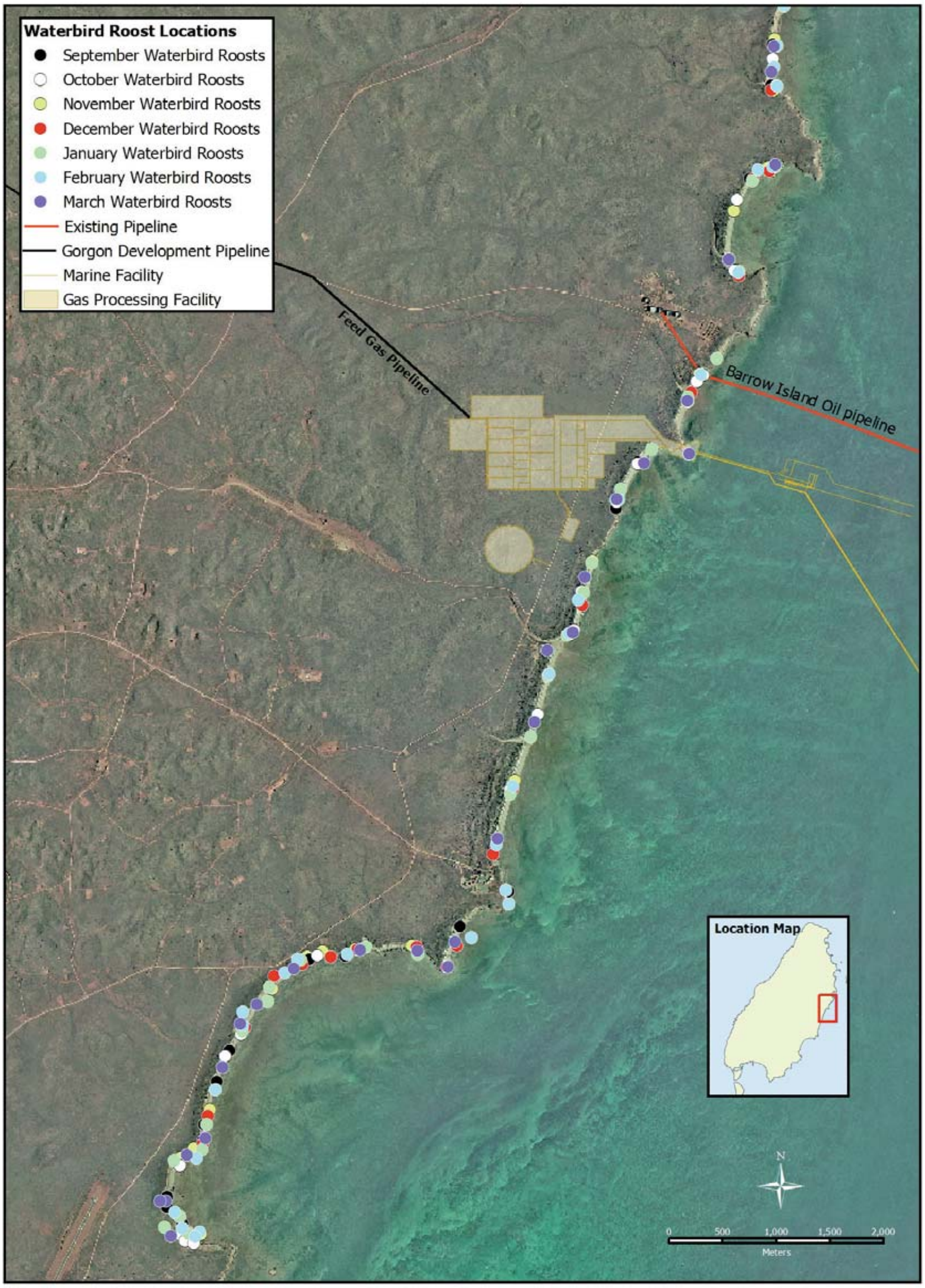

Figure 3-15 -East Coast of Barrow Island, Indicating Locations of all Roost Sites Recorded during Surveys from September 2003 to March 2004

Table 3-1 - Percentage of Waterbird records on Barrow Island in the Upper East and Mid East Regions, North and South of Town Point, between September 2003 and September 2004. Values are for abundant species only

Species	Total N records on Island (all months pooled)	Percentage present at Town Point
Red-necked stint	53 930	5.7
Grey-tailed tattler	20 818	11.0
Ruddy turnstone	14 261	8.6
Bar-tailed godwit	7 454	5.8
Lesser sand plover	6 569	6.9
Greater sand plover	7 175	9.5
Silver gull	6 469	8.2
Common tern	4 919	<0.1
Fairy tern	6 149	1.0
Caspian tern	1 031	27.8
Crested tern	8 620	13.5

The crested and Caspian terns are not abundant on Barrow Island, but have been included because they are the only regularly observed species with a distribution that is biased in favour of the north-east and mid-east regions.

Foraging

Only a small proportion of the littoral avifauna on Barrow Island forage on the reef platforms around Town Point. Twenty-two species and a maximum abundance of 249 waterbirds were observed foraging at Town Point between October 2003 and September 2004. Approximately one percent of the littoral avifauna on Barrow Island foraged on the surveyed section of shoreline up to 400 m north and south of Town Point (Table 3-2).

Table 3-2 - Total Number of Birds Foraging on Reef Platforms Adjacent to Town Point at low tide and the Percentage of the Total Number Present on the Island Observed at Town Point

Month	Northern reef platform	Southern reef platform	Total	Percentage of Island total
October 2003	77	90	167	1.06
November 2003	21	47	68	0.39
December 2003	74	104	178	1.24
January 2004	78	129	207	1.11
February 2004	75	132	207	1.07
March 2004	75	174	249	1.44
April 2004	28	32	60	0.92
May 2004	23	10	33	0.72
June 2004	26	35	61	0.94
July 2004	21	15	36	0.56
August 2004	19	35	54	0.74
September 2004	33	57	90	0.44

While approximately one percent of the waterbirds on the Island foraged at Town Point, the proportion was higher for some species (Table 3-3). These tended to be the less abundant species. The Town Point area was important for eastern reef egrets in January 2004, Australian pelicans in February 2004 and for Caspian and crested terns in March 2004. For all other species, less than seven percent of the individuals present on Barrow Island foraged at Town Point (Table 3-3).

Table 3-3 - The Maximum Number, Including Month Recorded, of Each Species Foraging on the Reef Platforms Around Town Point. Maxima are Presented as a Percent of the Total Island Population in that Month

Species	Maximum count	Month of count	Percentage of Monthly Total for Barrow Island
Australian pelican	3	February	15.0
Eastern reef egret	11	January	20.4
Osprey	1	October/December	4.8
Bar-tailed godwit	4	January	0.4
Whimbrel	3	January	3.2
Common greenshank	5	December	2.0
Common sandpiper	1	October/December	4.5
Grey-tailed tattler	32	October	1.4
Ruddy turnstone	30	October/March	2.0
Red-necked stint	62	October	0.8
Pied oystercatcher	9	February/April	3.1
Sooty oystercatcher	5	April	5.3
Grey plover	3	February	2.3
Red-capped plover	10	December/June	3.7
Greater sand plover	23	September	2.5
Lesser sand plover	1	March	0.1
Silver gull	45	January/February	5.6
Caspian tern	57	March	24.6
Crested tern	73	March	9.0
Lesser crested tern	3	March	22.8

Between 16 % and 65 % of the waterbirds on the reef platforms adjacent to Town Point were foraging within 200 m of the point (Table 3-4). These data indicate that the area immediately adjacent to Town Point is not of high significance to foraging waterbirds.

Table 3-4 - Abundance of Waterbirds Foraging in Intertidal Habitats within 200m of Town Point and the Proportion of All Waterbirds Foraging in this Area

Month of survey	Waterbird count <200 m	Waterbird count >200 m	Percentage waterbirds <200 m
October	57	110	34.0
November	14	54	20.6
December	53	125	29.8
January	56	151	27.1
February	52	155	25.1
March	40	249	16.1
April	18	42	42.8
May	13	20	65.0
June	12	49	24.5
July	9	27	33.3
August	13	41	31.7
September	27	63	42.9

3.1.4 Shearwaters and other Waterbirds on Double Island

Active shearwater burrows were found on both islets of Double Island in October 2003, with most activity across the top of the islands where the limestone is so deeply weathered by solution pipes that it resembles giant honeycomb. Burrows in this landscape are hard to examine because they start in small caverns that the birds access through solution pipes. These caverns lie approximately one metre below the surface of the ground. The solution pipes act as a common entrance to several burrows and make it very difficult to estimate the number of burrows present in this landscape.

Wedge-tailed shearwaters and eggs were present in the burrows on South Double Island in November 2003. North Double Island was not surveyed in November 2003. On the western side of South Double Island, there were approximately 500 burrows within an area of less than two hectares of sandy soil. Although these burrows were accessible and discrete, the sandy soil meant that there was a high risk of the burrows collapsing under the weight of the observers and the survey was curtailed. On the basis of this number of burrows in a small area and the area of limestone in which nests were located, the colony is probably used by 5000 to 10 000 pairs.

In November 2003, an estimated 4000 bridled terns were circling the islands and inspecting crevices in the limestone, presumably preparing to nest in these areas. Bridled terns were also observed in, or leaving, the caverns under the solution pipes. The islands are also important sites for other waterbirds. A pair of white-bellied sea-eagles with a recently-fledged chick was observed on South Double Island in November 2003. Approximately 165 pied cormorants and 24 eastern reef egrets were roosting on North Double Island in October 2003. The reef egret count was the highest single count for this species on Barrow Island. A reef egret nest with two eggs was found in October. Small numbers (<10 of each species) of ruddy turnstones, grey-tailed tattlers and greater sand-plovers were observed during both visits to Double Island.

3.2 Landbirds of the Gorgon Development Study Area

Abundances of landbirds in the proposed development area from September 2003 to August 2004 are presented in Table 3-5, 3-6 and 3-7. Results from landbird transects from October 2004 can be found in Attachment 5.

The abundance of landbirds in the study area appears to vary seasonally. The main bird species (white-winged fairy wren, singing honeyeater and spinifexbird) were recorded more often in late winter and early spring than in hotter months, with a slight increase in March, April and May 2004 in some species following cyclone Monty (Table 3-5). This almost certainly relates to changes in detectability due to the behaviour of the birds. Birds are more cryptic when sheltering from the sun and this behaviour is more critical in summer. Spinifexbirds also called more frequently in spring than in summer and were therefore easier to detect. In addition, there was some evidence to suggest that the fairy wren and honeyeater particularly may have been attracted to the observer in spring. These effects may have biased results in all months.

Table 3-5 - Total Abundance of Each Bird Species from September 2003 to August 2004. Data Pooled Across the Six Transects in Each Month

Species	Sep	Oc	No	De	Jan	Fe	Ma	Ap	My	Jn	Jl	Au	Total
Bar-shouldered dove	0	0	7	0	0	3	0	0	0	0	0	0	10
White-winged fairy wren	50	27	17	21	23	6	28	15	26	19	18	31	281
Singing honeyeater	7	3	0	0	0	0	1	7	9	2	2	3	34
Welcome swallow	0	1	0	0	0	0	1	0	2	1	1	0	6
Spinifexbird	10	13	5	4	8	5	8	14	14	5	7	28	121
Spotted harrier	0	0	0	0	0	0	0	1	0	0	0	0	1
Nankeen kestrel	0	0	0	0	0	0	0	0	0	0	0	1	1
White-breasted woodswallow	0	0	0	0	0	0	0	0	0	0	0	1	1
Total	67	44	29	25	31	14	38	37	51	27	28	64	455

Densities of each landbird species were calculated for each transect (Table 3-6) and for each of the vegetation types (Table 3-7), as defined in Table 2-3.

There were trends in landbird densities between transects for most species (Table 3-6). For example, the bar-shouldered dove was confined to Transect Two and the white-winged fairy wren tended to be more abundant on Transect Five. The spinifexbird densities tended to be lower on Transect Four. The singing honeyeater was not recorded on Transect Five and was recorded at low densities on the other transects.

Table 3-6 - Mean Densities (per hectare) for Bird Species along Six Transects in the Vicinity of the Development Area, September 2003 to August 2004. There were 24 surveys in each transect

Species	Landbird Transect						
		1	**2**	**3**	**4**	**5**	**6**
Bar-shouldered dove	Mean	0.00	0.10	0.00	0.00	0.00	0.00
	SE	-	0.07	-	-	-	-
White-winged fairy wren	Mean	0.42	0.22	0.30	0.48	0.84	0.27
	SE	0.09	0.07	0.06	0.09	0.16	0.07
Spinifexbird	Mean	0.24	0.13	0.23	0.13	0.18	0.13
	SE	0.05	0.04	0.05	0.03	0.05	0.03
Singing honeyeater	Mean	0.16	0.06	0.03	0.01	0.01	0.04
	SE	0.06	0.02	0.02	0.01	0.01	0.02

Landbird distributions showed close affinities to vegetation types (Table 3-7) as described below:

- Bar-shouldered doves were confined to vegetation type one (coastal *Acacia coriacea*).
- White-winged fairy wrens were least abundant in coastal vegetation types one and two, but particularly abundant in vegetation type five (low *Triodia* over limestone). Vegetation type five was poorly represented, however, so in general the fairy wren was associated with *Triodia* with or without shrubs but growing in shallow soil on limestone rises.
- Singing honeyeaters were largely confined to coastal vegetation types one and two (*A. coriacea* and *A. bivenosa* over *Triodia* on red sandy-loam).
- Spinifexbirds were found across all vegetation types, but were most abundant in types one, two and six. These were near-coastal and inland sites, but consisted of *Acacia* over *Triodia*.

Table 3-7 - Mean Densities (per hectare) of Landbirds in Each Vegetation Type. Data Pooled over the Six Transects, September 2003 to August 2004 2004. (n = 24)

Species	Vegetation Type (see Table 2-3)						
		1	**2**	**3**	**4**	**5**	**6**
Bar-shouldered dove	Mean	0.15	0	0	0	0	0
	SE	0.15	-	-	-	-	-
White-winged fairy wren	Mean	0.02	0.23	0.52	0.29	0.81	0.38
	SE	0.02	0.06	0.07	0.22	0.31	0.11
Spinifexbird	Mean	0.10	0.19	0.15	0.12	0.16	0.25
	SE	0.05	0.04	0.03	0.09	0.09	0.06
Singing honeyeater	Mean	0.29	0.03	0.03	0	0	0.04
	SE	0.12	0.01	0.01	-	-	0.02

4 Discussion

4.1 Littoral avifauna

Between September 2003 and September 2004, Barrow Island supported large numbers of littoral avifauna, with migratory shorebirds and terns being the most abundant. While the migratory species had the expected peaks in abundance in spring, most remained abundant throughout the survey period, indicating that Barrow Island is not only a staging post during southward migration, but is used through the summer non-breeding season by migrant species and during the winter by at least some birds. Sedgwick (1978) also noted migratory shorebirds in August 1978, before most species would have returned from migration, suggesting that many birds 'over-winter' on the Island. High counts of migratory shorebirds during the breeding season (winter in the southern hemisphere) have been recorded for a number of other sites in northern Australia (Bamford *et al.* in press).

The monthly patterns of variation in the abundance of migratory shorebirds on Barrow Island in 2003/2004 were unexpected, as sites on the north-west coast of Australia tend to be most important for such species during southward migration (Bamford *et al.* in press). Southward migration was evident for some species, for example greater sand plovers in September and red-necked stints, sanderlings and lesser sand plovers in October. However, the abundance of other species, for example the grey-tailed tattler and ruddy turnstone, varied little from September 2003 to February 2004. This suggests that many birds stayed upon the Island following their arrival on southward migration in September. Migrating bar-tailed godwit appear to arrive and simply stay on the Island. Even among those species with the expected southward migration peak, there was an increase in abundance in January and February. This may have been due to local movements of birds from the mainland to Barrow Island. The slightly lower numbers in December may reflect a gap between the southward migration period and this possible phase due to local movements. Barrow Island is unusual compared with other sites in the north-west of Australia in effectively acting as a terminus for migratory species.

Sites in the north-west of Australia tend to be less important during northward than southward migration, and on the basis of March data (early northward migration), this also seems to be the case for Barrow Island. The two sand plover species and the bar-tailed godwit increased slightly in abundance in March, but most species declined in numbers; some sharply. This decline may have been influenced by the passage of Cyclone Monty prior to the March survey.

The November peak in the abundance of common terns, also a migratory species, is consistent with southward movement through Barrow Island, whereas the fairy tern (subject to local movements but not an international migrant) seemed to congregate on the Island during its breeding season. However, fairy terns were not observed to breed on Barrow Island and a substantial proportion of the birds were immature or in non-breeding plumage. Numbers of silver gulls increased steadily from November to January and then remained at a high level up to March, possibly in response to the emergence of turtle hatchlings.

Barrow Island is an internationally significant littoral avifauna site because it meets the Ramsar criterion of supporting >1 % of a species population for the ruddy turnstone, red-necked stint, grey-tailed tattler, sanderling, greater sand-plover, lesser sand-plover, fairy tern and for the *ophthalmicus* race of the sooty oystercatcher. All these species are trans-equatorial migrants, except for the fairy tern, which undergoes only local movements and the sooty oystercatcher, which is a resident.

On the basis of the importance of the Island for six migratory waders (grey-tailed tattler, ruddy turnstone, red-necked stint, sanderling, greater sand-plover and lesser sand-plover), Barrow Island is equal tenth among the 147 important sites for migratory waders in Australia (Bamford *et al.* in press). For the grey-tailed tattler and ruddy turnstone, it is the fifth and fourth-most important site in Australia, respectively.

Ruddy turnstones, grey-tailed tattlers and red-necked stints were present on Barrow Island in August 1978 (Sedgwick 1978) at similar proportions to the current study. It is not clear how comprehensive the 1978 surveys were, but counts of most migratory shorebirds were much lower even than those recorded in September 2003. However, 36 black-tailed godwits, a species not seen during the current study, were recorded. Among non-migratory shorebirds and other littoral species, counts were broadly similar to those obtained in the present study.

The highest abundances of littoral avifauna on Barrow Island (over two-thirds of records of most species) are associated with the extensive tidal mudflats in the south and south-east of the Island, from Bandicoot Bay to the existing ChevronTexaco Camp. These areas are important for roosting and foraging and the birds appear to roost close to their foraging sites. The littoral avifauna habitats in Bandicoot Bay are recognised as being a key area for shorebirds and are proposed as a nature conservation area (CALM 2004). However, the current study has shown that the area of importance is greater than previously suggested.

Littoral avifauna were widely distributed around Barrow Island, usually associated with tidal mudflats or rocky intertidal pavements. However, littoral avifauna numbers were generally low in the vicinity of Town Point and the proposed development area, despite the extensive pavement reef and sand flats in this region. The grey-tailed tattler and the greater sand plover were the most abundant birds in the Town Point area. While the 12 km stretch of shoreline between Mattress Point and the ChevronTexaco Camp represents about 20 % of Barrow Island's coastline, less than nine percent of all littoral avifauna occurred in this area.

Town Point is a nesting site for the *ophthalmicus* race of sooty oystercatchers. Other nests were observed at Cape Dupuy on the northern coast and pairs of birds demonstrated mating behaviour at a number of other sites.

The reef platform around Town Point is not a major feeding site on Barrow Island. The number of birds that utilised the area was always less than 1.5 % of the Island total and was remarkably consistent between months, except for November 2003. Both the abundance of littoral avifauna and the proportion of the Island total in the Town Point area were much lower in November than in other months. This is probably due to the fact that the tide was much lower in November than in the other months. This would have resulted in more reef platform being exposed and, as a consequence, the birds being more widely dispersed and at lower density than at other times. It is also possible that the low tide meant that many foraging birds were feeding in depressions in the reef platform and, therefore, were missed by the count. It is recommended that all future counts be conducted at a standard low tide of 0.45 m (above chart datum) to remove any confounding effect of tide height.

When individual species were examined, the proportion of the Barrow Island total that foraged or roosted at low tide within 400 m of Town Point was generally low, but in March 2004 it was moderately high for two species common on the Island: Caspian terns (24.6 %) and crested terns (9.0 %). It is not clear why so many terns were present on the reef platform at Town Point in March.

Of all the littoral avifauna on Barrow Island, approximately one percent foraged within 400 m of Town Point, and less than 0.35 % foraged within the immediate vicinity of the Point (< 200 m). Habitat loss associated with construction of the landing and causeway will therefore directly affect approximately 0.35 % of littoral avifauna foraging habitat on Barrow Island.

4.2 Wedge-tailed Shearwaters on Double Island

The visits to Double Island confirmed the presence of a breeding colony of wedge-tailed shearwater with at least 500 nests in one small area on the South Island and a total colony size of 5000–10 000 pairs. There are hundreds of thousands of pairs of wedge-tailed shearwaters nesting on islands off the north-west and western coasts of Western Australia (Johnstone & Storr 1999).

Long-term monitoring of wedge-tailed shearwater breeding colonies elsewhere in the region has shown that breeding success varies from year-to-year amongst colonies, due to prevailing oceanographic conditions, even in years when breeding success is generally poor (Dunlop *et al.* 2002). Wedge-tailed shearwaters are reported to be tolerant of disturbance and human activities close to their breeding colonies (Marchant & Higgins 1990), but juvenile birds are sometimes attracted to lights and are injured or killed by flying into buildings and structures (Lane 1991). From a colony of 6000 pairs on Muttonbird Island (New South Wales), 176 juveniles were collected on the nearby mainland in the 1987 breeding season, some injured but most simply confused by the land and unable to find their way back to sea. Some of these birds came from resorts seven kilometres north of the breeding colony. Note that the Muttonbird Island colony itself appears unaffected by nearby commercial activities and low levels of human visitation.

4.3 Landbirds

The present investigations focussed on determining the density of the main landbird species in relation to different vegetation types within the proposed Development area. These data were used to calculate the importance of the Development area to landbirds by comparison with existing information, such as whole-of-island population estimates and densities of particular species, including relationships with vegetation type (Sedgwick 1978, Pruett-Jones & O'Donnell unpubl. and Pruett-Jones & Tarvin 2001).

Across the proposed Development area, the coastal *Acacia* shrublands supported the highest species richness and high densities of singing honeyeaters and spinifexbirds, but the inland habitats including *Melaleuca* shrublands over *Triodia* are important for the white-winged fairy wren, with inland *Acacia* shrublands over *Triodia* being important for the white-winged fairy-wren and spinifexbird.

The landbird assemblage of Barrow Island is depauperate. Of the 128 birds recorded on Barrow Island, 51 are landbirds and only 16 of these species are residents or regular migrants (Attachment 4). In an intensive study during September and October 2001, Pruett-Jones & O'Donnel (unpubl.) found five landbird species to be common. These were the spinifexbird, white-winged fairy-wren, singing honeyeater, white-breasted woodswallow and welcome swallow. Of these, the spinifexbird, white-winged fairy-wren and singing honeyeater were the only species recorded regularly in the present study, with the addition of the bar-shouldered dove in near-coastal *Acacia* shrubland. There was a suggestion by Pruett-Jones & O'Donnel (unpubl.) that white-breasted woodswallows may have declined in abundance since the surveys of Sedgwick (1978).

The spinifexbird has an estimated Island population of 17 800 (Sedgwick 1978) to 24 623 (Pruett-Jones & O'Donnel unpubl.), with the latter value based on density estimates in excess of one bird/ha; much greater than the 0.13 to 0.24 birds/ha determined in the present study and the 0.33 birds/ha from the October 2004 transects. The low values obtained in 2003/2004 are probably due to poor detectability of the species outside the breeding season, when most surveys took place. Numbers of spinifexbirds recorded in transects in September and October 2003 and August 2004 were up to three times the numbers seen at other times of the year and therefore suggest densities at least broadly similar to those obtained by Pruett-Jones & O'Donnel (unpubl.). Despite this, the proportional abundance of spinifexbirds in different vegetation types can be expected to be reasonably accurate. Pruett-Jones & O'Donnel (unpubl.) found densities of the spinifexbird to be highest where there was a shrub stratum emergent through the *Triodia,* and this trend also emerged in the proposed development area, with high numbers in *Acacia coriacea* over *Triodia* in coastal areas and in *Acacia bivenosa* over *Triodia* in inland areas. There was an exception to this trend, however, as spinifexbirds were recorded at only low densities in vegetation type three, *Melaleuca* over *Triodia* on limestone rises and ridges. This is a widespread habitat in the proposed development area and was well-sampled, so it would appear that it is of low suitability for spinifexbirds. Spinifexbirds may favour more openly branched shrubs such as *Acacia*.

The white-winged fairy wren has an estimated Island population of 8150 (Sedgwick 1978) to 7519 (Pruett-Jones & O'Donnel unpubl.), with densities found by the latter authors in the range 0.25 to 1.75 birds/ha. In the proposed development area, densities fell within this range in vegetation types three to six, but densities were much lower in coastal *Acacia* shublands. Estimates from the October 2004 transect data (1.05 birds/ha) also fell within the above range of values (Attachment 5). Pruett-Jones & O'Donnel (unpubl.) found that the white-winged fairy-wren was associated with complex vegetation structure. In the proposed development area it appeared to be associated with inland vegetation types in general, with a tendency to favour formations with complex vegetation structure. Unlike the spinifexbird, it was notably abundant in areas of *Melaleuca* over *Triodia*. The very high density in vegetation type five (*Triodia* with very low shrub densities on limestone ridges) may have been an artefact of small sample size.

Population estimates of singing honeyeaters on Barrow Island range from 3050 (Sedgwick 1978) to 3920 (Pruett-Jones & O'Donnel unpubl.). This species is generally associated with coastal *Acacia* shrublands. This was clear in the proposed development area but the mean density of 0.16 and 0.11 birds/ha in the September 2003 – August 2004 and October 2004 studies, respectively, is much lower than the 2.5 birds/ha reported by Pruett-Jones & O'Donnel (unpubl.) in coastal *Acacia* shrublands. The low values in the proposed development area are partly related to seasonal variations in detectability, as very few singing honeyeaters were detected within transects from November to March. Despite this, a density of 2.5 birds/ha appears higher than any observed even in September and October.

Population densities of singing honeyeaters on Barrow Island may be suppressed due to several years of below-average rainfall. Alternatively, singing honeyeaters are sometimes attracted to the observer, so the use of two observers by Pruett-Jones & O'Donnel (unpubl.) may have led to an over-estimation of the species' density.

The population densities and approximate extent of vegetation types in the proposed development area can be used to estimate population sizes of the three most abundant bird species. Populations in the proposed development area compared with Island estimates from Pruett-Jones & O'Donnel (unpubl.) or Sedgwick (1978) are outlined in Table 4-1.

Table 4-1 - Landbird Populations in the Proposed Development Area.

Species	Population in Gorgon study area (300 ha)	Current Barrow Island total population estimate	Percentage of total Island population
Bar-shouldered dove	6	180	3
Spinifexbird	48	24 623	0.2
White-winged fairy wren	141	7 519	1.9
Singing honeyeater	10	3 920	0.3

The results from the October 2004 survey (Attachment 5) suggest that the numbers of white-winged fairy-wrens on Barrow Island may be slightly greater than those listed in the table above. The density of white-winged fairy-wrens in October 2004 was approximately 1.05 birds/ha. Their preferred shrubland habitat covers about 8926 ha or approximately 40% of the island. Assuming that the density of wrens is consistent in their preferred habitat across the island, the total population is approximately 9336.

As the area of the proposed Gorgon Development is 300 ha, the number of white-winged fairy-wrens in the entire development area is probably about 315 birds, or 3.3 % of the total population.

For both the white-winged fairy-wren and bar-shouldered dove, the proposed Development area probably has good representation of their preferred habitat. The area does not appear to be as favourable for the spinifexbird and the singing honeyeater.

The white-winged fairy-wren on Barrow Island is an endemic race that has recently been identified as the most genetically-distinct of the white-winged fairy wren races (Driskell *et* al. 2002). These birds are abundant on Barrow Island. Other non-migratory avifauna on Barrow Island, although not recognised as distinct taxa, are assumed to be genetically distinct from mainland populations, as a result of their long period of isolation.

5 Conclusions

5.1 Littoral Avifauna

A minimum of 32 119 littoral avifauna of 50 species used the Barrow Island shoreline during the period September 2003 to September 2004, with the highest monthly count of all birds being 20 428 (September 2004). Barrow Island is of international significance for six migratory species: grey-tailed tattler, ruddy turnstone, red-necked stint, sanderling, greater sand plover and lesser sand plover. It is also significant for two non-migratory birds: fairy tern and the northern race of the sooty oystercatcher.

The littoral avifauna was dominated by migratory species that were expected to use Barrow Island mainly during their southward migration (October-November), as is the case elsewhere in the north-west of Australia. However, some species were more abundant in January and February, contributing to overall higher counts in summer than in spring. For most migratory species, Barrow Island appears to act as a destination rather than as a staging site.

Littoral avifauna in general were concentrated in the south-east and south of Barrow Island, from the existing ChevronTexaco Camp to the Bandicoot Bay area. Over half of the littoral avifauna each month were found in these parts of the Island.

The coastline in the vicinity of Town Point and the proposed Development area is of relatively low importance for littoral avifauna compared with other parts of Barrow Island. Town Point was not generally an important waterbird foraging or roosting site during the 2003/2004 summer, reflected by the low abundances in this area in relation to other parts of the Barrow Island shoreline. The only waterbird breeding observed near Town Point was a pair of sooty oystercatchers that nested on Town Point in September 2003 and 2004 and a pair of ospreys with a nest (not used in 2003) on Latitude Point.

5.2 Shearwater Rookeries on Double Island

Wedge-tailed shearwaters nest on both islets of Double Island, beneath limestone slabs and in sandy soil. The sandy rookery on the north-western corner of the southern island comprises about 500 burrows across an area of approximately two hectares. The total colony may contain 5000–10 000 pairs.

The Double Island rookery is of regional significance as these migratory birds are protected under international conventions.

5.3 Landbirds

The proposed Development area is not locally or regionally significant for landbirds. The abundance of landbirds in the Town Point hinterland is similar to the abundance in other parts of Barrow Island as reported in earlier studies. The proposed Development area has no unique features that might constitute critical habitat.

The landbird fauna of Barrow Island is depauperate but is notable for the presence of an endemic race of the white-winged fairy-wren listed under the EPBC Act and as Schedule One (Vulnerable) under the Wildlife Conservation Act. The Barrow Island white-winged fairy wren generally inhabits low shrubland (*Acacia*, *Melaleuca*) over *Triodia* on limestone hill slopes away from the coast within the proposed Development area. About 3.4

percent of Barrow Island's total population of white-winged fairy wren occurs within the 300 ha of the proposed development area.

White-winged fairy-wrens are the second most abundant landbird on Barrow Island (Pruett-Jones & Tarvin 2001) and their population status is unlikely to be affected by small changes in available habitat.

Bar-shouldered doves, singing honeyeaters and spinifexbirds also inhabit the proposed Development area. The Island populations of these birds are probably genetically distinct from populations on the nearby mainland, due to the long period of isolation and should be treated as endemic taxa.

The bar-shouldered dove and singing honeyeater were largely confined to *Acacia* over *Triodia*, particularly near the coast. Spinifexbirds were widespread, with some bias in favour of areas of emergent *Acacia* amongst *Triodia*.

6 References

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Attachment 1 - Regions, Sites and Months for Littoral Bird Surveys. Constant sites are those surveyed in every month from October 2003 to February 2004.

Region	Site	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Constant site
North East	Surf Point		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Sponge Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Pungens Head		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Oystercatcher Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Square Head North		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Square Bay		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Square Head South		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Pillow Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Pillow Head		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Ant Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Ant Point		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Bed Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Lucky's Head		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Lucky's Bay		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Barge Landing		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Bob's Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
North East	Boomerang Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
Upper East	Mattress Bay	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Upper East	Mattress Point	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Upper East	Dove Bay	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Region	Site	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Constant site
Upper East	Dove Point	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Upper East	Mushroom Rock Bay	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Upper East	Latitude Point	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Upper East	Pipeline Beach	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Mid East	Town Point	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Mid East	Yacht Club Beach	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Mid East	Camp Point		x	x	x	x	x	x	x	x	x	x	x	x	x
Lower East	Camp Beach	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lower East	Unnamed Point	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lower East	Shark Beach	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lower East	Shark Point	x	x	x	x	x	x	x	x	x	x	x	x	x	x
South East	Perentie Two Bay	x	x	x	x	x	x	x	x	x	x	x	x	x	x
South East	Perentie Two Point		x	x	x	x	x	x	x	x	x	x	x	x	x
South East	Perentie One Bay	x	x	x	x	x	x	x	x	x	x	x	x	x	x
South East	Perentie One Point		x	x	x	x	x	x	x	x	x	x	x	x	x
South East	Stokes Bay		x	x	x	x	x	x	x	x	x	x	x	x	x
South East	Stokes Point	x	x	x	x	x	x	x	x	x	x	x	x	x	x
South	Bandicoot Bay	x	x	x	x	x	x	x	x	x	x	x	x	x	x
South	Bandicoot Lagoon		x	x	x	x	x	x	x	x	x	x	x	x	x
South West	South East Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
South West	Sanderling Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
Lower West	Eagle's Nest Beach South					x	x	x	x	x	x	x	x	x	

Region	Site	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Constant site
Lower West	Eagle's Nest Beach North					x	x	x	x	x	x	x	x	x	
Lower West	Eagle's Nest Beach Point					x	x	x	x	x	x	x	x	x	
Lower West	West Point					x	x	x	x	x	x	x	x	x	
Lower West	Satellite Beach					x	x	x	x	x	x	x	x	x	
Lower West	Whale Beach					x	x	x	x	x	x	x	x	x	
Lower West	Whale Point					x	x	x	x	x	x	x	x	x	
Lower West	Groper Beach			x	x	x	x	x	x	x	x	x	x	x	
Lower West	Groper Point					x	x	x	x	x	x	x	x	x	
Lower West	The Ledge					x	x	x	x	x	x	x	x	x	
Mid West	Bogg's Beach			x	x	x	x	x	x	x	x	x	x	x	
Mid West	Bogg's Point					x									
Mid West	Biggada Creek			x	x	x	x	x	x	x	x	x	x	x	
Mid West	Turtle Bay		x	x	x	x	x	x	x	x	x	x	x	x	x
Mid West	John Wayne Beach			x	x	x	x	x	x	x	x	x	x	x	
Mid West	Petal Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
Upper West	Flacourt Bay		x	x	x	x	x	x	x	x	x	x	x	x	x
Upper West	Butler's Bridge					x	x	x	x	x	x	x	x	x	
Upper West	Y Beach					x	x	x	x	x	x	x	x	x	
Upper West	Cape Malouet								x	x	x	x	x	x	
Upper West	Obe's Beach					x	x	x	x	x	x	x	x	x	
North West	White's Beach					x	x	x	x	x	x	x	x	x	
North West	White's Point					x	x	x	x	x	x	x	x	x	

Region	Site	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Constant site
North West	Max's Beach					x	x	x	x	x	x	x	x	x	
North West	Max's Point					x	x	x	x	x	x	x	x	x	
North West	Tortuga Beach					x	x	x	x	x	x	x	x	x	
North	Tortuga Point					x	x	x	x	x	x	x	x	x	
North	Perched Beach					x	x	x	x	x	x	x	x	x	
North	Cape Dupuy		x			x	x	x	x	x	x	x	x	x	
North	Dupuy Beach		x			x	x	x	x	x	x	x	x	x	
North	First Beach		x			x	x	x	x	x	x	x	x	x	
North	Second Beach		x			x	x	x	x	x	x	x	x	x	
North	Oyster Rock		x			x	x	x	x	x	x	x	x	x	
North	Lighthouse Beaches		x			x	x	x	x	x	x	x	x	x	
North	Surf Point Beach		x	x	x	x	x	x	x	x	x	x	x	x	x
Number of sites:		18	52	50	50	76	75								46

Attachment 2 - Monthly Total Counts of Littoral Avifauna on Barrow Island. Species marked with an asterisk are recognised as migratory under state and federal legislation.

Species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Max
Little pied cormorant	0	0	0	0	2	0	11	1	2	2	2	2	0	11
Pied cormorant	306	19	135	60	81	135	398	146	280	518	250	659	332	659
Little black cormorant	0	0	0	0	0	11	0	0	0	0	0	0	0	11
Australian pelican	0	14	14	12	24	24	18	0	1	20	20	19	16	24
White-faced heron	0	8	5	0	7	5	1	0	3	2	2	0	0	8
Little egret*	0	0	0	0	0	0	0	0	0	0	0	0	10	10
Eastern reef egret*	42	30	17	21	54	40	73	63	45	40	56	48	46	73
Great egret*	0	0	0	0	1	0	0	0	1	0	0	0	0	1
Striated heron	7	5	5	2	5	2	7	6	7	9	6	4	12	12
Nankeen night heron	1	4	5	17	30	20	8	14	33	33	23	20	8	33
Osprey*	12	21	22	22	33	29	33	35	28	41	32	32	25	41
Brahminy kite	9	6	1	7	6	2	8	10	6	6	8	6	11	11
White-bellied sea-eagle*	4	7	2	5	3	4	3	9	5	11	6	1	6	11
Bar-tailed godwit*	251	660	766	790	952	970	1070	183	132	104	71	110	800	1070
Little curlew*	0	0	1	1	0	0	0	0	0	0	0	0	0	1
Whimbrel*	20	52	64	30	93	77	97	55	37	44	26	27	84	97
Eastern curlew*	3	8	3	3	6	2	5	2	1	1	0	1	3	8
Marsh sandpiper*	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Common greenshank*	54	188	203	255	224	227	108	49	33	20	34	59	188	255
Terek sandpiper*	1	8	15	2	16	13	9	8	3	0	1	1	7	16

Species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Max
Common sandpiper*	20	30	26	22	36	41	20	3	0	0	8	30	36	41
Grey-tailed tattler*	830	2368	1805	2060	2634	2535	2543	1090	428	448	429	594	1631	2634
Ruddy turnstone*	681	1531	1125	1171	1701	1725	1733	125	117	110	108	227	1476	1733
Great knot*	176	301	432	364	410	323	395	18	5	10	20	91	346	432
Red knot*	0	23	12	7	5	6	15	0	0	0	0	0	7	23
Sanderling*	0	177	36	96	56	75	96	24	0	1	4	29	93	177
Red-necked stint*	3005	7611	6860	5512	7011	7291	4845	1157	822	1033	1109	1400	4015	7611
Sharp-tailed sandpiper*	0	4	4	9	2	1	0	0	0	0	0	0	7	9
Curlew sandpiper*	128	102	133	168	145	128	85	7	4	5	4	54	105	168
Beach stone-curlew	0	0	0	0	4	3	5	2	5	4	3	3	5	5
Pied oystercatcher	112	261	256	269	321	341	345	352	362	334	344	333	348	362
Sooty oystercatcher	21	34	53	61	81	83	69	95	82	58	48	62	66	95
Pacific golden plover*	0	24	14	11	22	27	30	0	0	0	0	2	4	30
Grey plover*	58	141	114	162	188	142	178	12	5	20	9	9	159	188
Red-capped plover	171	208	182	271	243	355	133	266	226	262	250	200	323	355

Species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Max.
Lesser sand plover*	158	811	580	531	654	647	902	262	281	330	336	388	559	811
Greater sand plover*	729	372	572	455	659	821	499	234	206	164	211	777	903	903
Oriental plover*	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Oriental pratincole*	0	0	0	0	0	0	5	0	0	0	0	0	0	5
Silver gull	125	190	152	275	892	805	746	281	206	347	600	610	362	892
Gull-billed tern	0	12	1	5	3	4	0	1	1	4	8	10	0	12
Caspian tern*	29	43	56	73	116	161	232	78	59	62	35	36	41	232
Lesser crested tern*	78	63	83	69	150	107	40	37	98	175	137	113	318	318
Crested tern	83	76	627	78	337	610	815	749	957	2098	1605	109	334	2098
Roseate tern	0	0	46	8	0	0	1	0	0	55	606	721	7300	7300
Common tern*	0	7	1708	109	595	972	763	40	0	0	0	0	13	1708
Little tern*	0	28	37	19	0	2	31	12	3	0	0	0	0	37
Fairy tern	41	278	601	622	744	553	796	1060	81	137	57	512	429	1060
Bridled tern*	0	0	0	0	0	1	0	0	0	0	0	0	0	1
White-winged black tern*	0	0	314	0	151	35	140	1	0	0	0	0	0	314
Total Waterbirds	7155	15726	17087	13654	18697	19356	17319	6487	4565	6508	6468	7299	20428	32119

Attachment 3 - Number of Littoral Avifauna Counted in Each Region in Each Monthly Survey. These include numbers that are estimates for September to December 2003 based on proportions in complete counts. The percentage of waterbirds counted or estimated in that month in each region is also indicated.

Region	September 2003	October 2003	November 2003	December 2003	January 2004	February 2004
North	(3.7 %) 444	(2.1 %) 377	(5.4 %) 1028	(4.7 %) 763	(4.1 %) 766	(4.4 %) 852
North East	(4.3 %) 505	(6.6 %) 1165	(7.0 %) 1325	(5.1 %) 819	(7.9 %) 1473	(6.0 %) 1169
Upper East	(5.6 %) 662	(3.8 %) 676	(2.7 %) 514	(3.0 %) 479	(3.1 %) 580	(4.2 %) 807
Mid East	(4.6 %) 542	(5.6 %) 993	(4.4 %) 826	(2.5 %) 464	(3.8 %) 714	(4.6 %) 893
Lower East	(18.3 %) 2168	(13.5 %) 2380	(14.0 %) 2636	(16.2 %) 2610	(15.1 %) 2815	(17.7 %) 3420
South East	(24.5 %) 2902	(18.5 %) 3272	(16.6 %) 3132	(22.9 %) 3683	(20.3 %) 3790	(20.0 %) 3867
South	(27.6 %) 3270	(37.6 %) 6645	(41.0 %) 7743	(30.6 %) 4934	(34.4 %) 6423	(29.8 %) 5459
South West	(2.0 %) 235	(1.9 %) 329	(0.3 %) 65	(0.9 %) 151	(1.0 %) 192	(5.7 %) 1104
Lower West	(4.4 %) 519	(5.0 %) 883	(4.3 %) 803	(4.6 %) 742	(5.4 %) 1004	(3.4 %) 655
Mid West	(2.1 %) 248	(1.7 %) 304	(1.4 %) 261	(5.8 %) 940	(1.3 %) 240	(2.9 %) 562
Upper West	(<0.1 %) 4	(<0.1 %) 3	(<0.1 %) 3	(0.2 %) 27	(0.2 %) 43	(0.4 %) 69
North West	(3.0 %) 361	(3.6 %) 638	(2.9 %) 553	(3.1 %) 506	(3.5 %) 657	(2.6 %) 499
Total	11860	17665	18889	16118	18697	19356
Red-necked stint						
North	(1.3 %) 59	(1.2 %) 96	(1.3 %) 95	(1.5 %) 87	(0.8 %) 55	(1.9 %) 137
North East	(6.0 %) 265	(4.9 %) 392	(9.0 %) 642	(4.9 %) 282	(8.8 %) 614	(5.1 %) 374
Upper East	(4.3 %) 188	(2.8 %) 219	(3.1 %) 219	(2.6 %) 150	(2.2 %) 154	(4.2 %) 304
Mid East	(4.2 %) 185	(4.7 %) 370	(2.7 %) 190	(1.2 %) 70	(1.8 %) 125	(3.3 %) 237
Lower East	(26.5 %) 1169	(17.3 %) 1370	(18.2 %) 1298	(23.0 %) 1321	(16.4 %) 1152	(21.1 %)1538
South East	(26.2 %) 1156	(22.2 %) 1760	(19.7 %) 1408	(35.1 %) 2015	(30.0 %) 2104	(27.2 %) 1985
South	(25.4 %) 1123	(42.8 %) 3393	(42.1 %) 3013	(27.2 %) 1564	(35.2 %) 2470	(26.6 %) 1941

Region	September 2003	October 2003	November 2003	December 2003	January 2004	February 2004
South West	(0.5 %) 21	(0.4 %) 31	(0.6 %) 43	(0.4 %) 22	(0.1 %) 4	(7.6 %) 555
Lower West	(2.4 %) 104	(1.7 %) 135	(2.3 %) 167	(2.3 %) 135	(3.6 %) 255	(1.1 %) 77
Mid West	(2.9 %) 128	(1.8 %) 142	(0.6 %) 43	(1.3 %) 74	(0.6 %) 44	(1.6 %) 114
Upper West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
North West	(0.5 %) 20	(0.3 %) 25	(0.4 %) 32	(0.4 %) 25	(0.5 %) 34	(0.4 %) 29
Total	(100.0 %) 4418	(100.0 %)7933	(100.0 %)7150	(100.0 %)5745	(100.0 %)7011	(100.0 %)7291
Grey-tailed tattler						
North	(5.3 %) 70	(2.8 %) 77	(7.2 %) 149	(4.4 %) 104	(2.9 %) 77	(5.3 %) 134
North East	(5.9 %) 79	(10.4 %) 283	(12.7 %) 263	(11.9 %) 281	(14.2 %) 374	(12.5 %) 317
Upper East	(11.8 %) 157	(6.4 %) 175	(2.3 %) 48	(3.2 %) 75	(4.1 %) 109	(3.6 %) 91
Mid East	(5.6 %) 75	(8.4 %) 228	(9.3 %) 192	(3.0 %) 70	(5.4 %) 143	(6.2 %) 156
Lower East	(9.8 %) 130	(7.6 %) 208	(11.4 %) 236	(12.9 %) 304	(11.0 %) 289	(11.5 %) 294
South East	(20.2 %) 269	(18.8 %) 512	(19.3 %) 400	(19.3 %) 456	(18.1 %) 478	(22.1 %) 561
South	(28.5 %) 379	(33.5 %) 910	(26.4 %) 547	(33.8 %) 800	(28.8 %) 759	(29.7 %) 753
South West	(0.2 %) 2	(<0.1 %) 1	(0 %) 0	(0 %) 0	(0.1 %) 2	(2.5 %) 63
Lower West	(5.1 %) 68	(5.8 %) 159	(5.9 %) 122	(6.4 %) 152	(9.2 %) 243	(1.0 %) 25
Mid West	(1.7 %) 22	(1.0 %) 26	(0.3 %) 6	(0 %) 0	(0.2 %) 4	(1.9 %) 47
Upper West	(0.2 %) 2	(0 %) 0	(0 %) 0	(0 %) 0	(0.1 %) 2	(0 %) 0
North West	(5.8. %) 77	(5.1 %) 140	(5.3 %) 109	(5.2 %) 123	(5.8 %) 154	(3.7 %) 94
Total	(100.0 %) 1330	(100.0 %)2719	(100.0 %)2072	(100.0 %)2365	(100.0 %)2634	(100.0 %)2535
Ruddy turnstone						
North	(5.5 %) 83	(6.1 %) 132	(7.5 %) 119	(7.7 %) 128	(7.0 %) 119	(6.6 %) 114
North East	(6.4 %) 97	(8.6 %) 187	(9.0 %) 143	(4.6 %) 76	(10.3 %) 175	(9.9 %) 170
Upper East	(6.1 %) 92	(3.7 %) 81	2.8(%) 44	(4.2 %) 70	(4.9 %) 84	(5.3 %) 92

Region	September 2003	October 2003	November 2003	December 2003	January 2004	February 2004
Mid East	(3.1 %) 47	(3.5 %) 77	(3.1 %) 50	(6.4 %) 107	(1.8 %) 31	(5.4 %) 94
Lower East	(13.3 %) 201	(9.2 %) 199	(10.2 %) 163	(13.6 %) 226	(12.5 %) 213	(12.3 %) 212
South East	(15.0 %) 226	(12.0 %) 260	(19.6 %) 313	(22.4 %) 372	(14.6 %) 249	(18.4 %) 318
South	(21.4 %) 323	(28.4 %) 617	(22.1 %) 352	(12.8 %) 212	(22.2 %) 378	(15.0 %) 259
South West	(3.7 %) 56	(3.7 %) 81	(0.4 %) 6	(3.0 %) 50	(0.7 %) 12	(4.1 %) 70
Lower West	(12.2 %) 184	(11.6 %) 251	(12.2 %) 194	(11.6 %) 192	(12.0 %) 204	(11.1 %) 192
Mid West	(3.0 %) 45	(3.0 %) 66	(2.8 %) 44	(1.8 %) 30	(0.8 %) 41	(2.8 %) 49
Upper West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
North West	(10.2 %) 154	(10.2 %) 222	(10.5 %) 168	(12.0 %) 199	(11.5 %) 195	(9.0 %) 155
Total	(100.0 %) 1508	(100.0 %)2173	(100.0 %)1596	(100.0 %)1662	(100.0 %)1701	(100.0 %)1725
Common tern						
North	(0 %) 0	(22.2 %) 2	(19.3 %) 350	(3.9 %) 28	(2.9 %) 17	(0 %) 0
North East	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0.1 %) 1
Upper East	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0.1 %) 1
Mid East	(0 %) 0	(11.1 %) 1	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
Lower East	(0 %) 0	(22.2 %) 2	(4.9 %) 89	(8.6 %) 61	(55.3 %) 329	(42.5 %) 413
South East	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0.3 %) 2	(0 %) 0
South	(0 %) 0	(44.4 %) 4	(69.8 %) 1269	(1.1 %) 8	(41.0 %) 244	(47.1 %) 458
South West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(2.8 %) 27
Lower West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0.5 %) 5
Mid West	(0 %) 0	(0 %) 0	(6.1 %) 110	(86.3 %) 612	(0.5 %) 3	(6.9 %) 67
Upper West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
North West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
Total	0	(100.0 %) 9	(100.0 %)1818	(100.0 %) 709	(100.0 %) 595	(100.0 %) 972

Region	September 2003	October 2003	November 2003	December 2003	January 2004	February 2004
Bar-tailed godwit						
North	(6.3 %) 26	(4.8 %) 38	(7.4 %) 68	(6.6 %) 62	(9.3 %) 89	(6.4 %) 62
North East	(3.9 %) 16	(3.8 %) 30	(1.6 %) 15	(3.6 %) 34	(1.8 %) 17	(2.6 %) 25
Upper East	(1.5 %) 6	(2.5 %) 20	(1.2 %) 11	(1.3 %) 12	(1.2 %) 11	(2.0 %) 19
Mid East	(1.5 %) 6	(9.4 %) 74	(0.7 %) 6	(2.6 %) 25	(5.6 %) 53	(4.0 %) 39
Lower East	(25.6 %) 105	(15.4 %) 122	(15.3 %) 140	(11.2 %) 106	(11.0 %) 105	(12.6 %) 122
South East	(8.0 %) 33	(10.8 %) 85	(9.6 %) 88	(5.1 %) 48	(9.0 %) 86	(7.9 %) 77
South	(37.8 %) 155	(40.9 %) 323	(52.3 %) 480	(57.6 %) 545	(53.4 %) 508	(44.0 %) 427
South West	(0.5 %) 2	(0.1 %) 1	(0.4 %) 4	(0 %) 0	(0.3 %) 3	(6.9 %) 67
Lower West	(5.4 %) 22	(5.3 %) 42	(5.9 %) 54	(6.0 %) 57	(1.6 %) 15	(9.0 %) 87
Mid West	(4.6 %) 19	(2.0 %) 16	(0 %) 0	(0.4 %) 4	(0.4 %) 4	(1.2 %) 12
Upper West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
North West	(4.9 %) 20	(4.9 %) 39	(5.6 %) 51	(5.6 %) 53	(6.4 %) 61	(3.4 %) 33
Total	(100.0 %) 410	(100.0 %) 790	(100.0 %) 917	(100.0 %) 946	(100.0 %) 952	(100.0 %) 970
Lesser Sand Plover						
North	(1.3 %) 3	(2.1 %) 18	(2.2 %) 13	(2.0 %) 11	(1.5 %) 10	(1.5 %) 10
North East	(6.7 %) 15	(10.0 %) 84	(14.0 %) 84	(1.6 %) 9	(6.0 %) 39	(2.6 %) 17
Upper East	(11.2 %) 25	(2.7 %) 23	(7.5 %) 45	(2.2 %) 12	(0.3 %) 2	(2.6 %) 17
Mid East	(1.3 %) 3	(10.1 %) 85	(1.5 %) 9	(3.3 %) 18	(9.6 %) 63	(1.7 %) 11
Lower East	(29.5 %) 66	(12.9 %) 108	(7.5 %) 45	(16.4 %) 90	(9.0 %) 59	(17.9 %) 116
South East	(22.8 %) 51	(22.0 %) 184	(28.4 %) 170	(23.9 %) 131	(25.8 %) 169	(30.4 %) 197
South	(25.0 %) 56	(36.3 %) 304	(36.4 %) 218	(48.3 %) 265	(43.6 %) 285	(35.2 %) 228
South West	(0 %) 0	(0.2 %) 2	(0 %) 0	(0 %) 0	(0 %) 0	(5.7 %) 37
Lower West	(2.2 %) 5	(2.6 %) 22	(2.5 %) 15	(2.4 %) 13	(3.8 %) 25	(0.3 %) 2

Region	September 2003	October 2003	November 2003	December 2003	January 2004	February 2004
Mid West	(0 %) 0	(0.8 %) 7	(0 %) 0	(0 %) 0	(0 %) 0	(1.9 %) 12
Upper West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
North West	(0 %) 0	(0.1 %) 1	(0 %) 0	(0 %) 0	(0.3 %) 2	(0 %) 0
Total	(100.0 %) 224	(100.0 %) 838	(100.0 %) 599	(100.0 %) 549	(100.0 %) 654	(100.0 %) 647
Great sand plover						
North	(4.8 %) 55	(5.3 %) 22	(7.3 %) 46	(4.4 %) 22	(3.2 %) 21	(3.7 %) 30
North East	(8.3 %) 95	(12.4 %) 51	(6.0 %) 38	(3.6 %) 18	(16.1 %) 106	(8.5 %) 70
Upper East	(3.7 %) 43	(7.5 %) 31	(1.6 %) 10	(3.6 %) 18	(8.0 %) 53	(9.1 %) 75
Mid East	(4.3 %) 50	(3.2 %) 13	(10.1 %) 64	(0.8 %) 4	(1.7 %) 11	(5.5 %) 45
Lower East	(14.8 %) 170	(18.9 %) 78	(15.8%) 100	(20.4 %) 103	(12.7 %) 84	(11.6 %) 95
South East	(15.3 %) 176	(15.5 %) 64	(22.7 %) 144	(32.9 %) 166	(16.8 %) 111	(19.6 %) 161
South	(39.4 %) 453	(27.2 %) 112	(27.8 %) 176	(25.8 %) 130	(32.6 %) 215	(24.8 %) 204
South West	(0 %) 0	(1.2 %) 5	(0 %) 0	(0 %) 0	(0.3 %) 2	(7.2 %) 59
Lower West	(7.0 %) 80	(7.0 %) 29	(6.9 %) 44	(6.9 %) 35	(4.7 %) 31	(9.3 %) 76
Mid West	(0 %) 0	(0 %) 0	(0.2 %) 1	(0 %) 0	(0.5 %) 3	(0.7 %) 6
Upper West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
North West	(2.5 %) 29	(1.7 %) 7	(1.7 %) 11	(1.6 %) 8	(3.3 %) 22	(0 %) 0
Total	(100.0 %) 1151	(100.0 %) 412	(100.0 %) 634	(100.0 %) 504	(100.0 %) 659	(100.0 %) 821
Silver gull						
North	(12.0 %) 59	(11.2 %) 39	(9.0 %) 25	(10.1 %) 51	(12.1 %) 109	(13.4 %) 108
North East	(15.3 %) 75	(3.4 %) 12	(5.4 %) 15	(3.8 %) 19	(6.4 %) 57	(4.5 %) 36
Upper East	(4.7 %) 23	(2.3 %) 8	(9.4 %) 26	(2.0 %) 10	(3.8 %) 34	(7.5 %) 60
Mid East	(2.9 %) 14	(6.6 %) 23	(1.4 %) 4	(1.2 %) 6	(5.8 %) 52	(4.8 %) 39
Lower East	(7.3 %) 36	(10.1 %) 35	(7.9 %) 22	(6.0 %) 30	(10.1 %) 90	(6.2 %) 50

Region	September 2003	October 2003	November 2003	December 2003	January 2004	February 2004
South East	(7.3 %) 36	(17.5 %) 61	(12.9 %) 36	(7.7 %) 39	(4.7 %) 42	(5.2 %) 42
South	(14.7 %) 72	(11.5 %) 40	(13.3 %) 37	(26.2 %) 132	(5.4 %) 48	(3.9 %) 31
South West	(4.9 %) 24	(1.1 %) 4	(0 %) 0	(2.8 %) 14	(14.6 %) 130	(6.3 %) 51
Lower West	(10.8 %) 53	(11.8 %) 41	(7.2 %) 20	(11.5 %) 58	(10.9 %) 97	(6.8 %) 55
Mid West	(2.4 %) 12	(4.0 %) 14	(17.6 %) 49	(8.5 %) 43	(10.0 %) 89	(22.4 %) 180
Upper West	(5.7 %) 28	(5.7 %) 20	(5.8 %) 16	(5.8 %) 29	(4.3 %) 38	(7.3 %) 59
North West	(11.8 %) 58	(14.7 %) 51	(10.1 %) 28	(14.5 %) 73	(11.9 %) 106	(11.7 %) 94
Total	(100.0 %) 490	(100.0 %) 348	(100.0 %) 278	(100.0 %) 504	(100.0 %) 892	(100.0 %) 805
Fairy tern						
North	(0 %) 0	(0 %) 0	(5.5 %) 33	(15.0 %) 116	(18.3 %) 136	(6.7 %) 37
North East	(0 %) 0	(0 %) 0	(0.7 %) 4	(0 %) 0	(0 %) 0	(1.6 %) 9
Upper East	(27.9 %) 34	(0 %) 0	(0 %) 0	(0.3 %) 2	(0 %) 0	(0 %) 0
Mid East	(1.6 %) 2	(0 %) 0	(0.2 %) 1	(0 %) 0	(0 %) 0	(0 %) 0
Lower East	(0 %) 0	(0.4 %) 1	(2.1 %) 13	(0.9 %) 7	(8.3 %) 62	(19.9 %) 110
South East	(0 %) 0	(0 %) 0	(0 %) 0	(1.7 %) 13	(2.7 %) 20	(4.0 %) 22
South	(64.8 %) 79	(98.9 %) 277	(90.9 %) 550	(62.7 %) 484	(69.6 %) 518	(66.5 %) 368
South West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0.9 %) 5
Lower West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
Mid West	(0 %) 0	(0 %) 0	(0 %) 0	(19.4 %) 150	(0 %) 0	(0 %) 0
Upper West	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0	(0 %) 0
North West	(5.7 %) 7	(0.7 %) 2	(0.7 %) 4	(0 %) 0	(1.1 %) 8	(0.4 %) 2
Total	(100.0 %) 122	(100.0 %) 280	(100.0 %) 605	(100.0 %) 772	(100.0 %) 744	(100.0 %) 553

Region	March 2004	April 2004	May 2004	June 2004	July 2004	August 2004	September 2004
North	(4.5)% 785	(5.1%) 334	(8.3%) 379	(4.9%) 321	(4.4%) 283	(12.5%) 912	(39.4%) 8040
North East	(6.5%) 1122	(6.5%) 424	(3.4%) 153	(3.0%) 198	(3.4%) 222	(3.7%) 269	(5.2%) 1058
Upper East	(3.6%) 625	(3.6%) 232	(4.5%) 204	(2.2%) 141	(1.9%) 120	(2.4%) 177	(3.0%) 606
Mid East	(3.7%) 649	(3.5%) 225	(3.3%) 149	(1.2%) 77	(1.3%) 86	(2.6%) 193	(3.1%) 626
Lower East	(18.6%) 3226	(12.7%) 827	(26.0%) 1186	(16.9%) 1101	(11.6%) 749	(12.0%) 876	(10.9%) 2236
South East	(14.1%) 2440	(16.2%) 1053	(13.8%) 628	(12.1%) 785	(10.7%) 692	(18.1%) 1320	(11.4%) 2323
South	(21.4%) 3707	(21.0%) 1362	(24.9%) 1138	(23.2%) 1510	(20.9%) 1349	(27.8%) 2030	(16.8%) 3424
South West	(14.8%) 2555	(20.6%) 1336	(4.7%) 215	(24.4%) 1587	(5.7%) 369	(7.5%) 546	(6.2%) 1258
Lower West	(3.6%) 618	(3.5%) 227	(4.3%) 198	(6.9%) 451	(23.2%) 1501	(6.5%) 475	(1.4%) 289
Mid West	(4.7%) 806	(3.9%) 252	(4.8%) 218	(3.6%) 237	(10.8%) 701	(1.4%) 101	(0.8%) 165
Upper West	(0.2%) 31	(0.1%) 5	(>0.1%) 1	(0.2%) 14	(1.3%) 85	(0.3%) 24	(>0.1%) 5
North West	(4.4%) 755	(3.2%) 210	(2.1%) 96	(1.3%) 86	(4.8%) 311	(5.2%) 376	(1.9%) 398
Total	(100%) 17319	(100%) 6487	(100%) 4565	(100%) 6508	(100%) 6468	(100%) 7299	(100%) 20428
Red-necked stint							
North	(1.2%) 57	(6.2%) 72	(1.8%) 15	(1.0%) 10	(1.3%) 14	(3.4%) 47	(1.9%) 75
North East	(6.3%) 306	(8.6%) 99	(2.8%) 23	(1.4%) 14	(2.2%) 24	(2.7%) 38	(8.3%) 332
Upper East	(1.9%) 92	(4.2%) 49	(3.9%) 32	(1.8%) 19	(2.8%) 31	(2.0%) 28	(3.5%) 141
Mid East	(1.6%) 76	(1.7%) 20	(0.5%) 4	(0%) 0	(1.1%) 12	(1.1%) 16	(2.9%) 117
Lower East	(25.3%) 1228	(15.2%) 176	(38.2%) 314	(34.5%) 356	(35.8%) 397	(25.0%) 350	(21.5%) 865
South East	(17.5%) 846	(29.9%) 346	(4.4%) 36	(6.3%) 65	(9.2%) 102	(15.4%) 216	(22.1%) 889
South	(28.5%) 1379	(31.9%) 369	(47.6%) 391	(50.8%) 525	(40.2%) 446	(48.8%) 683	(33.5%) 1344
South West	(9.7%) 468	(2.0%) 23	(0%) 0	(0%) 0	(0.1%) 1	(0.1%) 1	(5.1%) 204
Lower West	(4.8%) 232	(0.3%) 3	(0.6%) 5	(2.0%) 21	(5.0%) 56	(0.7%) 10	(0%) 0
Mid West	(2.4%) 116	(0%) 0	(0.2%) 2	(0.1%) 1	(0%) 0	(0.3%) 4	(0.4%) 16

Region	March 2004		April 2004		May 2004		June 2004		July 2004		August 2004		September 2004	
Upper West	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
North West	(0.9%)	45	(0%)	0	(0%)	0	(2.1%)	22	(2.3%)	26	(0.5%)	7	(0.8%)	32
Total	(100%)	4845	(100%)	1157	(100%)	822	(100%)	1033	(100%)	1109	(100%)	1400	(100%)	4015
Grey-tailed tattler														
North	(5.0%)	127	(2.1%)	23	(0%)	0	(0%)	0	(11.7%)	50	(3.7%)	22	(6.0%)	98
North East	(12.1%)	307	(14.7%)	160	(10,7%)	46	(12.5%)	56	(12.8%)	55	(8.8%)	52	(12.4%)	203
Upper East	(5.7%)	144	(6.2%)	68	(8.4%)	36	(5.6%)	25	(2.8%)	12	(3.9%)	23	(4.8%)	79
Mid East	(7.7%)	195	(6.7%)	73	(3.7%)	16	(1.6%)	7	(0.5)	2	(1.5%)	9	(4.8%)	79
Lower East	(12.2%)	309	(11.7%)	127	(25.2%)	108	(22.5%)	101	(15.2%)	65	(20.5%)	122	(12.8%)	208
South East	(17.5%)	446	(17.7%)	193	(13.6%)	58	(10.5%)	47	(23.5%)	101	(16.2%)	96	(17.4%)	283
South	(29.5%)	751	(30.6%)	333	(38.3%)	164	(44.9%)	201	(28.7%)	123	(35.0%)	208	(28.3%)	462
South West	(0.7%)	17	(6.1%)	66	(0%)	0	(0%)	0	(0.5%)	2	(0.7%)	4	(3.6%)	58
Lower West	(0.8%)	21	(3.5%)	38	(0%)	0	(1.3%)	6	(3.7%)	16	(5.9%)	35	(2.5%)	40
Mid West	(1.4%)	36	(0.6%)	7	(0%)	0	(0%)	0	(0%)	0	(2.0%)	12	(2.5%)	41
Upper West	(>0.1%)	1	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
North West	(7.4%)	189	(0.2%)	2	(0%)	0	(1.1%)	5	(0.7%)	3	(1.9%)	11	(4.9%)	80
Total	(100%)	2543	(100%)	1090	(100%)	428	(100%)	448	(100%)	429	(100%)	594	(100%)	1631
Ruddy turnstone														
North	(6.4%)	111	(12.0%)	15	(10.3%)	12	(11.8%)	13	(7.4%)	8	(4.0%)	9	(8.4%)	124
North East	(10.8%)	188	(4.0%)	5	(0%)	0	(6.4%)	7	(7.4%)	8	(9.7%)	22	(10.4%)	154
Upper East	(5.2%)	90	(3.2%)	4	(3.4%)	4	(4.5%)	5	(0.9%)	1	(2.2%)	5	(4.6%)	68
Mid East	(4.8%)	84	(6.4%)	8	(0.9%)	1	(0%)	0	(1.9%)	2	(2.6%)	6	(5.1%)	75
Lower East	(15.7%)	272	(8.0%)	10	(11.1%)	13	(10.9%)	12	(3.7%)	4	(7.9%)	18	(13.3%)	197
South East	(17.0%)	294	(13.6%)	17	(21.4%)	25	(27.3%)	30	(29.6%)	32	(26.4%)	60	(16.2%)	239

Region	March 2004		April 2004		May 2004		June 2004		July 2004		August 2004		September 2004	
South	(12.7%)	220	(15.2%)	19	(17.1%)	20	(14.5%)	16	(13.9%)	15	(29.5%)	67	(15.7%)	231
South West	(6.5%)	113	(32.0%)	40	(7.7%)	9	(6.4%)	7	(2.8%)	3	(3.1%)	7	(8.2%)	121
Lower West	(7.8%)	136	(0%)	0	(7.7%)	9	(6.4%)	7	(13.0%)	14	(5.3%)	12	(5.0%)	74
Mid West	(3.8%)	65	(4.8%)	6	(0%)	0	(0%)	0	(0%)	0	(0.9%)	2	(2.4%)	35
Upper West	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
North West	(9.2%)	160	(0.8%)	1	(20.5%)	24	(11.8%)	13	(19.4%)	21	(8.4%)	19	(10.7%)	158
Total	(100%)	1733	(100%)	125	(100%)	117	(100%)	110	(100%)	108	(100%)	227	(100%)	1476
Common tern														
North	(0.3%)	2	(2.5%)	1	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(15.4%)	2
North East	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
Upper East	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
Mid East	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
Lower East	(25.3%)	193	(95.0%)	38	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(30.8%)	4
South East	(3.9%)	30	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
South	(36.4%)	278	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
South West	(31.1%)	237	(2.5%)	1	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(53.8%)	7
Lower West	(1.6%)	12	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
Mid West	(1.4%	11	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
Upper West	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
North West	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0
Total	(100%)	763	(100%)	40	(100%)	0	(100%)	0	(100%)	0	(100%)	0	(100%)	13
Bar-tailed godwit														
North	(4.0%)	43	(7.7%)	14	(9.8%)	13	(7.7%)	8	(0%)	0	(7.3%)	8	(5.3%)	42
North East	(2.6%)	28	(5.5%)	10	(0%)	0	(1.9%)	2	(0%)	0	(0.9%)	1	(1.8%)	14

Region	March 2004	April 2004	May 2004	June 2004	July 2004	August 2004	September 2004
Upper East	(2.1%) 22	(2.7%) 5	(4.5%) 6	(2.9%) 3	(5.6%) 4	(1.8%) 2	(2.4%) 19
Mid East	(3.4%) 36	(1.1%) 2	(0%) 0	(0%) 0	(0%) 0	(10.0%) 11	(5.0%) 40
Lower East	(24.7%) 264	(8.2%) 15	(12.1%) 16	(15.4%) 16	(9.9%) 7	(5.5%) 6	(20.5%) 164
South East	(5.3%) 57	(3.3%) 6	(0%) 0	(3.8%) 4	(23.9%) 17	(0%) 0	(8.8%) 70
South	(41.0%) 439	(32.8%) 60	(65.9%) 87	(61.5%) 64	(54.9%) 39	(73.6%) 81	(39.6%) 317
South West	(4.0%) 43	(38.8%) 71	(5.8%) 10	(5.8%) 6	(5.6%) 4	(0.9%) 1	(14.1%) 113
Lower West	(7.1%) 76	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(2.3%) 18
Mid West	(1.0%) 11	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0.3%) 2
Upper West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0
North West	(4.8%) 51	(0%) 0	(0%) 0	(1.0%) 1	(0%) 0	(0%) 0	(0.1%) 1
Total	(100%) 1070	(100%) 183	(100%) 132	(100%) 104	(100%) 71	(100%) 110	100%) 800
Lesser Sand Plover							
North	(4.0%) 36	(0.4%) 1	(0.4%) 1	(0.3%) 1	(0.3%) 1	(0.8%) 3	(1.1%) 6
North East	(11.1%) 100	(6.9%) 18	(1.1%) 3	(0%) 0	(0.3%) 1	(0.5%) 2	(12.5%) 70
Upper East	(2.1%) 19	(3.8%) 10	(7.5%) 21	(1.8%) 6	(0/9%) 3	(1.3%) 5	(4.3%) 24
Mid East	(4.1%) 37	(0.4%) 1	(1.4%) 4	(0%) 0	(0%) 0	(0.3%) 1	(2.1%) 12
Lower East	(15.6%) 141	(11.1%) 29	(27.4%) 77	(1.2%) 4	(3.0%) 10	(13.9%) 54	(12.0%) 67
South East	(22.5%) 203	(6.5%) 17	(2.5%) 7	(0.6%) 2	(0.6%) 2	(9.5%) 37	(19.3%) 108
South	(39.4%) 355	(58.8%) 154	(59.8%) 168	(94.5%) 312	(93.2%) 313	(73.7%) 286	(43.8%) 245
South West	(0.8%) 7	(12.2%) 32	(0%) 0	(1.5%) 5	(1.5%) 5	(0%) 0	(3.6%) 20
Lower West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0.3%) 1	(0%) 0	(0.9%) 5
Mid West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0.4%) 2
Upper West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0
North West	(0.4%) 4	(0%) 0	(0%) 0	(0%) 00	(0%) 0	(0%) 0	(0%) 0

Region	March 2004	April 2004	May 2004	June 2004	July 2004	August 2004	September 2004
Total	(100%) 902	(100%) 262	(100%) 281	(100%) 330	(100%) 336	(100%) 388	(100%) 559
Great sand plover							
North	(5.0%) 25	(3.0%) 7	(13.1%) 27	(5.5%) 9	(0.9%) 2	(7.1%) 55	(6.4%) 58
North East	(5.2%) 26	(15.0%) 35	(9.2%) 19	(10.4%) 17	(4.7%) 10	(10.4%) 81	(13.4%) 121
Upper East	(1.0%) 5	(4.3%) 10	(14.6%) 30	(9.8%) 16	(2.8%) 6	(5.0%) 39	(5.3%) 48
Mid East	(1.8%) 9	(6.0%) 14	(3.4%) 7	(0%) 0	(0%) 0	(5.4%) 42	(4.5%) 41
Lower East	(21.4%) 107	(16.7%) 39	(22.3%) 46	(1.2%) 2	(9.0%) 19	(15.1%) 117	(16.4%) 148
South East	(10.6%) 53	(7.7%) 18	(0.5%) 1	(2.4%) 4	(0%) 0	(8.1%) 63	(14.4%) 130
South	(49.5%) 247	(36.8%) 86	(35.0%) 72	(65.9%) 108	(75.8%) 160	(27.5%) 214	(25.6%) 231
South West	(1.2%) 6	(8.5%) 20	(0%) 0	(4.3%) 7	(2.4%) 5	(14.8%) 115	(7.9%) 71
Lower West	(0%) 0	(0.9%) 2	(0%) 0	(0%) 0	(0.5%) 1	(4.2%) 33	(1.6%) 14
Mid West	(1.8%) 9	(0%) 0	(1.9%) 4	(0%) 0	(1.4%) 3	(1.7%) 13	(1.6%) 14
Upper West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0
North West	(2.4%) 12	(1.3%) 3	(0%) 0	(0/6%) 1	(2.4%) 5	(0.6%) 5	(3.0%) 27
Total	(100%) 499	(100%) 234	(100%) 206	(100%) 164	(100%) 211	(100%) 777	(100%) 903
Silver gull							
North	(7.8%) 58	(7.8%) 22	(19.4%) 40	(3.2%) 11	(1.8%) 11	(17.7%) 108	(51.4%) 186
North East	(2.3%) 17	(5.0%) 14	(4.4%) 9	(0.9%) 3	(1.3%) 8	(1.3%) 8	(1.1%) 4
Upper East	(8.0%) 60	(7.5%) 21	(3.4%) 7	(4.0%) 14	(1.8%) 11	(1.3%) 8	(0.8%) 3
Mid East	(1.2%) 9	(16.0%) 45	(2.9%) 6	(2.3%) 8	(2.2%) 13	(1.8%) 11	(3.9%) 14
Lower East	(5.8%) 43	(8.2%) 23	(4.4%) 9	(10.4%) 36	(8.2%) 49	(4.4%) 27	(6.9%) 25
South East	(1.7%) 13	(3.2%) 9	(3.9%) 8	(15.6%) 54	(8.0%) 48	(9.5%) 58	(9.9%) 36
South	(3.2%) 24	(2.8%) 8	(3.9%) 8	(5.2%) 18	(1.7%) 10	(5.4%) 33	(8.3%) 30
South West	(6.6%) 49	(13.2%) 37	(30.6%) 63	(25.1%) 87	(9.8%) 59	(4.3%) 26	(1.7%) 6

Region	March 2004	April 2004	May 2004	June 2004	July 2004	August 2004	September 2004
Lower West	(3.8%) 28	(8.2%) 23	(6.8%) 14	(21.9%) 76	(37.8%) 227	(30.3%) 185	(5.2%) 19
Mid West	(35.7%) 266	(4.3%) 12	(8.7%) 18	(7.2%) 25	(20.5%) 123	(4.6%) 28	(5.0%) 18
Upper West	(2.9%) 22	(0.4%) 1	(0%) 0	(2.9%) 10	(5.0%) 30	(2.6%) 16	(0%) 0
North West	(21.0%) 157	(23.5%) 66	(11.7%) 24	(1.4%) 5	(1.8%) 11	(16.7%) 102	(5.8%) 21
Total	(100%) 746	(100%) 281	(100%) 206	(100%) 347	(100%) 600	(100%) 610	(100%) 362
Fairy tern							
North	(5.4%) 43	(0.8%) 9	(1.2%) 1	(2.2%) 3	(0%) 0	(1.2%) 6	(0.2%) 1
North East	(3.4%) 27	(0.2%) 2	(0%) 0	(0%) 0	(1.8%) 1	(0%) 0	(0%) 0
Upper East	(0.1%) 1	(0.1%) 1	(0%) 0	(8.0%) 11	(0%) 0	(0.4%) 2	(1.2%) 5
Mid East	(0.4%) 3	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0.5%) 2
Lower East	(7.2%) 57	(1.4%) 15	(93.8%) 76	(3.6%) 5	(0%) 0	(0%) 0	(0%) 0
South East	(0.4%) 3	(8.5%) 90	(0%) 0	(7.3%) 10	(7.0%) 4	(0%) 0	(0%) 0
South	(75.4%) 600	(7.1%) 75	(4.9%) 4	(32.8%) 45	(15.8%) 9	(18.2%) 93	(7.5%) 32
South West	(7.8%) 62	(81.9%) 868	(0%) 0	(43.1%) 59	(71.9%) 41	(61.3%) 314	(80.0%) 343
Lower West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(18.2%) 93	(9.8%) 42
Mid West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0
Upper West	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0	(0%) 0
North West	(0%) 0	(0%) 0	(0%) 0	(2.9%) 4	(3.5%) 2	(0.8%) 4	(0.9%) 4
Total	(100%) 796	(100%) 1060	(100%) 81	(100%) 137	(100%) 57	(100%) 512	(100%) 429

Attachment 4 - Bird Species Recorded from Barrow Island. Based on Sedgewick (1978) and WAPET (1991), with species apparently recorded for the first time on the Island during the 2003/2004 surveys marked with an asterisk. Under Status, species are classified as either: R = resident; M = regular migrant or V = vagrant. Under Habitat, species are classified as either: T = terrestrial; L = littoral (shoreline, shallows and inshore waters, including ephemeral wetlands); O = oceanic (marine) or OI = oceanic but breeding on offshore islets. The conservation status of species under the WA Wildlife Conservation Act, Federal EPBC Act and CALM priority list is indicated.

Species	Status	Habitat	Conservation status
Phasianidae (pheasants and quails)			
Brown quail *Coturnix ypsilophora*	R	T	
Anatidae (ducks, geese and swans)			
Black swan *Cygnus atratus*	V	L	
Australian wood duck *Chenonetta jubata*	V	L	
Grey teal *Anas gibberifrons*	V	L	
Podicepididae (grebes)			
Australasian grebe *Tachybaptus novaehollandiae*	V	L	
Procellariidae (shearwaters)			
Wedge-tailed shearwater *Puffinus pacificus*	M	OI	migratory
Diomedeidae (albatrosses)			
Yellow-nosed albatross *Diomedea chlororhynchos*	V	O	migratory
Hydrobatidae (storm-petrels)			
Wilson's storm-petrel *Oceanites oceanicus*	V	O	migratory
Sulidae (gannets and boobies)			
Masked booby *Sula dactylatra*	V	O	migratory
Brown booby *Sula leucogaster*	V	O	migratory
Anhingidae (darters)			
Darter *Anhinga melanogaster*	V	L	
Phalacrocoracidae (cormorants)			
Little pied cormorant *Phalacrocorax melanoleucos*	R*	L	
Pied cormorant *Phalacrocorax varius*	R	L	
Little black cormorant *Phalacrocorax sulcirostris*	R*	L	
Great cormorant *Phalacrocorax carbo*	R	L	
Pelecanoididae (pelicans)			
Australian pelican *Pelecanus conspicillatus*	R	L	
Fregatidae			
Lesser frigatebird *Fregata ariel*	V	O	migratory
Ardeidae (herons and egrets)			
White-faced heron *Ardea (Egretta) novaehollandiae*	R	L	
Little egret *Ardea (Egretta) garzetta*	V	L	

Species	Status	Habitat	Conservation status
Eastern reef egret *Ardea (Egretta) sacra*	R	L	migratory
Great egret *Ardea (Egretta) alba*	V*	L	migratory
Striated heron *Butorides striatus*	R	L	
Nankeen night heron *Nycticorax caledonicus*	R	L	
Accipitridae (kites, hawks and eagles)			
Osprey *Pandion haliaetus*	R	L	migratory
Black-shouldered kite *Elanus notatus*	R	T	
Square-tailed kite *Lophoictinia isura*	V	T	
Black-breasted buzzard *Hamirostra melanosternon*	V	T	
Whistling kite *Haliastur sphenurus*	V	T	
Brahminy kite *Haliastur indus*	R	L	
White-bellied sea-eagle *Haliaeetus leucogaster*	R	T	migratory
Spotted harrier *Circus assimilis*	R	T	
Wedge-tailed eagle *Aquila audax*	V	T	
Falconidae (falcons)			
Brown falcon *Falco berigora*	V	T	
Australian hobby *Falco longipennis*	V	T	
Nankeen kestrel *Falco cenchroides*	R	T	
Otidae (bustards)			
Australian bustard *Ardeotis australis*	V	T	Priority 4
Scolopacidae (sandpipers)			
Black-tailed godwit *Limosa limosa*	M	L	migratory
Bar-tailed godwit *Limosa lapponica*	M	L	migratory
Little curlew *Numenius minutes*	V	L	migratory
Whimbrel *Numenius phaeopus*	M	L	migratory
Eastern curlew *Numenius madagascariensis*	M	L	migratory
Marsh sandpiper Tringa stagnatalis	V	L	migratory
Common greenshank *Tringa nebularia*	M	L	migratory
Wood sandpiper *Tringa glareola*	V	L	migratory
Terek sandpiper *Tringa (Xenus) terek*	M	L	migratory
Common sandpiper *Tringa hypoleucos*	M	L	migratory
Grey-tailed tattler *Tringa brevipes*	M	L	migratory
Ruddy turnstone *Arenaria interpres*	M	L	migratory
Great knot *Calidris tenuirostris*	M	L	migratory
Red knot *Calidris canutus*	M	L	migratory
Sanderling *Calidris alba*	M	L	migratory
Red-necked stint *Calidris ruficolli*s	M	L	migratory
Sharp-tailed Sandpiper *Calidris acuminata*	M	L	migratory
Curlew Sandpiper *Calidris ferruginea*	M	L	migratory

Species	Status	Habitat	Conservation status
Burhinidae (stone-curlews)			
Beach stone-curlew *Esacus neglectus*	R	L	
Haematopodidae (oystercatchers)			
Pied oystercatcher *Haematopus longirostris*	R	L	
Sooty oystercatcher *Haematopus fuliginosus*	R	L	
Recurvirostridae (stilts and avocets)			
Black-winged stilt *Himantopus himantopus*	V	L	
Banded stilt *Cladorhynchus leucocephalus*	V	L	
Charadriidae (lapwings and plovers)			
Pacific golden plover *Pluvialis fulva*	M	L	migratory
Grey plover *Pluvialis squatarola*	M	L	migratory
Red-capped plover *Charadrius ruficapillus*	R	L	
Lesser sand plover *Charadrius mongolus*	M	L	migratory
Greater sand plover *Charadrius leschenaultii*	M	L	migratory
Oriental plover *Charadrius veredus*	V	L	migratory
Glareolidae (pratincoles)			
Australian pratincole *Stiltia isabella*	V	L	migratory
Laridae (gulls and terns)			
Silver gull *Larus novaehollandiae*	R	L	
Gull-billed tern *Sterna (Gelochelidon) nilotica*	R	L	
Caspian tern *Sterna (Hydroprogne) caspia*	R	L	
Lesser crested tern *Sterna bengalensis*	R	L	
Crested tern *Sterna bergii*	R	L	
Roseate tern *Sterna dougallii*	M	L/O	
Common tern *Sterna hirundo*	M	L/O	migratory
Little tern *Sterna albifrons*	M	L	migratory
Fairy tern *Sterna nereis*	?	L	
Bridled tern *Sterna anaethet*us	M	OI	migratory
White-winged black tern *Chlidonias leucoptera*	M	L	migratory
Lesser noddy *Anous tenuirostris*	?	O	
Columbidae (pigeons and doves)			
Crested pigeon *Ocyphaps lophotes*	V	T	
Peaceful dove *Geopelia placida*	V	T	
Bar-shouldered dove *Geopelia humeralis*	R	T	
Cacatuidae (cockatoos)			
Galah *Cacatua roseicapilla*	V	T	
Little corella *Cacatua sanguinea*	V	T	
Cockatiel *Nymphicus hollandicus*	V	T	
Psittacidae (lorikeets and parrots)			

Species	Status	Habitat	Conservation status
Budgerigar *Melopsittacus undulatus*	V	T	
Cuculidae (cuckoos)			
Oriental cuckoo *Cuculus saturatus*	*V	T	migratory
Pallid cuckoo *Cuculus pallidus*	R	T	
Horsfield's bronze-cuckoo *Chrysococcyx basalis*	R	T	
Black-eared cuckoo *Chrysococcyx osculans*	R	T	
Strigidae (hawk-owls)			
Southern boobook owl *Ninox novaeseelandiae*	V	T	
Tytonidae (barn owls)			
Barn owl *Tyto alba*	V	T	
Apodidae (swifts)			
Swiftlet species *Collocalia* sp.	V	T	
Fork-tailed swift *Apus pacificus*	?M	T	
White-throated needletail *Hirundapus caudacutus*	?M	T	
Halcyonidae (forest kingfishers)			
Red-backed kingfisher *Todiramphus pyrrhopygia*	V	T	
Sacred kingfisher *Todiramphus sanctus*	R	L	
Maluridae (fairy wrens)			
Barrow Island white-winged fairy wren *Malurus leucopterus edouardi*	R	T	Sched. 1, Vulnerable
Meliphagidae (honeyeaters)			
Spiny-cheeked honeyeater *Acanthagenys rufogularis*	V	T	
Singing honeyeater *Lichenostomus virescens*	R	T	
Brown honeyeater *Lichmera indistincta*	V	T	
Crimson chat *Epthianura tricolor*	V	T	
Dicruridae (flycatchers)			
Magpie-lark *Grallina cyanoleuca*	V	T	
Willie wagtail *Rhipidura leucophrys*	V	T	
Campephagidae (cuckoo-shrikes)			
Black-faced cuckoo-shrike *Coracina novaehollandiae*	V	T	
White-winged triller *Lalage sueurii*	V	T	
Artamidae (woodswallows)			
White-breasted woodswallow *Artamus leucorhynchus*	R	T	
Masked woodswallow *Artamus personatus*	V	T	
Black-faced woodswallow *Artamus cinereus*	V	T	
Corvidae (ravens and crows)			
Little crow Corvus bennetti	V	T	
Motacillidae (pipits and true wagtails)			
Richard's pipit *Anthus novaeseelandiae*	R	T	
Passeridae (finches and allies)			

Species	Status	Habitat	Conservation status
Painted firetail *Emblema picta*	V	T	
Zebra finch *Taeniopygia guttata*	R	T	
Hirundinidae (swallows)			
Welcome swallow *Hirundo neoxena*	R	T	
Tree Martin *Hirundo nigricans*	V	T	
Fairy Martin *Hirundo ariel*	V	T	
Sylviidae (Old World warblers)			
Spinifexbird *Eremiornis carteri*	R	T	
Brown songlark *Cincloramphus cruralis*	V	T	
Zosteropidae (silvereyes)			
Yellow white-eye *Zosterops luteus*	R	T	

Attachment 5 - Gorgon Development on Barrow Island. Technical Report on the White-winged Fairy-wren *Malurus leucopterus edouardi.*

Gorgon development on Barrow Island

Technical report

White-winged Fairy-wren *Malurus leucopterus edouardi*

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1 Introduction

The Gorgon Venture proposes to develop a gas processing facility on Barrow Island. The facility is proposed for Town Point on the east coast of the Island, with the associated gas feed pipelines running across the Island from a shore crossing at either North White's Beach or Flacourt Bay . The proposed development will result in the loss of some habitat for the endemic White-winged Fairy-wren *Malurus leucopterus edouardi*. The Barrow Island sub-species of the White-winged Fairy-wren is listed as Vulnerable under the *Wildlife Conservation Act 1950 (WA)* (Wildlife Conservation Act) and the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The aim of this study was to determine the number of White-winged Fairy-wrens inhabiting the proposed development area, and relate this to the estimated number of wrens in similar habitat on Barrow Island.

2 Methods

Surveys for the White-winged Fairy-wren were carried out in the late afternoon on the 22nd – 24th October 2004. The eight search areas surveyed are listed in Table 1. Each search area was approximately 100m wide and of variable length. The search areas were side-by-side and approximately 0.81 km^2 of the proposed 3 km^2 Development area was surveyed. The vegetation in the search areas generally consisted of mixed *Triodia* species with scattered clumps of *Acacia bivenosa* and scattered clumps of a *Melaleuca cardiophylla*.

Table 1. Location of each White-winged Fairy-wren search area. Each search area is a rectangular transect and all searches were carried out between 1500 and 1830hr.

Search Area	Date Searched	Eastern Edge	Western Edge	Northern Edge	Southern Edge	Area (m^2)
1	22-Oct-04	339450 E	337970 E	7700700 N	7700600 N	148000
2	22-Oct-04	339450 E	337970 E	7700600 N	7700500 N	148000
3	23-Oct-04	339160 E	338290 E	7700100 N	7700000 N	87000
4	23-Oct-04	339160 E	338290 E	7700200 N	7700100 N	87000
5	24-Oct-04	339236 E	337970 E	7700300 N	7700200 N	126600
6	24-Oct-04	339236 E	337970 E	7700300 N	7700400 N	126600
7	24-Oct-04	339800 E	339310 E	7700500 N	7700400 N	49000
8	24-Oct-04	339800 E	339395 E	7700650 N	7700550 N	40500

The search areas were surveyed by six people standing in a line, 20m apart, on one 100m wide front. The search area was swept by the six people moving forward into the search area at a walking pace, maintaining the straight line. Hand-held Global Positioning System (GPS) units were used to maintain the correct bearing at each boundary of the search line. If a bird was observed, the survey team paused while the observation was recorded. This ensured that a straight line was maintained.

As terrestrial birds are relatively uncommon on Barrow Island, all birds (in addition to White-winged Fairy-wrens) that were seen were recorded. Spectacled Hare-Wallabies (*Lagorchestes conspicillatus*) were also recorded. For each observation, notes were made on the species, the number of birds in the group, the habitat the birds were observed in, the soil type and the location in eastings and northings.

3 Results

The size of each search area ranged from 40500 to 148000m^2 (Table 1). The total area searched was 812700m^2, or 0.81km^2.

Three species of birds were recorded during the surveys: the White-winged Fairy-wren, Singing Honeyeater and Spinifex-bird (Table 2). The survey data for each species are presented in Appendix 1, and each species is discussed separately below.

Table 2. The number, the mean group size and density of the three bird species recorded during surveys 22nd – 24th October 2004.

Species	Number of records	Number of birds	Mean group size ± SD	Density (birds/km^2)
White-winged Fairy-wren *Malurus leucopterus edouardi*	23	85	3.7 ± 1.6	104.6
Singing Honeyeater *Lichenostomus virescens*	6	9	1.5 ± 0.8	11.1
Spinifex-bird *Eremiornis carteri*	26	27	1.0 ± 0.2	33.2

3.1 White-winged Fairy-wren

The White-winged Fairy-wren was observed on 23 occasions during the searches, with a total of 85 individual birds counted (Table 2). As the area of the proposed Gorgon development is 3 km^2, the number of White-winged Fairy-wrens in the entire development area is probably about 315 birds.

The density of White-winged Fairy-wrens was the highest of the three bird species observed; almost three times greater than the density of Spinifex-birds and almost 10 times greater than the density of Singing Honeyeaters. The mean group size of White-winged Fairy-wrens was 3.6 birds per group, which was larger than both the Singing Honeyeater and Spinifex-bird. The maximum number of White-winged Fairy-wrens recorded in a group was eight (Appendix 1).

The vegetation in the survey areas generally consisted of mixed *Triodia* species with scattered clumps of *Acacia bivenosa* and scattered clumps of *M. cardiophylla*. In 87% of White-winged Fairy-wren records, the habitat contained myrtaceous shrubs, and in 44% of records the habitat contained *A. bivenosa*. In 30% of records both *Melaleuca* shrubs and *A. bivenosa* were present.

White-winged Fairy-wren habitat is found over about 89.26 km^2 or approximately 40% of the island. The density of birds found in this study (Table 2) can be used to estimate the number of birds found in this habitat across the whole island, giving a figure of about 9336 birds.

3.2 Singing Honeyeater

The Singing Honeyeater, *Lichenostomus virescens*, was the least common bird observed, with a total of only nine birds recorded during surveys (Table 2). Consequently, the density of the Singing Honeyeater was very low compared with the other species observed. The Singing Honeyeater was usually recorded in association with *A. bivenosa* when habitat type was recorded (Appendix 1).

3.3 Spinifex-bird

The Spinifex-bird, *Eremiornis carteri*, was usually observed as single birds rather than in groups (Table 2). This species was three times more abundant than the Singing Honeyeater, but only about a third as abundant as the White-winged Fairy-wren. Of the 18 records where habitat was recorded, 39% of records were in habitats containing *M. cardiophylla* and 44% of records were in habitats containing *A. bivenosa*.

4 Discussion

Johnstone and Storr (2004) state that the White-winged Fairy-wren is moderately common to common on Barrow Island, and is one of the most abundant birds on the island. This bird has an estimated Island population of 8 150 (Sedgwick 1978) to 7 519 (Pruett-Jones & O'Donnel unpubl.). The results of this study suggest that the White-winged Fairy-wren is also the most abundant bird in the proposed development area. Development of the proposed area will result in the loss of about 315 White-winged Fairy-wrens or approximately 3-4% of the islands population.

Groups of White-winged Fairy-wrens appeared to be associated with clumps of *M. cardiophylla* or *A. bivenosa*. These shrubs may provide favoured areas of dense shelter for roosting and nesting. *Acacia bivenosa* may also provide higher perches from which to scan the surrounding landscape for danger. When re-vegetation is carried out in the future, it will be important to include *M. cardiophylla* and *A. bivenosa* as these are important elements of White-winged Fairy-wren habitat.

5 References

Johnstone, R.E. & Storr, G.M. (2004). *Handbook of Western Australian Birds. Volume 2: Passerines (Blue-winged Pitta to Goldfinch)*. Western Australian Museum, Perth.

Appendix 1. Observations of the (a.) White-winged Fairy-wren, (b.) Singing Honeyeater and (c.) Spinifex-bird in search areas 22nd – 24th October 2004.

a. White-winged Fairy-wren

Search area	Number of birds	Easting	Northing	Vegetation description	Soil
1	3	338669 E	7700673 N	Mixed *Triodia* with *M. cardiophylla* & *A. bivenosa*	Loam no exposed limestone
1	4	339008 E	7700578 N	*M. cardiophylla*	Rise with exposed limestone
2	1	339366 E	7700575 N	*Acacia coriacea* in *Triodia wiseana* with *M. cardiophylla* & *A. bivenosa*	-
2	3	338565 E	7700496 N	*Triodia wiseana* & myrtaceous shrub (20% cover)	Red loam, exposed limestone on lower slope
2	3	339300 E	7700520 N	Mixed *Triodia* with 15% mixed *A. bivenosa* & *M. cardiophylla*	Loam, no exposed limestone
2	4	338382 E	7700596 N	*M. cardiophylla*	Limestone ridge
2	6	338274 E	7700576 N	*M. cardiophylla* with mixed *Triodia*	Limestone ridge
3	2	338408 E	7700085 N	Mixed *Triodia* with *M. cardiophylla* & *A. bivenosa*	Red loam over limestone lower slopes
3	8	338308 E	7700085 N	Mixed *Triodia* with myrtaceous shrub & *A. bivenosa*	Red loam over limestone lower slopes
4	4	339152 E	7700180 N	*A. bivenosa* over *Triodia* sp.	Loam, no exposed limestone
4	4	338868 E	7700152 N	Mixed *Triodia* with *A. bivenosa*	-
4	5	338496 E	7700222 N	Myrtaceous shrub over *Triodia*	Loam no exposed limestone
5	2	338219 E	7700210 N	*M. cardiophylla* with *Triodia* sp.	Loam no exposed limestone

5	3	339129 E	7700197 N	*Acacia bivenosa* and *M. cardiophylla* over *Triodia* sp.	Loam no exposed limestone
5	3	339006 E	7700175 N	*M. cardiophylla* with *Triodia* sp.	Loam no exposed limestone
5	3	338123 E	7700165 N	*M. cardiophylla* with *Triodia* sp.	Exposed Limestone
5	3	337962 E	7700170 N	*M. cardiophylla* with *Triodia* sp.	Exposed Limestone
5	3	338756 E	7700285 N	*Triodia angusta* with *M. cardiophylla* (15% cover	Red loam
5	3	338756 E	7700285 N	Mixed *Triodia* with 15% *M. cardiophylla.*	Red loam
5	6	338676 E	7700298 N	Mixed *Triodia* with *M. cardiophylla* (15%)	Loam with some exposed limestone
5	6	338676 E	7700298 N	Mixed *Triodia* with 15% *M. cardiophylla.*	Low limestone rise
6	3	338957 E	7700270 N	Mixed *Triodia* with mixed *M. cardiophylla* & *Acacia* sp. (15%)	Sandy Loam plain
7	3	339812 E	7700398 N	*Acacia coriacea*	sand

b. Singing Honeyeater

Search area	Number of birds	Easting	Northing	Vegetation description	Soil
1	1	339104 E	7700601 N	-	-
1	2	338762 E	7700689 N	Mixed *triodia* with *A. bivenosa* (10%cover)	Red loam, no exposed limestone
1	3	339242 E	7700595 N	*A. coriacea*	-
2	1	338703 E	7700610 N	*M. cardiophylla* with *A. bivenosa*	-
3	1	338938 E	7699997 N	*A. bivenosa* over *Triodia* sp.	-
4	1	339024 E	7700211 N	*A. bivenosa* over *Triodia sp.*	Exposed Limestone

c. Spinifex-bird

Searcharea	Number of birds	Easting	Northing	Vegetation description	Soil
1	1	339056 E	7700700 N	Mixed *Triodia* with 5% *A. bivenosa*	Red loam
1	1	338834 E	7700684 N	Mixed *Triodia* with *A. bivenosa* & *M. cardiophylla* (shrub cover 5%)	Red loam with some exposed limestone
1	1	338840 E	7700595 N	*M. cardiophylla.*	Exposed Limestone
1	1	338518 E	7700591 N	*Triodia*	Red sandy loam
1	1	338744 E	7700646 N	*T. angusta*	Low limestone rise
2	1	338400 E	7700470 N	-	-
2	1	338382 E	7700596 N	*M. cardiophylla*	Limestone ridge
3	1	339124 E	7700000 N	*A. bivenosa* over *Triodia* sp.	
3	1	338274 E	7700001 N	*M. cardiophylla*	Limestone ridge
3	1	338630 E	7700075 N	*Triodia angusta* with *Hakea chordophylla* and mixed *Acacia*	-
3	1	3391114 E	7700066 N	-	-
3	1	338913 E	7700059 N	-	-
3	1	338697 E	7700045 N	-	-
3	1	338638 E	7700025 N	-	-
5	1	338525 E	7700209 N	*M. cardiophylla* with *Triodia* sp.	Loam no exposed limestone
5	1	338123 E	7700165 N	*M. cardiophylla* with *Triodia* sp.	Exposed Limestone

5	1	338438 E	7700262 N	*M. cardiophylla* over *Triodia wiseana*	-
5	1	339145 E	7700241 N	-	-
6	1	338317 E	7700255 N	-	-
6	1	338927 E	7700400 N	*A. bivenosa*	Loam
7	1	339432 E	7700398 N	*A. bivenosa*	Loam
7	1	339477 E	7700426 N	*T. angusta* with *A. bivenosa*	-
7	1	339618 E	7700453 N	-	-
8	1	339752 E	7700552 N	*A. coriacea*	Sand
8	1	339780 E	7700510 N	*T. angusta* with 15% *A. bivenosa*	Sandy Loam plain
8	2	339560 E	7700549 N	*T. wiseana* with *A. bivenosa*	Low rise with limestone exposed

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Technical Appendix C4

Short Range Endemics and Other Terrestrial Invertebrates

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

SHORT RANGE ENDEMICS AND OTHER TERRESTRIAL INVERTEBRATES

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1 Introduction

1.1 Project Background and Current Status

The Gorgon Venture is seeking approval to develop the Gorgon gas fields, located some 130 km off the north-west coast of Western Australia. The Gorgon field is the largest gas field ever discovered in Australia and, together with the other fields in the area, represents an estimated 40 trillion cubic feet of resource. Investigations and project design work are currently underway for the proposed development of gas processing facilities on Barrow Island off the north-west coast of Western Australia.

The Island has been an active onshore oilfield since 1967 and was gazetted as a Class A Nature Reserve in 1910. The proposed development proposal has passed through an Environmental, Social and Economic Review (the ESE Review) under the provisions of the *Environmental Protection Act 1986* (the EPA Act). The review addressed the proposed development's general ability to mitigate potential on-site impacts and generate social and economic benefits for the region, state and nation. The State Government has determined that the proposed development could proceed to a more detailed level of formal environmental assessment. The proposed development is currently subject to a more detailed definition and environmental investigation under the *EPA Act* at the level of an Environmental Review and Management Programme (ERMP). Consideration of the proposed development's implications for the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) are also being evaluated.

This report on terrestrial invertebrates and potential short-range endemics (SREs) provides input to the ERMP on this ecological factor.

1.2 Overview of Issues Relating to Terrestrial Invertebrates

Terrestrial invertebrates are of interest in the current formal assessment process for several reasons (see also EPA 2003), as outlined below:

- The principle issue of potential significance relating to this fauna is the potential of some groups to contain species that are SREs. Many recent publications have highlighted taxonomic groups of invertebrates with naturally small distributions (less than 10 000 km^2) (general; Harvey 2002, freshwater snails; Ponder and Colgan 2002, land snails; Clark and Richardson 2002). These taxa are variously described as narrow range endemics or SREs (see Harvey 2002) and are, in part, characterised by poor dispersal capabilities, confinement to disjunct habitats and low fecundity (Harvey 2002, Ponder and Colgan 2002). Given the importance of short-range endemism to the conservation of biodiversity, the assessment of such invertebrate taxa is potentially an important component of impact assessment. Examples of taxonomic groups that show high levels of short-range endemism in this respect include millipedes, mygalomorph spiders and freshwater and terrestrial molluscs.
- The terrestrial invertebrate fauna of Barrow Island is not well collected or described, thus the potential for currently undescribed fauna to be collected is relatively high. Some of these undescribed species may be of conservation significance or taxonomic interest.
- Although not the primary focus of this report, documentation of terrestrial invertebrates currently occurring in the study area will be important in a baseline context for future quarantine monitoring.

1.3 Previous Surveys

Terrestrial invertebrates on Barrow Island have been poorly surveyed and collected in the past. Most surveys have been primarily focused on particular groups of invertebrates and do not provide a detailed baseline inventory of the Island's terrestrial invertebrate assemblages. The majority of the specimens registered with the Western Australian Museum (WAM) have resulted from opportunistic collections by its Arachnology Department and various honorary associates of the museum, including Harry Butler.

The Arachnology Department collected a number of specimens in 1993, in conjunction with a vertebrate fauna survey for WAPET. That trip enabled the Department to collect a number of unique taxa for the WAM's collections. Various techniques were used to collect specimens, including wet pitfall traps, collection of leaf litter, vehicle vibration, head-torching at night, sweep-netting, and general opportunistic foraging. Coastal localities were chosen to look specifically for a particular species of pseudoscorpion (*Anagarypus heatwolei*), which was of taxonomic significance at the time. Other localities such as John Wayne Country, Bandicoot Bay, and the Valley of the Giants were also sampled to maximise collecting from a number of different habitat types on the Island.

A preliminary survey of land snails on Barrow Island was undertaken in 2002 by Shirley Slack-Smith, and represents the first systematic survey of non-marine molluscs on any part of the Island. The objective of the survey was to assess areas that may have been impacted by the land-based components of the proposed development and equivalent areas adjacent to the impact zone (Slack-Smith, 2002). The survey showed that none of the species found within the impact zone had distributional ranges restricted to that area, but it did not provide comprehensive information about the broader distributions of these species outside the area of the study (Slack-Smith, 2002).

2 Methodology

Biota Environmental Sciences was engaged to sample invertebrate assemblages from the proposed Development area to assess the importance of this area to potentially site-restricted invertebrate taxa. The surveys were conducted mainly by Dr Roy Teale, Dr Mike Craig, Karen Edward and Lee Mould. The survey team has considerable collection experience in terrestrial invertebrate surveys in the Pilbara region.

2.1 Field Collection

Several targeted invertebrate groups were sampled through opportunistic collections, which were supplemented with material from systematic pit trapping during the first survey (24 November to 2 December 2003). In the second survey (25 August to 1 September 2004), a combination of wet pitfall trapping, leaf litter collection and opportunistic collection methods were used to sample terrestrial invertebrate taxa within the project area, proposed alternative campsites, and areas of non-impact. WAM staff were consulted to identify invertebrate groups of interest, such as SRES, to enable prioritisation of collecting effort.

Invertebrate groups targeted during the surveys included:

- Araneae (spiders, in particular trapdoor and wolf spiders)
- Pseudoscorpionida (pseudoscorpions)
- Scorpionida (scorpions)
- Diplopoda (millipedes)

- Pulmonata (camaenid land snails).

Specific spider taxa, such as trapdoor, wolf and huntsman spiders, were collected whilst head-torching at night and from pit traps from systematic trapping sites. Burrow excavation was also undertaken to collect trapdoor spiders.

Hand foraging for invertebrates was carried out, including lifting rocks, peeling bark, and foraging through leaf litter and under *Triodia*. This enabled collection of other spider taxa, camaenid land snails, insects, scorpions, millipedes, centipedes, and pseudoscorpions. Leaf litter and other debris found beneath *Triodia* was collected and later sieved for invertebrates.

Rhagada sp. 2 land snails were colleted after rain from a wide range of sites on Barrow Island during 2004. These snails were transported live to the University of Western Australia for genetic analyses. Electrophoresis was used to determine levels of polymorphism in *Rhagada* sp. 2 and the degree of genetic connection between snails from different parts of Barrow Island. The laboratory report and interpretation of the analyses is included as Attachment 4.

2.1.1 Survey One

During the first survey, invertebrate pit traps, consisting of plastic ice-cream containers were placed in the ground (Trap sites BIIT1 – BIIT8) to supplement opportunistic collection and material from vertebrate pit traps.

The wet pitfall traps that were used in the second survey consisted of a 2 litre ice-cream container filled with ethylene glycol to a depth of 2 cm. A lid (with an 82 mm diameter hole) was then placed on the trap to reduce the potential by-catch of vertebrates. Four of these traps were placed flush with the ground at each trapping site. Traps were placed, if possible, in shaded microhabitats such as beneath *Triodia* hummocks or shrubs. Traps were open for six nights and the collected material from the four traps were pooled for each site. Material was rinsed from the traps using water and placed in jars which were labelled for each site and stored for processing.

A selection of sites were also chosen for collection of leaf litter samples during the 2004 survey. Two full bags of leaf litter and soil were collected from areas beneath large *Triodia* bushes and melaleuca trees. Bags were labelled and later sieved and examined for invertebrates.

Table 2-1 outlines the site codes for each sampling site and the type of collection method used at each of the different sites during the first survey. Figure 2-1, Figure 2-2 and Figure 2-3 show the positions of sampling sites for opportunistic and systematic invertebrate collections on Barrow Island during 2003.

2.1.2 Survey Two

During the 2004 survey, thirty sites were established for systematic wet pitfall trapping over six days from 25 August to 1 September. A selection of these sites were chosen for leaf litter sampling and hand foraging. In total, there were 30 wet pitfall sites, 22 leaf litter sites, and 21 hand foraging sites. Photos of the trapping sites and a list of the site codes, localities and type of collection method used are provided in Attachment 1.

Sites were chosen within the impact areas [(IA), including town point (TP)], proposed alternative campsites [(AC), including proposed administration block (AD)], and non-impact areas (NI). In each of these three categories, a number of replicated sites of four different vegetation associations were chosen for systematic invertebrate collections. These were *Triodia angusta* valleys (AV), *T. wiseana* on loamy soil (TL), *T. wiseana* on limestone (LM), and *Melaleuca cardiophylla* on limestone (ML). Six sites were also chosen in areas which are disturbed or more likely to support introduced species due to their proximity to points of entry onto the Island, such as the Barge Landing and the Warehouse.

Further details regarding sampling methods and sampling sites during the second survey in 2004 can be found in Attachment 1.

2.2 Curation and Limits on Identification

Trapdoor, wolf, and huntsman spiders were curated in 70 per cent ethanol with one or two legs removed and placed in 100 per cent ethanol for future molecular studies.

Invertebrate material which was collected via wet pitfalls was stored in ethylene glycol until it was transported to the WAM for processing and sorting. Material was first rinsed with water, then sieved out of the glycol and rinsed again. Specimens were then placed in jar of 70% ethanol to be sorted and identified.

Leaf litter samples were collected and stored in plastic bags. Each sample was sieved and examined for live invertebrates. All invertebrate material collected was immediately stored in 70% ethanol. All other material collected via foraging was placed in 70% ethanol. All material will be lodged with the WAM at the end of the project.

Specimens were identified by Biota scientists in consultation with WAM staff and using the WAM invertebrate collections. The level of specimen identification achievable was dependent on the level of taxonomic knowledge and expertise currently available. As a result, only a limited number of specimens could be identified to genus or species level. Only taxa belonging to groups known to include short-range endemics (mygalomorphs, pulmonate land snails, pseudoscorpions, millipedes), or for which expertise was readily available at the WAM (wolf spiders, other spider groups, scorpions, centipedes) were identified to genus or species level.

A large percentage of specimens collected from wet pitfall traps or sieved from leaf litter were juveniles. These individuals could not be identified to genus or species level and were not included in this report. This suggests that further surveys are required to collect adult specimens of certain taxa. Many groups are seasonal, with juveniles maturing at certain times of the year or after periods of rain. This is particularly prevalent in Mygalomorph spiders, where the males are generally only active after heavy rain. Female Mygalomorph spiders generally remain near or within their burrows. Attempts to dig up specimens from burrows only revealed juvenile spiders.

Many invertebrate taxa in Western Australia are currently under taxonomic revision, or in need of revision. In the absence of taxonomic keys or taxonomic resolution for many taxa, it is not possible to positively identify these invertebrates. While the WAM database was revised and updated specifically for this project, the lack of comprehensive collections of many invertebrate groups in Western Australia make it impossible to determine their distribution in other areas of the state.

2.3 Databasing for Regional Context

Key data for specimens lodged with the WAM were entered into the arachnology database. Data captured included taxonomy, location, number of specimens, sex of specimen, habitat, method of collection, and who determined the identification. In addition, a systematic search of the Department of Arachnology's collection was undertaken to locate all previous specimens collected from Barrow Island. The data from these specimens were then added to the arachnology database to provide a readily-accessible source of information on the Barrow Island collection. This was further supplemented by a second search of the arachnology collection to locate all those species or 'types' known to occur on Barrow Island (from the above work) that had also been collected from elsewhere on the mainland or other islands. The locations of these specimens were added to the database to provide regional context.

Table 2-1 – Localities of Sampling Sites and Collection Methods Used During the 2003 Survey

SITE CODE	LATITUDE	LONGITUDE	COLLECTION METHOD
BITP1	-20.789383	115.463033	Opportunistic
BITP2	-20.78925	115.46255	Opportunistic
BITP4	-20.788766	115.4636	Opportunistic
BIAP1	-20.800966	115.454366	Opportunistic
BIAP2	-20.802466	115.4483	Opportunistic
BIAP3	-20.80250	115.44833	Opportunistic
BIHT01	-20.78842	115.4629	Head-torching/opportunistic
BIHT02	-20.79488	115.42878	Head-torching/opportunistic
BIHT03	-20.80718	115.45078	Head-torching/opportunistic
BIHT04	-20.80247	115.4483	Head-torching/opportunistic
BIHT05	-20.80643	115.4524	Head-torching/opportunistic
BIHT06	-20.78938	115.46304	Head-torching/opportunistic
BIHT07	-20.78877	115.4636	Head-torching/opportunistic
BIHT08	-20.78892	115.46255	Head-torching/opportunistic
BIHT09	-20.77443	115.43518	Head-torching/opportunistic
BIHT10	-20.80453	115.44935	Head-torching/opportunistic
BIHT11	-20.78985	115.45583	Burrow excavation
BIHT12	-20.808	115.45063	Burrow excavation
BIHT13	-20.80683	115.45042	Burrow excavation
BIHT14	-20.78892	115.45528	Burrow excavation
BIHT15	-20.78894	115.45475	Burrow excavation
BIHT16	-20.77617	115.44979	Head-torching/opportunistic
BIHT17	-20.78408	115.45648	Head-torching/opportunistic
BIOP1	-20.6712	115.437316	Opportunistic
BIOP2	-20.670983	115.437	Opportunistic
BIOP3	-20.774433	115.435183	Opportunistic
BIOP4	-20.671083	115.43715	Opportunistic
BIOP5	-20.667633	115.454366	Opportunistic
BIOP6	-20.795033	115.4577	Opportunistic
BIOP7	-20.79235	115.438466	Opportunistic
BIOP8	-20.788333	115.463233	Opportunistic
BIMB01	-20.786793	115.45636	Vertebrate pitfall traps

SITE CODE	LATITUDE	LONGITUDE	COLLECTION METHOD
BIMB02	-20.784397	115.456096	Vertebrate pitfall traps
BIMB03	-20.799503	115.453349	Vertebrate pitfall traps
BIMB04	-20.78847	115.462011	Vertebrate pitfall traps
BIMB05	-20.791421	115.458619	Vertebrate pitfall traps
BIMB06	-20.776467	115.448205	Vertebrate pitfall traps
BI1.19	-20.7902	115.45645	Litter samples
BI1.21	-20.790033	115.456066	Litter samples
BI1.22	-20.789716	115.4557	Litter samples
BI1.23	-20.789583	115.455516	Litter samples
BI1.24	-20.789516	115.455383	Litter samples
BI1.25	-20.789316	115.455333	Litter samples
BI1.26	-20.789266	115.455066	Litter samples
BI1.27	-20.7891	115.454966	Litter samples
BI1.28	-20.789	115.454866	Litter samples
BI1.29	-20.79065	115.45695	Litter samples
BI1.41	-20.789816	115.45575	Litter samples
BI3.1	-20.788416	115.4629	Litter samples
BI3.3	-20.788283	115.462816	Litter samples
BI3.5	-20.78815	115.462716	Litter samples
BI3.7	-20.78807	115.4626	Litter samples
BI3.9	-20.787933	115.462483	Litter samples
BI3.10	-20.787866	115.462416	Litter samples
BI3.11	-20.787816	115.462383	Litter samples
BIIT1	-20.79587	115.4533	Invertebrate pitfall traps
BIIT2	-20.7958	115.4532	Invertebrate pitfall traps
BIIT3A	-20.79522	115.45287	Invertebrate pitfall traps
BIIT3B	-20.7953	115.4527	Invertebrate pitfall traps
BIIT4	-20.78802	115.45703	Invertebrate pitfall traps
BIIT5	-20.78435	115.46201	Invertebrate pitfall traps
BIIT6	-20.78478	115.4619	Invertebrate pitfall traps
BIIT7	-20.78549	115.4613	Invertebrate pitfall traps
BIIT8	-20.80573	115.45071	Invertebrate pitfall traps

Figure 2-1 - Survey Areas and Sampling Sites for Opportunistic and Systematic Invertebrate Collections on Barrow Island in 2003. See inserts A (Figure 2-2) and (Figure 2-3) for Detailed Sampling Localities and Site Codes

Figure 2-2 - (Insert A) Sampling Site Localities and Site Codes for Invertebrate Collections around Town Point and South-West of the Terminal Tanks in 2003. Trapline 1 Includes Litter Sample Sites BI1.19 - BI1.41. Trapline 3 Includes Litter Sample Sites BI3.1 - BI3.11

Figure 2-3 - (Insert B) Sampling Site Localities and Site Codes for Invertebrate Collections around Cape Dupuy in 2003

3 Results

3.1 Overview

More than 99 invertebrate taxa have been collected from Barrow Island, many of which could not be identified beyond family level. Of the invertebrate taxa specifically targeted during 2003, 22 spider taxa, four species of pseudoscorpion, three species of centipede, one millipede species, two species of scorpion (including a potentially new species), and five species of land snail were collected and identified (Table 3-1). A detailed breakdown of all specimens captured during the survey is provided in Attachment 2. Other species records for Barrow Island that were not collected during the study but have been recorded in the past are also shown in Attachment 2. Work is ongoing on many of these groups and further collecting on Barrow Island will add to this.

Table 3-1 - Summary of Invertebrate Taxa Collected During 2003

Class	Order	No. families	No. genera	No. identified species
Arachnida	Araneae	13	15	22
Arachnida	Pseudoscorpionida	2	3	4
Arachnida	Scorpionida	2	2	2
Myriapoda	Diplopoda	1	1	1
Myriapoda	Chilopoda	2	3	3
Gastropoda	Pulmonata	2	3	5

Sampling of terrestrial invertebrate taxa in 2004, particularly Arachnids and myriapods (known to contain short-range endemics) revealed more than 50 taxa. Many types of insects were also collected from this survey but could not be identified to species level at this stage due to poor taxonomic information, time and logistical constraints. Of the invertebrate taxa specifically targeted, 43 spider taxa, three genera of pseudoscorpion, four species of centipede, one millipede species, and two species of scorpion were collected and identified. Work is ongoing on many of these groups and in many cases, more detailed and extensive sampling is needed to provide further information on their natural distributions.

An order level summary of the invertebrate specimens collected from impact and non-impact sites during the study is provided in Table 3-2. A detailed breakdown of all specimens captured during the survey is provided as raw data in Attachment 1 and a list of all species found on Barrow Island has been collated from past field trips and past Museum records in Attachment 3.

Table 3-2 - Summary of Invertebrate Taxa Collected during 2004

Class	Order	No. families	No. genera	No. morphospecies
Arachnida	Acari	3+	4+	7+
Arachnida	Araneae	19	14	43
Arachnida	Pseudoscorpionida	1	3	3
Arachnida	Scorpionida	1	1	2
Myriapoda	Diplopoda	1	1	1
Myriapoda	Chilopoda	3	4	4

The section below represents an annotated list of the various invertebrate taxa collected during the 2003 study and new records for Barrow Island collected during the 2004 survey.

3.2 Acari (Mites/Ticks)

No Acari were collected in the 2003 survey. Three families of Acari could be identified from material collected from wet pitfall traps in 2004. These included Ioxidae, Caeculidae, and Trombiidae. Four specimens could not be placed within a family. Three juveniles were identified as *Amblyomma* but could not be identified. Two specimens of the family Caeculidae were collected from sites TLAC1 (*T. weiseana* on loam, alternate campsite) and LMAC2 (*T. wiseana* on limestone, alternate campsite), see Figure 2.2 in Appendix 1 for further details. A total of 12 specimens of the family Trombiidae were collected from numerous different habitats.

Very little research has been conducted on Acari, particularly mites, limiting identification of a number of groups. Caeculidae and Trombiidae are new family records for Barrow Island. Other species previously recorded from Barrow Island include: *Erythracarus decoris* (Anystidae), *Argas 'persicus'* (Argasidae) *Ornithodoros gurneyi* (Argasidae), *Amblyomma limbatum* (Ixodidae), *Haemaphysalis ratti* (Ixodidae), *Haemolaelaps marsupialis* (Laelapidae), and *Mesolaelaps antipodianus* (Laelapidae).

3.3 Araneae (Spiders)

Thirteen and 19 spider families were collected from the study area in 2003 and 2004, respectively (Table 3-1 and Table 3-2). Most spider families belong within the super family Araneomorphae ('modern spiders'), but one family (Nemesiidae) belongs within the super family Mygalomorphae ('ancient spiders').

3.3.1 Mygalomorph Spiders

Nemesiidae (Trapdoor Spiders)

Seven mygalomorph spider specimens belonging to the family Nemesiidae (Plate 3-1) were excavated from Y-shaped burrows, generally within *Triodia*-dominated habitats (sites BIHT11 – BIHT15) in 2003. Unfortunately, all specimens collected were juveniles and identification beyond family level was not possible. Specimens identified as *Aname mainae-group* have been previously collected from Barrow Island. However, taxonomic revision of this group is needed to determine whether Barrow Island specimens are taxonomically distinct from mainland species.

Systematic searches of the arachnology collection and database at the WAM discovered only one other species of mygalomorph spider, *Synothele butleri,* Raven 1994. This species of the family Barychelidae (brush-footed trapdoor spiders), has been found only on Barrow Island and is known only from one male specimen (T29867) (Attachment 2). The locality on Barrow Island where the specimen was collected is unknown.

Plate 3-1 - Juvenile Trapdoor Spider (Family Nemesiidae) Excavated from Y-shaped Burrow

3.3.2 Araneomorph Spiders (Modern Spiders)

Araneidae (Master Weavers)

One male, five females and one juvenile *Austracantha minax* Thorell 1859 (Christmas Spiders) were recorded from the study area in 2003. These specimens were collected by hand from webs at opportunistic site BIHT01 near Town Point (Attachment 2; Registration number T57725).

This particular species is relatively common and widespread (Figure 3-1) throughout Western Australia, South Australia, Tasmania and Queensland (Raven et al. 2002).

Other species of the family Araneidae that were not collected, but are known from Barrow Island, include *Argiope protensa* and *A. trifasciata* (Attachment 3).

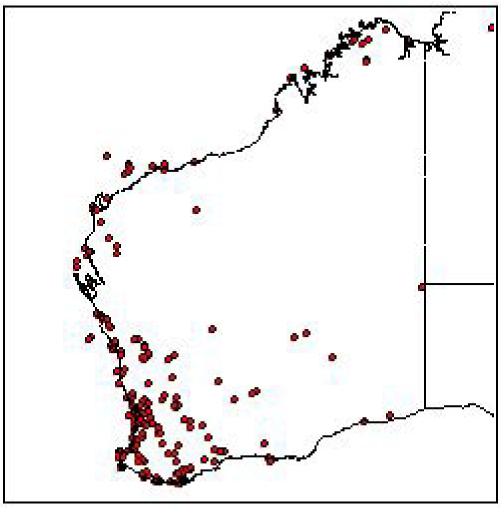

Figure 3-1 - Distribution of *Austracantha minax*

Deinopidae (Net-casting Spiders)

Two adult males of the genus *Deionopis* were collected in 2003 at vertebrate pit trapping sites BIMBO2 and BIMBO6, south-west of the Terminal Tanks in the proposed Development area (Registration numbers T57723, T57724; Attachment 2). A search of the WAM's arachnology database indicated that this species was the first record of *Deionopis* or other genera of Deinopidae from Barrow Island.

Gnaphosidae (Sac Spiders)

One female specimen belonging to the genus *Ceryerda* (T57715) was collected from BITP1, and one female of an unidentified genus (T57716) was collected at BI1.21 from beneath *Triodia* growing along a creek bed near Town Point in 2003.

A total of nine undescribed morpho-species of Gnaphosid spider were collected, mainly from wet pitfall traps, during 2004. Details of localities and habitat descriptions where the different species were collected are shown in Table 3.2 of Attachment 1. Two females differed in a number of characters to all males of this family and are considered to be different morphospecies.

Gnaphosid spiders are very abundant and diverse in the arid zone of Western Australia, so it is not surprising that many morphospecies were collected from this survey. Wet pitfall trapping is the most efficient method of surveying for these spiders. Nothing is known about the potential for this group to contain short-range endemics. More extensive surveying is needed to answer questions about wider distribution patterns and ecology of these species.

Lamponidae (White-tailed Spiders)

One species, *Lamponina scutata* Strand*,* was collected from the proposed development area in 2003. Two adult male specimens (T57721, T57722) were collected from vertebrate pit trapping sites BIMBO1 and BIMBO5 respectively. This species has previously been recorded from Barrow Island and is widespread within Western Australia (Figure 3-2). It also occurs in central and drier parts of Eastern Australia (Platnick 2000).

Three species belonging to the family Lamponidae were collected during the 2004 survey. Two of the species belong within the subfamily Lamponinae and one species within the subfamily Centrothelinae.

Within the Lamponinae, one male *Lampona ampeinna* and one male *Lamponina scutata* were collected in wet pits at sites MLIA1 and MLIA2 respectively (Figure 2.2 Attachment 1). These sites were in areas of *Melaleuca* on limestone within the proposed Development area. *Lampona ampeinna* is widespread in Western and central Australia. This particular species has not been collected from Barrow Island before but is known from Enderby Island in the Dampier Archipelago. *Lamponina scutata* is widespred in Western Australia (Figure 3-2).

A female specimen of *Notsodipus* sp 1 belonging to the subfamily Centrothelinae was collected near Town Point in an area of *T. wiseana* on loamy soil. In general, *Notsodipus* spp. are not an SRE and given the general biology of the group, the Barrow Island species is expected to occur on the mainland. This species is similar to *N.capaensis*, which is only known from the type locality at Cape Range. Although only known from the type locality, it is unlikely that it would be restricted to that area.

Lampona and *Notsodipus* are new genus records and Centrothelinae is a new subfamily record for Barrow Island. Neither have been recorded from Barrow Island previously.

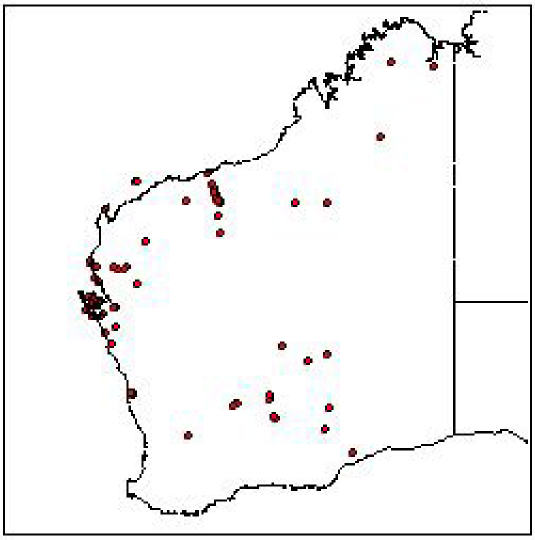

Figure 3-2 - Distribution of *Lamponina scutata*

Lycosidae (Wolf Spiders)

The family Lycosidae is the subject of a detailed taxonomic review by Dr. Volker W. Framenau of the Western Australian Museum. There are currently 145 wolf spider species in 22 genera in Australia (http://www.alphalink.com.au/~framenau/Lycosidae/) with an estimated 300–500 species awaiting description (Dr. Volker Framenau personal communication 2004). As a result, species names could not be allocated to a number of specimens collected from the proposed development area.

Four species of Lycosidae were collected during the 2003 survey, including *Hogna kuyani*-group, *Hoggicosa bicolor*-group, *Lycosa clara*, and *Venator* sp1. Most specimens were collected whilst head torching at night. Sixteen juvenile wolf spiders were collected from BIHT02 –05 and BIHT17 and could not be identified beyond family level.

Five specimens of the *H. kuyanii*-group (one adult male and four adult females; T57692-T57696) were collected from the ground whilst head torching at night (Plate 3-2). These specimens are similar to *H. kuyanii* and may be considered the same species (Dr. Volker Framenau personal communication 2004). The female genitalia (epigynum) of the specimens collected from the study area appear to be very similar to *H. kuyanii*, but colour patterning differs slightly. Variation in colour pattern is quite common within a number of wolf spider taxa, but may also be an artefact of the technique or duration of preservation of the WAM specimens.

Plate 3-2 - Adult Female *Hogna kuyani*-group (T57694)

Two male specimens of the *H. bicolor*-group were collected from site BIHT16 whilst head-torching at night. There are a number of species within the bicolor group which are currently under revision.

One specimen of *L. clara* was collected whilst head-torching at night at site BIMB02 south-west of the Terminal Tanks (T58762). This species is found throughout Australia and occurs across northern Western Australia (Figure 3-3) and also in the Northern Territory, Queensland, and New South Wales.

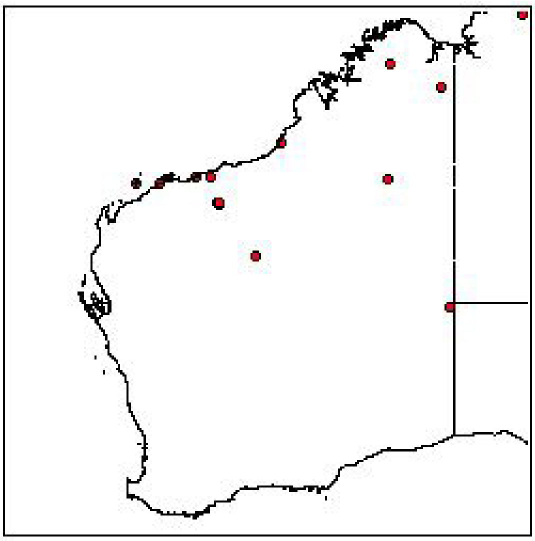

Figure 3-3 - Distribution of *Lycosa clara*

The most abundant wolf spider collected was *Venator* sp1. This particular species was miss-identified as *Lycosa meracula* Simon 1909 by McKay in 1979 and is a junior synonym of *Tetralycosa oraria* L.Koch 1876 (Dr Volker Framenau personal communication.). A total of 61 individuals (41 males, 17 females, and three juveniles) were collected from a number of sites within the proposed development area in 2003 (Attachment 2). Most specimens were collected in areas of *Acacia coriacea* and *Triodia* on pinkish-brown sands, either from vertebrate pitfall traps or whilst head-torching at night. This was the only species of wolf spider to be collected during the 2004 survey and was collected whilst head-torching at night on the beach near the existing ChevronTexaco camp. This species is known to inhabit coastal sandy soils and its habitat generally ranges from the wind-protected slopes of the coastal dunes to the wet sand of the beach (McKay 1979). Based on work undertaken by Dr Volker Framenau, this species of *Venator* is now considered to be a distinct taxon and will shortly be given a new name (Framenau et al., in press). It is known from a few sites in the adjacent Pilbara and Kimberley regions (Figure 3-4).

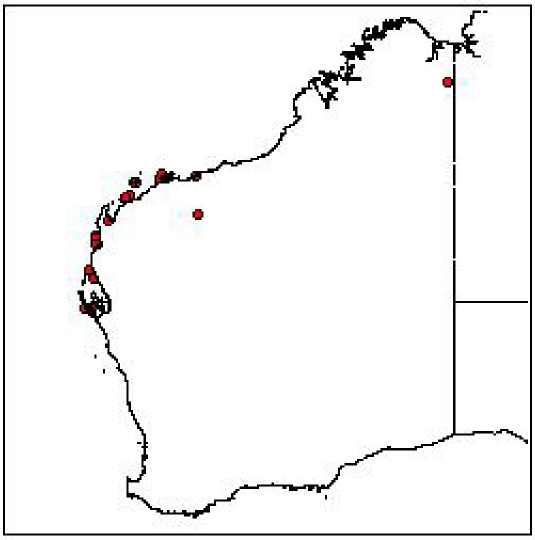

Figure 3-4 - Distribution of *Venator* sp1

Two additional species, *Lycosa laeta* and *Lycosa snelli*, have previously been collected from Barrow Island (Attachment 2). Both species have distributions outside Barrow Island. *L. laeta* is found in the Northern Territory, Queensland, Victoria, and Western Australia. *L. snelli* occurs on the mainland of Western Australia, ranging from the Wheatbelt to the Kimberley (Figure 3-5).

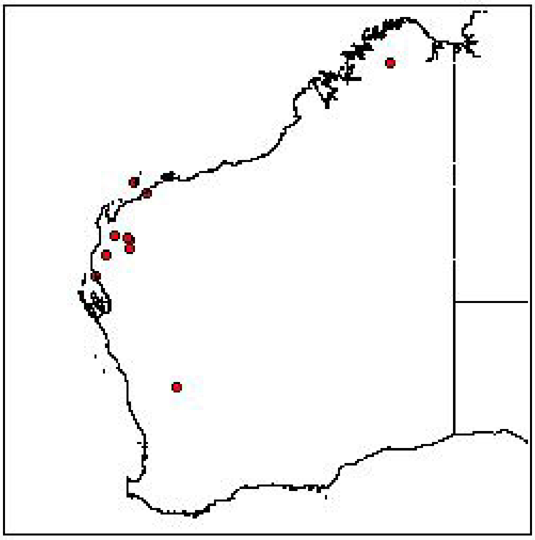

Figure 3-5 - Distribution of *Lycosa snelii.*

Miturgidae (Large Sac Spiders)

Four females, sixteen males, and six juveniles of the family Miturgidae were collected from vertebrate trapping sites BIMBO1- BIMBO6 in 2003. There is currently no comprehensive key available for the identification of species within the family Miturgidae (J. Waldock, WAM, personal communication 2004), and therefore, specimens could not be identified beyond family level. However, through visual assessment of male genitalia (male palp), at least three species of Miturgid spider are represented amongst the material collected from Barrow Island. Robert Raven from the Queensland Museum is currently revising the systematics of this family. The specimens lodged with the WAM will be available for his reviews.

Two described species of Miturgid spider, *Miturga serrata* and *Miturga occidentalis* were collected on previous field trips to Barrow Island. *M. serrata* was collected from Bandicoot Bay and the ChevronTexaco camp and is known only from these two specimens. *M. occidentalis* was collected near the camp. This species is known only from a few specimens but it has been collected from Barrow Island and Exmouth (Figure 3-6).

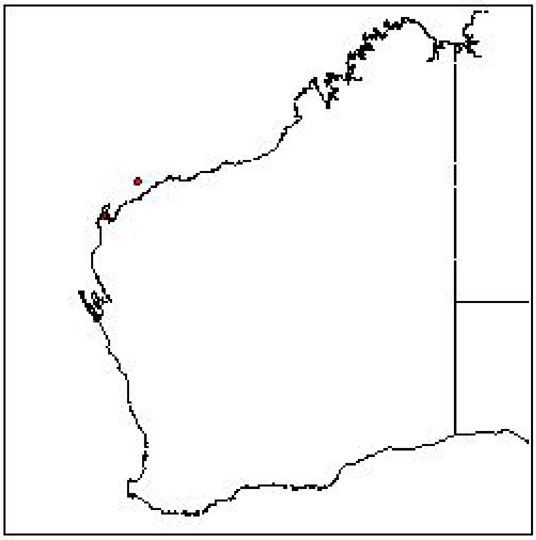

Figure 3-6 - Distribution of *Miturga occidentalis*

Oonopidae

One male and one female belonging to the genus *Opopaea* were collected from under *Triodia* on a creek bed (Site BI1.21, registration T57726) in 2003. The systematics of this spider family is currently being revised by Dr Mark Harvey at the WAM.

Five morphospieces belonging to four genera of Oonopid spider were collected from wet pitfall traps during the 2004 survey. These include *Gamasomorpha, Grymeus, Myrmopopae,* and *Opopaea*. Table 3.3 in Attachment 1 details the number of morphospecies of each genus, their localities and habitat descriptions.

Oonopids can generally only be collected by pitfall trapping. Most of the specimens collected are undescribed species and little can be said about their abundance or distribution on and off Barrow Island until further sampling is completed. It is likely that they are widely distributed on Barrow Island and may occur on the mainland also.

Two species of Oonopid spider have been described recently: *Grymeus 'nasutus'* (Harvey, in press) and *Orchestina 'barrow'* (Harvey, in press). *Grymeus 'nasutus'* has a distribution from Barrow Island to south of Shark Bay (Figure 3-7). *Orchestina 'barrow'* is only known from specimens from the ChevronTexaco camp and from Bandicoot Bay on Barrow Island (Figure 3-8).

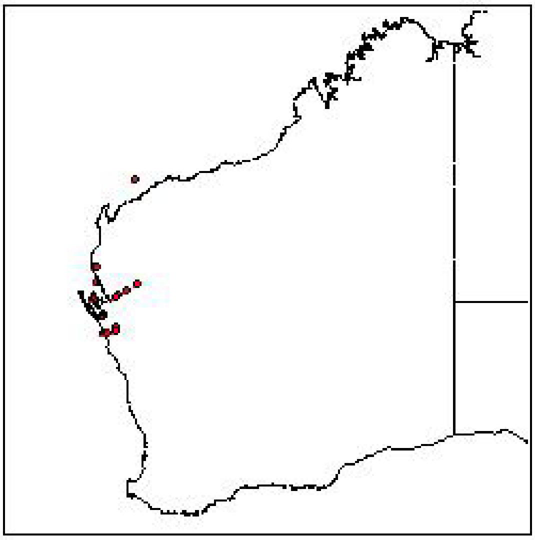

Figure 3-7 - Distribution of *Grymeus 'nasutus'*

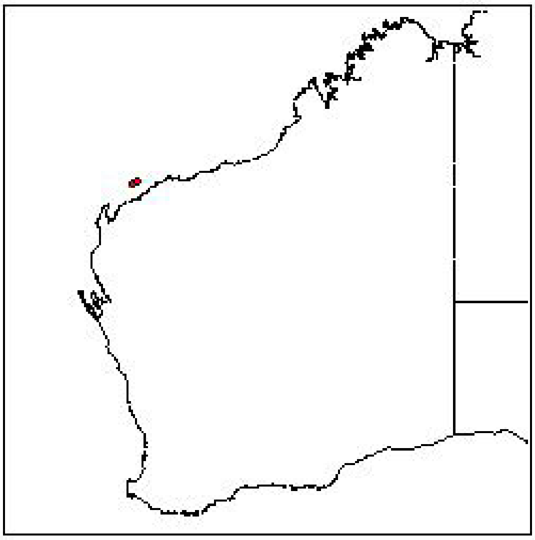

Figure 3-8 - Distribution of *Orchestina 'barrow'*

Salticidae (Jumping Spiders)

Two species of jumping spider belonging to the genus *Lycidas* were sieved from leaf litter collected from beneath *Triodia* in 2003 (Attachment 2). One female specimen of each species, *Lycidas* sp. 1 (T57717) and *Lycidas* sp. 2 (T57718), was collected from vertebrate trapping sites (BI3.11).

Five species from five Satticid genera were collected from Barrow Island during the 2004 survey: *Clynotis albobarbatus*-group, *Grayenulla waldochae*, *Lycidas* sp 1, *Pellenes* sp 1, and *Zenodorus* sp1. Table 3.5 in Attachment 1 shows the specimens of each species collected and provides the site code and site description for each species.

Clynotis albobarbatus-group has also been recorded from Bandicoot Bay on Barrow Island and is widespread on the mainland (Figure 3-9). Specimens of *Grayenulla waldochae* have only been collected from a limited number of sites. The genus is relatively common and widespread, but this species is only known from few specimens (Woodstock Station, Newman). It has not been previously collected from Barrow Island.

Undescribed species of *Lycidas* were collected from Barrow Island during the 2003 survey. The distribution of these morphospecies outside Barrow Island is unknown. However, it is unlikely that this genus would contain SRE's given the biology of the group.

Two genera, *Pellenes* sp. 1 and *Zenodorus* sp. 1 have not been recorded from Barrow Island previously, making them new genus records for the island. Other genera known from Barrow Island include *Jotus* (Bandicoot Bay), *Cytaea* (ChevronTexaco base), and *Holoplatys* (Cave B2).

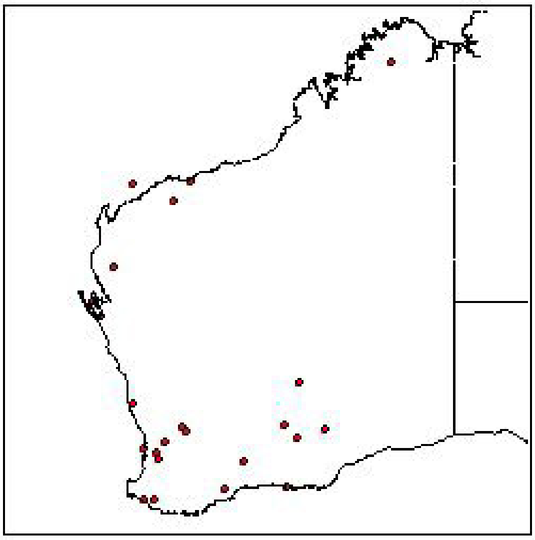

Figure 3-9 - Distribution of *Clynotis albobarbatus*-group

Sparassidae (Huntsman spiders)

Three species of huntsman spider, *Heteropoda hermitis* (Plate 3-3), *Neosparassus* sp. 1 and *Neosparassus* sp. 2, were collected from the proposed development area in 2003. One individual was a juvenile and could not be identified to genus or species level.

Plate 3-3 - *Heteropoda hermitis* (T57699)

Four specimens (three males and one female; T57699 – T57702) of *Heteropoda hermitis* Hogg were hand collected from the ground or rock wall whilst head torching at night (sites BIHT01 and BIHT04). This species is known from the Montebello Islands, Barrow Island, Lowendal Island, and Woodstock Station, Western Australia (Davies, 1993 Figure 3-10).

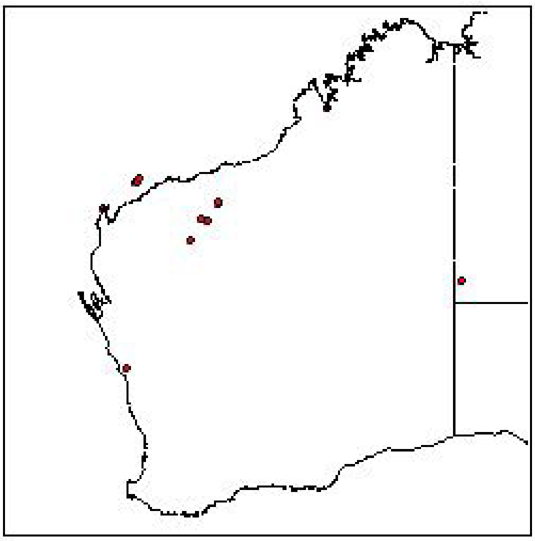

Figure 3-10 - Distribution of *Heteropoda hermitis*

Two distinct species of *Neosparassus* were collected from the proposed development area. As there is currently no identification key for this particular genus, species names could not be assigned but have been nominally referred to as sp. 1 and sp. 2. Two adult male *Neosparassus* sp. 1 were collected from beneath *Triodia* (sites BIHT02, BI3.5). A single *Neosparassus* sp. 1 was hand collected from *T. wiseana* on limestone at night whilst head-torching (site LMAD1) in 2004 (Attachment 1). One male and one female *Neosparassus* sp. 2 were collected from *A. coriacea* and beneath *Triodia* over pinkish-brown sands in 2003 (sites BIMBO4 and BIHT01).

Irileka iridescens (Hirst 1998) is another species of Sparassidae known from Barrow Island but not collected in the 2003 or 2004 survey. *Irileka iridescens* was collected on a previous field trip from Bandicoot Bay and lodged with the WAM. Huntsman spiders are currently under revision by David Hirst from the South Australian Museum, with many Australian species yet to be described.

Theridiidae (Comb-footed Spiders)

One male specimen (T57728) belonging to the genus *Euryopis* was collected from beneath *Triodia* along a creek bed (Site BI1.21). A female specimen (T57729) belonging to the family Theridiidae was damaged and could not be identified beyond family level.

The arachnology database has records of two described species of Theridiid spider from Barrow Island: the red-back spider, *Latrodectus hasseltii* and *Argyrodes* 'antipodiana-group'. The red-back spider has a widespread distribution covering much of Western Australia (Figure 3-11) whereas *Argyrodes* 'antipodiana-group' is only known from Barrow Island and the Montebello Islands (Figure 3-12).

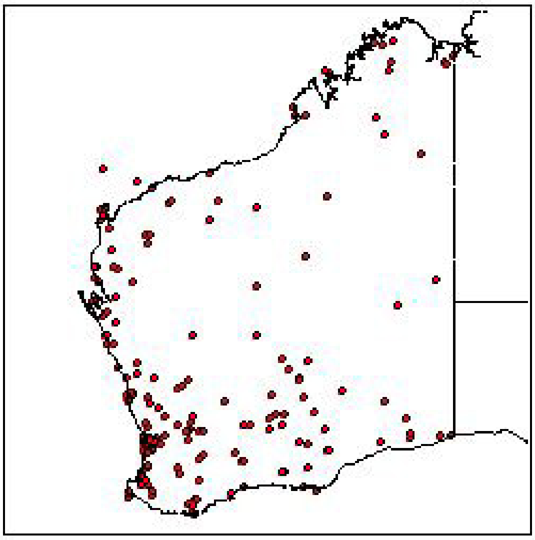

Figure 3-11 - Distribution of the Red back spider, *Latrodectus hasseltii*

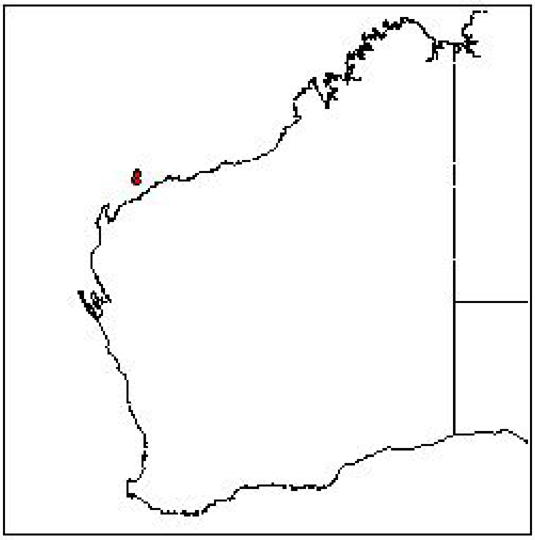

Figure 3-12 - Distribution of *Argyrodes* 'antipodiana – group', Known from Barrow Island and Montebello Islands

Thomisidae (Crab Spiders)

Two spider genera of the family Thomisidae were collected in 2003. Two adult male *Tharpyna* (T57720) were collected from under *Triodia* along a creek bed (Site BI1.21) and one female *Stephanopis* (T57719) was collected from under *Triodia* over pale red sand (Site BI3.1).

Three female *Stephanopis* sp 1 were hand collected from leaf litter under *T. wiseana* on limestone (site LMIA2) and one male *Tharpyn*a sp 1 was collected from a wet pitfall trap amongst *T. angusta* (site AVIA1).

Zodariidae

An unknown species of the family Zodariidae was collected from beneath *Melaleuca* (Site BIIT4) during the 2003 survey. The specimen was an adult female (T57727). Similarly, a single female specimen was collected under *Melaleuca* on limestone (site MLNI2) in 2004. This species has not been described and could not be identified to genus or species level.

A search of the WAM arachnology collection and database has shown that two described species of Zodariid spider occur on Barrow Island: *Minasteron minusculum* Baehr and Jocque 2000 and *Spinasteron 'harveyi'* Baehr (in press). *M. miniscolum* occurs on the mainland of Western Australia as well as Barrow Island (Figure 3-13), but *S. 'harveyi'* is known only from Barrow Island.

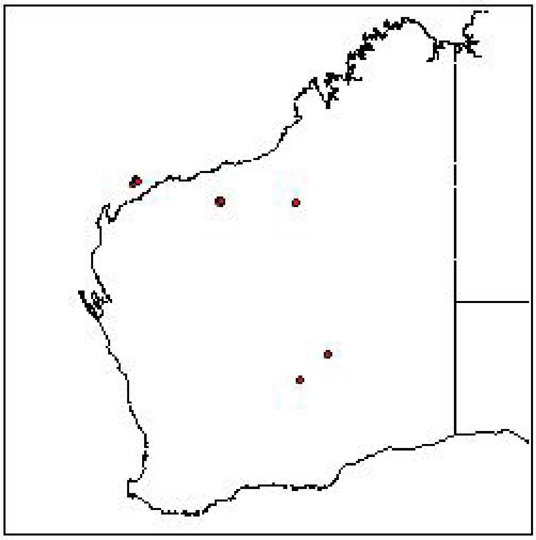

Figure 3-13 - Distribution of *Minasteron minusculum*

Corrinidae

Two adult male and one female *Supunna picta* (c.f) were collected from *T. angusta* valleys (sites AVAC1, AVAC2, AVNI2) using wet pitfall traps in 2004. This is a new record for Barrow Island. *Supunna picta* (c.f) is very common and has a widespread distribution on the Western Australian mainland.

Filistatidae

Four adult male specimens of *Wandella* sp 1 were collected from a range of different habitat types in 2004: *T. angusta* valleys (AVAC2), *T. wiseana* on limestone (LMNI1), *Melaleuca* on limestone (MLNI1), and *T. wiseana* on sandy loam soils (TLTP1) (Attachment 1). Three specimens were collected from wet pitfall traps and one specimen was sieved from leaf litter.

These specimens are different but quite similar to the described species *Wandella waldockae* Gray, which has not been collected from Barrow Island before. Other specimens from this family have been recorded from Shark Point, west of the ChevronTexaco warehouse and at Bandicoot Bay on Barrow Island, but have not been identified to a higher level.

Oxyopidae (Lynx Spiders)

Two morphospecies of Lynx spiders were collected in wet pitfall traps at sites QUCA and QUOA in 2004. No described species of Oxyopidae could be identified amongst the Barrow Island collection, but one genus, *Oxyopes* has been recorded previously. The WAM collection of lynx spiders is currently on loan overseas so no material could be databased for Barrow Island. These spiders are not generally ground dwellers, preferring to inhabit vegetation and would be better sampled by sweep-netting vegetation.

Pholcidae (Daddy long-legs)

Two native species of *Trichocyclus* were collected from wet pitfall traps in 2004. *Trichocyclus* sp. 1, a new, undescribed species, was found at the ChevronTexaco camp (site QUCA). *Trichocyclus nigropunctatus* was collected from an area dominated by *T. weiseana* on loamy soil (site TLAC1). *Trichocyclus nigropunctatus* has been recorded from Barrow in the past. Two other Pholcid spiders, *Crossopriza lyoni* and *Trichocyclus aranda,* are known from Barrow Island.

Prodidomidae

Two species of Prodidomid spiders belonging within the subfamily Molycriinae were collected during the 2004 survey from wet pitfall traps. A total of 12 individuals were collected. See table 3.4 in Attachment 1 for an outline of the localities where they were collected.

Two species have already been described for Barrow Island. *Prodidomus 'woodleigh'* has been collected from the ChevronTexaco camp on Barrow Island, and is known from the mainland. *'Wydundra' 'barrow'* was collected from Shark Point and is only known from Barrow Island.

Selenopidae

Two undescribed morphospecies of Selenopidae were collected from Barrow Island in 2004. One female Selenopid sp.1 was hand collected from under rocks amongst *Melaleuca* on limestone (site MLNI2) and two male specimens of Selenopid sp. 2 were collected from wet pitfall traps amongst *T. wiseana* on limestone (site LMNI1)). These morphospecies could not be identified to genus or species level. No other specimens of this family have been collected from Barrow Island in the past.

Tetragnathidae

One male spider of the family Tetragnathidae, subfamily Metinae, was collected from wet pitfall traps amongst *T. wiseana* on loamy soil (site TLAC1) in 2004. This species is undescribed and could not be identified beyond subfamily level. *Nephila edulis* and the genus *Tetragnatha* are known from Barrow Island and are recorded in the WAM arachnology database.

3.4 Pseudoscorpionida (Pseudoscorpions)

3.4.1 Garypidae

One specimen of a new species of *Synsphyronus* sp. nov. '*Barrow*' (Plate 3-4) was sieved from leaf litter beneath *Triodia* on limestone, west of Town Point (T57749, site BI1.41) in 2003. No specimens had been collected from the mainland or Barrow Island previously (M. Harvey personal communication 2004). This species has the potential to be a SRE, as many other species of this genus are restricted to small areas. A taxonomic description of this new species by Dr Mark Harvey at the WAM is currently in progress.

Plate 3-4 - Magnified image of *Synsphyronus* sp. nov. '*Barrow'*

Another Garypid pseudoscorpion (*Anagarypus heatwolei)* is also endemic to Barrow Island. It is found in more coastal areas on Barrow Island such as Bogg's Beach and Cape Malouet (Attachment 3).

3.4.2 Olpiidae

One species of *Austrohorus* and two species of *Xenolpium* were recorded from the proposed Development area in 2003. A number of specimens of this family were nymphs that could not be identified further.

Four specimens of *Austrohorus* (T57745 – T57748) were collected from beneath limestone (sites BITP2, BIHT-06, 07 and 09). Species of this genus are currently undescribed and the genus needs revision.

Six specimens of *Xenolpium* sp. 1 (Plate 3-5) were collected from beneath limestone (T57740 - T57742 from sites BIHT07 and BIHT08). Two specimens of *Xenolpium* sp. 2 (one male, one female) were collected from under *Triodia* on pale pink dunes and beneath limestone (T57743 & T57744 from sites BIHT-06 & BIIT-8).

In 2004, three genera of Olpiid pseudoscorpions, were collected from Barrow Island. These include *Indolpium*, *Xenolpium*, and Genus 1.

Six specimens of *Indolpium* sp 1 were found in a number of sites within the proposed Development area and at other sites. Two specimens were collected from wet pitfall traps and four were sieved from leaf litter. A total of 32 specimens of *Xenolpium* sp 1 were collected from leaf litter within the proposed Development area and other sites. This species was found at a number of different localities on the Island and within a number of different habitat types. One male specimen of an unknown genus was sieved from leaf litter collected at amongst *T. weiseana* on limestone (site LMAC2).

No specimens of *Synsphyronus* sp nov. \`barrow\`, or *Anagarypus heatwolei* were collected in the 2004 survey. *Synsphryronus* sp nov. \`barrow\` has only been collected from one site on Barrow Island within the project area. It is only known from one specimen and has the potential to be a short range endemic. There is insufficient information to determine the potential distribution of this species outside the project area, but it is unlikely that it would be restricted to the Development area.

Plate 3-5 – *Xenolpium* sp.

3.5 Scorpionida (Scorpions)

3.5.1 Buthidae

Six specimens of *Isometroides* were collected from beneath *Triodia* in 2003 (Attachment 2). The specimens are probably *Isometroides multipunctata* which has been previously recorded from Barrow Island and the adjacent mainland (Figure 3-14). The specimens collected during the current study have a slightly different colour pattern to preserved specimens of *I. multipunctata* in the WAM collections, possibly due to differing stages of development.

Two species of *Archisometrus* were collected during the 2004 survey, the first from a wet pitfall trap amongst *Melaleuca* on limestone (site MLNI1) and similar habitat at the barge-landing site (site QUBL1) and the other from leaf litter at Whites Beach amongst *T. wiseana* on limestone (site LMIA2) and amongst *T. wiseana* on loamy soil (site TLTP1) (Attachment 1). It is unknown whether these species have the potential to be SRE's. A taxonomic revision of this group is currently being completed.

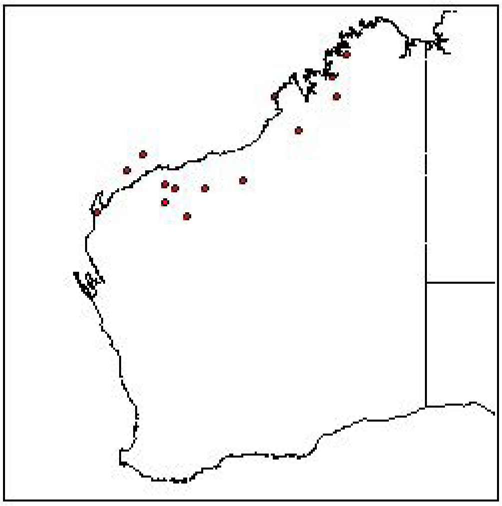

Figure 3-14 - Distribution of *Isometroides multipunctata*

3.5.2 Urodacidae

A single specimen of a large, dark scorpion belonging to the genus *Urodacus* was collected from the proposed development area whilst head-torching in an area dominated by *Triodia* over loamy soils in 2003. The specimen is different to any described species and is considered to represent a new, undescribed species (M. Harvey personal communication 2004). The only other specimen of this species was collected by W.H. Butler but no specific Barrow Island locality was recorded. However, unconfirmed sightings of large, black scorpions around the ChevronTexaco base from night-shift operators suggest that this species may occur outside the proposed Development area. No specimens of *Urodacus* sp. nov. *`barrow`* were collected on the 2004 survey.

3.6 Myriapoda (Centipedes and Millipedes)

3.6.1 Scutigeridae (House Centipedes)

During 2003, one species of Scutigerid centipede, *Allothereua leuseuri* was collected from two sites in the proposed Development area (BIMBO2 & BIMBO4). This species is widespread throughout Western Australia (Figure 3-15).

Two specimens of *Allothereua* were collected from leaf litter at sites TLNI2 (*T. wiseana* on loamy soil) and LMIA2 (*T. wiseana* on limestone, impact area) in 2004. As the individuals were juveniles, they could not be identified to species.

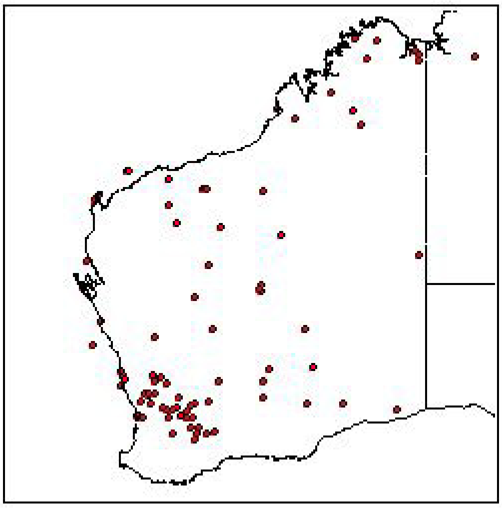

Figure 3-15 - Distribution of *Allothereua leuseuri*

3.6.2 Scolopendridae (Centipedes)

Two species of Scolopendrid centipede, *Ethmostigmus curtipes* and *Scolopendra laeta* were recorded from the proposed Development area.

Two specimens of *E. curtipes* were collected from dry pit-traps (Sites BIMB-O4, BIMB-05). This species has a wide distribution and is known to occur from central Western Australia at Robe River, between Roy Hill and Nullagine to the Eastern Goldfields (Koch 1983; Figure 3-16).

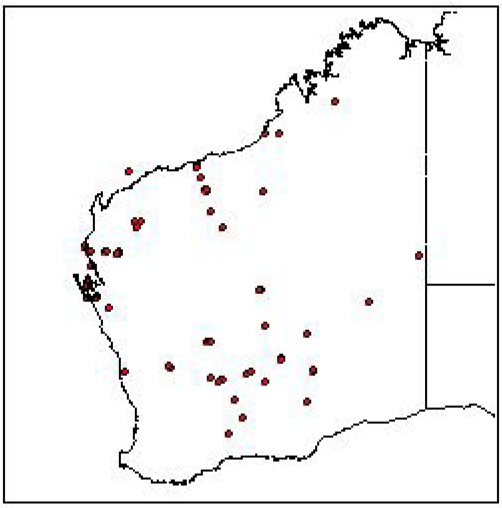

Figure 3-16 - Distribution of *Ethmostigmus curtipes*

Four specimens of *S. laeta* were collected from dry pit-traps and by opportunistic collecting (sites BIMBO1- 03, BIAP3). *Scolopendra laeta* is widely distributed over Australia, but is absent from north-east Queensland and Tasmania (Koch 1982; Figure 3-17).

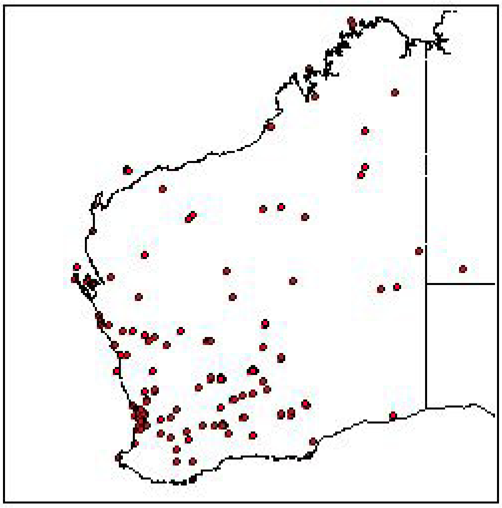

Figure 3-17 - Distribution of *Scolopendra laeta*

Three other species of Scolopendrid centipede have been collected from Barrow Island. These species are: *Scolopendra morsitans, Arthrorhabdus mjobergi* and *Cormocephalus strigosus* (Attachment 1). All three species have broad distributions outside of Barrow Island (Figure 3-18, Figure 3-19 and Figure 3-20).

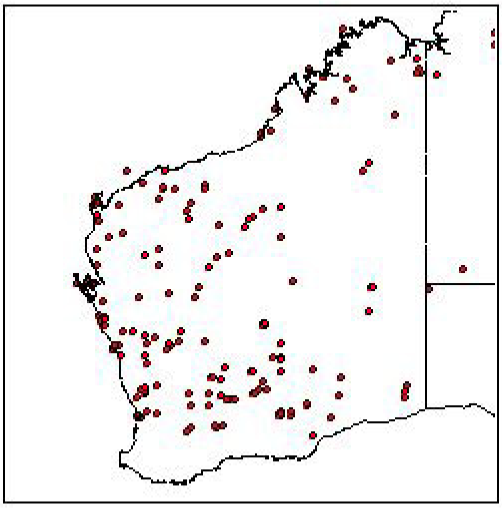

Figure 3-18 - Distribution of *Scolopendra morsitans*

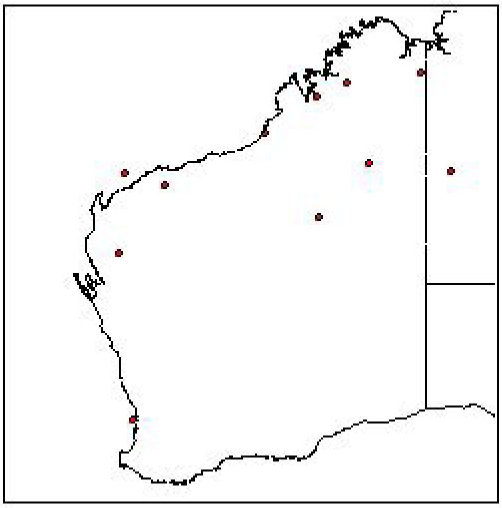

Figure 3-19 - Distribution of *Arthrorhabdus mjobergi*

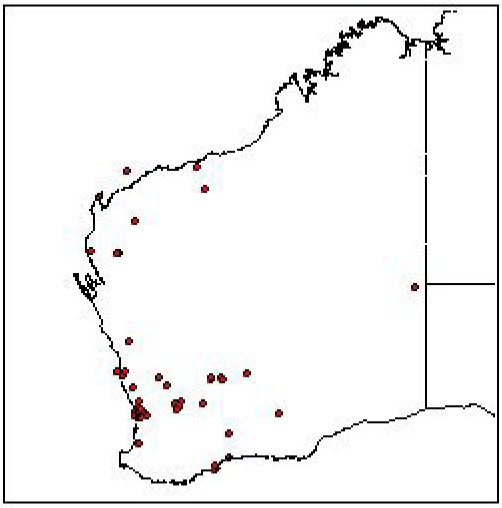

Figure 3-20 - Distribution of *Cormocephalus strigosus*

3.6.3 Geophilida

One unknown genus of centipede belonging to the order Geophilida was collected from leaf litter amongst *Melaleuca* on limestone (site MLNI1) in 2004. As no taxonomic key is available, further identification was not possible

3.6.4 Synxenidae (Pin cushion Millipedes)

One pin cushion millipede specimen was collected from the proposed Development area from leaf litter beneath *Triodia* (Site BI3.7) in 2003. This juvenile specimen probably belongs to the genus *Unixenis* but could not be identified to species.

A further 14 pin cushion millipedes belonging to the family Synxenidae were collected from wet pitfall traps at a number of sites within and outside the Development areas in 2004. Unfortunately further identification was not possible. These millipedes have been known to occur in plague proportions under certain conditions.

3.7 Pulmonata (Land Snails)

3.7.1 Camaenidae

Identification based on shell morphology indicated that there were two distinct species of *Rhagada* collected from the proposed development area in 2003. A total of 96 specimens of *Rhagada* sp. 1 and 53 specimens of *Rhagada* sp. 2 were collected (Attachment 2). Most specimens were hand-collected from beneath *Triodia* on pale red sand, red loamy sand or pale brown sand. A number of live specimens of each species were collected for genetic analysis.

Electrophoretic genetic analysis on *Rhagada* sp. 2 from a wide range of sites across Barrow Island indicated a low level of genetic divergence in this taxon (Attachment 4). This indicates that this species has not formed isolated genetic 'races' on the island and that snails in the development areas are genetically similar to snails in other parts of the island.

Quistrachia barrowensis was also collected from the proposed development area. A total of 85 specimens were collected from leaf litter under *Triodia* over pale red sand, under rocks on limestone ridge and rocky headlands, and under *Triodia* near cliff face (Attachment 2). A number of live specimens were kept for genetic analysis. The same camaenid taxa were also collected from several sites on Barrow Island by Slack-Smith (2002).

3.7.2 Pupillidae

Shells of Pupillid snails were collected from leaf litter under *Triodia* and under rocks (Attachment 2). As no live specimens were collected, further identification was limited. A total of 162 pupillid shells were collected, with species identified to date including the sinistrally coiling species *Pupoides contrarius* Smith, 1984 and the dextrally coiling species *Pupoides beltianus* Tate, 1894. Both of these species have been previously recorded from Barrow Island and other parts of the Western Australian mainland coast (Slack-Smith 2002).

3.8 Insecta (Insects)

Insects were identified to order or family level where possible. A summary of the insect orders and families collected is provided in Table 3-3.

Table 3-3 - Summary of Insect Taxa Recorded During the Survey

Order	Family	Common name
Thysanura	Lepismatidae	Silverfish
Blattodea	Blattidae	Cockroaches
Isoptera		Termites
Mantodea	Mantidae	Praying Mantids
Orthoptera	Acrididae	Grasshoppers
Hemiptera	Reduviidae	Assassin bugs
Coleoptera	Carabidae	Ground beetles
Diptera		Flies
Hymenoptera	Formicidae	Ants
Neuroptera	Myrmeleontidae	Ant Lions

A summary of the morphospecies of different insect orders and families collected during the 2004 survey is provided in Table 3.7 of Attachment 1.

Given that it is unlikely that the insect groups represented contain any SREs, they will not form a focus for currently ongoing identification work. They may, however, include some of the more significant focal groups for quarantine base line studies and the specimens have been retained for future analysis.

4 Discussion

Invertebrate taxa collected during the 2003 survey comprised 22 spider taxa, four species of pseudoscorpion, three species of centipede, one millipede species, two species of scorpion and five species of land snail.

Of the taxa recorded, those with the highest conservation significance were:

- The seven mygalomorph (trapdoor) spiders collected from *Triodia* habitats at five sites (see Section 3.2). Mygalomorph spiders are widespread on Barrow Island. This group contains known SREs, particularly in the Wheatbelt and other parts of the south-west of the state. The specimens from this study were too immature for identification, but further sampling could result in the collection of adult animals.
- The pseudoscorpions *Synsphronus* sp. nov. '*barrow', Angarypus heatwolei, Austrohorus* sp. 1*, Xenolpium* sp. 1 and *Xenolpium* sp. 2. The first species has not been recorded elsewhere on Barrow Island or the mainland, and is known only from one specimen collected from the proposed Development area (Section 3.4). This species could potentially be a SRE, with a highly-restricted distribution. *Angarypus heatwolei* is known only from Barrow Island, but has been collected from a number of localities across the Island. The other species are unlikely to be restricted to the Development area.
- The scorpion *Urodacus* sp nov. '*barrow'*. This species is known only from two specimens collected from Barrow Island and appears to be a new species (see Section 3.5). One specimen was collected within the proposed Development area and the other in the WAM collection came from an unknown locality. As so few specimens have been collected, it is unclear if the distribution of this species is restricted to a certain area.
- The land snails *Rhagada* sp. 1 and sp. 2, *Quistrachia barrowensis, Pupoides contrarius* and *P. beltianus* (Section 3.7). With poor dispersal powers, this group includes known SREs (Slack-Smith 2002). However, the genetic study has shown that *Rhagada* sp. 2 is not genetically fragmented on Barrow Island. *Rhagada* sp. 2 populations in the proposed Development area interbreed, at least periodically, with snails across the whole Island.

Some of the above taxa are likely to be SREs (distributions of less than 10 000 km^2 after Harvey 2002). In some cases, however, this is likely to amount to a distribution equating to Barrow Island. A number of endemic species, including *Quistrachia barrowensis* and *Angarypus heatwolei,* are known from several locations across the Island but have not been found on the mainland or nearby islands.

Terrestrial invertebrate sampling on Barrow Island in 2004 revealed more that 60 taxa of Arachnids and myriapods. In total, 43 spider taxa, over 7 morphospecies of mites/ticks, three species of pseudoscorpion, two species of scorpion, one species of millipede, and four species of centipede were collected.

No described species collected during this latter survey is known to be a Short-Range Endemic (SRE). Currently, there are nine species of Arachnid and one species of millipede that are considered endemic to Barrow Island. Many of these species are only known from one locality, so little is known about the distribution range of these species within Barrow Island. As more taxonomic work is undertaken, many more endemic species are expected to be discovered from material lodged with the WAM.

Groups of arachnids that have the potential to contain short-range endemics include Mygalomorph spiders, Oonopidae, Gnaphosidae, Prodidomidae, Miturgidae, Garypidae (and other pseudoscorpions), Buthidae and *Urodacus*. Some species within these groups have only been collected from Barrow Island. Many of these groups have been poorly collected in the state or are in need of taxonomic revision.

The pseudoscorpion *Synsphyronus* sp. nov. *'barrow'* is known only from the Town Point area. This species is potentially an SRE, with a highly restricted distribution. No further specimens of this species were collected from the 2004 survey, even though this group was targeted and a total of 39 pseudoscorpions were collected. Of the other pseudoscorpions, *Indolpium* sp. 1 and *Xenolpium* sp. 1 are considered to be common species also found on the mainland while the status of the specimen belonging within the unknown genus is uncertain.

The scorpion *Urodacus* sp. nov. *'barrow'* is only known from two specimens collected from Barrow Island. One specimen was collected within the impact area and the other came from an unknown locality on the Island. This species is likely to occur at low densities in similar habitats outside the proposed Development area. However, more sampling is needed to understand how restricted its distribution is, if restricted at all.

The status of Mygalomorph spiders on Barrow remains poorly understood, due to the lack of adult specimens and the need for further taxonomic work on some genera. One species known to be endemic to Barrow Island is the brush-footed trapdoor spider *Synothele butleri*, which is only known from one male specimen collected from an unknown locality on Barrow. Another species of the *Aname mainae* – group, has been collected from the island, but a taxonomic revision of this group is needed to determine whether specimens from Barrow Island are taxonomically distinct from the mainland specimens.

A longer term, widespread invertebrate survey on Barrow Island is needed to collect adult specimens of taxa that mature, or are active, at different times of the year. A minimum of 12 months is recommended for wet pitfall trapping, with the traps cleared every 3 to 4 months.

A review and comparative analysis of the existing collections of the Western Australian Museum aimed to address the status of invertebrates collected from Barrow Island and provide a greater understanding of their distributions. It involved comparisons of the specimens collected from the proposed development area with those already contained within the Western Australian Museum collections. The systematic search and review of the arachnology collection and database revealed a number of unique taxa (11 species) that are known only from Barrow Island (Attachment 3). A number of these species are known only from one specimen (Holotype), and for some, a specific locality on Barrow Island had not been recorded. Many Western Australian invertebrates are poorly known at high taxonomic levels. The specimens from the 2003 and 2004 surveys, lodged with the WAM, will provide a valuable resource for ongoing taxonomic revision of many invertebrate groups.

None of the invertebrate taxa known from the proposed development area are listed as Schedule or Priority fauna by the Department of Conservation and Land Management, or listed as threatened under the EPBC Act.

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Attachment 1 - Barrow Island Short Range Endemics and Other Terrestrial Invertebrates (Biota Invertebrate Survey April 2005 Report)

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Barrow Island Short Range Endemics and Other Terrestrial Invertebrates

RPS Bowman Bishaw Gorham | The Gorgon Venture

Invertebrate Fauna Survey

April 2005

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Barrow Island SREs and Terrestrial Invertebrates

Contents

Figures

1.0 Introduction

1.1 Project Background and Current Status

The Gorgon Venture (a joint venture between ChevronTexaco, Shell and ExxonMobil), is in the process of seeking approval to develop the Gorgon gas fields located some 130 km off the north-west coast of Western Australia. The Gorgon field is the largest gas field ever discovered in Australia and together with the other fields in the area represents an estimated 40 trillion cubic feet of resource. Investigations and project design work are currently underway for the development of gas processing facilities on Barrow Island off the north-west coast of Western Australia.

The island has been an active onshore oilfield since 1967 and was also gazetted as a Class A Nature Reserve in 1910. The proposal has already passed through an Environmental, Social and Economic Review (the ESE Review) under the provisions of the *Environmental Protection Act 1986*. This addressed the Gorgon Gas development's general ability to mitigate potential on-site impacts and generate social and economic benefits for the region, state and the nation. The outcome of this process was that the State Government determined that the proposal could proceed to a more detailed level of formal environmental assessment. The project is currently subject to this more detailed definition and environmental investigation under the *Environmental Protection Act 1986* at the level of an Environmental Review and Management Programme (ERMP). Consideration of the project implications for the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the *EPBC Act*) are also being evaluated.

This report on terrestrial invertebrates and potential short-range endemics (SREs) represents a supporting technical document, providing input to the ERMP on this ecological factor.

1.2 Overview of Issues Relating to Terrestrial Invertebrates

Terrestrial invertebrates are of interest in the current formal assessment process for several reasons (see also EPA 2003 and Biota 2004). These are outlined below.

- There is potential for some groups of terrestrial invertebrates to contain species that are short-range endemics (SREs). This issue can be of great consequence, especially when considering the conservation of biodiversity (see Biota 2004 & Harvey 2002 for detailed overview of issues). As a result, the assessment of such invertebrate taxa is a potentially important component of impact assessment.
- The terrestrial invertebrate fauna of Barrow Island is still poorly documented and only a small proportion has been described. The potential for currently undescribed fauna to be collected is still relatively high. Very little is known about wider distributions of certain taxa, and many taxa may be of conservation significance or taxonomic interest.
- Quarantine issues are becoming increasingly important. Documentation of terrestrial invertebrates occurring on Barrow Island for a quarantine monitoring program is essential in addressing these issues.

1.3 Previous Surveys

Terrestrial invertebrates on Barrow Island have generally been poorly documented in the past. Most surveys have been primarily focused on particular groups of invertebrates and do not provide a detailed baseline inventory of the terrestrial invertebrate assemblages on Barrow Island.

The Arachnology department collected a number of specimens in 1993 in conjunction with a Verterbrate fauna survey for WAPET. This trip was not a specific survey for the company, but enabled the department to collect a number of unique taxa for the museum collections. Coastal localities were chosen to look specifically for a particular species of pseudoscorpion (*Anagarypus heatwolei*), which was of taxonomic significance at the time.

A preliminary survey of Land snails on Barrow Island was undertaken in 2002 by Shirley Slack-Smith, and represents the first survey of non-marine molluscs on any part of Barrow Island. The objective of the survey was to assess areas that may have been impacted by the land-based components of the proposed Gorgon Development on Barrow Island, and equivalent areas adjacent to the impact zone (Slack-Smith, 2002).

A recent survey of the terrestrial invertebrates of Barrow Island (Biota 2004) aimed to provide preliminary assessment of potential SRE's and other terrestrial invertebrates that may be adversely affected by the development. In addition to this, a search of the Department of Arachnology's collection and database was undertaken to locate species or "types" that were known to occur on Barrow Island. Two undescribed species were identified as potential SRE's and were considered endemic to the island. These species were *Synsphyronus* sp. nov. 'barrow' and *Urodacus* sp. nov. 'barrow'. Both specimens were found within the project area and are only known from a single locality. As a result, insufficient information was available to determine how restricted their distributions were.

1.4 Objectives of this report

The objective of this report is to provide further assessment of potential short-range endemics (SREs) and other terrestrial invertebrates that may occur within the project area and proposed alternative campsites on Barrow Island. Sampling for invertebrates was focused within the impact zones and equivalent areas adjacent to the project area and alternative campsites. Sites were chosen to maximise the number of habitat types surveyed. This report will also provide regional context for the species collected within the impact area and to provide a baseline species list to aid future quarantine programmes.

2.0 Methodology

2.1 Field Collection

A combination of wet pitfall trapping, leaf litter collection and opportunistic collection methods were used to sample terrestrial invertebrate taxa within the project area, proposed alternative campsites, and areas of non impact. Particular invertebrate groups that have the potential to exhibit SREs were targeted during the survey. These include:

- Araneae (Spiders);
- Pseudoscorpionida (Pseudoscorpions);
- Scorpionida (Scorpions);
- Diplopoda (Millipedes)

Wet pitfall traps

The wet pitfall traps that were used in the survey consisted of a 2 litre ice-cream container filled with ethylene glycol to a depth of 2cm. A lid (with an 82mm diameter hole) was then placed on the trap to reduce the potential by-catch of vertebrates. Four of these traps were placed flush with the ground at each trapping site. Traps were placed, if possible, in shaded microhabitats such as beneath Spinifex or shrubs. Traps were open for six nights and the collected material from the four traps were pooled for each site. Material was rinsed from the traps using water and placed in jars which were labelled for each site and stored for processing.

Leaf litter samples

A selection of sites were chosen for collection of leaf litter samples. Two full bags of leaf litter and soil were collected from areas beneath large Spinifex bushes and melaleuca trees. Bags were labelled and later sieved and examined for invertebrates.

Hand foraging

Hand foraging was conducted at each leaf litter site for one hour. Foraging included lifting rocks for pseudoscorpions and foraging through raked leaf litter and under Spinifex. Planned head torching and black-lighting at night for wolf spiders, huntsman spiders and scorpions was not successful due to the presence of a full moon at the time of the field survey. The moon is said to have an effect on the activity of certain invertebrate taxa. However, some specimens were collected via head-torching.

2.2 Survey sites

Thirty survey sites were established for systematic wet pitfall trapping over six days from the 25th August to the 1st September 2004. A selection of these sites were chosen for leaf litter sampling and hand foraging. In total, there were 30 wet pitfall sites, 22 leaf litter sites, and 21 foraging sites. Photos of the trapping sites were shown in Appendix 1, and a list of the site codes, localities, and type of collection method used is provided in Table #.

Sites were chosen within the impact areas [(IA), including town point (TP)], proposed alternative campsites [(AC), including proposed administration block (AD)], and non-impact areas (NI). In each of these three categories, a number of replicated sites of four different vegetation associations were chosen for systematic invertebrate collections. These were *Triodia angusta* valleys (AV), *Triodia weiseana* on loamy soil (TL), *Triodia weiseana* on limestone (LM), and *Melaleuca* on limestone (ML). Six quarantine sites were also chosen in areas which are disturbed or have the potential to possess introduced species, such as the Barge landing and the Warehouse.

2.3 Curation and Limits on Identification

Invertebrate material which was collected via wet pitfalls was stored in ethyene glycol until it was transported to the WAM for processing and sorting. Material was first rinsed with water, then sieved out of the glycol and rinsed again. Specimens were then placed in jar of 70% ethanol to be sorted and identified.

Leaf litter samples were collected and stored in plastic bags. Each sample was sieved and examined for live invertebrates. All invertebrate material collected was immediately stored in 70% ethanol. All other material collected via foraging was placed in 70% ethanol. All material will be lodged with the WAM at the end of the project.

The level of specimen identification achievable was dependent on the level of taxonomic knowledge and expertise currently available. As a result, only a limited number of specimens could be identified to genus or species level. Only taxa belonging to groups known to include short-range endemics, or for which expertise was readily available at the WA Museum (eg wolf spiders, other spider groups, scorpions, and centipedes) were identified to genus or species level.

Table 2.1. Sampling sites, habitat descriptions, and collection method used (T-trap, L–litter, F–foraged)

SITE TYPE	SITE CODE	EASTING	NORTHING	HABITAT DESCRIPTION	T	L	F
IMPACT SITES	AVIA1	338883	7700492	*Triodia angusta* valley	*	*	*
	AVIA2	338789	7700333	*Triodia angusta* valley	*		
	LMIA1	338509	7700465	*Triodia weiseana* on limestone	*		
	LMIA2	339270	7700280	*Triodia weiseana* on limestone	*	*	*
	MLIA1	338941	7700598	*Melaleuca* on limestone	*	*	*
	MLIA2	338889	7700210	*Melaleuca* on limestone	*		
	TLIA1	339284	7700636	*Triodia weiseana* on loamy soil	*	*	*
	TLTP1	339934	7700416	*Triodia weiseana* on loamy soil	*	*	*
ALTERNATE CAMP	AVAC1	337398	7699196	*Triodia angusta* valley	*	*	*
	AVAC2	338404	7699386	*Triodia angusta* valley	*	*	*
	LMAC1	337346	7697104	*Triodia weiseana* on limestone	*	*	*
	LMAC2	338511	7699431	*Triodia weiseana* on limestone	*	*	*
	LMAD1	339056	7699662	*Triodia weiseana* on limestone	*	*	*
	MLAC1	337503	7697172	*Melaleuca* on limestone	*	*	*
	MLAC2	337312	7699160	*Melaleuca* on limestone	*	*	*
	TLAC1	338592	7699512	*Triodia weiseana* on loamy soil	*	*	*
NON IMPACT SITES	AVNI1	337563	7700791	*Triodia angusta* valley	*		
	AVNI2	338259	7701134	*Triodia angusta* valley	*	*	*
	LMNI1	338532	7701830	*Triodia weiseana* on limestone	*	*	*
	MLNI1	339262	7700983	*Melaleuca* on limestone	*	*	*
	MLNI2	338236	7701339	*Melaleuca* on limestone	*	*	*
	TLNI1	339450	7700894	*Triodia weiseana* on loamy soil	*	*	*
	TLNI2	339217	7701636	*Triodia weiseana* on loamy soil	*	*	*
	TLNI3	337899	7699073	*Triodia weiseana* on loamy soil	*		
QUARANTINE SITES	QUBL1	340945	7707607	Barge landing	*		
	QUBL2	341044	7707397	Barge landing	*		
	QUCA1	338212	7696255	Campsite	*		*
	QUNA1	334200	7691887	New Airport	*		
	QUOA1	336058	7699963	Old Airport	*		
	QUWH1	331998	7697305	Warehouse	*		
OTHER	WHTSBCH	334697	7710312	Whites Beach		*	*
	FLACBAY	331199	7705342	Flacourt Bay		*	*
	SHRUBBY	339877	7707052	*Eucalyptus* grove		*	

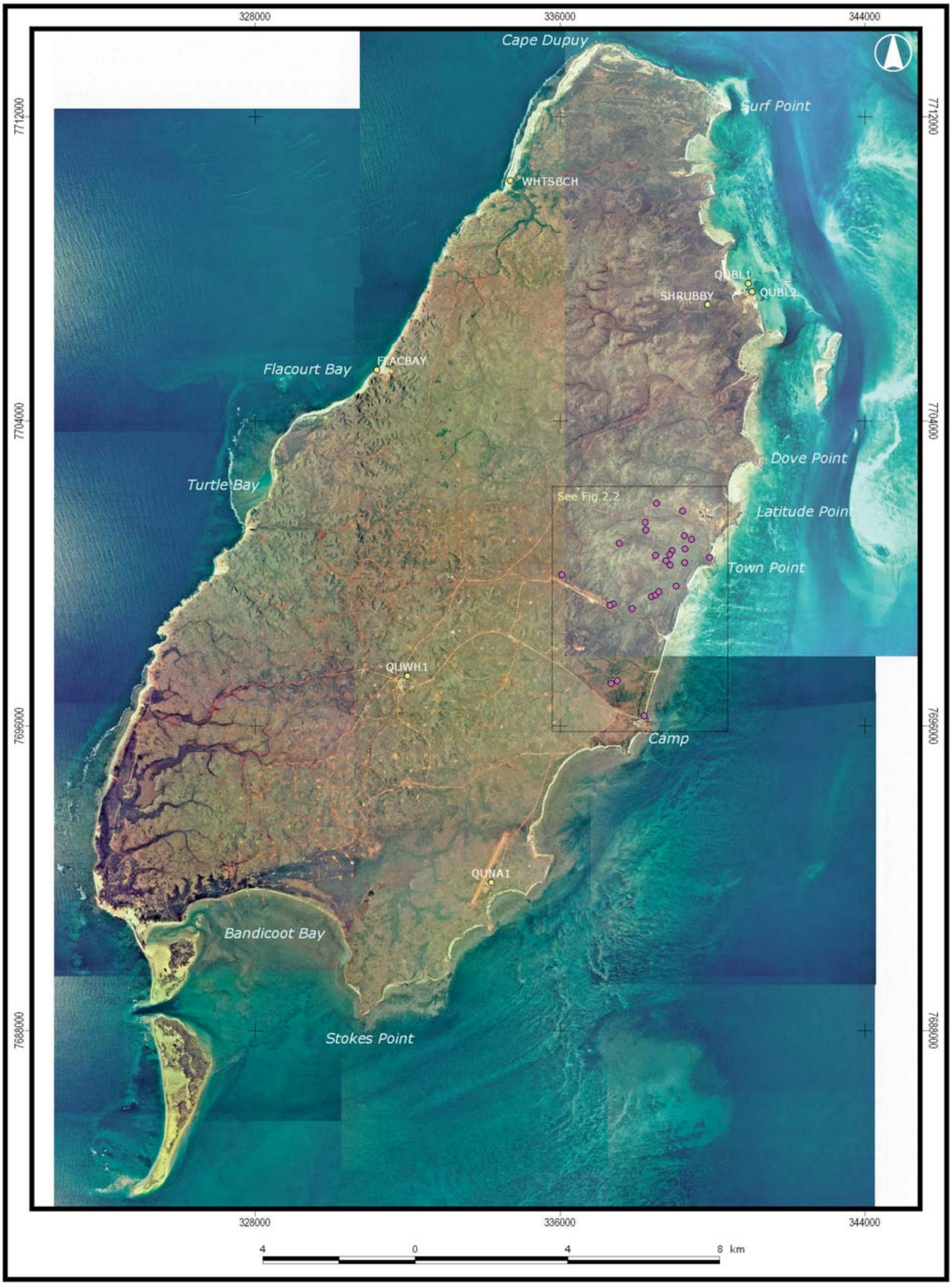

Figure 2.1. Survey areas and sampling sites for systematic wet pitfall trapping, leaf litter sampling, and opportunistic collections of invertebrates on Barrow Island. See Figure 2.2 for detailed sampling localities and site codes.

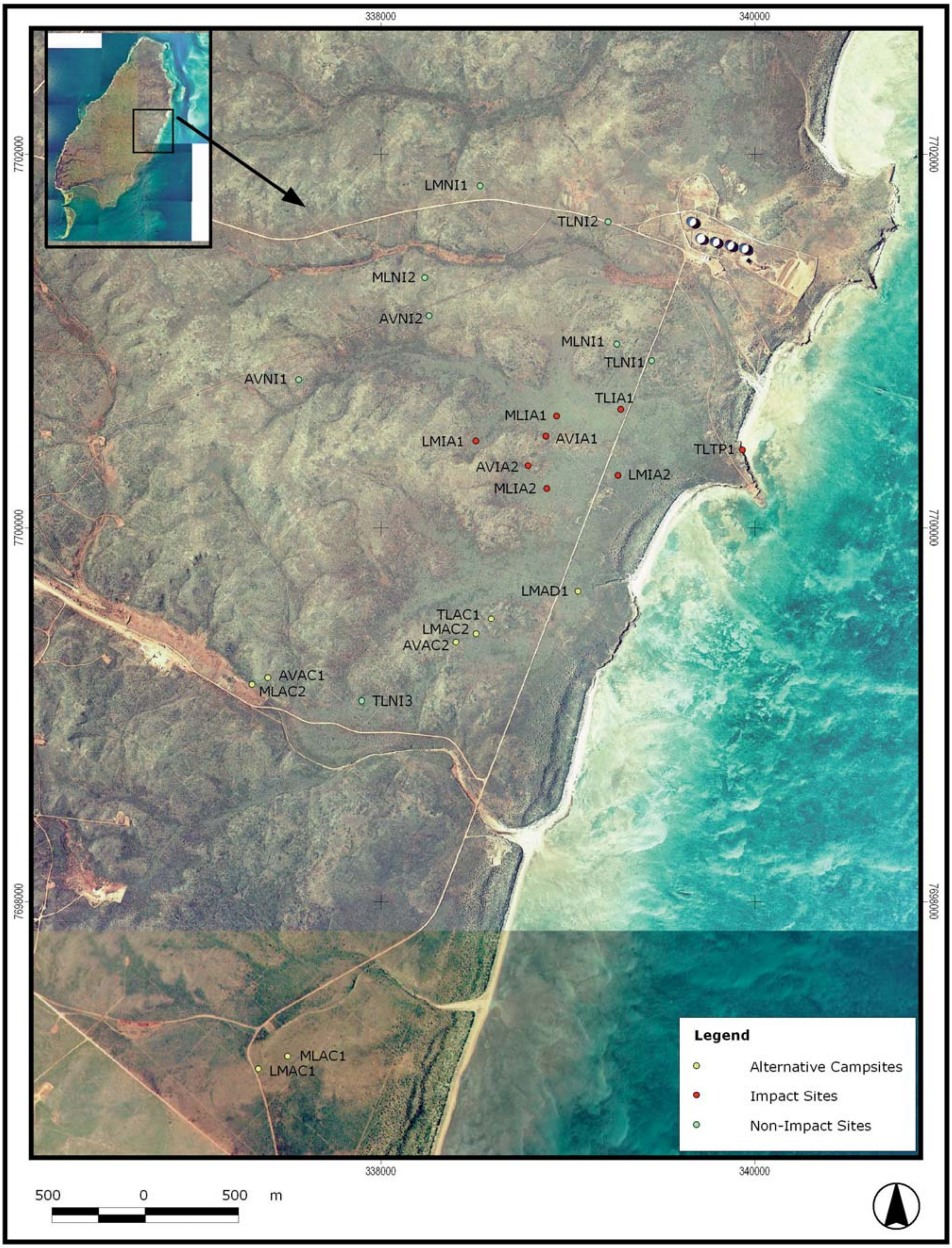

Figure 2.2. Sampling site localities and site codes for invertebrate collections within impact areas, alternative campsite areas, and non-impact areas.

3.0 Results

3.1 Overview

Sampling of terrestrial invertebrate taxa, particularly Arachnids and myriapods (known to contain short-range endemics) revealed more than 50 taxa. Many types of insects were also collected from this survey but could not be identified to species level at this stage due to poor taxonomic information, time and logistical constraints. Of the taxa identified, the majority are still undescribed and many could not be identified beyond family level. Of the invertebrate taxa specifically targeted, 43 spider taxa, three genera of pseudoscorpion, four species of centipede, one millipede, and two species of scorpion were collected and identified. Work is still ongoing on many of these groups and in many cases, more detailed and extensive sampling is needed to provide further information on their natural distributions.

An order level summary of the invertebrate specimens collected from impact and non-impact sites during the study is provided in Table 3.1. A detailed breakdown of all specimens captured during the survey is provided as raw data in Appendix 2 and a list of all species found on Barrow Island, collated from past field trips and past Museum records, is shown in Appendix 3.

Table 3.1: Summary of invertebrate taxa collected

Class	Order	No. families	No. genera	No. morphospecies
Arachnida	Acari	3+	4+	7+
Arachnida	Araneae	19	14	43
Arachnida	Pseudoscorpionida	1	3	3
Arachnida	Scorpionida	1	1	2
Myriapoda	Diplopoda	1	1	1
Myriapoda	Chilopoda	3	4	4

3.3 Acari (Mites/ Ticks)

Three families of Acari could be identified from material collected from wet pitfall traps. These included Ioxidae, Caeculidae, and Trombiidae. Four specimens could not be placed within a family. *Amblyomma triguttatum* (Ioxidae) was hand collected near Base and has been collected previously on Barrow Island and on the mainland. Three specimens were identified as *Amblyomma* but could not be identified further as they were juveniles. Two specimens belonging within the family Caeculidae were collected from sites TLAC1 (*Triodia weiseana* on loam, alternate campsite) and LMAC2 (*Triodia weiseana* on limestone, alternate campsite). A total of 12 specimens belonging within the family Trombiidae were collected from numerous sites within both impact and non-impact sites, covering different habitat types.

Very little research has been conducted on Acari, particularly mites, limiting identification of a number of groups. Caeculidae and Trombiidae are new family records for Barrow Island. Other species recorded from Barrow Island previously include: *Erythracarus decoris* (Anystidae), *Argas 'persicus'* (Argasidae) *Ornithodoros gurneyi* (Argasidae), *Amblyomma limbatum* (Ixodidae), *Haemaphysalis ratti* (Ixodidae), *Haemolaelaps marsupialis* (Laelapidae), and *Mesolaelaps antipodianus* (Laelapidae).

3.4 Araneae (Spiders)

Araneidae (Master Weavers)
The species *Austracantha minax* Thorell (Christmas spiders) has previously been collected from Barrow island (North of Town Point). An additional female specimen was hand

collected from site LMAD1 during the current survey. The site is situated in an area proposed for the development of the administration block and is dominated by *Triodia weiseana* on limestone. This particular species is relatively common and widespread throughout Western Australia, Tasmania, and Queensland (see Biota 2004). No other species belonging to the family Araneidae were collected during this survey.

Corrinidae

Two adult male and one female *Supunna picta* (c.f) were collected from *Triodia angusta* valleys at alternate camp and non-impact sites AVAC1, AVAC2, and AVNI2 using wet pitfall traps. This species is very common and has a widespread distribution on the mainland of WA. However, *S. picta* (c.f.) is a new record for Barrow Island.

Filistatidae

Four adult male specimens of *Wandella* sp 1 were collected from a range of different habitat types: *Triodia angusta* valleys (AVAC2), *Triodia weiseana* on limestone (LMNI1), *Melaleuca* on limestone (MLNI1), and *Triodia weiseana* on sandy loam soils (TLTP1). These sites encompass areas within the proposed alternative campsites, as well as non-impact areas. Three specimens were collected from wet pitfall traps and one specimen was sieved from leaf litter.

These specimens are different but quite similar to the described species *Wandella waldockae* Gray, which has not been collected from Barrow Island before. Other specimens from this family have been recorded from Sharp Point, West of Warehouse, and Bandicoot Bay on Barrow Island, but have not been identified to a higher level.

Gnaphosidae (Sac Spiders)

A total of nine undescribed morpho-species of Gnaphosid spider were collected mainly from wet pitfall traps. Details of localities and habitat descriptions where the different species were collected are shown in Table 3.2. The two female species could not be matched to any males that were collected and are considered to be different morphospecies, differing in a number of characters.

Table 3.2: Localities, site descriptions, and details of Gnaphosid morphospecies collected.

Morpho-species	No.	Sex	Site code	Site description
Sp 1	1	Male	QUOA1	Old airport quarantine site
Sp 2	2	Male	AVNI2 QUOA1	*Triodia angusta* valley, non-impact site Old airport quarantine site
Sp 3	1	Male	MLAC2	*Melaleuca* on limestone, alternate campsite area
Sp 4	2	Male	AVIA1 QUBL2	*Triodia angusta* valley, impact area Barge landing Quarantine site
Sp 5	1	Male	AVNI1	*Triodia angusta* valley, non-impact site
Sp 6	1	Male	MLAC1	*Melaleuca* on limestone, alternate campsite area
Sp 7	2	Female	WHBC	Whites Beach
Sp 8	1	Female	AVAC1	*Triodia angusta* valley, alternate campsite area
Sp 9	1	Male	MLIA2	*Melaleuca* on limestone, impact area

Gnaphosid spiders are known to be very abundant and diverse in the arid zone, so it is not surprising that there were large numbers of morphospecies collected from this survey. Wet pitfall trapping is the most efficient method of surveying for these spiders. In the preliminary survey, another species of Gnaphosid, *Ceryerda* sp 1, was collected from Town Point. This specimen could only be identified to genus level. Nothing is known about the potential for this group to contain short-range endemics. More extensive surveying is needed to answer questions about wider distribution patterns and ecology of these species.

Lamponidae (White-tailed Spiders)
Three species belonging to the family Lamponidae were collected from this survey. Two species belong within the sub family Lamponinae and one species within the Centrothelinae.

Within the Lamponinae, one male *Lampona ampeinna* and one male *Lamponina scutata* were collected in wet pits at sites MLIA1 and MLIA2 respectively. These sites were situated in areas of *Melaleuca* on limestone within the impact area. *Lamponina scutata* Strand, has been previously recorded from Barrow Island and has a widespread distribution within Western Australia (Biota 2004). *Lampona ampeinna* is widespread in Western and central Australia. This particular species has not been collected from Barrow Island before but is known from Enderby Island.

A female specimen *Notsodipus* sp 1 belonging to the subfamily Centrothelinae was collected near Town Point in an area of *Triodia weiseana* on loamy soil. In general this genus does not have the potential for SRE given the general biology of the group and would be expected to occur on the mainland. This species is similar to *N.capaensis*, which is only known from the type locality at Cape Range. Although only known from the type locality, it is unlikely that it would be restricted to that area.

Lampona and *Notsodipus* are new genus records and Centrothelinae is a new subfamily record for Barrow Island. Neither have been recorded from Barrow Island previously.

Lycosidae (Wolf Spiders)
One species of wolf spider was collected whilst head-torching at night on the Beach near the camp. This species, *Venator* sp 1, was collected in abundance during the preliminary survey of Barrow Island Terrestrial Invertebrates. Many more species were collected on the previous survey because they were specifically targeted and the conditions were more suitable for head-torching at night. This method is the most efficient method of collecting wolf spiders. Six species are known to occur on Barrow Island. These include *Venator* sp 1, *Lycosa snelli*, *Lycosa laeta*, *Lycosa clara*, *Hoggicosa bicolour*, and *Hogna kuyanii* group. All these species have distributions outside Barrow Island.

Oecobiidae
Five specimens of *Oecobius navus* were collected from wet pitfall traps. 1 male specimen from site LMIA2 (*Triodia weiseana* on limestone, impact area) and 4 male specimens from site QUWH (Warehouse quarantine site) were collected. This species has previously been recorded from the camp area and is a common introduced species. Three species can be found in Australia, two of which are introduced.

Oonopidae
Five morphospieces belonging to four genera of Oonopid spider were collected from wet pitfall traps during the survey. These include *Gamasomorpha, Grymeus, Myrmopopae, and Opopaea*. Table 3.3 details the number of morphospecies of each genus, their localities and habitat descriptions.

Oonopids are generally only collected from pitfall trapping. Because the traps were only open for a short period of time, there is not enough data to state whether they are short-range endemics. Most of the specimens collected are undescribed species and little can be said about their abundance or distribution on and off Barrow Island. Trapping efforts need to be more widespread on the island and over longer time frames.

Table 3.3: Localities, site descriptions, and details of Oonopid spiders collected.

Genus	Species	No.	Sex	Site code	Site description
Gamasomorpha	Sp 1	2	Male	LMAC1	*Triodia weiseana* on limestone, alternate campsite
				LMAC2	*Triodia weiseana* on limestone, alternate campsite
	Sp 2	1	Male	LMIA2	*Triodia weiseana* on limestone, impact area
Grymeus	Sp 1	1	Male	TLNI3	*Triodia weiseana* on loamy soil, non-impact site
Myrmopopae	Sp 1	3	Male	AVAC2	*Triodia angusta* valley, alternate campsite
				MLIA1	*Melaleuca* on limestone, impact area
				MLNI1	*Mlealeuca* on limestone, non-impact area
Opopaea	Sp 1	2	Male	LMNI1	*Triodia weiseana* on limestone, non-impact site

Five genera have been recorded from Barrow previously, but only two species have been described, *Grymeus* '*nasutus*' and *Orchestina 'barrow'* (Harvey, in press). *Grymeus 'nasutus'* has a distribution from Barrow Island to South of Shark Bay. *Orchestina 'barrow'* is only known from Barrow Island but has been collected from different areas of the island (Biota 2004).

Oxyopidae (Lynx Spiders)
Two morphospecies of Lynx spiders have been identified from wet pitfalls at sites QUCA (Campsite Quarantine site) and QUOA (Old airport Quarantine site). No identified species of Oxyopidae have been found on Barrow Island, but one genus, *Oxyopes* has been recorded. The museum collection of lynx spiders is currently on loan overseas so no material could be databased for Barrow Island. These spiders are not generally ground dwellers, preferring to inhabit vegetation. Pitfall trapping for these particular spiders is not the most appropriate method. The most efficient method is sweep-netting vegetation.

Pholcidae (Daddy long-legs)
It appears that two female species of *Trichocyclus* have been collected from wet pitfall traps. *Trichocyclus* sp 1, a new undescribed native species, was found at the campsite quarantine site (QUCA). *Trichocyclus nigropunctatus* was collected from an alternate campsite area dominated by *Triodia weiseana* on loamy soil (TLAC1). *Trichocyclus nigropunctatus*, which is a native species, has been recorded from Barrow in the past. *Crossopriza lyoni* and *Trichocyclus aranda* have been recorded for Barrow Island and are also found on the mainland (Biota 2004).

Prodidomidae
Two species of Prodidomid spiders belonging within the subfamily Molycriinae were collected during the survey from wet pitfall traps. A total of 12 individuals were collected. See table 3.4 for an outline of the localities were they were collected.

Two species have already been described for Barrow Island. *Prodidomus 'woodleigh'* has been collected from the Camp on Barrow Island, and is known from the mainland.

'Wydundra' 'barrow' was collected from Shark Point and is only known from Barrow Island (Biota, 2004).

Table 3.4: Localities, site descriptions, and details of Prodidomid spiders collected.

Species	Site code	Females	Males	Site description
Sp 1	MLIA2		1	*Melaleuca* on limestone, impact area
	MLNI2	1		*Melaleuca* on limestone, non- impact site
	QUBL2		2	Barge landing Quarantine site
	QUNA1	1	2	New airport Quarantine site
	QUOA1	1		Old airport Quarantine site
	AVIA2	1		*Triodia angusta* valley, alternate campsite
	LMAD1		1	*Triodia weiseana* on loamy soil, administration block site
Sp 2	LMAD1	1		*Triodia weiseana* on loamy soil, administration block site
	MLAC2	1		*Melaleuca* on limestone, alternate campsite

Salticidae (Jumping Spiders)
Five species (five genera) of jumping spiders were collected from Barrow Island: *Clynotis albobarbatus-group*, *Grayenulla waldochae*, *Lycidas* Sp 1, *Pellenes* Sp 1, and *Zenodorus* Sp1. Table 3.5 shows the specimens of each species collected and the site code and site description for each species.

Clynotis albobarbatus-group has been recorded from Barrow Island in the past from Bandicoot Bay and is widespread on the mainland (see Biota 2004). Specimens of *Grayenulla waldochae* have only been collected from a limited number of sites. The genus is relatively common and widespread, but this species is only known from few specimens (Woodstock station, Newan). It has not been previously collected from Barrow Island.

Table 3.5: Localities, site descriptions, and details of Jumping spiders collected.

Genus	Species	No.	Sex	Site code	Site description
Clynotis	*albobarbatus* - group	1	Female	MLIA1	*Melaleuca* on limestone, impact area
Grayenulla	*waldochae*	1	Male	LMIA1	*Triodia weiseana* on limestone, impact area
		1	Male	TLAC1	*Triodia weiseana* on loamy soil, alternate camp
		1	Male	TLNI3	*Triodia weiseana* on loamy soil, non-impact
		1	Male	QUBL2	Barge landing Quarantine site
Lycidas	Sp 1	1	Male	TLIA1	*Triodia weiseana* on loamy soil, impact area
Pellenes	Sp 1	1	Female	QUCA	Campsite Quarantine site
Zenodorus	Sp 1	1	Female	FLBAY	Flacourt Bay

Undescribed species of *Lycidas* have been collected from Barrow previously. No information is known about the distribution of these morphospecies outside Barrow Island. However, it is unlikely that this genus would contain SRE's given the biology of this group. The two genera, *Pellenes* and *Zenodorus* have not been recorded from Barrow Island previously, making them new genus records for the island. Other genera known from Barrow Island include *Jotus* (Bandicoot Bay), *Cytaea* (Base), and *Holoplatys* (Cave B2).

Selenopidae

Two undescribed morphospecies of Selenopidae were collected from Barrow Island. One female Sp 1 was hand collected from under rocks at site MLNI2 (*Melaleuca* on limestone, non-impact area), and two male specimens of Sp 2 were collected from wet pitfall traps at site LMNI1 (Triodia weiseana on limestone, non-impact area). These morphospecies could not be identified to genus or species level. No other specimens of this family have been collected from Barrow in the past.

Sparassidae

One male *Neosparassus* sp 1 was hand collected from Spinifex at night whilst head-torching at site LMAD1 (*Triodia weiseana* on limestone, alternate campsite). Two other unidentified species belonging to the genus Neosparassus had been collected on the previous survey but are yet to be named. The taxonomy of this genus is currently being revised by David Hirst of the South Australian Museum.

Described species belonging to the family Sparassidae that have been recorded from Barrow Island include *Heteropoda hemitis* and *Irileka iridescens* (See Biota 2004). *H. hermitis* is known from outside Barrow Island but it is unknown whether *I. Iridescens* is found outside Barrow.

Tetragnathidae

One male specimen belonging within the family Tetragnathidae, and the subfamily Metinae, was collected from wet pitfall traps at site TLAC1 (*Triodia weiseana* on loamy soil, alternate campsite). This species is undescribed and could not be identified beyond subfamily level. *Nephila edulis and* the genus *Tetragnatha* are known from Barrow Island and are recorded in the Arachnology database at the Western Australian Museum.

Thomisidae

Two genera belonging the family Thomisidae were represented amongst the specimens collected during the survey. Three female *Stephanopis* sp 1 were hand collected from leaf litter at site LMIA2 (*Triodia weiseana* on limestone, impact area). One male *Tharpyn*a sp 1 was collected from wet pitfall traps at site AVIA1 (*Triodia angusta* valley, impact area). These genera have been found on the previous field trip near terminal tanks, at the campsite and North of town point (Biota 2004). No described species have been registered for Barrow Island previously.

Zodariidae

One female specimen belonging within the family Zodariidae was collected from leaf litter at site MLNI2 (Melaleuca on limestone, non-impact area). This species has not been described and could not be identified to genus or species level.

Only two described species of Zodariidae has been recorded from Barrow. *Minasteron minusculum* and *Spinasteron `harveyi`. M. minisculum* occurs on the mainland of WA as well as Barrow Island, but *S.`harveyi`* is only known from Barrow Island. Other genera previously recorded from Barrow include: *Asteron*, *Australutica*, *Habronestea, Neostorena,* and *Nostera*.

Zoridae

Four morphospecies belonging to the family Zoridae were identified from wet pitfall traps during the survey. Table 3.6 shows the morphospecies, which are currently undescribed, the site were they were collected and the habitat they were collected from.

Table 3.6: Localities, site descriptions, and details of Zorid spiders collected.

Species	Site code	Females	Males	Site description
Sp 1	AVIA2		1	*Triodia angusta* valley, impact site
	AVNI2		1	*Triodia angusta* valley, non- impact site
	MLNI1		2	*Melaleuca* on limestone, non- impact site
	TLNI1		1	*Triodia weiseana* on loamy soil, non-impact site
	TLNI3		1	*Triodia weiseana* on loamy soil, non-impact site
	TLTP1		1	*Triodia weiseana* on loamy soil, Town Point
Sp 2	TLNI2	2		*Triodia weiseana* on loamy soil, non-impact site
Sp 3	LMNI1	1		*Triodia weiseana* on limestone, non-impact site
Sp 4	AVNI1	1		*Triodia angusta* valley, non- impact site

One genus of Zorid spider, *Argoctenus*, has previously been collected from Barrow Island from litter outside a cave and from the campsite. No described species have been recorded for Barrow Island.

3.5 Pseudoscorpionida (Pseudoscorpions)

Four genera of pseudoscorpions, belonging to the family Olpiidae, have been collected from Barrow Island. These include *Austrohorus* (Biota 2004), *Indolpium*, *Xenolpium*, and Genus 1.

Six specimens of *Indolpium* sp 1 were found in a number of sites within the impact area and alternate camp sites. Two specimens were collected from wet pitfall traps and four were sieved from leaf litter. A total of 32 specimens of *Xenolpium* sp 1 were collected from leaf litter within impact, non-impact, and alternate camp sites. This species was found at a number of different localities on the Island and within a number of different habitat types. One male specimen of an unknown genus was sieved from leaf litter collected at site LMAC2 (*Triodia weiseana* on limestone, alternate camp site). There is insufficient information to determine whether this species has the potential to be a SRE.

No specimens of *Synsphyronus* sp nov. `barrow`, or *Anagarypus heatwolei* were collected in this secondary survey. *Synsphryronus* sp nov. `barrow` has only been collected from one site on Barrow Island within the project area (Biota 2004). It is only known from one specimen and has the potential to be a short range endemic. There is insufficient information to determine the potential distribution of this species outside the project area, but it is unlikely that it would be restricted within the bounds of the impact area.

3.5 Scorpionida (Scorpions)

Two species belonging to the genus *Archisometrus* (Buthidae) were collected during the survey. One species was collected from wet pitfall traps at sites MLNI1 (*Melaleuca* on limestone) and QUBL1 (Barge-landing site) and another species was collected from leaf litter at Whites Beach and sites LMIA2 (*Triodia weiseana* on limestone) and TLTP1 (*Triodia weiseana* on loamy soil). It is unknown whether these species have the potential to be SRE's. A taxonomic revision of this group is currently being completed.

No specimens of Urodacus sp nov. `barrow` were recollected on this survey (Biota 2004).

3.6 Myriapoda (Centipedes and Millipedes)

Scutigeridae (House centipedes)
Two specimens of *Allothereua* were collected from leaf litter at sites TLNI2 (*Triodia weiseana* on loamy soil, non-impact site) and LMIA2 (*Triodia weiseana* on limestone, impact area). As the individuals were juveniles, they could not be identified further. The previous survey collected the species *Allothereua leuseuri* which is known to be widespread throughout WA.

Scolopendridae (Centipedes)
Two species of Scolopendrid centipede, *Etmostigmus curtipes* Koch and *Scolopendra laeta* Haase were collected from wet pitfall traps at sites QUBL1, MLAC2, and LMNI1. Both species are known to be widely distributed over the mainland (Koch 1982; Koch 1983). Other species known from Barrow include *Scolopendra morsitans, Arthrohabdus mojoberg,* and *Cormocephalus strigosus*. All have distributions outside of Barrow Island (Biota 2004).

Geophilida
One unknown genus of centipede belonging to the order Geophilida was collected from leaf litter at site MLNI1 (*Melaleuca* on limestone, non-impact site). As no key is available, further identification was not possible.

Synxenidae (Pin cushion millipedes)
A total of 14 pin cushion millipedes belonging to the family Synxenidae were collected from wet pitfall traps at a number of sites within and outside the impact areas. Unfortunately further identification was not possible. These millipedes have been known to occur in plague proportions under certain conditions.

3.7 Insecta (Insects)

Insect specimens were sorted and identified to morphospecies where possible. A summary of the number of morphospecies collected for different insect orders and families is provided in Table 3.7.

Table 3.7: Summary of insect morphospecies numbers collected from Barrow Island

Common Name	Order	No. Morphospecies
	Embioptera	1
Praying Mantis	Mantodea	2
Beetles	Coleoptera	19
Moths/Buterflies	Lepidoptera	5
Termites	Isoptera	2
Grasshoppers	Orthoptera	8
Bugs	Hemiptera	16
Flies	Diptera	14
Wasps/bees	Hymenoptera	24
Ants	Hymenoptera - Formicidae	24
Silverfish	Thysanura	3
Cockroaches	Blattodea	4

Spring tails	Collembola	2

3.8 Isopoda

Four morphospecies of Isopoda were identified from the material collected from wet pitfall traps. Three species were collected within both impact and non-impact sites but one species was only collected from site TLTP1 (Town Point).

Attachment 3 - Sea Turtle Light Orientation Arena Experiments 1-6 February 2005. Report to ChevronTexaco Australia Pty Ltd by Pendoley Environmental, April 2005.

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PROPOSED GORGON GAS DEVELOPMENT
BARROW ISLAND

SEA TURTLE LIGHT ORIENTATION ARENA EXPERIMENTS

1 – 6 FEBRUARY 2005

by

PENDOLEY ENVIRONMENTAL PTY LTD

13 APRIL 2005

1 Introduction

This report provides the results of arena experiments carried out on Barrow Island in February 2005. The study is a follow-up to experiments carried out in April 2004 which were limited by difficulties in sourcing sufficient study animals. The timing of the study earlier in the 2005 summer nesting and hatchling season ensured the availability of suitable study animals. This study was designed and implemented by K Pendoley of Pendoley Environmental Pty Ltd and is based on similar studies carried out on green, flatback and hawksbill hatchlings between 1993 and 2004. Prof Stuart Bradley (Head of Animal Biology, School of Biology and Biotechnology, Murdoch University) carried out the statistical analyses.

The objectives of the study were to;

- Investigate the impacts of sodium vapour, fluorescent and metal halide light on flatback sea turtle hatchlings at different light intensities (250 W and 500 W).
- Trial experimental methods to test hatchling response to light glow.
- Collect qualitative (spectra) and quantitative (Lux) data from the different light sources (at both intensities) at each arena location.
- Test the behavioural response of hatchlings during reuse in experimental trials.

2 Methods

The arena experiments were carried out on Barrow Island between 1-5 February 2005 over 5 nights of a late rising waxing moon (i.e. under no moon conditions). The personnel involved in this project are listed by affiliation below:

- Pendoley Environmental Pty Ltd; Kellie Pendoley, Anna Vitenbergs, Karen Edward, Jarrad Sherborne, Patrick Cullen.
- Crackpots; John Norton, Paul Tod.

The pit fall arena experimental design and test methods were the same as those used in April 2004.[1] The light array used in 2004 was reinstalled on Yacht Club Beach North, however the location was shifted 100 m north of the April 2004 position to avoid the potential influence of light glow along the creek line from inland infrastructure. The lights, consisting of 2 x 250 W high pressure sodium vapour (sodium), 2 x 250 W metal halide (metal), 14 x 36 W fluorescent fixtures mounted on a 3 m tall stand (Plate 1), were built by the marine and environmental service company, Crackpots. The array was assembled on location and powered by a 5 KVa 'silent' running diesel generator positioned 25 m from the light array. The generator was placed on a rubber base to prevent the motor vibrations travelling along the beach and potentially influencing the hatchling response during the arena trials.

The arenas were installed at 100 m, 200 m, 500 m and 800 m from the light array along North Yacht Club Beach (Figure 1). Each circular arena was 5 m in diameter with a 20 cm deep trench around the circumference. The trench was divided into 12 numbered segments of 30°. The first segment divider was installed at the closest point to the ocean and the rest placed in 30° increments from that location.

The experiments were carried out using flatback hatchlings and were scheduled to coincide with the peak of the flatback hatching season. All hatchlings were collected from Yacht Club Beach the same evening as each trial was run. Hatchlings were held in the dark until use. None of the hatchlings tested were held for more than 2 hours prior to the

[1] Pendoley, K. (2004). Gorgon Proposed Gas Development Sea Turtle Hatchling Arena Experiments. April 2004, Perth, unpublished report to SKM/ChevronTexaco: 47.

experiments and none for longer than a total of 5 hours. On completion of the experiments hatchlings were released from the barge landing on the north east coast of Barrow Island. This site was selected to avoid the high numbers of predators present off Yacht Club Beach.

2.1 Light experiments

Experimental light trials (250 W light, 500 W light, 500 W glow) were carried out using 30 – 50 animals at each arena. All four arenas were used for each trial. Each animal group was tested against the four light regimes in the following order; control, sodium, metal, fluorescent and control. The controls at the start and end of each light group were used to monitor the animals for learned behaviour. Each experimental trial was completed in a single night ensuring the study animals were exposed to the same environmental conditions throughout a single trial.

For each of the four light regimes, the hatchlings were released at the center of each arena using a remote mechanism. They were allowed 2-5 minutes to reach the trench at the edge of the arena prior to collection. The number in each segment, as well as those remaining in the center, was scored and the hatchlings returned to the center in preparation for the next light regime trial.

The three different experimental trials carried out were:

- 250 W bare light, control, sodium, metal and fluorescent lights at 100 m, 200 m, 500 m and 800 m arenas
- 500 W bare light, control, sodium, metal and fluorescent lights at 100 m, 200 m, 500 m and 800 m arenas
- 500 W shielded light (glow), control, sodium, metal and fluorescent lights at 100 m, 200 m, 500 m and 800 m arenas.

2.2 Light intensity measurements

Light measurements were made using an OceanOptics spectroradiometer which provides a characteristic spectral chart for each light source and includes the energy emissions in $uW/nm^2/cm$ at each wavelength. The spectroradiometer also provides a photometric measure of emissions in Lux. The Lux values have been used as a basis on which to assess and compare hatchling behaviour over distance and light type. However it should be noted that the limitations on instrument sensitivity may reduce the accuracy of these light measurements over large distances or at very low light intensity (i.e. at the 500 m and 800 m arenas).

2.3 Reuse experiments

Experiments were run to assess the impact of reusing hatchlings in different light trials. Reuse of hatchlings was necessary since the total number of animals needed for each of the three experimental trials was very high (~500 animals on each night of the study), and it was not possible to find and collect 500 animals in one night. The reuse trials were carried out at the 200 m arena using 250 W light intensity. One hundred and twenty hatchlings were divided into four bags. The order of testing against the three light regimes is listed below.

Bag 1	Bag 2	Bag 3	Bag 4
Control	Sodium	Metal	Fluorescent
Sodium	Metal	Fluorescent	Control
Metal	Fluorescent	Control	Sodium
Fluorescent	Control	Sodium	Metal

The first light treatment each bag of animals was exposed to was their first exposure to the arena and light. The hatchlings were tested under the different light conditions in sequence to determine if previous exposure to different light sources had any impact on their behaviour.

3 Results and Discussion

3.1 Light measurement results

The light spectra for each light types are shown in Figures 2 – 5 for each arena location. These figures show the spectral distribution curve for each light type, in units of $uW/cm^2/nm$ in addition to a photometric measure of emissions in Lux. Commercial light meters such as those typically used in industrial settings, measure in units of Lux and include only the light emissions most visible to the human eye (i.e. in the 500 nm to 650 nm range). The Lux values presented in this report therefore include only the spectral emissions between 500 nm and 650 nm and ignore the spectral peaks above and below this range. Experimental work with green turtles has shown that light in the 350 nm – 450 nm range is also visible to this, and presumably other, turtle species[2].

3.2 Hatchling reuse trials

The trials to test the impact that reusing hatchlings may have had on animal behaviour was run on all light types at 250 W. The results for these trials (Figure 6) show that the hatchlings oriented in the same way under a given light regime regardless of their exposure history. For example hatchlings exposed to sodium and metal halide light before being exposed to the fluorescent light oriented in the same direction as hatchlings that had no previous light exposure. A chi-square analysis was run to test the effect of reusing hatchlings. The results found no significant difference in the orientation of hatchlings with no previous light exposure compared to re-used animals ($p = 0.087$). This result suggests hatchlings are responding to the different lights as if it was their first exposure and are not exhibiting learned behaviour. The analysis also tested the effect of the light treatments on hatchling behaviour and found a statistically significant difference between the behaviour of animals in the control trials and the light trials. These differences were investigated further during 250 W and 500 W light trials.

3.3 250 W and 500 W light trials

The light types (i.e. sodium, metal and fluorescent) used in these experiments were selected to be representative of the lighting typically used in industrial settings. The light

[2] Witherington, B. E. and K. A. Bjorndal (1991a). "Influences of wavelength and intensity on hatchling sea turtle phototaxis: implications for sea-finding behaviour." Copeia **4**: 1060-1090.

intensities (250 W and 500 W) were selected, based on previous studies, to provide a range of light most likely to elicit a detectable response in the hatchlings. The experimental trials were split into 250 W and 500 W trials and run over separate nights. The data was analysed statistically in the same manner, i.e. 250 W results as a dataset distinct from the 500 W results.

Both datasets were subject to global multinomial logistic regression with light treatments as a factor and distance as a covariate, and direction as the multinomial dependent variable (including all control and light treatment data amalgamated, i.e. light versus no light). The results found a statistically significant difference in the response of hatchlings under control conditions and light treatment conditions ($p = 0.000$). The light treatment clearly had an impact on hatchling orientation. The analysis also found that the hatchling behaviour differed significantly with distance (and consequently light intensity) from the light source ($p = 0.000$).

Distance was tested further by splitting both the 250 W and 500 W light trial data (excluded controls) into two groups; near (representing the 100 m and 200 m arena results) and far (representing the 500 m and 800 m results). The analysis of the 500 W dataset found that hatchling behaviour in the two near arenas was not significantly different (indicating that the light type was not important), nor was it significantly different between the in two far arenas. The 250 W trials, however, showed a significant difference in the hatchling behaviour in the near (100 m and 200 m) arena group while no significant difference was evident in the 500 m and 800 m arenas.

In order to look at fine scale trends, the data from each individual arena location was then subject to an analysis which compared hatchling orientation under control vs. light treatment conditions. A binary logistic regression analysis performed on the complete set of controls (run at the start and end of each group of light treatments) and including distance as a covariate, found no significant difference in hatchling orientation permitting the control data to be pooled for subsequent statistical analyses. The binary regression assumed animals either oriented towards the ocean (within the 85° and 115° segments) or they did not (all other directions). A series of 2 x 2 contingency chi-square tests were performed for the number of animals oriented to the ocean versus the number not, in the presence of a particular light type versus the absence of light. The results of these tests are shown in Table 3. Since twelve separate contingency tests were performed for each of the 250 W and 500 W trials the results were subject to a sequential Bonferroni correction in order to account for repeat testing. The results showed that all three light treatments (sodium, metal and fluorescent), at both 250 W and 500 W light intensities, had a significant impact on hatchling orientation (relative to the controls) at 100 m and 200 m.

At 500 m and 500 W light intensity hatchlings tested against all three light types also show a significant response to the light relative to the controls however at 800 m the fluorescent light was the only emission source to show a (weakly) significant response relative to the controls. In contrast the 250 W trials found no significant effect from the three light types at 500m or 800m with the single exception of the metal halide at 500 m.

These results are shown graphically in Figures 7 (sodium), 8 (metal) and 9 (fluorescent). The figures include the results of both the 250 W and 500 W light intensity trials, sorted by the measured Lux value. The sodium vapour light trials appear to influence hatchling behaviour at light 500 W at 500 m (estimated light intensities of ≥ 0.19 Lux) while the light detectable at 500 m and 250 W (estimated intensities of ≤ 0.09 Lux) did not cause a detectable difference (from controls) in hatchling behaviour. The effect of metal halide light was detectable at lower light intensities than the sodium light, with hatchling behaviour being modified at 500 m and 500 W of light (estimated light intensities of • 0.05 Lux, Figure 8). Hatchling behaviour was not significantly affected at 800 m and 500 W of light (estimated intensities of ≤ 0.04 Lux). The fluorescent light results show a clear influence on behaviour under distance and light intensity combinations up to 500 m, and 500 W (estimated intensities of ≥ 0.14 Lux) however at 500 m the 250 W light intensity of 0.06 Lux did not elicit a significant response in hatchling behaviour while 500 W of fluorescent light at 800 m (estimated intensity of 0.05 Lux) did show a weakly significant response.

3.4 500 W glow trials

These trials were carried out using the same methodologies as the 250 W and 500 W light trials. The light sources were placed on the sand and the orientation manipulated to shield the bulbs so that the only light visible was a faint glow in the sky above the light fixtures. It was not possible to completely control the light spill, which illuminated the sand dunes behind the beach out to a distance of ~200 m. Methods to better control light spill and glow will be investigated prior to any further experimental work being carried out on hatchling response to light glow. It was also not possible to obtain a quantitative measure of light intensity since the light emissions were below the limit of sensitivity of the spectroradiometer. Investigations are underway to source a more sensitive instrument for future sea turtle experiments and light surveys.

A preliminary analysis of the data was carried out. As was done for the 250 W and 500 W light trials a global multinomial logistic regression with light glow treatments as a factor and distance as a covariate, and direction as the multinomial dependent variable (including all control and light glow treatment data amalgamated, i.e. light glow versus no light glow) was performed on the data. The results indicated that both treatment and distance were highly significant ($p = 0.000$) indicating that glow did have an impact on the direction hatchlings were taking and the impact varied with distance. The tests repeated without the control data again indicated that distance was highly significant ($p = 0.000$) but that the actual light type (sodium, metal or fluorescent) used to generate the glow had no effect ($p = 0.61$). The analysis of the glow effects was not taken further since it was not possible to identify a threshold glow intensity beyond which an effect could be detected.

4 Conclusions

This series of experiments has investigated the following:

- the acceptability of reusing hatchlings in light trials
- the influence of sodium vapour, metal halide and fluorescent light on flatback hatchlings over a range of exposure intensities
- experimental methods for testing the effect of light glow on flatback hatchlings.

The results suggest that reusing hatchlings did not compromise the behaviour of the animals during repeat trials. It is therefore acceptable and results from trials reusing hatchlings are therefore valid.

The experiments show a difference in hatchling response to sodium vapour, metal halide and fluorescent light sources. Hatchlings respond to sodium light at estimated intensities of ≥ 0.19 Lux, while metal and fluorescent light sources influence hatchling behaviour at intensities an order of magnitude lower at estimated intensities of ≥ 0.05 Lux. These results provide evidence to support the recommendations made to the Gorgon Development to use sodium vapour light sources, over metal halide or fluorescent light sources, in the vicinity of sea turtle rookeries.

The results of the preliminary experimental trials on light glow suggest that glow is influencing hatchling behaviour over distance. However, refinements to the experimental methods, in addition to sourcing measurement instruments with more sensitive detection limits, are required to further define the threshold level of light glow that causes misorientation in sea turtle hatchlings.

Table 1: Lux measurements from 500 W light sources

	100 m	200 m	500 m	800 m
Control	0	0	0	0
Sodium vapour	5.16	1.31	0.19	0.06
Metal halide	2.38	0.59	0.12	0.04
fluorescent	3.09	0.77	0.14	0.05

Table 2: Lux measurements from 250 W light sources

	100 m	200 m	500 m	800 m
Control	0	0	0	0
Sodium vapour	2	0.52	0.09	0.04
Metal halide	0.80	0.21	0.05	0.03
fluorescent	1.38	0.36	0.06	0.03

Table 3: Chi^2 analysis results (corrected for repeat testing using the sequential Bonferroni correction) for 500 W and 250 W light treatment trials. * = significant at 0.05, ** =significant at 0.01, *** =significant at 0.001, ns = not significant

Light wattage	distance	treatment	Chi value	p	Significance using sequential Bonferroni correction
500 W	100	sodium	48.515	0	***
	100	metal	51.232	0	***
	100	fluorescent	50.333	0	***
	200	sodium	21.546	0	***
	200	metal	27.221	0	***
	200	fluorescent	21.165	0	***
	500	sodium	8.422	0.0037	*
	500	metal	7.159	0.0075	*
	500	fluorescent	7.009	0.0081	*
	800	sodium	0.084	0.7719	ns
	800	metal	0.001	0.9813	ns
	800	fluorescent	5.857	0.0155	*
250 W	100	sodium	53.429	0	***
	100	metal	58.784	0	***
	100	fluorescent	46.735	0	***
	200	sodium	47.709	0	***
	200	metal	72.121	0	***
	200	fluorescent	62.656	0	***
	500	sodium	1.386	0.2391	ns
	500	metal	9.943	0.0016	**
	500	fluorescent	4.344	0.0371	ns
	800	sodium	0.606	0.4363	ns
	800	metal	0.41	0.522	ns
	800	fluorescent	0.41	0.5221	ns

Figure 1: Arena locations on Yacht Club Beach

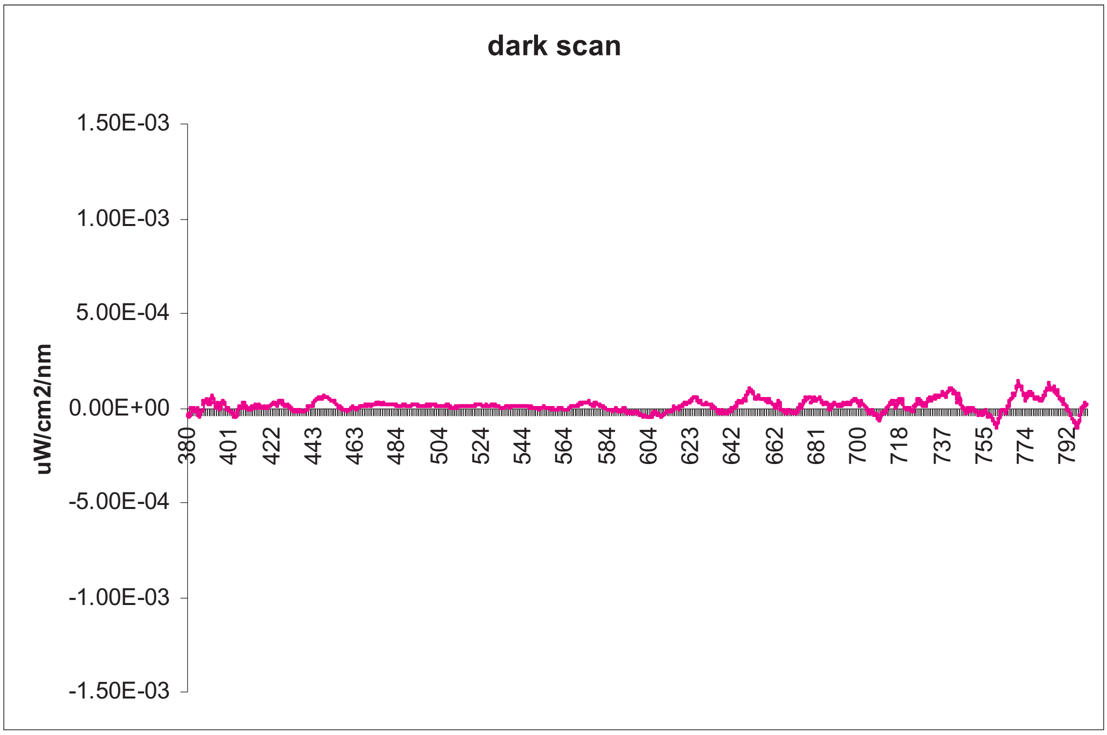


Figure 2: Dark sky scan

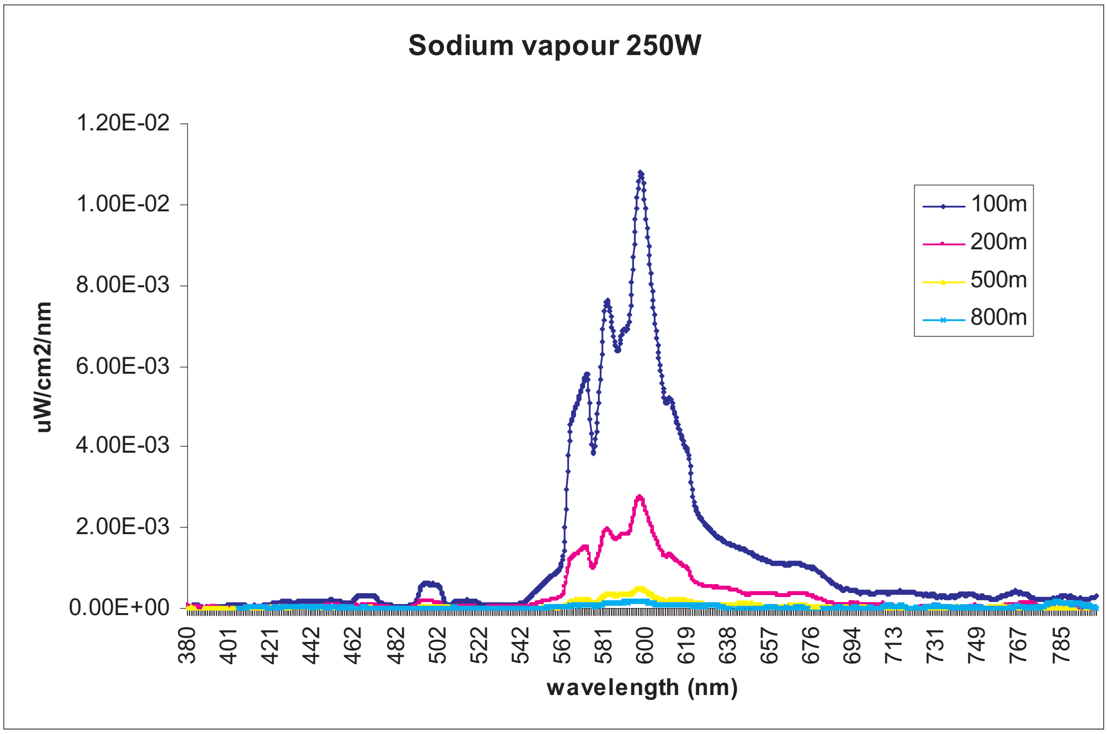


Figure 3: 250 W Sodium vapour light from 100 m, 200 m, 500 m and 800 m arenas. Orange shading covers region of the spectrum that is included in the photometric Lux measurements.

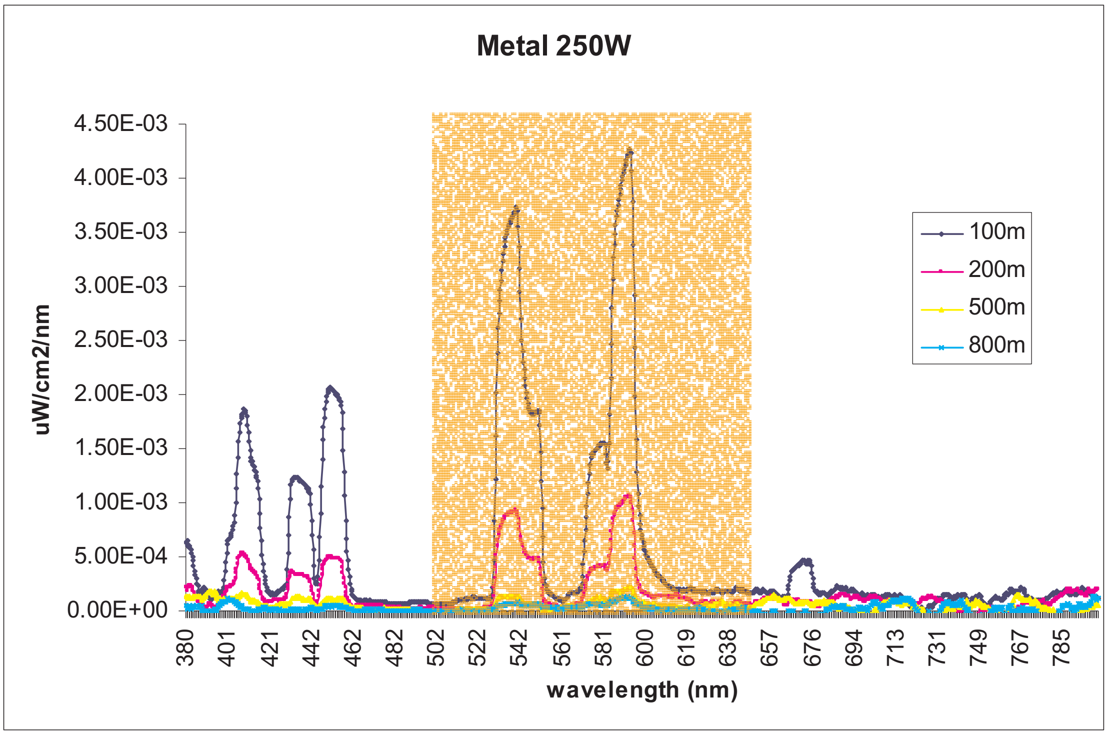


Figure 4: 250 W Metal halide light from 100 m, 200 m, 500 m and 800 m arenas. Orange shading covers region of the spectrum that is included in the photometric Lux measurements.

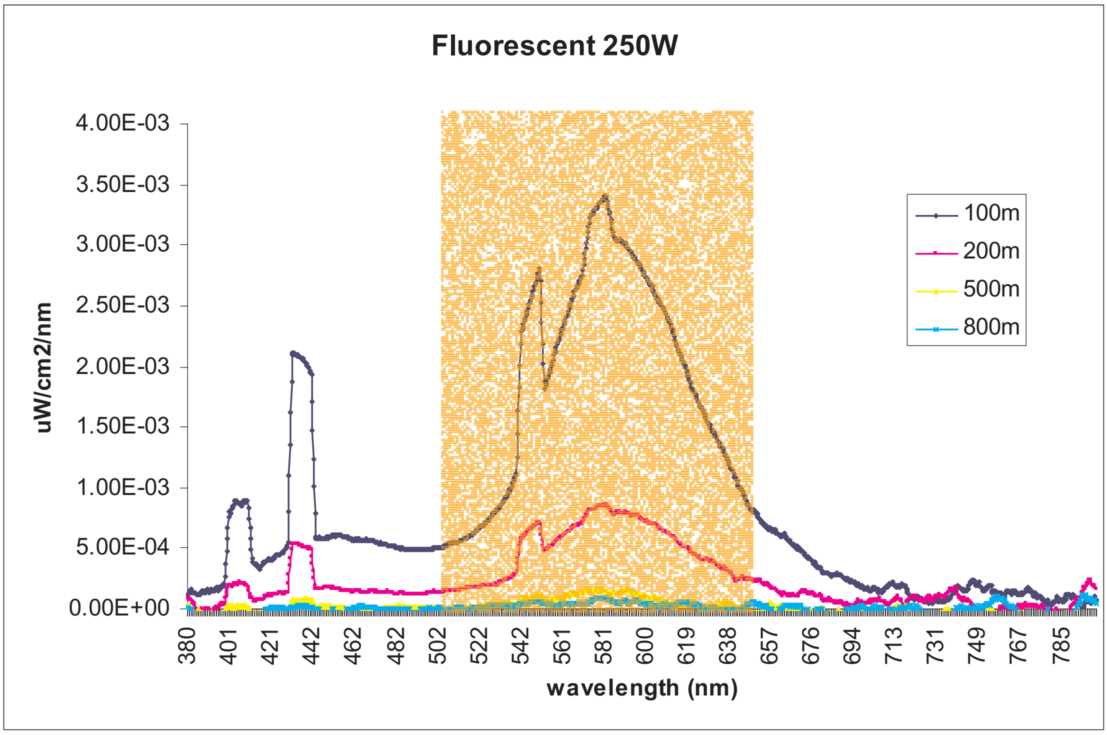


Figure 5: 250 W Fluorescent light from 100 m, 200 m, 500 m and 800 m arenas. Orange shading covers region of the spectrum that is included in the photometric Lux measurements.

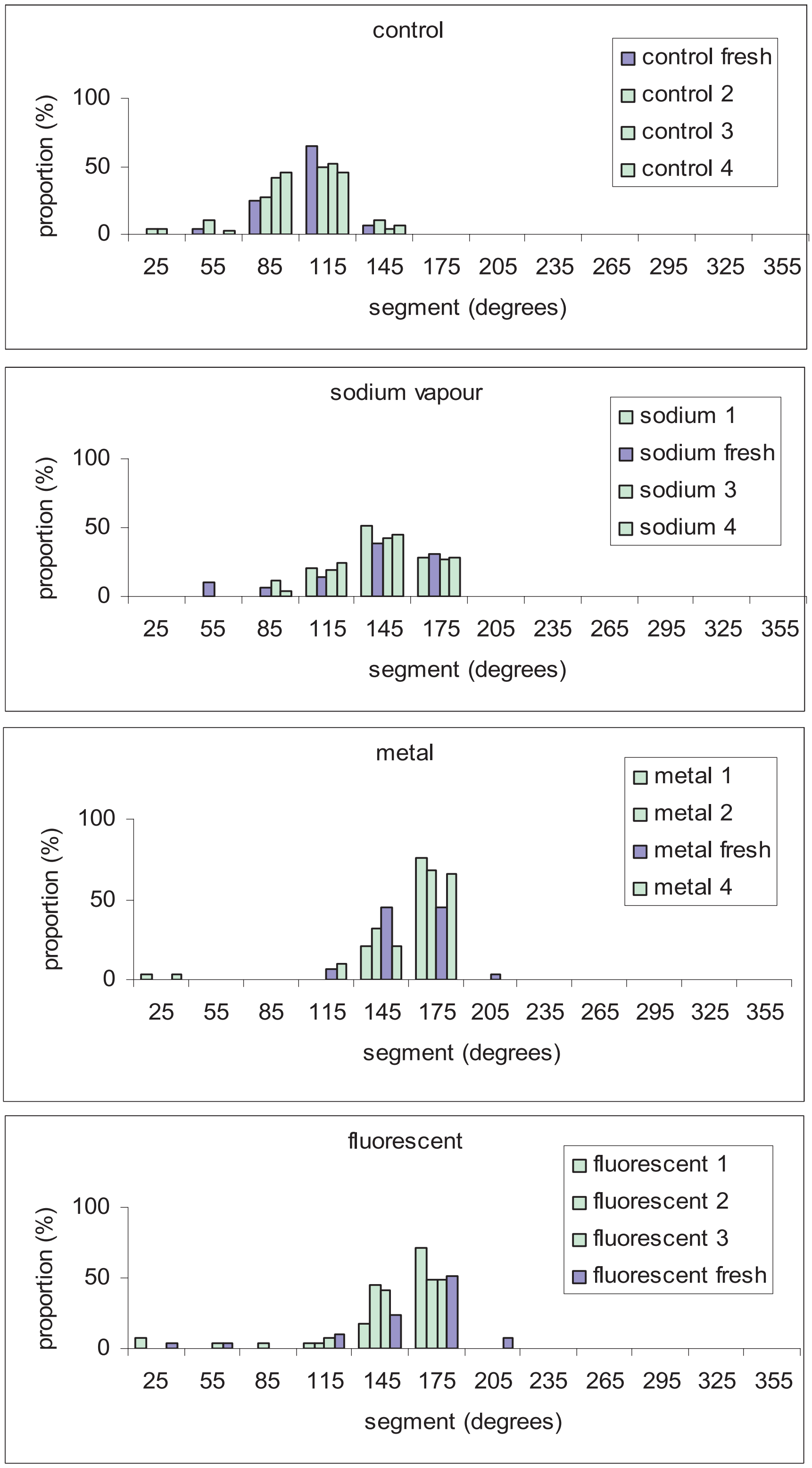
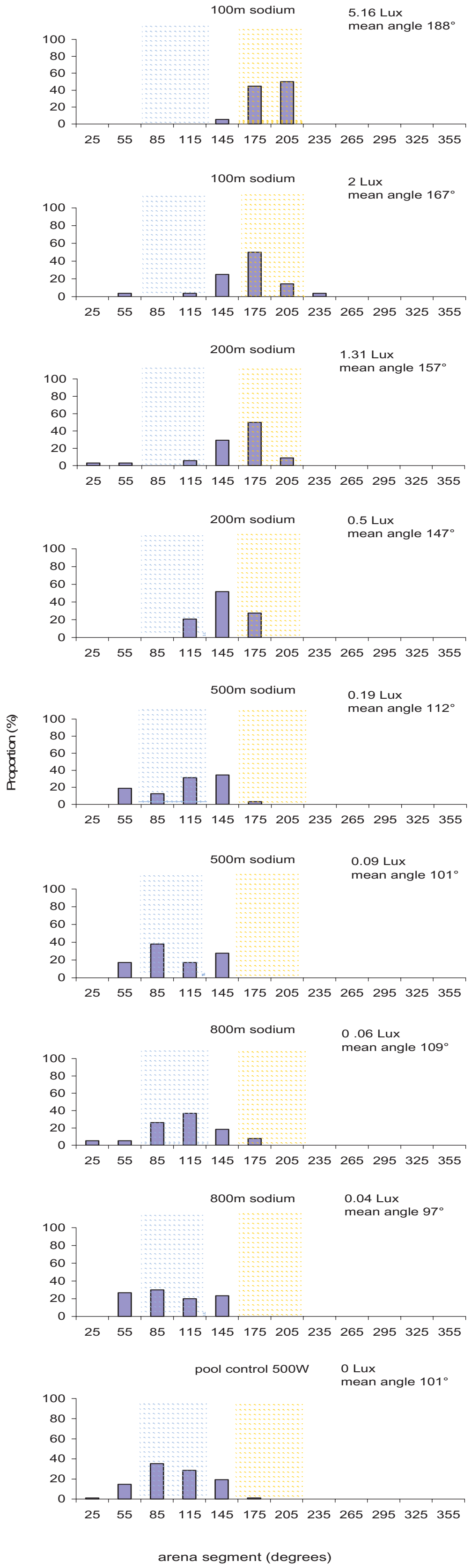
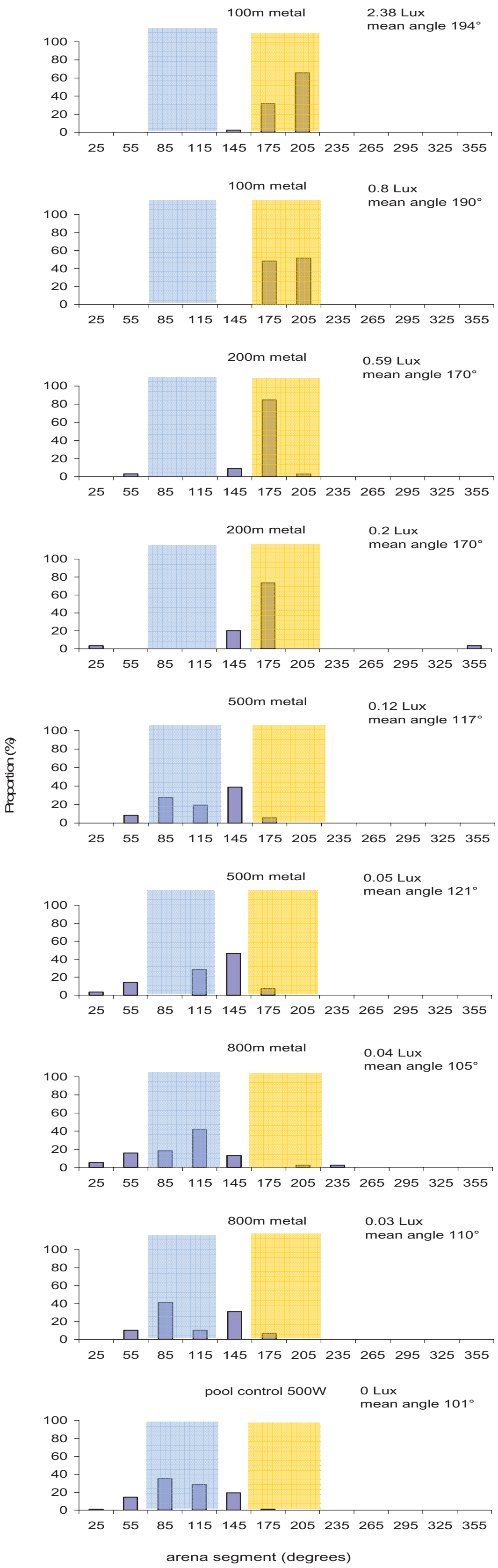


Figure 6: 250 W multiuse trials. Numbers in legend represent bag number (see Section 2.3 for details)



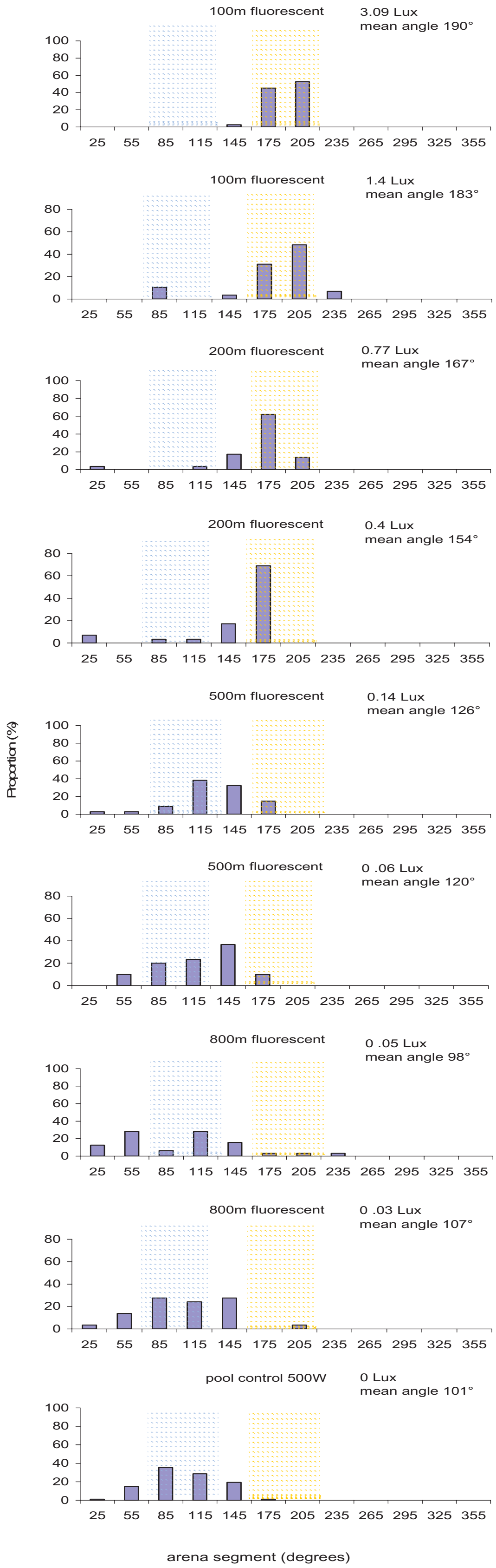
wattage	p value codes	significance of difference relative to controls
500W	***	strong difference
250W	***	strong difference
500W	***	strong difference
250W	***	strong difference
500W	*	slight differnce
250W		no difference
500W		no difference
250W		no difference

Figure 7: Plots of sodium vapour arena results, 250 W and 500 W trials sorted by Lux value. Blue wash represent the arena segments oriented most closely to the ocean, yellow wash represents the arena segments oriented towards the light array.



wattage	p value size	difference relative to pooled controls
500W	***	strong difference
250W	***	strong difference
500W	***	strong difference
250W	***	strong difference
500W	*	slight difference
250W	**	moderate difference
500W		no difference
250W		no difference

Figure 8: Plots of metal halide arena results, 250 W and 500 W trials sorted by Lux value. Blue wash represent the arena segments oriented most closely to the ocean, yellow wash represents the arena segments oriented towards the light array



wattage	p value size	difference relative to pooled controls
500W	***	strong difference
250W	***	strong difference
500W	***	strong difference
250W	***	strong difference
500W	*	slight difference
250W		no difference
500W	*	slight difference
250W		no difference

Figure 9: Plots of fluorescent arena results, 250 W and 500 W trials sorted by Lux value. Blue wash represent the arena segments oriented most closely to the ocean, yellow wash represents the arena segments oriented towards the light array

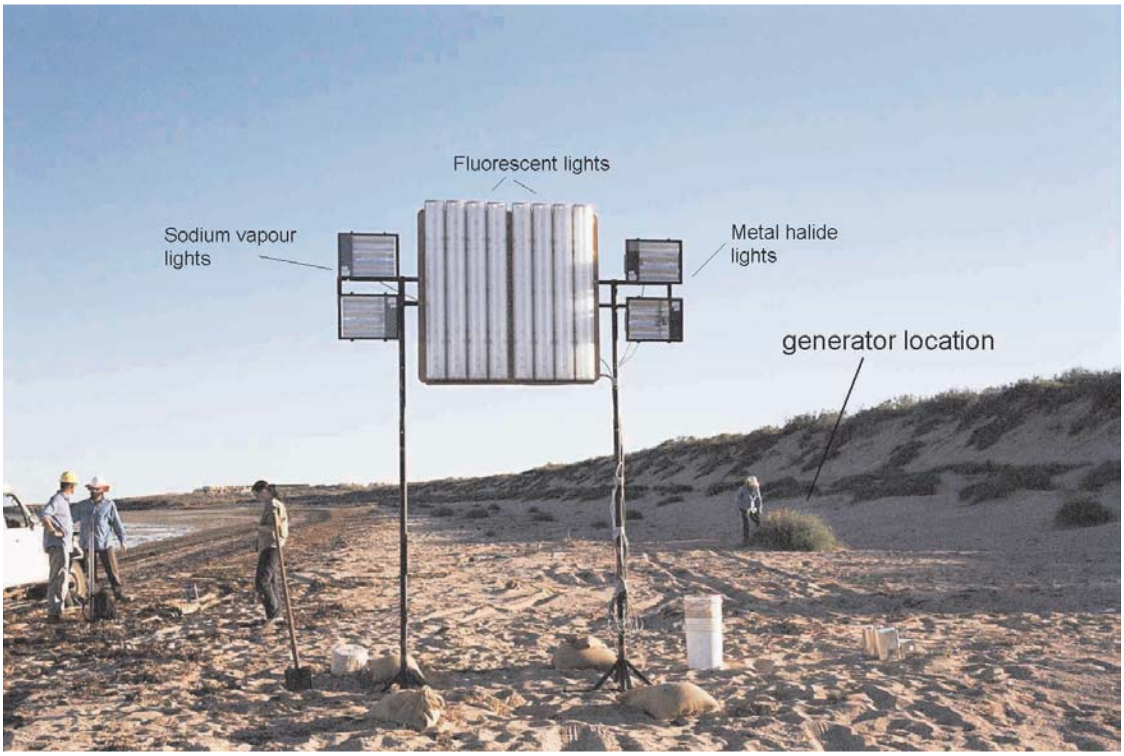


Plate 1: Light array set up for light trials (photo K Pendoley)

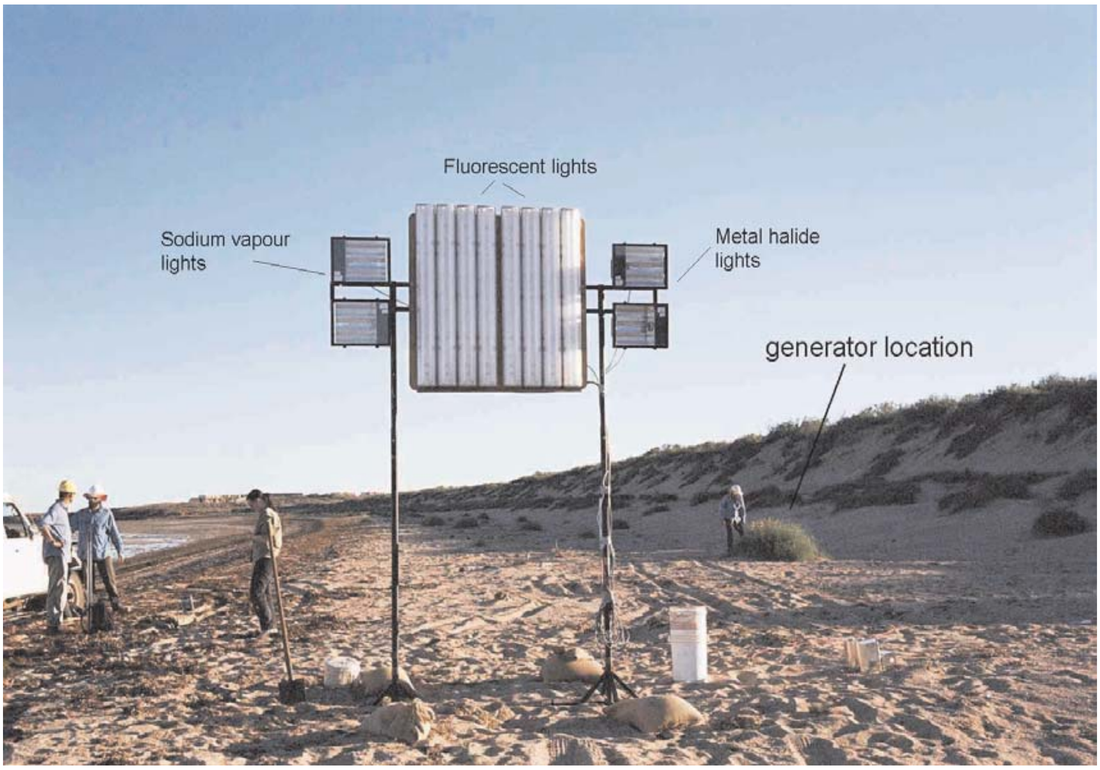


Plate 2: Light array set up for glow trials. (photo A Vitenbergs)

Arachnid and Myriapod Taxa collected from survey

Appendix 2

Appendix 2: Fauna collected from Barrow Island Invertebrate survey (M – male, F – female, J – juvenile).

CLASS	ORDER	FAMILY	GENUS	SPECIES	SITE CODE	NO.	METHOD
Arachnida	Acari			sp 1	LMAC1	1	Wet pitfalls
Arachnida	Acari			sp 2.	MLAC2	1	Wet pitfalls
Arachnida	Acari			sp 3.	QUCA	1	Wet pitfalls
Arachnida	Acari			sp 4.	QUNA1	1	Wet pitfalls
Arachnida	Acari	Caeculidae			LMAC2	1	Wet pitfalls
Arachnida	Acari	Caeculidae			TLAC1	1	Wet pitfalls
Arachnida	Acari	Ixodidae	*Amblyomma*	*triguttatum*	Basecamp	2F	Hand col.
Arachnida	Acari	Ixodidae	*Amblyomma*		LMAD1	1J	Wet pitfalls
Arachnida	Acari	Ixodidae	*Amblyomma*		TLTP1	1J	Wet pitfalls
Arachnida	Acari	Ixodidae	*Amblyomma*		QUOA1	1J	Wet pitfalls
Arachnida	Acari	Trombiidae			AVAC1	4	Wet pitfalls
Arachnida	Acari	Trombiidae			LMAC2	3	Wet pitfalls
Arachnida	Acari	Trombiidae			MLIA2	1	Wet pitfalls
Arachnida	Acari	Trombiidae			MLNI1	1	Wet pitfalls
Arachnida	Acari	Trombiidae			MLNI2	2	Wet pitfalls
Arachnida	Acari	Trombiidae			QUBL2	1	Wet pitfalls
Arachnida	Araneae	Araneidae	*Austracantha*	*minax*	LMAD1	1F	Hand col.
Arachnida	Araneae	Corrinidae	*Supunna*	*picta (c.f)*	AVAC1	1F	Wet pitfalls
Arachnida	Araneae	Corrinidae	*Supunna*	*picta (c.f)*	AVAC2	1M	Wet pitfalls
Arachnida	Araneae	Corrinidae	*Supunna*	*picta (c.f)*	AVNI2	1M	Wet pitfalls
Arachnida	Araneae	Corrinidae	*Supunna*	*picta (c.f)*	TLTP1	1F	Wet pitfalls
Arachnida	Araneae	Filistatidae	*Wandella*	sp 1.	AVAC2	1M	Wet pitfalls
Arachnida	Araneae	Filistatidae	*Wandella*	sp 1.	LMNI1	1M	Wet pitfalls
Arachnida	Araneae	Filistatidae	*Wandella*	sp 1.	MLNI1	1M	Wet pitfalls
Arachnida	Araneae	Filistatidae	*Wandella*	sp 1.	TLTP1	1M	leaf litter
Arachnida	Araneae	Gnaphosidae		sp 1.	QUOA1	1M	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 2.	AVNI2	1M	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 2.	QUOA1	1M	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 3.	MLAC2	1M	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 4.	AVIA1	1M	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 4.	QUBL2	1M	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 5	AVNI1	1M	Wet pitfalls

CLASS	ORDER	FAMILY	GENUS	SPECIES	SITE CODE	NO.	METHOD
Arachnida	Araneae	Gnaphosidae		sp 6	MLAC1	1M	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 7	Whites Beach	2F	leaf litter
Arachnida	Araneae	Gnaphosidae		sp 8	AVAC1	1F	Wet pitfalls
Arachnida	Araneae	Gnaphosidae		sp 9	MLIA2	1M	Wet pitfalls
Arachnida	Araneae	Lamponidae	*Lampona*	*ampeinna*	MLIA1	1M	Wet pitfalls
Arachnida	Araneae	Lamponidae	*Lamponina*	*scutata*	MLIA2	1M	Wet pitfalls
Arachnida	Araneae	Lamponidae	*Notsodipus*	sp 1.	TLTP1	1F	Wet pitfalls
Arachnida	Araneae	Lycosidae	*Venator*	sp 1	Yacht Club Beach	1M	Head torch
Arachnida	Araneae	Oecobiidae	*Oecobius*	*navus*	LMIA2	1M	Wet pitfalls
Arachnida	Araneae	Oecobiidae	*Oecobius*	*navus*	QUWH1	4M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Gamasomorpha*	sp 1	LMAC1	1M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Gamasomorpha*	sp 1	LMAC2	1M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Gamasomorpha*	sp 2.	LMIA2	1M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Grymeus*	sp 1	TLNI3	1M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Myrmopopaea*	sp 1	AVAC2	1M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Myrmopopaea*	sp 1	MLIA1	1M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Myrmopopaea*	sp 1	MLNI1	1M	Wet pitfalls
Arachnida	Araneae	Oonopidae	*Opopaea*	sp 1	LMNI1	2M	Wet pitfalls
Arachnida	Araneae	Oxyopidae		sp 1	QUCA	1F	Wet pitfalls
Arachnida	Araneae	Oxyopidae		sp 2.	QUOA1	1M	Wet pitfalls
Arachnida	Araneae	Pholcidae	*Trichocyclus*	sp 1	QUCA	1F	Wet pitfalls
Arachnida	Araneae	Pholcidae	*Trichocyclus*	*nigropunctatus*	TLAC1	1F	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	AVIA2	1F	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	AVNI1	1M	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	AVNI2	1M, 1F	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	LMAD1	1M	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	MLIA2	1M	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	MLNI2	1F	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	QUBL2	2M	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	QUNA1	2M, 1F	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 1	QUOA1	1F	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 2.	LMAD1	1F	Wet pitfalls
Arachnida	Araneae	Prodidomidae		sp 2.	MLAC2	1F	Wet pitfalls

CLASS	ORDER	FAMILY	GENUS	SPECIES	SITE CODE	NO.	METHOD
Arachnida	Araneae	Salticidae	*Clynotis*	*albobarbatus - group*	MLIA1	1F	leaf litter
Arachnida	Araneae	Salticidae	*Grayenulla*	*waldochae*	LMIA1	1M	Wet pitfalls
Arachnida	Araneae	Salticidae	*Grayenulla*	*waldochae*	QUBL2	1M	Wet pitfalls
Arachnida	Araneae	Salticidae	*Grayenulla*	*waldochae*	TLAC1	1M	Wet pitfalls
Arachnida	Araneae	Salticidae	*Grayenulla*	*waldochae*	TLNI3	1M	Wet pitfalls
Arachnida	Araneae	Salticidae	*Lycidas*	sp 1.	TLIA1	1M	Wet pitfalls
Arachnida	Araneae	Salticidae	*Pellenes*	sp 1.	QUCA	1F	Wet pitfalls
Arachnida	Araneae	Salticidae	*Zenodorus*	sp 1.	Flacourt Bay	1F	leaf litter
Arachnida	Araneae	Selenopidae		sp 1.	MLNI2	1F	Hand col.
Arachnida	Araneae	Selenopidae		sp 2.	LMNI1	2M	Wet pitfalls
Arachnida	Araneae	Sparassidae	*Neosparassus*	sp 1.	LMAD1	1M	Leaf litter
Arachnida	Araneae	Tetragnathidae		sp 1.	TLAC1	1M	Wet pitfalls
Arachnida	Araneae	Thomisidae	*Stephanopis*	sp 1.	LMIA2	3F	Leaf litter
Arachnida	Araneae	Thomisidae	*Tharpyna*	sp 1.	AVIA1	1M	Wet pitfalls
Arachnida	Araneae	Zodariidae		sp 1.	MLNI2	1F	leaf litter
Arachnida	Araneae	Zoridae		sp 1.	AVIA2	1M	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 1.	AVNI2	1M	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 1.	MLNI1	2M	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 1.	TLNI1	1M	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 1.	TLNI3	1M	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 1.	TLTP1	1M	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 2.	TLNI2	2F	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 3.	LMNI1	1F	Wet pitfalls
Arachnida	Araneae	Zoridae		sp 4.	AVNI1	1F	Wet pitfalls
Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium*	sp 1.	LMAC2	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium*	sp 1.	LMIA2	1	Wet pit
Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium*	sp 1.	MLAC2	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Indolpium*	sp 1.	QUBL1	1	Wet pitfalls
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	Flacourt Bay	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	LMAD1	1	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	LMIA2	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	LMIA2	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	MLIA1	2	Leaf litter

CLASS	ORDER	FAMILY	GENUS	SPECIES	SITE CODE	NO.	METHOD
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	MLNI1	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	MLNI1	3	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	MLNI2	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	TLAC1	1	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	TLIA1	1	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	TLNI2	9	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	TLTP1	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	Valley of Giants	1	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp 1.	Whites Beach	2	Leaf litter
Arachnida	Pseudoscorpiones	Olpiidae	Genus 1	sp 1.	LMAC2	1M	Leaf litter
Arachnida	Scorpiones	Buthidae	*Archisometrus*	sp 1.	MLNI1	1M	Wet pitfalls
Arachnida	Scorpiones	Buthidae	*Archisometrus*	sp 1.	QUBL1	1M	Wet pitfalls
Arachnida	Scorpiones	Buthidae	*Archisometrus*	sp 2.	LMIA2	1F	Leaf litter
Arachnida	Scorpiones	Buthidae	*Archisometrus*	sp 2.	TLTP1	1M	Leaf litter
Arachnida	Scorpiones	Buthidae	*Archisometrus*	sp 2.	Whites Beach	1J	Leaf litter
Myriapoda	Geophiliida				MLNI1	1	Leaf litter
Myriapoda	Scolopendrida	Scolopendridae	*Ethmostigmus*	*curtipes*	MLAC2	1	Wet pitfalls
Myriapoda	Scolopendrida	Scolopendridae	*Ethmostigmus*	*curtipes*	QUBL1	1	Wet pitfalls
Myriapoda	Scolopendrida	Scolopendridae	*Scolopendra*	*laeta*	LMNI1	1J	Wet pitfalls
Myriapoda	Scutigerida	Scutigeridae	*Allothereua*		LMIA2	1J	Leaf litter
Myriapoda	Scutigerida	Scutigeridae	*Allothereua*		TLNI2	1J	Leaf litter
Myriapoda	Polyxenida	Synxenidae			AVAC2	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			AVNI1	2	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			AVNI2	2	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			LMIA2	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			MLIA1	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			MLIA2	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			MLNI2	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			QUBL1	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			TLAC1	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			TLNI3	1	Wet pitfalls
Myriapoda	Polyxenida	Synxenidae			TLTP1	2	Wet pitfalls

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List of Taxa recorded from Barrow Island

Appendix 3

Appendix 3. List of families, genera, and species recorded from Barrow Island (Species in bold are Endemic to Barrow Island).

ORDER	FAMILY	GENUS	SPECIES
Acari	Anystidae	*Erythracarus*	*decoris*
Acari	Argasidae	*Argas*	*`persicus`*
Acari	Argasidae	*Ornithodoros*	*gurneyi*
Acari	Caeculidae		
Acari	Ixodidae	*Amblyomma*	*limbatum*
Acari	Ixodidae	*Amblyomma*	*triguttatum*
Acari	Ixodidae	*Haemaphysalis*	*ratti*
Acari	Laelapidae	***Haemolaelaps***	***marsupialis***
Acari	Laelapidae	***Mesolaelaps***	***antipodianus***
Acari	Trombiidae		
Araneae	Ammoxenidae	***Barrowammo***	***waldockae***
Araneae	Araneidae	*Argiope*	*protensa*
Araneae	Araneidae	*Argiope*	*trifasciata*
Araneae	Araneidae	*Austracantha*	*minax*
Araneae	Araneidae	*Larinia*	
Araneae	Barychelidae	***Synothele***	***butleri***
Araneae	Clubionidae	*Cheiracanthium*	
Araneae	Clubionidae	*Clubiona*	
Araneae	Ctenizidae	*Conothele*	
Araneae	Deinopidae	*Deinopis*	
Araneae	Desidae	*Badumna*	
Araneae	Filistatidae	*Wandella*	
Araneae	Gallieniellidae	*Meedo*	*houstoni*
Araneae	Gnaphosidae	*Ceryerda*	
Araneae	Lamponidae	*Lampona*	*ampeinna*
Araneae	Lamponidae	*Lamponina*	*scutata*
Araneae	Lamponidae	*Notsodipus*	
Araneae	Lycosidae	*Hogna*	*kuyanii*
Araneae	Lycosidae	*Lycosa*	*clara*
Araneae	Lycosidae	*Lycosa*	*laeta*
Araneae	Lycosidae	*Lycosa*	*snelli*
Araneae	Lycosidae	*Venator*	
Araneae	Micropholcommatidae	*Textricella*	
Araneae	Miturgidae	*Miturga*	*occidentalis*
Araneae	Miturgidae	***Miturga***	***serrata***
Araneae	Mysmenidae		
Araneae	Nemesiidae	*Aname*	*mainae group*
Araneae	Oecobiidae	*Oecobius*	*navus*
Araneae	Oonopidae	*Gamasomorpha*	
Araneae	Oonopidae	*Grymeus*	*`nasutus`*
Araneae	Oonopidae	*Myrmopopaea*	
Araneae	Oonopidae	*Opopaea*	
Araneae	Oonopidae	***Orchestina***	***`barrow`***
Araneae	Pholcidae	*Crossopriza*	*lyoni*
Araneae	Pholcidae	*Trichocyclus*	*aranda*
Araneae	Pholcidae	*Trichocyclus*	*nigropunctatus*
Araneae	Prodidomidae	***`Wydundra`***	***`barrow`***
Araneae	Prodidomidae	*Prodidomus*	*`woodleigh`*

ORDER	FAMILY	GENUS	SPECIES
Araneae	Salticidae	*Clynotis*	*albobarbatus - group*
Araneae	Salticidae	*Cytaea*	
Araneae	Salticidae	*Grayenulla*	
Araneae	Salticidae	*Holoplatys*	
Araneae	Salticidae	*Jotus*	
Araneae	Salticidae	*Lycidas*	
Araneae	Salticidae	*Pellenes*	
Araneae	Salticidae	*Zenodorus*	
Araneae	Segestriidae		
Araneae	Selenopidae		
Araneae	Sparassidae	*Heteropoda*	*hermitis*
Araneae	Sparassidae	*Irileka*	*iridescens*
Araneae	Sparassidae	*Neosparassus*	
Araneae	Tengellidae	*Bengalla*	
Araneae	Tetragnathidae	*Nephila*	*edulis*
Araneae	Tetragnathidae	*Tetragnatha*	
Araneae	Theridiidae	*Argyrodes*	*`antipodiana` group*
Araneae	Theridiidae	*Euryopsis*	
Araneae	Theridiidae	*Icona*	
Araneae	Theridiidae	*Latrodectus*	*hasseltii*
Araneae	Thomisidae	*Stephanopis*	
Araneae	Thomisidae	*Tharpyna*	
Araneae	Trochanteriidae	*Morebilus*	*diversus*
Araneae	Zodariidae	*Asteron*	
Araneae	Zodariidae	*Australutica*	
Araneae	Zodariidae	*Habronestes*	
Araneae	Zodariidae	*Minasteron*	*minusculum*
Araneae	Zodariidae	*Nostera*	
Araneae	Zodariidae	*Spinasteron*	*`harveyi`*
Araneae	Zoridae	*Argoctenus*	
Pseudoscorpiones	Chernetidae	*Nesidiochernes*	
Pseudoscorpiones	Garypidae	***Anagarypus***	***heatwolei***
Pseudoscorpiones	Garypidae	***Synsphyronus***	***sp. nov. `barrow`***
Pseudoscorpiones	Olpiidae	*Austrohorus*	
Pseudoscorpiones	Olpiidae	*Indolpium*	
Pseudoscorpiones	Olpiidae	*Xenolpium*	
Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*
Scorpiones	Buthidae	*Archisometrus*	
Scorpiones	Buthidae	*Isometroides*	*`multipunctata`*
Scorpiones	Urodacidae	***Urodacus***	***sp. nov. `barrow`***
Scolopendrida	Scolopendridae	*Arthrorhabdus*	*mjobergi*
Scolopendrida	Scolopendridae	*Cormocephalus*	*strigosus*
Scolopendrida	Scolopendridae	*Ethmostigmus*	*curtipes*
Scolopendrida	Scolopendridae	*Scolopendra*	*laeta*
Scolopendrida	Scolopendridae	*Scolopendra*	*morsitans*
Scutigerida	Scutigeridae	*Allothereua*	*leuseuri*
Geophilida	Oryidae		
Polydesmida	Pachybolidae	***Speleostrophus***	***nesiotes***
Polydesmida	Paradoxosomatidae		
Polyxenida	Polyxenidae	*Unixenus*	

ORDER	FAMILY	GENUS	SPECIES
Polyxenida	Synxenidae		

Attachment 2 - Invertebrate Specimens Collected from Systematic and Opportunistic Sampling

CLASS	ORDER	FAMILY	GENUS	SPECIES	SITE CODE	SPECIMENS	REGISTRATION No.
Arachnida	Araneae	Araneidae	*Austracantha*	*minax*	BIHT01	1 M, 5 F, 1 J	T57725
Arachnida	Araneae	Deinopidae	*Deinopis*		BIMBO2	1 M	T57724
Arachnida	Araneae	Deinopidae	*Deinopis*		BIMBO6	1 M	T57723
Arachnida	Araneae	Gnaphosidae			BI1.21	1 F	T57716
Arachnida	Araneae	Gnaphosidae	*Ceryerda*		BITP1	1 F	T57715
Arachnida	Araneae	Lamponidae	*Lamponina*	*scutata*	BIMBO1	1 M	T57721
Arachnida	Araneae	Lamponidae	*Lamponina*	*scutata*	BIMBO5	1 M	T57722
Arachnida	Araneae	Lycosidae	*Hogna*	*kuyanii group*	BIHT05	1M, 4 F	T57692 to 57696
Arachnida	Araneae	Lycosidae	*Hoggicosa*	*bicolor*	BIHT16	2	T57697 to 57698
Arachnida	Araneae	Lycosidae	*Lycosa*	*clara*	BIMBO2		T58762
Arachnida	Araneae	Lycosidae	*Venator*	sp1	BIHT01	16	T57673 to 57681
Arachnida	Araneae	Lycosidae	*Venator*	sp1	BIMBO3	18	T57691
Arachnida	Araneae	Lycosidae	*Venator*	sp1	BIMBO4	3	T57689
Arachnida	Araneae	Lycosidae	*Venator*	sp1	BIMBO5	24	T57690
Arachnida	Araneae	Miturgidae			BIMBO1	1 F	T57714
Arachnida	Araneae	Miturgidae			BIMBO2	5 M, 1F , 1J	T57712
Arachnida	Araneae	Miturgidae			BIMBO3	5	T57707
Arachnida	Araneae	Miturgidae			BIMBO4	4 M	T57708 to 57710
Arachnida	Araneae	Miturgidae			BIMBO5	3 M, 1 J	T57711
Arachnida	Araneae	Miturgidae			BIMBO6	1 M, 2 J	T57713
Arachnida	Araneae	Nemesiidae			BIHT11-BIHT15	7J	Not registered
Arachnida	Araneae	Oonopidae	*Opopaea*		BI1.21	1 M, 1 F	T57726
Arachnida	Araneae	Salticidae	*Lycidas*	sp2	BI3.11	1 F	T57718
Arachnida	Araneae	Salticidae	*Lycidas*	sp1	BI3.11	1 F	T57717
Arachnida	Araneae	Sparassidae	*Heteropoda*	*hermitis*	BIHT01	1M	T57701
Arachnida	Araneae	Sparassidae	*Heteropoda*	*hermitis*	BIHT04	2 M, 1 F	T57699 to 57702
Arachnida	Araneae	Sparassidae	*Neosparassus*	sp1	BI3.5	1 M	T57703

CLASS	**ORDER**	**FAMILY**	**GENUS**	**SPECIES**	**SITE CODE**	**SPECIMENS**	**REGISTRATION No.**
Arachnida	Araneae	Sparassidae	*Neosparassus*	sp1	BIHT02	1 M	T57704
Arachnida	Araneae	Sparassidae	*Neosparassus*	sp2	BIHT01	1 F	T57706
Arachnida	Araneae	Sparassidae	*Neosparassus*	sp2	BIMBO4	1 M	T57705
Arachnida	Araneae	Theridiidae			BIHT10	1 F	T57729
Arachnida	Araneae	Theridiidae	*Euryopis*		BI1.21	1 M	T57728
Arachnida	Araneae	Thomisidae	*Stephanopis*		BI3.1	1 F	T57719
Arachnida	Araneae	Thomisidae	*Tharpyna*		BI1.21	2 M	T57720
Arachnida	Araneae	Zodariidae			BIIT4	1 F	T57727
Arachnida	Pseudoscorpiones	Garypidae	*Synsphyronus*	sp. Nov. `*barrow*`	BI1.41	1	T57749
Arachnida	Pseudoscorpiones	Olpiidae	*Austrohorus*		BIHT06	1 F	T57746
Arachnida	Pseudoscorpiones	Olpiidae	*Austrohorus*		BIHT07	1	T57747
Arachnida	Pseudoscorpiones	Olpiidae	*Austrohorus*		BIHT09	1 J	T57748
Arachnida	Pseudoscorpiones	Olpiidae	*Austrohorus*		BITP1	1 F	T57745
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp1	BIHT07	1 F	T57740
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp1	BIHT08	1 M, 2 F, 2 J	T57741 to 57742
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp2	BIIT8	1 M	T57744
Arachnida	Pseudoscorpiones	Olpiidae	*Xenolpium*	sp2	BIHT06	1 F	T57743
Arachnida	Scorpiones	Buthidae	*Isometroides*	*multipunctata*	BI1.21	1	T57752
Arachnida	Scorpiones	Buthidae	*Isometroides*	*multipunctata*	BIHT10	2	T57753 to 57754
Arachnida	Scorpiones	Buthidae	*Isometroides*	*multipunctata*	BIMBO4	1	T57750
Arachnida	Scorpiones	Buthidae	*Isometroides*	*multipunctata*	BIMBO5	1	T57751
Arachnida	Scorpiones	Urodacidae	*Urodacus*	sp. Nov. '*barrow*`	BIMBO1	1	T57739
Chilopoda	Scolopendrida	Polyxenidae	*unixenis*		BI3.7	1	T57738
Chilopoda	Scolopendrida	Scolopendridae	*Ethmostigmus*	*curtipes*	BIMBO4	1	T57732
Chilopoda	Scolopendrida	Scolopendridae	*Ethmostigmus*	*curtipes*	BIMBO5	1	T57733
Chilopoda	Scolopendrida	Scolopendridae	*Scolopendra*	*laeta*	BIAP3	1	T57737
Chilopoda	Scolopendrida	Scolopendridae	*Scolopendra*	*laeta*	BIMBO1	1	T57734
Chilopoda	Scolopendrida	Scolopendridae	*Scolopendra*	*laeta*	BIMBO2	1	T57736
Chilopoda	Scolopendrida	Scolopendridae	*Scolopendra*	*laeta*	BIMBO3	1	T57735
Chilopoda	Scutigerida	Scutigeridae	*Allothereua*	*leuseuri*	BIMBO2	1	T57731

CLASS	ORDER	FAMILY	GENUS	SPECIES	SITE CODE	SPECIMENS	REGISTRATION No.
Chilopoda	Scutigerida	Scutigeridae	*Allothereua*	*leuseuri*	BIMBO4	1	T57730
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BITP1	4 (live)1(dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BI3.1	1 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BI3.3	7 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BIOP1	8 (live) 8(dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BIOP2	11(live) 24(dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BIOP3	2 (live) 2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BI1.19	3 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BIOP4	20 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BI1.29	1 (live)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BIOP7	3 (live) 9 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp1	BI1.25	1 (live) 5 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BITP1	1 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BITP4	7 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI3.1	1 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BIOP1	2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BIOP2	7 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BIOP3	2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI1.19	2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI3.5	1 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI3.10	1 (live)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BIOP5	2 (live)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BIAP1	2 (live) 1 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI3.11	3 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI3.9	1 (live) 2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI3.3	1 (live)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BIAP2	1 (live)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BI1.26	1 (live) 2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Rhagada*	sp2	BIOP8	1 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BITP1	9 (live)	

CLASS	ORDER	FAMILY	GENUS	SPECIES	SITE CODE	SPECIMENS	REGISTRATION No.
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BITP2	5 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BITP4	5 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI3.1	2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI3.3	1 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.19	2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI3.5	4 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI3.10	5 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BIOP5	2 (live) 3 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BIAP1	1 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI3.11	2 (live) 7 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI3.9	1 (live) 3 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BIAP2	5 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.21	4 (live) 1 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BIOP6	2 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.29	6 (live)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.24	5 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.28	2 (live) 2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.26	1 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.27	2 (dead)	
Gastropoda	Pulmonata	Camaenidae	*Quistrachia*	*barrowensis*	BI1.22	2 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI3.1	3 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI3.3	9 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI3.5	16 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI3.11	10 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI3.9	10 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.21	6 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.24	20 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.28	8 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.26	11 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.25	28 (dead)	

CLASS	**ORDER**	**FAMILY**	**GENUS**	**SPECIES**	**SITE CODE**	**SPECIMENS**	**REGISTRATION No.**
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.23	3 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BIOP8	4 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.27	15 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.41	12 (dead)	
Gastropoda	Pulmonata	Pupillidae	*Pupoides*		BI1.22	7 (dead)	

Attachment 3 - Registered Species Collected from Barrow Island (Species in bold are Endemic to Barrow Island)

ORDER	FAMILY	GENUS	SPECIES
Acari	Anystidae	*Erythracarus*	*decoris*
Acari	Argasidae	*Argas*	*`persicus`*
Acari	Argasidae	*Ornithodoros*	*gurneyi*
Acari	Caeculidae		
Acari	Ixodidae	*Amblyomma*	*limbatum*
Acari	Ixodidae	*Amblyomma*	*triguttatum*
Acari	Ixodidae	*Haemaphysalis*	*ratti*
Acari	Laelapidae	***Haemolaelaps***	***marsupialis***
Acari	Laelapidae	***Mesolaelaps***	***antipodianus***
Acari	Trombiidae		
Araneae	Ammoxenidae	***Barrowammo***	***waldockae***
Araneae	Araneidae	*Argiope*	*protensa*
Araneae	Araneidae	*Argiope*	*trifasciata*
Araneae	Araneidae	*Austracantha*	*minax*
Araneae	Araneidae	*Larinia*	
Araneae	Barychelidae	***Synothele***	***butleri***
Araneae	Clubionidae	*Cheiracanthium*	
Araneae	Clubionidae	*Clubiona*	
Araneae	Ctenizidae	*Conothele*	
Araneae	Deinopidae	*Deinopis*	
Araneae	Desidae	*Badumna*	
Araneae	Filistatidae	*Wandella*	
Araneae	Gallieniellidae	*Meedo*	*houstoni*
Araneae	Gnaphosidae	*Ceryerda*	
Araneae	Lamponidae	*Lampona*	*ampeinna*
Araneae	Lamponidae	*Lamponina*	*scutata*
Araneae	Lamponidae	*Notsodipus*	
Araneae	Lycosidae	*Hogna*	*kuyanii*
Araneae	Lycosidae	*Lycosa*	*clara*
Araneae	Lycosidae	*Lycosa*	*laeta*
Araneae	Lycosidae	*Lycosa*	*snelli*
Araneae	Lycosidae	*Venator*	
Araneae	Micropholcommatidae	*Textricella*	
Araneae	Miturgidae	*Miturga*	*occidentalis*
Araneae	Miturgidae	***Miturga***	***serrata***
Araneae	Mysmenidae		
Araneae	Nemesiidae	*Aname*	*mainae group*
Araneae	Oecobiidae	*Oecobius*	*navus*
Araneae	Oonopidae	*Gamasomorpha*	
Araneae	Oonopidae	*Grymeus*	*`nasutus`*
Araneae	Oonopidae	*Myrmopopaea*	
Araneae	Oonopidae	*Opopaea*	
Araneae	Oonopidae	***Orchestina***	***`barrow`***
Araneae	Pholcidae	*Crossopriza*	*lyoni*
Araneae	Pholcidae	*Trichocyclus*	*aranda*
Araneae	Pholcidae	*Trichocyclus*	*nigropunctatus*
Araneae	Prodidomidae	***`Wydundra`***	***`barrow`***
Araneae	Prodidomidae	*Prodidomus*	*`woodleigh`*
Araneae	Salticidae	*Clynotis*	*albobarbatus* - group

ORDER	FAMILY	GENUS	SPECIES
Araneae	Salticidae	*Cytaea*	
Araneae	Salticidae	*Grayenulla*	
Araneae	Salticidae	*Holoplatys*	
Araneae	Salticidae	*Jotus*	
Araneae	Salticidae	*Lycidas*	
Araneae	Salticidae	*Pellenes*	
Araneae	Salticidae	*Zenodorus*	
Araneae	Segestriidae		
Araneae	Selenopidae		
Araneae	Sparassidae	*Heteropoda*	*hermitis*
Araneae	Sparassidae	*Irileka*	*iridescens*
Araneae	Sparassidae	*Neosparassus*	
Araneae	Tengellidae	*Bengalla*	
Araneae	Tetragnathidae	*Nephila*	*edulis*
Araneae	Tetragnathidae	*Tetragnatha*	
Araneae	Theridiidae	*Argyrodes*	*\`antipodiana\`* group
Araneae	Theridiidae	*Euryopsis*	
Araneae	Theridiidae	*Icona*	
Araneae	Theridiidae	*Latrodectus*	*hasseltii*
Araneae	Thomisidae	*Stephanopis*	
Araneae	Thomisidae	*Tharpyna*	
Araneae	Trochanteriidae	*Morebilus*	*diversus*
Araneae	Zodariidae	*Asteron*	
Araneae	Zodariidae	*Australutica*	
Araneae	Zodariidae	*Habronestes*	
Araneae	Zodariidae	*Minasteron*	*minusculum*
Araneae	Zodariidae	*Nostera*	
Araneae	Zodariidae	*Spinasteron*	*\`harveyi\`*
Araneae	Zoridae	*Argoctenus*	
Pseudoscorpiones	Chernetidae	*Nesidiochernes*	
Pseudoscorpiones	Garypidae	***Anagarypus***	***heatwolei***
Pseudoscorpiones	Garypidae	***Synsphyronus***	***sp. nov. \`barrow\`***
Pseudoscorpiones	Olpiidae	*Austrohorus*	
Pseudoscorpiones	Olpiidae	*Indolpium*	
Pseudoscorpiones	Olpiidae	*Xenolpium*	
Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*
Scorpiones	Buthidae	*Archisometrus*	
Scorpiones	Buthidae	*Isometroides*	*\`multipunctata\`*
Scorpiones	Urodacidae	***Urodacus***	***sp. nov. \`barrow\`***
Scolopendrida	Scolopendridae	*Arthrorhabdus*	*mjobergi*
Scolopendrida	Scolopendridae	*Cormocephalus*	*strigosus*
Scolopendrida	Scolopendridae	*Ethmostigmus*	*curtipes*
Scolopendrida	Scolopendridae	*Scolopendra*	*laeta*
Scolopendrida	Scolopendridae	*Scolopendra*	*morsitans*
Scutigerida	Scutigeridae	*Allothereua*	*leuseuri*
Geophilida	Oryidae		
Polydesmida	Pachybolidae	***Speleostrophus***	***nesiotes***
Polydesmida	Paradoxosomatidae		
Polyxenida	Polyxenidae	*Unixenus*	
Polyxenida	Synxenidae		

Attachment 4 - Genetic Diversity of Rhagada Land Snails on Barrow Island

Genetic diversity of *Rhagada* land snails on Barrow Island

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Summary

(a) Genetic analyses confirmed the presence of two genetically distinct species of *Rhagada* snails on Barrow Island: a smaller species restricted to the northern tip of the island, and a larger species widespread over the remainder of the island.
(b) These two species are genetically the most distinctive of all species of *Rhagada* examined from the Pilbara Region, highlighting the conservation value of Barrow Island for these endemic snails.
(c) Comparisons amongst 19 samples of the widespread large species revealed distinct populations, with unusually low levels of genetic subdivision, and no detectable geographic pattern on the island.
(d) No evidence was found to indicate that populations of these snails in the area of the proposed Gorgon development are genetically distinctive.

1. Introduction

Terrestrial invertebrates often have less capacity for dispersal and smaller geographic distributions than species of vertebrates (e.g., Harvey 2002). Limited dispersal and narrow distributions increase both the likelihood of locally distinct genetic forms and their vulnerability to extinction. Land snails are well recognised in both contexts (e.g., Ponder 1997).

In the Pilbara Region, the dominant group of land snails is the genus *Rhagada*, which is endemic to northern Western Australia (Solem 1997). Although mainland species tend to have distributions spanning hundreds of km, unique species restricted to islands have been described in the Dampier Archipelago (Solem 1997). There appear to be two species of *Rhagada* on Barrow Island, the smaller species being approximately 10 mm diameter, and the larger species about 20 mm diameter. These species have not been taxonomically described or assigned to any described species. The small species has been found only on the northern end of Barrow Island, whereas the large species is abundant and widespread over the rest of the island.

In this study, allozyme electrophoresis was used to examine genetic diversity of *Rhagada* on Barrow Island, to answer questions at three levels:

(a) Are the two apparent species on Barrow Island genetically distinct? Because shells can vary greatly among populations of the same species (e.g., Johnson *et al.* 1993; Johnson & Black 2000), independent genetic evidence for species distinctness is important for evaluating the relationships of the small and large forms.

(b) Are the species on Barrow Island genetically unique? Unusually high levels of genetic similarity have been found among species of *Rhagada* on the mainland and in the Dampier Archipelago (Johnson *et al.* 2004). Comparison of the species on Barrow Island with those from the Pilbara Region will determine whether the Barrow species are unique.

(c) How much genetic divergence is there among populations, and what is the pattern of that divergence, in the widespread larger species on Barrow Island? Are there genetically distinct groups of populations? Specifically, does the area of the proposed Gorgon development include genetically unique populations?

2. Methods

2.1 Samples

Samples of live, adult *Rhagada* were obtained between March and July 2004, at 21 sites, providing a good coverage of the island (Fig. 1). These included two samples of the small species, restricted to the northern portion of the island, and 19 of the large species, spanning the remainder of the island. Three of the samples of the large species were from the Gorgon area.

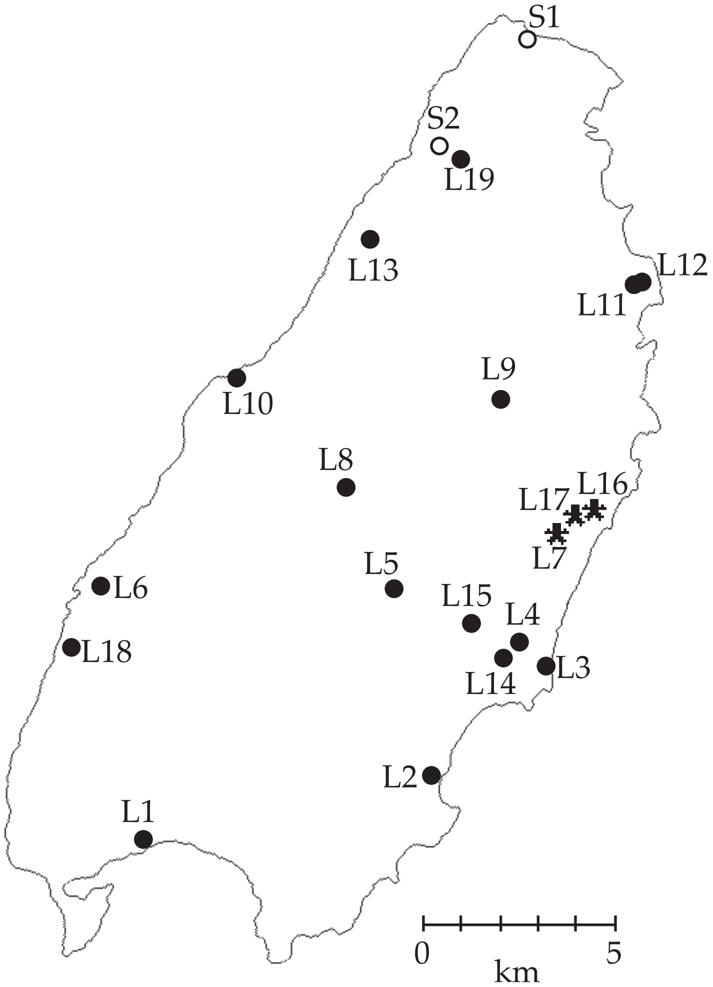

Figure 1. Sample sites of *Rhagada* on Barrow Island. Open circles = small species. Filled symbols = large species, with asterisk = Gorgon area.

In the laboratory, the snails were activated overnight, by placing them on moist tissue paper in sealed plastic boxes, and were then frozen at -80°C, pending allozyme electrophoresis. This ensured that the processed snails were alive and active.

2.2 Allozyme electrophoresis

Preparation of samples and allozyme electrophoresis followed the procedures used in a previous study of *Rhagada* from the Pilbara mainland and Dampier Archipelago (Johnson *et al.* 2004). Thirteen enzymes, representing 15 gene loci, were successfully examined: adenylate kinase (EC 2.7.4.3; *Ak* locus); arginine phosphokinase (EC 2.7.3.3; *Apk*); glucosephosphate isomerase (EC 5.3.1.9; *Gpi*); isocitrate dehydrogenase (EC 1.1.1.42; *Idh1* and *Idh2*); lactate dehydrogenase (EC 1.1.1.27; *Ldh*); leucine amino peptidase (EC 3.4.-.-; *Lap*); leucyl-glycylglycine peptidase (EC 3.4.-.-; *Pep-lgg*; TEB); leucyl-leucine peptidase (EC 3.4.-.-; *Pep-ll*); leucyl-tyrosine peptidase (EC 3.4.-.-; *Pep-lt*); valyl-leucine peptidase (EC 3.4.-.-; *Pep-vl*); phosphoglucomutase (EC 5.4.2.2; *Pgm1* and *Pgm2*); phosphogluconate dehydrogenase (EC 1.1.1.43; *Pgd*); superoxide dismutase (EC 1.15.1.1; *Sod*).

Samples were processed in two stages. First, four snails from each site were examined for all fifteen loci. Both the large and the small species were included, providing genetic comparison between the two apparent species on Barrow Island. In addition, a sample of *Rhagada convicta* (the most widespread species on the mainland) from Mundabullagana Station (20°08'09.7"S, 118°01'31.0"E) was included. This provided a link to the published genetic comparisons among all known species of *Rhagada* from the Pilbara mainland and most of the species from the Dampier Archipelago (Johnson *et al.* 2004), placing the species on Barrow Island in the broader context.

In addition to determining whether the species on Barrow Island are genetically distinct, this first stage of electrophoresis determined which enzymes were genetically variable in the large, widespread species on Barrow Island. These variable enzymes were then examined in larger samples of this species from all 19 sites. Five sites (L14-17, L19 in Fig. 1) were represented by small samples (10-11 snails), while the other 14 sites had more reliable samples of 33 to 52 snails.

2.3 Analysis of data

Allelic frequencies were calculated at each locus, and differences between populations were measured over all 15 loci as Nei's (1978) genetic distance. The matrix of genetic distances was summarized by a UPGMA phenogram, using PHYLIP (Felsenstein 1993). The phenogram was illustrated with the help of TreeView (Page 1996). This analysis included all 21 samples from Barrow Island, and the species of *Rhagada* from the Pilbara mainland and the Dampier Archipelago (Johnson *et al.* 2004).

For the variable loci in the large species on Barrow Island, genetic subdivision among all 19 samples was measured as Wright's fixation index, F_{ST} , using GENEPOP (Raymond & Rousset 1995), as implemented on the web (http://biomed.curtin.edu.au/genepop). Statistical significance of genetic differences among populations was tested by randomization contingency tests, using GENEPOP. Differences between pairs of sites were measured as pairwise F_{ST} . The matrix of pairwise F_{ST} was summarized by multidimensional scaling (MDS; Systat version 5.0 for Macintosh computers), to look for possible genetic groupings across the island. Pairwise F_{ST} was also plotted against geographic distance between sites, to determine whether there was a pattern of isolation by distance. In these analyses, special attention was paid to the samples from the proposed Gorgon area, to determine whether these populations are genetically unique.

3. Results and Discussion

3.1 Comparisons between species

The genetic comparisons confirmed the distinctness of the large and small species of *Rhagada* on Barrow Island. The two species are completely distinct at the *Ldh*, *Pgd* and *Pgm1* loci, and have very different frequencies of alleles at the *Gpi*, *Idh1* and *Pep-vl* loci (Table 1). Co-occurrence of species of *Rhagada* is extremely rare (Solem 1997; Johnson *et al.* 2004). The two species on Barrow Island fit this general pattern, with complementary distributions on the island. The absence of local co-occurence means that we do not have direct evidence of intrinsic reproductive isolation. Nevertheless, the species were found within 0.8 km of each other, and the genetic differences were consistent throughout the distributions of both types.

The genetic distinctness of these two species on Barrow Island is unusual, because comparisons amongst all species of *Rhagada* on the Pilbara mainland did not reveal unique alleles in any of them. Although not unusually divergent for congeneric species, the Barrow Island species are genetically the most distinctive in this region. The phenogram illustrates the distinctness from the species of *Rhagada* on the Pilbara mainland and the Dampier Archipelago, as well as the high degree of similarity of populations within each of the species (Fig. 2).

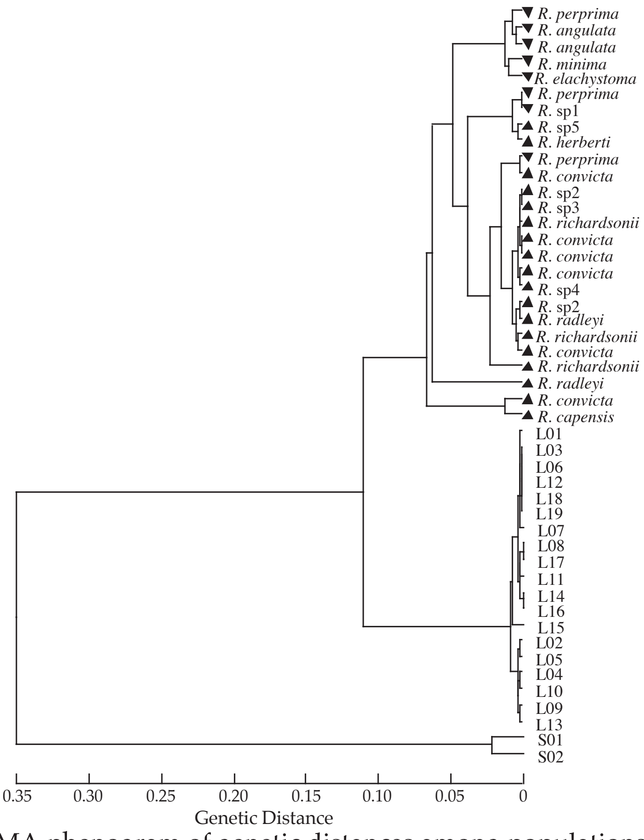

Figure 2. UPGMA phenogram of genetic distances among populations of the two species of *Rhagada* on Barrow Island and species on the Pilbara mainland (upright triangles) and Dampier Archipelago (inverted triangles). Site codes for Barrow Island as in Fig. 1 (small species = S01 to S02; large species = L01 to L19).

Table 1. Allelic frequencies at variable gene loci in samples of *Rhagada* species from Barrow Island. N = sample sizes for *Gpi*, *Idh1* and *Pgm1*; for other loci, sample sizes were four individuals. The nine invariant loci examined are not shown. * = Gorgon area

		Gpi			*Idh1*		*Ldh*		*Pep-vl*		*Pgd*		*Pgm1*			
Site	N	*152*	*100*	*52*	*100*	*91*	*111*	*100*	*100*	*95*	*100*	*67*	*144*	*111*	*100*	*78*
Large species																
L01	33	0.045	0.894	0.061	0.303	0.697	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L02	40	0.025	0.975	...	0.138	0.863	1.000	...	1.000	...	1.000	...	0.062	...	0.938	...
L03	40	...	1.000	...	0.262	0.738	1.000	...	1.000	...	1.000	...	0.025	...	0.975	...
L04	40	0.013	0.913	0.075	0.363	0.637	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L05	48	...	0.938	0.062	0.229	0.771	1.000	...	1.000	...	1.000	...	0.010	...	0.990	...
L06	40	...	1.000	...	0.389	0.611	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L07*	30	...	1.000	...	0.350	0.650	1.000	...	1.000	...	1.000	...	0.017	...	0.983	...
L08	40	...	0.988	0.013	0.112	0.887	1.000	...	1.000	...	1.000	...	0.025	...	0.975	...
L09	40	...	0.925	0.075	0.375	0.625	1.000	...	1.000	...	1.000	...	0.025	...	0.975	...
L10	36	...	0.972	0.028	0.278	0.722	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L11	40	...	0.925	0.075	0.262	0.738	1.000	...	1.000	...	1.000	...	0.062	...	0.938	...
L12	48	...	0.969	0.031	0.302	0.698	1.000	...	1.000	...	1.000	...	0.083	...	0.917	...
L13	40	...	0.950	0.050	0.325	0.675	1.000	...	1.000	...	1.000	...	0.062	...	0.938	...
L14	11	...	0.955	0.045	0.227	0.773	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L15	11	0.045	0.864	0.091	0.136	0.864	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L16*	10	...	0.950	0.050	0.150	0.850	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L17*	10	...	1.000	...	0.300	0.700	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L18	52	0.048	0.952	...	0.404	0.596	1.000	...	1.000	...	1.000	...	...	...	1.000	...
L19	10	...	0.950	0.050	0.200	0.800	1.000	...	1.000	...	1.000	...	...	...	1.000	...
Small species																
S20	4	0.500	0.500	...	...	1.000	...	1.000	0.500	0.500	...	1.000	...	1.000	...	...
S21	4	1.000	...	...	...	1.000	...	1.000	0.375	0.625	...	1.000	...	0.875	...	0.125

3.2 Spatial variation within the large species on Barrow Island

Because the small species of *Rhagada* is restricted to the northern end of Barrow Island, it is well away from the area of the Gorgon development. Further genetic analysis was conducted on the widespread, large species, to determine the amount and pattern of genetic divergence across the island, and how the Gorgon area fits into this pattern. Only three of the 15 allozyme loci had multiple alleles in the large species on Barrow Island. At two of these (*Gpi* and *Pgm1*), one allele predominated in all sites, with alternative alleles occurring at frequencies < 0.1 at many sites (Table 1). Only the *Idh1* locus was consistently polymorphic, with the less common $Idh1^{100}$ allele having frequencies of 0.112 to 0.404 among the 19 sites. Based on these three variable loci, the level of genetic subdivision across the island was small, with an overall F_{ST} of 0.023. For land snails, this is a low level of subdivision over the distances represented by these sites. The low level of genetic subdivision suggests that these populations do not have a long history of isolation. However, additional variable genetic markers would be necessary to have confidence in the actual level of subdivision. Nevertheless, although the subdivision was modest, it was statistically significant ($P < 0.01$) for each of the three loci. This indicates that populations are locally independent, as expected for land snails, with their limited capacity for dispersal. On the mainland, for example, demographically independent populations of *R. capensis* span less than 40 m (Johnson & Black 1991), well below the scale of resolution of the present study.

The multidimensional scaling of the pairwise values of F_{ST} showed no distinct groupings of populations (Fig. 3). There was also no pattern of isolation by distance across the island (Fig. 4). These analyses include the five small samples, as well as the 14 large samples. Removal of the small samples had no effect on the search for spatial pattern.

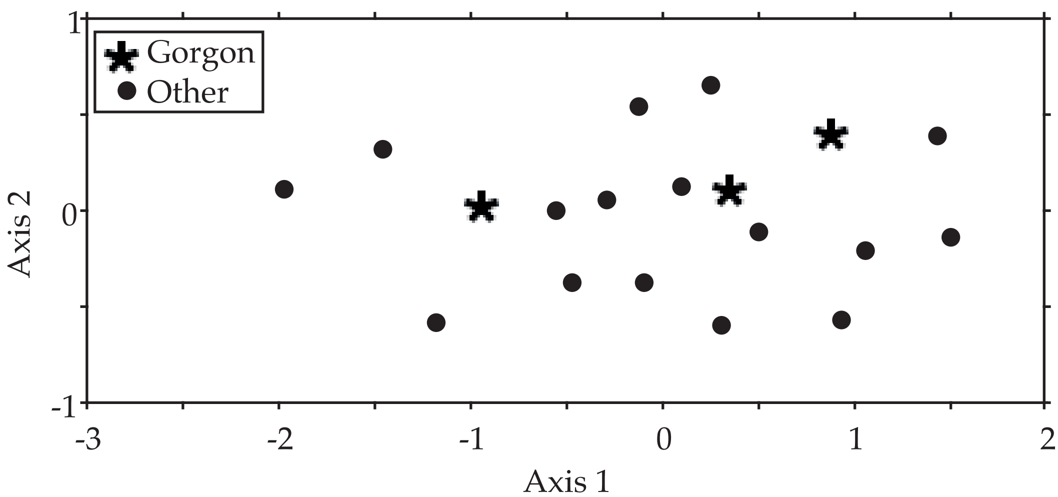

Figure 3. Multidimensional scaling of pairwise F_{ST} among 19 samples of the large species of *Rhagada* on Barrow Island. Sites from the Gorgon area indicated by asterisks.

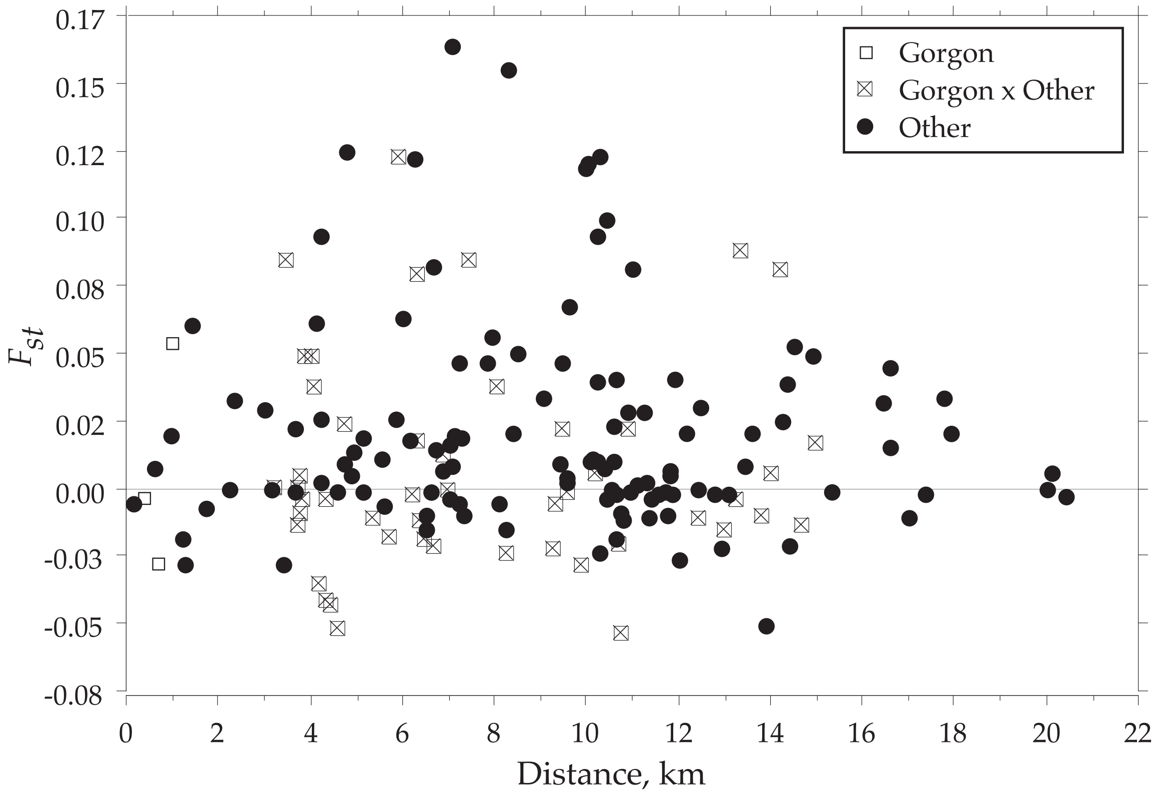

Figure 4. Plot of pairwise F_{ST} against geographic distance between populations of the large species of *Rhagada* on Barrow Island.

The differences between populations were due largely to the variation of allelic frequencies at the more variable *Idh1* locus, and these frequencies showed no obvious pattern across the island (Fig. 5).

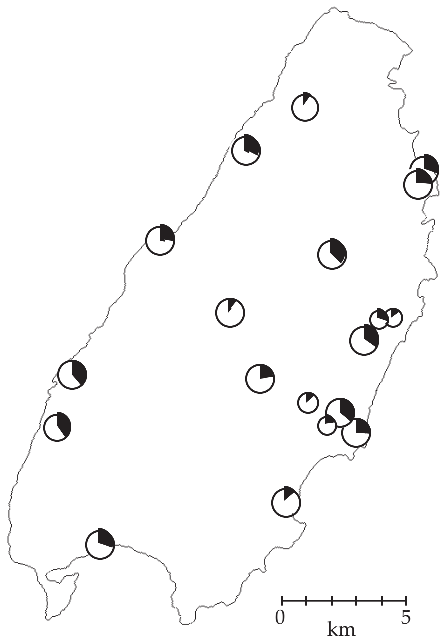

Figure 5. Frequencies of the $Idh1^{100}$ (shaded segments) and $Idh1^{91}$ (white segments) alleles. Small circles = small samples.

The Gorgon sites were well within the range of variation among the populations of the large species (Figs. 3 and 4). At the *Gpi* locus, the Gorgon site with a large sample was one of four sites with only the Gpi^{100} allele (Table 1). That Gorgon site was one of nine sites with the $Pgm1^{144}$ allele, which it had at a frequency of 0.017, compared with the average of 0.020 among all 19 sites. Allelic frequencies at the *Idh1* locus in the Gorgon sample were also unexceptional (Fig. 5, Table 1).

Taken together, the genetic patterns within the large species of *Rhagada* on Barrow Island give no indication of areas with genetically distinct populations. The frequencies of the common alleles at the *Idh1* locus show only modest variation across the island, and even the relatively uncommon alleles at the *Gpi* and *Pgm1* loci are widespread, not characterizing particular portions of the island. In the specific context of the area of the Gorgon development, there is no indication of genetically unusual populations of these snails.

4. Conclusions

These genetic comparisons confirm the occurrence of two morphologically and genetically distinct species of *Rhagada* on Barrow Island. These are the two most genetically divergent species of *Rhagada* so far examined in the Pilbara Region, highlighting the conservation significance of Barrow Island for these endemic snails. In contrast with the substantial genetic divergence between the two species, little genetic divergence was found among populations of the widespread, larger species. The small genetic differences were statistically significant, however, indicating that populations are locally independent, as is typical of land snails. Despite independence of local populations, the level of genetic subdivision of the large species on Barrow Island over distances of up to 20 km is exceptionally low for a land snail. The low level of subdivision, combined with the lack of clear spatial pattern, suggests that these populations do not have a history of major isolation of sets of populations within the island. Although additional genetic markers would be desirable, the present study gave no indication that the area of the proposed Gorgon development includes genetically unusual populations of these snails.

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Technical Appendix C5

Subterranean Fauna

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

SUBTERRANEAN FAUNA

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1 Introduction

ChevronTexaco Australia and its joint venturers propose to develop a gas processing facility at Town Point on Barrow Island and to construct a pipeline across the island from North White's Beach to the gas facility. Potential impacts to the underlying karst habitats and the rich diversity of subterranean fauna that it supports, require assessment under the *Environmental Protection Act 1986* (EP Act) and the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Biota Environmental Sciences were engaged to collate existing literature on the subterranean fauna of Barrow Island and to instigate field studies to redress the lack of knowledge on diversity and distribution of the fauna.

This report describes the current understanding of the subterranean fauna of the proposed Development area and its likely conservation significance. It also documents progress on the genetic investigations and investigative sampling work conducted in the vicinity of the proposed Gorgon Development. Field studies and identifications are ongoing and the completed studies will be reported separately. Recent draft field reports are attached to this Technical Appendix to illustrate the status of the surveys..

1.1 Overview of Subterranean Fauna

Subterranean fauna has been known from Western Australia since the 1940s, with the blind gudgeon *Milyeringa veritas*, 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. The increase in knowledge and general profile of subterranean communities in Western Australia has been due largely to work conducted by the Western Australian Museum, which focussed initially on Cape Range (Humphreys 1993), and has also included substantial work on Barrow Island (see Section 1.2).

Two broad categories of fauna are generally considered to comprise true subterranean fauna:

- stygofauna — groundwater-dwelling, aquatic fauna (including stygobites; obligate groundwater dwellers)
- troglobites — obligate cave or karst-dwelling, terrestrial subterranean fauna occurring above the watertable.

A broad overview of typical ecological characteristics of subterranean fauna and their environment is provided in Table 1-1.

Table 1-1 - Characteristics of Subterranean Ecosystems and their Components (adapted from Gibert et al. 1994)

Environment	Constant darkness
	Physical inertia which increases with depth
	Predictability: hydrologic and chemical variation usually not very evident in interstitial environments
	Restricted variety of habitats: lack of vegetation, reduction of space
	Habitat heterogeneity results from arrangement of grains, void size, physical and chemical characteristics of aquifers within the pore space
Organisms	Obligate groundwater dwellers
	Morphological, physiological and behavioural specialisations to subterranean environment: • general lack of pigmentation • ocular regression • appendages long and numerous • highly developed chemical and mechanical receptors • convergence of vermiform body shape for different taxa
Biocenosis	Dominance of one species
	Richness, diversity and density low and variable
	A-type strategy of Greenslade (1983): • slower metabolic rates and growth, reduced motor output • lengthening of each stage of the lifecycle, late maturity, increase in longevity • less frequent reproduction, lower fecundity • unique behaviours such as stereotropism, thigmotropism and thigmotactism
Functional Characteristics	Heterotrophy and allotrophy
	Short, simple food webs with few trophic links
	Detritus feeders dominant
	System with low productivity
	Invertebrate diets not specialised, polyphagous

Groundwater food webs are typically almost entirely heterotrophic, with bioproduction primarily dependent on the transport of resources (biomass, detritus) from the surface (allotrophy; Gibert et al. 1994). There are few primary producers (chemolithotrophic bacteria; Danielopol et al. 1994). Groundwater microbes (i.e. bacteria, fungi and protozoans) are the primary consumers, with general short direct trophic links to most meiofauna in the system. It is worth noting that Barrow Island appears to potentially represent an exception to this rule (see Section 1.3; Humphreys in press).

The distribution of subterranean fauna species appears to be generally more restricted than that of surface fauna analogues. High levels of endemicity are also typically characteristic of subterranean taxa, often at high taxonomic levels. 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 in particular Barrow Island and Cape Range, are regarded as geological relicts, descendants from ancient pre-Gondwanan lineages, with species characterised by restricted distributions and a low tolerance to disturbance. The stygofauna of Barrow Island represent relict lineages closely related to fauna of Gondwana, the Tethys Sea and epigean ancestors that occurred prior to the break-up of Pangaea (see review in Humphreys 2001).

1.2 Previous Work on Barrow Island

Work on Barrow Island's subterranean ecosystems has been carried out for a number of years by the Western Australian Museum. This has included seven sampling visits to the Island over the past decade and Humphreys (in press) has recently assembled a summary account of the findings of this work on stygofauna and troglofauna. This included documentation of the known subterranean fauna, its distribution and conservation status. Stable isotope analysis data were also presented indicating that some of the groundwater ecosystems on the Island may be chemoautotrophic — that is that their energy production is derived via bacterial systems from petroleum rather than surface inputs, as with most subterranean systems (Humphreys in press).

Other key studies that have been completed on the subterranean fauna of Barrow Island include:

- *Haptolana pholeta* sp. nov., the first subterranean flabelliferan isopoda crustacean (Cirolanidae) from Australia (Bruce and Humphreys 1993).
- *Speleostrophus nesiotes*, the first known troglobitic spiroboloid millipede, from Barrow Island, Western Australia (Hoffman 1994).
- Freshwater amphipods from Barrow Island, Western Australia (Bradbury and Williams 1996).
- Two new species of anchialine amphipods from Barrow Island, Western Australia (Bradbury and Williams 1996a).
- The hypogean fauna of Cape Range Peninsula and Barrow Island, north -Western Australia (Humphreys 2000).

1.3 Legislative Framework

In addition to the more general requirements of the *Environmental Protection Act 1986* (EP Act), there are two acts relevant to subterranean fauna.

1.3.1 Wildlife Conservation Act 1950

In Western Australia, all native fauna species are protected under the *Wildlife Conservation Act 1950* (Wildlife Conservation Act). The Act is administered by the Department of Conservation and Land Management (CALM). Fauna species that are considered rare, threatened with extinction or have high conservation value are specially protected under the Act. Classification of rare and endangered fauna under the *Wildlife Conservation (Specially Protected Fauna) Notice* recognises four distinct schedules of taxa, with Schedule One taxa being those 'which are rare or likely to become extinct'. In addition to this statutory classification, CALM also classifies other fauna under four different Priority codes, recognising other species which are of poorly known conservation status or which could become threatened if conditions change.

1.3.2 Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

Under the EPBC Act, an 'action' consists of 'a project, development, undertaking, activity or series of activities'. Actions are required to be referred under the EPBC Act if they take place on Commonwealth land or are an action by the Commonwealth, or are likely to significantly impact a matter of National Environmental Significance (NES). There are currently seven NES factors identified in the Act. One of these, relating to threatened flora and fauna species and threatened ecological communities, is relevant to the conservation of subterranean biota. Certain threatened species, including some subterranean fauna, are formally listed under the EPBC Act and actions which impact on these require referral to the Federal Minister for the Environment to determine if the action will be a 'controlled action' for the purposes of the Act and be subject to Federal formal environmental assessment.

2 Approach and Methodology

2.1 General Approach

The approach to this study has consisted of:

- liaison and consultation with the Western Australian Museum (Drs. Bill Humphreys and Mark Harvey), CALM Woodvale (Dr. Stuart Halse, Adrian Pinder and Jane McRae), CALM Karratha (Dr. Peter Kendrick) and the University of WA School of Animal Sciences (Dr. Terrie Finston);
- a search of the specimen records database of the Western Australian Museum for stygofauna and troglobite records from Barrow Island
- background literature searches (via on-line databases, biological abstracts and other sources), sourcing and review
- Three phases of field survey and subterranean fauna sampling within the proposed development area, with additional reference sampling across the rest of the Island.

More detail on the methodology for specific components of the work completed to date is provided in the Sections 2.2 and 2.3. Phase three work that is still in progress is outlined in Section 2.4, Attachment 2 (November/December 2004 field survey) and Attachment 3 (February/March 2005 field survey).

2.2 Field Sampling Methodology

2.2.1 Stygofauna Sampling – Phase One (August 2002)

Stygofauna were sampled from 34 bores, drillholes and wells by means of modified plankton haul nets between 9/8/02 and 13/8/02. The nets were constructed from 200 μm mesh, with apertures of various sizes attached to a weighted catch jar. Each hole was dragged at least three times. If fauna were observed in the sample, further samples were taken. Once the net reached the bottom, it was agitated gently to bring the benthos and any fauna above the net before dragging the column. On the surface, the net was flushed thoroughly with water bailed from the same hole and the resultant sample placed in a labelled plastic bag within a shaded esky. A hygiene protocol was followed at the completion of each hole whereby nets and catch bottles were washed clean to avoid any sample contamination between boreholes.

Samples were not fixed prior to sorting as live stygofauna are more easily observed and recovered. Samples were sorted under a dissecting microscope (magnification up to 40 x). Stygofauna specimens were tracked and preserved in 100 per cent ethanol (suitable for both morphological and DNA analyses). A subsample of live amphipods collected was frozen in liquid nitrogen for use in ongoing genetic (allozyme) analysis work being conducted at the University of Western Australia (see Section 2.3).

Sampling for stygofauna was conducted at 18 boreholes closest to the proposed gas processing facility, most of which were located in the immediate vicinity of the Terminal Tank farm (see Table 2-1). Of these, four were substantially affected by hydrocarbons and could not be adequately sampled. A further 20 boreholes were sampled on other parts of Barrow Island to provide additional reference data and material for genetic and morphological analysis (see Section 2.3; Table 2-1).

Table 2-1 - Boreholes Sampled on Barrow Island During the August 2002 Survey (Coordinates in UTMs, AGD84 datum)

Borehole	Area	Easting	Northing	Comments
MW3	Terminal tanks area	-	-	
MW4	Terminal tanks area	-	-	Oil affected – not sampled
MW7	Terminal tanks area	340159.00	7701530.00	
MW7nr1	Terminal tanks area	340158.00	7701532.00	Trog fauna trap installed
MW8	Terminal tanks area	-	-	
MW9	Terminal tanks area	-	-	
MW13	Terminal tanks area	340228.00	7701084.00	
MW14	Terminal tanks area	-	-	
MW15	Terminal tanks area	-	-	Oil affected –sampled
MW16	Terminal tanks area	340001.00	7701183.00	
MW16nr1	Terminal tanks area	340068.00	7701219.00	Trog fauna trap installed
MW16nr2	Terminal tanks area	340246.00	7701370.00	Oily – trog trap installed
MW17	Terminal tanks area	340343.00	7701456.00	
MW18	Terminal tanks area	340421.00	7701304.00	
MW21	Terminal tanks area	-	-	Oil affected –sampled
MW22	Terminal tanks area	-	-	Oil affected – not sampled
Terminal tanks water bore	Terminal tanks area	-	-	Clean
Abandoned seismic hole	Terminal tanks area	-	-	Dry – trog trap installed
AMW10	Reference	334192.00	7691344.00	Airport monitoring well
AMW11	Reference	334188.00	7691340.00	Airport monitoring well
AMW15	Reference	334191.00	7691330.00	Airport monitoring well
AMW18	Reference	334206.00	7691339.00	Airport monitoring well

Borehole	Area	Easting	Northing	Comments
AMW19	Reference	334196.00	7691301.00	Airport monitoring well
AMW20	Reference	334206.00	7691327.00	Airport monitoring well
B14 South	Reference	328637.00	7692399.00	
C62	Reference	332790.00	7690453.00	
C62NR1	Reference	332797.00	7690466.00	
C65	Reference	331896.00	7689829.00	
F41A North	Reference	330400.00	7694380.00	
L18A	Reference	333183.00	7699032.00	
L32j	Reference	331038.00	7697999.00	
L4N1	Reference	332213.00	7698310.00	
J16j	Reference	331488.18	7697437.23	
L8	Reference	332663.63	7697030.81	> 30 m water column
Tip MW 1	Reference	328195.00	7699302.00	Very turbid
Tip MW 2	Reference	328195.00	7699302.00	Very turbid – not sampled
Washdown pond MW1	Reference	-	-	Very turbid
Washdown pond MW2	Reference	-	-	Very turbid

2.2.2 Stygofauna Sampling – Phase Two (November 2003)

The second phase of stygofauna sampling followed essentially the same methodology as earlier sampling work on the proposed development area. Stygofauna were sampled from bores, drillholes and wells by means of modified plankton haul nets between 25/11/03 and 28/11/03. The sampling, curation and data management procedures were completed as outlined for the August 2002 sampling phase (see Section 2.2.1).

Stygofauna were sampled from 19 bores during this second phase of sampling; seven in the Terminal Tanks area (north of the proposed gas processing facility site) and a further 12 boreholes on other parts of Barrow Island (Table 2-1). This was largely a targeted exercise, focussing on holes that previously yielded fauna. Boreholes that proved to be contaminated with hydrocarbons, blocked or excessively turbid during the phase one sampling (Section 2.2.1; Biota Environmental Sciences 2002) were not revisited as part of the November 2003 sampling.

Table 2-2 - Boreholes Sampled on Barrow Island During the November 2003 Survey (Coordinates in UTMs, AGD84 datum)

Borehole	Location	Easting	Northing	Comments
MW3	Terminal tanks area	340102	7701401	
MW7	Terminal tanks area	340159	7701530	
MW7nr1	Terminal tanks area	340158	7701532	Trog fauna trap installed
MW9	Terminal tanks area	-	-	
MW13	Terminal tanks area	340228	7701084	
MW14	Terminal tanks area	-	-	
MW16nr1	Terminal tanks area	340068	7701219	Troglofauna trap installed
MW16nr2	Terminal tanks area	340246	7701370	Troglofauna trap installed
MW17	Terminal tanks area	340343	7701456	
MW18	Terminal tanks area	340421	7701304	
AMW10	Remainder of Barrow I	334192.00	7691344.00	Airport monitoring well
AMW11	Remainder of Barrow I	334188.00	7691340.00	Airport monitoring well
AMW15	Remainder of Barrow I	334191.00	7691330.00	Airport monitoring well
AMW18	Remainder of Barrow I	334206.00	7691339.00	Airport monitoring well
AMW19	Remainder of Barrow I	334196.00	7691301.00	Airport monitoring well
C62	Remainder of Barrow I	332790.00	7690453.00	
C65j	Remainder of Barrow I	331896	7689829	
C77j	Remainder of Barrow I	-	-	
L32j	Remainder of Barrow I	331038	7697999	
L4N1	Remainder of Barrow I	332213	7698310	
L8	Remainder of Barrow I	332663	7697030	> 30 m water column
X62M	Remainder of Barrow I	-	-	

2.2.3 Stygofauna Sampling – Phase Three

Phase three represents the initiation of the Subterranean Fauna Sampling Programme designed in consultation with the EPA and CALM. Phase three sampling takes advantage of recently drilled geotechnical/subterranean fauna bores within the proposed Development area.

Stygofauna was sampled from a range of bores both within and outside the proposed Development area from 30 November 2004 to 3 December 2004 (Attachment 3) and 28 February 2005 and 4 March 2005 (Attachment 4). Additional sampling in April 2005 will be reported separately.

2.2.4 Troglobitic Fauna Sampling

There are no known caves located within the proposed development area or any other obvious surface expressions of substantial karst development. Foot traverses of the area were carried out by members of the Gorgon terrestrial study team and no significant formations were noted. As a result, troglobitic fauna sampling was limited to installation of litter traps in four abandoned drill holes within the proposed development area (Table 2-1). Traps were again installed in these locations during the second phase of sampling (Table 2-2). Troglobitic fauna sampling was also undertaken as part of the latter two sampling surveys. Results from the November/December 2004 survey and February/March 2005 survey can be found in Attachment 3 and Attachment 4, respectively.

Traps were constructed from 60 mm internal diameter PVC stormwater pipe cut to a length of 120 mm. Both ends were blocked with aviary mesh after the tubing was filled with wet leaf litter. Leaf litter material was gathered from the ground surface on the Island, particularly from the bases of *Melaleuca* and *Ficus* shrubs. The litter was soaked in water and irradiated in a microwave oven on the maximum power setting (to kill any invertebrates present and assist in break-down). Wet litter was added to the traps and kept in sealed containers until immediately prior to insertion into the boreholes. After the installation of each trap, the opening of each borehole was sealed to maintain humidity and to minimise the input of surface fauna into the traps.

2.3 Identifications and Genetic Analyses

Specimens were sorted live and, as far as possible, identified in an on-site laboratory prior to curation. In some cases it was possible to identify material to species level at this stage, but for most of the recovered fauna, this represented order or family level taxonomic resolution.

More detailed identification of the Phase One material was carried out by Jane McRae at CALM Woodvale, utilising existing taxonomic descriptions and keys published by various taxonomic authorities. Adrian Pinder of CALM Woodvale carried out further identification of worm taxa collected. With the exception of amphipods consumed in genetic investigations, the collected specimens have been lodged with the Western Australian Museum and are currently contributing to ongoing taxonomic work.

Frozen material, primarily amphipods, was also subject to electrophoretic analysis by Dr. Terrie Finston at the University of Western Australia, School of Animal Sciences. This work is also ongoing and has more recently been extended to include mitochondrial DNA analyses.

2.4 Limitations of this Report

Several limitations should be recognised in the interpretation of this report:

The installation of purpose-built bores for sampling subterranean fauna within the proposed gas processing facility was not completed during phases 1 or 2. Consequently, sampling reported in this document has been limited to the opportunistic use of existing boreholes, resulting in poor spatial coverage of the proposed gas processing facility. The closest bores to the proposed development were those in the vicinity of the Terminal Tanks, located approximately 500 m to the north of the proposed development. These bores had only a few metres of penetration into the aquifer, and therefore limited saturated thickness present to sample. No sampling for stygofauna or troglobitic fauna has been possible in the proposed development area during phases 1 or 2. Sampling during November/December 2004 (Attachment 3) and February/March 2005 (Attachment 4) was undertaken within the proposed development area. The results of these two sampling surveys can be found in those respective attachments.

As most bores in the study area are cased for their entire length, troglobitic fauna sampling has been limited to a small number of relatively shallow, opportunistic sites.

As outlined in Section 2.3 the work completed to date represents work in progress in respect of species level consideration of fauna distribution.

3 Results

3.1 Stygofauna

3.1.1 Summary

Stygofauna were recovered from 13 of the 38 bores visited during the phase one sampling (34 per cent of sites; 345 specimens). Five of these locations were within the Terminal Tanks area to the north of the proposed gas facility site (see Figure 3-1). Stygofauna were recovered from ten of the 19 bores visited during the second field survey (53 per cent of sites). This relatively high rate was due to targeting of prospective sites (see Section 2.2.2). Two hundred and four specimens were collected, of which 25 were recorded from three bores in the Terminal Tanks area (MW13, MW17 and MW18).

A combined summary of the relative abundances of the various stygal taxa collected during both rounds of sampling for the proposed development is presented in Table 1-1. The collected specimens represented five classes, nine orders and 12 families, with a total of 23 taxa (including ten described species). Thirteen of these taxa were recorded from the Terminal Tanks area, the closest location sampled to the proposed gas processing facility. Nine of the 23 taxa were recorded from both this area and other parts of the Island (see Table 1-1).

Further sampling for stygofauna, including within the proposed development area, was undertaken in November/December 2004 and February/March 2005. The results of these surveys can be found in Attachment 3 and Attachment 4 for the 2004 and 2005 surveys, respectively.

Table 3-1 - Stygofauna Abundance Recorded from the Terminal Tanks Area and Other Reference Sites Sampled Across the Island (August 2002 and November 2003 data sets combined)

Taxon	Terminal	Reference	Total
Isopoda: Cirolanidae (*Haptolana pholeta)*	-	27	27
Isopoda: Oniscideae sp. nov. 1	1	-	1
Amphipoda: Melitidae (*Nedsia sculptilis/macrosculptilis*)	-	2	2
Amphipoda: Melitidae (*Nedsia* nr. *hulberti)*	-	1	1
Amphipoda: Melitidae (*Nedsia* spp.)	27	125	152
Amphipoda: Bogidiellidae (*Bogidella* sp.)	1	3	4
Copepoda: Cyclopoida (*Diacyclops* aff. *humphreysi)*	4	4	8
Copepoda: Cyclopoida (*Diacyclops* sp.)	2	-	2
Copepoda: Cyclopoida (*Halicyclops rochai)*	-	15	15
Copepoda: Cyclopoida (*Halicyclops* sp.)	1	2	3
Copepoda: Cyclopoida	-	28	28
Copepoda: Harpacticoida (*Sarsameira* sp.)	17	3	20
Copepoda: Harpacticoida (*Phyllopodopsyllus wellsi)*	1	-	1
Copepoda: Harpacticoida (*Phyllopodopsyllus* aff. *thiebaudi)*	1	3	4
Copepoda: Harpacticoida (*Phyllopodopsyllus* sp. 1)	1	-	1
Copepoda: Calinoida: sp. nov. 1	1	81	82
Decapoda: Atyidae (*Stygiocaris stylifera*)	-	148	148
Thermosbenacea (*Halosbaena tulki)*	13	48	61
Vertebrata: Perciformes (*Milyeringa veritas)*	-	2	2
Ostracoda: sp.	-	4	4
Nematoda: sp. 1	-	4	4
Oligochaeta: Phreadrilidae: sp. 1	2	4	6
Polychaeta: sp. 1	-	3	3
	72	507	579

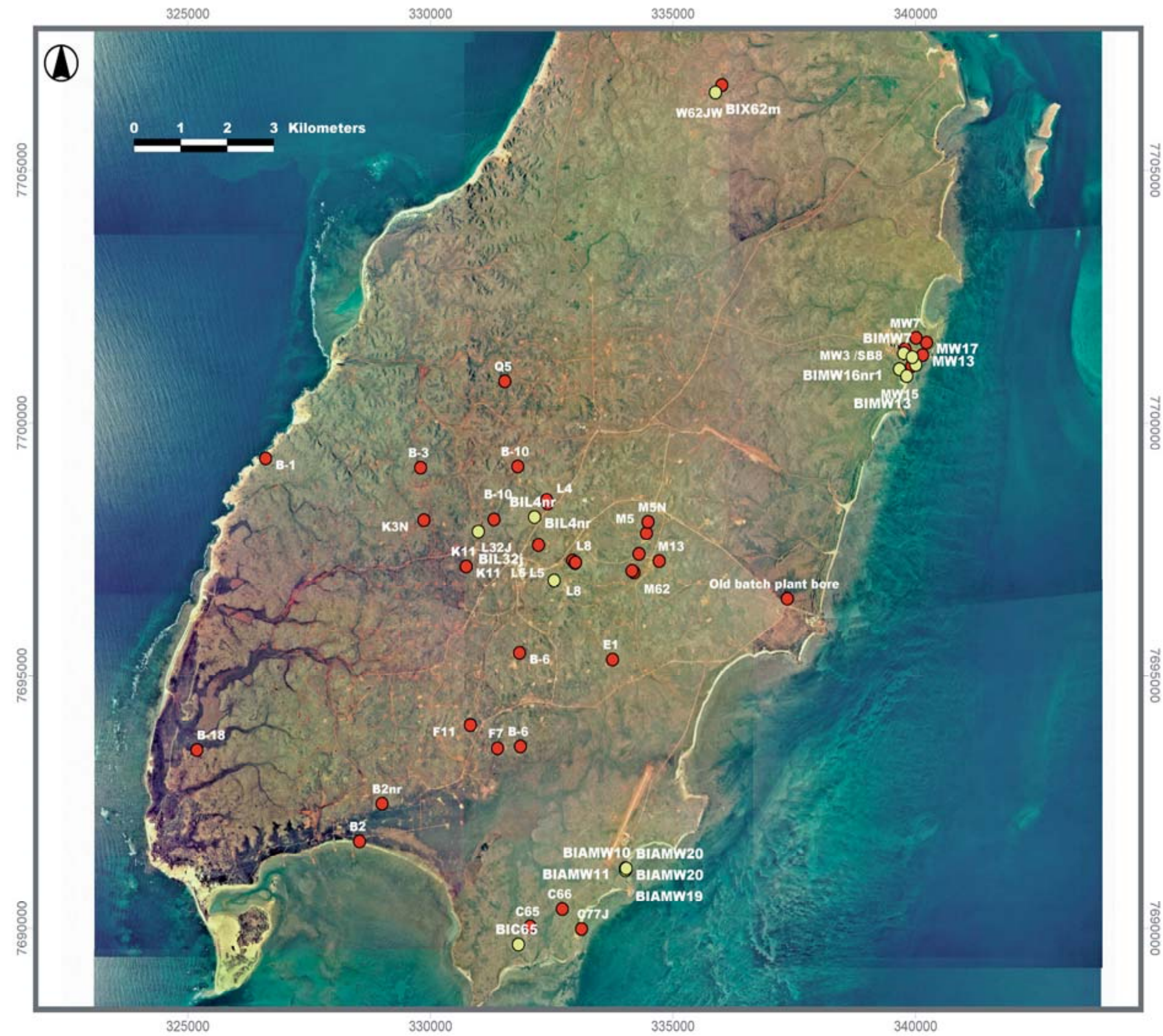

Figure 3-1 - Borehole Sampling Locations on Barrow Island which Yielded Stygofauna

(Red = historical sampling, yellow = current study).

Copepods were the most abundant and taxonomically diverse component of the recorded fauna, accounting for 28 per cent of the 507 specimens collected and nine of the 22 taxa currently documented (41 per cent of the species richness) (see Table 1-1). The amphipods were the next most common and species-rich group, with 159 individuals (31 per cent) representing at least four species. The numerical and species level dominance of these two orders is a common feature of stygal communities (Biota Environmental Sciences unpublished data). The identification of amphipods belonging to the genus *Nedsia* was limited by the lack of mature and intact animals amongst the collected specimens. The aytid decapod *Stygiocaris stylifera* was the next most abundant group and species recorded during the sampling programme (148 individuals; Table 1-1).

With the exception of the polychaete worm collections, the second phase of sampling did not collect any new taxa beyond those of the first sampling phase for the proposed development (Biota Environmental Sciences 2003). The stygal polychaete collections are of considerable interest, however, being the first records of stygal polychaetes from

Barrow Island (Humphreys, W.F. 2003. Personal communication). The resolution of morphological identification and taxonomic work on this material is limited at present. This is being advanced as part of ongoing work (see Section 1). Additional taxa may be resolved from the collected material as part of this.

3.1.2 Annotated List

Phylum Nematoda

Four nematodes were collected during the survey but the specimens were extremely small and have curated poorly. They could not be located for more detailed examination. The animals were not recorded from the sample sites near the proposed gas processing facility and, given the state of stygal nematode taxonomy, it is unlikely that they could have been identified beyond the family level (Pinder, A. 2002. Personal communication).

Class Oligochaeta

Four oligochaete specimens were collected from well L8 (outside the proposed development area) during the phase one sampling, and two from the Terminal Tanks area during phase 2. These specimens belonged to the family Phreadrilidae and represent the first record of this family from Barrow Island (Pinder, A. 2002. Personal communication; Attachment 2). The specimens are therefore likely to represent an undescribed species, but the material collected was not mature enough to allow for a formal description.

Class Ostracoda

Four ostracods were collected during the survey, all from areas away from the site of the proposed gas facility (Table 3-1). These await examination by an ostracod specialist, but it is possible that they represent a previously unknown species, given that the recent review of the Island's fauna by Humphreys (in press) lists no ostracods for Barrow Island and the Western Australian Museum's records contain only two other ostracod records (see Attachment 1).

Order Copepoda

The copepods were the most diverse group amongst the stygofauna, with nine taxa representing three families (see Table 1-1). The presence of the calinoid copepods was significant in that there are no calinoid copepod species currently described for Barrow Island (McRae, J. 2002. Personal communication), although material has previously been collected by the Western Australian Museum (Attachment 1).

Most other species were either confirmed or tentatively identified as previously described species (Table 3-1). Three of the copepod taxa, *Diacyclops* sp., *Phyllopodopsyllus wellsi* and *Phyllopodopsyllus* sp. 1, were recorded from the Terminal Tanks area (Figure 3-2). *Phyllopodopsyllus wellsi* has been previously described and is known to occur on Cape Range (McRae, J. 2004. Personal communication). The other two taxa appear to represent currently undescribed species.

Figure 3-2 - Copepod Records

(Red = Calinoida, light blue = Harpacticoida, dark blue = Cyclopoida).

Order Thermosbaenacea

A single species of thermosbaenacean was collected during the survey, *Halosbaena tulki*, which has previously been documented as relatively widespread and common across the Island (Humphreys in press). The species was present in reasonable abundance within the Terminal Tanks area (near the proposed gas processing facility; n=13) and elsewhere on the Island (n=48) (Table 1-1).

Order Isopoda

Two families were represented amongst the isopods, the Cirolanidae and the Oniscideae (Table 3-1). The most commonly recorded species was the cirolanid *Haptolana pholeta* (27 records from four locations, all away from the proposed gas processing facility) (Plate 3-1; Figure 3-3). This species was described from Barrow Island in 1993 (Bruce and Humphreys 1993) and occurs at least four other sites on the Island (Humphreys in press; Appendix 1).

Plate 3-1 - Isopoda: *Haptolana pholeta*

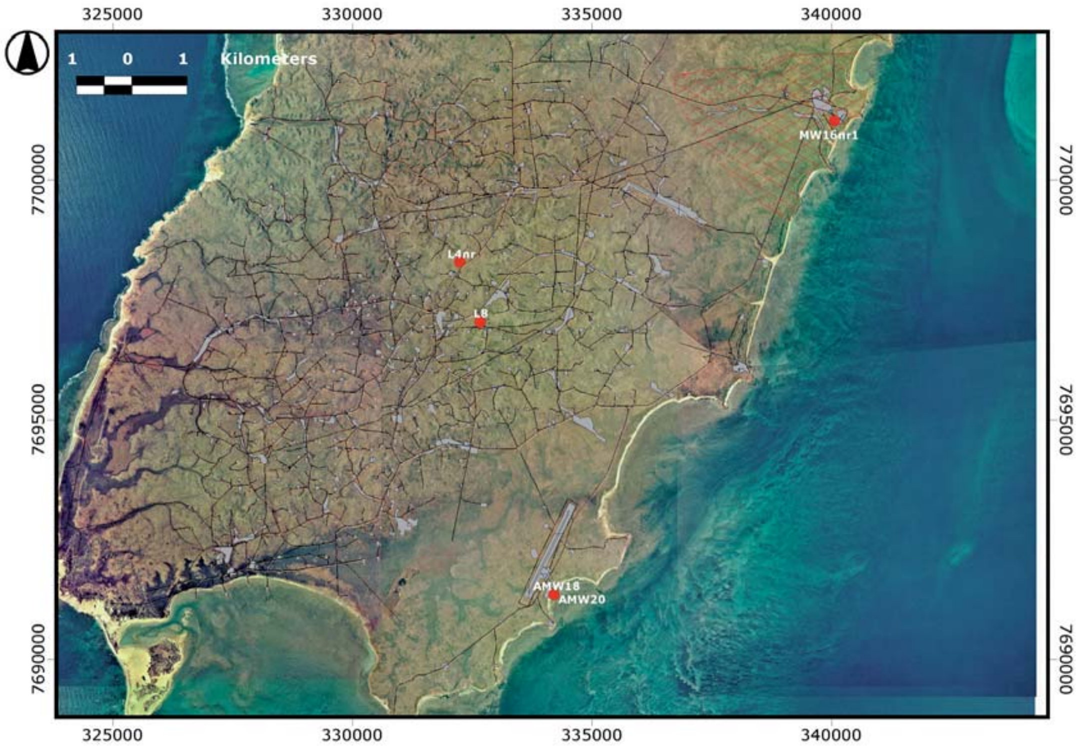

Figure 3-3 - Isopod records

The other family of isopods represented was the Oniscideae, with a single animal recorded from an old bore adjacent to Terminal Tanks monitoring well MW16 (MW16nr1) (Figure 3-3). This is a significant specimen as it is the first record of an aquatic oniscoid isopod from Barrow Island and probably represents a previously undescribed species (see Section 4).

Order Amphipoda

Two families were represented amongst the collected material (

Figure 3-4). The majority of the amphipods collected (156 of 160 individuals) were melitid amphipods of the genus *Nedsia* (Table 3-1). This is a difficult group to identify with confidence and this material needs to be dissected and slide-mounted to be identified. Two animals recorded from areas away from the gas processing facility have been identified as *Nedsia sculptilis*/ *macrosculptilis* (bores AMW18 and L4nr) and one as *Nedsia* nr. *hulberti* (bore L32j) (Bradbury and Williams 1993; Humphrey in press). Many of the remaining amphipod specimens were juvenile, damaged or incomplete, lacking many of the diagnostic characters required by Bradbury and Williams (1993) and Bradbury (2001). It may not be possible to take this material to species-level identification based on morphology but the material has been lodged with the Western Australian Museum and is currently being examined by John Bradbury of the University of Adelaide. Allozyme electrophoretic data have provided some insight into species level distributions in this genus (Section 3.1.3, and DNA analyses may provide further clarification on species distributions).

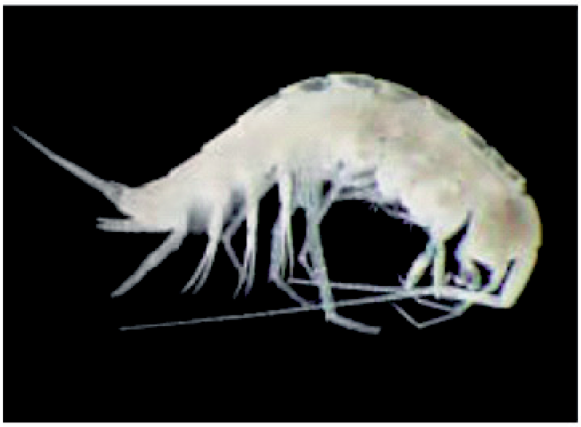

Plate 3-2 - Amphipoda: *Nedsia sculptilis*

(Photo: J. McRae, CALM)

Figure 3-4 – Amphipoda Records

(Pl blue = Melitidae, Dk blue = Bogidiellidae)

The remaining amphipods were all from areas other than the Terminal Tank farm (AMW18 at the airport and L8 near the base), and belong to the family Bogidiellidae. These four specimens are of considerable significance, as the only previously described member of this family from Barrow Island is *Bogidomma australis*. This monospecific genus was erected specifically as Bogidomma was the only stygal amphipod with eyes — a feature absent from the bogidiellids collected during the current study. It is most likely that these new specimens belong to the genus *Bogidiella* (McRae, J. 2002. Personal communication) and probably represent an undescribed species.

Order Decapoda

One decapod crustacean was collected during the current study, the atyid *Stygiocaris stylifera* (Plate 3-3). It was relatively abundant where present (n=148 from three locations, all outside the proposed development area). This species is known to be fairly widespread on the Island, having been recorded from 16 locations during previous Western Australian Museum surveys (Humphreys in press).

Plate 3-3 - Decapoda*: Stygiocaris stylifera*

Plate 3-4 - Vertebrata*: Milyeringa veritas*

Class Vertebrata

One stygal vertebrate was recorded during the study, the blind gudgeon *Milyeringa veritas* (Plate 3-4). This species is listed as Schedule One under the Wildlife Conservation Act and as Vulnerable under the EPBC Act. It is one of only two-known stygal vertebrate species in Australia, with Cape Range the only known locality outside Barrow Island (Humphreys 2001). Two individuals were collected (one during each sampling phase), both from bore L8 away from the proposed gas processing facility. The recovered specimens were preserved in liquid nitrogen to provide for any future electrophoretic work that may be undertaken.

3.1.3 Results of Genetics Investigations to Date

Genetic analyses of stygal specimens from Barrow Island have recently been advanced by Dr Terrie Finston of the School of Animal Sciences, University of Western Australia. Electrophoretic investigations completed to date have focussed on the amphipod fauna. This order is the most diverse and widespread stygal group on the Island, making it a key group for such study. Analysis to date has resulted in the identification of five genetic groups approximately equating to species 'types' in terms of genetic difference (see Attachment 2).

Amphipods from Barrow Island were analysed for 20 allozyme loci following standard methods for protein electrophoresis (see Attachment 2). For comparative purposes, known specimens of amphipods from the families Bogidiellidae and Melitidae (genus *Nedsia*), were included in these analyses.

Of the seven bores from which material was analysed, five contained a single genetic type, while two of the bores (L32j and AMW18) contained two genetic types (Attachment 1). A cluster analysis using Nei's genetic distances among samples and the neighbour-joining clustering algorithm suggested the presence of five genetic types or 'species' level groups (Attachment 2). These were differentiated by the presence of two or more fixed differences among the 20 loci. Six of the groups showed affinities with the Melitids from other regions of the Pilbara. Two (MW14nr1 and MW17-4) represent unique types.

Table 3-2 - Species Level Group Results from Electrophoretic Analyses of Amphipoda to Date

Bore	Number of genetic types	Genetic type group ('species')	Comments
L32j	2	Group 2 Group 5	1 common type (n = 13), similar to Paraburdoo Melitids 1 rare type (n = 1), similar to Mt. Brockman Melitids
L8	1	Group 2	(n = 2) similar to Mt. Brockman Melitids
MW14nr1	1	Group 1	(n = 1) unique genetic type
MW7	1	Group 5	(n = 1) similar to Paraburdoo Melitids
AMW19	1	Group 5	(n = 1) similar to Paraburdoo Melitids
AMW18	2	Group 3	(n = 2) similar to Mt. Brockman Melitids (n = 3) similar to Paraburdoo Melitids but unable to score many loci
MW17	1	Group 4	(n = 1) unique genetic type

Two of the species level groups therefore appear to be relatively widespread on the Island (Table 3-2). Species Group Two is represented at both L32j and L8 (~2.5 km apart), whilst Group Five was recorded from both AMW19 (at the airport) and MW7 (~12 km away at the Terminal Tanks area). Three of the species groups suggested by the electrophoretic data are currently only known from single bore locations, two of which are not near the proposed gas processing facility (Table 3-2).

The findings available to date indicate several species level groups within the genus *Nedsia* on Barrow Island. This is broadly consistent with the morphological analysis of Bradbury and Williams (1996) and Bradbury (2002), in the sense that several, patchily-distributed species were recognised. However, specific paired comparisons between genetic and morhphological analyses have not yet been carried out. These results should therefore be interpreted with caution, as a limited number of loci could be scored for some individuals, and sample sizes were relatively low (Attachment 2). Ongoing work may help resolve the situation, including the use of mitochondrial DNA markers to better address specific questions regarding species level distributions (see Section 4).

3.2 Troglobitic Fauna

As limited field sampling has been possible to date (see Section 2.2), an initial assessment was completed based on the habitat of the area and known records from previous work on the Island (Biota Environmental Sciences 2002; Section 3.2.1). The results of surveys carried out in November/December 2004 and February/March 2005 can be found in Attachment 3 and Attachment 4, respectively.

3.2.1 Desktop Review

The Western Australian Museum's database includes 324 records of terrestrial invertebrate taxa collected from caves or other subterranean environments on Barrow Island. The distribution of these records on the Island is shown in Figure 3-4. A detailed listing of these records is provided in Attachment 1.

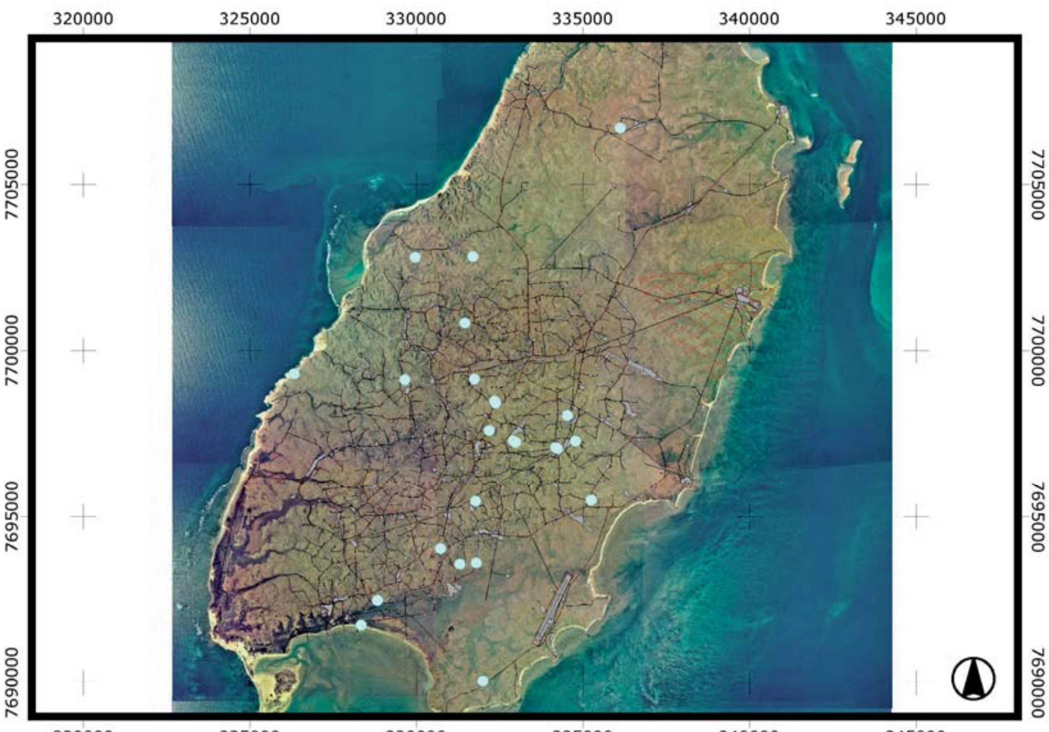

Figure 3-5 - Troglobitic Fauna Records from Barrow Island (Source: Western Australian Museum)

The majority of the known troglofauna records are associated with caves, although some are from fauna recorded during borehole sampling (see Appendix 1). There are no previous records of troglobitic fauna from the proposed development area. This is probably a function of sampling access availability to the karst underlying the site as well as the apparent lack of caves with suitable microclimates. There is considerable evidence of subsurface cavities on the Island that do not open to the surface (Humphreys in press), but current seismic and geotechnical data do not indicate any significant voids at the proposed development area. It is likely that the limestone strata below the proposed development area provide suitable habitat for troglobitic fauna, but this is likely to be limited by the extent of caverns and fracturing.

It is expected that most of the area traversed by the proposed feed gas pipeline is similar in nature in this respect, with the exception of the area on the western side of the Island approaching the Flacourt Bay option. In this locality the karstic development becomes more massive and developed with the formation of gorges and incised drainages reminiscent of the geomorphological features of Cape Range (Biota Environmental Sciences 2002).

A proportion of this fauna contains terrestrial invertebrate taxa that are not strongly troglobitic and are probably accidentals or troglophiles rather than a true component of the troglofauna. This includes ants (Hymenoptera: Formicidae), several beetle taxa (Coleoptera), springtails *(Collembola),* and ticks (Acarina: Ixodidae) (see Attachment 2).

Humphreys (in press), provides an account of the true troglobitic species currently described from Barrow Island and this is summarised in Table 3-3.

Table 3-3 - Troglobitic Fauna Species Known from Barrow Island

Species	Records	Conservation Status
Draculoides bramstokeri (Schizomida: Hubbardiidae)	7	Schedule 1 (Wildlife Conservation Act)
Speleostrophus nesiotes (Diplopoda: Trigoniulinae)	1	Schedule 1; (Wildlife Conservation Act)
Nocticola sp. nov. (Blattodea: Nocticolidae)	1	Undescribed species
Isopoda: Oniscidea: sp. indet.	5	Undescribed species
Arachnida: Scorpiones: sp. nov. (family uncertain)	1	Undescribed genus

The majority of these troglofauna records have come from cave 6B1 (Ledge Cave), which is a highly significant site for this fauna. It is situated in the south-west of the Island, well removed from the proposed gas processing facility. Of the troglobitic species documented from the Island, the schizomid *Draculoides bramstokeri* is known to be widespread, having been recorded from several sites on Barrow Island and also occurring across Cape Range (Biota Environmental Sciences 2002; Humphreys in press).

Other potentially troglobitic species have also been collected from Barrow Island (see Attachment 1) but the taxonomy of some of these groups has not been advanced. One potentially troglobitic species stands out in particular: the blind snake *Ramphotyphlops longissimus*. This species is known from only a single specimen recovered during removal of a well casing on the Island (Aplin 1988; Humphreys in press). The species is depigmented, has very reduced eyes and an extremely vermiform morphology. It is possibly troglobitic, which would make *R. longissimus* the only known reptile troglobite in the world (Humphreys in press).

3.2.2 Sampling Results

Litter traps recovered during Phase one and Phase two of the sampling program have collected largely epigean and edaphobitic (deep soil) fauna. This has included isopods (slaters), ants (epigean taxa) and collembolans (springtails). The only troglobitic species recorded during sampling for the proposed development to date is a single schizomid from MW16nr in the Terminal Tanks area. Liaison with Dr Mark Harvey of the Western Australian Museum determined that the specimen was a *Draculoides* and probably *D. bramstokeri* (Schedule 1). This species has been recorded from several other locations on Barrow Island and on Cape Range (Biota Environmental Services 2003). Unfortunately, the traps installed during November 2003 could not be recovered due to sediment burial arising from run-off during a cyclonic event during early 2004.

Preliminary data from Phase three sampling is included in Attachments 3 and 4.

4 Summary

4.1 Conservation Significance

Barrow Island is well recognised as being of high conservation significance for subterranean fauna communities at the state, national and international levels of consideration. The subterranean fauna of the Island demonstrates a high level of endemicity and species diversity, with over twenty 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. There is also evidence to suggest that the subterranean ecosystems of Barrow Island may be at least locally driven by chemautotrophic energy sources, rather than traditional allotrophic (surface energy) inputs.

Twelve of the species known from the Island are listed as Schedule fauna under the Wildlife Conservation Act and one is listed as 'vulnerable' under the EPBC Act. This tally includes three Schedule One species recorded during the current study, *Milyeringa veritas, Nedsia hulbertii* and *N. macrosculptilis,* none of which were recorded from the proposed development area (see Section 3.1). Five other *Nedsia* species are also Schedule listed and it is possible that some of these are represented amongst the specimens collected from the Terminal Tanks area. This includes *Nedsia hulbertii* which has previously been recorded from the area by the Western Australian Museum (MW17; Humphreys in press).

In addition to the currently described and Schedule listed fauna, a significant component of the Island's troglofauna and stygofauna comprises poorly sampled or undescribed taxa. This is illustrated by the results of the current survey which yielded several specimens that are either currently undescribed or are entirely new records for the Island (see Section 3.1). Of these taxa, four were recorded outside and four within the proposed development area. Of the undescribed taxa within the area of investigation, two are copepods and may correspond to material contained within the 'Copepoda: indet.' group listed in Humphreys (in press). The oniscid Isopod specimen appears to be the first representative of this family known from the Island and was recovered from MW16nr1. Further work is being undertaken on this material. The status and conservation significance of these undescribed taxa is unknown, but it is likely that they are endemic to Barrow Island, given the biogeographic patterns generally evident amongst the described fauna (Humphreys, 2000). It is worth noting that these specimens are not only new species, but representatives of new genera and family level records for the Island in some instances, highlighting the levels of biodiversity involved.

All of Barrow Island has high conservation value. On the basis of the available information , the specific conservation values represented in the vicinity of the proposed development area would be ascribed high conservation value in a regional context because it:

- has records of Schedule One fauna (the stygobite *Nedsia hulbertii* and the troglobite *Draculoides bramstokeri*)
- is the only known location for *Nedsia chevronia* (well MW15; Bradbury, 2002)
- has records of undescribed stygofauna taxa not known from elsewhere on the Island.

4.1.1 Ongoing Work

Investigations into troglobitic and stygobitic subterranean fauna of Barrow Island are ongoing. Additional sampling in Phase three of the study will provide quantitative data with which to better assess the significance of the subterranean assemblages in the potential impact areas of Barrow Island.

Additional sampling is in progress in the proposed development area to address the key limitations that exist with respect to the sampling completed to date and the resulting data. The results of the first two of these surveys (November/December 2004 and February/March 2005) can be found in Attachment 3 and Attachment 4. The data from these surveys will be presented separately when identifications are complete.

4.1.2 Lack of Data on Subterranean Fauna in the Proposed Development Area

Project definition and other investigations (including geotechnical, hydrology and hydrogeology studies), have now allowed for the more accurate delineation of the actual impact on the proposed development area. This impact area is, however, outside the sampling work completed during either the first or second phases of sampling that is reported here. The lack of data within 'impact' sites is being redressed in Phase three sampling. A subterranean fauna sampling program has been developed and agreed with environmental agencies. The program is tied-in with the geotechnical investigation of the karst structure of the proposed development area, that was completed in August-September 2004.

The preliminary results are included in Attachments 3 and 4. Further data will be provided by the April 2005 sampling and reported subsequently. All of the data collected to date will be reviewed once the agreed sampling plan has been completed.

4.1.3 Limitations on Existing Electrophoretic Data

Dr Terrie Finston at the University of Western Australia is currently continuing her analysis of material collected from Barrow Island. This will include additional electrophoresis, and has expanded to analysis of DNA markers. It is hoped that this work, particularly the latter technique (which allows for increased samples sizes), will clarify the situation with respect to species level relationships amongst amphipod populations on Barrow Island, and between populations on the Island and the mainland. These relationships are important in assessing the conservation significance of the Barrow Island subterranean taxa and the potential impacts of the proposed development.

4.1.4 Level of Morphological Identification and Taxonomic Resolution

Whilst genetic analysis is a valuable and powerful tool, there is also a requirement to advance alpha (morphology-based) taxonomy in relation to this fauna. A proportion of the material collected to date could be identified to species level, but some groups (particularly the Amphipoda) are more problematic. Additional efforts are ongoing to engage specialist taxonomists to resolve morphology-based identifications as far as possible. This may be limited in some cases by the nature of the material, in respect of size, intactness and maturity. Lodgement of the collected fauna with the Western Australian Museum is the first step in this process and has been completed. Ongoing collections will significantly increase the representation of Barrow Island subterranean fauna in the Western Australian Museum collection.

Preliminary contact has been made with key taxonomists in some groups who have agreed to examine the material collected for the proposed development (specifically Mr John Bradbury of the University of Adelaide (Amphipoda) and Dr Mark Harvey of the Western Australian Museum (Schizomida and other troglobitic taxa). This work will pursue the identification of collected specimens against existing keys where possible, and the advancement of new taxonomic descriptions for previously undocumented taxa (notably the polychaete worms and the oniscid isopods previously uncollected from Barrow Island).

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6 Glossary

Allotrophy	External inputs of organic matter to the ecosystem.
Allozyme	Alternative forms of the same protein coded for by different genes at the same locus.
Aytid	Decapod crustacean belonging to the family Aytidae.
Chemautotrophs	Organisms deriving nourishment from chemical reactions and inorganic substances.
Chemolithotroph	An organism which obtains its energy from the oxidation of inorganic compounds.
Detritus	The mixture of organic and inorganic material on surfaces that forms the food of some animals.
DNA	Deoxyribonucleic Acid – the fundamental genetic material of all cells.
Electrophoresis	A lab technique for separating proteins based on their different mobility through an electric field.
Epigean habitat	Terrestrial, dwelling in habitats on the ground surface.
Heterogeneity	The provision of a variety of habitats through increased habitat complexity; provides for a greater number of niches.
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 preformed organic molecules.
Locus	The place at which a particular gene resides on the DNA or genetic map.
Meiofauna	Fauna that will pass through a 500 μm sieve but not a 40 μm sieve.
Melitid	Amphipod crustacean belonging to the family Melitidae
Oniscid	Isopod crustacean belonging to the family Onisciddeae
Protozoan	Single celled organisms in the Kingdom Protista.
Stereotropism	See Thigmotropism.
Stygobites	Obligate groundwater-dwelling fauna.
Stygofauna	A general term to describe groundwater-dwelling fauna.
Thigmotactism	The tendency of many small organisms to seek maximum surface area contact.
Thigmotropism	Directional growth in response to the stimulus of direct contact.
Vermiform	Worm-type body organisation.

Attachment 1 - Western Australian Museum Stygofauna and Troglofauna Records from Barrow Island

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-1	-20.79806	115.33139	Arachnida	Araneae	Ctenidae (JW)		
B-1	-20.79806	115.33139	Arachnida	Acarina	Ixodidae	*Amblyomma*	*triguttatum*
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Arachnida	Acarina			
B-1	-20.79806	115.33139	Malacostraca	Amphipoda	Melitidae	*Nedsia*	*hurlberti* Bradbury & Williams, HOLOTYPE
B-1	-20.79806	115.33139	Malacostraca	Amphipoda	Hadziidae	*Liagoceradocus subthalassicus Bradbury & Williams*	
B-1	-20.79806	115.33139	Arachnida	Araneae	Oecobiidae	*Oecobius*	sp.
B-1	-20.79806	115.33139	Arachnida	Araneae	Gnaphosidae		
B-1	-20.79806	115.33139	Arachnida	Araneae	Ctenidae		
B-1	-20.79806	115.33139	Arachnida	Araneae	Gnaphosidae		
B-1	-20.79806	115.33139	Arachnida	Araneae	Stiphidiidae	*Janusia*	
B-1	-20.79806	115.33139	Arachnida	Araneae	Gnaphosidae		
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria			
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Insecta	Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139		Blattaria	Nocticolidae	*Nocticola*	sp.
B-1	-20.79806	115.33139	Maxillopoda: Copepoda	Calanoida			
B-1	-20.79806	115.33139	Maxillopoda: Copepoda	Calanoida			

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-1	-20.79806	115.33139	Insecta	Coleoptera	Trogidae	*Omorgus*	*dilaticollis* (Macleay)
B-1	-20.79806	115.33139	Insecta	Coleoptera	Carabidae		
B-1	-20.79806	115.33139	Insecta	Collembola			
B-1	-20.79806	115.33139	Insecta	Collembola			
B-1	-20.79806	115.33139		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B-1	-20.79806	115.33139		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B-1	-20.79806	115.33139		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B-1	-20.79806	115.33139	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	*stylifera* Holthuis
B-1	-20.79806	115.33139	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	*stylifera* Holthuis
B-1	-20.79806	115.33139	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	*stylifera* Holthuis
B-1	-20.79806	115.33139	Insecta	Diptera			
B-1	-20.79806	115.33139	Insecta	Diptera			
B-1	-20.79806	115.33139	Insecta	Diptera			
B-1	-20.79806	115.33139	Insecta	Diptera			
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	*Ploiaria*	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	*Ploiaria*	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	*Ploiaria*	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera	Reduviidae: Emesinae	*Ploiaria*	sp.1
B-1	-20.79806	115.33139	Insecta	Hemiptera			
B-1	-20.79806	115.33139	Insecta	Hemiptera	Cixiidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139	Insecta	Hymenoptera	Formicidae		
B-1	-20.79806	115.33139		Hymenoptera	Formicidae		
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	*Laevophiloscia yalgoonensis Wahrberg 1922*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	*Laevophiloscia yalgoonensis Wahrberg 1922*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	*Laevophiloscia yalgoonensis Wahrberg 1922*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	*Laevophiloscia yalgoonensis Wahrberg 1922*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	*Laevophiloscia yalgoonensis Wahrberg 1922*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	*Laevophiloscia yalgoonensis Wahrberg 1922*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda	Philosciidae	*Laevophiloscia yalgoonensis Wahrberg 1922*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda			
B-1	-20.79806	115.33139		Isopoda: Oniscidea	Philosciidae	*?Laevophiloscia Wahrberg, 1922 sp. nov.*	
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Malacostraca	Isopoda: Oniscidea			
B-1	-20.79806	115.33139	Insecta	Psocoptera			
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-1	-20.79806	115.33139	Arachnida	Scorpionida	Ischnuridae	*Liocheles*	sp.
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Diplopoda	Spirobolida	Pachybolidae :Trigoniulinae	*Speleostrophus nesiotes Hoffman 1994*	
B-1	-20.79806	115.33139	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-1	-20.79806	115.33139			Japygidae		
B-2	-20.71667	115.38333	Insecta	Lepidoptera			
B-2	-20.71667	115.38333	Insecta	Lepidoptera			
B-2	-20.71667	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-2	-20.71667	115.38333	Arachnida	Araneae	Theridiidae	*Icona*	sp.
B-2	-20.71667	115.38333	Arachnida	Acarina			
B-2	-20.71667	115.38333	Arachnida	Araneae	Theridiidae		
B-2	-20.71667	115.38333	Arachnida	Araneae			
B-2	-20.71667	115.38333	Arachnida	Araneae	Pholcidae		
B-2	-20.71667	115.38333	Arachnida	Araneae	Theridiidae		
B-2	-20.71667	115.38333	Insecta	Coleoptera			
B-2	-20.71667	115.38333	Insecta	Collembola			
B-2	-20.71667	115.38333	Insecta	Hemiptera	Cixiidae?		
B-2	-20.71667	115.38333	Insecta	Hymenoptera	Formicidae		
B-2	-20.71667	115.38333	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-2	-20.71667	115.38333	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-2	-20.71667	115.38333	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-2	-20.71667	115.38333	Malacostraca	Isopoda: Oniscidea			
B-2	-20.71667	115.38333	Malacostraca	Isopoda: Oniscidea			
B-2	-20.71667	115.38333	Insecta	Lepidoptera			
B-2	-20.71667	115.38333	Insecta	Psocoptera			
B-2	-20.71667	115.38333	Insecta	Psocoptera			
B-3	-20.80000	115.36331	Arachnida	Acarina	Ixodidae	*Amblyomma*	*limbatum* Neumann
B-3	-20.80000	115.36331	Arachnida	Acarina	Ixodidae	*Amblyomma*	*limbatum* Neumann
B-3	-20.80000	115.36331	Arachnida	Acarina			
B-3	-20.80000	115.36331	Insecta	Coleoptera	Trogidae	*Omorgus*	*dilaticollis* (Macleay)
B-3	-20.80000	115.36331	Insecta	Coleoptera	Trogidae	*Omorgus*	*dilaticollis* (Macleay)
B-3	-20.80000	115.36331	Insecta	Coleoptera	Dermestidae	*Dermestes*	*frischi* Kugelann
B-3	-20.80000	115.36331	Insecta	Collembola			
B-3	-20.80000	115.36331	Insecta	Collembola			

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-3	-20.80000	115.36331	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-3	-20.80000	115.36331	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-3	-20.80000	115.36331	Insecta	Hymenoptera	Formicidae		
B-3	-20.80000	115.36331	Arachnida	Acarina	Ixodidae	*Amblyomma*	sp.
B-3	-20.80000	115.36331	Arachnida	Araneae	Heteropodidae	*Heteropoda*	sp
B-3	-20.80000	115.36331	Arachnida	Araneae	Pholcidae		
B-3	-20.80000	115.36331	Arachnida	Araneae	Ctenidae		
B-3	-20.80000	115.36331	Arachnida	Araneae	Pholcidae	*Trichocyclus*	
B-3	-20.80000	115.36331	Insecta	Coleoptera	Trogidae		
B-3	-20.80000	115.36331	Insecta	Collembola			
B-3	-20.80000	115.36331	Insecta	Diptera			
B-3	-20.80000	115.36331	Insecta	Hemiptera			
B-3	-20.80000	115.36331	Insecta	Hymenoptera	Formicidae		
B-3	-20.80000	115.36331	Insecta	Hymenoptera	Formicidae		
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Armadillidae: Buddelundiinae	*Barrowdillo pseudopyrgoniscus Dalens*	
B-3	-20.80000	115.36331	Malacostraca	Isopoda	Philosciidae		*Laevophiloscia yalgoonensis* Wahrberg 1922
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea			
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea			
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea	Philosciidae		
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea		*Barrowdillo*	
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea	"Porcellenid"		
B-3	-20.80000	115.36331	Malacostraca	Isopoda: Oniscidea			
B-3	-20.80000	115.36331		Pscocidae			
B-3	-20.80000	115.36331	Insecta	Thysanura	Lepismatidae	*Heterolepisma*	sp.
B-3	-20.80000	115.36331	Diplopoda				epigean species

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-3	-20.80000	115.36331		Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	*Heteropoda*	sp
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	*Heteropoda*	sp.
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Insecta	Coleoptera	Tenebrionidae	*Brises*	sp.
B-4	-20.76667	115.38333	Insecta	Hemiptera	Reduviidae: Emesinae	*Stenolemus*	*giraffa* Wygodzinsky
B-4	-20.76667	115.38333	Arachnida	Araneae	? Gnaphosidae (JW)		
B-4	-20.76667	115.38333	Arachnida	Araneae	? Cyclotenidae (JW)		
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	*Heteropoda (JW)*	
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Pholcidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Cyclotenidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Gnaphosidae		
B-4	-20.76667	115.38333	Arachnida	Araneae	Heteropodidae	*Heteropoda*	
B-4	-20.76667	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-4	-20.76667	115.38333	Malacostraca	Isopoda: Oniscidea			
B-4	-20.76667	115.38333	Malacostraca	Isopoda: Oniscidea		*Barrowdillo*	
B-4	-20.76667	115.38333	Insecta	Psocoptera			
B-4	-20.76667	115.38333	Diplopoda				epigean species
B-5	-20.76667	115.36667	Arachnida	Acarina	Ixodidae	*Amblyomma*	*limbatum* Neumann
B-5	-20.76667	115.36667	Arachnida	Araneae	Pholcidae		
B-5	-20.71667	115.38333	Arachnida	Araneae	Pholcidae		
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Emesinae	*Stenolemus*	*giraffa* Wygodzinsky
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-5	-20.76667	115.36667	Arachnida	Pseudoscorpionida	Atemnidae	*Oratemnus*	sp. nov.
B-5	-20.76667	115.36667	Arachnida	Araneae	Heteropodidae (JW)	*Heteropoda*	
B-5	-20.76667	115.36667	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-5	-20.76667	115.36667	Malacostraca	Isopoda: Oniscidea		*Buddelundia*	
B-5	-20.76667	115.36667	Malacostraca	Isopoda: Oniscidea	Pholoscidae		

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-5	-20.76667	115.36667	Arachnida	Pseudoscorpionida	Atemnidae	*Oratemnus*	sp. nov.
B-5	-20.76667	115.36667	Insecta	Psocoptera			
B-6	-20.83333	115.38333	Arachnida	Acarina			
B-6	-20.83333	115.38333	Arachnida	Acarina			
B-6	-20.85000	115.38333	Arachnida	Araneae	Araneidae	*Argiope*	*protensa*
B-6	-20.83333	115.38333	Arachnida	Araneae	Oonopidae	*?Opopaea*	sp.
B-6	-20.83333	115.38333	Arachnida	Araneae	Theridiidae	*Euryopis*	sp.
B-6	-20.85000	115.38333	Arachnida	Araneae			
B-6	-20.85000	115.38333	Arachnida	Araneae	Desidae	*Badumna*	
B-6	-20.83333	115.38333	Arachnida	Araneae	Oonopidae		
B-6	-20.83333	115.38333	Arachnida	Araneae	Gnaphosidae		
B-6	-20.83333	115.38333	Arachnida	Araneae	Zoridae		
B-6	-20.83333	115.38333	Arachnida	Araneae	Amaurobidae		
B-6	-20.85000	115.38333	Arachnida	Araneae	Pholcidae		
B-6	-20.83333	115.38333	Insecta	Blattodea			
B-6	-20.83333	115.38333	Insecta	Blattodea			
B-6	-20.83333	115.38333	Insecta	Coleoptera	Carabidae: Pterostichini	*Prosopogmus*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae: Entiminae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae: Cryptorhynchinae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Ectychini	*Ectyche*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Crypticini	*Microcrypticus*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Opatrini	*Mesomorphus*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Carabidae: Pterostichini	*Prosopogmus*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae: Entiminae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Ectychini	*Ectyche*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Tenebrionidae: Opatrini	*Mesomorphus*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Curculionidae:		

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
					Crytptorhynchinae		
B-6	-20.83333	115.38333	Insecta	Coleoptera	Lathridiidae: Lathridiinae	*genus?*	
B-6	-20.83333	115.38333	Insecta	Coleoptera	Ptiliidae		
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.83333	115.38333	Insecta	Collembola			
B-6	-20.85000	115.38333	Insecta	Diptera			
B-6	-20.83333	115.38333	Insecta	Diptera			
B-6	-20.83333	115.38333	Insecta	Diptera			
B-6	-20.83333	115.38333	Mollusca	Gastropoda			
B-6	-20.83333	115.38333	Mollusca	Gastropoda			
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae	*Centrogonus*	sp. 1
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-6	-20.85000	115.38333	Insecta	Hemiptera	Reduviidae: Reduviinae	*Centrogonus*	sp.1
B-6	-20.85000	115.38333	Insecta	Hemiptera			
B-6	-20.85000	115.38333	Insecta	Hemiptera			
B-6	-20.83333	115.38333	Insecta	Hemiptera			
B-6	-20.83333	115.38333	Insecta	Hemiptera			
B-6	-20.85000	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.83333	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.83333	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.85000	115.38333	Insecta	Hymenoptera	Formicidae		
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.83333	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.83333	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.83333	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Malacostraca	Isopoda: Oniscidea			
B-6	-20.85000	115.38333	Insecta	Isoptera			

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B-6	-20.83333	115.38333	Insecta	Orthoptera			
B-6	-20.85000	115.38333	Insecta	Orthoptera			
B-6	-20.83333	115.38333	Diplopoda	Polyxenida	Polyxenidae		
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida	Olpiidae	*Xenolpium*	sp.
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida	Cheiridiidae		
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida	Olpiidae		
B-6	-20.83333	115.38333	Arachnida	Pseudoscorpionida	Cheiridiidae		
B-6	-20.83333	115.38333	Insecta	Psocoptera			
B-6	-20.83333	115.38333	Insecta	Psocoptera			
B-6	-20.83333	115.38333	Insecta	Psocoptera			
B-6	-20.85000	115.38333	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	*Acrotelsella*	sp.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	*Heterolepisma*	sp.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	*Acrotelsella*	sp.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae	*Heterolepisma*	sp.
B-6	-20.83333	115.38333	Insecta	Thysanura	Lepismatidae		
B-6	-20.83333	115.38333	Insecta				
B-6	-20.85000	115.38333	Gastropoda				
B-8	-20.83333	115.41667	Insecta	Hemiptera	Reduviidae: Emesinae	*Stenolemus*	*giraffa* Wygodzinsky
B-10	-20.80000	115.38333	Insecta	Coleoptera	Pselaphidae		
B-10	-20.80000	115.38333	Insecta	Diptera			
B-10	-20.80000	115.38333	Insecta	Hemiptera			
B-10	-20.80000	115.38333	Malacostraca	Isopoda: Oniscidea		*Barrowdillo*	
B-10	-20.80000	115.38333	Insecta	Psocoptera			
B-10	-20.80000	115.38333	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-10	-20.80000	115.38333	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B-18	-20.85000	115.31667	Ostracoda	Ostracoda	Candonidae: Paracypridinae	*Phlyctenophora mesembria Wouters*	
B-18	-20.85000	115.31667	Copepoda				
B -1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B -1	-20.79806	115.33139	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
Q5	-20.78472	115.38083		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
"F Cave"			Arachnida	Araneae	Pholcidae	*Trichocyclus*	sp. nov.
B2	-20.86667	115.35000	Malacostraca	Amphipoda	Melitidae	*Nedsia*	*fragilis* Bradbury & Williams, HOLOTYPE
B2	-20.86000	115.35472	Maxillopoda: Copepoda	Calanoida			
B2	-20.86000	115.35472	Maxillopoda: Copepoda	Calanoida			
B2	-20.86667	115.35000	Maxillopoda: Copepoda	Calanoida			
B2	-20.86667	115.35000	Maxillopoda: Copepoda	Calanoida			
B2	-20.86667	115.35000	Maxillopoda: Copepoda	Calanoida			
B2	-20.86667	115.35000	Insecta	Coleoptera	Curculionidae: Cryptorhynchinae		
B2	-20.86667	115.35000	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2	-20.86667	115.35000	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2	-20.86667	115.35000	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2			Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2			Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2	-20.86000	115.35472		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2	-20.86000	115.35472		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2	-20.86000	115.35472		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2	-20.86667	115.35000	Insecta	Hymenoptera	Formicidae		
B2	-20.86667	115.35000	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B2	-20.86667	115.35000	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B2	-20.86667	115.35000	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B2			Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
B2	-20.86667	115.35000	Malacostraca	Isopoda: Oniscidea	Armadillidae		
B2	-20.86667	115.35000	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri*	
B2	-20.86000	115.35472	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri*	
B2	-20.86667	115.35000	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
B2	-20.86667	115.35000	Malacostraca	Syncarida Bathynellacea	Parabathynellidae,	*Atopobathynella*	sp. nov.
B2	-20.86667	115.35000	Malacostraca	Syncarida Bathynellacea	Parabathynellidae	*Atopobathynella*	sp. nov.
B2	-20.86667	115.35000	Malacostraca	Syncarida Bathynellacea	Parabathynellidae,	*Atopobathynella*	sp. nov.
B2	-20.86667	115.35000	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
B2	-20.86000	115.35472		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
B2	-20.86000	115.35472	Maxillopoda: Copepoda	Calanoida			
B2	-20.86000	115.35472		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
B2	-20.86000	115.35472	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri*	
B7			Malacostraca: Pancarida	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
C38	-20.86917	115.40111		Araneae	Pholcidae		
C38	-20.86917	115.40111		Collembola			
C65	-20.88222	115.38500	Arachnida	Acarina			
C65	-20.88222	115.38500	Arachnida	Araneae			
C65	-20.88222	115.38500	Maxillopoda: Copepoda	Calanoida			
C65	-20.88222	115.38500		Cyclopoida		*Halicyclops*	*rochai* Delaurentiis et al 1999
C65	-20.88222	115.38500	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
C65	-20.88222	115.38500	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
C65	-20.88222	115.38500		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
C65	-20.88222	115.38500		Isopoda: Oniscidea			
C65	-20.88222	115.38500		Collembola			
C65	-20.88222	115.38500		Araneae			
C65N	-20.87833	115.39250	Ostracoda				
C66	-20.87917	115.39167	Malacostraca	Amphipoda	Melitidae	*Nedsia*	*macrosculptilis* Bradbury & Williams, HOLOTYPE
C66	-20.87917	115.39167	Maxillopoda: Copepoda	Calanoida			
C66	-20.87917	115.39167	Maxillopoda: Copepoda	Calanoida			
C66	-20.87917	115.39167	Maxillopoda: Copepoda	Calanoida			
C66	-20.87917	115.39167	Maxillopoda: Copepoda	Calanoida			
C66	-20.87917	115.39167	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
C66	-20.87917	115.39167	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
C66	-20.87917	115.39167	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
C66	-20.87917	115.39167	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
C77J	-20.88278	115.39556	Maxillopoda: Copepoda	Calanoida			
C77J	-20.88278	115.39556	Maxillopoda: Copepoda	Cyclopoida		*Halicyclops*	*rochai* Delaurentiis et al 1999
E1	-20.83472	115.40250	Maxillopoda: Copepoda	Calanoida			
E1	-20.83472	115.40250		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
F11	-20.84606	115.37309	Arachnida	Araneae			

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
F11	-20.84606	115.37309	Arachnida	Araneae	Trochanteriidae		
F11	-20.84611	115.37306	Maxillopoda: Copepoda	Calanoida			
F11	-20.84606	115.37309	Maxillopoda: Copepoda	Calanoida			
F11	-20.84611	115.37306	Insecta	Coleoptera			
F11	-20.84611	115.37306	Maxillopoda: Copepoda	Cyclopoida		*Diacyclops*	"*humphreysi unispinosa* n. ssp."
F11	-20.84611	115.37306		Cyclopoida		*Halicyclops*	*rochai* Delaurentiis et al 1999
F11	-20.84611	115.37306		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
F41A			Maxillopoda: Copepoda	Calanoida			
F41A			Maxillopoda: Copepoda	Calanoida			
F41A				Hemiptera	Meenoplidae		
F53S	-20.84361	115.38083		Collembola			
F7	-20.85028	115.37861	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri*	
G19			Maxillopoda: Copepoda	Calanoida			
G19			Maxillopoda: Copepoda	Calinoida			
G19			Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
G19			Arachnida	Scorpionida	Buthidae	*Lychas*	*marmoreus*?
G19			Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
K11	-20.81778	115.37250	Malacostraca	Amphipoda	Melitidae	*Nedsia*	?*urifimbriata* Bradbury & Williams ALLOTYPE?
K11	-20.81778	115.37250	Malacostraca	Amphipoda	Melitidae	*Nedsia*	*urifimbriata* Bradbury & Williams, HOLOTYPE
K11			Arachnida	Araneae			
K11			Insecta	Hymenoptera			
K3N	-20.80944	115.36389	Copepoda	Cyclopoida	Cyclopidae	*Halicyclops*	*longifurcatus*
K3N	-20.80944	115.36389	Maxillipoda: Copepoda	Cyclopoida	Cyclopidae	*Halicyclops*	*longifurcatus*
K3N	-20.80944	115.36389	Maxillipoda: Copepoda	Harpacticoida	Ameiridae	*Inermipes*	*humphreysi* Lee & Huys; HOLOTYPE & PARATYPES
K3N	-20.80944	115.36389	Maxillipoda: Copepoda	Harpacticoida	Ameiridae	*Inermipes*	*humphreysi* Lee & Huys; HOLOTYPE & PARATYPES
K3N	-20.80944	115.36389	Copepoda	Harpacticoida	Ameiridae	*Inermipes*	*humphreysi* Lee & Huys; PARATYPES
L 16			Malacostraca	Amphipoda	Melitidae	*Nedsia*	straskaba Bradbury & Williams, HOLOTYPE
L 16			Malacostraca	Amphipoda	Melitidae	*Nedsia*	*straskraba* Bradbury & Williams, 1996
L 16			Maxillopoda: Copepoda	Calanoida			

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
L 16			Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
L 16			Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L17			Maxillopoda: Copepoda	Calanoida			
L17			Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L17			Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L2	-20.80917	115.36417		Collembola			
L32J	-20.80944	115.37833		Amphipoda			
L32J	-20.80944	115.37833	Maxillopoda: Copepoda	Calanoida			
L32J	-20.80944	115.37833	Maxillopoda: Copepoda	Calanoida			
L32J	-20.80944	115.37833		Collembola			
L32J	-20.80944	115.37833	Maxillopoda: Copepoda	Cyclopoida		*Diacyclops*	"*humphreysi unispinosa* n. ssp."
L32J	-20.80944	115.37833	Amphipoda				
L32J	-20.80944	115.37833		Araneae	Pholcidae		
L4	-20.80667	115.38944	Malacostraca	Amphipoda	Melitidae	*Nedsia*	*humphreysi* Bradbury & Williams, HOLOTYPE
L4	-20.80667	115.38944	Malacostraca	Amphipoda		*Nedsia*	sp. nov.? (cf *sculptilis*)
L4	-20.80667	115.38944	Malacostraca	Amphipoda			
L4	-20.80611	115.38917	Maxillopoda: Copepoda	Calanoida			
L4	-20.80667	115.38944	Maxillopoda: Copepoda	Calanoida			
L4	-20.80667	115.38944	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L4	-20.80611	115.38917		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L4	-20.80611	115.38917		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L4	-20.80608	115.38922	Copepoda	Harpacticoida			
L4	-20.80611	115.38917	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri*	
L4	-20.80667	115.38944	Arachnida	Schizomida	Hubbardiidae	*Draculoides bramstokeri Harvey and Humphreys sp. nov.*	
L4	-20.80667	115.38944	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L4	-20.80611	115.38917		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L4	-20.80667	115.38944		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L4	-20.80667	115.38944	Amphipoda				
L4N	-20.80608	115.38922	Malacostraca	Amphipoda			
L4N	-20.81728	115.39506	Malacostraca	Amphipoda			
L4N	-20.81728	115.39506	Maxillopoda: Copepoda	Calanoida			

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
L4N	-20.81728	115.39506	Insecta	Coleoptera			
L5	-20.81409	115.38747	Maxillopoda: Copepoda	Calanoida			
L5	-20.81409	115.38747	Maxillopoda: Copepoda	Calanoida			
L5	-20.81409	115.38747	Insecta	Hymenoptera	Formicidae		
L8	-20.81739	115.39497	Arachnida	Acarina			
L8	-20.81728	115.39506	Arachnida	Acarina			
L8	-20.81694	115.39444	Malacostraca	Amphipoda	Bogidielliedae	*Bogadomma*	*australis* Bradbury & Williams
L8	-20.81694	115.39444	Malacostraca	Amphipoda	Bogidiellidae	*Bogidomma*	*australis* Bradbury & Williams, HOLOTYPE
L8	-20.81694	115.39444	Malacostraca	Amphipoda		*Nedsia*	*sculptilis*
L8	-20.81694	115.39444	Malacostraca	Amphipoda	Melitidae	*Nedsia*	*sculptilis* Bradbury & Williams, HOLOTYPE
L8	-20.81728	115.39506	Malacostraca	Amphipoda			
L8	-20.81694	115.39444	Arachnida	Araneae			
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Calanoida			
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Calanoida			
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Calanoida			
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Calanoida			
L8	-20.81739	115.39497	Maxillopoda: Copepoda	Calanoida			
L8	-20.81739	115.39497	Maxillopoda: Copepoda	Calanoida			
L8	-20.81728	115.39506	Maxillopoda: Copepoda	Calanoida			
L8	-20.81728	115.39506	Maxillopoda: Copepoda	Calanoida			
L8	-20.81728	115.39506	Maxillopoda: Copepoda	Calanoida			
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Calanoida			
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Calanoida			
L8	-20.81694	115.39444	Insecta	Coleoptera			
L8	-20.81728	115.39506	Insecta	Collembola			
L8	-20.81728	115.39506	Insecta	Collembola			
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Cyclopoida		*Diacyclops*	"*humphreysi unispinosa* n. ssp."
L8	-20.81694	115.39444	Maxillopoda: Copepoda	Cyclopoida		*Halicyclops*	*rochai* Delaurentiis et al 1999
L8	-20.81728	115.39506	Maxillopoda: Copepoda	Cyclopoida		*Halicyclops*	*rochai* Delaurentiis et al 1999
L8	-20.81694	115.39444		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81694	115.39444		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
L8	-20.81694	115.39444		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81739	115.39497		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81739	115.39497		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81728	115.39506		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
L8	-20.81694	115.39444	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	*stylifera* Holthuis, 1960
L8	-20.81694	115.39444	Copepoda	Harpacticoida	Ameiridae	*Inermipes*	*humphreysi* Lee & Huys; PARATYPE
L8	-20.81728	115.39506	Insecta	Hymenoptera	Formicidae		
L8	-20.81694	115.39444	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
L8	-20.81694	115.39444		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
L8	-20.81694	115.39444		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
L8	-20.81694	115.39444		Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
L8	-20.81728	115.39506	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
L8	-20.81694	115.39444	Insecta	Psocoptera			
L8	-20.81694	115.39444	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444	Malacostraca	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81728	115.39506		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
L8	-20.81694	115.39444	Amphipoda				
L8	-20.81694	115.39444	Amphipoda				
L8	-20.81694	115.39444	Amphipoda				
L8	-20.81889	115.40667	Amphipoda				
L8	-20.81739	115.39497	Amphipoda				

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
L8	-20.81739	115.39497		Collembola			
L8	-20.81739	115.39497	Amphipoda				
L8	-20.81728	115.39506	Pisces		Eleotridae	*Milyeringa*	*veritas*
L8	-20.81728	115.39506	Amphipoda			*Nedsia*	
M13	-20.81719	115.41233	Malacostraca	Amphipoda			
M13	-20.81719	115.41233	Arachnida	Araneae	Desidae		
M13	-20.81719	115.41233	Insecta	Diptera			
M13	-20.81719	115.41233	Insecta				
M5	-20.81222	115.40972		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
M5	-20.81222	115.40972	Malacostraca	Isopoda	Cirolanidae	*Haptolana*	*pholeta* Bruce & Humphreys
M52	-20.81586	115.40814	Maxillopoda: Copepoda	Calanoida			
M52	-20.81586	115.40814	Maxillopoda: Copepoda	Calanoida			
M52	-20.81586	115.40814		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
M5N	-20.81017	115.41006	Arachnida	Araneae	Pholcidae		
M5N	-20.81017	115.41006	Arachnida	Araneae	Pholcidae		
M5N	-20.81017	115.41006	Maxillopoda: Copepoda	Calanoida			
M5N	-20.81017	115.41006	Maxillopoda: Copepoda	Calanoida			
M5N	-20.81017	115.41006	Maxillopoda: Copepoda	Cyclopoida		*Halicyclops*	*rochai* De Laurentiis et al 1999
M5N	-20.81017	115.41006	Maxillopoda: Copepoda	Cyclopoida		*Halicyclops*	*rochai* Delaurentiis et al 1999
M5N	-20.81017	115.41006	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
M5N	-20.81017	115.41006	Insecta	Hemiptera: Fulgoroidea?			
M5N	-20.81017	115.41006		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
M62	-20.81889	115.40667	Arachnida	Acarina			
M62	-20.81919	115.40706	Arachnida	Acarina			
M62	-20.81919	115.40706	Malacostraca	Amphipoda			
M62	-20.81919	115.40706	Malacostraca	Amphipoda			
M62	-20.81889	115.40667	Maxillopoda: Copepoda	Calanoida			
M62	-20.81919	115.40706	Maxillopoda: Copepoda	Calanoida			
M62	-20.81919	115.40706	Maxillopoda: Copepoda	Calanoida			
M62	-20.81889	115.40667	Maxillopoda: Copepoda	Cyclopoida		*Diacyclops*	"*humphreysi unispinosa* n. ssp."
M62	-20.81889	115.40667		Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
M62	-20.81889	115.40667	Amphipoda				

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
M62	-20.81919	115.40706	Foramenifera				
M62			Maxillopoda: Copepoda	Calanoida			
M62			Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
Malouet Cave			Arachnida	Araneae	Ctenidae	*Janusia*	sp.3
Malouet Cave			Arachnida	Araneae	Pholcidae		
MW13	-20.78083	115.46694		Harpacticioda		*Inermipes*	*humphreysi* Lee & Huys
MW13 / SB31	-20.78083	115.46694		Harpacticioda		*Inermipes*	*humphreysi* Lee & Huys
MW15	-20.78278	115.46472	Amphipoda				
MW15	-20.78278	115.46472	Amphipoda				
MW15	-20.78278	115.46472	Amphipoda				
MW17	-20.77861	115.46778	Amphipoda				
MW3 /SB8	-20.77972	115.46333	Malacostraca	Syncarida Bathynellacea			
MW3 /SB8	-20.77972	115.46333	Syncaridae	Bathynellacea			
MW7	-20.77775	115.46561		Cyclopoida		*Diacyclops*	"*humphreysi unispinosa* n. ssp."
N62			Arachnida	Acarina			
N62			Arachnida	Araneae	Pholcidae	*Trichocyclus*	
N62			Arachnida	Araneae			
N62			Insecta	Collembola			
N62			Insecta	Diptera			
N62			Insecta	Hemiptera	Reduviidae: Emesinae		
N62			Malacostraca	Isopoda: Oniscidea			
N62			Malacostraca	Isopoda: Oniscidea		*Barrowdillo*	
N62			Insecta	Orthoptera			
Old batch plant bore	-20.82417	115.43861		Cyclopoida		*Allocyclops*	"*barrowi* n.sp. Karanovic"
Old batch plant bore	-20.82417	115.43861		Collembola			
Old batch plant bore	-20.82417	115.43861		Acarina			
Q5	-20.78472	115.38083	Maxillopoda: Copepoda	Calanoida			
Q5	-20.78472	115.38083	Maxillopoda: Copepoda	Calanoida			
Q5	-20.78472	115.38083	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
Q5	-20.78472	115.38083	Insecta	Hymenoptera			

Cave or well	**Dec Lat**	**Dec Long**	**Class**	**Order**	**Family**	**Genus**	Species
Q5	-20.78472	115.38083	Thermosbaenacea	Thermosbaenacea		*Halosbaena*	*tulki* Poore & Humphreys, 1992
S87	-20.76667	115.38333	Arachnida	Araneae	Salticidae	*Zenodorus*	?*orbiculatus*
S87	-20.76667	115.38333	Arachnida	Araneae	Zodariidae	*Habronestes*	sp
W62JW	-20.73222	115.42611	Malacostraca	Amphipoda		*Nedsia*	*hurlberti*
W62JW	-20.73222	115.42611	Maxillopoda: Copepoda	Calanoida			
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
W62JW	-20.73222	115.42611	Malacostraca	Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.
X62JW	-20.73222	115.42611	Malacostraca	Amphipoda			
X62JW	-20.73222	115.42611	Arachnida	Araneae	Theridiidae	*Latrodectus*	*hasseltii*
X62JW	-20.73222	115.42611	Maxillopoda: Copepoda	Calanoida			
X62JW	-20.73222	115.42611	Maxillopoda: Copepoda	Calanoida			
X62JW	-20.73222	115.42611		Decapoda: Natantia	Atyidae	*Stygiocaris*	sp.

Attachment 2 - Interim Advice on Electrophoretic Investigations by University of Western Australia Zoology

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The University of Western Australia

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Genetic Diversity in samples of stygobitic amphipods from Barrow Island

4 June 2004

Frozen specimens of amphipods from seven bores from Barrow Island were analysed for 20 allozyme loci following standard methods for protein electrophoresis. For comparative purposes, specimens of amphipods from the families Bogidiellidae and Melitidae (genus *Nedsia*), were included in the analyses from other sites where they are known (Cape Preston, Mount Brockman, and Paraburdoo)

In the following discussion, the word “group” may be loosely interpreted to mean “species” however, as will be explained in the concluding remarks, we must be cautious with the interpretation of species boundaries based on allozyme data alone.

Of the seven bores, five contained a single genetic group, while two of the bores (L32j and AMW18) contained two genetic groups (Table 1). In order to test for similarities among groups from different bores, a cluster analysis (using multi-dimensional scaling of Nei’s genetic distances among samples) was used to group genetically similar samples. This analysis indicated the presence of six distinct genetic groups in the Barrow Island material, which were differentiated by the presence of two or more fixed differences among the 20 loci (Figure 1). Three of the groups (2, 3, and 5), accounting for six bores, showed affinities with melitids from other regions of the Pilbara. The other three (1, 4, and 6) represent groups that have not yet been detected in other bores.

Table 1. Number of genetic groups in each sample and brief description of their affinities. Where two distinct groups were found in a bore, they are labelled species a and b.

Bore	Number of genetic groups	Comments
L32j	2	species a (n = 13), similar to Paraburdoo melitids species b (n = 1), similar to Mt. Brockman melitids
L8	1	(n = 2) similar to Mt. Brockman melitids
14nr1	1	(n = 1) unique genetic type
MW7	1	(n = 1) similar to Paraburdoo melitids
AMW19	1	(n = 1) similar to Paraburdoo melitids
AMW18	2	species a (n = 2) similar to Mt. Cape Preston melitids species b (n = 3) unique genetic group but unable to score many loci
M17-4	1	(n = 1) unique genetic type

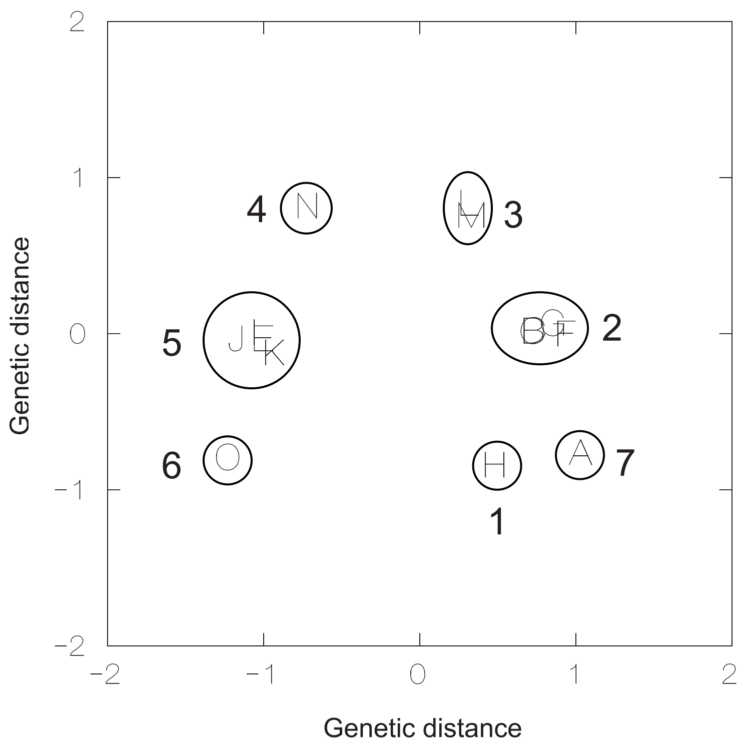

Figure 1. Multidimensional scaling of genetic distances for distinct bore x species groups.

Group 1:
H Barrow 14nr1

Group 2:
B Homestead meltid
C Homestead meltid
D Homestead meltid
F Barrow L32J-species b
G Barrow L8

Group 3:
L Cape Preston melitid
M Barrow AMW18-species a

Group 4:
N Barrow AMW18-species b

Group 5:
E Barrow L32J-species a
I Barrow MW7
J Barrow AMW19
K Paraburdoo melitid

Group 6:
O: Barrow M17-4

Group 7:
A Paraburdoo bogidiellid

In 1996, Bradbury and Williams described seven new species of the genus *Nedsia* (family Melitidae) plus a single species in the family Bogidiellidae from samples from Barrow Island. These descriptions were based on exhaustive documentation of morphological differences among specimens. The allozyme data showed the presence of six distinct genetic groups some of which may correspond to species already described by Bradbury and Williams.

In this study, distinct genetic groups were identified by fixed differences at two or more loci between populations. Fixed differences may arise when movement of individuals or gene flow between two populations ceases. If the populations remain isolated for a long period of time, differentiation may arise to the point that the two populations are no longer able to interbreed. Speciation occurs as a result of this process. Fixed differences may also arise between groups that are isolated for shorter periods of time, but may still retain the ability to interbreed if they were to come into contact again. Given the small sample sizes at each bore, differences may also arise from sampling error. That is, what appears to be a fixed difference may in fact be due to sampling an individual from a population that carries a rare allele, while other individuals not sampled carry that allele in heterozygous form along with other more common alleles found in other populations. If sample sizes were increased, we may find that populations that differ at only one or two loci actually converge. Finally, differences may arise due to localised selection acting on isolated populations.

In this study, there is a large split between groups 1, 2, 3 and 7, and groups 4, 5, and 6 (Figure 1). This is due to differences at 6-8 loci between the two groups. However, differences between populations within groups differ by only 1-3 loci. At this level of differentiation, it is sometimes difficult to determine if the differences represent real species differences, or are due to stochastic events such as sampling error described above. Breeding experiments are sometimes used as a test of reproductive incompatibility, however, given the protracted life cycles of stygobitic fauna, this sort of test is impractical. For this reason, it is important to combine both morphological and genetic data to come to a final conclusion on the number of species present. If the genetic groups correspond well to morphological groups, then differences detected at only a few loci in this study indeed represent species differences. However, if the genetic groups do not correspond to morphological species, then other factors such as small sample sizes may be playing a part. Finally, the use of other molecular markers, such as sequence divergence at mitochondrial genes, may help clarify species boundaries.

Attachment 3 - Barrow Island – Interim Subterranean Fauna Sampling Results – November/December 2004

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Biota Environmental Sciences

Barrow Island – Interim Subterranean Fauna Sampling Results – November/December 2004

We provide here a summary of the recent work completed on Barrow Island in commencing implementation of the Gorgon development Subterranean Fauna Sampling Programme.

Sampling for stygofauna was undertaken over five days from 30th November 2004 to 3rd December 2004. A total of 43 boreholes were sampled for stygofauna during this period (Table 1.1). These included recently installed boreholes situated inside and outside of the plant footprint. Boreholes were also sampled in two locations outside of the plant area, at the island Base and processing facility areas. The methodology for this work was consistent with both the Subterranean Fauna Sampling Programme and previous work undertaken by Biota on Barrow Island.

Ten boreholes were also profiled for water physico-chemical parameters (Table 1.2). These boreholes were selected due to their target geology (halocline). The halocline depth bores were installed specifically in order to investigate the potential for marine lineage stygofauna below the halocline, which would indicate a deeper, marine origin fauna. Readings were taken every five metres below ground level, to the total drilled depth (typically ~50 m). Various parameters were recorded, including dissolved oxygen, conductivity, depth and temperature. The data from this exercise will be combined within the full report, pending 2005.

Troglofauna traps were installed within 43 boreholes (see Table 1.3), in accordance with the Subterranean Fauna Sampling Programme. The sorting and curation of specimens to preliminary identification level was undertaken in the camp laboratory, with further analysis and identification undertaken in the office laboratory in Perth. More detailed taxonomic identification (i.e. to species level) is planned to be undertaken by the submission of the curated specimens to staff at the University of Western Australia and Western Australian Museum and other specialist taxonomists. Stygofauna were collected from 10 bores, including one borehole within the project impact area and nine outside of the project area (see Table 1.4). Some troglobitic taxa were also collected during the field visit, opportunistically recovered from bores sampled for stygofauna.

The installed troglofauna traps are scheduled for retrieval in January 2005, and sorting of samples to be undertaken on return to Perth, in the Biota office laboratory.

Table 1.1: Details of boreholes visited inside and outside of the proposed Gorgon Gas project area, indicating which boreholes were sampled and the Stygofauna collected (WGS84 datum Zone 51).

Boreholes	Easting	Northing	Comments	Dates Sampled
A4	335329	7702611	3 hauls	29/11/04 - 01/12/04
B1	340113	7700371	3 hauls	29/11/04 - 01/12/04
B3	339690	7700465	3 hauls	29/11/04 - 01/12/04
B4	339459	7700690	3 hauls	29/11/04 - 01/12/04
B5	339304	7700415	3 hauls	29/11/04 - 01/12/04
6A	338869	7700186	3 hauls	29/11/04 - 01/12/04

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B7	339265	7700282	3 hauls	29/11/04 - 01/12/04
B8	339183	7700106	3 hauls	29/11/04 - 01/12/04
B9	339064	7700221	3 hauls	29/11/04 - 01/12/04
B10	338966	7700305	3 hauls	29/11/04 - 01/12/04
B11	338790	7700469	3 hauls	29/11/04 - 01/12/04
B12	338578	7700655	3 hauls	29/11/04 - 01/12/04
B13	338968	7700106	3 hauls	29/11/04 - 01/12/04
B14	339096	7699852	3 hauls	29/11/04 - 01/12/04
B15	338862	7700009	3 hauls	29/11/04 - 01/12/04
B16	338762	7700078	3 hauls	29/11/04 - 01/12/04
B17	338648	7700195	3 hauls	29/11/04 - 01/12/04
B18	338582	7700270	3 hauls	29/11/04 - 01/12/04
B19	338491	7700337	3 hauls	29/11/04 - 01/12/04
B20	338335	7700480	3 hauls	29/11/04 - 01/12/04
B21	338125	7700679	3 hauls	29/11/04 - 01/12/04
B22	338388	7700222	3 hauls	29/11/04 - 01/12/04
B23	338393	7699997	3 hauls	29/11/04 - 01/12/04
B24	338291	7700118	3 hauls	29/11/04 - 01/12/04
B26	338681	7699356	3 hauls	29/11/04 - 01/12/04
B27	338462	7699556	3 hauls	29/11/04 - 01/12/04
CHW1	331945	7697424	3 hauls	29/11/04 - 01/12/04
CHW2	332913	7700890	3 hauls	29/11/04 - 01/12/04
CHW3	332870	7700851	3 hauls	29/11/04 - 01/12/04
BMW1	332847	7700930	3 hauls	29/11/04 - 01/12/04
BMW4	332820	7700883	3 hauls	29/11/04 - 01/12/04
BMW5	331999	7697055	3 hauls	29/11/04 - 01/12/04
BMW6	331870	7697078	3 hauls	29/11/04 - 01/12/04
BMW7	331864	7697228	3 hauls	29/11/04 - 01/12/04
S1	337433	7701733	3 hauls	29/11/04 - 01/12/04
S2	338465	7701878	3 hauls	29/11/04 - 01/12/04
S3	339423	7701776	3 hauls	29/11/04 - 01/12/04
S4	336298	7699910	3 hauls	29/11/04 - 01/12/04
S5	337101	7699396	3 hauls	29/11/04 - 01/12/04
S6	338220	7699071	3 hauls	29/11/04 - 01/12/04
S7	335167	7698272	3 hauls	29/11/04 - 01/12/04
S8	336189	7697735	3 hauls	29/11/04 - 01/12/04
S9	337097	7696971	3 hauls	29/11/04 - 01/12/04

Table 1.2: Details of halocline boreholes profiled for physico-chemical parameters.

Boreholes	Date logged	Comments
A4	29/11/04	Logged
B5	29/11/04	Logged
B8	29/11/04	Logged
B12	29/11/04	Possible collapse or pinched pipe at ~10 m
B18	29/11/04	Logged
B24	29/11/04	Logged
B26	29/11/04	Logged
S3	29/11/04	Logged
S5	29/11/04	Logged
S9	29/11/04	Logged

Table 1.3: Details of boreholes where Troglofauna traps were installed, including trap and interval depths in Metres. BGL = Below Ground Level

Boreholes	Easting	Northing	Comments	Depth/ Intervals BGL
A4	335329	7702611	3 traps	5, 10, 15
A6	337811	7700967	1 trap	6-10
B1	340113	7700371	1 trap	5
B3	339690	7700465	1 trap	6
B4	339459	7700690	1 trap	5
B5	339304	7700415	1 trap	6
6A	338869	7700186	2 traps	6, 11
B8	339183	7700106	2 traps	5, 10
B9	339064	7700221	2 traps	6, 11
B10	338966	7700305	1 trap	6-10
B11	338790	7700469	1 trap	6-10
B12	338578	7700655	2 traps	5, 10
B13	338968	7700106	1 trap	6-10
B15	338862	7700009	2 traps	5, 10
B16	338762	7700078	1 trap	6-10
B17	338648	7700195	1 trap	6-10
B18	338582	7700270	2 traps	5, 10
B19	338491	7700337	1 trap	6-10
B20	338335	7700480	2 traps	5, 10
B21	338125	7700679	1 trap	6-10
B22	338388	7700222	1 trap	6-10
B23	338393	7699997	1 trap	6-10
B24	338291	7700118	3 traps	5, 10, 15
B26	338681	7699356	3 traps	5, 10, 15
B27	338462	7699556	3 traps	5, 10, 15
CHW1	331945	7697424	4 traps	5, 12, 25, 46
CHW2	332913	7700890	4 traps	5, 12, 21, 36
CHW3	332870	7700851	4 traps	7, 16, 30, 44
BMW1	332870	7700851	4 traps	6, 15, 24, 37
BMW4	332847	7700930	4 traps	5, 18, 26, 39

Boreholes	Easting	Northing	Comments	Depth/ Intervals BGL
BMW5	332820	7700883	4 traps	5, 11, 21, 37
BMW6	331999	7697055	3 traps	5, 15, 33
BMW7	331870	7697078	1 trap	5, 9, 16, 26
S1	331864	7697228	Blocked past 7m, 1 trap	7
S2	338465	7701878	3 traps	7, 14, 22
S3	339423	7701776	2 traps	5, 11
S4	336298	7699910	2 traps	6, 12
S5	337101	7699396	1 trap	6
S6	338220	7699071	1 trap	6
S7	335167	7698272	3 traps	7, 13, 19
S8	336189	7697735	2 traps	7, 13
S9	337097	7696971	1 trap	5
Tony's Hole	338113	7700633	2+ traps	5, 10

Stygofauna Sampling Results

One of the bores where stygofauna were collected was within the impact area of the development footprint (B18), with nine bores outside (B18, BMW1, BMW4, BMW5, BMW6, BMW7, S4, S5, S6 and S9) (Table 4.1). Four stygofauna taxa and two species of troglofauna were collected. The stygofauna collected represented three higher taxonomic groups as follows; Class Malacostraca (Order Amphipoda), Class Copepoda, Class Ostracoda and Class Decapoda (*Stygiocaris stylifera*). Troglofauna taxa collected represented two higher groups; Class Arachnida (Schizomid; *Draculoides bramstokerii*) and Class Collembola. The preliminary results from the stygofauna sampling are listed in Table 1.4.

Table 1.4: Preliminary results of stygofauna sampling (Am = Amphipod, Col = Collembola, Co = Copepod, Os = Ostracod, Sh = Schizomid, St = *Stygiocaris stylifera* (Decapoda)).

Boreholes	Easting	Northing	Taxa
B18	338582	7700270	Am (1) Co (1)
BMW1	332847	7700930	Col (1) Sc (2)
BMW4	332820	7700883	Co (4)
BMW5	331999	7697055	Col (1)
BMW6	331870	7697078	Sc (1)
BMW7	331864	7697228	Am (1) Co (1) Sc (1)
S4	336298	7699910	Co (2)
S5	337101	7699396	Am (1) Co (3)
S6	338220	7699071	Am (5) Co (4) St (3)
S9	337097	7696971	Os (1) St (9)

Other Comments

A small percentage of the boreholes were inaccessible beyond a certain depth due to possible PVC piping constrictions or possible hole collapse. This affected the both the data logging of one bore (B12), depth of stygofauna sampling and the installation of the anticipated number of troglofauna traps in a number of other bores.

Attachment 4 - Barrow Island – Interim Subterranean Fauna Sampling Results – February/March 2005

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Barrow Island – Interim Subterranean Fauna Sampling Results – March 2005

We provide here a summary of the recent work completed on Barrow Island in the ongoing implementation of the Gorgon development Subterranean Fauna Sampling Programme.

Sampling for stygofauna and troglofauna trap insertion was undertaken over five days from 28 February 2005 to 4 March 2005. A total of 33 boreholes were visited for stygofauna sampling, of which 31 were sampled (Table 1.1). These included recently installed boreholes situated inside and outside of the plant footprint. Boreholes were also sampled in two locations outside of the plant area, at the island base and the central processing facility areas. The methodology for this work was consistent with both the Subterranean Fauna Sampling Programme and previous work undertaken by Biota on Barrow Island.

Following the stygofauna sampling exercise, troglofauna traps were installed within 43 boreholes (Table 1.2), in accordance with the Subterranean Fauna Sampling Programme. The sorting and curation of specimens to preliminary identification level was undertaken in the camp laboratory, with further analysis and identification undertaken in the office laboratory in Perth. More detailed taxonomic identification (i.e. to species level) and genetic analyses are scheduled to be undertaken after the submission of the specimens to staff at the University of Western Australia, the Western Australian Museum and other specialist taxonomists. Stygofauna were collected from 13 bores, including five boreholes within the project impact area and eight outside of the project area (Table 1.3). Some troglobitic taxa were also collected during the field visit, opportunistically recovered from bores sampled for stygofauna.

The troglofauna traps installed in December 2004 were retrieved on 24 January 2005, and sorting of trap contents was undertaken on return to Perth, in the Biota office laboratory. The results of the troglofauna survey are given in Table 1.4. Troglofauna were recorded from 35 of the 42 boreholes sampled, and are further discussed in the Troglofauna Sampling Results section.

Table 1.1: Details of boreholes visited inside and outside of the proposed Gorgon Gas project area, indicating which boreholes were sampled for stygofauna (WGS84 datum Zone 50).

Boreholes	Easting	Northing	Comments	Dates Sampled
A4	335329	7702611	3 hauls	28/02/05 - 03/02/05
B1	340113	7700371	3 hauls	28/02/05 - 03/02/05
B3	339690	7700465	3 hauls	28/02/05 - 03/02/05
B4	339459	7700690	3 hauls	28/02/05 - 03/02/05
B5	339304	7700415	3 hauls	28/02/05 - 03/02/05
6A	338869	7700186	3 hauls	28/02/05 - 03/02/05
B8	339183	7700106	3 hauls	28/02/05 - 03/02/05
B9	339064	7700221	3 hauls	28/02/05 - 03/02/05
B12	338578	7700655	Heavily silted, sample aborted	28/02/05 - 03/02/05
B15	338862	7700009	3 hauls	28/02/05 - 03/02/05

B18	338582	7700270	3 hauls	28/02/05 - 03/02/05
B20	338335	7700480	Possible blockage at 30m	28/02/05 - 03/02/05
B21	338125	7700679	3 hauls	28/02/05 - 03/02/05
B24	338291	7700118	3 hauls	28/02/05 - 03/02/05
B26	338681	7699356	3 hauls	28/02/05 - 03/02/05
B27	338462	7699556	3 hauls	28/02/05 - 03/02/05
CHW1	331945	7697424	3 hauls	28/02/05 - 03/02/05
CHW2	332913	7700890	3 hauls	28/02/05 - 03/02/05
CHW3	332870	7700851	3 hauls	28/02/05 - 03/02/05
BMW1	332847	7700930	3 hauls	28/02/05 - 03/02/05
BMW4	332847	7700930	3 hauls	28/02/05 - 03/02/05
BMW5	331999	7697055	3 hauls	28/02/05 - 03/02/05
BMW6	331870	7697078	3 hauls	28/02/05 - 03/02/05
BMW7	331864	7697228	3 hauls	28/02/05 - 03/02/05
S1	337433	7701733	3 hauls	28/02/05 - 03/02/05
S2	338465	7701878	3 hauls	28/02/05 - 03/02/05
S3	339423	7701776	3 hauls	28/02/05 - 03/02/05
S4	336298	7699910	3 hauls	28/02/05 - 03/02/05
S5	337101	7699396	3 hauls	28/02/05 - 03/02/05
S6	338220	7699071	3 hauls	28/02/05 - 03/02/05
S7	335167	7698272	3 hauls	28/02/05 - 03/02/05
S8	336189	7697735	3 hauls	28/02/05 - 03/02/05
S9	337097	7696971	3 hauls	28/02/05 - 03/02/05

Table 1.2: Details of boreholes where troglofauna traps were installed, including trap and interval depths in metres. BGL = Below Ground Level

Boreholes	Easting	Northing	Comments	Depth/ Intervals BGL
A4	335329	7702611	3 traps	5, 10, 15
A6	337811	7700967	1 trap	8
B1	340113	7700371	1 trap	5
B3	339690	7700465	1 trap	6
B4	339459	7700690	1 trap	5
B5	339304	7700415	1 trap	6
6A	338869	7700186	2 traps	6, 11
B8	339183	7700106	2 traps	5, 10
B9	339064	7700221	2 traps	6, 11
B10	338966	7700305	1 trap	6-10
B11	338790	7700469	1 trap	6-10
B12	338578	7700655	2 traps	5, 10
B13	338968	7700106	1 trap	6-10
B15	338862	7700009	2 traps	5, 10
B16	338762	7700078	1 trap	6-10
B17	338648	7700195	1 trap	6-10
B18	338582	7700270	2 traps	5, 10
B19	338491	7700337	1 trap	6-10
B20	338335	7700480	2 traps	5, 10
B21	338125	7700679	1 trap	6-10
B22	338388	7700222	1 trap	7
B23	338393	7699997	1 trap	6-10
B24	338291	7700118	3 traps	5, 10, 15
B26	338681	7699356	3 traps	5, 10, 15
B27	338462	7699556	3 traps	5, 10, 15
CHW1	331945	7697424	4 traps	5, 12, 25, 46
CHW2	332913	7700890	4 traps	5, 12, 21, 36
CHW3	332870	7700851	4 traps	7, 16, 30, 44
BMW1	332870	7700851	4 traps	6, 15, 24, 37
BMW4	332847	7700930	4 traps	5, 18, 26, 39
BMW5	332820	7700883	4 traps	5, 11, 21, 37
BMW6	331999	7697055	3 traps	5, 15, 33
BMW7	331870	7697078	4 traps	5, 9, 16, 26
S1	331864	7697228	Blocked past 7m, 1 trap	7
S2	338465	7701878	3 traps	7, 14, 22
S3	339423	7701776	2 traps	5, 11
S4	336298	7699910	2 traps	6, 12
S5	337101	7699396	1 trap	6
S6	338220	7699071	1 trap	6
S7	335167	7698272	3 traps	7, 13, 19
S8	336189	7697735	2 traps	7, 13
S9	337097	7696971	1 trap	5
Non-referenced	338113	7700633	1 trap	8

Stygofauna Sampling Results

Four of the bores where stygofauna were collected are located within the proposed development footprint (impact area); B4, B18, B21 and B24. Stygofauna were recorded from five bores outside of the proposed development footprint (A4, BMW7, S5, S6 and S9) (Table 1.3). Five stygofauna taxa and three species of troglofauna were represented amongst the collected specimens. The stygofauna represented amongst collected represent four higher taxonomic groups as follows; Class Malacostraca (Order Amphipoda and Order Bathynellacea), Class Copepoda, Class Ostracoda and Order Decapoda (*Stygiocaris stylifera*). The troglofauna species represent three higher groups; Class Arachnida (Schizomid; *Draculoides bramstokerii*), Class Collembola and Class Malocastraca (Order Isopoda). The preliminary results from the stygofauna sampling are listed in Table 1.3.

Table 1.3: Preliminary results of stygofauna sampling (including troglofauna records in bold) Am = Amphipod, Ba = Bathynellid Col = Collembola, Co = Copepod, Is = Isopod, Os = Ostracod, Sc = Schizomid, St = *Stygiocaris stylifera* (Decapoda). Boreholes where stygofauna have previously been recorded are indicated with ***.**

Boreholes	Easting	Northing	Taxa
A4	335329	7702611	Am (1) + remains, **Is (remains)**
B4	339459	7700690	Am (5)
B18 *	338582	7700270	Am (4)
B21	338125	7700679	Ba (4)
B24	338291	7700118	Am (1)
B27	338462	7699556	**Is (1)**, **Sc (1)**
BMW1	332847	7700930	**Is (1)**, **Sc (2)**
BMW5	331999	7697055	**Is (1)**, **Sc (2)**
BMW6	331870	7697078	**Sc (2)**
BMW7 *	331864	7697228	Am (1), Co (1)
S5 *	337101	7699396	Am (1), St (4)
S6 *	338220	7699071	Co (10), Is (1), St (4)
S9 *	337097	7696971	Am (1), **Col (1)**, St (7)

Troglofauna Sampling Results

Troglofauna taxa were collected form bores located both inside and outside of the proposed development footprint. A total of 10 species were collected, representing four higher taxonomic groups, Class Arachnida, Class Collembola, Class Insecta and Class Oligochaeta. These groups comprise seven orders, Acarina, Haplotaxida, Hemiptera Hymenoptera Isoptera, Psuedoscorpionida and Schizomida. The preliminary results from the troglofauna sampling are listed in Table 1.4.

Table 1.4: Preliminary results of troglofauna sampling. (n=number of specimens)

Borehole	Trap No	Taxa	N	Depth m
A4	1	Isoptera	5	5
	2	Collembola	1	10
	2	Isoptera	1	10
A6	1	Acarina	2	6
B4	1	Isoptera	2	5
B5	1	Acarina	2	6
6A	1	Oligochaete	6	6
	2	Collembola	1	11
	2	Oligochaete	4	11
B8	1	Isoptera	3	5

Borehole	Trap No	Taxa	N	Depth m
B9	1	Collembola	1	6
	2	Collembola	1	11
B10	1	Archaeognath	1	6-10
B11	1	Collembola	7	6-10
	1	Schizomid	1	6-10
B12	1	Isoptera	2	5
	2	Oligochaete	11	10
B13	1	Collembola	2	6-10
	1	Oligochaete	5	6-10
B15	2	Acarina	2	10
	2	Collembola	2	10
B18	1	Collembola	3	5
	1	Hemiptera	1	5
	1	Schizomid	1	5
	2	Collembola	3	10
	2	Schizomid	3	10
B20	1	Acarina	2	5
	1	Collembola	2	5
B23	1	Collembola	1	6
	1	Oligochaete	8	6
B24	1	Isoptera	1	5
	1	Undetermined taxon	1	5
	1	Thysanura	1	5
B26	1	Acarina	2	5
	3	Collembola	8	15
	3	Oligochaete	1	15
B27	1	Oligochaete	30+	5
	2	Collembola	12	10
	3	Collembola	1	15
CHW1	1	Isoptera	4	5
	3	Isoptera	30	12
	4	Collembola	1	46
	4	Acarina	1	46
CHW2	1	Acarina	6	5
	2	Collembola	6	12
	3	Collembola	30	21
CHW3	2	Isoptera	3	16
	3	Isoptera	1	30
	4	Isoptera	3	44
BMW1	1	Isoptera	7	6
BMW5	1	Isoptera	25	5
	2	Diptera	16	11
	3	Diptera	3	21
	3	Hymenoptera	1	21
	4	Collembola	1	37
BMW6	1	Collembola	6	5
	2	Collembola	3	15
	2	Oligochaete	5	15
	3	Isopod	1	33

Borehole	Trap No	Taxa	N	Depth m
	3	Oligochaete	5	33
	3	Schizomid	1	33
BMW7	1	Isoptera	30	5
	1	Pseudoscorpion	1	5
	3	Collembola	1	16
	3	Oligochaete	11	16
S1	1	Isoptera	1	7
S2	2	Collembola	3	14
	2	Schizomid	1	14
S3	1	Collembola	2	5
S4	2	Schizomid	1	6
S5	1	Oligochaete	10	6
S6	1	Collembola	4	6
S7	1	Isopod	2	7
	2	Isopod	4	13
	2	Schizomid	1	13
	3	Schizomid	1	19
S8	1	Acarina	2	7
S9	1	Collembola	5	5
Non- referenced	1	Acarina	1	5
	1	Isopod	1	5
	1	Schizomid	1	5

Other Comments

Some of the species recorded still require further taxonomic and genetic work to confirm their status as troglobitic invertebrates, and not troglophilic specimens sharing similar morphological characteristics.

A small percentage of the boreholes were inaccessible beyond a certain depth due to possible PVC piping constrictions or possible hole collapse. This affected the sampling and the installation of the planned number of troglofauna traps in a number of other bores. One bore (B12) was not sampleable for stygofauna due to the heavy silts content and difficulty retrieving the nets.

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Technical Appendix C6

Protected Marine Species

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

PROTECTED MARINE SPECIES

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Report No: R03206
April 2005

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1 Introduction

ChevronTexaco Australia Pty Ltd (ChevronTexaco) and its joint-venture partners, Shell Development Australia and Mobil Australia Resources Company (Gorgon JointVenturers) propose to develop a gas processing facility on Barrow Island. A description of the proposal is contained within the main report.

In order to assist with the assessment of the environmental implications of this venture, ChevronTexaco engaged RPS Bowman Bishaw Gorham to conduct a literature review of protected marine species occurring within the proposed development area. This report describes the results of the literature review, combined with opportunistic field observations recorded as part of the marine ecological surveys. This information was used in the environmental risk assessment for the proposed development, as described in Chapter 11 of the main report.

2 Methodology

Methods used for this report include:

- desktop review of the available literature on marine species
- liaison with APPEA, Department of Environment and Heritage, Department of Conservation and Land Management, Department of Fisheries, Department of Industry and Resources and the Department of Environment (Western Australia)
- liaison with research personnel (independent researchers, universities and the Western Australian Museum)
- review of existing in-house information and previous surveys undertaken in the region by Bowman Bishaw Gorham, including the North West Shelf Environmental Resource Atlas (Bowman Bishaw Gorham 1995)
- opportunistic observations collected during field surveys for the Gorgon Development.

Field surveys investigating intertidal and marine ecology and assessing the conservation significance of areas pertaining to the Gorgon Development were undertaken during August 2002, January 2003 and January 2004. The surveys included investigations of the supratidal, intertidal and marine areas on the east and west coasts, at locations likely to be affected by the development and operation of the proposed marine facilities. During these field surveys the presence of larger protected marine species was noted.

The marine facilities and operations of the Gorgon development on Barrow Island that will potentially impact marine species include:

- the Gorgon gas field development and pipeline to Barrow Island (west coast)
- materials offloading jetty, dredged channel and product loading facilities (east coast)
- dredged spoil disposal
- domestic gas pipeline route (east coast).

This report comprises a review of the available information describing protected marine species found in the Barrow Island area. Discussion of these species' habitat, behaviour and diet is also incorporated in the review.

The ecology, occurrence, and conservation status of seabirds and shorebirds is addressed separately (refer Appendix C3).

3 Regional Marine Environment

The Rowley Shelf is a large sedimentary shelf in the West Pilbara, mainly in the geological province known as the Carnarvon Basin. Barrow Island, the Montebello Islands and the Lowendal Islands are the most offshore of the southern Rowley Shelf islands. These islands are separated from the inner part of the Rowley Shelf by the Flinders Fault and collectively form the Barrow-Montebello Complex (Wilson et al. 1994). The Barrow Island system emerges as a north-tending promontory extension of the Rowley Shelf. This island system comprises Trealla limestone, flanked and veneered by Pleistocene and Holocene sediment deposits (LeProvost et al. 1987).

Offshore tropical open waters are typically nutrient-impoverished and therefore generally support limited marine life. Inshore tropical waters typically support more developed communities with large species diversity. Marine environments around Barrow Island include a mix of limestone pavements, reefs and sands and support a diverse faunal assemblage. The Western Australian Museum has identified 500 species of reef fish on northern Ningaloo Reef and the Muiron Islands, over 600 species at the Rowley Shoals, 457 species at the Montebello Islands and 335 species from the Dampier Archipelago (Hutchins 1994; Allen 1998). Barrow Island waters are expected to support a similar suite of fishes to those found at the Montebello Islands.

Soft sediment habitats generally support limited vertebrate species but include a diverse assemblage of burrowing and crawling invertebrate infauna. Fine sediments generally accumulate in low energy areas and these generally support more diverse and abundant infaunal assemblages.

4 Marine Reserves and Conservation Parks

The purpose of marine reserves is to ensure that representative marine habitats and ecosystems are preserved within an environmentally robust management framework. The marine environments associated with the Barrow, Lowendal and Montebello Islands are proposed to become a marine conservation area and be included within such a management framework. The proposal for the Montebello/Barrow Island marine conservation reserves includes separate marine parks incorporating all of the Montebello Islands, Biggada Reef and Bandicoot Bay at Barrow Island and a marine management area, including the remainder of Barrow Island and the Lowendal Islands.

All of the islands in the region are either nature reserves or conservation parks. Barrow Island is a Class A nature reserve. Reserve boundaries extend to the low water mark, therefore all fauna and flora in the intertidal zones on Barrow Island are protected within the Class A nature reserve. The following terrestrial reserves are located within 50 km of Barrow Island: Boodie Double Middle Islands Nature Reserve, Great Sandy Island Nature Reserve, Lowendal Nature Reserve and Montebello Islands Conservation Park.

All marine conservation reserves in Western Australia extend to a depth of 200 m below the seabed. The airspace above a reserve is not height limited (EPA 2003). In terms of the operation of the Western Australian *Conservation and Land Management Act 1984* (CALM Act), the airspace above terrestrial national parks and reserves is not explicitly considered to be a part of those reserves (EPA 2003).

Under the CALM Act and the New Horizons policy (Government of Western Australia 1997) there are classes of marine conservation reserves in which petroleum drilling and production are not permitted and there are terrestrial areas which are not available for exploration and production activities (EPA 2003).

5 Protected Marine Species

5.1 Legislation and International Conventions

5.1.1 Environment Protection and Biodiversity Conservation Act 1999

Fauna designated as threatened or migratory under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) are protected by that act. A number of marine species in Commonwealth waters are listed as protected marine species. Species are also protected from activities outside of these areas that are likely to affect critical populations in Commonwealth waters.

The EPBC Act has very specific 'triggers', related to defined matters considered to have National Environmental Significance (NES). Under the EPBC Act, a proponent is required to refer to the Department of Environment and Heritage for assessment, on behalf of the Commonwealth Minister for Environment and Heritage (under Part 9 of the Act), any action that is likely to significantly impact a matter of NES.

Of the seven NES matters identified within the EPBC Act that trigger the Commonwealth assessment and approvals regime, three are of particular relevance to the proposed Gorgon development. These matters are:

- listed threatened species
- listed migratory species
- Commonwealth marine areas.

The distributions of threatened or migratory marine fauna that may be affected by offshore activity are restricted and frequently have seasonal variations. Listed migratory species cover a broad range of species with different life cycles and population sizes. Consequently, what is an ecologically significant proportion of the population varies for each species, and therefore each circumstance needs to be evaluated. Appropriate planning can often be applied to reduce the likelihood of activities causing significant environmental impacts, as defined by the EPBC Act.

Factors considered include whether the species is endangered; whether the activities would be in a migratory path adjacent to a feeding, breeding or resting area; whether calves or pregnant females may be affected and whether significant numbers (relative to the species or populations) of the species may be affected.

5.1.2 Wildlife Conservation Act 1950

All native vertebrates are protected under the Western Australian *Wildlife Conservation Act 1950*. All species are wholly protected throughout Western Australia at all times.

5.1.3 Fish Resources Management Act 1994

The Western Australian *Fish Resources Management Act 1994 (*the FRM Act) and the *Fish Resources Management Regulations 1995* aim to conserve, develop and share the fish resources of the state for the benefit of present and future generations. The Act and Regulations aim to conserve fish and protect their environment. To that end, some fish species of particular conservation concern are protected within the Act and Regulations.

5.1.4 International Conventions

(IUCN) – Red List of Threatened Species

The IUCN Red List of Threatened Species (IUCN Red List) provides taxonomic, conservation status and distribution information on taxa that have been evaluated using the IUCN Red List Categories and Criteria. The main purpose of the IUCN Red List is to catalogue and highlight those taxa facing a higher risk of global extinction (those listed as Critically Endangered, Endangered and Vulnerable) and this system is designed to determine the relative risk of extinction. The IUCN Red List also includes information on taxa that cannot be evaluated because of insufficient information (Data Deficient) and on taxa that are either close to meeting the threatened thresholds, or that would be threatened, were it not for an ongoing taxon-specific conservation programme (Near Threatened).

Bonn Convention

The Bonn Convention provides a 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. Conservation of these habitats is one of the principle actions taken for endangered species as listed under the Bonn Convention and for species or groups of species which are the subject of Agreements under the Bonn Convention.

CITES

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement aimed at ensuring that international trade in specimens of wild animals and plants does not threaten their survival.

5.2 Listed Marine Species

A list of protected marine fauna that may occur within the study area is provided in Table 5-1. These include:

- fish – 37 species
- mammals (cetaceans, whales, dolphins and dugong) - 45 species
- reptiles – 20 species.

The likely occurrence of these animals in the Barrow Island area, in particular their use of areas that will potentially be influenced by the proposed development, is described in Section 6.

Table 5-1 - Protected Fish, Mammals and Reptiles (and their Conservation Status) Possibly Occurring in the Vicinity of Barrow Island

Common Name	**Scientific Name**	**Conservation Status**				
		Commonwealth[1]	**State [2,3]**	**IUCN[4]**	**Bonn Convention[5]**	**CITES[6]**
Fish						
Grey nurse shark	*Carcharias taurus*	V	S1 [2]	V		
Great white shark	*Carcharodon carcharias*	V	S1[2], S2 [3]	V		III
Whale shark	*Rhincodon typus*	V	S2[3]	V	II	
Beady pipefish, steep-nosed pipefish	*Hippichthys penicillus*	L				(II)
Bend stick pipefish, short-tailed pipefish	*Trachyrhamphus bicoarctatus*	L				(II)
Blue-finned ghost pipefish, robust ghost pipefish	*Solenostomus cyanopterus*	L				(II)
Braun's pughead pipefish, pug-headed pipefish	*Bulbonaricus brauni*	L				(II)
Brock's pipefish	*Halicampus brocki*	L				(II)
Cleaner pipefish, Janss' pipefish	*Doryrhamphus janssi*	L				(II)
Double-ended pipehorse/pipefish, alligator pipefish	*Syngnathoides biaculeatus*	L		DD		(II)
Flagtail pipefish, negros pipefish	*Doryrhamphus negrosensis*	L				(II)
Flat-face seahorse	*Hippocampus planifrons*	L		V		II
Glittering pipefish	*Halicampus nitidus*	L				(II)
Helen's pygmy pipefish	*Acentronura larsonae*	L				(II)
Indonesian pipefish, Gunther's pipehorse	*Solegnathus lettiensis*	L		V		(II)
Ladder pipefish	*Festucalex scalaris*	L				(II)
Leafy seadragon	*Phycodurus eques*		S2[3]	DD		(II)
Long-nosed pipefish, straight stick pipefish	*Trachyrhamphus longirostris*	L				(II)
Many-banded or banded pipefish	*Doryrhamphus multiannulatus*	L		DD		(II)
Mud pipefish, Gray's pipefish	*Halicampus grayi*	L				(II)
Muiron Island pipefish	*Choeroichthys latispinosus*	L				(II)

Common Name	Scientific Name	Conservation Status				
		Commonwealth[1]	State [2,3]	IUCN[4]	Bonn Convention[5]	CITES[6]
Pacific short-bodied pipefish, short-bodied pipefish	*Choeroichthys brachysoma*	L				(II)
Pig-snouted pipefish	*Choeroichthys suillus*	L				(II)
Pipehorse, Hardwicke's pipefish, pallid seahorse	*Solegnathus hardwickii*	L		V		(II)
Potato cod	*Epinephelus tukula*		S2[3]			
Queensland groper	*Epinephelus lanceolatus*		S2[3]			
Ribboned seadragon, ribboned pipefish	*Haliichthys taeniophorus*	L				(II)
Ringed pipefish	*Doryrhamphus dactyliophorus*	L				(II)
Rock pipefish	*Phoxocampus belcheri*	L				(II)
Spiny seahorse	*Hippocampus histrix*	L		DD		II
Spiny-snout pipefish	*Halicampus spinirostris*	L				(II)
Spotted seahorse, yellow seahorse	*Hippocampus kuda*	L		V		II
Three-keel pipefish	*Campichthys tricarinatus*	L				(II)
Tidepool pipefish	*Micrognathus micronotopterus*	L				(II)
Tiger pipefish	*Filicampus tigris*	L				(II)
Western spiny seahorse, narrow-bellied seahorse	*Hippocampus angustus*	L		DD		II
Weedy seadragon	*Phyllopteryx taeniolatus*			DD		(II)
Mammals: Dugong						
Dugong	*Dugong dugon*	V	S4[2]	V	II	
Mammals: Baleen Whales						
Southern right whale	*Eubalaena australis*	E (C)	S1[2]	LR	I	I
Blue whale	*Balaenoptera musculus*	E (C)	S1[2]	E		I
Pygmy blue whale	*Balaenoptera musculus brevicausa*	(C)		E	II	I
Bryde's whale	*Balaenoptera edeni*	(C)		DD	II	I

Common Name	Scientific Name	Conservation Status				
		Commonwealth[1]	State [2,3]	IUCN[4]	Bonn Convention[5]	CITES[6]
Fin whale	*Balaenoptera physalus*	V (C)	S1[2]	E	II	I
Humpback whale	*Megaptera novaeangliae*	V (C)	S1[2]	V	I	I
Minke whale	*Balaenoptera acutorostrata*	(C)		LR		I
Sei whale	*Balaenoptera borealis*	V (C)	S1[2]	E	II	I
Mammals: Beaked and Toothed Whales						
Andrews' beaked whale	*Mesoplodon bowdoini*	(C)		DD		II
Arnoux's beaked whale	*Berardius arnuxii*	(C)		DD		I
Strap-toothed beaked whale	*Mesoplodon layardii*	(C)		DD		II
Blainville's beaked whale	*Mesoplodon densirostris*	(C)		DD		II
Cuvier's beaked whale	*Ziphius cavirostris*	(C)		DD		II
Dwarf sperm whale	*Kogia simus*	(C)		DD		
Ginkgo-toothed beaked whale	*Ziphius cavirostris*	(C)		DD		II
Gray's beaked whale	*Mesoplodon grayi*	(C)		DD		II
Hector's beaked whale	*Mesoplodon hectori*	(C)		DD		II
Longman's beaked whale	*Mesoplodon pacificus*	(C)		DD		II
Melon-headed whale	*Peponocephala electra*	(C)		DD		II
Pygmy sperm whale	*Kogia breviceps*	(C)		DD		
Shepherd's beaked whale	*Tasmacetus shepherdi*	(C)		DD		II
Southern bottlenose whale	*Hyperoodon planifrons*	(C)		DD		I
Sperm whale	*Physeter macrocephalus*	(C)		DD	I	I
True's beaked whale	*Mesoplodon mirus*	(C)		DD		II
Mammals: Dolphins						
Killer whale	*Orcinus orca*	(C)		DD	II	II
False killer whale	*Pseudorca crassidens*	(C)		DD		II

Common Name	Scientific Name	Conservation Status				
		Commonwealth[1]	State [2,3]	IUCN[4]	Bonn Convention[5]	CITES[6]
Long-finned pilot whale	*Globicephala melas*	(C)		DD	II	II
Short-finned pilot whale	*Globicephala macrorhynchus*	(C)		DD		II
Pygmy killer whale	*Feresa attenuata*	(C)		DD		II
Bottlenose dolphin	*Tursiops truncatus s. str.*	(C)		DD	II	II
Common dolphin	*Delphinus delphis*	(C)		DD	II	II
Dusky dolphin	*Lagenorhynchus obscurus*	(C)		DD	II	II
Fraser's dolphin	*Lagenodelphis hosei*	(C)		DD	II	II
Indo-Pacific humpbacked dolphin	*Sousa chinensis*	(C)		DD		I
Irrawaddy dolphin	*Orcaella brevirostris*	(C)		DD	II	II
Pantropical spotted dolphin	*Stenella attenuata*	(C)		DD	II	II
Risso's dolphin	*Grampus griseus*	(C)		DD	II	II
Rough-toothed dolphin	*Steno bredanensis*	(C)		DD		II
Southern right whale dolphin	*Lissodelphis peronii*	(C)		DD		II
Spinner dolphin	*Stenella longirostris*	(C)		DD	II	II
Spotted bottlenose dolphin	*Tursiops aduncus*	(C)		DD	II	
Spotted dolphin	*Stella attenuata*	(C)		DD		
Striped dolphin	*Stenella coeruleoalba*	(C)		DD	II	II
Reptiles						
Loggerhead turtle	*Caretta caretta*	E	S1[2]	E	I & II	I
Flatback turtle	*Natator depressus*	V	S1[2]	DD	II	I
Green turtle	*Chelonia mydas*	V	S1[2]	E	I & II	I
Hawksbill turtle	*Eretmochelys imbricata*	V	S1[2]	CE	I & II	I
Leathery turtle, leatherback turtle	*Dermochelys coriacea*	V	S1[2]	CE	I & II	I
Olive ridley turtle	*Lepidochelys olivacea*	E	S1[2]	E	I & II	I

Common Name	**Scientific Name**	**Conservation Status**				
		Commonwealth[1]	**State [2,3]**	**IUCN[4]**	**Bonn Convention[5]**	**CITES[6]**
Horned seasnake	*Acalyptophis peronii*	L				
Short-nosed seasnake	*Aipysurus apraefrontalis*	L				
Dubois' seasnake	*Aipysurus duboisii*	L				
Spine-tailed seasnake	*Aipysurus eydouxii*	L				
Olive seasnake	*Aipysurus laevis*	L				
Stokes' seasnake	*Astrotia stokesii*	L				
Spectacled seasnake	*Disteira kingii*	L				
Olive-headed seasnake	*Disteira major*	L				
Turtle-headed seasnake	*Emydocephalus annulatus*	L				
North-western mangrove seasnake	*Ephalophis greyi*	L				
Fine-spined seasnake	*Hydrophis czeblukovi*	L				
Elegant seasnake	*Hydrophis elegans*	L				
Seasnake	*Hydrophis ornatus*	L				
Yellow-bellied seasnake	*Pelamis platurus*	L				

[1]Commonwealth – Environment Protection and Biodiversity Conservation Act 1999

CE – Critically Endangered (NES), E – Endangered (NES), V – Vulnerable (NES), L – Listed, (C) – Cetacean, M – Migratory, MM – Migratory Marine – (NES – Matters of National Environmental Significance)

[2] State - Wildlife Conservation Act 1950

S1 – Schedule 1, fauna that are rare or likely to become extinct, S2 – Schedule 2, fauna presumed to be extinct, S4 – Schedule 4, other specially protected fauna

[3] State - Fish Resources Management Act, 1994

Listed in Fish Resources Management Regulation, 1995, Schedule 2, Part 2, totally protected fish

[4] International Union for the Conservation of Nature and Natural Resources (IUCN) – Red List of Threatened Species: CE – Critically Endangered, E – Endangered, V – Vulnerable, LR – Lower Risk – classified as either conservation dependent (CD) or near threatened (NT), DD – Data Deficient –insufficient knowledge to determine threatened status.

[5]Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention): I – Appendix I, Endangered Migratory Species, II – Appendix II, Migratory Species.

[6]Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES 2000): I - Appendix I, species threatened with extinction. II - Appendix II, includes species not necessarily threatened with extinction, but in which trade must be controlled to avoid utilisation incompatible with their survival. III - Appendix III includes all species which any Party identifies as being subject to regulation within its jurisdiction for the purpose of preventing or restricting exploitation, and as needing the cooperation of other Parties in the control of trade. Parentheses indicates the species are proposed for listing at the time of writing this report.

6 Occurrence of Protected Marine Species near Barrow Island

6.1 Fish

6.1.1 Conservation Significance and Protection Status

Some species of fish known to occur around Barrow Island are afforded protection under the EPBC Act and are specially protected under Schedule 1, Division 5 (Fish) of the Wildlife Conservation Act as animals that are rare or likely to become extinct.

Large fish of the family Serranidae, commonly termed grouper or cod, are considered vulnerable to exploitation. All potato cod (*Epinephelus tukula*) are protected under the FRM Act, as are all serranids greater than 1200mm in total length or 30kg in weight.

Fish in the family Syngnathidae include seahorses, pipefish, pipehorses and seadragons. All syngnathids and solenostomids (ghost pipefish) are listed as marine species under Part 13, s248 of the EPBC Act and are protected in Commonwealth waters (NSW Fisheries 2003a). The entire genus of *Hippocampus* (seahorses) is listed under Appendix II of CITES to improve the management of international trade. Consideration is currently being given to listing the entire family of Syngnathids under Appendix II of CITES (NSW Fisheries 2003b).

The weedy seadragon (*Phyllopteryx taeniolatus*) and the leafy seadragon (*Phycodurus eques*) are both protected under the *Commonwealth Fisheries Administration Act 1991*(FA Act) and are listed on the IUCN Red List of Threatened Animals due to the lack of information on the species. The leafy seadragon is also protected under the FRM Act.

6.1.2 Sharks

Protected species of sharks that may occur near Barrow Island include grey nurse sharks, great white sharks and whale sharks.

Grey nurse sharks (*Carcharias taurus*) are regionally widespread and are relatively common on Ningaloo Reef and presumably also in the waters surrounding Barrow Island. The grey nurse shark was listed in August 2000 as Vulnerable under the EPBC Act. This species is also protected under the Wildlife Conservation Act, Schedule 1 and listed on the IUCN Red List of Threatened Animals as Vulnerable worldwide. Their life-history and reproductive strategies, such as their preference for inshore rocky reef habitats and their tendency to aggregate, make them particularly vulnerable to human-induced pressures (NSW Fisheries 2002).

The great white shark (*Carcharodon carcharias*) is protected under the EPBC Act, where it is listed as Vulnerable. It is also protected under the Wildlife Conservation Act, under Schedule 1, and is assessed as Vulnerable by the IUCN. Great white sharks have a global distribution and are thought to have local populations that show some evidence of migratory behaviour. This species is thought to have a low reproductive rate and the estimated Australian population is fewer than 10 000 mature individuals (CITES). These sharks are protected from commercial fishing in Western Australian waters.

A great white shark was observed in Exmouth Gulf in 2003, so they may also occasionally visit the Barrow Island area. It is highly unlikely that any great white sharks will be vulnerable to impact by the proposed development.

Whale sharks (*Rhincodon typus*) migrate to the Ningaloo Reef each year between January and August. Whale sharks have also been observed ranging from Shark Bay to the Dampier Archipelago and would certainly occur, at times, in the area of the proposed development. The migration destinations of the whale sharks encountered on Ningaloo reef are the subject of ongoing research, but details of life history are presently very limited.

6.1.3 Seadragons

Two species of seadragon occur in Australia, the 'common' or weedy seadragon (*Pyllopteryx taeniolatus*) and the leafy seadragon (*Phycodurus eques*). Both are protected under the FA Act and are listed on the International Red List of Threatened Animals, primarily due to the lack of information on these species. Both are distinguished by leafy appendages or seaweed like camouflage and by having a stiff, non-prehensile tail.

Both the leafy seadragon and the weedy seadragon inhabit rocky reefs, seaweed beds, seagrass meadows and structures colonised by seaweed. Leafy seadragons are often found living in S*argassum* seaweed, which is mimicked by the animal's leaf-like appendages. The seadragons' diet mainly consists of sea lice, mysid shrimps and other small crustaceans. They generally occur individually or in small groups.

Seadragons are found in shallow coastal waters to 50 m depth, but usually occur in water between four and ten metres deep. Seadragons are thought to settle in shallow water as juveniles and move into slightly deeper water with age.

Seadragons can be caught as bycatch in trawling nets and are widely sought in the aquarium fish trade and for traditional Chinese medicines. They are also at risk from loss of habitat due to degradation of seagrass meadows and seaweed beds.

Both the leafy seadragon and the weedy seadragon have been recorded from Geraldton and unconfirmed sightings have been made in Shark Bay and near Onslow. It is thus possible that one or both species occur at Barrow Island, presumably in association with the extensive *Sargassum* beds that occur in the region.

6.1.4 Pipefish

Pipefish are widespread throughout the Pilbara region in both offshore and nearshore habitats. Little is known of the distribution and breeding seasons of the individual species that may occur around Barrow Island, however, it is likely that several could occur within the development area. Only two pipefish species have been recorded from Barrow Island (Western Australian Museum unpublished data 2004) and these have also been recorded during scientific studies of other Pilbara locales.

Protected pipefish that may occur at Barrow Island occupy habitats that are regionally widespread.

6.2 Reptiles

Reptiles have successfully adapted to the marine environment and three of four reptilian orders have marine representatives. These are the Chelonia (sea turtles), the Squamata (sea snakes) and the Crocodilia (crocodiles). The study area does not support crocodiles, however, it does contain diverse and abundant populations of sea turtles and sea snakes.

6.2.1 Sea turtles

Six of the world's seven species of marine turtle frequent the Pilbara region, but only four are confirmed as breeding in the area (Marine Turtle Newsletter 1993). All sea turtles are protected under Schedule 1 of the Wildlife Conservation Act*,* by the Bonn Convention and the EPBC Act. All marine turtle species occurring in Australian waters are protected by CITES. Five of the seven turtle species are listed as endangered on the IUCN Red List. The Bonn Convention gives all Indo-Pacific turtles a priority for conservation (Pendoley 1997).

Of the six species of sea turtles occurring in the region (green, flatback, hawksbill, loggerhead, leatherback and olive ridley), three species (green, flatback and hawksbill) are known to nest on Barrow Island beaches (Prince 1990). Leatherback turtles (*Dermochelys coriacea)* are the most globally widespread of sea turtles, but possibly the least abundant. They do not nest on Barrow Island, however, they would occur as infrequent visitors, most commonly in deeper offshore waters.

Green turtles (*Chelonia mydas*) are the most abundant sea turtle species in Pilbara waters, nesting on most sandy beaches in the region. The most important Western Australian green turtle nesting beaches are considered to be at the Lacapede Islands (refer Appendix C7: Sea Turtles), with other major nesting beaches being located at North West Cape, the Muiron Islands, Serrurier Island and on islands of the Dampier Archipelago (Prince 1990)., Barrow Island is also of regional significance for green turtle nesting, with large numbers utilizing all Barrow Island west coast beaches.

Adult green turtles feed on algae and thus feed in relatively shallow waters. They are always common in inshore Barrow Island waters, particularly along the west coast and in Bandicoot Bay. Green turtles are known to undertake widespread migrations, but the routes of Barrow Island animals are largely undetermined. Green turtles from other locations are known to migrate between Indonesia, Queensland, Northern Territory and Western Australia (Environment Australia 2000a).

Flatback turtles (*Natator depressus*) nest in moderate numbers on east coast beaches of Barrow Island. They are also known to nest on Ashburton, Thevenard and Airlie Islands, which are at the southern limit of nesting activity. Flatback turtles feed in offshore waters, mostly on soft-bodied prey such as sea cucumbers, soft corals and jellyfish (Environment Australia 2000b). They are therefore generally only found close to Barrow Island when adults are nesting and when hatchlings are coming off the beaches.

Loggerhead turtles (*Caretta caretta*) have a more temperate distribution than green, hawksbill and flatback turtles, with the islands of the Dampier Archipelago being the northern limit for nesting in Western Australia. Major nesting areas occur on the Muiron Islands and the islands within Shark Bay (Environment Australia 2001b). Occasional nesting may also occur on Barrow Island beaches. Loggerhead turtles feed mainly on large molluscs, but eat other benthic invertebrates such as holothurians. They have been observed in the waters around Barrow Island.

Leatherback turtles are the largest of the world's sea turtles and have the greatest worldwide distribution (Environment Australia 2001a). They are, however, uncommon throughout their range and rarely breed in Australia. Olive ridley turtles (*Lepidochelys olivacea*) in Australian waters are only known to nest in the far north, predominantly in the Northern Territory and Cape York regions. Neither leatherback nor olive ridley turtles have been reported from the study area, but are expected to be occasional visitors, particularly in offshore waters.

Appendix H describes in detail the sea turtle research that has been undertaken on Barrow Island.

6.2.2 Sea Snakes

Sea snakes are protected under the EPBC Act. Sea snakes are widespread throughout the Pilbara region in offshore and nearshore habitats. Storr et al. (1986) estimated that nine genera and 22 species of sea snakes occur in Western Australian waters.

Sea snakes are very common in shallow waters around Barrow Island, in offshore waters west of the island and in inshore waters between Barrow Island and the mainland. The sea snake assemblage appears to be both species-rich and abundant in the proposed development area.

6.3 Mammals - Cetaceans

6.3.1 Protection Status

Following the recommendations of the Frost Inquiry into Whales and Whaling in 1978, the Australian Parliament passed the *Whale Protection Act 1980* (Whale Protection Act). This Act provided for the preservation, conservation and protection of all cetaceans in Commonwealth waters (3-200 nautical miles from the coast). Complementary legislation in Australian States and Territories protects all cetaceans in coastal waters (less than three nautical miles from the coast). The EPBC Act designates all Australian waters as an Australian Whale Sanctuary. The Act also provides for the addition of coastal waters to the Sanctuary if a state or territory agrees and prohibits Australian citizens from killing, capturing and interfering with cetaceans anywhere in the world.

Australia was one of the 15 original countries that signed the International Convention for the Regulation of Whaling (ICRW) in 1946. The International Whaling Commission (IWC) was established under the ICRW to regulate whaling and conserve whale stocks. In recent years it has concentrated on strategies to manage and allow recovery of whale populations. Australia has promoted a strong conservation position in the IWC since whaling ended in 1978 (DEH 2004).

In addition to protection under the EPBC Act, humpback whales (*Megaptera novaeangliae*), which are common in the Barrow Island region, are specially protected under Schedule 1 of the Wildlife Conservation Act as animals that are rare or likely to become extinct.

6.3.2 Regional Occurrence

The Australian cetacean fauna is diverse, with 43 of the 79 species recognised worldwide (54 per cent) having been recorded in Australian Commonwealth waters (Bannister et al. 1996). This list includes 26 species of whale and 17 species of dolphin.

Five of the whale species found in Australian waters are considered threatened and are listed as endangered or vulnerable under the EPBC Act. In addition, a number of whale and dolphin species are migratory (visiting Australia for only part of the year or having populations that straddle international borders) and are listed under the Bonn Convention. Two of these threatened species, the blue whale (*Balaenoptera musculus*) and humpback whale (*M. novaeangliae*) are listed on the Department of Environment and Heritage (DEH) website as occurring in the Barrow Island region.

The known feeding, breeding and resting areas of blue whales and humpback whales and the times when whales are believed to be present in these areas are summarised in Table 6-1.

Blue and humpback whales undertake extensive annual migrations from Antarctic waters into the tropics. Extensive studies of humpback migrations have identified prime migration routes, resting and calving areas (Jenner et al. 2001), but these are variable from year-to-year. There is a lesser understanding of the occurrence, population and migratory characteristics of blue whales in Western Australian waters. However, in broad terms, the period in which whales are likely to migrate through the region extends from April/May through to November.

The main mating season for the blue whale extends over four to five months during the winter, from early April to late August, with peak conceptions occurring in late May and early June. The mean date for calving for the blue whale in the southern hemisphere is about mid-April (Gambell 1979).

Pygmy blue whales are a subspecies of the true blue whale, in that they are slightly smaller (growing to 25 m compared to 30 m). They are confined largely to the tropical regions of the Indian Ocean, southern Australian waters and east to New Zealand. Recent studies suggest they target smaller, more localised and ephemeral aggregations of several species of krill, rather than the vast swarms of the Antarctic krill (*Euphausia superba)* found near the Antarctic ice edge (WA Blue Whale Study Group 2002). Differentiation between blue and pygmy blue whales is difficult. The bulk of these whales occurring in tropical Western Australian waters are thought to be of the pygmy blue whale sub-species.

Humpback whales are the most common of the migratory and threatened whales occurring in the Barrow Island region. They migrate from the Southern Ocean into the Kimberley tropics each year to mate and calve, before returning to their Antarctic feeding grounds. Present estimates place the population of humpback whales migrating along the west coast of Australia at 3000–4000, many of which are expected to move through the western-most parts of the study area each year.

Migrating humpback whales generally pass through the Pilbara region seaward of the shallow islands, including Barrow Island. The northern migration follows a more offshore route than the southern migration, and is broadly centered on the 200 m bathymetric contour. Humpback whales appear to migrate south in a much more dispersed manner than when traveling north, with whales more often moving and resting in shallow inshore waters.

Whales are seldom reported from the area between Barrow Island and the mainland, possibly due to the extensive shoals and strong currents found in that area (Jenner et al. 2001). Sightings of whales from 1991 to 1996, recorded by the crews of rig tenders, seismic vessels and platform personnel and reported to the Centre for Whale Research, show whales migrating as far offshore as the 1000 m isobath or approximately 50 nm west of the islands. The humpback migratory route in the vicinity of Barrow Island is shown in Chapter 11 (Figure 11.4) of the main EIS/ERMP reports.

Table 6-1 - Summary of Endangered Whale Species that Occur in the Barrow Island Region and their Known Aggregation Areas and Migratory Paths (Assessed for Western Australian Waters only and Interpreted from the Department of Environment and Heritage website 2004).

Protection Status	Species found in Western Australian Waters	Recognised Aggregation Areas (Breeding and Resting Areas) for Western Australia	Migration Season (assessed for Western Australian Waters only)
Listed critically endangered or endangered species and a listed migratory species	Blue whale (*B. musculus*)	Rottnest	Nov –Dec (N/A to north West Australia).
Listed vulnerable species and a listed migratory species	Humpback whale (*M. novaeangliae*)	King Sound, Broome Shark Bay, Carnarvon North West Cape, Ningaloo, Perth Flinders Bay, Cape Leeuwin.	Mid July –Mid September (mid west WA coast) Late July – early August and late August – early September; (north west coast)

A number of other whale species occur off the north Western Australian coast and may occur in the survey area, at least on occasion. Whales reported from the region include the sei *(Balaenoptera borealis)*, fin *(B. physalus)*, minke *(B. acutorostrata),* and Brydes *(B. edeni)* whales, with sperm (*Physeter macrocephalus*) and melon headed (*Peponocephala electra*) whales possible, as surmised by their distribution range (Baker 1990). Attachment 1 provides other cetaceans in Australian waters listed as Threatened and/or Migratory Species under the EPBC Act.

Southern right whales were occasionally caught from the Norwegian Bay Whaling station prior to them becoming protected (Bridgewater 1990). These are a southern species occasionally observed in Perth waters, and those caught off the Ningaloo Reef would presumably have been rare visitors. Southern right whales were hunted to near extinction in Australian waters and, although recovering, the population is still very low. It is highly unlikely they ever occur near Barrow Island.

The bottle-nosed dolphin (*Tursiops truncates*) and the Indo-Pacific humpbacked dolphin (*Sousa chinensis*) have resident populations within the shallow waters of the inner Rowley Shelf, including Barrow Island. Although less well understood, a number of deep water dolphins occur off the north Western Australian coast and may also occur in the survey area, at least on occasion. Spinner *(Stenella longirostris)* and striped *(Stenella coeruleoalba)* dolphins are common offshore tropical species (Swan et al. 1994) and are expected to be relatively common in the offshore waters of Barrow Island. Less common inhabitants may include the common (*Delphinus delphis*), Risso's (*Grampus griseus*), spotted *(Stella attenuata)* and rough-toothed *(Steno bredanensis)* dolphins, with three of the latter being stranded on Barrow Island in 1971 (Baker 1990). Attachment 1 contains a summary of the dolphin species listed under the EPBC Act as migratory species.

Killer *(Orcinus orca)* and false killer whales (*Pseudorca crassidens*) are large members of the dolphin family and are known in the area from sightings in 1971 and from strandings on Barrow Island in 1970 (Butler 1975). The pygmy killer whale (*Feresa attenuate*) could occur as a rare visitor to the area.

6.4 Mammals – Dugongs

The Dugong (*Dugong dugon*) is the only member of the family Dugongidae and joins the northern hemisphere manatees as the only living representatives of the order Sirenidae. Dugong occur in the temperate shallow waters of the Indian and Pacific oceans, but are most abundant in the marine waters of northern Australia.

Dugong are provided special protection under Schedule Four, other specially protected fauna, Division One (mammals) of the Wildlife Conservation Act and are listed as threatened (Vulnerable) under the EPBC Act.

Dugong are known to occur around the islands of the North West Shelf (Prince 2001), although not in the large concentrations seen further south in Exmouth Gulf or Shark Bay (Prince 1986). Dugong typically occur in shallow, warm waters that support the *Halodule* and *Halophila* seagrasses on which they feed.

Feeding animals generally occur over seagrass meadows at depths of five to ten metres. They are the only wholly herbivorous marine mammal and their seasonal movements and feeding grounds are little understood. Dugong are sensitive to temperatures below approximately 20°C and tend to be found in warmer waters in winter.

Dugong were not observed in the proposed development area during the any of the three field surveys (August 2002, January 2003 and January 2004), but were observed in March 2004 at Varanus Island and over Barrow Shoals (Fitzpatrick, J. 2004. Personal communication). Dugong have been previously observed off the east coast of Barrow Island, at the Lowendal Islands to the northeast and at a number of other islands of the region (Prince 2001).

Dugong are likely to pass through and possibly feed on seagrass around Barrow Island. However, the sparse nature of the seagrasses, combined with the presence of large food reserves to the north and south, means that Barrow Island waters are unlikely to be of major significance for breeding or feeding activities of this species. Dugong are believed to calve predominantly in August to September and produce one calf every three to seven years (Swan et al. 1994). The dugong is a long-lived mammal with a lifespan of 50–60 years and a minimum pre-reproductive period of 9–10 years for both sexes (Swan et al. 1994). Individual animals are likely to be disturbed by noise and shipping activity, however, population level effects are unlikely.

7 Conclusion

More than one hundred protected marine species have been identified as occurring, or likely to occur, in the waters surrounding Barrow Island.

7.1 Fish and Invertebrates

Protected fish and invertebrate species are known, or likely, to occur in both the nearshore and offshore waters surrounding Barrow Island. The habitats which they occupy are generally widespread throughout the Pilbara region. There are no known features in the proposed development area or surrounds to suggest that significant concentrations would be expected to occur.

7.2 Cetaceans

Humpback whales generally are likely to rest occasionally around Flacourt Bay and Double Island (sighted on occasions) and pass through the region seaward of Barrow Island on their annual migration between the Southern Ocean and the Kimberley. Their northern migration is broadly centered on the 200 m bathymetric contour, and they are likely to pass through the area around the Gorgon gas field.

The southern migration of adults and calves tends to be more inshore and some use inshore areas such as the area near Flacourt Bay and Double Island to rest. Other whales and deep water dolphins that occur off the northwestern Australian coast that may occur in the survey area tend to have widely dispersed populations and there are no known features in the survey area or surrounds that suggest that significant concentrations would be expected within the development area.

7.3 Reptiles

Barrow Island is an important feeding and nesting area for sea turtles, primarily flatback turtles on the east coast and green turtles on the west coast.

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Attachment 1 - Other Cetaceans in Australian Waters Listed as Threatened and/or Migratory Species under the EPBC Act.

Listed vulnerable species	Sei whale (*Balaenoptera borealis*)
	Fin whale (*Balaenoptera physalus*)
Listed migratory species	Spectacled porpoise (*Phocoena diotropica*)
	Indo-Pacific humpback dolphin (*Sousa chinensis*)
	Dusky dolphin (*Lagenorhynchus obscurus*)
	Indian Ocean bottlenose dolphin (*Tursiops aduncus*)
	Pantropical spotted dolphin (*Stenella ttenuate*)
	Spinner dolphin (*Stenella longirostris*)
	Fraser's dolphin (*Lagenodelphis hosei*)
	Irrawaddy dolphin (*Orcaella brevirostris*)

Technical Appendix C7

Sea Turtles

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

SEA TURTLES

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1 Introduction

Six species of sea turtle occur in north Western Australian waters: green turtles (*Chelonia mydas),* flatback turtles (*Natator depressus*), loggerhead turtles (*Caretta caretta*), hawksbill turtles (*Eretmochelys imbricata*), leatherback turtles (*Dermochelys coriacea*) and olive ridley turtles (*Lepidochelys olivacea*). Among these, leatherback turtles have the greatest distribution worldwide, but are uncommon throughout their range and rarely breed in Australia. Green turtles are the most common and breed extensively across northern Western Australia. Flatback turtles are endemic to Australian tropical waters and the Muiron Islands appear to be the southern limit of their distribution in Western Australia. The loggerhead turtle has a more temperate distribution and the Dampier Archipelago appears to be the northern limit of nesting. The hawksbill turtle, has been documented nesting as far south as North West Cape. The northward limit of their range has not been established for Western Australia. The least common species, the olive ridley, has been recorded off the coast of Exmouth and the Kimberley but is not known to nest on Western Australian beaches (Prince 1993; Morris, K. 2005. Personal Communication).

The conservation status of sea turtles in Australia is summarised in Table 1-1. All sea turtles are protected under the *Wildlife Conservation Act 1950* (Wildlife Conservation Act) and all but the flatback turtle are scheduled species. Green, loggerhead and hawksbill turtles are listed migratory species under the Bonn Convention and the Commonwealth *Environmental Protection Biodiversity Conservation Act 1999* (EPBC Act). All species are listed as Endangered (loggerhead) or Vulnerable (green, hawksbill, leatherback and flatback) under the EPBC Act and are of National Environmental Significance (NES) requiring protection under the EPBC Act.

Table 1-1 - Conservation Status of Sea Turtles in Australia

Common name	Scientific name	Threatened Species List			
		National List of Threatened Species (EPBC Act)	Species That Are Likely to Become Extinct (Wildlife Conservation Act)	Convention on International Trade of Endangered Species (CITES)	Bonn Convention
Loggerhead turtle	*Caretta caretta*	Endangered Migratory	Schedule I	Threatened with extinction	Endangered migratory species
Green turtle	*Chelonia mydas*	Vulnerable Migratory	Schedule I	Threatened with extinction	Endangered migratory species
Hawksbill turtle	*Eretmochelys imbricata*	Vulnerable Migratory	Schedule I	Threatened with extinction	Endangered migratory species
Flatback turtle	*Natator depressus*	Vulnerable Migratory	Schedule I	Threatened with extinction	Migratory Species
Leatherback	*Dermochelys coriacea*	Vulnerable Migratory	Schedule I	Threatened with extinction	Endangered migratory species
Olive Ridley	*Lepidochelys olivacea*	Endangered Migratory	Schedule I	Threatened with extinction	Endangered migratory species

Schedule 1 – Fauna that is rare or is likely to become extinct. Declared to be in need of special attention.

2 Life Cycle

Information on the entire life cycle of sea turtles is minimal on a global basis and virtually non-existent for Western Australian populations. Most of the knowledge on sea turtles in Western Australia comes from tagging programs. Broadly, all sea turtles follow a similar life cycle. Adults migrate from remote feeding grounds to their mating area. Following mating the females move to nesting areas while the males return to their foraging grounds. After several months of nesting and internesting (the interval between individual nesting events when a new clutch of eggs is being formed inside the female) the females also return to the feeding grounds and begin to build up condition for the next reproductive migration, one to five years later.

Hatchlings leave their natal beaches and migrate to open ocean nursery habitat (believed to be in convergent zones) where they spend 5–20 years. Immature turtles then migrate to shallow near-shore feeding grounds until they reach sexual maturity at 30–50 years. They then travel to the general vicinity of the nesting beaches they originated from to begin the reproductive cycle again.

Flatback turtle behaviour varies slightly from this generalised life cycle. Unlike other species, they do not have a pelagic phase to their life cycle. Instead hatchlings grow to maturity in shallow coastal waters thought to be close to their natal beaches (Musick & Limpus 1996). There is evidence, however, that some flatback turtles engage in long-distance migrations between feeding grounds and remote nesting beaches (Parmenter 1994).

The renesting interval differs for the three turtle species that regularly nest on Barrow Island. Green turtles return on an approximate five year cycle, hawksbill turtles return around three years, while flatback turtles may nest annually or biennially (Miller 1996. Personal observation). Whilst at their nesting beaches, females from all three species lay 3–5 clutches of eggs over a 2–3 month time frame. The internesting period for all three species is approximately two weeks. The three species that commonly nest in the Barrow Island region display a staggered nesting season. Hawksbill turtles commence nesting in August and peak in October. Flatback turtles commence nesting in late November/ December, peak in January and finish by February/March. Green turtles appear to have a slightly longer nesting season, commencing in November, peaking in January/February and finishing in April (Pendoley in prep, this study 2004).

Sea turtles inhabit different habitats depending on the life cycle phase. These habitats are discussed below.

3 Regional Habitats

Four types of sea turtle habitat can be identified. They are:

- near-shore aggregation habitats
- nesting and internesting grounds
- feeding grounds, juveniles and adults (10+ years)
- early juvenile nursery and developmental habitat (0–10 years).

Sea turtle habitats have not been systematically studied in Western Australia and there is little information published on this topic. The following has been taken from field observations, published and unpublished reports (Prince 1990; Pendoley in prep; Pendoley & Fitzpatrick 1999; Prince et al. 2001).

3.1 Aggregation Habitats

Green turtles aggregate off the west coast of Barrow Island during the spring and summer months. Observations from shore indicate that many of these animals are mating. Summer mating aggregations have also been observed within the Montebello Island group south of North West Island and east of Trimouille Island (Pendoley. 1998-2003. Personal observation). Large aggregations (hundreds) of animals have also been documented west of Hermite Island between Wonnich Reef and the Wonnich platform late in the summer (Pendoley. K. 1998. Personal observation). The purpose of these aggregations has not been established.

Figure 3-1 shows the results of an aerial survey carried out by CALM in April 2000, at the end of the nesting season (Prince et al. 2001). These animals are thought to be green turtles. The map confirms the aggregations west of the Montebello Islands and also shows a concentration of turtles over the Barrow Shoals, off the south east coast of Barrow Island as well as near Serurrier and Thevenard Islands. The purpose of these aggregations late in the season has not been studied, however, it is possible that these are resident animals on feeding grounds.

Aggregations of male green turtles have been observed in shallow near shore waters, prior to the summer nesting season, within the Mangrove Island group south of Barrow Island (Pendoley & Fitzpatrick 1999). The purpose of this aggregation is also unknown.

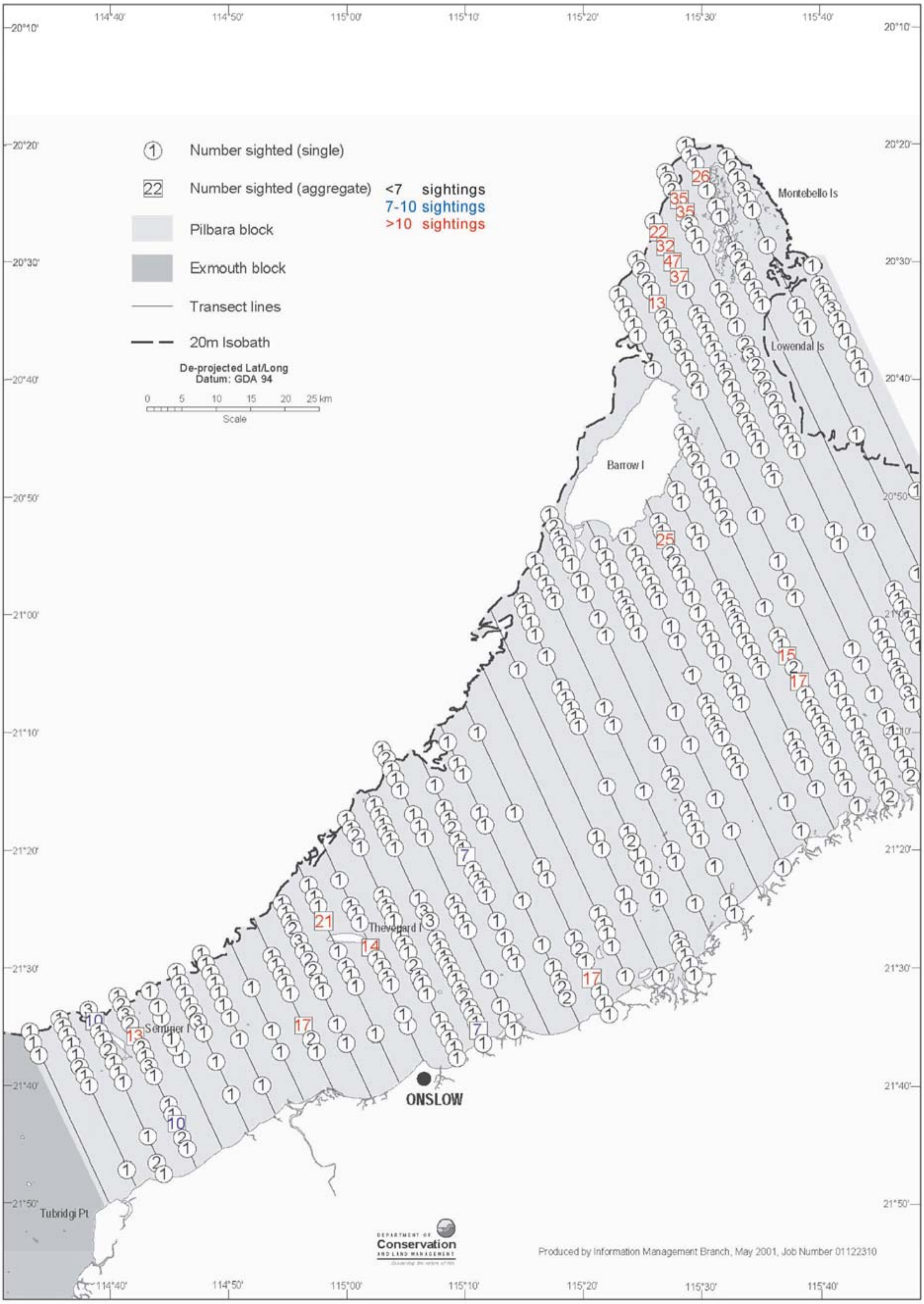


Figure 3-1 - Pilbara Aerial Sea Turtle Survey, April 2000
(Source: Prince et al. 2001)

3.2 Nesting and Internesting Habitat

3.2.1 NW Shelf

The status of sea turtle nesting in Western Australia has been summarised in Prince (1990). Of the four species typically found nesting on the North West Shelf, only three are commonly found in the Barrow Island region (Pendoley in prep.).

Green turtles are recognised as the most abundant turtle species in northern Western Australian waters. Major Pilbara nesting sites occur at North West Cape, Muiron Islands, Serurrier Island, west coast of Barrow Island and the Dampier Archipelago. The largest Western Australian green turtle rookeries are hundreds of kilometres to the north east at the Lacepede Islands in the Kimberley. The west coast Barrow Island rookery is regionally important (Pilbara) but appears to be smaller than the Lacepede Island rookery, where nightly nesting effort numbers in the thousands.

There is no published data on green turtle internesting grounds in Western Australia, however, studies elsewhere suggest internesting grounds are close to nesting beaches, in 10-18 m of water (Stoneburner 1982; Mortimer & Portier 1989; Meylan 1995; Tucker et al. 1995; Pendoley in prep.). Preliminary analysis of satellite tracking data for Barrow Island green turtles suggests a similar trend (Pendoley in prep.).

After green turtles, flatback turtles are the next most abundant nesting species in northern Australian waters. Important Pilbara rookeries used by flatback turtles include the east coast of Barrow Island, Munda Station, Cape Thouin and Port Hedland. Flatback turtles are commonly found nesting on islands in the Montebello and Lowendal Island groups (Pendoley 2004 in prep.).

Flatback turtle internesting grounds are also unknown for the North West Shelf region and particularly for the Barrow, Lowendal, Montebello Island complex. They are thought to favour nearby soft bottom habitat.

The most significant hawksbill turtle rookery in Western Australia is located on Rosemary Island in the Dampier Archipelago. This rookery is not only significant on a regional scale but is considered one of the largest in the Indian Ocean. Nesting numbers on Rosemary Island are around 100+ animals per night at the peak of the season (Vitenbergs, A. 2004. Personal communication). These numbers are one-to-two orders of magnitude higher than numbers documented at any other Western Australian rookery. Low level nesting occurs within the Barrow, Lowendal and Montebello Island groups. The number of hawksbill turtles nesting on the offshore Pilbara islands is an order of magnitude lower than flatback turtle nesting effort.

No published information is available on hawksbill turtle internesting habitat in Western Australia. Telemetry studies in the Caribbean have found hawksbill turtle internesting is similar to other species, in that the females remain within several kilometres of their nesting beaches during this period (Starbird & Hillis 1992). Unpublished data from telemetry studies on hawksbill turtle nesting on Varanus Island supports this finding (Pendoley in prep.).

3.2.2 Barrow Island

Surveys carried out between 1998 and 2004 have identified 78 potential sea turtle nesting beaches on Barrow Island (Pendoley in prep.) (Figure 3-2). Each beach has been numbered, commencing with B1 at Whitlock Beach and continuing in an anticlockwise direction around Barrow Island. The beach numbers (B#) are listed in Table 1-1 along with the beach names shown on this figure.

Regular beach surveys of track density indicate that turtle usage of these beaches varies spatially, and there is high variation in inter-annual nesting effort.

Selected beaches were monitored routinely for sea turtle nesting activity and the results are shown in Figure 3-3 and Figure 3-4. This data shows the maximum number of animals nesting per night per kilometre of beach and represents a summary of the relative nesting effort for each species on east and west coast beaches.

Green turtles favour the west coast of Barrow Island. Between 1998 and 2004, peak nesting effort on the census beaches was in the order of hundreds of animals per kilometre. In poor years the lowest maximum can fall to less than five animals per kilometre. Green turtle use of east coast beaches is significantly lower and for years when hundreds of turtles nest on the west coast beaches, only 10–20 green turtles per night might use the east coast beaches (Pendoley in prep.).

Satellite telemetry of green turtles nesting on John Wayne Beach indicates the nesting and internesting habitat for these animals is located within several kilometres of the west coast nesting beaches and extends around to the north eastern beaches and waters (Pendoley in prep.). The rocky intertidal/subtidal platforms that are a common feature of west coast beaches are also an internesting habitat. These are approximately 10–100 m wide and are often broken up by rock pools. These pools and reefs are used by post-nesting sea turtles (Plate 3-1 and Plate 3-2).

On low tide, females leaving the beach after nesting can be found with anything from their head to their entire body submerged in these pools (Plate 3-1). Female green turtles also use the beaches to rest after nesting and can frequently be seen sleeping on the intertidal sand and at the waters edge. This shallow near shore zone is also used by mating pairs.

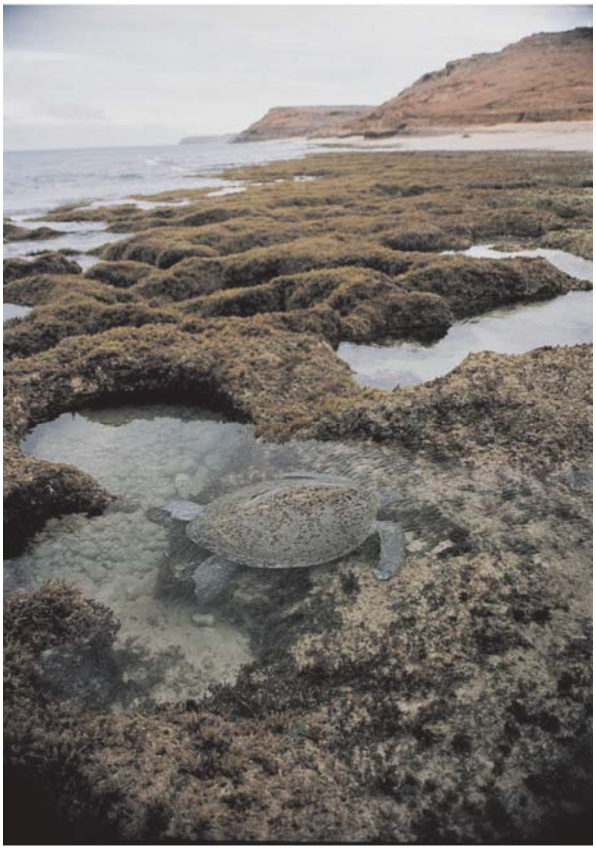


Plate 3-1 - Female Green Turtle Sleeping in Rock Pool in Flacourt Bay, January 2004

Plate 3-2 - Post-nesting Female Green Turtles Sleeping on Intertidal Platform off V Beach, Cape Dupuy, January 2003

Flatback turtle nesting on the east coast of Barrow Island is regionally significant. East coast census beach nesting effort between 1998 and 2004 ranged from 40–100 animals per kilometre (Pendoley in prep.). Flatback turtle nesting appears to display fewer year-to-year fluctuations than green turtles. This might be accounted for by the lack of a long-distance migration in flatback turtles. Green turtles feed for several years to build up sufficient body fat reserves to make the long-distance migration to their nesting grounds and back. Flatback turtles nest alongside green turtles on west coast beaches, flatback turtle numbers are an order of magnitude lower than green turtles.

Internesting habitat for east coast flatback turtles has not been identified. However, since they favour a soft bottom habitat, the internesting grounds are likely to be off the edge of the wide intertidal platform, stretching into the navigation channel running the length of the east coast (Parmenter 1994). Post-nesting females are commonly found on low tide sleeping on the intertidal platform off the east coast rookery (Plate 3-3).

Plate 3-3 - Post Nesting Female Flatback Turtle Resting on East Coast Intertidal Platform Reef, January 2001

Low numbers of hawksbill turtles use Barrow Island beaches. Nests have been found at Surf Point, John Wayne Beach, Terminal Beach and several other east coast beaches, however, the number of hawksbill turtle tracks on the east and west coast beaches suggests fewer than ten animals per week nest on Barrow Island (Pendoley in prep.).

The internesting habitat has not been identified for hawksbill turtles nesting on Barrow Island.

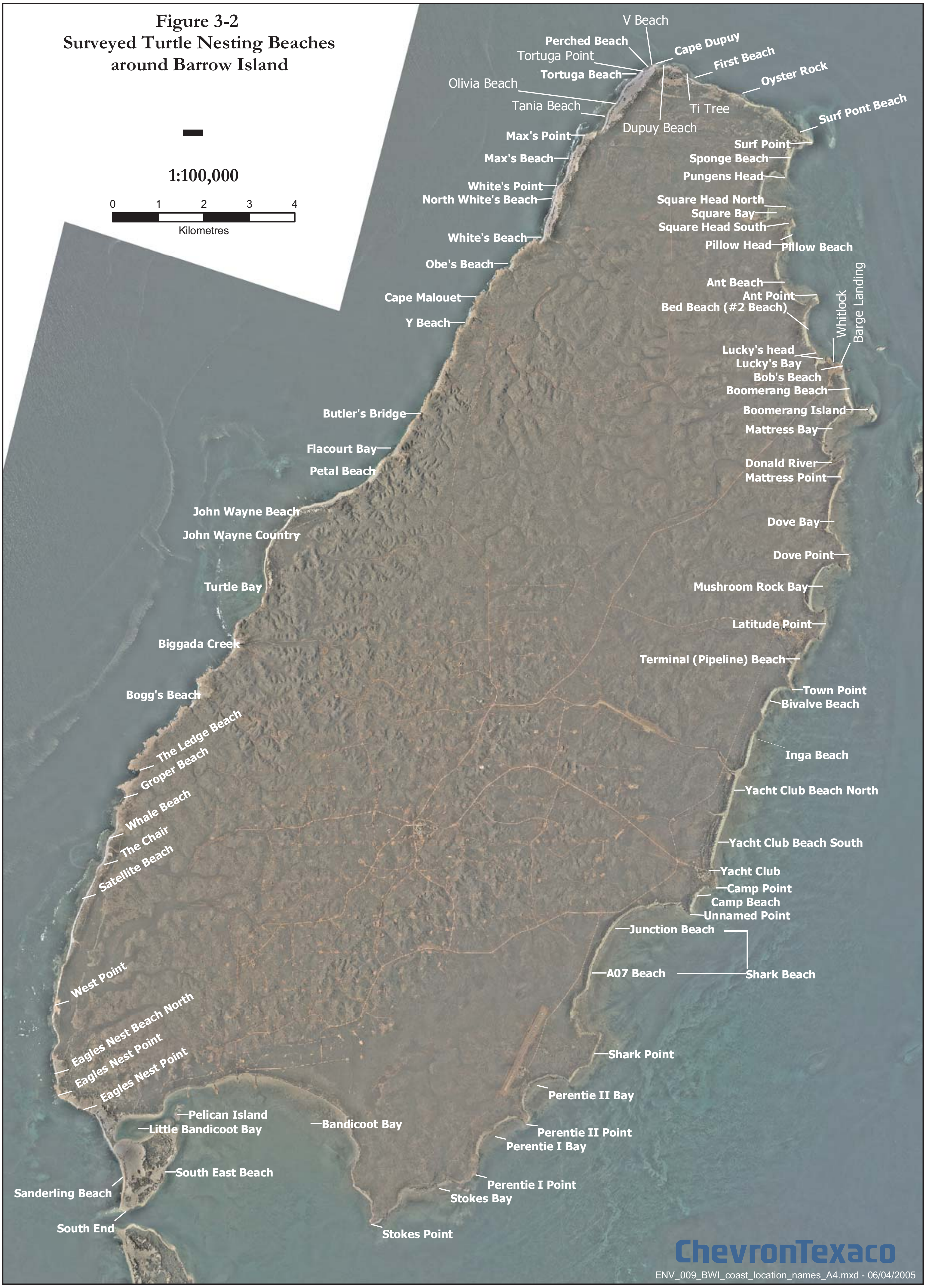
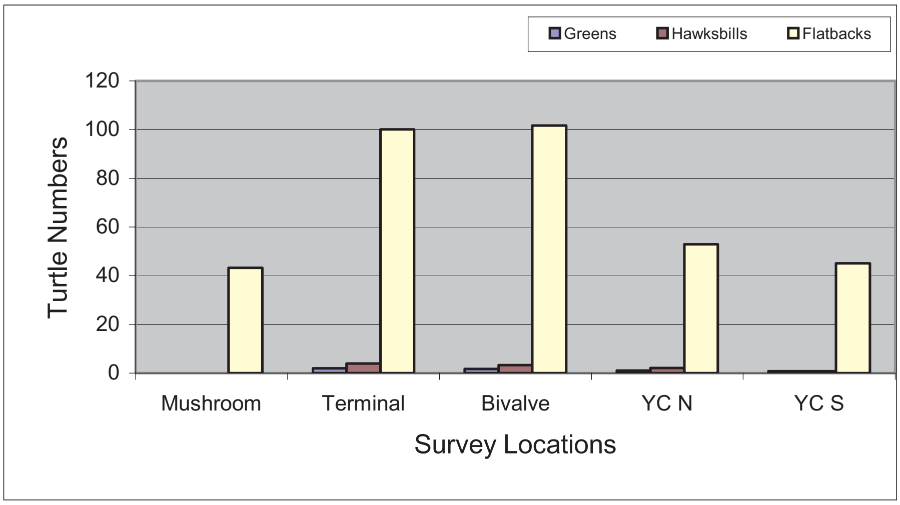


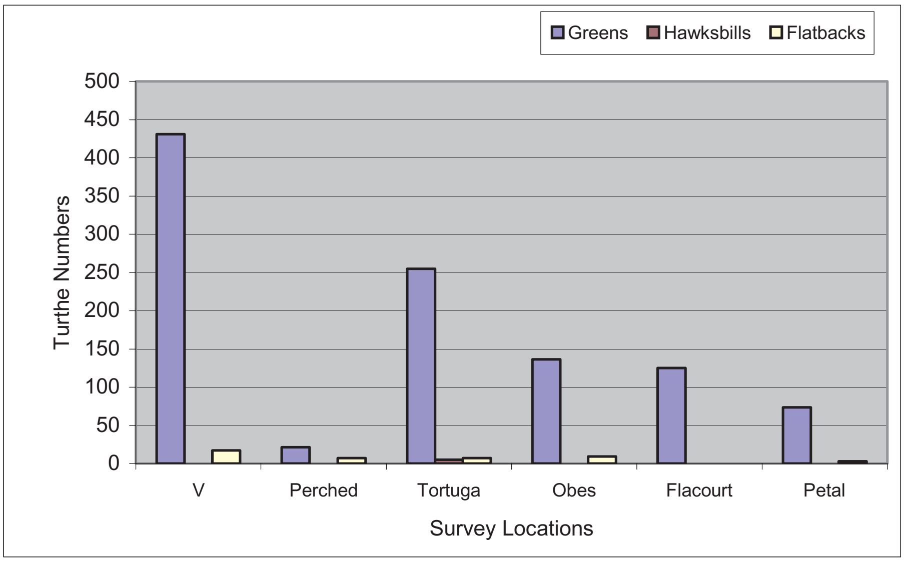
Figure 3-2
Surveyed Turtle Nesting Beaches around Barrow Island



YCN – Yacht Club North

YCS – Yacht Club South

Figure 3-3 – Maximum Number of Green, Flatback and Hawksbill Turtles Nesting on Selected East Coast Beaches 1998-2004 maximum animals/night/km (for n>7 survey days)



V= V Beach

Figure 3-4 - Maximum Number of Green, Flatback and Hawksbill Turtles Nesting on Selected West Coast Beaches 1998-2004, maximum animals/night/km (for n>7 survey days)

3.3 Feeding Grounds

Sea turtle feeding grounds have not been mapped for the North West Shelf.

The preferred diet for adult green turtles is seagrass and algae. Hawksbill turtles feed on sponges and soft coral and are generally associated with reef habitat. Flatback turtles eat jellyfish and soft-bodied benthic invertebrates such as sea pens and soft corals in habitats with unconsolidated substrates (Bjorndal 1994).

Turtles found in an area outside of the nesting season are likely to be residents of the region and their presence is indicative of feeding grounds. Juvenile and adult (male and female) green turtles have been observed feeding year-round on algae-covered rocky intertidal and subtidal platforms off the west cost of Barrow Island, indicating that the area is a feeding ground.

Flatback turtles forage in turbid shallow near-shore water in areas five to 20 m deep (Limpus et al. 1983). While the location of the flatback turtle feeding grounds off Barrow Island has not been documented, there is some evidence that juvenile flatback turtles are using the Barrow Island region as a developmental habitat. Two post hatchling flatback carapaces (14 cm CCW, 16 cm CCL) have been found on the Island, suggesting they are present around Barrow Island (Pendoley & Ford 2000; Pendoley & Vitenbergs 2003).

Hawksbill turtles are likely to feed on reef habitat in the Barrow Island region. Satellite tracking surveys of hawksbill turtles from Varanus and Rosemary Islands have identified feeding grounds in the Mary Anne and Great Sandy Island groups to the south of Barrow Shoals (Pendoley in prep.).

4 Monitoring: November 2003 to January 2004

Between November 2003 and January 2004, intensive monitoring of nightly sea turtle nesting effort was carried out on east and west coast beaches. The beaches surveyed were those potentially impacted by the proposed development.

4.1 Methods

A total of 11 beaches were surveyed over three to five consecutive days in November 2003, December 2003 and January 2004 (Figure 3-2). Each monthly survey was carried out during spring tides. The beaches selected for monitoring on the west coast were those being considered for the proposed feed gas pipeline crossing. The beaches monitored on the east coast were all in the vicinity of the proposed development at Town Point. In November 2003 and January 2004 additional beaches were surveyed (45 and 14 beaches respectively) to provide a broad picture of nesting effort for all of Barrow Island.

Monitoring of the 11 beaches in the proposed development area consisted of counting the number of overnight tracks left by each species. A line was drawn in the sand on each beach and the number of tracks crossing the line then counted. The line was redrawn each day so that an accurate count of the nightly nesting could be determined. This is referred to as the 'line census' (LC) count.

A count was also made of tracks left on the fresh sand below the last high tide line. This count, termed 'below high tide' (BHT) documents the number of animals crossing the beach since the previous night's high tide and is used on beaches that cannot be visited daily. This BHT count underestimates nesting activity, as tracks left by animals traversing the beach prior to the high tide are erased by the incoming high tide.

Additional beaches were surveyed using the BHT count method. These beaches were surveyed over the same week of spring tides as the 11 beaches in the proposed development area. The two counting methods were then used to compare nesting effort between beaches.

4.2 Results and Discussion

4.2.1 Barrow Wide Beaches - Below High Tide (BHT) Counts

Table 4-1 lists BHT counts for the average number of animals nesting overnight for every beach surveyed on Barrow Island between November 2003 and January 2004. BHT counts were used as this method was used on all beaches (proposed development area plus additional snapshot beaches) and allowed for direct comparison of nesting effort between the two sets of survey beaches.

The table shows limited (0–1 per night) flatback activity on four of the central east coast beaches between the ChevronTexaco camp and the beach to the north of the Terminal Tanks (B66, B67, B69, B72) in November 2003. None of the other 40 beaches surveyed had overnight nesting by flatback turtles. The December 2003 counts covered proposed development area beaches only and showed a single flatback turtle on one west coast beach (Tortuga), while activity on the central east coast beaches had started to increase.

The January 2004 survey included a snapshot survey of the north-east beaches, in addition to the regular proposed development area beaches. These beaches were surveyed so that the central eastern beaches could be examined in a wider spatial context. These results showed the December 2003 increase in flatback turtle nesting continued into January for the central east coast beaches with an average of 4–13 animals per night being recorded.

By comparison, January 2004 nesting on the more northerly east coast beaches was lower, 0–1 animal per night. Similar results were found for flatback turtles on west coast beaches (0–1 animal per night).

Green turtles favour north and west coast beaches, with numbers increasing from November 2003 (0–11 animals per night) to January 2004 (0–19 per night) on all beaches surveyed. Several of the north-eastern beaches showed evidence of low level green turtle nesting (0–3 animals per night between November 2003 and January 2004).

Low (average 1–2 animals per night) hawksbill turtle nesting was found on north-east coast beaches surveyed in November 2003 and none were documented for any of the beaches surveyed in December 2003 and January 2004.

Table 4-1 –Average Number of Animals per night/km (Average Number of Animals/Night in Brackets). November 2003 – January 2004, BHT count only (blank cells = beach not surveyed)

		Flatback			Green			Hawksbill		
Code	Beach name	Nov.03	Dec.03	Jan.04	Nov.03	Dec.03	Jan.04	Nov.03	Dec.03	Jan.04
North coast										
B11	Surf Point	0			2.3 (1)			4.5 (2)		
B12		0			0			0		
B13		0			0			0		
B14		0			0			0		
B15		0			7.7 (5)			0		
B16	Ti Tree	0	0	0	0	9.4 (1)	9.4 (1)	4.7 (0.5)	0	0
West coast										
B17	V	0	0	8.6 (1)	0	17.2 (1)	103.4 (6)	0	0	0
B18	Perched	0	0	0	0	3.6 (0.5)	7.1 (1)	0	0	0
B19	Tortuga	0	0.6 (0.25)	0	9.7 (4)	17.0 (7)	34 (14)	0	0	0
B20	Olivia	0			5.9 (4)			0		
B21	Tania	0			2.4 (1)			0		
B22	Max's coast	0			5.7 (2)			0		
B23	Whites N	0			0			3.1 (1)		
B24	Whites S	0			5.1 (2)			0		
B25	Obes			4.5 (0.5)			45.4 (5)			0
B27	Y Station			0			50 (6)			0
B28	Butlers			0			100 (8)			0
B29	Flacourt	0	0	0	0	30 (6)	95 (19)	0	0	0
B30	Petal	0	0	0.9 (0.3)	8.8 (3)	17.6 (6)	50 (17)	0	0	0
B31 32	John Wayne	0			3.1 (2.5)			0		
B33	Silver	0			8.9 (4)			0		
B34	Tonto coast	0			0.9 (1)			0		
B35	Turtle Bay N	0			0			0		
B36	Turtle Bay S	0		0	0		0	0		0
B37	Parking lot	0		0	0		20 (2)	0		0
B43	Whale	0			0			0		
B44	Loop	0			0			0		
B45 56	Satellite N	0			8 (8)			0		
B47	S W ledge	0			0			0		
B48	Eagles Nest N	0			8.4 (4)			0		
B49	Eagles Nest S	0			0			0		
B50	South End W	0			4.8 (11)			0		
South coast										
B51	South End SE	0			0			0		
B52	South End E	0			0			0		
B53	South End N	0			0			0		
B54	LBB N	0			0			0		
East coast										
B66	YC S	0.8 (1)	5 (6)	3.3 (4)	0	0	0	0	0	0
B67	YC N	1.1 (1)		14.1 (13)	0		0	0		0

		Flatback			Green			Hawksbill		
Code	Beach name	Nov.03	Dec.03	Jan.04	Nov.03	Dec.03	Jan.04	Nov.03	Dec.03	Jan.04
B68	Inga	0			0			0		
B69	Bivalve	0.5 (0.3)	10 (6)	20 (12)	0	0	0.3 (0.2)	0	0	0
B70	Terminal	0	6 (3)	12 (6)	0	0	0	0	0	0
B72	Mushroom	1.2 (1)		9.9 (8)	0		0	0		0
B73	Mattress S	0			0			0		
B74	Mattress Pt	0		0	0		0	7.1 (1)		0
B1	Whitlock	0		0	0		6.7 (1)	0		0
B2		0		0	0		0	0		0
B3		0		0	0		6.4 (3)	0		0
B4		0		2.9 (1)	0		0	2.9 (1)		0
B5		0		0	3.8 (1)		3.8 (1)	3.8 (1)		0
B6	Square Bay	0		0	0		0	0		0
B7		0		0	0		0	0		0
B8		0		0	0		0	0		0
B9		0		2.7 (1)	0		0	0		0
B10	Sth Surf Point	0			0			0		

4.2.2 Census Counts (LC), East and West Coast

East Coast

The east coast is a low energy environment relative to the more exposed west coast. East coast beaches are typically narrow (3–28 m wide) and subject to low wave energy. The beaches are gently sloped with 5–10 m dunes backing the supratidal zone. *Spinifex longifolius* grows in a band along the base of the dunes at the top of the beach. Sea turtle nests are typically concentrated between the high tide line and the base of the dune line, however, it is not uncommon for females to nest on top of, or behind, the dunes The intertidal zone is flat and very broad (100–500 m wide).

Beaches within the development area were surveyed over three to six consecutive nights in November and December 2003 and January 2004. Since these beaches were surveyed over a number of days it was possible to collect data on the exact number of animals traversing the beach overnight, by using a line census method where every track is recorded, regardless of the whether it was made before or after the high tide.

This line census data for the east coast of Barrow Island is shown in Table 4-2 and lists the density and number of animals, as a range, visiting the surveyed beaches. The results show little or no, green, hawksbill or flatback turtle activity in November 2003. Green and hawksbill turtle counts were also low for December while the flatback turtle nesting numbers increased in December and again in January.

The highest single count was 61 flatback turtles on one night in January 2004 on Bivalve Beach, adjacent to Town Point. This same beach also recorded a minimum of four flatback turtles within the same six day monitoring period in January, demonstrating the wide variability that is commonly seen over consecutive nights. Limited monitoring in 2001 and 2002 suggests that nesting numbers drop off in February (Pendoley in prep.) from a January peak.

The conversion of data to densities for inter beach comparisons shows a consistent peak in nesting density, over the three months from November to January, at Bivalve Beach. The average number of animals per night per kilometre of beach decreases on the beaches to the north and south of this location.

Green and hawksbill turtle nesting on east coast beaches remained very low throughout the entire monitoring period.

Table 4-2 - East Coast Census Beaches, Average Number/Night/km Line Census (LC) Count (nightly range in brackets)

	Flatback			Green			Hawksbills		
	Nov	Dec	Jan	Nov	Dec	Jan	Nov	Dec	Jan
Yacht Club South	nr	7.9 (0-24)	9.6 (6-19)	nr	0.0	0.0	nr	0.0	0.0
Yacht Club North	nr	nr	37.3 (25-44)	nr	nr	0.0	nr	nr	0.0
Bivalve	1.1 (0-1)	19.45 (8-13)	48.7 (4-61)	0.3 (0-1)	0.0	0.3 (0-1)	1.1 (0-2)	0.0	0.0
Terminal	0.0	11.34 (2-6)	29.6 (3-30)	0.0	0.66 (0-1)	0.0	0.0	0.0	0.0
Mushroom	nr	nr	28.8 (12-35)	nr	nr	0.0	nr	nr	0.0

NR – no record

The extreme variability in overnight track counts can be smoothed out by averaging the number of nesting animals over the total number of survey days. The results for the east coast beaches shown in Table 4-2 indicate that flatback turtle nesting is of the same order of magnitude (tens of animals per night) for the beaches surveyed.

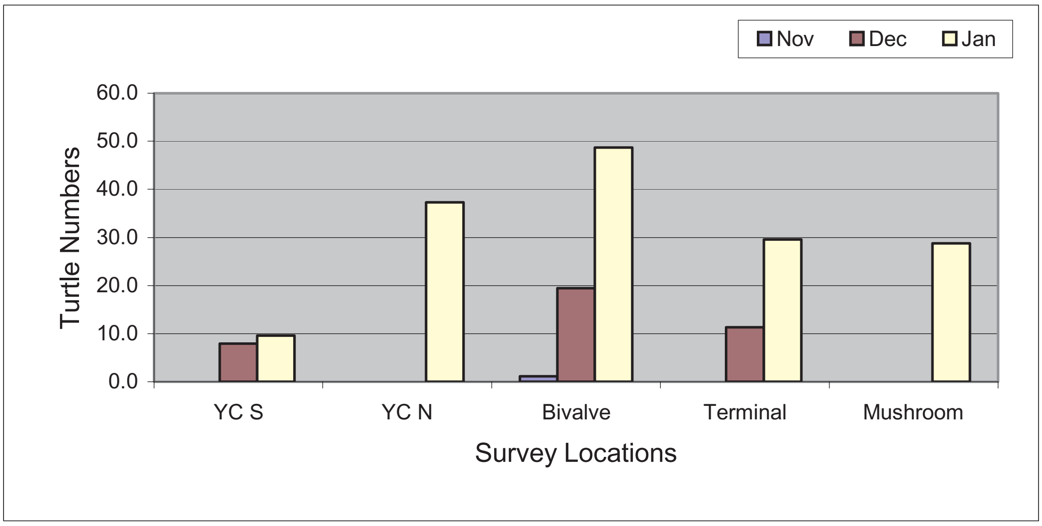


Figure 4-1 - East Coast Flatback Turtle Nesting Densities (animals/night/km), Line Census Counts

Note: Yacht Club North (YC N) and Mushroom were not surveyed in December

Peak flatback turtle hatchling (Plate 4-1) emergence time is approximately six to eight weeks after egg laying. The peak hatchling period is February and March for the east coast of Barrow Island, with nest emergences extending into April. Field observations confirm these results (Pendoley in prep.).

Plate 4-1 - Flatback Turtle Hatchling, East Coast Barrow Island, January 2004

West Coast

The west coast of Barrow Island is a high energy environment with water depths dropping rapidly off the edge of the continental shelf. Compared to the east coast, these beaches are generally wider (10–70 m) and where an intertidal rock platform is absent, the beach slope drops steeply into the water. A narrow (10–20 m) intertidal rocky platform abuts most of the rocky headlands along the west coast (Plate 4-2). These macroalgae-covered platforms are grazed extensively. The limestone platforms in the intertidal zone of most beaches north and south of the Biggada Reef complex midway down the west coast are wider (~100 m).

Plate 4-2 – Algae Covered Rocky Intertidal, West Coast Barrow Island, Used as Feeding Ground by Resident Green Turtles, South Flacourt Beach, January 2004

Monitoring in November and December 2003 and January 2004 concentrated on beaches of potential interest for the proposed gas feed pipeline crossing and included the three beaches west and south of Cape Dupuy (V, Perched, Tortuga) beaches and at John Wayne, Flacourt and Petal beaches. The results of the intensive monitoring program are shown in Table 4-3.

Table 4-3 - West Coast Census Beaches, Average Number/Night/km Line Census Count (nightly range in brackets)

	Flatback			**Green**			**Hawksbills**		
Beach	Nov	Dec	Jan	Nov	Dec	Jan	Nov	Dec	Jan
V	0.0	0.0	4.3 (0-1)	17.2 (0-2)	46.0 (0-5)	137.9 (0-11)	0.0	0.0	0.0
Perched	0.0	0.0	1.8 (0-1)	0.0	4.8 (0-1)	10.7 (0-3)	0.0	0.0	0.0
Tortuga	0.0	0.8 (0-1)	1.8 (0-2)	8.9 (3-4)	25 (6-18)	42.5(6-29)	0.0	0.0	0.0
Obes	nr	nr	0.3 (0-1)	nr	nr	78.8 (4-15)	nr	nr	0.0
Flacourt	0.0	0.0	0.0	5 (0-2)	38.35 (3-13)	83.35 (9-25)	0.0	0.0	0.0
Petal	0.0	0.0	0.6 (0-1)	9.6 (0-6)	24.5 (3-14)	37.1 (6-25)	0.0	0.0	0.0

nr = no record

Green turtles are the principal species nesting on the west coast of Barrow Island. Nesting over the three months surveyed peaked in January. The data has been converted to densities to allow between beach comparisons of nesting effort. The results show the two small beaches, V Beach (58 m long) and Obes Beach (110 m long) are heavily used in January, with a maximum average of 11 and 15 animals per night respectively nesting on these beaches. Of the three longer beaches, Tortuga, Flacourt and Petal (412 m, 200 m and 340 m long respectively) the highest density nesting is on Flacourt Beach (average of 83 animals per night per kilometre). These three beaches had a similar maximum number of animals per night nesting in January (25–29 animals).

Scattered low level flatback turtle nesting was evident on the west coast beaches in January 2004, while only two records of hawksbill turtle nesting were collected in December 2003.

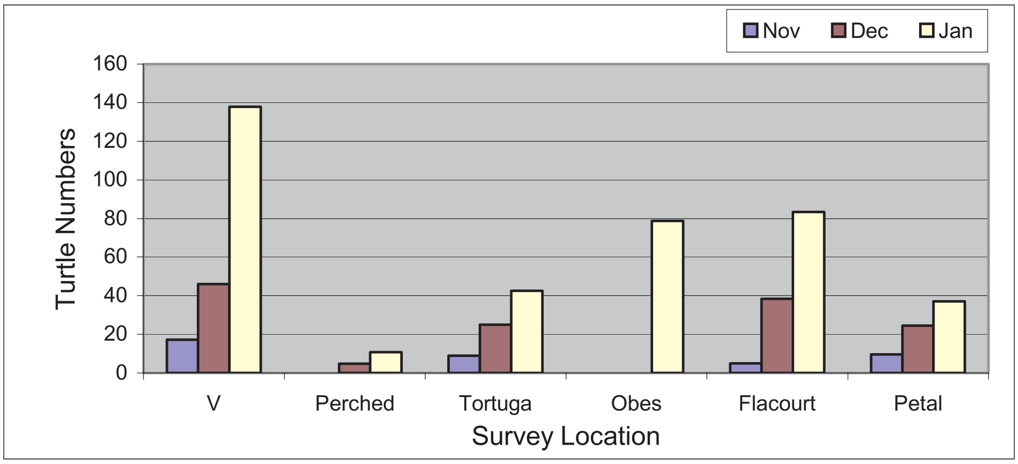


Figure 4-2 - West Coast Greens Turtle Nesting Densities (animals/night/km), Line Census Counts

Note: Obes Beach was not surveyed in November and December

Green turtle nesting peaks in December and January, with hatchlings emerging six to eight weeks later in February and March (Plate 4-3).

Plate 4-3 - Green Turtle Hatchlings, West Coast Barrow Island, January 2004

5 Monitoring: November 2004 to February 2005

Between November 2004 and February 2005, monitoring of nightly sea turtle nesting effort was undertaken on east and west coast beaches. The monitoring program was similar to monitoring undertaken in November 2003-January 2004 but was expanded to address changes to the proposed development, include beaches previously not sampled and extend the monitoring period to adequately cover the peak in green turtle nesting on the west coast. Results of this monitoring are presented in Attachment 1 and summarised below.

5.1 Methods

Seven east coast and six west coast beaches were surveyed over a minimum of three consecutive days at, or close to, the peak of spring tides in November 2004, December 2004, January 2005 and February 2005. The beaches monitored in this period were the same as those monitored in November 2003-January 2004 with the following exceptions. Bed Beach (#2 Beach), Junction Beach and A07 Beach on the east coast were monitored following queries from CALM regarding sea turtle nesting on the south east coast of Barrow Island. White's Beach and North White's Beach on the west coast were included following the inclusion of North White's Beach as an alternative feedgas pipeline shore crossing location. Mushroom Beach on the east coast was not monitored in November 2004-February 2005 due to time constraints involved with monitoring new beaches. Similarly, Obes Beach and Petal Beach and on the west coast and V Beach near Cape

Dupuy were not monitored due to the addition of White's and North White's Beach to the monitoring program.

Turtle nesting activity was quantified using the LC method, as per November 2003-January 2004 monitoring. However, BHT counts were not monitored during November 2004-February 2005.

5.2 Results and Discussion

5.2.1 East Coast

Line census data recorded over the two seasons of monitoring (November 2003-Janauary 2004 and November 2004-Febraury 2005) shows little or no, green, hawksbill or flatback turtle nesting activity in November. Green and hawksbill turtle nesting activity remained low whilst flatback turtle nesting numbers increased in December and peaked in January before dropping off in February (Attachment 1 – Figure 7).

Peak flatback turtle nesting density was focussed on beaches on the central east coast, with Bivalve Beach showing the highest peak during January of both years. Very limited green, hawksbill and flatback turtle nesting activity was recorded on Bed Beach (#2 Beach), to the north of the central beaches. Junction Beach and A07 Beach (Shark Beach) to the south of the central beaches showed lower nesting activity than the central beaches for all three turtle species (Attachment 1 – Figure 7).

5.2.2 West Coast

Line census data recorded over the two seasons of monitoring of west coast beaches shows that green turtle nesting rises steadily from November and peaks in January and February. Green turtle nesting density was greatest at Tortuga Beach, Flacourt Beach, White's Beach and Ti Tree Beach whilst nesting densities were lower at Perched Beach and North White's Beach (Attachment 1 – Figure 8). However, the only tracks recorded at North White's Beach were from turtles that had used White's Beach and crawled into the North White's Beach survey area. Flatback and Hawksbill turtle nesting activity remained low throughout the survey months.

6 Light Experiments

Lighting associated with the proposed development may affect the nesting behaviour of adult turtles and the sea-finding behaviour of turtle hatchlings. Light experiments were conducted on the beaches south of Town Point, where the light has the greatest potential to affect flatback turtle nesting.

Two experiments on the effects of artificial light on flatback turtle hatchling sea-finding behaviour were conducted in April 2004 and February 2005. Reports on the experimental methods and results are included in Attachment 2 and 3.

The pilot study in April 2004 established the experimental procedure and that flatback and green turtle hatchlings are attracted to artificial lights. The experiment in February 2005 showed conclusively that artificial lights can reduce the sea-finding success of flatback turtle hatchlings over hundreds of metres.

7 Conclusions

Nesting flatback turtles favour mid-east coast beaches on Barrow Island. Of the beaches surveyed, the highest average density of flatback turtle tracks (48/night/km) was recorded in January 2004 on Bivalve Beach. Flatback turtle nesting densities are highest on the central east coast between Mushroom Beach and Yacht Club South Beach, and decrease to the north and south.

Green turtles favour west coast beaches. On average, 10 to 137 green turtles nested each night on each kilometre of beaches along the north-west coast of Barrow Island over the study period. Green turtle nesting density is consistently high along the west coast beaches during the peak of the nesting season.

Hawksbill turtles nested in very low numbers (< 10 per week) all around the Island throughout the study.

Barrow Island is a feeding ground for green turtles and appears to be a feeding ground and juvenile habitat for flatback turtles.

The superior nesting habitat for green turtles (i.e. sand > 1 m deep) at Flacourt Bay supports a larger population of nesting green turtles than the shallow sands at North White's Beach. Nesting at North White's Beach is dominated by very low numbers of hawksbill turtles, probably because they are able to nest in shallow (30–40 cm) sand.

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Attachment 1 - Sea Turtle Monitoring Program Results November 2004 to February 2005. Report by Pendoley Environmental, April 2005.

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PROPOSED GORGON DEVELOPMENT

SEA TURTLE MONITORING PROGRAM RESULTS
NOVEMBER 2004 TO FEBRUARY 2005

REPORT BY

PENDOLEY ENVIRONMENTAL PTY LTD

5 APRIL 2005

1 Introduction

This report presents the results of the second year of census beach monitoring for the proposed Gorgon gas development on Barrow Island.

The objective of the program was to quantify sea turtle beach usage and nesting effort on selected census beaches on the island. The program over the past two seasons has focussed on beaches that are close to potential Gorgon infrastructure locations on the east and west coast of Barrow Island. Monitoring was conducted over the four months thought to be the peak of the nesting season during earlier regional sea turtle surveys (Pendoley 2005a in prep).

The results of the monitoring program have been analysed to provide information on the geographical distribution and timing of adults nesting and hatchling emergences on Barrow Island.

Acknowledgments

This program was designed and implemented by K. Pendoley with field assistance provided by Anna Vitenbergs, Karen Edward, Jarrad Sherborne, Patrick Cullen, Sue McDonald and Jennifer Langmead.

2 Methods

Seven east coast (Figures 1 - 3) and six west coast beaches (Figures 4 - 6) were surveyed over a minimum of three days at (or close to) the peak of the spring tides in November, December and January (2003/2004 and 2004/2005) and February (2004/2005). The beaches surveyed over the 2004/2005 season are the same as 2003/2004 with the following exceptions; #2/Bed Beach, Junction Beach and A07 Beach on the east coast were added to satisfy CALM queries regarding lower nesting on the south east coast in the draft ERMP. Whites Beach and North Whites Beach on the west coast were included after North Whites Beach was proposed as an alternative pipeline crossing location.

Turtle crawl activity was quantified from overnight tracks crossing a line dug into the sand at the commencements of each monitoring period (Plate 1). This line was redrawn daily.

While these line census track counts provide an accurate count of the number of turtle crawls crossing the beach overnight it does not show how many individuals visit the beach, nor does it provide information on the nesting success rate arising from each beach visit. Consequently, the 2004/2005 program was amended to include counts of actual nests associated with each overnight track. This entailed the surveyor inspecting the entire length of every track to determine if the animals nested or not.

The limitations on these methods include

1. Strong overnight winds or unexpectedly high tides often erases the line resulting in an underestimate or loss of a nights track count.
2. At the peak of the nesting period in December and January high densities of tracks may result in the complete obliteration of the line.
3. At peak nesting periods the large number of tracks and nests frequently made it impossible to find nests associated with the tracks crossing the line.

3 Results and Discussion

The line census track counts, and nest emergence counts, for the 2003/2004 and 2004/2005 nesting seasons (Table 1) have been used to investigate the following.

1. Beach use preferences for east and west coast census beaches (Figures 7 - 10) using monthly track densities for between beach comparisons.
2. Daily fluctuations in animals beach visits relative to the tides (Figure 11) using raw daily track count data.
3. Year-to-year variations in animal beach visits (Figure 12) using raw daily track data.
4. Peak nesting months (Figure 13) using averaged daily track data for each survey month.
5. Nesting success rate of each beach crawl event, using track counts and confirmed nest counts.
6. Peak nest emergence months, (Figure 14) using monthly average number of nest emergences relative to average number of tracks.
7. Hawksbill nesting on Barrow Island.

3.1 Beach preferences

The census beaches on both coasts were selected to be representative of the different coastal beach types, taking into account the results of earlier beach surveys (K Pendoley 2005 in prep) and potential infrastructure locations for the Gorgon gas plant pipelines and offshore facilities. The density of flatback, green and hawksbill line census tracks found on the seven east coast and six west coast beaches are shown in Figure 7 (east coast) and Figure 8 (west coast). These figures clearly show the significant preferences of flatback turtles for east coast beaches and green turtles for the west coast. A student ttest analysis of the number of green and flatback turtles crossing the line per night on east vs west coast beaches confirmed this difference ($p < 0.001$ for flatback east coast vs west coast, green east coast vs west coast, flatback east coast vs green east coast and flatback west coast vs green west coast). Evidence of hawksbill beach usage was present in low numbers on both east and west coast beaches (see section 3.7).

Within the east coast beach group, flatbacks turtles favour the central beaches (Terminal, Bivalve, YC N and YC S). Very limited nesting activity for all three species was seen on beach #2 to the north, while slightly greater track densities were found on Junction and A07 Beaches to the south of the central beaches. A one way ANOVA of the of the line census track data collected at the peak of the nesting season in January (2004 and 2005) tested the hypothesis that there is no difference in track line counts on the east coast census beaches. The ANOVA calculations found a significant difference in the track count means for this group of beaches ($p<0.0001$). The ANOVA plot, (Figure 9, plots the mean and 95% confidence intervals for the line census data) shows the differences between these beaches.

Intermittent surveys of the coast south of A07 Beach and the coast bordering Bandicoot Bay, between 1998 and 2005, have found little or no evidence of sea turtle nesting. This is probably due to the lack of suitable nesting sand on these sections of the coast. Beaches north of #2 Beach are difficult to access, however, the coast between Surf Point and The Barge landing have been inspected on three separate occasions (October 2000, November 2002, November 2003). These results, in conjunction with the findings of west coast green satellite tracking programs, suggest green turtles use these beaches along with flatback turtles and that the flatback usage is low, relative to the mid east coast beaches. Routine census beach monitoring at the peak of the nesting season is required to better quantify sea turtle species usage of these beaches.

Green turtle usage of west coast beaches shows highest track density on Tortuga Beach, Flacourt Beach and Whites Beach, followed by Ti Tree Beach, Perched Beach and North Whites Beach. The only tracks documented on North Whites Beach occurred at the southern end of the beach section, where animals using Whites beach had crawled along the beach and into the North Whites Beach survey area. The lack of nesting activity on this section of beach is due to a rocky ledge emergent from the beach face and a very shallow sand layer on the underlying rocky ledge. The beach profiles at Perched Beach and Ti Tree Beach are very similar to North Whites Beach with nesting confined to the limited areas of deep sand on all three beaches. The ANOVA analysis of daily track counts shows a significant difference in the mean number of tracks found on the west coast beaches ($p<0.0001$). This is shown graphically in Figure 10.

3.2 Daily track fluctuations

The line census track count method used a minimum of three consecutive days of monitoring (on each beach) over the peak of the spring tides as representative of nesting effort for each month. The representativeness of this survey method was tested in December 2004 when line census tracks on Bivalve Beach and YC N Beach were counted over a 14 day period. The results are plotted on Figure 11, along with the peak nightly tide height. The plot shows the broad day-to-day fluctuations in track counts with flatback numbers on Bivalve Beach ranging from 0-32 line census tracks recorded between December 2^{nd} and 16^{th}, and 3-59 line census tracks recorded on YC N Beach for the same period.

A linear regression analysis of the Bivalve Beach data suggest there is insufficient evidence from the study to conclude that there is a correlation between the number of tracks per day and the tide height ($r^2 = 0.2111$ and $p=0.0567$). Conversely, the YC N data did show a significant correlation between tide height and the daily number of line census tracks ($r^2 = 0.397$ and $p = 0.014$). These results provide evidence to support an increase in the number of survey days in a given monthly census period.

3.3 Year-to-year variability

The need to conduct routine surveys over a number of years is demonstrated by the results shown in Figure 12 which shows daily line census track counts from the same survey days in December 2003 and December 2004. The number of flatback turtle beach crawls in December 2004 was almost double the number for the same time period (and tidal cycle phase) in 2003.

3.4 Peak nesting months

The number of tracks counted in each month over the 2 summers of turtle surveys was averaged and plotted in Figure 13. A one-way ANOVA of this data showed a significant difference between the months ($p<0.0001$). The figure shows a peak in flatback nesting in December and January compared to November and February.

The green turtle track data suggests a more seasonally dispersed nesting effort with peak nesting occurring a month behind the flatback peak, in January and February. The ANOVA of this data confirms there is a significant difference between the four months of data ($p<0.001$).

3.5 Nesting success rate

Prior to the current monitoring season, line census track data have been used as an indication of the size of the nesting turtle populations. This assumes every track represents an individual that successfully nests every time she crawls up a beach. This assumption was tested over the 2004/2005 monitoring period. Where possible, every track was traced and presence or absence of a nest noted. The results show that of the 1003 flatback tracks traced, 53% of them terminated in a nest, while 48% of the 542 green tracks traced produced a successful nesting. Of the nine hawksbill tracks found only three nests were visible.

It is clear from these results that the identification of successful nesting events provides greater accuracy when enumerating the nesting population of Barrow Island.

3.6 Nest emergences

While not a primary objective of the monitoring program, counts of overnight nest emergence were made to aid in the quantification of successful nesting of Barrow Island sea turtle populations. A nest emergence was counted for hatchling track groups of six or greater. The results shown in Figure 14 plots the average number of tracks per day for green and flatback turtles against the average number of nests recorded over the same survey days. Sea turtle egg incubation time is inversely related to incubation temperature and ranges from 50 to 80 days (Ackerman 1996). Nests on Barrow Island are therefore expected to emerge one to two months after deposition. Based on the available 2004/2005 data flatback nest emergences should decline in March. In the absence of nesting data for green turtles in March it is not possible to predict when the green turtle nest emergence will begin to decline.

3.7 Hawksbill nesting on Barrow Island

Low numbers (relative to green and flatback turtles) of hawksbill tracks and nests have been documented on Barrow Island beaches since systematic beach surveys commenced in 1998 as part of a PhD program. A search of over 2,500 beach survey day records collated during the PhD and Gorgon census beach surveys has identified evidence (tracks and live hatchlings) of hawksbill nesting on all north coast beaches, 10 west coast beaches (from Cape Dupuy to the South End) and 19 east coast beaches (between Surf Point and A07). The lack of records on all Barrow Island beaches is probably a function of sampling effort and an increased survey effort on beaches not visited regularly is likely to find evidence of hawksbill nesting.

Hawksbill nesting does not appear to be concentrated on any of the coasts surveyed. However, the evidence of their presence is most visible on the small rocky beaches (or rubbly beach corners) of the beaches on the north east coast where the shallow sand depth precludes successful green or flatback nesting.

3.8 Nesting population size estimates

A recent review of the status of sea turtles in Australia has found that, while significant nesting populations of green, flatback and hawksbill turtles occur in Western Australia the census data upon which accurate assessments of the size of the nesting populations are sparse. The review concluded that the status of the nesting populations is currently undetermined for green turtles (Limpus 2004a in prep), hawksbill turtles (Limpus 2004b in prep) and flatback turtles (Limpus 2004c in prep). The review also confirmed a total lack of information on hawksbill and flatback foraging grounds and limited information on green foraging grounds. The available information on population sizes is summarized below.

The green turtle population in Western Australia is from a single genetic stock that nests from the North West Cape to the Lacepede Islands. The large size of this population (estimated to be on the order of 1,000's – 10,000's) is significant on a world scale and the largest in the Indian Ocean (Prince 1994a; Fitzsimmons, Moritz et al. 1997; Limpus 2002; Limpus 2004a in prep).

The largest hawksbill population in the Indian Ocean is represented by a single genetic stock that is centered on Rosemary Island in the Dampier Archipelago and extends south to North West Cape. The size of the annual nesting population is estimated at 10's – 100's . The northern extent of the population has not been confirmed but may extend into the Kimberley (Broderick, Moritz et al. 1994; Prince 1994a; Limpus 2002; Limpus 2004b in prep).

Flatbacks are endemic to subtropical and tropical Australian waters. Approximately 30% of the total Australian breeding population is found in Western Australia, split into two genetically distinct stocks. The northern stock nests during winter in Western Arnhem land in the Northern Territory, while the southern, summer breeding stock, nests from North West Cape to the Lacepede Islands and is estimated at 100's to 1000's of individuals nesting annually (Fitzsimmons, Moritz et al. 1996; Limpus 2002; Limpus 2004c in prep).

The very limited nesting data collected from Barrow Island over the 2004/2005 season had been used to make a rough estimate of the size of the nesting green and flatback populations at Barrow Island. Caution must be used when reviewing this data since sea turtle nesting numbers undergo broad annual cyclic fluctuations and consequently the estimate can be substantially higher or lower than the actual population size.

The assumptions used to calculate a nesting population size were as follows. Green turtles; use confirmed nest data, 12 day internesting period, 5 year remigration period, 3 nests per season, 80% of seasonal nesting animals present. Flatback turtles; 16 day internesting, 3 year remigrations, 3 nests per season, 80-% of the seasonal nesting animals present. The results suggest the east coast flatback nesting population is around 10,000 animals while the west coast green population is greater than 100,000 animals. The results from long term tagging programs are required to conduct more precise population estimates and population models.

4 Conclusion

The second year of monitoring has confirmed the preference of flatback turtles for the east coast nesting sites and the green turtle preference for the west coast. Flatback nesting is concentrated most strongly on the mid east coast beaches while green nesting is highest on beaches with suitably deep nesting sand. Hawksbill nesting is significantly lower and spread around most of the Barrow Island coastline.

The results have shown a wide day-to-day and year-to-year variability in animal beach visits and should be taken into account when planning future sea turtle monitoring programs. The results also show that the total number of tracks on a beach is not necessarily representative of the nesting effort with 47% of flatback tracks and 52% of green tracks representing unsuccessful nesting crawls.

The analysis of track data on a monthly basis found a strong concentration of flatback nesting over a 2 month period between December and January. The green track results suggest this species nesting is spread over a longer period, peaking in January and February, a month behind the flatbacks. A program to monitor the census beaches in March and April is recommended to identify the end of the nesting season for both green and flatback sea turtles. Based on the results of this program hatchling emergences peak in February for both greens and flatbacks however, the trend in the data suggests emergences are likely to extend into March and April. Additional monitoring is recommended to accurately identify the end of the hatchling emergence period.

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Gorgon census beach data, line census track data, tracks/km per day, Dec 2003 to Feb 2005

					Flatback			Green			Hawksbill		
month	Beach code FINAL	Beach Common name	km	n	avg	stdev	se	avg	stdev	se	avg	stdev	se
Nov	16	Ti Tree	0.1	7	0.0	0.0	0.0	10.0	18.3	6.9	3.3	8.2	3.1
Dec	16	Ti Tree	0.1	8	0.0	0.0	0.0	6.3	7.4	2.6	0.0	0.0	0.0
Jan	16	Ti Tree	0.1	9	0.0	0.0	0.0	17.8	12.0	4.0	0.0	0.0	0.0
Feb	16	Ti Tree	0.1	5	0.0	0.0	0.0	8.0	13.0	5.8	0.0	0.0	0.0
Nov	17	V	0.06	6	0.0	0.0	0.0	22.2	13.6	5.6	0.0	0.0	0.0
Dec	17	V	0.06	8	0.0	0.0	0.0	54.2	40.6	14.3	2.1	5.9	2.1
Jan	17	V	0.06	9	3.7	7.3	2.4	109.3	40.1	13.4	0.0	0.0	0.0
Feb	17	V	0.06	5	0.0	0.0	0.0	83.3	39.1	17.5	0.0	0.0	0.0
Nov	18	Perched	0.14	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	18	Perched	0.14	8	0.0	0.0	0.0	1.8	3.3	1.2	0.0	0.0	0.0
Jan	18	Perched	0.14	9	0.8	2.4	0.8	8.7	10.0	3.3	0.0	0.0	0.0
Feb	18	Perched	0.14	5	0.0	0.0	0.0	15.7	11.7	5.2	0.0	0.0	0.0
Nov	19	Tortuga	0.41	6	0.0	0.0	0.0	10.2	5.0	2.0	0.0	0.0	0.0
Dec	19	Tortuga	0.41	8	0.3	0.9	0.3	29.6	11.5	4.1	0.3	0.9	0.3
Jan	19	Tortuga	0.41	9	1.6	2.7	0.9	52.8	22.1	7.4	0.0	0.0	0.0
Feb	19	Tortuga	0.41	5	0.0	0.0	0.0	55.1	23.9	10.7	0.0	0.0	0.0
Nov	23	North Whites	0.32	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	23	North Whites	0.32	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	23	North Whites	0.32	5	0.0	0.0	0.0	3.8	5.1	2.3	0.0	0.0	0.0
Feb	23	North Whites	0.32	5	0.0	0.0	0.0	0.4	0.4	0.2	0.0	0.0	0.0
Nov	24	Whites	0.39	3	0.0	0.0	0.0	4.3	1.5	0.9	0.0	0.0	0.0
Dec	24	Whites	0.39	5	0.0	0.0	0.0	21.5	7.2	3.2	0.0	0.0	0.0
Jan	24	Whites	0.39	5	0.0	0.0	0.0	29.2	12.0	5.4	0.0	0.0	0.0
Feb	24	Whites	0.39	5	0.0	0.0	0.0	11.8	6.4	2.9	0.0	0.0	0.0

					Flatback			Green			Hawksbill		
month	Beach code FINAL	Beach Common name	km	n	avg	stdev	se	avg	stdev	se	avg	stdev	se
Nov	29	Flacourt	0.2	10	1.5	4.7	1.5	5.0	3.3	1.1	0.0	0.0	0.0
Dec	29	Flacourt	0.2	7	0.0	0.0	0.0	27.1	20.0	7.5	0.0	0.0	0.0
Jan	29	Flacourt	0.2	11	0.0	0.0	0.0	61.8	34.5	10.4	0.0	0.0	0.0
Feb	29	Flacourt	0.2	5	0.0	0.0	0.0	58.0	20.5	9.2	0.0	0.0	0.0
Nov	54	A07	0.4	0	-	-	-	-	-	-	-	-	-
Dec	54	A07	0.4	6	7.9	6.4	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Jan	54	A07	0.4	5	10.0	5.9	2.6	1.0	2.2	1.0	0.0	0.0	0.0
Feb	54	A07	0.4	5	1.5	2.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	55	Junction	0.72	3	0.5	0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Dec	55	Junction	0.72	6	13.4	8.5	3.5	0.0	0.0	0.0	0.1	0.4	0.2
Jan	55	Junction	0.72	6	6.3	3.7	1.5	0.2	0.6	0.2	0.0	0.0	0.0
Feb	55	Junction	0.72	5	1.1	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Nov	66	YC S	1.2	3	3.3	4.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0
Dec	66	YC S	1.2	26	11.5	12.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0
Jan	66	YC S	1.2	12	20.3	12.7	3.7	0.0	0.0	0.0	0.0	0.0	0.0
Feb	66	YC S	1.2	5	2.0	2.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Nov	67	YC N		3	2.7	2.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Dec	67	YC N	0.93	13	22.0	19.3	5.3	0.1	0.3	0.1	0.0	0.0	0.0
Jan	67	YC N	0.93	10	26.7	15.1	4.8	0.0	0.0	0.0	0.0	0.0	0.0
Feb	67	YC N	0.93	5	2.8	4.1	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Nov	69	Bivalve	0.6	6	4.0	7.2	3.0	0.0	0.0	0.0	0.7	1.5	0.6
Dec	69	Bivalve	0.6	17	22.9	14.5	3.5	0.1	0.4	0.1	0.0	0.0	0.0
Jan	69	Bivalve	0.6	11	38.6	30.7	9.2	0.2	0.5	0.2	0.0	0.0	0.0
Feb	69	Bivalve	0.6	5	2.0	2.2	1.0	0.3	0.7	0.3	0.0	0.0	0.0

					Flatback			Green			Hawksbill		
month	Beach code FINAL	Beach Common name	km	n	avg	stdev	se	avg	stdev	se	avg	stdev	se
Nov	70	Terminal		6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	70	Terminal	0.5	17	14.5	19.9	4.8	0.1	0.5	0.1	0.0	0.0	0.0
Jan	70	Terminal	0.5	13	30.6	16.1	4.5	0.0	0.0	0.0	0.0	0.0	0.0
Feb	70	Terminal	0.5	5	3.2	2.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Nov	2	Ant Point S	0.5	0	-	-	-	-	-	-	-	-	-
Dec	2	Ant Point S	0.5	5	0.0	0.0	0.0	0.8	1.1	0.5	0.4	0.9	0.4
Jan	2	Ant Point S	0.5	6	0.80	1.10	0.45	0.00	0.00	0	0.333333	0.755929	0.308607
Feb	2	Ant Point S	0.5	5	0.0	0.0	0.0	2.0	1.4	0.6	0.0	0.0	0.0

EAST COAST CENSUS BEACH LOCATIONS AND SURVEY BOUNDARIES

Figure 1: East coast survey beaches – north east coast; #2/Bed Beach

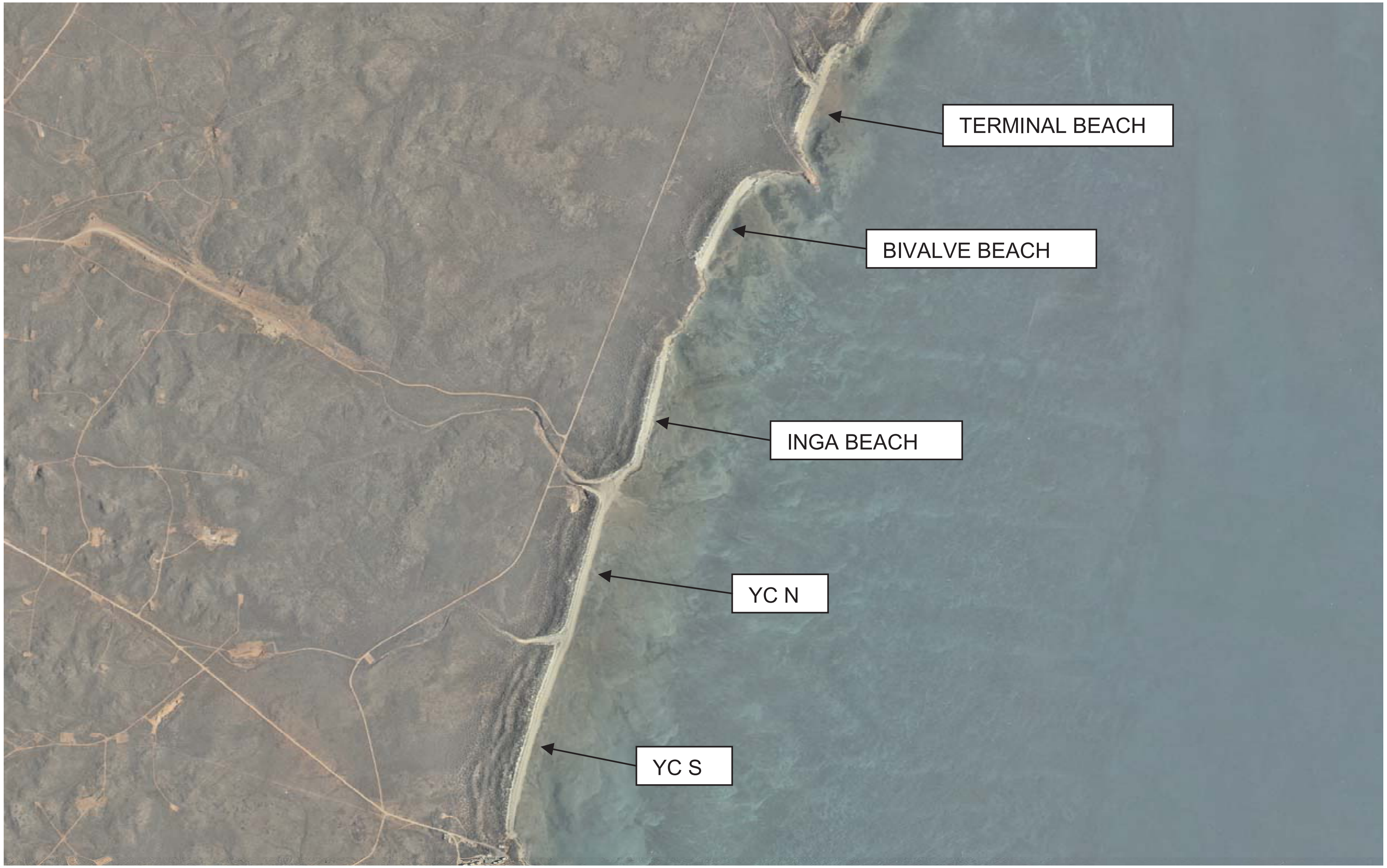

Figure 2: East coast survey beaches – mid east coast; Terminal Beach, Bivalve Beach, YC N, YC S

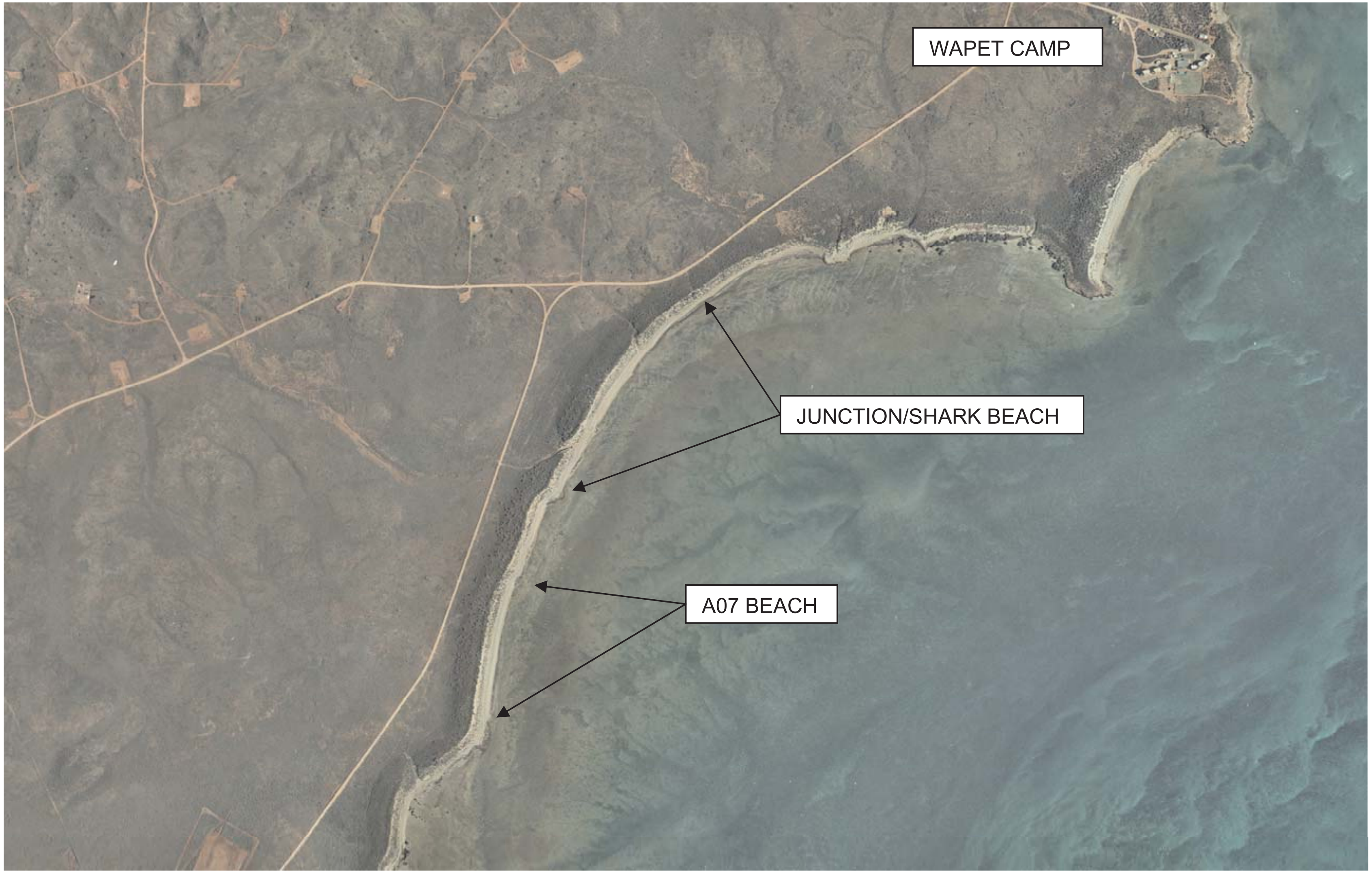

Figure 3: East coast survey beaches – south east coast; Junction/Shark Beach, A07 Beach

WEST COAST CENSUS BEACH LOCATIONS AND SURVEY BOUNDARIES

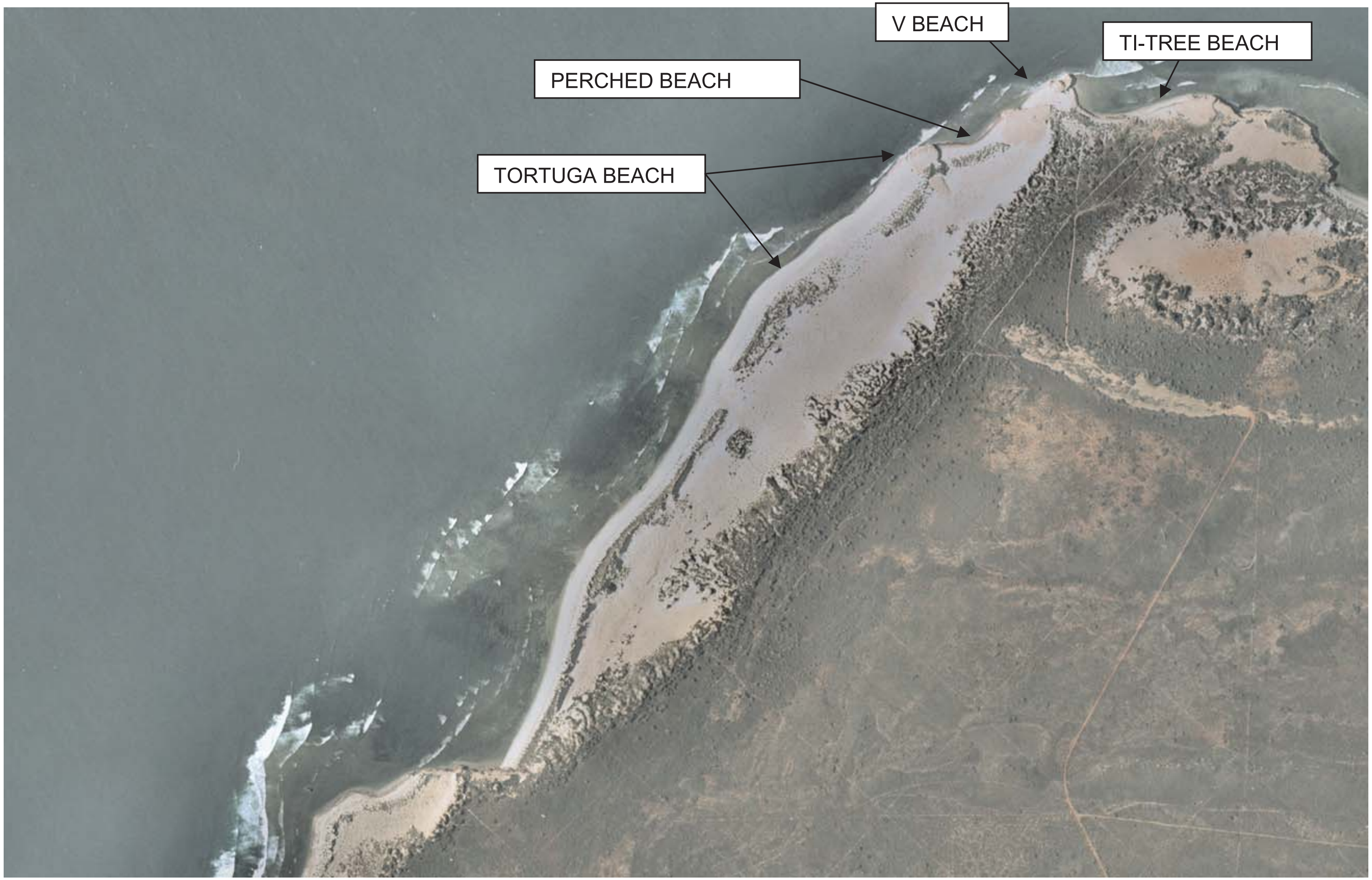

Figure 4: West coast survey beaches – north west; Ti Tree Beach, Perched Beach, Tortuga Beach

Figure 5: West coast survey beaches – west central; Flacourt Beach

Figure 6: West coast survey beaches – North Whites Beach, Whites Beach

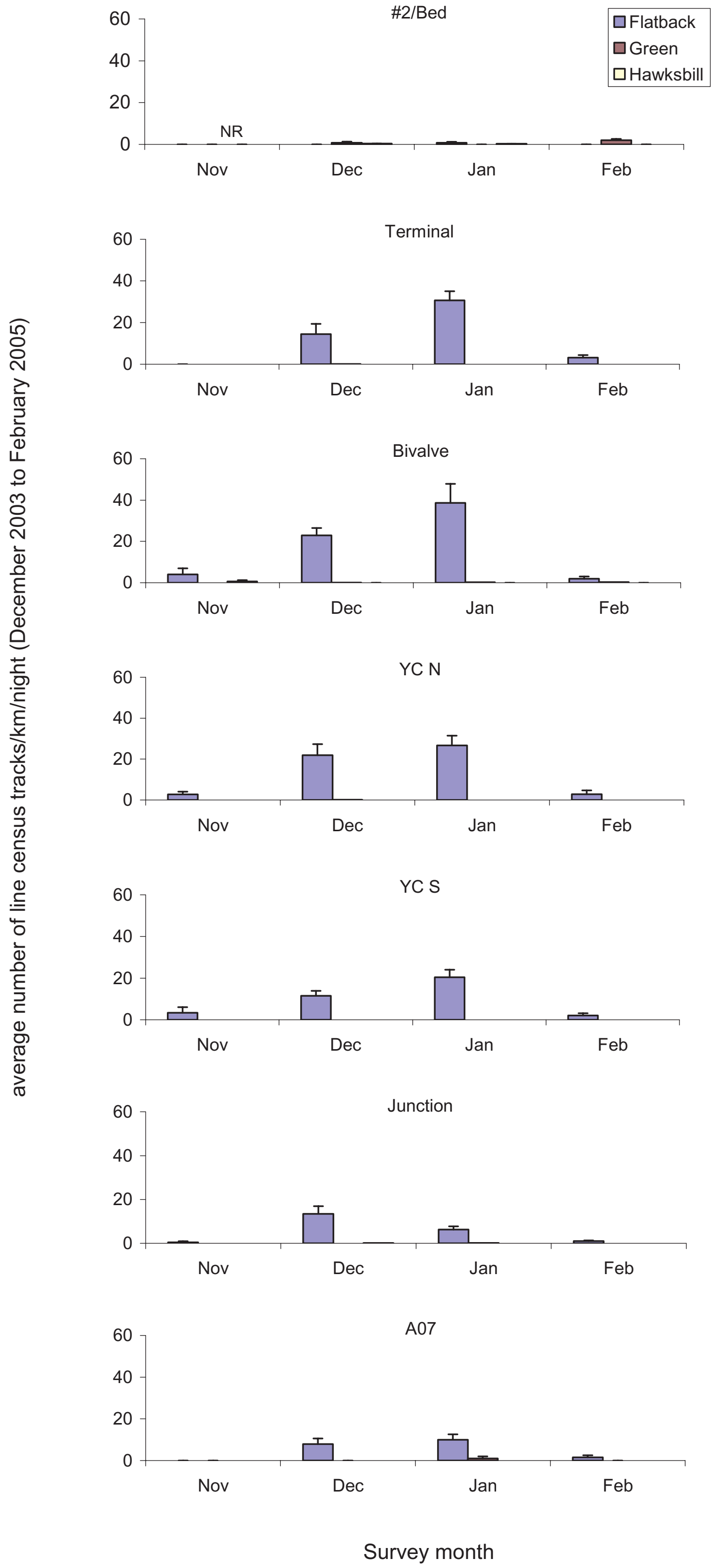

Figure 7: East coast census beaches, flatback, green and hawksbill line census track density. December 2003 to February 2005 data (Standard error bars). NR = Not Recorded

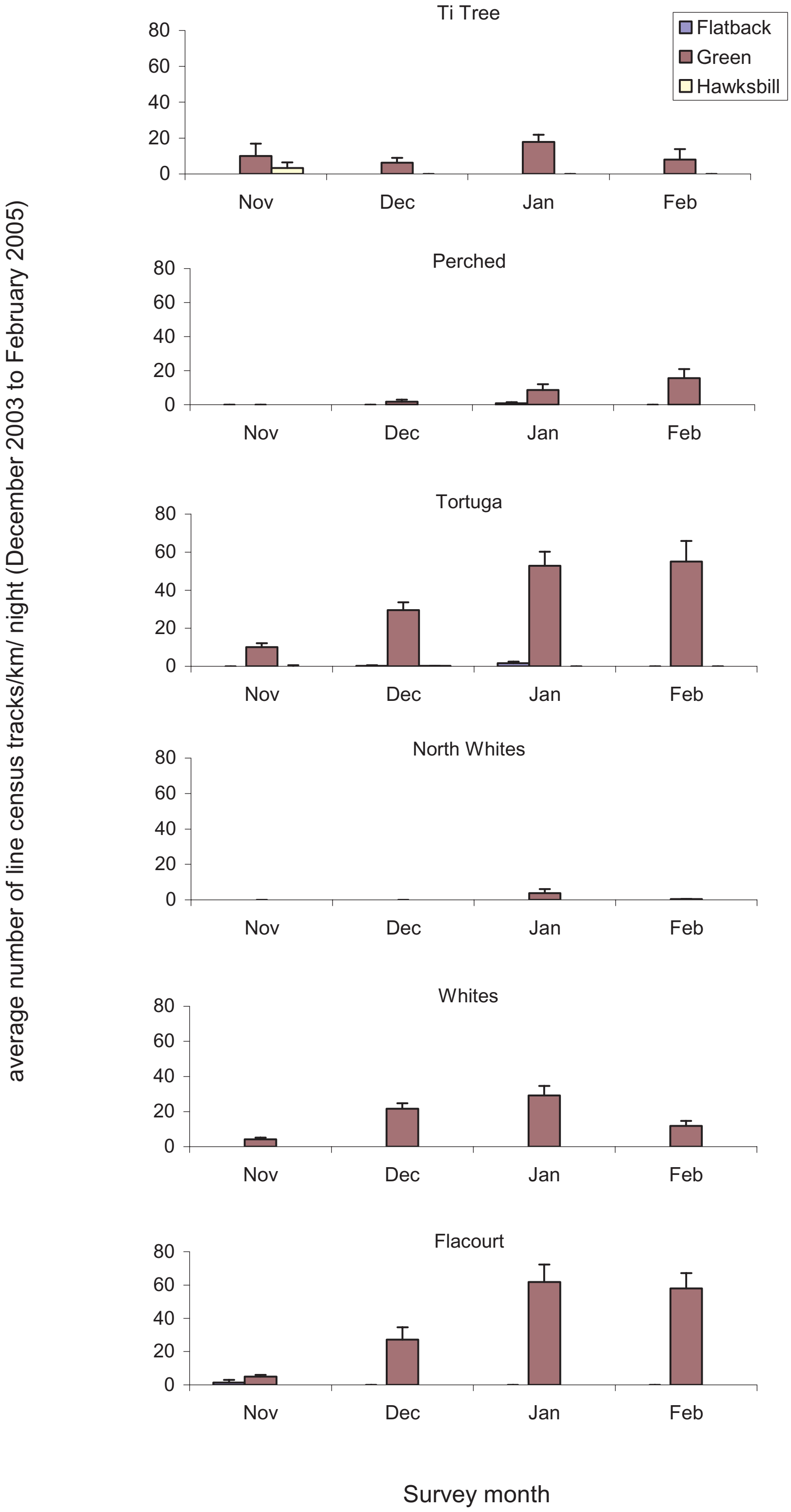

Figure 8: West coast census beaches, flatback, green and hawksbill line census track density. December 2003 to February 2005 data (Standard error bars). NR = Not Recorded

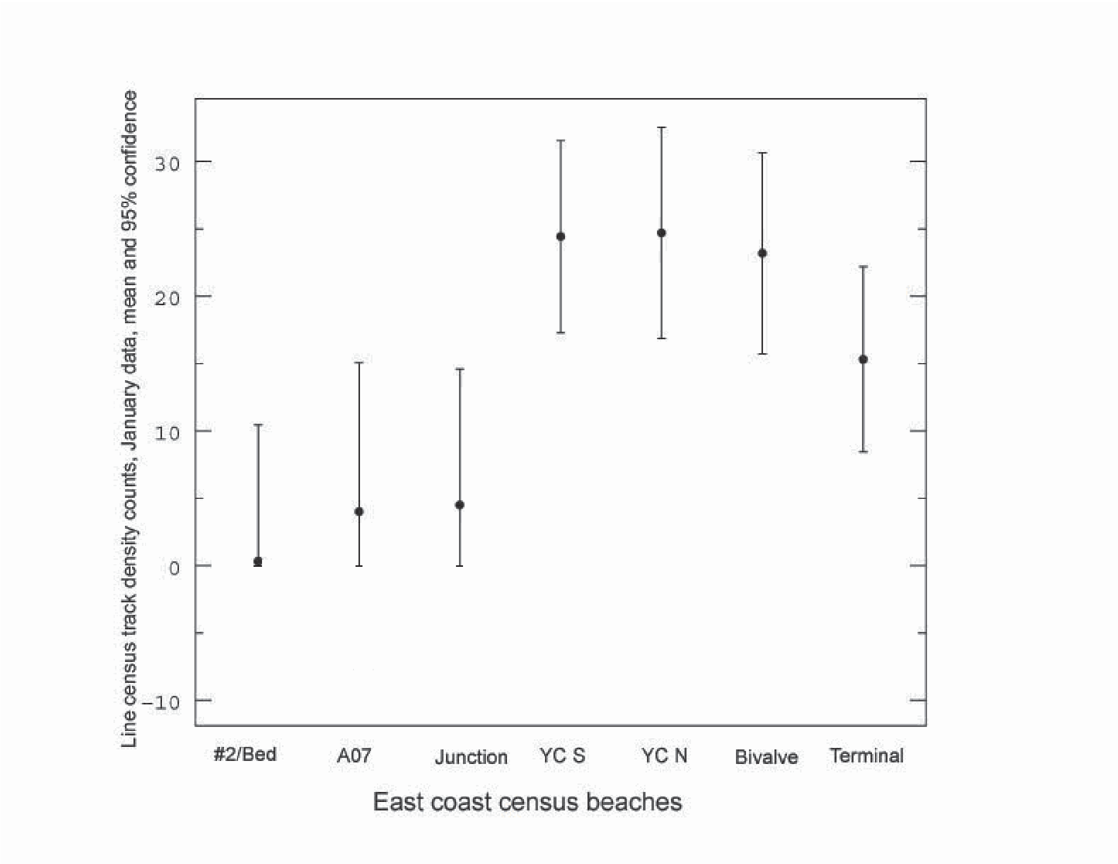

Figure 9: ANOVA plot of east coast survey beaches Flatback line census track counts

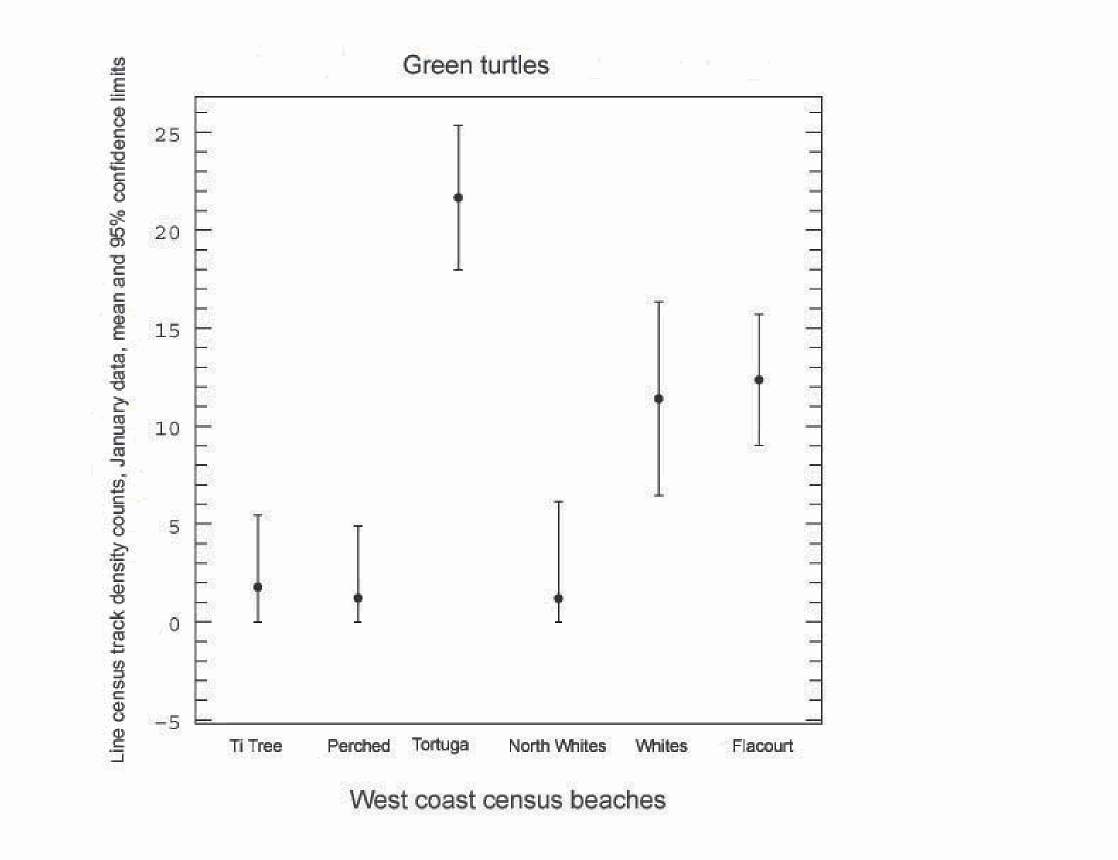

Figure 10: ANOVA plot of west coast survey beaches Green line census track counts

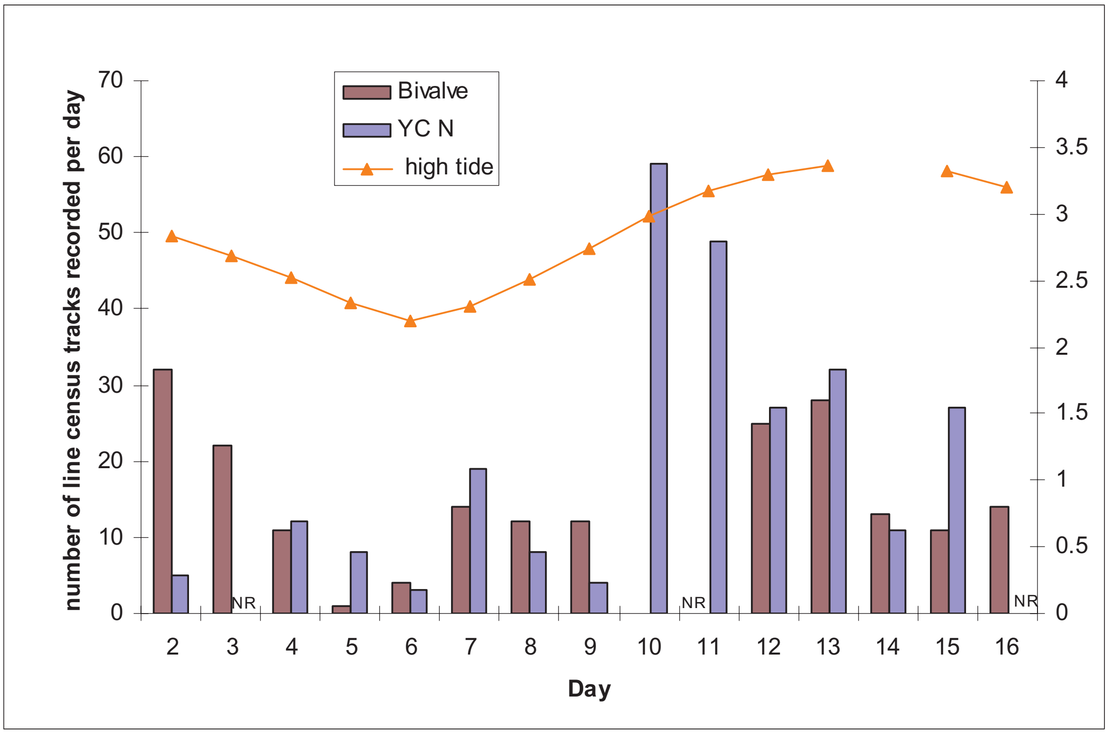

Figure 11: Example of daily fluctuations in track numbers on Bivalve Beach and YC N beaches in December 2004. NR = Count not recorded for that day

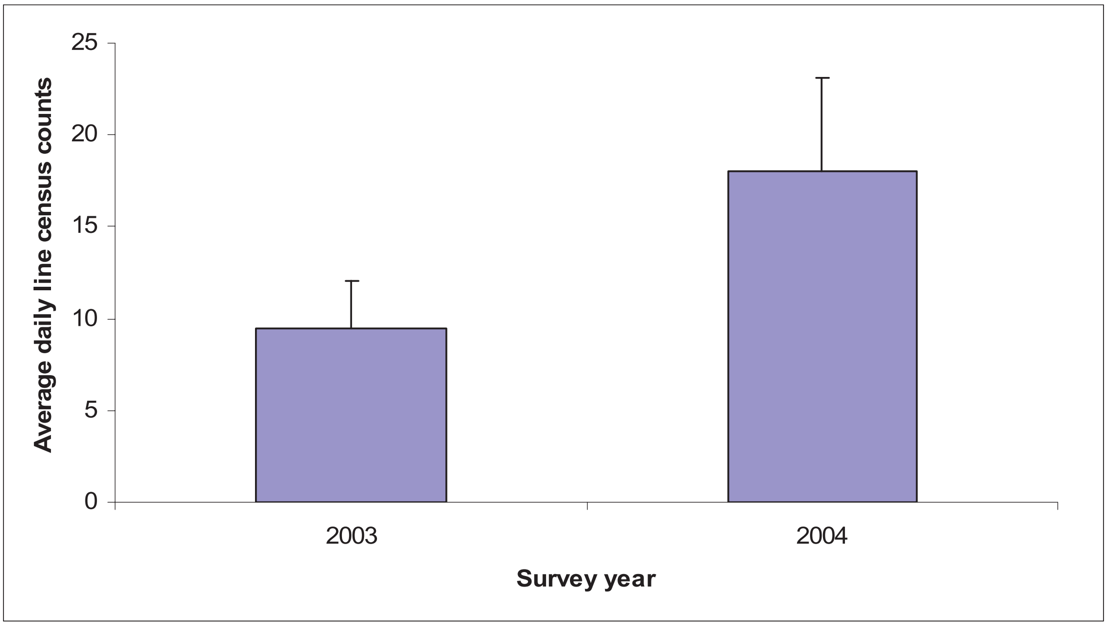

Figure 12: Average line census track counts for flatback turtles at YC S over the same two week period in December 2003 and December 2004. Error bars are standard errors.

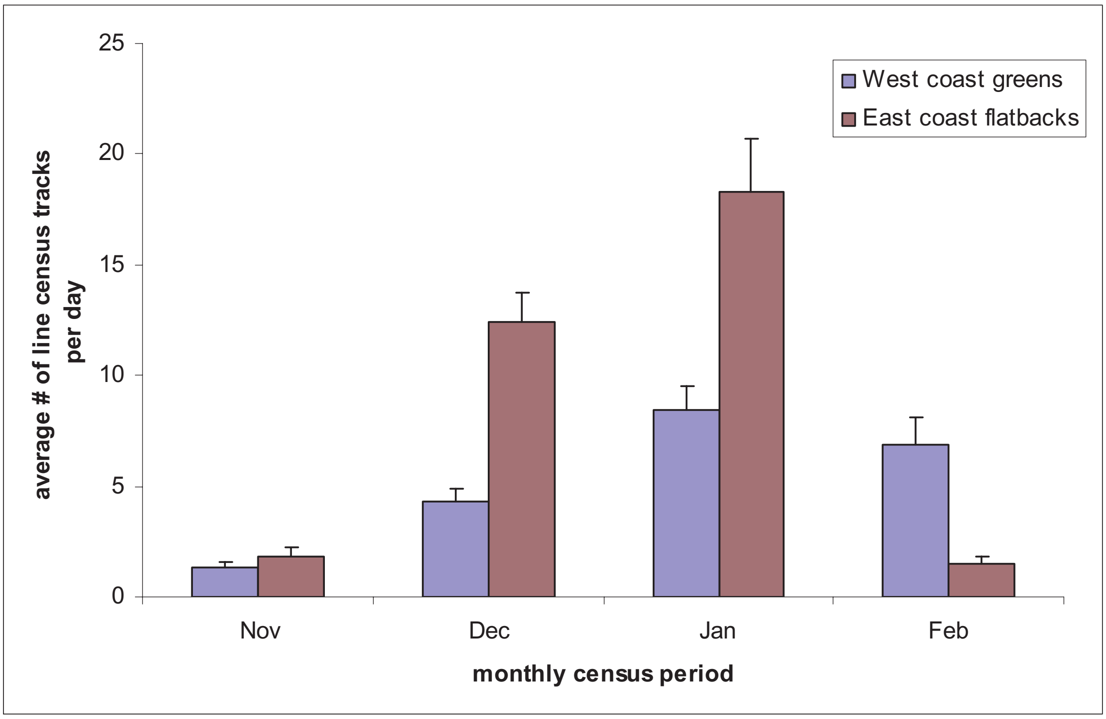

Figure 13: Average number of green and flatback line census tracks recorded on Barrow Island census beaches during each monthly survey period (2003/2004 and 2004/2005 data). Error bars are standard errors.

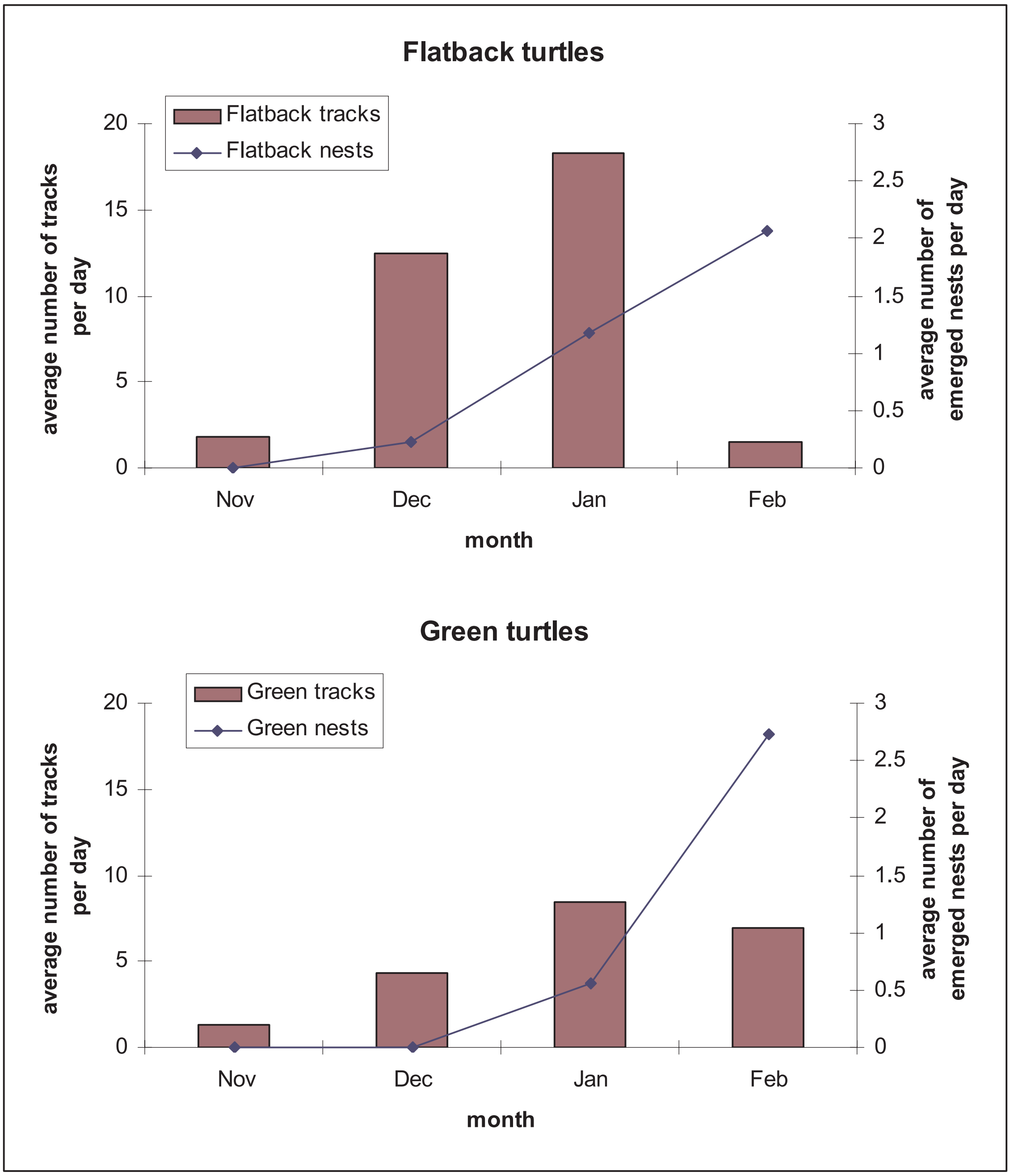

Figure 14: Comparison between the monthly average number of line census tracks vs the average number of emerged nests

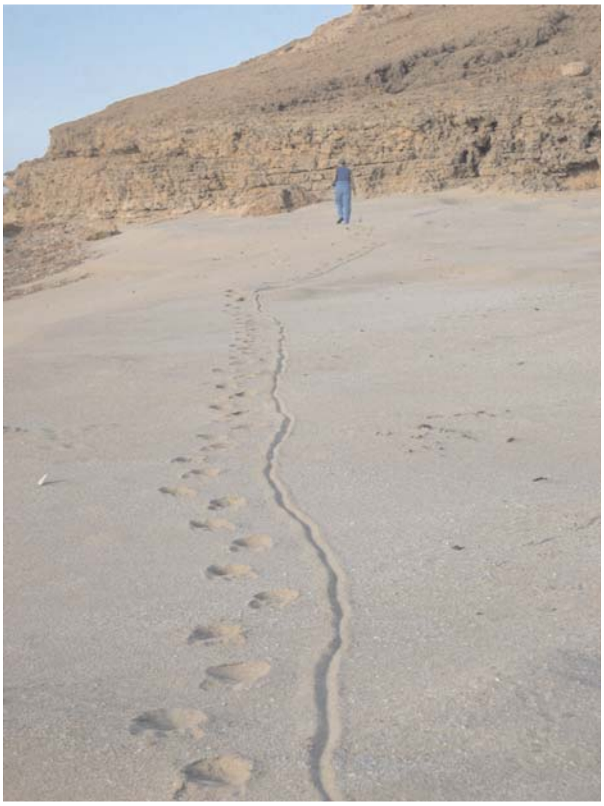

Plate 1: Track census being line installed on a beach. Turtle tracks crossing this line overnight are counted and the line reinstalled for the next nights count

Attachment 2 - Sea Turtle Hatchling Arena Experiments 16-23 April 2004. Report to Sinclair Knight Merz by Pendoley Environmental, May 2004.

GORGON PROPOSED GAS DEVELOPMENT

SEA TURTLE HATCHLING ARENA EXPERIMENTS

16 – 23 APRIL 2004

REPORT TO SINCLAIR KNIGHT MERZ

BY

PENDOLEY ENVIRONMENTAL PTY LTD

12 MAY 2004

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Plate 1: Arena layout, note white segment dividers and central (star picket) release point (photo A Vitenbergs)

Plate 2: Light array and generator on North Yacht Club Beach (Barrow Island)

Appendix 1: Supplemental Barrow Island Light Measurement Data, April 2004 – Baseline Light Field

1 Introduction

The preliminary risk assessment for the Gorgon development identified potential impacts of light on sea turtle hatchlings as an issue requiring further investigation. Little data is available in the literature on the effects of either different light intensities or industrial lighting on sea turtle hatchlings.

Consequently the Gorgon project team commissioned a field study to investigate the effects of three light types typically used in oil field settings on flatback and green turtle hatchlings. This study was designed and implemented by K Pendoley of Pendoley Environmental with the assistance of J Fitzpatrick of Bowman Bishaw Gorham.

The objectives of the study were to;

- investigate the impacts of sodium vapour, fluorescent and metal halide light on sea turtle hatchlings at different light intensities (250W and 500W) and at 90° angle (from vertical),
- investigate the impacts of three light types and two light intensities at four different distances (100m, 200m, 500m and 800m), on green and flatback hatchlings,
- investigate the impacts of sodium vapour and metal halide light impacts at 45° angle (from vertical),
- investigate the impacts on flatback hatchlings as a priority and green hatchlings if flatbacks were unavailable,
- collect qualitative (spectra) and quantitative (Lux and cd/m^2) data from the different light sources at each arena location, and
- collect qualitative and quantitative data from the flares and the most common electric light types currently used on Barrow Island.

2 Methods

The arena experiments were carried out on Barrow Island between 16 and 22 April 2004, over 6 nights of the new moon. The personnel involved in this project are listed by affiliation below.

- Pendoley Environmental Pty Ltd; Kellie Pendoley, Anna Vitenbergs
- Bowman Bishaw Gorham; Jeremy Fitzpatrick, Michelle Rhodes, John Norton, Paul Tod
- SKM; Pamela Mende

The pit fall arena experimental design was broadly similar to that used by Witherington (1992) who tested high pressure sodium, low pressure sodium, yellow incandescent, red incandescent and white incandescent lights against hatchling response (manipulated to emit either 1.9 Lux or 6.2 Lux). This circular pitfall arena design (Plate 1) has been used successfully in the past (Witherington, 1992, Mrosovsky and Carr, 1967, Pendoley, 2000).

An array of lights consisting of 2 x 250W high pressure sodium vapour (sodium), 2 x 250W metal halide (metal), 14 x 36W fluorescent fixtures mounted on a 3m tall stand (Plate 1) were built by the marine and environmental service company, Crackpots. The array was assembled on location and powered by a 5 KVa 'silent' running diesel generator positioned 25m from the light array.

The arenas were installed at 100m, 200m, 500m and 800m from the light array along North Yacht Club Beach (Figure 1). Each arena was 10m in diameter with a 40cm deep trench around the circumference of the circle. The trench was divided into 12 numbered segments of ~30°. The first segment divider was installed at the closest point to the ocean and the rest placed in 30° increments from that location.

The experiments took place towards the end of the sea turtle breeding season and hatchlings were difficult to find. All hatchlings were sourced from Barrow Island with Flatback hatchlings collected from Yacht Club Beach and green hatchlings collected from John Wayne, Olivia and V Beaches on the west coast of Barrow Island. Hatchlings were collected on the day of each trial, either in the afternoon or evening. None of the hatchlings tested were held for more than 6 hours prior to the experiments and none for longer than a total of 9 hours. Since hatchlings were so difficult to find it was necessary to reuse the hatchlings for repeat treatments each night. Each group was held at the same arena for the duration of the trials. Where hatchlings were lost from individual arenas the numbers were made up with animals from the other arenas so that the number in each arena for each trial was approximately even.

The hatchlings were released at the center of each arena using a remote release mechanism and allowed 5 minutes to reach trench at the edge of the arena. Hatchlings were then collected and the number in each segment, as well as those remaining in the center, was scored.

The lack of available hatchlings put significant limits on the experimental conditions. Flatbacks were more difficult to find than greens. Statistical analyses dictate that trials should be run with 30 fresh hatchlings of each species for each light type. The lack of hatchlings meant that a minimum of 15 hatchlings were used for the entire night of each trial and they were reused for each different light source (i.e. each group run a minimum of 4 times in each arena (i.e. for control, sodium, fluorescent and metal light types). A minimum number of animals was therefore tested over the first 5 nights to assess the hatchling response at a minimum number of distances (100m, 200m and 500m arenas) and under two light intensities of 250W and 500W (direct, 90° and angled, 45°). On the last day of the survey 44 green hatchlings were collected and tested at one distance only (200m) to investigate the potential effects of reusing animals. The results are presented in section 3.3.

The five different experimental trials were;

- Flatback hatchlings, 500W lights, 90° light angle, animals reused in all light trials
- Green hatchlings, 500W lights, 90° light angle, animals reused in all light trials
- Green hatchlings, 250W lights, 90° light angle, animals reused in all light trials
- Green hatchlings, 250W lights, 45° light angle, animals reused in all light trials
- Green hatchlings, 250W lights, 45° light angle, 200m arena only, animals used only once per light type trial

Light measurements were made using an OceanOptics spectroradiometer which provides a characteristic spectral chart for each light source and includes the energy emissions in $uW/nm^2/cm$ at each wavelength. The spectroradiometer also provides a photometric measure of emissions in Lux. Light emissions in workplaces are typically reported in Lux and are measured by readily available Lux meters. For this study a Topcon IM-5 Lux meter was used to measure the photometric light emissions while a Topcon BM-9M luminance meter was used to assess the sensitivity of the instrument to light sources over large distances. Both meters were supplied by TechRentals of Welshpool WA.

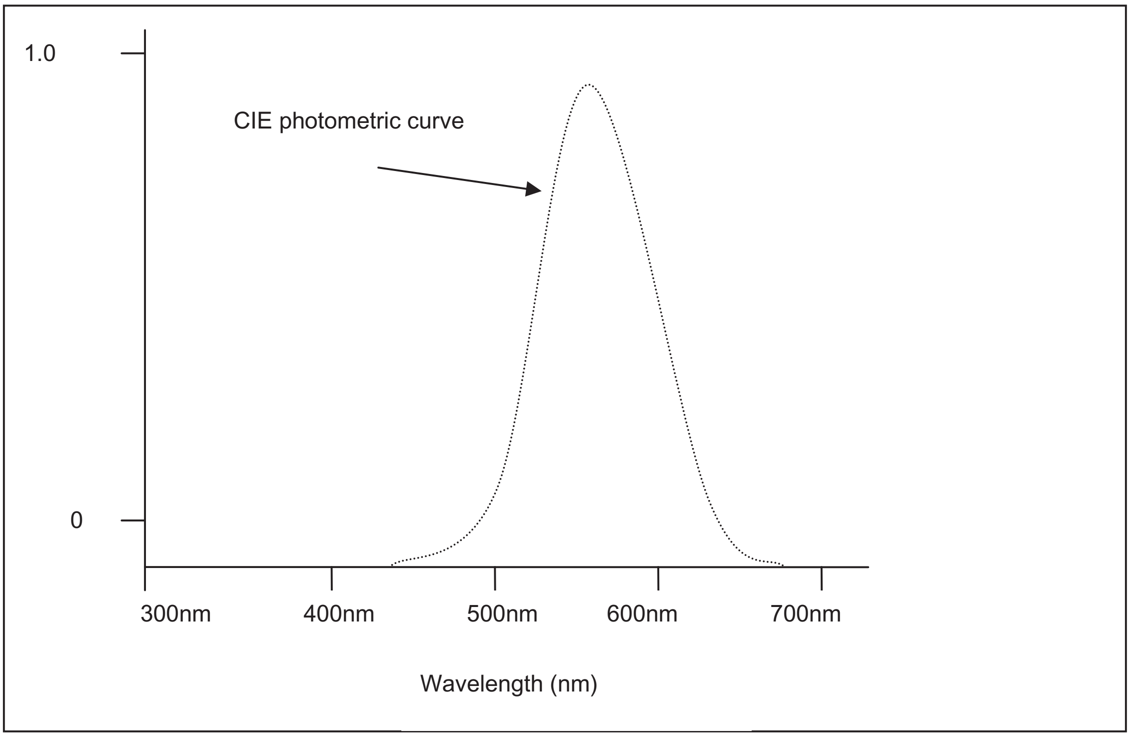
3 Results and Discussion

3.1 Light measurement results

These results are shown in Table 1 and Figures 2 – 5 for the arena locations. Supplemental light measurements from lights at operational areas around Barrow Island (as at April 2004) are given in Appendix 1.

The loss in light intensity over distance for the three light sources tested is similar for the three light type (Figures 2 - 4). Of the three instruments used the OceanOptics Spectrometer (OO Spec) and the TopCon illuminance meter are the most sensitive over long distances. The OO Spec has an advantage over the illuminance meter in that it is capable of characterising the spectral signature of the light, the illuminance meter can only provide a quantification of the light.

The Lux values for the different light types were measured at each of the four arenas (Table 1). Values ranged from .001 – 6.7 lx at 100m, 0 – 1.38 lx at 200m, 0.0105 – 0.016 at 500m and 0 – 0.0661 at 800m. It is important to note that light measurements in lux units represent a measure of the light emissions weighted to the human eye (see CIE diagram on the next page) and includes little of the light emissions between 300 – 500nm and above 650nm in the measurement. Green sea turtles are known to respond to light in the 350 – 450 nm range (Witherington and Bjorndal, 1991).



3.2 Flatback results, 500W, 90° light angle, multiple use hatchlings

The primary objective of this study was to investigate the impacts of different types of lights at two intensities on flatback hatchlings. These trials were run using 500W light at a 90° angle and multiple use of hatchlings. The 100m arena was run on the night of April 17th while the 200m and 500m trials were run the following night. There were insufficient hatchlings to run all trials on the same night.

The basic statistics shown in Table 1 includes the angle of the mean vector (u) for the individual light trials at each arena location. This angle represents the mean direction for the group of hatchlings. The length of the mean vector (r) gives an indication of how directed the group was with r = 0 representing the animals spread evenly around the arena while r =1 indicated the hatchlings were strongly oriented in the same direction. Scattering of hatchlings is frequently seen when the animals are affected by light.

The hatchling orientation and scattering is shown in Figures 7 – 11. An example of the figure layout is shown below. The blue dots represent the segment individual hatchlings fell into under the different light conditions. The arrow is the orientation vector; the direction representing the mean orientation direction taken by the hatchlings and the length a measure of how directed the group was. Starting from due north (0°) the ocean is at ~100°, the light array at ~200° and the dunes at ~280°.

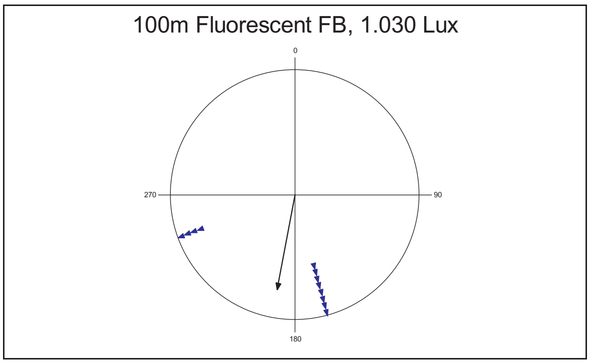


Figure 7 shows the arena distribution plots for the flatback trials at 100m, 200m and 500m. At 100m the control group was oriented in the direction of the ocean (u = 116°) while the trials with sodium, fluorescent and metal lights crawled in the direction of the light source (u = 191° - 197°). The vector length (r) suggests the animals were oriented in a specific direction. A Rayleigh's uniformity test was also run to test the consistency of the direction taken, with p values <0.05 indicating the selection of a preferred direction as opposed to random distribution around the circle. The Rayleigh's test results show that with the exception of sodium vapour there was a preferred direction for all light types and the control. Sodium vapour light was tested twice, once after the control trial when only 2 of the 13 hatchlings in the group responded and a second time following the metal halide and fluorescent trials when all 12 of the remaining hatchlings responded to the sodium vapour light. These results suggest that the sodium vapour light was influencing the hatchlings response. This result requires further detailed investigation.

At 200m the control and sodium light trial showed similar mean vector directions (78° and 70°) while the fluorescent and metal trial were oriented more closely to the light direction (metal > fluorescent 178° and 156°). The r values indicate greatest scattering in the sodium trial (0.571) than in the fluorescent and metal trial (r = 0.954 – 0.978) and may indicate a very low level response to the sodium vapour light. The Rayleigh's test results were all <0.05 indicating the hatchlings all showed a preferred direction.

At 500m the mean vector for all light types was oriented strongly towards the ocean (u = 75° - 88° and r = 0.9 – 0.993) suggesting the light has little or no impact on the hatchlings over this distance. The Rayleigh's test result showed the hatchlings were selecting a direction and were not responding randomly.

3.3 Green results

3.3.1 Green hatchlings 500W, 90° light angle, reuse hatchlings

The first set of green hatchling trials to be run were against 500W of light angled at 90° from vertical. The full strength lights were used to assess the range of hatchling response to the different light sources. All four arenas were used (100m, 200m, 500 and 800m). The generator was operating during the control run for this trial since the potential effect of generator vibrations was not immediately recognised.

This data is shown in Table 3 and Figure 8. The 100m control results show the hatchlings were widely scattered and directed towards the light array and generator location (u = 173° and r = 0.620). In the absence of outside influences they were expected to be highly oriented towards the ocean The effects of the sodium, fluorescent and the metal lights are reflected in higher mean vector length values (r = 0.854 – 0.957) oriented towards the light sources (u = 183° – 203°) indicating the effects of the all three light types at 500W is strong at 100m.

At 200m, the hatchlings response to no light (control) were more directed towards the ocean (u = 121° and r = 0.822) than at 100m. The effects of the three light types on hatchling orientation (towards the lights) are clear at this distance with r values of 0.964 – 0.968 and mean vectors angles of 172° – 181°.

The control trials for the 500m and 800m arenas are oriented most strongly towards the ocean (note, the statistics for the control at the 500m arena were affected by the escape of two thirds of the hatchlings during the control trial). The mean vector angle for all light trials at 500m and 800m were similar (u = 77° - 123°) and the vector length showed greater scattering (r = 0.679 – 0.883) than the sites closer to the light sources. A preliminary assessment of these results in the field indicated there was little difference between the 500m and 800m; hence the 800m arena was dropped in favour of maintaining a minimum of 15 animals per trial in the 100m, 200m and 500m arenas during subsequent trials.

3.3.2 Green hatchlings, 250W, 90° light angle, reuse hatchlings

This trial was run to assess the effects of reducing the light from 500W to 250W. The potential influence of the generator was also recognised and tested during these trials.

At 100m the control (generator on) group showed broad scattering around the arena (r = 0.379) and a mean vector angle of 160° in the direction of the light source. The effects of the 250W sodium, fluorescent and metal lights are clear at this distance (100m) with mean vector angles ranging from 177° - 186° towards the light source and strong clustering around this vector (r = 0.807 – 0.964). The control (generator on) run at the end of the light trials showed less scattering (r = 0.636) and a mean vector angle of 122°. The final control (generator off) trial also showed scattering (r = 0.699) however the mean angle of the hatchling orientation was more strongly directed towards the ocean (u = 87°) suggesting that the generator vibrations may have been influencing the hatchlings at the 100m arena.

At 200m the controls run before and after the light trials showed similar scattering as they oriented towards the ocean (generator on). The influence of the sodium vapour, fluorescent and metal halide lights is still present with the mean vector angles ranging from 154° - 172°. The scattering affect from the sodium vapour light is greater (r= 0.513) than from the fluorescent and metal halide lights which sowed strong directivity towards these light sources (r = 0.864 – 0.853). The control trial with the generator off was oriented towards the ocean (as was the generator on trial) however the orientation vector showed less scattering than the trial with the generator on.

At 500m several of the hatchlings in the initial control trial scattered widely (r=0.665) however the bulk of the hatchlings oriented in the same ocean direction (u=114°). The sodium vapour trial also showed broad scattering (r=0.529) and a mean vector angle in an ocean direction (89°). The fluorescent and metal trials were also oriented towards the ocean (u=92° and 121°, r=0.847 and 0.895). The final control trials, with and without the generator operating, had very similar mean vector angles (60° and 58°) however the trial with no generator was more directed than the trial with the generator (r =0.857 vs. 0.582). The generator was not thought to be affecting the hatchlings at this distance (525m) since the sound/vibration of the generator could not be detected by the human ear beyond 325m. It is not clear what may have been causing the scattering in the hatchlings at this distance.

3.3.3 Green hatchlings 250W, 45° angle light, reuse animals

This trial investigated the effect of altering the angle of the light sources. The two light sources that could be physically manipulated (sodium and metal light sources) were turned downwards to an angle of 45° from vertical. These trials were run the same night as the 250W, 90° angle trials. The same animals were used for both the 45° and 90° trials. The results for these trials are shown in Table 5 and Figure 10.

The control runs at 100m with the generator on and off show similar scattering and varied mean vector results as the 90° trials, ie oriented in the direction of the light array/generator location. With the generator operating the hatchlings had mean vectors between 149° – 203°. However the orientation and scattering of the animals seen in the two controls run with and without the generator was similar in this animal group (149° and 140°, 0.539 and 0.638).

At 100m the response to the sodium and metal lights was very similar for the two different lights angles. The difference in light angles at this distance did not appear to make a difference to hatchling orientation.

At 200m the control runs for both light angle trials (both with and without the generator) were almost identical with all hatchlings orienting towards the ocean. The response of hatchlings to the two light angles for the sodium and metal trials were also similar with both orienting in the direction of the light source.

At 500m the control, sodium and metal halide mean vectors were all showed a greater orientation towards the ocean (r = 65° - 75°) than the 90° trials (58° -121°). This result suggests the change in light angle was effective at 500m but not at 200m.

3.3.4 Green hatchlings, 250W, 90° light angle, single use animals

This trial was run on the final night of the field trip and was done to test the effects of reusing animals on hatchling response. The effects of the generator was also investigated further using a larger (statistically valid) sample size.

Generator affects

The 44 green hatchlings that were available were initially divided into three groups (group 1, group 2 and group 3) for the single use (per light source) trials. They were all tested at the 200 m arena since a preliminary review of the previous results at this arenas indicated they were responding to the light at this distance. Furthermore a crude method for determining the extent of the generator sound/vibration along the beach (human ear pressed to a wooden shovel handle) suggested the sound/vibrations could be detected at the 200m arena (up to a maximum of 375m).

The results are shown in Table 6 and Figure 11. Group 1 was tested with the lights off but the generator running and then tested against the sodium light. Group 2 was tested against the fluorescent light only and group 3 against the metal halide and then a second control (generator on) and a final control (generator off). Finally all 44 animals were run with no light and the generator on and no light with the generator off.

These results show that the two controls using different groups of animals run at the start and then again at the end of the trials (generator on) were both oriented towards the ocean (u = 82° and 86°), however the second control at the end of the light trials showed a greater degree of scattering than the initial trial (r = 0.908 vs. 0.769). The final group 3 control was done with the generator turned off (no ground vibrations) and the resulting orientation vector was skewed away from the generator location (67°) and was strongly directed (r = 0.884).

The final two control trials (no lights, generator on and off) were done using all 44 animals. Without the generator operating the hatchlings oriented strongly on a mean bearing of 49° (r = 0.947) while with the generator operating this mean vector swung slightly towards the vibration source (u = 81°) and the hatchlings scatter across a greater area (r = 0.835). The sample size for these final two trials (44 animals) was big enough to meet the criteria for the Chi-squared test which showed a significant difference between the two groups ($p<0.05$). These results suggest the generator may have had a detectable effect on hatchling orientation.

Reuse of hatchlings effects

To determine if the reuse of hatchlings affected the subsequent choices of the animals the results of the single use trials were compared with the results from reused animals at the 200m arena.

The mean vector angle and length for green hatchlings tested under the same photic conditions (250W light,) are listed below.

Hatchling response to 90° angle 250W light, 200m arena, single use vs reuse.

	Mean vector angle (u)		Mean vector length (r)	
	Single use	Multiple use	Single use	Multiple use
Control generator on	82	99	0.908	0.855
Sodium	120	154	0.697	0.513
Fluorescent	134	193	0.808	0.864
Metal	160	172	0.993	0.853
Control generator on	86	68	0.769	0.814
Control generator off	67	75	0.884	0.863

The trends in the data suggest that, with the exception of the fluorescent trial, the hatchling response is similar for single use and multiple use animal trials. This provides some confidence that the animals were not repeating learned behaviours when tested with different light conditions. The lack of consistency in behaviour under the influence of sodium vapour light was common throughout the experimental program.

The experimental conditions did not permit the isolation of the generator as a test variable. Conclusions that can be drawn from these results are there for limited by the potential impacts of the generator on animal behaviour at the 100m and 200m arenas.

3.4 *Synthesis of results*

The results of the study findings have been summarised in Tables 7 and 8. A subjective assessment of the orientation vector is listed as either towards the ocean (O) or towards the light (L). For trials where the vector is not clearly directed towards either of the locations the results are assigned an L/O or a O/L depending on the which direction they appear to be favouring. The values for the directivity (or scattering) of the orientation vector (r) is also listed for each test condition. In the absence of statistically rigorous sample sizes these data can be used as an indicator of hatchling response to the test light conditions.

All controls for green hatchlings tested at the 100m arena oriented in the direction of the generator. A glow from inland facilities was also visible at this location and may have contributed to the orientation of the hatchlings. The number of trials run for flatbacks was very limited however the results for trials run at the same location suggest they were not influenced by the generator or the inland glow.

Trials using the three different light types suggest flatbacks are sensitive to 500W (90°) light from sodium vapour, metal halide and fluorescent sources at 100m and to metal halide and fluorescent sources at 200m. No impacts were detected at 500m. The quantitative values for the three light types at this location were 6.71 lux (sodium vapour), 4.52 lux (fluorescent) and 3.38 lux (metal halide). At 200m the quantitative values fell to 1.38 lux (sodium vapour), 0.83 lux (fluorescent) and 0.554 lux (metal halide). The scattering data for flatbacks support these results with generally less scattering seen at 500m (r values > 0.9) and than at the 100m and 200m arenas (r values <0.9)

Green hatchlings appeared to respond to 500W (90°) sodium vapour, fluorescent and metal halide light at 100m and 200m. At 500m the hatchlings generally oriented in the direction of the ocean and scattered more widely than at the 100m and 200m locations where the influence of light was the greatest. Lux values at 500m were 0.161 (sodium vapour), 0.104 (fluorescent) and 0.1 (metal halide). Scattering was also seen at the 800m arena, most notably under fluorescent and metal halide light, suggesting possible low level influences from these lights (0.0476 lux fluorescent and 0.0481 lux metal halide).

Reducing the light intensity to 250W (@ 90°) did not reduce the impacts on the green hatchlings at 100m and 200m which continued to orient strongly towards the lights. However the degree of scattering increased under the 250W lights. The orientation at 500m remained relatively unchanged as did the scattering behaviour,

Reducing the angle of the sodium vapour and metal halide lights (only two that could be physically adjusted) to 45° (@ 250W) also did not affect the response of hatchlings. They continued to orient towards the light sources at 100m and 200m and appeared unaffected by the light at 500.

4 Conclusions

The three different light measuring instruments showed a systematic decrease in light intensity with distance. The OceanOptics Spectrometer was more sensitive to light signals over a greater distance than the Lux meter. The illuminance meter was also able to target light sources over a greater distance than the Lux meter.

The vibrations from the generator appeared to have a detectable effect on hatchling orientation, however this requires further testing using larger animal groups and over different distances.

Flatback hatchlings, with all three lights at 500W, appeared to be influenced by the light at 100m. Fluorescent and metal halide lights attracted flatback hatchlings at 200m, while sodium vapour may have influenced the hatchlings as they crawled towards the ocean at 200m (as indicated by increased scattering) Flatback hatchlings appeared unaffected by the light sources at 500m.

Green hatchlings were attracted to the three light types (500W) at 100m and 200m. The intensity of the three lights at this distance was ≥ 3 lux. The light may also have influenced their seaward orientation at 500m (measured intensity 0.1 lux for all three lights) and possibly 800m (0.04 – 0.06 lux) as represented by an increase in scattering at these distances. Reducing the intensity of light from 500W to 250W did not stop the hatchlings crawling towards the lights at 100m and 200m distance, and the response at 500m was similar to the 500W trials. Similarly angling the 250W lights did not appear to reduce the impact of the light at 100m and 200m however it did to reduce the impact on the hatchlings at 500m

While the test groups were to small to statistically test the significance of hatchling orientation in single and multiple animals use groups, a comparison of the two trials (single use and multiple use groups) at the 200m arena suggest the mean vector angle and length results were similar and therefore the reuse of animals may not have adversely affected the behaviour of the hatchlings in repeated trials.

5 References

Mrosovsky, N. and Carr, A. (1967) Preference for light of short wavelengths in hatchling green sea turtle *Chelonia mydas* tested in their natural nesting beaches. *Behaviour,* **28,** 217-231.

Pendoley, K. (2000) In *Second ASEAN Symposium and Workshop on Sea Turtle biology and Conservation* (Eds, Pilcher, N. and Ismail, G.) ASEAN Academic Press, Kota Kinabalu, Borneo, pp. 130-142.

Witherington, B. E. (1992) Sea finding behaviour and the use of photic cues by hatchling sea turtles. PhD thesis. University of Florida, Gainesville.

Witherington, B. E. and Bjorndal, K. A. (1991) Influence intensity and wavelength on hatchling sea turtle photaxis; implications for sea finding behaviour. *Copeia,* **4,** 1060-1090.

Table 1: Illuminance and irradiance - light measurement results (all lights 90° angle)

Light source being measured	Spec File name	spectrometer (Lux)	Meter (Lux)	Illuminance cd/m2	arena site lights being measured from
Whole light array, sodium, metal, fluorescent	bwi 17	0.0100	0.02		800m
Sodium 500W	bwi 18	0.0661			800m
Metal 500W	bwi 20	0.0481		19	800m
dark sky over ocean	bwi 19	0.0000		1	800m
Fluorescent 500W	bwi 21	0.0476			800m
Fluorescent 500W dup	bwi 22	0.0475		12	800m
Whole light array, sodium, metal, fluorescent	bwi 23	0.3210	0.1	95	500m
Sodium 500W	bwi 24	0.1610	0.06	47	500m
metal 500W	bwi 25	0.1000	0.08	30	500m
Fluorescent 500W	bwi 26	0.1040	0.09	33	500m
dark sky over ocean	bwi 27	0.0111	0	1	500m
south along beach	bwi 28	0.0149	0	1	500m
west over dunes	bwi 29	1.047-2	0	1	500m
north along beach	bwi 30	0.0118	0	1	500m
Whole light array, sodium, metal, fluorescent		not recorded			200m
Sodium 500W	bwi 33	1.380	0.25	369	200m
Sodium 500W	bwi 36	1.240	0.23	374	200m
metal 500W	bwi 34	0.554	0.13	232	200m
Fluorescent 500W	bwi 31	0.820	0.13	254	200m
Fluorescent 500W	bwi 35	0.833	0.18	249	200m
dark sky over ocean	bwi 32	-0.010	0	0	200m
dark sky over ocean	bwi 37	0.239	0	0	200m
Sodium 500W	bwi 38	6.710	1.33	1656	100m
dark sky over ocean	bwi 39	0.001	0	0	100m
metal 500W	bwi 40	3.380	0.79	988	100m
Fluorescent 500W	bwi 41	4.520	1.03	1097	100m

Table 2: Flatback basic statistics results

	100m arena				200m arena				500m arena			
data set code	1	2	3	4	42	44	46	48	43	45	47	49
test light type	Control gen on	Metal	Sodium	Fluoro	Control gen on	Sodium	Fluoro	Metal	Control gen on	Sodium	Fluoro	Metal
Number of Observations	13	13	2	12	17	15	13	5	18	15	13	11
Mean Vector (μ)	116°	197°	195°	191°	78°	70°	156°	178°	88°	75°	84°	81.°
Length of Mean Vector (r)	0.728	0.734	0.876	0.754	0.875	0.571	0.954	0.978	0.977	0.993	0.902	0.9
Rayleigh Test (p)	0.0004	0.0003	0.244	0.0004	5.46E-07	0.006	1.27E-06	0.002	7.06E-08	4.27E-07	5.16E-07	0

Data file - C:\Program Files\Oriana2\BWI FBs.ori

Table 3: Green hatchlings 500W 90° angle

data code	6	10	14	18	22	7	11	15	19	23	8	12
Variable	Control gen on	Sodium	Fluoro	Metal	Control gen on	Control gen on	Sodium	Fluoro	Metal	Control gen on	Control gen on	Sodium
arena location (meters)	100	100	100	100	100	200	200	200	200	200	500	500
light wattage (W)	500	500	500	500	500	500	500	500	500	500	500	500
light angle (degrees)	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°
Number of Observations	22	19	20	20	19	22	19	20	20	20	8	20
Mean Vector (μ)	173°	203°	193°	183°	187°	121°	181°	172°	174°	83°	83°	123°
Length of Mean Vector (r)	0.620	0.957	0.939	0.854	0.542	0.822	0.982	0.978	0.964	0.672	0.714	0.661
Rayleigh Test (Z)	8.443	17.388	17.647	14.599	5.592	14.852	18.315	19.147	18.595	9.018	4.083	8.746
Rayleigh Test (p)	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.012	0.000

Data file - C:\Program Files\Oriana2\oriana output files\Gs all labels grpd.ori

Table 3: Green hatchlings 500W 90° angle contd.

data code	16	20	24	9	13	17	21	25
Variable	Fluoro	Metal	Control	Control gen on	Sodium	Fluoro	Metal	Control gen on
arean location (meters)	500	500	500	500	500	800	800	800
light wattage (W)	500	500	500	500	500	500	500	500
light angle (degrees)	90°	90°	90°	90°	90°	90°	90°	90°
Number of Observations	19	19	19	22	19	15	21	20
Mean Vector (μ)	90.423°	106.495°	109.709°	77.514°	80.765°	100°	92.196°	71.592°
Length of Mean Vector (r)	0.857	0.747	0.822	0.913	0.883	0.841	0.697	0.910
Rayleigh Test (Z)	14.277	10.602	12.845	18.356	14.814	10.597	10.193	16.570
Rayleigh Test (p)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4: Green hatchlings 250W 90° angle

data code	50	53	56	59	62	65	51	54	57	60	63	66	52	55	58	61	64	67
Variable	Control gen on	Sodium	Fluoro	Metal	Control gen on	Control gen off	Control gen on	Sodium	Fluoro	Metal	Control gen on	Control gen off	Control gen on	Sodium	Fluoro	Metal	Control gen on	Control gen off
arena location (meters)	100	100	100	100	100	100	200	200	200	200	200	200	500	500	500	500	500	500
light wattage (W)	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
light angle (degrees)	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°
Number of Observations	15	14	13	14	13	14	16	14	15	14	15	14	14	16	15	15	15	14
Mean Vector (μ)	160°	186°	181°	177°	122°	87°	99°	154°	193°	172°	68°	75°	114°	89°	121°	92°	60°	58°
Length of Mean Vector (r)	0.379	0.964	0.807	0.838	0.636	0.699	0.855	0.513	0.864	0.853	0.814	0.863	0.665	0.529	0.847	0.895	0.582	0.857
Rayleigh Test (Z)	2.155	13.019	8.461	9.839	5.266	6.838	11.703	3.688	11.206	10.179	9.941	10.430	6.186	4.475	10.760	12.024	5.073	10.277
Rayleigh Test (p)	0.115	0.000	0.000	0.000	0.003	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.001	0.009	0.000	0.000	0.005	0.000

Data file – C:\Program Files\Oriana2\oriana output files\Gs all labels grpd.ori

Table 5: Green hatchlings 250W 45° angle

data code	68	71	74	77	80	69	72	75	78	81	70	73	76	79	82
Variable	Control gen on	Sodium	Metal	Control gen on	Control gen off	Control gen on	Sodium	Metal	Control gen on	Control gen off	Control gen on	Sodium	Metal	Control gen on	Control gen off
arena location (meters)	100	100	100	100	100	200	200	200	200	200	500	500	500	500	500
light wattage (W)	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
light angle (degrees)	90°	45°	45°	45°	45°	45°	45°	45°	45°	45°	45°	45°	45°	45°	45°
Number of Observations	13	12	15	15	15	14	14	14	14	14	15	15	14	14	14
Mean Vector (μ)	203°	172°	189°	149°	140°	105°	160°	163°	93°	84°	65°	71°	75°	75°	74°
Length of Mean Vector (r)	0.772	0.986	0.972	0.539	0.638	0.846	0.881	0.909	0.752	0.758	0.945	0.892	0.915	0.934	0.917
Rayleigh Test (Z)	7.752	11.661	14.161	4.351	6.114	10.010	10.871	11.562	7.910	8.042	13.406	11.946	11.714	12.215	11.782
Rayleigh Test (p)	0.000	0.000	0.000	0.011	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Data file - C:\Program Files\Oriana2\oriana output files\Gs all labels grpd.ori

Table 6: Green hatchlings 250W 45° and 90° angle, animals used once per light source

data code	83	84	85	86	87	88	89	90
Variable	Control Generator on	Sodium	Fluoro	Metal	Control generator on	Control Generator off	Control generator off	Control generator on
arena location (meters)	200	200	200	200	200	200	200	200
light wattage (W)	250	250	250	250	250	250	250	250
light angle (degrees)	90°	45°	90°	45°	90°	90°	90°	90°
single use trials group #	1	1	2	3	3	3	all	all
Number of Observations	15	15	12	15	15	15	44	44
Mean Vector (µ)	82°	120°	134°	160°	86°	67°	49°	81°
Length of Mean Vector (r)	0.908	0.697	0.808	0.993	0.769	0.884	0.947	0.835
Rayleigh Test (Z)	12.374	7.296	7.830	14.804	8.870	11.730	39.465	30.699
Rayleigh Test (p)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Data file - C:\Program Files\Oriana2\oriana output files\Gs all labels grpd.ori

Table 7: Summary of arena orientation results, multiple use data.

Orientation vector u directed to Ocean (O) or Light (L). Vector length, r value, given in brackets

	Flatbacks 500W 90°			Greens 500W 90°				Greens 250W 90°			Greens 250W 45°		
	100m	200m	500m	100m	200m	500m	800m	100m	200m	500m	100m	200m	500m
Control	O (0.728)	O (0.875)	O (0.977)	L (0.620)	O/L (0.822)	O (0.714)	O (0.913)	L/O (0.379)	O (0.855)	O (0.665)	L (0.772)	O (0.846)	O (0.945)
Sodium vapour	L (0.876)	O (0.571)	O (0.993)	L (0.957)	L (0.982)	O/L (0.661)	O (0.883)	L (0.964)	L/O (0.513)	O (0.529)	L (0.986)	L (0.881)	O (0.892)
Fluorescent	L (0.754)	L (0.954)	O (0.902)	L (0.939)	L (0.978)	O (0.857)	O (0.843)	L (0.807)	L (0.864)	O (0.847)	-	-	-
Metal halide	L (0.734)	L (0.978)	O (0.900)	L (0.854)	L (0.964)	O (0.747)	O (0.691)	L (0.838)	L (0.853)	O (0.895)	L (0.972)	L (0.909)	O (0.915)
Control generator	O	O		-	-	-	-	O (0.636)	O (0.814)	O (0.582)	L/O (0.539)	O (0.752)	O (0.934)
Control no generator	-	-	-	-	-	-	-	O (0.699)	O (0.863)	O (0.857)	L/O (0.638)	O (0.758)	O (0.917)

Table 8: Summary of Greens arena orientation results, single use,

Lights are 250W, 45° and 90° angle, Ocean (O) vs Light (L) choices

	200m
Control generator	O (0.908)
Sodium vapour (45°)	O/L (0.697)
Fluorescent (90°)	O/L (0.808)
Metal halide (45°)	L (0.993)
Control generator	O (0.769)
Control no generator	O (0.884)
Control generator (n=44)	O (0.947)
Control no generator (n=44)	O (0.835)

Figure 1: Arena locations on North Yacht Club Beach, Barrow Island

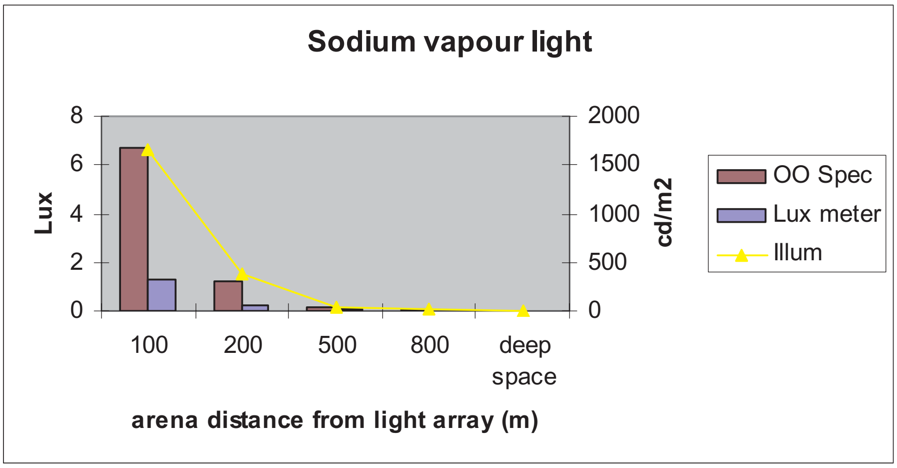


Figure 2: Sodium light intensity values at the 4 arena locations

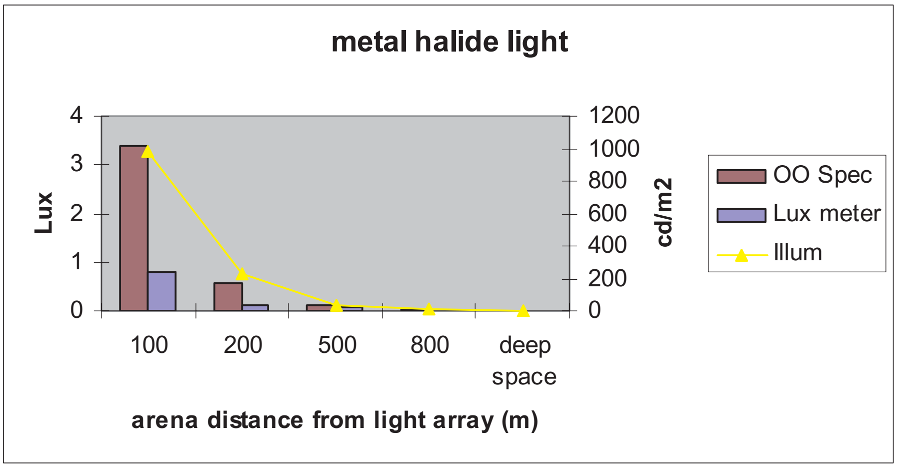


Figure 3: Fluorescent light intensity values at the 4 arena locations

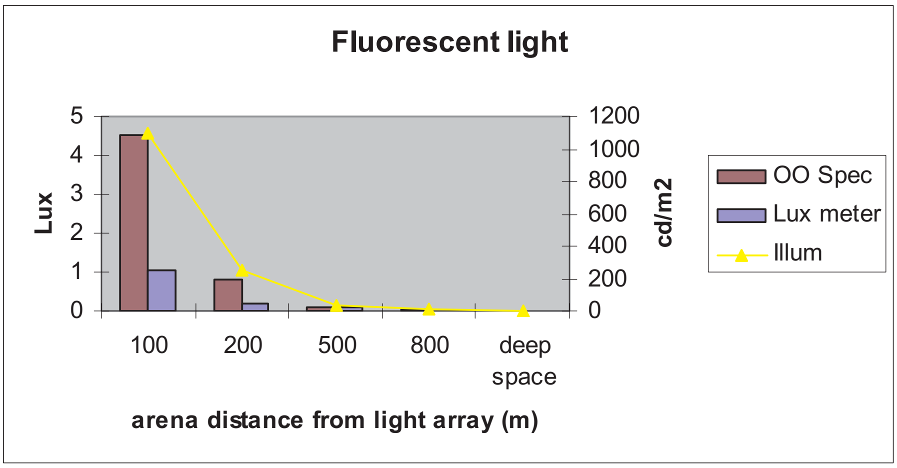


Figure 4: Metal halide light intensity values at the 4 arena locations

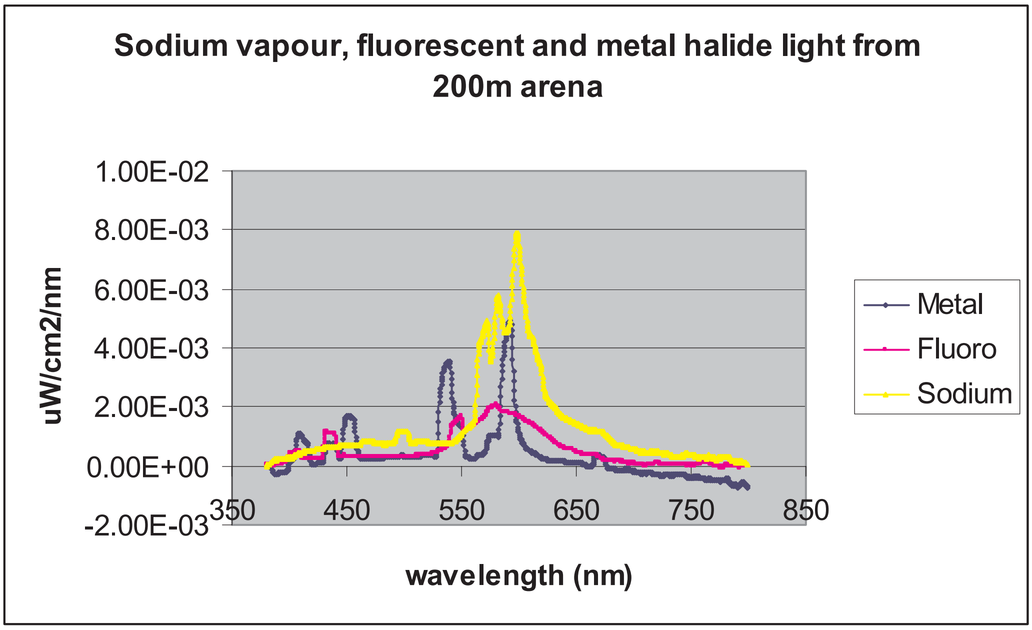


Figure 5: 500W Metal halide, fluorescent and sodium vapour light spectra from 200m.

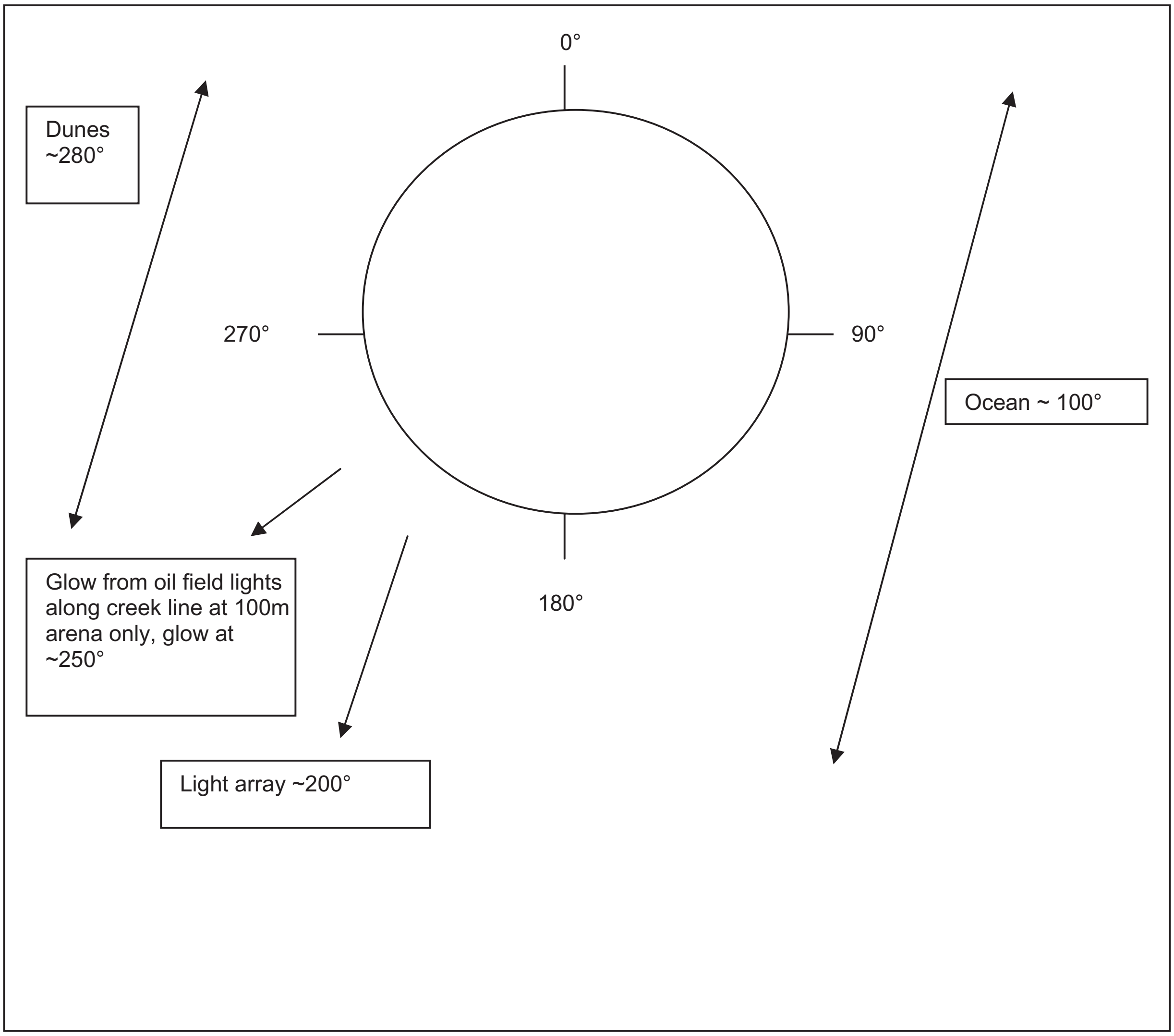
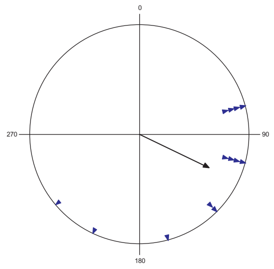
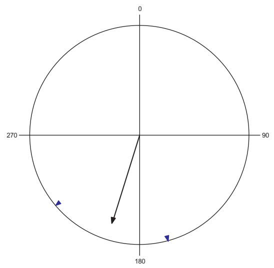

0°
Dunes ~280°
270°
90°
Ocean ~ 100°
Glow from oil field lights along creek line at 100m arena only, glow at ~250°
180°
Light array ~200°

Figure 7: Flatbacks 500W lights

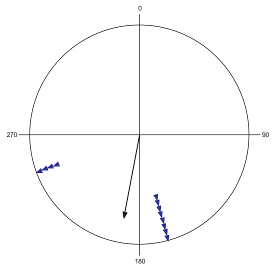
100m control FB, 0 Lux



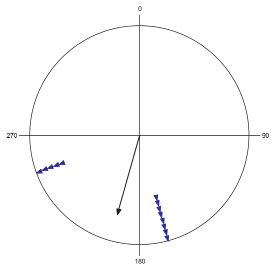
100m Sodium vapour FB, 1.330 Lux



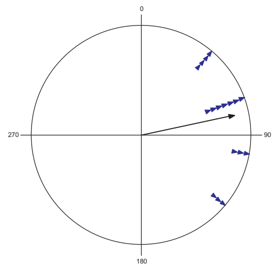
100m Fluorescent FB, 1.030 Lux



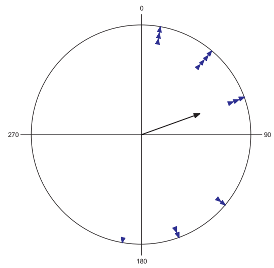
100m Metal halide FB, 0.790 Lux



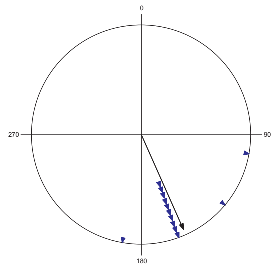
Control 200m FB, 0 Lux



200m Sodium vapour FB, 0.230 Lux



200m Fluorescent FB, 0.180 Lux



200m Metal halide FB, 0.130 Lux

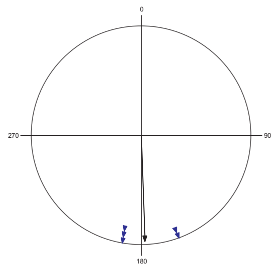
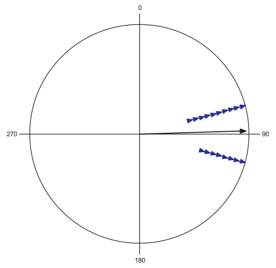
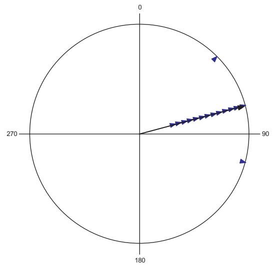


Figure 7 contd.

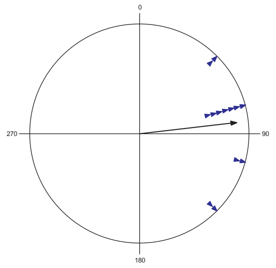
Control 500m FB, 0 Lux



500m Sodium vapour FB, 0.06 Lux



500m Fluorescent FB, 0.09 Lux



500m Metal halide FB, 0.08 Lux

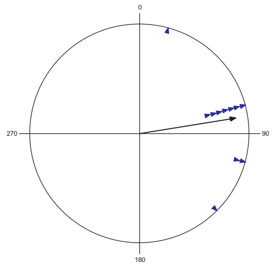
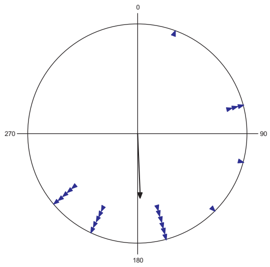
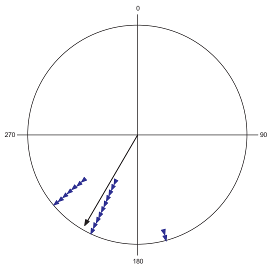


Figure 8: Green 500W and 90°,multiple use

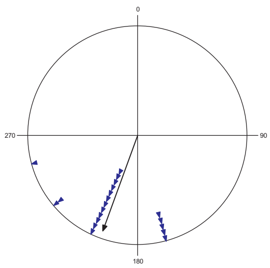
6 control G 500W 100m



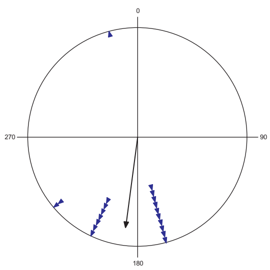
10 Na vap G 500W 100m



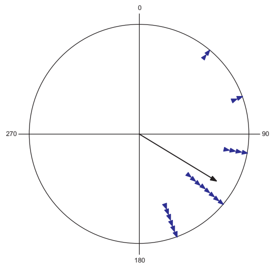
14 Flouro G 500W 100m



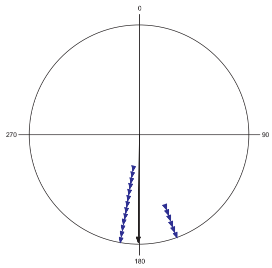
18 Metal G 500W 100m



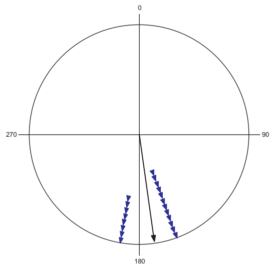
7 control G 500W 200m



11 Na vap G 500W 200m



15 Flouro G 500W 200m



19 Metal G 500W 200m

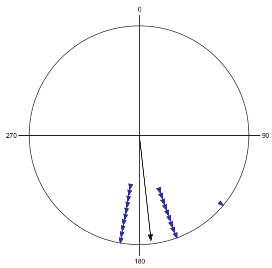
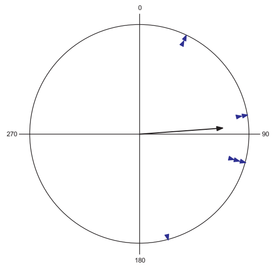
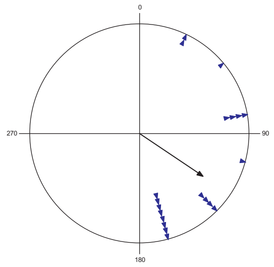


Figure 8: contd.

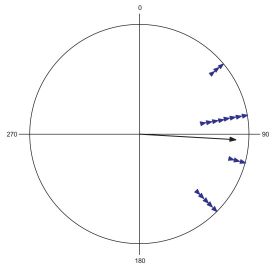
8 control G 500W 500m



12 Na vap G 500W 500m



16 Flouro G 500W 500m



20 Metal G 500W 500m

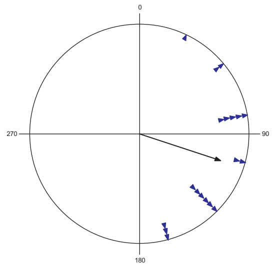
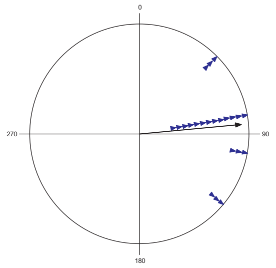
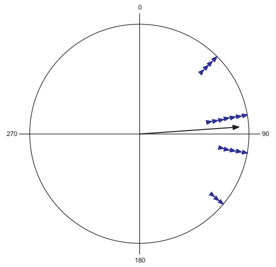


Figure 8: contd

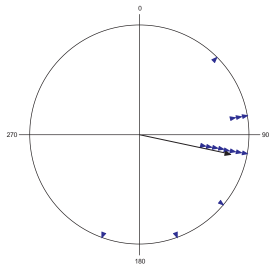
9 control G 500W 800m



13 Na vap G 500W 800m



17 Flouro G 500W 800m



21 Metal G 500W 800m

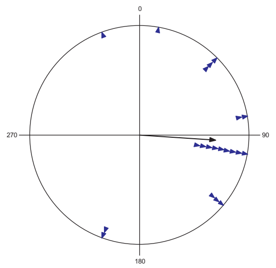
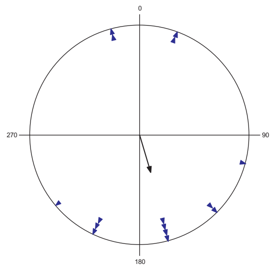
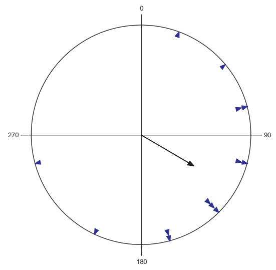


Figure 9: Green multiple use, 250W, and 90° light angle

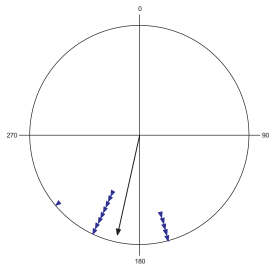
50 control G 250W 100m



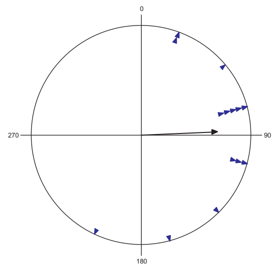
62 control G 250W 100m



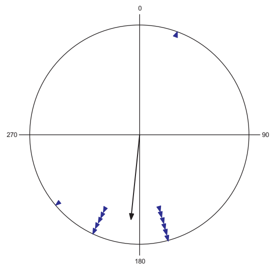
53 Na vap G 250W 100m



65 control ng G 250W 100m



56 Flouro G 250W 100m



59 Metal G 250W 100m

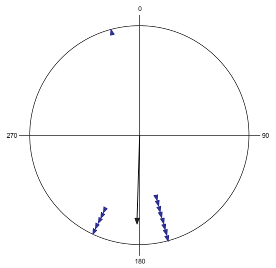
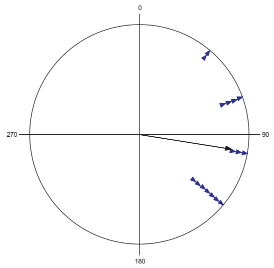
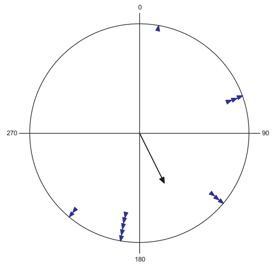


Figure 9 contd.

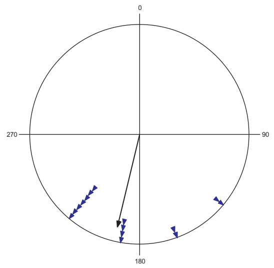
51 control G 250W 200m



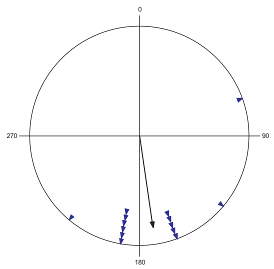
54 Na vap G 250W 200m



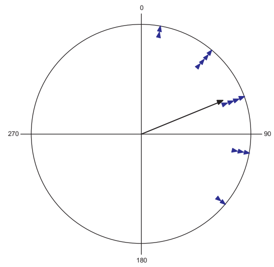
57 Flouro G 250W 200m



60 Metal G 250W 200m



63 control G 250W 200m



66 control ng G 250W 200m

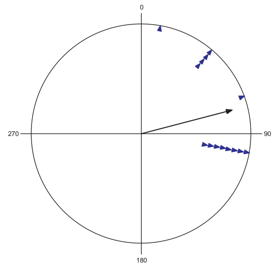
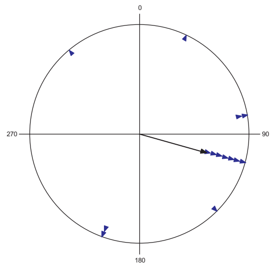
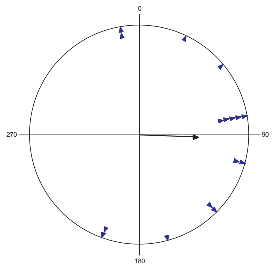


Figure 9: contd

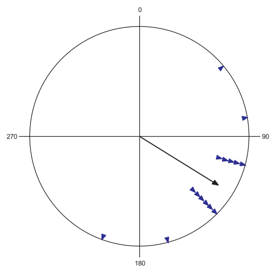
52 control G 250W 500m



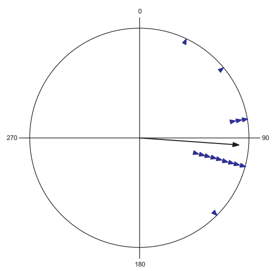
55 Na vap G 250W 500m



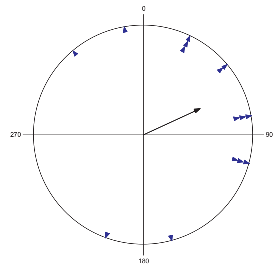
58 Flouro G 250W 500m



61 MEtal G 250W 500m



64 control G 250W 500m



67 control ng G 250W 500m

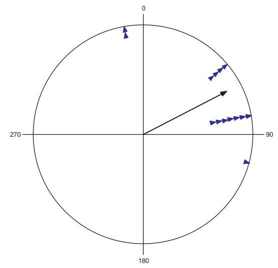
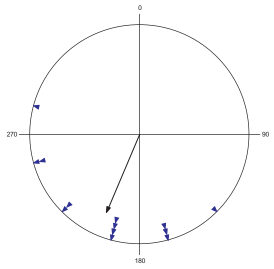
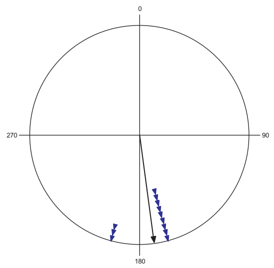


Figure 10: Green 250W, 45° light angle

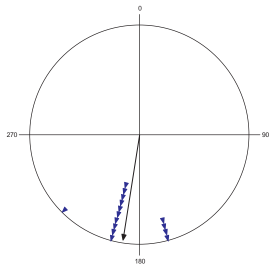
68 control G 250W 45d 100m



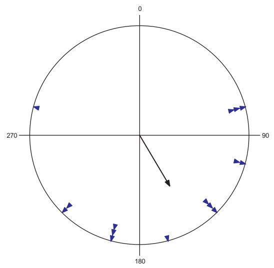
71 Na vap G 250W 45d 100m



74 Meatl G 250W 45d 100m



77 control G 250W 45d 100m



80 control ng G 250W 45d 100m

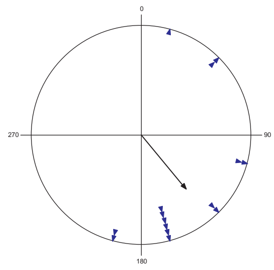
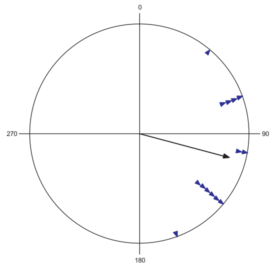
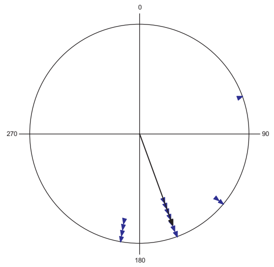


Figure 10: contd

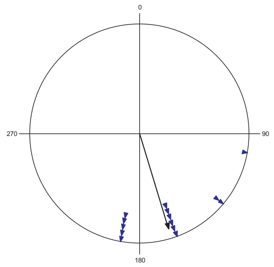
69 control G 250W 45d 200m



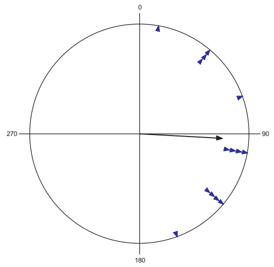
72 Na vap G 250W 45d 200m



75 Metal G 250W 45d 200m



78 control G 250W 45d 200m



81 control ng G 250W 45d 200m

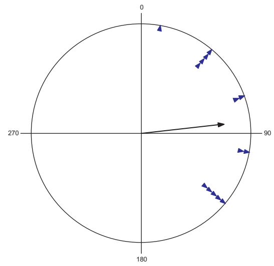
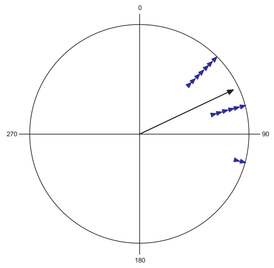
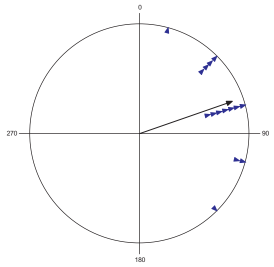


Figure 10: contd

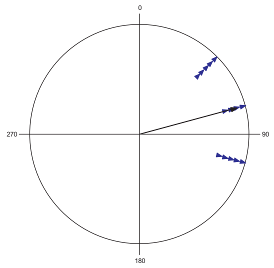
70 control G 250W 45d 500m



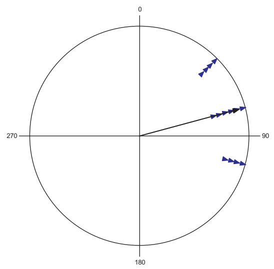
73 Na vap G 250W 45d 500m



76 Metal G 250W 45d 500m0



79 control G 250W 45d 500m



82 control ng G 250W 45d 500m

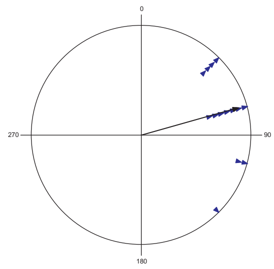
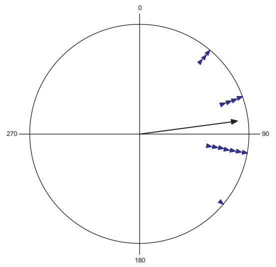
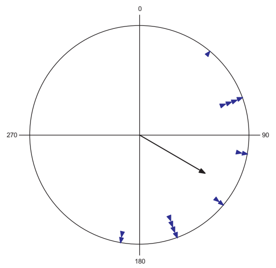


Figure 11: Green, single use per light type 250W

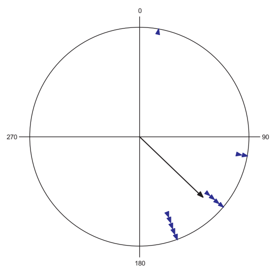
83 control G 250W grp 1 200m



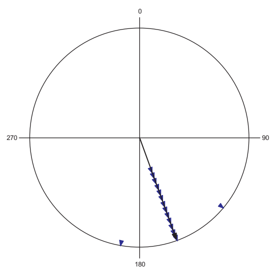
84 Na vap G 250W grp 1 200m



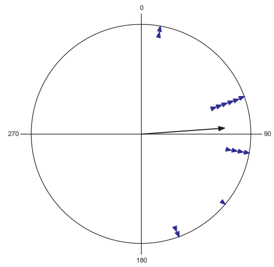
85 Fluoro G 250W grp 2 200m



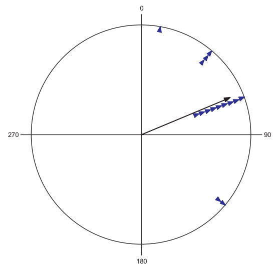
86 Metal halide G 250W grp 3 200m



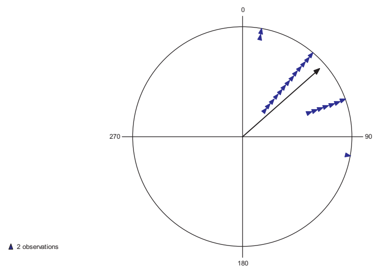
87 control G 250W grp 3 200m



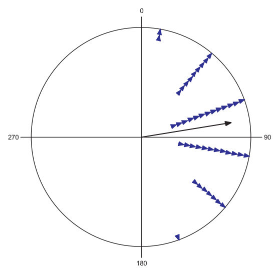
88 control ng G 250W grp 3 200m



89 control ng G 250W all 200m



90 control G 250W all 200m



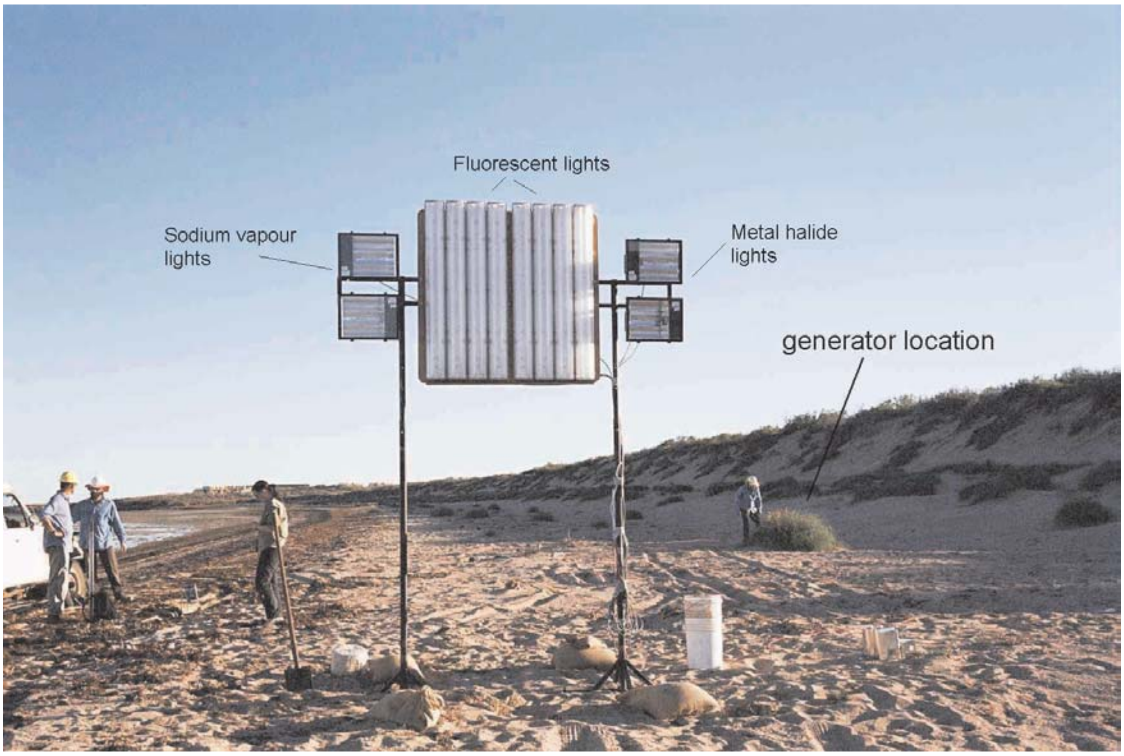


Plate 1: Light array and generator on North Yacht Club Beach (photo K Pendoley)

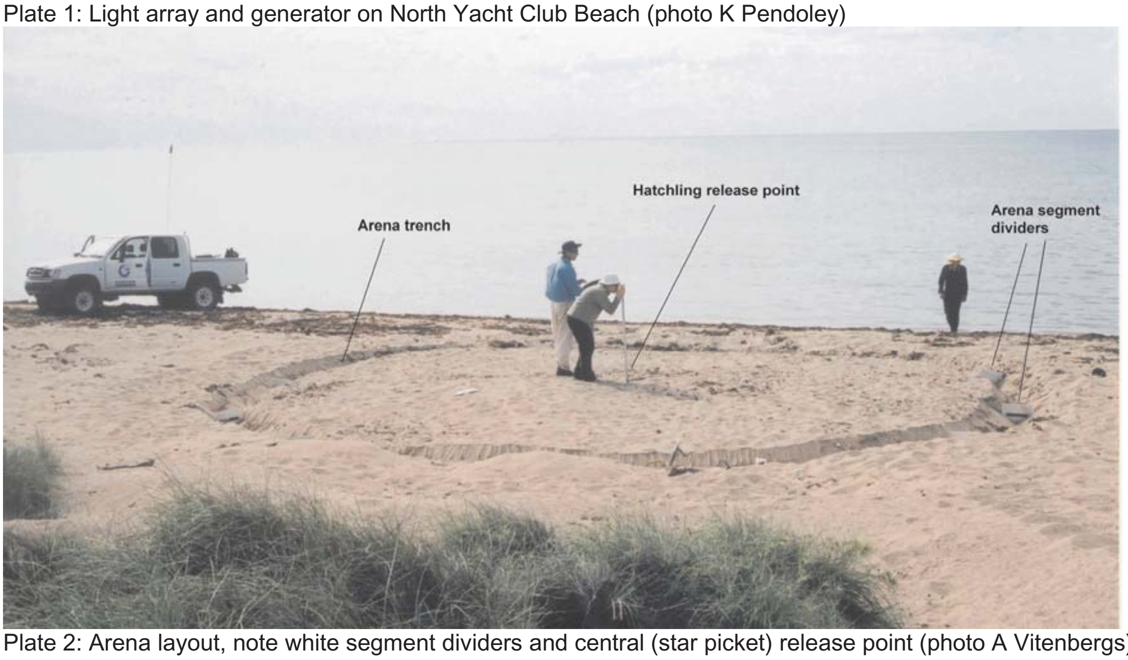


Plate 2: Arena layout, note white segment dividers and central (star picket) release point (photo A Vitenbergs)

Appendix 1: Additional Light Measurement Data, April 2004– Barrow Island Baseline Light Field

Light source being measured	OO Spec (Lux)	Topcon Lux – Meter (Lux)	Topcon Illuminance Meter (cd/m2)	site lights being measured from	Notes
80W Na vapour SBP			27	first bush on north side of creek bed, 173m from suck back pump	Spec calibrated in lab. First reading over top of suck back pump (SBP). Dark scan taken prior to all of subsequent readings
80W Na vapour SBP	7.59E-02		27	first bush on north side of creek bed, 173m from suck back pump	Over suck back pump
80W Na vapour SBP			27	first bush on north side of creek bed, 173m from suck back pump	Over suck back pump
dark sky over ocean			0	Scan over ocean = detector noise = deep space	
	4.36E-01			83m from suck back pump	
dark sky over ocean			0	83m from suck back pump	
suck back pump	4.77E+01	1.01E+01	1,780	from 7m away	
TT 400W Na vapour	8.95E+01		9,000	from 25m away	In front of Terminal Tanks control room. Pole about 8m tall
TT 40W? Na vapour	1.58E+00		252	from 30m	light mounted on wall on Terminal Tank control room , bullet style, flat end
sky glow over TTs			0	suck back pump	
80W Na vapour SBP			131	along beach, 83m from suck back pump	similar location I measured lights from last trip, called it 100m south of suck back pump
80W Na vapour SBP			4	500m at the south end of Terminal Beach	
glow south over rocks			0	glow to the south, towards our light array on Yacht Club Beach and camp	

Light source being measured	OO Spec (Lux)	Topcon Lux – Meter (Lux)	Topcon Illuminance Meter (cd/m2)	site lights being measured from	Notes
Terminal Tank lights			160?	creek mouth on Terminal Beach, lights are visible and bright up creek line	
TT 400W Na vapour		7.01		0m	Under light, transect away from pole, first few meters in shadow of light box Light mounted to shine down at ~45 degrees from upright.
TT 400W Na vapour		10.07		5m	
TT 400W Na vapour		25.90		10m	
TT 400W Na vapour		16.02		15m	
TT 400W Na vapour		12.03		20m	
TT 400W Na vapour		8.34		25m	
camp lights, Na vapour			1.000?	light array at Camp Creek	
dark sky over ocean			0	light array at Camp Creek	
CPF metal halide separator	1.00E+01	4.30	220	road opposite separators, next to big bush, 40m away	Lux meter value includes light integrated from whole area, includes lights beside and behind it, 18.4.2004, see map for target light, this one was on corner closest to the control room
CPF metal halide control room	2.14E+00	2.60	355	road opposite separators, next to big bush, 40m away	Illuminance was 559 cd/m when target both lights on pole
CPF flare	2.50E+00	0.50	1007	road opposite separators, next to big bush, 100m away	
CPF metal halide		8.99		base of light next to control room at CPF	no other lights in this area so this representative of the one metal halide only

Light source being measured	OO Spec (Lux)	Topcon Lux – Meter (Lux)	Topcon Illuminance Meter (cd/m2)	site lights being measured from	Notes
CPF metal halide		10.30		5m	
CPF metal halide		6.77		10m	
CPF metal halide		3.48		15m	
CPF metal halide		2.09		20m	
CPF metal halide		1.19		25m	
deep space	2.45E+0				after done dark scan
dark scan					with cap on collector, represents noise in the detector
CPF metal halide	7.21E-02		2	road opposite Q38 765m away	
CPF flare	5.00E-02		16	road opposite Q38 720m away	
Glow over TTs Sodium vapour			2.000?	parking lot at top of Terminal Beach	from behind bushes, illuminance meter detector loose, results questionable
glow over J station flare			42.000?	parking lot at top of Terminal Beach	from behind bushes, illuminance meter detector loose, results questionable
glow over light array on Yacht Club			71.00?	parking lot at top of Terminal Beach	from behind bushes, illuminance meter detector loose, results questionable
glow over CPF			43.00?	parking lot at top of Terminal Beach	from behind bushes, illuminance meter detector loose, results questionable
J station flare	9.478+0	1.78	1670	165m from parking lot across road	
J station flare	9.17E-01	0.86	567	corner of spaghetti junction, 361m	

Light source being measured	OO Spec (Lux)	Topcon Lux – Meter (Lux)	Topcon Illuminance Meter (cd/m2)	site lights being measured from	Notes
Hg vapour white, in heavy duty workshop	4.992+0	5.34	281	19m	Lux meter is measuring the whole bank of lights, cant isolate one
Hg vapour green in heavy duty workshop	6.09E+0		967	13m	
Hg vapour bank of lights		78.3		0m	Lux meter is measuring the whole bank of lights, cant isolate one
Hg vapour bank of lights		27.9		5m	Lux meter is measuring the whole bank of lights, cant isolate one
Hg vapour bank of lights		5.67		10m	Lux meter is measuring the whole bank of lights, cant isolate one
Hg vapour bank of lights		1.73		15m	Lux meter is measuring the whole bank of lights, cant isolate one
Hg vapour bank of lights		1.1		20m	Lux meter is measuring the whole bank of lights, cant isolate one
Light is Fire truck shed	2.36	0.84	574	21m	
Light over wash bay	1.19	2.86	1659		illuminance meter playing up hard to get consistent data
Terminal tank (TT) light	3.08	1.52	146	100m	
TT light	0.0905	0.07	6	500m	
TT light	0.0393	0.03	6	1000m	
TT light	0.0140	0.01	2	2000m	
TT light	-0.007	0.01	1	2,880m	cant do 3000m as road dips into airport creek

Attachment 3 - Sea Turtle Light Orientation Arena Experiments 1-6 February 2005. Report to ChevronTexaco Australia Pty Ltd by Pendoley Environmental, April 2005.

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PROPOSED GORGON GAS DEVELOPMENT
BARROW ISLAND

SEA TURTLE LIGHT ORIENTATION ARENA EXPERIMENTS

1 – 6 FEBRUARY 2005

by

PENDOLEY ENVIRONMENTAL PTY LTD

13 APRIL 2005

1 Introduction

This report provides the results of arena experiments carried out on Barrow Island in February 2005. The study is a follow-up to experiments carried out in April 2004 which were limited by difficulties in sourcing sufficient study animals. The timing of the study earlier in the 2005 summer nesting and hatchling season ensured the availability of suitable study animals. This study was designed and implemented by K Pendoley of Pendoley Environmental Pty Ltd and is based on similar studies carried out on green, flatback and hawksbill hatchlings between 1993 and 2004. Prof Stuart Bradley (Head of Animal Biology, School of Biology and Biotechnology, Murdoch University) carried out the statistical analyses.

The objectives of the study were to;

- Investigate the impacts of sodium vapour, fluorescent and metal halide light on flatback sea turtle hatchlings at different light intensities (250 W and 500 W).
- Trial experimental methods to test hatchling response to light glow.
- Collect qualitative (spectra) and quantitative (Lux) data from the different light sources (at both intensities) at each arena location.
- Test the behavioural response of hatchlings during reuse in experimental trials.

2 Methods

The arena experiments were carried out on Barrow Island between 1-5 February 2005 over 5 nights of a late rising waxing moon (i.e. under no moon conditions). The personnel involved in this project are listed by affiliation below:

- Pendoley Environmental Pty Ltd; Kellie Pendoley, Anna Vitenbergs, Karen Edward, Jarrad Sherborne, Patrick Cullen.
- Crackpots; John Norton, Paul Tod.

The pit fall arena experimental design and test methods were the same as those used in April 2004.[1] The light array used in 2004 was reinstalled on Yacht Club Beach North, however the location was shifted 100 m north of the April 2004 position to avoid the potential influence of light glow along the creek line from inland infrastructure. The lights, consisting of 2 x 250 W high pressure sodium vapour (sodium), 2 x 250 W metal halide (metal), 14 x 36 W fluorescent fixtures mounted on a 3 m tall stand (Plate 1), were built by the marine and environmental service company, Crackpots. The array was assembled on location and powered by a 5 KVa 'silent' running diesel generator positioned 25 m from the light array. The generator was placed on a rubber base to prevent the motor vibrations travelling along the beach and potentially influencing the hatchling response during the arena trials.

The arenas were installed at 100 m, 200 m, 500 m and 800 m from the light array along North Yacht Club Beach (Figure 1). Each circular arena was 5 m in diameter with a 20 cm deep trench around the circumference. The trench was divided into 12 numbered segments of 30°. The first segment divider was installed at the closest point to the ocean and the rest placed in 30° increments from that location.

The experiments were carried out using flatback hatchlings and were scheduled to coincide with the peak of the flatback hatching season. All hatchlings were collected from Yacht Club Beach the same evening as each trial was run. Hatchlings were held in the dark until use. None of the hatchlings tested were held for more than 2 hours prior to the

[1] Pendoley, K. (2004). Gorgon Proposed Gas Development Sea Turtle Hatchling Arena Experiments. April 2004, Perth, unpublished report to SKM/ChevronTexaco: 47.

experiments and none for longer than a total of 5 hours. On completion of the experiments hatchlings were released from the barge landing on the north east coast of Barrow Island. This site was selected to avoid the high numbers of predators present off Yacht Club Beach.

2.1 Light experiments

Experimental light trials (250 W light, 500 W light, 500 W glow) were carried out using 30 – 50 animals at each arena. All four arenas were used for each trial. Each animal group was tested against the four light regimes in the following order; control, sodium, metal, fluorescent and control. The controls at the start and end of each light group were used to monitor the animals for learned behaviour. Each experimental trial was completed in a single night ensuring the study animals were exposed to the same environmental conditions throughout a single trial.

For each of the four light regimes, the hatchlings were released at the center of each arena using a remote mechanism. They were allowed 2-5 minutes to reach the trench at the edge of the arena prior to collection. The number in each segment, as well as those remaining in the center, was scored and the hatchlings returned to the center in preparation for the next light regime trial.

The three different experimental trials carried out were:

- 250 W bare light, control, sodium, metal and fluorescent lights at 100 m, 200 m, 500 m and 800 m arenas
- 500 W bare light, control, sodium, metal and fluorescent lights at 100 m, 200 m, 500 m and 800 m arenas
- 500 W shielded light (glow), control, sodium, metal and fluorescent lights at 100 m, 200 m, 500 m and 800 m arenas.

2.2 Light intensity measurements

Light measurements were made using an OceanOptics spectroradiometer which provides a characteristic spectral chart for each light source and includes the energy emissions in uW/nm^2/cm at each wavelength. The spectroradiometer also provides a photometric measure of emissions in Lux. The Lux values have been used as a basis on which to assess and compare hatchling behaviour over distance and light type. However it should be noted that the limitations on instrument sensitivity may reduce the accuracy of these light measurements over large distances or at very low light intensity (i.e. at the 500 m and 800 m arenas).

2.3 Reuse experiments

Experiments were run to assess the impact of reusing hatchlings in different light trials. Reuse of hatchlings was necessary since the total number of animals needed for each of the three experimental trials was very high (~500 animals on each night of the study), and it was not possible to find and collect 500 animals in one night. The reuse trials were carried out at the 200 m arena using 250 W light intensity. One hundred and twenty hatchlings were divided into four bags. The order of testing against the three light regimes is listed below.

Bag 1	Bag 2	Bag 3	Bag 4
Control	Sodium	Metal	Fluorescent
Sodium	Metal	Fluorescent	Control
Metal	Fluorescent	Control	Sodium
Fluorescent	Control	Sodium	Metal

The first light treatment each bag of animals was exposed to was their first exposure to the arena and light. The hatchlings were tested under the different light conditions in sequence to determine if previous exposure to different light sources had any impact on their behaviour.

3 Results and Discussion

3.1 Light measurement results

The light spectra for each light types are shown in Figures 2 – 5 for each arena location. These figures show the spectral distribution curve for each light type, in units of $uW/cm^2/nm$ in addition to a photometric measure of emissions in Lux. Commercial light meters such as those typically used in industrial settings, measure in units of Lux and include only the light emissions most visible to the human eye (i.e. in the 500 nm to 650 nm range). The Lux values presented in this report therefore include only the spectral emissions between 500 nm and 650 nm and ignore the spectral peaks above and below this range. Experimental work with green turtles has shown that light in the 350 nm – 450 nm range is also visible to this, and presumably other, turtle species[2].

3.2 Hatchling reuse trials

The trials to test the impact that reusing hatchlings may have had on animal behaviour was run on all light types at 250 W. The results for these trials (Figure 6) show that the hatchlings oriented in the same way under a given light regime regardless of their exposure history. For example hatchlings exposed to sodium and metal halide light before being exposed to the fluorescent light oriented in the same direction as hatchlings that had no previous light exposure. A chi-square analysis was run to test the effect of reusing hatchlings. The results found no significant difference in the orientation of hatchlings with no previous light exposure compared to re-used animals ($p = 0.087$). This result suggests hatchlings are responding to the different lights as if it was their first exposure and are not exhibiting learned behaviour. The analysis also tested the effect of the light treatments on hatchling behaviour and found a statistically significant difference between the behaviour of animals in the control trials and the light trials. These differences were investigated further during 250 W and 500 W light trials.

3.3 250 W and 500 W light trials

The light types (i.e. sodium, metal and fluorescent) used in these experiments were selected to be representative of the lighting typically used in industrial settings. The light

[2] Witherington, B. E. and K. A. Bjorndal (1991a). "Influences of wavelength and intensity on hatchling sea turtle phototaxis: implications for sea-finding behaviour." Copeia **4**: 1060-1090.

intensities (250 W and 500 W) were selected, based on previous studies, to provide a range of light most likely to elicit a detectable response in the hatchlings. The experimental trials were split into 250 W and 500 W trials and run over separate nights. The data was analysed statistically in the same manner, i.e. 250 W results as a dataset distinct from the 500 W results.

Both datasets were subject to global multinomial logistic regression with light treatments as a factor and distance as a covariate, and direction as the multinomial dependent variable (including all control and light treatment data amalgamated, i.e. light versus no light). The results found a statistically significant difference in the response of hatchlings under control conditions and light treatment conditions ($p = 0.000$). The light treatment clearly had an impact on hatchling orientation. The analysis also found that the hatchling behaviour differed significantly with distance (and consequently light intensity) from the light source ($p = 0.000$).

Distance was tested further by splitting both the 250 W and 500 W light trial data (excluded controls) into two groups; near (representing the 100 m and 200 m arena results) and far (representing the 500 m and 800 m results). The analysis of the 500 W dataset found that hatchling behaviour in the two near arenas was not significantly different (indicating that the light type was not important), nor was it significantly different between the in two far arenas. The 250 W trials, however, showed a significant difference in the hatchling behaviour in the near (100 m and 200 m) arena group while no significant difference was evident in the 500 m and 800 m arenas.

In order to look at fine scale trends, the data from each individual arena location was then subject to an analysis which compared hatchling orientation under control vs. light treatment conditions. A binary logistic regression analysis performed on the complete set of controls (run at the start and end of each group of light treatments) and including distance as a covariate, found no significant difference in hatchling orientation permitting the control data to be pooled for subsequent statistical analyses. The binary regression assumed animals either oriented towards the ocean (within the 85° and 115° segments) or they did not (all other directions). A series of 2 x 2 contingency chi-square tests were performed for the number of animals oriented to the ocean versus the number not, in the presence of a particular light type versus the absence of light. The results of these tests are shown in Table 3. Since twelve separate contingency tests were performed for each of the 250 W and 500 W trials the results were subject to a sequential Bonferroni correction in order to account for repeat testing. The results showed that all three light treatments (sodium, metal and fluorescent), at both 250 W and 500 W light intensities, had a significant impact on hatchling orientation (relative to the controls) at 100 m and 200 m.

At 500 m and 500 W light intensity hatchlings tested against all three light types also show a significant response to the light relative to the controls however at 800 m the fluorescent light was the only emission source to show a (weakly) significant response relative to the controls. In contrast the 250 W trials found no significant effect from the three light types at 500m or 800m with the single exception of the metal halide at 500 m.

These results are shown graphically in Figures 7 (sodium), 8 (metal) and 9 (fluorescent). The figures include the results of both the 250 W and 500 W light intensity trials, sorted by the measured Lux value. The sodium vapour light trials appear to influence hatchling behaviour at light 500 W at 500 m (estimated light intensities of ≥ 0.19 Lux) while the light detectable at 500 m and 250 W (estimated intensities of ≤ 0.09 Lux) did not cause a detectable difference (from controls) in hatchling behaviour. The effect of metal halide light was detectable at lower light intensities than the sodium light, with hatchling behaviour being modified at 500 m and 500 W of light (estimated light intensities of • 0.05 Lux, Figure 8). Hatchling behaviour was not significantly affected at 800 m and 500 W of light (estimated intensities of ≤ 0.04 Lux). The fluorescent light results show a clear influence on behaviour under distance and light intensity combinations up to 500 m, and 500 W (estimated intensities of ≥ 0.14 Lux) however at 500 m the 250 W light intensity of 0.06 Lux did not elicit a significant response in hatchling behaviour while 500 W of fluorescent light at 800 m (estimated intensity of 0.05 Lux) did show a weakly significant response.

3.4 500 W glow trials

These trials were carried out using the same methodologies as the 250 W and 500 W light trials. The light sources were placed on the sand and the orientation manipulated to shield the bulbs so that the only light visible was a faint glow in the sky above the light fixtures. It was not possible to completely control the light spill, which illuminated the sand dunes behind the beach out to a distance of ~200 m. Methods to better control light spill and glow will be investigated prior to any further experimental work being carried out on hatchling response to light glow. It was also not possible to obtain a quantitative measure of light intensity since the light emissions were below the limit of sensitivity of the spectroradiometer. Investigations are underway to source a more sensitive instrument for future sea turtle experiments and light surveys.

A preliminary analysis of the data was carried out. As was done for the 250 W and 500 W light trials a global multinomial logistic regression with light glow treatments as a factor and distance as a covariate, and direction as the multinomial dependent variable (including all control and light glow treatment data amalgamated, i.e. light glow versus no light glow) was performed on the data. The results indicated that both treatment and distance were highly significant ($p = 0.000$) indicating that glow did have an impact on the direction hatchlings were taking and the impact varied with distance. The tests repeated without the control data again indicated that distance was highly significant ($p = 0.000$) but that the actual light type (sodium, metal or fluorescent) used to generate the glow had no effect ($p = 0.61$). The analysis of the glow effects was not taken further since it was not possible to identify a threshold glow intensity beyond which an effect could be detected.

4 Conclusions

This series of experiments has investigated the following:

- the acceptability of reusing hatchlings in light trials
- the influence of sodium vapour, metal halide and fluorescent light on flatback hatchlings over a range of exposure intensities
- experimental methods for testing the effect of light glow on flatback hatchlings.

The results suggest that reusing hatchlings did not compromise the behaviour of the animals during repeat trials. It is therefore acceptable and results from trials reusing hatchlings are therefore valid.

The experiments show a difference in hatchling response to sodium vapour, metal halide and fluorescent light sources. Hatchlings respond to sodium light at estimated intensities of ≥ 0.19 Lux, while metal and fluorescent light sources influence hatchling behaviour at intensities an order of magnitude lower at estimated intensities of ≥ 0.05 Lux. These results provide evidence to support the recommendations made to the Gorgon Development to use sodium vapour light sources, over metal halide or fluorescent light sources, in the vicinity of sea turtle rookeries.

The results of the preliminary experimental trials on light glow suggest that glow is influencing hatchling behaviour over distance. However, refinements to the experimental methods, in addition to sourcing measurement instruments with more sensitive detection limits, are required to further define the threshold level of light glow that causes misorientation in sea turtle hatchlings.

Table 1: Lux measurements from 500 W light sources

	100 m	200 m	500 m	800 m
Control	0	0	0	0
Sodium vapour	5.16	1.31	0.19	0.06
Metal halide	2.38	0.59	0.12	0.04
fluorescent	3.09	0.77	0.14	0.05

Table 2: Lux measurements from 250 W light sources

	100 m	200 m	500 m	800 m
Control	0	0	0	0
Sodium vapour	2	0.52	0.09	0.04
Metal halide	0.80	0.21	0.05	0.03
fluorescent	1.38	0.36	0.06	0.03

Table 3: Chi^2 analysis results (corrected for repeat testing using the sequential Bonferroni correction) for 500 W and 250 W light treatment trials. * = significant at 0.05, ** =significant at 0.01, *** =significant at 0.001, ns = not significant

Light wattage	distance	treatment	Chi value	p	Significance using sequential Bonferroni correction
500 W	100	sodium	48.515	0	***
	100	metal	51.232	0	***
	100	fluorescent	50.333	0	***
	200	sodium	21.546	0	***
	200	metal	27.221	0	***
	200	fluorescent	21.165	0	***
	500	sodium	8.422	0.0037	*
	500	metal	7.159	0.0075	*
	500	fluorescent	7.009	0.0081	*
	800	sodium	0.084	0.7719	ns
	800	metal	0.001	0.9813	ns
	800	fluorescent	5.857	0.0155	*
250 W	100	sodium	53.429	0	***
	100	metal	58.784	0	***
	100	fluorescent	46.735	0	***
	200	sodium	47.709	0	***
	200	metal	72.121	0	***
	200	fluorescent	62.656	0	***
	500	sodium	1.386	0.2391	ns
	500	metal	9.943	0.0016	**
	500	fluorescent	4.344	0.0371	ns
	800	sodium	0.606	0.4363	ns
	800	metal	0.41	0.522	ns
	800	fluorescent	0.41	0.5221	ns

Figure 1: Arena locations on Yacht Club Beach

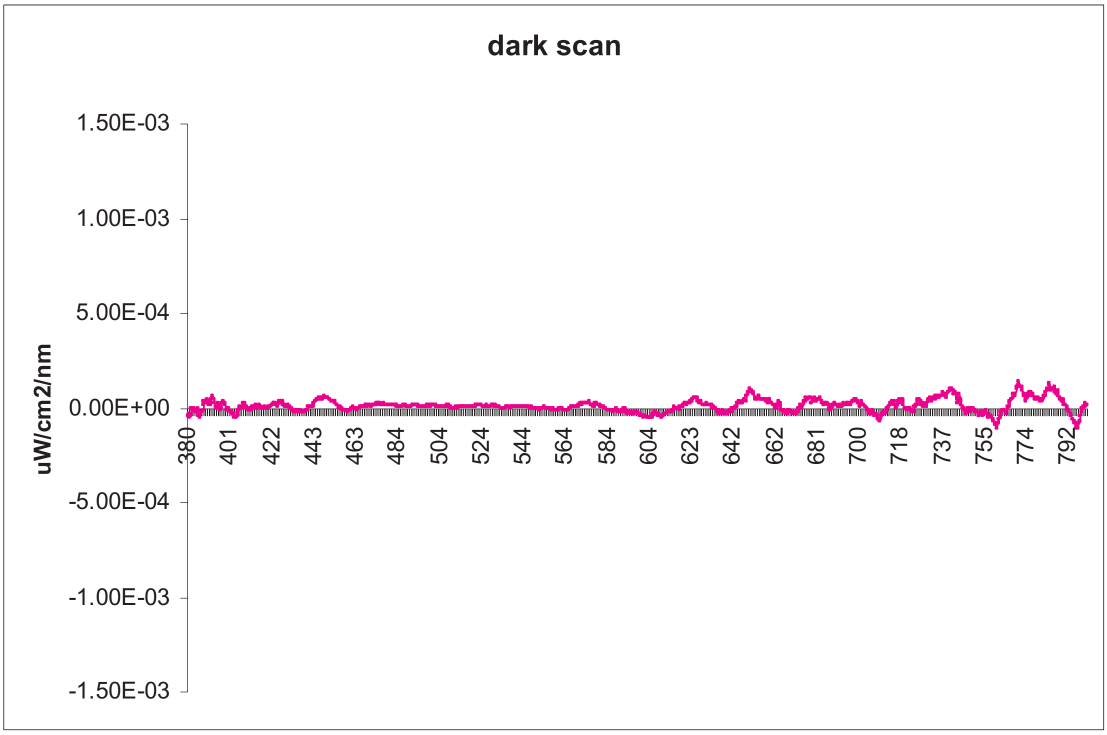


Figure 2: Dark sky scan

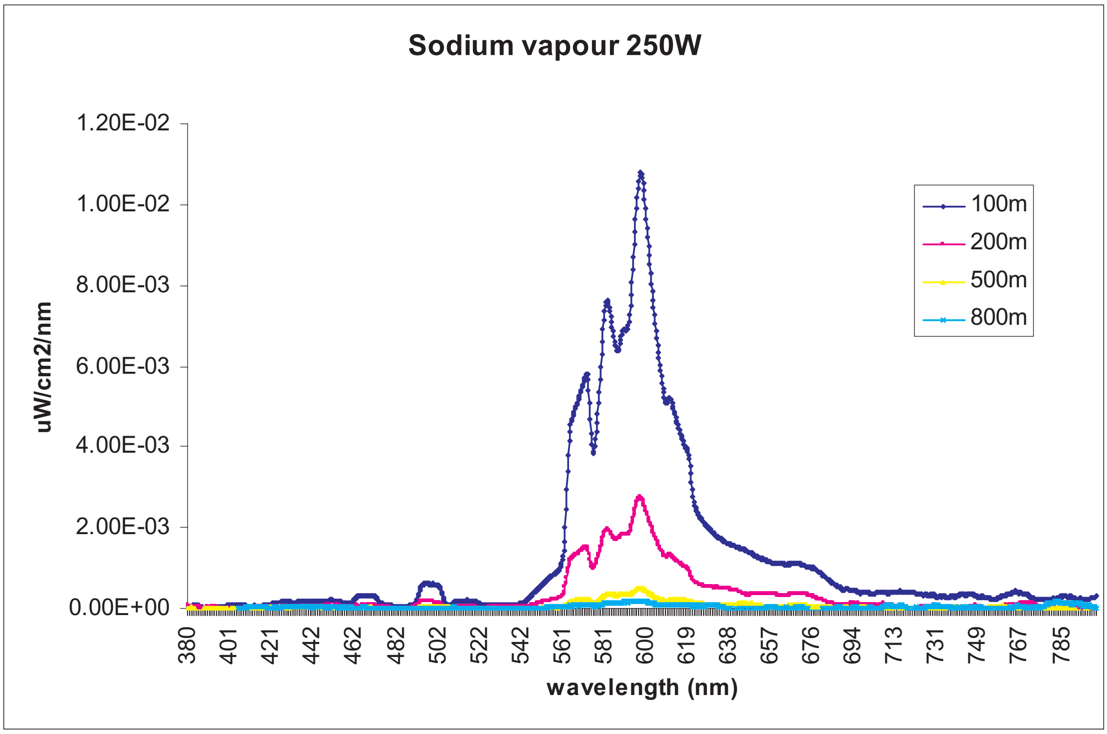


Figure 3: 250 W Sodium vapour light from 100 m, 200 m, 500 m and 800 m arenas. Orange shading covers region of the spectrum that is included in the photometric Lux measurements.

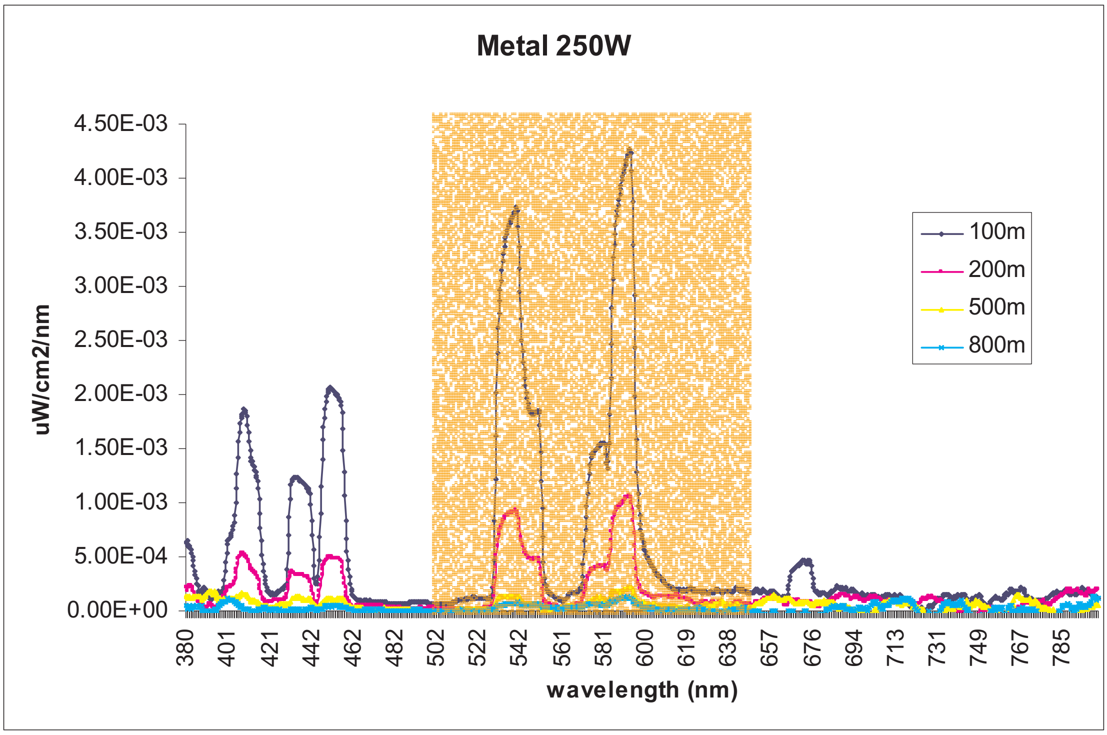


Figure 4: 250 W Metal halide light from 100 m, 200 m, 500 m and 800 m arenas. Orange shading covers region of the spectrum that is included in the photometric Lux measurements.

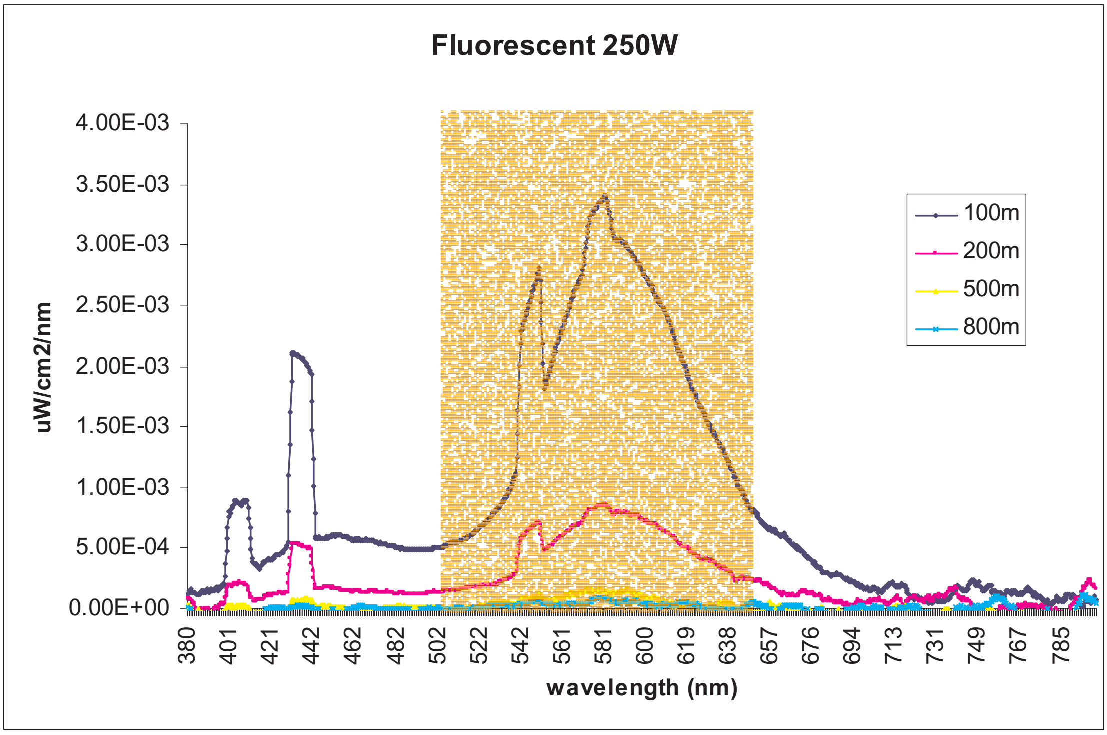


Figure 5: 250 W Fluorescent light from 100 m, 200 m, 500 m and 800 m arenas. Orange shading covers region of the spectrum that is included in the photometric Lux measurements.

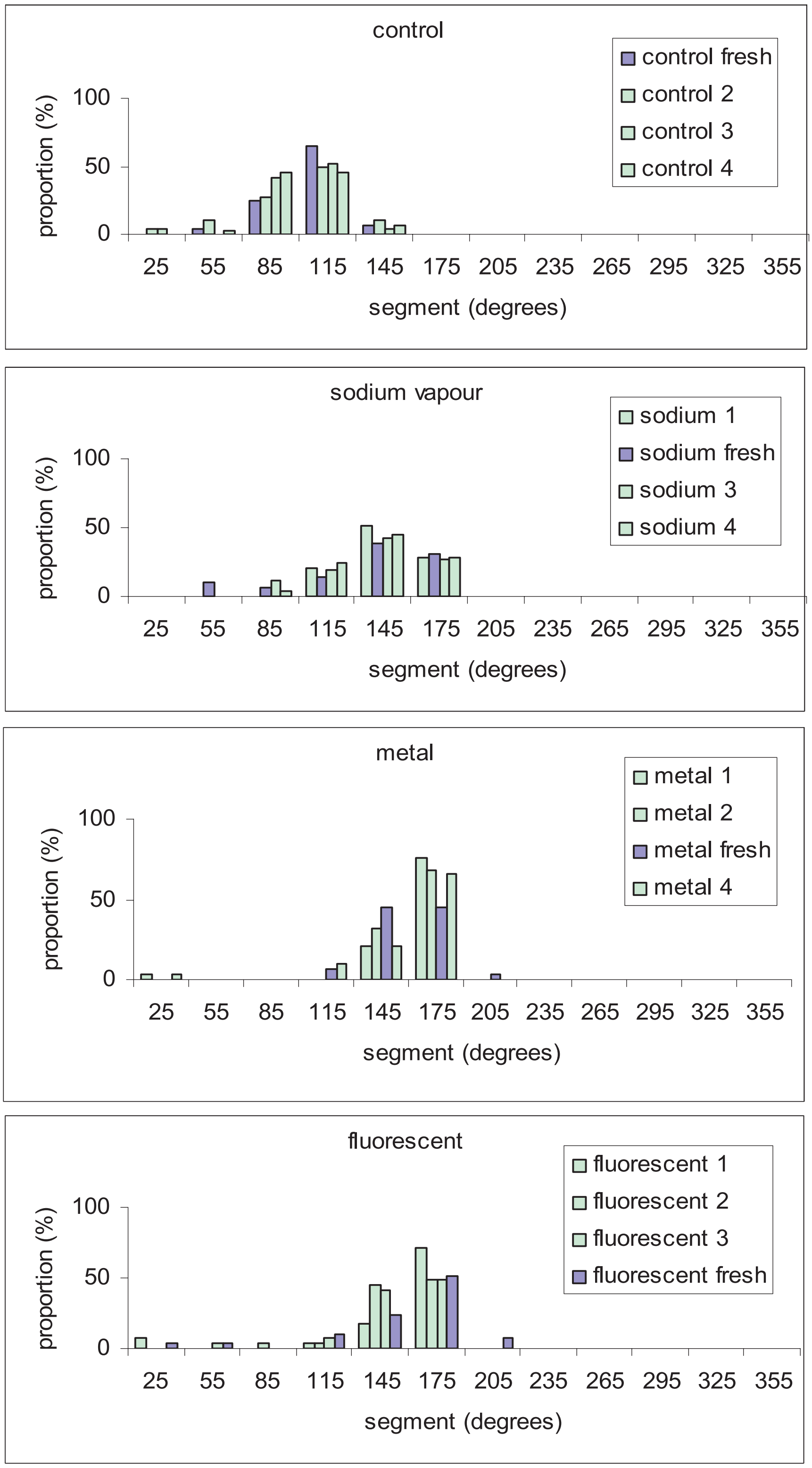
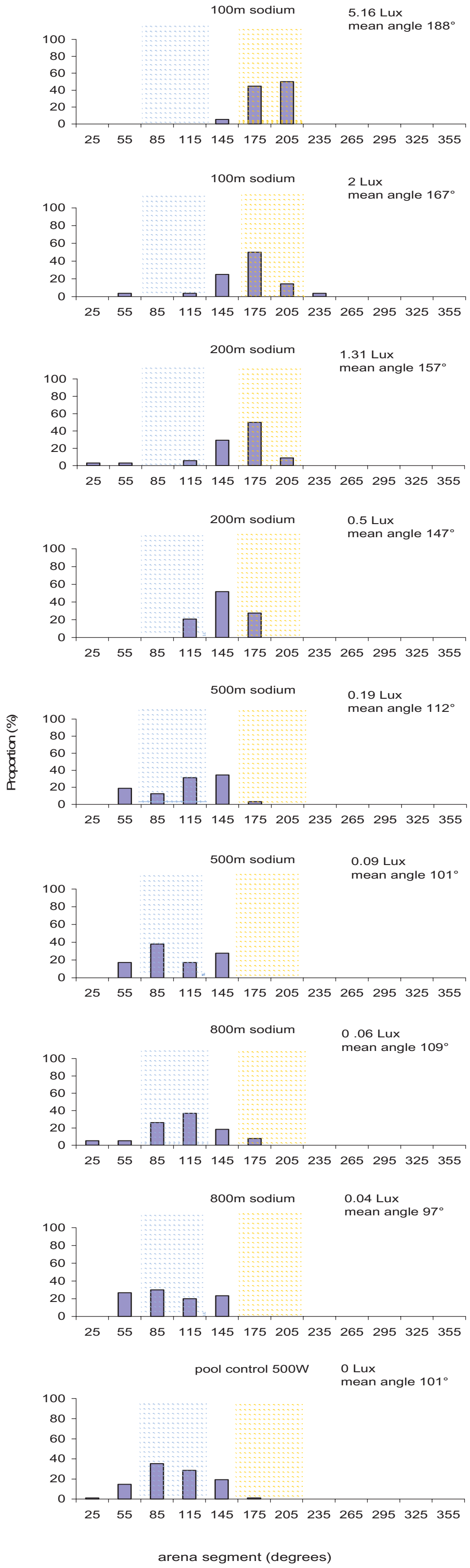
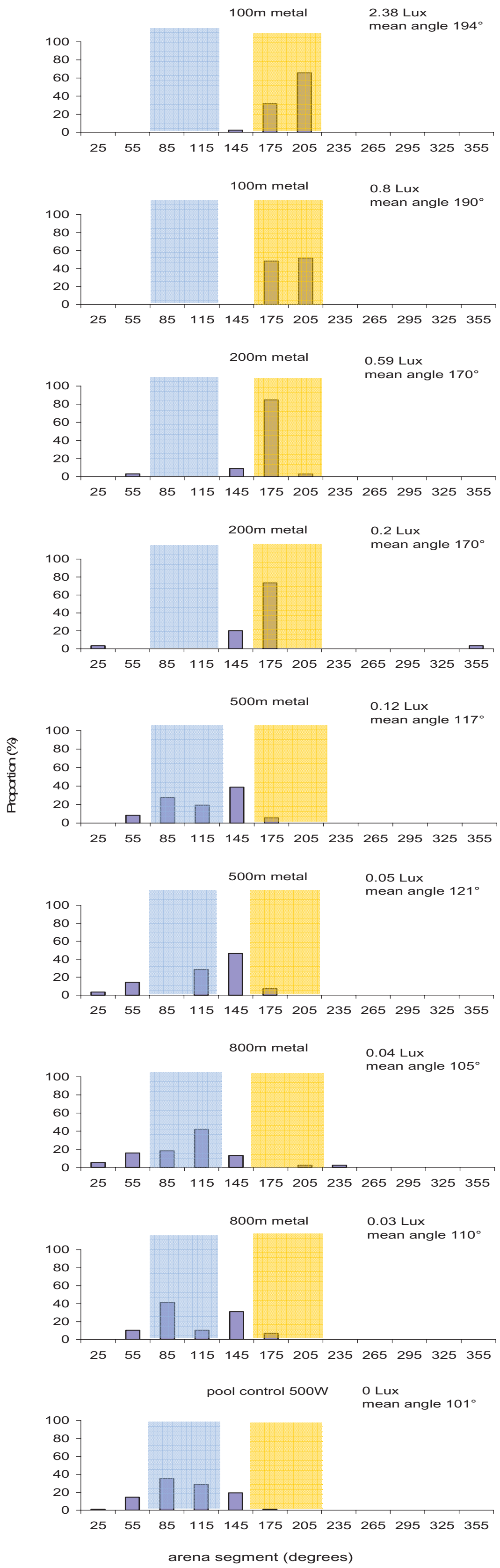


Figure 6: 250 W multiuse trials. Numbers in legend represent bag number (see Section 2.3 for details)



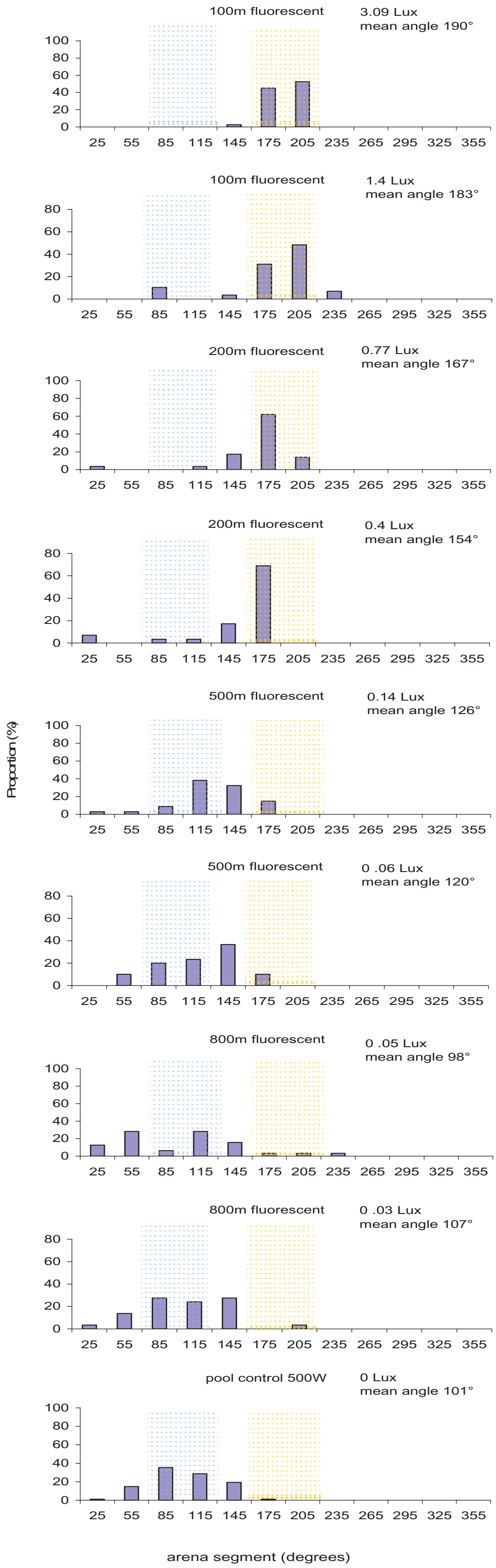
wattage	p value codes	significance of difference relative to controls
500W	***	strong difference
250W	***	strong difference
500W	***	strong difference
250W	***	strong difference
500W	*	slight differnce
250W		no difference
500W		no difference
250W		no difference

Figure 7: Plots of sodium vapour arena results, 250 W and 500 W trials sorted by Lux value. Blue wash represent the arena segments oriented most closely to the ocean, yellow wash represents the arena segments oriented towards the light array.



wattage	p value size	difference relative to pooled controls
500W	***	strong difference
250W	***	strong difference
500W	***	strong difference
250W	***	strong difference
500W	*	slight difference
250W	**	moderate difference
500W		no difference
250W		no difference

Figure 8: Plots of metal halide arena results, 250 W and 500 W trials sorted by Lux value. Blue wash represent the arena segments oriented most closely to the ocean, yellow wash represents the arena segments oriented towards the light array



wattage	p value size	difference relative to pooled controls
500W	***	strong difference
250W	***	strong difference
500W	***	strong difference
250W	***	strong difference
500W	*	slight difference
250W		no difference
500W	*	slight difference
250W		no difference

Figure 9: Plots of fluorescent arena results, 250 W and 500 W trials sorted by Lux value. Blue wash represent the arena segments oriented most closely to the ocean, yellow wash represents the arena segments oriented towards the light array

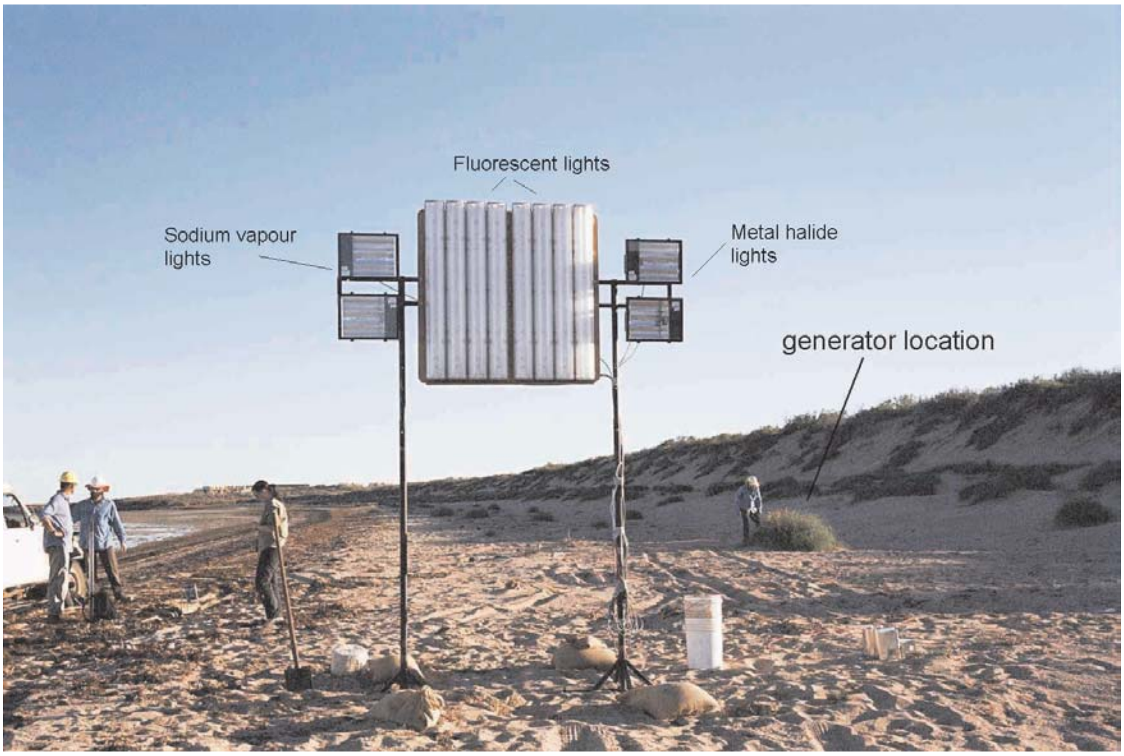


Plate 1: Light array set up for light trials (photo K Pendoley)

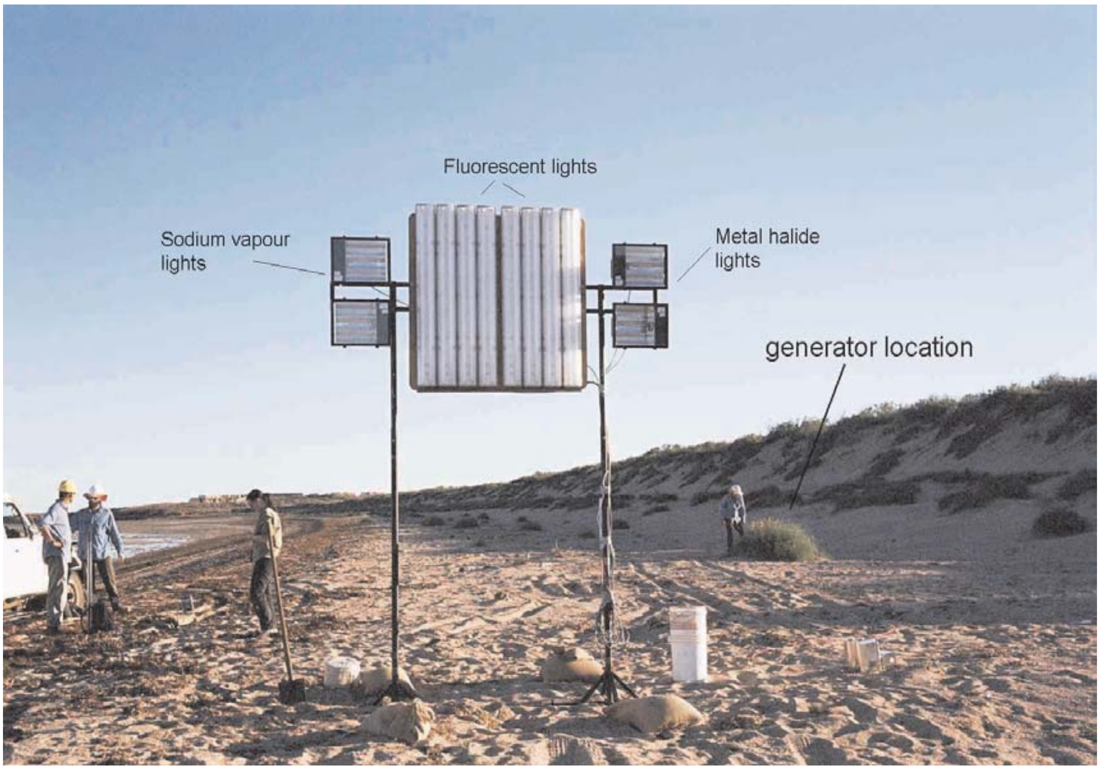


Plate 2: Light array set up for glow trials. (photo A Vitenbergs)

Attachment 4 - Barrow Island Light Survey 9-11 March 2004. Report to ChevronTexaco Australia Pty Ltd by Pendoley Environmental, March 2004.

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PROPOSED GORGON GAS DEVELOPMENT

BARROW ISLAND LIGHT SURVEY

9-11 MARCH 2004

REPORT TO SINCLAIR KNIGHT MERZ

BY

PENDOLEY ENVIRONMENTAL PTY LTD

24 MARCH 2004

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Tables

Figures

Plates

Front piece plate: Metal halide lights and flare at the CPF

1 Introduction

This study was commissioned by Sinclair Knight Merz on behalf of ChevronTexaco Australia. It forms a component of the environmental engineering and biological risk assessment for the Gorgon Gas Development project.

1.1 Literature Review and Background

Large oil and gas processing facilities are typically operated 24 hours a day. Illumination is therefore required for night shift operators working in and around facilities. Historically the most common type of light used in industrial settings are unshielded high pressure sodium vapour, low pressure sodium vapour, halogen and fluorescent lights which are generally elevated high above the facilities.

All of these anthropogenic light sources emit in the visible range of the electromagnetic spectrum. Visible light falls between short wavelength ultra-violet (<400 nm) and long wavelength infra-red (>700 nm) radiation. The spectrum of visible light is shown below and ranges from 400 nm (violet) to 700 nm (red).

<400 ultra-violet	400-450 violet	450-500 blue	500-570 green	570-590 yellow	590-610 orange	610-700 red	>700 infra-red

White light, such as that produced by most electric light sources, consists of a mixture of the different colours of light.

The amount of photopic (light adapted) light falling on a unit of area over a given distance is termed illuminance and is measured in lumens/m^2 or Lux. Lux is a measure of the power of visible light and depends on the sensitivity of the human eye. It is based on the CIE Luminous Efficacy Curve for photopic conditions (Figure 1). The CIE curve has minimal response to light at the ends of the spectrum (400-500 nm and 625-700 nm) and has a peak response at 555 nm. Hence the quantification of light emissions in Lux will include little of the light that is emitted between 400-500 nm and 625-700 nm and will be an underestimate of the amount of the total light that is being emitted.

Some typical illuminance values are:

Bright sunlight	100,000 lx
Cloudy day	10,000 lx
Night sports field	200 – 1,000 lx
Residential street	1 – 10 lx
Full moon	1 lx
Cloudy moon	0.25 lx

(Sources www.schorsch.com and www.pc.ibm.com)

The amount of illumination received by a sensor (or eye) varies inversely with the square of the distance from the point source. So if the distance from a point source is doubled the intensity is reduced by a factor of 4. Tripling the distance decreases the intensity by a factor of 9 and so on. As the distance from a point source increases the intensity of the light that can be detected decreases.

The two main sources of light are incandescent and gas discharges. Incandescent sources can be anything that produces light when heated to 1000°K or more. Natural incandescent sources are candle light fire and the sun. Man made sources are tungsten filament light bulbs. Passing an electric charge through a gas can also produce light. The colour of the light is a function of the gas used. The intensity of the light is a function of the density of the gas. High pressure light sources will produce a more intense light relative to a low pressure sources (i.e. high pressure sodium vapour vs. low pressure sodium vapour). Common gas discharge sources are sodium vapour, mercury vapour and fluorescent lights.

Light sources are characterized by their colour, temperature and spectral power distribution. A light source with a cool colour temperature, such as a candle flame (1900°K) will emit greater amounts of long wavelength red/yellow light than short wavelength blue/green light. Conversely the much higher temperature of the sun (25,000°K) emits light weighted towards the blue end of the spectrum. As the temperature of the source increases, the colour of emitted light moves from red to yellow to blue.

Lights are generally described using a spectral power distribution curve. This is a visual profile of the colour characteristics of a specific light source. A light type emits different amounts of energy at each wavelength across the visual spectrum (380nm-780nm). The graph of the power emitted across the spectrum is termed the Relative Power Distribution Curve for that light source.

The power distribution curves show consistent characteristics for the two main light sources. Incandescent light sources such as the sun or a flame emit an even power output across the spectrum. Gas discharge sources on the other hand are characterized by spikes and a marked unevenness in the amount of energy emitted at different wavelengths.

Turtles and Light

The many properties of light, temperature, intensity, wavelength, directivity and polarization are all thought to play a role in sea turtles hatchling orientation (Lohmann, Witherington et al. 1997). Brightness of a light is a function of intensity and wavelength and how the eye perceives light.

Electroretinography (ERG) studies (Granda and Dvorak 1977) have shown that Green turtles are most sensitive to violet to yellow light (400nm- 600nm). Relative to the human eye this is skewed toward the blue end of the spectrum (Lutz and Musick) and is thought to be an adaptation to reduce the attractiveness of the rich yellow – red light of the rising and setting sun and moon. It is this light that is not registered by standard photometers measuring in Lux.

Physiological studies by Granda and Dvorak, 1977) have shown that sea turtles see both colour and form well. These researchers have shown that the spectral sensitivity curves for sea turtles fall between 400 and 700nm, with peak sensitivity in the short wavelength region between 400 and 640nm. Sensitivity falls off rapidly between 640nm and 700nm. Light emitting in the short wavelength blue, green and yellow range is therefore thought to be most disruptive to sea turtle orientation.

Industry sponsored studies have been carried out on electric lights and gas flares at Thevenard Island (Hick 1995) and Varanus Island (Hick and Caccetta 1997; Pendoley

2004a in prep). Similar methods and equipment were used for this current study on Barrow Island.

1.2 Objectives and scope

The primary aim of this project was to measure the intensity and spectral signature of electric lights and flares typically found on Barrow Island.

The existing light field on east coast Barrow Island beaches was also measured to provide a baseline measure of the existing light field at two east coast turtle nesting beaches prior to development activities.

2 Methods

The field survey took place over 2 nights, March 9-11, 2004. The survey team comprised K. Pendoley and A. Vitenbergs both of Pendoley Environmental Pty Ltd.

The field light monitoring program was conducted using an Ocean Optics USB2000 miniature spectroradiometer. The measurable light levels and spectral characteristics were gathered from point source lights at the WAPET Camp (measured from Yacht Club Beach), the Landing (Plate 6), the Terminal Tanks area (Plate 7) , the suck back pump on Terminal Beach (Plates 8 and 9), the Central Processing Facility (CPF) and the Base area. Measurements of the CPF and J Station flares were also made. Measurements were made up to 500 m from light sources. This was the limit of the spectroradiometer's sensitivity to the individual light sources. Baseline light measurements were made on fixed bearings from the beach sites (approximately 90°, 180°, 270° and 360°).
GPS positions were taken to allow sites to be revisited over time. Originally this survey was timed to coincide with a late evening moonrise (>50% moon phase, waxing moon), however that survey was delayed due to tropical cyclone Evan. The moonrise during the rescheduled survey (March 9-11) was earlier in the evening (2025 hrs March 9 and 2110 hrs March 10) and did not allow time for measurements both before and after moonrise at all locations. The moon was waning at the time of the survey; phases were 93.5% March 9 and 86.8% March 10. It is important for any questions about why measurements were not made both before and after moon rise and also for anyone who might do future monitoring,

The passage of tropical cyclone Evan caused some damage to field lighting. Consequently the first night of the survey the Terminal Tank lights were not operational. Access to electrical maintenance personnel was limited since the staff were involved with repairs throughout the field. Consequently, the detail on field lighting contained here is a reflection of the limited amount of time that electrical maintenance personnel could spend assisting this project.

3 Results

Table 1 is a list of the spectral measurements collected over the two nights of March 9 and 10, 2004. The light files are coded for location as follows.

YC	Yacht Club
TB	Terminal Beach
TL	The Landing
CPF	Central Processing Facility
FB	Flacourt Bay
JF	J station flare
B	Base area

Selected spectra have been graphed and the figure numbers are also listed in Table 1 for reference. Each survey location is shown in the applicable Plates (1-5). Relative power distribution curves (spectra) are shown in Figures 1-5. The results are presented by location below.

Yacht Club Beach – Figure 1, Plate 1

Lights were measured from two locations on Yacht Club Beach, YC1 and YC 2. The target lights (both measured from YC1) were the twin 80 W sodium vapour lights behind the gym in the parking lot (Fig 1a) and the 400 W sodium vapour light on the mess (Figure 1b). Only the gym light was detectable from YC2, at a distance of 285 m. All other scans (north, south, west and east) from these two locations produced spectra with light signals undetectable above base line noise and is representative of a dark night sky. (e.g. Fig 1d).

The sodium vapour light spectra show the characteristic spiking of gas discharge sources. The peak at 500nm is in the blue region; however most of the light is concentrated in the yellow/orange/red region between 570 and 650 nm.

Terminal Beach – Figure 2, Plate 2

Spectra's were collected from four locations on Terminal Beach; at the suck back pump, 100 m along the beach, 192 m along the beach at the creek bed and 500 m along the beach from the rocks at the south end of the beach. North, south, east and west spectra were collected from each location (Fig 2a-2d) as well as scans specifically targeting the 80 W sodium vapour light at the suck back pump from each location (Fig 2e – 2g). Fig 2e also shows the increase in light intensity that occurred as the sodium vapour suck back pump light warmed up after turning it on. All but the scans specifically targeting the suck back pump light produced spectra characterised by baseline noise (no light signals detectable). The 80 W sodium vapour light at the suck back pump was detectable from a maximum of 192 m.

A scan of the sky above the terminal tanks is shown in Fig 2h. Little sky glow was observed over the tanks from the beach and the spectral scan of the sky over tanks from the suck back pump (583 m away) found no signal detectable above background spectrometer noise. A representative 400 W sodium vapour light was measured from 25 m away and is shown in Fig 2i.

An example of moon light is shown in Fig 2j and was measured from the suck back pump location with the light turned off. The spectra shows the characteristic even power distribution across the spectrum, which is typical of an incandescent light source, peaking at 550 nm.

The Landing – Figure 3, Plate 3

400 W sodium vapour lights were present at the Landing. Scans of these lights from 30 m and 80 m are shown in Fig 3a. Because these lights are held within a box structure it was possible to scan them as shielded lights by collecting spectral response of the sky glow over the light from behind the fixture. The result is shown in Fig 3b and is indistinguishable from baseline noise.

Central Processing Facility – Figure 4, Plate 4

The incandescent emissions from the CPF flare are shown in Fig 4a (from 946 m), Fig 4b (from 723 m) and Fig 4c (from 126 m). These spectral emissions are faintly detectable for 723 m and clearly show the spectral emission continuum across the wavelengths, peaking at 700 nm, from 126 m. This flare has a flow rate of ~8,500 m^3/day.

The same range of distances was used to measure the bright white lights at the CPF. These lights were labelled as high pressure sodium (HPS) and low pressure sodium

(LPS) on the as built drawings for the facility however the spectral scan indicates these lights are actually metal halides (Fig 4d-4f). A visual assessment of the lights further showed they did not emit the characteristic yellow coloured light generally seen in sodium vapour lights (see front page plate). Figure 4f clearly shows the strong spectral emissions spiking between 400 and 600 nm.

J station flare – Figure 5, Plate 5

The J station flare was measured from 2 distances, 168 m and 371 m (Fig 5a). The spectra are characteristic of incandescent light sources, emitting strongly from 600 nm onwards (orange/red region) with a peak in emissions occurring at 700 nm.

The greater flow rate of the J Station flare (~ 7 times) over the CPF flare is reflected in the relative intensity signals with the J station signal 7 times greater than the CPF flare.

Base – Figure 6, Plate 5

Two other light types typically found in industrial settings were scanned at the Base area, a mercury vapour light (Figure 6a) and a 36 W Fluorescent (Figure 6b). Both are gas discharge lights and are characterised by the spiked and uneven power spectrum that is typical of these light sources.

The mercury vapour is common in workshop settings and produces a bright white light that may be tinged with green as a result of strong emission spikes at 400 - 500 nm. Similarly the fluorescent light is a bright white light that emits strongly from 400 – 650 nm with spiking between 400 and 550 nm.

4 Discussion and Conclusions

- The light types commonly used on Barrow Island include; Sodium vapour, 80 W, yellow street light style, common at separator stations and in parking areas
- Sodium vapour 400 W, yellow box style, common in field locations such as the Landing, the Terminal Tanks, separator stations, airport, parking and lay down areas.
- Fluorescent 18 W (2' long) and 36 W (4' long), white light, over doorways to buildings, and control rooms at separator stations
- Metal halides, bright white at the CPF facility.
- Mercury vapour, bright white lights with or without a green tinge, in workshop areas
- Incandescent tungsten bulbs, bulkhead lighting around camp (not measured but identified by the field maintenance staff).

This list is not exhaustive; there was not sufficient time to fully document all of the light locations, types and wattages on the island. It is likely a more thorough survey would identify additional light sources and types such as halogens and incandescent and possibly additional metal halide lights. This study focussed on the lights most commonly used and those most visible from turtle nesting beaches.

The most common light type used in outdoor field locations at Barrow Island are the sodium vapour lights (nominally 80 W and 400 W). With the exception of the suck back pump light, these lights are typically located atop 6-8 m tall poles and are oriented at ~20° from vertical. These are the lights that are most visible to turtle nesting beaches near the Landing (Plate 6), the Terminal Tanks (Plate 7), Terminal Beach suck back pump (Plates 8 and 9) and the WAPET Camp locations (Plate 10).

Less common are the metal halide (CPF), fluorescent and mercury vapour lights.

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 meters. The quantification of light emissions is a function of numerous factors including light source type and power (wattage), detector sensitivity, ability to target a light source, distance to the light source and atmospheric scattering. Because the measurement of light is limited by the sensitivity of the measuring instrument and it is not unusual for a light (and particularly a glow) to be visible to the human (and sea turtle) eye but undetectable by an instrument (ie spectrometer, lux meter, illuminance meter). It cannot be assumed that because an instrument cannot detect a light emission that the sea turtles cannot see it.

Studies on the response of sea turtle hatchlings to different light wavelengths suggest that while they are able to see light up to 640 nm, hatchlings respond most strongly to short wavelengths, particularly at low light levels at night (Witherington and Bjorndal 1991; Witherington 1992; Pendoley 2000; Pendoley 2004a in prep). Sea turtle hatchlings integrate the light field across a 180° horizontal field of view when engaged in sea finding. Because of this they are often susceptible to misorientation from low intensity light glow spread across a wide horizontal area. Distant point sources of light are thought to be disregarded as cues by hatchlings since they resemble stars. However bright point sources of light will attract hatchlings if they are located close (distance depends on the type and intensity of the light) to the animal. The hatchlings become trapped by the light and blinded to the surrounding darkness.

Consequently the lights most disruptive to sea turtle hatchlings on Barrow are likely to be the bright white lights that emit low wavelength light, such as fluorescent, metal halide and mercury vapour. These low wavelength blue/green emissions of these lights are strongly detected by dark adapted eyes (scotopic vision) and are therefore likely to be highly disruptive to sea turtle hatchlings at low intensities at night. These lights were not found at any of the coastal locations monitored during this survey.
The lights least disruptive to sea turtles are the flares and the sodium vapour lights that are currently used at the coastal locations on Barrow. These lights emit at higher wavelengths to moonlight and are therefore less attractive to hatchlings in comparison. The yellow light also causes less atmospheric scatter than white lights, reducing glow in the sky (www.darksky.org/handbook/le-hb-v1-14.html), with LPS lights producing less glow and scatter than HPS.

Under certain conditions however these lights can still be disruptive to Flatback hatchlings. Whilst conducting the light survey, a group of ~30 Flatback hatchlings that had been rescued from a perentie during the day were released that night on Terminal

Beach. Half of the group was released within 100 m of the light and the other at 192 m from the light (at the creek bed location), all of the animals oriented along the beach towards the suck back pump light and were found half an hour later trapped within the light spill at the base of the light.

Additional biological surveys are planned for April 2004 to further study the impacts of different light types, intensities and presentation (bare bulb vs. shielded) on Flatback hatchlings.

In summary

- HPS and LPS are the most common light sources on Barrow Island
- The existing sodium vapour lights are visible from turtle nesting beaches however little of this spectral energy reaches the beaches.
- The sodium vapour lights produced little visible sky glow from east coast nesting beaches.
- Individual lights can be detected up to a maximum of 250m (depending on type and wattages) using the Ocean Optics USB2000 spectroradiometer.
- Most scans of the night sky at beach locations registered little or no light above the baseline noise signal.

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Plate 6: 400W sodium vapour lights at the Landing

Plate 7: 400W sodium vapour light at the Terminal Tanks

Plate 8: 40W sodium vapour light at the suck back pump

Plate 9: 40W sodium vapour light at the suck back pump, close up

Plate 10: twin 80W sodium vapour street lights over camp parking lot.

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Technical Appendix C8

Marine Benthic Habitats

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

MARINE BENTHIC HABITATS

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April 2005

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1 Introduction

ChevronTexaco Australia Pty Ltd (ChevronTexaco), on behalf of the Gorgon Venture participants, proposes to develop a gas processing facility on Barrow Island. Marine infrastructure for the proposed development would have elements on both the east and west coast of Barrow Island, comprising:

- a feed gas pipeline or pipelines from the offshore Gorgon gas field to the west coast of Barrow Island with a shore crossing at North White's Beach or Flacourt Bay
- a causeway and materials offloading facility (MOF) at Town Point with associated dredged channel for barge access on the east coast
- an open-pile jetty from the MOF to an offshore product loading (tanker) facility with dredged shipping channel and turning basin
- a domestic gas pipeline and fibre optic cable from the east coast of Barrow Island to the mainland.

Impacts to marine biodiversity are extremely difficult to assess in the absence of regional baseline studies of faunal or flora diversity. In light of the paucity of information on the distribution and abundance of much of the state's marine biodiversity (predominantly invertebrates), the twin goals of maintaining biodiversity and maintaining ecosystem function can be achieved through protection of the benthic habitats on which the ecosystems depend. Marine managers generally assess the conservation significance of areas such as marine conservation reserves on the basis of benthic habitats according to their significance to important fauna, their contribution to ecosystem productivity (benthic primary producers) or their assumed role in maintaining biodiversity, for example IMCRA (1998), CALM (2004), EPA (2003).

ChevronTexaco, on behalf of the Gorgon Venture participants, engaged RPS Bowman Bishaw Gorham to survey marine benthic habitats in the proposed development areas to assist in the formal assessment of the environmental implications of the proposal. This report describes the results of current and previous surveys in the area, in a regional context, to facilitate assessment of potential impacts associated with the proposed development.

Intertidal habitats, including mangroves and marine protected species are covered in separate technical appendices (Appendices C6 and C9). Impacts on benthic primary producers are covered in Chapter 11 of the main report.

Dredging of the access channels to the offshore product offloading facility and MOF would require disposal of dredged material to a designated spoil ground. Seabed surveys are underway to examine potential dredge spoil grounds off the east coast of Barrow Island. The dredge spoil ground would be sited and assessed within the procedures of a dredging licence application under the *Environment Protection (Sea Dumping) Act 1981* and will be reported separately.

2 Methods

The survey comprised a review of the available information describing the marine environment of the area and field surveys at the locations of proposed infrastructure. Assessment of potential impacts from the proposed development was based on the results of field observations, general knowledge of the area from previous surveys and literature on the area.

2.1 Field Surveys

Field surveys were undertaken during August 2002, January 2003 and January 2004 to identify any areas of high conservation significance within the areas of potential impact from the proposed Development. The survey team examined subtidal benthic habitats in the following areas:

- near the existing and proposed offshore wells
- along the feed gas pipeline route to the west coast of Barrow Island
- in the areas associated with the nearshore facilities on the east coast
- along the domestic gas pipeline to the mainland.

Subtidal, benthic marine habitats were surveyed using a combination of video transects and snorkel diver surveys.

Video transect surveys involved towing an underwater video camera behind the survey vessel to assess benthic habitats in the possible development and nearby reference areas. Marine biologists assessed the videography as it was captured to characterise benthic habitats and assemblages. Positional accuracy along the survey routes was monitored using GPS receivers linked to real time GIS and navigation software.

Snorkel diver surveys involved marine biologists 'bounce' diving to examine and photograph benthic habitats that were identified from existing aerial photography of the area or from the video surveys.

2.2 Habitat Distribution and Mapping

Broad-scale habitat maps for the east and west coast development areas were created from aerial photography flown in October 2001. Ground-truth data collected during the August 2002, January 2003 and January 2004 surveys were used to confirm habitat descriptions in potential impact areas and to assist in characterising the broader distribution of benthic habitats apparent in other areas from the aerial photography. The extent of the ground-truthing surveys is shown in Figure 2-1 and Figure 2-2.

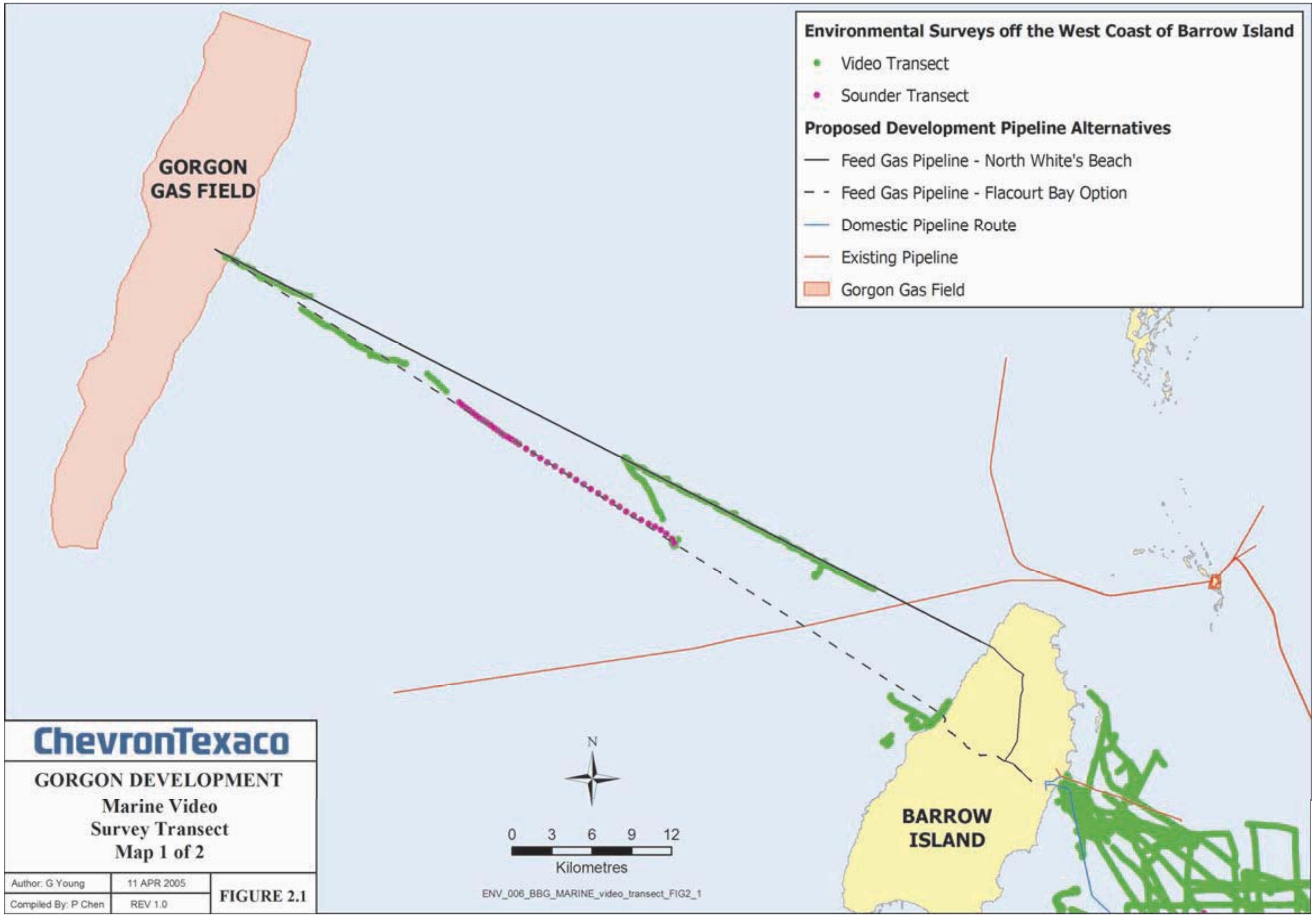

Figure 2-1 - Environmental Surveys off the West Coast of Barrow Island

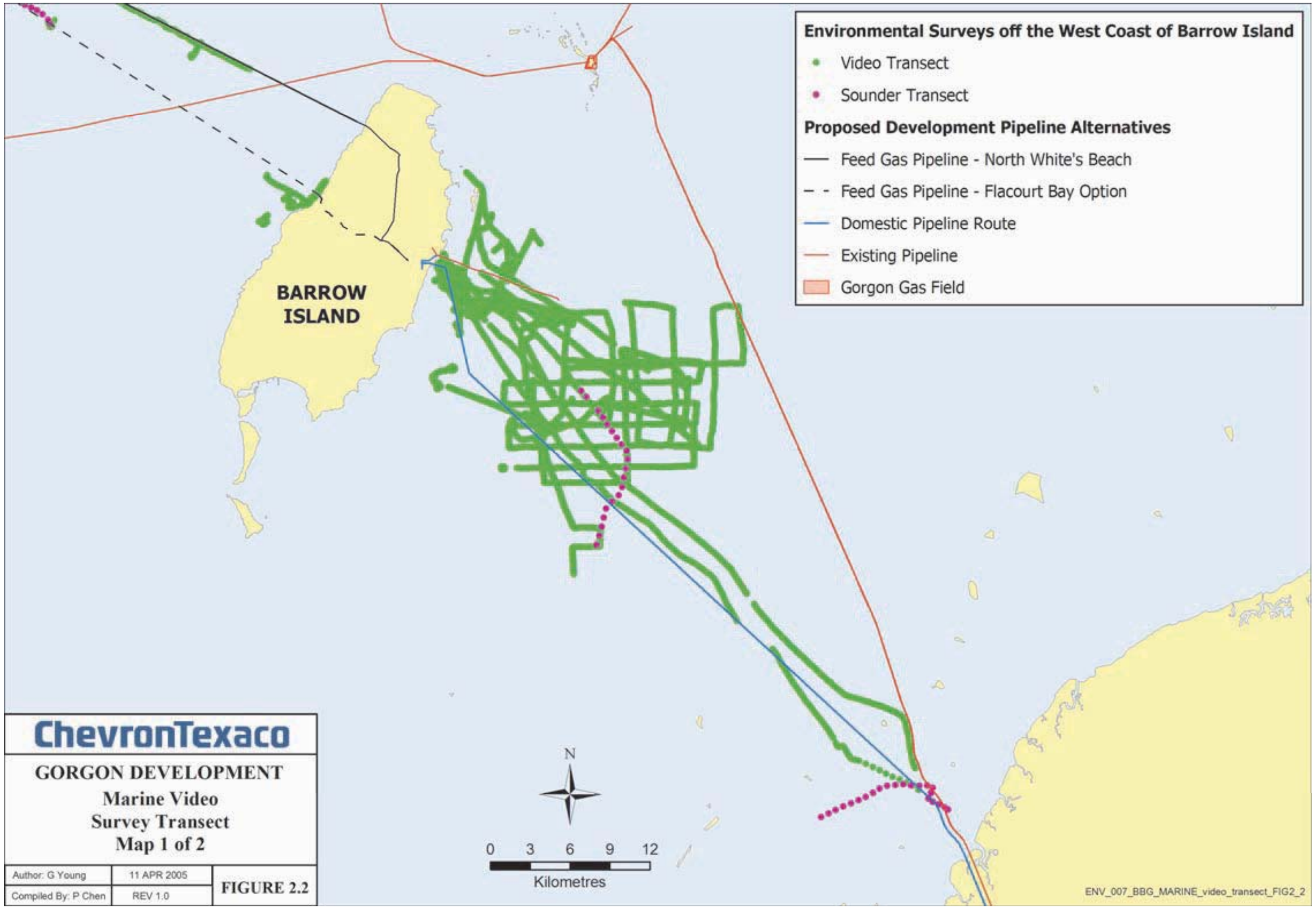

Figure 2-2 - Environmental Surveys off the East Coast of Barrow Island and Along the Proposed Domestic Gas Pipeline Route to the Mainland

Mapping of habitats from the aerial photography in areas beyond the ground-truthed survey area also incorporated field data from previous surveys and an existing regional habitat map (Bancroft and Sheridan 2000; CALM 2004). The proposed development area has been mapped at finer resolution and is better ground-truthed than the regional benthic habitat map (CALM 2004). The habitat data for the east coast of Barrow Island has been submitted for incorporation into the revision of the Draft Management Plan for the Montebello/Barrow Islands (CALM 2004) and in revision of CALM's regional marine GIS database.

The extent of high-profile seabed features was further distinguished from the survey vessel's sounder trace and from bathymetry data produced during side-scan sonar surveys by Fugro Survey.

3 Regional Marine Environment

3.1 Introduction

The Rowley Shelf is a large, shallow (less than 20 m) submarine limestone shelf extending up to 80 km from the West Pilbara coast. The shelf is composed mainly of Pleistocene limestone overlain in places by sediments of various thickness and particle size. The geomorphology of the shelf is characterised by chains of islands running roughly parallel to the mainland coast.

Barrow Island, the Montebello Islands and the Lowendal Islands are the furthest offshore islands on the Rowley Shelf. These islands are separated from the inner part of the Rowley Shelf by the Flinders Fault and collectively form the Barrow-Montebello Complex (Wilson et al. 1994).

The proximity of Barrow Island to the western edge of the Rowley Shelf results in a wide range of oceanographic conditions around the Island. The west coast is highly energetic, being subject to persistent southerly winds and strong influence of deep ocean swell and large-scale, along-shelf currents. The east coast is far less energetic and is more strongly influenced by tidal currents.

3.2 Regional Benthic Habitats

The large variety of oceanographic and physical conditions occurring in the region, notably water depth, substrate type, turbidity, tidal regime and energetics, create a large variety of marine benthic habitats and associated assemblages of flora and fauna. This section describes the following five main subtidal habitats that dominate the region:

- coral reefs and bombora
- seagrass and macroalgae meadows
- invertebrate filter feeder assemblages on pavement
- deeper high profile reefs
- soft sediments.

3.2.1 Coral Communities

Coral assemblages and reefs provide a structurally-complex habitat for a diverse array of fish and invertebrates. The habitat value of a coral area is dependent on its structural complexity, age, stability and proximity to other coral habitats. Corals spawn annually or bi-annually and the constant cycle of death and recruitment is vital in maintaining the ecological function of the habitat.

The broad, shallow Rowley Shelf contains a vast variety of coral habitats and communities. The principal coral habitats include turbid inshore pavements, raised limestone shoals, fringing coral reefs around sand cays and offshore reefs in clear water. The small islands along the mainland coast are also generally fringed by reef platforms supporting diverse coral assemblages in relatively turbid water.

The diversity of coral communities in the region was illustrated by a Western Australian Museum survey in 1993, where 150 species of corals representing 54 genera were identified from the Montebello Islands (Marsh 1993).

A number of coral communities within the Barrow-Montebello Complex have been recognised as regionally significant and have been afforded special protection within the sanctuary zones of the Montebello Islands Marine Park and the Barrow Island Marine Park (CALM 2004). These coral communities include:

- Fringing reef communities to the west of the Montebello Islands.
- Patch reefs and bomboras stretching along the south eastern Montebello Islands.
- Biggada Reef on the west coast of Barrow Island.

Although the distribution of corals within the Montebello/Barrow Islands Marine Conservation Reserves is not well known, other extensive coral communities within the Barrow-Montebello Complex which have high species diversity or their known distribution within the region is restricted, may likewise be considered to be of regional significance. These coral communities include:

- An extensive coral reef on the eastern side of the Lowendal Shelf.
- Coral patch reef and bombora fields on the southern end of the Lowendal Shelf.
- Dugong Reef
- Batman Reef
- Barrow Island Shoals.

Locally significant coral communities in the waters surrounding Barrow and the Lowendal Islands include:

- Coral assemblages that fringe parts of the north-east and east coasts of Barrow Island.
- Coral assemblages on the eastern side of Double Island.
- A series of bomboras along a raised limestone ridge offshore of Shark Point on the eastern side of the Barrow Island.

3.2.2 Coral Communities Surrounding Barrow Island

Biggada Reef (Figure 3-1) is an extensive, largely intertidal coral reef on the west coast of Barrow Island that extends into the subtidal zone. It is the basis of the Barrow Island Marine Park (CALM 2004) and is the best developed seaward coral reef on the west side of the Island. Subtidal coral habitats are well developed in the lagoon of Turtle Bay and on the south western side of the fringing reef (Plate 3-1).

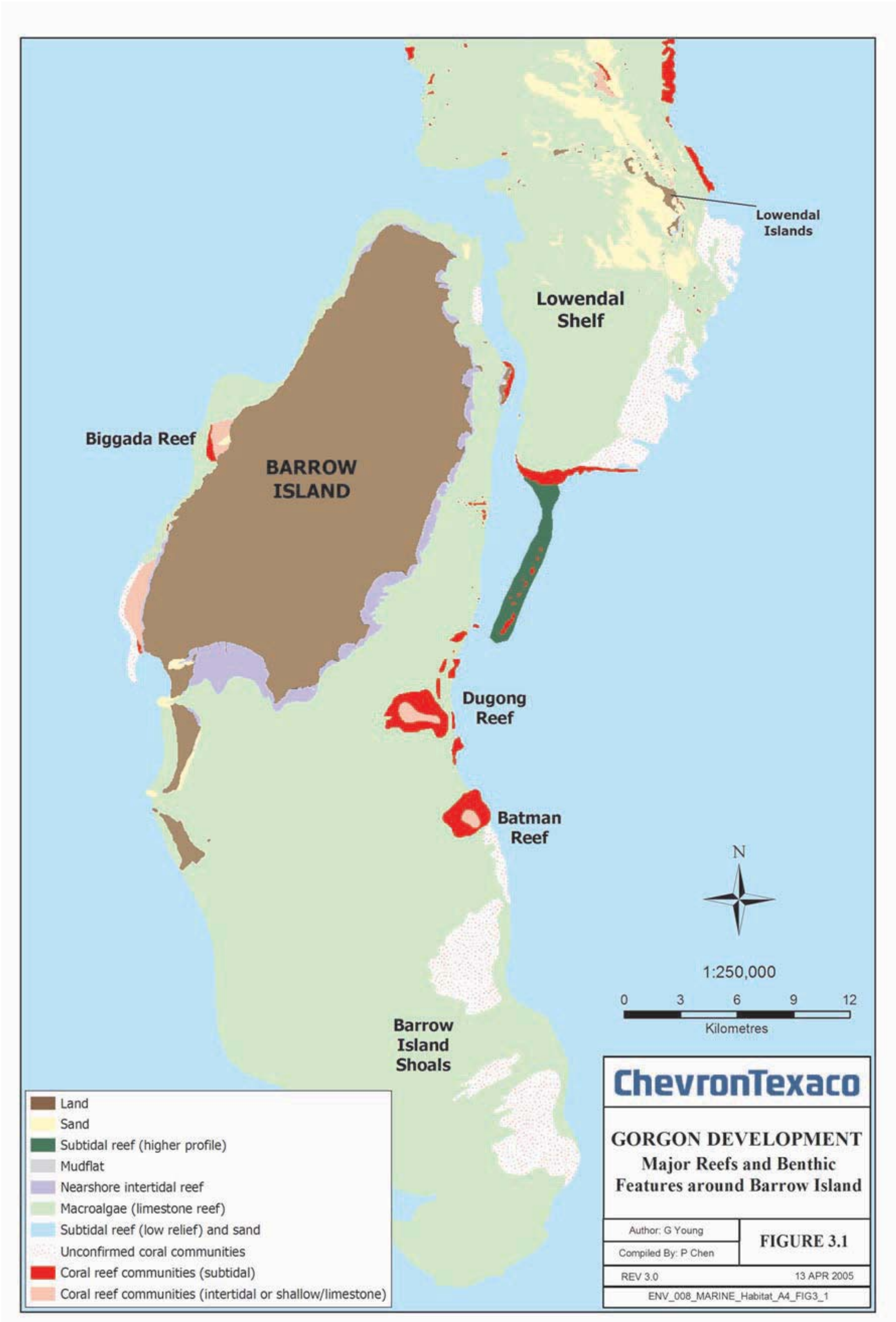

Figure 3-1 - Major Reefs and Benthic Features Around Barrow Island

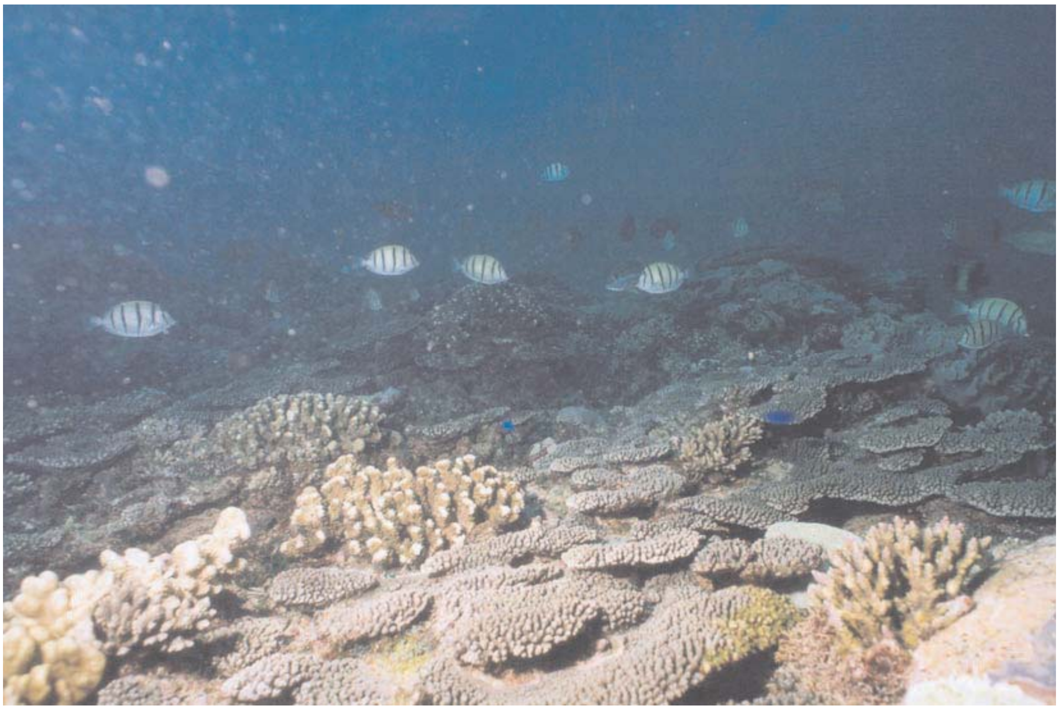

Plate 3-1 - Corals on the Southern End of Biggada Reef

A large *Acropora* thicket on the southern end of the Lowendal Shelf is partly dead, but structurally intact (Plate 3-2). The size of this relatively-fragile habitat indicates the area is little affected by cyclonic swells. Large coral bombora fringe the south-western edge of the shelf. These bombora are predominantly *Porites* colonies with numerous other associated corals (Plate 3-3).

Plate 3-2 - *Acropora* Coral Reef on the South-Western Edge of the Lowendal Shelf

Plate 3-3 - Coral Bomboras Along the South-Western Edge of the Lowendal Shelf

Large coral patch reefs have developed along the edge of Barrow Island Shoals, on the south east side of Barrow Island (Figure 3-1). The largest of these, Dugong Reef, was severely degraded, possibly due to an anoxic event associated with coral spawning in 1991. Surveys conducted on the reef in 1994 (Bowman Bishaw Gorham 1994) identified at least 4.2 km^2 of dead coral. Another highly diverse live coral community on Barrow Island Shoals was less affected.

Narrow coral assemblages fringe parts of the north-east and east coasts of Barrow Island. The extent and species composition of the north eastern coral community are unknown. It lies approximately 1.5 km from the shore and extends at least three kilometres along the edge of the shallow subtidal platform between Square Bay and Ant Point. The eastern coral community, offshore from Shark Point, comprises isolated patches of coral that extend for up to 1.3 km and run roughly parallel to the coast of Barrow Island. Preliminary observations indicate a series of large *Porites* bomboras and mixed coral species bomboras, rising out of approximately 5–8 m water depth at both locations.

The reef platform fringing the east coast of Barrow Island also supports scattered small coral bombora (up to 1.5 m high). There are also many bombora covered with macroalgae that appear to be overgrown dead corals.

3.2.3 Seagrass and Macroalgae

Seagrasses and macroalgae are important components of shallow tropical marine environments. They are important primary producers and significant contributors to the productivity of the region. In addition to providing energy and nutrients for detrital and grazing food webs, they provide food for protected animals such as dugong (*Dugong dugon*) and green turtles (*Chelonia mydas*). Dense seagrass and macroalgal meadows enhance the habitat value of abiotic benthic habitats by increasing structural diversity and by stabilising soft substrates. Seagrass and macroalgae habitats vary seasonally in response to water temperature, day length, reproductive cycles, physical disturbance and regrowth.

Seagrasses occur within the photic zone throughout the Montebello/Barrow Island region and although widespread, they generally form sparse communities in the Barrow Island region (CALM 2004). The most common species are *Halophila ovalis* and *Syringodium isoetifolium*. Less common species include *Cymodocea angustatus*, *Halodule uninervis*, *Thalassia hemprichii* and *Thalassodendron ciliatum*.

Halophila spp. are the most common seagrasses on shallow soft substrates and sand veneers throughout the area. They extend from the intertidal zone to approximately 15 m water depth. Sparse seagrass meadows are also widespread along the mainland coast on the shallow subtidal sediments, although these meadows probably have a narrower depth range due to the high turbidity of nearshore mainland waters.

Macroalgae are very common components of marine environments in the shallow waters of the Pilbara. CALM (2004) estimate that macroalgae meadows make up 40 per cent of the benthic habitats of the Montebello/Barrow Islands Marine Conservation Reserve. Abundant macroalgae in the region include Phaeophytes (brown macroalgae) such as *Sargassum*, *Dictyopterus*, *Dictyota, Cystoseira* and *Padina*, Chlorophytes (green macroalgae) such as *Halimeda*, *Codium* and *Caulerpa* and Rhodophytes (red macroalgae) such as *Hydrolithon* and *Laurencia*.

Large brown macroalgae, especially *Sargassum*, dominate the extensive shallow limestone pavement reef around Barrow Island (Plate 3-4). They have the largest thalli and contribute most to the biomass on shallow pavement reefs. *Sargassum* spp. undergo large seasonal variations in biomass, having a summer growth and reproductive stage, followed by winter senescence. During summer, the extremely foliose thalli of this species may exceed one metre in height. In winter, when the reproductive thalli are shed, the senescent stipes are generally less than 20 cm high.

The biomass of macroalgae and seagrass meadows is also controlled by physical stressors such as wave energy, sedimentation and insolation. On the high-energy west coast platforms of Barrow Island, the macroalgae form short dense ‘turfs’. On the calmer subtidal platforms on the east coast and in deeper areas beyond the wave zone on both coasts, the meadows are more luxuriant.

Plate 3-4 - *Sargassum*-dominated Macroalgae Bed on Pavement Reef off the East Coast of Barrow Island

3.2.4 Filter Feeding Communities

Deeper limestone pavements on the southern Rowley Shelf sometimes support a diverse community dominated by attached filter-feeding invertebrates. These communities typically contain diverse assemblages of tubular, digitate, laminar, branching, globose and encrusting sponge species in association with gorgonians, including sea fans (Subergorgiidae and Plexauridae) and sea whips (Leptogorgiidae), colonial and solitary ascidians, bryozoans, algae and small scleractinian corals (e.g. *Turbinaria*). These assemblages of sessile, filter-feeding invertebrates are attached to the pavement reef and provide a habitat for fish and mobile invertebrates.

Filter-feeder dominated pavement habitats are widespread between Barrow Island and the mainland and in areas of exposed pavement on the west coast of the Island. It is likely that any area of exposed pavement reef, in water too deep for macroalgae to become established, will support a filter-feeding assemblage. The habitat value of these areas is dependent on how well developed the assemblages are. Areas that are regularly smothered by sand sheets are unlikely to support more than a sparse, transient assemblage.

3.2.5 High Profile Reefs

Deeper, high-profile reefs off both coasts of Barrow Island support filter-feeding assemblages, however, their value as habitat for larger organisms, such as fish, is in their structural complexity. Shallow, high-profile reefs support macroalgae and also provide shelter for fish. Reefs standing up to 5–8 m above the surrounding seabed generally have undercut caves and ledges and are important refugia for larger vertebrate fauna.

Extensive high-profile rocky reefs are generally linear features, either adjacent to a high energy shoreline or remnants of historical shorelines. There are high-profile reefs on both sides of Barrow Island and probably throughout the Montebello/Barrow Islands region.

A large reef ridge runs parallel to the east coast of Barrow Island from the south end of the Lowendal Shelf. There are numerous high-profile rocky lumps (possibly dead corals) on the platform adjacent the east coast of Barrow Island. These are relatively isolated and presumably of lower habitat value than extensive reef areas.

On the west coast of Barrow Island there are high-profile reefs adjacent to the shore and there are two rocky ridges of variable height in 40–50 m water depth offshore. The nearshore reefs are covered with dense *Sargassum* and other algae and provide habitat for fish and turtles. The offshore ridges run in a north-south orientation and are of variable height above the seabed. They support invertebrates and an abundant fish fauna.

3.2.6 Soft Sediments

Soft sediment habitats generally support a diverse assemblage of burrowing and crawling infauna, but are generally too unstable for larger attached organisms. These habitats offer little structural diversity and are dominated by detrital-based faunal food webs. Their habitat value is generally dependent on oxygenation levels through the sediment profile, particle size, wave energy and the amount of allochthonous organic matter in the sediments. Finer sediments and detritus generally accumulate in low energy areas and support richer infaunal assemblages.

Soft sediment habitats are widespread in deeper offshore areas off the west coast of Barrow Island and throughout the region. These fine sands, silts and clays are expected to support diverse infaunal assemblages, as is evident at East Spar (Kinhill 1999). Sediments in the shallower area off the east coast of Barrow Island are less stable and generally comprise coarser particles. These sediments are affected by wave energy and currents and tend to be relatively mobile. Pavement habitats between Barrow Island and the mainland are covered by a sediment veneer that appears to periodically move, exposing areas of pavement reef. Sessile benthic organisms that require hard substrates for attachment, such as gorgonians, are frequently seen emerging through a shallow veneer of sand (Plate 3-5). These mobile sand sheets are generally of lower habitat value to infauna and are less likely to support diverse infaunal assemblages.

Plate 3-5 - Scattered Soft Corals and Seagrass on Sand in Deeper Waters off the East Coast of Barrow Island

3.3 Conservation Reserves and Protected Fauna

A number of areas within the Montebello/Barrow Islands region are currently protected under state or Commonwealth legislation. Some of the faunal species in the area are also specifically protected. See Appendix C6 for coverage of marine protected fauna.

3.3.1 Conservation Areas

Within the Montebello/Barrow Islands region, there are two conservation parks and four nature reserves vested in the Nature Conservation Commission (Osborne et al. 2000):

- Montebello Islands Conservation Park (2 sections).
- Barrow Island Nature Reserve.
- Boodie and Double Islands Nature Reserve.
- Lowendal Islands Nature Reserve.
- Great Sandy Island Nature Reserve.

The Montebello Islands Conservation Park (Reserve Nos. 42196 and 42197) comprises more than 100 islands, islets and rocks. The islands are reserved as a Class A conservation park to the high water mark and as a Class C park down to low water.

The Lowendal Islands Nature Reserve comprises the land above the high water mark on 40 islands, islets and rocks including Varanus Island. It is a Class C Nature Reserve (Reserve No. 33502). Class C Nature Reserves are now referred to as reserves with conservation orders.

Barrow Island is a Class A Nature Reserve down to the low water mark (Reserve No. 11648). Barrow Island was given reserve status in 1908. Middle, Boodie, Pascoe, Boomerang and Double Islands, immediately south and east of Barrow Island, make up a Class C Nature Reserve (Reserve No. 38728) that extends down to the low water mark on these islands.

CALM (2004) has established system of marine conservation reserves to encompass the Montebello/Barrow Islands region. Within the Barrow Island Marine Management Area there are two areas of special protection, one a marine park and the other a marine conservation management area. The Barrow Island Marine Park covers Biggada Reef and surrounds on the west coast of Barrow Island, while the Bandicoot Bay Conservation Area (benthic fauna/seabird protection) covers the waters of Bandicoot Bay on the southern end of the island (CALM 2004).

The Great Sandy Island Nature Reserve is a Class B Nature Reserve (No. 33831) extending down to low water. The reserve includes one of the sand cays known as the Barrow Island Shoals to the south of Barrow Island and 25 islands between Barrow Island and the mainland coast.

4 Local Marine Environment

4.1 West Coast Development Areas

4.1.1 Gorgon Gas Field and Outer Feed Gas Pipeline route

The Gorgon gas field lies in approximately 200 m of water, 70 km off the west coast of Barrow Island. Video transects along the offshore end of the proposed feed gas pipeline route indicate that the seabed is primarily characterised by soft sediments. The survey followed the proposed pipeline route out to 180 m water depth. Rough weather precluded survey of the actual well-sites, however, the homogeneity of the seabed over the previous ten kilometres suggest the seabed at these sites is similarly soft sediment habitat.

The sediments are heavily bioturbated indicating a well-developed infaunal assemblage. These habitats are very widespread in the region and are of low conservation significance.

4.1.2 Feed Gas Pipeline Corridor

The benthic habitats along the proposed pipeline corridor are predominantly soft sediments of varying grain size, with isolated rocky reefs and patches of exposed pavement reef. The proposed pipeline route crosses the existing East Spar pipeline approximately ten kilometres from shore.

Sediment grain sizes tend to be smaller in the deeper offshore areas and larger in the surge affected nearshore areas. The nearshore sediments are rippled in many areas, indicating that they are continually reworked by swells. While the fine offshore sediments are heavily bioturbated, the coarser inshore sediments appear to support less infauna.

Scattered areas of exposed pavement reef support sparse filter-feeding assemblages, dominated by seawhips, gorgonians and sponges. There are rock piles associated with the East Spar pipeline and areas of exposed pavement reef near the point where the two pipelines would cross.

These habitat types are very widespread in the region and are of low conservation significance.

There is a high profile reef in 40–45 m water depth approximately 14 km off the west coast of the Island that rises several metres above the surrounding seabed. The reef is characterised by areas of exposed rocky platform reef and areas of upstanding reef. The platform reef supports scattered black corals (*Cirripathes*, *Antipathes*), sponges, seawhips (*Junceella*) and branching gorgonians. The upstanding reef with large ledges supports encrusting or lithophagic sponges and abundant fish. The reef appears to be part of a linear series of reefs that run north-south. Side scan data revealed features of a similar profile approximately five kilometres south of the pipeline corridor.

A second high-profile reef area was encountered in approximately 40 m water depth and 24 km offshore. This reef supported encrusting sponges, scattered deepwater coral (*Pachyseris*) and rubble around the reef. This reef was also evident in the side scan data.

The rocky reefs are large features that provide structural diversity to an otherwise planar seabed. They are of higher conservation significance as they are less widespread than the soft sediment habitats.

4.1.3 Shore Crossing at North White's Beach or Flacourt Bay

Benthic habitats in the nearshore areas off North White's Beach and Flacourt Bay are both characterised by bare sand habitats interspersed with areas of exposed limestone pavement and high profile rocky reef near the beach with no significant coral communities (Figure 4-1).

The high-profile reefs extend offshore from the rocky headlands to five to ten metres water depth. They stand up to three metres above the surrounding seabed, are undercut with small caves and ledges and are dissected by channels. They support well-developed macroalgae meadows dominated by *Sargassum*, *Dictyopterus* and *Halimeda* and scattered small corals such as *Acropora* and *Turbinaria* (Plate 4-1).

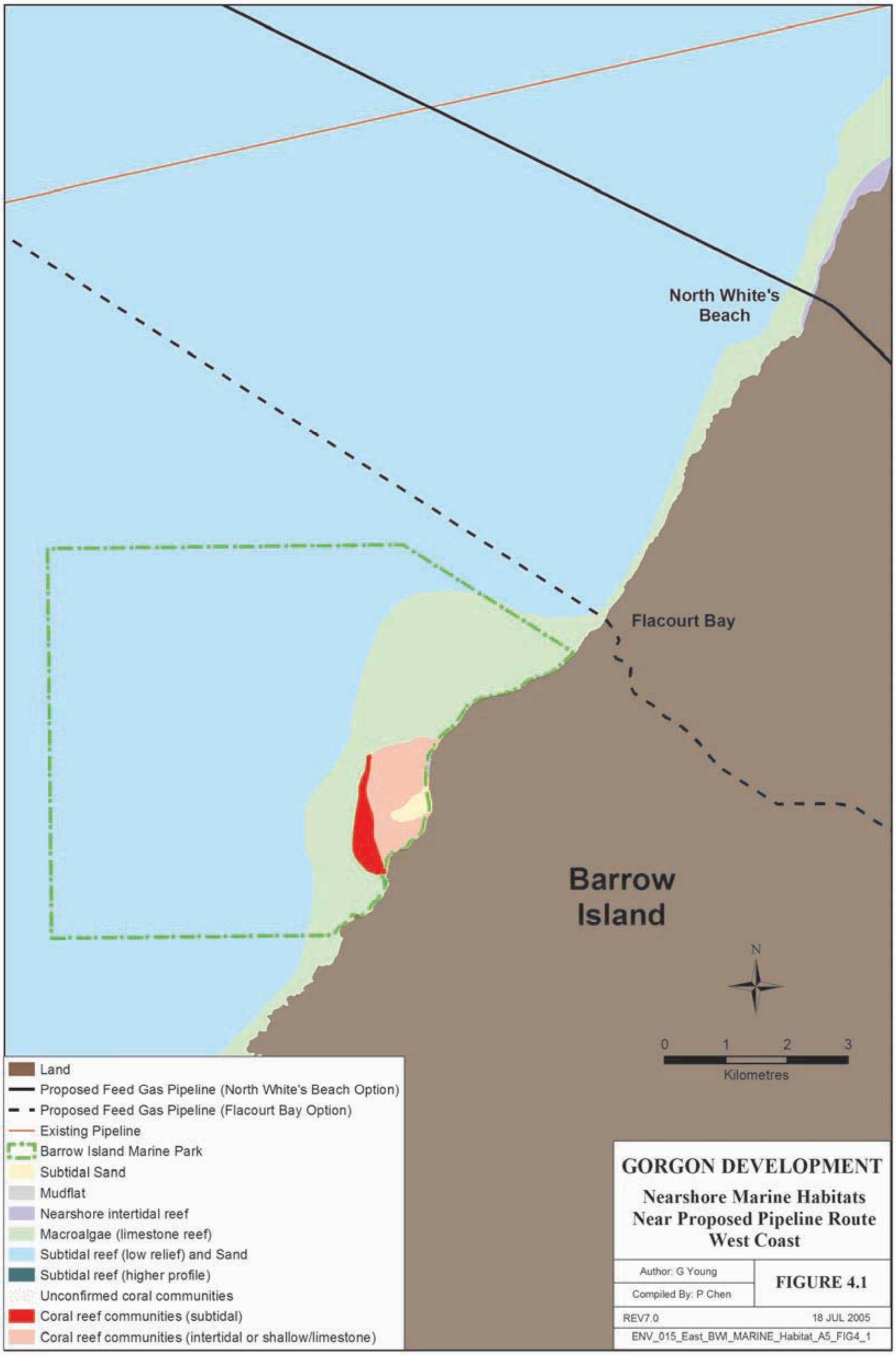

Figure 4-1 - Nearshore Marine Habitats near the Proposed Pipeline Route on the West Coast of Barrow Island

Plate 4-1 - *Sargassum*-dominated Reef in Nearshore Waters at Flacourt Bay

The seabed adjacent to the sandy beaches is characterised by rippled coarse sand in mobile sheets over pavement reef that is exposed in places. The sediments support a very sparse assemblage of epibiota. Many areas of sand are completely bare and the lack of obvious bioturbation suggests that large infaunal species are not abundant in the area. The absence of seagrass and stoloniferous macroalgae is consistent with the instability of the sandy sediments due to the high wave energy regime on this coast.

The exposed pavement habitat in the high-energy zone near the beach supports a dense cover of turfing brown and red macroalgae and small corals. The macroalgal turf on the shallow subtidal/intertidal pavement at Flacourt Bay is short and dense and obviously subject to extreme wave energy. It is also likely that this pavement reef is buried periodically. The macroalgae in the dissected pavement reef at North White's Beach tend to have longer thalli and probably higher biomass.

The proposed alternative Flacourt Bay shore crossing and nearshore section of the pipeline are approximately 1.3 km north of Biggada Reef. At the northern end, Biggada Reef is characterised by rocky pavement reef with macroalgae and scattered small corals. The significant corals that are proposed to be protected in the Barrow Island Marine Park are located approximately 3–4 km south of the proposed alternative pipeline route.

This coral assemblage extends into the intertidal zone and is best developed at the southern end of the reef. The south-western end of the reef front is dominated by rugged morphology scleractinian corals, such as *Pavona* and soft corals that are resistant to the high wave energy of this area. Corals are scattered throughout the lagoon inside Biggada Reef at Turtle Bay.

4.2 East Coast Development Areas

The locations of areas surveyed by towed underwater video transects or snorkel diving on the east coast are shown in Figure 2-2. The benthic habitats in the proposed Development area are shown in Figure 4-2 and are described below.

4.2.1 Causeway, MOF and MOF Access Channel

The proposed causeway and MOF-access channel would cross the intertidal and shallow subtidal platform reef adjacent to Town Point. Benthic habitats in this area are typical of the nearshore seabed along the east coast of Barrow Island. The subtidal pavement reef along the edge of the Island is overlain by a thin veneer of sediment and dominated by *Sargassum,* with other macroalgae such as *Dictyopterus*, scattered small hard corals (*Acropora*, *Turbinaria*), soft corals (*Rumphella*) and occasional coral bomboras of *Porites* and other coral genera up to one metre high. The biomass of *Sargassum* varies seasonally, peaking in spring and summer.

Sargassum-dominated benthic primary producer habitats within the proposed Development area are of minor conservation significance because the habitat is very widespread and the causeway is likely to provide hard substrate suitable for macroalgae that is not inundated by sand.

Approximately 42 ha of *Sargassum*-dominated pavement habitat would be removed or buried by the proposed marine facilities.

4.2.2 Jetty, Tanker Loading Facility and Access Channel

The proposed jetty would run south-east from the MOF across the macroalgal dominated limestone reef close to the island and the low relief subtidal platform reef further offshore before terminating in the deeper soft sediments off the edge of the limestone platform (Figure 4-2).

On top of the platform reef adjacent to the Island, the open-piled jetty would run across *Sargassum*-dominated limestone pavement reef and two areas of coral. The *Sargassum*-dominated pavement is very widespread and of low conservation significance. The coral reef area comprises scattered bombora and isolated patch reefs (*Porites*, *Merulina*, *Pectinia*). The coral communities are of local significance, but have not been identified as regionally significant in CALM's assessment of the conservation values of the region (CALM 2004). The benthic primary producers in this area that would be affected during the construction of the jetty comprise a small area of coral habitat and *Sargassum*-dominated pavement habitat. Effects would be highly localised, limited to those areas directly impacted during pile driving or drilling for pile setting. Significant recolonisation of the jetty piles is expected.

To the east of the coastal platform reef, the channel between the Lowendal shelf and Barrow Island experiences tidal currents of up to several knots. The scoured seabed in the channel is characterised by pavement and rubble with patchy thin veneers of sand. The pavement reef supports macroalgae and a sparse assemblage of invertebrates, such as gorgonians, sea whips, scleractinian corals and sponges. Towards the southern end of the channel where the proposed jetty would cross, the tidal stream is weaker and deeper sand veneers overlay the pavement reef in this area.

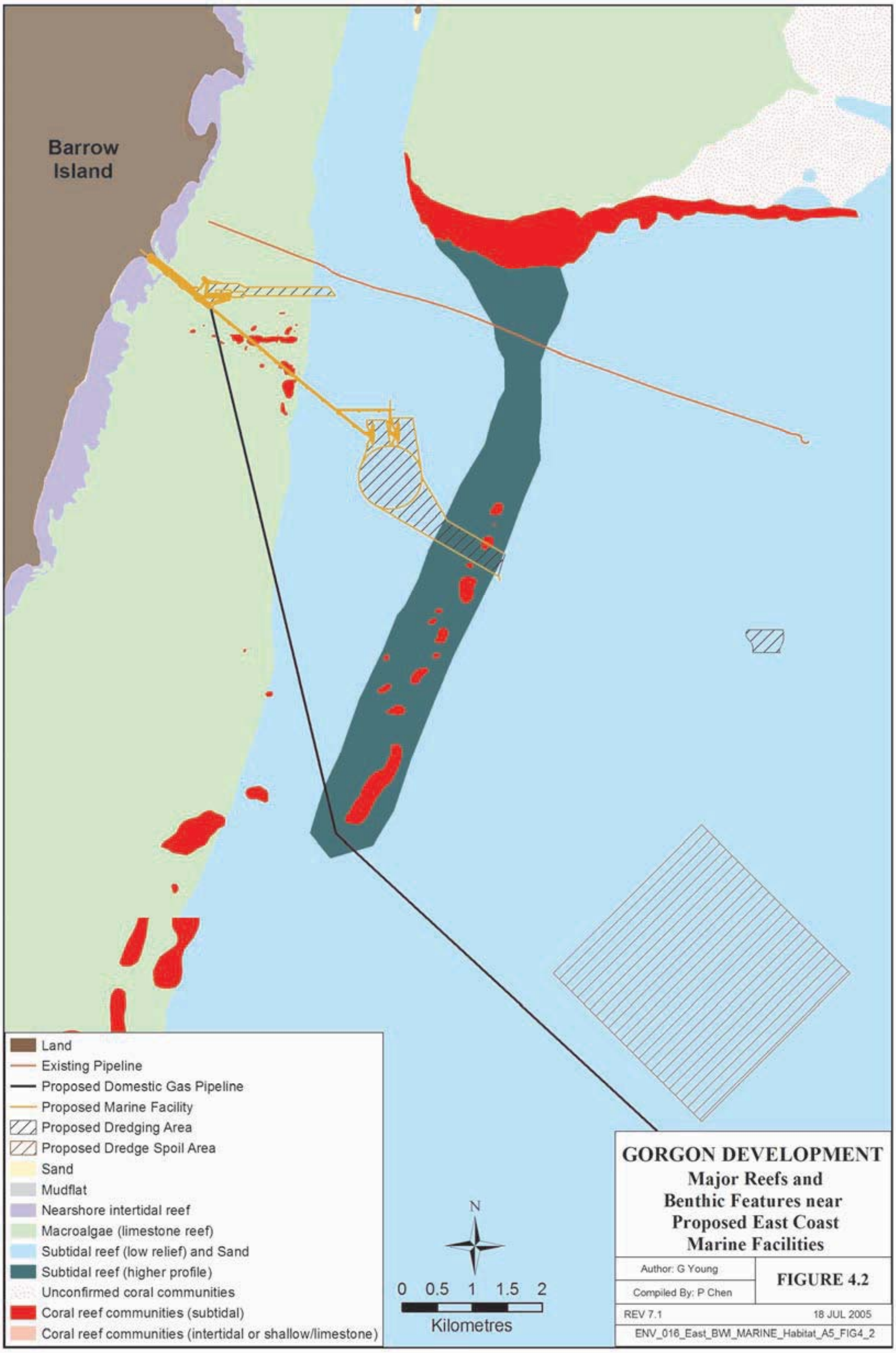

Figure 4-2 - Nearshore Marine Habitats near the Proposed Pipeline Route, Jetty and Shipping Channel on the East Coast of Barrow Island

The benthic habitats in the area to be dredged for the proposed tanker loading facility and turning basin comprise pavement reefs with sand veneer in ten metres water depth. The sand supports relatively-dense stands of seapens in some places (Plate 4-2), but is generally bare and of little conservation significance.

Plate 4-2 - Seapens on Sand off the East Coast of Barrow Island

The proposed dredged access channel for the tankers would cross the ridge of exposed limestone that extends southwards from the south-western end of the Lowendal shelf. This ridge stands about 2–4 m above the seabed and is characterised by rocky boulders, macroalgae and a sparse filter-feeding assemblage. In the deeper (12–14 m) areas of the dredged channel, the benthic habitats comprise sandy sediments and areas of exposed pavement reef. The exposed pavement reef supports scattered soft corals (*Rumphella*) and gorgonians (Plate 4-3). The sediments support sparse seagrass (*Halophila*), sea stars, heart urchins and holothurians.

A small volume of sand (~100,000 m^3) is proposed to be dredged from an area within the LNG access channel, approximately 3 km east of the limestone ridge. This area, which covers approximately 15 ha, is comprised predominantly of sandy sediments overlying limestone pavement and is generally bare and of little conservation significance.

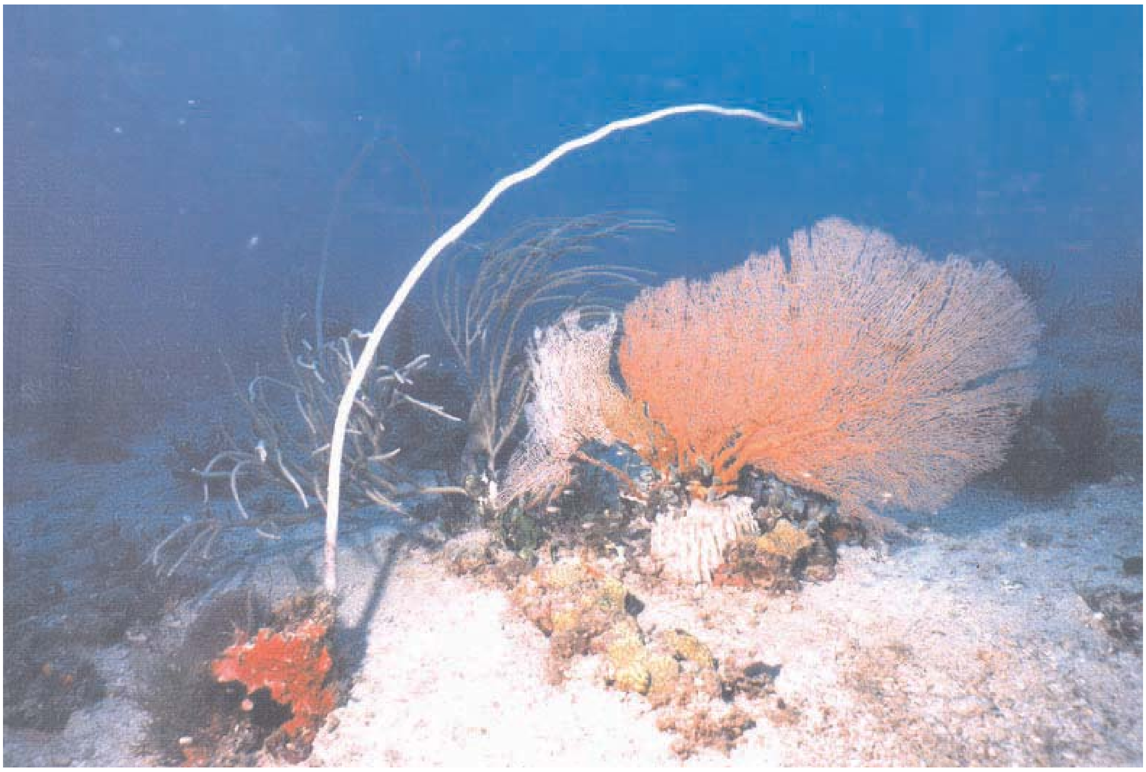

Plate 4-3 - Sparse Filter Feeding Assemblage on Hard Substrate off the Southern Edge of the Lowendal Shelf

4.2.3 Domestic Gas Pipeline Route to the Mainland

The proposed domestic gas pipeline corridor runs approximately 60 km across the seabed from Town Point to the mainland coast (Figure 4-2). Benthic habitats along the route are dominated by sand veneers over pavement reef, with scattered seagrass on the sediments and filter-feeding assemblages on exposed pavement. Video transect routes are shown in Figure 2-2.

The exposed pavement habitats and occasional coral bomboras (*Porites*, *Montipora)*, support hydroids, seawhips, gorgonians and scattered small corals (*Turbinaria*). These areas appear to be inundated irregularly by sand and the associated benthic assemblages are expected to be spatially and temporally variable.

Sediment habitats include bare, rippled sand in higher energy areas, fine bioturbated sediments, sandy sediments with stoloniferous macroalgae and seagrass and silty sediments in turbid water near the mainland coast. Epibenthic assemblages are generally very sparse with the exception of medium densities of crinoids and soft corals on sediments in the shallow (less than seven metres) waters near the mainland coast. Seagrass meadows are expected to be widespread, but temporally variable in shallow water habitats along the mainland Pilbara coast.

Localised patches of very high bivalve density were encountered in 6.5 m water depth approximately 13 km from the mainland coast. These mussel beds appear to comprise mainly dead bivalves and the structural habitat diversity they provide is likely to be locally significant for small invertebrates.

5 Sensitivity and Conservation Significance

The major environmental sensitivities within the proposed Development area relate to coral habitats. Protected mammals and reptiles that may be affected by impacts on these habitats are covered in Appendix C6**.**

The coral assemblages on the south-western corner of the Lowendal Shelf are of regional conservation significance. The extensive patch of *Acropora* in this location is one of the few extensive patches of fragile acroporid corals in the region. Some of the *Porites* coral bombora in the area are three to four metres high and are estimated to be several hundred years old. These corals support diverse assemblages of fish and invertebrates.

The coral reef areas on the subtidal pavement adjacent to Barrow Island are locally significant because they represent a benthic habitat with restricted distribution around the Island. The individual coral bomboras are of low conservation significance as they are very widely distributed along the east coast of the island.

The seagrasses in the proposed Development area mainly comprise species such as *Halophila* and *Halodule*. The plants are small and the meadows are too sparse to provide habitat for the fauna usually associated with high-density seagrass meadows. These seagrasses are unlikely to be of high importance to local dugong or sea turtle populations.

Halophila, *Syringodium* and *Halodule* recover rapidly from disturbance and recolonise disturbed areas from sediment seed banks. These genera are widespread throughout the area and the low-density seagrass in the development area has low conservation significance.

The *Sargassum*-dominated macroalgae beds on both the east and west coasts of Barrow Island are of low conservation significance as they are widely distributed and recover rapidly from disturbance. These beds undergo large seasonal biomass fluctuations each year and are adapted to an environment that is periodically buried with sand and thus undergo cycles of loss and recolonisation on the reefs around Barrow Island.

The significance of the effects of the proposed Development on benthic primary producer habitats is discussed in Chapter 11 of the ERMP report.

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Technical Appendix C9

Intertidal Habitats

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GORGON DEVELOPMENT ON BARROW ISLAND

TECHNICAL REPORT

INTERTIDAL HABITATS

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Report No: R03208
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1 Introduction

ChevronTexaco Australia Pty Ltd (ChevronTexaco), on behalf of the Gorgon Venture participants, proposes to develop the Gorgon gas fields utilising a processing, storage and offloading facility on Barrow Island. Marine infrastructure for the proposed development includes elements in intertidal habitats on the east and west coasts of Barrow Island, comprising:

- a shore crossing at North White's Beach or Flacourt Bay on the west coast of Barrow Island
- a causeway at Town Point on the east coast incorporating shore crossings for export pipelines
- a shore crossing near Robe River on the mainland for the domestic gas pipeline.

RPS Bowman Bishaw Gorham has conducted a number of studies of intertidal habitats around Barrow Island prior to the present proposal. Le Provost Environmental Consultants (1991) surveyed intertidal habitats around the Island in 1990. Further studies of the areas expected to be affected by the proposed development have been undertaken to assist formal environmental assessment of the proposal (Bowman Bishaw Gorham 2003). This report describes the results of the current field surveys and relates the findings to existing information for similar areas within the region.

2 Methods

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 26 to 28 January 2004. The surveys also covered adjacent intertidal habitats.

Intertidal areas were surveyed as close as possible to spring low tide to maximise the time for survey and the area of exposed habitat. Marine biologists with experience in intertidal surveys around Barrow Island and nearby mainland sites examined the area extending from the very low intertidal to supra-tidal zones.

3 Regional Intertidal Environment

3.1 Introduction

The Montebello/Lowendal/Barrow Islands region is characterised by limestone islands, running along the western edge of the Rowley Shelf, exposed to open ocean swells on their west coasts and sheltered on their east coasts.

The Leeuwin Current connects the Montebello/Lowendal/Barrow Island regions with areas further north and provides the area with an ongoing source of recruits for re-establishment of new biotic habitats or recovery of disturbed ones.

Wave energy plays a major role in the physical structure of intertidal habitats, and exposure to salinity and the desiccating effects of the sun play major roles in shaping biotic intertidal habitats. The local distribution of intertidal habitats is affected by the regular passage of tropical cyclones that shape sandy beaches, redistribute boulders and sand sheets over intertidal platforms and, in extreme cases, cause widespread destruction of biotic habitats.

The ongoing effects of exposure to wave energy have led to the development of different intertidal habitats on the west and east coasts of the region's islands. 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 and platforms. Mangroves have developed on sheltered coasts of the islands and along the mainland coast.

Tidal inundation plays a major role in shaping the distribution of the essentially marine assemblages of intertidal habitats. Biotic habitats in the intertidal zone are generally represented by stunted and resilient ecomorphs of marine macrophytes, due to the physiological stress imposed by the environment.

3.2 Intertidal Habitats of Barrow Island Region

There are six main intertidal habitats around Barrow Island and along the mainland coast that characterise the region's intertidal environment, as described in the following:

- limestone platform reefs
- rocky shores
- sandy beaches
- sand/mud flats
- coral reefs
- mangals

These are described in more detail in the following sections.

3.2.1 Limestone Platform Reefs

Geomorphology

Coastal limestone is often eroded into gently sloping wave-cut benches in the intertidal zone, known as rock platforms or rock flats. Extensive intertidal rock platforms occur on both the west and east coasts of Barrow Island. These are backed in the higher intertidal zone by either beach slopes or notched rocky headlands.

There are distinct differences between the west coast and east coast rock platforms of Barrow Island. On the west coast, the intertidal platforms tend to be narrower than those on the east coast. The west coast platforms range from a few metres to two hundred metres wide, whereas the east coast platforms are generally several hundreds of metres wide. The west coast is highly energetic, particularly over the winter period when swell generated in the Southern Ocean reaches Barrow Island. West coast rock platforms usually have a discrete outer edge that bears the brunt of wave action at low tide (Plate 3-1 and 3-5). Typically, the outer edge is at or very close to the 0 m LAT datum (low spring tide).

Plate 3-1 – High Wave Energy on the West Coast near White's Beach

The east coast is much less energetic, with large waves restricted to the irregular passage of cyclones. East coast rock platforms typically grade imperceptibly into the subtidal zone without a distinct edge (Plate 3-2). These can be very wide, in places exceeding 1 km.

Plate 3-2 - East Coast Limestone Platform near Town Point

Rock platforms may slope gradually from the upper intertidal level down to the low tide level, or there may be distinct steps or changes of slope that create microclimates and allow the formation of biotic zones. Rock platforms on the west coast are typically dissected by deep and irregular gutters caused by erosion. There are often sand and rubble-filled drainage gutters in the upper intertidal zone.

The different energy regimes that prevail on the east and west coasts also maintain different covers of sediments on the platforms present around the Island. West coast platforms are generally bare of sediments, except for coarse deposits in drainage channels and fronting sandy beaches. In contrast, east coast platforms typically have a thin layer of fine sand over most of the low profile limestone reef. The sand is deeper in basins and rock pools, but absent on upstanding ridges and boulders.

Macroalgal Assemblages

Benthic communities are very different on rock platforms in various areas of Barrow Island.

The outer platforms on the west coast are generally moderately to densely vegetated with macroalgae (*Sargassum*, *Caulerpa* and *Halimeda*). The middle flats in the wave zone usually support a dense, but low algal turf (Plate 3-3).

Plate 3-3 - Dense Macroalgae Bed on West Coast Rock Platform

Exposure to solar radiation, desiccation and sand deposition appear to restrict the formation of macroalgae meadows to the lower intertidal, rock pools and subtidal pavements. The highly exposed mid and upper intertidal pavements support little macroalgal cover.

Intertidal Faunal Assemblages

Intertidal pavement reefs support a diverse assemblage of vertebrates and invertebrates, particularly in vegetated areas and areas of increased structural diversity, such as rock pools, boulders and upstanding rocks.

Some species exhibit horizontal zonation on the reef flat. Generally, the species richness is higher in the lower intertidal zone. For example, scleractinian and soft corals are generally common and diverse in the lower intertidal on both east and west Barrow Island coasts, but few species live at higher levels. Some coral genera are particularly resistant to exposure and these are generally the representatives found in areas where sparse corals occur. These genera include *Goniastrea, Plesiastrea, Porites, Platygyra, Acropora* and *Euphyllia*. The exception occurs at Biggada Reef, where a very diverse and abundant coral reef community extends from the base of the reef, in approximately eight metres water depth, up into the lower intertidal.

Where there are high rocks in the mid-to-lower intertidal zone, barnacles and molluscs may occur that are otherwise restricted to the upper intertidal zone. For example, the mussel *Brachidontes ustulatus* and the rock oyster *Saccostrea*, which normally live in a band in the upper intertidal zone, occur on high rocks in the mid-to-lower intertidal zones.

Beach sand may be eroded to expose the beach rock at the base of the beach slope. When beach rock is exposed for extended periods, it is colonised by some of the suite of molluscs and barnacles that generally live in intertidal notch habitats. However, the vertical zonation patterns that are characteristic of the notch habitats are often poorly defined in exposed beach rock habitats.

East coast rock platforms often have a relatively wide zone of sediments on the inner flat with associated infaunal and epifaunal communities (Plate 3-4). The surface layer of oxygenated sediment is generally less than 5-10 cm deep (inset Plate 3-4). These flats are uncommon on the west coast.

Plate 3-4 - Wide Sediment Zone on the Limestone Pavement South of Town Point. The inset shows the shallow oxygenated layer (pale) with anoxic sediment underneath (grey)

Related to these physical differences in habitat, there are significant differences in species assemblages occupying the west and east coast rock platforms. Although the majority of species found on Barrow Island limestone pavements occur around the Island, some species are restricted to one coast. An example is the molluscan genera *Conus*, *Modiolus* and *Rhinoclavis,* all of which have species restricted to the habitats specific to each coast (Table 3-1).

Table 3-1 - Species of Three Intertidal Molluscan Genera Restricted to Either the East Coast or the West Coast of Barrow Island

West Coast	East Coast
Conus textile	*Conus victoriae*
Conus geographus	*Conus novaehollandiae*
Conus vexillum	*Conus monachus*
Conus miles	
Conus lividus	
Modiolus auriculatus	*Modiolus sp. nov.*
Rhinoclavis bituberculatum	*Rhinoclavis vertagus*

This pattern occurs throughout the West Pilbara region and is the basis of the distinction between the *Offshore Pilbara Region* and the *Nearshore Pilbara Region* made in the Marine Parks and Reserves Working Group Report (Wilson et al. 1994) and in the ecosystem-based classification of IMCRA (1998). The differences between intertidal communities on the west and east coasts of Barrow Island are a localised example of the differences between offshore and nearshore regional sub-province communities.

3.2.2 Rocky Shores

Intertidal limestone cliffs in the West Pilbara region are typically double-notched in the upper intertidal zone (Plate 3-5). The double notches are created by erosion of the cliff face above and below the protective or accretionary band of oysters in the central zone. The depth of the eroded lower notch in some areas is increased by burrowing invertebrates. The most important of these are the barnacle *Lithotrya* and the bivalves *Petricola* and *Lithophaga.*

Plate 3-5 - Notched Upper Intertidal Zone on the West Coast of Barrow Island

Two species of littorinid gastropod are ever-present in the upper notch at Barrow Island. *Nodilittorina pyramidalis* extends up into the supralittoral zone and *N. millegrana* extends down to the upper edge of the oyster zone. At most west coast sites there may also be one or more of *N. australis, N. nodosa* and *Littoraria undulata* in the upper notch. These latter species are rare at east coast sites.

The alga, *Bostychia tenella*, is usually present in both the oyster zone and the lower part of the upper notch. One of two species of the pulmonate snail genus *Ophiocardula* are often present in the algae zone.

The oyster zone is composed of clusters of the rock oyster *Saccostrea cuccullata*, sometimes in association with a second *Saccostrea* species in more sheltered sites. The oyster zone provides habitat for the gastropod *Planaxis sulcatus* and a variety of other invertebrates, most of which are nestlers rather than borers. These animals are not generally restricted to the oyster zone and also extend onto the rock surfaces above and below it.

The lower notch is habitat for several species confined to that zone, for example the grazing gastropods *Cellana radiata*, *Monodonta labio* and *Turbo cinerea,* the boring bivalves *Lithophaga malaccana* and *Petricola lapicida* and the boring barnacle *Lithotyra valentiana.*

A variety of species inhabit both the lower notch and the inner part of the rock platform. For example, the molluscs *Nerita chamaeleon*, *N. albicilla*, *Siphonaria* sp. and *Onchidium* sp. and the two large chitons, *Acanthopleura spinosa* and *A. gemmata* are conspicuous in these habitats. *Acanthopleura spinosa* sometimes extends up into the lower part of the upper notch and *A.gemmata* sometimes extends out onto the inner rock platform. Cemented barnacles are also an important element of intertidal notch communities. Three or four species of barnacles are usually present in the Barrow - Montebello Complex intertidal notch habitats.

The composition of the species assemblage in intertidal notch sites varies among sites and not all of the typical species are always present. Sand scouring is an obvious cause of absence of some species in the lower notch. In general, intertidal notches on the wave-exposed west coast shores of Barrow Island tend to be more species-rich than comparable habitats of the more sheltered east coast shores.

3.2.3 Sandy Beaches

Sandy beaches around Barrow Island are typical of those found on Rowley Shelf islands. They are generally wide with steep intertidal zones on wave-exposed shores and relatively narrow and gently sloping along sheltered shores. The beaches are generally depauperate of invertebrates other than ghost crabs and burrowing bivalves. The ghost crab *Ocypode* sp. commonly burrows on the middle and upper beach slope. The bivalves *Donax cuneata* and *Paphies striata* burrow in the sand of the lower slope, with the latter confined to less wave-exposed beaches.

The importance of sandy beaches in the region is primarily related to their significance for turtle nesting (Plate 3-6), seabird nesting, roosting and foraging (Plate 3-7), and as foraging areas for terrestrial species, such the perentie (*Varanus giganteus*), brushtail possum (*Trichosurus vulpecula*), golden bandicoot (*Isodon auratus*) and water rat (*Hydromys chrysogaster*).

Plate 3-6 - Turtle Tracks at White's Beach

Plate 3-7 - Shorebirds Roosting in the Upper Intertidal Zone

Turtles nest in beach sands above the high tide mark and only use the beach slopes as a conduit between the ocean and nest sites. The beaches in the region are important nesting sites for most of the locally occurring species. Sandy beaches on the west coast of Barrow Island are heavily utilised by green turtles, while beaches in the Montebello and Lowendal Islands groups are important hawksbill turtle nesting sites. Flatback turtles nest on various beaches in the area, including those on the east coast of Barrow Island.

Shorebirds, such as terns and oyster catchers, nest on sandy beaches on islands in the Montebello and Lowendal Islands groups and on Barrow Island.

3.2.4 Sand and Mud Flats

Large intertidal sand flats are relatively uncommon on the offshore Rowley Shelf. There are sand sheets and bars on the northern end of Thevenard Island and at Barrow Island. Intertidal sand flats are much more extensive along the mainland coastline, including areas where the domestic gas pipeline is proposed to come ashore.

Extensive intertidal sand flats occur at southern Barrow Island, while limited areas occur around Surf Point at the northern extent of the Island. Observations of the northern sand sheets suggest they support a very limited faunal community. These are energetic areas comprised of well sorted sediments. Some of the more protected northern sand flats support seagrasses, particularly members of the genera *Halophila*, *Halodule* and *Thalassodendron*. Areas with seagrass contain increased invertebrate fauna, usually dominated by gastropods, particularly of the genera *Pseudovertagus, Rhinoclavis* and *Turbo*.

The intertidal sand flats in Bandicoot Bay support a diverse benthic and burrowing fauna (LeProvost 1991). At high tide, the intertidal sand flats provide foraging habitat for many larger carnivores such as shovelnose rays and sharks (Plate 3-8).

Plate 3-8 - Sharks Foraging over Intertidal Sand Flats in Bandicoot Bay

The natural sand flats support extensive areas of seagrasses and macroalgae. Seagrass of the genus *Halophila* are the most prevalent, with lesser amounts of *Syringodium* and *Thalassodendron*. The gastropods *Pseudovertagus* and *Rhinoclavis* are very common, particularly within the seagrass-dominated areas. The brown octopus (*Octopus cyanea)*, commonly found on limestone pavements on both the east and west coasts, is also common on the Bandicoot Bay sand flats. Compound ascidians are widespread, in places occurring as discrete, mono-specific mats.

The main macroalgal genus on the flats is *Sargassum*, with lesser *Padina*, *Caulerpa*, *Halimeda* and *Penicillus*. The macroalgae community is more prolific in the deeper intertidal and sub-tidal zones. This area also supports species with lower exposure tolerance, such as soft corals, particularly from the genera *Sarcophyton* and *Lobophyton*.

Mainland sand flats are generally muddier than those associated with the offshore islands. These support seagrasses in the very low intertidal, particularly *Halophila* and *Halodule*. Macroalgae is usually very poorly represented on the mainland sand flats, generally being restricted to *Halimeda*, *Caulerpa* and *Penicillus* in the low intertidal.

Mainland sand flat faunal communities range from diverse to depauperate. The diversity of invertebrates in the intertidal zones around Cape Preston formed the basis of the recommendation of the Marine Parks and Reserves Working Group (Wilson et al. 1994) for consideration of the area for reserve status. Other areas have very low species diversity with limited attached or burrowing fauna above the low intertidal level.

3.2.5 Coral Reefs

Coral communities are generally sub-tidal, however, many coral species are very tolerant to exposure and, in places, form reefs which extend into the lower intertidal. Many of the intertidal platforms which surround the islands of the Rowley Shelf contain small emergent reefs, and there are at least two large intertidal coral reefs in the region:

- unnamed reef on the southwest side of Thevenard Island
- Biggada Reef on the west coast of Barrow Island.

The intertidal coral reef at Biggada Reef in Turtle Bay on the west coast of Barrow Island extends approximately 1.5 km northward and 0.5 km offshore from Biggada Creek. This area has been proposed as a Marine Park (CALM 2004). The reef crest and lagoon areas support extensive expanses of corals that are exposed on very low tides. Surveys of the intertidal component of this coral community in 1995 revealed a diverse fauna, including at least 64 species of scleractinian (hard) coral, 32 species of echinoderm and 75 species of shelled mollusc (Bowman Bishaw Gorham 1996).

Another example of an emergent coral community occurs at Dugong Reef of the east coast of Barrow Island on the Barrow Island Shoals. The majority of corals on this reef occur in the shallow sub-tidal zone, but some of the larger colonies are intertidal on spring tides. Corals from the genera *Porites* and *Goniastrea* are the most common large colonies exposed on low tides (Plate 3-9).

Plate 3-9 - Small Coral Colony on the East Coast of Barrow Island Exposed – During the Low Tide

3.2.6 Mangals

The large mangrove forests (mangals) growing along the Pilbara coastline are composed of up to six different mangrove species. Mangals on the offshore islands tend to be small stands of the white mangrove *(Avicennia marina*) together with the red mangrove *Rhizophora stylosa*. White mangroves grow at several localities on the protected south and east coasts of Barrow Island, but generally only occurs as a narrow zone of stunted trees.

Although the faunal assemblage associated with Barrow Island mangals is usually species poor, consistent with the mangals limited size and floral diversity, the mangals are not unimportant because of the additional diversity, albeit relatively minor, of species and habitats they add. Ospreys (*Pandion haliaetus*), brahminy kites (*Haliastur indus*) and white-bellied sea eagles (*Haliaeetus leucogaster*) use the trees as roosting sites. The small mangal in Square Bay has an associated population of red fiddler crabs (*Uca* sp.).

On the mainland, well developed mangals extend from the Dampier Archipelago south-west to Exmouth Gulf. Six mangrove species are known from the region; the most common being *Avicennia marina* and *Rhizophora stylosa*. Less common species are *Ceriops tagal, Aegialitis annulata, Bruguiera exaristata, Aegiceris corniculatum* and *Osbornia octodonta*.

Mainland mangals support a range of associated faunal species, many of which are restricted to that environment. Common mangal fauna include burrowing infauna such as peanut worms (sipunculids), crabs and mud lobsters (*Thallasina*) and epifauna such as gastropods, mud skippers and crabs. Some littorine whelks and barnacles are limited to mangrove trees.

4 Local Intertidal Habitats

4.1 West Coast Development Areas

4.1.1 Shore Crossing at North White's Beach or Flacourt Bay

The proposed pipeline route to North White's Beach crosses an intertidal limestone reef platform and a sandy beach with an exposed beach rock bench. The upper surface of the eroded reef platform is essentially bare, presumably due to exposure to the sun at low tide. The holes and fissures in the reef support brown macroalgae such as *Sargassum* with larger thalli than the turfing algae at Flacourt Bay. The exposed beach rock appears to experience cycles of sand burial and exposure and does not support an abundant assemblage of intertidal fauna. The faunal assemblage is expected to be temporally variable, dominated by littorine gastropods that settle on exposed intertidal rock surfaces opportunistically (Plate 4-1).

The southern end of North White's Beach is sheltered from sea and swell energy by the low cliffs of a headland and the intertidal and supratidal areas include boulders and vertical rock faces. The intertidal assemblages in this area are dominated by rock oyster (*Saccostrea*) zones with the associated mollusc and cirripede (barnacle) fauna characteristic of this habitat.

Plate 4-1 - Intertidal Zone at North White's Beach

Green turtles cross the intertidal zones of the sandy beaches at Flacourt Bay and, to a lesser, extent North White's Beach as described in Appendix C7. Migratory waterbirds are expected to roost on the sandy beach occasionally, but these are not an important areas for avifauna (Appendix C3).

The proposed alternative feed gas pipeline to Flacourt Bay would cross the broad sandy beach running between two high rocky headlands. The beach is exposed to high wave energy and changes shape as sand is eroded or deposited. The limestone pavement underlying the beach is, at times, exposed 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 4-2).

Plate 4-2 - Intertidal Pavement Reef and Sandy Beach at Flacourt Bay

This high energy section of the coastline does not support well developed intertidal assemblages. Wave action on the intertidal areas of the nearshore pavement reef precluded survey and is also expected to restrict the diversity of flora and fauna that can persist there. Intertidal areas of the steep sandy beaches are very narrow and support limited assemblages of bivalves and crustaceans.

The intertidal habitats in these two areas are typical of intertidal areas along the west coast of Barrow Island and are of low conservation significance.

4.2 East Coast Development Areas

4.2.1 Town Point Causeway and Landing

Physical Setting

The proposed causeway extends from the rocky headland at Town Point, through the boulder-strewn upper intertidal zone and across the intertidal part of the platform reef fringing the east coast of the Island (Plate 4-3). The development at Town Point would bury or subsume the rocky shoreline at the point and approximately 400 m of the shoreline extending south. The landing area would occupy approximately 200 m of the width of the causeway. Intertidal habitats in the area of the proposed development are described below.

Plate 4-3 - Town Point Intertidal Zone

The limestone pavement reef slopes gently into the lower intertidal and subtidal zones approximately 200 m seaward from the boulder zone at Town Point and up to 500 m from the adjacent beaches. There is a large shallow lagoon surrounding Town Point with a narrow break in the platform reef open to the sea. This channel appears to have been blasted for barge access during construction of the previous landing.

There are extensive intertidal platform reefs with large rock pools and channels, often with sandy bottoms, to the north and south of Town Point. These platforms are backed by sandy beaches.

The headland was previously developed as a landing with concrete armour across the seaward area of the headland. The landing was demolished in the early 1990s, however, remains of the concrete armour and associated debris are still evident in the upper intertidal boulder zone. There is a pile of boulders immediately offshore from the point.

The intertidal areas north of Town Point and Terminal Beach were previously disturbed during construction of the large oil storage facility (Terminal Tanks). Tank modules were brought in across the intertidal platform to a channel cut through the beach dunes and hinterland.

Intertidal Biota

The invertebrate assemblage of the upper intertidal boulder zone is relatively poorly developed. It is dominated by barnacles, small limpets and occasional oysters (*Saccostrea*). Small corals (*Pleasiastrea, Porites*, Mussidae) and juvenile fish were observed in small permanent rock pools.

The limestone pavements support a relatively low diversity biotic assemblage. Boring bivalves (*Lithophaga*) were the most broadly distributed mollusc. Large rock oysters (*Chalma*) and bastard oysters (*Pinctada alba*) were present in low numbers over most of the pavements. Strap shells were present under most of the rocks investigated and along the edges of rock pools. Orange sea cucumbers (*Holothuria hilla*) were abundant, being found under most of the rocks investigated. The common octopus (*Octopus cyanea*) was abundant in rock pools and crevices across the platform. Sand filled pools contained large numbers of gastropods *Pseudovertagus* and *Rhinoclavis.*

The lower component of the platform had less sediment cover and supports a more abundant and diverse epibiota, including macroalgae, sponges, scleractinian corals, octocorals, zooanthids, hydroids and ascidians. Common macroalgae include *Sargassum*, *Halimeda, Padina, Caulerpa* and *Turbinaria*. Sponge morphologies included large encrusting lithophagid sponge, ball, digitate and other encrusting species.

The coral assemblage is dominated by various species of *Goniastrea*, with some colonies of *G. favulus* exceeding 80 cm in diameter and extending at least 60 cm above the low tide level. Less common corals include *Porites, Euphyllia*, *Lobophyllia, Plesiastrea, Favia, Favites, Turbinaria, Platygyra* and *Acanthastrea*. Octocorals (soft corals) observed include *Sarcophyton, Lobophytum, Sinularia, Nepthea* and *Dendronephthya*.

Macrophyte assemblages vary from almost bare exposed rock to low turf to luxuriant thalli in rock pools and the lower intertidal. The surface of the upper intertidal pavement was essentially bare of macrophytes. The surface of the platform that is regularly exposed supports a low turf with entrained sediment. The rock pools supported the most well developed macrophyte assemblage.

Macroalgal turfs generally comprise red algae including *Laurencia*, *Chondria*, *Ceramium*, *Centroceras clavulatum*, *Gelidiopsis* and *Hypnea*.

Macrophytes in the rock pools included *Sargassum* and *Cystoseira* with thalli up to 30 cm long and seagrasses (*Halophila, Halodule* and *Thalassia*) in densities ranging from occasional plants to small meadows (Plate 4-4).

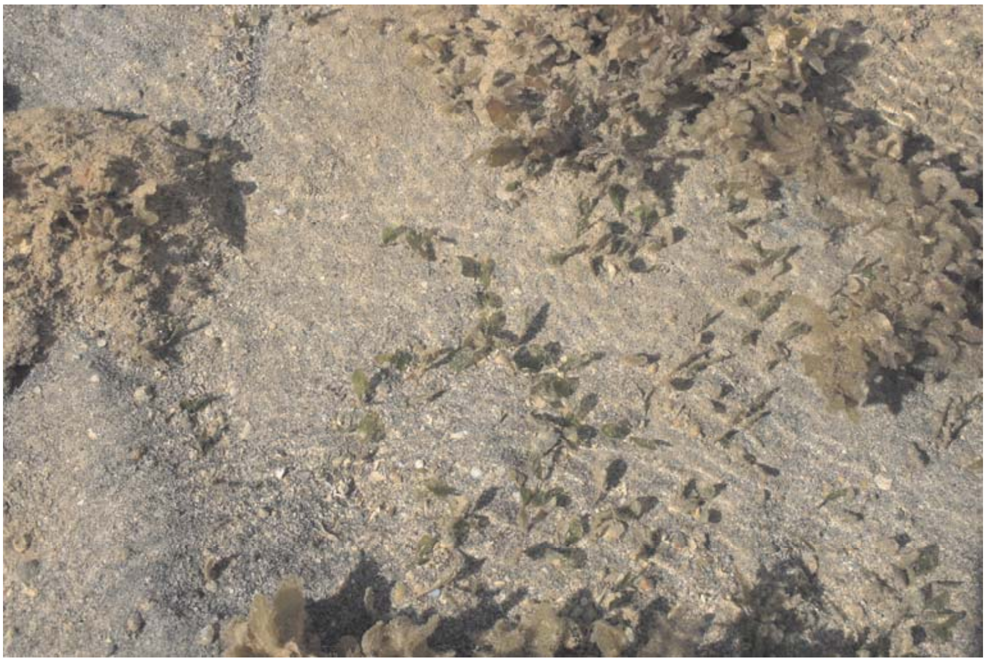

Plate 4-4 - *Halophila* and *Sargassum* in Shallow Intertidal Rock Pool at Town Point

Deeper rock pools support mobile marine faunal assemblages comprising juveniles and larger individuals trapped by the outgoing tide, such as squid, fish and large hermit crabs (*Dardanus* sp.).

The intertidal habitats and associated assemblages at Town Point are widespread along the east coast of Barrow Island and are of low conservation significance.

4.2.2 Mainland Shore Crossing

East of Passage Island

The proposed shore crossing for the domestic gas pipeline from Barrow Island is adjacent to the existing domestic gas pipeline from Varanus Island to Compressor Station 1 on the mainland. Intertidal habitats in the area east of Passage Island comprise broad intertidal sand/mud flats overlying pavement reef and mangals with tidal creeks. In adjacent areas of the coast there are exposed pavement reefs, with small boulders and silt veneer seaward of and within the mangroves.

The existing pipeline crosses an extensive intertidal sand and mud flat on the mainland shore that extends up to 3 km seaward from the mangrove zone (Plate 4-5).

Plate 4-5 - Extensive Sand Flat near Proposed Domestic Gas Shore Crossing on Mainland

The mangrove zone is regularly dissected by muddy tidal creeks, the longest of which extended some kilometres inland. The water in the creeks is very turbid. The mangrove communities are dominated by *A. marina* and *R. stylosa* (Plate 4-6).

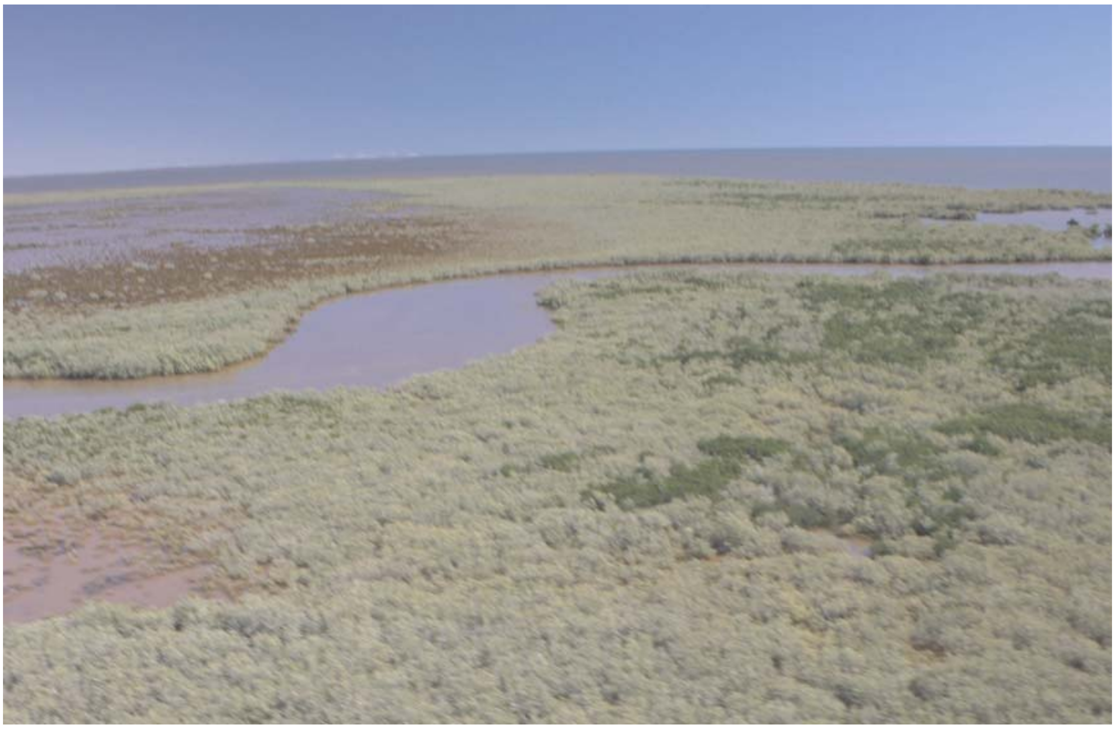

Plate 4-6 - A*vicennia marina/Rhizophora stylosa* Mangal and Samphire (brown) on Mainland Coast Near Proposed Domestic Gas Pipeline Shore Crossing

The existing gas pipeline easement through the mangroves has minor regrowth (Plate 4-7) and appears to be stable. There is no sign of ongoing edge effects such as would be expected from the exposure of acid-sulphate soils or major erosion.

Plate 4-7 - Existing Mainland Pipeline Crossing

The upper intertidal zone comprises salt-affected sand and mud substrates with samphire, but no exposed rock. The tidal influence extends 5-10 km inland from the mangrove zone and ends in a broad unvegetated salt pan.

Intertidal Biota

The upper intertidal zone is dominated by an extensive mangrove system. *Avicennia marina* is generally the dominant mangrove species along the seaward and landward edges of the mangal. *Rhizophora stylosa* forms a taller canopy in the midst of the mangal (darker green in Plate 4-6).

The fauna of the mangal includes abundant red fiddler crabs (*Uca*), occasional portunid crabs including mud crabs (*Scylla serrata*), mud skippers (*Periopthalmus vulgaris*), mud lobsters (*Thalassina anomala*), crawling gastropods and rock oysters (*Saccostrea*) attached to the pneumatophores and trunks of trees in the lowest part of the zone. A juvenile sea eagle was also observed roosting in the mangroves.

The broad intertidal sand flat seaward of the mangroves supports a sparse faunal assemblage of echinoderms, molluscs, crustaceans and other invertebrates. Common taxa include nemertean worms, gastropods (*Nassarius*, *Polinices*, *Syrinx*), digitate sponges and small sand dollars (*Echinodiscus* sp.).

Shallow drainage channels and the lower intertidal areas support soft corals (*Dendronephthya* sp.), macroalgae (*Caulerpa*, *Penicillus*) and razor mussels (*Pinna* sp.).

The intertidal sand and mud flats slope very gradually into the shallow subtidal zone. A broad area of this habitat is probably exposed on extreme low tides. This zone supports a much more abundant benthic assemblage dominated by seagrasses and crinoids.

The seagrass assemblage is dominated by *Halophila*, with lesser *Halodule* (Plate 4-8). The seagrass patches extend higher up the zone in shallow depressions that hold water longer than the surrounding sand flats. Macroalgae (*Halimeda, Caulerpa*, *Penicillus*) were less abundant and were restricted to small plants.

Plate 4-8 - Intertidal *Halophila* and *Halodule* Seagrass Meadow on Mainland Coast Near Proposed Domestic Gas Pipeline Shore Crossing

Small feather stars (crinoids) and large asteroids (*Protoreaster*) were abundant and appear to migrate with the incoming and outgoing tides, such that they occurred in large numbers in water less than 50 cm deep. They were observed swimming with the falling tide but were rarely observed beached.

Corals were restricted to very occasional *Trachyphyllia* and *Duncanopsammia* colonies sitting unattached on the sandy sediments. Soft corals are very poorly represented in the low intertidal, being limited to occasional *Dendronephthya* colonies. The rippled fine sands devoid of hard substrate do not favour a diversity of molluscs.

All of these habitats and assemblages are widespread along the mainland coast.

East of Cowle Island

The intertidal zone east of Cowle Island comprises a flat, limestone pavement extending approximately 400 m seaward of the mangrove zone (Plate 4-9). The uppermost extent of the intertidal zone was not examined, but the exposed limestone pavement extends at least 80 m into the mangrove forest.

Plate 4-9 - Intertidal Zone at Alternate Pipeline Crossing Location

A very thin laver of fine sediment coated the pavement across the mid intertidal level. Small and medium sized rock pools occurred across the intertidal zone below the mangroves. Undercut ledges occurred along the edges of some of the pools, while the floor of the pools was predominantly coarse sands.

Intertidal Biota

The dense mangrove forest appeared to be a mono-specific stand of medium sized *A. marina* trees with a narrow band of *Aegialitis* along the seaward edge. These were growing on rocky pavement with minimal sediments. The associated fauna was relatively depauperate, being limited to mangrove littorines (*Nodilittorina scabra*), small portunid crabs, hermit crabs, stunted rock oysters (*Saccostrea*), mud skippers and various small fish in the shallow perched waters.

The mid-tidal zone generally had a limited range of micro habitats, with sediment deposits on the pavements reducing the substrates suitable for many invertebrates. Small rock ledges supported xanthid and grapsid crabs and occasional gastropods (Turbinidae, Trochidae). One particularly large rock pool contained *Sargassum*, *Cystoseira*, stunted macroalgae, small fish, nemerteans and soft coral.

Rock pools and boulders in the lower intertidal zone supported a diverse and abundant biotic assemblage. Macrophytes were common, including stunted *Sargassum, Padina, Caulerpa*, *Halimeda* and other turfing macroalgae. Seagrasses (*Halophila, Halodule* and *Thalassia*) were moderately common in sandy rock pools.

The lower intertidal faunal assemblage was dominated by gastropods (*Cypraea stolida*, *C. gracilis*, *C. erones*, *Conus novaehollandiae*, *Astralium*, *Trochus hanleyanus*, *Melo amphora*, *Angaria*, muricids, *Trochus*, *Turbo*). Other molluscs included large dorid nudibranchs under loose rocks, *Octopus cyanea* and lithophagic mussels. Other abundant taxa in the lower intertidal zone included holothurians (*Holothuria hilla*, *H. atra*), asteroids (*Protoreaster*), mantis shrimps (stomatopods), hermit crabs (anomurids), small portunid and xanthid crabs and a large mud crab (*Scylla serrata*).

Corals were common in the immediate sub-tidal zone, with a narrow band of moderate coral cover fringing the intertidal zone. Some corals extended into the intertidal zone, particularly members of the genus *Goniastrea*. Less common were other members of the family Faviidae, including *Platygyra, Favites* and *Plesiastrea*. Other corals observed in the low intertidal included small colonies of *Euphyllia*, *Porites* and *Goniopora*.

All of these habitats and taxa are very widespread along the mainland coast. They are all of low conservation significance, except the mangroves, which the EPA (2001) has identified throughout the Pilbara region as having high conservation significance and particular areas as having very high significance (regionally significant arid zone mangrove areas). The proposed shore crossing is approximately 6 km from the nearest mangal of very high conservation significance.

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Technical Appendix D1

Quarantine Expert Panel Advice

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

QUARANTINE EXPERT PANEL
ADVICE TO THE GORGON JOINT VENTURE

TECHNICAL APPENDIX D1

Prepared for:

ChevronTexaco Australia Pty. Ltd.
250 St Georges Terrace
PERTH WA 6000

Prepared by:

Dr. Bernard Bowen
Chairman,
Quarantine Expert Panel

30th September 2004

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Tel/Fax (08) 9386 4122

30 September 2004

Mr Paul Oen
General Manager
ChevronTexaco Australia Pty Ltd
PO Box S1580
PERTH WA 6845

Dear Paul

I have pleasure in presenting to you a report of the Gorgon Quarantine Expert Panel.

The purpose of the report is to provide Gorgon with an overview of the work of the Panel since its establishment by the Gorgon Joint Venture in October 2003. It is timely that this be done as Gorgon is now preparing its Environmental Impact Statement / Environmental Review and Management Programme (EIS/ERMP) document.

The work of the Panel has been greatly assisted by the involvement of Mr Russell Lagdon, Mr Geoff Prior, Mr Sean Reddan and Mr Richard Stoklosa.

The Panel is of the view that with the release of the EIS/ERMP it may have concluded its role, at least for phase 1. However, following its release Gorgon will need to expand its work on the details of an effective quarantine management system and Gorgon may find value in continuing a form of advice from specialists and the community generally.

The Panel requests Gorgon to consider this matter in relation to the form of an advisory panel which Gorgon may need in the next phase of the quarantine management process.

Panel members take this opportunity to express their thanks to Gorgon for the opportunity to provide advice and steer the direction of quarantine management on Barrow Island.

Yours sincerely

Bernard Bowen
(Chairman, Gorgon Quarantine Expert Panel)

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1 Introduction

The Gorgon Joint Venture established a Panel of specialists (Gorgon Quarantine Expert Panel) in October 2003 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.

Membership of the Panel (Attachment 1) was based on the expert advice each participant could bring to the discussions. Two observers from the State conservation departments also attended the meetings (Attachment 1). Terms of Reference and a Panel Charter were established and are set out in Attachments 2 and 3.

The Panel has been serviced by officers of the Gorgon Joint Venture (see Attachment 1). All participants (Panel members, observers and secretariat) at Panel meetings have entered fully into the discussions and brought the benefit of their expertise to those discussions. However, neither the observers nor the secretariat were involved in the preparation of this report.

The Panel records its thanks for the involvement of and assistance provided by Mr Russell Lagdon, Mr Geoff Prior, Mr Sean Reddan and Mr Richard Stoklosa.

The purpose of this report is to provide Gorgon with an overview of the work of the Panel since its establishment in October 2003. It is timely that this be done as Gorgon is now preparing its Environmental Impact Statement / Environmental Review and Management Programme (EIS/ERMP) document, which is expected to include considerable detail on quarantine management.

The overview is set out below in sections 2 to 8. Section 9 provides advice of the Panel to the Gorgon Joint Venture on the way forward.

2 Meetings and Procedures

The Panel has met on eight occasions. At the conclusion of each meeting, a Brief Summary of the outcomes of the meeting was prepared within one week and made public through the Gorgon website. The record of each meeting has also been made available publicly on the website following confirmation of the record at the next Panel meeting.

The secretariat provided by Gorgon has been very professional. The staff have greatly assisted the work of the Panel and have readily given attention to the advice provided. Most members of the Panel have been available to accept Gorgon's invitation to visit Barrow Island and have benefited from an inspection and a briefing. One member has extensive knowledge of the Island as a research scientist.

3 Terms and Definitions to establish a quarantine and risk glossary

The Panel advised Gorgon that there was a need to have a glossary of terms and definitions to be used in the development the Quarantine Management System (QMS), the Quarantine Management Plan (QMP) and the EIS/ERMP documentation.

The Panel worked with Gorgon and a glossary in now available.

4 The approach to preparing the Quarantine Management System

One of the matters first considered by the Panel was the approach to developing a QMS. The QMS has to provide confidence that there is a very high probability that the goal of 'no introductions' can be met and that if introductions do occur there are appropriate monitoring and contingency arrangements in place.

The Panel advised Gorgon that the following activities should be given high order attention.

- Establishing standards for acceptable risk, which need to be developed in consultation with, and be broadly acceptable to, stakeholders including those within the wider community.

- Identifying the organism groups of concern and undertaking the required baseline surveys (designed to incorporate future surveillance and monitoring).

- Providing the community with the opportunity to engage in the process for setting standards and developing a 'better than' world's best practise QMS.

- Establishing policies and processes and defining responsibilities such that the risk standards are able to be met.

- Establishing surveillance and monitoring programs for detection of introduced species and environmental change and for compliance with system and plan procedures.

- Establishing contingency and response plans.

- Proposing a process for independent (third party) system audits.

5 Risk assessment, QMS and QMP

Risk assessment, including the establishment of standards for acceptable risk, has been a major item of consideration for the Panel. The Panel has contributed to the development of a "How-to Guide" for conducting risk based assessments of quarantine hazards on Barrow Island. Rather than 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, where risk data are available, the Panel suggested that informed judgements be made following the development of a process for identifying and classifying threats within the context of the likelihood of the introduction, survival, detection and eradication of introduced species.

The Panel's advice on risk assessment assisted the Gorgon team to establish:

- A community consultation strategy with respect to quarantine management risks and strategies;

- A series of IMEA (infection modes and effects analysis) and HAZOP (hazard and operability) workshops to identify major groups of organisms of quarantine concern, possible infection pathways to Barrow Island, how infection might occur and the array of barriers that should be developed to reduce the risks; and

- A draft Quarantine Policy for the Gorgon Joint Venture.

The outcomes of the Panel discussions, the HAZOP/IMEA workshops and the community consultations have been:

- Recognition that in practical terms the goal of 'no introductions' would not be achieved. It was agreed, however, noting the island's very high biodiversity and conservation values, that the establishment of an introduced species on Barrow Island Nature Reserve, which includes a number of surrounding islands, or its surrounding waters would be unacceptable.

- Recognition that the introduction of micro-organisms will occur every time people and fresh food enter the Island. While many of these may not survive in the natural environment, the extent to which some species may establish on Barrow Island is unknown.

- A report from the community to the Gorgon Joint Venture and to the Environmental Protection Authority on acceptable quarantine risk standards for Barrow Island (Risk Standards Report). The report set out that the risk of establishment of introduced species is acceptably low if it conforms to the Risk Standard Framework described in the report. However, it was recognised that the proposed development would not be able to meet the Risk Standard Framework in so far as micro-organisms and marine species are concerned.

- Recognition that the connectivity of the marine environment is likely to lead to introduced species near the coast also being found in the waters around Barrow Island.

- Identification of the most important pathways to be considered for quarantine management, noting that Gorgon's schedule and the availability of relevant experts has not yet permitted detailed examination of all of the identified infection pathways.

- Progress towards the development of a Quarantine Management System and a Quarantine Management Plan, which would apply to the existing ChevronTexaco activities and the proposed Gorgon venture as well as to all other people visiting Barrow Island.

- A Contents Table for the Quarantine Management Plan.

- Recognition that whilst pre-border quarantine would be the prime activity, border and post border segments of the quarantine (biosecurity) framework (inspection, surveillance, monitoring, eradication responses) are also essential elements of the Quarantine Management System. Whilst animals such as introduced rats and mice are readily identified as having major consequences should incursions occur, it was recognised that it would not be possible to predict the consequences of most other potential incursions. Accordingly, all species of plants and animals were included in the statement that the establishment of an introduced species on Barrow Island would be unacceptable.

- Recognition that species of plants and animals may arrive on Barrow Island in a manner which is outside the control of Gorgon (eg. birds or air-borne organisms), and that such incursions will need to be given attention in the Quarantine Management System.

- A worked example of the quarantine management specifications, termed Design Guides, required for the pathway of raw materials (aggregate and sand) so as to give effect to the standards set out in the Risk Standards Report.

- Progress towards the development of Design Guides for two further pathways of 'Food and Perishables' and 'People' which will need to be included in the appendices to the EIS/ERMP document.

- A review by Gorgon of some of the pathways leading to a change in project design such that road base material will now not be taken to Barrow Island and consideration is being given to precasting concrete wherever possible to reduce the transport of aggregate and sand.

- Recognition that the details of the quarantine management measures (barriers) necessary for addressing many pathways cannot be formalised until the project's procedural and engineering processes are well advanced.

- Recognition that the development of the quarantine management programs is an iterative process, and that this process must include independent reviews by specialists to assess the effectiveness of the detailed quarantine measures proposed by Gorgon in relation to the risk standards set out in the Risk Standards Report.

- Advice to Gorgon that baseline surveys of the marine and terrestrial environments are essential elements of a Quarantine Management System and should be well underway before the operational phase of the proposed development.

- Recognition that the current paucity of information concerning most organism groups that occur on and adjacent to the Barrow Island Nature Reserve (including lack of taxonomic research and lack of experts capable of identifying specimens) and the short development time frame means that baseline data collection will not have progressed to a stage that the Panel would consider desirable before construction is proposed to commence.

- An annotated outline of the quarantine chapter in the EIS/ERMP document.

Gorgon has made good progress towards the preparation of a Quarantine Management Plan. The Company has the potential to achieve international recognition for the quarantine standards and management measures being planned for an industrial development on an island with very high biodiversity and conservation values. In addition, Gorgon has developed a community consultation process which provides an opportunity through meetings and workshops for considerable public input.

6 A transparent process

The Panel has provided advice on the need for a high degree of transparency in relation to the meeting records not only for the meetings of the Panel, as set out above in Section 2, but also for the Gorgon Community Consultation meetings and the associated Workshops.

Draft Meeting Records have been prepared by the secretariat for each Community Consultation meeting and for each Workshop. These drafts were distributed to each participant and suggested amendments invited. Following receipt of the suggested amendments the Meeting Records were finalised by the meeting chairman. The Meeting Records were then distributed to each participant and also made available on the Gorgon website. At each Community Consultation Meeting and Workshop participants had a further opportunity to comment on the previous Meeting Record. If a participant so desired, the chairman accepted comments on the meeting record in writing and these then became an attachment to the subsequent meeting record.

7 Information gathering

The Panel has provided advice to Gorgon on the need for additional information in relation to the development and long term operation of a Quarantine Management System. This has included advice on the adequacy of surveys of the marine environment as well as giving attention to the potential for introductions of invertebrates and micro-organisms.

In response, the following reports have either been completed or are in the process of completion. The Panel understands that Gorgon will make the reports available on the Gorgon website prior to the release of the EIS/ERMP document and will form part of the Appendices of that document.

- Baseline Studies and Data Gaps.
- Micro-organism threats to terrestrial vertebrate fauna of Barrow Island.
- Micro-organism threats to Barrow Island flora.
- Micro-organism threats to Barrow Island marine environment.
- Quarantine Procedural Review – Benchmarking Study.

Gorgon has also funded the Department of Conservation and Land Management (CALM) to prepare a comprehensive Barrow Island bibliography, and it is anticipated that this will be made public through a CALM publication.

8 The Panel in relation to the release of the EIS/ERMP document

The Panel is aware that the proposed release date for the EIS/ERMP document was amended during the year from August to December 2004. This decision took into account advice received from the Panel and the discussions at the Community Consultation meetings. The Panel is conscious of the size and difficulty of the task of developing an effective Quarantine Management System, particularly because of the very high biodiversity and conservation importance of Barrow Island. The Panel has worked closely with Gorgon to provide advice to assist in developing risk standards, a Quarantine Management System and a Quarantine Management Plan.

The Panel will not be in a position to provide advice on the text of the draft EIS/ERMP document, but the Panel has endeavoured to provide advice which has assisted Gorgon in giving attention to the matters of high priority in relation to the development of an effective Quarantine Management System.

9 Advice of the Panel to the Gorgon Joint Venture on the way forward

Coordination of the biological surveys

Comprehensive knowledge of the plants, animals and micro-organisms of Barrow Island and surrounding waters is an essential element of an effective quarantine management system in relation to the detection of introduced species as well as assessments of ecological change. The Panel is of the view that surveys to gain the required knowledge over time can best be achieved by engaging lead specialists in three broad areas of flora, vertebrates and invertebrates. However, a coordinating mechanism is essential and this will require the services of a suitably qualified, experienced person, or team, to be responsible for integrating the surveys and the data flowing from those surveys.

Protocol for action in the event of an incursion being detected

A process needs to be established at an early stage that defines the protocols to be adopted in the event that an incursion of an introduced species is detected. The protocol would include the communication required, the authority to act, the principles supporting the methods to be employed, the equipment that needs to be available and the mechanisms to verify outcomes.

Conclusion of the work of the Panel

The Panel is of the view that with the release of the EIS/ERMP document it may have concluded its role, at least for phase 1. However, following release of the EIS/ERMP document Gorgon will need to expand its work on the details of an effective quarantine management system and Gorgon may find value in continuing a form of advice from specialists and the community generally.

The Panel requests Gorgon to consider this matter in relation to the form of an advisory panel which Gorgon may need in the next phase of the quarantine management process.

Panel members take this opportunity to express their thanks to Gorgon for the opportunity to provide advice and steer the direction of quarantine management on Barrow Island.

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Attachment 1

Gorgon Quarantine Expert Panel Membership

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Gorgon Quarantine Expert Panel

'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 Environment and Heritage
Keith Collins	Risk Management Specialist
Diana Jones	WA Museum
Malcolm Nairn	Biosecurity Consultant
Greg Pickles	WA Department of Agriculture
Sandra Potter	Australian Antarctic Division
Andre Schmitz	Australian Wildlife Conservancy
John Scott	CSIRO Entomology

Observers

Warren Tacey	WA Department of Environment
Norm Caporn	WA Department of Conservation & Land Management

Secretariat

Russell Lagdon	Gorgon Joint Venture, (HES Manager)
Sean Reddan	Gorgon Joint Venture, (Environmental Advisor)
Richard Stoklosa	Gorgon Joint Venture, (Risk Specialist)
Geoff Prior	Gorgon Joint Venture, (Construction and Logistics Advisor)

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Attachment 2

Gorgon Quarantine Expert Panel

Terms of Reference

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Gorgon Quarantine Expert Panel
Terms of Reference

Preamble

The establishment of a Quarantine Management System (QMS) to meet the goal of no introduced species on Barrow Island and in the surrounding waters is a critical element of a referral document by the Gorgon Joint Venture to the Environmental Protection Authority (EPA) under Part IV of the Environmental Protection Act.

The EPA set out in its Bulletin 1101 that if the Western Australian Government ("Government") gave in-principle approval for access to Barrow Island, the Gorgon Joint Venture would need to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island, and that the process would need to include appropriate technical experts as well as ensuring a high level of transparency and community involvement.

The Government has given in-principle approval for access to Barrow Island.

The QMS would set new benchmarks in best practice conservation performance and would include the set of standards for the performance of the quarantine measures. The Gorgon Joint Venture would also be required to demonstrate that it could meet the risk standards with a very high degree of confidence.

The Joint Venture has established a Gorgon Quarantine Expert Panel to assist in the development of the QMS and to ensure that this is undertaken in a transparent manner with community involvement. However, the Gorgon Joint Venture recognises that the final responsibility for the QMS resides with the Joint Venture Company in relation to the preparation of the referral document to the EPA.

The purpose of the Expert Panel is 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.

Composition of the panel is based on the expert advice each participant can provide.

Terms of Reference

1 Agree upon the 'boundary conditions' and precise outputs expected from the Expert Panel in relation to the QMS.

2 Define roles, responsibilities and expectations of members of the Expert Panel (eg. meeting attendance, continuity of support).

3 Gain appreciation of existing quarantine operations, procedures and performance history.

4 Define the focus for the development of the QMS noting the requirements for best practice outcomes.

5 Discuss and agree on the work, schedule and resources required to develop the criteria for acceptable quarantine risks, performance standards, baseline surveys, contingency planning, monitoring/audit requirements, and transparency of operation, including reporting, and external review of performance.

6 Discuss and agree on mechanisms and protocols for communication of the work of the Expert Panel.

7 Develop a 'road map' of work to be undertaken and the scheduling of that work.

8 Review and comment on documentation proposed, including risk management strategies, in relation to the preparation of the QMS.

9 Provide high-level advice to the Gorgon Joint Venture which will contribute to the development of an effective QMS.

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Attachment 3

Gorgon Quarantine Expert Panel

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Gorgon Quarantine Expert Panel
Charter

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."

Clarification notes:

- "No introduced species" relates to all activities of ChevronTexaco, including those of existing oilfield operations, as operator of the Gorgon Development, and its contractors.
- The term "introduced species" relates not only to species that are exotic to Australia but also to species that occur on the mainland but not on Barrow Island.
- Including the surrounding Islands of Boodie, Middle, Pasco, Boomerang, Double and Prince Rock.
- The Quarantine Management System will apply to the construction, operation and decommissioning phases of the Gorgon Development, as well as any other person travelling to Barrow Island.
- The Panel will provide advice on a set of biosecurity measures designed to achieve the purpose.
- In the case of micro-organisms, the principle of preventing the introduction of species not already present on Barrow Island can best be addressed by adopting a risk management approach to each of the operational pathways so that material likely to harbour potentially harmful micro-organisms are prevented where ever possible from entering the island. Such an approach recognises the difficulty of identifying the enormous range of micro-organisms which currently exist on the island as well as those that could enter via a variety of avenues some of which have nothing to do with human intervention. It also recognises that micro-organisms will have entered and will continue to enter Barrow Island in or on humans and their food, most of which are unlikely to affect the indigenous biodiversity. The pre-border, border and post-border quarantine (biosecurity) management measures will take into account those micro-organisms known, or expected to be harmful to the biodiversity of Barrow Island.

Objectives 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's best practice 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

To achieve our purpose and objectives we commit to:

- Every point of view is important and is to be respected by others
- Where our opinions differ, we will respect those differences but strive to resolve them through an agreed process
- Talk freely (i.e. contribute our input and opinion freely)
- Be aware of the different roles and positions we hold or represent (i.e. beyond the Expert Panel) and find a way to handle them (i.e. to ensure we contribute our expertise to the Panel)

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Technical Appendix D2

How-to Guide for Conducting Risk-based Assessments of Quarantine Threats to Barrow Island

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

HOW-TO GUIDE FOR CONDUCTING RISK-BASED ASSESSMENTS OF QUARANTINE THREATS TO BARROW ISLAND

TECHNICAL APPENDIX D2

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How-to Guide
for Conducting Risk-based Assessments of Quarantine Threats to Barrow Island

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Revision 0	**26 November 2003**	**Draft for review**
Revision 1	**10 December 2003**	**Incorporating Quarantine Expert Panel comments**
Revision 2	**10 February 2004**	**Released for community consultation**
Revision 3	**12 March 2004**	**Incorporating stakeholder comments and released for risk assessment workshop support**
Revision 4	**30 July 2004**	**Incorporating stakeholder comments and workshop experience**
Revision 5	**29 April 2005**	**Incorporating stakeholder comments and workshop experience, and defining the acronyms PBA and QHAZ**

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ACKNOWLEDGEMENTS

This "How to Guide" has benefitted from substantial consultation with technical experts and stakeholders. I wish to thank the Quarantine Expert Panel, in particular, for their strategic advice and useful suggestions in their reviews of this risk-based approach toward managing quarantine threats to Barrow Island: Bernard Bowen (Chairman), Andrew Burbidge, Norm Caporn (Observer), David Carter, Keith Collins, Diana Jones, Malcolm Nairn, Greg Pickles, Sandra Potter, Andre Schmitz, John Scott and Warren Tacey (Observer).

The participation and useful observations of 45 technical specialists in 17 workshops through April 2005 is acknowledged. Many of these specialists attended several workshop sessions, and to them I am grateful for their commitment and enthusiasm. Their involvement has advanced the methodology and laid the foundations for continuing progress.

Numerous community stakeholders who attended eight public meetings and workshops have offered constructive and insightful comments on this methodology, and the difficult task of setting standards for acceptable risk.

Finally, I wish to recognise the commitment of ChevronTexaco Australia and the Gorgon Joint Venture for their support of this risk-based approach and the development of a rigorous methodology to underpin it.

Richard Stoklosa

1 Introduction

This document has been prepared to outline the methodology for conducting a risk-based assessment of potential quarantine threats on Barrow Island. There is a need to address the potential hazards of introduced terrestrial and marine pests during the construction and operation of the proposed Gorgon LNG gas plant, and associated marine terminal and CO_2 re-injection facilities. Increased movements of personnel and material on aircraft and marine vessels present a threat to the unique conservation values of the Island as a Class A Nature Reserve. The development of a Quarantine Management System (QMS) is being undertaken with advice from the Gorgon Quarantine Expert Panel. The outcomes of the risk-based assessment are to contribute to the development of the QMS.

Ecological risk assessment is rapidly becoming an appealing discipline for best practice environmental management. Regulatory authorities use risk assessment to manage a variety of ecological hazards, including non-indigenous species and genetically modified organisms. Given the complexity of ecological systems, there are few 'off-the-shelf' guidelines which apply to the wide range of environmental assessments that are undertaken. Substantial efforts are underway by numerous regulatory authorities to develop environmental risk assessment methods and techniques suitable for a wider variety of assessments.

It is the aim of this How-to Guide to draw upon the best practices for ecological risk assessment and apply them in a transparent and repeatable manner. The objective is the assessment of threats to the conservation values of Barrow Island, however the approach could be applied to nature reserves in general, or locations otherwise having high conservation value. This document will address the early activities of a staged risk assessment process, in which potential hazards will be subjected to a screening process to identify those which present risks that must be managed in a QMS. More sophisticated risk analysis may be necessary for hazards which pose significant risks to the conservation values of native species. Future adjustments to the approach and methodologies suggested here are likely based on experience, and will be reflected in revisions of this document to improve the quality of the risk assessment process.

The risk assessment and risk management of quarantine issues will continue through the proposed Gorgon Development lifecycle. It is necessary to structure the initial stages of this risk-based assessment to enable Gorgon to outline the essential elements of the QMS during the environmental impact assessment process to the Western Australian government for community consultation and project approval.

2 Background

A risk-based management framework is being used to address the threat of introducing non-indigenous species to Barrow Island. The management framework will be developed directly from the risk-based assessment of potential quarantine threats. The risk assessment is undertaken in accordance with AS/NZS 4360, *Risk management*, and incorporates the guidelines contained in the related handbook for environmental risk management (HB203 2004).

The focus areas addressed by the Expert Panel which will form the basis for the QMS are:

- Performing a risk assessment of potentially invasive terrestrial and marine species from project construction and operational activities. A systematic hazard evaluation of potential 'invasion pathways' will be undertaken. Risk analysis may be undertaken at various levels of complexity in a staged approach, initially starting with a pathway-driven analysis of potentially invasive biological groups. This first level may be used for qualitative estimates of the likelihood of a non-indigenous species arriving at Barrow Island. Subsequent levels of the risk analysis, if required, could qualitatively and/or quantitatively address the ecological risk of a potentially invasive species establishing, persisting and competing with native species. A staged approach to risk assessment is desirable to initially screen out hazards which are clearly manageable, and to apply more sophisticated risk analysis techniques (where available) to hazards which appear to represent more significant threats. Advice of the Expert Panel and community points to a qualitative risk assessment in the absence of data and knowledge of complex ecological systems.

- Identifying the biological groups of interest and undertaking a literature search with regard to their ecological functioning and potential 'invasiveness' in an arid sub-tropical setting such as found on Barrow Island. Conducting baseline studies of flora and fauna, and identifying data gaps which should be rectified to improve the quality of the management plans to be developed. Planning future monitoring requirements as a result of knowledge gained from baseline studies.

- Providing the community with the opportunity to engage in the process for delivering a QMS which will protect the conservation values of Barrow Island. The methodology and proposed standards for acceptable risk will be communicated with stakeholders and the public, and consultation will be undertaken to ensure that relevant concerns are fully considered.

- Establishing policies, organisational and administrative processes and responsibilities which ensure that standards for acceptable risk are achieved. Training and induction requirements for personnel and visitors will be addressed.

- Establishing monitoring programs for the rapid and effective detection of introduced species, and compliance with QMS procedures. Requirements for independent auditing of the QMS will be addressed to ensure that the system achieves its performance objectives and is continuously improved.

- Establishing contingency and response plans in the event of a quarantine breach. These will include 'rapid response decision guides' which rely on advice from technical specialists to formulate an appropriate response to the detection of a non-indigenous species.

The QMS developed through this framework will evolve during the project approvals process, and will be designed to address specific threats throughout the project lifecycle. Potential quarantine threats will be identified as major equipment is sourced and ongoing logistics arrangements are contemplated. The risk-based QMS will be designed to incorporate new information as it becomes available so that potential quarantine threats are effectively managed.

A staged approach will address the EPA requirements for submission of a strategic management plan at the time when the ERMP is submitted for review. Detail of specific policies, procedures and administrative details will be incorporated in the QMS prior to project construction. This staged approach will allow improvements and incorporate new information as it becomes available, supporting the desired world-class standard of the management system.

This risk assessment methodology outlines the methods to be used to perform comprehensive and systematic identification of potential quarantine threats (hazards), which is the most important part of any risk assessment. Without a thorough and complete understanding of the threats, risks could be underestimated or the QMS could fail to recognise and control risks to acceptable levels.

3 Guiding principles

Environment Protection Authority Bulletin 1101 (EPA 2003) recommended to the Western Australian government that if the proposed development of a gas plant on Barrow Island was to proceed, "it could only be with a policy of 'zero tolerance of invasions' target and an associated quarantine regime of sufficient, demonstrated rigour to achieve this." In view of the government's in-principle approval to proceed with the assessment of the proposal, the EPA has advised environmental requirements including independent expert advice and transparent public processes to decide the acceptable risk to conservation values of Barrow Island. To accomplish this, the proponent is required to develop a set of standards for acceptable risks, and to demonstrate that the risk standards can be met with a very high level of confidence. The approach is to adopt a risk-based assessment process, using the guidance contained in AS/NZS 4360 and applying it to ecological systems with regard to best practices.

Following a thorough literature search in 2003, there were no known risk assessment methods which would address the threat of invasive alien species to the conservation values of native animals and plants on a Nature Reserve and surrounding waters, to meet the EPA guidelines. It was necessary, then, to adopt the best practices from methods which have proven to be valuable in the analysis of biological stressors (Suter 1993; Beer & Ziolkowski 1995), introduction of non-indigenous species (Bomford 2003; CSIRO 2001; Hayes & Hewitt 1998; Pheloung 2001; USDA 2000), quarantine risk assessment (Biosecurity Australia 2001, 2002 and 2003; FAO 1996), the release of genetically modified organisms (OGTR 2003b; RCEP 1991), and relevant industry experience (Stoklosa 1988 and 1999). Independent reviews of quarantine risk assessment practices were also considered (eg 'The Nairn Report', DPIE 1996).

Since the initial literature search in November 2003, at least one relevant example of environmental risk assessment for the protection of island conservation values has emerged. The Department of Environment and Heritage (DEH) identified that the potential introduction of marine and terrestrial species to The Ashmore Reef National Nature Reserve and the Cartier Island Marine Reserve, due to the high level of vessel traffic and visitation, represented a significant threat to the natural values and conservation objectives of these Reserves. A risk-based assessment of the threat of introductions has been proposed by Russell *et al* (2003). This recent work supports the argument for the risk-based approach described here.

The full range of potential pests which could threaten the conservation values of Barrow Island must be considered. It would be desirable to be able to identify every potential pest species in all biological groups. Clearly this cannot be achieved in the short term. Prior to approval of the Gorgon Development, the suppliers of major plant and equipment have not yet been identified, and the potential pests originating from the locations of suppliers, or vessels used for transport, cannot be determined. Even without this knowledge, a risk-based assessment can commence by considering the 'biological groups' (or perhaps phenotypes) which may pose a threat of introduced species within the usual ICZN taxonomic classification scheme (eg Phylum, Class, Order, Family, Genus, Species). It would be practical to consider biological groups at the Family level wherever possible (eg Muridae—mice and rats), or to identify convenient subgroups of Orders (eg winged arthropods). Using such a taxonomic classification to identify potential pests ensures comprehensive consideration of organisms of interest, and allows experts in various disciplines to contribute to the risk assessment in a structured manner. Advice to be considered will include characteristics of the lifecycle stages of these biological groups, the environmental parameters which affect survival and persistence (eg temperature, salinity, rainfall, soils, habitat structure, seasonal events, etc), and the competency to survive the journey and establish viable populations at the recipient port. In some cases, it may be possible to specifically consider one or more 'indicator species' within a wider biological group, which could be used for assessment purposes if its activity and management regime is protective of the wider organisms represented in the group.

The exception to direct hazard identification and risk assessment of potential pests would be micro-organisms. Some specific bacteria, viruses, fungi, or other pathogens might be identified as known threats to native species in the general region, carried by airborne spores or vectors such as seabirds which routinely visit offshore islands in the area. It would be an impossible task to identify all potential pathogens, as only a fraction of micro-organisms are even described by the scientific community. Instead, it would be more productive to consider any special circumstances where specific pathogens of known concern could be associated with host species, or entrained in cargoes or people arriving at Barrow Island (eg temperature controlled containers, goods and conditions which might provide a culture medium, unique types of equipment packaging, luggage, etc).

Hazard evaluation is the most important part of any risk assessment, and must be systematic, rigorous and transparent. Failure to identify potential hazards can result in risk estimates which are too low, or management practices which fail to recognise and control risks to acceptable levels. It is desirable for hazard evaluation to involve a range of technical disciplines and specialists with operational experience, making use of 'inductive' techniques which are designed to identify hazards which may lie outside the professional experience of the individual analysts involved. The selection of appropriate techniques to address these guiding principles is discussed in Section 4 of this document.

Pathway-driven hazard evaluations are the most useful starting point for assessing the risks of introduced alien species, as there are a limited number of inspection facilities where goods are packaged prior to shipment to Barrow Island (eg Welshpool, Dampier). Other pathways of interest include personnel and small articles arriving from airports in passenger aircraft, originating at commercial airports and other nearby facilities (eg Varanus Island, Thevenard Island). Pathway-driven hazard evaluations must also consider major equipment arriving in Australia from foreign ports which will require special arrangements for quarantine inspections and clearance prior to delivery to Barrow Island, specialised vessels to be used for construction activities (eg survey vessels, dredges, etc), and product tanker vessels.

The assessment criteria, or 'endpoint' for the classification of risk is relatively simple, given the EPA recommendations for assessing the project and the Gorgon Venture's objectives for protecting the conservation values of Barrow Island. The assessment standard for acceptable risk can be stated as:

> *A zero tolerance of invasions target, where the risk of introducing an alien species to Barrow Island is sufficiently low to prevent the possibility of establishment and invasion.*

This assessment standard for acceptable risk must be stated in operational terms with advice from technical experts and stakeholders, to enable the assessor to use 'measurement endpoints' to classify risk. The standards for acceptable risk should be established with regard to the analysis of pathways, such that the likelihood of introduction can be estimated for various biological groups, providing a metric which can be monitored and verified with operational experience. Using the likelihood of introducing an alien species to Barrow Island provides a simple, clear and verifiable risk metric, which avoids the complexity of estimating the likelihood of impacts to the conservation values of the Island when little data exists to make informed predictions. The acceptance standard for the introduction of one group of organisms may be different than another, based on expert advice and stakeholder consultation.

The forward plan for improving risk-based assessment of quarantine hazards is to develop more understanding of the suitability of non-indigenous species to survive in the Barrow Island environment, and to determine monitoring and contingency strategies which enable detection and control of any introductions which may occur. As more data becomes available, more confident predictions of survival and detection of alien species may be achievable to characterise risk.

4 Selection of hazard evaluation techniques

Formal hazard evaluation studies have their origins in the chemical process, nuclear and aerospace industries (among others) over a period of more than 40 years. During this time, published guidelines have been developed to describe the techniques used in these studies (CCPS 1992), and there is a wealth of experience in applying them to a variety of industrial risk assessments. The application of the same tools to ecological problems has been attempted to a much lesser extent, however the benefits of performing rigorous hazard evaluation as a basis for an understanding of ecological risk are clear (RCEP 1991; Suter 1992). The general approach is to adapt the familiar tools used in industrial hazard evaluation to their analogies in natural systems.

Hazard evaluation can sometimes be performed by a single person, depending upon the specific need for the analysis, the technique selected, the perceived hazard of the situation being analysed, and the resources available. Clearly, it is preferable for a team of technical and operational specialists to be involved in hazard evaluation and risk analysis than relying on the experience of a single analyst. Whilst the team approach demands a high level of commitment from a number of people, the benefits lie in the exchange of ideas and information which allows for lateral thinking and creative analysis of potential hazards. 'Inductive' techniques—those which involve creatively analysing the ways in which planned activities could fail in their intended purpose—are preferable to 'deductive' techniques in the analysis of ecological risk. Deductive techniques require a precise understanding of the response of a system to well-described events, which are more readily applied to well-understood physical processes (eg industrial equipment, computerised control systems) than the less predictable behaviour of living systems.

There are a number of hazard evaluation techniques which have been applied to industrial situations (CCPS 1992; AS/NZS 3931 1998), and methods used in risk analysis have been noted in the Standards Australia handbook for environmental risk management (HB203 2004 – Appendix G). Of these, the following range of techniques have been published for identifying hazards in ecological systems, particularly with respect to biosecurity and invasion of pest species (in alphabetical order, with references to published applications of each technique in brackets):

- Fault tree analysis (Hayes 2002a);
- Hazard and operability (HAZOP) analysis (RCEP 1991);
- Hazard checklists (OGTR 2003a);
- Hierarchical holographic modelling (HHM), a form of the 'paired comparisons' technique (Hayes *et al* 2004—in preparation);
- Import risk analysis (Biosecurity Australia 2003);
- Infection modes and effects analysis, or IMEA (Hayes 2002b) — the analogy to failure modes and effects analysis, or FMEA, used in the risk analysis of industrial systems;
- Relative ranking, a form of 'hazard indices' (Bomford 2003; Pheloung 2001; USDA 2000); and
- Retrospective analysis, a form of the 'review of historical data' technique (Biosecurity Australia 2001).

Hazard evaluation and risk analysis techniques which may be considered for some types of ecological assessments might also include preliminary hazard analysis (PHA), event tree analysis, human reliability analysis (HRA), and modelling techniques such as Monte-Carlo simulation (Stoklosa 1999). The general limitation of any of these proven industrial methods is in their ability to handle the less certain interactions of biological systems, compared to the well described physics and chemistry of industrial processes.

Of these techniques, six involve inductive reasoning: event tree, IMEA, fault tree, HAZOP, HHM and PHA. The strength of inductive reasoning lies in its ability to discover "what can go wrong?" using the imagination and ingenuity of a group of analysts with appropriate technical and operational expertise. Inductive techniques enable the identification of hazards which lie outside the professional experience of an individual analyst. Hazard identification for all new risk assessment paradigms, such as the risk of introduced species to the conservation values of a nature reserve, must begin with inductive techniques. Only with improved understanding of the performance of operational barriers and the interactions of biological systems, can analysts begin to also adopt deductive approaches such as checklists and unstructured brainstorming techniques. If brainstorming techniques were adopted for each new ecological assessment, hazard identification would become a haphazard process (Suter 1992, page 394). Systematic, inductive hazard evaluation techniques are therefore preferred in the current situation.

The advantages and disadvantages of hazard evaluation techniques which might be applied to the current situation are compared in Table 4.1. Note that the HAZOP and IMEA [FMEA] techniques are described in AS/NZS 3931 as "fundamental" methods for hazard evaluation.

Rather than invent an entirely new hazard evaluation technique, the aim is to select those which are best suited to the analysis of the new risk assessment objectives to be considered here. It is prudent to give higher consideration to those inductive techniques which have proven applications in biosecurity and the invasion of pest species. Techniques must be selected to address pathways of introduction and activities designed to be barriers to introduction along each pathway. Table 4.1 suggests that the focus should be on the proven IMEA, fault tree and HAZOP techniques. These techniques have been applied to introduced species and biosecurity. The PHA technique may also be considered as a precursor to a detailed HAZOP analysis of barriers at the conceptual or preliminary design stage. The selection of appropriate hazard evaluation techniques for the protection of the conservation values of a class A Nature Reserve has not been specifically addressed in the current technical literature, nor have standards for acceptable levels of risk been established in this context.

The fault tree technique is discarded for the initial identification of hazards, however, because of the complexity of the effort to construct detailed and accurate fault trees for every combination of pathways and biological groups of concern. Uncertainties in causal events and circumstances would frustrate the construction of fault trees, as would temporal components of biological systems. This does not mean that a fault tree approach should be excluded categorically, as it may augment the other methods in certain circumstances where such detail could aid the understanding of threats.

Methods currently used for import risk analysis have also been discarded as the basis for this methodology, as these typically require quantitative or semi-quantitative risk analysis techniques which are applied to a very narrow range of organisms and hosts, to determine whether they will become pest species if imported from a foreign country as a result of trade. Import risk analysis is used to establish the types of quarantine barriers that could be adopted to prevent an unfair exclusion of imports among trading nations. Import risk analysis also aims to analyse the economic consequences of an introduction to specific types of agricultural crops (and arguably to a lesser extent environmental consequences). In contrast, the aim of this methodology is to assess the risk of any introduction to Barrow Island, a Class A Nature Reserve, and develop barriers to address specific threats of introduction along pathways where NIS could be introduced.

Table 4.1 Techniques used in hazard evaluation (after AS/NZS 3931).

Hazard evaluation technique	Description and usage	Application to assessment of quarantine hazards	
		Advantages	Drawbacks
Inductive techniques			
Event tree analysis	A hazard identification and frequency analysis technique which employs inductive reasoning to translate different initiating events into possible outcomes.	Potential to augment another hazard evaluation technique to describe ecological consequences from the 'bottom-up', if there is sufficient understanding to predict the behaviour and interactions of an introduced biological group.	Insufficient information to predict outcomes when initiating event is the introduction of non-indigenous species whose behaviour is not well described. Limited usefulness outside of well-understood species interactions.
Infection modes and effects analysis (IMEA) *Analogous to failure modes and effects analysis (FMEA)*	A **fundamental** hazard identification and frequency analysis technique which analyses all the fault modes of a given equipment item for their effects both on other components and the system.	Proven technique for introduced pests (Hayes, 2002b). Highly structured, has the potential to identify all potential hazards, prioritises hazards on the basis of causes and consequences.	Time consuming when used to identify an exhaustive list of combinations of failures which lead to accidental introductions.
Fault tree analysis	A hazard identification and frequency analysis technique which starts with the undesired event and determines all the ways in which it could occur (displayed graphically).	Proven technique for introduced pests (Hayes, 2002a) and incident investigation. Highly structured, 'top-down' analysis of undesirable events.	Analysis for all types of accidental introductions among all biological groups would be an impossible task. A highly complex fault tree would be required for each pathway and organism
Hazard and operability (HAZOP) analysis	A **fundamental** hazard identification technique which systematically evaluates each part of the system to see how deviations from the design intent can occur, and whether they can cause problems.	Proven technique for introduced pests (RCEP. 1991). Highly structured, has the potential to identify all potential hazards, captures existing safeguards and corrective/ preventive measures.	Classical application of this technique does not prioritise hazards. This limitation can be overcome, however, if estimates of likelihood and consequences are included in the analysis.
Paired comparisons — Hierarchical holographic modelling (HHM)	A means of estimation and ranking of a set of risks by looking at pairs of risks and evaluating just one pair at a time.	Considers pair-wise interactions of all components of the system.	Data to support such an analysis for all biological groups is lacking. Analysis would have low confidence.
Preliminary hazard analysis (PHA)	A hazard identification and frequency analysis technique that can be used early in the design stage to identify hazards and assess their criticality.	Commonly carried out during conceptual development of a project when there is little information on design details or operating procedures. Can be a precursor to further hazard identification and risk analysis (such as a HAZOP when detailed design is available).	Provides results which are subject to further analysis when more detailed information becomes available.

Table 4.1 Techniques used in hazard evaluation (after AS/NZS 3931), concluded.

Hazard evaluation technique	Description and usage	Application to assessment of quarantine hazards	
		Advantages	Drawbacks
Non-inductive techniques			
Checklists	A hazard identification technique which provides a listing of typical hazardous substances and/or potential accident sources with need to be considered. Can evaluate conformance with codes and standards.	None for the current situation, as potential hazards cannot be identified by any 'standard' rules or mechanisms.	'Typical' sources of hazards and/or potential introduction scenarios are not well understood in the system under study. Under these circumstances, checklists fail to assist the analyst to be thorough.
Hazard indices — Relative ranking	A hazard identification/ evaluation technique which can be used to rank different system options and identify the less hazardous options.	Weed risk assessment (WRA) an example of a method to determine the 'invasiveness' of a species based on climate and geographical data.	Indices for a wide range of biological groups which might be introduced are unknown, making the technique of little use outside of few proven applications. Relative ranking is actually an analysis strategy rather than a single, well-defined analysis method.
Human reliability analysis (HRA)	A frequency analysis technique which deals with the impact of people on system performance and evaluates the influence of human errors on reliability.	Usually performed to augment other hazard evaluation techniques, for situations where it is necessary to analyse factors which influence human performance.	No data available on human performance factors which might influence reliability of various barriers to introduction.
Modelling techniques	A means of conducting predictive frequency analysis, using a model of the system which evaluates variations in input conditions and assumptions.	None for the current situation.	Modelling of ecological systems should not be undertaken without a detailed and confident understanding of the behaviour and interactions of biological systems which must be expressed in quantitative, mathematical terms.
Review of historical data — Retrospective analysis	A hazard identification technique that can be used to identify potential problem areas and also provide an input into frequency analysis based on accident and reliability data, etc.	Review of some data is possible to identify situations where cargoes are infected with organisms at some locations (eg Welshpool, Dampier, Barrow Island). Available data could be used to augment other techniques (eg experience of Australian Antarctic Division, AQIS, Defence in East Timor).	Very limited data to predict the behaviour and interactions of the system under study, or to confidently predict frequency of infected cargoes.

The IMEA technique can be applied to the 'carriers' of introduced organisms from the port of origin to Barrow Island (eg materials, equipment, personnel, aircraft, marine vessels). It is unlikely that a direct measure, either quantitative or qualitative, of ecological effects or even survival of introduced species will be achievable in the first instance for many biological groups.[1] The IMEA should be structured to consider 'introduction' (arrival on Barrow Island and surrounding waters) as a measure of the likelihood of exposure, and 'detection' and 'eradication' as a surrogate for potential consequences. In cases where experts can make judgments of the likelihood of survival of an introduced species, survival could also be scored as a surrogate for potential consequences. Estimates of introduction, survival, detection and eradication are made qualitatively using a scoring system, as generally described by Hayes (2002b) in the assessment of the spread of marine organisms by small craft (discussed in Section 5.2 of this document).

The HAZOP analysis can be applied to activities which are intended to be quarantine barriers along the pathways from the port of origin (eg Welshpool, Dampier, overseas ports, private and commercial airports) to Barrow Island. If detailed designs of barriers (eg inspection, testing, treatment) to exclude introduced species from material and personnel movements are provided for each pathway, then the HAZOP technique can be applied to identify and evaluate deviations from the intended performance of these barriers. For this methodology, the HAZOP technique for quarantine threats is given the more intuitive label of 'QHAZ', or quarantine hazard analysis.

The PHA technique is likely to be more useful than a rigorous QHAZ analysis during the early development of quarantine barriers, when only conceptual or preliminary information is available. A PHA can contribute to the analysis and improvement of barriers to meet performance expectations at the early stages of development, as a precursor to QHAZ analysis when detailed designs become available. The PHA technique for quarantine threats is given the more intuitive label of 'PBA', or preliminary barrier analysis.

The combination of IMEA, QHAZ and PBA techniques appear to be the most appropriate methods for assessing the risk of introducing non-indigenous organisms to Barrow Island. To augment the IMEA, QHAZ and PBA techniques, it will be useful to reference any historical data and operating experience from other quarantine efforts (the last hazard evaluation technique listed in Table 4.1).

Details of the risk-based assessment methodology are described in Section 5 of this document.

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[1] Collective advice of the Quarantine Expert Panel, 28 November 2003.

5 Risk-based assessment methodology

The framework for a risk-based assessment of the threat of introduced alien species is expressed with regard to AS/NZS 4360 in Figure 5.1.

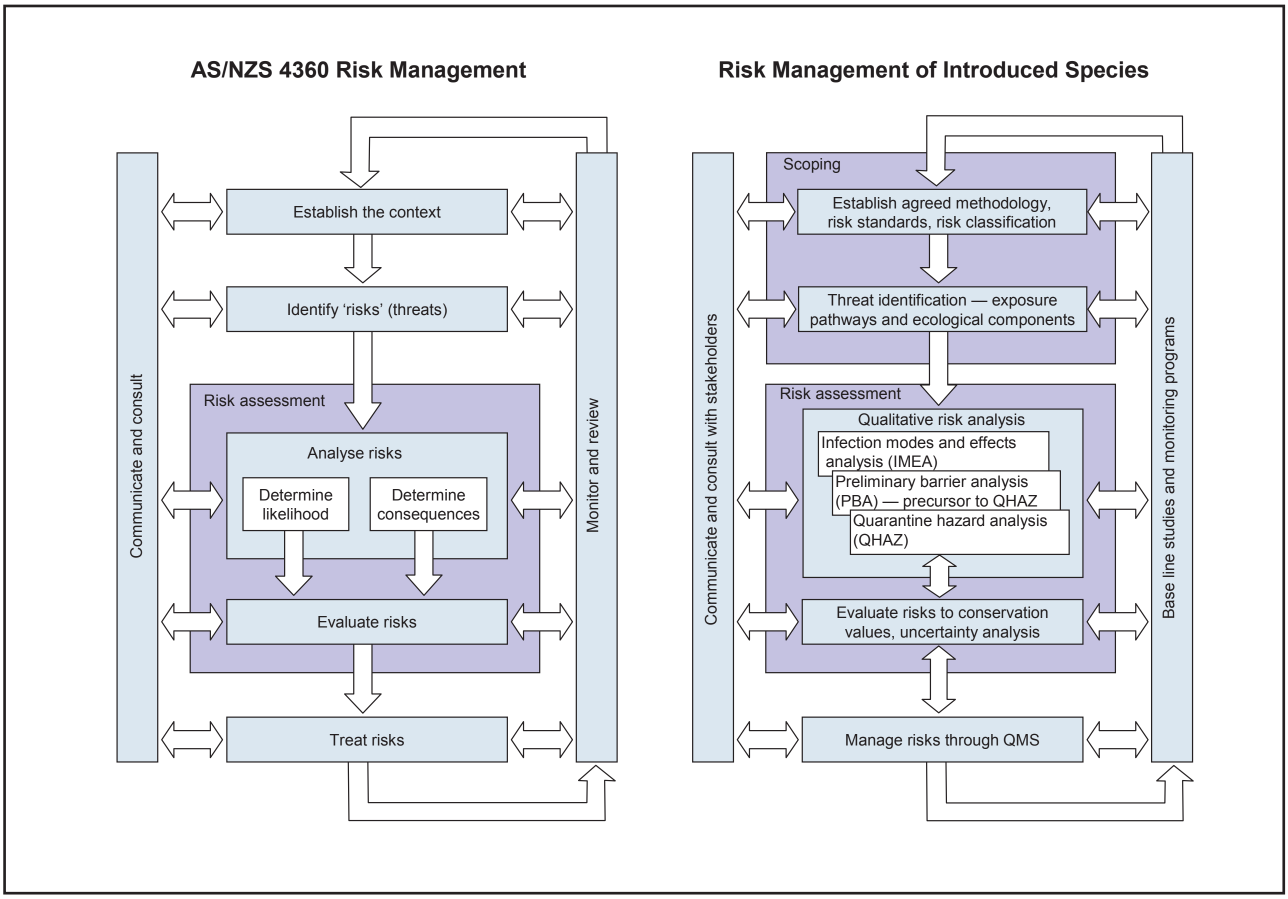

Figure 5.1 Comparison of risk management framework for introduced species to AS/NZS 4360.

To evaluate potential quarantine hazards, the following steps are taken to assist Gorgon to identify and design appropriate quarantine barriers, with clear emphasis given to pre-border prevention of introduced organisms:

1. Describe individual pathways for material and personnel movements from ports of origin to Barrow Island. These will include: types and quantities of materials (or people); layout of facilities used to receive, pack and ship consignments; steps and equipment used in the process of handling materials (or people); and a description of transport vessels (marine vessels, aircraft, trucks). Each pathway is to represent a potential threat of introducing non-indigenous species to Barrow Island, and may encompass different types of materials and equipment which would be subject to common handling and transport activities. Examples of personnel and commodity pathways are listed in Table 5.1. However, this list may grow as construction and operational activities are identified which entail new threats to be managed. In the first instance, these pathways might not include quarantine barriers to introduced species, to allow the workshop participants to identify infection scenarios and consider possible preventive measures.

2. Identify biological groups which may 'infect' materials (or people) handled on the subject pathway. These might include organisms which are present in the materials to be transported, or associated with the equipment and facilities where consignments are handled. An indicative list of biological groups is presented in Table 5.2 for reference.[2] Equally important in the preparation for hazard evaluation is to identify potential pest species (and propagules) which may exist at each port where materials and people are processed for departure. Lists of potential invasive species and biological groups should be sourced from specialists and museums with expertise in terrestrial and marine organisms of interest in Western Australia. These potential pest groups should include, but not be limited to, those listed in Table 5.2.

3. Prepare information for workshops which are to involve environmental specialists (with expertise in the relevant biological groups of concern), material handling and transport specialists familiar with existing operations, and an experienced facilitator. Information should include a description of activities unique to each pathway, and operational experience regarding the performance of quarantine controls for similar types of activities. This operational experience should be sourced from past Barrow Island oil asset activities as well as any broader quarantine experience (eg Australian Antarctic Division, Department of Defence, Australian Quarantine and Inspection Service, and international sources). Individual workshops may address one or more pathways and one or more biological groups.

4. Convene workshops and describe the pathways to all participants (types of materials and types of vessels), and agree on the components of the pathways which may be a source of 'infection' of introduced species. Explain the hazard evaluation procedure for all participants and clarify information on pathways.

5. Perform infection modes and effects analysis (IMEA) on all components of each pathway (refer to Section 5.2.1). Record details of how infections occur, existing safeguards, estimates of risk, and identify possible measures to prevent infections for consideration.

6. Describe conceptual quarantine barriers which could be considered to reduce risk, and undertake preliminary barrier analysis (PBA) of the barrier concept (Section 5.2.2). Re-evaluate risk based on the expected performance of the conceptual barrier.

7. Review and select appropriate barriers for detailed design, based on practicality and effectiveness for reducing risk.

8. Once the design of barriers is advanced to detailed plans, but prior to finalising the design for construction/implementation, undertake quarantine hazard analysis (QHAZ) to evaluate the design intention of selected barriers (Section 5.2.3). Identify improvements which will make barriers more effective. Re-evaluate risk based on expected performance of the barrier.

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[2] Prepared in consultation with the Quarantine Expert Panel, 22 January 2004.

Table 5.1 Conceptual list of potential introduction pathways for consideration in hazard evaluations (persons and cargoes, modes of transport).

▪ Personnel and accompanying luggage	▪ Aggregate, sand
▪ Personal goods consigned for transport	▪ Cement
▪ Skid equipment, accommodation units	▪ Plant, including earthmoving equipment and vehicles
▪ Pre-fabricated modules	▪ Pipe
▪ Food and perishables	▪ Steel
▪ Containerised goods	▪ Marine vessels, aircraft, road transport

Table 5.2 Conceptual list of biological groups for consideration in hazard evaluations.

Terrestrial groups	Marine groups
Vertebrates (eg mammals, birds, reptiles [snakes, geckoes], amphibians, fresh and brackish water fishes)	**Vertebrates** (eg fin fish, sea snakes)
Soil-dwelling invertebrates (eg arthropods [termites, worms]) **Above-ground invertebrates** (eg ants, terrestrial molluscs) **Subterranean fauna** (eg stygofauna [crustaceans, worms], troglofauna [insects, millipedes])	**Invertebrates** (eg molluscs, crustaceans, coelenterates [hydroids, jellyfish, corals], ascidians [sea squirts], worms, echinoderms [sea urchins, starfish], bryozoans)
Plants (vascular plants, non-vascular plants)	**Plants** (eg algae, sea grasses)
Micro-organisms (eg fungi, bacteria, viruses)	**Micro-organisms** (eg zooplankton, phytoplankton, fungi, dinoflagellates, bacteria)

A 'roadmap' of the risk assessment process, based on the approach described here is presented in Figure 5.2. An essential element of the process is the involvement of independent technical specialists to identify threats, recommend appropriate quarantine barriers, and estimate risk.

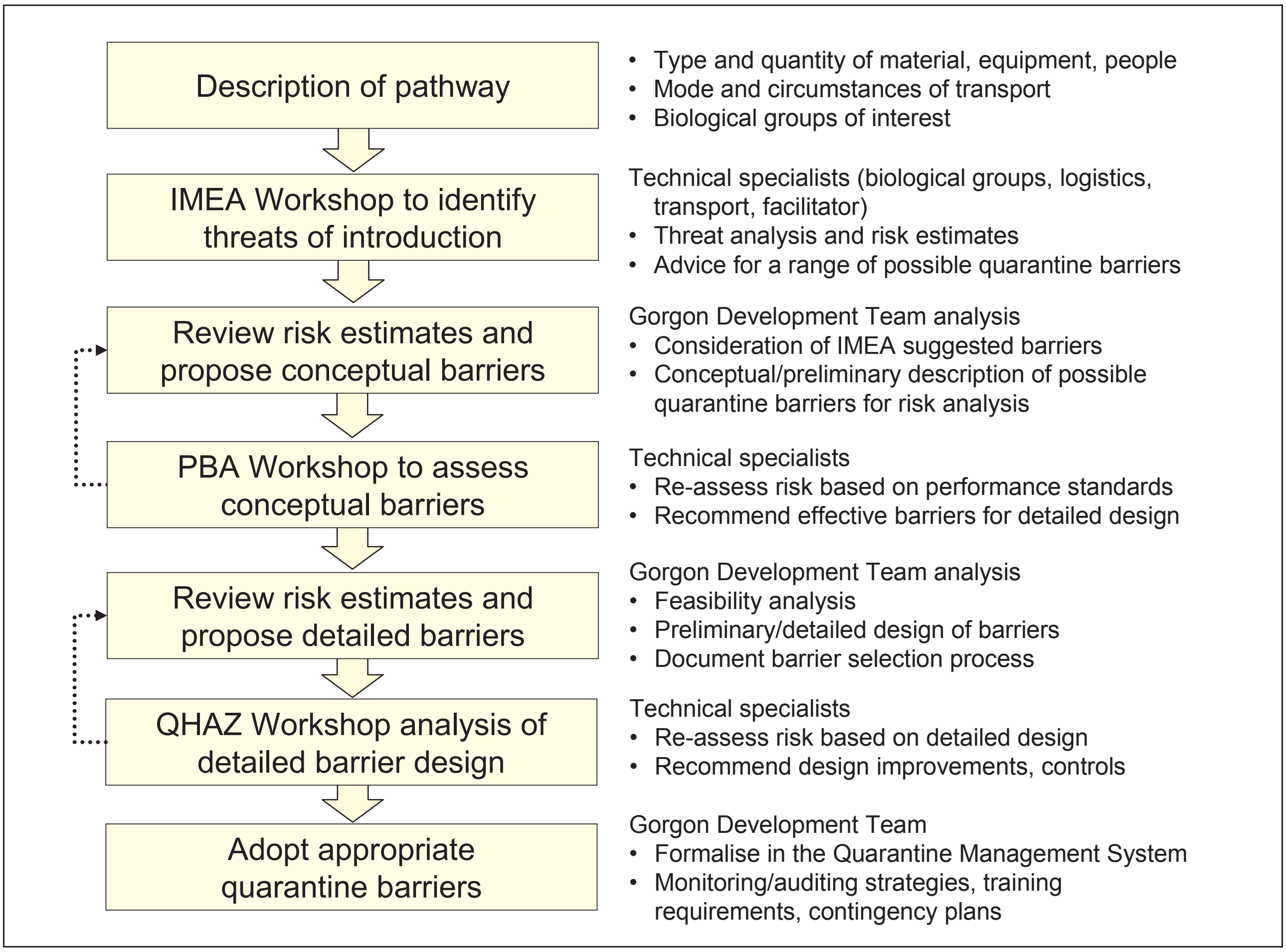


Figure 5.2 Roadmap of the risk assessment process.

5.1 Establishing the context

The context of the risk-based assessment is outlined in the guiding principles presented in Section 3 of this document. The selection of appropriate hazard evaluation techniques is discussed in Section 4.

The priority for quarantine management is to first prevent the arrival of infected cargoes, people and vessels at Barrow Island. For purposes of quarantine hazard identification and risk assessment, Barrow Island is considered the 'border' for introductions. The emphasis, then, is 'pre-border' prevention of introductions to the Barrow Island terrestrial and marine environment.

When considering pathways for the potential introduction of organisms, it is important to also acknowledge the potential for the arrival of organisms from natural processes and events (eg seabirds, regional marine currents, wind and cyclones).

5.2 *Hazard identification*

The IMEA technique has been applied to biological systems as a hazard identification tool for marine pests (Hayes 2002b), and has been selected for evaluating the hazards of introduced species to Barrow Island and the surrounding marine environment. There is also evidence that the QHAZ approach can be effectively applied to biological hazards (after the HAZOP application in RCEP 1991), when the intent of the system which manages those hazards can be fully described—the 'barriers' to introduction. The PBA technique can be used as a precursor to QHAZ analysis, to assist in the selection of effective barriers at the concept selection phase of development.

The methodology described here takes advantage of these three inductive analysis tools. The rationale for selecting these particular hazard evaluation tools is discussed in Section 4 of this document.

5.2.1 *Infection modes and effects analysis*

Borrowing the methodology from a proven hazard evaluation technique based on failure modes and effects analysis, or FMEA (CCPS 1992; Hayes 2002b), we can estimate the risk of invasion as a function of the likelihood of introduction, the likelihood of survival, the likelihood of detection, and the efficacy of eradication. The analogy to FMEA is an 'infection modes and effects analysis', or IMEA which is used here.

The term 'infection' represents the introduction of a introduced species on people or material any point along the exposure pathway between the port of origin and Barrow Island, analogous to 'contamination' which is more commonly used in the context of chemicals or waste material. IMEA is an inductive technique which allows a group of analysts working together to identify hazards and consequences which may be outside the professional experience of individual participants.

The first step in the IMEA is to identify the 'components' of each pathway which could be infected with alien species (introduced species which originate outside the Barrow Island environment). For coastal vessels (Hayes 2002b), examples of vessel components are the hull skin, propeller surfaces, bilges and anchor wells. Workshop participants should agree on a suitable organisation of components. For example, in the case of marine vessels, it may be more convenient to organise components around dry 'zones' of vessels, splash zones, wet zones, and seabed contact. Infection modes are identified for each of these components, with reference to biological groups. The infection modes for anchor wells, for example, might be retained water and retained sediment which contains live organisms or propagules. The surface of a timber hull component has three infection modes: external fouling, internal fouling, and borers.

The IMEA considers the possible infection modes of the 'components' of material and transport vessels, the survival of biological groups during the journey to the recipient port, the ability to detect an introduction, and the predicted success of response measures to control and eradicate the introduced species or biological group. Each component/infection mode combination is subject to the IMEA hazard evaluation, leading to a potentially large number of specific hazards identified for risk assessment.

Based on the analysis of a team of technical specialists, the potential effects of infections, or introductions, can be estimated qualitatively using a scoring system. The likelihood of introduction at the recipient port, the likelihood of survival, the likelihood of detection, and the likelihood of eradication can be scored, each on a scale of 1-10. An example of such a scoring system used for ballast water risk assessment is suggested by Hayes (2002b), and is adapted for the current objectives in Table 5.3. In some cases, technical experts with knowledge of specific biological groups may be unable to estimate the likelihood of survival due to technical uncertainty associated with the complexity of ecological systems.

Table 5.3 Scoring system for infection modes and effects analysis.

Pre-border quarantine		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

Judgments regarding the likelihood of eradication may incorporate the likelihood of isolating and controlling an introduced species if eradication is difficult to achieve. An example is the current situation of buffel grass on Barrow Island, which is considered a pest weed but has been isolated to locations where it is being controlled.

In the first instance, the scoring of infection, survival, detection and eradication may be made without regard to current material handling and quarantine management practices. Existing safeguards, as they relate to individual infection modes, may be discussed in order to suggest preventive measures. However, it is not the intention to adopt all existing safeguards without considering innovative types of quarantine barriers to prevent the introduction of organisms. In cases where performance data from other quarantine operations is available to the workshop participants, it should be used to predict the efficacy of preventive measures which might be considered for Gorgon development activities.

Scoring should be undertaken with regard to the biological groups of interest. It may be convenient to select an 'indicator species' or subgroup for the purpose of scoring, with the intent of choosing one or more known species which represent a more acute invasion hazard. Whenever this approach is taken, the species considered in the scoring is recorded in the workshop record, with the intent of assessing risk in a manner which does not underestimate the hazards of the wider biological group.

The infection scores in Table 5.3 represent a qualitative range of likelihoods that cargoes, people or vessels will be infected with non-indigenous organisms. While there may be the possibility of technical experts interpreting the qualitative infection scores slightly differently among themselves, there is clearly more variability in the scores due to the range of organisms which are the subject of these judgements. Perfectly consistent interpretation of each scoring level is desirable if sufficient data were available to guide judgments of the likelihood of infection. In the more realistic situation of having limited data (typical in the analysis of ecological systems), participants in the IMEA workshop assign maximum and minimum scores for infection, survival, detection and eradication to each of the infection modes, as illustrated in Figure 5.3. The recording of maximum and minimum scores reflects the uncertainty of participants to precisely estimate these likelihoods in the risk analysis.

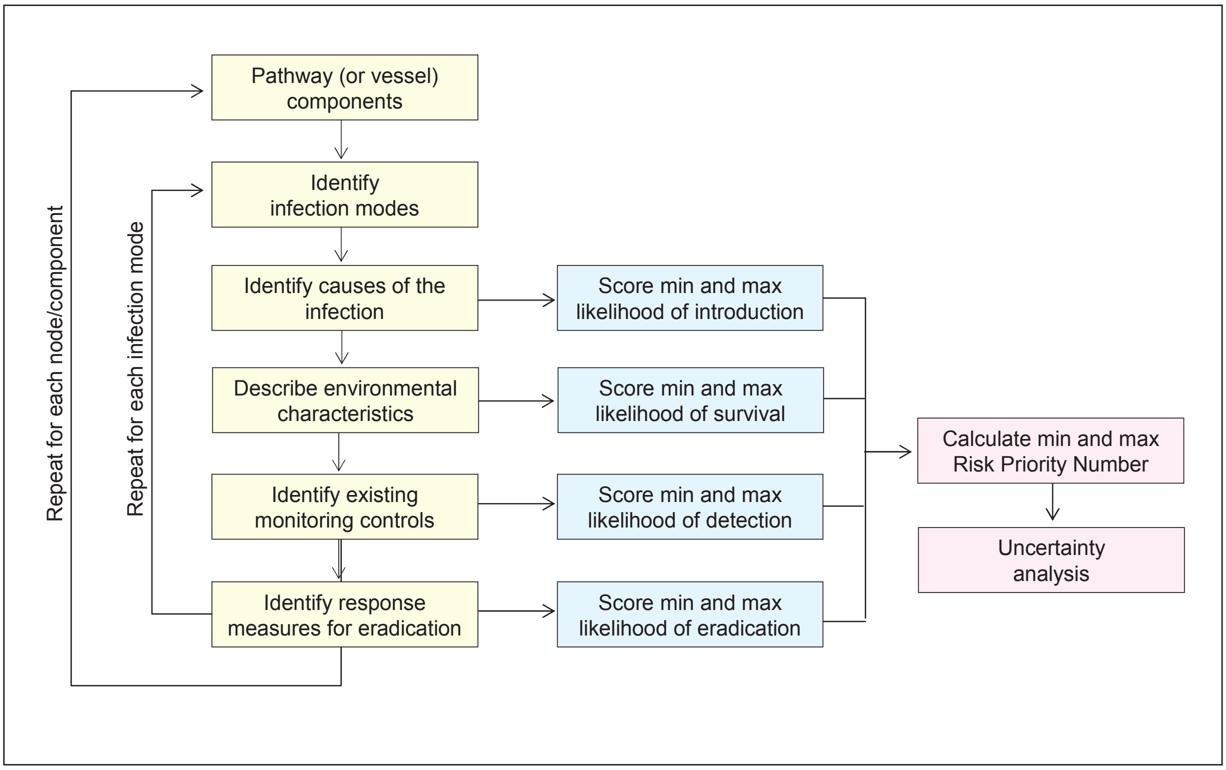


Figure 5.3 IMEA hazard evaluation and scoring process.

Workshop experience has indicated that the range of scores recorded by one group of participants is generally adopted by subsequent workshop participants. Although there are no direct precedents for interpreting scores for quarantine threats, several technical experts have attended multiple workshops (14 specialists have attended more than one workshop through April 2005, and of those 12 have attended three to eight workshops). The repeated involvement of these independent specialists has set a *de facto* standard for applying the scoring system which is recorded and communicated to subsequent workshop participants. Reports of the early workshop records have been made available, and community stakeholders have been invited to attend these workshops as observers. Workshop facilitators have observed that participants have embraced the scoring system shown in Table 5.3, particularly when uncertainty is captured in the recording of maximum and minimum scores.

An IMEA workshop is primarily focused on the infection of cargoes and the survival of organisms prior to arrival on Barrow Island, which is considered the 'border' for quarantine purposes. Unless details of monitoring and eradication strategies are known, estimates of detection and eradication are deferred for later analysis. Thus, the IMEA workshop is primarily interested in the 'pre-border' prevention of infections at the early stages of pathway analysis.

Detection and eradication are 'post-border' activities to prevent invasions, and are taken to be independent of specific terrestrial or marine pathways of introduction. An analysis of post-border monitoring strategies is necessary to estimate risk scores for detection and eradication. It should be noted that eradication may only be an option when detection occurs early enough to contain and control an organism before it is able to establish a wide spatial distribution or monoculture, and when the environmental impacts (eg collateral damage to the native environment) of eradication are acceptably low.

From the IMEA score of infection and survival a Risk Priority Number (RRN) can be calculated to compare the relative magnitude of each hazard (Hayes 2002b). Analysis of risk using the RPN results from the IMEA analysis is discussed in Section 5.3. The RPN is not a risk level, only a relative indication of hazards which may require high priority for preventive measures or corrective action.

Information captured from an IMEA workshop is recorded in a format under the types of headings shown in Table 5.5. Existing safeguards with regard to each infection mode are noted, as are any preventive/corrective measures which are suggested by the IMEA participants. If adoption of any specific preventive/corrective measures clearly reduce the likelihood of the infection or survival of an infection mode, this information can also be recorded in the meeting record.

Table 5.4 Example of information captured in an IMEA analysis.

Pathway: P1. Pre-packaged material received at Welshpool for transport to Barrow Island by container vessel.						
Component: C1. Packed sea container.						
IMEA ref no	**Infection mode**	**Effects**	**Existing safeguards**	**Score (min, max)**		**Preventive/ corrective measures**
				Infection	**Survival**	
1	Internal entrainment	Viable arthropod larvae (ants) released.	None.	3, 4	4,6	Train personnel to recognise larval stages of organisms.
2		Viable weed propagules (kapok) released.	None.	5, 8	7, 9	Detain containers in isolation area for inspection by trained personnel. Infection improved to 3, 4
…						

The IMEA does not attempt to predict the ecological impacts of an introduced species which may have the ability to thrive and reproduce in the Barrow Island terrestrial or marine environment. Such predictions cannot be made with confidence for all biological groups.[3]

5.2.2 Preliminary barrier analysis

The PBA hazard evaluation technique is used early in the concept selection phase, when possible quarantine barriers are being considered for reducing the risk of introductions on specific exposure pathways. The PBA is a means of identifying critical requirements for effective barriers early in the selection process, and is a precursor to a more rigorous QHAZ analysis of design details when they become available.

To conduct the PBA early in the concept selection phase of barrier design, a preliminary description of the proposed barrier must be developed to the extent possible. This may include layout of proposed facilities, examples of comparable equipment and processes used elsewhere, and reference to relevant standards and practices. A workshop of technical specialists is convened to assess the effectiveness of contemplated barriers for specific pathways (referred to as a 'barrier workshop'). Workshop participants are invited on the basis of their experience and ability to explain the technical application of the barriers, logistics aspects of the pathways, and expertise in the biological groups which are targeted by the barriers under consideration.

The purpose of the PBA is to utilise the experience of technical specialists to identify how contemplated quarantine barriers might fail to prevent the infection of cargoes. The causes and effects of potential breaches are evaluated against planned safeguards, and similar to the IMEA technique, qualitative judgments of the likelihood of infection and survival of organisms is recorded.

The results of the PBA are captured in a database, using a reference numbering strategy which identifies contemplated barriers which are applicable to specific steps in an exposure pathway. Information is recorded in a format under the types of headings shown in Table 5.5. The example reflects the early concept selection phase, where the contemplated barrier is described at a conceptual level.

Table 5.5 Example of information captured in a PBA workshop.

Barrier: B1. Kitchen containment facility.					
Pathway steps: S5. Receiving food and perishables from trucks at the loading dock. S6. Unpacking and transfer to food storage locations.					
Ref no	**Potential quarantine breach**	**Causes**	**Consequences**	**Existing safeguards**	**Preventive/ corrective measures**
1	High pressure washing removes chemical treatment of surfaces.	Untreated habitat suitable for invertebrates.	Survival of invertebrates.	None.	Chemical treatment regime.
2	Live invertebrates undetected in transport container.	Incomplete selection of traps, or wrong specification.	Failure to trap invertebrates of concern.	Live trapping and baiting stations on barges.	Obtain expert advice on trap selection.
…					

[3] Collective advice of the Quarantine Expert Panel, 28 November 2003.

5.2.3 Quarantine hazard analysis

A QHAZ technique is used to systematically identify deviations from intended activities which are designed to prevent the infection of materials and personnel arriving at Barrow Island. To conduct a QHAZ, it is first necessary to construct a detailed description of the 'nodes' in the flow of materials and personnel from their port of origin. The analogy to industrial systems, where HAZOP analysis is common practice, is the 'process flow diagram'. It is anticipated that a single port (eg Welshpool, Dampier, commercial airports, outlying islands) will have one or more discrete pathways for the handling of various types of materials and people. Each pathway must be fully described in terms of the processing steps from the arrival of materials and people at the port, to departure for their destination. The description of the flow of materials and personnel used in the pathways for the IMEA is likely to be the starting point, which may be updated as the project develops.

The QHAZ analysis further requires a description of the proposed quarantine barriers (inspection, cleaning, testing, baiting, fumigation, chemical treatment, etc) which are to be applied at various nodes (steps) in the flow of materials and personnel. At the early stages of the project, barriers may be described at a conceptual or preliminary level, where a PBA (Section 5.2.2) is undertaken to assist with evaluating the efficacy of the proposed barrier. As the project develops and more detail becomes available on the design of quarantine barriers, a detailed QHAZ analysis can be undertaken.

Equally important in the preparation for QHAZ analysis is to identify potential pest species (and propagules) which may exist at each port where materials and people are processed for departure. Lists of potential invasive species and biological groups should be sourced from specialists and museums with expertise in terrestrial and marine organisms of interest in Western Australia. These potential pest groups should include, but not be limited to, those listed in Table 5.2.

Once the pathways and barriers are fully described, the QHAZ analysis can be conducted to identify potential hazards arising due to deviations from the intended activities involved at each barrier (eg fumigation of sea containers). The QHAZ analysis relies on having a small group of the 'right people' involved, facilitated by an experienced risk assessor. Workshops should be organised to focus on complete pathways with expertise available for a variety of biological groups, and should include about 4–8 selected technical specialists and operational personnel to be effective.

Guide words are used to trigger the discussion of deviations from the intended activities at each barrier, with regard to the potential infection of materials and personnel by various organisms. The QHAZ facilitator uses guide words to prompt an inductive type of analysis of how planned activities could deviate from their intended actions or results. Suggested guide words which may be used in the QHAZ analysis are listed in Table 5.6, drawing on the experience of the author and other workers (RCEP 1991; CCPS 1992).

Table 5.6 Suggested QHAZ guide words for evaluation of introduction pathways.

▪ More than	▪ Incomplete	▪ Where else
▪ Less than	▪ Reverse	▪ When else
▪ Other than	▪ No verification	▪ Wrong time
▪ As well as	▪ Part of	▪ Wrong place
▪ Not enough	▪ Lack of	

The results of the QHAZ analysis are captured in a database, using a reference numbering strategy which identifies pathways and nodes. Information is recorded in a format under the types of headings shown in Table 5.7. The example reflects an advanced stage of design, where it is possible to analyse the performance of the proposed quarantine barrier in detail.

Table 5.7 Example of information captured in a QHAZ analysis.

Pathway: P1. Pre-packaged material received at Welshpool for transport to Barrow Island by container vessel.						
Pathway step: S1. Fumigation of packed container at contractor premises, prior to transport to wharf.						
Ref no	**Guide word**	**Deviation from intended action**	**Causes**	**Consequences**	**Existing safeguards**	**Preventive/ corrective measures**
1.1	Not enough	Insufficient mass of fumigant injected into sea container.	Failure of gas delivery timer or solenoid delivery valve.	Arthropod larvae and weed propagules remain viable.	None.	Test gas delivery timer and valve prior to each fumigation event.
1.2			Wrong (lower) concentration of fumigant from supplier	Not immediately evident that fumigation was only partially effective.	Gas bottles marked with concentration of fumigant.	Require supplier to perform quality assurance testing.
1.3			Slow leakage of gas from container		Visual inspection of containers for damaged seals prior to use.	Perform monthly integrity testing of container seals.
…	…					

It is desirable to estimate the likelihood of infection during the QHAZ analysis of deviations from planned activities. Estimates of likelihood can be supported by incident/near miss data when it is available, performance data from other quarantine operations, or by the judgment of participants in the workshop.

In the case of biological infections of materials or personnel processed at a port, such estimates are likely to be a difficult task. The main purpose of the QHAZ, then, is to identify the circumstances of infection hazards at a donor port with regard to planned barriers, and to utilise the expertise and operating experience of the participants to suggest possible preventive/corrective actions.

Preventive/corrective actions are recorded without prejudice to reduce either the likelihood of the deviation and/or the severity of the consequences. These suggestions for improvement of the barriers are then available in the risk management step (Section 5.5), to identify the appropriate management controls which could be implemented to reduce risk to acceptable levels.

5.3 Risk and uncertainty analysis

Borrowing from the risk of introducing non-indigenous species in ballast water (Hayes & Hewitt 2000), and using the analogy of biological groups which may be represented by an indicator species, the risk of introduction can be estimated on the basis of a combined probability:

$$Risk_{introduction} = p(\omega) \cdot p(\phi) \cdot p(\psi) \cdot p(\upsilon) \qquad [1]$$

where: p(ω) is the probability that the donor port is infected with the organism;

p(ϕ) is the probability that the vessel (or aircraft) becomes infected with this organism;

p(ψ) is the probability that the organism survives the vessel's journey; and

p(υ) is the probability that the organism will survive in the recipient port—Barrow Island.

Note that this combined probability does not attempt to predict the potential establishment and persistence of an introduced alien species in the native environment of Barrow Island. In the first instance, we seek to estimate only the likelihood of introduction.

The first two terms, p(ω) and p(ϕ) can be estimated from information on potential pest organisms found at each port (using existing databases, expert knowledge and stakeholder input), and a rigorous hazard evaluation of activities at each port. These estimates rely on information generated by a QHAZ analysis, conducted with regard to individual pathways where living organisms and viable propagules could be loaded onto vessels for transport to Barrow Island.

The IMEA carries these risk estimates forward, and estimates the last two terms of the risk of introduction, p(ψ) and p(υ). If fully quantitative estimates were possible for all four terms, then a probabilistic risk could be calculated for the introduction of alien species to Barrow Island. In the absence of data to support fully quantitative risk estimates, we can adopt a semi-quantitative approach using the IMEA scoring system (Table 5.4) suggested by Hayes (2002).

Using the IMEA scoring system to allow analysts to estimate the potential effects of infection modes, a Risk Priority Number (RPN) can be calculated when the likelihood of survival can be estimated:

$$RPN = IntroductionScore \cdot SurvivalScore \qquad [2]$$

The range of the RPN is therefore 1-100.

It may be useful to capture the maximum and minimum scores among participants for each IMEA workshop, and to average the minimum and maximum scores which might be estimated by separate groups of workshop participants (n>1):

$$RPN_{\min} = \frac{1}{n}\left[\sum_{i=1}^{n}(MinIntroductionScore_i \cdot MinSurvivalScore_i)\right] \quad [3]$$

$$RPN_{\max} = \frac{1}{n}\left[\sum_{i=1}^{n}(MaxIntroductionScore_i \cdot MaxSurvivalScore_i)\right] \quad [4]$$

Such an approach enables the risk assessor to capture a range of scores and to measure variance in the risk estimates of separate groups of participants, or even among individuals in a single workshop (although the data processing task could be significant).

The range of maximum and minimum RPN's indicate the variability in the participants risk estimates, and is therefore an indication of uncertainty in the risk estimates. The variance of individual scores (x_i), compared to the overall average of all minimum and maximum scores ($\bar{x}$), yields a measure of variance (σ):

$$\sigma = \frac{\sum_{i=1}^{2n}\left(x_i - \bar{x}\right)}{2n-1} \quad [5]$$

where: x_i are the maximum and minimum scores, requiring the sum over 2n.

5.4 Risk standards

The EPA in its advice to government on the proposed development of a gas plant on Barrow Island (EPA 2003) stated: "The proponent be required to 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."

To fully address the EPA advice to government (EPA 2003), risk reduction strategies (quarantine barriers) should also meet or exceed current best practice. In this regard, risk is reduced to a level 'as low as reasonably practicable', or ALARP, in accordance with AS/NZS 4360 for risk management.

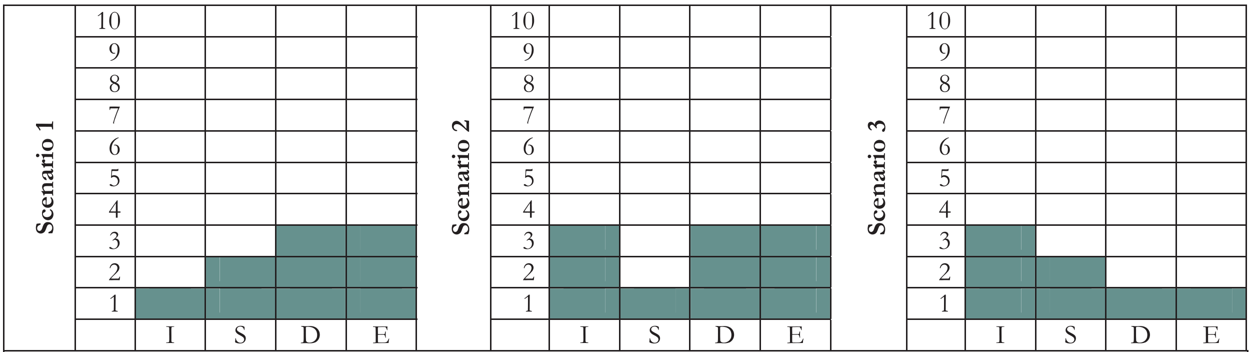
The development of standards for acceptable risk has included the involvement of technical experts and significant community consultation. Community stakeholders on the development of standards for acceptable risk "…proposed that consequences which resulted in the ***establishment*** of an introduced species would be unacceptable" [emphasis added] (Bowen 2004).

While 'establishment' of a species may be an ideal endpoint for risk assessment, the complexity of ecological systems prevents us from making qualitative or quantitative estimates of establishment (refer to Section 3). The prevention of establishment is expressed in terms of the operational endpoints of introduction, survival, detection and eradication. As such, standards for acceptable risk relate to these operational endpoints, as defined by the scoring system in Table 5.3.

Where the IMEA, PBA and QHAZ techniques seek to estimate the likelihood of infection at any pathway step, an overall likelihood of introduction is needed to address risk standards, as a result of qualitatively combining the likelihoods of infection at each step. The analogy in quantitative risk analysis is the calculation of conditional probability (refer to Section 5.3, Equation [1]). It may be possible to use decision rules to combine qualitative estimates of infection, based on the proposition that the residual likelihood of introduction along the overall pathway must be less than the likelihood of infection at any particular step. This would be the case as long as cargo, people and vessels were not threatened with re-infection along the pathway, such that the barriers were only as good as those applied at the very last pathway step prior to arrival at Barrow Island.

5.4.1 Community involvement

Community involvement in the setting of standards for acceptable risk resulted in a proposition that certain combinations of risk estimates could represent risk standards which are acceptable to the community (from the definitions in Table 5.3, where 'introduction' on the overall pathway is substituted for 'infection' at any particular pathway step). While the details are not formally endorsed by all community stakeholders, the proposed scenarios summarised in Figure 5.4 were recognised as the key outcomes of community involvement in this process. Scenarios 1, 2 and 3 are listed in decreasing order of importance to community stakeholders, consistent with the emphasis on the prevention of introductions.



Note: Community expectation of the range of acceptable scores.

Scoring on the vertical axis of each matrix (1-10) is defined in Table 5.3 of this document.
Scenarios 1, 2 and 3 are presented in decreasing order of importance to community stakeholders.

I = Introduction
S = Survival
D = Detection
E = Eradication

Figure 5.4 Community expectations for acceptable risk (Bowen 2004).

The community expectations for acceptable risk were constrained to terrestrial flora and fauna. It was suggested that the scenarios shown in Figure 5.4 were not applicable to micro-organisms or marine introductions.

5.4.2 Consideration of community expectations for acceptable risk

Notwithstanding the primary objective of preventing pre-border infections of cargoes and people, the risk assessment process should address both border and post-border quarantine threats with regard to the introduction of a species to the native environment on Barrow Island. It will be possible to re-assess risk estimates, or to combine risk estimates on each pathway if the overall risk of introduction is conditional on an organism 'slipping through' a number of quarantine barriers.

Analysis of the food and perishables pathway is the most convincing argument for *border* and *post-border* quarantine arrangements when setting standards for acceptable risk. This is because food and perishables obviously consist of plant matter and may harbour invertebrate organisms which are difficult to entirely eliminate. The risk of having food and perishable cargoes infected with invertebrates and plant propagules can only be assessed in the context of a border containment and eradication facility. The detection and eradication of any organisms which might escape the border containment facility (post-border quarantine) should also be considered. Border and post-border quarantine arrangements for organisms arriving at Barrow Island may be quite independent of the pathways through which they were introduced.

A risk analysis which considers pre-border, border and post-border quarantine barriers may meet community expectations for acceptable risk (the 'green' region of the risk scores shown in Figure 5.4). A rationale for accepting risks just outside the community's acceptable risk region of Figure 5.4 would be to acknowledge that, in general, the risk of post-border establishment in the native environment is going to be lower than the risk of pre-border introduction, and to provide for workable detection and monitoring strategies in any case.

For threats of introductions which carry a residual level of risk that exceeds the community expectations, the Quarantine Management System would be required to demonstrate that the barriers adopted for that pathway exceed current best practice, and that there are no other practicable measures suggested by independent technical experts which could be adopted to further reduce risk. In this case, risk would be reduced to a level 'as low as reasonably practicable', or ALARP, as described in AS/NZS 4360 for risk management. In Biosecurity Australia terms, the quarantine threat would be addressed with an 'appropriate level of protection', or ALOP (Biosecurity Australia 2003).

Once barriers are adopted and documented in design guides or specifications, a risk assessment (PBA or QHAZ) workshop of independent technical specialists, experienced construction and operational specialists and designers is convened to confirm that the proposed barriers can be implemented and will function as intended (Figure 5.2). This step verifies that attention has been given to an effective number of risk reduction strategies identified during the risk assessment process and review of best practice, and that risk is reduced to ALARP. It is also an opportunity to fine tune the design guides or specifications to improve the implementation and performance of adopted barriers.

The test for reducing risk to an acceptable level is to demonstrate that quarantine barriers can be implemented, that the barriers will perform as expected, and that the barriers are sustainable for the duration of the activity they are designed to manage. The involvement of technical experts in various biological disciplines ensures that quarantine barriers will work as intended. The Quarantine Management System ensures that the adopted quarantine barriers are sustainable, and that their performance is regularly reviewed and improved.

5.4.3 Marine organisms

The community expectations for acceptable risk were not considered to be applicable to micro-organisms or marine introductions. In the marine environment, the prevention of introductions from sources independent of the proposed Gorgon Development is an impossible task (eg regional ocean currents, littoral drift, seabirds, cyclonic events). In addition, there are few examples of eradicating marine invasions (URS 2003; McEnnulty *et al* 2001). The distribution of marine organisms in North West Australia typically occurs over hundreds of kilometres, compared to the limited spatial distribution of terrestrial organisms on Barrow Island. Non-indigenous species established in the region can spread to other suitable habitats as a result of planktonic larval reproductive stages common to numerous species. It is also apparent that non-indigenous species establish new populations where they can exploit a suitable ecological niche in a natural or disturbed environment.

Community expectations for acceptable risk, based on terrestrial flora and fauna, are problematic for the waters surrounding Barrow Island when non-indigenous species could arrive quite independently of proposed Gorgon Development activities. Risk standards for marine organisms then, would emphasise prevention of introductions, focussing on risk reduction measures which meet or exceed best practices, and an appropriate range of barriers suggested by technical specialists to demonstrate that risk is reduced to ALARP.

5.4.4 Micro-organisms

In the case of micro-organisms it is not practical to attempt to prevent all introductions, as a very wide range of micro-organisms will be routinely carried by people 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 and people.

In the investigation of wildlife mortality events where disease was the suspect causal agent, it is not always possible to identify the infecting micro-organisms with certainty (Anon 2001). It is constructive to engage technical experts to review specific micro-organism threats to Barrow Island, and to suggest strategies for the prevention of known pathogens in cargoes and people.[4] The risk standard for micro-organisms would focus on risk reduction measures for pathways which could be infected with specific pathogens, and specific risk reduction measures to prevent the spread of disease to wildlife suggested by technical specialists. Risk reduction measures would be expected to meet or exceed best practices, incorporating an appropriate range of barriers to demonstrate that risk is reduced to ALARP.

5.5 Risk management

All information generated from the hazard identification and risk assessment process is to be captured in a Risk Register, in accordance with AS/NZS 4360 for risk management. The purpose of the Risk Register is to make the risk profile of various activities visible to the risk manager and stakeholders, and to enable the risk manager to monitor the implementation and efficacy of risk reduction strategies.

High risk pre-border infection modes (those with high combined introduction, survival, detection and eradication scores) should receive first priority for hazard management, followed by medium risk infection modes. In general, the risk management strategy should give attention to (in order of importance):

1. Eliminating the likelihood of introduction;
2. Reducing the likelihood of introduction;
3. Reducing the likelihood of survival;
4. Improving detection methods; and
5. Improving control and eradication responses to introduction.

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[4] Collective advice of the Quarantine Expert Panel, 18 March 2004.

The first priority of quarantine management is to prevent the introduction of species from arriving 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 an introduced species on Barrow Island. Pre-border quarantine management and quarantine barriers on pathways of exposure are not likely to prevent the arrival of introduced species in all cases, in spite of a rigorous Quarantine Management System (QMS).

The likelihood of survival at the border, and post-border detection and eradication of an introduced species is given consideration in the risk-based assessment of quarantine management. This addresses the community expectation that consequences which result in the establishment of an introduced species would be unacceptable. Establishment is prevented from the application of pre-border, border and post-border quarantine management practices.

In cases where risks cannot be further reduced to meet the community expectations for acceptable risk (Figure 5.4), the QMS would be designed to ensure that risk is reduced to ALARP and that risk management is consistent with best practice approaches. The QMS would require that monitoring programs and contingency plans are developed to detect introductions of relevant biological groups (and particularly known invasive species) early enough to formulate a response.

Quarantine threats identified from the risk assessment process and the barriers adopted to reduce risk to ALARP are captured in the Risk Register. Design guides and performance specifications for each type of adopted quarantine barrier are to be developed. The QMS is to be used by the Gorgon Joint Venture, its contractors and suppliers to develop specific designs, procedures, processes and programs for managing quarantine threats to Barrow Island.

6 Future direction

With additional data from monitoring activities and specialist studies of potentially invasive species, it may be possible in the future to incorporate estimates of the likelihood of an introduced population persisting, competing for habitat, and becoming predators of native species. Further understanding of detection and control measures may allow better estimates of the likelihood that introduced species can be contained and eradicated. And finally, improved understanding of the ecology of Barrow Island might even allow estimates of the likelihood that native species will recover following eradication of an alien species. As further information becomes available in the longer term, it will be desirable to incorporate these types of factors into the hazard evaluation and risk analysis of introduced species.

Development of a world-class Quarantine Management System for Barrow Island will involve continuing baseline and investigative studies of the ecology of the Island and surrounding waters, development of specific management plans, mitigation strategies, monitoring and auditing programs, and communication with stakeholders. As these aspects of the Quarantine Management System evolve, they will be both guided by the outcomes of a risk-based assessment of quarantine hazards, and will provide new information for revised estimates of risk in a continuous process of re-evaluation and improvement.

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Technical Appendix D3

Report to the Community Consultation Meeting on the Risk Standards Workshops

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

REPORT TO THE COMMUNITY CONSULTATION MEETING ON THE RISK STANDARDS WORKSHOPS

TECHNICAL APPENDIX D3

Prepared for:

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August 2004

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Barrow Island Quarantine

Report to the Community Consultation Meeting on the Risk Standards Workshops

By Bernard Bowen

1 PREFACE

The Chairman of the Risk Standards Workshops, Bernard Bowen, provided a report on the outcomes of the Workshops to the Community Consultation Meeting on 16 June 2004. The report was discussed and there was broad agreement that the advice from Workshop #3 represented the views of the Community Consultation Meeting. However, during the course of the discussion some suggested changes to the layout of the report were proposed and agreed upon. Also, some additional information from the Records of the Workshops needed to be included in the report.

During the discussions the point was made, quite properly, that those who attended both the Workshops and the Community Meetings did so as individuals and thus the views expressed should not be read as representing one way or the other the views of the organisation with which they were associated. Also, the discussions should not be interpreted as all participants necessarily being in agreement.

The meeting agreed that the Chairman of the Community Consultation Meeting, Bernard Bowen, would amend his report and distribute it to those attending the Meeting for checking. He would then transmit the amended report to the Gorgon Joint Venture and to the Environmental Protection Authority.

The amended report is set out below.

2 INTRODUCTION

As Chairman of the Risk Standards Workshops I have pleasure in providing this report which brings together the outcomes of the three Workshops held on 10 March, 21 April and 12 May 2004.

The Workshops were held as a result of discussions at the Barrow Island Quarantine Community Consultation Meeting held on 18 February 2004. The purpose of the Workshops was to provide a forum for discussing and progressing advice on a set of standards for acceptable risk to the conservation values of Barrow Island.

This report provides a brief overview of the outcomes of the three Workshops, describes a proposed risk standards framework, sets out the advice flowing from Workshop #3, and provides advice from the Community Consultation Meeting held on 16 June 2004. A copy of the Meeting Record is attached (Appendix 1). Also attached are copies of the Records of the three Workshops (Appendix 2).

3 THE WORKSHOPS

The report of Workshop #1 (10 March 2004) was presented to the Community Consultation Meeting held on 20 April 2004. The reports of Workshop #2 (21 April 2004) and Workshop #3 (12 May 2004) formed part of the documentation attaching to the Agenda for the Community Consultation Meeting held on 16 June 2004. (Note: copies of the Workshop Records are provided in Appendix 2).

Participants are encouraged to read the full text of the reports of the three Workshops to gain a better understanding of the views expressed and the development of the set of standards. However, the main outcomes of the Workshop discussions were:

- Workshop #1:
    - Discussion firstly focussed on the consequences of introductions, noting that in practical terms zero introductions would not be achievable.
    - Consequences which resulted in the establishment of introduced species would be unacceptable.
    - Judgements were needed about acceptable risks in relation to the likelihood of introductions, survival, detection and eradication such that the establishment of a species would not occur.
    - Developed a Risk Standards Framework comprised of three scenarios which form the Framework package.
- Workshop #2:
    - Progressed the discussions of the Risk Standards Framework taking into account the advice provided by the Community Consultation Meeting of 20 April 2004.
    - Requested some additional information and agreed to meet again on 12 May 2004.
- Workshop #3:
    - Clarified the priority use of the draft Risk Standards Framework, noting that the Gorgon Joint Venture has a goal of no introduced species on Barrow Island and in surrounding waters.
    - Agreed, with a small number of participants abstaining, that the risk of establishment of introduced species is acceptably low if it conforms to the Risk Standard Framework, but noting that the risk needs to be considered in the priority order discussed in the Workshop.
    - Established some constraints on the use of the Framework.

4 THE PROPOSED RISK STANDARD FRAMEWORK

The proposed Risk Standard Framework is set out below, followed by a number of constraints on the use of the Framework.

The Environmental Protection Authority set out in its Bulletin 1101 that "The proponent be required to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island". As set out in Workshop #1, the Framework has three scenarios which form a package for the 'set of standards for acceptable risks'.

The risk scoring profiles referred to in the Framework are those used in Table 5.3 of the 'How to Guide for Conducting Risk-based Assessments of Quarantine Hazards on

Barrow Island' presented at the first Community Consultation Meeting held on 18 February 2004.

The highest priority use of the Framework would need to be Scenario 1 followed by Scenarios 2 and 3.

Framework Scenario 1

Introduction has a score of 1, but survival, detection and eradication each have scores of greater than 1, as follows (also refer to Attachment 1, Scenario 1):

- the introduction was extremely remote, highly unlikely (score 1);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- there was a high likelihood of detection, or less (score 3 or less); and
- there was a high likelihood of eradication, or less (score 3 or less).

Framework Scenario 2

Introduction, detection and eradication each have a score greater than 1, but survival has a score of 1, as follows (also refer to Attachment 1, Scenario 2):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was not suitable for survival (score 1);
- there was a high likelihood of detection, or less (score 3 or less); and
- there was a high likelihood of eradication, or less (score 3 or less).

Framework Scenario 3

Introduction and survival each have scores greater than 1, but detection and eradication each have a score of 1, as follows (also refer to Attachment 1, Scenario 3):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- it was virtually certain that detection would occur (score 1); and
- it was virtually certain that eradication would be successful (score 1).

Constraints on the use of the Framework

- Detection would need to be within an acceptable timeframe in the context of the biology of the species concerned.
- Eradication consequences would need to be acceptable.
- The Framework could not be applied to (i) micro-organisms and (ii) marine quarantine.
- The terms used to describe the risk score need to be given meaning in terms of experience elsewhere. This is intended to assist the public in the meaningful interpretation of risk scores.
- To instil confidence in the definitions (descriptions) of risk levels, there is a need to improve the level of rigour of these definitions.

5 ADVICE FROM WORKSHOP #3

- Workshop #3 agreed, with a small number of participants abstaining, that the risk of establishment of introduced species is acceptably low if it conforms to the Risk Standard Framework, but noting that the risk needs to be considered in the priority order set out in Section 4.

- If a risk profile was ALARP (as low as reasonably practicable) but was not within the risk standard, it should not be judged to provide an acceptable risk.

Advice has not been provided on what should happen outside the acceptable risk standard. Judgements would have to be made by those charged with that task (eg EPA, Government).

6 CONSIDERATION BY THE COMMUNITY CONSULTATION MEETING

The Environmental Protection Authority recommended to Government in Bulletin 1101 on the Gorgon proposal that should the Government agree in principle to access to Barrow Island for a gas processing complex "The proponent be required to 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".

A process has been implemented which has involved the community and included technical experts. The process has been transparent and the Workshops have been open for attendance by any member of the public. Records of the meetings of the Workshops have been publicly available.

At the Community Consultation Meeting held on 16 June 2004 some suggested changes to the Chairman's report were discussed. Following the adoption of these changes no one present expressed an objection to the proposed Risk Standard Framework. However, the point was made, quite properly, that those who attended both the Workshops and the Community Meetings did so as individuals and thus the views expressed should not be read as representing one way or the other the views of the organisation with which they were associated. Also, the discussions should not be interpreted as all participants necessarily being in agreement.

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Attachment 1

Risk Standards Framework

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Risk Standards Framework - Scenario 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.	Virtually certain to eradicate.	1
The introduction is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection.	Very high likelihood of eradication.	2
There is a slight chance of introduction.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection.	High likelihood of eradication.	3
There will be a small number of introductions each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection.	Moderate chance of eradication.	4
An occasional number of introductions are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection	Medium chance of eradication.	5
Introductions have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection.	Low chance of eradication.	6
Introductions occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection.	Slight chance of eradication.	7
There is a high occurrence of introductions each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection.	Very slight chance of eradication.	8
There is a very high occurrence of introductions each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection.	Remote chance of eradication.	9
Introductions occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect.	Almost impossible to eradicate.	10

Key

Low Risk	Medium Risk	High Risk

Risk Standards Framework - Scenario 2

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.	Virtually certain to eradicate.	1
The introduction is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection.	Very high likelihood of eradication.	2
There is a slight chance of introduction.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection.	High likelihood of eradication.	3
There will be a small number of introductions each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection.	Moderate chance of eradication.	4
An occasional number of introductions are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection	Medium chance of eradication.	5
Introductions have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection.	Low chance of eradication.	6
Introductions occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection.	Slight chance of eradication.	7
There is a high occurrence of introductions each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection.	Very slight chance of eradication.	8
There is a very high occurrence of introductions each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection.	Remote chance of eradication.	9
Introductions occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect.	Almost impossible to eradicate.	10

Key

Low Risk	Medium Risk	High Risk

Risk Standards Framework - Scenario 3

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.	Virtually certain to eradicate.	1
The introduction is remote, unlikely.	The environment is suitable for the survival of only resistant diapause/resting stages.	Very high likelihood of detection.	Very high likelihood of eradication.	2
There is a slight chance of introduction.	The environment is suitable for the survival of only very tolerant species.	High likelihood of detection.	High likelihood of eradication.	3
There will be a small number of introductions each year.	The environment is suitable for the survival of tolerant species.	Moderate chance of detection.	Moderate chance of eradication.	4
An occasional number of introductions are expected each year.	The environment is suitable for the survival of a range of species.	Medium chance of detection	Medium chance of eradication.	5
Introductions have a moderate occurrence frequency each year.	The environment is suitable for the survival of most species.	Low chance of detection.	Low chance of eradication.	6
Introductions occur frequently each year.	The environment is suitable for the survival and growth of tolerant species.	Slight chance of detection.	Slight chance of eradication.	7
There is a high occurrence of introductions each year.	The environment is suitable for the survival and growth of most species.	Very slight chance of detection.	Very slight chance of eradication.	8
There is a very high occurrence of introductions each year.	The environment is suitable for the survival, growth and reproduction of tolerant species.	Remote chance of detection.	Remote chance of eradication.	9
Introductions occur continuously throughout the year.	The environment is suitable for the survival, growth and reproduction of most species.	Almost impossible to detect.	Almost impossible to eradicate.	10

Key

Low Risk	Medium Risk	High Risk

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Appendix 1

Barrow Island Quarantine
Community Consultation Meeting Record
Meeting #3 16 June 2004

Editor's note:

This is a record of meeting proceedings only and does not include the 'Invitation and Attendance Record' (Appendix 1).

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Barrow Island Quarantine
Community Consultation Meeting #3

MEETING RECORD
16th June 2004

Contents

1. Particulars of Meeting

Held: 6:15 pm to 8:50 pm
16th June 2004
Perth Zoo Conference Centre - Theatre

Please refer to Appendix 1 for a record of invited persons and attendees.

Material provided: 1) PowerPoint slides presented at meeting
(Above materials are available upon request from Sean Reddan)

2. Welcome and Purpose of Meeting

The Chairman opened the meeting by welcoming those present and outlined the agenda. He then invited Russell Lagdon to address the meeting, and introduce those present from Gorgon.

3. Record of the Community Consultation Meeting of 20th April 2004

The Chairman referred to the Record of the Community Consultation Meeting held on 20th April, and briefly outlined the feedback received in response to the initial draft.

4. Gorgon Status Report

Russell Lagdon addressed the meeting with regard to the following matters:

- Environmental approvals schedule – following advice from the Expert Panel, and concerns noted at prior Community Consultation meetings, the schedule for public release of Environmental Impact Statement / Environmental Review and Management Program (EIS / ERMP) documents has been pushed back from late August to 6th December.

  Points raised in response to the amended schedule were:
  - A question was asked if the public consultation period will be extended to account for the Christmas period. The usual practice of the EPA is to extend the period by two weeks when the Christmas period is included.
  - The schedule still appeared tight
  - There was a need to work on a practical protocol for Gorgon to provide an opportunity for community consultation after the release of the EIS / ERMP document.

- Quarantine resources – an illustration of the personnel and resources being invested in the quarantine effort show that Gorgon currently has 25 people working on the development of quarantine solutions.

- Newspaper advertisements – following publication of 3 newspaper advertisements calling for expressions of interest in the quarantine development process, it was reported there was a total of 18 responses, 3 of which were from members of the general public.

- Quarantine stakeholder site visits – a summary of stakeholder visits to Barrow Island, and the Welshpool and Dampier logistics facilities was presented. It was noted that a further visit to Barrow Island was planned for the following week, and included some people present at the meeting.

- A question & answer facility has been developed on the Gorgon website and is due go live within a matter of days.

5. Report to the Community Consultation Meeting on the Risk Standards Workshops

Bernard Bowen provided an overview of the Report by the Chairman to the Community Consultation Meeting on the Risk Standards Workshops. Those attending Workshop #3 had agreed, with a small number of participants abstaining, that the risk of establishment of introduced species is acceptably low if it conforms with the Risk Standard Framework set out in workshop #1, but there were listed some constraints on the use of the Framework.

Issues raised in response to the report were:

- In response to a question, the Chairman advised that three interests had abstained, one of which was the officer from the Department of Environment because he is part of the Service Unit to the EPA.
- The point was quite properly made that those who attended both the workshops and the community meetings did so as individuals and thus the views expressed should not be read as representing one way or the other the views of the organisation with which they were associated.
- A number of suggested amendments to the Report presented by the Chairman were put to the meeting. As a result, the Chairman proposed that he revise the Report taking into account the suggested amendments and write it in a form suitable for transmittal by the Community Consultation Meeting to the Gorgon Joint Venture and to the Environmental Protection Authority. It was agreed that this revised report would be circulated to all participants for comment and then be finalised by the Chairman for transmission by him.
- Subject to the above amendments, those present at the Community Consultation Meeting expressed no objection to the advice contained in the report of Workshop #3, but again it needs to be noted that this should not be interpreted as all participants necessarily being in agreement.

6. Report on the Technical Risk Assessment Workshops

Richard Stoklosa presented a progress report on the IMEA / HAZOP workshops and the process of assessment of individual pathways.

The point was made that it was important to benchmark the scoring system used so that there was uniformity of judgement between workshops.

7. Quarantine Management System

The Chairman invited Russell Lagdon to introduce Nick Croston and Jane Aberdeen who have been engaged by Gorgon to assist in the development of a Quarantine Management System. An overview of the approach being used in the context of Management Systems (MS) and ISO 14001 International Standards was presented. A distinction between a QMS and a Quarantine Management Plan (QMP) was introduced.

After some discussion with regards to the level of detail, and amount of information currently available the Chairman confirmed that a workshop would be held to involve the community in the development the QMS.

8. Meeting Review and Close

The Chairman thanked the participants and asked if there were any further matters for consideration.

A point was raised that a forum similar to this Community Consultation Meeting is needed to discuss and review the site selection process which led the Gorgon Joint Venture to identifying Barrow Island as the preferred site. This point was acknowledged by the Chairman. Russell Lagdon invited comment on such matters to be taken up with him directly.

The Chairman confirmed that a draft record of the meeting will be distributed to those in attendance for review and comment.

Meeting closed: 8.50 pm.

9. Action Register

Actions arising from this meeting are listed below.

Item #	Action	Who	When
	▪ Convene QMS workshop	Reddan	TBD

10. Appendix 1 – Invitation and Attendance Record

Attachment.

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Appendix 2

Barrow Island Quarantine
Risk Standards Workshop Records

Workshop #1	**10 March 2004**
Workshop #2	**21 April 2004**
Workshop #3	**12 May 2004**

Editor's note:

These records reference workshop proceedings only, and therefore do not include the following:

Workshop #1	**Attachment 1 Risk Standards Framework (provided as an attachment to this Chairman's Report).**
Workshop #2	**Attachment 1 Standards for Acceptable Risk (provided as attachment 2 to Risk Standards Workshop #3 Record).**
Workshop #3	**Attachment 1 Correspondence from Waterbird Conservation Group (provided in full workshop record at www.gorgon.com.au).**

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Barrow Island Quarantine
Risk Standards Workshop #1

WORKSHOP RECORD
10th March 2004

CONTENTS

1. Particulars of Workshop

Held: 4:00 pm to 6:45 pm
10th March 2004
Kings Park and Botanic Gardens – Administration Building Theatre

Attendees:

Bernard Bowen	Chairman
Eva Crockenberg	Waterbird Conservation Group
Barry Muir	Environmental Consultant
Meg Wilson	Waterbird Conservation Group
Paul Wilson	Waterbird Conservation Group
John Bailey	Conservation Commission
Keith Morris	CALM
Cameron Poustie*	Conservation Council
Peter Baldwin	Conservation Commission
Keith Collins	Expert Panel
Andrew Burbidge	Expert Panel
Malcolm Nairn	Expert Panel
Richard Stoklosa	Secretariat (Gorgon)
Sean Reddan	Secretariat (Gorgon)
Russell Lagdon	Secretariat (Gorgon)

Apologies: Warren Tacey (Department of Environment), Chris Tallentire (Conservation Council)
*Cameron Poustie was present for part of the Workshop due to other commitments

Attachments: 1) *Development of Risk Standards for Acceptable Quarantine Risk – Status Report*

Supporting document handed out at meeting is available upon request from Sean Reddan - *Barrow Island Quarantine Risk Standards Workshop*

2. Workshop Purpose – (Bernard Bowen)

The Workshop was planned as a result of discussions at the Barrow Island Quarantine Community Consultation Meeting held on 18 February 2004. At that meeting the Chairman proposed that as part of the way forward there be a generic-type Workshop to provide advice on the standards for acceptable risk using the information set out in the "How-to Guide" document which had been distributed.

Accordingly, the purpose of the Workshop could be described as providing a forum for discussing and progressing advice on a set of standards for acceptable risk to the conservation values on Barrow Island.

3. Background Information

The Chairman drew attention to some of the advice provided by the Environmental Protection Authority in its Bulletin 1101 on the Gorgon proposal.

(i) "No accepted risk standards or clear precedents for an acceptable level of risk to conservation values."

(ii) "The proponent be required to engage in the development of a set of standards for acceptable risks to the conservation values of Barrow Island."

(iii) "If access to Barrow Island is agreed, the prospective developers should be required to engage in a rigorous and public process, involving appropriate technical expertise. to set an acceptable risk limit."

(iv) "If economic, strategic and social values are judged by Government to justify the risks to the environment and conservation values, then substantial steps should be taken to insure that the risks are kept to an absolute minimum.."

(v) "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."

Also, Gorgon has set a goal of no introduced species on Barrow Island and surrounding waters.

All participants at the Workshop entered fully into the discussions. However, there were two understandings:

(i) Not all of the participants agreed with a risk assessment approach.

(ii) The Record of the Workshop should not be read to suggest that each participant supported all or any of the matters that were discussed.

4. Outcomes of the Workshop

The discussion firstly focussed on the consequences of introductions, noting that in practical terms zero introductions would not be achievable.

Following a lengthy discussion, and noting the EPA statement of a required policy of 'zero tolerance of invasions' target, it was proposed that consequences which resulted in the establishment of an introduced species would be unacceptable.

The Workshop took this as a working statement and discussed the notion of 'acceptable risks' that the establishment of a species would not occur. There was a broad understanding that the risks would not be zero but, as set out in the EPA statement (iv) above, the risks would need to be kept to an absolute minimum. This is consistent with reducing risk to a level 'as low as reasonably practicable' (ALARP) with regard to Australian Standard 4360 for risk management, and the biosecurity terminology of an 'appropriate level of protection' (ALOP).

The Workshop examined the information provided in Table 5.3 of the "How-to Guide" document with a view to making judgements about acceptable risks, in relation to the likelihood of introductions, survival, detection and eradication, such that the establishment of a species would not occur.

As a starting point, if it was judged by people expert in relation to understanding a particular group of animals that:

- the introduction was extremely remote, highly unlikely (score 1);
- the environment was not suitable for survival (score 1);
- it was virtually certain that detection would occur (score 1); and
- it was virtually certain that eradication would be successful (score 1);

the risks would be acceptable.

The discussions then focussed on other frameworks, using Table 5.3, which may provide a set of standards for acceptable risk.

The first framework was based on detection and eradication both having a score of 1 and introduction and survival a score of more than 1, as follows (refer also to attachment 1):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- it was virtually certain that detection would occur (score 1); and
- it was virtually certain that eradication would be successful (score 1).

The second framework was based on detection and eradication both having scores of greater than 1 but survival having a score of 1, as follows (refer also to attachment 1):

- there was a slight chance of introduction, or less (score 3 or less);
- the environment was not suitable for survival (score 1);

- there was a high likelihood of detection, or less (score 3 or less);and
- there was a high likelihood of eradication, or less (score 3 or less).

The third framework was based on detection and eradication both having scores of greater than 1, but introduction having a score of 1, as follows (refer also to attachment 1):

- the introduction was extremely remote, highly unlikely (score 1);
- the environment was suitable for the survival of only resistant diapause/resting stages (score 2);
- there was a high likelihood of detection, or less (score 3 or less);and
- there was a high likelihood of eradication, or less (score 3 or less).

The three frameworks described above would then form a package for the 'set of standards for acceptable risks.'

There was discussion about whether all areas not coloured green in the draft framework risk standards numbers one to three (attachment 1), should be red (i.e., high risk), or whether some might be coloured yellow (i.e., medium risk). Most of those attending the workshop were of the view that because Barrow Island is a very high value nature reserve, all areas not coloured green, should be considered 'high risk.' However, there was another view that the use of a yellow band (medium risk) may be appropriate in some circumstances and needs further consideration.

5. Summary

The set of standards described in 4 above appear to be consistent with the advice of the EPA about the target of 'zero tolerance of invasions' and the goal of Gorgon of 'no introduced species'.

This set of standards requires testing through the specialist workshops, which are being undertaken as part of the risk assessment process described in the "How-to Guide", and further discussion and consideration through workshops and the wider community.

6. Workshop Review

The Workshop had provided an opportunity for all participants to provide inputs to the discussion on quarantine (biosecurity) standards for acceptable risks to the conservation values of Barrow Island in a relaxed and cooperative atmosphere.

The Chairman thanked the participants for their attendance and valuable input to the Workshop discussions. He suggested that there was likely to be a need for further meetings of the Workshop group as additional technical information became available.

The Workshop concluded at 6:45 pm.

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Barrow Island Quarantine
Risk Standards Workshop #2

WORKSHOP RECORD
21st April 2004

CONTENTS

1. Opening and Particulars of Workshop

Held: 5:00 pm to 7:50 pm
21st April 2004
Perth Zoo Conference Centre – Seminar Room 2

Attendees:	Bernard Bowen	Chairman
	Eva Crockenberg	Waterbird Conservation Group
	Meg Wilson	Waterbird Conservation Group
	Paul Wilson	Waterbird Conservation Group
	John Bailey	Conservation Commission
	Keith Morris	CALM
	Cameron Poustie	Conservation Council
	Peter Baldwin	Conservation Commission
	Keith Collins	Expert Panel
	Andrew Burbidge	Expert Panel
	Malcolm Nairn	Expert Panel
	Richard Stoklosa	Secretariat (Gorgon)
	Sean Reddan	Secretariat (Gorgon)
	Russell Lagdon	Secretariat (Gorgon)
	Warren Tacey	Department of Environment
	Andre Schmitz	Expert Panel
	Diana Jones	Expert Panel
	John Scott	Expert Panel
	Sandra Potter	Expert Panel
	David Carter	Expert Panel

Apologies: None

Attachments: 1) *Standards for Acceptable Risk (2 pages)*

2. Workshop Record

The Chairman opened the workshop and made reference to the record of the Risk Standards Workshop #1 held on 10th March 2004. Correspondence received from the Waterbird Conservation Group was acknowledged at this point and distributed to those present at the workshop. This relates directly to correspondence dated 7th April 2004, and 14th March 2004.

The Chairman invited representatives of the Waterbird Conservation Group to speak to their submission. The Chairman stated that a submission from the Waterbird Conservation Group handed to the Chairman at the Community Consultation Meeting on 20th April 2004 would be attached to the record of that meeting.

The Chairman also verified the point that the Record of the Workshop should not be read to suggest that each participant supported all or any of the matters that were discussed.

3. Community Consultation Meeting of 20th April 2004

The Chairman provided a summary of the main points raised at the Community Consultation Meeting held on 20th April. Specific points were:

(i) Mal Nairn reported on the outcomes of the workshop held on 10th March 2004

(ii) The Scoping Document approved for release by the EPA on 8th April 2004, set out that the proponent would develop a set of proposed standards for acceptable risk.

(iii) The standards set out in the record of the meeting of 10th March 2004 (the ‘green’ area) may be appropriate but what happens in the likely event that a risk for a pathway or a group of animals would exceed the ‘green’ risk profiles.

4. Report on Risk Standards

Richard Stoklosa presented a number of hypothetical cases to describe the application of the proposed draft set of risk standards (refer to Attachment #1).

Some present at the workshop sought clarification of what was being demonstrated, and what meaning could be attached to a situation if the risk score could not be reduced to one where it is a requirement of the draft risk standard. The discussion touched upon issues such as consequence, and the application of varying standards for different organisms.

The Chairman proposed that a ‘set of acceptable standards’ refers to the ‘green’ area as designated in the draft framework risk standards. The area outside the ‘green’ area needed more discussion and should form the basis of workshop discussion.

The discussion focussed principally on the nature of advice which could be provided to the EPA if it was found that for any pathway or group of animals independent of pathways Gorgon was unable to deliver on the proposed risk standards.

Points arising from the discussions were:

- A precautionary approach would need to be adopted.
- There was a need to propose a method for better understanding the terms ‘the introduction is extremely remote’, ‘highly unlikely’, ‘the introduction is remote, unlikely’, ‘there is a slight chance of introduction’ and so on.
- The baseline surveys have not yet been progressed to a level which would allow confidence in detection of introduced plants and animals.
- Consideration of consequences was raised again, as it was in Workshop 1. The question was posed as to whether one risk framework could fit both the terrestrial and marine environments.
- Use of the proposed risk framework may differ if it is being used to consider pathways and if it is being used to consider groups of animals.
- It was noted that Gorgon was looking to the workshop and the community to provide its view on standards for acceptable risk rather than the company presenting a proposed risk profile.
- The discussion would be enhanced if Gorgon could provide some examples of quarantine barriers and procedures using the risk framework such that the establishment of a species would not occur.
- Gorgon should commit to a risk scaling of 3 as an upper limit.
- There would be value in having information on the concept of ALARP (“as low as reasonably practicable).

5. Summary

The Chairman thanked participants for their inputs into the discussion and proposed that the meeting be adjourned until May 2004. He proposed that he arrange to have a brief paper prepared which may assist in the further discussion of the subject.

The proposal was adopted as a way forward and the group agreed to reconvene on Wednesday 12th May 2004 at 4.00 pm. The Workshop adjourned at 7.50 pm.

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Barrow Island Quarantine Risk Standards Workshop #3

WORKSHOP RECORD
12th May 2004

Contents

1. Particulars of Workshop

Held: 4:00 pm to 6:45 pm
12th May 2004
Subiaco Oval, Subiaco – Outridge Room

Attendees:

Attendees:	Bernard Bowen	Chairman
	Meg Wilson	Waterbird Conservation Group
	Paul Wilson	Waterbird Conservation Group
	John Bailey	Conservation Commission
	Norm Caporn	CALM
	Cameron Poustie	Conservation Council
	Peter Baldwin	Conservation Commission
	Keith Collins	Expert Panel
	Andrew Burbidge	Expert Panel
	Malcolm Nairn	Expert Panel
	Richard Stoklosa	Secretariat (Gorgon)
	Sean Reddan	Secretariat (Gorgon)
	Warren Tacey	Department of Environment
	John Scott	Expert Panel
	Barry Muir	Environmental Consultant

Apologies: Russell Lagdon

Attachments: 1) *Waterbird Conservation Group letter dated 7th April 2004*
2). Discussion paper – '*Setting Standards for Acceptable Risk'*

2. Opening

The Chairman thanked participants for attending this reconvened Workshop which will be described as Workshop #3.

The Chairman opened the meeting by providing a review of the background to the purpose for the workshop and referenced relevant aspects of Environmental Protection Authority (EPA) Bulletin 1101, *Environmental Advice on the Principle of Locating a Gas Processing Complex on Barrow Island Nature Reserve*.

In the discussion on the Chairman's opening comments a number of points were made, including :

- The short timeframe for the preparation of the Gorgon environmental impact documents is being driven by the proponent, not by government.
- Although 'in-principle' access to Barrow Island has been approved by the Western Australian Government, consideration of other sites for location of the development is required under the joint Federal/State EIS/ERMP assessment process.
- The set of standards for acceptable risks being discussed relate to the proposal that the Gorgon development proceeds on Barrow Island.

3. Consideration of the letter from the Waterbird Conservation Group

The Chairman referred to the 7th April 2004 letter received from the Waterbird Conservation Group (WCG) and distributed at the 21st April workshop and invited the WCG to address the workshop. The WCG reiterated a number of concerns with regards to the proposed Gorgon development, and was also concerned that the proposed marine conservation reserve (in the vicinity of Barrow Island) and biodiversity conservation legislation may be 'pre-empted' by the proposed development.

The Group was particularly concerned to ensure that:

- The biodiversity of Barrow Island was not reduced in any manner.
- Consideration of risks be within the context of overall or cumulative risk.

Workshop participants were invited to comment on the WGC submission. Points raised included:

- There was support for the tenor of the letter.
- The WCG document was structured around a policy of 'no risk' of introductions.
- The Workshop discussions were based on the proposition that while introductions may inadvertently occur, consequences which resulted in the establishment of an introduced species would be unacceptable.

The Chairman confirmed the 7th April 2004 letter would be included with the Workshop Record as an attachment, (Attachment 1).

Further consideration of the WCG letter then focussed on clarifying the priority use of the draft Risk Standards Framework noting that the Gorgon goal is 'no introductions'. Following discussion, the proposed qualifying text in support of the Framework was proposed by the workshop.

In regard to the draft Risk Standards Framework, the highest priority be 1) below followed by 2)a and 2)b:

1) *Risk of 'introduction' of 1 is considered acceptable level of risk*
2) *If the risk of 'introduction' is 2 or 3 , the risk is acceptable if and only if either:*
    a. *'survival' is 1*
    or
    b. *'detection and eradication' are both 1.*

Notes

1) *Detection would need to be within an acceptable timeframe*
2) *Eradication consequences would need to be acceptable.*
3) *The approach to micro-organisms and marine quarantine may need further consideration in the application of the Framework.*

Further discussions addressed the following matters:

- The terms used to describe the risk score need to be given meaning in terms of experiences elsewhere. This is intended to assist the public in the meaningful interpretation of risk scores.
- To instil confidence in the definitions (descriptions) of risk levels, there is a need to improve the level of rigour of these definitions.

The Chairman summarised the discussion that there appeared to be a general consensus that the Framework (described in the Record of Workshop 1), and clarifying statement set out above, represented a reasonable approach to the development of a set of standards of acceptable risks such that the establishment of introduced species would not occur.

The words agreed upon by the Workshop, with a small number of participants abstaining, was that 'the risk of establishment of introduced species is acceptably low if it conforms with the Risk Standard Framework', but noting that the Framework needs to be considered in the priority order set out above.

4. Consideration of the record of the Workshop #2

The Chairman identified a number of minor omission and edits in section 4 and section 5.
A number of comments were tabled in relation to the record of the Workshop #2 (21st April 2004). It was agreed that the following three dot points be added to the record in section 4:

- The baseline surveys have not yet been progressed to a level which would allow confidence in detection of introduced plants and animals.

- It was noted that Gorgon was looking to the workshop and the community to provide its view on standards for acceptable risk rather than the company presenting a proposed risk profile.

- There would be value in having information on the concept of ALARP ('as low as reasonably practicable').

- Gorgon should commit to a risk scaling of 3 as an upper limit.

5. Consideration of the paper prepared by Richard Stoklosa

Richard Stoklosa presented the discussion paper *Setting Standards for Acceptable Risk* which highlighted the pre-border, border, and post-border nature of quarantine management which would need to be applied to the management of risk.

A general discussion of the paper addressed the following points:

- While the pre-border barriers would be the prime quarantine activity, participants acknowledged that the prevention of 'introductions' in the proposed risk framework was not limited to pre-border actions.
- A question was raised as to whether detection and eradication could occur pre-border. It was clarified that pre-border 'detection' was considered 'infection' and treated in a different manner from the post-border detection and eradication scenario.
- Participants noted but did not discuss the information provided on ALARP. However, if a risk profile was ALARP but not within the Risk Standard Framework, it should not be judged to provide an acceptable risk.
- Opportunities may exist to test the QMS in environments similar to Barrow Island, and as a principle the QMS should be tested in advance of operation.
- It may be necessary to consider the full raft of options for risk management and consideration should be given to listing such in the EIS /ERMP even if all barriers are not utilised.
- There would be value in having a register of quarantine incidences relating to both pre- and post-border.

The Chairman summarised the discussion with respect to aspects of the Quarantine Management System that whilst pre-border quarantine would be the prime activity, both border and post-border segments of the quarantine (biosecurity) framework (introduction, survival, detection and eradication) are essential elements of the Quarantine Management System. The Chairman confirmed that the discussion paper *Setting Standards for Acceptable Risk* would be attached to the record of the workshop without implying that it had been endorsed or otherwise by those attending. This is Attachment 2.

6. Formulation of advice (or array of advice or report) to be transmitted to the next Community Consultation Meeting.

The Chairman set out that the Workshop had now concluded its work on providing advice to the next Community Consultation Meeting.

The advice is that a Risk Standard Framework had been developed, as reported to the last Community Consultation Meeting, and that the Workshop (with some participants abstaining) has proposed that the risk of establishment of introduced species would be acceptably low if it conformed with the Framework.

The Workshop also advises the Community Consultation Meeting that:

- A qualifying text be included setting out a priority order for operation of the framework as set out in Section 3 of this Workshop #3 report.
- If a risk profile was ALARP (as low as reasonably practicable) but was not within the risk standard, it should not be judged to provide an acceptable risk.
- No advice was offered on what should happen outside the acceptable risk standard. Judgements will have to be made by those charged with that task (eg. EPA, Government).

7. Close

The Chairman thanked all of the participants for their contributions to the discussions at the three Workshops held on risk standards.

The Workshop closed at 6:45 pm.

oooOOOooo

Attachment 2

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Setting standards for 'acceptable risk'

Risk-based assessment of quarantine threats to Barrow Island

The EPA policy of a "zero tolerance of invasions target" (stated in EPA Bulletin 1101) has been previously adopted by the Gorgon Development as a 'goal of no introductions'. A risk assessment of 'pre-border' quarantine threats and potential quarantine barriers was considered the most protective approach in view of the advice of the Expert Panel that the 'invasiveness' of species could not be accurately predicted in every situation.

A number of risk assessment workshops have been undertaken and are in progress to identify quarantine threats, using the methodology described in the *How-to guide for conducting risk-based assessments of quarantine hazards on Barrow Island* (E-Systems, 2004). These workshops have, to date, focused on the threat of the arrival of organisms at Barrow Island. Independent experts have made judgments of the likelihood of infections/introductions and survival of terrestrial and marine organisms on several pathways of potential exposure (eg food and perishables, aggregate and people). These judgments have been made without regard to possible protective measures or quarantine barriers to prevent the arrival of introduced species.

Early experience indicates that the scoring system used to estimate the likelihood of introduction and survival of organisms results in 'high' scores (toward the maximum of 10 on a scale of 1 to 10), when undertaking the infection modes and effects analysis (IMEA) workshops without the benefit of possible quarantine barriers. It is also evident from workshop discussions that although these scores will be re-assessed once beyond best practice quarantine barriers are selected by Gorgon, the estimates of introduction and survival are not going to be reduced to the '1' end of the scoring scale in many cases for pre-border quarantine threats and barriers.

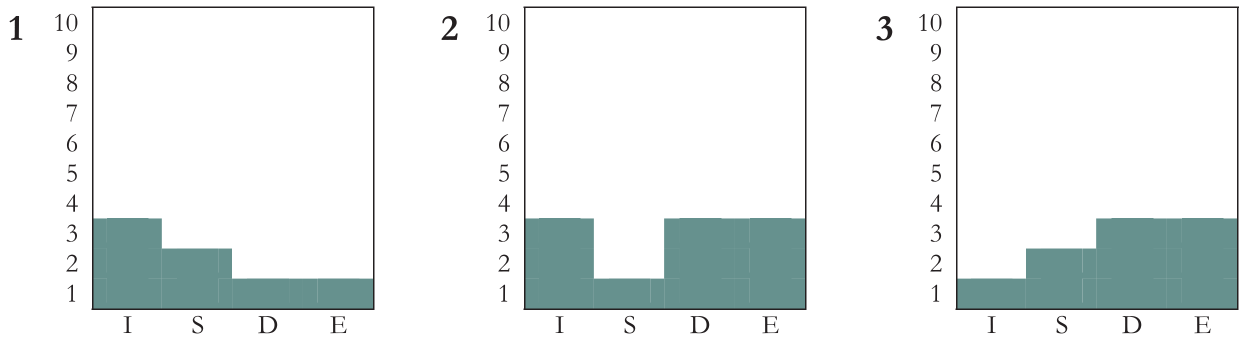
Starting point for acceptable risk

In view of the early results of risk assessment workshops for specific exposure pathways, it was recognised by workshop participants that in practical terms the 'goal of no introductions' would not be achievable. As a result, the first risk standards workshop to seek community consultation on the task of setting standards for acceptable risk (10 March 2004) recorded in the workshop record that "it was proposed that consequences which resulted in the ***establishment*** of an introduced species would be unacceptable" [emphasis added].

Testing of the suggested acceptable risk standards from the quarantine risk assessment workshops (facilitated by E-Systems) indicates that expert judgments about the pre-border likelihood of introductions and survival are not likely to fall into the three types of acceptable risk scenarios ('frameworks') that were put forward for consideration as a starting point in the first risk standards workshop (Figure 1).

Risk standards workshop participants engaged in considerable discussion on the matter of what to do about judgments of risk which do not fall into the 'green' region of acceptable risk, shown in Figure 1. This paper suggests a process for reducing risk to the green region of these matrices, and a process to manage residual risks which cannot be reduced to the green region.

Figure 1. Starting point of community expectations for acceptable risk (10 March Workshop).



Note: Scoring on left side of matrix (1-10) is defined in Table 5.3 of the *How-to Guide*.
Bold numbers 1, 2, 3 on left of matrices designates three acceptable risk scenarios ('frameworks').

I = Infection/introduction
S = Survival
D = Detection
E = Eradication

Pre-border, border and post-border quarantine

Gorgon has stated that the first priority of Quarantine Management is to prevent the introduction of species prior to their arrival on Barrow Island. As such, risk assessment workshops, to date, have focused on *pre-border* quarantine threats and barriers to assess the likelihood of the arrival of an introduced species on Barrow Island. Pre-border quarantine management and quarantine barriers on pathways of exposure are not likely to prevent the arrival of introduced species in all cases, in spite of the best efforts to do so. Gorgon has stated that detection and eradication of any introduced species are also given consideration in the risk-based assessment of quarantine management.

Analysis of the food and perishables pathway is the most convincing argument for *border* and *post-border* quarantine arrangements when setting standards for acceptable risk. The risk of having food and perishable cargoes infected with invertebrates and plant material can only be assessed in the context of a border containment and eradication facility, and the early detection and eradication of any organisms which might escape the border containment facility (post-border quarantine). Border and post-border quarantine arrangements for organisms arriving at Barrow Island may be quite independent of the pathways through which they were introduced.

Risk assessment workshops have only considered border quarantine of introduced organisms on the food and perishable pathway to date, using the HAZOP procedure for a proposed quarantine-designed kitchen facility. There appears to be more scope for proposing other border and post-border protection measures on Barrow Island for all of the other pathways, with a view toward re-assessing the risk of releasing introduced species to the native environment.

This is consistent with the community expectation that consequences which result in the establishment of an introduced species would be unacceptable. Establishment is prevented from the application of pre-border, border and post-border quarantine management practices.

There is an opportunity to specifically consider the types of border facilities and cargo offloading areas which can be designed to contain, detect and eradicate introduced species which may arrive on Barrow Island, before these species can enter the native environment. Post-border monitoring and contingency plans should also be considered when estimating the risk of the establishment of an introduced species. To date, the risk assessment process has only considered pre-border quarantine risks, and should be expanded to take border and post-border risk reduction strategies into account when attempting to meet community expectations for acceptable risk. The suggested relationship of the risk assessment process to the prevention of the establishment of an introduced species is shown in Figure 2. Not all introductions to the native environment necessarily result in establishment.

The risk assessment process shown in Figure 2 would allow Gorgon to re-assess risks of introduction for selected quarantine barriers prior to arrival on Barrow Island (pre-border), at a quarantine containment facility on Barrow Island (border), and as a result of proposed monitoring and contingency plans (post-border). It is a precautionary approach because risk is based on judgments of introduction, survival, detection and eradication of organisms which may arrive on Barrow Island. The community expectation is the prevention of the establishment of an introduced species, which goes beyond the release of an introduced organism to the native environment considered in the risk-based assessment of quarantine threats. The likelihood of establishment of a species is going to be less than or equal to the likelihood of introduction.

Process to be used to meet community standards for acceptable risk

The risk assessment process should be expanded to address both border and post-border quarantine threats with regard to the introduction of a species to the native environment on Barrow Island. It will be possible to re-assess risk estimates, or to combine risk estimates on each pathway if the overall risk of introduction is conditional on an organism 'slipping through' a number of quarantine barriers.

An expanded risk assessment process (pre-border, border and post-border) would allow Gorgon to reduce risk to levels which meet or come very close to the community expectations for acceptable risk discussed in the first risk standards workshop (Figure 1). A possible rationale for accepting risks just outside the 'green' region of Figure 1 would be to acknowledge that, in general, the risk of establishment is going to be lower than the risk of introduction to the native environment, and to provide for workable detection and monitoring strategies in any case.

Management of residual risk which exceeds community expectations for acceptable risk

There may be some threats of introduction on some particular pathways which carry a residual level of risk that exceeds the 'green' region of Figure 1. In such a situation, Gorgon would need to demonstrate that the proposed quarantine management system and barriers adopted for each pathway exceed current best practice, and that there are no other practicable measures suggested by independent technical experts which could be adopted by Gorgon to further reduce risk.

In this case, risk would have to be reduced to a level 'as low as reasonably practicable', or ALARP, as described in AS/NZS 4360 for risk management. In Biosecurity Australia terms, the quarantine threat would have to be addressed with an 'appropriate level of protection', or ALOP. The reduction of risk to a manageable level is a fundamental tenet of risk management practices. In the case of quarantine risk to Barrow Island, all reasonable barriers and management practices would need to be adopted to meet the EPA policy of a 'zero tolerance of invasions target'. It is proposed that risks which have been reduced to ALARP, in consultation with technical experts and community stakeholders, could be regarded as manageable risks which should warrant special attention in the Quarantine Management System (QMS).

In cases where risks cannot be further reduced to meet the community expectations for acceptable risk, the QMS would need to be designed to ensure that specific monitoring programs and contingency plans are developed to detect introductions of the relevant biological groups as early as possible. Specific plans and procedures would need to be detailed in the Quarantine Management Plans (QMP's) to be developed for each pathway activity, and for each type of border facility and post-border quarantine system proposed by Gorgon (refer to Figure 2). As for any introduction detected in the native environment, this would enable Gorgon to rapidly eradicate introduced species to prevent establishment and potential consequences from occurring, and communicate progress to stakeholders.

Figure 2. Relationship of the risk assessment process to the prevention of establishment.

Prevention of the establishment of an introduced species	Risk assessment process (for each exposure pathway)	Quarantine Management System (QMS)	Quarantine Management Plans (QMP's)
Pre-border quarantine (prior to arrival on Barrow Island)	• IMEA, HAZOP workshops to systematically identify threats • Scoring of introduction and survival • Design of barriers to prevent infection of cargoes • Estimates of risk (infection/ introduction and survival)	• Beyond current best practice cargo and people management strategies (pathway-specific) • Auditing of performance • Continual improvement • Competency standards • Communication with stakeholders	• Design of cargo and people handling systems • Procedures for the operation and maintenance of quarantine barriers • Assignment of responsibility, training • Reporting and actions for non-compliance, procedural breach, and incident investigation
	Residual risk — Goal of no introductions		
Border quarantine (arrival at Barrow Island)	• HAZOP workshops to analyse border facilities • Scoring of introduction, survival, detection and eradication • Design of barriers to contain and eradicate arrivals on Barrow Island • Re-assess risk with border quarantine measures	• Beyond current best practice border quarantine measures and facilities (biological group-specific) • Auditing, improvement, competency and communication as above	• Design of containment areas and facilities • Procedures for cargo and people handling • Assignment of responsibility, training • Procedures and actions for non-compliance, procedural breach, and incident investigation
	Residual risk — Prevention of establishment of an introduced species		
Post-border quarantine (Barrow Island native environment)	• Analysis of monitoring programs for early detection • Analysis of contingency plans to eradicate introduced species and limit potential consequences • Scoring of detection and eradication • Re-assess risk with post-border quarantine measures	• Beyond current best practice post-border quarantine measures and systems (biological group-specific) • Demonstrate risk reduction exceeds current best practice, risk reduced to ALARP • Auditing, improvement, competency and communication as above	• Contingency plans and procedures • Resource requirements for monitoring and incident response • Assignment of responsibility, training • Procedures and actions for incident investigation

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Technical Appendix D4

Record of Community Consultation

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

RECORD OF COMMUNITY CONSULTATION

TECHNICAL APPENDIX D4

Prepared by:

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December 2004

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Record of Community Consultation

Chronology of Barrow Island Quarantine Meetings and Workshops

Meeting/Workshop	Venue	Date
Barrow Island Quarantine Community Consultation Meeting #1	Perth Zoo	18/2/04
Barrow Island Quarantine Risk Standards Workshop #1	Kings Park Boardroom	10/3/04
Barrow Island Quarantine Community Consultation Meeting #2	Perth Zoo	20/4/04
Barrow Island Quarantine Risk Standards Workshop #2	Perth Zoo	21/4/04
Barrow Island Quarantine Risk Standards Workshop #3	Subiaco Oval	12/5/04
Barrow Island Quarantine Community Consultation Meeting #3	Perth Zoo	16/6/04
Barrow Island Quarantine – Quarantine Management System / Management Plan Workshop	Subiaco Oval	17/8/04
Barrow Island Quarantine Community Consultation Meeting #4	Perth Zoo	9/9/04

Please note: records of all meetings and workshops are available online at www.gorgon.com.au under the 'Managing Our Environment' tab.

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Technical Appendix D5

Quarantine Procedural Review – Benchmarking Study

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

QUARANTINE PROCEDURAL REVIEW
- BENCHMARKING STUDY

TECHNICAL APPENDIX D5

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October 2004

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Gorgon Development

Quarantine Procedural Review

Benchmarking Study

October 2004

Consultants

M.P. Bond
A. Catley
K.A. Doyle

Executive Summary

In considering the establishment of a Gas Processing Complex on the Barrow Island Nature Reserve, the Western Australian Environmental Protection Authority advised the WA Government that as a matter of principle, industry should not be located on a nature reserve and specifically not on Barrow Island. However the Authority went on to advise that, if the project were to proceed, it could only be on the basis of a "zero tolerance of invasion" target, and implementation of an associated quarantine regime of sufficient demonstrated rigor to achieve this.

In the broad context of protecting and maintaining the conservation values of an environmentally-sensitive area, the authors were engaged by Chevron Texaco to undertake a Quarantine Procedural Review, to identify quarantine procedures in Australia and elsewhere, that were considered to represent the best current practice. Various 'exposure pathways' for potential incursion of harmful and/or non-indigenous organisms were considered, together with appropriate quarantine procedures used elsewhere to address the associated risks. Wherever possible, specific references have been listed, where 'best practice' can be identified. For other potential pathways for an incursion, the consultants have suggested quarantine procedures that might be applied from experience in similar circumstances.

To complement the desk-top benchmarking study, two of the consultants (MPB and AC) undertook a brief familiarisation visit to Barrow Island and the Toll cargo consolidation depot at Welshpool in June 2004, to gain a first-hand appreciation of present quarantine arrangements, oil-field operations and planning for the proposed gas complex.

It should be noted that most national quarantine strategies aim to prevent the introduction and establishment of specific pests and diseases into areas where they do not occur, and to eradicate, control or limit the spread of such introduced pests and diseases. This is achieved by regulating the movement of people, goods, vessels, aircraft, animals, plants, mail and other things, which provide potential pathways for the passage of pests and diseases. These harmful pests and diseases usually are recognised as such, and the quarantine measures are designed with these specific targets in mind.

The impact of quarantine measures on international trade and commerce is subjected to close scrutiny by the World Trade Organisation. Member countries are now signatories to the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), which aims to eliminate any unfair restriction of trade under the pretext of quarantine requirements. The SPS Agreement requires members to ensure that quarantine measures have a minimal negative effect on trade, and are based on sound scientific principles, including a transparent, objective risk analysis process.

Given the inextricable link between quarantine and trade, it is difficult to make a totally objective judgement as to 'world's best practice', because different procedures are used by various national quarantine services, depending on their perceptions of risk, the prevailing circumstances and operational constraints. In addition to the targeting of specific pests and diseases, it is noteworthy that the protection of the environment and biological diversity is now recognised as an integral element of the quarantine risk assessment process.

This report also makes particular reference to the Australian Antarctic Territory and the Galapagos Islands, where stringent quarantine measures have been implemented, with the aim of protecting unique and threatened ecosystems.

The review has concluded that the quarantine measures implemented thus far on Barrow Island generally appear to have been successful, with relatively few recorded incursions during the past 40 years. Continuing studies of the Island's flora and fauna, particularly of the invertebrates and micro-organisms, should enhance the capacity of the management authorities to meet their environmental objectives, into the future.

Contents

Quarantine Procedural Review – Benchmarking Study

The Western Australian Environmental Protection Authority (EPA), in its advice to the WA Government on the Principle of Locating a Gas Processing Complex on Barrow Island Nature Reserve (Bulletin 1101), advised that as a matter of principle, industry should not be located on a nature reserve and specifically not on Barrow Island. However the Authority went on to advise that "if the project were to proceed, it could only be with a policy of a 'zero tolerance of invasion' target, and an associated quarantine regime of sufficient demonstrated rigor to achieve this".

The quarantine target of zero tolerance for the entry and establishment of non-indigenous species on Barrow Island and in the surrounding marine environment is significantly different from the quarantine standards that are generally accepted and applied by national quarantine services.

Development of a quarantine strategy aimed at the preservation or restoration of healthy ecosystems has been addressed by the Institute of Pacific Islands Forestry (USDA Forest Service), as part of the 'Pacific Island Ecosystems at Risk' (PIER) project.[31] The fundamental purpose of the project is to compile and disseminate reference information on exotic plant species of known or potential threat to Pacific islands ecosystems. The *Toolkit of Best Prevention Management Practices* emphasises that exclusion methods based on identified pathways provide the most effective way to concentrate efforts at sites (intervention points) where pests are most likely to enter national boundaries. The *Toolkit* provides a comprehensive account of some useful strategies and case studies dealing with invasive plant and animal species.

National quarantine services

The objectives of a national quarantine strategy are to prevent the introduction and spread of pests and diseases into areas where they do not occur, and to eradicate, control or limit the spread of such introduced pests and diseases. This is done under legislative powers by regulating the movement of people, goods, vessels, animals, plants, mail and other things, which are potential pathways for the introduction or spread of pests and diseases.[52]

Ideally, an effective quarantine service will have three tiers of defence against the introduction of exotic pests and diseases. The first tier (quarantine barrier) consists of well-trained and equipped personnel supported by the necessary legislation to regulate the importation of animals, plants and goods that may pose quarantine risks. The second tier of defence is an ongoing survey and monitoring program to detect exotic pests and diseases before they can become established over large areas, where eradication would be too difficult or costly. The third tier of defence is the capacity to respond to exotic pests, diseases and weeds that have become established, by initiating containment, eradication and control programs.

International trade

In the context of the current trends in global commerce and international trade, the impact of quarantine on these activities has come under close scrutiny by the World Trade Organisation (WTO), which was established in 1995. It is widely recognised that quarantine measures have the potential to unfairly restrict free trade across international borders. To address this issue, members of the WTO are signatories to an associated treaty, the Agreement on the Application of Sanitary and Phytosanitary Measures, commonly referred to as the SPS Agreement.[60] This was designed to address trading regulations for animal and plant products, to ensure that strict health and safety regulations are not used as an excuse for restricting trade to protect domestic producers.

The SPS Agreement sets out the basic rules. It allows countries to set their own quarantine standards but it also stipulates that regulations must be based on sound scientific principles. They should be applied only to the extent necessary to protect human, animal or plant life or health and they should not arbitrarily or unjustifiably discriminate between countries where identical or similar conditions prevail. It includes requirements for transparency of sanitary and phytosanitary regulations, recognition of concepts of pest- or disease-free areas and areas of low pest or disease prevalence and science-based risk analysis.

Member countries are encouraged to use international standards, guidelines and recommendations where these exist. However, members may use measures that result in higher standards, if there is adequate scientific justification. They can also set higher standards based on appropriate assessment of risks provided that the approach is consistent, not arbitrary.

In relation to international standards, guidelines and recommendations, the SPS Agreement recognises the competency of the Office International des Epizooties (OIE), the International Plant Protection Convention (IPPC) and the Codex Alimentarius Commission in developing the standards for measures to protect animal health, plant health and human health (food standards) respectively.

The SPS Agreement provides for measures to address trade disputes between member countries, with provision for sanctions under the WTO Agreement to be applied where trading rules are breached. As a result most countries are committed to incorporating standards, guidelines and recommendations, where they exist, into their quarantine systems.

Sanitary and phytosanitary standards

The development of international standards for sanitary and phytosanitary measures is a very complex process, requiring input and consultation from approximately 200 countries. Furthermore, there are many highly complex scientific issues to consider, and these may be beyond the technical resources of the less well-developed countries. Consequently, as a matter of priority, standards, particularly for plants and plant products, have been developed based on broad principles rather than detailed procedures for quarantine operations such as border activities, inspections and treatments.

The OIE *Terrestrial Animal Health Code*[53] and *Aquatic Animal Health Code*[54] provide detailed standards for the major animal diseases as they relate to trade in animals and animal products. As with the plant standards, these do not cover all animal diseases or all commodities, and are based on the current state of scientific knowledge.

Perhaps the most important standard for plants and plant products that has gained wide acceptance is *International Standard for Phytosanitary Measures No. 2, "Guidelines for Pest Risk Analysis".*[33] A Pest Risk Analysis is the starting point for assessing the quarantine risks associated with particular imports from individual countries. The risk analysis also considers options for managing risks to achieve an appropriate level of protection. Finally a decision is made on the appropriate phytosanitary measures that are required. A similar process developed by the OIE, operates for imports of animals and animal products.

Risk analyses are mainly initiated in response to proposals to import a commodity, material or species that has not been previously imported or not been imported from a particular source, either a country or part of a country. They may also be prompted by perceptions of changed risks with established imports. In some cases an analysis may be conducted on a particular pest or disease rather than a particular commodity; in such cases possible pathways for entry may involve several commodities.[15, 23, 35, 42, 44, 45]

The risk analysis process can be very complex. It is necessary to collate all available information concerning the pests and diseases likely to be associated with the commodity or species in both the importing and exporting countries to ascertain those pest species or organisms that might be provided with a pathway for entry on the commodity. An assessment is then made of all these to determine their potential economic, environmental and social importance, their potential to be introduced and become established and their potential to spread in the importing country.

For plant pests, a pest or disease may be categorised as a "quarantine pest", or a "regulated non-quarantine pest" both of which are defined in the IPPC and may attract phytosanitary measures.[33] The OIE animal codes list diseases according to their harmful potential and their capacity to spread within and between countries.[32, 36, 53, 54]

Management of risk

Options to manage the risks are then considered, so as to achieve the appropriate level of protection as determined by the importing country. These measures must be

a) no more stringent than measures applied to the same pests, if present within the territory of the importing contracting party; and

b) limited to what is necessary to protect plant and animal health and/or safeguard the intended use and can be technically justified by the contracting party concerned.[16, 20, 22]

All the steps in a risk analysis must be fully documented to include sources of information and the rationale for decisions, so that the process is completely transparent. Documented risk analyses are also valuable references for other countries engaged in risk analysis where the same or related pests and diseases are involved.

Whereas in the past, quarantine measures were unlikely to be seriously challenged, the new rules relating to transparency, equivalence and dispute resolution require a structured approach to risk analysis that is detailed in the guidelines.

Pest and disease risk analyses for animals and plants and their products require high levels of economic and scientific resources. Another important issue in pest and disease risk analyses is that completely objective quantitative risk assessments of potential pests, diseases and weeds are rarely possible because of the large number of biological and environmental factors that come into play and the paucity of scientific data. Import risk analyses usually include quantitative, semi-quantitative and qualitative elements. Furthermore, the SPS Agreement allows the "appropriate level of protection" to be determined by individual member countries. As a consequence, it is not unusual for disputes to arise over matters of scientific judgement or opinion, and this may lead to protracted and expensive research programs to seek resolution.[23, 41, 44, 45]

The scope of the IPPC extends beyond pests directly affecting cultivated plants to also cover the protection of wild flora. Some pests may primarily affect other organisms, but thereby cause deleterious effects in plant species, or on plant health in particular habitats or ecosystems. Examples include parasites of beneficial organisms, such as biological control agents. To protect the environment and biological diversity without creating disguised barriers to trade, environmental risks and risks to biological diversity should be assessed as part of a Pest Risk Analysis. International Standard for Phytosanitary Measures No. 11, *Pest risk analysis for quarantine pests, including analysis of environmental risks and living modified organisms –Annex 1*, provides comment on the scope of the IPPC in regard to environmental risk.[35]

World's best practice

Given the inextricable and complex linkages between quarantine and trade, objective assessments of 'world's best practice' are difficult to make, because different procedures are used by quarantine services depending on their perceptions of risk, the prevailing circumstances and operational constraints. Furthermore, the SPS Agreement has a particular clause dealing with the principle of 'equivalence' which requires member countries of the WTO to accept different sanitary or phytosanitary measures of other members as equivalent, if the exporting member objectively demonstrates to the importing country that its measures achieve that importing country's appropriate level of sanitary or phytosanitary protection.

For the purpose of this study, the consultants have drawn largely on their knowledge of quarantine systems in Australia, Canada, Japan, New Zealand, United States of America and the United Kingdom, and experience in other countries to identify procedures which are applied to address quarantine risks in the various 'exposure pathways' that have been identified in the context of protecting the environmentally-sensitive area of Barrow Island. While several national quarantine systems incorporate procedures and features that can be regarded as 'best current practice', no single system provides all these elements.

Protection of conservation values

Taking into account Barrow Island's unique status in Australia as a Class A Nature Reserve, with significant conservation values and a relatively undisturbed terrestrial environment, the consultants sought information on quarantine management systems that have been implemented in other similarly protected areas. Only two comparable situations, the Galapagos Islands and Antarctica were identified, primarily on the basis of their isolation and with limited access by air and sea so that there are opportunities for regulating everything that crosses their 'borders'.

Galapagos Islands

Galapagos is a World Heritage Site with its biodiversity under threat from many invasive alien species. Programs are in place to eliminate the introduced terrestrial species of plants and animals and to prevent further introductions.[57] It should be noted that these programs are primarily aimed at the restoration of ecosystems that have been degraded by earlier incursions.

A dedicated inspection and quarantine system, SICGAL (Sistena de Inspeccion y Cuarentina para Galapagos), was established in 2000 under the control of the Ecuadorian Plant Quarantine Service and with technical support and training provided by the Charles Darwin Research Station on Galapagos.[26, 55]

SICGAL is responsible for inspecting luggage and cargo that arrives on the islands or that is transported between islands. Inspectors check luggage at the airport in Ecuador before check-in and also on arrival in Galapagos. Travellers must declare any kind of organic matter in their possession. Live animals and fresh flowers are prohibited entry to Galapagos. Food, plant and animal products and seeds for sowing are restricted or prohibited. Legislation enacted by the Ecuadorian Government provides for penalties for non-compliance with procedures, including confiscation, fines and imprisonment up to three months.[19]

Restrictions also apply to vessels cruising the islands, with a requirement for inspection by SICGAL officials. [27]

Australian Antarctic Territory

Details of quarantine procedures for protection of the Antarctic environment are summarised in a recent publication of the Australian Antarctic Division (AAD). Under a Memorandum of Understanding, the Tasmanian State Quarantine Service and the AAD are collaborating to strengthen the quarantine integrity of the Australian Antarctic Territory, Macquarie Island and the Territory of Heard and McDonald Islands.

A key component of this quarantine strategy is the implementation of a rigorous inspection procedure for vessels and a wide range of cargo. This is complemented by a comprehensive processing procedure for all personnel and their luggage, and special requirements for fresh fruit and vegetables. Details of quarantine procedures for protection of the Antarctic environment are provided in the recent paper by Sandra Potter, Logistics Section, Australian Antarctic Division (Attachment 1).

Barrow Island

Strict quarantine procedures have been implemented on Barrow Island since the 1960s when oil was first discovered there. These procedures appear to have been effective, based on a review of available information on the quarantine activities to date, and a visit to the Island in June 2004, which provided an opportunity to see the current quarantine procedures. Since oil exploration commenced, there appear to have been only two recorded breaches of quarantine which resulted in recorded vertebrate introductions – two house mice were found in a drilling rig in 1995 and a single mouse was found in a car wreck imported for emergency training purposes in 1998. In both cases the pests were contained and eradicated. Black rats believed to have been introduced to the island by pearlers in the latter part of the 19th century, apparently were eradicated by 1998. [40]

At present, there are no known invasive vertebrate fauna on the island, but there are four designated introduced weed species, which occur in low incidences around the airport and camp facilities. There is a substantial gap in information regarding the status of indigenous and introduced invertebrates on Barrow Island because comprehensive baseline studies have not been undertaken. However, existing quarantine arrangements on Barrow Island appear to compare favourably with contemporary modern quarantine practices.

Chevron Texaco has conducted a series of risk assessment workshops to review potential pathways for entry and risks of introduction and establishment of biological groups in hazard evaluations. The workshops considered the following conceptual list of potential introduction pathways in hazard evaluation of persons and commodities transported to the Island:

- Personnel and accompanying luggage
- Personal goods imported by employees and contractors
- Skid equipment, accommodation units, personnel buildings
- Food and perishables
- General supplies
- Containerised goods
- Aggregate and sand
- Cement
- Pre-fabricated modules for plant construction
- Plant, including earthmoving equipment, vehicles
- Steel
- Pipe
- Marine vessels.

Table 1 provides a summary of procedures that are used by various national quarantine services to address potential risks of spreading pests and diseases along these pathways. These types of quarantine procedures are a benchmark for what is considered current best practice.

Management of quarantine

The objectives of a modern quarantine management system are explicitly stated and realistic, taking account of the environment and circumstances in which it must operate. This helps to instil a sense of common understanding and ownership amongst all stakeholders including regulatory personnel, the general community and in particular individuals and organisations involved in activities such as production, manufacturing, packaging, warehousing, transportation and quarantine activities.

Level of Control

As quarantine operations impact on the free movement of people, goods and vessels, the organisation or authority responsible for managing a quarantine system will have properly constituted powers, preferably under appropriate legislation.[37] There will also be provision for sanctions to be imposed for non-compliance with quarantine requirements. Environmentally-sensitive areas such as the Galapagos are protected by stringent laws designed to protect the threatened ecosystems.[19]

In addition, the legislation should protect the rights of individuals, companies, organisations and special groups who might be inconvenienced or incur additional responsibilities as a result of quarantine requirements.

Quarantine barrier controls

A basic principle of quarantine management is to address the risks before arrival of the commodity, material or animal at the country of destination.[25] The concept of the continuum of quarantine covering all activities from pre-shipment, through border controls to post-border control of waste disposal, monitoring and surveillance is firmly established in the most highly-developed quarantine services in countries such as Australia, USA, New Zealand and Japan.[2, 3, 38, 39] As much as possible, risks are managed before export by sourcing low risk goods, implementing appropriate treatments and conducting thorough inspections. In protecting sensitive environmental areas, this means that as far as possible, quarantine procedures are completed before entry of people or materials into those areas.

As an integral part of modern quarantine systems, many countries have compiled lists of goods that are prohibited or restricted imports.[2, 3, 38, 39] Travellers are required to declare any prohibited or restricted goods; the declaration may be oral or written. This is supported by a regulatory regime to detect any non-compliance, and in that event, imposition of appropriate penalties.

Such a procedure emphasises the importance of quarantine requirements and reduces the probability of 'accidental' introductions, especially by short-term visitors or workers, who might not fully understand the significance of quarantine measures.

Personnel

Authorised inspection and other personnel with appropriate training and expertise are located at all intervention points in the quarantine process, including designated airports, seaports, border checkpoints, pre-clearance sites and approved premises. Inspectors play a crucial role in determining the effectiveness of a quarantine system, and their decision-making skills, conscientiousness and integrity are of great importance. A simplified summary of the quarantine processes shows some of the inspectors' key activities (Diagram 1).

[With reference to Diagram 1, a quarantine protocol is a detailed set of import conditions specified on an import permit issued by the quarantine authority of an importing country. It often involves a formal agreement between quarantine agencies of exporting and importing countries in relation to certification of origin, testing, treatment, packaging or other requirements performed in the country of export.]

All personnel responsible for a modern quarantine system are appropriately trained to perform their duties effectively and efficiently. A useful model is the MAF (New Zealand) *Biosecurity Standard for Appointing Supervisors of Animal Quarantine and Containment* ((July 2000), which lists relevant competency standards.[49, 50] To be effective, the quarantine system should have the support and co-operation of all the people involved. A high profile quarantine awareness program directed at all personnel, suppliers of equipment and provisions and shipping and aircraft transportation should be implemented and regularly reviewed and updated.

Training and Awareness

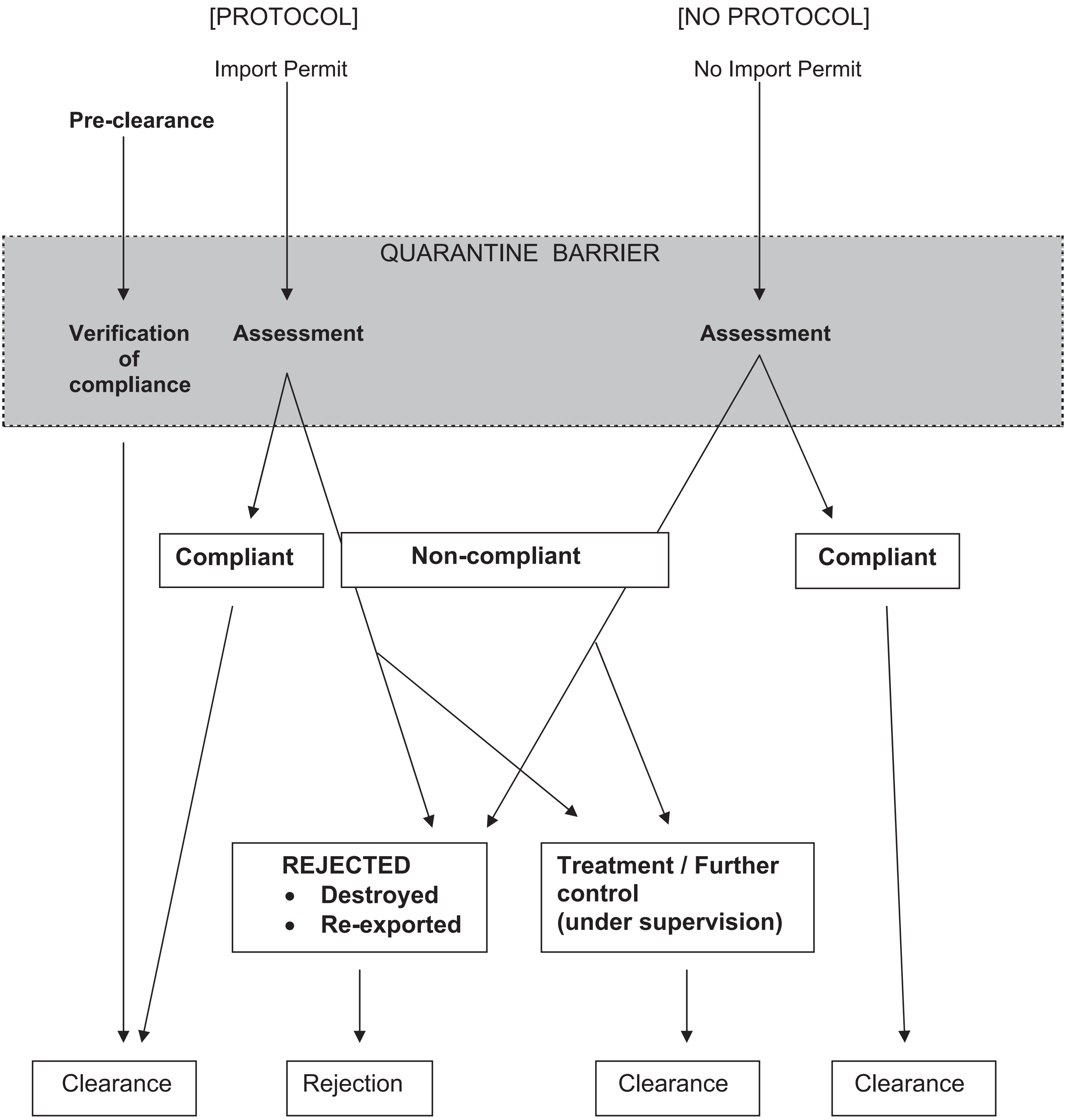
It is widely acknowledged that quarantine services need the cooperation of all sectors of the community to be effective. To achieve this, requires a high level of awareness of the importance and objectives of quarantine. Awareness levels are raised by programs designed to reach particular individuals, groups or organisations by a range of activities including advertising, displays, meetings, special presentations to target audiences etc. Using these methods, it is important to create an organisational culture of awareness and responsibility. The “Quarantine matters!” project devised by AQIS, utilising a range of media and celebrities to promote quarantine awareness, has been very successful. The Northern Australia Quarantine Strategy (NAQS) also has an awareness program aimed specifically at residents and visitors to the Torres Strait region. This has been well received and supported throughout the region.

Another example devised by the AAD, is the *Environmental Code of Conduct for Australian Field Activities in Antarctica*, which is used to remind personnel of their environmental and quarantine responsibilities.[11]

Operational Manuals

Procedural manuals should be available to all personnel to cover quarantine procedures relevant to their responsibilities. A system should be in place to ensure that manuals are regularly reviewed and updated as required. It should be noted that the New Zealand Ministry of Agriculture and Forestry procedures generally are prepared in the ISO Standards format.[43, 45, 46, 48] The USA Animal and Plant Health Inspection Service (APHIS) and Australian Quarantine and Inspection Service (AQIS) manuals also are very good models.[1, 12, 13]

Diagram 1 - Flow chart, showing typical quarantine intervention points for imported goods



NOTE – Procedures in bold-face require decisions by quarantine inspectors.

Databases

To assist in managing quarantine systems, computerised databases which record all quarantine incidents including interceptions, treatments, non-compliance and other events should be maintained and used to identify emerging risks, trends and operational problems, so that they can be addressed in a timely manner. Such databases also provide a valuable historical record, for retrospective analysis and investigation.

Facilities

Appropriate facilities are provided at all sites where quarantine operations are conducted along the pathways for entry of vessels (by air and sea), passengers, luggage and goods. This especially applies to the barrier facilities at border crossings.[41]

In Australia, AQIS approves a range of facilities where post-entry quarantine inspections and treatments may be carried out on a wide range of plants, animals, equipment and machinery, plant and animal products, etc.[17] These Quarantine Approved Premises (QAP) are registered by AQIS and conform to various criteria, to provide an appropriate level of security and control against the introduction of pests and diseases. For example, the requirements for a QAP (Class 1) cover the following components:

- security
- isolation, to prevent any cross-contamination
- hygiene (cleaning facilities, secure disposal, handling of quarantine waste)
- comprehensive and accurate records
- inspection facilities (well-designed, with good lighting, etc.)
- cargo handling facilities and equipment.

Quarantine Procedures for Specific Exposure Pathways

1. Aircraft [1]

Quarantine procedures directly related to aircraft, excluding passengers, baggage and cargo, mainly involve inspection for pests, contaminant materials and compliance with disinsection* requirements and quarantine security while the aircraft are on the ground. External surfaces of aircraft, including undercarriages and wheels are not considered to be significant risks for commercial aircraft operating from hard-sealed surfaces. However rare events such as bee swarms, ant infestations, mud-nest and paper-nest wasps, occasionally occur on and around engines and undercarriages. When detected by airline personnel and brought to the attention of quarantine officials, appropriate quarantine procedures are instituted.

Aircraft transiting airports for short periods and not loading or unloading cargo, may receive cursory inspections after passengers have disembarked.

* 'Disinsection' is a quarantine term, referring to the application of an insecticide to kill insect vectors of human and animal diseases.

Disinsection of passenger cabins and cargo holds may be required to target particular vectors of human and animal diseases and to a lesser extent, some agricultural pests. Depending on the circumstances, disinsection can be done by the crew using aerosol canisters under compliance agreements before departure, in-transit or on-arrival either before or after passengers disembark. Disinsection may also be performed by the application of residual insecticides to aircraft surfaces in passenger cabins and cargo holds at scheduled intervals of time.

Quarantine action may also be required as the result of inspection of cabins, cargo holds and galleys and the detection of prohibited plant or animal material or contamination by such material. Incidents involving live animals escaping and hiding on aircraft are widely reported, and in such cases quarantine officials are required to approve any necessary action to capture the animal.

General quarantine management procedures for aircraft might also include sealing of food stores while the aircraft is on the ground, prohibition on removal of garbage or supervision of its removal in sealed secure containers. Responsibility for these procedures is often given to crew or contractors under compliance agreements which incorporate significant penalties for breaches.

- **Passengers and accompanying luggage** [1]

  Best quarantine practice for passengers and luggage has several aspects, including

  - awareness programs, providing advice to passengers at ticketing, and also signage in departure lounges,
  - inspection of shoes at check-in, and cleaning facilities,
  - in-flight information,
  - passenger declaration, either oral or written,
  - questioning at check-in, regarding animal or plant products,
  - screening of baggage for animal and plant items of quarantine interest, using X-ray equipment or detector dogs,
  - amnesty bins and audio messages encouraging disposal of unacceptable items,
  - facilities for identification, holding and return of any intercepted material.

- **Air Cargo** [27]

  Cargo clearance is a major quarantine activity. It involves close liaison with customs authorities and customs brokers. Manifests are screened to identify any goods of quarantine concern, and requiring subsequent quarantine action. Goods which have been assessed as high quarantine risk require a permit for importation, often under detailed protocol conditions extending back to the source of the goods.

  Air cargo containers are designed to meet airworthiness standards and are mostly of metal construction. They are normally unpacked at approved break-bulk depots at airports, and are accompanied by

  - a declaration by the exporter or consignor regarding absence of timber or straw,
  - an accurate description of the goods,
  - a declaration regarding the cleanliness of the container.

2. Shipping

- **Vessel clearance** [21]

  Quarantine and public health practice includes hygiene inspection of ships. Holds, galleys and crew quarters are inspected for pets, insects, rodents, plants and other material of quarantine concern. If these items are detected, appropriate quarantine measures are applied; these may include treatment, destruction or secure containment while the vessel is in port.

  Ships' effluent is controlled by port authorities, and garbage is held on board, in environmentally-sensitive areas such as the Galapagos and Antarctica. In other situations, garbage must be treated and disposed of in an approved manner; usual methods are sterilisation by boiling, incineration to ash, deep burial or maceration and disposal in an approved sewerage system. At all times, garbage must be covered and secure.

- **Sea Cargo** [12, 47, 48]

  The sea transport of goods in containers is a very common practice that requires particular quarantine attention. In order to streamline the handling of containerised goods, a modern quarantine system makes a clear distinction between the container itself and the cargo.

  Depending on the country of origin and the type of construction, a container will be assessed and treated so as to minimise quarantine risk. In Australia, each container is usually accompanied by a Cleanliness Declaration and a Packing Declaration, which will incorporate a
    - straw packing statement,
    - timber packing statement (dunnage etc.),
    - bark statement (as to whether any timber has bark on it).

  Packing Declarations are not required for hard-frozen containers (held at -18^{o} C for at least seven days) or ISO tank containers; Cleanliness Declarations are required.

  The exporter or consignor is required to provide an accurate description of the goods, which is used to assess the appropriate quarantine treatment. Any goods which are designated as 'subject to quarantine', will be directed to an approved break-bulk depot, for unpacking and inspection. Any restricted or incorrectly-documented cargo will be subject to special inspection, and any prohibited goods ordered into quarantine for destruction or re-export.

- **Rats and mice**

  Rodent control measures are routinely undertaken on vessels in accordance with the World Health Organisation International Health Regulations.[58,59] These procedures include verification of de-ratting and exemption certificates, and placement of rat guards on hawsers.

- **Emergency landings, itinerant yachts**

  Cruising yachts and other pleasure vessels receive particular quarantine attention, mainly due to the likelihood of pets and foodstuffs such as fresh animal and plant products of uncertain origin. Wooden vessels have the potential for insect infestation, such as dry-wood termites and borers. They also pose a particular risk, because of the risk of introduction of hull-fouling invasive species. [51]

  An effective national quarantine strategy will make provision for appropriate inspection and treatment procedures, and rapid response capability, in the event of an emergency landing.

3. Ballast water

The introduction of invasive marine species into new environments in ships' ballast water has been identified as one of the greatest threats to the marine environment. In developing the current best practice, organisations such as Lloyd's Register have been at the forefront in assisting shipowners develop safe, practical and effective strategies for ballast water management.

In February 2004, a new benchmark for dealing with ballast water was established, with the adoption by the International Maritime Organisation (IMO) of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments*.[30] AQIS has recently issued a *Maritime Awareness Kit*, which includes updated Australian requirements for ballast water management, consistent with the IMO Convention.[14] AQIS and CSIRO Marine Research also have compiled a list of 33 potentially harmful invasive marine species.

The US Coast Guard is investigating the efficacy of several ballast water management approaches, including the establishment of a new ballast water discharge standard and procedures for approving ballast water treatment systems. In May 2004, the US Department of Transportation Volpe National Transportation Center was commissioned to conduct an assessment of such existing systems.[56]

4. Hull fouling

There is a wide range of aquatic organisms that may potentially be introduced via shipping, hull fouling and ballast water, and there is limited understanding of their taxonomy, biogeography and potential harmful impacts. In Hawaii, hulls of vessels are inspected, to enable early detection of harmful species.[51]

Following an infestation of the exotic Black Striped Mussel (*Mytilopsis sp.*) in Darwin Harbour in 1999, the Northern Territory Government implemented a successful containment and eradication program. This includes the inspection, treatment (anti-fouling) and clearance of vessels by the NT Department of Primary Industry and Fisheries Aquatic Pest Management Team. [31]

5. Dredge equipment

Dredges and dredging equipment that are moved internationally are subject to the same quarantine requirements as other vessels, ie hygiene, cleanliness, declarations, inspection for verification and penalties/sanctions for non-compliance. Control of dredges within a nation's territorial waters to prevent the spread of marine organisms is not normally the responsibility of quarantine authorities.

6. Foodstuffs [5, 6, 7, 8]

Foodstuffs are always subject to quarantine control. Higher risk materials may require permits under detailed protocol conditions, to contain the risk before arrival at final destination. Other foodstuffs are subject to inspection, for contamination with prohibited material or pests and diseases. Treatments including re-export, disinfestation, sterilisation, etc may be applied as required.

Some commercially-produced canned, bottled, frozen or freeze-dried foodstuffs are considered lower risk, and may have less restrictive import conditions. These are considered by quarantine authorities on a case-by-case basis, taking into account the particular quarantine risks.

7. Plant, earth-moving equipment, and vehicles [9, 13]

These items constitute major quarantine risks, because of the likelihood of contamination with soil and plant material and associated organisms. They are generally difficult to clean due to limited accessibility. Consequently, dismantling before cleaning is necessary, prior to shipment. Cleaning may involve use of high-pressure water or steam, or fumigation.

8. Aggregate, cement and sand

Clean rocks, aggregate, cement and sand (washed) *per se* are not generally considered to be pathways for movement of animal and plant pests, in the context of national quarantine processes. However, as there is a strong likelihood of contamination of aggregate and sand with soil or other organic material, these normally require approval to import after consideration of the potential quarantine risks. For imports into Australia AQIS requires information on identity, origin, freedom from soil and any treatments given to the goods. For bulk materials (containerised or in ships' holds), this includes details as to how the goods are sourced, stockpiled, stored and the measures taken to exclude birds, rodents and other animals from the storage areas. Washing of sand and aggregate before shipment may also be required. For example, AQIS has approved the importation of certain kinds of minimal risk sands, aggregates and minerals from particular sources, subject to washing and other controls to contain the risks and preserve the integrity of the material from the source through the handling and transportation path to the point of importation into Australia.. [16]

If soil or contamination cannot be easily removed, the goods are not permitted importation.

9. Pipe

Pipe represents a particular risk for the introduction of pests and diseases, either as contaminants or harbourage for rodents, reptiles, molluscs, insects, spiders etc. Pre-shipment measures by exporters are warranted, to address the identified risks. These measures might include inspection, cleaning, fumigation with methyl bromide and re-sealing to prevent the reintroduction of pest species.

10. Construction equipment

These items can be contaminated or provide harbourage for pests and diseases, and are routinely inspected by quarantine officers.

11. Portable accommodation units

Portable accommodation units may harbour a range of pests, diseases and unwanted animals. As they are difficult to inspect, it would be appropriate to apply precautionary treatment such as fumigation with methyl bromide.

12. Mail

In most developed countries, quarantine control is exercised over all incoming mail, which is screened for restricted or prohibited material, using consignor declarations, X-ray equipment and detector dogs at international mail centres. Particular attention is given to articles sent as ‘small packets’ and ‘parcel post’.

Surveillance and Monitoring Programs

Some developed countries have implemented monitoring programs for insect vectors of human and animal diseases at airports and seaports, and also early detection of plant pests and disease.[29]

In the US and other developed countries, surveys for early detection of alien species are carefully planned, according to internationally agreed standards, such as the Guidelines for Surveillance, produced by the International Plant Protection Convention. [2]

The Department of Agriculture, Fisheries and Forestry (Australia) has prepared a Disease Watch Awareness Kit, which is due to be released in the near future. This is aimed at protecting the marine environment, by encouraging the reporting of diseases affecting aquatic species.

Contingency Response Planning

A crucial part of early detection is an agreed contingency plan that clearly sets out responsibilities of the stakeholders, channels of communication, etc. The contingency planning components of most national quarantine strategies are aimed at specific high-risk target species or organisms.

Some countries have developed comprehensive plans for responding to incursions of foreign animal and plant diseases.[42, 45] For example, the Australian Veterinary Emergency Plan (AUSVETPLAN) [10] and the Australian aquatic animal health plan (AQUAVETPLAN) [18] are among the most advanced emergency response plans for animal diseases in the world. For incursions of exotic plant pests, the US has developed a series of comprehensive response plans.[2, 4, 8]

Where the environmental, economic or social consequences of an incursion are less well understood, the provisions of a contingency plan have to be broader and more flexible. If the contingency plan cannot be directed at specific targeted species of concern (as is the case with conventional national biosecurity arrangements), the process is more challenging. It is essential to identify any harmful invading species, and strong reliance is placed upon appropriate technical expertise, required for early identification and planning a rapid and effective response.

Conclusions

Since the 1960s, a range of quarantine measures have been implemented for Barrow Island. These procedures generally appear to have been successful, with relatively few recorded incursions of non-indigenous species. However, there are notable gaps in the available information, particularly the lack of adequate baseline studies for invertebrate fauna.

The proposal to establish a Gas Processing Complex on Barrow Island requires a rigorous environmental assessment process, and development of a stringent and effective quarantine management system. This benchmarking study focused on the various identified 'exposure pathways' for potential incursion of harmful and/or non-indigenous organisms. Based on the authors' knowledge and experience, appropriate procedures which are used by advanced national quarantine services to mitigate the chances of such incursions have been identified.

The quarantine measures presently used to protect the sensitive environments of the Australian Antarctic Territory and the Galapagos Islands, are considered to be especially relevant. This is notwithstanding the extremely harsh climatic conditions of Antarctica, and the primarily restorative efforts needed in the Galapagos, to rectify the damage of earlier incursions.

In considering procedures adopted by contemporary national quarantine services, it is important to note the inextricable links between quarantine and trade. This benchmarking study was done in the context of the World Trade Organization Treaty on the Application of Sanitary and Phytosanitary Measures, which requires that such measures are the least restrictive to provide an appropriate level of protection to importing countries.

In the current global trading environment, quarantine measures are designed to facilitate commerce by managing risks with the minimum disruption to trade. While the primary focus for quarantine measures is frequently on pests and diseases of plants and animals, environmental protection against the threats posed by invasive species of plants and animals is also recognised as a legitimate concern of quarantine authorities. Formal arrangements are now well established between quarantine and conservation agencies in many developed countries.

In this study, no attempt has been made to rank the effectiveness of procedures identified, in terms of best current quarantine practice. The primary objective of quarantine is to prevent the spread of pests and diseases, while minimising the adverse effects on trade. The least restrictive measures that manage the risk to an appropriate degree should be used. For example, in considering the management of a particular pest or disease risk, the options available to a quarantine service may range from simple inspection on arrival, through increasingly restrictive treatments involving washing, heating and/or chemical treatments, all of which would provide an appropriate level of protection. The more restrictive and costly measures should not necessarily be applied, if the simpler and less costly measures provide the appropriate level of protection.

Quarantine 'best practice' encompasses science-based risk management, high quality technical resources and well-designed procedures. An effective quarantine service must have clearly defined objectives and these will differ between countries depending on the resources they wish to protect and the relative values attributed to them. The threats and potential impacts posed by imports should then be identified by a rigorous risk analysis covering possible pathways for entry of pests and diseases which are likely to lead to their establishment. Options for managing risks should then be considered, and the least restrictive measures applied, consistent with achieving the appropriate level of protection for the particular circumstances. The view of the consultants is that 'world's best practice' also requires comprehensive surveillance and monitoring programs for early detection of incursions and a capacity to respond quickly and effectively to any incursions that are detected.

In the case of Barrow Island where protection of conservation values is the prime objective of the management authorities, the elements of an effective quarantine system have been implemented over many years. On the basis of interception records provided by Chevron Texaco Australia Pty Ltd and information obtained on a visit to the Island, the authors consider that the quarantine arrangements have been successful in meeting their objective. Ongoing investigations of the flora and fauna, particularly of the invertebrates and micro-organisms, should enhance the capacity of the management authorities and industry operators to continue to achieve their environmental objectives for Barrow Island, into the future.

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Table 1 - Quarantine measures for potential pathways

Pathway	Quarantine Procedure	Reference
Personnel, luggage	Incoming passenger declaration to Customs and/or Quarantine Officers. Both written and oral declarations are used. Random and intuitive inspection of luggage by Customs/Quarantine officers. X-ray examination of luggage. Detector dogs trained to detect odours of plant and animal material.	Australia (AQIS) USA (APHIS) [1]
Passenger baggage (Hawaii to other parts of USA)	Examine carry-on baggage and question passengers re fruits, vegetables and other restricted items they might have in their possession.	USA (APHIS)[8]
Personal goods imported by employees and contractors	Incoming passenger declaration. Detector dogs in Customs arrival hall.	Australia (AQIS) USA (APHIS) [1]
Accommodation units, personnel buildings	Inspection and treatment if necessary.	Australia (AQIS) [15]
	Precautionary fumigation with methyl bromide.	Australia (AQIS)
Food and perishables	Permit to import with conditions prescribed according to assessed risk taking into account, origin, treatment received and end use.	Australia (AQIS) [15] USA (APHIS) [5]
Fresh fruits and vegetables (entering USA)	Except in a few cases, all shipments of approved fresh fruits and vegetables require a permit. Lack of a permit is not grounds to refuse entry to a shipment. If the importer does not have a permit, one may be issued at the port of entry.	USA (APHIS) [5]
Unprocessed seeds (grain and nuts) for human consumption (entering USA)	Sample and inspect to determine if prohibited or infested/infected with pests or disease or contaminated with regulated material. Take appropriate regulatory action	USA (APHIS) [7] Australia (AQIS) [15]

Pathway	Quarantine procedure	Reference
Miscellaneous and processed plant products (entering USA)	Inspection for pests or evidence that a pest is present. Practically, this term also includes the examination of articles to determine compliance with regulations and capability to disseminate pests. Inspection must also include the review and examination of documents to establish compliance with regulations and the acceptance/permissibility of an article.	USA (APHIS) [6]
General supplies	Subject to quarantine. Cargo manifests screened to determine if further quarantine intervention such as verification, inspection or treatment is required.	Australia (AQIS) [13, 15, 16] USA (APHIS)
Containerised goods	Containers and contents assessed separately in relation to quarantine risks. Interior of container must be clean and free from quarantinable material, eg residues of previous cargoes, soil, infested or contaminated dunnage and/or pallets and other packing materials (straw, tyres, hessian etc.) Packers, certification organisations or official government certification may be acceptable evidence to permit delivery to importer. In some cases tailgate inspections might be necessary to verify certification and contents before delivery. Delivery destination might also be regulated if further inspection or verification is required during or after unpacking. Containerised cargo receives the same assessment as for break bulk cargo, however as it is not as accessible for inspection some quarantine services allow delivery to importer if the goods are treated, inspected and/or otherwise conform in respect of packaging materials and are certified by approved authorities.	Australia (AQIS) [12] New Zealand (MAF) [47, 48]
Aggregate and sand	Aggregate *per se* does not present a quarantine risk. However most quarantine services would be concerned about the risk of contamination with soil or organic matter. Therefore a permit to import would usually be required. For imports into Australia AQIS requires information on identity, origin, freedom from soil and any treatments given to the goods. For bulk (containerised or ships' holds) details of how the goods are sourced, stock piled, stored and the measures taken to exclude birds, rodents and other animals from the storage areas. Washing of sand and aggregate before shipment is also required. Inspection on arrival is also required. If soil or contamination is found and cannot be easily removed, the goods are not permitted importation.	Australia (AQIS) ICON [16]

Pathway	Quarantine Procedure	Reference
	As it would be difficult, if not impractical, to satisfactorily inspect large quantities of aggregate, it would not be unreasonable to require precautionary cleaning with water immediately before or during loading.	
Cement	Cement should not constitute a serious quarantine risk either bagged or bulk, provided it is kept free from cross contamination during and after manufacture. The end use of the material would further reduce any associated quarantine risks. As for all imported goods it would be subject to inspection.	
Pre-fabricated modules for plant construction	Timber components would require inspection and treatment if insect infestation or fungi were found. If inspection is impractical, timber components could be immunised against insect and fungal attack and certified by an acceptable authority. Other alternatives would be heat treatment or fumigation but these would provide only temporary protection. Again certification would be required. Non timber components should be inspected for cleanliness and freedom from contaminants and pests. If inspection is impractical, the material could be fumigated with methyl bromide and sealed to prevent reinfestation.	Australia (AQIS) [16]
Plant, including earthmoving equipment, vehicles	Earthmoving equipment is a serious quarantine risk because of the high probability it could be contaminated with soil. It should be inspected and cleaned before shipment. Detailed inspection and cleaning frequently requires dismantling. Cleaning can best be done with high pressure water or steam.	Australia (AQIS) [13]
Pipe	As for plant and machinery. Fumigation with methyl bromide could be used as a precautionary treatment for pests harbouring in pipes. They could then be sealed against re-introduction.	Australia (AQIS) [13]
Mail	All incoming items screened for restricted or prohibited material, using consignor declarations, X-ray equipment and detector dogs at international mail centres.	USA (APHIS) [1]

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Attachment 1

XXVII ATCM
Information Paper
IP 071
Agenda Item: 4 d
AUSTRALIA
Original: English

ATCM XXVII
Cape Town, 2004

AUSTRALIA'S ANTARCTIC QUARANTINE PRACTICES

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AUSTRALIA'S ANTARCTIC QUARANTINE PRACTICES

INTRODUCTION

1. Australia recognises that the introduction of alien species to Antarctica by human agency is an increasingly significant environmental risk associated with the conduct of Antarctic operations. The approach taken to the quarantine management of the Australian Antarctic Program (AAP) activities reflects Australia's commitment to Annex II of the Protocol on Environmental Protection to the Antarctic Treaty.

2. The key protection strategies adopted are outlined in this paper and reflect:

- the desirability of delivering a high level of biosecurity while maintaining operational efficiency in the logistical support of Antarctic science programs;
- the desirability of focussing on the application of measures prior to departure for Antarctica;
- the need to adopt a precautionary approach; and
- the importance of expeditioner participation in, and understanding of, quarantine management initiatives.

INSPECTION MEASURES

3. Inspections of AAP vessels leaving Hobart are conducted by Tasmania's (State government) quarantine body, Quarantine Tasmania, under a Memorandum of Understanding with the Australian Antarctic Division (AAD). The inspections include an examination of the vessels' accommodation, storerooms, galley, waste management areas, helicopters, workboats, cargo holds and machinery spaces for conditions of quarantine concern. Specific checks are undertaken for indicators of the presence of rats, a particular concern with respect to Australia's subantarctic islands. Although 'clean ship status' is ascertained on a voyage-by-voyage rather than seasonal basis, rat baits are placed on all AAD-chartered vessels.

4. Program cargo is consolidated and packed in a dedicated ship-side facility that is accredited to 'Class One Sea and Air Freight Depot' standard by Australia's national quarantine authority, the Australian Quarantine and Inspection Service (AQIS). The cargo facility is regularly audited against prescribed security, hygiene, isolation, staff quarantine training, and administration standards.

5. Cargo containers and their contents are also routinely inspected. Gas bottles, vehicles, machinery, and other items recognised to be particularly prone to contamination, are brushed, steam-cleaned and/or hot washed before loading to dislodge any encrusted soil and organic matter including hitch-hiking invertebrates. In view of the environmental and occupational health and safety issues associated with the use of fumigants and chemical sprays, and the practicalities of protecting large volumes of cargo in the period between treatment and shipment, only the highest risk items are treated using these methods.

6. Fresh fruit and vegetables are inspected in accordance with internationally recognised phytosanitary protocols – 600 units or a 2 per cent sample for each consignment. The inspections address quality and contamination issues, requiring that fruit and vegetables are

intact, clean, and free from abnormal external moisture, foreign smell or taste, disease, insect infestation, soil and other foreign matter.

7. Dressed poultry products are inspected for evidence of disease, in particular, Newcastle's disease, avian tuberculosis, yeast infection, avian encephalomyelitis and salmonella infection under existing arrangements for the inspection of commercial Australian poultry. Poultry meat and eggs are restricted to station use in recognition of the difficulties in the application of complicated food handling protocols in remote field conditions.

8. Expeditioners' hand/cabin luggage is subject to inspection by Quarantine Officers and/or passive quarantine detection dogs that are trained to react to a wide range of organic scents. The dogs also screen mail shipped to the stations. Their presence at ship departures readily attracts the attention of the public and therefore plays an important role in heightening quarantine awareness.

9. Compulsory pre-disembarkation procedures include closely monitored gear cleaning sessions that are repeated at each landing. Seams, pockets, tripods, back-packs, and tool boxes are among areas or items that are targeted.

ADMINISTRATIVE MEASURES

10. The potential for Antarctic operations to introduce alien species and translocate endemic species is among the issues examined in the environmental impact assessment (EIA) process. The conduct of hydroponics, an activity identified as a potentially significant refuge for unintentional introductions, has been assessed at the Initial Environmental Evaluation level. Protection measures in place include the supply of only sterilised seeds and growing media, the incineration of waste plant matter and growing media, and monitoring for invertebrates using a range of trapping methods.

11. Expeditioners are briefed on quarantine issues at nominated stages in their pre-departure preparations and, along with the ship crews, receive additional training during their voyage to Antarctica. Subject matter covered includes the means by which plant material, alien species and disease agents may be inadvertently introduced; measures necessary to prevent transfers between aggregations of wildlife; waste management; and procedures for dealing with any cargo infestations.

12. The AAD sources a wide variety of goods and services from the commercial sector. Guidelines for contractors and purchasing officers specify environmental protection considerations and processes supporting the AAD's environmental management policy. Recent AAD staff and suppliers' innovations that have helped minimise introductions include changes to the design of cage pallets such that they are less susceptible to contamination and are easier to clean, the redesign of clothing to avoid the use of seed-attracting fastenings, such as Velcro, and the deployment of fumigating ozone units in containers of produce being shipped to Antarctica.

ON-SITE MANAGEMENT ACTIVITIES

13. Station leaders, field leaders and voyage leaders are responsible for the on-site management of environmental issues. They are also appointed Inspectors under Australian legislation enacting the Protocol, namely the *Antarctic Treaty (Environment Protection) Act (1980)*.

14. Feeding wildlife is strictly prohibited. Food waste is stored indoors prior to its high temperature incineration. Liquid drained from thawing poultry products is boiled for twenty minutes before its entry into station sewerage systems. The by-products of these systems are returned to Australia for further treatment and disposal.

15. Expeditioners are required to report quarantine issues – discoveries of introduced species, soil contamination of equipment, supplier non-compliance with environmental requirements – via AAD's incident reporting scheme.

16. An unusual mortality event response plan provides instructions to expeditioners on actions to be undertaken if sick or dead animals are discovered in unusually high numbers or with signs that suggest disease. The plan includes procedures to reduce the likelihood of station personnel spreading the infectious agent if disease is involved, information on personal safety precautions, and debriefing procedures. An associated response kit contains equipment necessary to record an event, undertake post-mortem examinations and prepare samples for transport and subsequent analysis.

SUMMARY

17. Australia's Antarctic quarantine protection practices are reviewed regularly as new threats and pathways for introductions are identified, as quarantine management technologies are advanced, as risks analyses are completed, and as the review of incident reports suggest that existing procedures require improvement. While no amount of activity will provide absolute protection against introductions, the measures described in this paper are expected to individually and cumulatively reduce the environmental risks that alien species pose. A vigilant approach to pre-voyage quarantine management measures provides a major line of defence. Inspection and education strategies are primary mitigation tools.

18. For further information on Australia's Antarctic quarantine management activities please contact: Ms Sandra Potter, Environmental Policy Officer at the Australian Antarctic Division, Channel Highway, Kingston Tasmania 7050, Australia, or by email: sandra.potter@aad.gov.au.

Attachment 2 - Consultants

Dr M.P. Bond

Michael Bond has wide-ranging experience in animal health and production, and as a senior veterinary administrator at State and National levels; he held the position of Chief Veterinary Officer for Western Australia for eight years. During this time, in his capacity as Chief Quarantine Officer (Animals), Dr Bond also was responsible for all Commonwealth animal quarantine operations in WA. He also contributed to the Commonwealth/State Task Force which designed and implemented the Northern Australian Quarantine Strategy. Subsequently, he worked as Director of Corporate Services at the WA Department of Environmental Protection. During the past four years, Dr Bond has undertaken consultancies in Australia and overseas, primarily related to intellectual property and patent protection, but also several related to quarantine management and border control.

Mr A. Catley

A. (Mick) Catley is an agricultural entomologist with 24 years experience in Australian plant quarantine and export inspection, including 12 years as Director of the Australian Plant Quarantine Service. Since his retirement from AQIS in 1995 he has maintained his interest in plant quarantine as a consultant. His quarantine and inspection experience covers operations, technical support, training, legislative requirements, policy and market access negotiations. He has wide international experience having represented AQIS on many occasions at multilateral and bilateral forums. He was directly involved in the international activities leading to the concepts of Risk Analysis and International Standards for Phytosanitary Measures and as Vice Chairman of The Asia and Pacific Plant Protection Commission, he played a leading role in acceptance of these concepts by Asian countries. He has advised foreign governments and international agencies on plant quarantine and plant protection matters and has participated in a range of aid projects in the Asia and Pacific region

Dr K.A. Doyle

Kevin Doyle is presently Veterinary Director of the Australian Veterinary Association. Previously, for eight years he was Deputy Chief Veterinary Officer for Australia. For 17 years he was head of Branches responsible for animal quarantine and exports and, for some time, of plant and general quarantine. He was also responsible, for various periods, for endemic and exotic disease control programs and animal and plant health research within the Department of Primary Industries and Energy. He was also an elected member of the International Animal Health Code Commission of the Office International des Epizooties (World Organisation for Animal Health), Paris. Dr Doyle has a special interest in quarantine risk analysis and infectious disease, and has published papers on quarantine and risk analysis.

Technical Appendix D6

Report on Baseline Studies and Data Gaps

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

REPORT ON BASELINE STUDIES AND DATA GAPS

TECHNICAL APPENDIX D6

Prepared for:

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November 2003

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GORGON QUARANTINE EXPERT PANEL

REPORT ON BASELINE STUDIES AND DATA GAPS

Andrew A Burbidge and John K Scott, 22 November 2003

OUR BRIEF

Among the key issues that arose from the Expert Panel meeting on 3 and 4 November 2003 were to establish:

- What's there now.
- What may come on to Barrow and surrounds.
- What constitutes "introduced".
- Information to make decisions.

The relevant objective statement developed at the meeting was:

Objective 2: Identify the major organism groups of concern and the required baseline surveys (designed to incorporate future monitoring).

The strategic action identified for Objective 2 was:

Establish a Baseline Survey Group eg to:

- Discuss and identify the species from island knowledge to be a likely threat of introduction (including literature search).
- Short term planned commencement of baseline studies.
- Longer term ongoing studies required in future (biological survey expert to be consulted).

WHAT CONSTITUTES INTRODUCED?

Island ecosystems, like any natural area, are not frozen in time and changes may occur due to natural rates of species immigration and loss or extinction. Pathways for natural introduction of new species on Barrow Island include:

- Propagules transported in the wind, e.g., during cyclones.
- Floating debris, e.g., logs.
- Fresh water plumes following major rainfall events on the mainland including wave surge associated with cyclones.
- Birds or bats carrying seeds or diseases.
- Dust or airborne soil carrying micro-organisms.

Considerable work has been done estimating species turnover on islands (Lomolino 2000, Whittaker 1998). A local example, Rottnest Island, has a turnover of about 1% of the vascular flora per year (Rippey *et al*. 2003). This reflects many pathways for the arrival and extinction of introduced species (0.7% per annum) whereas the native species changeover was 0.3% against a background of an overall decline in number during the previous 50-year period. The rate of native species turnover on Barrow Island is unknown, but being a dry climate well removed from the mainland with few introduction pathways, it would be expected to be very low.

Any new species not introduced to the island due to human activity would fall into the following two categories:

- Alien species from neighbouring islands or from the mainland. An example is Kapok bush (*Aerva javanica* Amaranthaceae); a plant with seeds enclosed in a woolly covering that could be dispersed to the island via a cyclone. This species is introduced to Australia (it is widespread in the Pilbara and in the Montebello Islands) and eradication procedures should apply for any population established on the island.
- Native species that arrive naturally from neighbouring islands or the mainland. Here judgement would have to be made on a case by case basis, bearing in mind that native species can also behave as exotics outside their natural range and have the potential to create ecosystem change. As a precaution, eradication would have to be assumed as the first response. It might be necessary to have recourse to an expert group as part of deciding whether or not to eradicate the new arrival. However, the past history of the island indicates that arrival of new native species must be very rare because most species that could disperse to the island would have already done so in the past.

DIMENSIONS OF THE PROBLEM OF ISLAND INTRODUCTIONS

We conducted a brief literature review, including internet searches. We restricted our search to islands smaller than the North and South Islands of New Zealand. There is a large, world-wide body of literature concerning non-indigenous species that have established on islands and the changes they have wrought on local biodiversity. For example, most extinctions of birds world-wide since 1600 have been on islands; most are due to introduced species. Rather than attempt to provide comprehensive lists, we have provided some examples in order to demonstrate the diverse range of organisms involved.

Vertebrates

A wide range of vertebrate species has been introduced to islands. Some of these have been introduced on purpose to support primary production or as pets, or during often misguided attempts at biological control. Many introductions have been ‘accidental’. Table 1 provides examples of vertebrates that have been introduced and established on islands around the world. Some islands and island groups have suffered from large numbers of introduced species, eg, Singapore has more than 100 species of introduced birds, mainly via the enormous cage-bird trade that operates there. There have been many introductions of exotic mammals to Australian islands, mainly rats, mice, cats, sheep, goats and foxes, and there have been at least 41 local mammal extinctions, plus some bird extinctions as a result. Research shows that these extinctions are strongly correlated with exotic mammal introductions. There have been no comprehensive studies of the possible effects of exotic micro-organisms on island mammals in Australia.

Invertebrates

Table 2 lists some invertebrates that have established on islands. Invertebrate introductions are not as well documented as those for vertebrates, nevertheless, the many introductions, mostly ‘accidental’ have led to major biodiversity loss. For example, Hawaii has 85 species of introduced snails. Throughout the Pacific about 100 widespread alien snails introduced through human activities are replacing about 5,000 native and highly endemic land snail species. In an Australian example, honey bees, a centipede species, a cockroach species, two termite species, two fruit fly species, several species of spiders, several species of ants and the giant African snail have been introduced to Christmas Island. The recent development of supercolonies in the yellow crazy ant threatens many endemic species (vertebrates and invertebrates) and control is proving expensive. Even ‘remote’ islands have introduced invertebrates, eg, there are three introduced spiders and an introduced beetle species on subantarctic South Georgia.

Micro-organisms

There appears to be few papers on micro-organisms that have been introduced to islands; however, an expert in this field may be able to find many more examples. The few references we found may also reflect a lack of studies (Table 3). Some micro-organism introductions have been catastrophic; one example is the extinction of several species of endemic honeycreepers (birds) in the Hawaiian islands.

Plants

There is an extensive literature on plant introductions to islands around the world showing that islands are particularly susceptible to invasion. Table 4 shows some Australian examples, ranging from islands with relative few introductions to islands where over half the flora consists of introduced species. Many introduced species are associated with human-related disturbance. Extensive habitat modification has occurred on some islands and these areas are occupied by introduced species. A subset of the introduced species is the cause of change to ecosystems relatively untouched by human related disturbance (transformer species – Richardson *et al*. 2000). Past introductions have been accidental or as contaminants of agricultural practices. The most significant group of recent introductions are associated with garden plants. Considerable time lags of up to 50 years may be involved in the process of establishment of an introduced plant species. The ability to be introduced and colonise is not limited to particular groups of plants and transformer species have included the range of life forms from annual grasses to trees.

Can we predict which species may establish on Barrow Island if introduced?

The process of predicting which species will establish if introduced is well developed in Australia as part of the quarantine barrier. Plant species undergo a "weed risk assessment" to determine if they are a threat to agriculture or the environment in Australia. Proposals for the importation of animals have to be assessed by the Australian Quarantine and Inspection Service and the Department of Environment and Heritage, mainly by a process of public review of submissions assessing the risk of invasiveness and potential to vector diseases. A number of reasons make this type of system unsuitable for Barrow Island, an island with an exceptionally low presence of introduced species.

Organisms generally become pests at a low rate, but the considerable damage that could be caused by a successful coloniser on Barrow Island requires any prediction system to have an extremely high level of accuracy. Smith *et al*. (1999) show that when an event is rare it becomes much harder to forecast reliably because of the "base rate effect". If the risk assessment is 85% accurate then the probability of making correct pest identification is about 10%, which would be unsatisfactory.

Experience supports the idea that a known pest of agriculture is highly likely to become a pest of agriculture in an area of introduction with similar climate. Even so, the level of predictability is low (Scott and Panetta 1993). For weeds it has not proved possible to predict which species will become invasive in environmental areas (Daehler 1998, Scott and Panetta 1993, Williamson 1999) unless the prediction is between neighbouring areas (Lockwood *et al*. 2001).

Predicting which animals might establish is also fraught with difficulty. While many introduced animals have established only in places with similar climates and habitats, other species once naturally limited to relatively small areas are now widespread and occupy habitats very different from their 'native' ones (eg, feral cats on subantarctic Macquarie Island and Marion Island). There are also many examples of species failing to establish on one or several occasions after introduction, and then at a later time establishing and quickly becoming a pest. Thus past experience of introductions failing to establish (eg, house mice on Barrow Island) is not a good prediction of future probability of establishment.

Recommendation: All organisms exotic to the island be treated as potential threats to the ecology of the island.

PATHWAYS

Possible pathways for human-caused introductions to Barrow Island include:

1. Equipment and goods brought to the island by sea.
2. Equipment and goods brought to the island by air.
3. Tankers and other vessels that moor to the proposed jetty.
4. Food brought to the island to feed the work force.
5. Propagules brought to the island by people in personal effects, eg, seeds on clothing, organisms in soil on footwear.
6. Diseases or propagules carried by humans, eg, in blood or other tissues, or in the alimentary tract.
7. Diseases brought to the island in introduced animals or plants.
8. Propagules arriving on the island with flotsam and jetsam from passing boats.

Establishment of many introduced species can be enhanced if new or disturbed habitats are available, eg, soil affected by construction, moist areas around buildings, lawns.

Recommendation: Further assessment of specific pathways be undertaken as part of the risk assessment process.

BASELINE STUDIES

The first step should be to audit surveys already carried out; at this time we have been unable to do so as most 'grey literature' reports are not published and have not been provided to us. An initial useful step would be for a specialist librarian to be commissioned to prepare a bibliography of the island, concentrating on publications related to organisms. Such a document will help the expert panel and be very useful for future baseline studies. However, it is clear that there is limited information on what species currently occur on Barrow Island.

Recommendation: A bibliography (with abstracts) of the biology of Barrow Island and nearby areas be commissioned and published as soon as possible.

Recommendation: Critical documents, particularly those that form part of baseline studies, be placed in public libraries (e.g., the Department of Conservation and Land management (CALM)) so that they are publicly available.

The second step might be to review incursions that have happened since the 1960s. The list provided to us includes vertebrates (black rat, house mouse, cat, dog, a tree frog), an invertebrate (honey bee) and several plants (aloe vera, blackberry, kapok, buffel grass, cape weed, double gee, wild passionfruit, nightshade species). (Discussion within the Expert Panel suggests that the list is incomplete.) Some of these clearly have the potential to be highly invasive; with others it is impossible to predict outcomes.

We suggest that it is not useful to depend on the list of past incursions in order to predict future incursions. The list may significantly under-report past incursions because of inadequate reporting systems in the past, as well as the lack of monitoring of invertebrates such as ants and spiders (the WA Museum has two species of introduced spider from Barrow Island in its collection (Dr Mark Harvey, personal communication)). Also, as discussed above, it is not possible to predict with any confidence which species may arrive in future and which of these may establish.

ANIMAL SURVEYS

In recommending which animal groups should be the subject of baseline surveys in the short term on Barrow Island, we have considered the following issues:

- many animal taxa from a wide range of upper level taxonomic groups have established on islands throughout the world;
- there is a broad consensus among invasive species experts that it is not possible to predict which species might establish on islands, once introduced;
- a monitoring program for mammals is in place (although it may require modification to meet Gorgon requirements) and a monitoring program for birds is a low priority;
- information on which species of reptiles and amphibians occur on Barrow is adequate, however, there is no monitoring program in place and the house gecko (*Hemidactylus frenatus*) is a common introduction around the tropics, including the Pilbara coast;
- information on most invertebrate animal groups on Barrow is poor or absent;
- Barrow is an arid island with mainly limestone derived (calcareous) soils; and
- a limited number of invertebrate groups could be surveyed and monitored without extensive and time-consuming taxonomic research.

Recommendation: The following animal groups be surveyed in the short term.

1. Ground-dwelling arthropods: ants, cockroaches, centipedes, millipedes, scorpions and spiders.
2. Web-building spiders and other spider groups that may have been or may be transported in food or equipment.
3. Terrestrial molluscs.
4. Termites.
5. Earthworms.
6. Subterranean fauna.
7. Monitoring for introduced reptiles, particularly the house gecko, should be undertaken.
8. Mammals.

Ground-dwelling arthropods. These groups can be sampled and monitored effectively using ‘permanent’ pitfall traps that require servicing infrequently (although the design of permanent pitfall traps on Barrow may need modification because of the abundance of bandicoots and some other animals). Expertise in sampling, sorting and identifying these animals has been developed within CALM and the WA Museum during the past surveys of the Southern Carnarvon Basin and Wheatbelt and similar work is currently a part of the Pilbara Region Biological Survey. The distribution of many of these organisms shows strong correlation with surface type and climatic parameters and tight biogeographic patterns are often evident. An important sub-group is ants. Ant taxonomy and distribution in tropical and arid Australia is well documented and ants have proved to be highly invasive on islands elsewhere.

Spiders. Spiders are easily transported in equipment, partly due to their ability to build webs and hide in confined spaces. Spider taxonomy is adequate to allow identification of indigenous and introduced species.

Terrestrial molluscs. Snail taxonomy and distribution in northern Australia is relatively well documented. Snails are particularly well adapted to karsts and often show high levels of diversity and endemism in karstic environments. Snails have proved to be highly invasive on islands elsewhere in the world. While some survey work on snails has occurred (Slack-Smith 2002), it needs extending in time and space.

Termites. Because they can be readily transported in wood, termites are highly invasive and damaging in island environments. A Barrow Island species list (with vouchers in Australian National Insect Collection) is available from the early 1970s (Perry 1972). Termite taxonomy is well advanced.

Earthworms. Earthworms are readily transported in soil. Past introductions include eucalypts planted around the camp, lantana planted near the terminal and exotic indoor plants all of which would have been transported to the island in soil in pots. It would be useful to survey the earthworm fauna of the island to establish which native species occur there and whether there have been any introductions. This would allow future monitoring.

Subterranean fauna. These may not appear to be an obvious candidate for baseline studies and quarantine monitoring. However, Barrow Island supports many species of both troglofauna and stygofauna, many of which are, on current data, endemic (Humphreys 2001) and monitoring of this group is likely to be a requirement for general monitoring of the effects of the Gorgon development (and should already be current because of the possible effects of the oilfield—drilling mud contamination, disposal of produced water at shallow depths, anode wells, surface oil and chemical spills). Past effects, if any, should be quantified as much as possible in order to isolate possible future effects associated with introductions of equipment, etc. for the gas plant and future operation of the gas plant and oil field. Barrow stygofauna inhabit an anchialine system and invasion of exotics from the adjacent sea are not out of the question. There is now evidence that, in at least some anchialine systems, sea water circulates into the system at depth, and returns to the sea at the level of the freshwater/saltwater interface (Beddows *et al*. 2002). If present, this kind of circulation clearly provides some measure of filtration, but the effects of this process in relation to pollution and introduced species are clearly dependent upon rates of transport and substrate types.

Mammals. Barrow has several endemic taxa of mammals and monitoring of them, as well as monitoring to detect introduced mammals, is important. The current mammal monitoring project has been in place for about five years and is due for review (Burbidge *et al.* 2004). It should be continued with any expansion necessary to monitor the effects of the gas plant.

Animal survey methodology

Important considerations in survey design on Barrow Island are:

- sampling efficiency in an arid place like Barrow Island for many groups of organisms is likely to be highly dependent on rainfall—a period of sampling under drought conditions is unlikely to detect many cryptic taxa,
- sampling in different seasons, independent of high rainfall events, will reveal additional taxa,
- baseline studies need to be thorough and sampling must take place over an appropriate length of time in relation to the biological characteristics of the organisms being sampled,

- pitfall trap design needs to take account of the abundant small vertebrate fauna, especially small mammals and reptiles, and should meet Animal Ethics Committee requirements,
- those tendering to undertake baseline studies should be required to demonstrate that they understand the basic principles of sampling theory and are capable of identifying the specimens collected to an appropriate taxonomic level.

The baseline surveys to be carried out on Barrow Island should meet guidelines so that they are comparable in quality and can be used for monitoring (McKenzie and Morris 2002). The following characteristics should be a requirement:

- sampling must be site-based, ie, in fixed, permanently-marked quadrats or transects;
- sampling must be quantitative, using standardised sampling methods such as pit-fall traps;
- sampling must be replicated, ie, there should be additional sample sites in the same habitat type to measure sampling efficiency;
- sampling must be conducted in different seasons and under different climatic conditions, including sampling after heavy summer and winter rainfall, so that taxa that are detectable only at specific times of the year or only in good seasons are sampled;
- sampling must cover enough sites positioned in places where introductions are likely, so as to maximise the probability of early detection of introduced species; and
- monitoring must be frequent enough to maximise the possibility of eradication should introduced species be detected.

Vouchering of biological collections from Barrow Island is vital because

- identifications by field workers may be challenged, and
- continuing taxonomic research, often using DNA technology, will result in biological entities currently considered to be a single species being split into two or more species.

Vouchering should, where appropriate, include the collection of tissue for DNA taxonomic research.

Recommendation: All workers should be required to lodge voucher specimens in appropriate public collections; for most animal groups this should be the Western Australian Museum and for plants the Western Australian Herbarium. It may be necessary to provide funds to collection managers to ensure that the specimens are properly stored and identified.

PLANT SURVEYS

From the quarantine management point of view, the objective of surveys and other monitoring of plants is to detect incursions by exotic plant species so that they can be eradicated. Australian experience in eradicating of exotic plant incursions shows that it is most successful if detected early, if detection is possible at very low densities and where all infestations are known (Mack and Lonsdale 2002). A range of sampling methods will be needed to detect plant incursions:

- A whole island Flora census will be needed regularly (each ten years or so). The plant species identification should be backed by voucher specimens lodged at a recognised herbarium. These specimens would contain the DNA needed for retrospective analyses.
- Lack of correct species identification is a major barrier to detecting the introduction of exotics. Efforts should be made to identify all species on Barrow Island that have not been named or that have been poorly identified. An example of a high priority species group for improved identification would be the figs because they provide resources for animals. A population genetics approach would be required to establish the status of the five taxa. Further taxonomic clarity will be required for many species groups that include weedy species, eg. *Indigofera* spp., *Euphorbia* spp., *Sida* spp. and *Heliotropium* spp. This work

should involve international experts of particular plant groups and should be coordinated through the WA Herbarium.

- Vascular plants are reasonably well known for the island, but there appears to be no information on lower plants such as mosses and lichens. While these groups contain many cosmopolitan species, they do comprise an important element of the ecosystems of dry regions (in particular lichens on the soil) and are easily introduced with soil. A census of these types of plant should be added to the overall census of island flora.
- Monitoring quadrats, replicated in different vegetation types. While these quadrats will mostly serve the purpose of monitoring vegetation changes, they are useful checks for the presence of exotic species and as a check on plant health, which might indicate the arrival of an exotic insect or disease.
- Targeted monitoring following perturbations with a frequency of inspection of each three months:
    - Fire.
    - Significant rainfall events such as cyclones.
    - Significant erosion due to rain or wave action.
    - Soil disturbance following construction.
- Targeted surveys to check for the presence of previous introductions. At least 10 years of monitoring is required following eradication.

Additional surveys to delimit any exotic introduction will be necessary following initial detection. Many species spread, not by progressively expanding distribution, but by establishing "nascent foci" some distance (depending on dispersal mechanism) from the initial source. The degree of sampling required would depend on the dispersal ability of the species. All of these approaches do not resolve the problem that the monitoring and surveys have to detect something of unknown identity that may or may not be present. Innovative approaches to this problem will be needed to determine the effectiveness of the alien species detection process.

Recommendation: That a range of surveys and monitoring activities be undertaken to establish mechanisms for detecting incursions by plant species. These activities would include:

- Surveys to verify the census of the island, particularly following significant rain and targeting disturbance sites.
- Surveys to include lower plants such as mosses and lichens.
- Improved identification of poorly known species groups.
- Establishment of monitoring plots in a range of vegetation types.
- Establish monitoring for exotic species on the perimeter of introduction gateways, including early warning plots that would be artificially disturbed by cultivation or/and water.

DISEASE MICRO-ORGANISM SURVEYS

There has been no survey to identify possible exotic diseases of Barrow Island animals or plants. In the early years of the oilfield development, rubbish disposal was far from ideal and many animals had access to rotting food in open tips. Similar access is known to have led to development of *Salmonella* and other diseases on other islands, including Rottnest. Today, food disposal is much better; however, native mammals such as bandicoots and native birds such as silver gulls and singing honeyeaters are common (and beg for food) around the camp and food disposal areas. Baseline studies of animal (particularly mammal and bird) diseases are necessary so that any changes resulting from the large number of additional people, food and equipment associated with the Gorgon development can be assessed.

Most native plant diseases with airborne spores have probably already been dispersed from the mainland to the island. However, many soilborne plant diseases do not disperse as readily without vectors, but can cause devastation to vegetation communities, leading to a complete change in community structure (eg. *Phytophthora* species).

Recommendation: Gorgon should to seek advice from relevant experts concerning suitable baseline studies for plant and animal diseases.

MARINE INTRODUCED ORGANISM SURVEYS

This report does not cover the issue of the threat of introductions to the marine environment due to ballast water and fouling organisms, the effects of antifouling chemicals, and the creation of novel habitats due to marine substrate disturbance during dredging and construction. It is recommended that a separate analysis by experts in this area be undertaken as soon as possible.

Recommendation: A report on baseline studies and data gaps for the marine environment surrounding Barrow Island be prepared by relevant experts.

BASELINE SURVEYS TO ESTABLISH LIKELY THREATS

Any organism exotic to the island is a potential threat given that it is very difficult to predict what types of organisms would establish on the island. However, the threat would have to be higher if the organism came from any part of the world that has very similar climate and soils to Barrow Island. Secondly, an examination of similar areas would produce an "alert list" of organisms that should be watched for especially, thus improving the quarantine effort. Similar areas can be defined as those with the same type of climate and soils.

Figures 1 and 2 show a preliminary analysis identifying those areas of Australia and the world that have a climate similar to Barrow Island. As would be expected, the nearby coastal mainland, from the Cape Range to Karratha, has the most similar climate. Note information on nearby islands is not available for this analysis. Further away (figure 2), the most similar climates are found in southern Baja California (La Paz), Galapagos Islands (Baltra) and dry coastal Ecuador (Manta), around the Red Sea (Jidda) and coastal regions of Arabia (Masirah Island).

Barrow Island is a limestone island and the closest region with similar geological origins is the Cape Range – North West Cape area. This area already shares a significant number of plant species with Barrow Island (55%, Keighery and Gibson 1993). Combining climate and geomorphology indicates that the North West Cape peninsula would be the most similar region biogeographically to Barrow Island. The next closest region would be the adjacent mainland including the Burrup Peninsula. Both areas could be usefully surveyed to indicate organisms with a high likelihood of establishment on the island, and that should be specifically included in surveys as part of baseline studies on the island. For example, species representing high risk of introduction from the North West Cape peninsula include the exotic species onion weed (*Asphodelus fistulosus*), doublegee (*Emex australis*) and buffel grass, (*Cenchrus ciliaris*). The latter two have already appeared on Barrow Island. Secondly, the repetition of baseline studies on Barrow Island, North West Cape peninsula and the Burrup Peninsula/Dampier area, for groups of organisms without baseline data, would identify organisms to be included in the alert list.

Recommendation: Baseline surveys be extended to nearby islands and nearby mainland regions, in particular, the North West Cape peninsula and Burrup Peninsula/Dampier to determine species with a high risk of introduction.

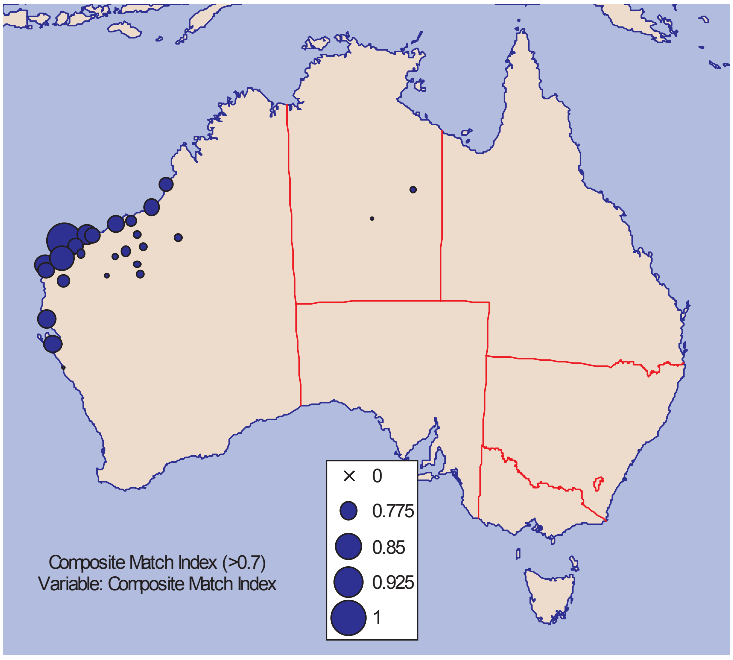

Figure 1. CLIMEX match climates – climate stations similar to Barrow Island in Australia. The larger the dot, the more similar the climate station to that of Barrow Island. Climate attributes used in the analysis include maximum and minimum temperate, total rainfall, rainfall pattern, and relative humidity.

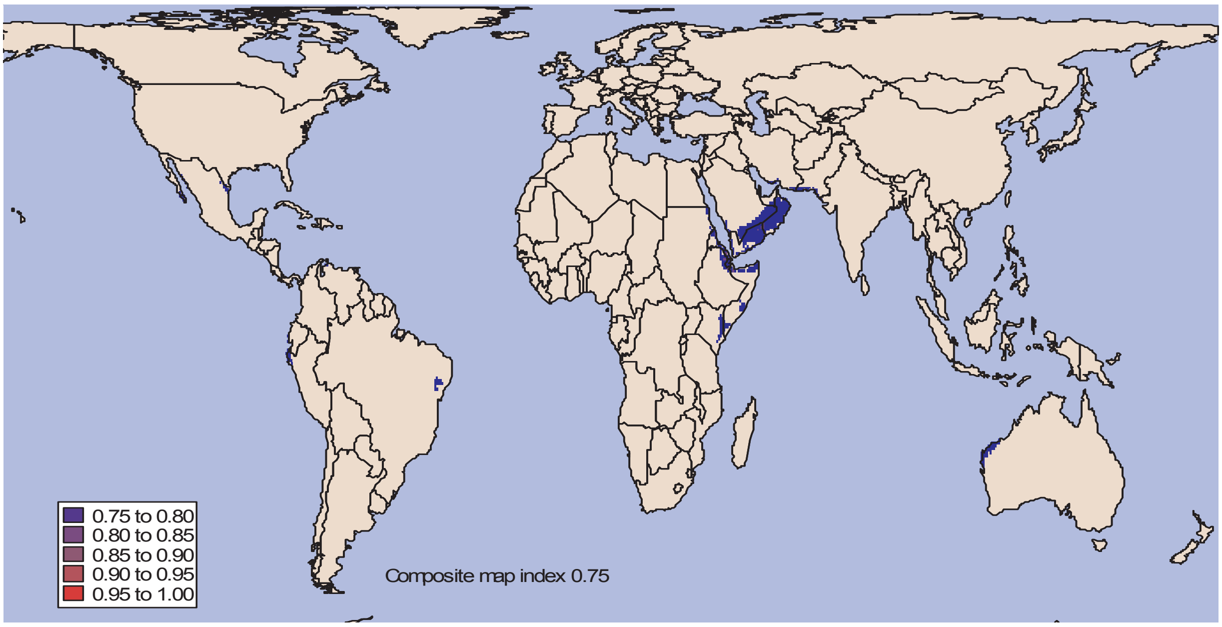

Figure 2. CLIMEX match climates using world climate surface for similarity to Barrow Island. Further analysis will be required to take into account the irregular rainfall pattern for Barrow Island.

Who does the work?

We believe it important that the best people available conduct the baseline studies. There would be considerable benefits in contracting this work to CALM and the WA Museum. Once the groups to be surveyed have been agreed, and the people who are to do the work selected, a workshop should be held where all participants discuss sampling procedures and agree on the location of quadrats and other relevant matters. Coordination with other biological studies commissioned by ChevronTexaco as part of its research/monitoring associated with the Gorgon development is vital. Seeking advice from relevant experts not involved in the studies would also be appropriate.

The presence of a number of scientist teams on the island will in itself create quarantine problems. Procedures will be needed to ensure the highest level of quarantine standards to prevent introduction of organisms and cross contamination of sampling sites (eg. procedures are practiced to prevent movement of subterranean fauna from one site to another during sampling (Biota Environmental Services 2002)).

Recommendation: The coordination of terrestrial animal and plant baseline studies be contracted to CALM and the WA Museum. If these organisations cannot carry out the work, they should be asked to advise on survey design and review ongoing work.

Recommendation: A workshop be organised to coordinate and review sampling procedures, including quarantine during sampling, before the baseline studies start.

Timing

Biological surveys, including baseline studies, need to take place in a variety of seasons over at least three years. Short term surveys usually fail to detect a significant proportion of species.

Significant rainfall events are impossible to plan for in advance. However, sampling in the six months following significant rainfall on the island will be critical for accurately detecting species present on the island. The next period when this rainfall is likely is February to April 2004. Also of critical importance is the date of likely start of construction.

Recommendation: We recommend that animal and plant baseline studies get underway as soon as possible. In the context of such studies, the period available before construction begins is very short.

EXPERTISE IN NATURAL HISTORY SKILLS

One of the most effective ways of monitoring an ecosystem for incursions is the presence of skilled observers with natural history experience and biological training. Such people, with an acquired knowledge of the island, would take part in the monitoring and guarding the island's ecosystem. The company should ensure that once employed, such people are nurtured and encouraged to remain in the same job for some years. This approach should not be at the expense of the education of the entire workforce who should be encouraged to take an interest in the special conservation nature of the island and the threat posed by introduced species.

Recommendation: That part of the monitoring and quarantine surveillance system include graduate biologist staff with natural history skills and interest, based on the island.

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Table 1. Some vertebrate animals that have been introduced to islands.
Data sources include Charles Darwin Research Station (2003), IUCN/SSC Invasive Species Specialist Group (ISSG) (2003), ISSG Global Invasive Species Database (2003), McKenzie *et al.* (1995) and Sherley (2000).

Species	**Group**	**Island**
Alopex lagopus, Arctic Fox	mammal	Aleutian Islands
Axis sp., Axis Deer	mammal	Maui, Lana'i
beaver, raccoon, rat, squirrel, muskrat, Sitka black-tailed deer, Rocky Mountain elk	mammal	Haida Gwaii, Queen Charlotte Islands, Canada
Bos taurus, cattle	mammal	many
Bubalis bubalis, Water Buffalo	mammal	Moloka'i
Canis lupus familiaris, dog	mammal	many
Canis lupus dingo, Dingo	mammal	several Australian islands
Capra hircus, goat	mammal	many
Cavia porcellus, Guinea Pig	mammal	Laysan
Cervus timoriensis, Rusa Deer	mammal	Mauritius
Felis sylvestris catus, Feral Cat	mammal	many
Herpestes javanicus, Small Indian Mongoose	mammal	many
Lepus nigricollis, Black-naped Hare	mammal	Gunners Quoin
Marmota calagita, Hoary Marmot	mammal	Aleutian Islands
Microtus spp., voles	mammal	Aleutian Islands
Mouflon	mammal	Hawaii
Mus domesticus/musculus, House Mouse	mammal	many
Oryctolagus cuniculus, rabbit	mammal	many
Ovis aries, Sheep	mammal	many
Peromyscus sp., deer mice	mammal	Aleutian Islands
Petrogale penicillata, Brush-tailed Rock-wallaby	mammal	Rangitoto and Motutapu Islands
Phalanger orientalis, Common Cuscus	mammal	Bougainville, Moiko, Nissan, Buka
Pronghorn	mammal	Lana'i
Rangifera tarandus, Reindeer, Caribou	mammal	Aleutian Islands
Rattus exulans, Polynesian Rat	mammal	many
Rattus norvegicus, Brown (Norway) Rat	mammal	many
Rattus rattus, Black (Ship) Rat	mammal	many
Spermophilus parryi, ground squirrel	mammal	Aleutian Islands
Suncus maurinus, Indian House Shrew	mammal	many, incl. Guam, Maldives, Mauritius
Suncus murinus, Musk Shrew	mammal	Guam, Palau, Mariana Islands
Sus scrofa, Pig	mammal	many
Thylogale browni, a pademelon	mammal	New Ireland
Trichosurus vulpecula, Common Brushtail Possum	mammal	Kapiti, Rangitoto, Motutapu
Vulpes vuples, Red Fox	mammal	Australian islands, Aleutian Islands
Acridotheres tristis, Common Mynah	bird	many
Anas platyrhynchos, Mallard Duck	bird	many
Cacatua galerita, Sulphur-crested Cockatoo	bird	Palau
California Quail	bird	Hawaii

Species	Group	Island
Cettia diphone, Thrush	bird	Hawaii
Circus approximans, Harrier	bird	Tetiaroa Island
Columba livia, Rock Dove (Pigeon)	bird	Hawaii, many others
Corvus albus, Indian house crow	bird	Seychelles
Corvus moneduloides, New Caledonian Crow	bird	Mare Island
Gallus gallus, Red Jungle Fowl	bird	many
Java Sparrow	bird	Hawaii
Passer spp., sparrows	bird	Canary Islands, many others
Pycnonotus cafer, Red-vented Bulbul	bird	Fiji, Tonga and possibly Tahiti
Red Avadavit	bird	Hawaii
Sturnus vulgaris, Common Starling	bird	now widespread
Tyto alba affinis, Barn owl	bird	Seychelles
Boiga fusca, Brown Tree Snake	reptile	Guam, Mariana Is
Calotes versicolor, Changeable Lizard	reptile	Singapore
Gehyra mutilata, House Gecko	reptile	Christmas I (Indian Ocean)
Lycodon aulicus capucinus, Wolf Snake	reptile	Christmas I (Indian Ocean)
Lycodon aulicus, Wolf Snake	reptile	Ile aux Aigrettes
Lygosoma bowringii, Grass Skink	reptile	Christmas I (Indian Ocean)
Ramphotyphlops braminus, Black Blind Snake	reptile	Christmas I (Indian Ocean)
Bufo marinus, Cane Toad	amphibian	many, including Sir Edward Pellew Group, NT
Eleutherodactylus coqui, a tree frog	amphibian	Hawaii, Virgin Is
Eleutherodactylus planirostris, a tree frog	amphibian	Hawaii
*Litorea aurea,*Green and Gold Bellfrog	amphibian	New Caledonia
Litoria fallax, a tree frog	amphibian	Guam
Rana catesbeiana, a bullfrog	amphibian	many
Rana pipiens, American Bullfrog	amphibian	Singapore, others?
Carp, including goldfish	fish	Canary Islands, others
Gambusia affinis/holbrooki, Mosquito Fish	fish	many
Tilapias (Cichlidae), several species	fish	many
various aquarium fish	fish	many

Table 2. Some invertebrate animals that have been introduced to islands.
Data sources as in Table 1.

Species	Group	Island
Anoplecta lateralis, a cockroach	insect	Galapagos Islands
Blattodea sp. German Cockroach	insect	Canary Islands, many others
Periplaneta americana, American Cockroach	insect	Galapagos, many others
Bactrocera species, fruit flies	insect	Nauru
Coptotermes formosanus, Formosam Termite	insect	Hawaii, probably many other islands
Aedes albopictus, Asian Tiger Mosquito	insect	many
Culex pipiens quinquefasciatus	insect	Galapagos, vector for avian malaria
Culex quinquefasciatus, Avian Malaria Mosquito	insect	many, tropical
Icerya purchasi, Cottony cushion scale	insect	Galapagos
mealy bug	insect	Aldabra
Oryctes rhinoceros, Coconut Rhinoceros Beetle	insect	Many
Trechisibus antarcticus, a carabid beetle	insect	South Georgia
Xylosandrus compactus, Black-twig Borer	insect	Many
Polistes versicolor, a wasp	insect	Galapagos Islands
Vespula pensylvanica, Yellowjacket Wasp	insect	Hawaii
Anoplolepis longipes, Yellow Crazy Ant	insect	Christmas I (Indian Ocean), Seychelles, Hawaii, Guam, many others
Monomorium destructor, Singapore Ant	insect	Koolan Island, many other places
Monomorium floricola, ant	insect	Many
Linepithema humile, Argentine Ant	insect	Hawaii, Australia
Pheidole megacephala, Big-headed Ant	insect	Many
Solenopsis geminita, Tropical Fire Ant	insect	many, including Galapagos
Solenopsis invicta, Red Fire Ant	insect	Many
Wasmannia auropunctata, Little Fire Ant	insect	Galapagos, many others
Anyphaenoides octodentata, a spider	spider	Galapagos Islands
Eidmanella pallida, a spider	spider	Galapagos Islands
Tetragnatha maxillosa, a spider	spider	Society Islands
Tetragnatha nitens, a spider	spider	Society Islands
Zoropsis spinimana, a spider	spider	Canary Islands
Scolopenda morsitans, a centipede	chilopoda	Koolan Island, WA
Centruroides gracilis, Bark Scorpion	scorpion	Canary Islands
Dichogaster bolaui, an earthworm	earthworm	Koolan Island, WA
earthworms, several spp.	earthworm	Hawaii, Galapagos
Platydemus manokwari, a flatworm	flatworm	several
Achatina fulica, Giant African snail	mollusc	many
Euglandina rosea, Cannibal Snail, Rosy Wolf Snail	mollusc	many
Pomacea canaliculata, a freshwater snail	mollusc	Hawaii

Species	Group	Island
freshwater snails, many species	mollusc	many
Helix aspersa, Garden Snail	mollusc	many
Laevicaulis alte, a slug	mollusc	Koolan Island, WA

Table 3. Some micro-organisms that have been introduced to islands.
Data sources as in Table 1.

Species	Group	Island
avian pox virus	micro-organism	Galapagos, affects Darwin's finches
coccidiosis	micro-organism	Galapagos
Marek's disease	micro-organism	Galapagos
Plasmodium relictum, Avian Malaria Parasite	micro-organism	Hawaii, has caused the extinction of several bird species
Salmonella, various	micro-organism	Galapagos, Rottnest

Table 4. Some Australian islands in relation to size, number of plant species, total and introduced.

Island	Size	Number of plant species	% introduced (number of spp.)	Reference
Tiwi Islands (Melville and Bathurst)	7,775 km^2	772	12% (95)	Fensham and Cowie 1998
Dirk Hartog Island	620 km^2	294	12% (36)	Burbidge and George 1978
Wessel Islands (35 islands) and English Company Islands (47 islands)	371 km^2 154 km^2	684	Very low, present on 8 islands only	Woinarski 2000
Christmas Island	137 km^2	380	46% (173)	Du Puy 1993
Cocos (Keeling) Islands	30+ islands over an area of 135 km^2	121	47% (57)	Telford 1993
Macquarie Island	118 km^2	41	12% (5)	Hnatiuk 1993
Heard Island	700 km^2	12	8% (1)	Hnatiuk 1993
Norfolk Island	34.6 km^2	445	62% (274)	Green 1994
Lord Howe Island	16.6 km^2	459	48% (218)	Green 1994
Rottnest Island	17 km^2	196	42% (83)	Rippey *et al.* 2003

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Technical Appendix D7

Barrow Island Marine Surveys

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GORGON DEVELOPMENT ON BARROW ISLAND

BARROW ISLAND MARINE SURVEY S

TECHNICAL APPENDIX D7

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Barrow Island Preliminary Survey
for Introduced Marine Pest Species

Preliminary Report

As recommended by Wells & Huisman (2004), a 'short and sharp' survey of the waters off Barrow Island is being conducted for potentially introduced species. The survey will target areas where species are most likely to have been introduced, particularly species on the Commonwealth's list of declared marine pest species (Table 1). In addition, a broader group of species will be surveyed for possible introductions to Barrow Island. For operational reasons the survey was divided into two components:

- An investigation of subtidal habitats off the islands conducted by diving and snorkelling from 11 to 16 August 2004; and

- A subsequent survey of intertidal habitats, which is currently planned for 17 to 21 September.

The present report deals specifically with results of the August diving trip in terms of 'declared marine pest species'. A full report on the presence or absence of 'declared marine pest species' will be submitted shortly after completion of the intertidal survey. This will be followed later by a report on a broader list of possible introduced marine species in the area.

Table 1. Declared marine pest species (NIMPIS 2002).

Group	Species	Notes
Dinoflagellates	*Alexandrium catenella*	Cryptogenic in southeastern Australia
	Alexandrium minutum	Introduced to southern Australia
	Alexandrium tamarense	Cryptogenic in southwestern Australia
	Gymnodinium catenatum	Cryptogenic in southeastern Australia
Macroalgae	*Caulerpa taxifolia*	Native to northwestern Australia, but there is an invasive strain
	Undaria pinnatifida	Introduced to southeastern Australia
Echinoderm	*Asterias amurensis*	Introduced to southern Australia
Ctenophore	*Mnemiopsis leidyi*	Not recorded from Australia
Worm	*Sabella spallanzanii*	Introduced to southern Australia
Molluscs	*Corbula gibba*	Introduced to southeastern Australia
	Crassostrea gigas	Introduced to southern Australia
	Mytilopsis sallei	Introduced Darwin and eradicated
	Potamocorbula amurensis	Not recorded from Australia

Marine benthic algae and phytoplankton, John Huisman

Pest species as included in the NIMPIS 'Declared marine pests' list were absent at all sites visited. Of the species listed, *Undaria pinnatifida* usually occurs in colder waters and is unlikely to survive any introduction to Barrow Island. *Caulerpa taxifolia* was absent from locations visited in the present survey and was not recorded during the intertidal surveys conducted by BBG in the mid 90s. The species is widespread in the region, however, and has been recorded from the Dampier Archipelago, the Montebello Islands and Broome (Huisman & Borowitzka, 2003; Huisman, unpubl. obs.). Its natural presence at Barrow I. is therefore likely. *Caulerpa taxifolia* occurs as two 'strains', one invasive and therefore a pest, the other non-invasive. A PCR-based assay is necessary to establish whether a particular population belongs to the invasive strain (Fama *et al.* 2002). Although previous collections from the region were not tested, it is unlikely they represent the invasive strain, which thus far is known from eastern Australia, the Mediterranean, and California.

Other species of benthic algae and seagrasses collected were typical of the Indo-West Pacific region. Most are widespread.

None of the dinoflagellates species regarded as marine pests were found in the fresh or preserved samples collected in the present survey. Plankton samples contained a mix of the dinoflagellates *Ceratium* (several species) and *Prorocentrum lima* (rarely), plus various diatoms including *Licmophora*, *Rhizosolenia*, *Chaetoceras*, *Pleurosigma*, *Asterionella*, *Leptocylindrus*, *Nitzschia* and *Navicula*. Of these only *Prorocentrum* could be considered potentially harmful, as in bloom proportions it can cause diarrhetic shellfish poisoning if shellfish from affected areas are consumed. This species is worldwide in distribution, however, and its presence at Barrow I. is expected. It was present in only low numbers in the samples. Sediments were course-grained and included no evidence of dinoflagellate cysts. Genera present in sediments included the diatoms *Pleurosigma*, *Campylodiscus*, *Surirella*, and *Amphora*.

Marine invertebrates, Fred Wells

None of the invertebrate 'declared marine pest species' was recorded on the diving trip. As can be seen on Table 1, the comb jelly, or ctenophore, *Mnemiopsis leidyi* has not been recorded in Australia. There are no experts for this group in the country. The expedition did not search directly for this species, but no unusual numbers of comb jellies were found. Similarly, the bivalve *Potamocorbula amurensis* has not been recorded from Australia, and none were found. Most of the remaining species (the starfish *Asterias amurensis,* the tubeworm *Sabella spallanzanii* and the bivalve *Corbula gibba*) are temperate species which are unlikely to be found in the tropical waters off Barrow Island. The oyster *Crassostrea gigas* is also a temperate species, but is intertidal. It was not located at the sites along shore where snorkelling was conducted during the diving survey. Further searches for this species, and the others, will be conducted during the intertidal survey. The mussel *Mytilopsis sallei* was recently introduced to Darwin. It inhabited the protected waters of three marinas where its populations exploded exponentially. Fortunately, the three areas where it occurred could be sealed off and the population was eradicated. As a tropical species, *M. sallei* is the most likely of the declared marine pests to occur at Barrow Island, but it was not recorded during the diving survey.

Appropriate samples were retained for examination for other potentially introduced species.

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Introduced marine species in the waters of Barrow Island, with emphasis on barnacle species.

Report to ChevronTexaco

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February 2005

Introduction

Exotic species introductions are considered one of the major threats to biodiversity worldwide (Padilla *et al*., 1996). Whilst the introduction of terrestrial plants, animals and freshwater vertebrates in Australia is relatively well documented and their ecological and economic effects recognised, the same cannot be said for the documentation, or the impact, of introduced marine species. The dearth of baseline studies around the Australian coast severely restricts our information regarding exotic marine introductions, especially of marine invertebrates (Jones, 1992a). In Western Australia, the long coastline, the inadequate taxonomic understanding of many species and groups, and the poor biotic lists available for many aquatic habitats, further exacerbate difficulties in recognizing marine introductions (Hass & Jones, 1999).

Three vectors for the introduction of marine exotics have been recognised: via ballast water discharge and hull fouling (considered accidental introductions), and through aquaculture (deliberate introductions) (Carlton, 1985; Jones, 1991). Marine species have been introduced into a number of Australian localities. Accidental introductions have been much more numerous, and have occurred widely over varying time frames. The European mussel, *Mytilus galloprovincialis* (previously considered to be *Mytilus edulis*) is widely distributed in the harbours and bays of southern Australia and may have been introduced by early European ships arriving in Australia. Some recent introductions, such as the Japanese sea star, *Asterias amurensis,* in Tasmania and the European fan worm, *Sabella spallanzanii,* in Victoria, have caused extensive ecological dislocations and damage to fisheries. Most recently, an infestation of the Black striped mussel, *Mytilopsis sallei*, which has the potential to devastate the pearl industry, foul aquaculture cages and block drains and sewers, was found in a marina at Darwin and successfully eradicated.

Jones (1992a) recorded 113 marine introductions into Australian waters, tabulating 25 exotic marine species from the waters of Western Australia. Most of the Western Australian introductions have been identified from major ports. Over half the species (13) recorded were introduced by shipping, mainly as fouling organisms (11), and eight were introduced via ballast water (Jones 1992a).

Furlani (1996) provided a summary of 72 invertebrate, vertebrate and plant species known or thought to have been introduced into the Australian marine environment Also listed were species not yet recorded from Australia but which have the potential to colonise the waters adjoining the continent. However, although the document provides a good introduction to the problem of marine introductions into Australian waters, it contains various inaccuracies.

Hass & Jones (1999) increased to 30 the number of introduced marine species in Western Australian waters, the majority of which were crustaceans. They recorded 27 introduced species in the Swan River/Cockburn Sound area with the next highest being Bunbury Harbour with four. Only one introduced species, the barnacle *Megabalanus tintinnabulum*, was recorded from the Barrow Island/Dampier region. More recently, Jones (2003, 2004) recorded six fouling barnacle species in the Dampier region. Two of these (*Balanus amphitrite* and *B. trigonus*) are considered cryptogenic and four introduced species (*Balanus reticulatus, Megabalanus ajax, M. rosa* and *M. tintinnabulum*). *Megabalanus ajax, M. rosa, M. tintinnabulum* and *Balanus reticulatus* have all been recorded previously from Australian waters (Jones *et al.,* 1990; Jones, 1991; 1992a; 1992b; 2003; 2004; Jones & Hewitt, 1997) but the record of *Balanus reticulatus* is the first from Western Australian waters. Thus a total of 31 marine organisms (excluding ballast water and ballast sediment species) are now recorded as introductions into Western Australian waters. Most of these introductions are temperate, not tropical, species. The species that can be considered as introductions into the tropical northwestern Australian marine environment are listed in Table 1.

In September 2004 a baseline marine survey was conducted for ChevronTexaco in the waters of Barrow Island, on the northwestern coast of Western Australia, to determine whether any introduced pest species as listed by the National Introduced Marine Pest Information System (NIMPIS) (Hewitt *et al*., 2002) were present. NIMPIS was developed to provide accurate information on the biology, ecology and distribution of introduced marine species and potential control options for those designated as pests. The barnacles collected during the Barrow Island marine survey are reported on in this paper.

Material Collected

Samples were collected by Fred Wells and John Huisman in September 2004 at Barrow Island. The specimens are housed in the Western Australian Museum crustacean collection.

Results

Ten barnacle species were present in the samples (Table 2). This cirripede fauna contains the following elements:

1. Common northwestern Australian intertidal and shallow water species

Newmanella vitiata (Darwin, 1854: 340)
Tetraclita squamosa (Bruguière, 1789: 170)
Tetraclitella multicostata (Nilsson-Cantell, 1930: 2)

Chthamalus malayensis Pilsbry, 1916: 310
Armatobalanus quadrivittatus (Darwin, 1854: 284)

These species are typical of the cirripedian fauna of the tropical/warm temperate waters of Australia.

2. Indo-Malayan shallow water species not previously recorded from northern Australian waters

Balanus poecilotheca Krüger, 1911a: 48

This is the first record of this species from Australia waters. It is not, however, considered to be a fouling or a pest species.

3. Fouling species previously collected from Barrow Island (specimens in WA Museum collection)

Megabalanus tintinnabulum (Linnaeus, 1758: 668)

Specimens of this species are housed in the WA Musuem crustacean collection. The species is considered to be an introduction but not as a pest species.

4. Fouling species not previously collected from Barrow Island

Megabalanus ajax (Darwin, 1854: 214 (part))
Megabalanus rosa (Pilsbry, 1916: 61)
Balanus reticulatus Utinomi, 1967: 216

These species are all considered to be introductions but are not included as pest species on the NIMPIS list.

Discussion

The present report documents four barnacle species (*Balanus reticulatus, Megabalanus ajax, M. tintinnabulum* and *M. rosa)* that may be regarded as marine introductions into the waters of Barrow Island. Three of the species, *Balanus reticulatus, Megabalanus tintinnabulum* and *M. rosa*, are well known, widely distributed fouling species.

Balanus reticulatus was originally described from Japan (Utinomi 1967) but now has a widespread, circumtropical distribution - SE USA to W Indies; Mediterranean Sea; Malaysia to SE Africa; Hong Kong, to Gulf of Siam; east Asia from China, Yellow Sea, S China Sea; Australia; Japan and Hawaii to Malay Archipelago. In Australia, the species has been collected from the North Barnard Islands, Queensland (Lewis 1981), and in Western Australia from Yanchep Marina (Jones 1992b), more recently from the Dampier Archipelago (Jones 2003, 2004) and now from Barrow Island. The species has also recently been recorded from Darwin (Northern Territory) as well as from immigrant boats, submarines and shipping visiting various Australian ports (Jones unpublished data). In the Dampier Archipelago, *Balanus reticulatus* appears to be dominant in intertidal areas of Withnell Bay on the western lower Burrup Peninsula. The species is also present, at lower densities, on the eastern side of the Burrup Peninsula, as well as throughout the Dampier Archipelago and along the mainland, from Cape Preston to the west and Point Cleaverville to the east (Jones 2003, 2004). Utinomi (1967) has suggested that ship transport is responsible for the widespread distribution of this Japanese species. The means of *Balanus reticulatus* introduction into the waters of Western Australia are unknown, but the higher densities at Withnell Bay are close to the Woodside LNG jetty facility, supporting Utinomi's suggestion of distribution by ship transport. Shipping may also be assumed to be the vector for the introduction of the species to the waters of Barrow Island.

Megabalanus ajax is an Indo-West Pacific species, attaching mainly to corals (e.g. *Millipora complanata* Lamarck) but also occasionally known as a fouler of ships hulls (Jones, 1992a; 2003; 2004; Jones unpublished data). The species has been recorded from Queensland as well as from Western Australia (Shark Bay, the Muiron Islands, the Dampier Archipelago and now from Barrow Island). The possible vector for the introduction of this species to the waters of Barrow Island is shipping.

The appearance of the Japanese fouler, *M. rosa*, in the waters of Western Australia appears to be recent, the first specimens being collected in 1981 (Jones, 1992a). *Megabalanus rosa* is now established on the central and the north-western coast of Western Australia (Shark Bay, Carnarvon, Barrow Island, the Dampier Archipelago, Port Hedland and Cockatoo Island) as well as on the lower east coast of Australia (Woolongong, Port Botany and Port Kembla in New South Wales) (Jones *et al*., 1990; Jones, unpublished data). These are all areas that receive international shipping and, therefore, ship fouling is the most probable dispersal mechanism for this species. Allen (1953) recorded *M. rosa* with *M. volcano* and *Balanus albicostatus* on aircraft carriers and other vessels returning to Australia after service in Korean and Japanese waters. However, it is not known where these vessels docked and Allen (1953) did not record these species as established on the Australian coastline. It seems unlikely that *M. volcano* has become established in Australia as there are no records of its presence since that time. However, *B. albicostatus* has, more recently, been recorded from Victoria, albeit with few occurrences (Marine Research Group of Victoria, 1984).

Megabalanus tintinnabulum is a well known, cosmopolitan, hull-fouling species, first recorded in Western Australian waters in 1949 (Jones, 1990; 1991; 1992a). Jones (1990) suggested that this was an introduction via shipping since most Western Australian collection localities are in the vicinity of ports or areas that receive international shipping (e.g. Kwinana, Fremantle, Carnarvon, Barrow Island, Thevenard Island, Dampier, Cape Lambert, Cockatoo Island). Although early reports of *M. tintinnabulum* occurring on the eastern Australian coast may be erroneous (Allen 1953; Jones, 1990; 1991), records of the species have been confirmed from Bass Strait and the lower, mid and north-eastern coasts of Australia (Jones *et al*. 1990; Jones, unpublished data).

Although four potentially introduced barnacle species were found during the survey, none of these are considered to be pest species as none are included on the NIMPIS marine pest species list. However, once construction at Barrow Island begins and vessels begin to arrive from various Australian and foreign ports, the possibility of marine introductions and the establishment of potential marine pest species will increase dramatically. This is a situation that requires future long-term monitoring. Such future introductions are most likely to be species already established at Dampier and/or the Fremantle-Cockburn Sound area. No data are available as to whether the presence of introduced species in Western Australia (or Australia) has caused any ecological consequences, or whether they have had any adverse impacts on native species and, thus, any adverse impacts on biodiversity. It must also be noted that many introduced species have been recorded as one or a few individuals on one or a few occasions.

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Table 1: Species considered to be introductions into the NW Australian marine environment.

H = hull fouling

T = ballast tanks

U = unknown

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
ASCIDEACAE (Sea squirts)				
Botrylloides leachi (Savigny, 1816)	1899	**U** **WA** - Dampier Arch.; Rowley Shoals; Geraldton; Cockburn Sound; Bunbury; Albany; **Qld.** - Moreton Bay; Wistari Reef; Heron I.; Green I.; Lizard I.; C. Flattery, Townsville; **NSW** - Port Jackson; Bateman's Bay; Port Hacking; Lord Howe I.; Solitary Is; Norfolk I.; **Vic.** - Portsea Pier; **S Aust.** - Topgallant I.	**U** Distribution: Europe, Atlantic	Herdman, 1899 Kott, 1985 Furlani, 1996
Botryllus schlosseri (Pallas, 1766)		**H?** **WA** - Rowley Shoals; Shark Bay; Cockburn Sound; Swan R.; Albany; **Qld.** - Moreton Bay; Wistari Reef; Heron I.; Lizard I.; **Vic.** - Port Phillip Bay; Tas. - Bruny I.; **S Aust.** - E Great Australian Bight;	**U** Distribution: NE Atlantic to Mediterranean	Hartmeyer & Michaelsen, 1928 Kott, 1985 Sabbadin & Graziani, 1967 Furlani, 1996

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
		St Vincent Gulf; Yorke Pen.		
Styela plicata (Lesueur, 1823)	?1878	**H** **WA** - Monte Bello Is; Cockburn Sound; **Qld.** - Moreton Bay; Hervey Bay; Ross R.; **NSW** - Botany Bay; Port Jackson; Port Hacking; Port Kembla; Port Stephens; **Vic.** - Port Phillip Bay; Geelong; **S Aust.** - St Vincent Gulf; Spencer Gulf	**?H** Distribution: Philippines	Hartmeyer & Michaelsen, 1928 Kott, 1952 Kott, 1985 Kott & Goodbody, 1982 Hutchings *et al.,* 1987 Furlani, 1996
CRUSTACEA Cirripedia (Barnacles)				
Balanus amphitrite Darwin, 1854		**?H** Common fouler throughout **WA, S Aust., Vic., NSW, Qld, NT**	**U** Distribution: cosmopolitan in tropical, subtropical and temperate waters	Jones, 1992a
Balanus cirratus (Darwin, 1854)		**?H** Common fouler throughout **NWA, Qld**	**U** Distribution: Indo-west Pacific	Jones, 1992a
Balanus reticulatus Utinomi, 1967	1981 1992	**?H** **Qld** **WA** Yanchep Marina; Barrow I.; Dampier Archipelago	**?H** Distribution: Japan	Utinomi, 1967; Lewis 1981; Jones, 1992a; 2003; 2004
Balanus trigonus Darwin, 1854		**?H** Common fouler throughout **WA, NT, S Aust., Vic., Tas., NSW, Qld**	**U** Distribution: cosmopolitan in tropical and warm temperate seas.	Jones, 1992a
Megabalanus ajax (Darwin, 1854)		**?H** Occasional fouler throughout tropical and warm temperate seas in **WA** and **Qld**	**U** Distribution: Indo-west Pacific	Jones, 1992a; 2003; 2004
Megabalanus rosa (Pilsbry, 1916)	1981	**?H** **WA -** records	**?H** Distribution: Japan,	Allen, 1953; Jones, *in* Hutchings *et*

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
		from near ports (e.g. Port Hedland, Dampier, Barrow I., Carnarvon) **NSW –** off Wollongong	China, Taiwan	*al.,* 1987; Jones *et al.,* 1990; Furlani, 1996; Jones, 2003; 2004
Megabalanus tintinnabulum (Linnaeus, 1758)	1949	**H** **WA** - most records from near ports (Kimberley to Albany); **NSW** – Botany Bay, Port Kembla **Vic.** - Bass Str.; **NT** - Port Essington, Darwin	**U** **Distribution:** **c**osmopolitan	Allen 1953; Jones *in* Hutchings *et al.,* 1987 Jones, 1990; 1991; 1992a; Jones *et al.,* 1990; Furlani,, 1996
CRUSTACEA Isopoda				
Paracerceis sculpta (Holmes, 1904)	1996 1975	**H** **WA** - Bunbury, Mandurah, Fremantle, Port Denison; **Qld** - Townsville	**U** Distribution: California, USA, Brazil, Mexico, Italy, Spain	Harrison & Holdich, 1982b; Hutchings *et al.,* 1987; Furlani, 1996; Hass & Jones, 1999
Paradella dianae (Menzies, 1962)	1980 1971	**H** **WA** - Swan River; **Qld.** -Townsville, N Stradbroke I.	**U** Distribution: California, USA, Brazil, Puerto Rico or Marshall Islands	Harrison & Holdich, 1982a Hutchings *et al.,* 1987 Furlani, 1996
Sphaeroma serratum Fabricius, 1787	1980	**H** **WA** -	**U** Distribution: Widespread	Holdich & Harrison, 1983 Hutchings *et al.,* 1987 Furlani, 1996
BALLAST WATER				
22 zooplankton species, 45 other planktonic taxa including: crustaceans, molluscs, polychaete worms, arrow worms, coelenterates, sea squirts	1976-78	**T** **WA** -Dampier, C Lambert; **NSW** - Eden; **Tas**. - Triabunna	13 Japanese ports natural distribution uncertain	Williams *et al.* 1988
DINOPHYTA Toxic dinoflagellate cysts				

SPECIES	POSSIBLE DATES AND MEANS OF INTRODUCTION		POSSIBLE ORIGIN	REFERENCE
Alexandrium catenella (Whedon et Kofoid) Balech, 1985 **(**causes paralytic shellfish poisoning, PSP)	1989	**T** **WA** - Port Hedland; **Vic.**, - Port Philip Bay	Distribution: Japan	Jones, 1991 Hallegraeff *et al.* 1988 Hallegraeff & Bolch 1991 Hallegraeff *et al.* 1990
BALLAST SEDIMENT				
16 invertebrate species, 21 invertebrate taxa including: crustaceans, polychaete worms	1977-78	**T** **WA** - Cape Lambert, **NSW** - Sydney, Eden; **Tas. -** Triabunna	7 Japanese ports Natural distribution Japan/N Pacific/ uncertain	Williams *et al.* 1988

Table 2: Barnacle species collected from Barrow Island in September 2005

Label	Collection date	Identification	Nos individuals	Comments
BR1-7 Crus		*Newmanella vitiata*	12	
BW1-8C	17/09/04	*Newmanella vitiata*	6	
BW1-9	18/09/04	*Newmanella vitiata*	4	
BW1-10 Crus	18/09/04	*Newmanella vitiata*	12	
		Tetraclita squamosa	3	
		Tetraclitella multicostata	6	
		Chthamalus malayensis	3	
BW1-14 Crus	20/09/04	*Megabalanus ajax*	8	**Introduced species**
		Tetraclita squamosa	1	
		Chthamalus malayensis	4	
		Newmanella vitiata	9	
BW1-9 Crus		*Megabalanus tintinnabulum*	7	**Introduced species**
		Tetraclita squamosa	1	
BW1-2 Crus		*Megabalanus tintinnabulum*	9	**Introduced species**
BR1-2		*Megabalanus tintinnabulum*	20	**Introduced species**
		Megabalanus rosa	8	**Introduced species**
		Balanus reticulatus	26	**Introduced species**
		Balanus poecilotheca	4	
		Armatobalanus quadrivittatus	2	
BW1-15	20/09/04	*Tetraclita squamosa*	2	

Label	Collection date	Identification	Nos individuals	Comments
		Chthamalus malayensis	3	
BR1-12		*Tetraclita squamosa*	many	
BR1-4		*Tetraclita squamosa*	many	
BR1-2		*Megabalanus tintinnabulum*	19	**Introduced species**
		Megabalanus rosa	2	**Introduced species**

Technical Appendix D8

Pathogenic Micro-organism Threats to the Terrestrial Vertebrate Fauna of Barrow Island

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

PATHOGENIC MICRO-ORGANISM THREATS TO THE TERRESTRIAL VERTEBRATE FAUNA OF BARROW ISLAND

TECHNICAL APPENDIX D8

Prepared for:

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August 2004

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Pathogenic Micro-organism Threats to the Terrestrial Vertebrate Fauna of Barrow Island

A Quarantine Assessment Report to the Gorgon Joint Venture

August 2004

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MURDOCH UNIVERSITY
PERTH, WESTERN AUSTRALIA

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Table of Contents

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1. Background

1.1 Barrow Island

Barrow Island covers an area of 23,567 hectares and is situated 56 km off the Pilbara coast of Western Australia. It has been isolated from the mainland for approximately 6000 - 8000 years (Buckley, 1983; Sharrad and King, 1981), and as such forms an important sanctuary for its flora and fauna. In recognition of its pristine and unique nature, Barrow Island was declared a permanent reserve Class A for the protection of flora and fauna in 1910 (Cox, 1977), and is internationally recognised as a unique biodiversity repository. Introduced stock or feral animals have not grazed its vegetation and introduced predators have not affected its animal assemblages. Barrow Island Nature Reserve is probably the largest island in Australia, and one of the largest land masses in the world that has no introduced animals, making it one of the oldest and most valuable biodiversity conservation reserves in the world (CCWA, 2003; EPA, 2003).

1.2 Oil production and Barrow Island

In addition to Barrow Island's unique conservation and biodiversity values, it has been an actively producing oilfield since 1964 (Butler, 1970). West Australian Petroleum Pty. Ltd. (WAPET) operated the oilfield until 1999, when it was taken over by ChevronTexaco Australia Pty. Ltd. Since 1964 approximately 1000 wells have been drilled on the island, and these along with their attendant roads, gravel pits, campsites and other ancillary activities have only disturbed approximately 3% of the island's total area (Anon., 2003). With the proposed development of the gas processing facility on Barrow Island, this figure is expected to increase to 5% of the total area (Anon., 2003). Surveys of the vertebrate fauna commenced in 1964 to obtain information regarding the impact, if any, of this industry on the island fauna. Monitoring of the island wildlife has continued to the present, with very little indication of any adverse impact on vertebrate populations (Burbidge *et al.*, 2000a; Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Butler, 1970; Butler, 1975; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999; Serventy and Marshall, 1964; Smith, 1976).

The continued integrity of the Barrow Island wildlife can be attributed, at least in part, to the stringent quarantine policies put in place by ChevronTexaco with regard to anything coming onto Barrow Island (Anon., 2002b). These procedures have helped to ensure that introductions of invasive species (both animals and plants) do not occur. However, with the recent proposal to expand operations on Barrow Island, the issue of preventing microbial introductions has been identified as an important issue. Therefore this report is intended to assess the potential risk that introduced micro-organisms may pose to the terrestrial vertebrate fauna of Barrow Island.

1.3 Definitions

The terms micro-organism and parasite are used to describe the range of infectious agents, including viruses, bacteria, fungi, protozoa and helminths in this report. The terms pathogen and pathogenic are used to describe those infectious agents that are capable of causing disease. The term infectious is used to describe the capability of the micro-organisms to be transmitted to or between individual animals but is not in itself an indication of pathogenicity. External parasites (ticks, fleas, lice, flies etc.) may contribute a pathogenic effect to their host species (eg. anaemia), however they are deemed to be outside the scope of this report. Nevertheless, their role as vectors of infectious diseases will be discussed in the appropriate section(s). For the purpose of this report vectors are defined as invertebrate species capable of maintaining and introducing micro-organisms (eg. mosquitoes, ticks, fleas).

2. Importance of Micro-organisms in Wildlife

2.1 Importance of disease-causing micro-organisms

Disease-causing micro-organisms of wildlife occur in many different forms in a wide range of species which, when expressed in free-ranging populations, can have a significant effect on wildlife ecologies (Morner *et al.*, 2002). Whilst some micro-organism infections may occur as symptomless, subclinical disease with no obvious impact and/or consequence, occasionally there are dramatic epizootic outbreaks characterised by high morbidity and mortality (Morner *et al.*, 2002). As such, under certain conditions, micro-organisms can be considered a major evolutionary force and an important threat to biodiversity (Gulland, 1995; May, 1988; Scott, 1988).

The impact of micro-organisms on the survival, reproduction or dispersal of host individuals will depend upon the virulence of the pathogen, the infective dose and the resistance of the host to infection (Anderson and May, 1978; Gulland, 1995). These parameters can be modified by a number of factors such as malnutrition, overcrowding, stress and multiple parasitism that complicate the dynamics of the host-pathogen interaction (Gulland, 1995). Micro-organisms may also indirectly affect the survival of the host by increasing their susceptibility to predation or by reducing their competitive fitness (Berdoy *et al.*, 1995; Scott, 1988; Webster, 2001). Therefore, the consequences of these disease-causing agents may well be as important at the population level as at the immediate level of the individual (Lyles and Dobson, 1993).

2.2 Genetic Fitness and Infectious Diseases

Conservation biologists hypothesize that endangered species are especially vulnerable to infectious disease due to their small population sizes, leading to reduced genetic diversity and a reduced ability of the host to respond to pathogens in an evolutionary sense (Lyles and Dobson, 1993; O'Brien and Evermann, 1988). A lack of genetic variability in a population significantly improves the odds of an infectious disease-causing devastating effects, because when it overcomes one individual defence system it more likely than not will overcome the others in a genetically uniform population (O'Brien and Evermann, 1988; Ralls *et al.*, 1979). The same is true of island populations that have been isolated for long periods of time, such as on Barrow Island. Indeed, the reduced genetic diversity observed in some Barrow Island species (CCWA, 2003; King, 1998), could very well increase the effects of any debilitating disease should one be introduced to the island.

2.3 Population Size and Threshold Density

Host population size has a profound effect on the dynamics of a pathogen as every parasite requires a minimum density of hosts (threshold population) whereby it can maintain itself (Bartlett, 1960; Dobson and May, 1986; Lyles and Dobson, 1993). Ironically, the presence of a threshold for establishment suggests that small populations of species are relatively protected from virulent pathogens as there may be too few individuals present to continuously support an infection (Lyles and Dobson, 1993). However, this perceived level of protection actually increases the susceptibility of these animals to catastrophic disease outbreaks, as small populations of species are at a greater risk from non-host-specific pathogens than host-specific pathogens.

The susceptibility of small populations to pathogens may also be enhanced by the loss of endemic diseases once the population size falls below the critical levels required for the maintenance of such diseases (Cunningham, 1996). These populations risk becoming immunologically naïve, resulting in low levels of acquired immunity (Cunningham, 1996; Viggers *et al.*, 1993). Without this level of exposure, these populations are at an increased risk of being adversely affected by epidemics of what were previously endemic diseases, as well as new and emerging diseases (McCallum and Dobson, 1995).

2.4 Human Involvement in Disease Outbreaks

A common factor driving the emergence of wildlife disease is the anthropogenic movement of pathogens into new geographic locations – a phenomenon termed 'pathogen pollution' (Cunningham, 1996; Daszak *et al.*, 2000). Pathogen pollution is rooted in the unprecedented globalisation of agriculture, commerce, human travel and the transport of domestic animals and their products (Daszak *et al.*, 2001). Human landscape changes that remove portions of host populations, alter host migration patterns or increase host density are also likely to increase the risk of pathogen emergence (Dobson and May, 1986). Pathogen introductions have a particularly high impact when naïve host populations are involved and introduced pathogens may contribute to the competitive success of the invading carrier hosts (Hudson and Greenman, 1998).

2.5 Disease and Biodiversity

Wildlife populations have long been considered a link in the chain of pathogen emergence, by forming the reservoirs from which pathogens may emerge (Daszak *et al.*, 2001). However, wildlife populations are seldom the guilty party in the event of a disease outbreak, though more often than not they bear the brunt of its effects. Emerging infectious wildlife diseases have been responsible for mass mortalities as well as local (population) extinctions and global (species) extinctions (Cunningham and Daszak, 1998; Daszak and Cunningham, 1999). This direct loss of biodiversity due to infectious disease may lead to further impacts on ecosystems via 'knock-on' effects. These knock-on effects may lead to the extinction of species further up the food chain that remain uninfected by the pathogen. Hence, apart from the immediate direct and indirect effects on individual animal species, the introduction of disease may also have broad, long-term, and unforeseeable effects on ecosystems (Cunningham, 1996).

3. Vertebrate Species on Barrow Island

3.1 Mammal Species Present on Barrow Island

Barrow Island Nature Reserve is best known for its abundant mammal species. Oil exploration on Barrow Island commenced in 1954 (Cox, 1977), and since then, although a complete census has not been performed, numerous studies of the vertebrate fauna have been undertaken, focussing primarily upon the mammal fauna (Burbidge *et al.*, 2000a; Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Butler, 1970; Butler, 1975; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999; Serventy and Marshall, 1964; Smith, 1976). Presently there are 14 resident species and 1 vagrant species of mammal (Table 1) recognised as occurring on Barrow Island (Anon., 2002a).

Despite the relatively low number of mammal species present on Barrow Island, its mammal fauna is highly significant, as six of its species are listed as threatened pursuant to the *Wildlife Conservation Act 1950* (CCWA, 2003; EPA, 2003). Additionally, the Black-flanked Rock-wallaby (*Petrogale lateralis*) has declined across much of its former range due to habitat disturbance and introduced predators (Anon., 2002a; CCWA, 2003), whilst five of the mammal taxa (*Bettongia lesueur*, *Isoodon auratus barrowensis*, *Lagorchestes conspicillatus conspicillatus*, *Macropus robustus isabellinus* and *Pseudomys nanus ferculinus*) are regarded as being endemic subspecies or races (Anon., 2002a; CCWA, 2003; EPA, 2003).

Table 1. Terrestrial mammal species resident on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM mammal monitoring reports.

Family	Species	Common Name
Dasyuridae	*Planigale* sp. *Pseudantechinus* sp.	- -
Macropodidae	*Lagorchestes c. conspicillatus* *Macropus robustus isabellinus* *Petrogale lateralis*	Barrow Island Spectacled Hare-wallaby Barrow Island Euro Black-flanked Rock-wallaby
Peramelidae	*Isoodon auratus barrowensis*	Barrow Island Golden Bandicoot
Phalangeridae	*Trichosurus vulpecula arnhemensis*	Northern Brush-tailed Possum
Potoroidae	*Bettongia lesueur*	Barrow Island Boodie
Emballonuridae	*Taphozous gergianus*	Common Sheathtail Bat
Mollosidae	*Tadarida (Nyctinomus) australis*	White-striped Bat
Vespertilionidae	*Vespadelus (Eptesicus) finlaysoni*	Inland Cave Bat
Pteropodidae	*Pteropus alecto*	Black Flying-fox (vagrant)
Muridae	*Hydromys chrysogaster* *Pseudomys nanus ferculinus* *Zyzomys argurus*	Water-rat Barrow Island Chestnut Mouse Common Rock-rat

3.2 Reptile Species Present on Barrow Island

Barrow Island has an abundant terrestrial reptile fauna, comprising 35 species of lizard and 8 species of snake (Table 2). The assemblage of reptile species present on Barrow Island is somewhat more diverse than would typically be expected due

Table 2. Terrestrial reptile species present on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM fauna monitoring reports.

Family	Species	Common Name
Lizards		
Agamidae	*Ctenophorus caudicintus*	Ring-tailed Dragon
	Gemmatophora longirostris	Long-nosed Water-dragon
	Pogona minor	Bearded Dragon
Gekkonidae	*Diplodactylus jeanae*	
	Diplodactylus stenodactylus	Crowned Gecko
	Gehydra variegata	Tree Dtella
	Gehydra pilbara	Pilbara Dtella
	Heteronotia binoei	Bynoe's Gecko
Pygopodidae	*Delma borea*	
	Delma nasuta	
	Delma tincta	
	Lialis burtonis	Burton's Legless-lizard
	Pygopus nigriceps	Hooded Scalyfoot
Scincidae	*Carlia triacantha*	
	Cryptoblepharus carnabyi	
	Ctenotus duricola	
	Ctenotus grandis	
	Ctenotus hanloni	
	Ctenotus pantherinus acripes	
	Ctenotus saxatilis	
	Ctenotus serventyi	
	Cyclodomorphus melanops	
	Eremiascincus richardsonii	
	Glaphyromorphus isolepis	
	Lerista bipes	
	Lerista elegans	
	Lerista muelleri	
	Menetia greyii	Dwarf Skink
	Morethia lineoocellata	
	Morethia ruficauda	
	Notoscincus ornatus	
	Proablepharus reginae	
Varanidae	*Varanus acanthurus*	Spiny-tailed Goanna
	Varanus brevicauda	Short-tailed Goanna
	Varanus giganteus	Perentie

Snakes Boidae	*Antaresia stimsoni*	Stimson's Python
Elapidae	*Brachyurophis (Vermicella) approximans* *Demansia rufescens* *Furina ornate* *Pseudechis australis* *Suta (Rhinoplocephalus) monachus*	 Rufous Whip-snake Moon Snake Mulga Snake Monk Snake
Typhlopidae	*Ramphotyphlops ammodytes* *Ramphotyphlops longissimus*	

primarily to its geographic location, which encompasses species from both northern and southern regions (Smith, 1976). Whilst the majority of Barrow Island's reptile species are represented on the Australian mainland, the skink *Ctenotus pantherinus acripes* is an endemic subspecies, and the blind snake *Ramphotphlops longissimus* is the only endemic vertebrate species exclusive to Barrow Island (Anon., 2002a).

3.3 Amphibians Present on Barrow Island

The Western Australian Museum database suggests that three species of frog may occur on Barrow Island; *Cyclorana maini*, *C. platycephala* (Water-holding Frog), and *Litoria rubella* (Inland Tree Frog) (Anon., 2002a). However, there are no records of the Water-holding Frog and the Inland Tree Frog is believed to be an introduced specimen from the mainland in 1965 (Anon., 2002a). At present the only frog species recognised as being present on Barrow Island is *Cyclorana maini* (Table 3), which is also widespread throughout the adjacent Pilbara region (Anon., 2002a).

Table 3. Amphibian species present on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM fauna monitoring reports.

Family	Species	Common Name
Hylidae	*Cyclorana maini*	-

3.4 Bird Species Present on Barrow

Barrow Island is recognised as providing major and significant habitat for migratory wading birds which are protected by international treaty and by Commonwealth and State law (CCWA, 2003). As such, 110 species of birds have been recorded on Barrow Island, of which only 32 species are known to breed there (CCWA, 2003), making the island a major stopover/feeding ground for both locally and internationally migratory birds. Whilst some bird pathogens may potentially be brought on to Barrow Island via food and/or materials, the greatest potential for micro-organism introductions would be through migratory birds which is thus outside the control of Gorgon. Therefore it has been decided that the inclusion of birds in the present study under the aspect of controlling micro-organism introductions is outside the scope of this report as it would not be feasible to attempt to prevent birds from bringing micro-organisms onto Barrow Island.

3.5 Population Sizes and Dynamics

The mammal fauna on Barrow Island is currently subject to an annual monitoring programme run by the Department of Conservation and Land Management (DCLM) (Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999). Several attempts have been made to obtain estimates of population size for the larger mammal species on Barrow Island prior to the establishment of a mammal monitoring programme by DCLM (Butler, 1970; Short and Turner, 1991; Short and Turner, 1993; Short *et al.*, 1988). However, obtaining accurate population size estimates agreeable to all parties has proven difficult due to the variety of techniques used (eg. spotlight transects, monitoring grids, quadrat surveys, track count surveys) and the sampling errors associated with each technique. Data collected via spotlighting surveys has generally been considered inaccurate due to variation between different operators as well as the visibility of particular mammal species. However, it is still a common and widespread method used to estimate species population size.

The spotlight monitoring transects set up and run by DCLM on Barrow Island since 1998 using the same techniques and transects (detailed in their mammal monitoring reports) have provided data collected by a common means over a number of years, providing an estimation of population size for the larger mammal species (Table 4). However, there is no similar data available for the smaller mammal species present on Barrow Island. Likewise, there is a dearth of information regarding population size and distribution of reptile species on Barrow Island with data on their patterns of distribution limited to reports of them being closely related to the soil type, areas of accumulation of leaf litter and to distinctive vegetation types present across the island (Anon., 2002a).

Table 4. Estimates of minimum total population size of commonly sighted mammals on Barrow Island, sourced from Burbidge *et al.* (2003).

	Barrow Island Euro	Boodie	Brushtail Possum	Golden Bandicoot	Spectacled Hare-wallaby
Butler (1970)	200+	400+	-	1000+	600+/800+*
Short *et al.* (1988)	1500	2500	-	3200	8600
Burbidge *et al.* (1998)	914 (554-1526)	2884 (1883-4589)	1360 (1149-1945)	3679 (2867-4235)	1661 (1389-1988)
Burbidge *et al.* (2000)	761 (462-1268)	564 (444-716)	650 (491-861)	1753 (855-1333)	1016 (749-1067)
Morris *et al.* (2001)	935 (497-1714)	2223 (1583-3125)	1366 (951-1973)	1971 (1515-2597)	888 (720-1098)
Morris *et al.* (2002)	528 (305-924)	1718 (1368-2176)	910 (683-1213)	1679 (1327-2133)	828 (650-1053)
Burbidge *et al.* (2003)	851 (462-1607)	1896 (1454-2472)	1468 (1033-2110)	2528 (2031-3145)	1137 (908-1423)

*600+ estimated in 1966, 800+ estimated in 1969 (Butler, 1970).

4. Micro-organisms Infecting Barrow Island Terrestrial Vertebrates or Related Mainland Species

4.1 Micro-organisms present on Barrow and surrounding islands

Despite the extremely high biodiversity conservation values of Barrow Island, there is relatively little published data on the biology and ecology of its terrestrial vertebrate species and even less is known of its invertebrate fauna. Very little information exists regarding micro-organisms present on Barrow Island. Therefore, in assessing and compiling a list of potential micro-organisms that may pose a risk to the vertebrate fauna on Barrow Island, we have had to extrapolate our results from studies on similar vertebrate species which have been conducted elsewhere in Australia, and in some instances overseas.

The only known research conducted on Barrow Island related to micro-organisms involved the isolation of *Salmonella* species from seagulls in 1986 and several observed cases of "Lumpy Jaw" in euros (presumably *Fusobacterium necrophorum*) (Butler, W. H. pers. comm., 2004). Recent studies carried out by a PhD student on Barrow Island have detected ticks and fleas on mammals however their identification is still ongoing. In addition, analysis of ticks from mammalian hosts has identified two novel *Rickettsia* species within the Spotted Fever Group and these are still being characterised. Spotted Fever Group rickettsiae are zoonotic organisms that are well documented as disease agents in many parts of the world including Australia. The pathogenicity of these rickettsiae for humans and animals on the island is as yet unknown.

4.2 Micro-organisms infecting Barrow Island vertebrates and related species in Australia

Due to the dearth of information regarding micro-organisms present in the terrestrial vertebrate species of Barrow Island it was necessary to refer to the literature detailing the occurrence of micro-organisms in similar and related host species elsewhere in

Australia. However, in comparison to the amount of information available regarding pathogens of humans and domestic livestock, there is still very little information available with regard to disease/infection risks for Australian native mammals, and even less for reptiles.

The typically destructive techniques involved with collecting and identifying internal parasites has lead most investigations to focus on the study of parasites in the more common native species (O'Donoghue and Adlard, 2000; Spratt *et al.*, 1990), however systematic surveys of native species are still rare. As such, comprehensive records of parasitic infections and disease infections are known for very few of our native species. Similarly, the less invasive methods required for surveying gastro-intestinal parasites of wildlife species has resulted in a more thorough understanding of them as opposed to the more cryptic species of pathogen. In addition, much of the available information relates to surveys of fauna for infectious micro-organisms rather than to actual disease occurrence.

Diseases in wild populations should be investigated from the perspective that multiple aetiological agents and predisposing factors are involved (Fowler, 1982), as they are an aspect of wildlife death-rate that must be understood in order to gain an accurate view of population dynamics (Speare *et al.*, 1989). The occurrence and localisation of disease in wildlife is determined by a variety of factors, including those that relate to the host, the causative agent and the environment (Morner *et al.*, 2002). Indeed many parasites have well-established commensal relationships with their host species and outbreaks of disease only occur following a shift in the hosts' ecology caused by environmental or physical stress. The vast majority of parasitic species recorded from host animals have no obvious pathological effects upon their host under normal conditions. Therefore, the presence of a parasitic agent in a host species does not necessarily indicate the occurrence of disease.

For the purpose of this review of the species of micro-organism that may potentially pose a risk to the terrestrial vertebrate species present on Barrow Island, we have grouped the mammalian species into their family assemblages (except for the bats which have been grouped into their order Chiroptera), the reptile species into lizards and snakes, and the single frog species is dealt with as a whole.

Additionally, the micro-organisms known to occur in these vertebrate hosts are presented in three sections. The first list of micro-organisms describes those genera that have been reported as occurring in the above host groups throughout Australia, encompassing both disease-causing as well as commensal micro-organisms. These are presented in Appendices 1-3 for the mammals, reptiles and amphibians respectively. Secondly, an abbreviated list, including only those pathogens reported as causing disease in host species representative of the Barrow Island vertebrate fauna, is presented for the mammals (section 4.2.1; Table 5), reptiles (section 4.2.2; Table 6) and amphibians (section 4.2.3; Table 7). Thirdly, a shortened list is presented concerning only those micro-organisms considered to pose a significant risk to the Barrow Island vertebrate fauna. This list is based on pathogenicity, transmission risk to Barrow Island and occurrence in Western Australia fauna (section 4.2.4).

4.2.1 Mammalian hosts

The abbreviated list of pathogens reported as potentially causing disease in mammalian host species representative of the Barrow Island fauna is presented in Table 5. Below is a brief synopsis of the disease syndromes for each pathogen listed.

4.2.1.1 Viruses

Wart Disease in bandicoots – newly discovered unidentified viral disease-causing debilitating wart-like lesions in Western Barred bandicoots from Bernier Island off Western Australian coast, cross species infectivity unknown (Swan *et al.*, in prep.).

Macropod Herpesvirus – cause of conjunctivitis, muco-cutaneous blisters and ulcerations and may progress to death; reported as a cause of disease in numerous species of captive macropods, clinical disease not reported from free-ranging macropods (Speare *et al.*, 1989).

Macropod Poxvirus – causes two types of lesions including wart-like lesions in several species of wild macropods; its natural history in free-ranging populations is unknown (Speare *et al.*, 1989).

Table 5. List of mammalian groups present on Barrow Island and pathogens reported as causing disease in these species elsewhere in Australia.

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Dasyuridae	Bacteria	*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
Antechinus sp.		*Leptospira*	soil; water	Yes	E Aust	(Arundel *et al.*, 1977)
Planigale sp.	Protozoa	*Babesia*	vector	Yes?	E Aust	(Arundel *et al.*, 1977)
		Cryptosporidium	faecal; water	Yes	SE Aust	(Barker *et al.*, 1978)
		Giardia	faecal; water	Yes	Tas	(Milstein and Goldsmid, 1997)
		Toxoplasma	food; water	Yes	WA	(Haigh, 1994)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)
		Pelecitus	vector	Yes	Aust	(Spratt, 1979)
		Marsupostrongylus	vector	Yes	E Aust	(Spratt, 1979; Spratt, 1984)
		Ophidascaris	faecal	Yes	Aust	(Speare *et al.*, 1984)
		Spirometra	vector	Yes	Aust	(McMillan and Walker, 1969)
Peramelidae	Viruses	Wart disease	animal	Yes	WA	(Swan *et al.*, in prep.)
Barrow Island Golden Bandicoot	Bacteria	*Chlamydia*	animal	Yes	WA	(Warren *et al.*, in prep.)
		Salmonella	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	WA	(Adams, 2003)
		Giardia	faecal; water	Yes*	WA	(Adams *et al.*, in press)
		Toxoplasma	food; water	Yes	WA	(Adams, 2003)
		Trypanosoma	exprmtl; vector	Yes	Qld?	(Bettiol *et al.*, 1998)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Phalangeridae	Bacteria	*Bacillus*	faecal	No	Aust	(Speare *et al.*, 1984)
Northern Brushtail Possum		*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
		Leptospira	soil; water	Yes?	SE Aust	(Durfee and Presidente, 1979)
		Mycobacterium	soil	No	SE Aust	(Corner and Presidente, 1980)
		Pseudomonas	animal	Yes	SE Aust	(Speare *et al.*, 1984)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	SE Aust	(Power *et al.*, 2003)
		Giardia	faecal; water	Yes*	Tas	(Milstein and Goldsmid, 1997)
		Leishmania	exprmtl; (vector)	Yes	Qld?	(Backhouse and Bolliger, 1951)
		Toxoplasma	food; water	Yes	NSW	(Canfield *et al.*, 1990; Cook and Pope, 1959)
		Trypanosoma	exprmtl; (vector)	Yes	Qld?	(Backhouse and Bolliger, 1951)
		Hepatazoon	?	Yes	SE Aust	(Speare *et al.*, 1984)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)
		Marsupostrongylus	vector	Yes*	Qld	(Speare *et al.*, 1984)
		Ophidascaris	faecal	Yes	Qld	(Presidente, 1978)
Potoroidae	Bacteria	*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
Barrow Island Boodie		*Salmonella*	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	Aust	No record
		Giardia	faecal; water	Yes*	Aust	No record
		Toxoplasma	food; water	Yes	Aust	(Patton *et al.*, 1986)
	Helminths	*Angiostrongylus*	vector	Yes?	Qld, NSW	(Prociv and Carlisle, 2001)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Macropodidae	Viruses	Macropod herpesvirus	animal	Yes	WA	(Britt *et al.*, 1994)
Barrow Island Euro		Macropod poxvirus	animal	Yes	WA	(Speare *et al.*, 1989)
Spectacled Hare-wallaby		Wallal & Warrego viruses	vector	Yes	WA	(Hooper *et al.*, 1999)
Black-flanked Rock Wallaby	Bacteria	*Fusobacterium*	soil	Yes	WA	(Speare *et al.*, 1989)
		Leptospira	soil; water	Yes?	SE Aust	(Durfee and Presidente, 1979)
		Salmonella	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	NSW	(Power *et al.*, 2004)
		Giardia	faecal; water	Yes*	Tas	(Milstein and Goldsmid, 1997)
		Leishmania	vector	Yes	NT	(Rose *et al.*, 2004)
		Toxoplasma	food; water	Yes	WA	(Jakob-Hoff and Dunsmore, 1983)
		Trypanosoma	exprmtl; vector	Yes	Aust?	(Noyes *et al.*, 1999)
	Fungi	*Microsporum*	soil	Yes	Aust	(McAleer, 1980; Speare *et al.*, 1989)
		Trichophyton	soil	Yes	Aust	(McAleer, 1980; Speare *et al.*, 1989)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(McKenzie *et al.*, 1978)
		Filaroids	vector	Yes	Aust	(Speare *et al.*, 1989)
		Pelecitus	vector	Yes*	Aust	(Speare *et al.*, 1989; Spratt, 1972)
		Globocephaloides	soil	Yes*	Aust	(Arundel *et al.*, 1977)
		Hypodontus	soil	Yes*	Aust	(Beveridge, 1979; Speare *et al.*, 1989)
		Marsupostrongylus	vector	Yes	Aust	(Speare *et al.*, 1989)
		Strongyloides	soil	Yes	Aust	(Arundel *et al.*, 1977; Speare *et al.*, 1983)
		Echinococcus	soil	Yes*	WA	(Lymbery *et al.*, 1990)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Chiroptera	Viruses	Australian Bat Lyssavirus	animal	Yes	Qld	(Warrilow *et al.*, 2003)
Common Sheathtail Bat	Bacteria	*Leptospira*	soil; water	Yes?	Aust	(McCoy, 1974)
White-striped Bat		*Salmonella*	faecal; food; water	Yes*	Aust	(McCoy, 1974)
Inland Cave Bat		*Mycobacterium*	soil	Yes*	Aust	(McCoy, 1974)
Black Flying-fox (vagrant)	Protozoa	*Toxoplasma*	food; water	Yes	Aust	(Hoar *et al.*, 1998)
		Trypanosoma	exprmtl; vector	Yes	Aust	(Hoar *et al.*, 1998; Molyneux, 1991)
	Fungi	*Histoplasma*	soil	Yes*	Aust	(Hoar *et al.*, 1998)
		Blastomyces	soil	Yes*	Aust	(Hoar *et al.*, 1998)
		Cryptococcus	soil	Yes*	Aust	(Hoar *et al.*, 1998)
	Helminths	*Angiostrongylus*	vector	Yes	NSW, Qld	(Barrett *et al.*, 2002)
Muridae	Viruses	Mossman Virus (MoV)	?	No	Qld	(Miller *et al.*, 2003)
Barrow Island Chestnut Mouse		Murine Cytomegalovirus	animal	Yes	WA	(Moro *et al.*, 1999)
Common Rock-rat		Murine corona virus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
Water-rat		Murine rotavirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Mouse adenovirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Parvovirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Reovirus type 3	animal	Yes	SE Aust	(Smith *et al.*, 1993)
	Bacteria	*Leptospira*	soil; water	No	Qld	(Glazebrook *et al.*, 1978)
		Pseudomonas	soil; water	Yes	Qld	(Glazebrook *et al.*, 1978)
		Salmonella	faecal; food; water	Yes*	Qld	(Glazebrook *et al.*, 1978)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	WA	(Swan *et al.*, in prep.)
		Toxoplasma	food; water	Yes	WA	(Smales and Obendorf, 1996)
	Helminths	*Angiostrongylus*	vector	No	WA	(Prociv and Carlisle, 2001)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

Wallal and Warrego virus – orbiviruses responsible for kangaroo blindness throughout Australia; outbreaks have been observed in both kangaroos and euros in Western Australia (Hooper *et al.*, 1999).

Australian Bat Lyssavirus – closely related to rabies; present in numerous species of Australian bat; Black Flying-foxes (*Pteropus alecto*) are known to be infected with Australian Bat Lyssavirus (Warrilow *et al.*, 2003).

Mossman virus – a novel paramyxovirus and respiratory pathogen of both introduced and native rodents in Queensland; disease-causing potential is unclear (Miller *et al.*, 2003).

Murine Cytomegalovirus – has been detected in domestic mice in WA on Thevenard Island; no evidence of transmission to native mice and experimental infections did not produce infections (Moro *et al.*, 1999).

Murine corona virus, Murine rotavirus, Mouse adenovirus, Mouse parvovirus and Mouse reovirus type 3 – these viruses are a widespread cause of disease in domestic mice throughout south-eastern Australia; none of these viruses have been detected in surveys of domestic mice in WA (Moro *et al.*, 1999; Smith *et al.*, 1993).

4.2.1.2 Bacteria

Bacillus – enteric infection often spreading to the liver (Tyzzer's disease), spores shed in faeces are environmentally resistant for at least 12 months (Speare *et al.*, 1984).

Chlamydia – obligate intracellular pathogen causing a wide range of diseases including enteritis, respiratory disease, polyarthritis, conjunctivitis urogenital tract disease and abortion, symptoms range from inapparent through to severe in its many different host species; currently a disease of concern in reintroduced and translocated bandicoots in Western Australia (Bodetti *et al.*, 2003).

Fusobacterium – soil-borne micro-organism; causative agent of "Lumpy Jaw" in macropods, associated with various stress factors, often degenerates to terminal septicaemia in affected animals; widespread occurrence in Australia (Speare *et al.*, 1989).

Leptospira – bacterial pathogen passed in the urine of many rodents; infective to a wide range of hosts; associated with abortion in infected hosts (Speare *et al.*, 1989).

Mycobacterium – causative organism of tuberculosis, infections are generally atypical (Corner and Presidente, 1980).
Pseudomonas – associated with pouch infections leading to death of pouch young due to peritonitis and/or septicaemia (Speare *et al.*, 1984).
Salmonella – can cause gastroenteritis and septicaemia in mammals, infections appear to be related to nutritional and environmental stressors; zoonotic infections reported from marsupials in Western Australia (Iveson and Bradshaw, 1973; Speare *et al.*, 1989).

4.2.1.3 Protozoa

Babesia – blood-borne parasite associated with anaemia and post-mating mortalities in male dasyurids, may potentially facilitate other infections (Arundel *et al.*, 1977).
Cryptosporidium – can cause gastroenteritis in both young and adult animals, environmental and stress factors may influence infections, known to cause deaths in young and juvenile animals, prevalent in water sources throughout Australia (Hallier-Soulier and Guillot, 2000; Power *et al.*, 2004).
Giardia – disease symptoms range from asymptomatic to severe diarrhoea; responsible for malabsorption; common water source contaminant; human strains shown to be readily infective to bandicoots (Bettiol *et al.*, 1997).
Hepatozoon – blood borne haemogregarine, associated with decreases in body condition and anaemia in animals (Speare *et al.*, 1989).
Leishmania – causative agent of cutaneous inflammation and skin lesions in kangaroos; transmitted between hosts by sandflies, potential zoonotic pathogen (Rose *et al.*, 2004).
Toxoplasma – ubiquitous obligate intracellular parasite infective to virtually all species of warm-blooded animals, common cause of death in captive and wild Australian marsupials (Obendorf and Munday, 1990; Reddacliff *et al.*, 1993).
Trypanosoma – blood-borne parasites causing anaemia, ulcerative gastritis, enteritis and death in its hosts; prevalent throughout southeast Asia; shown to be infective to native marsupials (Bettiol *et al.*, 1998; Reid *et al.*, 2001).

4.2.1.4 Fungi

Blastomyces, ***Cryptococcus*** – fungal genera causing granulomatous disease of mucous membranes; typically acquired from direct contact with soil enriched with bat faeces (Hoar *et al.*, 1998).

Histoplasma – soil saprophyte, thrives in warm, moist environments especially if enriched with organic material; infection occurs predominantly through aerosols and direct contact with contaminated soils (Hoar *et al.*, 1998).

Microsporum, ***Trichophyton*** – soil-borne and animal associated fungi; causative agents of Ringworm; common in captive mammal species throughout Australia, though can cause infections in stressed populations (Speare *et al.*, 1989).

4.2.1.5 Helminths

Angiostrongylus – nematode parasite cycled through slugs/snails with a rodent definitive host; causes neurological disorders and mortalities in non-specific hosts such as macropods and bandicoots (Prociv and Carlisle, 2001).

Echinococcus – cestode parasite cycled between dogs and macropods; intermediate stages form large fluid filled cysts in lungs, liver and other internal organs (Lymbery *et al.*, 1990).

Globocephaloides, ***Hypodontus*** – common nematode parasites of macropods capable of causing anaemia and hypoproteinaemia; known to cause death in wild macropods (Speare *et al.*, 1989).

Marsupostrongylus – mosquito-borne lungworms often associated with a mild to severe interstitial pneumonia; severity usually determined by the number of parasites infecting the lung (Spratt, 1984).

Ophidascaris – nematode found in numerous marsupial species; pythons as definitive host; mortalities have been reported in intermediate hosts such as possums and small dasyurids due to migration of larvae within host (Speare *et al.*, 1984).

Pelecitus – blood-borne nematode; transmitted by biting tabanid flies; infection in macropod hosts ranges from asymptomatic to severe disease (Speare *et al.*, 1989).

Strongyloides – nematode parasite commonly occurring in macropods, may cause focal hyperaemia, responsible for deaths of captive macropods though usually well tolerated by host (Speare *et al.*, 1989).

4.2.2 Reptilian hosts

The abbreviated list of pathogens reported as causing disease in reptilian host species representative of the Barrow Island reptile fauna is presented in Table 6. A brief synopsis of the disease associated with each pathogen is presented below. Diseases occurring in reptile species outside of Australia may have the potential to infect Australian reptiles given their common evolutionary ancestry, however this was deemed to be outside the scope of this report as at this point in time the ports of origin of vessels supplying Barrow Island have not been confirmed. Nevertheless, it must be noted that reptiles can be brought to Barrow Island from outside Australia via equipment and vessels and may therefore act as a source of exotic reptilian disease.

4.2.2.1 Viruses

Ophidian paramyxovirus – recently reported virus affecting numerous snake species; cause of "die-offs" in viperid, elapid, boid and colubrid snakes; produces intranuclear inclusion bodies in lung and brain, respiratory disease associated with wasting and death; reported in snakes from several collections in New South Wales (Ross, 2004).
Inclusion body disease – primarily a boid-specific disease; cause of regurgitation and central nervous system signs; no available treatment and infection is invariably fatal in pythons; present in snakes in Western Australia (Bush, 2000).
Wamena virus – reported to have caused disease in a python in Queensland (Daszak *et al.*, 1999).

4.2.2.2 Bacteria

Chlamydia - obligate intracellular pathogen causing a wide range of diseases in numerous host species; symptoms range from inapparent to severe; present in reptiles in Australia (Bodetti *et al.*, 2002; Jacobson and Telford, 1990).
Dermatophilus – cause of skin disease and debilitation of crocodiles in the Northern Territory (Fenwick, pers. comm., 2004).

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Table 6. List of reptilian groups present on Barrow Island and pathogens reported as causing disease in these species elsewhere in Australia.

Group	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Lizards	Viruses	Ophidian Paramyxovirus	vector?	?	?	No reports
		Inclusion Body Disease	vector?	?	?	No reports
	Bacteria	*Salmonella*	faecal; food; water	Yes*	Aust	(Iveson *et al.*, 1969)
		Leptospira	soil; water	Yes*		No reports
		Rickettsia	vector	Yes*	Aust	(Stenos *et al.*, 2003)
		Dermatophilus	soil; animal	Yes	NT	(Fenwick pers. comm.., 2004)
	Protozoa	*Cryptosporidium*	faecal; water	Yes	Aust	(Oros *et al.*, 1998; Xiao *et al.*, 2004)
	Helminths	*Angiostrongylus*	vector	Yes	Thailand	(Radomyos *et al.*, 1994)
Snakes	Viruses	Ophidian Paramyxovirus	vector(?)	Yes	NSW	(Ross, 2004)
		Inclusion Body Disease	vector	Yes	WA	(Bush, 2000; Carlisle-Nowak *et al.*, 1998)
		Wamena virus	?	?	Qld	(Daszak *et al.*, 1999)
	Protozoa	*Cryptosporidium*	faecal; water	Yes	NSW	(Boylan *et al.*, 1985)
	Fungi	*Chrysosporium*	animal; faecal	Yes*	Qld	(Vissiennon *et al.*, 1999)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

Salmonella – cause of gastroenteritis; known to occur in reptiles in Western Australia (Iveson *et al.*, 1969).

4.2.2.3 Protozoa

Cryptosporidium – cause of chronic gastro-intestinal disease in snakes with protracted clinical disease eventually resulting in death; generally results in only subclinical infections in lizards; most reports originating from captive reptiles however survey of free-ranging reptiles in South Australia reported infections occurring in snakes (O'Donoghue, 1992; O'Donoghue, 1995).

4.2.2.4 Fungi

Chrysosporium – ubiquitous mould commonly occurring in soil, rarely disease-causing in humans and animals (Vissiennon *et al.*, 1999).

4.2.2.5 Helminths

Angiostrongylus - nematode parasite cycled through slugs/snails with a rodent definitive host, infective stages recently reported in varanid lizards from Thailand (Radomyos *et al.*, 1994).

4.2.3 Amphibian hosts

The abbreviated list of pathogens reported as causing disease in amphibian host species belonging to the family Hylidae is presented in Table 7. A brief synopsis of the disease associated with each pathogen is presented below.

4.2.3.1 Viruses

Bohle virus – highly virulent ranavirus causing systemic infections in frogs from eastern Australia; tadpoles appear to be most susceptible (Daszak *et al.*, 1999).

Table 7. List of pathogens reported as causing disease in amphibian species elsewhere in Australia that may infect *Cyclorana maini*.

Family and Species	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Hylidae	Viruses	Bohle virus	?	?	Aust	(Hengstberger *et al.*, 1993)
Cyclorana maini	Bacteria	*Chlamydia*	animal	Yes	Qld	(Berger *et al.*, 1999)
		Leptospira	soil; water	Yes*	Aust	(Charon *et al.*, 1975)
	Fungi	*Batrachochytrium*	animal	Yes	WA	(Berger *et al.*, 2000; Morell, 1999)
		Mucor	animal; faecal	Yes	Aust	(Berger *et al.*, 1997)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

4.2.3.2 Bacteria

Chlamydia – cause of a wide range of diseases in mammalian hosts; recently reported in amphibians (Berger *et al.*, 1999).

4.2.3.3 Fungi

Batrachochytrium – ubiquitous fungi found in aquatic habitats and moist soil; cause of chytridiomycosis and responsible for mass deaths in amphibans in Australia and worldwide (Daszak *et al.*, 1999).
Mucor – report of disease occurring in frogs belonging to the family Hylidae in Australia (Berger *et al.*, 1997).

4.2.4 Pathogens posing disease risks to Barrow Island fauna

Tables 5-7 are extensive lists of those micro-organisms recognised as infecting native animals but not necessarily causing disease. It is therefore important to look more closely at those that are potentially pathogenic for the vertebrate fauna on Barrow Island. In consideration of this Table 8 lists those micro-organisms that pose the greatest threat to the fauna and their potential routes of transmission. The list has been compiled based on available information from the literature. In all cases these organisms have been associated with disease on more than one occasion and most have been described in Western Australia or are suspected to be present. Details of disease syndromes and related references have already been supplied (section 4.2.1, 4.2.2 and 4.2.3). Although some of these micro-organisms do not cause severe disease the potential effects of debilitation on isolated populations are unclear. However, it must be stressed that without any background information a number of these micro-organisms may already be present on the island. Similarly, micro-organisms not on this list may also be capable of causing disease in the Barrow Island fauna.

Table 8. Pathogenic micro-organisms that pose the highest risk to the Barrow Island terrestrial vertebrate fauna.

Pathogen	Species Affected	Infection Route
Chlamydia	all	animal
Cryptosporidium	all	faecal; water
Toxoplasma	all	food; water
Salmonella	all	faecal; food; water
Wart Disease	bandicoots	animal
Wallal & Warrego virus	macropods	vector
Globocephaloides/Hypodontus	macropods	soil
Australian Bat Lyssavirus	bats	animal
Ophidian Paramyxovirus	reptiles	animal; vector(?)
Inclusion Body Disease	reptiles	animal; vector(?)
Batrachochytrium	frogs	animal
Trichophyton, Microsporum	all	animal; soil

4.2.5 Zoonotic diseases of concern on Barrow Island

Zoonoses are those infections carried by animals capable of causing disease in humans. As stated previously little is currently known of the micro-organisms on Barrow Island or their zoonotic capability (apart from the presence of Spotted Fever Group rickettsiae and *Salmonella* strains), however a number of those that could potentially establish in the wildlife and thus pose a risk are outlined in Table 9.

Previous reports of zoonotic disease on Barrow Island are limited to the possible presence of Q fever (*Coxiella burnetii*), however this caused considerable concern among the workforce in 2002 (Fenwick pers. comm., 2004). With the presence of an expanded workforce on Barrow Island a brief discussion of potential zoonotic diseases, either present or at risk of introduction, was deemed important.

Table 9. Micro-organisms that pose a zoonotic risk to the Barrow Island workforce should they be transmitted to the Barrow Island fauna.

Pathogen	Disease in Animal	Reservoir Host	Infection Route	Reference
Cryptosporidium sp.	Yes	all	faecal; water	(O'Donoghue, 1992)
Salmonella sp.	Yes	all	faecal; water	(Iveson and Bradshaw, 1973)
Coxiella	No	mammals	vector	(Fenwick pers. comm., 2004)
Spotted Group Rickettsiae	No	mammals	vector	(Fenwick pers. comm., 2004)
Ross River virus	No	macropods	vector	(Mackenzie *et al.*, 2001)
Barmah Forest virus	No	marsupials	vector	(Mackenzie *et al.*, 2001)
Murray Valley encephalitis	No	macropods	vector	(Cordova *et al.*, 2000)
Australian Bat Lyssavirus	Yes	bats	animal	(Warrilow *et al.*, 2003)

Cryptosporidium – readily transmissible between host species; highly resistant stages able to persist in environment for long periods of time; commonly found to be contaminating water sources; contact with animals is a known risk factor (Hallier-Soulier and Guillot, 2000; O'Donoghue, 1992).

Salmonella – common cause of gastroenteritis in both animals and humans; readily transmitted via food and faecal contamination; contact with marsupials has been reported as causing infection in humans in Western Australia (Iveson and Bradshaw, 1973).

Coxiella – cause of Q fever; maintained in animal and arthropod reservoirs; transmission via aerosols, dust and ticks; cause of concern on Barrow Island however organism has not been isolated; studies are ongoing as to its presence on the island (McDiarmid *et al.*, 2000; Storer *et al.*, 2003).

Spotted Fever Group Rickettsiae – tick-borne organisms causing disease in people in Australia; maintained in animal and arthropod reservoirs; transmission via tick bites; two new species recently isolated from ticks on Barrow Island, significance uncertain, further studies ongoing (Fenwick pers. comm., 2004).

Ross River virus – mosquito-borne virus causing an epidemic polyarthritis, macropods considered to be reservoir hosts, most prevalent in coastal areas and salt marshes; considered to be an emerging disease; increased awareness has lead to improved diagnosis and higher incidence of disease detection (Mackenzie *et al.*, 2001).

Barmah Forest virus – mosquito borne virus causing epidemic polyarthritis-like disease; similar to but distinct from Ross River virus; circulates between mosquitos and terrestrial animals, particularly marsupials; considered an emerging disease; increasing incidence due to greater awareness of symptoms (Mackenzie *et al.*, 2001).

Murray Valley encephalitis – mosquito-borne virus typically more prevalent throughout the Kimberley though reported as far south as the northern Goldfields in Western Australia following excessive rainfall in 2000 (Broom *et al.*, 2002; Cordova *et al.*, 2000).

Australian Bat Lyssavirus – closely related to the rabies virus; cause of illness and neurological disorders in bats; two cases of infection in humans, both resulting in fatal encephalitis; research has shown that two genetically distinguishable strains occur, one in frugivorous bats and the other in insectivorous bats; insectivorous bat colonies are present on Barrow Island and frugivorous bats have also been recorded on the island (Mackenzie, 1999; Mackenzie *et al.*, 2001).

5. Pathogen Pathways

Major transmission pathways for exotic organisms onto Barrow Island have been identified in relation to the movement of building and related materials, personnel and their belongings, and food. These pathways are common for movements between the Australian mainland, other countries and Barrow Island. In addition to higher organisms, these pathways are also potential routes for micro-organism incursions onto the island. For the purpose of this report the high risk pathogens for Barrow Island identified in Table 8 have been used as examples of how transmission onto the island might occur. Table 10 details the micro-organisms associated with each pathway and possible steps to prevent introductions. Many of the major pathways listed below are linked to each other and will be discussed in further detail.

Table 10. Potential pathways for high risk micro-organisms onto Barrow Island and recommended procedures for minimising pathogen entry.

Pathway	Pathogen	Steps to Avoid Introduction
Soil	*Globocephaloides* *Hypodontus*	Sterilisation (eg. steam or chemical) Containment of soil within development site, and isolation from island fauna
Equipment	Wart Disease Wallal & Warrego virus *Globocephaloides* *Hypodontus*	Disinfection (eg. spraying) Cleaning to remove soil Inspection for vector species prior to shipping Futher monitoring on island or at materials off-loading facility
Food	*Cryptosporidium* *Salmonella* *Toxoplasma*	Inspection of fresh produce Appropriate protocols to dispose of food scraps around camp and in the field HACCP plans at food supply areas to include steps to avoid introduction
People	*Cryptosporidium* *Salmonella* Ophidian Paramyxovirus Inclusion Body Disease Wart Disease Ringworm	Reporting of disease symptoms eg. diarrhoea Appropriate protocols for disposal of human waste, both around camp and in the field Education for workforce on risk factors involved with introductions eg. pet ownership
Personal Goods	Ophidian Paramyxovirus Inclusion Body Disease Chytridiomycosis	Disinfection protocols on arrival eg. footbaths, change of clothes Quarantine inspection Education
Transport Vessels	Wallal & Warrego virus Ophidian Paramyxovirus Inclusion Body Disease	Control of onboard vermin eg. baiting, spraying Only essential vessel landings to occur Thorough inspection of all materials carried Regular inspection of transport vessels

5.1 Soil

Soil is primarily involved in the transport of dormant or environmental stages of pathogens (eg. *Globocephaloides* and *Hypodontus* larvae, *Toxoplasma* oocysts). This can occur when soil/aggregate destined for Barrow Island is contaminated prior to its arrival on the island (eg. soil associated organisms, animal faeces). Soil can also transfer pathogens via infected vector species (both vertebrate and invertebrate). For example, the mechanical transmission of *Toxoplasma gondii* has been demonstrated with earthworms and cockroaches (Bettiol *et al.*, 2000; Wallace, 1972).

5.2 Equipment

The movement of equipment onto Barrow Island can facilitate the transport of micro-organisms via soil, animals or insect vectors. Strategies to prevent animal incursions and soil contamination are currently under review. Insect vectors such as mosquitoes can be trapped inside vehicles and their larvae can be present in puddles of water present inside vehicle tyres or other equipment. Additionally, vertebrate animals including mammals and reptiles can also be introduced via equipment, particularly in large prefabricated modules stored for long periods of time prior to shipping to Barrow Island. Invertebrate vectors such as mosquitoes, ticks and fleas can potentially introduce a number of infections identified in the high risk and zoonotic lists (Table 8 and 9).

5.3 Food

Micro-organisms capable of causing disease in wildlife are commonly found in unprocessed foodstuffs such as meat and fresh produce (eg. *Toxoplasma*, *Salmonella*), and this may pose a significant risk to the Barrow Island fauna. While food brought onto the island for the workforce should be strictly controlled, it may still be contaminated with micro-organisms. Therefore, food scraps fed to animals in the camp or transported outside the camp by birds or people may also transmit these micro-organisms to animals. Uncontrolled routes also exist whereby food can be brought onto the island (eg. inadvertent or smuggled introductions by workforce or disposal from nearby vessels), and these may pose an even greater risk to the Barrow Island wildlife. Finally, invertebrate vectors capable of transmitting disease (eg. cockroaches, flies), may be brought onto the island inside shipments of food.

5.4 People and personal goods

People are capable of transmitting micro-organisms either directly (eg. *Salmonella*, *Cryptosporidium*) or indirectly via vectors (eg. ticks fleas) or contaminated clothing and/or personal goods (eg. viruses, ringworm fungi). These introductions would for the most part be inadvertent and can be controlled by appropriate education and inspection protocols. It must be noted that people are also capable of introducing micro-organisms via smuggled goods such as food, soil contaminated personal goods or (rarely) animals, although similar procedures to those mentioned above should prevent this from occurring.

5.5 Transport vessels

As with the previous pathways, transport vessels may introduce micro-organisms via soil contaminated equipment, invertebrate vectors or vertebrate hosts. Appropriate quarantine strategies should significantly reduce the risk, however monitoring procedures as discussed in the recommendations (section 7) should be put in place. Of particular concern is the issue of privately owned watercraft landing on Barrow Island without being subject to any of the above mentioned quarantine procedures or restrictions. The current development of the Montebello and Barrow Islands Marine Conservation Reserves will result in an increased number of privately owned watercraft visiting the region. With this will come a significant increase in the number of watercraft wishing to make landfall on Barrow Island. If these are not subject to the same quarantine restrictions and procedures as the transport barges ferrying goods and equipment to the island, then these watercraft greatly increase the chance of a quarantine breach and foreign organism introduction(s). The potential for these events to occur puts the Barrow Island wildlife at risk.

5.6 Other pathways

Other pathways with the potential to introduce pathogens onto Barrow Island include: strandings of cetaceans (eg. whales, dolphins) and the "hauling out" of pinnipeds (eg. seals, sea-lions) on the beaches; transmission of disease by wild/migratory birds; and the washing ashore of storm debris (either from the mainland or other islands).

Although these are not deemed to pose a major risk for micro-organism introductions to Barrow Island, they still warrant consideration.

6. Conclusions

6.1 Predisposition of Barrow Island vertebrate fauna to disease

Being an island population, the Barrow Island fauna is isolated from other wildlife populations therefore the opportunities for the introduction of infections from outside are severely limited. In some respects this can be seen as beneficial, as island populations generally only have to deal with a subset of the diseases that their mainland counterpart populations have to. However, this reduced level of challenge can often lead to immunologically naïve populations that, when faced with new or even endemic infections, may suffer much higher levels of mortality and morbidity than do their mainland counterparts that are frequently challenged.

6.2 Genetic bottle neck experienced after separation of Barrow Island from Australian mainland has resulted in a genetically depauperate terrestrial vertebrate fauna

Small island populations isolated for long periods of time, such as those on Barrow Island, typically experience a reduction in genetic diversity due to a lack of "fresh" genetic material in the form of individuals moving between populations. This inbreeding can manifest in numerous ways, such as the reported anaemic status of the island's larger mammal species. The probable genetic homogeneity of the Barrow Island fauna means that if a disease has a debilitating effect on one individual, there is a much greater chance that it will have the same effect on the rest of the population. Thus, the risk of a catastrophic depopulation of a species on the island, following the introduction of what may well be deemed a benign disease, is increased.

6.3 Insufficient data available regarding micro-organisms associated with the vertebrate fauna on Barrow Island

Clearly this report is principally literature-based and relies on the supposition that many of the micro-organisms reported from mainland fauna are transmissible to the Barrow Island fauna. However, the almost complete lack of information regarding micro-organisms present in the vertebrate fauna on Barrow Island (coupled with the dearth of information regarding pathogens and native fauna in general) severely limits the effectiveness of any assumptions made in this regard. As a consequence, the limited data available regarding those species of micro-organism already present on Barrow Island means that in the event of a disease outbreak in the vertebrate fauna, Gorgon would have difficulty in determining whether it was due to an introduced or an endemic pathogen.

6.4 Zoonotic diseases and occupational safety

This report has identified a number of zoonotic diseases that are either present in the wildlife or that could potentially be introduced to Barrow Island. Many of these that are currently of little significance may be of greater concern given the much larger workforce that will be required to construct the gas processing facility. Additionally, the potential for people infected with zoonotic infections arriving for work on the island should not be overlooked, as many of these diseases have incubation periods during which infection is not noticeable or detectable. Given the presence of ticks and mosquitos on Barrow Island, there is significant potential for the fauna to act as a reservoir for many of these diseases, some of which may also cause disease in the vertebrate fauna, particularly those populations under stress. As with other micro-organisms, there is little data available on the presence of zoonotic pathogens on the island however studies are underway to investigate the status of tick-borne infections and their potential to cause occupational diseases.

6.5 Risk of introduction of exotic micro-organisms to Barrow Island

While it is impossible to completely exclude the introduction of 'exotic' micro-organisms onto the island, the risks of introducing micro-organisms potentially pathogenic for the terrestrial vertebrate fauna is considered to be low. However, this is reliant upon appropriate quarantine strategies and effective surveillance and monitoring systems being installed. Although a number of pathways by which micro-organisms might gain access to Barrow Island have been identified, the most likely pathways for micro-organism incursions onto the island are considered to be people (including personal goods) and foodstuffs. This view is based on three factors: i) the relative ease with which all other materials can be exposed to high levels of inspection, cleansing and disinfection; ii) the reduced ability of other materials to support viable stages of pathogenic micro-organisms and iii) the documented role of animals and foodstuffs in the frequent transmission of pathogens.

7. Recommendations

The importance of disease in wildlife populations, particularly in pristine environments such as Barrow Island, is of growing concern and must be approached in a methodical and thorough manner. Two examples are the recent reports on the risk assessments for introducing non-indigenous species to Heard and McDonald Islands (Chown, 2003) and diseases of Antarctic wildlife (Australia, 2001). The recommendations arising from the current report deal primarily with the biosecurity of Barrow Island, the health of the native terrestrial fauna and the health and safety of the future Gorgon workforce.

7.1 Biosecurity

7.1.1 Background information on the terrestrial fauna and their endemic micro-organisms

At present there is practically no information available regarding micro-organisms present in the vertebrate fauna or the environment on Barrow Island. As such, a disease outbreak would have to be considered to be associated with an introduced infection. To combat this, it is vital that baseline data is acquired on potentially pathogenic micro-organisms already present in the wildlife. In addition, as a complete census of the Barrow Island fauna has not been performed, it would be advisable to discuss ways of getting accurate population figures in order to monitor the ongoing status of the endemic populations. Such information would be extremely valuable in the unlikely event of a disease occurrence on the island and would help to provide the company with information to refute claims of negligence.

7.1.2 Monitoring of mainland quarantine sites for infections in potential vector species

Whilst a baseline survey of micro-organisms in the Barrow Island vertebrate fauna is considered important for the management of biosecurity on the island, this only addresses post-border quarantine issues. To properly manage the quarantine and biosecurity of Barrow Island an understanding of the micro-organisms occurring in potential vector species present at pre-border quarantine sites is also of high importance. Knowledge of the presence/absence of micro-organisms in potential vector species (rats, mice, mosquitoes, tabanid flies etc) at and around pre-border quarantine sites (i.e. Welshpool, Onslow, Dampier) allows risk assessments to be made regarding current practices, and supports the implementation of pro-active quarantine control measures. Whilst it is recognised that the level of quarantine management is such that the possibility of invasive species landing on Barrow Island is extremely low, the risk of micro-organisms being transported to Barrow Island in goods containing vector species still exists. Therefore, an assessment and ongoing monitoring of the micro-organisms present at these quarantine sites should be an important part of the biosecurity programme.

7.1.3 Disease surveillance system

It is well recognised that countries which conduct disease surveillance of their wild animal populations are more likely to detect the presence of infectious and zoonotic diseases and to swiftly adopt counter measures (Morner *et al.*, 2002). However, it is intrinsically more difficult to monitor diseases in wildlife than in domestic animals, as sampling opportunities may only occur at selected times or locations. In addition, the occurrence of disease in wildlife populations is not static, and the Barrow Island fauna experiences a seasonal exposure to biting arthropods as well as nutritional and environmental stresses. Thus, the development of surveillance and monitoring programmes is a vital first step towards providing an appropriate level of understanding of the health status of wildlife populations. Aspects of a surveillance system for disease on Barrow Island would include the collection and analysis of opportunistic wildlife samples from road kill and other animal mortalities, which, provided relevant information relating to the findings is collected and stored for future reference, will help to create a comprehensive database over time. Additionally, regular health monitoring, as outlined below, should also be established for the terrestrial vertebrate fauna on Barrow Island. The development of both passive and active surveillance systems for disease on the island will assist in the long term protection of the Barrow Island fauna.

7.1.4 Health monitoring of Barrow Island vertebrate fauna

Monitoring of the vertebrate fauna for a range of micro-organisms should be performed twice a year if possible (during spring and autumn to compensate for any seasonal fluctuations in pathogen prevalence). This would entail trapping and the collection of faecal, blood and ectoparasite (ticks and fleas) samples from the vertebrate fauna to allow the detection of micro-organisms of potential concern. As regular population monitoring is performed by DCLM, health monitoring should be integrated with this and other animal-associated activities as far as possible to reduce the stresses on the animals. Analysis of information gained through monitoring would assist in the anticipation of mortality events or adverse health problems.

7.1.5 Laboratory development

While the analysis of samples from the monitoring would usually be performed in mainland laboratories, improvements to the laboratory facility present at the current camp on Barrow Island is highly recommended. This facility could become a designated area on the island for disease/quarantine matters to be investigated, and would include offices for quarantine staff, repositories for storage of opportunistic samples (e.g. roadkills, suspicious deaths) and laboratory space for visiting researchers and monitoring personnel.

7.1.6 Contingency plans in the event of a suspected wildlife mortality event

In a setting such as Barrow Island it is highly likely that non-specialist personnel will discover an unusual morbidity, mortality or disease event in the wildlife. In such an event it is necessary to be able to contact and relay information and instructions to specialists with regard to the correct sampling and storage of specimens (Morner *et al.*, 2002). The drafting of policies and regulations to be followed in the event of an incident or disease epidemic occurring on the island (e.g. contacts of relevant scientists/institutes, types of samples and information to be collected, informing and liaising with island personnel, overseeing occupational safety issues etc.) will improve the capability of researchers to respond to such incidents. Therefore, it is recommended that dedicated quarantine officers should be employed and be present on the island at all times. These employees will undergo training in the correct procedures to follow should an incident occur (eg. potential vector species brought onto island, unexplained mortalities observed), will have the ability to liaise with visiting scientists in regard to quarantine and disease issues on the island and will ensure that as much relevant data relating to the incident is collected as possible including GIS data. The quarantine officers will liaise with the medical staff on the island to ensure that potential infections in the workforce related to animal contact are also investigated and prevented and will be involved in the ongoing education of the workforce on biosecurity issues.

7.1.7 Education of the workforce

Increasing the understanding of the workforce as to the importance of Barrow Island biosecurity with regard to micro-organisms in addition to the plant and vertebrate pest species is vital, as they are potentially the "eyes and ears" of the quarantine management strategies. Information regarding not only the key species of concern and the company's quarantine strategies, but also the correct procedure(s) to follow in the event of an incident or observation should be an integral component of the induction process. Examples of this would be the discussion of contact details for quarantine officer(s) and the procedures for dealing with road-kill incidents and observed mortality events. As discussed later, health protection strategies for those in contact with animals should also be stressed.

Regular on-site meetings or seminars to discuss wildlife and quarantine issues would be important to get the support of the workforce. For example, these could identify risk factors for bringing disease onto the island or the possibility of diseases associated with handling animals, both on and off the island. Such information sessions could be used to alert workers who have visited Queensland within the last two weeks to the potential for presenting with symptoms of tick typhus or Q fever, those from the southwest of Western Australia to the possible exposure to Ross River virus, and even workers from Southeast Asia to the potential risk of tropical zoonoses. Other information could include the risks associated with handling pets at home and the potential for bringing disease or disease vectors (reptile viruses, cat fleas) onto the island on themselves or on personal equipment. This type of education should not be alarmist but should help the workforce to be aware of disease issues and of their role in keeping the island's biosecurity intact.

7.1.8 Footbaths at airport

Use of disinfectant footbaths at the airport would play an important part in decreasing the risk of soil-borne pathogens coming onto Barrow Island, and would serve as a physical reminder to the workforce of the importance Gorgon places on quarantine.

This would supplement the use of educational media (posters, leaflets etc.) on the island highlighting the importance of quarantine and informing the workforce of the correct steps to take in the event of a perceived quarantine breach.

7.1.9 Foodstuffs

Alcohol is not permitted to be brought onto Barrow Island and the same should apply to food regardless of whether it was sourced from the local shop in Perth or the back yard garden. Food (fresh or packaged) can act as an ideal transport medium for agents potentially infectious for both wildlife and people, and all food brought onto the island should be subject to the same quarantine procedures. Bringing home grown foodstuffs onto Barrow Island circumvents existing quarantine procedures and would greatly increase the risk of micro-organisms coming onto the island. Therefore, food should only be brought onto Barrow Island via supplies for the mess, with any alternate or unusual food wanted on the island by the workforce to be requested via the kitchen staff.

One area of concern is the removal of food from the mess and its discard in areas where it might be scavenged by wildlife. This includes both the camp area and the field. While it is not intended to prevent food removal from the mess for future consumption, education of the workforce as to the consequences of discarded food scraps should be a priority. Specialised containers for disposal of such scraps could also be included around the camp and in vehicles.

Provisions for the disposal of kitchen scraps are already in place on the island, with incineration being the method of choice, however, with the expanded workforce consideration should be given to the significant increase in waste that will occur.

7.1.10 Reducing contact between wildlife and the workforce

Isolation of the work camp from the Barrow Island environment and fauna will reduce the potential for pathogens being transmitted to the wildlife and will create a designated border/post-border quarantine area. Vermin-proof fencing around the processing, equipment and camp areas, coupled with electrified pads at entry points, would provide a physical barrier that would prevent the escape of any potential vertebrate vectors onto the island and aid in keeping the workforce and native fauna separated. While it is pleasant for the workforce to be surrounded by animals such as bandicoots in the camp area, their presence and their scavenging habits could compromise the quarantine strategies being developed. As foodstuffs are considered to be one of the most important pathways for potential pathogens onto the island, stores should be vermin and wildlife-proof.

7.1.11 Sewage disposal

In addition to physical separation of people and animals, consideration must also be given to the separation of human waste from the environment. Current procedures incorporate a closed effluent disposal and treatment system however, as discussed previously the expansion of the workforce necessitates careful planning to ensure that biosecurity is not compromised. Regular monitoring of the effluent for potential pathogens (e.g. *Salmonella*, *Cryptosporidium*) following treatment should be included in the island's disease surveillance strategy.

7.1.12 Provision for other potential breaches of biosecurity

A number of potential pathways for micro-organisms to enter the island exist that are difficult to control. These include migratory birds, bats and aquatic mammals. In addition, unlawful landing of tourist boats onto the island could compromise the island's biosecurity. Provision should be made for the monitoring of migratory bird and bat populations for micro-organisms if possible, and stranded aquatic mammals should be removed immediately, or if dead, be subject to inspection and sampling by the quarantine officer. To prevent unlawful landings, material could be developed for dispersal via tour operators, local marinas and the media.

7.2 Health and Safety

7.2.1 Health monitoring of Barrow Island workforce

Workers on Barrow Island suffering diarrhoeal illness should be encouraged to report this to the medical personnel on site and to have samples taken for analysis if possible. This would assist in the monitoring for infectious organisms such as *Salmonella* and *Cryptosporidium* on the island, and is a standard practice within the meat and food industries.

7.2.2 Potential zoonotic infections in the Barrow Island workforce

Potential zoonotic infections have been listed in Table 9. While these are not likely to be a major cause for concern, education programs regarding their presence, methods of transmission and control would be useful. Additionally, in the light of previous concerns over Q fever in the workforce on Barrow Island and the presence of Spotted Fever Group rickettsiae in ticks it would be useful for all new long term or high risk workers (those working in tick infested areas) to undergo pre-employment blood tests with serum stored for future reference. Whether this was made a mandatory requirement is up to the company to decide.

Due to the morbidity currently associated with tick bites in employees on the island it is considered important to investigate the ecology of ticks and the incidence of tick bites, particularly if infections are likely to be present in these ticks. Some data has been gathered on tick bites in conjunction with the company medical staff however more comprehensive studies are required. This can be done in association with the current study of ticks on the mammalian fauna.

7.2.3 Portable toilets for “off-site” work groups

Faecal contamination of the environment has been identified as an important pathway of infection for the vertebrate fauna of Barrow Island. Pathogens such as *Cryptosporidium* and *Salmonella* species are capable of being transmitted directly from the workforce to the fauna should employees openly defecate in the environment. With the current workforce on Barrow Island of approximately 100 employees, this is not a common occurrence. However, with an increase to potentially 3000 employees on the island and "off-site" work groups (i.e. construction crews building the overland pipeline), this becomes a potentially significant pathway for micro-organisms to be transmitted to the native fauna. Portable chemical toilets should accompany groups of workers who will be working away from toilet facilities.

7.2.4 Contact between workforce and wildlife

Preventing the potential transmission of micro-organisms or vectors from the workforce to the Barrow Island wildlife requires limiting the interface between the two. This would mean that situations such as the presence of golden bandicoots in the wet mess area and around the entrance to the mess/kitchen need to be controlled. Although the close proximity and interaction of this novel and enjoyable experience does much to foster an appreciation for the wildlife amongst the workforce, it is also potentially an avenue for the transmission of disease from people to the wildlife and vice versa.

Personal clothing brought onto the island has the potential to transmit micro-organisms, particularly where it belongs to workers who have pets or regular contact with animals at home. If possible casual clothing should be either freshly laundered or left off the island and be provided by the company.

8. Contacts and Acknowledgements

The following institutions and organizations were contacted over the course of this review for the purpose of obtaining information over the course of this report. These institutions are not listed in any particular order.

Australian Wildlife Health Network
Department of Conservation and Land Management
Agricultural Department of Western Australia
Perth Zoo
Taronga Park Zoo
Armadale Reptile and Wildlife Centre
ChevronTexaco Australia Pty. Ltd.

The following people need to be acknowledged for their assistance in providing information pertaining to this report. These people are acknowledged in no particular order.

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Dr Kristin Warren
Professor Mal Nairn
Dr Rupert Woods
Ms Jenny Mills
Ms Joanne Smith
Mr Russell Hobbs
Ms Felicity Donaldson
Dr David Obendorf

9. Feedback

Over the course of this report we have received feedback and comment from numerous people with various backgrounds. Of particular note was an email received, following a request for information on the Australian Wildlife Health Network, from Dr David Obendorf who has been involved in wildlife disease research in Australia since the early 1970's and has published numerous papers in this field. In his email, Dr David Obendorf made some valuable suggestions and raised several important issues, and as such we feel that the inclusion of his email in this report is both pertinent and warranted.

Date: Thu, 1 Jul 2004 23:13:39 + 1000
From: David Obendorf <davidobendorf@tassie.net.au>
To: padams@central.murdoch.edu.au
Cc: rwoods@zoo.nsw.gov.au
Subject: Response to the posting with AWHN

Dear Peter,

I was interested to read your request for assistance in relation to monitoring of wildlife diseases and pathogens on Barrow Island WA.

I congratulate you on contemplating doing such a study!

I'm guessing that this might be a baseline study for any pre-existing disease-causing agents and pathogens of native fauna – focussing on the significant ones.

I have had a long-standing interest in wildlife disease monitoring, and I sense that islands with unique ecologies and high biodiversities are really great places to strategically test biosecurity theory about quarantine and containment capabilities.

One of the potential difficulties in any such study aiming to assess the microbiological biodiversity of a diverse population of terrestrial vertebrates (mammals, reptiles, amphibians and ?birds) is the need for a range of specialist diagnostic capabilities you might use to test.

In a remote area you almost need a mini-diagnostic lab or the ability to get samples to existing labs.

Yes, you might focus on significant pathogens already identified and/or isolated from related species or in animals interacting with human & synanthropic hosts (like introduced rodents, feral cats, dogs and livestock species).

I would commend you to a paper I co-authored a few years ago for the OIE. ['Surveillance & monitoring of wildlife disease' 2002 by Torsen Morner, David Obendorf, Marc Artios and Michael Woodford, Rev. Sci. Tech. Off. Int. Epiz. **21(1)**]. In it we try to explain the need to take advantage of opportunistic mortality & morbidity events involving wildlife – either in multiple-animal events or from a series of point incidents over time. We also highlight the value of retrospective databases and historical searches for case pathologies or investigations which assist with the direction of prospective research studies.

Cutting to the chase, you might need to initially focus [on] one or two indicator host species as *case species studies*. They could be chosen on the basis of population size, sheer biomass impact on the island ecology, possible interface potential between the humans & their synanthropes (if there are any) or maybe just because they are a threatened species.

As we explain in our paper overt disease expression causing morbidity or mortality is usually the first indication that a new pathogen might have arrived <u>or</u> that epizootiological factors in the population are favouring the expression of a pre-existing endemic pathogen.

It is always easier to work from a clinical malady involving wildlife to defining the pathological diagnosis, then the aetiological diagnosis (i.e. possible exogenous pathogen) and finally the pathogenesis of infection and epidemiology. You need to be also lucky to have access to good samples and that isn't that easy with wildlife investigation in hot climates!

Just screening for a range of microbes can be done but it takes up lots of resources and usually can only focus on the easily recoverable (parasites), culturable (fungi & clinical bacteria and possibly some viruses).

Your access to animals for bleeding, necropsy examination or parasite sampling will be critical to how much you can realistically achieve in any short-term study.

Maybe serum & tissue can [be] collected and banked for retrospective screening when you do have a mass mortality or morbidity event.

You can almost guarantee that the microbial biodiversity of Barrow Island vertebrates will be quite large indeed.

Microbes that might be useful to assess include *Salmonella* (by faecal culture)…I understand that Quokkas on Rottnest Island have a high prevalence of this gut bug. But this type of survey might only be an incidental finding. It would need to be linked to something epidemiological.

The questions I would first ask is:

1. Are there any known disease-causing pathogens associated with mortality or morbidity in any Barrow Island animals?

2. On mainland WA are there any disease-associated *threatening processes* that have caused the decline of similar species that also exist on Barrow Island? If so, do these organisms *per se*, or their vectors, pose a biosecurity entry/establishment & spread risk to the island?

By adopting this approach you might focus on highly significant pathogens in any initial screening efforts. It is likely to appeal to WA Conservation Authorities as well!

Or you might decide to look for a novel (& high profile) virus such as Bat Lyssavirus, or arboviruses by serology through collaboration with a reference laboratory.

Any pathogen screening of a wide range of terrestrial fauna, in my opinion, needs to be strategic and focussed on potential biodiversity risks of pathogen introductions with new animals, insect vectors or breakdowns in island quarantine protocols.

Keep me posted on your work.

Best of luck with your studies,

Regards

David Obendorf

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Appendix 1

Extended list of micro-organism genera reported as occurring in those mammalian hosts belonging to the taxonomic groups outlined below in Australia.

	Mammals		
	Dasyuridae (Dasyurids)		
Viruses	No Records		
Bacteria	*Chlamydia*	*Leptospira*	*Salmonella*
Protozoa	*Babesia*	*Hepatozoon*	*Toxoplasma*
	Cryptosporidium	*Klossiella*	
	Giardia	*Sarcocystis*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Fibricola (T)*	*Pelecitus (N)*
	Anatrichosoma (N)	*Filaria (N)*	*Peramelistrongylus (N)*
	Angiostrongylus (N)	*Filaroides (N)*	*Pharyngostomoides (T)*
	Anoplotaenia (C)	*Gigantorhynchus (A)*	*Physaloptera (N)*
	Antechiniella (N)	*Gnathostoma (N)*	*Plagiorchis (T)*
	Antechinostrongylus (N)	*Gongylonema (N)*	*Pseudoleucochloridium (T)*
	Australiformis (A)	*Hymenolepis (C)*	*Pseudorictularia (N)*
	Baylisascaris (N)	*Inglechina (N)*	*Psilorchis (T)*
	Brachylaima (T)	*Linstowia (C)*	*Seurechina (N)*
	Brachylecithum (T)	*Mackerrastrongylus (N)*	*Spirometra (C)*
	Breinlia (N)	*Maritrema (T)*	*Spirura (N)*
	Capillaria (N)	*Marsupostrongylus (N)*	*Sprattellus (N)*
	Cercopithifilaria (N)	*Mehlisia (T)*	*Sprattia (N)*
	Choanotaenia (C)	Metacestode (C)	*Strongyloides (N)*
	Coelomotrema (T)	*Metaplagiorchis (T)*	*Synhimantus (N)*
	Copemania (N)	*Metathelazia (N)*	*Taenia (C)*
	Cyathospirura (N)	*Mirandula (C)*	*Tetrabothriostrongylus (N)*
	Cylicospirura (N)	*Nasistrongylus (N)*	*Trichinella (N)*
	Dasyurotaenia (C)	*Neodiplostomum (T)*	*Trichuris (N)*
	Denticulospirura (N)	*Oochoristica (C)*	*Woolleya (N)*
	Dessetostrongylus (N)	*Ophidascaris (N)*	*Zonorchis (T)*
	Dipetalonema (N)	*Parastrongyloides (N)*	
	Echinonema (N)	*Patricialina (N)*	
	Peramelidae (Bandicoots)		
Viruses	Arbovirus (Ross River virus)	Wart disease - Papilloma-like virus	
Bacteria	*Chlamydia*	*Salmonella*	*Serpulina*
Protozoa	*Babesia*	*Entamoeba*	*Theileria*
	Cryptosporidium	*Hepatozoon*	*Toxoplasma*
	Giardia	*Klossiella*	*Trypanosoma*
	Eimeria	*Sarcocystis*	

Fungi	No Records		
Helminths	*Abbreviata (N)*	*Fibricola (T)*	*Ophidascaris (N)*
	Angiostrongylus (N)	*Filostrongylus (N)*	*Parastrongyloides (N)*
	Asymmetracantha (N)	*Heterakis (N)*	*Peramelistrongylus (N)*
	Australiformis (A)	*Hymenolepis (C)*	*Physaloptera (N)*
	Bashkirovitrema (T)	*Labiobulura (N)*	*Plagiorhynchus (A)*
	Beveridgiella (N)	*Linstowia (C)*	*Platynosomum (T)*
	Brachylaima (T)	*Mackerrastrongylus (N)*	*Spirometra (C)*
	Breinlia (N)	*Marsupostrongylus (N)*	*Sprattia (N)*
	Capillaria (N)	*Mehlisia (T)*	*Strongyloides (N)*
	Cercopithifilaria (N)	*Metathelazia (N)*	*Tetrabothriostrongylus (N)*
	Cylicospirura (N)	*Mirandula (C)*	*Trichuris (N)*
	Dipetalonema (N)	*Nicollina (N)*	*Woolleya (N)*
	Echinonema (N)	*Oochoristica (C)*	
	Phalangeridae (Possums)		
Viruses	No Records		
Bacteria	*Bacillus*	*Leptospira*	*Pseudomonas*
	Chlamydia	*Mycobacterium*	
Protozoa	*Cryptosporidium*	*Hepatozoon*	*Toxoplasma*
	Eimeria	*Leshmania*	*Trypanosoma*
	Giardia	*Sarcocystis*	
Fungi	No Records		
Helminths	*Adelonema (N)*	*Echinococcus (C)*	*Parastrongyloides (N)*
	Amplicaecum (N)	*Fasciola (T)*	*Paraustrostrongylus (N)*
	Angiostrongylus (N)	*Filarinema (N)*	*Patricialina (C)*
	Anoplotaenia (C)	*Filostrongylus (N)*	*Profilarinema (N)*
	Bertiella (C)	*Gongylonema (N)*	*Protospirura (N)*
	Breinlia (N)	*Marsupostrongylus (N)*	*Sprattia (N)*
	Capillaria (N)	*Nematodirus (N)*	*Strongyloides (N)*
	Cooperia (N)	*Odilia (N)*	*Toxocara (N)*
	Dipetalonema (N)	*Ophidascaris (N)*	*Trichostrongylus (N)*
	Potoroidae (Bettongs)		
Viruses	No Records		
Bacteria	*Chlamydia*	*Salmonella*	
Protozoa	*Cryptosporidium*	*Klossiella*	*Toxoplasma*
	Eimeria	*Sarcocystis*	
	Giardia	*Theileria*	
Fungi	No Records		

Helminths	*Anoplotaenia (C)*	*Dasyurotaenia (C)*	*Paraustrostrongylus (N)*
	Angiostrongylus (N)	*Filarinema (N)*	*Peramelistrongylus (N)*
	Australiformis (A)	*Globocephaloides (N)*	*Potorostrongylus (N)*
	Breinlia (N)	*Gongylonema (N)*	*Potoxyuris (N)*
	Calostaurus (C)	*Hymenolepis (C)*	*Progamotaenia (C)*
	Capillaria (N)	*Labiostrongylus (N)*	*Raillietina (C)*
	Cloacina (N)	*Mastophorous (N)*	*Strongyloides (N)*
	Corollostrongylus (N)	*Ophidascaris (N)*	*Trichuris (N)*
	Macropodidae (Macropods)		
Viruses	Ross River virus	Foot and Mouth Disease	Mucosal Disease Virus
	Macropod Herpesvirus	Murray Valley encephalitis	Encephalomyocarditis virus (EMCV)
	Macropod Pox Virus	Wallal and Warrego virus	
Bacteria	*Chlamydiales*	*Leptospira*	*Salmonellae*
	Coxiella	*Mycobacteria*	*Tetanus*
	Fusobacterium	*Rickettsia*	
Protozoa	*Acanthamoeba*	*Globidium*	*Monocercomonas*
	Babesia	*Hammondia*	*Pfeifferinella*
	Cryptosporidium	*Heterotricha*	*Pneumocystis*
	Cycloposthium	*Ileocystis*	*Retortomonas*
	Dasytricha	*Isotricha*	*Sarcocystis*
	Eimeria	*Klossiella*	*Toxoplasma*
	Entamoeba	*Leishmania*	*Trichomonas*
	Entodinium	*Lymphocystis*	*Trypanosoma*
	Giardia	*Macropodinium*	
Fungi	*Microsporum*	*Trichophyton*	

Helminths	*Alocostoma (N)*	*Fasciola (T)*	*Pelecitus (N)*
	Amphicephaloides (N)	*Filarinema (N)*	*Pharyngostrongylus (N)*
	Angiostrongylus (N)	*Filaroides (N)*	*Physaloptera (N)*
	Anoplotaenia (C)	*Foliostoma (N)*	*Physocephalus (N)*
	Antechinostrongylus (N)	*Gemellicotyle (T)*	*Polydelphis (N)*
	Arundelia (N)	*Globocephaloides (N)*	*Popovastrongylus (N)*
	Austrostrongylus (N)	*Gongylonema (N)*	*Progamotaenia (C)*
	Bancroftiella (C)	*Hypodontus (N)*	*Rugopharynx (N)*
	Baylisascaris (N)	*Labiostrongylus (N)*	*Rugostrongylus (N)*
	Beveridgea (N)	*Macropicola (N)*	*Spirostrongylus (N)*
	Breinlia (N)	*Macroponema (N)*	*Strongyloides (N)*
	Calostaurus (C)	*Macropostrongyloides (N)*	*Sutarostrongylus (N)*
	Capillaria (N)	*Macropostrongylus (N)*	*Taenia (C)*
	Cassunema (N)	*Macropotrema (T)*	*Tethystrongylus (N)*
	Cloacina (N)	*Macropoxyuris (N)*	*Thallostonema (N)*
	Coronostrongylus (N)	*Maplestonema (N)*	*Thylonema (N)*
	Cosmostrongylus (N)	*Marsupostrongylus (N)*	*Thylostrongylus (N)*
	Cyclostrongylus (N)	*Monilonema (N)*	*Thysanotaenia (C)*
	Cylicospirura (N)	*Ophidascaris (N)*	*Trigonostonema (N)*
	Dasyurotaenia (C)	*Papillostrongylus (N)*	*Triplotaenia (C)*
	Dipetalonema (N)	*Paralabiostrongylus (N)*	*Wallabinema (N)*
	Dorcopsinema (N)	*Paramacropostrongylus (N)*	*Woodwardostrongylus (N)*
	Dorcopsistrongylus (N)	*Parapharyngostrongylus (N)*	*Zoniolaimus (N)*
	Durikainema (N)	*Pararugopharynx (N)*	
	Echinococcus (C)	*Parazoniolaimus (N)*	
	Chiroptera (Bats)		
Viruses	Australian Bat Lyssavirus	Hendra virus	
	Menangle virus	Nipah virus	
Bacteria	*Borrelia*	*Leptospira*	*Shigella*
	Coxiella	*Mycobacterium*	
	Escherichia	*Salmonella*	
Protozoa	*Eimeria*	*Polychromophilus*	*Trypanosoma*
	Haemosporidia	*Toxoplasma*	
Fungi	*Blastomyces*	*Cryptococcus*	*Scopulariopsis*
	Candida	*Histoplasma*	*Sporotrichum*
Helminths	*Angiostrongylus*		

	Muridae (Rodents)		
Viruses	Minute virus of mice (MVM)	Mouse hepatitis virus (MHV)	Murine reovirus (reo3)
	Mouse adenovirus (MAdV)	Murine cytomegalovirus (MCMV)	Murine rotavirus
Bacteria	*Leptospira*	*Pseudomonas*	*Salmonella*
Protozoa	*Acanthamoeba*	*Eperythrozoon*	*Plasmodium*
	Babesia	*Giardia*	*Sarcocystis*
	Bartonella	*Hammondia*	*Spironucleus*
	Besnoitia	*Hepatozoon*	*Toxoplasma*
	Cryptosporidium	*Hexamita*	*Trichomonas*
	Eimeria	*Klossiella*	*Trypanosoma*
	Entamoeba	*Naegleria*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Hepatojarakus (N)*	*Pseudoporrorchis (A)*
	Amplicaecum (N)	*Hymenolepis (C)*	*Raillietina (C)*
	Angiostrongylus (N)	*Mastophorus (N)*	*Rictularia (N)*
	Ascaris (N)	*Microphallus (T)*	*Spirometra (C)*
	Ascarops (N)	*Moniliformis (A)*	*Spirura (N)*
	Aspiculuris (N)	*Monopylidium (C)*	*Strongyloides (N)*
	Capillaria (N)	*Neoascaris (N)*	*Syphacia (N)*
	Choanotaenia (C)	*Neodiplostomum (T)*	*Taenia (C)*
	Cosmocephalus (N)	*Nippostrongylus (N)*	*Toxocara (N)*
	Echinococcus (C)	*Odilia (N)*	*Trichostrongylidae (N)*
	Eucoleus (N)	*Oligorchis (C)*	*Trichosomoides (N)*
	Fibricola (T)	*Physaloptera (N)*	*Trichuris (N)*
	Ganguleterakis (N)	*Plagiorchis (T)*	
	Gongylonema (N)	*Protospirura (N)*	

Letters in parentheses indicate major taxonomic groups for helminth parasites.

A = Acanthacephala

C = Cestoda

N = Nematoda

T = Trematoda

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Appendix 2

Extended list of micro-organism genera reported as occurring in both lizards and snakes in Australia.

	Reptiles		
	Lizards		
Viruses	Adenoviridae	Iridoviridae	Polyomaviridae
	Herpesviridae	Ophidian Paramyxovirus	Poxviridae
	Inclusion Body Disease	Parvoviridae	
Bacteria	*Dermatophilus*	*Rickettsia*	
	Leptospira	*Salmonella*	
Protozoa	*Babesia*	*Globidia*	*Pirhemocyton*
	Billbraya	*Haemocystidium*	*Plasmodium*
	Bodo	*Haemogregarina*	*Sarcocystis*
	Copromonas	*Haemoproteus*	*Schellackia*
	Cryptosporidium	*Hemolivia*	*Trichomonas*
	Eimeria	*Hepatozoon*	*Trypanosoma*
	Endamoeba	*Isospora*	
	Fallisia	*Nyctotherus*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Mesocoelium (T)*	*Pneumonema (N)*
	Acanthocephala (A)	microfilaria (N)	*Porrorchis (A)*
	Acanthotaenia (C)	*Microphallus (T)*	*Pseudorictularia (N)*
	Angiostrongylus (N)	*Moaciria (N)*	*Pseudothamugadia (N)*
	Ascaridoidea (N)	*Oochoristica (C)*	*Raillietascaris (N)*
	Ascaris (N)	*Ophidascaris (N)*	*Skrjabinelazia (N)*
	Bothridium (C)	*Ophiotaenia (C)*	*Skrjabinodon (N)*
	Brachylecithum (T)	*Oswaldofilaria (N)*	*Skrjabinoptera (N)*
	Cardianema (N)	Oxyuridae (N)	*Sphaerechinorhynchus (A)*
	Cylindrotaenia (C)	*Oxyuris (N)*	*Spinicauda (N)*
	Dioctowittus (N)	*Paradistomum (T)*	*Spirometra* (C)
	Filarioidea (N)	*Parapharyngodon (N)*	*Strongyluris (N)*
	Hastospiculum (N)	*Pharyngodon (N)*	*Tanqua (N)*
	Hedruris (N)	Pharyngodonidae (N)	*Terranova (N)*
	Herpetostrongylus (N)	*Physaloptera (N)*	*Tetracotyle (T)*
	Johnpearsonia (N)	*Physaloptera (N)*	*Thelandros (N)*
	Kapsulotaenia (C)	Physalopteridae (N)	Trichostrongyloidea (N)
	Kreisiella (N)	*Physalopteroides (N)*	*Veversia (N)*
	Maxvachonia (N)	*Piestocystis (C)*	*Wanaristrongylus (N)*
	Mermithidae (N)	*Piratuboides (N)*	

	Snakes		
Viruses	Adenoviridae	Iridoviridae	Wamena virus
	Herpesviridae	Ophidian paramyxovirus	
	Inclusion Body Disease	Parvoviridae	
Bacteria	No Records		
Protozoa	*Babesia*	*Entamoeba*	*Schellackia*
	Caryospora	*Haemogregarina*	*Trichomonas*
	Cryptosporidium	*Pirhemocyton*	*Trypanosoma*
	Eimeria	*Sarcocystis*	
Fungi	*Chrysosporium*		
Helminths	*Abbreviata (N)*	*Hastospiculum (N)*	*Piestocystis (C)*
	Acanthotaenia (C)	*Herpetostrongylus (N)*	*Polydelphis (N)*
	Ascarididae (N)	*Hydrophitrema (T)*	*Proteocephalus (C)*
	Ascaris (N)	*Kalicephalus (N)*	*Simhatrema (T)*
	Atrophecaecum (T)	*Maxvachonia (N)*	*Sphaerechinorhynchus (A)*
	Bothridium (C)	*Moaciria (N)*	*Spinicauda (N)*
	Capillaria (N)	*Ophidascaris (N)*	*Spirometra (C)*
	Dioctowittus (N)	*Ophiotaenia (C)*	Spiruroidea (N)
	Dolichopera (T)	*Paraheterotyphlum (N)*	*Sterrhurus (T)*
	Goezia (N)	*Physaloptera (N)*	
	Harmotrema (T)	Physalopteridae (N)	

Letters in parentheses indicate major taxonomic groups for helminth parasites.

A = Acanthacephala

C = Cestoda

N = Nematoda

T = Trematoda

Appendix 3

Extended list of micro-organism genera reported as occurring in amphibians in Australia.

Amphibians			
	Frogs		
Viruses	Adenoviridae	Herpesviridae	Polyomaviridae
	Bohle virus	Iridoviridae	Poxviridae
Bacteria	*Chlamydia*	*Leptospira*	
Protozoa	*Amoeba*	*Karotomorpha*	*Retortamonas*
	Balantidium	*Monocercomonas*	*Spironucleus*
	Chilomastix	*Myxidium*	*Trichomastix*
	Copromonas	*Myxobolus*	*Trichomitus*
	Entamoeba	*Myxosporidium*	*Trichomonas*
	Giardia	*Nyctotherus*	*Trypanosoma*
	Haemogregarina	*Opalina*	*Zelleriella*
	Hoarella	*Protoopalina*	
Fungi	*Batrachochytrium*	*Mucor*	
Helminths	No Records		

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Technical Appendix D9

Plant Pathogen Threats to Barrow Island

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

PLANT PATHOGEN THREATS TO BARROW ISLAND

TECHNICAL APPENDIX D9

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PLANT PATHOGEN THREATS TO BARROW ISLAND

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Summary

An examination of specimen-based plant pathology herbarium databases and the scientific literature revealed that only two plant pathogens have been recorded from Barrow Island or neighbouring islands. These pathogens, *Aecidium* sp. and *Uredo* sp., both occur on *Acanthocarpus verticillata* and certainly represent different stages of the same undescribed rust fungus.

Records of plant pathogens from mainland Australia indicated that 126 plant pathogens have been reported from the approximately 350 species of host plant that occur on Barrow Island. One of these, the soil-borne pathogen *Phytophthora cinnamomi*, was assessed as having the greatest potential to threaten the resident flora through the movement of soil, although it is unlikely that the arid, tropical environmental conditions on Barrow Island are conducive to its establishment. It is estimated that there could be over 4,000 indigenous plant pathogens on Barrow Island.

Background

Barrow Island is situated in the arid tropics directly between the Gorgon area gas fields which are approximately 130 km off the north-west coast of Western Australia and the Australian mainland. As well as sustaining one of Australia's most important oilfields, Barrow Island is a declared Class A Nature Reserve of international importance with unique conservation values for the protection of its flora and flora (Gorgon Australian Gas, 2003). Strict quarantine policies imposed by the operator of the oilfields have ensured that very few invasive plant species have established on Barrow Island. The aim of this report is to identify the plant pathogens that occur on Barrow Island and to assess the risk that all plant pathogens from the mainland pose to the resident flora.

Methodology

Vegetation and flora surveys list the resident flora of Barrow Island at about 350 species (Astron Environmental, 2002). Three specimen-based databases, Australian Plant Pest Database (APPD), Australian Plant Disease Database (APDD) and Queensland Department of Primary Industries Plant Pathology Herbarium Database (BRIP) were interrogated for the presence of records of plant pathogens on these host plants from Barrow Island and neighbouring islands as well as from mainland Australia. The scientific literature was also examined to determine reports of plant pathogens on these hosts. The identified pathogens were assessed to determine the level of risk that they posed to the resident flora of Barrow Island.

Results

Only two records of plant pathogens on Barrow Island and neighbouring islands were found (Table 1). Records of plant pathogens from mainland Australia indicated that 126 plant pathogens have been reported from the approximately 350 species of host plant that occur on Barrow Island (Appendix I). The table contains only plant pathogenic fungi as there were no reliable records of bacteria, viruses and nematodes. Only those pathogenic fungi that had been identified to species level were listed. The soil-borne fungus, *Phytophthora cinnamomi*, was considered to pose a potential risk to the resident flora of Barrow Island.

Table 1. Plant pathogens recorded from Barrow Island and neighbouring islands.

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	LOCATION	REFERENCES
Aecidium sp.	Rust	*Acanthocarpus verticillata*	Varanas Island, Lowendal group, 10 km E Barrow Island	APDD, Shivas (1989)
Uredo sp.	Rust	*Acanthocarpus verticillata*	Varanas Island, Lowendal group, 10 km E Barrow Island	APDD, Shivas (1989)

Discussion

The analysis in this report has been done against a background that very little is known about plant pathogens on native plants in Australia. Most of the records of plant pathogens in Australia are from agriculturally important or cultivated plants as the published Australian State plant diseases lists indicate, for example, see Shivas (1989) for Western Australia. There is some specialised knowledge for particular groups of fungi on native plants, for example, smut fungi (Ustilaginomycetes) on grasses and sedges (Shivas & Vánky, 2003), powdery mildews (Erysiphales) (Pascoe, unpublished) and rusts (Uredinales) (Walker, unpublished).

There are about 165 genera of plants on Barrow Island (Astron Environmental, 2002). Shivas & Hyde (2002) estimated that the number of fungal plant pathogens specific to vascular plant genera in the tropics was about 25. It follows that there may be up to 4,000 indigenous genera-specific fungal plant pathogens on Barrow Island. This number reflects the potential biodiversity of fungi on Barrow Island rather than an indication of the amount of disease, as most, if not all of these fungi will cause diseases of minor significance and be a normal part of the ecosystem.

Despite the potential diversity of fungi on Barrow Island, the only records of pant pathogens from Barrow Island and neighbouring islands are the two rusts, *Aecidium* sp. and *Uredo* sp., reported on fruits of *Acanthocarpus verticillata* A.S. George collected at Varanas Island, which is 10 km of Barrow Island (Shivas, 1989). These two rusts are certainly the aecidial and uredinial stages of the same rust as APDD records show that both were collected by V. Long and C. Nicholson on 15 Oct 1986. This rust is apparently undescribed, and possibly even endemic to islands in the region, as there are no species of rust described from the host plant family Xanthorrhoeaceae in Australia.

There are at least 126 plant pathogenic fungi (Appendix I) that have been reported from the mainland on hosts that occur on Barrow Island. This number is an underestimate in that only pathogens that had been identified to species level were considered. Many records of microfungi that had been identified only to generic level were excluded, for example *Alternaria*, *Colletotrichum*, *Phoma*, *Phomopsis* and *Oidium*. Exclusion of microfungi not identified to species level is justified on grounds that many of these are probably weak pathogens or secondary invaders. Identification to species level is necessary to fully determine the threat that the micro-organisms pose, especially for the purpose of quarantine pest risk assessments.

There are several potential pathways by which plant pathogens might enter Barrow Island (Table 2). Of these pathways, the movement of soil provides the greatest risk of introducing harmful plant pathogens, particularly soil-borne fungi such as *Phytophthora* spp. and nematodes, which may have wide host ranges. Soil (topsoil, plant nursery mixes) includes any material on the surface of the earth in which plants can grow. Sand is not a risk unless it has had plants growing in it, which would mean it was collected from within a metre of the earth's surface.

Two soil-borne plant pathogens warrant mention. *Verticillium dahliae* is a plurivorous pathogen that causes severe diseases in the tropics and sub-tropics. It forms sclerotia and survives for long periods in the soil. It invades the vascular system of host plants and causes a characteristic wilt syndrome. In Australia it has been isolated from native and introduced plants in several host plant families and is widespread (APDD, 2004). It is most likely to be found on herbaceous weeds and cultivated plants, for example ornamentals and vegetables. It is not considered to pose a significant threat to the native plants populations.

In Western Australia, the destruction of large areas of natural plant communities by *Phytophthora cinnamomi* Rands is unique (Weste, 1994). The disease is known as jarrah dieback but more than 1,000 plant species are susceptible. *P. cinnamomi* is a serious root rot pathogen and has demonstrated ability to cause explosive pandemics in Australia. However the arid tropical climate on Barrow Island is not conducive to the establishment *P. cinnamomi*. Furthermore *P. cinnamomi* may already be present on Barrow Island and surveys are needed to determine this. There are no other plant diseases on the adjacent mainland that were identified as presenting a threat to the flora of Barrow Island.

Table 2. Potential pathways for plant pathogens to enter Barrow Island and neighbouring islands.

PATHWAY	PATHOGENS	RECOMMENDED QUARANTINE PRECAUTIONS
Soil and sand (including as contaminated equipment, machinery, personal goods etc.)	Soil-borne fungi Nematodes	Sterilisation Disinfection Cleaning Containment
Wind	Many foliar fungi produce wind-borne spores	Surveillance

PATHWAY	PATHOGENS	RECOMMENDED QUARANTINE PRECAUTIONS
Propagating material (incl. cuttings, seed)	Most pathogens	Restrictions and controls Use material certified as disease free
Fresh food	Seed-borne fungi Post-harvest fungi Viruses	Inspection Education
Insects (incl. as infested food, in cargo and baggage)	Some plant viruses are insect transmitted.	Inspection Surveillance

Recommendations

1. Determine the common plant pathogens on Barrow and surrounding islands through targeted surveys. This knowledge will provide baseline information about (i) the health status of the resident flora and (ii) the biodiversity of plant pathogens on the islands. Virtually nothing is known about the indigenous plant pathogens on Barrow Island. Interestingly the only plant pathogen collected from the region is an undescribed rust fungus.

   Targeted surveys are essential, as specialised skills are required to identify and classify microfungi, bacteria, viruses and nematodes. As 95% of plant diseases are caused by microfungi (Shivas & Hyde, 1996) these should receive the highest priority. A field survey should be done during or at the end of the wet season when plant growth is most vigorous and plant pathogens most active. This survey should also target diseases of introduced plants (particularly weeds), garden and amenity plants as well as the native plants. A short survey (7 days) by plant pathologist(s) experienced in tropical diseases would certainly identify any current or emerging plant health issues.

2. That on-going surveillance and identification of plant pathogens on Barrow Island be facilitated through linkages with plant disease diagnostic laboratories and/or plant disease herbaria in Australia. These linkages will allow the rapid determination of the cause of plant diseases in incidental samples not obtained through a targeted survey. This will only be successful if those who may encounter diseased plants are trained in plant disease identification and how to prepare specimens for submission to a diagnostic laboratory or herbarium. There are numerous methods used to collect and submit different types of pathogens, that is fungi, bacteria, viruses and nematodes.

3. Ensure that adequate safeguards are in place to prevent the movement of soil-borne pathogens, for example *Phytophthora cinnamomi*, to Barrow Island. The ability of *P. cinnamomi* to cause devastating disease in natural plant communities in Western Australia is of concern although it is unlikely to establish in an arid tropical environment. Despite the unlikelihood that *P. cinnamomi* is present on Barrow Island,

it is recommended that a survey be undertaken to verify its presence or otherwise on Barrow Island.

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Appendix I. Pathogens recorded in Australia on hosts present on Barrow Island.

Abbreviations –APDD = Australian Plant Disease database; BRIP = plant pathology herbarium records held by the Queensland Department of Primary Industries and Fisheries.

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Albugo blytii	White rust	*Alternanthera nodiflora*	A minor disease.	APDD
Albugo centaurii	White rust	*Centaurium erythraea*	A minor disease.	APDD
Albugo platensis	White rust	*Boerhavia coccinea* *Boerhavia schomburgkiana*	A minor disease.	APDD
Albugo quadrata	White rust	*Portulaca oleracea*	A minor disease.	APDD
Alternaria sonchi	Early blight	*Sonchus oleraceus*	Widespread.	APDD
Alternaria solani	Early blight	*Solanum nigrum*	A minor disease.	APDD
Arkoola nigra	Leaf spot	*Crotalaria medicaginea* *Rhynchosia minima*	A minor disease.	APDD
Armillaria luteobubalina	Root rot	*Eucalyptus gomphocephala*	A primary pathogen causing decline and death that is widely distributed in eucalypt communities in Australia.	APDD
Aulographina eucalypti	Leaf spot	*Eucalyptus camaldulensis* *Eucalyptus torquata*	A widespread pathogen causing minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Bipolaris papendorfii	Leaf spot	*Bothriochloa bladhii*	A widespread pathogen causing minor disease.	Sivanesan (1987)
Bipolaris perotidis	Leaf spot	*Aristida holathera var. holathera (syn. Aristida browniana)*	Native fungus that has been reported on several grass species. Occurs in WA and Qld.	BRIP
Bipolaris zeae	Leaf spot	*Cenchrus ciliaris*	A widespread pathogen causing minor disease.	Sivanesan (1987)
Botrytis cinerea	Stem wilt	*Senna artemisioides*	A minor disease.	APDD
Cercospora apii s. lat.	Leaf spot	*Ipomoea pes-caprae*	Widespread on many hosts.	APDD
Cercosporella dioscoreophylli	Leaf spot	*Tinospora smilacina*	A minor disease.	APDD
Cerotelium fici	Smut	*Ficus opposita*	A widespread pathogen on *Ficus*.	APDD
Cintractia axicola	Smut	*Fimbristylis dichotoma*	A widespread pathogen.	APDD
Cintractia bulbostylidis	Smut	*Bulbostylis barbata*	Known only from the type location in NT.	APDD
Cintractia limitata	Smut	*Cyperus iria*	Widespread pathogen but rarely collected on this host.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Cintractia lipocarphae	Smut	*Bulbostylis barbata*	Known only from the type location in central Australia.	APDD
Claviceps annulata	Ergot	*Eulalia annulata*	A minor disease.	APDD
Claviceps cynodontis	Ergot	*Cynodon dactylon*	A widespread pathogen causing a minor disease.	APDD
Claviceps hirtella	Ergot	*Cenchrus ciliaris*	A native fungus only occurring in Qld.	APDD
Claviceps pusilla	Ergot	*Bothriochloa bladhii* *Dichanthium sericeum* *Themeda australis*	Reported from many grass species in Australia.	APDD
Cochliobolus cymbopogonis (anamorph Curvularia cymbopogonis)	Leaf spot	*Bothriochloa bladhii* *Sarga plumosum*	Minor disease on several grasses.	Sivanesan (1987)
Cochliobolus cynodontis (anamorph Bipolaris cynodontis)	Leaf spot	*Cynodon dactylon*	Widespread and often severe on this host.	Sivanesan (1987)
Cochliobolus dactyloctenii (anamorph Bipolaris dactyloctenii)	Leaf spot	*Dactyloctenium radulans*	Minor disease.	Sivanesan (1987)

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Cochliobolus hawaiiensis (anamorph Bipolaris hawaiiensis)	Leaf spot	*Dichantium sericeum*	A minor disease.	APDD
Cochliobolus heterostrophus (anamorph Bipolaris maydis)	Leaf spot	*Bothriochloa bladhii*	Reported as a minor disease on this host in WA.	APDD
Cochliobolus peregianensis (anamorph Bipolaris peregianensis)	Leaf spot	*Cynodon dactylon*	Only recorded from Qld.	Sivanesan (1987)
Cochliobolus spicifer (anamorph Bipolaris spicifera)	Leaf spot, root rot	*Bothriochloa bladhii* *Dactyloctenium radulans*	Spring dead spot of *Cynodon dactylon* and foot rot of winter wheat are the main diseases caused by this pathogen. Occurs throughout Australia on grasses.	Sivanesan (1987)
Colletotrichum caudatum	Leaf spot	*Bothriochloa bladhii*	Minor disease on this host in Qld.	APDD
Colletotrichum truncatum	Leaf spot	*Tribulus terrestris*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Curvularia andropogonis	Leaf spot	*Eulalia aurea*	Minor disease.	APDD
Curvularia bothriochloae	Leaf spot	*Bothriochloa bladhii*	A native fungus causing a minor disease on this host in Qld.	Sivanesan, Alcorn & Shivas (2003)
Curvularia uncinata	Leaf spot	*Aristida contorta*	A minor disease reported from NSW.	APDD
Erysiphe trifolii	Powdery mildew	*Sesbania cannabina*	Common on some genera of legumes.	APDD
Glomerella cingulata (anamorph Colletotrichum gloeosporioides)	Anthracnose	*Cleome viscose* *Portulaca oleracea*	Widespread on many host plants.	APDD
Gonotophragmium mori	Leaf spot	*Ficus opposita var. micrantha*	A minor disease.	APDD
Kordyana celebensis	Leaf spot	*Commelina ensifolia*	A minor disease.	APDD
Laetisaria fuciformis	Red thread	*Aristida contorta*	A widespread disease of turf grasses that occurs in cool and humid areas.	APDD
Leptosphaeria korrae	Root rot	*Cynodon dactylon*	A widespread disease of grasses.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Leptosphaeria narmari	Spring dead spot	*Cynodon dactylon*	A widespread disease of grasses.	APDD
Macalpinomyces eriachnes	Smut	*Eriachne mucronata*	Minor disease.	APDD
Macalpinomyces ewartii	Smut	*Sarga plumosum*	Minor disease.	APDD
Macalpinomyces tubiformis	Smut	*Chrysopogon fallax*	Only known from the type collection in Qld.	Shivas & Vánky (2004)
Masseeëlla capparidis	Leaf rust	*Flueggea virosa* subsp. *Melanthesoides*	Only known from Qld.	APDD
Meliola clerodendricola	Black mildew	*Clerodendron tomentosum*	Minor disease.	APDD
Miyagia pseudosphaeria	Black mildew	*Sonchus oleraceus*	Widespread in Australia.	APDD
Moreaua fimbristylidis	Smut	*Fimbristylis dichotoma*	Only known from central Australia.	APDD
Mycosphearella cryptica	Leaf spot	*Eucalyptus camaldulensis* *Eucalyptus gomphocephala*	Widespread on eucalypts in Australia.	APDD
Nigrocornus scleroticus	Stem gall	*Chrysopogon fallax* *Eriachne mucronata* *Sarga plumosum* *Themeda australis*	Widespread on tropical grasses.	APDD
Passalora fusimaculans	Leaf blight	*Bothriochloa bladhii*	Worldwide on many grass species.	Crous & Braun (2003)
Peronospora farinose	Downy mildew	*Chenopodium melanocarpum* *Chenopodium pumilio*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Peronosclerospora maydis	Downy mildew	*Sarga plumosum*	Minor disease.	APDD
Peronosclerospora noblei	Downy mildew	*Sarga plumosum*	Minor disease.	APDD
Phaeophleospora epicoccoides (synonyms *Kirramyces epicoccoides, Phaeoseptoria eucalypti*)	Leaf spot	*Eucalyptus camaldulensis*	Widespread in Australia.	APDD
Phaeophleospora eucalypti (synonyms *Kirramyces eucalypti, Pseudocercospora eucalypti*)	Leaf spot	*Eucalyptus camaldulensis*	Widespread in Australia.	APDD
Phleospora myopori	Leaf spot	*Myoporum acuminatum*	Minor disease.	APDD
Phyllachora cynodontis	Tar spot	*Cynodon dactylon*	Minor disease.	APDD
Phyllachora hakeicola	Tar spot	*Hakea lorea*	Minor disease.	APDD
Phyllachora infectoria	Tar spot	*Ficus virens*	A minor disease.	APDD
Phyllachora ischaemi	Tar spot	*Chrysopogon fallax* *Dichantium sericeum* *Themeda australis*	Widespread on many grasses causing minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Phyllachora platyelliptica	Tar spot	*Themeda australis*	A minor disease.	APDD
Phyllachora rhytismoides	Tar spot	*Ficus opposita*	Widespread on *Ficus*.	APDD
Phytophthora nicotianae var. *parasitica*	Root rot	*Swainsona formosa*	Widespread and with a wide host range.	APDD
Plasmopara halstedii	Downy mildew	*Arctotheca calendula*	Rarely collected.	APDD
Pseudocercospora atromarginalis	Leaf spot	*Solanum nigrum*	A minor disease.	APDD
Pseudocercospora conspicua	Leaf spot	*Cleome viscosa*	Known only from Qld.	APDD
Pseudocercospora dolichandrones	Leaf spot	*Dolichandrone heterophylla*	Only known in Australia from one collection.	APDD
Pseudocercospora sabbatiae	Leaf spot	*Centaurium erythraea*	A minor disease.	APDD
Pseudocercospora stahlii	Leaf spot	*Passiflora foetida*	Widespread on this host.	APDD
Puccinia arthrocnemi	Leaf rust	*Halosarcia halocnemoides*	Known only from SA.	APDD
Puccinia bassiae	Leaf rust	*Sclerolaena convexula*	Minor disease.	APDD
Puccinia canaliculata	Leaf rust	*Cyperus iria*	Widespread in Australia but rarely collected on this host.	APDD
Puccinia cynodontis	Leaf rust	*Brachyachne* sp. *Cynodon dactylon*	Widespread in Australia.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Puccinia cyperi-tegetiformis	Leaf rust	*Cyperus bifax*	Known only from NSW.	APDD
Puccinia dielsiana	Leaf rust	*Threlkeldia diffusa*	A minor disease.	APDD
Puccinia duthiae	Leaf rust	*Bothriochloa bladhii* *Dichantium sericeum*	Widespread in tropical Australia.	APDD
Puccinia heterospora	Leaf rust	*Abutilon leucopetalum*	Widespread in Australia.	APDD
Puccinia kochiae	Leaf rust	*Enchylaena tomentosa*	Minor disease.	APDD
Puccinia levis	Leaf rust	*Sarga plumosum*	Widespread in Australia.	APDD
Puccinia versicolor	Leaf rust	*Themeda australis*	A minor disease.	APDD
Puccinia xanthii	Leaf rust	*Flaveria australasica*	Widespread in Australia on several hosts.	APDD
Pyricularia grisea	Eye spot	*Cenchrus ciliaris*	Widespread in Australia.	APDD
Sclerotinia homeocarpa	Dollar spot	*Cynodon dactylon*	Widespread particularly as a disease of golf greens.	APDD
Sclerotinia sclerotiorum	Root and stem rot	*Arctotheca calendula*	Widespread and with a wide host range.	APDD
Septoria perforans	Leaf spot	*Arctotheca calendula*	Rarely collected.	APDD
Septoria sonchi	Leaf spot	*Sonchus oleraceus*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Setosphaeria holmii (anamorph Exserohilum holmii)	Leaf blight	*Dactyloctenium radulans*	Rarely collected.	APDD
Setosphaeria rostrata (anamorph Exserohilum rostratum)	Leaf spot	*Cynodon dactylon* *Dactyloctenium radulans*	Widespread on many grasses in Australia.	APDD
Sphaerotheca fuligenea	Powdery mildew	*Erythrina vespertilio*	Widespread in Australia causing the important cucurbit powdery mildew.	APDD
Sporisorium andropogonis	Smut	*Dichantium sericeum*	Widespread in Australia.	APDD
Sporisorium benguetense	Smut	*Themeda australis*	Only known from one location in northern Qld.	APDD
Sporisorium bothriochloae	Smut	*Dichantium sericeum*	A minor disease.	APDD
Sporisorium centrale	Smut	*Themeda australis*	Only know from one location in central Australia.	APDD
Sporisorium confusum	Smut	*Aristida holathera var. holathera*	This smut is widespread in Australia on several *Aristida* spp.	Vánky (2001)
Sporisorium doidgeae	Smut	*Bothriochloa bladhii* *Dichantium sericeum*	Widespread in Australia.	Vánky & Shivas (unpublished)

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Sporisorium exsertum	Smut	*Themeda australis*	Widespread in Australia.	APDD
Sporisorium fallax	Smut	*Chrysopogon fallax*	Widespread but rarely collected.	Shivas & Vánky (2004)
Sporisorium langdonii	Smut	*Themeda australis*	Rarely collected.	APDD
Sporisorium lanigeri	Smut	*Cymbopogon ambiguus* *Cymbopogon bombycinus*	Widespread.	APDD
Sporisorium mutabile	Smut	*Cymbopogon bombycinus*	Widespread.	APDD
Sporisorium normanensis	Smut	*Cynodon dactylon*	Known only from one location in Qld.	Vánky & Shivas (2003)
Sporisorium ryleyi	Smut	*Sarga plumosum*	Minor disease.	Vánky & Shivas (2003)
Sporisorium sorghi	Smut	*Sarga plumosum*	Minor disease.	Vánky & Shivas (2003)
Sporisorium tenue	Smut	*Bothriochloa bladhii*	Widespread in Australia.	Vánky & Shivas (unpublished)
Sporisorium themedae	Smut	*Themeda australis*	Rarely collected.	APDD
Sporisorium tumefaciens	Smut	*Chrysopogon fallax*	Widespread but rarely collected.	Vánky & Shivas (unpublished)
Sporisorium tumeforme	Smut	*Chrysopogon fallax*	Rarely collected.	Vánky & Shivas (2004)
Sporisorium walkeri	Smut	*Themeda australis*	Widespread.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Thanatephorus cucumeris (anamorph Rhizoctonia solani)	Root rot	*Cynodon dactylon*	Widespread in Australia on many plants.	APDD
Tilletia cape-yorkensis	Smut	*Whiteochloa airoides*	Known only from the type location in northern Qld.	APDD
Tilletia opaca	Smut	*Spinifex longifolius*	Rarely collected.	APDD
Uromyces orientalis	Smut	*Indigofera linifolia*	A minor disease.	APDD
Uromyces salsolae	Smut	*Salsola tragus*	Rarely collected.	APDD
Uromyces scaevolae	Rust	*Scaevola spinescens*	A minor disease.	APDD
Uromycladium tepperianum	Gall rust	*Acacia bivenosa*	Widespread on *Acacia* in Australia.	APDD
Ustilago altilis	Smut	*Triodia pungens*	Widespread in tropical Australia.	APDD
Ustilago cynodontis	Smut	*Cynodon dactylon*	Very common wherever couch grass is grown.	APDD
Ustilago latzii	Smut	*Triraphis mollis*	Known only from the type location in central Australia.	APDD
Ustilago porosa	Smut	*Sarga plumosum*	Minor disease.	APDD
Ustilago radulans	Smut	*Dactyloctenium radulans*	Minor disease.	APDD

PATHOGEN	DISEASE OR COMMON NAME	HOST PLANTS	PEST STATUS	REFERENCES
Ustilago schmidtiae	Smut	*Enneapogon polyphyllus*	Minor disease.	APDD
Ustilago spermophora	Smut	*Sporobolus australasicus*	Minor disease on several grasses.	APDD
Verticillium dahliae	Vascular wilt	*Euphorbia drummondii* *Portulaca oleracea* *Salsola tragus* *Solanum nigrum* *Sonchus oleracuea*	An important pathogen of many introduced herbaceous plants.	APDD

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Technical Appendix D10

Conceptual Quarantine Barriers – Subject to Feasibility Analysis and Design

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GORGON DEVELOPMENT ON BARROW ISLAND

CONCEPTUAL QUARANTINE BARRIERS
Subject to Feasibility Analysis and Detailed Design

TECHNICAL APPENDIX D10

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June 2005

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CONTENTS

1 Introduction

Three high-risk exposure pathways identified by the Quarantine Expert Panel were selected for priority assessment to demonstrate confidence in the ability to manage quarantine threats. The three pathways represent what are considered the greatest threats of introducing non-indigenous species to Barrow Island. The three priority pathways are:

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

This document details the full list of quarantine barriers which have been suggested by technical experts at the *conceptual* level to meet the Joint Venturers' standards for acceptable risk on the three priority pathways. These conceptual quarantine barriers have been recorded through Infection Modes and Effects Analysis (IMEA) workshops, have been subject to assessment in Preliminary Barrier Analysis (PBA) workshops, and have been classified as either 'key barriers' or 'non-key' barriers. Key barriers are those which are expected to be highly effective in mitigating the risk of introducing a non-indigenous species, while non-key barriers may offer additional options to further reduce risk.

All of the conceptual quarantine barriers suggested by workshop participants will undergo feasibility analysis. Upon completion of the feasibility analysis and engagement of front-end engineering design contractors, specific quarantine barriers will be selected for detailed specifications and design, and will be subject to further risk assessment by technical experts to confirm that the barriers will perform as expected, using a Hazard and Operability (HAZOP) analysis technique. The application of the HAZOP process to this quarantine assessment is known as a 'QHAZ' analysis and is described in the *How to Guide for Conducting Risk-based Assessments of Quarantine Hazards on Barrow Island* (E-Systems 2005).

All of the pathways which result in the arrival of materials, supplies and personnel to Barrow Island will be subject to exactly the same process of threat identification and development of quarantine barriers, utilising the expertise of technical specialists and communication of quarantine barriers to government and stakeholders.

Seventeen risk assessment workshops have been completed through April 2005, involving 26 ecologists and conservation specialists attending multiple workshops (plus 15 construction, logistics and environmental specialists, and ten government observers). Information on pathway-specific quarantine threats and suggested barriers has been captured in quarantine risk assessment workshop reports (available on the Gorgon Development website, www.gorgon.com.au).

The quarantine barriers for the three priority pathways are presented in subsequent sections of this document, followed by an explanation of how quarantine barriers will be implemented. All information presented in this document is sourced from the records of quarantine risk assessment workshops.

2 'Sand and Aggregate' Pathway

Conceptual quarantine barriers which are subject to feasibility analysis for the procurement, handling and transport of sand and aggregate are described in this section of the document. Sand and aggregate is to be used for the construction of proposed facilities at Barrow Island.

Conceptual quarantine barriers for the sand and aggregate pathway have been identified to reduce the risk of introducing non-indigenous species at each step of the pathway. The pathway steps start at the quarry and include all activities for handling cargoes through their arrival at the Barrow Island Materials Offloading Facility (marine wharf), as shown in Figure 2.1.

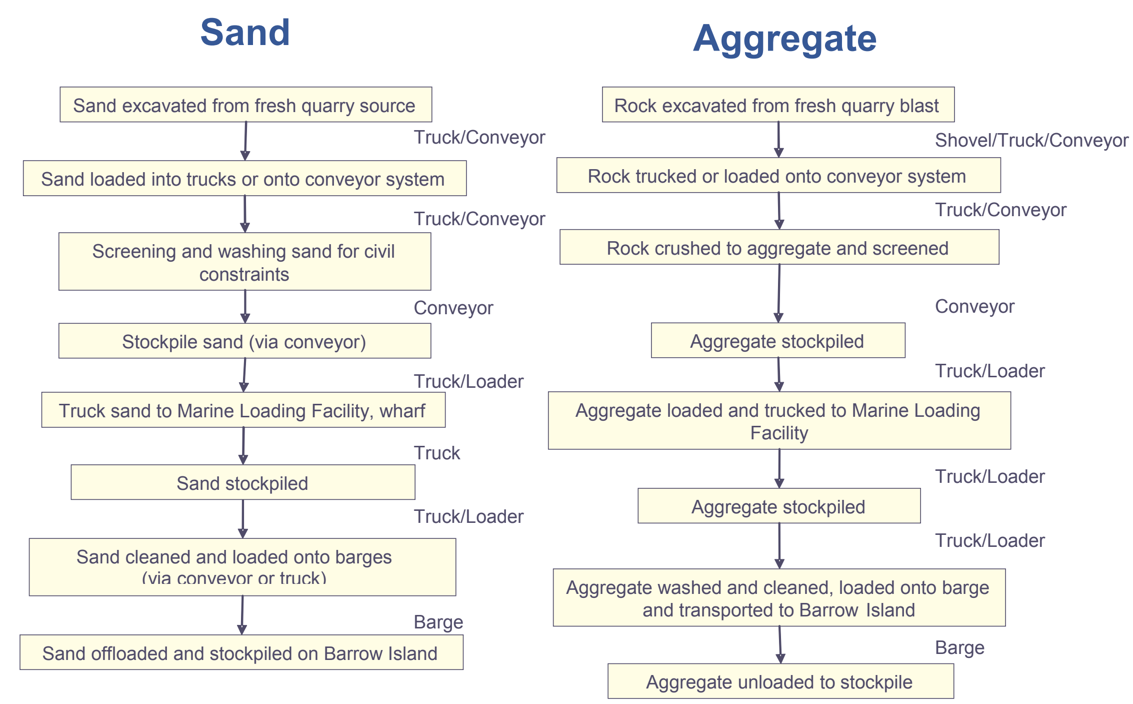

Figure 2.1: 'Sand and Aggregate' Pathway Steps

Of the quarantine barriers identified by technical experts, several barriers were singled out as key barriers. Quarantine barriers are listed in Table 2-1 by pathway step for reference, and numbered as per the relevant PBA workshop report for sand and aggregate (4 November 2004). Key barriers are designated with the 🔑 symbol beside the workshop barrier number. Some of the quarantine barriers apply to more than one pathway step, and these are listed at the top of Table 2-1.

Table 2-1: Conceptual Quarantine Barriers Identified for the 'Sand and Aggregate' Pathway

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
All pathway steps	B9 🔑	Induct all personnel in quarantine management expectations before commencing work. Conduct ongoing inductions and training in quarantine management. Ensure that all footwear and clothing is free of seeds, plant and animal matter. Prohibit cuffs on trousers.
	B44 🔑	Ensure compliance with quarantine requirements through a regular schedule of audits and checks (specifically noted in the mainland marine loading facility pathway step).
Quarry activities	B1 🔑	Implement a site selection process for quarry or pit (and possibly transport corridors), including a baseline flora and fauna survey. Conduct on-going flora and fauna surveys.
	B2 🔑	Establish a site-specific environmental management plan (throughout operations).
	B3	Obtain all necessary environmental approvals for quarry operations.
	B4	Implement weed management practices at the quarry or pit site.
	B5	Manage stormwater, including diverting stormwater off-site to minimise the formation of surface water ponds in the quarry or pit.
	B6	Control personnel access and movement through fencing, gates and a site office.
	B7	Establish a dedicated quarry or pit, or fenced area to segregate Gorgon operations from other users.
	B8	Implement a dust management strategy.
	B10	Minimise night-time operations. Operate under lighting that minimises potential for invertebrate infestation (particularly insects).
	B11	Erect fencing at crushing and screening areas to minimise fauna incursions.
	B12	Strategically locate overburden and stockpiles to minimise blow-back of into the quarry or pit. Ensure sufficient distance between locations and the blast line. Remove vegetation and topsoil (including seed bank) prior to blasting.
	B13 🔑	Wash-down and decontaminate all vehicles prior to commencing quarry operations. Minimise use of all non-essential vehicles. Consider drive-through wash area with high pressure jets, possible chemical treatment (eg sodium hypochlorite) to decontaminate tyres.
	B14	Decontaminate the crushing and screening equipment prior to processing raw materials. Alternatively, use a dedicated crusher and screen.
	B15	Manage operations to minimise the length of time that sand and aggregate are stockpiled before transport to the mainland marine loading facility.
	B16	Undertake vehicle maintenance outside main quarry area.
	B17	Develop requirements for appropriate packaging of supplies brought into the quarry, such that they are free from contamination. Remove packaging material from the quarry in a timely manner.
	B18	Maintain quarry floor and operating areas such that saltation, vegetation, waste materials and food scraps are minimised.

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B19	Monitor tailings for invertebrates (and other biological groups). In the event that invertebrates or other biological groups are discovered, quarantine the infested area and decontaminate.
	B20	Ensure that aggregate dries completely before stockpiling or loading onto trucks.
	B21	Consider chemical disinfection of water, or using high temperature water for washing.
	B22	Monitor stockpiles for invertebrates. In the event that invertebrates or other biological groups are discovered, quarantine the infested area and decontaminate.
	B23	Minimise stockpiling of material during peak cyclone season.
	B24	Establish a buffer area around stockpile to exclude terrestrial species.
	B25	Start-up the sand or aggregate loading conveyor for a sufficient period to shake-off invertebrates between uses.
	B26	Treat conveyor system with a chemical residual herbicide/insecticide.
	B27	Re-wash and re-process any sand or aggregate which is spilt from a conveyor system to the ground.
	B28	Design the stockpile area to be on the order of 60 m x 20 m x 9 m (height).
Road transport	B29 🔑	Wash-down and decontaminate all vehicles. Consider drive-through wash area with high pressure jets, possible chemical treatment (eg sodium hypochlorite) to decontaminate tyres.
	B30 🔑	Comprehensively inspect and clean trucks put into transport service from other jobs. Inspect and clean trucks before each loading.
	B31 🔑	Ensure that trucks do not make any stops along the roadway between the quarry and the mainland marine loading facility.
	B32 🔑	Establish a dedicated truck fleet and pre-qualify road transport contractors.
	B33	Develop contingency plans for spilt loads.
	B34	Minimise invertebrate (particularly spider) infestation of tarps used to cover cargoes when not in use.
Mainland marine loading facility	B35 🔑	Construct a hard-stand (cement) area for the loading dock.
	B36	Establish secure fencing around the loading zones.
	B37	Minimise stockpile time on the wharf (limit of four weeks). Cover and monitor stockpile for infestation. In the event that invertebrates or other biological groups are discovered, quarantine the infested area and decontaminate.
	B38	Plan for the full turnover of stockpiles to ensure that material does not remain at the wharf for more than four weeks (e.g. to avoid infestation of 'tramp ants').
	B39	Eliminate or manage lighting in stockpile area to minimise invertebrate (insect) attraction, especially within 2–3 days of loading barge.
	B40	Minimise barge loading activities in non-daylight hours.
	B41	Establish a dedicated wharf area/loading area.
	B42	Establish dedicated handling equipment.
	B43	Ensure that storage and handling of aggregate on the wharf does not compromise previous efforts to reduce infections.

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B45	Maintain good 'housekeeping' and facility hygiene practices at all times.
	B46	Chemically treat mooring lines and gangways. Establish a quarantine area on the wharf.
	B47	Install mooring dolphins to keep vessels separated from the wharf.
	B48	Use gangways with rollers to enable constant movement of vessel and gangway when moored.
	B49 🔑	Wash-down and decontaminate all vehicles prior to entering the mainland marine loading facility. Minimise use of non-essential vehicles.
	B50	Develop a contingency plan for unauthorised visitors, or vessels mooring alongside barge.
	B51 🔑	Consider heat sterilisation, chemical treatment and washing of sand and aggregate as it is being loaded into barges.
	B52	Establish dedicated barges for Gorgon Development cargoes.
	B53 🔑	Clean barge hulls and decks to not less than Australian Quarantine Inspection Service (AQIS) requirements.
	B54	Wash cargo bays (with sea water under high pressure) and treat with insecticide before loading.
	B55 🔑	Cover cargo with tarp or enclose cargo in hold or cover. Store tarps such that infestation between uses is minimised.
	B56 🔑	Sample sand and aggregate during loading for quarantine compliance. If contamination is detected after a barge sails, the infected cargo is not landed on Barrow Island. Infected cargoes to be quarantined and decontaminated.
	B72 🔑	Covered conveyors for loading cargo.
Sea transport	B57 🔑	Inspect and clean barge prior to loading. Low-dosage insecticide treatment in cabin areas, including treatment of soft furnishings. Bait for cockroaches and rodents.
	B58 🔑	Wash cargo bay (eg high pressure seawater), and treat with insecticide prior to loading.
	B59 🔑	Enclose living quarters to exclude flying insects. Control insects in living quarters with electric 'fly zappers', sticky traps, baits, etc during voyages.
	B60	Inspect and conduct regular maintenance of baits and insect control mechanisms.
	B61 🔑	Train and induct barge operations personnel in quarantine management procedures (also applies to sea transport pathway step).
	B62 🔑	Store food in living quarters in compliance with quarantine standards for food and perishables (refer to Section 3.0). Alternatively, source food from kitchen facilities on Barrow Island.
	B63 🔑	Maintain good hygiene standards on barge deck and in cabin areas.
	B64	Cover cargo with tarps throughout the voyage.
	B65 🔑	Maintain good housekeeping practices. Minimise lighting after daylight hours, including sources of light which are away from cargo bays.
	B66	Discourage birds from landing on vessels.
	B67	Enable mooring and handling lines to be immersed in seawater on voyage.
	B68	Prohibit fishing on commercial barges during voyages.

Sand and aggregate pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B69	Develop a contingency plan for supporting any (other) vessels in distress.
	B70	Inspect cargo to ensure integrity and quarantine compliance before barge landing on Barrow Island.
Arrival and unloading on Barrow Island	B71 🔑	Establish a chain of custody for transport cargo, to ensure quarantine requirements have been undertaken.
	B73 🔑	Take weather conditions into account in barge landing procedures.

3 'Food and Perishables' Pathway

Conceptual quarantine barriers which are subject to feasibility analysis for the procurement, handling and transport of food and perishables are described in this section of the document. This pathway specifically represents the level of effort required to service the construction camp for the proposed development, however the same quarantine barriers would also apply to a much smaller operational workforce.

All food and perishable items included in this pathway (for consumption at the Barrow Island construction camp) are transported by road and barge. Quarantine barriers for food and perishables stored, handled and consumed on aircraft are considered in the 'Personnel and accompanying luggage pathway' (refer to Section 4).

Conceptual quarantine barriers for the food and perishables pathway have been identified to reduce the risk of introducing non-indigenous species at each step of the pathway. The pathway steps start at the food growers and suppliers, and include all activities for handling cargoes through their arrival at a Barrow Island kitchen facility, as shown in Figure 3.1.

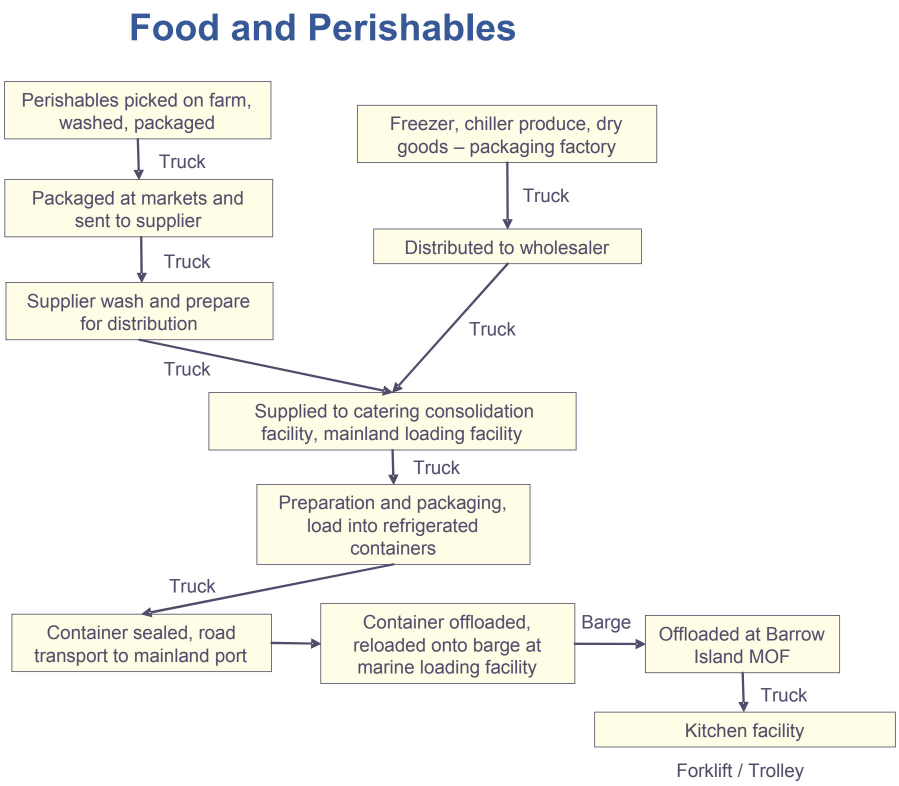

Figure 3.1: 'Food and Perishables' Pathway Steps

Most of the quarantine barriers identified by technical experts are considered to be key barriers. Quarantine barriers are listed in Table 3-1 by pathway step for reference, and numbered as per the relevant PBA workshop report for food and perishables (5 November 2004). Key barriers are designated with the 🔑 symbol beside the workshop barrier number.

Table 3-1: Conceptual Quarantine Barriers Identified for the 'Food and Perishables' Pathway

Food and perishables pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
All pathway steps	B9 🔑	Induct all personnel in quarantine management expectations before commencing work. Conduct ongoing inductions and training in quarantine management, and include conservation values of Barrow Island. Ensure that all footwear and clothing is free of seeds, plant and animal matter. Prohibit cuffs on trousers. Note: Barrier number B48 is identical to B9, and is not repeated here.
	B24 🔑	Regularly audit and check to ensure quarantine compliance (specifically noted in the mainland marine loading facility pathway step).
Growers and suppliers	B1 🔑	Prequalification and auditing of all food suppliers to ensure food safety compliance under Australian guidelines and regulations. Quarantine requirements to include food and packaging free from soils, visible invertebrates, etc.
	B4 🔑	Education of all supplier personnel in quarantine awareness and Barrow Island conservation values (also applies to mainland loading facility step).
Centralised mainland loading facility	B2. 🔑	Establish a central facility in Perth for receiving, packaging and dispatch of all chilled, fresh and dry foods. This will also include additional washing and processing of food and perishables identified as high risk by technical specialists. Prepared food to be vacuum-packed.
	B3	Prohibit high risk foods and perishables where risk cannot be reduced by processing.
	B5 🔑	Limit external packaging where possible by supplying food in pre-approved plastic containers, or on plastic pallets. Minimise packaging with organic materials such as wood. Packaging to be selected to facilitate manual handling and inspection.
	B6 🔑	All food and perishables from suppliers received into warehouse within the loading facility, and distributed for cleaning, processing and/or packaging.
	B7 🔑	Food to be packaged into consignments, inspected and checked, and loaded into chilled containers.
	B8 🔑	All equipment regularly cleaned and disinfected to maintain good hygiene and housekeeping practices.
	B9 🔑	Induct all personnel in quarantine management expectations before commencing work. Conduct ongoing inductions and training in quarantine management, and include conservation values of Barrow Island. Ensure that all footwear and clothing is free of seeds, plant and animal matter. Prohibit cuffs on trousers.
	B10 🔑	Food and perishables warehouses will operate under the Australian health regulations and guidelines.
Road transport	B11	Install air curtains on building entries and exits to minimise incursions of invertebrates into food processing and packaging areas.
	B12	Clean and treat internal spaces of all containers before packing. Seal containers upon completion of loading.
	B13	Place flour trays or other means of detection in containers for 12 hours prior to the container leaving the loading facility.
	B14 🔑	Wash-down and decontamination of all vehicles. Consider drive-through wash area with high pressure jets, possible chemical treatment (eg sodium hypochlorite) to decontaminate tyres.

Food and perishables pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
	B15 🔑	Comprehensive inspection and cleaning for trucks put into transport service from other jobs. Inspect and clean trucks before each loading.
	B16 🔑	Ensure that trucks do not make any stops along the roadway between the mainland loading facility and the mainland marine loading facility.
	B17 🔑	Establish a dedicated truck fleet and pre-qualify road transport contractors.
Mainland marine loading facility	B18 🔑	Inspect all six sides of containers.
	B19 🔑	Construct a hard-stand (cement) area for the loading dock.
	B20 🔑	Establish secure fencing around the loading zones.
	B21	Minimise barge loading activities in non-daylight hours.
	B22 🔑	Establish a dedicated wharf area/loading area.
	B23 🔑	Establish dedicated handling equipment.
	B25 🔑	Maintain good 'housekeeping' and facility hygiene practices at all times.
	B26 🔑	Chemically treat mooring lines and gangways. Establish a quarantine area on the wharf.
	B27 🔑	Install mooring dolphins to keep vessels separated from the wharf.
	B28 🔑	Use gangways with rollers to enable constant movement of vessel and gangway when moored.
	B29 🔑	Wash-down and decontamination of all vehicles prior to entering the mainland marine loading facility. Minimise use of non-essential vehicles.
Sea transport	B30 🔑	Develop a contingency plan for unauthorised visitors, or vessels mooring alongside barge.
	B31 🔑	Dedicated barges for Gorgon Development cargoes.
	B32 🔑	Clean barge hulls and decks to not less than AQIS requirements.
	B33 🔑	Wash cargo bay (with sea water under high pressure) and treat with insecticide before loading.
	B34 🔑	Inspect barge prior to loading for quarantine compliance. If contamination is detected after a barge sails, the infected cargo is not landed on Barrow Island. Infected cargoes to be quarantined and decontaminated.
Arrival and unloading on Barrow Island (kitchen facility and waste management)	B35 🔑	Establish a purpose-built kitchen facility on Barrow Island to receive food and perishable containers. The kitchen facility is to function as an effectively sealed building and truck loading area. Install dark-coloured doors.
	B36 🔑	Implement a barrier between the food preparation and serving areas to retard the movement of invertebrates and seeds. Barrier may include environmental, chemical and/or physical controls.
	B37 🔑	Waste treatment to minimise contamination of the Barrow Island environment.
	B38 🔑	Process all food before it leaves the kitchen facility.
	B39 🔑	Establish effective sewage treatment system.
	B40 🔑	Implement a barrier between the food serving area and the Barrow Island environment to retard the movement of invertebrates and seeds. Barrier may include environmental, chemical and/or physical controls.
	B41 🔑	Filter air prior to discharge from the kitchen facility.

Food and perishables pathway step	**Workshop barrier number** (🔑=key barrier)	**Quarantine barrier**
	B42 🔑	Perform chemical treatment inside and outside of the kitchen facility.
	B43 🔑	Install 'insect zappers' in all loading and food preparation areas.
	B44 🔑	Establish a chilled area in the kitchen facility for receiving food and perishables on Barrow Island, where food containers are to be unloaded. Maintain a temperature of 12°C to reduce activity of flying insects.
	B45 🔑	High pressure water hosing of the facility at the end of each shift.
	B46 🔑	Include traps in the design specifications of the kitchen facility to facilitate ongoing monitoring.
	B47 🔑	Regularly clean and disinfect all equipment to maintain good hygiene and housekeeping practices.
	B49 🔑	Establish higher risk and lower risk quarantine zones in the kitchen facility, with restricted personnel movement between the two areas. Require food and perishables to undergo processing (eg cleaning, washing, blanching, chopping) to reduce risk before it crosses a barrier into a lower risk zone.
	B50 🔑	Wash all fresh vegetables in a saline solution and potable water during processing.
	B51 🔑	Install air handling exhaust hoods in higher risk quarantine zones of the kitchen facility. Exhaust hoods to contain air filtration systems.
	B52 🔑	Double-bag all waste produced within the kitchen facility, prior to removal to a central waste processing area.

In addition to the conceptual quarantine barriers described above, additional barriers primarily related to reducing threats of introducing non-indigenous species as a result of waste management activities will undergo feasibility analysis and detailed design. These additional barriers include:

- Installation of an incinerator for waste management;
- Incineration of cardboard and plastics used for packaging;
- Fencing of the incinerator unit to exclude intrusion by native fauna;
- Processing waste in the incinerator following each meal period to minimise storage;
- Separation of waste water to grey water and sewage water;
- Excluding kitchen waste water from re-use as grey water for dust suppression, due to potential entrainment of seed material;
- Consideration of subsurface fauna in feasibility studies for reinjection of waste water (from waste systems or reverse osmosis separation plant);
- Return of waste material (eg waste oil, sewage sludge) to the mainland for processing or disposal; and
- Consideration of the design of above ground waste water storage tanks to exclude intrusion by native fauna.

4 'Personnel and Accompanying Luggage' Pathway

Conceptual quarantine barriers which are subject to feasibility analysis for the movement of 'personnel and accompanying luggage' by aircraft are described in this section of the document. This pathway includes only those activities associated with moving the large construction work force to and from Barrow Island from mainland airports. Any contemplated use of the Barrow Island airfield for inter-island aircraft flights will be the subject of a different pathway, and will undergo the same type of assessment.

The quarantine barriers for the personnel and accompanying luggage pathway have been identified to reduce the risk of introducing non-indigenous species at each step of the pathway. The pathway steps start at the point where personnel pack their personal belongings, and include all activities for processing luggage and personnel through their arrival at the Barrow Island airport, as shown in Figure 4.1.

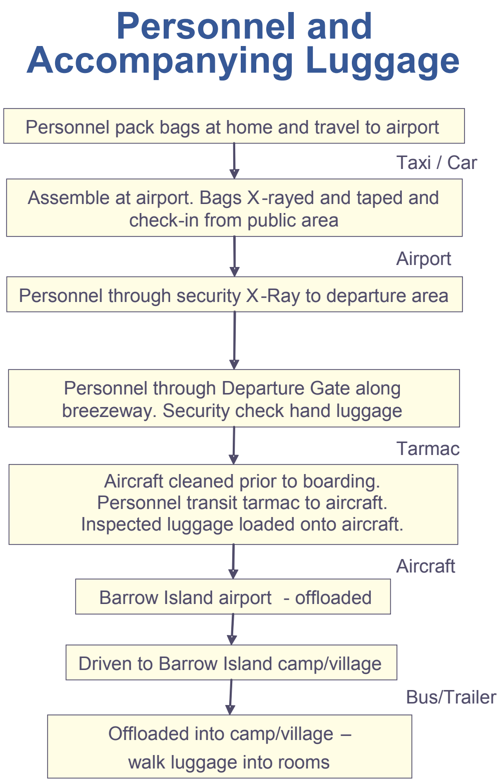

Figure 4.1: 'Personnel and Accompanying Luggage' Pathway Steps

The storage and handling of cargo which is shipped through a mainland logistics facility is being more comprehensively assessed on the 'containerised goods' pathway (separately from people and luggage), which is subject to the same type of assessment. Cargo is checked in at a mainland airport for transport with personnel and luggage. Quarantine barriers were considered with an emphasis on prevention of introductions at the point where cargo arrives at an airport for loading.

Of the conceptual quarantine barriers identified by technical experts, four barriers were singled out as key barriers. Quarantine barriers are listed in Table 4-1 by pathway step for reference, and numbered as per the relevant PBA workshop report for people and luggage

(29 October 2004). Key barriers are designated with the 🔑 symbol beside the workshop barrier number.

Table 4-1: Conceptual Quarantine Barriers Identified for the 'Personnel and Luggage' Pathway

People and luggage pathway step	**Workshop barrier number** (🔑=key barrier)	**Quarantine barrier**
Packing of luggage for work or visit Recruitment, selection and training of personnel	B1 🔑	Develop pre-employment agreements, including personal awareness training and inductions to appreciate quarantine risks and management. Provide list of prohibited items and require a statutory declaration by travellers.
	B2	Issue standard work clothing, boots, for use only on Barrow Island. Provide laundry services.
	B3	Consider issuing personal clothing and providing cleaning/laundry services.
	B4	Issue standard luggage to facilitate inspection and manual handling.
	B5	Ship personal items (eg specialised tools and equipment) through mainland logistics facility. Provide electronics (eg televisions, music players) and recreational facilities and equipment within the construction camp.
	B6	Establish a list of prohibited items as part of quarantine induction training. Reasons for prohibited items to be explained.
Check-in at mainland airports People, hand luggage, air crews, in-flight catering transported in the passenger cabin of aircraft	B7 🔑	Inspect every bag of personal luggage (x-ray and visual), by trained inspectors. Opportunities to further reduce risk if small organisms can be detected and eliminated during inspections.
	B9	Establish the same inspection processes (x-ray, visual) for air crew.
	B10	Establish procedures for personal inspection, subject to checklist provided at induction (cuffs, pockets, socks, etc). Allow additional check-in time to process people.
	B11	Require x-ray equipment to be capable of detection of invertebrates and vertebrates (pending further analysis of technology and alternatives).
	B12	Tag and seal carry-on luggage after passing quarantine inspection.
	B13	Self-check personnel clothing to verify compliance. Provide awareness training and reinforcement (eg posters at airport).
	B20	Establish a dedicated passenger assembly and waiting lounge which is segregated from other airport passengers. Establish dedicated transfer bus and air curtain where people board aircraft.
Loading of aircraft Checked personal luggage, and mainland logistics cargo, transported in the cargo hold of aircraft	B8 🔑	Establish a dedicated luggage handling circuit at the airport, segregated from other airport check-in activities. Dedicated equipment subject to chemical treatment. Establish a chain of custody and chemical treatment to reduce the risk of infections and cross-contamination on the outside surfaces of luggage. Establish air curtain where luggage and cargo is transferred to aircraft. Manage lighting to avoid attraction of invertebrates.
	B11	Require x-ray equipment to be capable of detection of invertebrates and vertebrates (pending further analysis of technology and alternatives).
	B12	Tag and seal checked luggage after passing quarantine inspection.
	B21	Containerise luggage for loading onto aircraft.

People and luggage pathway step	Workshop barrier number (🔑=key barrier)	Quarantine barrier
Flight to Barrow Island Airport facilities and aircraft	B14	Provide quarantine awareness training to air crew and airport personnel. Establish a list of prohibited items to in-flight catering contractors. Establish a contingency plan for managing quarantine during evacuation flights (eg cyclone evacuation of Barrow Island).
	B15	Establish dedicated aircraft and air crews. Restrict aircraft to Perth — Barrow Island flights (or flights between other mainland airport and Barrow Island). Establish procedures for quarantine clearance of standby or replacement aircraft. Consider steam cleaning of all candidate aircraft (fleet of BAe146) on a regular maintenance schedule.
	B16 🔑	Clean aircraft to meet prescribed quarantine standards, including disinfection of cargo hold prior to departure. Treat cabin with insecticide, establish vertebrate controls. Clean and inspect in-flight food catering trolleys prior to food being loaded into aircraft. Consider removing carpet from passenger cabin.
	B17	Apply residual chemical treatment to aircraft using insecticide and herbicide (pending further analysis of compatibility with airframe components, safety and human health considerations). Noted that cleaning of aircraft to remove dirt and seeds may be more effective than herbicide application.
	B18	Include quarantine compliance checks in the pre-flight checks conducted by the Air Captain (pending further investigation, may be the role of a trained quarantine inspector authorised to access aircraft).
	B19	Inspect internal aircraft spaces (passenger cabin, luggage compartments, cargo holds) for quarantine compliance prior to loading aircraft. Develop inspection program to allow random re-checking with additional staff, and establish response procedures for breaches. Establish 'no-go' criteria for grounding aircraft on quarantine grounds, to be decided by a Joint Venture representative or major contractor representative.
	B22	Establish procedures for allowing only dedicated personnel who have undertaken quarantine awareness training to have access to aircraft.

References

E-Systems, 2005. *"How to Guide" for Conducting Risk-based Assessments of Quarantine Hazards on Barrow Island*. Prepared for ChevronTexaco Australia Pty. Ltd., Perth, Western Australia.

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Technical Appendix E1

Cultural Heritage Assessment and Management Plan – Proposed Gorgon Development, Pilbara, North-Western Australia

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Cultural Heritage Assessment & Management Plan - Proposed Gorgon Development, Pilbara, North Western Australia

April 2004

For
Environmental Resources Management Australia Pty Ltd & ChevronTexaco Australia Pty Ltd

By
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Eddie McDonald
Alistair Paterson
Corioli Souter
Bruce Veitch

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DISCLAIMER

The authors are not accountable for omissions and inconsistencies that may result from information which may come to light in the future but which was not forthcoming at the time of this research.

ABSTRACT

This document details the results of detailed cultural heritage desktop research conducted for the proposed Gorgon Development on the Pilbara Coast and Barrow Island. An assessment of Indigenous, historic and maritime cultural heritage research is made and a description of preliminary field investigations in March 2004 on Barrow Island is also included in Appendix 2.

It is clear from the assessment that Barrow Island holds an unusual place in the pre-history and history of Western Australia. While some cultural heritage assessments have occurred on the island and mainland pipeline route it is concluded that they are insufficient for ChevronTexaco Australia's (CTA) proposal. There remains the high probability that unidentified cultural heritage is within the proposed Gorgon Development area. The major conclusions of the report are:

1. The three Indigenous communities (Yabburara/Mardudhunera, Kurama Marthudunera and Thanlanyji) who have expressed an interest need to be consulted in relation to cultural heritage management within the proposed Gorgon Development. This consultation may include physical inspection of the proposed development on Barrow Island and on the mainland.
2. That at present:
   a) Two identified cultural heritage sites may be impacted on Barrow Island by the Flacourt Bay Gas Feed Pipeline option.
   b) Four identified cultural heritage sites may be impacted on the mainland.
3. Owing to the low level of formal investigation, prior to construction all proposed ground disturbance areas, including the seabed, should be systematically surveyed for Indigenous, historical and maritime cultural heritage.
4. Proposed construction should be monitored in areas of high potential for sub-surface cultural material.

This document also contains a detailed cultural heritage management plan (CHMP) for the proposed development.

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1 INTRODUCTION

This document details the results of cultural heritage desktop research conducted for the proposed Gorgon Development on the Pilbara Coast, Western Australia, including Barrow Island. The assessment includes three components; Indigenous anthropology and archaeology, historical archaeology and maritime archaeology. Appendix 2 details the results of a preliminary archaeological field investigation conducted on Barrow Island. Its aim was to visit a number of previously recorded sites that may be impacted by the Gorgon Development and inspect areas within the development that have the high potential for cultural material. In addition the document contains a detailed cultural heritage management plan (CHMP) for the proposed development.

1.1 PERSONNEL

The following people participated in the compilation of the report:

Name	Qualifications	Organisation & Project Experience
Fiona Hook	BA(Hons)	*Archae-aus Pty Ltd* Archaeologist – Indigenous; 10 years – Indigenous archaeological assessments; 8 years -management of cultural heritage projects.
Eddie McDonald	PhD	*Ethnosciences* Anthropologist – Indigenous; 27 years – Indigenous anthropological assessments and management of cultural heritage projects in WA.
Alistair Paterson	PhD	*Eureka, University of Western Australia* Archaeologist – Historical; 10 years – Historical archaeological assessments and management of research grants. Currently a lecturer in Archaeology.
Corioli Souter	BA, Post Grad Dip	*Department of Maritime Archaeology, Western Australian Maritime Museum* Archaeologist – Maritime; 6 years – Maritime archaeological assessments and management of research grants. Currently an assistant curator.
Bruce Veitch	PhD	*Archae-aus Pty Ltd* Archaeologist – Indigenous; 15 years - Indigenous archaeological assessments; 12 years - management of cultural heritage projects.

Each component was completed by the following people:

Heritage Component	Desktop Research & Report Writing	Barrow Island Site Visit (March 2004)	Management Plan
Indigenous Anthropology & Indigenous Community Consultation	Eddie McDonald		Eddie McDonald
Indigenous Archaeology	Fiona Hook Bruce Veitch	Bruce Veitch	Fiona Hook Bruce Veitch
Historical Archaeology	Alistair Paterson	Alistair Paterson	Alistair Paterson
Maritime Archaeology	Corioli Souter	Corioli Souter	Corioli Souter
Project Management & Report coordination	Fiona Hook		

1.2 METHODOLOGY

The project brief requested that Archae-aus "assess and report on the potential Cultural Heritage impacts (indigenous and non-indigenous) and recommend a plan (Cultural Heritage Plan) to avoid, mitigate and manage activities that may have the potential to impact Cultural Heritage Sites" for the proposed Gorgon Development. To achieve this, research involved the following components:

1. Desktop research.

   This component involved the authors utilising resources held by the following organisations:

   a) Battye Library.

   b) ChevronTexaco Library.

   c) Department of Indigenous Affairs (DIA).

   d) Heritage Commission.

   e) Western Australian Museum.

   f) Western Australian Maritime Museum.

   g) University of Western Australia Library.

   In addition the authors spoke to the following people regarding cultural heritage:

   a) Dr Ken Aplin – palaeontologist at CSIRO.

   b) Harry Butler– consultant to ChevronTexaco.

   c) Dr Alan Dench – linguist at UWA.

   d) Dr Michael McCarthy – maritime archaeologist with WA Maritime Museum.

   e) Jo Pritchard – historian with Local History Office, Shire of Roebourne.

   f) Peter Randolph – heritage officer in DIA.

   g) Dr Peter Veth – Deputy Director of Research at AIATSIS.

   h) Anna Vitenbergs - historian with Local History Office, Shire of Roebourne.

2. Indigenous Community Consultations.

   The consultations for this study aimed at ascertaining if Indigenous people wished to be consulted regarding cultural heritage within the Gorgon Development. At the time of the consultations no discussion had occurred between CTA and Indigenous groups. Discussions via telephone and email were held with the following groups:

   a) Thanlanyji were contacted through Ms Glenys Hayes (Coordinator of the Buurabalayji Thalanyji Association Inc.). In addition the anthropologist held brief discussions with a number of elders in Onslow.

   b) Kurama Marthudunera were contacted through Robin Stevens (Acting Heritage Manager for Pilbara Native Title Service).

   c) Yabburara/Mardudhunera were contacted through their heritage advisor Ron Parker (Consultant Anthropologist).

3. Preliminary Fieldwork.

   a) In March 2004 a preliminary investigation of the proposed development on Barrow Island was conducted by archaeologists Alistair Paterson, Corioli Souter and Bruce Veitch. The aim of this was twofold: firstly, to relocate previously recorded cultural heritage sites within and adjacent to the Gorgon Development; and secondly to inspected the proposed development area in preliminary detail, with spot checks undertaken at areas of high archaeological potential such as coastal areas and claypans. The results of this assessment are detailed in Appendix 2.

4. Preparation of desktop assessment and Cultural Heritage Management Plan.

1.3 GLOSSARY

This glossary list refers to technical terms in used in this report.

Adze – stone tool designed for working the surface of wooden objects (Horton 1994:36; McCarthy 1976:29-34).

Artefact scatter - locations where a range of activities has occurred such as the manufacture and maintenance of tools and the processing of foods. In the context of Indigenous archaeological sites, flaked and ground stone artefacts are the most common artefact type.

Backed artefact - a thin flake with steep, bipolar retouch on one lateral margin and a sharp edge on the opposite margin.

Barracoon - a rough barrack, set of sheds, or enclosure, in which Black slaves (originally), convicts, etc., are temporarily detained (Simpson & Weiner 1989).

Cutter – a ship with one mast rig with gaff mainsail, stay foresail, jib and topsail, and running or reefing bowsprit (de Kerchove 1961).

Eloura - large backed artefact (McCarthy 1976:29).

Flaked Artefact – stone, glass or porcelain artefacts that possess one or more of the following characteristics: a positive or negative ring crack; a distinct negative or positive bulb of percussion or force; a definite eraillure scar beneath a striking platform; and definite remnants of flake scars (e.g. dorsal scars and ridges) (Andrefsky 1998: xxi-xxxvii; Hiscock 1984: 128).

Ground Artefact – usually hard wearing stone such as granite, basalt or ironstone with clear evidence of polishing on one or more surfaces. A number of different types occur in Australia including mullers and millstones used for flat grinding of seeds, ochre; and mortars and pestles for pounding ochre, bones and plant material (Smith 1986:33).

Holocene - the most recent geologic era; from about 10,000 years ago to the present.

Last Glacial Maximum - the period of time, approximately 18,000-22,000 years ago, during the last great ice age when glaciers, ice sheets and sea ice reached their maximum thickness and aerial extent.

Lock Hospital - a hospital for the treatment of venereal diseases (Simpson & Weiner 1989).

Lugger – see pearling lugger.

Midden, Shell – scatter, pile or mound of the remains of one or thousands of shellfish meals (Horton 1991:982).

Pearling Lugger – a local name given in North West Australia to small ketch rigged boats employed in pearl fisheries. Usually planked in Australian Jarrah, copper fastened and copper sheathed. A fast sailer which is sometimes fitted with an auxiliary engine (de Kerchove 1961).

Pedestrian Survey – archaeological survey technique involving the visual inspection of the ground surface while walking across the landscape (Banning 2002:40).

Pleistocene - the glacial epoch preceding the Holocene, extending back from 10,000 years ago to about 1.8 million years ago. The Pleistocene and Holocene epochs comprise the Quaternary period (Horton 1994:876)

Reduction Area - a cluster of flaked stone artefacts which represent the remains of the flaking of a core. Artefacts within a reduction area can usually be conjoined and represent a single flaking event.

Retouched Artefact – where the artefact exhibits flake scars extending onto the ventral surface and/or deriving from the ventral surface. These flake scars may form during use or treadage, as well as during knapping.

Rock-shelter - overhang, cave or cliff face that contains evidence of human occupation in the form of stone artefacts, economic shell species, charcoal, faunal material or rock art.

Shell Scatter – see midden above.

Stratified cultural deposit –cultural material and sediment layered in a way that mimics rock layers in geology. The lower levels of the deposit are older than the levels above if no disturbance has occurred.

Systematic Survey – assessment of a given area by spacing survey team at an equal distance with each team member responsible for inspecting along linear / zigzag transect (Banning 2002:41).

Vehicle Survey – assessment of a given area by inspecting the ground surface from a slow moving vehicle (Banning 2002:40).

Windscreen Survey (see Vehicle Survey).

2 GORGON DEVELOPMENT

The development is described in detail in the 2003 EIS/ERMP (Gorgon Australian Gas 2003). In summary, the proposed Gorgon Development comprises the following components:

1. Sub-sea gathering infrastructure at the Gorgon gas fields.
2. 70 km long feed gas pipeline to bring gas/well stream fluids to Barrow Island from the Gorgon gas field. There are currently two options, one landing at Flacourt Bay and the second at White's Beach.
3. Gas processing facility on the east coast of Barrow Island.
4. Port facilities on the east coast of Barrow Island.

5. CO_2 pipeline and sequestration system from the gas processing facility. In its current form this pipeline is approximately 5 km long and extends north from the proposed gas processing facility.
6. 80 km long domestic gas (DOMGAS) infrastructure piping gas from Barrow Island to the mainland. It is proposed to run the DOMGAS pipeline parallel with the pre-existing Apache gas pipeline and join the Dampier-Bunbury Natural Gas Pipeline at Compressor Station 1.

3 LEGISLATION

3.1 *INDIGENOUS HERITAGE*

All Indigenous heritage sites and objects are protected under Western Australia's *Aboriginal Heritage Act 1972* (*AHA*). Section 17 of the *AHA* states that it is an offence to -

1. alter an Indigenous site in any way, including collecting artefacts;
2. conceal a site or artefact; or
3. excavate, destroy or damage in any way an Indigenous site or artefact;

without the authorisation of the Registrar of Aboriginal Sites under Section 16 or the Minister of Indigenous Affairs under Section 18 of the *AHA*.

The *AHA* protects sites and objects that are significant to living Indigenous people as well as Indigenous sites of historical, anthropological, archaeological and ethnographic significance. The *AHA* is currently administered by the Department of Indigenous Affairs (DIA).

Indigenous heritage sites are also protected under the *Commonwealth Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (HPA*). The *HPA* complements state/territory legislation and is intended to be used only as a 'last resort' where state/territory laws and processes prove ineffective. Under the *HPA* the responsible Minister can make temporary or long-term declarations to protect areas and objects of significance under threat of injury or desecration. The *HPA* also encourages heritage protection through mediated negotiation and agreement between land users, developers and Indigenous people.

Indigenous human remains are protected under the *AHA* and the *HPA*. In addition the discovery of human remains requires that the following people are informed: the State Coroner or local Police under Section 17 of the *Coroners Act 1996*; the State Registrar of Aboriginal Sites under Section 15 of the *AHA*; and the Federal Minister for Indigenous Affairs under Section 20 of the *HPA*.

A recent document finalised by the Environmental Protection Authority (2004:4) states that Indigenous heritage will be assessed as a *relevant environmental factor* during formal EIA assessments by the EPA.

3.2 *HISTORIC HERITAGE*

Indigenous archaeological sites created following European exploration and settlement in the 1800s are protected under Western Australia's *Aboriginal Heritage Act 1972* (see Section 3.1).

The Heritage Council is Western Australia's advisory body on heritage matters and focuses on places, buildings and sites under the *Heritage of Western Australia Act 1990* (*HWAA*). The Heritage Council's mission is to provide for and encourage the conservation of places significant to the cultural heritage of WA, and would thus have an interest in historic sites on Barrow Island. It should be stated however, that the Heritage Council has largely been unconcerned with the archaeological resource, focusing instead on historic standing buildings.

Barrow Island is included on the state register as: 'Place No: 14365 Name: Barrow Island Marine Area – part'. We presume this is solely on the basis of its environmental value although no boundaries or locations for this listing are provided in the register. It should be noted that:

> The Heritage of Western Australia Act 1990 requires Local Government Authorities and State Government Agencies to seek the advice of the Heritage Council if they are considering development of a place that is entered in the Register of Heritage Places. Work may not proceed before advice has been received and the work must comply with the advice (Electronic Document, accessed 1 April 2004, http://www.heritage.wa.gov.au/b_development_referrals.html)

Although CTA is not a Local Government Authority/Government Agency, the Heritage Council should be informed of the results of any archaeological surveys if historic finds are identified on the island. It would appear the listing on the State Register of Historic Places is one by default following the creation of a Marine Park on the Register of the National Estate (Place 17417) for environmental value. For that nomination there was no study of heritage value, although the potential was recognised: "It is possible that cultural values, both indigenous and non-indigenous, of National Estate significance may exist in this place".

Any historical archaeological material at Barrow Island would derive from seafaring contexts as all visitors would have arrived in boats. As such there is potential for archaeological sites and isolated artefacts to be subject to the Western Australian *Maritime Archaeology Act 1973* (see Section 3.3).

3.3 MARITIME HERITAGE

The State *Maritime Archaeology Act 1973* (*MAA*) protects the remains of ships lost before 1900 and any associated relics. Section 4 of the *MAA* defines what constitutes a maritime archaeological site: and includes remains of an historic ship; an area where any relic is known to be located; any structure, campsite, fortification or other location of historic interest associated with an historic ship. A maritime archaeological site may be below the low water mark, between the tide marks or on land. This section of the *MAA* specifically relates to material from and including the remains of an "historic ship", which is defined as any ship that before the year 1900 was lost, wrecked or abandoned, or was stranded, on or off the coast of Western Australia. The term "relic" is any thing of historic interest that appears to have formed part of, or to have been carried by or derived from or associated with any historic ship, and any thing to which the provisions of Section 6(3) of the *MAA* apply. The same legislation includes protection of material derived from or associated with any ship, regardless of whether it is "historic". Section 6(3) vests in the Western

Australian Museum, on behalf of the Crown, property in and the right to possession of any object, which in the opinion of the Director of the Museum, was abandoned in the State before 1900 and was derived from or associated with any ship and which, immediately prior to 1973, was not in the lawful possession of any person (Crown Law advice 18/02/98, MA27/80).

The *Historic Shipwrecks Act 1976* (*HSA*) is Federal legislation which protects all shipwrecks in Commonwealth waters and associated relics which are more than 75 years old. Shipwrecks which have not been located are still protected under the *HSA*.

4 CULTURAL HERITAGE ASSESSMENT

The Gorgon Development has been assessed for Indigenous anthropology and archaeology as well as historical and maritime cultural heritage with an emphasis on archaeological sites. The results of the assessment are detailed below.

4.1 INDIGENOUS HERITAGE

4.1.1 Indigenous Anthropology

4.1.1.1 Language Groups

Tindale (1974) identifies three tribal or language group territories on the Northwest coast that are of relevance to the Gorgon Development. These “tribes” are from north to south:

1. Mardudunera [Martuthunira]
2. Noala [Nhuwala]
3. Talandji [Thalanyji]

Tindale (1974:248) describes the location of the Mardudunera as follows:

> Coastal plain north of the Fortescue River; north to visited islands of the Dampier Archipelago on log rafts; inland only to the foot of the ranges. These are perhaps the people described by King, (1827:i.38) as tide riding on logs near Lewis Island.

Noala country is described by Tindale (1974:254) as follows:

> Coastal plain from about Cape Preston near the mouth of the Fortescue River southwest in a strip about 40 miles (65 km.) wide to a line running south from Onslow, but not extending to the Ashburton River, which is held by the Talandji. They kept near the seashore and went out to Barrow and Monte Bellow Islands using a form of wooden “canoe”… Inland areas, away from creeks, could only be visited after rain when the claypans were filled. Most of their livings came from tidal inlet fish traps.

Tindale (1974:256) describes Talandji country as follows:

> Along the Ashburton River from the coast to Nanutarra, Boolaloo, and the lower Henry River. .. Their extension to the coast at Exmouth Gulf coast is

> probably due to late migration, offshore fresh water spring or springs at [‘Pi:ltan] (now within Onslow township) was an ultimate water supply base.

Other research has raised issues about Tindale’s descriptions of the country of various groups in the west Pilbara area. For example, Dench (1987:5), following extensive linguistic fieldwork in the area, argues that Martuthunira country is more extensive than described by Tindale and notes that:

> On the west cost, the grass plains and mudflats between the Robe River and the Cane River were shared with the Nhuwala. Warramboo Creek (Wartampu) is described as the boundary though the Nhuwala foraged as far north to the northeast as the Robe River.

Of the groups referred to by Tindale (1974) few people now identify as Nhuwala and they tend to be considered as part of the Thalanyji community resident in Onslow and other Northwest towns (Dench 1987). The last Martuthunira speaker died some years ago, however, a number of people claim interests in Martuthunira country and these claims are symbolised in the names of their native title claims.

There are three Registered Native Title Claims encompassing the people from the language groups in the area and with registered interests in the sea and offshore islands:

1. Yabburara/Mardudhunera (WC96_089)
2. Kurama Marthudunera (WC99_012)
3. Thanlanyji (WC99_045)

Wong-Goo-Tt-Oo (WC98_040) claim is located further to the east and encompasses the sea and offshore islands in the vicinity of the Cape Preston. However, none of the active native title claims encompasses Barrow Island, though a representative of the Thalanyji group noted that it was their original intention to extend their claim to cover the island.

4.1.1.2 Ethnographic Evidence for Indigenous Offshore Island Use

Tindale (1974:254) mentions the use of offshore islands by two of the three groups mentioned above, namely the Mardudunera [Martuthunira] and Noala [Nhuwala] and specifically mentions the Noala visiting “Barrow and Monte Bellow Islands using a form of wooden ‘canoe’”. However, it is not clear what sort of craft and what type of usage of the islands he is referring to[1].

Though not referring to the use of the islands by the Thalanyji, there is no reason to believe that the Thalanyji, like their coastal neighbours, did not have water craft and

[1] It has not been possible to inspect Tindale’s field journals as the Archives in the South Australian Museum have closed for two to three months because of staffing problems. Copies of the journals are held by the Family History Unit of the Department of Indigenous Affairs. However, access to the journals is restricted to members of the Aboriginal families mentioned in the journals or those with written permission from these families. The officer in charge of the unit has reported that she can find no reference to “canoes” in Tindale’s journal entries for the Noala [Nhuwala].

visit the offshore islands. Indeed, Bates (1985:257-258) notes the exploitation of offshore islands by Aboriginal people:

> Along the Northwest coast there is [sic] a number of small islands which the natives of the Roebourne district are able to reach … In the early days the natives transported themselves to the various islands by means of logs of mangrove wood, two of these being joined neatly together end to end … while a third and shorter piece formed a primitive stern.

Bates (1985:258) goes on to mention that coastal Indigenous people of the Ashburton and Northwest Cape also used a type of raft, similar to those used in the Roebourne area, though these were made from corkwood rather than mangrove trees. Bates (1985:258) also mentions that the last of the traditional log rafts were seen in operation at Lewis Island in 1883 and that "present day" (c. 1909) Aborigines use "white man's boats" for sea excursions.

The implications from Tindale and Bates' research is that Northwest coastal Indigenous people used traditional watercraft to visit offshore islands, including Barrow and the Montebello Islands and that by the turn of the Nineteenth Century Indigenous people were using non- Indigenous boats to continue their sea based activities, possibly including visits to Barrow Island. There are also recorded visits to the island by Indigenous people in circumstances controlled by European Australians, including forced involvement with the pearling industry (see Section 4.2, below). A representative of Thalanyji community reports that elders recall at least one of the now deceased members of the community visiting the island in the company of non-Indigenous people on a regular basis when they were young.

4.1.1.3 Mythological Connections

In addition to the foraging on Barrow and other offshore island reported by Tindale (1974) one ostensible mythological connection to Barrow has been mentioned. Dench (pers. comm.) recalled that during his Martuthunira field work in the 1980s his informants had recounted the mythology relating to the origins of Pannawonica Hill [*Parlapuni*]. Basically the narrative relates how the hill had its origins in the sea to the west and was carried to its present location on the head of a spirit bird:

> .. the mark of this hill, dragged from near Mardie Station, from the ocean, has left a big flat, where Pannawonica went across. We all know, the old fells know that – you can still see it, the main highway goes across it. It's come from west to east, where he travelled in the valley there. And in the hills where he came through, he made a V mark – you can see like that for a long distance, about ten of twelve mile, where that fells went in there. He went straight for Pannawonica … (related by the late Gordon Lockyer in Brehaut & Vitenbergs 2001:35-36).

Dench (pers. comm.) recalls that in one version of the myth *Parlapuni* was reported to have come from Barrow Island. Other versions, however, point more northwest towards the Dampier Archipelago for the origins of Pannawonica Hill. However, both versions of the mythological narrative may be equally valid within the Guruma [Kurrama] and Martuthunira communities.

4.1.1.4 Known Indigenous Groups and Cultural Heritage Sites

4.1.1.4.1 Barrow Island

A search of the Register of Aboriginal Sites held by the DIA reveals that no ethnographic sites are listed on Barrow Island. This absence of listed ethnographic sites may reflect the more recent historical attenuation of links with the island. However, representatives of all the groups consulted indicated that they did have an interest in cultural heritage on Barrow Island.

1. A spokesman for the Yabburara/Mardudhunera claimants reports that:

   > They have expressed the view that the Island was once part of their area and that they have concerns regarding the new development there as far as heritage sites are concerned.

2. The Pilbara Native Title Service (PNTS) Acting Manager of Heritage has noted that a number of people in the Kurama Marthudunera group have expressed an interest in the island's heritage.
3. A Thalanyji representative reports that the group's elders say that the Thalanyji people, including people of Nhuwala descent, have interests in the Island's heritage.

Clearly, Indigenous people have an interest in the proposed Gorgon Development on Barrow Island and clearly wish to be consulted. This consultation may include physical inspection of the proposed development on Barrow Island.

4.1.1.4.2 Mainland

The planned onshore pipeline on the mainland is within Martuthunira country (Murphy & McDonald 1990). The area is within both Martuthunira Native Title claim areas: Yabburara/Mardudhunera (WC96_089) and Kurama Marthudunera (WC99_012).

A search of the Register of Aboriginal Sites held by the DIA reveals that two ethnographic sites, both associated with Peters Creek, are located close to the proposed DOMGAS pipeline on the mainland (Map 4-2). First, Peters Creek is a Named Place: *Nyungarrarra* (Site ID 17429) (McDonald, Hales & Associates 1994) and second, Warlu Waterhole: (Site ID 17004), situated in the Creek, is listed as a mythological site with an associated artefact scatter (McDonald Hales and Associates 2001; Stevens 1998) (Appendix 1). In addition a 'waterhole' known to Martuthunira informants was identified along the Apache/Hadson pipeline (Murphy & McDonald 1990), which has not been registered with the DIA (Appendix 1). This site is associated with an archaeological site, which is discussed in Section 4.1.2.1.2, below).

These two Indigenous groups need to be consulted in relation to cultural heritage management within the proposed Gorgon Development on the mainland. The Indigenous groups may request a physical inspection of the proposed development.

4.1.2 Indigenous Archaeology

4.1.2.1 Barrow Island

Barrow Island occupies a potentially important position in the Indigenous archaeology of north-western and continental Australia. Barrow Island has remained an under researched area of the Pilbara coast with only two Indigenous archaeological surface surveys conducted on the Island (Quartermaine Consultants 1994; Quartermaine 1997).

When Indigenous people first arrived on the Australian continent approximately 45,000 BP[2] (Bowdler 1990; Roberts *et al.* 1990a; 1990b), Barrow Island was a dissected limestone hill on a large coastal sand plain with the coast 10 km to the west (Figure 4-1) (Veth 1994; Veth *et al.* in press). The first Indigenous occupation evidence for the immediate area dates to circa 32,000 years ago at Cape Range and circa 30,000 years ago on the Montebello Islands (Morse 1993a; Przywolnik 2002; Veth 1994; Veth *et al.* in press:13). At the height of glacial maximum, about 18,000 BP, the coastline moved 50 km west from Barrow Island (Figure 4-1). During this period Indigenous occupation patterns appear to have been very different from those of more recent millennia. The removal of so much water from the water cycle, of which a lowering of sea levels by 130 m was symptomatic, resulted in marked reconfigurations of Indigenous populations in many parts of Australia, especially arid areas such as Barrow Island. Indigenous populations appear to have concentrated around identified refuge and corridor areas that offered greater resource reliability, such as the arid Pilbara coast (Morse 1993c:277, 290; Veth *et al.* in press:75; Veth 1993). During the glacial maximum Barrow Island, the Montebello Islands and the Cape Range areas would have been in the hinterland of the coastal plain with perhaps reduced though still highly detectable archaeological evidence remaining from such use (eg. Morse 1993c; Przywolnik 2002; Veth 1994; Veth *et al.* in press).

As the climate ameliorated the sea level rose with Barrow and Montebello Islands cut off from the mainland around 8,000 BP (Figure 4-1) (Veth 1994). Indigenous people lived on the Montebello Islands during this period and it is most likely that they also utilised the greater Barrow/Montebello land mass. The sea reached its current level circa 7,500 BP. At 7,000 BP the Montebello Islands were abandoned by Indigenous people most likely owing to the scarcity of potable water and perhaps moving to the larger Barrow Island or to the mainland (Veth *et al.* in press:5). As no detailed archaeological excavations have occurred on Barrow Island it cannot be determined whether Indigenous people occupied the island after 7,000 BP. As sea levels rose the perched freshwater on the Montebellos was contaminated by sea water. Owing to its greater height above sea level fresh water on Barrow would not have been contaminated (Veth *et al.* in press:32). Lack of occupation evidence from the Montebello Islands and the fact that from the mainland to Barrow Island was a 60 km

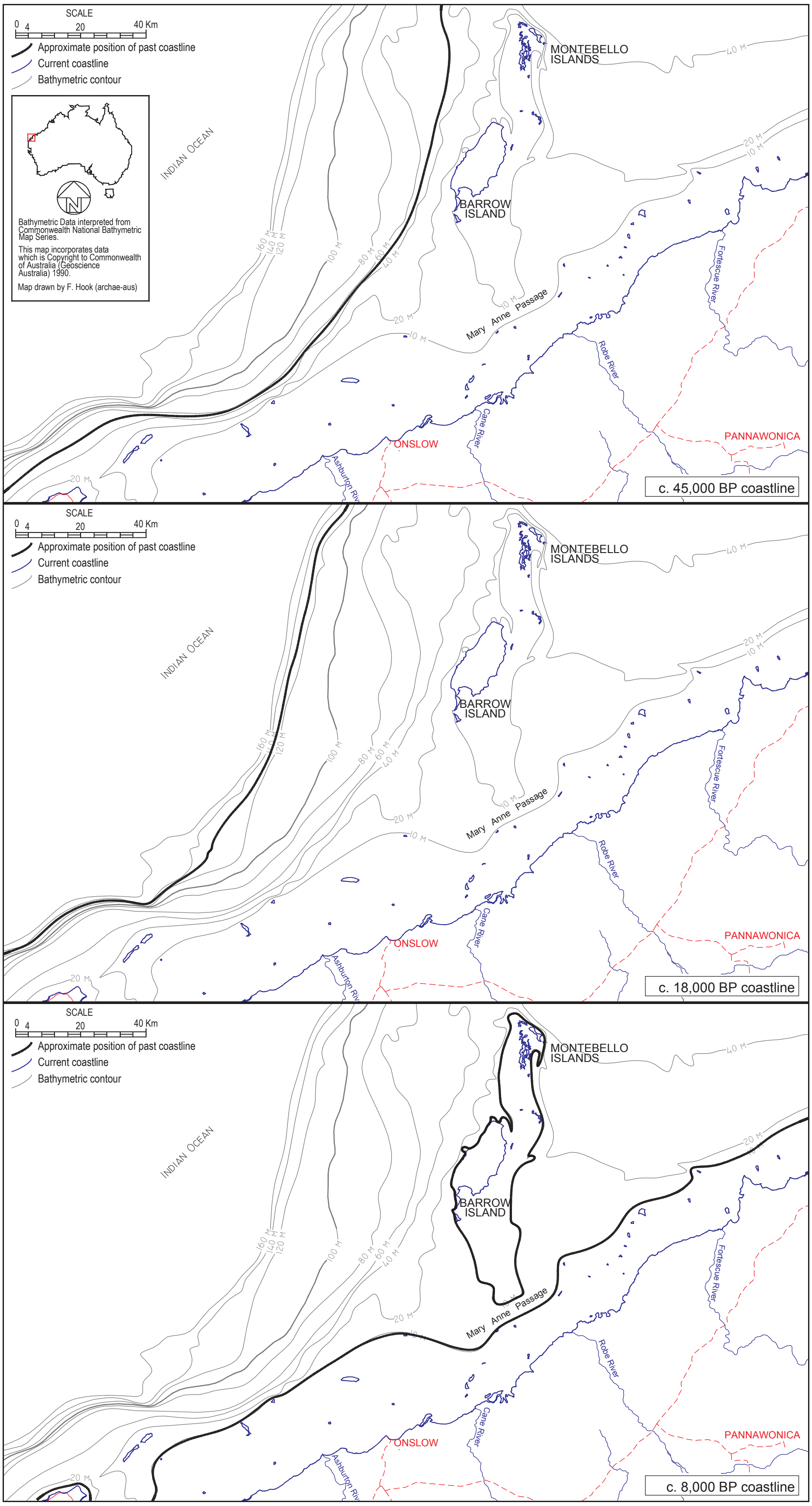
[2] Years **B**efore **P**resent (1950).

journey by sea from circa 6,000 BP suggests that Barrow would not have been revisited by Indigenous people during the mid or late Holocene (Crawford 1986 cited in Veth *et al.* in press:2, see also 70). However, the evidence of possible canoe use by Indigenous people on the Pilbara coast (Bates 1985:257-258; Tindale 1974:254) and in particular reference by Tindale (1974:254) to the Noala accessing Barrow and the Montebello Islands by a type of canoe raises the possibility of Holocene use of the island.

Furthermore, Quartermaine Consultants (1994) recorded two adze slugs and an *elouera* on the Barrow Island. The first adzes appear in the archaeological record in Australia by the mid-late Holocene after the Barrow / Montebello Islands were abandoned (Hiscock 1994; Hiscock & Veth 1991:342; Jones 1985; White & O'Connell 1982:106-133). Although some backed artefact forms may have occurred earlier in eastern Australia, convincing evidence is not found beyond the eastern seaboard (Bowdler & O'Connor 1991; Hiscock & Attenbrow 1998). Indeed adzes are seen to be confined to the mid-Holocene even by some of those who propose earlier dates for backed artefacts (Jones 1985). If the identification of adzes on Barrow is correct it suggests that the island was occupied after insulation and visited from the mainland after 7,000 BP. Alternatively, the adzes may have been made by Indigenous people visiting the island during historic times (see section 4.2). Adzes, however, were used to make objects from hardwood, of which there is very little on Barrow Island today. During the March 2004 visit to the island, the "adze slug" noted in site 883/FS01 (Quartermaine Consultants 1994:15) was seen (Appendix 3). This object, in the opinion of Bruce Veitch, is not an adze slug but a retouched flake. These three artefacts therefore need further inspection and an accurate typological identification**.** In addition, the dating of stratified sub-surface cultural deposits on Barrow Island would be desirable to resolve when / if the island was abandoned by Indigenous people.

During the historical period Indigenous people were present on the island, and historical sources describe them being brought to Barrow Island by Europeans. The evidence of their presence on the island is quite marked (see descriptions of flaked glass & porcelain artefacts in Quartermaine Consultants 1994:15-22, Fig 15 & 16). This aspect of the island's history is discussed in more detail in Section 4.2.

Figure 4-1. Sea levels at 45,000 BP, 18,000 BP and 8,000 BP (Chappell & Shackleton 1986; Chappell & Thom 1977:281; Veth 1994).



Barrow Island therefore has the potential to contain material evidence directly relevant to "a number of fundamental and critical research questions related to the history of coastal exploitation in Australian archaeology" (Veth *et al.* in press:3). These questions revolve around the following points.

1. Barrow Island lies between Cape Range Peninsula and the Montebello Islands which were initially occupied by Indigenous people at 34,200±1050 years BP and 27,220±650 years BP respectively (Morse 1988; 1993d; Przywolnik 2002; Veth 1994; Veth *et al.* in press). The presence of two areas with such long occupation records either side of Barrow Island strongly suggests that the island will also contain Indigenous archaeological material of great antiquity in both rock shelter (Quartermaine Consultants 1994:22) and possibly stratified sites in sand dunes (Bowdler 1999; Morse 1988; 1993b; Przywolnik 2002; Veitch & Warren 1992).
2. Barrow Island has a limestone geological base offering potentially very good preservation conditions in stratified cultural deposits which is unusual for the Pilbara and arid Australia. As a consequence of both its limestone base geology and the potential to contain stratified material, Barrow Island may contain well preserved organic remains, offering possibly unique insights into past subsistence strategies and the use and manufacture of organic items (eg. Morse 1993b; Wallis & O'Connor 1998). Of note is the fact that shell beads were recovered from the Cape Range peninsula, being among the oldest jewellery known to humanity (Morse 1993b).
3. Barrow Island may contain material relevant to investigating human responses to sea level changes and other environmental changes during strategic periods of the Pleistocene and later Holocene, especially during and immediately after marine transgressive phases (Beaton 1985; 1995; Bowdler 1999:82; Veth *et al.* in press:3-4). Indeed it is still unknown whether Indigenous people remained on Barrow Island after insulation around 7,000 years ago, and if so, for how long (Dortch & Morse 1984; Quartermaine Consultants 1994; Veth *et al.* in press:5).
4. The presence of artefactual material made of volcanic, metamorphic or siliceous sedimentary stone on Barrow Island would inform on patterns of "contact and/or mobility strategies" over time given the absence of these raw materials (excluding limestone) on Barrow Island (Veth *et al.* in press:5). Other raw material types, such as ironstone, quartz and chert, that have been used to manufacture flaked and ground stone artefacts have come from elsewhere most likely the mainland.

To date documented Indigenous archaeological research on Barrow Island comprises two surveys concentrating on surface archaeology with 12 archaeological sites recorded and registered with the DIA (Quartermaine Consultants 1994; Quartermaine 1997). In addition, collected artefactual material from Indigenous sites is held by the Western Australian Museum (WAM) and by WAPET/ChevronTexaco on Barrow Island. Previous surveys, recorded Indigenous sites and the collected artefacts are discussed further below.

4.1.2.1.1 Previous Surveys

The initial survey conducted by Quartermaine Consultants (1994:11) covered 10% of the island using pedestrian and vehicular transects. In addition to the 1994 survey, a proposed Plant and Associated Facilities area measuring 4.2 km² on the north-eastern tip of the island was sample surveyed (Quartermaine 1997). Very little of the Gorgon Development has been systematically inspected for Indigenous archaeological sites. Specifically, 2.2% of the proposed Gas Processing and Port Facility (1550 ha, see Gorgon Australian Gas 2004:10, Figure 2) has been thus assessed (calculated from Quartermaine Consultants 1994:11, Figure 2). While the coverage of the proposed pipelines appears relatively high (approximately 85% of the Flacourt Bay Feed Gas Pipeline Option, 75% of the White's Beach Feed Gas Pipeline Option and approximately 71% of the CO_2 Pipeline), most of this was covered from a slow moving vehicle, with only 1.3% of the CO_2 Pipeline surveyed on foot. Windscreen surveys (from a slow moving vehicle) are usually used for preliminary inspections rather than a survey method prior to development (Banning 2002:40; Collins & Molyneaux 2003:43, 52-63).

> Older archaeological surveys typically entailed searching visually for archaeological remains … from a motor vehicle (so-called "windscreen surveys") … Although such surveys continue, at least for preliminary reconnaissance, it is now much more common for visual inspection of the surface to be accomplished through pedestrian surveys (Banning 2002:40).

Compounding the difficulty in identifying artefactual material on the ground from a slowly moving vehicle is the fact that Barrow Island has not had any major fires for the last 30 to 40 years (Quartermaine Consultants 1994:12), rendering ground visibility very low. Furthermore during the March 2004 Barrow Island visit it was observed that a number of the sites recorded by Quartermaine Consultants (1994) have been affected by cyclonic activity (see Appendix 2 for a discussion for these changes). This suggests that additional cultural material may have been exposed since the 1994 and 1997 surveys (Quartermaine Consultants 1994; Quartermaine 1997).

In light of the above, to assess adequately the possible impact of the proposed development on Indigenous cultural heritage**,** additional systematic pedestrian sample surveys will be required of the proposed disturbance areas. A number of areas of high archaeological potential exist on the island some of which were identified by Quartermaine Consultants (1994:5) and include claypans, drainage lines and coastal dunes (Map 4-3). Claypans and coastal dunes in particular have the potential for the presence of sub-surface cultural material. During construction of the Gorgon Development these areas must be monitored by qualified Indigenous archaeologists for this potential.

4.1.2.1.2 Sites

The Register of Aboriginal Sites maintained by the DIA has records of 13 Indigenous archaeological sites on Barrow Island (see Appendix 1), 12 of which were identified during the survey conducted by Quartermaine Consultants (1994). One of the 13 sites (8951) comprises six flaked stone artefacts donated to the Western Australian Museum that were collected in the 1960s by WAPET employees (Dortch & Morse 1984). This area has been assessed by the DIA as "Not a Site" because no information was provided regarding artefact provenance. The remaining 12 sites comprise surface artefact scatters with artefacts manufactured from volcanic, metamorphic and siliceous sedimentary stone as well as glass and porcelain (Quartermaine Consultants 1994). Five of the sites were assessed as of low archaeological significance, six as moderate and one as having high archaeological significance. Six of these surface sites may have sub-surface cultural material, owing to their position in claypans.

In addition to the 12 artefact scatters, four rock shelters / caves with the potential for sub-surface cultural material were recorded on the west coast of the island (Quartermaine Consultants 1994:22, 25). Evidence from these sites in particular has the potential to address some of the research issues outlined above. Of note here is the fact that none of the rock shelter / caves identified by Quartermaine Consultants (1994) and the March 2004 field trip appeared to contain surface artefacts. This is consistent with the suggestion that these sites have not been used for several millennia.

Quartermaine Consultants (1994) also recorded a number of sites that contained historical material (called Pearling Camps), including flaked glass and porcelain artefacts. These sites are discussed in more detail in Section 4.2

Of the 13 DIA registered Indigenous archaeological sites, two are either very close to or may be impacted by the proposed development (Map 4-1). Site 888 (FS06 Area C) is in the path of the proposed CO_2 Pipeline (Quartermaine Consultants 1994:33). Site 887 (FS05) appears to be located immediately north of the CO_2 Sequestration System. A site recorded during the March 2004 Field Trip (GD04-01) is located adjacent to the Flacourt Bay Feed Gas Pipeline (Map 4-1). The White's Beach Feed Gas Pipeline also passes close to a recorded freshwater soak.

Site 887 (FS05) was recorded as a sparse scatter of flaked and ground stone artefacts in the base of a deflated dune at Cape Dupuy (Quartermaine Consultants 1994:17, 39). A total of four artefacts were recorded and the site was assessed as having low archaeological significance. The site is at the northern end of the CO_2 Sequestration System and it does not appear that the site will be impacted (Map 4-1). During the March 2004 field trip Veitch, Paterson and Souter visited this site and assessed that the site had been affected by cyclonic activity. The number of artefacts present in this area was possibly up to 500 and an *in situ* flaked stone reduction area was noted. If this site is to be disturbed additional site recording and test excavation will be required.

Site 888 (FS06) is an scatter of flaked stone, glass and porcelain artefacts spread out over a series of claypans (Quartermaine Consultants 1994:17-18, 40). Artefacts occur in six areas and the proposed CO_2 Pipeline passes through Area C (Map 4-1). A total of six artefacts were recorded from Area C and this site was assessed as having moderate archaeological significance. Quartermaine Consultants (1994:18) recommend that prior to any disturbance the site be test excavated to determine the potential for stratified cultural material. During the March 2004 fieldtrip Veitch, Paterson and Souter visited this site. Some parts of the site were found to have similar numbers of flaked stone artefacts to those noted in 1994 while others such as Area C were found to be less. Area C was found to contain only one ironstone flake fragment. This result raises the possibility of movement and burial of artefacts in claypans thereby forming stratified deposits and is consistent with Quartermaine Consultants (1994) findings. This site will need to be test excavated to determine the presence/absence of sub-surface cultural material prior to any proposed disturbance by CTA.

A rock shelter with potential for sub-surface cultural material was identified in Flacourt Bay (GD04-01) during the March 2004 site visit (Appendix 1 and 2). No artefactual material was on the surface, however, and due to safety requirements the survey team did not enter the rock shelter beyond the drip-line. This site is 90 m north-east of the Flacourt Bay Pipeline option centreline and will not be impacted by the Gorgon Development.

4.1.2.1.3 Collected Artefacts

The Western Australian Museum has in its collection a total of 18 artefacts from Barrow Island. They were collected by WAPET employees in the 1960s and WAM staff in the 1980s. The artefacts include flakes, debris, a possible baler shell water carrier (*Melo* spp.), baler shell fragments and three possible artefacts (weathered limestone and ironstone) (see Dortch & Morse 1984 for a description of six artefacts). The flaked stone artefacts are manufactured from ironstone, quartz, limestone and chert. The possible baler shell water carrier was collected from a dune blow-out 0.5 km east of Cape Dupuy. This blow-out location fits that of site 887 (FS05) recorded by Quartermaine Consultants (1994:17). The remaining 17 artefacts have no provenance recorded.

A large number of collected artefacts are housed in the Barrow Island Environment Laboratory. These artefacts have been collected by WAPET staff and heritage consultants since the 1960s. In excess of 150 Indigenous artefacts are in the collection, including flaked and ground stone artefacts and flaked/retouched glass artefacts. These need to be recorded and catalogued to ascertain if they were collected from areas within the Gorgon Development. The vast majority, however, have no provenance recorded.

4.1.2.2 Mainland

This general area of the Pilbara coastline contains a range of archaeological sites that include shell scatters and middens, artefact scatters near claypans and Indigenous burials in dunes (Lantzke 1999; Murphy & McDonald 1990; Przywolnik 2002; Veitch 1993; Veitch & Hook 1993; Veitch & Warren 1992). These sites generally date to the last 7,000 years when the coastline approximated its current position (Figure 4-1).

4.1.2.2.1 Previous Surveys

A number of Indigenous archaeological assessments have been conducted in the area surrounding the proposed DOMGAS pipeline. The existing Apache/Hadson pipeline was surveyed for Indigenous archaeological sites by Murphy and McDonald (1990). Four Indigenous archaeological sites were identified, but the report has not been lodged with the DIA and the sites have not been registered. The sites comprise two flaked stone artefact scatters and two shell middens (see Appendix 1). Three sites were close the Apache/Hadson pipeline route which was moved to avoid them. The fourth site is 7 km south-west of the Apache/Hadson pipeline. Three of these sites may be impacted by the proposed DOMGAS pipeline (Map 4-2).

In addition a series of proposed drilling sites were surveyed for Indigenous sites in the vicinity of the Apache/Hadson pipeline (Lantzke 1999). Two sites were identified, one (DIA 17833) of which is located 5 km south-west of the DOMGAS pipeline and will not be impacted (Map 4-2).

While surveys for Indigenous archaeological sites have occurred in the vicinity of the proposed DOMGAS pipeline, it is not possible to state categorically that all Indigenous archaeological sites have been identified. To assess adequately the possible impact of the proposed development on Indigenous cultural heritage, systematic pedestrian sample surveys will be required prior to construction. Section 5 discusses procedures for the discovery, reporting and management of archaeological resources.

4.1.2.2.2 Sites

Currently there are eight Indigenous sites recorded in the general vicinity of the DOMGAS pipeline (see Appendix 1 for a complete list). Of these four may be impacted; Hadson 1, Hadson Midden 1, Hadson Midden 2 and Macey Wreck.

Hadson 1 is a scatter of flaked and ground stone artefacts in a claypan. Nine artefacts were recorded in a 2 m² sample square and the scatter was estimated as measuring 500 m by 500 m in area (Murphy & McDonald 1990). The Hadson pipeline was altered to avoid this site. The proposed DOMGAS pipeline may impact this site, which should therefore be relocated to determine its position in relation to the proposed pipeline. If the site is to be impacted then additional recording will be required.

Hasdon Midden 1 is a scatter of flaked stone artefacts and some shell. No site size is provided, although four artefacts were recorded in a 2 m² sample square. Economic shell species identified in the site include: *Saccostrea* spp., *Terebralia* spp., *Anadara* spp. and *Melo* spp. Given the presence of coral blocks and mangrove branches amongst the economic shell, Murphy and McDonald (1990) couldn't rule out the possibility that this site may be natural; created by storm surges during cyclones. The proposed DOMGAS pipeline may impact this site, and it should be relocated to determine its position in relation to the proposed pipeline. If the site is to be impacted then additional recording will be required. Depending on the site recording it may also need to be test excavated to determine the potential for stratified cultural material.

Hadson Midden 2 is a scatter of two flakes and one muller immediately behind the coastal mangroves (Murphy & McDonald 1990). Economic shell species were identified at the site including: *Anadara* spp., *Terebralia* spp., *Melo* spp., *Syrinx* spp. and *Tectus* spp. Murphy & McDonald (1990) concluded that "at such close proximity to the shoreline, much of this shell could have been deposited through wave action, but the artefacts indicate that some were probably the result of gathering activities". DOMGAS pipeline may impact this site, which should therefore be relocated to determine its position in relation to the proposed pipeline. If the site is to be impacted then additional recording will be required. Depending on the site recording it may also need to be test excavated to determine the potential for stratified cultural material. It is noted, however, that penetrometer tests along the Apache/Hadson pipeline indicate that beneath a thin crust the mangrove mud is semi-liquid (Murphy & McDonald 1990) and that test excavation may be pointless. This geomorphological factor requires further investigation before test excavations are conducted.

Possible retouched glass artefacts were identified on the Macey's Shipwreck site near the Apache pipeline during a maritime archaeology survey (McCarthy 1991). This site may be impacted by one of the proposed DOMGAS pipeline, even though the location of the shipwreck is uncertain. The identification of these artefacts is yet to be determined by an Indigenous archaeologist. This site needs to be relocated to determine its position in relation to the proposed pipeline. If the site is to be impacted then additional recording will be required including the identification of the retouched glass artefacts.

4.2 HISTORIC HERITAGE

4.2.1 Barrow Island

Barrow Island is potentially significant for the historical archaeology of north Western and continental Australia. The reasons are as follows.

1. Remoteness and potential for preservation (as demonstrated for Dampier Islands).
2. Types of sites (rarity).
3. Significance of association with historical activities (regional, state, national and international).

The following list summarises the historical activities reported in historical sources. The list does not contain any references, however, Appendix 3 contains an annotated summary of sources used to compile the list.

1. Explorers
   a) 1840: H.M.S. *Beagle* visited Barrow Island.
   b) 1846: J. Lort Stokes visited Barrow Island.
   c) 1864: Captain Jarman exploration of island (20 December 1864). Probably camped at Whitlock Cove.
   d) 1900: J.T. Tunney visit for two months.
   e) 1917, 1918: Naturalist F. Lawson Whitlock (1917, unknown time; 1918, two weeks). Camp based at Whitlock Cove and exploration of neighbouring coastal zone from Surf Point to Dove Point and Double Island.
2. Whaling
   a) Whalers were probably present in these waters from 1800 onwards, with records from the 1840s. Two reported whalers at Barrow Island were:
      i) 1842, 21 June, 4 August: *Stephania.*
      ii) 1864, 22 July: *Canton.*
3. Pearl shell industries
   a) The foundation for the pearling industry closely followed exploration and settlement for pastoralism. Exploration to Nickol Bay by AC Gregory in 1861 marks the inception of the industry with the collection of several tonnes of mother-of-pearl and pearls (Moore 1994). Pearl shell industries operated with varying degrees of success from this period up until the 1930's, especially on the Montebello Islands.

b) It would appear that the colonial government was not aware of how many pearling camps operated from Barrow Island. The reporting of the measles epidemic in 1885 by Blair E Mayne to the Legislative Council would indicate that some knew of the pearling operations.

c) In 1926 one pastoral lessee applicant reported that the island was used by pearlers.

4. Quarantine station

a) September 1884: measles epidemic. Barrow Island was converted into a quarantine station for Aboriginal people with measles, apparently those from the pearl shell industries, brought from mainland. Location unknown, but would be sheltered anchorage. Schooner *Amy* as medical ship, with no description of accommodation on Barrow Island for the ill. The numbers of people involved in the epidemic is no known nor is the number who died.

5. Lock Hospital

a) 1908, Barrow Island Lock Hospital, presumably for venereal diseases. Requisition for blankets in 1908 granted. Location not yet known nor relationship with Nature Reserve created in 1908.

6. Aboriginal uses

a) Pre-European use (see Section 4.1 above).

b) 1884: Quarantine Station (see above).

c) 19th century: Aboriginal slave markets (reports related to 1870s), see point 7 below.

d) 1908: Barrow Island Lock Hospital (probably abandoned in favour of Bernier and Dorre Islands by 1909).

e) 1908: Aboriginal Reserve (for Lock Hospital).

7. Barracoon and slave market

a) There are references to Aboriginal people being taken from the Ashburton region to Barrow Island to be sold, presumably to pearlers, in the later 19th century. In 1880 the police found 22 Aboriginal people who had been marooned on Barrow Island, a crime for which a pearler was fined.

b) Specifically, during the first half of the 1870s, Captain Cadell, an infamous Scottish adventurer, reportedly established slave markets for pearl shell operators on Barrow Island (also Delambre and Enderby islands), both of female and male Aboriginals.

8. Pastoral industry

a) 1873: application by F. McRae and Co. (Cossack, Roebourne) for a pastoral, turtle shell and fish oil lease. (In 1880 F. McRae signed for 22 Aboriginal men who were then marooned on Barrow Island by a third party).

b) 1874, August: lease for turtle and general fishing for James Grimmond Anderson, and for pastoralism.

c) 1897: leased by William MacNean (Roebourne) for pastoral purposes (transferred to Cooke).

d) 1880, August: Messrs. Henry J. Cooke and James Morrell, sheep station lease. They were reportedly not satisfied some months later and were considering abandoning the lease. It was reportedly for sale on 24 January 1882 along with 600 sheep.

e) 1892: Leased to James Archibald Haste (Carnarvon), although lease lapsed in 1893.

f) 1897, July: Application by James Clarke and Co. for pastoral lease for Barrow Island. (Probably not taken up).

g) 1900, February: Application by John Hurst for pastoral lease for Barrow Island.

h) 1902, January: Application by James Waterhouse King for pastoral lease for Barrow Island.

i) 1904, August: Application by Alexander Stevens (Onslow pearler) for pastoral lease for Barrow Island. (Lease forfeited in 1907).

9. Turtle fishing

   a) 1871, 1872: descriptions related to establishment of turtle fishing industry on Barrow and Delambre islands by C. Lambert Smith.

   b) 1873: application by F. McRae and Co. (Cossack, Roebourne) for a pastoral, turtle shell and fish oil lease. (In 1880 he signed for 22 Aboriginal men who were then marooned on Barrow Island by a third party).

   c) 1874, August: lease for turtle and general fishing for James Grimmond Anderson, and for pastoralism.

   d) 1900, November: application for turtle fishing lease by Emmeline Collier Clark (100 acres).

10. Phosphate extraction

   a) 1883: Possible extraction of guano had begun as a ship visited expecting to collect a cargo of guano.

   b) 1907, August: Application by F.C. Broadhurst for 50,000 acres of land (Barrow Island) for phosphate extraction (presumably following his successful guano extraction industry in the Abrolhos Islands).

   c) 1923: Licence for removal of guano and phosphates for A.G. Kidson-Hunter.

11. Nature Reserve

   a) 1907, August: declared a reserve for native game under the Game Act.

   b) 1910, February: declared Class A Nature Reserve. Soon after this classification visits by naturalists such as L. Whitlock occurred.

12. Oil extraction

   a) 1964: oil discovered at Rough Range. Exploration extended to include Barrow Island.

   b) 1964: first oil well drilled.

   c) 1967: commercial production began with over 800 well and production peaking in 1971 with 50,000 barrels per day.

   d) 2000: Chevron took over management of assets. Today approximately 455 wells are producing oil and people working and living on the Island number from 150-200 and rotate in two-week shifts.

It is difficult to determine whether all of these activities occurred, and some indeed may merely reflect 19th century speculation. This is most pertinent for the pastoral leases described above: there is no evidence for sheep pastoralism having occurred at this place. However, it is reasonable to suspect that many such activities did in fact take place; their absence from historical annals being common to records of much of colonial Australia.

It would appear that the island was used by pearlers for a long period of time, and had several other historical functions. A recent survey by Paterson and Souter of historical sites on islands in the nearby Dampier Archipelago found archaeological evidence for many similar activities despite a paucity of historical reports. This was a remote and poorly serviced frontier of colonial Australia, and many of the actions were intended to be conducted beyond the gaze of officialdom; accordingly the paucity of comprehensive historical accounts is not surprising.

The types of historical archaeological material that could be expected to occur on Barrow Island includes: artefact scatters, foundations, burials. There are numerous drownings reported in the waters around the island, although the bodies were not necessarily recovered. There are also murders reported for the Barracoon in the 19th century. The following are five reported burials; however, given the evidence from similar islands in the Dampier Islands, other burials would be expected along the coast of Barrow Island:

1. 1872, European man;
2. 1887, Malay seaman;
3. 1904, Malay pearler;
4. 1904, Chilean sail maker;
5. 1885: there were Aboriginal deaths at the measles quarantine station.

4.2.1.1 Previous Surveys

While the Quartermaine Consultants (1994) survey was for Indigenous archaeological sites, the report does contain information relating to historical sites. A total of five locations with historical material were recorded (labelled Pearling Camps). Three sites were recorded with flaked/retouched glass artefacts made by Indigenous people most likely brought to the island by Europeans. Modified glass artefacts have been found in Aboriginal contexts across Australia, and are essentially unknown for European contexts (cf. Wilkie 1996). If the artefacts are found to be made in ways consistent with Aboriginal tool manufacture then it is widely assumed that they are Aboriginal (Allen & Jones 1980; Cooper & Bowdler 1998; Freeman 1993; Harrison 1996; 2000). In addition historical material was noted at South End, Bandicoot Bay and Square Bay (Quartermaine Consultants 1994:19-20, 22, 25). The material identified includes limestone foundations, boat parts, bottles, brass studs and buttons most likely associated with pearling camps.

The site descriptions by Quartermaine Consultants (1994) and observations made during the visit to Barrow Island in 2004 (see Appendix 2) suggest that:

1. Where possible the beach pipeline landing sites of Whites Beach, Flacourt Bay and the area south of Town Point should be surveyed for historical sites. These

areas were surveyed briefly in March 2004 and there are no surface archaeological sites other than site GD04-02, which is a small scatter of late 19th century olive bottle glass at Flacourt Bay (see Section 4.2.1.2, below). The area at the Town Point landing was visited briefly on a medium tide and material related to the WAPET landing was present on the coast. None appeared to be older material, although a more comprehensive survey would be required to support this position.

2. The area to be developed at Cape Dupoy should be surveyed. This area was visited but no proper survey was conducted.

The historical uses of the island tend to be coastal as all visitors required access to the island by the coast. Accordingly sheltered beaches and the neighbouring islands should be considered areas of high potential for historical archaeological sites. Section 5 discusses procedures for the discovery, reporting and management of archaeological resources.

4.2.1.2 Sites

Two sites with historical material may be affected by the proposed Gorgon Development; site 888 (FS06) and GD04-02.

Flaked glass and porcelain was identified at site 888 (FS06) in Area A (Quartermaine Consultants 1994:17-18, Appendix 3). Area C may be impacted by the proposed CO_2 Pipeline and while no historical material was identified at this part of the site, there is potential for sub-surface cultural material. This site is discussed in more detail in Section 4.1.2.1.2, above (see also Appendix 1 and 2). An historical archaeologist should participate in any test excavation of this site.

Site GD04-02 was identified during the March 2004 field visit (see Appendix 1 and 2). This glass artefact scatter is in Flacourt Bay and may be impacted by the proposed Feed Gas Pipeline. The scatter comprises glass fragments from a single light olive glass bottle or a champagne beer bottle common in the late 1800s and early 1900s. While rare on Barrow Island, elsewhere along the Australian coast this is a common artefact, and could be collected prior to the site being disturbed. There may however be buried archaeological material at this site and the procedures for site disturbance detailed in Section 5 should be followed.

While not within the Gorgon Development, the most significant historical site identified to date is a pearlers' camp at Bandicoot Bay [DIA site 891 (FS09)], which is of national, state and regional significance. Of great interest are the flaked/retouched glass artefacts identified by Quartermaine Consultants (1994:19-10, Figure 15) as Kimberley points (Figure 4-2). If this identification is correct this is an extremely rare site which may indicate the presence of Indigenous people from areas beyond the Pilbara. This is not recorded in documentary sources and thus the archaeological record is the primary data set. Artefactual material has been collected from this site in the past and it must be protected from future visitation from current and future workers on Barrow Island.

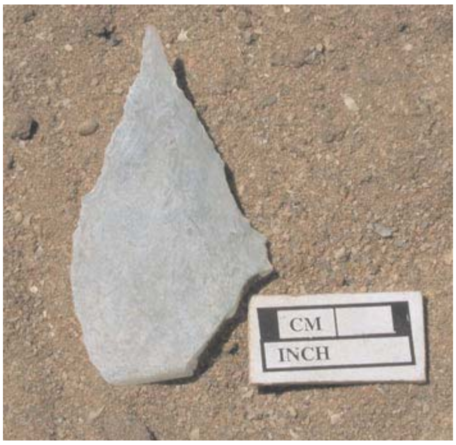
4.2.1.3 Collected Artefacts

A large number of collected artefacts are housed in the Barrow Island Environment Laboratory. These artefacts have been collected by WAPET staff and consultants since the 1960s. In excess of 200 historical artefacts are in the collection, including Indigenous flaked/retouched glass artefacts, bottles, nails, buttons and shells. They have not been catalogued and no provenance is recorded for the majority of the artefacts.

Also included are historical artefacts from previously recorded site 891 (FS09) which were displayed on a foam 'museum-type' display in the past by WAPET employees. The artefacts included metal clothing items, fasteners, glass artefacts, ship parts and a clay pipe. Some of these items have been affixed with solvent fixatives (glue) to a backing board. The fixture of these items may have affected them and thus require attention by a curator qualified to stabilise historical artefacts subjected to damage of this type.

Other artefacts of unknown provenance are included in the collection; unfortunately these are of little scientific value outside of their archaeological context. They do however indicate quite a rich historical and maritime history of the island and should be recorded and catalogued to ascertain if they were collected from areas within the Gorgon Development.

Figure 4-2. Retouched glass artefact - Bandicoot Bay Pearling Camp (891/FS09)



4.2.2 Mainland

On the mainland the DOMGAS pipeline may impact on a maritime site. Thi shipwreck site contains possible historical flaked glass artefacts and is discussed in more detail in the Maritime Archaeology Section 4.3.1. No formal historical cultural heritage studies have taken place along the DOMGAS pipeline. To assess adequately the possible impact of the proposed development on historic/maritime cultural heritage, systematic pedestrian sample surveys will be required prior to construction.

4.3 MARITIME HERITAGE

An archival search has been undertaken to identify potential maritime archaeological sites, namely shipwrecks, in the study area. There are no known shipwreck sites on the proposed Gorgon pipeline routes although archival sources suggest that a number of significant vessels have been lost in the Onslow/Barrow Island region. The vessels identified have not been located post-wrecking and the exact position of sites is not known. Utilising Government archives from the Department of Customs, Harbour and Lights; and Police as well as newspaper reportage, research has been undertaken in an attempt to identify what vessels were lost in the vicinity of Barrow Island and to give an approximate location of the wreck sites. An assessment of the following shipping registers was also carried out to locate potential sites in the region:

1. *Register of Wrecks; Strandings and Mishaps of British Ships, Port of Fremantle* Her Majesty's Customs, Perth. (Transcribed by McKenna, R., 1967).
2. *Ships Registered in Western Australia* National Archives. Perth (Transcribed by Dickson, R. Report–Department of Maritime Archaeology, WA Maritime Museum No.80.).
3. *Register of Wrecks and Casualties in Western Australia 1897-1942, Her Majesty's Customs* Department of Marine and Harbours. (Transcribed by Dickson, R. Report–Department of Maritime Archaeology, WA Maritime Museum No. 56).
4. *Register of Accidents and Incidents from 1916-1972.* Department of Marine and Harbours. (Transcribed by Dickson, R., Report–Department of Maritime Archaeology, WA Maritime Museum No. 56).
5. *Register of Shipping Arrivals and Departures at the Port of Fremantle* (Battye Acc No. 1076).

The majority of shipwrecks recorded, occurred during cyclonic activity in the summer months in the Onslow region. It is important to note that a number of vessels engaged in pearling operations in the North West were unregistered pearling luggers. Consequently there is little archival evidence relating to the types and actual numbers of vessels working and/or lost in the region. The potential for lugger shipwreck sites to occur in the vicinity of Barrow Island must therefore be considered given the proximity of the island to 19th century pearling grounds and shipping routes related to that industry. Whether there is any residual wreckage, which would constitute an archaeological site, can only be determined on discovery. The Fugro video survey of one proposed track for the pipeline does not reveal any immediate cultural material although at particular points on the route the surveyor reported marginal visibility (Jeremy Fitzpatrick, BBG pers. comm. 25/02/04). Although shipwreck sites most often occur in shallow reef areas, the possibility of sites in deep water also needs to be acknowledged. Based on the recent inspection by the WA Maritime Museum, Department of Maritime Archaeology, of a lugger site off Port Hedland (Gainsford & Kimpton 2003), it should be noted that the potential exists for wreck sites to occur in deeper water, from vessels foundering during cyclonic conditions.

The pearl shell fishery established in Western Australia in the nineteenth century was first centred in Nickol Bay, near Karratha around 1864 and later Broome in the

Kimberley circa 1880[3]. The story of the pearling industry unfolds in contemporary accounts in the local press and in various diaries and reminiscences such as those of R.J. and T.C. Sholl, A.R Richardson, L.C. Burges, Charles Harper, the McCrae brothers and others. Streeter's (1886) account of 'Pearls and Pearling Life' gives a first hand and most useful coverage of many aspects of the industry. The subject has also been covered in recent times by de La Rue (1979), Albertus Bain (1982) and in numerous unpublished accounts.

The cyclones which resulted in major losses to the pearling fleets and other craft in the pearling grounds between and including Exmouth Gulf and Broome are as follows:

1. 1881/01/07 Five identified luggers wrecked. At least six other pearling vessels, reportedly damaged or stranded, survived on this occasion, some to be victims of similar weather patterns in later years.
2. 1882/03/06 One identified lugger lost.
3. 1905/02/08 Two identified luggers lost.
4. 1909/04/06 Four identified luggers and 24 lives lost. The luggers are unregistered but two have been identified as the *Elsie* and *Penguin*.
5. 1911/02/06 Two identified luggers lost.

The archival research undertaken to identify potential maritime archaeological sites, focuses on the area from West Tryal Rocks gas field to Barrow Island. Even though a number of potential sites have been identified in this report relating to the proposed pipeline route to the mainland, this information should be considered as preliminary only, as the mainland DOMGAS pipeline has not been surveyed. The research thus far suggests there are expected to be a number of sites in the Mary Ann Passage and Yammadery Creek areas. Appendix 4 gives a comprehensive list of 13 projected sites in the region. Four of these are considered most likely to be in the Barrow Island area:

1. *Wild Wave* (1873).
2. *Ruby* (1882).
3. *Marietta* (1905).
4. *Curlew* (1911).

Acoustic characteristics and seabed interpretation by Fugro along parts of the proposed Flacourt Bay Pipeline option and the propose Port Facility were inspected as part of this assessment (Fugro 2003). Fugro grouped 10 bottom types along the route (A-J) ranging from uniform low acoustic reflectivity (sand), grading to higher acoustic reflectivity (sand-rock/reef with vegetation). The seabed along the majority of the Feed Pipeline is smooth with the exception of areas of moderate to high relief rock outcrop [KP 10.8 (40 m depth) and KP 12.38 (43 m depth); KP24.9 (53 m depth) to KP 27.26 (55 m depth)]. The Fugro recommendation that a block survey be carried out in the anticipated areas of very uneven seabed to choose an optimum route is also

[3] The exact number of vessels operating in this industry is unclear in the archival sources as many of the vessels were unregistered. Furthermore owing to the frontier nature of the North-West colonial government controls and inspections were very limited.

supported as these locations have the highest probability for wreck sites. Any further sub-sea acoustic and/or video image of the proposed development should be made available to a maritime archaeologist for assessment.

Figure 4-3. Pearling luggers, North-west coast Western Australia (Copyright McKenna Collection, WA Maritime Museum)

Other WA Museum records relating to maritime archaeological sites mentions two on Barrow Island:

1. A whaling harpoon was discovered in 6 feet of water by Mr Charlie Alt while skin diving in 1969 at Cape Poivre on the West Coast of Barrow Island (MA 439/71).
2. A 'man-made rock ring wall' which is described as '10ft and almost circular with only two sections visible'. A small hole was dug by WAPET employees again in 1969 approximately 2x2 ft but there was 'noting apparent'. This site was assessed as a 'maritime' structure and referred to the Department of Maritime Archaeology in 1985. McCarthy in his visits to the Montebellos in 1985 mentions seeing similar sites on Hermite Island which fit this description which he identified as wells or shafts (McCarthy, 1985. MA 439/71).

These sites were not investigated during the March 2004 preliminary survey as they are located outside the proposed Gorgon Development.

4.3.1 Mainland

On the mainland the DOMGAS pipeline may impact on a maritime site, but no formal maritime cultural heritage studies have taken place. There is a reported shipwreck close to Varanus gas pipeline located below high water mark. This site was examined in 1991 when identified in a preliminary survey for the Apache/Hadsen Gas pipeline (McCarthy 1991). The wreck appears to be that of a small unidentified late nineteenth-early twentieth century wooden sailing vessel of approximately 20 m in length that was engaged in the Northwest coastal pearling trade (McCarthy 1991:6). Although heavily salvaged, the wreck still possesses some cultural significance as one of the few tangible remains of the late nineteenth century pearling industry. The suggestion of Indigenous associations was made with the discovery of ‘worked’ nineteenth century bottle glass in association with the site. The wreck cannot be accurately dated though it is felt that it may pre-date 1900 and could therefore be protected under the *Maritime Archaeology Act 1973* (McCarthy 1991:8). In light of the above, to assess adequately the possible impact of the proposed development on historic/maritime cultural heritage, systematic pedestrian sample surveys will be required prior to construction.

4.4 CONCLUSIONS

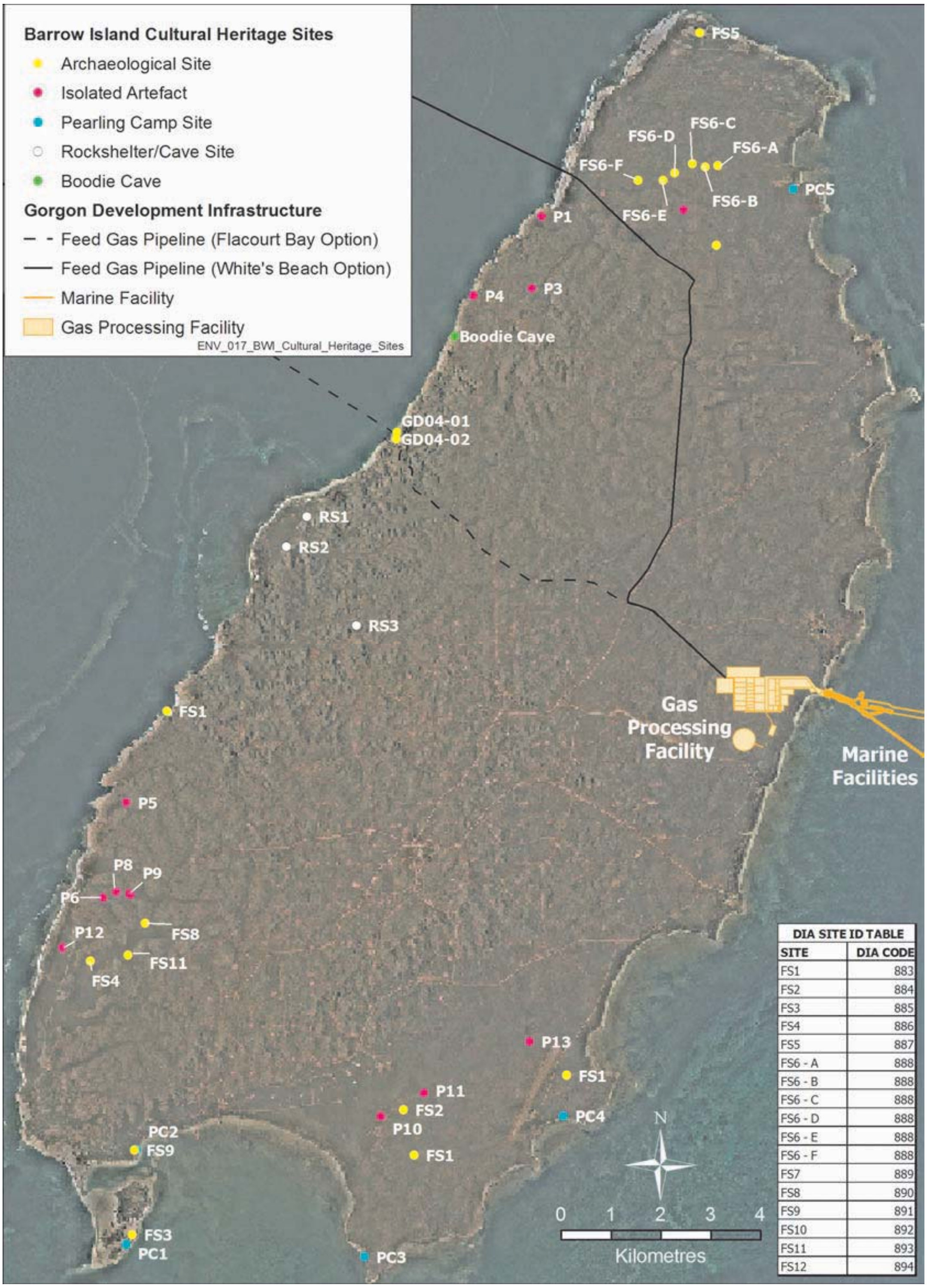
It is clear from the above assessment that Barrow Island and other islands in the immediate region like the Montebello’s and Lowendal’s hold an unusual place in the pre-history and history of Western Australia. While some cultural heritage assessments have been undertaken on Barrow Island and mainland pipeline route it is concluded that additional site specific cultural heritage studies are required to identify cultural heritage sites that may exist within the development.

The major conclusions of the assessment are:

1. Three Indigenous communities (Yabburara/Mardudhunera, Kurama Marthudunera and Thanlanyji) have expressed an interest and need to be consulted in relation to cultural heritage management within the proposed Gorgon Development. This consultation may include inspection of the proposed development on Barrow Island and on the mainland.
2. That at present:
   a) Two identified cultural heritage sites may be impacted on Barrow Island by the proposed Flacourt Bay Feed Gas Pipeline Option (see Map 4-1).
   b) Four identified cultural heritage sites may be impacted on the mainland (see Map 4-1).
3. Owing to the low level of formal investigation, prior to construction all proposed ground disturbance areas including the seabed should be systematically surveyed for Indigenous, historical and maritime cultural heritage.
4. Proposed construction should be monitored in areas of high potential for sub-surface cultural material. Areas of high potential have been identified as occurring in the following topographic features; claypans, coastal dunes and adjacent to drainage lines (Map 4-3).

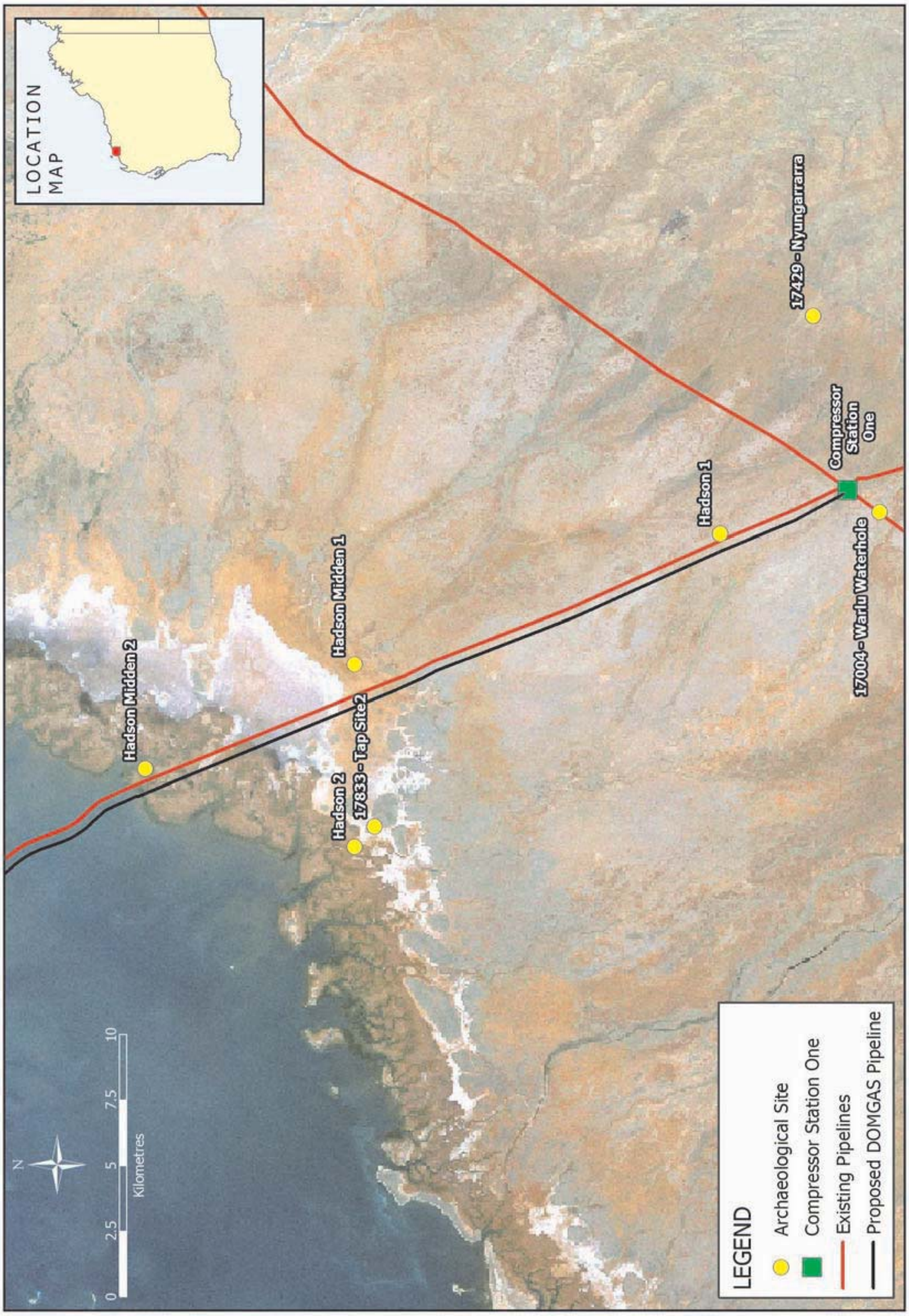
In accordance with the brief from CTA a draft Cultural Heritage Management Plan (CHMP) has been prepared for the development (see Section 5). This CHMP contains recommendations regarding how CTA can manage known and unidentified cultural heritage within the Gorgon Development.

Map 4-1. Gorgon Development- location of cultural heritage sites on Barrow Island

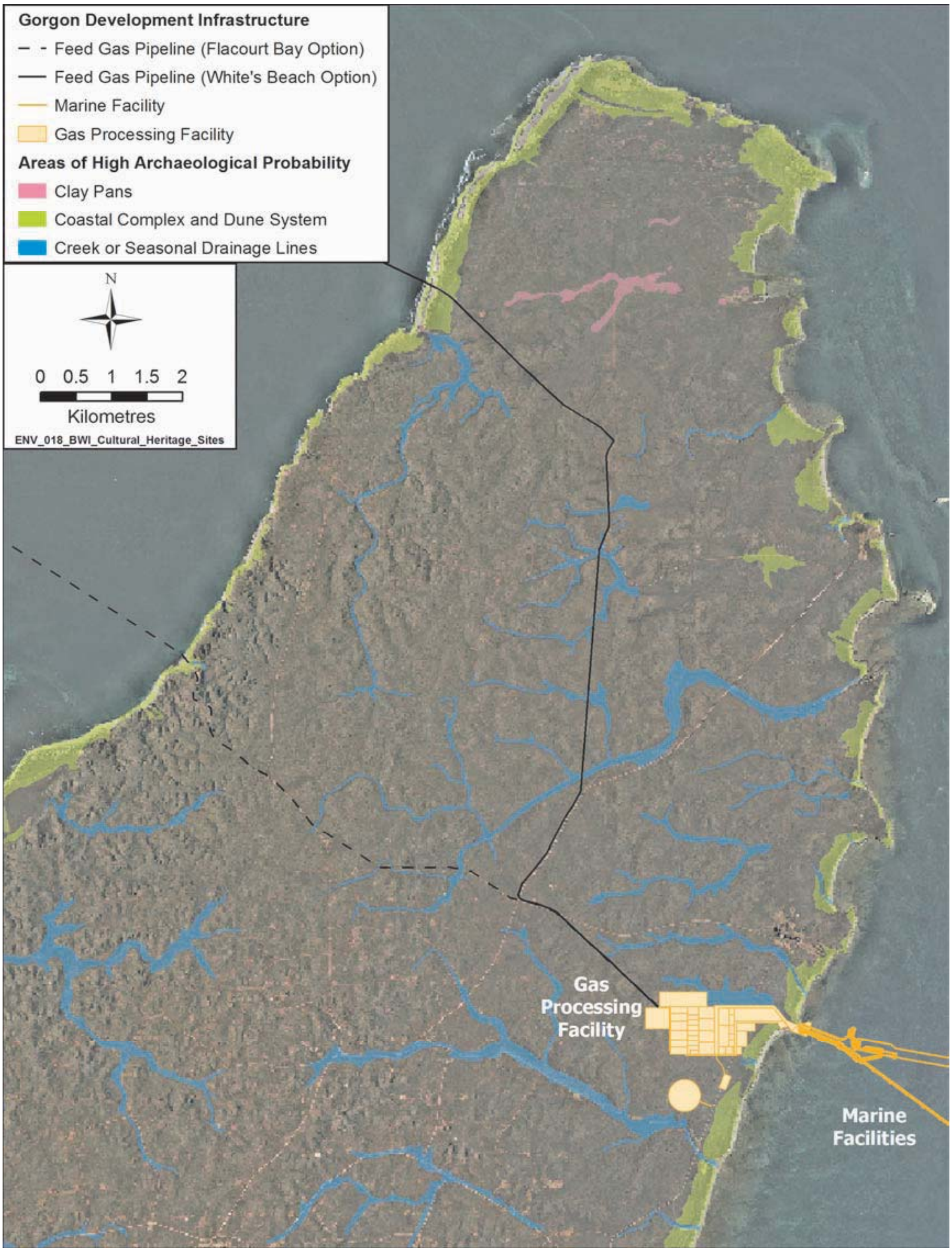


DIA SITE ID TABLE	
SITE	DIA CODE
FS1	883
FS2	884
FS3	885
FS4	886
FS5	887
FS6 - A	888
FS6 - B	888
FS6 - C	888
FS6 - D	888
FS6 - E	888
FS6 - F	888
FS7	889
FS8	890
FS9	891
FS10	892
FS11	893
FS12	894

Map 4-2. Gorgon Development- location of cultural heritage sites on Mainland



Map 4-3. Barrow Island high archaeological potential areas



5 DRAFT CULTURAL HERITAGE MANAGEMENT PLAN

5.1 CULTURAL HERITAGE PRINCIPALS

Cultural heritage is an important resource to all Australians. To protect this resource, the following principles and procedures are recommended:

1. Prior to construction all proposed ground disturbance areas should be inspected/surveyed by qualified Indigenous, historical and maritime cultural resource management (CRM) practitioners.
    a) At least 50% of the Gorgon Development should be systematically surveyed for Indigenous and historical/maritime terrestrial archaeological sites.
2. Indigenous people should be consulted and given the opportunity to inspect the proposed development on Barrow Island and the mainland with a qualified anthropologist.
3. In areas with the high potential for sub-surface cultural material (such as claypans, coastal dunes and adjacent to drainage lines), any proposed ground disturbance should be monitored by qualified CRM practitioners.
4. All reasonable precautions are to be taken to protect cultural places from damage caused by construction and associated activities.
5. To facilitate an awareness of cultural heritage, a suitable induction program should be included for all personnel associated with and involved in the construction of the Gorgon Development.
6. A Cultural Heritage Officer should be employed during the construction phase to provide on the ground advice. This cultural heritage officer should have experience in both Indigenous and historical CRM.
7. When appropriate, additional professional expertise should be sought on archaeological matters, such as advice from a physical anthropologist if human skeletal material is identified.
8. Surveying, monitoring and management of Indigenous sites should involve Indigenous people.
    a) During the ethnographic survey the anthropologist should determine the level and detail of the Indigenous community's involvement in the monitoring and management of Indigenous sites that will be impacted by the Gorgon Development.
    b) Respect for Indigenous culture by all parties is fundamental to effective Indigenous cultural heritage management.
    c) Indigenous people's beliefs and cultural knowledge remain their property.

5.2 CHMP RESPONSIBILITIES

1. CTA and its contractors should meet all its obligations with respect to the CHMP.
2. CTA should ensure that the appropriate permits governing cultural heritage management are in place before the commencement of construction. This could include but is not restricted to:

a) Permission under Section 18 of the *Aboriginal Heritage Act 1972* from the Minister of Indigenous Affairs to disturb Indigenous cultural heritage sites that will be impacted by the proposed development.

b) Section 16 permit from the Registrar of Aboriginal Sites under the *Aboriginal Heritage Act 1972* to excavate for archaeological investigation purposes any Indigenous archaeological sites with the potential for sub-surface cultural material that will be impacted by the development.

c) The Heritage Council of Western Australia should be advised of and, if required, consulted regarding historical sites given that the island is listed on the State Register of Historic Places.

d) The Director of the WA Maritime Museum and the Director of the Western Australian Museum should be advised, in writing, regarding the discovery of all maritime archaeological sites.

3. CTA should ensure that all areas likely to be impacted are assessed for cultural heritage by qualified CRM practitioners and Indigenous people before commencement of ground disturbance.
4. CTA should ensure that its staff and contractors are aware of their responsibilities under the CHMP to protect cultural heritage sites within and adjacent to the Gorgon Development. CTA should ensure that all personnel on site attend an induction course covering:
    a) Relevant cultural heritage legislation.
    b) Obligations under the CHMP, specifically their responsibilities regarding the protection and management of cultural heritage.
    c) Types of cultural heritage sites and guides on how to identify them.
    d) Procedures for reporting new cultural heritage sites and objects.

5.2.1 Notification and Reporting

1. The Cultural Heritage Officer, Government departments, Indigenous organisations and CTA should provide each other with all necessary information to carry out the CHMP and this information should be provided in a timely manner.
2. CTA and its contractors should endeavour to provide the Cultural Heritage Officer with daily briefings of work schedules at least two days prior to the implementation of the work schedule to allow coordination of any monitoring arrangements. (It is expected that the necessity for these briefings will reduce as construction on site becomes established).
3. The Cultural Heritage Officer should be informed of any substantial alterations to the work schedule as soon as is practicable and in sufficient time to allow the arrangement of the presence of the required monitors.
4. In the event of wet weather, industrial action, equipment unavailability or other factors halting construction, the Project Manager or other designated person shall notify the Cultural Heritage Officer without delay that work is to be suspended and when resumption is expected.
5. The Cultural Heritage Officer should maintain the following records:
    a) Daily work reports for Cultural Heritage Officer and monitors.

b) Site inspection reports, including reports on discovery and disposition of material during monitoring.

c) Incident reports relating to any breach of the CHMP.

6. Reports on fieldwork during construction should be prepared on a weekly basis by the Cultural Heritage Officer. Copies should be forwarded to CTA, the Indigenous people, the DIA, the Maritime Museum and the Heritage Council.

7. Incident reports relating to any breach of the CHMP shall be forwarded to CTA, the relevant cultural heritage authority and the Indigenous people as soon as practicable after the event.

5.2.2 Review Process

1. There should be periodic reviews (frequency to be determined by the review committee listed below) of the implementation of the CHMP. The review committee should consist of:
   a) Cultural Heritage Officer.
   b) An appointed representative of each of the Indigenous groups.
   c) Nominated authority for the DIA.
   d) Nominated authority for the Heritage Council.
   e) Nominated authority for the Maritime Museum.
   f) CTA Environmental Officer.
   g) CTA Project Manager.
2. The committee should examine all aspects of the implementation of the CHMP and prepare a report.
   a) The Cultural Heritage Officer should coordinate the report production and forward to all members of the review committee.
   b) All parties should consider in good faith all recommendations of the review committee and implement them as part of the CHMP.

5.3 PROTECTION OF CULTURAL HERTIAGE SITES

1. Prior to the commencement of ground disturbance activities CTA should ensure that the proposed development is surveyed for cultural heritage sites. Specifically:
   a) Indigenous Heritage
      i) Inspection of proposed disturbance areas by Indigenous people and a qualified anthropologist.
      ii) Sample survey by qualified archaeologists of not less than 50% of proposed disturbance areas.
   b) Historical Heritage
      i) Sample survey by suitably qualified archaeologists of not less than 50% of proposed disturbance areas.
   c) Maritime Heritage
      i) Sample survey by suitably qualified archaeologists of not less than 50% of proposed disturbance areas in terrestrial contexts (above the low water mark).

ii) In relation to the underwater development areas, detailed acoustic and/or video imaging should be carried out prior to disturbance to ensure there is no maritime cultural material, shipwreck or otherwise.

2. That ground disturbance in areas with high potential for sub-surface cultural material (coast and claypans) should be monitored by the Cultural Heritage Officer and Indigenous people.
3. All known site details are listed in Appendix 1. Each site location should be assessed by CTA to determine its position in relation to the proposed development. Some sites might be found to occur outside the proposed disturbance areas.

5.3.1 Known Cultural Heritage Sites

1. Management practices should follow the recommendations for each site as detailed in Table 5-1 and Appendix 1.
2. Known cultural heritage sites should be recorded on all work plans and maps.
3. Before any activities begin near a recorded cultural heritage site, the site should be identified and flagged by the Cultural Heritage Officer.
4. Protection of the site may include the erection of temporary barriers or fences on advice from the Cultural Heritage Officer.
5. Access to cultural heritage sites should be restricted to essential personnel and contractors should adjust activities to ensure avoidance of any culturally significant sites during their activities.

5.3.2 Inadvertent Discovery

Places and items of cultural significance may be uncovered during the construction phase, particularity on coastal and claypan areas. These could include:

1. Burials (particularly within coastal dunes).
2. Indigenous artefacts.
3. Historical / maritime artefacts, structures or shipwrecks (particularly within 200 m of the high-tide mark).

5.3.2.1 Burials

As discussed in Sections 4.2 and 4.2.2, there is the potential for burials on Barrow Island. The discovery of human remains[4] brings into play the following legislation:

1. *Coroners Act 1996* – all human remains.
2. *Aboriginal Heritage Act 1972* – Indigenous burials.
3. *Commonwealth Aboriginal and Torres Strait Islander Heritage Protection Act 1984* - Indigenous burials.
4. *Maritime Archaeology Act 1973* and the Federal *Historic Shipwrecks Act 1976* - burials associated with "historical ships".

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[4] The term 'human remains' is used as a generic term, no disrespect to Indigenous people, their relatives or other people of Aboriginal or Torres Strait Islander descent is intended or implied in its use.

Should human remains be found during construction, the following procedure should be adopted.

1. On discovery of skeletal material:
   a) All work should cease at the location and the Cultural Heritage Officer should be notified, if not already present at the location.
   b) Reasonable efforts to protect the remains shall be made. Note that the material should not be removed or disturbed further but buffer zones or temporary barriers may be appropriate.
   c) Construction workers and operational personnel should comply with the instructions of the Cultural Heritage Officer. Construction may continue at an agreed distance away from the site.
   d) All personnel and contractors on site should be advised that it is an offence under the *Coroners Act 1996* and the relevant heritage legislation to interfere with the remains.
   e) The Works Manager or Supervisor and the CTA Project Manager should be notified.
   f) Under Section 17 of the *Coroners Act 1996* the local Police / Coroners office must be notified. Direction in the first instance should be taken from the Police. However, given the potential significance of any burials, an archaeologist/physical anthropologist with demonstrable experience in excavating Indigenous and historical burials should supervise the removal of the human remains, as the skills required for this form of excavation are beyond that of police forensic teams.
   g) If human remains are suspected to be Indigenous then the Registrar of Aboriginal Sites at the DIA must be informed. In addition the Federal Minister for Indigenous Affairs needs to be informed.
   h) At the same time as other individuals and agencies are contacted, the Cultural Heritage Officer should notify Indigenous people of the discovery, the steps which have been taken and make appropriate arrangement for nominated Indigenous people to attend the site, if not already present.
   i) Indigenous people should be consulted as to the management of the material once Indigenous origin has been determined.
   j) No further work at the locations should be undertaken until all parties have been consulted and agreement has been reached.
   k) The location of the burial should be recorded in sufficient detail for its future protection.
2. In consultation with the Police/Coroner and DIA staff steps need to be taken to identify the skeletal material. A physical anthropologist should be engaged to complete this task on site.
3. Any remedial works should be undertaken in consultation with the Cultural Heritage Officer, the DIA and Indigenous people.
4. If the human skeletal remains are Indigenous or unknown, and all parties agree to the relocation of the material:

   a) Section 18 approval to disturb and a Section 16 permit to excavate for archaeological purposes under the *Aboriginal Heritage Act 1972* should be obtained to conduct this work.
   b) A data recovery programme, planned in consultation with the Indigenous people, a qualified physical anthropologist and the DIA, should be developed and implemented. This should include recording of the location of the burial and other features as required by the Indigenous people.
   c) Representatives of the Indigenous people should be present during the recovery phase.
   d) A suitable keeping place or re-interment location should be negotiated between CTA, the Indigenous people and the DIA.
5. If the human skeletal remains are non-Indigenous and of a historical nature and cannot be avoided:
   a) The Heritage Commission and the Maritime Museum should be consulted regarding the proposed disturbance
   b) A data recovery programme, planned in consultation with the Heritage Commission / Maritime Museum and a qualified historical archaeologist / physical anthropologist, should be developed and implemented.
   c) An historical archaeologist / physical anthropologist with demonstrable experience in excavating burials should supervise the removal of the grave contents.
   d) The curation / collection of any excavated materials should be negotiated between CTA and the Heritage Commission / Maritime Museum.

5.3.2.2 Indigenous Archaeological Sites

1. The potential for surface and buried cultural deposits is potentially high in coastal areas and claypans. If surface or buried material is uncovered during construction, the following procedures should be undertaken:
   a) All work in the immediate vicinity of the find must cease and reasonable efforts to secure the discovery should be made. Work can continue at an agreed upon distance from the site. Note that the material should not be removed or disturbed further but barriers or temporary fences may be erected as a buffer around the remains if required.
   b) The Cultural Heritage Officer, if not already present, and appropriate CTA managers should be notified.
   c) DIA should be contacted and advised of the situation.
   d) The Cultural Heritage Officer should create accurate records, including map references and photographs of the material and an *in situ* evaluation of the find.
   e) A written statement of the Cultural Heritage Officer findings and recommendations should be provided to the DIA and the Indigenous people for their consideration.
   f) Based on the recommendations of the Cultural Heritage Officer, decisions regarding the treatment of the find shall be made in consultation with the Indigenous people and the DIA.

2. If the find cannot be evaluated without further archaeological work, then the following procedure should be undertaken:
   a) Section 18 approval to disturb and a Section 16 permit to excavate for archaeological purposes under the *Aboriginal Heritage Act 1972* should be obtained to conduct this work.
   b) A data recovery program planned in consultation with the Indigenous people, a qualified archaeologist and the DIA should be developed and implemented.
   c) Representatives of the Indigenous people should be present during the data recovery phase.
   d) Based on the results of the data recovery program the find shall be evaluated in consultation with the Indigenous people, the archaeologist and the DIA.
   e) Should burials be located, refer to burials policy procedure in Section 5.3.2.1.

5.3.2.3 Historical Archaeological Sites

Management of historical sites in Western Australia is controlled primarily under *Heritage of Western Australia Act 1990* which follows the *Burra Charter* (www.icomos.org/australia/burra.html) which in turn provides guidelines for the management of historic sites.

1. The potential for surface and buried cultural deposits is potentially high in coastal areas. If surface or buried material is uncovered during construction, the following procedures should be undertaken:
   a) All work in the immediate vicinity of the find must cease and reasonable efforts to secure the discovery should be made. Work can continue at an agreed upon distance from the site. Note that the material should not be removed or disturbed further but barriers or temporary fences may be erected as a buffer around the remains if required.
   b) The Cultural Heritage Officer, if not already present, and appropriate CTA managers should be notified.
   c) The Heritage Council should be contacted and advised of the situation.
   d) If Indigenous cultural material is also identified refer to procedures in Section 5.3.2.2.
   e) If maritime cultural material is also identified refer to procedures in Section 5.3.2.4.
   f) The Cultural Heritage Officer should create accurate records, including map references and photographs of the material and an *in situ* evaluation of the find.
   g) A written statement of the Cultural Heritage Officer findings and recommendations should be provided to the Heritage Council for their consideration.
   h) Based on the recommendations from the Cultural Heritage Officer, decisions regarding the treatment of the find shall be made in consultation with the Heritage Council.
2. If the find cannot be avoided and evaluated without further archaeological work, then the following procedure should be undertaken:

a) A data recovery program planned in consultation with a qualified historical archaeologist and the Heritage Council should be developed and implemented.

b) Based on the results of the data recovery program the find shall be evaluated in consultation with the Heritage Council.

c) Should burials be located, refer to burials procedure in Section 5.3.2.1.

5.3.2.4 Terrestrial Maritime Archaeological Sites

1. Maritime archaeological sites located above the high water mark may be protected by the State *Maritime Archaeology Act 1973*. In the discovery of material the procedures followed should be the same as that for historical archaeological sites (see Section 5.3.2.3 above).
2. Written notice of discoveries should be given to the Director of the WA Maritime Museum.
3. Decisions regarding the treatment of the find shall be made in consultation with the Director of the WA Maritime Museum or his delegated representative and the Heritage Council.
4. If the site also contains Indigenous material consultation should be extended to include Indigenous people, and the DIA.

5.3.2.5 Underwater Maritime Archaeological Sites

1. Maritime archaeological sites located below the high water mark are protected by the Federal *Historic Shipwrecks Act 1976*. If identified the following should occur:

   a) All work in the immediate vicinity of the find must cease and reasonable efforts to secure the discovery should be made. Work can continue at an agreed upon distance from the site. Note that the material should not be removed or disturbed further.

   b) The Cultural Heritage Officer, if not already present, and appropriate CTA managers should be notified.

   c) The WA Maritime Museum should be contacted and advised of the situation.

   d) The Cultural Heritage Officer should create accurate records, including GPS positions and photographs of the material (if possible).

   e) Decisions regarding the treatment of the find shall be made in consultation with the Director of the WA Maritime Museum or his delegated representative who may then recommend an *in situ* evaluation of the find by a qualified maritime archaeologist.

Table 5-1. Gorgon Development – Cultural Heritage Management Issues and Strategies

COMPONENT	CURRENT SITUATION	DESIRED OUTCOMES	STRATEGIES & RECOMMENDATIONS
Indigenous Heritage - Anthropology	**Barrow Island** No ethnographic surveys have occurred. Indigenous people associated with the Yabburara/Mardudhunera, Kurama Marthudunera and Thanlanyji Indigenous groups have expressed an interest in being consulted regarding Indigenous heritage issues on Barrow Island.	Involvement of Indigenous people in the management of cultural heritage on the island well in advance of construction.	The Yabburara/Mardudhunera, Kurama Marthudunera and Thanlanyji Indigenous communities need to be consulted and physical inspection of the proposed development on Barrow Island with a qualified anthropologist and selected members of the Indigenous communities may be required.
	Mainland No ethnographic surveys have occurred. Two ethnographic sites identified close to Apache/Hadson pipeline. Indigenous people associated with the Yabburara/Mardudhunera, and Kurama Marthudunera Indigenous groups have expressed an interest in being consulted regarding Indigenous heritage issues on the mainland.	Involvement of Indigenous people in the management of cultural heritage on the mainland well in advance of construction.	The Yabburara/Mardudhunera, and Kurama Marthudunera Indigenous communities need to be consulted and physical inspection of the proposed development on the mainland with a qualified anthropologist and selected members of the Indigenous communities may be required.
Indigenous Heritage - Archaeology	**Barrow Island** Limited Indigenous archaeological assessment has occurred.	Identification of all Indigenous archaeological sites within/adjacent to proposed development well in advance of construction.	Detailed pedestrian sample survey conducted by qualified archaeologists of the proposed disturbance areas. Survey should cover at least 50% of the proposed disturbance areas.
	Potential for sub-surface cultural material on the coast and in claypans.	Management of potential sub-surface cultural material during construction.	Engagement of Cultural Heritage Officer during ground disturbance activities. Test-excavation of potential locations if warranted. Monitoring of construction in coastal and claypan areas by qualified archaeologist and Indigenous people.
	At present one known Indigenous site may be impacted by the Flacourt Bay Pipeline Option (see Appendix 1). Until the development footprint is finalised by CTA and those proposed disturbance areas are inspected the possibility exists that additional Indigenous archaeological sites are present.	Avoid if possible. If cannot be avoided then suitable recording work will be required and the appropriate permits obtained to disturb the sites.	Ensure sites are protected from inadvertent damage. To facilitate this CTA should: 1. Engage a Cultural Heritage Officer. 2. Ensure that all construction personnel participate in a Cultural Heritage Induction. If Indigenous sites cannot be avoided then: 1. An application should be made under Section 18 of the *Aboriginal Heritage Act 1972* to disturb the required sites. 2. Detailed recording of sites will be required by qualified archaeologists. 3. If the potential for sub-surface cultural material is identified the site must be test-excavated to determine this potential. A Section 16 permit (*Aboriginal Heritage Act 1972)* will need to be obtained from the DIA to conduct this work.

COMPONENT	CURRENT SITUATION	DESIRED OUTCOMES	STRATEGIES & RECOMMENDATIONS
			4. Indigenous people will have to be consulted regarding the proposed site disturbance.
	Mainland No archaeological assessment has occurred on the mainland infrastructure. The Apache/Hadsen pipeline was surveyed for Indigenous sites; however, no details are available.	Identification of Indigenous archaeological sites within/adjacent to proposed development well in advance of construction.	Detailed pedestrian transects of mainland infrastructure conducted by qualified archaeologists. Survey should be at least a 50% sample.
	There is the potential for sub-surface cultural material on the coast and in claypans.	Management of potential sub-surface cultural material during construction.	Engagement of Cultural Heritage Officer during ground disturbance activities. Test-excavation of potential locations if warranted. Monitoring of construction in coastal and claypan areas by qualified archaeologist and Indigenous people.
	Three known Indigenous archaeological sites are in the vicinity of the DOMGAS Pipeline (see Appendix 1). Until the footprint is finalised by CTA and those proposed disturbance areas are inspected the possibility exists that additional Indigenous archaeological sites are present within the proposed development.	Avoid if possible. If cannot be avoided then additional recording work will be required and the appropriate permits obtained to disturb the sites.	Ensure sites are protected from inadvertent damage. To facilitate this CTA should: 1. Engage a Cultural Heritage Officer. 2. Ensure that all construction personnel participate in a Cultural Heritage Induction. If Indigenous sites cannot be avoided then: 1. An application should be made under Section 18 of the *Aboriginal Heritage Act 1972* to disturb the required sites. 2. Detailed recording of sites will be required by qualified archaeologists. 3. If the potential for sub-surface cultural material is identified the site must be test-excavated to determine this potential. A Section 16 permit (*Aboriginal Heritage Act 1972)* will need to be obtained from the DIA to conduct this work. 4. Indigenous people will have to be consulted regarding the proposed site disturbance and the ethnographic significance of the sites.
Historical & Maritime Heritage – terrestrial	**Barrow Island** Limited historical archaeological assessment has occurred. There is a strong potential for sites to be found, particularly in the near coastal zone.	Identification of historical archaeological sites within / adjacent to proposed development well in advance of construction.	Detailed pedestrian sample survey conducted by qualified archaeologists of the proposed disturbance areas. Survey should cover at least a 50% of the proposed disturbance areas, with emphasis on coastal zones.
	Potential for sub-surface cultural material on the coast, especially burials.	Management of potential sub-surface cultural material during construction.	Engagement of Cultural Heritage Officer during ground disturbance activities. Test-excavation of potential locations if warranted. Monitoring of construction in coastal areas by Cultural Heritage

COMPONENT	CURRENT SITUATION	DESIRED OUTCOMES	STRATEGIES & RECOMMENDATIONS
			Officer.
	At present one known historical site may be impacted by the development (see Appendix 1). Until the development footprint is finalised by CTA and those proposed disturbance areas are inspected the possibility exists that additional historical archaeological sites are present.	Avoid if possible. If cannot be avoided then suitable recording work will be required and the appropriate permits obtained to disturb the sites.	Ensure sites are protected from inadvertent damage. To facilitate this CTA should: 1. Engage a Cultural Heritage Officer. 2. Ensure that all construction personnel participate in a Cultural Heritage Induction. If historical sites cannot be avoided then: 1. Detailed recording of sites will be required by qualified archaeologists. 2. If the potential for sub-surface cultural material is identified the site must be test-excavated to determine this potential: a) The Heritage Council must be informed and give their approval. b) If the site contains Indigenous or maritime components refer to relevant procedures above and below.
	Mainland No historical archaeological assessment has occurred. There is a strong potential for sites to be found, particularly in the near coastal zone.	Identification of all historical archaeological sites within/adjacent to proposed development well in advance of construction.	Detailed pedestrian sample survey conducted by qualified archaeologists of the proposed disturbance areas. Survey should cover at least 50% of the proposed disturbance areas, with emphasis on coastal zones.
	Potential for sub-surface cultural material on the coast, especially burials.	Management of potential sub-surface cultural material during construction.	Engagement of Cultural Heritage Officer for life of construction. Test-excavation of potential locations if warranted. Monitoring of construction in coastal areas by qualified historical archaeologist.
	At present one known historical/maritime site may be impacted by the Flacourt Bay Pipeline Option (see Appendix 1). Until the development footprint is finalised by CTA and those proposed disturbance areas are inspected the possibility exists that additional historical archaeological sites are present.	Avoid if possible. If cannot be avoided then suitable recording work will be required and the appropriate permits obtained to disturb the sites.	Ensure sites are protected from inadvertent damage. To facilitate this CTA should: 1. Engage a Cultural Heritage Officer. 2. Ensure that all construction personnel participate in a Cultural Heritage Induction. If historical sites cannot be avoided then: 1. Detailed recording of sites will be required by qualified archaeologists. 2. If the potential for sub-surface cultural material is identified the site must be test-excavated to determine this potential: a) The Heritage Council must be informed and give its approval. b) If the site contains Indigenous or maritime components refer to relevant procedures above and below.

COMPONENT	CURRENT SITUATION	DESIRED OUTCOMES	STRATEGIES & RECOMMENDATIONS
Maritime Heritage - underwater	**Barrow Island** There has been no physical archaeological assessment of the underwater area designated for the proposed pipelines. Until the development footprint is finalised by CTA and those proposed disturbance areas are inspected the possibility exists that shipwreck sites are present.	Identification of shipwreck sites within/adjacent to proposed development well in advance of construction.	Detailed acoustic and/or video imaging should be carried out along proposed disturbance areas, similar to that already conducted by Fugro for sections of pipeline and port facility. As recommended by Fugro (2003), additional detailed video/sonar survey work should be carried out in areas of moderate to high relief rock outcrop only. The Fugro recommendation that a block survey is carried out in the anticipated areas of very uneven seabed to choose an optimum route is also supported. This material should be made available to a maritime archaeologist to determine whether maritime cultural material, shipwreck or otherwise is present. Depending on the results of the above physical inspection by maritime archaeologists of potential areas may be required.
	At present no shipwreck sites have been identified within the proposed development.	If shipwreck sites are identified avoid if possible If cannot be avoided then suitable recording work will be required and the appropriate permits obtained to disturb the sites.	Ensure sites are protected from inadvertent damage. To facilitate this CTA should: 1. Ensure that all construction personnel participate in a Cultural Heritage Induction. If shipwreck sites cannot be avoided then: 1. Decisions regarding the treatment of the find shall be made in consultation with the Director of the WA Maritime Museum or his delegated representative. 2. Recommendations may include: a) An *in situ* evaluation of the find. b) Detailed excavation and recording. c) Removal of cultural material and curation in the WA Maritime Museum.

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APPENDIX 1

LIST OF KNOWN CULTURAL HERITAGE SITES IN IMMEDIATE VICINITY OF GORGON DEVELOPMENT

Barrow Island

Category	Code (Site Name)	Site Type	Location	Easting*	Northing*	Brief Description	Within Gorgon Development?	Recommendation if Cannot be Avoided	Reference
Indigenous	GD04-01 (Flacourt Bay 01)	Possible Site, Rock shelter	Flacourt Bay	331540	7705613	Identified during March 2004 field visit. Rock shelter with potential for sub-surface cultural material. No surface material noted.	Possibly c. 80 m north-east of Flacourt Bay Gas Feed Gas Pipeline centreline	Record in more detail. Test excavate to determine potential for sub-surface cultural material.	Appendix 2
Historical	GD04-02 (Flacourt Bay 02)	Bottle Scatter	Flacourt Bay	331534	7705477	Identified during March 2004 field visit. Five pieces of light olive beer bottle glass manufactured in late 19th – early 20th Century.	Yes Flacourt Bay Gas Feed Gas Pipeline centreline	Record in more detail. Test excavate to determine potential for sub-surface cultural material.	Appendix 2

* = Zone 50; Datum GDA 94; Grid Reference Accuracy ± 20m

Mainland

Category	Code (Site Name)	Site Type	Location	Easting*	Northing*	Brief Description	Within Gorgon Development?	Recommendation if cannot be avoided	Reference
Indigenous	17429 (*Nyungarrarra*)	Ethnographic (named place)	Inland Peters Creek	398502	7629610	Named creek, '*Nyungar*' translates as Blue Sky.	No		McDonald, Hales & Associates (1994)
Indigenous	17004 (*Warlu* Waterhole)	Ethnographic (mythological)	Inland Peters Creek	390974	7627050	'Waterhole' located in Peters Creek Associated with water-source is a scatter of flaked artefacts	No	Relocate to define location accurately.	Stevens (1998) McDonald, Hales & Associates (2001)
Indigenous	(Hadson 1)	Ethnographic (water-source) Artefact Scatter	Inland Adjacent Apache pipeline	390141	7633154	'Waterhole' known to Martuthunira informants; "used by local Aboriginal people as a water source as they moved to the coast". Associated with water-source is a scatter of flaked and ground stone artefacts in a claypan. Nine artefacts recorded in a 2 m² sample square. Scatter measures 500 m by 500 m in	Possibly DOMGAS Pipeline	Consult with relevant Indigenous groups Relocate and record archaeological component in detail. Possible test excavation.	Murphy & McDonald (1990)

Category	Code (Site Name)	Site Type	Location	Easting*	Northing*	Brief Description	Within Gorgon Development?	Recommendation if cannot be avoided	Reference
						area.			
Indigenous	(Hadson 2)	Artefact Scatter	Coast	378141	7647154	Scatter of flaked stone artefacts on a sand island in coastal flat. Shell fragments (*Melo* spp., *Anadara* spp.) present, however, the report does not state whether cultural or natural.	No	Relocate to define location accurately.	Murphy & McDonald (1990)
Indigenous	(Hadson Midden 1)	Shell & Artefact Scatter	Saltpan/sandplain Adjacent Apache pipeline	385141	7647154	Scatter of flaked stone artefacts and some shell: *Saccostrea* spp., *Terebralia* spp., *Anadara* spp. and *Melo* spp. Given the presence of coral blocks and mangrove branches shell scatter may be natural.	Possibly DOMGAS Pipeline	Relocate and record in detail to determine whether shell scatter is cultural or natural. .Possible test excavation.	Murphy & McDonald (1990)
Indigenous	(Hadson Midden 2)	Shell & Artefact Scatter	Coast Adjacent Apache pipeline	381141	7655154	Scatter of two flakes and one muller immediately behind coastal mangroves. Economic shell species present: *Anadara* spp., *Terebralia* spp., *Melo* spp., *Syrinx* spp. and *Tectus* spp. Shell scatter may be result of water action given close proximity to mangroves.	Possibly DOMGAS Pipeline	Relocate and record in detail to determine whether shell scatter is cultural or natural. Possible test excavation.	Murphy & McDonald (1990)
Indigenous	17833 (Tap Site 2)	Shell & Artefact Scatter	Coast	378938	7646377	Small scatter of shells and flaked stone artefacts. Artefacts manufactured from chert, dolerite and basalt. Site on shore of salt flat island.	No	Relocate to define location accurately.	Lantzke (1999:4)
Indigenous	18026 (PC 33)	Artefact Scatter	2 km south-west of Compressor Station 1	390068	7625886	Sparse scatter of four flaked stone artefacts. Artefacts in a stony exposure.	No	No further work required	McDonald Hales and Associates (2001)
Historical Maritime Indigenous	(Maceys Wreck)	Shipwreck Artefact Scatter	Coast, near Hadsen/Apache pipeline	Not provided	Not provided	Remains of nineteenth century lugger with associated glass remains, including possible Indigenous material	Possibly DOMGAS Pipeline	Relocate and record. Indigenous archaeologist to identify possible retouched glass artefacts.	McCarthy (1991)

* = Zone 50; Datum GDA 94; Grid Reference Accuracy ± 100m

APPENDIX 2

CULTURAL HERITAGE ASSESSMENT ON BARROW ISLAND – MARCH 2004 (VEITCH, PATERSON & SOUTER)

Activity Summary

Day	Activity	Description
16 March 2004	Travel to Barrow Is. Induction Project Orientation	Preliminary inspection of proposed development and general tour of island.
17 March 2004	Reconnaissance	Inspected previously recorded sites 888 (FS06) and 889 (FS07). Also visited possible Gas Feed Pipeline landing at Flacourt Bay. Spot checks on road side along possible pipeline routes.
18 March 2004	Reconnaissance	Inspected possible Gas Feed Pipeline landing White Beach and Gas Processing Facility Area. Inspected previously recorded sites 887 (FS05), Boudie cave, Pearlers Camp 891 (FS09). Examined collected Indigenous and historical artefacts in Environment laboratory.
19 March 2004	Reconnaissance Travel to Perth	Inspected Port Facility on eastern side of Island and possible jetty location. Photographed artefacts from Environment laboratory collection.

The proposed development areas were inspected in preliminary detail, with spot checks undertaken at areas of high archaeological potential such as coastal areas and in claypans (see Quartermaine Consultants 1994 for a discussion of some of these areas). Inspections were made at the coastal pipeline crossings at Flacourt Bay, White's Beach and Town Point. In addition a 60 m wide transect was walked through the centre of the proposed Gas Processing Facility area. Inspections were made of the coast at Town Point and at low tide the seaward side of Town Point was also inspected.

Four previously recorded Indigenous sites were visited [887 (FS05), 888 (FS06), 889 (FS07) and 891 (FS09)]. In addition two new cultural heritage sites were identified in Flacourt Bay; a rock shelter with the possibility for sub-surface Indigenous cultural material (GD04-01); and one historical site (GD04-02) (Appendix 1).

Indigenous Archaeology – summary of findings (B Veitch)

Previously Recorded Sites

Site 887 (FS05)

This artefact scatter is located well north of the proposed Gorgon Development and will not be impacted. The original recording identified six artefacts, including four collected artefacts (Quartermaine Consultants 1994:17, Appendix 3). During the March 2004 visit an estimated flaked stone artefact population of between 100 and 500 was noted. The artefact scatter also comprises exposed stone artefact reduction areas that have been revealed as the dune has deflated. The new artefacts have been exposed as a result of cyclonic activity. If the site is to be impacted it is recommended that further recording work including test excavation is warranted.

Site 888 (FS06 Area C)

This artefact scatter is located well north of the proposed Gorgon Development and will not be impacted. Quartermaine Consultants (1994:17-18, Appendix 3) recorded six flaked stone artefacts in Area C, however, during the March 2004 visit only one artefact was relocated. In other parts of the site (Area A, B, D) less material was also noted. This is most likely the result of siltation and water action during cyclonic weather, exposing and burying artefacts. As recognition of this Quartermaine Consultants (1994:18) recommended that test excavations were warranted at this site. In most cases on the mainland, artefacts are noted on the margins of claypans, while on Barrow they appear to be in them. This raises the possibility that the artefacts observed by us and Quartermaine Consultants (1994:17-18) are not in primary locations of discard. Given that CTA intend to place concrete footings every 2 m along the length of the proposed CO_2 Pipeline (Tony Cotton pers. comm.), Area C should be test excavated in accordance with the recommendations made by Quartermaine Consultants (1994:18).

Site 889 (FS07)

This artefact scatter is located well north of the proposed Gorgon Development and will not be impacted. The scatter was recorded in 1994 as comprising four artefacts in a small claypan (Quartermaine Consultants 1994:18). During the March 2004 visit only the quartz flake was relocated. Like site 888 the claypan at site 889 has been affected by cyclonic activity burying and exposing artefacts. This site, therefore, has the potential for sub-surface cultural material and should be test excavated prior to any disturbance (cf. Quartermaine Consultants 1994:18).

General Comments

The differences between the numbers of artefacts in 1994 and 2004 in sites 887, 888 and 889 all stem from cyclonic activity. Two cyclones have passed over the area since 1994 (Olivier and Monty), leaving their mark on the landscape:

1. Scoured out deposits in the eastern part of the dunes swale in which 887 is located, resulting in one reduction area and considerably more artefacts being revealed.
2. Wash-sedimentation occurring at 888 and 889 that seems to have either buried or washed artefacts away.
    a) It seems unlikely that artefacts would have been washed away given that the claypans are in low points on the landscape.
    b) It seems more likely that the artefacts that Quartermaine Consultants (1994) recorded have been buried in the claypan features by siltation associated with wash from cyclonic rains. A sea sponge was noted in site 888 Area B which may support this proposition.

As a result of this cyclonic activity the surface archaeological signature of these sites and therefore other parts of the island has altered since 1994.

Newly Recorded Sites

GD04-01

A potential site was recorded at Flacourt Bay (50K 331540mE 7705613mN; Datum GDA 94). GD04-01 is a small rock shelter with the potential for sub-surface cultural material. No artefactual material was on the surface, but due to safety requirements the survey team did not enter the rock shelter beyond the drip-line. The proposed Flacourt Bay Gas Feed Pipeline option may disturb this rock shelter. The rock shelter should be test excavated prior to any disturbance to determine the potential for sub-surface cultural material.

Boodie Cave

In addition, Boodie Cave was visited. This was recorded by Quartermaine Consultants (1994:22, 25) as a site with potential sub-surface cultural material, but is not in the proposed Gorgon Development. This cave has considerable potential to contain stratified cultural remains; however, as with site GD04-01 no surface artefactual material was noted during the March 2004 visit. The lack of surface cultural material is consistent with the proposition that Barrow Island was abandoned from approximately 7,000 BP.

Proposed Development

A number of factors suggest that the surface archaeology on and near the proposed Gorgon Development has undergone substantial changes since Quartermaine Consultants conducted their assessment in 1994. As a result of cyclonic weather some sites have more artefactual material than originally recorded as a result of erosion, while in other sites sedimentation appears to have concealed artefacts, possibly forming stratified cultural deposits. These processes have been occurring for millennia. The possibility exists therefore that there will be stratified and newly revealed archaeological material within the proposed Gorgon Development that was not visible during the 1994 survey (Quartermaine Consultants 1994)[5]. Most of the proposed development covers areas that have low potential for Indigenous archaeological material. However, given that parts of the development occur on the coast or in low lying areas that may have features such as claypans, a systematic pedestrian survey is the only way to establish with any confidence the presence or absence of additional cultural heritage.

[5] It also needs to be emphasised that the assessment by Quartermaine Consultants (1994) did not cover very much of the proposed Gorgon Development. Further, as has been shown, their results may no longer apply to the contemporary situation given the geomorphic processes outlined above.

Historical & Maritime Archaeology – summary of findings (A Paterson & C Souter)

Previously Recorded Sites

Site 891 (FS09)

This artefact scatter is on the southern end of the island and will not be impacted by the proposed Gorgon Development. The original recording identified many historical artefacts, including glass retouched by Indigenous people (Quartermaine Consultants 1994:19-20, Figure 15). The site originates from a pearlers' camp, although not surprisingly the identity of the ship associated with the site is not known given the paucity of historical accounts. The presence of Indigenous people in a pearlers' camp is supported by the documentary review, although it is not clear whether they were present willingly or by force. During the March 2004 visit an estimated flaked glass artefact population of between 10 and 20 was noted. If the site is to be impacted in future it is recommended that a complete excavation by conducted by an archaeologist qualified in contact archaeology. All workers on the island should avoid the site. Removal of any material may contravene the Western Australian *Aboriginal Heritage Act 1972* and the *Maritime Archaeology Act 1973*.

Newly Recorded Sites

GD04-02

This artefact scatter, of glass, is in Flacourt Bay (50K 331534mE 7705477mN; Datum GDA 94) and may be impacted by the proposed Gorgon Development, specifically the Flacourt Bay Feed Gas Pipeline option. The site comprises glass fragments from a single light olive glass bottle of a champagne beer type common in the late 1800s and early 1900s. While rare on Barrow Island, elsewhere along the Australian coast this is a common artefact and could be collected prior to the site being disturbed. There may however be buried archaeological material at this site and the procedures for site disturbance detailed in Section 5 of this report should be followed.

General Comments

As with the Indigenous archaeology it is clear from the review of documents and the field visit that there is the potential for additional historical sites within the Gorgon Development on Barrow Island. Additional survey and monitoring work will be required to identify historical sites prior to construction.

It is also suggested given number of references to Whitlock Cove in the historical sources that that this area should be surveyed for historical/maritime material. It is acknowledged that this area is not within the proposed Gorgon Development, however, for wider management issues on the island it would be advisable to have this area inspected (see below).

Interest in the archaeological survey was expressed by some workers on the island in March 2004 to those taking part in the survey. Such interest could be harnessed to protect the archaeological resources, especially when it is made clear that the archaeological resource is non-renewable. One worker who knew of a site stated he wanted to return with a metal detector and explore the locality for more finds: an understandable curiosity which however would contravene a number of heritage acts. Workers should be made aware of these limitations and procedures should reflect a policy of reporting archaeological finds and not removing anything from a site until the proper procedures have been followed.

Conclusions

Most of the proposed Gorgon Development on Barrow Island covers areas that have low potential for cultural heritage. But since parts of the development are likely to take place in places of high cultural heritage potential, such as on the coast and along creeks or seasonal drainage lines, a systematic pedestrian survey is the only way to establish with any confidence the presence or otherwise of additional cultural heritage within the Gorgon Development on Barrow Island. It is therefore strongly recommended that an Indigenous, historical / maritime pedestrian survey of the proposed development on Barrow Island be undertaken prior to construction activities. Given the potential for sub-surface cultural material in these high potential areas it is also suggested that proposed construction works are monitored by qualified Cultural Heritage Management practitioners.

During the field visit the collection of flaked stone artefacts in the Barrow Island Environmental Laboratory was inspected. The idea was discussed with Tony Cotton (CTA HES Supervisor) that the collection might be better housed in the Western Australian Museum. It is suggested that this matter be raised with relevant State heritage departments such as the DIA, the WA Museum and the Maritime Museum.

The field visit strengthened the proposition that a number of Indigenous sites on Barrow Island could contain sub-surface cultural material, with Boodie Cave having the highest such potential. Results from archaeological excavations at rock shelters/caves such as Boodie Cave and to a lesser extent open surface scatter sites such as 888 and 889 have the potential to answer fundamental questions regarding Indigenous occupation of the region from 30,000 years ago. Barrow Island also has unusual historical sites that warrant further research. CTA, in our opinion, has the opportunity to support cultural heritage research on the island, similar to research currently conducted into the rare fauna, palaeofauna and flora. Such cultural heritage research places CTA in a proactive and positive situation with regard to cultural heritage.

In view of the interest expressed by some of the workers on Barrow Island in cultural heritage and their lack of knowledge regarding the protection of these sites, it is also suggested that the proposed Gorgon Development Cultural Heritage Induction (see Section 5) is extended to include all workers on the island. In addition, CTA may wish to consider the production of information boards detailing the cultural history of the island and the types of sites and artefacts present. These information boards may be strategically placed on the island, perhaps at the airport or in the induction room.

APPENDIX 3

ASSESSMENT OF HISTORICAL SOURCES RELATED TO BARROW ISLAND – FEBRUARY 2004 (PATERSON)

Introduction

A survey of historical documents was conducted to establish the range of historical events that occurred on Barrow Island. The focus of this survey was on 19th century events as these tend to be considered more significant than those of the 20th century; this, however, is a subjective distinction and a more comprehensive knowledge of the potential total history of site use is the intention of this survey.

Historical sources are not necessarily true. Where it is felt a source is unsubstantiated we have suggested cautionary use.

Historical events described in these documentary sources are not always linked to a specific site on Barrow Island. This clearly presents a problem for management; however the combined use of historical and archaeological surveys provides the most comprehensive understanding of the cultural resources of Barrow Island. The archaeological surveys provide the most useful record of historical sites on the island which, together with the data detailed here and in earlier documentary surveys (see below), provides a list of known historical sites in the surveyed areas plus a "best fit" interpretation of their historical use.

There have been several earlier studies of the historical sources related to Barrow Island. This desktop study does not repeat such data (which may however feed into Appendix 1 and Section 4.2 above).

This survey was assisted by Ms Annie Carson (BA Hons, UWA) and Jo Pritchard and Anna Vitenbergs (Local History Office, Shire of Roebourne).

Primary Sources

Author(s):	Robert Langdon (ed)
Title:	Where the Whalers Went: An index to the Pacific ports and islands visited by American whalers, and some other ships, in the 19th century.
Archive:	Mitchell Library, Sydney
Reference no.	Q387.54041
Year(s):	1984

Site/person/event(s) associated with: Barrow Island – early whaling – *Stephania* (1842) and *Canton* (1864)

Description: The list of places on page 263 lists Barrow Island early whaling as being reportedly visited by the *Stephania* (21 June, 4 August 1842) and *Canton* (22 July, 1864). The latter is possible, as is the former, however this is a very early era for whaling in the northwest which predates permanent occupation in the region. Any sites related to either would be extremely significant. There were many reports of American whalers operating in this region in the 1840s and later decades. Other key places were the Montebello Islands, the Dampier Islands (especially Rosemary Island which was reportedly visited in 1801 by whalers), Exmouth Gulf, Shark Bay, and Bedout Island. These reports suggest regular informed whaling in the region with a probable presence on Barrow Island of whalers in the period after 1801, especially after 1840.

Author(s): Jarman, Capt.
Title: The 'Tien Tsin's' Track to the Harding River
Archive: Exploration Diaries; Volume 5, 1858-1865
Reference no. PR 5441 / Battye
Year(s): 1863
Site/person/event(s) associated with: Barrow Island – early sightings – Capt. Jarman

Description: The 'Exploration Diaries' consist of six volumes of excerpts taken from the original diaries and papers of various explorers and pioneers in Western Australia. Pages 54-60 are excerpts from Captain Jarman's journey to Nickol Bay in the barque 'Tien Tsin' in 1863. He mentions sighting Barrow Island:

"Saturday, May 2. – Lat. 20deg. 21min., long. 114deg. 21min., abreast of Barrow Isle; the soundings from N.W. Cape thus far on Admiralty Chart are very correct…" (p. 55).

Author(s): Burges, L. C
Archive: Battye – Exploration Diaries; Volume 5, 1858-1865
Reference no. PR 5441
Year(s): 1864
Date: October 8, 1864
Site/person/event(s) associated with: Barrow Island – early sightings – L.C. Burges

Description: Extract from the journal of Mr. L.C. Burges, a pastoralist who travelled on board the *Flying Foam* from Fremantle to Roebuck Bay to explore the north-west and assess the suitability of the area for settlement. Left Fremantle October 3, 1864, arrived Roebuck Bay October 13, 1864. This passage describes sailing close to Barrow and Montebello Islands.

"Saturday, October 8. – We are ….. [words obliterated] distance north of the Cape this morning in consequence of a strong current out of the gulf, running in a southerly direction. 4 p.m. – Barrow Island visible from the masthead. 5 p.m. – The Monte Bello Isles are in view now. At 8 p.m. the captain changed his course after passing between the reef and one of the Monte Bello Isles, and got into a regular harbour where we had to come to an anchor for the night in 2 ¾ fathoms of water." (p.397).

Author(s): Captain Jarman
Title: Perth Gazette and Times
Archive: Battye Microfilm
Reference No. 994.11/ PER
Date: 27.1.1865
Site/person/events associated with: Barrow Island – early exploration – Capt. Jarman

Description: Jarman describes anchoring at Barrow Island in what is probably Whitlock Cove, on December 18, 1864. He provides a detailed account of the surrounding environment and vegetation he and his party encountered during their walk on the island. Observations of interest include an apparent lack of water, plenty of wallabies and some kangaroo, and turtle tracks. Camped overnight and commenced turtle hunting in the early hours of the next morning.

December 19, 1864, traversed westward across the island, noting dense masses of spinifex and sporadic outcrops of calcined limestone. Jarman notes stumbling across a solitary tree, the only one noted by him on the island. Jarman then set the island alight in order to increase the quality of the spinifex for grazing by the wallabies in the hope they would 'fatten up'. Left the island early December 20, 1864.

Author(s): Whitlock, F. Lawson
Title: Notes on Northwestern Birds. *Emu,* Vol. 17(4): 166-179.
Archive: 2nd Floor Battye Stack
Reference No. 590 EMU
Year(s): 1918
Site/person/events associated with: Barrow Island – visit by F. Lawson Whitlock, 1918

Description: Naturalist F. Lawson Whitlock describes in detail his two-week visit to Barrow Island. His aim was to learn all he could about the little-known Black and White Wren of Barrow Island. Hence, most of the article is concerned with the description and recording of his observations of these animals. As the article could not be photocopied, relevant details about his trip to the island have been transcribed here:

“We left Cossack on Wednesday, 24th October 1917, and reached Barrow Island on Saturday, 27th October.” (p.171).

“… more often the coast was a mere fringe of low sand hills, with infrequent and small patches of mangroves. Our anchorage was a natural little port, easily entered at high tide, and well protected from a heavy sea by its very narrow entrance [Whitlock Cove]. Immediately to the east, and not more than a half-mile away, was Double Island. Fresh water was obtainable on Double Island and near our anchorage by digging in the sand above high water mark.” (p.173).

“My beat was the before-mentioned sandy peninsula, and also about 5 miles of coastal country on the north side of our harbour. I also made several trips half-way across the island, but the bird-life of the interior was so sparse and uninteresting…” (p.173).

“I was on the island to a fortnight, and also put in a day on the neighbouring Double Island.” (p.173).

“There was no shade or shelter apart from an awning over our boat and a small patch of mangroves a hundred yards away. I tried camping ashore, and erected a tent-fly furnished with mosquito netting, but this was soon torn off by strong winds.” (p.174).

“Turtle were plentiful, and my Japanese boatmen brought many eggs back to the cutter.” (p.174).

Whitlock drew a map of his ‘beat’, the area he covered on the island during his visit; a photograph of the map was taken and has been attached.

Author(s): Mayne, Blair E

Title: Votes and Proceedings of the Legislative Council, 1885

Archive: Batty Microfilm

Reference No. Q328.941 WES

Year(s): 1885

Date: 21 May, 1885

Site/person/events associated with: Barrow Island – quarantine station; Montebello Islands – pearl diving

Description: “Report by the Inspector of Pearl Shell Fisheries, for the Season 1884-1885.” 2-page letter written by Inspector Mayne who was stationed at Cossack when he wrote this report.

“At the commencement of the season, September, we had the misfortune to have the measles epidemic raging amongst the natives, thereby causing the boats to be very late at starting. I have great pleasure in now being able to contradict many statements that are afloat with regard to the inhuman treatment the natives get from their employers. For as soon as it was observed that measles has broken out, Barrow Island was converted into a quarantine station, with the schooner *Amy* into the medical ship tending to their wants; whilst the schooners *Expert* and *Pearl* were kept constantly running to and from the main, bringing over the sick ones and returning the convalescent. So, from the great care that was bestowed, the death rate was very small. I am unable to procure any definite figures. The natives themselves speak very highly of the treatment shown towards them by the whites.” (p.3).

“The boats using the Diving Apparatus have also found some new ground at the Monte Bello Group, where some very fine specimens of both shell and pearls have been got. They afterwards migrated to King Sound, where also they have been doing good work…” (p.3).

Author(s): Haynes, T.H.

Title: Mother-o’-pearl shell culture: report to the Montebello Shell Syndicate Ltd.

Archive: Battye PR Cabinet

Reference No. PR 1692

Year(s): 1912

Site/person/events associated with: Montebello Shell Syndicate

Description: Report on the state of the mother-of-pearl cultivation venture begun by the Montebello Shell Syndicate, brainchild of Thomas Haynes. There is a proposition its management over to the federal government.

No references to Barrow Island.

Author(s): Department of Fisheries and Wildlife. Extension and Publicity Service
Title: The pearling industry of Western Australia, 1850-1979.
Archive: Battye Stack
Reference No. 338.372411 WES
Year(s): 1979
Site/person/events associated with: Pearl Industry W.A – history – Montebello Shell Syndicate

Description: Brief overview of the development of the pearling industry in Western Australia, with explanations of pearl formation and cultivation. No reference to Barrow Island, but p.16 refers to the unsuccessful venture into pearl shell cultivation at the Montebello Islands with Thomas Haynes and the Montebello Shell Syndicate in 1900.

Author(s): Montague, P.D
Title: The Monte Bello Islands. *Geographical Journal* 42(1): 34-44
Archive: JSTOR – www.jstor.org/
Year(s): 1913
Site/person/events associated with: Montebello Islands – visit by P.D. Montague

Description: P.D. Montague was a scientist who visited the Montebello Islands and then published this article about the vegetation and wildlife on Hermite and Tremouille islands and several surrounding lagoons. He often refers to similarities in the ecology of both Barrow Island and the Montebellos suggesting that he may also have visited Barrow Island at some stage, or perhaps, given his description of Barrow's location, he may simply have sailed around it and taken notes.

Title: The Marine Underwriters' Association of Western Australia: Report of Committee with Balance Sheet for the Year Ended 30th April 1967
Archive/Location: Battye Serial Stack
Reference no. 368.22 MAR/ Battye
Year(s): 1966-1967
Site/person/event(s) associated with: Barrow Island Oil Shipment

Description: (p.19) "The tanker P.J. Adams began loading the first commercial cargo of Barrow Island oil on Sunday, April 23 and will earn the first pay cheque in 15 years for the West Australian Petroleum Pty. Ltd."

"This shipment marks the culmination of an intensive testing programme of the Barrow Island discovery."

Author(s): Serventy, D.L and A.J. Marshall
Title: A Natural History Reconnaissance of Barrow and Montebello Islands 1958
Archive/Location: Battye Cabinet
Reference no. 591.99413 SER
Year(s): 1964
Site/person/event(s) associated with: Barrow Island – Natural History

Description: Serventy and Marshall report on the findings of their visit to the Barrow, Lowendall and Montebello islands between 18-24 September 1958. Includes a referenced overview of previous visits to the islands by other naturalists, and includes details of Serventy's and Marshall's own research and campsites. Most of the report describes the vegetation, mammals and birds recorded during reconnaissance. 18-21 September was spent on Barrow Island, 21-22 on Lowendall Island and 22-24 on the Montebellos (p.3).

Relevant details of Barrow Island include (p.4):

- 1840 H.M.S. *Beagle,* type specimens of the local race of the euro were collected
- 1846 J. Lort Stokes recorded observations on the euro and other fauna
- 1900 J.T Tunney collected birds and mammals
- 1917 and 1918 F. Lawson Whitlock camped and observed the bird life
- 1945 G.P Whitley skirted the western coastline of Barrow Island on a fisheries survey in lugger *Isobel* but did not land.
- 1952 Personnel associated with the testing of the atomic bomb made sparse natural history observations.

Serventy and Marshall camped in the same general area as Whitlock. A little cove (Whitlock Cove) opposite Double Island (p.5).

Author(s): Tull, Malcolm

Title: The development of Western Australia's fishing industry: a preliminary survey.

Archive: Battye Cabinet

Reference No. 338.3727 TUL

Year(s): 1990

Site/person/events associated with: Maritime industries – Western Australia

Description: Report for Murdoch University on the historical development of the whaling, sealing, pearling and fishing industries in Western Australia. It details the importance of major industry areas such as Shark's Bay, however neither Barrow Island, nor the Montebello Islands are mentioned.

Lease Applications and Maps

Title: The Eastern Districts Chronicle

Archive: Battye Microfilm

Reference No. 994.12 YOR

Date: 27 August, 1880

Site/person/events associated with: Barrow Island – pastoral use

Description: Short newspaper article announcing the commencement of Messrs. Henry J. Cooke and James Morrell's pastoral lease on Barrow Island.

"Messrs. Henry J. Cooke and James Morrell, who as already notified, have taken Barrow Island on the N.W Coast for a sheep station, leave overland for the destination in about a fortnight from the present time, travelling with a flock of sheep, with which to make a start on their new run. The best wishes of many friends in these districts will go with them. Accounts given by those who have recently visited this Island are favourable in the extreme…"

Title: The Eastern Districts Chronicle

Archive: Battye Microfilm

Reference No. 994.12 YOR

Year(s): 1881

Date: 23 September 1881

Site/person/events associated with: Barrow Island – pastoral use

Description: Short newspaper article announcing that Messrs. Cook and Morrell are leaving Barrow Island.

"We much regret to learn that Messrs. Cook & Morrell who went up some months ago with sheep to take possession of Barrow Island are by no means satisfied with this locality which we hear they have some idea of abandoning. These gentlemen however, have succeeded in securing other runs with which we heartily wish them better luck."

Archive: State Records Office – CSO Files / Battye

Reference No. RM/R23 – Battye Microfilm

Year(s): 1871

Date: 11 August, 1871

Site/person/events associated with: Barrow Island – leases – C.L Smith

Description: A letter drafted from the Governor Resident of Roebourne to the Surveyor General's Office in Perth to request a Class A licence for turtle fishing on Barrow Island (50,000 acres) and Delambre Island on behalf of Mr. C. Lambert Smith. May have been one of the first applications for the lease of an island other than for pastoral purposes given the nature of the application and the response in which the Survey General instructed that the applicant could have access to the islands until the time when proper rental regulations could be drawn up. There is no map accompanying this application.

Archive: State Records Office – CSO Files / Battye

Reference No. SDUR/S6/611/ Battye Microfilm

Year(s): 1872

Date: 9 July 1872

Site/person/events associated with: Barrow Island – leases – C.L. Smith

Description: Application by C. Lambert Smith to the Surveyor General for an extension of his lease to fish turtle at Barrow and Delambre Islands. Extension was granted until June 1873.

Archive: State Records Office – CSO Files / Battye

Reference No. N352/ Battye Microfilm

Year(s): 1874

Date: August 30, 1874

Site/person/events associated with: Barrow Island – leases – J.G. Anderson

Description: Special Lease application form by James Grimmond Anderson for '…turtling and fish preserving generally, and the rights of grazing stock on same if found not to interfere with the habits of the turtle.'

There is no map accompanying this application but the lease does not appear to be restricted to any one area of Barrow Island.

Archive: State Records Office – CSO Files / Battye

Reference No. 67/1212/ Battye Microfilm

Year(s): 1897

Date: 23 July, 1897

Site/person/events associated with: Barrow Island – leases – James Clarke and Co.

Description: Application for pastoral lease of 50,000 acres of land on Barrow Island by James Clarke & Co. No map accompanying application.

Archive: State Records Office – CSO Files / Battye

Reference No. 94/281/ Battye Microfilm

Year(s): 1900

Date: 5 February, 1900

Site/person/events associated with: Barrow Island – leases – John Hurst

Description: Application for a pastoral lease for 50,000 acres of land on Barrow Island by John Hurst from Perth. Includes a sketch map of Barrow Island.

Archive: State Records Office – CSO Files / Battye

Reference No. 152/316 / Battye Microfilm

Year(s): 1900

Date: November, 1900

Site/person/events associated with: Barrow Island – leases – E.C Clark

Description: Application for a special lease for turtling on Barrow Island by Emmeline Collier Clark from East Fremantle. Unlike previous applications, Clark only applied for 100 acres and not the whole island, the positioning of which is shown in the sketch map drawn on the application.

Archive: State Records Office – CSO Files / Battye

Reference No. 94/489 / Battye Microfilm

Year(s): 1902

Date: 28 January, 1902

Site/person/events associated with: Barrow Island – leases – J.W. King

Description: Application for a pastoral lease for 50,000 acres of land on Barrow Island by James Westerhouse King. Sketch map included.

Archive: State Records Office – CSO Files / Battye

Reference No. 96/307 / Battye Microfilm

Year(s): 1904

Date: 22 August, 1904

Site/person/events associated with: Barrow Island – leases – A. Stevens

Description: Application for a pastoral lease for 50,000 acres of land on Barrow Island by Alexander Stevens. Listed as a pearler from Onslow. Sketch map included.

Archive: State Records Office – CSO Files / Battye

Reference No. 152/967 / Battye Microfilm

Year(s): 1907

Date: 6 August, 1907

Site/person/events associated with: Barrow Island – leases – F.C. Broadhurst

Description: Entry in the Dept. Lands and Surveys Lease Applications book under the name of F.C. Broadhurst. Application for a special lease of 50,000 acres of land on Barrow Island for the purpose of 'shipping, working and exporting phosphates.'

Author(s): Dept. Lands and Surveys

Title: North West Division – West Pilbara

Archive: State Records Office – Dept. Lands and Surveys records

Year(s): 1908-1971

Site/person/events associated with: Maps – West Pilbara, including the coastline and offshore islands, eg. Barrow and Montebello Islands.

Description: A series of 5 maps drawn up by the Dept. Lands and Surveys to supplement one after the other as each was cancelled. Each one is roughly 1m x 0.65m in dimension and they all use the scale of 1:237600, or 3¾ of a mile per inch on the map. Each one is listed:

> *Cons 4567, Item 111/2, Title 506009, 1908-1914:* The section of Barrow Island has 'A.E. Hall' written on it, a reference perhaps to the lease that A.E Hall once owned on the island. All leases became void after the island was reclassified as an Aboriginal Reserve in 1908. Harry F. Johnston was the Surveyor General. (see photo).
>
> *Cons 4567, Item 111/3, Title 506010, 1914-1921:* Very similar to 506009, Harry F. Johnston Surveyor General. (see photo).
>
> *Cons 4567, Item 111/4, Title 506011, 1921-1925:* H.S. King Surveyor General.
>
> *Cons 4567, Item 111/5, Title 506012, 1925-1951:* J.P Camm Surveyor General
>
> *Cons 4567, Item 111/6, Title 506013, 1951-1971:* W.V Fyfe Surveyor General. Increased detail regarding the contours of the island and its bays.

Secondary Sources

Author(s): Cox, Josephine M

Year: 1977

Title: Barrow Island: an historical documentation

Publisher: Author

City: Perth

Call no./Library: Q994.13 BAR/ Battye

Site/person/event(s) associated with: Barrow Island – documentary sources and history

Description: A comprehensive research thesis which documents known historical evidence for the visitation and/or use of Barrow Island prior to oil exploration and settlement by WAPET. Includes information regarding the first sightings of the island and hydrographic surveys, leases, scientific studies, reserve history and conservation.

Where possible, the original documents referred to in this study have been obtained and/or copied. Includes some maps.

Author(s): Butler, H. and J. Cox

Year: 1982

Title: Barrow Island

Publisher: West Australian Petroleum Pty. Ltd.

City: Perth

Pages: 1-16

Call no./Library: PR 994.13 BAR/ Battye

Site/person/event(s) associated with: Barrow Island – history, oil exploration

Description: Small tourist-style information booklet with a brief outline of the island's history, climate, geology, vegetation, fauna, oil history and current status. Includes an index of place names and their history where possible.

History (unreferenced) –1801-1803 French Commander-in-Chief Nicolas Baudin sighted the island and thinking it was part of the mainland, did not survey. Named Cape Dupuy, Cape Malouet, Cape Poivre and Flacourt Bay.

- 1818 Lieutenant Phillip Parker King named the island Barrow Island
- 1840 Commander John Clements Wickham and Lieutenant John Lort Stokes in the *Beagle* visited the island and made observations of the fauna.
- 1900 Tunney, John T. spent two months collecting birds and mammals.
- 1908 Declared Nature Reserve
- 1910 Class 'A' Reserve.
- 1917-1918 Naturalist F. Lawson Whitlock visits
- 1952 F.L. Hill of the Royal Navy
- 1964 D. Goodall – botanist
- 1969 A.A Burbidge and A.R Main
- 1964-1967 W.H. Butler frequently visits

Oil Field History - 1954 – first recognised as anticline to trap oil

- 1962-62 Light airplane landing strip and beach landing facilities built
- 1964 Drilling commences
- 1967 First oil shipment

Includes small map of Barrow Island oil fields

Author(s): De La Rue, Kathy

Year: 1979

Title: Pearl Shell and Pastures

Publisher: Cossack Project Committee (Inc)

Edition: 1st

Call no./Library: 994.1 1979/ Reid Library (UWA).

Site/person/event(s) associated with: Barrow Island – Aboriginal quarantine station.

Description: Detailed and well-referenced social history of the North-West, particularly the Pilbara region and the districts of Roebourne and Port Hedland. Focuses on the development of the pearling and pastoral industries at places like Onslow, Cossack, Roebourne and inland Pilbara. The reference to Barrow Island indicates the presence of a quarantine station c.1884-1885.

"On one occasion at least, they surpassed the terms of the Act by setting up a quarantine station with intensive medical care on Barrow Island, when a measles epidemic broke out among the Aboriginal divers in the 1884-1885 pearling season." (p.99).

Author(s): Forrest, K

Year: 1996

Title: The Challenge and the Chance: the colonisation and settlement of North West Australia 1861-1914.

Publisher: Hesperian Press

City: Perth, Western Australia

Edition: 1st

Call no./Library: 994.1303 1996 CHA/ Reid Library (UWA).

Site/person/event(s) associated with: Barrow Island – barracoons and slave markets; Exploration history of Barrow Island

Description: Referenced history of the exploration, colonisation and settlement of the north-west of Western Australia. References to exploration of the north-west coastline:

"Earlier, when King [Phillip Parker] surveyed Barrow, Lowendal and Trimouille Islands he decided these were the elusive Tryal Rocks, 'the dread of every voyager to the Eastern Islands for the last two centuries.'" (p.3)

"The first settlement in Western Australia took place in 1829, and Lort Stokes made the next voyage of coastal survey in the H.M.S *Beagle* in 1838. He came to the same conclusion as King. The group of islands, named by the French the Monte Bello, and consisting of Barrow, Lowendal and the Trimouille Islands, within their encircling reefs, were the dreaded Tryals of former days…" (p.3).

"The *Mystery* (17 tons) came from Fremantle and in July Sholl paid her master, Peter Hedland, ten pounds to search the Monte Bellos, Barrow Island and the islands off Exmouth Gulf." (p.47).

"The following year Sholl received verification of Cadell's infamies by letters from the Government Resident of Koepang and from Lt. Ross of *The Flower of Yarrow*. Ross informed him of Cadell's barracoons on Barrow Island an the ill-treatment he and his crew meted out to 30-40 divers. He starved them all. Cadell himself maimed two for life and murdered another." (p.111).

"David Forrest, brother of the Surveyor General, and one of the first pastoralists to openly defend the Aborigines, rarely put pen to paper but now, deeply angered at the continuing 'plight of the poor creatures', he wrote at length on the kidnapping still rife on the Ashburton. He described the 'well-equipped' and 'fully rationed' parties who travelled down from the Hammersley Ranges to the head of the Ashburton 'procuring all the young natives for pearl shell diving.' He maintained Rouse and his brother-in-law Joseph McCarthy led well equipped armed parties and took the natives against their will, shipping them out from Hooley's Creek to Barrow Island." (p.192).

Author(s): Bain, M. A

Year: 1982

Title: Full Fathom Five

Publisher: Artlook Books

City: Perth, Western Australia

Pages: (see chapter 2: pp.26-37)

Edition: 1st

Call no./Library: 338.371412 1982 FUL/ Reid Library (UWA).

Site/person/event(s) associated with: Barrow Island – barracoons and slave markets

Description: Comprehensive referenced history of the pearling industry in North-West Western Australia. Refers to Captain Francis Cadell and his association with establishing slave markets for pearling vessel operators on Barrow Island:

"Intermingled with lengthy reports of murder and rape were serious rumours of blackbirders having established barracoons (slave markets) on islands near the coast where kidnapped Aborigines were sold when the pearling season commenced. There was talk too, of female barracoons on Enderby, de Lambre and Barrow Islands where women were sold to the highest bidder." (p.28).

"In 1874 when an English yacht arrived at Cossack to commence pearling, the captain delivered a letter to Sholl from the Resident at Koepang. He stated that the local rajahs were complaining strongly that their indentured men were not being paid in many cases and a large number were being ill-treated. The Resident confirmed, too, the rumours of established barracoons run by a pastoralist and Cadell on the de Lambre and Barrow Islands and that Sustenance and another stranger to the coast had been responsible for the female market on Enderby Island." (p.30).

Author(s): Bain, M.A.

Year: 1983

Title: Some incidents in the heyday of pearling

Journal/Vol/No: Early Days; Volume 9, No.1

Pages: 37-48

Call no./Library: 994.1 WES/ Battye

Site/person/event(s) associated with: Barrow Island – barracoons and slave markets

Description: Referenced social history of the pearling industry of the North-West, focusing on the treatment of Aboriginal and Asian divers. Refers to the existence of a slave market on Barrow Island.

"Some men gave up the idea of searching for m.o.p. when they realised that easier money was to be made by establishing slave markets or 'barracoons' on islands that lay off shore from Shark Bay to King Sound. Young female aborigines at such markets at Enderby, Lambre and Barrow Islands were sold to the highest bidder. When the police began searching islands around the Dampier Archipelago, the 'barracoons' were transferred further to the north-east, and the Lacepede Islands … became a favoured resort." (p.41).

Unfortunately this particular situation described has not been referenced and so the original source could not be consulted for further investigation.

Author(s): McCarthy, Mike

Year: 1992

Title: Failure and success: the Broadhursts and the Abrolhos guano industry

Journal/Vol./No: Studies in Western Australian History, V13

Pages: 10-23

Call no./Library: 994.1 STU

Site/person/event(s) associated with: Barrow Island – guano collection

Description: Article documents the exploits of Charles Edward Broadhurst involved in a range of industries in the North-West such as pearling in Shark's Bay and collecting Guano in the Abrolhos islands.

With regards to Broadhurst's initial forays into collecting guano McCarthy states that, "Unknown to officials in Perth, however, a large amount of unauthorised harvesting of guano occurred on several remote islands further north. It is now known that guano was worked on the Lacepede Islands, Browse Island, Ashmore Reef, Jones Island (in Napier Broome Bay), Lesueur Island, Monte Bello Islands and Barrow Island." (p.12).

Author(s): Cairns, Lynne and Graeme Henderson

Year: 1995

Title: Unfinished Voyages – Western Australian shipwrecks 1881-1900

Publisher: University of Western Australia Press

City: Nedlands, Perth, Western Australia

Edition: 1st

Call no./Library: 994.1 CAI/ Reid Library (UWA)

Site/person/event(s) associated with: Barrow Island – guano collection

Description: Reference guide to shipwrecks and shipping history of Western Australia. Refers to the barque *Oleander* and the shipping of guano from Barrow Island.

"During September 1883, the barque *Oleander* (Official Number 43921) was in Fremantle Harbour awaiting a suitable charter. After the master, James Joass, had obtained a licence to load guano at Shark Bay, the ship was chartered for that purpose and left Fremantle in ballast on 24 September. On arrival at Shark Bay, some 80 tonnes of cargo was loaded. Then the vessel proceeded to Barrow Island where it was intended to complete loading, but as no cargo was available there, Joass returned to Shark Bay to take on more guano." (p.63).

Author(s): George, C. D.

Year: 1996

Title: The pearling industry in Australia and Papua New Guinea, 1949-1977, and the part played by the author and the Japanese.

Call no./Library: Q639.412 GEO

Site/person/event(s) associated with: Montebello Shell Syndicate

Description: There is no reference to Barrow Island in this book, however George does mention the establishment of the Montebello Shell Syndicate by T.H. Haynes in 1904 in his brief discussion on the early development of pearling in Australia.

Author(s): Marie-Stephanie

Year: 1996

Title: Monte Bello Island Pearling

Journal/Vol/No: Exmouth Expression, January 1996

Pages: 10

Call no./Library: Q994.13 EXM/ Battye

Site/person/event(s) associated with: Montebello Island group - pearling history

Description: 1-page article describing the history of the islands from the visit of Nicolas Baudin in 1801 to the pearling industry today.

Early pearling - Thomas Haynes held pearling licence from 1902-1913. 1981 Dick Morgan established Morgan & Co., a pearling company that operates from Hermite Island.

Author(s): Stanbury, Myra

Year: 1994

Title: Mother-of-Pearl shell cultivation: an early 20th Century experiment in the Montebello Islands, Western Australia.

Journal/Vol/No: The Great Circle, 16(2)

Pages: 90-120

Call no./Library: 387.2 GRE/ Battye

Site/person/event(s) associated with: Montebello Islands – pearl shell cultivation

Description: Article describes the history of pearl shell cultivation in the Montebello Islands, with reference to similar experiments conducted elsewhere in the state at the time such as Broome. Details the attempts by Thomas Haynes to cultivate m.o.p. shell in the Montebello Islands from 1901 to 1908. Includes archaeological evidence for pearling camps on the islands and hence gives a good idea of what similar pearling camps on Barrow Island may or may have looked like.

Author(s): Bartlett, Norman

Year: 1954

Title: The Pearl Seekers

Publisher: Andrew Melrose Limited

City: London

Edition: 1st

Call no./Library: 639.412/ Reid Library (UWA)

Site/person/event(s) associated with: Barrow Island - pearling

Description: Unreferenced history of the pearling industry in Australia and Torres Strait. Emphasis has been placed on the industry of Western Australia, particularly in the north around Broome. Bartlett describes the pearling grounds of Barrow Island:

"Thirty miles south of the Monte Bellos are the Barrow Island Shoals, probably the richest of the Australian pearling grounds, where they still fish the best pearls, although the area is too dangerous to tempt present-day pearlers who can get good shell easier elsewhere." (p.23).

Author(s): Coate, Yvonne and Kevin

Year: 2000

Title: More Lonely Graves of Western Australia

Publisher: Hesperian Press

City: Perth, Western Australia

Edition: 1st

Call no./Library: B/994 COA/ Battye

Site/person/event(s) associated with: Montebello Islands – burials

Description: Reference guide to individual burials and cemetery records for West Australia, including off-shore and at-sea burials.

"BRAHNN, died 2.1.1887 aged about 30 years on the MONTE BELLO ISLANDS. A Malay seaman on the Osprey, who died of natural causes." (p.44).

Author(s): Coate, Yvonne and Kevin

Year: 2000

Title: More Lonely Graves of Western Australia

Publisher: Hesperian Press

City: Perth, Western Australia

Edition: 1st

Call no./Library: B/994 COA/ Battye

Site/person/event(s) associated with: Barrow Island – burials

Description: Reference guide to individual burials and cemetery records for West Australia, including off-shore and at-sea burials.

"ANDREAS, died 5.10.1904 aged 45 years on board the lugger *Marietta* – buried on BARROW ISLAND in the Mary Ann Passage by Allic. Witnesses present at the burial were Dolha and Mattir. The informant was M. Fredrikson, master pearler, Onslow. A seaman, who died suddenly of unknown causes. He was born on one of the Malay islands and he had lived in Western Australia for 18 years." (p.10).

Author(s): Coate, Yvonne and Kevin

Year: 2000

Title: More Lonely Graves of Western Australia

Publisher: Hesperian Press

City: Perth, Western Australia

Pages:

Edition: 1st

Call no./Library: B/994 COA/ Battye

Site/person/event(s) associated with: Barrow Island – burials

Description: Reference guide to individual burials and cemetery records for West Australia, including off-shore and at-sea burials.

"LOCHRIN Joe, died 1.10.1904 aged 55 years, on board the schooner *Cutty Sark* off Barrow Island near Mary Ann Passage – buried on BARROW ISLAND by J. Montengre. Witnesses present at the burial were Rubino and Pablo. The informant was A. Harding, resident and partner of Onslow. A sail maker, whose sudden death was of unknown causes. He was born in Chile, South America, and had lived in Western Australia for 2 years." (p.224).

Author(s): Coate, Yvonne and Kevin

Year: 2000

Title: More Lonely Graves of Western Australia

Publisher: Hesperian Press

City: Perth, Western Australia

Edition: 1st

Call no./Library: B/994 COA/ Battye

Site/person/event(s) associated with: Barrow Island – burials

Description: Reference guide to individual burials and cemetery records for West Australia, including off-shore and at-sea burials.

"Bin Usop Dollah, died 8.2.1905 aged 20 years from lugger *Ellen* off Pascoe Island near Barrow Island – drowned at sea. A sailor, who drowned and his body was not recovered. He was born in Malacca and had lived in Western Australia for 9 months." (p.36)

Author(s): Coate, Yvonne and Kevin

Year: 2000

Title: More Lonely Graves of Western Australia

Publisher: Hesperian Press

City: Perth, Western Australia

Edition: 1st

Call no./Library: B/994 COA/ Battye

Site/person/event(s) associated with: Barrow Island – burials

Description: Reference guide to individual burials and cemetery records for West Australia, including off-shore and at-sea burials.

"Deichi Matsumoto, died 8.2.1905 aged 24 years – drowned at sea off Pascoe Island near Barrow Island. A sailor on the lugger *Ellen*, who was drowned and his body was not recovered." (p.101)

Author(s): Gribble, John B.

Year: 1905

Title: Dark deeds in a sunny land or, blacks and whites in the North-west Australia

Publisher: Daily News

City: Perth

Call no./Library: CSO 3678/86

Site/person/event(s) associated with: Barrow Island – burials

Description: European man at Barrow Island died in 1872. Both Carley and Captain Tuckey, who first saw the body, swore an oath that they felt he had been murdered. Official inquiry resulted in a suicide decision. Victim was supervising a large number of Aborigines.

Author(s): WAPET

Year: 1987

Title: Barrow Island Environmental Research: list of references on Barrow Island and adjacent areas

Publisher: WAPET Technical Information Services

Pages: 1-15

Call no./Library: Q333.72 BAR/ Battye

Site/person/event(s) associated with: Barrow Island - environmental research

Description: Bibliographic reference to reports, documentation and journal articles associated with the environmental and ecological aspects of Barrow Island to date (1987). Also includes a list of references regarding publicity relating to Barrow Island.

Author(s): Butler, W. H.

Year: 1983

Title: The Barrow Island experience: a presentation to the 53rd ANZAAS Congress

Publisher: WAPET

City: Perth, W.A

Pages: 1-7

Call no./Library: PR12958/ Battye

Site/person/event(s) associated with: Barrow Island – conservation and preservation

Description: Provides a brief outline of Barrow Island's history and the development of its oil resources. Historical section is brief and not referenced, the emphasis of the presentation highlighting WAPET's procedures for the conservation and preservation of the island's environment.

Author(s): Murray, Robert

Year: 1991

Title: From the edge of a timeless land: a history of the North West Shelf gas project.

Publisher: Allen and Unwin

City: Sydney, Western Australia

Edition: 1st

Call no./Library: 338.27285 MUR/ Battye

Site/person/event(s) associated with: Barrow Island – oil production

Description: History of the development of the North West gas shelf project and the oil and gas industries. References to Barrow Island refer mainly to the oil production and its value. Early references briefly describe WAPET's exploration on the island from the 1950s to the drilling of Barrow 1.

Author(s): Wilkinson, Rick

Year: 1988

Title: A Thirst for Burning: the story of Australia's oil industry

Publisher: David Ell Press

City: Sydney, NSW

Pages: 21 & 38

Edition: 2nd

Call no./Library: 338.27282 WIL/ Battye

Site/person/event(s) associated with: Barrow Island – oil production

Description: Details the history and current status of the oil industry throughout Australia and the major oil fields. References to Barrow Island refer mainly to the early phases of exploration (1954, 1956, 1962, 1963), and the current status of WAPET's drilling on the island.

Author(s): Playford, Phillip E.

Year: 1970

Title: Petroleum exploration in Western Australia; past, present and future.

Journal/Vol./No: Journal of the Royal Society of Western Australia, V54, No.1.

City: Perth

Pages: 1-13

Call no./Library: 506 ROY/ Battye

Site/person/event(s) associated with: Barrow Island - oil fields

Description: Article briefly describes the history of oil exploration in Western Australia with particular attention paid to the developments of West Australian Petroleum Pty. Ltd (WAPET).

Barrow Island oil discovered 1964, first shipment of crude oil from the island 1967. Provides a map of the oil fields on the island, including oil and gas wells and abandoned wells.

Author(s): Gorgon Australian Gas

Year: 2003

Title: Environmental, Social and Economic Review of Gorgon Gas Development on Barrow Island

Publisher: ChevronTexaco

City: Perth, Western Australia

Location: http://www.gorgon.com.au/

Site/person/event(s) associated with: Barrow Island - oil fields

Description: Contains summary of history of oil exploration and extraction on Barrow Island.

"In 1953 West Australian Petroleum Pty Ltd (WAPET) discovered oil at Rough Range, near Exmouth. This prompted an extensive program of geological surveys and exploration drilling in the northern Carnarvon Basin.

Drilling commenced on the Barrow One well on 7 May 1964 and in the first week of July the well produced flowing oil. Two years later, Barrow Island was declared a commercial oil discovery, Western Australia's first. Production began in April 1967 at over 8000 barrels of oil per day, peaking in 1971 at 50 000 barrels per day and in December 2003, the 300 millionth barrel of oil was produced.

Since 1967, more than 800 wells have been drilled, including more than 500 oil production wells, over 250 water injection wells, and various gas producer and water disposal wells. Oil is pumped to the surface using beam pumps in the majority of producing wells, the remaining wells using gas-lift or natural flow. Today, approximately 455 wells are producing oil.

In February 2000 Chevron took over operatorship of the assets previously managed by WAPET. Today ChevronTexaco continues the task of managing a producing oilfield on behalf of its partners Santos Offshore Pty Ltd and Mobil Australia Resources Company Pty Ltd. Personnel working and living on the Island number from 150-200 and rotate in two-week shifts. By 2024, the expected life of the field, it is estimated that Barrow Island will have produced 360 million barrels of oil" (p. 6).

Author(s): Gibbs, Martin

Year: 1995

Title: The Historical Archaeology of Shore-Based Whaling in Western Australia 1836-1879

City: Perth

Call no./Library: Q338.37295 GIB

Site/person/event(s) associated with: Whaling Western Australia – history

Description: PhD Thesis, submitted to the University of Western Australia, 1995.

Whilst there are no references to Barrow Island or the Montebello Islands in this text, Gibbs' discussion of the history of shore-based whaling in the North-West includes details of the history and archaeological survey of the operation that existed on Malus Island (Dampier Archipelago) from 1870-1877.

Author(s): Idriess, Ion L.

Year: 1937

Title: Forty Fathoms Deep: pearl divers and sea rovers in Australian seas

Publisher: Angus and Robertson Limited

City: Sydney

Call no./Library: 639.412/ Reid Library (UWA)

Site/person/event(s) associated with: Pearling Western Australia - history

Description: Unreferenced social history recounting stories of individual pearl divers, most of whom worked around Broome.

No references to Barrow Island or Montebello Islands.

Author(s): Shepherd, B.W

Year: 1975

Title: A History of the Pearling Industry off the North-West Coast of Australia From its Origins Until 1916.

Call no./Library: Q639.412/ Battye

Site/person/event(s) associated with: Pearling industry, North-West Western Australia

Description: MA Thesis submitted to the University of Western Australia, 1975.

Comprehensive history of the pearling industry of the North-West, focusing on the contribution of the Shark Bay industries to the overall economic growth of this part of the state. Covers the contribution of Aboriginal and Asian labour to the industry as well as the development of pearling technology until 1916.

No references to Barrow Island or the Montebello Island group.

Author(s): Battye, J.S

Year: 1985

Title: The History of the North West of Australia: embracing the Kimberley, Gascoyne and Murchison districts.

Publisher: Hesperian Press

City: Carlisle, Western Australia

Edition: 2nd

Call no./Library: Q994.13 HIS / Battye

Site/person/event(s) associated with: North-West Australia - history

Description: History of the exploration and settlement of the North West, particularly the Kimberley, Gascoyne and Murchison districts. Although there is some detail given about early explorations up north, the details regarding the voyage of the H.M.S 'Beagle' and Captain Wickham do not include visits to Barrow Island. Barrow Island does not feature in the chapters on the pearling and pastoral industries either.

Author(s): Hardie, Jenny

Year: 1981

Title: Nor'-Westers of the Pilbara Breed

Publisher: Sands & McDougall (Aust.) Pty. Ltd.

City: Perth, Western Australia

Edition: 1st

Call no./Library: 994.1 1981 NOR/ Reid Library (UWA)

Site/person/event(s) associated with: North-West History – Port Hedland

Description: Referenced social history of the settlement of the Pilbara, particularly Port Hedland, and the development of the pastoral and to a lesser extent, pearling industries. History does not extend back to include earlier exploration phases for the North-West coast.

No references to either Barrow or Montebello Islands or the use of offshore islands in the vicinity.

APPENDIX 4

ASSESSMENT OF HISTORICAL SOURCES RELATED TO SHIPWRECK SITES IN THE BARROW ISLAND REGION – FEBRUARY 2004 (SOUTER)

Shipwreck Sites Protected Under the *Historic Shipwrecks Act 1976*– Not Found

Vianen **Ship** **1628/01/25 (refloated)**

Historical Precís: One of the earliest ships to founder on the West Coast, the VOC ship *Vianen* was a wooden vessel of 400 tons enroute from Batavia (Jakarta) to Goeree, Zeeland in the Netherlands. In a letter from the Governor-General to the managers of the East India Company, November 3, 1628, the grounding and refloating of the vessel in the vicinity of Barrow Island is described;

…[We] thought fit to give orders for the ship Vyanen to sail to the strait of Balamboan. [She] sailed [from Batavia] thither on the 14th of January, and from there stood out to sea on the 25th do. She was by head-winds driven so far to south-ward that she came upon the South-land beyond Java where she ran aground, so that she was forced to throw overboard 8 or 10 lasts of pepper and a quantity of copper, upon which through God's mercy she got off again without further damage….

The incident is recorded in Tasman's instructions where it is noted that after the *Vianen* had come across the coast unexpectedly in latitude 21º S she had sailed for 50 miles along the coast but no specific observations had been made. A chart by VOC cartographer Hessel Gerritsz in 1618 has annotations which date to the *Vianen's* sighting of the coast. These marks conform to modern charts and suggest that the vessel grounded in the Port Hedland region, incorporating Barrow and the Montebello islands.

Location:

Lat Max	20º 00	Long Max	115º 10
Lat Min	21º 00	Long Min	115º 50

Sources:

Schilder, G., 1976, Australia unveiled, the share of the Dutch navigators in the discovery of Australia. Theatrum Orbis Terrarum, Amsterdam.

Letter of the Governor General and Councillors to the Heeren XVII, 3 November 1628, in Heeres, J.E., 1899. The part borne by the Dutch in the discovery of Australia 1606-1765., Royal Dutch Geographical Society, Leiden.

Ariel **Schooner/Lugger** **1868/01/04**

Historical Precís: This Tasmanian built wooden schooner (Official number 30805), of 26 tons was built in Hobart in 1845 was engaged in pearling when it foundered with Joseph Barrett as Master.

On 25 January 1868 *Ariel* was lost off Locker Point, 50 km west of Ashburton with all hands and around a ton of shell. This was the first recorded tragedy on the pearling grounds of Western Australia and though it was an indication of the risks associated with the industry it did not deter the rest of the pearlers (McCarthy 1996).

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

Perth Gazette, 3 April 1868

Inquirer, 1 April 1868

RJS, 25/1/1868, Battye Library

Henderson, G., 1988 *Unfinished Voyages: Western Australian Shipwrecks 1851-1880* UWA Press. Nedlands.

McCarthy, M., 1996 *Charles Edward Broadhurst: A Remarkable Nineteenth Century Failure*. Unpublished Mphil Thesis. Murdoch University.

Wild Wave (China)	**Brig**	**1873/08/30**

Historical Precís: The *Wild Wave* (Official number 43302) was built at Abenraa in Denmark, in 1858 by Peter Lund. The vessel's master was Captain Edward Fothergill and the owner George Howlett. The 180-ton wooden vessel, measuring 31.4 metres by 7.4 metres by 3.9 metres, had one deck with a break, two masts, a round stern and a snake's head figure (Henderson 1988:134).

The ship was enroute to Singapore with a cargo of sandalwood at the time of wrecking. The evidence indicates that the *Wild Wave* was normally employed in the intercontinental trade out of Singapore and that its brief trading period along the Australian coast was speculative until a return cargo to Singapore could be arranged (Batten, MA 439/71). The *Wild Wave* sailed from Fremantle on August 25 with 27 passengers and a crew of 15 Malays. At noon on the 30th, the ship was in latitude 25º 55' South, with Point Cloates bearing north-east 50 kilometres away. The vessel sped past the North West Coast and Barrow Island. Captain Fothergill thought the brig would be well to the west of Barrow Island, but a current had brought it quite close to land. The studding sails were taken in and a lookout posted on the foreyard at midnight. However, the brig was going at 13 kilometres per hour, one and a half hours later, when the officer saw breakers ahead (Captain Edward Fothergill, evidence at the Inquiry held at Cossack, 18 October 1873, CSR 736, fol. 128). The brig struck and at once filled with water. The boats were made ready to leave the ship, and at daylight the crew saw the Montebellos, 13 kilometres to the East (Henderson 1988:133). They made for the Southern end of the group and set up camp, probably on Hermite Island. Lockier Burges in his reminiscences *The Pioneers of the Nor'-West, Australia* in 1913 states that the *Wild Wave* was lost in the vicinity of 'Big Sandy Island' but that name is not listed in the *Gazetteer* (Henderson 1988:133). The wreck was later sold at auction for £200 to Cossack importer Charles Crouch, who salvaged most of the cargo of sandalwood and mining equipment (*Inquirer*, 29 October 1873).

Location:

Lat Max	20º 00	Long Max	115º 10
Lat Min	21º 00	Long Min	115º 50

Sources:

George Howlett to John Absolon, 1 May 1872, Habgood Papers, 813A, Battye Library

Captain Edward Fothergill, evidence at the Inquiry held at Cossack, 18 October 1873, C.S.R. 736, fol. 128

Henderson, G & K.J., 1988 *Unfinished Voyages: Western Australian Shipwrecks 1851-1880* University of WA Press, Nedlands.

Division of Natural Mapping, Dept. of Minerals and Energy, 1975 *Gazetteer* Australian Government Publishing Service, Canberra.

Inquirer, 29/10/1873

Inquirer 29/10/1873 fr 3d

Inquirer 5/11/1873 fe 3d

Inquirer 27/8/1873

Morning Star	**Lugger**	**1881/01/07**

Historical Precís: At the beginning of the 1880s**,** those involved in the pearling industry were still ignorant of the weather patterns in the North West. A devastating cyclone struck the coast between Exmouth Gulf and Cossack on 7 January 1881 and decimated the unsuspecting pearling fleet (*Herald* 12/2/1881).

In April 1867, the first of a new style of larger pearling boats, the *Morning Star,* was employed for the purpose of harvesting shell. (RJS, 28/4/1867 Battye). These vessels ranged from around 5 tons upwards. Despite the early failures, large boats such as the *Morning Star* were to prove the next step in the developing pearling industry. Not only could they act as a mother vessel to their smaller counterparts and as a transport and storage medium for the shell, but they also could accommodate the shell gatherers themselves. They were the next step up from a small land based open boat and were obviously needed in the efficient pursuit of the shell (McCarthy 1996).

Details of the vessel have not been found as it was unregistered. Archival sources indicate that it was anchored at the time of the cyclone in the vicinity of Yammerdery Creek along with the luggers *Alpha, Baningara, Emma, Florence, Kate, Nautilus, Adela and Yule* (Henderson & Cairns 1995:14). Similarly an *Unidentified Lighter* was also reported lost in the pearling grounds west of Yammadery Creek during this cyclone (Henderson & Cairns 1995).

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

Herald 12 /2/1881

Henderson, G., and Cairns, L., 1995 *Unfinished Voyages: Western Australian Shipwrecks 1881-1900* UWA Press. Nedlands.

McCarthy, M., 1996 *Charles Edward Broadhurst: A Remarkable Nineteenth Century Failure*. Unpublished Mphil Thesis. Murdoch University RJS, 28/4/1867 Battye Library

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Ruby **Lugger/Cutter** **1882/03/06**

Historical Precís: The cutter *Ruby* (Official Number (753089) set sail for the pearling grounds from Point Walcott and was lost when a cyclone struck the region. The Custom's revenue vessel *Myra* was dispatched to search for the missing vessel. A report indicated that Aborigines had seen wreckage near Depuch Island, but a thorough search of the area around the islands of the Montbello and Lowendal groups found no trace of the cutter. Bad weather had prevented Captain Pemberton Walcott of the *Myra* from searching Barrow Is and there was a faint hope that the *Ruby's* crew may have reached there, but it was generally concluded that the vessel must have foundered at sea during the cyclone, all hands being lost.

Location:

Lat Max	10º 00	Long Max	112º 00
Lat Min	26º 40	Long Min	115º 50

Sources:

Inquirer 29 /5/1882

Inquirer 5 /4/ 1882

West Australian 4 /4/ 1882

West Australian 12 May 1882

Herald 13 /5/ 1882

Herald 3 /6/ 1882

Henderson, G., and Cairns, L., 1995 *Unfinished Voyages: Western Australian Shipwrecks 1881-1900* UWA Press. Nedlands.

Register of British Ships. National Archives Perth. Transcribed by Parsons, R., (1971)

SS Dolphin **Cutter** **1902/06/14**

Historical Precís: The *SS Dolphin* (Official number 72472), of 24 tons foundered off Beadon Point, NW Coast of WA. J. Clarke (Owner); Crew 4; Osman bin Buleah (Master); passengers 3; Vessel valued at £200; Cargo values at £400.

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

Register of Wrecks and Casualties in Western Australia 1897-1942, Her Majesty's Customs, Department of Marine and Harbours. (Transcribed by Dickson, R Report–Department of Maritime Archaeology, WA Maritime Museum No. 56)

Marietta **Lugger** **1905/02/08**

Historical Precís: The *Marietta*, a pearling lugger working off the North West coast was not a registered vessel, and is therefore not listed in the Shipping Registers. McKenna's transcription of the Register of Wrecks however, records the following details:

Stereas (Owner); Scuttled at Barrow Island to avoid total loss.

Another secondary source corroborates this and adds that the vessel may also have been called *Marutta* or *Marcella* (Barnett, 1983). No entries for these names were found in a search of the Registers.

Location:

Lat Max	20º 00	Long Max	115º 10
Lat Min	21º 00	Long Min	115º 50

Sources:

McKenna, R., 1967 Transcription of *Register of Wrecks; Strandings and Mishaps of British Ships, Port of Fremantle* Her Majesty's Customs, Perth.

Barnett, J., 1983 *An Illustrated Map and Brief History of Shipwrecks along the WA Coast*. Unpublished. Battye Library.

Ellen **Lugger** **1905/02/08**

Historical Precís: The *Ellen* was an unregistered lugger; Alex Burney (Owner); Harry B. Johnson (Master) which was swamped by heavy seas at Onslow, WA. While the vessel was at anchor, the chain parted causing the boat to drift and founder. All five crew were lost and the vessel valued at £500.

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

Register of Wrecks and Casualties in Western Australia 1897-1942, Her Majesty's Customs, Department of Marine and Harbours.(Transcribed by Dickson, R Report–Department of Maritime Archaeology, WA Maritime Museum No. 56)

McKenna, R., 1967 Transcription of *Register of Wrecks; Strandings and Mishaps of British Ships, Port of Fremantle* Her Majesty's Customs, Perth.

RN 791 Battye Library

Curlew **Lugger** **1911/02/06**

Historical Precís: The *Curlew* (Official Number 101614); was a pearling lugger of 11 tons built and registered in Fremantle in 1892; A.R. Harding (Owner); Crew 7; C,F Nyshom (Master). The *Ships Registered in Western Australia* archive records it as wrecked in a hurricane at Onslow in cyclone, with one survivor while the *Register of Wrecks and Casualties in Western Australia* records the vessel as wrecked lagoon at Hermite Is. Montebellos with all 7 crew saved, no cargo.

Location:

Lat Max	20º 00	Long Max	115º 10
Lat Min	21º 00	Long Min	115º 50

Sources:

Register of Wrecks and Casualties in Western Australia 1897-1942, Her Majesty's Customs, Department of Marine and Harbours.(Transcribed by Dickson, R Report–Department of Maritime Archaeology, WA Maritime Museum No. 56)

Ships Registered in Western Australia National Archives. (Transcribed by Dickson, R. Report–Department of Maritime Archaeology, WA Maritime Museum No.80.)

McKenna, R., 1967 Transcription of *Register of Wrecks; Strandings and Mishaps of British Ships*, Port of Fremantle Her Majesty's Customs, Perth.

Lapwing **Lugger** **1911/02/07**

Historical Precís: The pealing schooner *Lapwing* (Official no. 102227) of 11.26 tons was reported as a total wreck near the MonteBello Islands. The owner is recorded as F.L. Parkes.

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

McKenna, R., 1967 Transcription of *Register of Wrecks; Strandings and Mishaps of British Ships, Port of Fremantle* Her Majesty's Customs, Perth.

Moana **Lugger** **1920/08/17**

Historical Precís: The *Moana,* (Official number 118529) a lugger engaged in pearling, was for a large part of it's life ownded by the Broome Pearling Company. The vessel foundered in Mary Ann Passage after a collision with the *SS Bambra* resulting in the loss of 7 lives. P.J Smith is listed as the owner at the time of wrecking. The vessels is also sometimes referred to as *Moara* (Dept. Harbour and Lights *Record of Shipping Casualties* AN16/3 ACC 1056).

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

Register of Wrecks and Casualties in Western Australia 1897-1942, Her Majesty's Customs, Department of Marine and Harbours.(Transcribed by Dickson, R Report–Department of Maritime Archaeology, WA Maritime Museum No. 56)

Ships Registered in Western Australia National Archives. (Transcribed by Dickson, R. Report–Department of Maritime Archaeology, WA Maritime Museum No.80.)

McKenna, R., 1967 Transcription of *Register of Wrecks; Strandings and Mishaps of British Ships, Port of Fremantle* Her Majesty's Customs, Perth.

Dept. of Harbour and Lights *Record of Shipping Casualties* AN16/3 ACC 1056

SS Bambra Log Book 1920(2) AN 16/14 ACC 1056

AN 16/5 ACC 1036 & 1066 *SS Bambra* collision with lugger *Moara* in Mary Ann Passage

Shipwreck Sites Not Protected– Not Found

Boreas **Lugger** **1932/05/04**

Historical Precís: Official number 140171; A.E. Iverson, G.W. Lort, L. J. Jones of Onslow (Owners) Wrecked NE end of Weld Is.

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

AN 16/5 ACC 1066 1936 837 Wreck of luggers.

Rosebud **Lugger** **1933/09/12**

Historical Precís: Official number 1022417, 12 tons wrecked nr Broome(?) or Airlie Is. NE of Onslow Samuel H. J. N. Clark, of Beadon, storekeeper (Owner).

Location:

Lat Max	10º 00	Long Max	115º 00
Lat Min	21º 45	Long Min	115º 50

Sources:

HMC 40/3 McKenna Collection 681, WA Maritime Museum

AN 16/5 ACC 1066 1936 837 Wreck of luggers

McKenna, R., 1967 Transcription of *Register of Wrecks; Strandings and Mishaps of British Ships, Port of Fremantle* Her Majesty's Customs, Perth.

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Technical Appendix E2

Visual Assessment Report

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FINAL REPORT

GORGON

Technical Appendix
Visual Assessment Report

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FINAL REPORT

GORGON

Technical Appendix

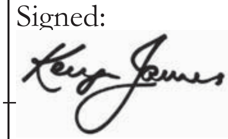
Visual Assessment Report

0013438 RPT1 Revision b

For and on behalf of Environmental Resources Management Australia

Approved by: Keryn James

Signed:



Position: Partner

Date : 3 May 2005

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Executive Summary

Visual Assessment

Aims

The Gorgon Joint Venture Project Development Team aims to reduce the visual impacts of the proposed works by considering the landscape character of the development area in the design, construction, rehabilitation, operation and ongoing maintenance of all facilities and associated infrastructure.

The proposed Gorgon Development comprises the following components:

1. Sub-sea gathering infrastructure at the Gorgon gas fields.
2. 70 km long feed gas pipeline to bring gas/well stream fluids to Barrow Island from the Gorgon gas field. Onshore Barrow Island there are currently two options, one landing at Flacourt Bay and the second at North White's Beach.
3. Gas processing plant & port facilities on the east coast of Barrow Island.
4. 80 km long domestic gas (DOMGAS) infrastructure piping gas from Barrow Island to the mainland.
5. On the mainland the DOMGAS pipeline corridor remains underground along side an existing gas easement. This alignment crosses through Mardie Station (Stock Grazing Property) to join the Dampier-Bunbury Natural Gas Pipeline at Compressor Station One (CS1).

Existing Environment

The Development area has been divided into offshore and onshore components. The onshore component will generally relate to Barrow Island, whereas the mainland (Mardie Station) underground component will mostly be referred to in construction and mitigation measures outlined in the main report.

Offshore

The sub-sea gas-gathering system will be located on the sea floor at the Gorgon gas fields 70 kilometres west of Barrow Island. The feed gas pipeline both from the sub-sea gas-gathering system to Barrow Island and the 80km long domestic feed gas pipeline from Barrow Island to the mainland does not have any visual impact implications above the waterline.

Onshore Barrow Island

The landscape of Barrow Island is arid and rugged accommodating spectacular views of low grey green vegetation interspersed with ochre red termite mounds. On the coastline weathered rocky headland contrast with white secluded sandy beaches and aqua-blue water.

Landscape form consists of limestone uplands, dry creek beds, red inland sands, white coastal dunes, beaches, clay and salt flats and intertidal flats.

Due to the arid climate vegetation covers is low, generally sparse and up to 90% of species are related to three types of spinifex, *Triodia wiseana, Triodia angusta* and *Triodia epactica*.

Existing oil extraction infrastructure, such as wells and associated pumping equipment are intermixed throughout the central region of the island with the tallest structure being the communication tower (120m high) situated on the highest central upland point (65m above sea level).

In 1910 Barrow Island was pronounced a Class A Nature Reserve with the unique status of attaining no introduced species, flora or fauna.

For the purpose of the visual assessment the landform on the island can be broadly divided into five landscape units defined on the basis of dominant plant species, associated landform, soils, underlying geology and vegetation unit surveys.

These five landscape units are:

- West Coastal Complex;
- East Coastal Complex;
- Valley Slopes and Escarpments;
- Limestone Ridges; and
- Creek or Seasonal Drainage lines.

These units are described in Chapter 2.4 'Baseline Landscape Character'.

Onshore Mainland DOMGAS Pipeline

The mainland landscape, upon leaving the coastal mangrove zone, is described as a non-vegetated salt plain. Following the proposed/existing easement east, low hummocks of grassland/spinifex become dispersed through the red soil salt flats. These vegetated hummocks join to provide a flat open sparsely vegetated shrub and grassland, as it approaches CS1.

The landscape can be described as being moderately disturbed with evidence of local soil erosion, cleared vegetation evident along existing pipeline easement, disturbed soil/rock due to stock grazing. There is evidence of introduced vegetation species within this landscape.

The Mainland can be described as having the following 4 landscape units:

- Coastal Mangrove Zone
- Red/Grey Non-vegetated Salt Flats
- Vegetated Hummocks within Salt Flats
- Low Lying Shrub and Grasslands

These units are further described in Chapter 2.4 'Baseline Landscape Character'.

Potential Visual Impacts and Visual Mitigation

Methodology

The assessment process commenced at the very broad scale in order to gain an understanding of the landscape setting in which the project was located. It then focussed in greater detail on the position of the components and their relationship within their immediate setting.

The landscape on Barrow Island was initially divided into 5 units as listed above to discuss **baseline landscape character**. Within each of these units, change resulting from the infrastructure can be accommodated to varying degrees without significantly altering the setting. This was determined as **Landscape Absorptive Capability** and is assessed in broad terms within the **Baseline Landscape Character** study. This process assists in the understanding of the visual interaction occurring between the project infrastructure and the setting as a precursor to the more detailed analysis.

At the more detailed level, due to the deficiency of human receptors which is applied in the process of measuring **Visual Amenity**, the seen value of a landscape character, the assessment concentrated on evaluating **Visual Effect**, the degree to which the project infrastructure changed the appearance of the landscape as a result of development. Through qualitative and quantitative assessment tools these values were then considered in determining the relative levels of **Visual Impact** (the measure of visual effect in the landscape) during and immediately after construction.

Various **Visual Impact Mitigation** measures were then recommended to assist in obtaining a greater visual integration of the infrastructure into the setting, thereby reducing its visibility or visual effect.

The assessment methodology is discussed in detail within Appendix A. The remainder of the chapter is summary of the assessment findings.

Areas of Visual Amenity

Offshore

The amenity of this visual setting is considered to be nil due to the gas collecting and transporting infrastructure situated below sea level.

Onshore Barrow Island

Visual Amenity is described as 'the value of a landscape in terms of what is seen' (GLVIA 2002). Therefore it was concluded that due to the deficiency of human receptors within this landscape visual amenity is perceived as low to very low.

Onshore Mainland DOMGAS Pipeline

Due to the lack of human receptors within close proximity to the proposed DOMGAS pipeline location (all 220,000ha of the station is used for stock grazing purposes), visual amenity is also perceived as low to very low.

Visual Absorption Capability

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. The Visual Absorption Capabilities of the landscape units in the Development area are listed in Table 1 below.

Table 1. 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

Onshore Mainland - Mardie Station

As with Barrow Island the landscape character of the mainland is predominantly open & flat with sparse covering vegetation, therefore the visual absorption capability of this landscape would be considered as low.

Visual Effect

The visual effect is the degree of change/contrast that occurs in the appearance of the landscape as a result of the development.

Onshore Barrow Island Pipeline(s)

The degree of visual effect involved with the pipeline will generally be associated with how the landscape absorbs a linear form within a natural setting. This has most consequence when the corridor parts from an established road easement.

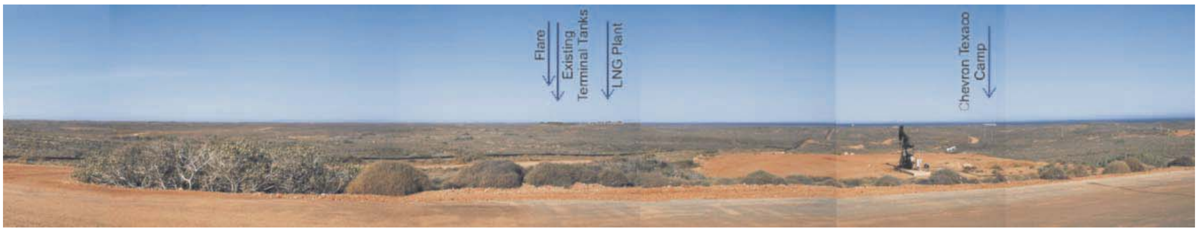
Much regard will be given to construction in particular, the clearance of vegetation and disturbance of the ground surface. Long term visual effects will be negligible, as the alignment design option, rehabilitation and construction management will be carried out in an effective manner.

LNG Plant and Port Facilities

The visual effect of the LNG plant, port facilities and temporary construction camp will depend on the viewer's position within the infrastructure viewshed. If the Plant is viewed beyond the surrounding ridgeline, beyond that which surrounds the drainage line flat (LNG Plant site) the visual effect will range from slight to negligible.

This is due to the screening and integration of Plant mass with the undulating terrain and the softening of distance when high points in the terrain do allow views to the LNG Plant and port facilities (refer Figure 1 below illustrating modelled view from Base Castle, highest viewing point in the central uplands).

Figure 1. Viewing simulation of LNG Plant at completion of construction from Base Castle Communication Tower.



Where the LNG Plant, port facilities and construction camp is viewed within the drainage line flat or upon the nearby surrounding ridgeline (within the 5km viewshed) the visual effect will be moderate to substantial as the structure contrasts with the immediate landscape.

Figure 2. Viewing simulation looking north on ridgeline from Chevron Camp, approximately 4km from LNG Plant and port facilities site.

Onshore Mainland DOMGAS Pipeline

The DOMGAS pipeline will be located underground, in close proximity to the existing Apache pipeline. As the pipeline infrastructure will not be viewed, regard will be given to the construction easement in particular, the clearance of vegetation and disturbance of the ground surface. Apart from a wider clearance easement, long term visual effects will be negligible, as rehabilitation and construction management will be carried out in an effective manner.

Figure 3. View of existing onshore mainland pipeline corridor, viewing east towards Compressor Station 1.

Visibility of Components

Offshore

The offshore facilities gas collecting facility will not be visible from the ocean's surface or from land.

Onshore Barrow Island Pipeline(s)

The pipeline routes will not be regularly visible until seen from within the road easement or from a road vantage point. The pipeline infrastructure will be most visible on the upland 'Limestone Ridges' landscape unit. Furthermore the pipe infrastructure will be substantially visible when vegetation is sparse in between the shared road corridor or when the pipeline route intersects with the road.

LNG Plant & Port Facilities

The LNG Plant will be moderately visible from within the central eastern area of the island and offshore while approaching the central island mass from the east. Visibility of the plant from the central upland area of Barrow Island will be negligible with views mostly screened by undulating topography and intervening ridgelines.

The viewshed analysis in Figure 4. below, illustrates where the comprehensive height (calculated at 20m above respective ground level) of the proposed LNG Plant will be seen. The flare height is approximately 150m tall and due to its thin structure in contrast to the Plant structure the visual impact is considered negligible (refer chapter 4.6.4 Flare and Illumination).

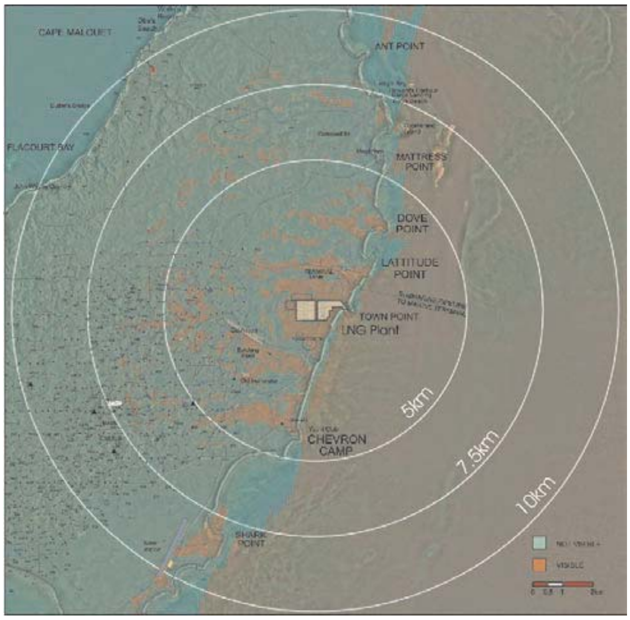


Figure 4. Showing Viewshed of Gorgon LNG Plant

Seven (7) computer generated images from 7 viewpoints in chapter 4 illustrate varying views of the LNG Plant from various distances and viewshed vantage points. These illustrate what components will be seen from person's (workers) from within the viewshed.

Onshore Mainland DOMGAS Pipeline

Once operational, visibility of the pipeline infrastructure will be nil.

Assessment Results - Visual Impact

Detailed findings are included in Chapter 4 of the Report. The following provides a summary of key results.

Onshore Barrow Island Pipeline(s)

The visual impact of the gas pipeline options will be negligible to moderate. Areas of substantial impact will occur in a small number of locations where vegetation is sparse along the central upland 'Limestone Ridges'.

LNG Plant and Port Facilities

The visual impact of the proposed LNG plant and port facilities will be moderate to substantial for views within 5km of the central eastern section of Barrow Island. The anticipated impacts from key viewing locations are summarised in Table 2 and noted in detail in Chapter 4. 6.

Table 2. Indicative Areas of Visual Impact

Viewing Location	Impact*
View 1 – Chevron Camp	Moderate
View 2 – Town Point	Substantial to Severe
View 3 – Communication Tower, Base Castle	Negligible
View 4 – Ocean View at 5km	Moderate to Substantial
View 5 – Road Junction, Old Airport	Substantial
View 6 – New Airport	Negligible to None
View 6 – Ridgeline West of Terminal Tanks	Substantial **Criteria definitions in Methodology Appendices A 1.5*

Within the 5km viewing area the LNG plant will be in stark contrast to the low vegetated nature of the landscape. Given the arid conditions and the lack of substantial indigenous vegetation that may be able to be used to screen the LNG Plant, the impact level would not significantly reduce over time.

Onshore Mainland DOMGAS Pipeline

During construction, the visual impact will be negligible, as there are no human receptors except the construction workers. The visual impacts of completed pipeline corridor will be negligible to none, as rehabilitation and construction management will be carried out in an effective manner.

Visual Impact Mitigation

The landscape of the project area is one of great significance and fragility and already a portion of the Barrow Island has viewed man-made development from a low to moderate extent.

Given the relative scarcity of vegetation of any physical stature due to the environmental conditions of the project area, amelioration methods that rely on the growth of vegetation to hide the visual effects of the LNG plant will be ineffective and therefore inappropriate.

Therefore, where practicable, the components of the proposed pipeline easements and LNG plant will be located to make use of existing infrastructure and topography to minimise visual disturbance and optimise visual blending and screening where possible.

The visual effect of the reinstated pipeline both on Barrow Island/Mainland and the benching works that occur around the LNG Plant pad will depend upon the degree to which it is noticeable due to a contrast occurring between disturbed areas and the surrounding natural ground surface. This may 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 plane.

The dominant colour of the weathered and oxidised surface rock is a light (sun bleached) cream to pink in colour. However, when the rock is fractured or the surface disturbed the colours become deeper and the underlying rust red-ochre earth becomes a dominant contrast. Therefore, it is very important that different soil profiles are stored separately and replaced in the same locations and that excavated rock is reburied where practicable.

Given the difficulty of achieving effective rehabilitation, planning and management should focus on minimising the area of disturbance to vegetation. Experience gained from other revegetated pipelines and benched platforms within the area have demonstrated that the harsh conditions will make revegetation with the same pre-development species difficult.

To assist with this process, revegetation will commence immediately following reinstatement, using direct topsoil placement that matches that of the particular location rather than the broader area. This topsoil contains a local seed pool and from experience is the most effective way of achieving germination. Impact Mitigation and Rehabilitation methods are explained in detail within Chapter 4.4 of this report. In addition, ongoing research into collecting propagation material from the plant site prior to construction to allow stocks of appropriate revegetation species to be grown is to be further investigated.

Environmental Management Objectives:

- To reduce visual impacts to an acceptable level.
- To consider the landscape character in the design, construction, rehabilitation, operation and ongoing maintenance of all facilities and associated infrastructure.

Environmental Management Strategies:

Onshore Pipeline(s) inluding mainland DOMGAS easement

- The extent of vegetation clearing will be minimised.
- Disturbance of soil and rock outcrops will be minimised.
- Construction easement width will be minimised and disturbance to areas outside the easement will be avoided.
- Soil and rock will be replaced to match the existing layers/profiles.
- Revegetation will commence immediately with local direct topsoil replacement or a species mix matching that of the exact location rather than the broader area.
- Infrastructure/easements will be designed and managed to minimise visual impact.

LNG Plant & Port Facilities

- The extent of vegetation clearing will be minimised.
- Propagation material for revegetation will be collected from both the Camp site and LNG Plant site prior to construction.
- Where practicable, the LNG plant components will be located and benched so that they optimise the advantage of the low-lying area and surrounding ridge lines.
- Surface and sub surface material will be stockpiled separately and will be utilised in areas exposed such as terraces, unused roads and as appropriate. Topsoil is not to be stockpiled higher than 1m, and used as soon as practicable.
- Soil and rock will be replaced to match the existing layers/profiles.
- Where practicable, rehabilitation of site benching and unused construction roads/areas will commence immediately with direct topsoil placement that matches that of the exact location rather than broader area.
- Infrastructure surfaces, Port Facilities will be of a colour that minimises visual impact where practicable (non-contrasting colours to vegetation and ocean).

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1 Introduction

Aims

The Gorgon Joint Venture Project Development Team aims to reduce the visual impacts of the proposed works by considering the landscape character of the development area in the design, construction, rehabilitation, operation and ongoing maintenance of all facilities and associated infrastructure.

Objectives

The objectives of the Visual Assessment Report are:

- to assess the visual impacts of the proposed LNG plant and associated infrastructure, from view points within the view shed of the development on and around Barrow Island,

- to assess the impact of the proposed, pipeline(s) and associated infrastructure on the landscape character of the localities through which it runs, and

- to determine a landscape strategy which would help to mitigate significant impacts and to integrate the proposed LNG plant and pipeline(s) into the landscape.

Issues To Be Addressed

Landscape impacts are assessed separately from visual impacts, whereas the receptors of landscape impacts are essentially the elements that comprise the physical environment, such as vegetation, watercourses and built form, the receptors of visual impact are the human users of the physical environment.

As described in the Guidelines for Landscape and Visual Impact Assessment, Spon Press 2nd Edition (GLVIA 2003).

'*The sensitivity of visual receptors and views are dependent on:*

the location and context of the view;

the expectations and occupation or activity of the receptor;

the importance of the view, which may be determined with respect to its popularity or numbers of people affected…'

The Guidelines further state that,

'…the least sensitive receptors are likely to be people at their place of work, or engaged in similar activities… …In this process more weight is usually given to changes in the view or visual amenity.' (GLVIA 2003)

The assessment of the change to, or impact on, the visual amenity of an area involves consideration of two separate but closely interlinked factors:

'Views' are defined as 'what can be seen from an identified location'. However, to interpret views, it is necessary to understand the context of the view.

'Landscape' refers to the context of a view, comprising not only physical appearance, but also population and such factors as built elements, 'naturalness' and scenic beauty. It can be described only up to a point, because the value ascribed to a landscape will vary from person to person and their specific relationship to the land.

Due to Barrow Island's stringent quarantine conditions and isolation to public activity the landscape relationship to human receptors is significantly unique. Workers associated with the oil and gas projects are the only person's to view the development.

Therefore this visual assessment will focus on the visual changes to the landscape in response to the LNG Plant/Port facilities and Pipeline corridor(s) pre-development and construction.

Factors to be considered in assessing the visual impacts of a development are:

- vegetation cover,

- topography,

- degree of existing human modification to the 'natural' landscape and dominance of man-made elements and,

- the proposed developments viewshed (relating to view spread and distance) and specific human vantage points within this viewshed.

The assessment of landscape and visual impacts was undertaken using the following assumptions:

- The parameters of human vision provide some guide in measuring relative visual impacts of the above ground components (ie. LNG Plant and pipeline easement).

- As distance increases, visual impacts are reduced.

- Topography and vegetation can help screen, filter views.

- Perception of beauty and what is visually intrusive can vary.

The visual assessment report is based on interpretation of quantitative assessment (which is based on measurable parameters), and a qualitative assessment, which is based on accurately visualising the proposed works within the existing landscape, and assessing the landscapes ability to absorb that impact.

Methodology

The landscape assessment has been undertaken in accordance with the methodology recommended by the UK Institutes of Landscape and Environmental Management and Assessment. This methodology is consistent with the preparation of Environmental Impact Assessments in accordance with EU Directives and can be applied to the Barrow Island context.

The visual assessment will discuss changes that the proposed development will make to the existing landscape, these being visible from surrounding viewshed locations. The methodology is set out in detail in Appendix A. however in summary the visual assessment is based on the following:

- Determine existing visual Baseline Landscape Character Units and regulatory special values that may apply to this area;

- Within the above description discern the Visual Absorptive Capability of the Baseline Landscape Character Units in the Development - Visual Absorption Capability is a measure of the relative ability of a landscape to absorb visual change. A landscape with a high absorptive capability is able to absorb more visual change than one with a low capability;

- Determine the extent of the viewshed/visual catchment;

- Locate viewpoints within the viewshed where the visual effect (changes to the landscape) can be best described;

- Quantitatively assess the potential visual impact by comparing measurements of viewing size and distance to determine view angles, which relate to the parameters of human vision;

- Qualitatively assess the visual impact by utilising computer simulations to accurately describe and simulate the change to the landscape from identified viewpoints; and,

- Recommend mitigation measures to ameliorate visual impact.

Infrastructure Components

The following components form the Gorgon Gas project.

Offshore Gas Fields

The sub-sea gas-gathering system will be located on the sea floor at the Gorgon gas fields 70 kilometres west of Barrow Island and does not have any visual impact implications above the waterline.

Onshore Gas Pipelines and Corridors

The onshore pipeline will transport gas from the western shore crossing location and head in an easterly direction following closely to an existing road easement, then onto the LNG Plant site. An outgoing gas pipeline will transport gas from the LNG Plant across the eastern shoreline towards the mainland for domestic gas purposes (DOMGAS) and along a 4km jetty to a ship gas loading facilities.

LNG Plant & Port Facilities

The LNG Plant will include a number of structures located above ground associated with the processing and storage of gas. It is expected that the gas plant *(internal infrastructure)* will have a total infrastructure area of approximately 300ha**.** This will include:

- Storage tanks,
- Towers, Pumps and Compressors,
- Offices, workshop and stores,
- Flare and utility systems,
- Racks and Pumps,
- On site turning bays and provisions for vehicle parking.

The Port Facilities include:

- A Material Offloading Facility (MOF) A jetty that extends approximately1km in length directly east of the LNG Plant, and
- A ship gas loading jetty, a smaller thin structure that extends diagonally approximately another 3km from the end of the MOF.

Proposed LNG Plant & Port Facilities detail shown in Chapter 3 Figure 3.4.

Onshore Mainland DOMGAS Pipeline

A sub-sea pipeline from Barrow Island LNG Plant will transport compressed domestic gas to the Western Australian mainland for use in the industrial and domestic gas markets. The pipeline will join existing gas pipeline alignments before crossing the mainland West Coast south of Dampier and will continue east to Compressor Station One.

With regard to the following Visual Impact Assessment report the gas pipeline components on the mainland will be situated underground therefore this pipeline easement will only be referred to in regard to general construction and visual mitigation measures outlined to lesson temporary and long term visual impact.

2 Baseline Landscape Character

2.1 Introduction

The assessment of baseline landscape characteristics discusses the following:-

- A regional assessment to identify landscape character units with similar environmental and geological characteristics, discussing their ability to absorb the impacts associated with the pipeline easement(s) and associated infrastructure;

- Describe the proposed route alignment, and the location and surrounding landscape for proposed shore crossing(s) and proposed onshore pipeline corridor(s);

- Describe the landscape characteristics surrounding the location under consideration for an onshore LNG Plant;

- Identify surrounding viewpoints from where visual changes to the landscape will be noticeable from human vantage points and can be best described.

Project Alignment Plan

The plan (Figure 2.1) on the following page illustrates the proposed options for the alternative shore crossing(s), above ground gas pipeline corridors and LNG Gas Plant location. This plan provides a context for further assessment of the regional landscape character types, local landscape characteristics and surrounding viewpoints associated with:

Island Shore Crossing(s)

- North White's Beach
- Flacourt Bay

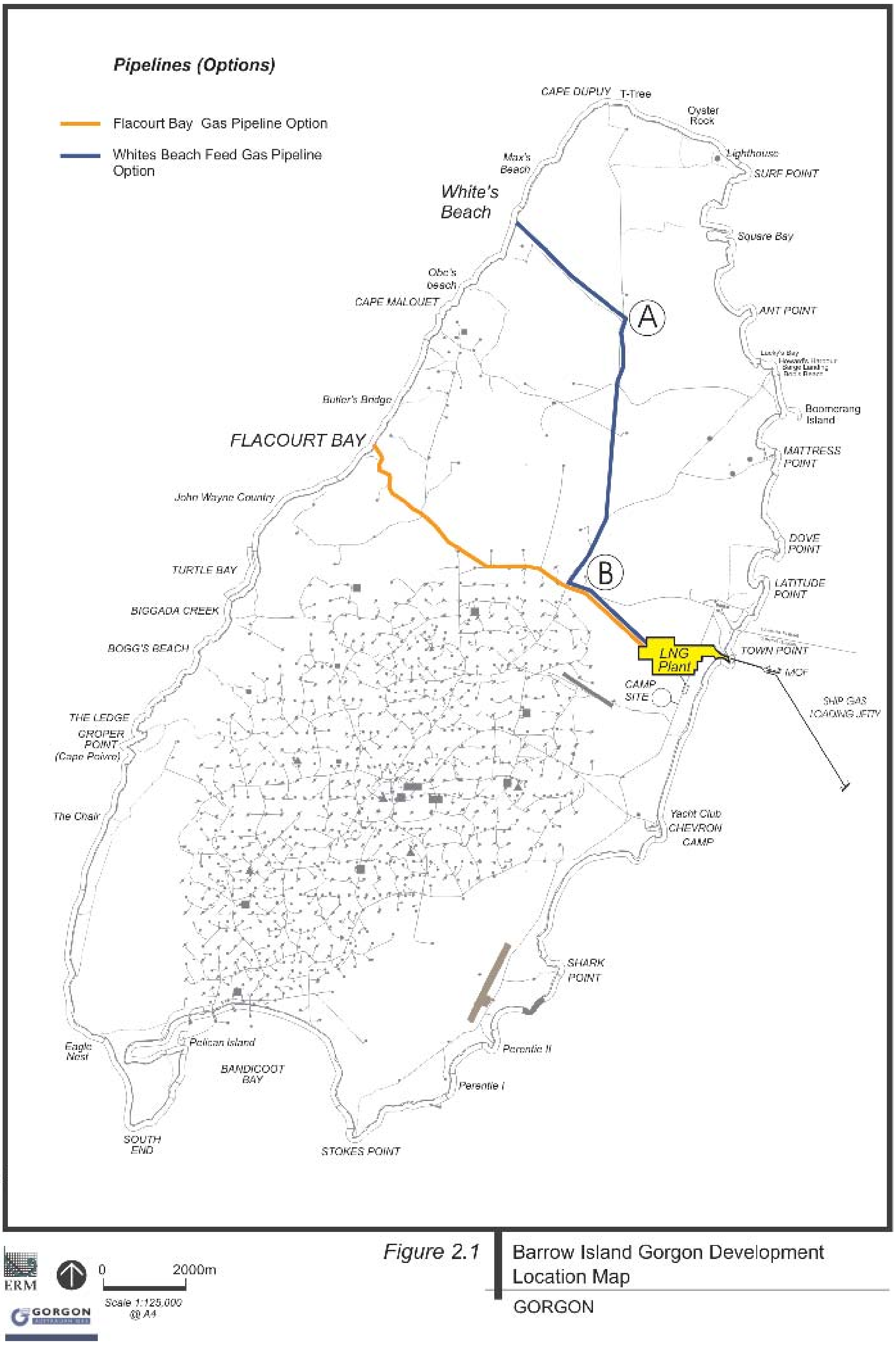
Island Onshore Gas Pipeline Route with possible connections from

- North White's Beach
- Flacourt Bay

Proposed LNG Plant site and Port Facilities

- Mid east point on Island directly west of Town Point.

Figure 2.1 – Barrow Island Gorgon Development Location Map



Onshore Mainland DOMGAS Pipeline

Gas pipeline aligns with existing gas services offshore and crosses the shoreline South of Dampier aligned with existing gas pipeline easements. The pipeline then continues underground to Compressor Station One.

Regional Baseline Landscape Characteristics

Barrow Island Landscape Overview

Barrow Island is elongated oval in shape, 25km in length and 10km in width with total area of about 234km squared. The highest area on the island is 65 metres above sea level. Generally the island can be said to slope toward the sea on the eastern side from higher erosional cliffs and deeply eroded gullies to the west.

An overview of Barrow Islands landscape consists of limestone uplands, dry creek beds, red sands, white dunes, beaches, clay and salt flats and intertidal flats.

The area of the island can increase up to 20% at low tide as a result of shallow offshore conditions and a mean spring tidal range of 2.5m.

Vegetation is low and sometimes sparse due to the arid climate and plant types vary on the island depending on the landform, soil depths and proximity to the sea. Up to 90% of vegetation on Barrow Island are related to three species of spinifex, *Triodia wiseana, Triodia angusta* and *Triodia epactica*.

Oil extraction infrastructure can be sporadically viewed throughout the island with the tallest structure being the communication tower (120m high) situated on the highest central point. The largest visually intrusive man-made structures are the oil terminal tanks situated on the central eastern coastline. These are 5 approximately 25m high by 60m wide bulk oil collection tanks have inturn a relatively low view shed which is contained to the central eastern part of the Island due to Barrow Islands rolling limestone ridges and central upland topography.

More frequently viewed are the less intrusive well heads that are dotted around the central and south central areas of Barrow Island.

Termite mounds, another common vertical element, are spread across much of the Island's landscape. They can sit up to 2m above the vegetation and are ochre red in contrast to the grey green of the spinifex type vegetation.

Four landscape units for Barrow Island have been defined on the basis of dominant plant species, associated landform and soils as a result of flora surveys by Buckley(1983), Trugden(1989) EM Mattiske and Associates (1993;97) and recently expanded by Astron Environmental (1992).

For the purpose of the visual assessment the coastal unit has been further broken down into two separate units due to contrasting visual differences of the West and East Coast to make five landscape   These five landscape units are:

- West Coastal Complex;
- East Coastal Complex;
- Valley Slopes and Escarpments;
- Limestone Ridges;
- Creek or Seasonal Drainage lines.

Figure 2.2 below identifies the location of the various landscape character units within the Island Study area.

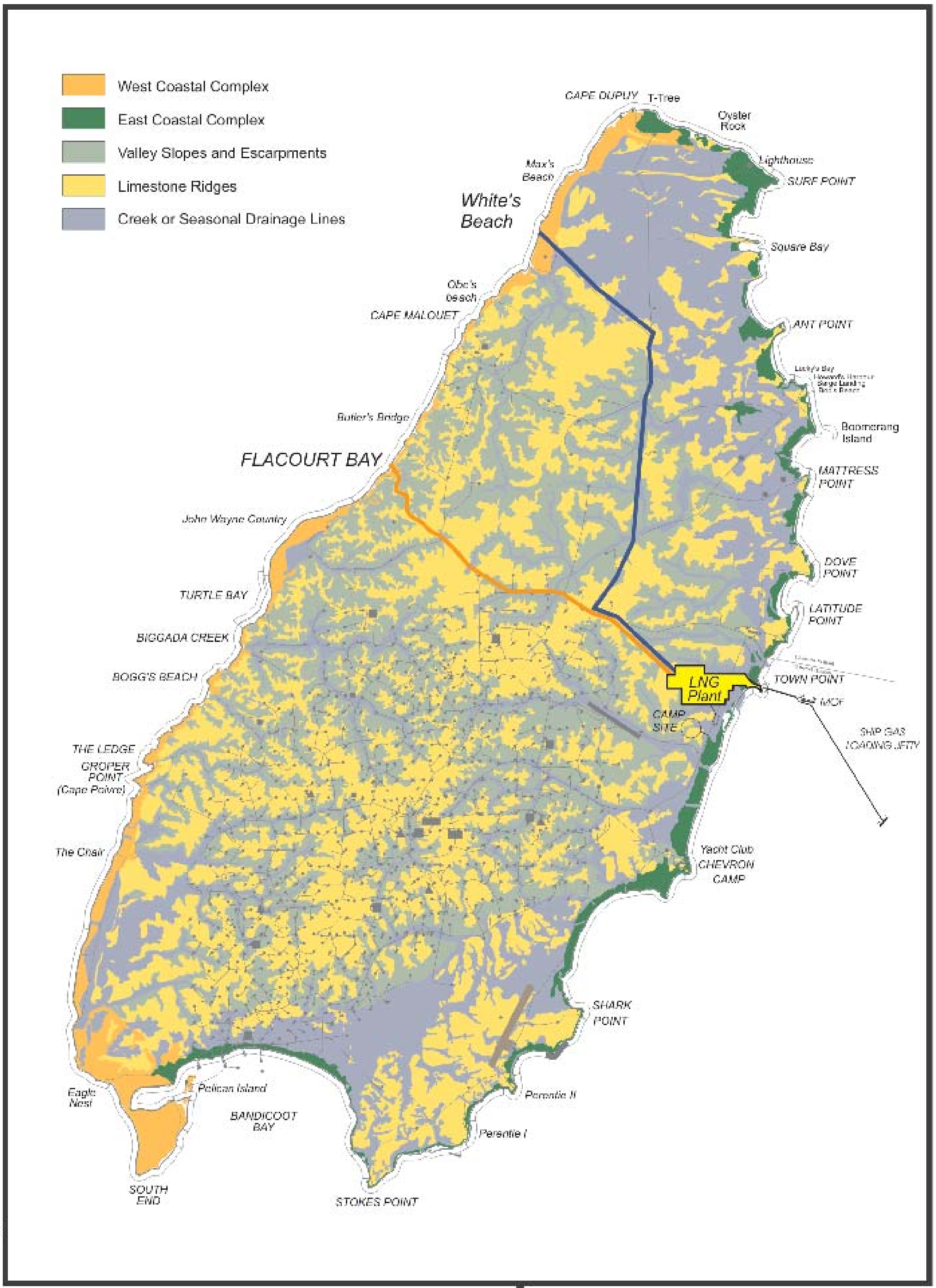


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Figure 2.2 Landscape Character Units

GORGON

Baseline Landscape Character Units

This section describes the visual landscape character types within the regional study area. Units are based on areas with similar visual characteristics in terms of their ability to absorb visual change. Often the character units relate to areas with similar environmental, flora and geological features. For the purpose of this Visual Assessment within Barrow Island there have been 5 Landscape Character Units defined and on the Mainland (Mardie Station) there are 4.

Onshore Barrow Island Landscape Character Units

Unit 1 – West Coast Complex

The western ocean coastline absorbs the wind and wave action associated with the open Indian Ocean. The coastline topography varies from rocky weathered steep sheer cliffs to less steep traversable inclines. Typically the existing sandy beaches are narrow and fit between the weathered rocky headlands.

This coastline is a significant feature of Barrow and the western area is highly rated in terms of world significance and accordingly is regarded as sensitive to potential visual disturbance.

Figure 2.3 - View northerly direction of rugged cliffs located along western coastline north of Flacourt Bay towards Butler's Bridge

Except for low priority tracks leading to individual beach's there is no man-made influences viewed in this Landscape Character Unit together with this pristine natural setting this landscape Character is seen to have a low potential to absorb visual change.

Plants in Unit 1 are sparse and cling to the limestone outcrops. The vegetation is described as Low Mixed Shrubland with dominant species of *Frankenia pauciflora* & *Hedyotis crouchiana*.

Figure 2.4 - View southerly direction of western coastline across Flacourt Bay towards John Wayne Country and sheltered reef coral of Turtle Beach beyond

Unit 2 – East Coast Complex

In contrast, Barrow Island's eastern coastline is somewhat more protected and a slight land gradient meets the ocean. Vegetated sand dunes and large tidal flats occur more readily and the 2.5m tidal variance is quite noticeable along this coastline.

Figure 2.5 - View in southerly direction from Town Point with a receding tide.

Figure 2.6 – Same view in southerly direction from Town Point showing high tide.

Vegetation types that occur along this coastline are dominated by the more hardier *Triodia angusta*.

Figure 2.7 – View in northerly direction from Town Point showing oil Terminal Tanks on left and centre right Apache oil rig monopods visible on the ocean horizon.

Existing man-made infrastructure is situated and viewed readily along this coastline (ie. Barge docking infrastructure, 5 large oil terminal yanks, new and old Airports, Well Infrastructure and the Chevron Camp site).

Due to man-made visual disturbance and low-lying nature of the landscape its ability to absorb further development becomes moderate.

Unit 3 – Valley Slopes and Escarpments

Steeper formed valleys and escarpments tend to occur on the western side of the Island that leave exposed limestone ridges, escarpments and relatively deep valleys.

Typical vegetation on the valley slopes and escarpments is described as open low shrubland with dominant species of *Triodia wiseana* with mixed emergent lower growing shrub species such as *Acacia bivenosa/Petalostylis labicheiodes* and *Petalostylis trichodemoides* situated on the southern escarpments.

The hilly terrain within this unit provides views from the elevated areas, however this characteristic may also assist to absorb visual disturbances due to intervening ridgelines therefore the absorptive capability of this landscape unit is considered as being low to moderate.

Figure 2.8 - View easterly towards central uplands showing vegetation on the limestone ridges

Unit 4 – Limestone Ridges

This landscape unit type occurs generally throughout the central north-south upland plateaus of the Island. The terrain ranges from steeper slopes in the west to and flatter more gentle undulations as the ridges continue east.

Typical vegetation on the limestone ridges includes the sensitive Hummock Grassland of *Triodia wiseana* with low mixed shrubs including *Acacia gregorii*.

Figure 2.9 - View easterly from the central uplands towards terminal tanks proposed LNG plant showing vegetation, power poles, and road easement. East-west gas pipeline is proposed to run through this area along side road easement.

This landscape unit has limited capacity to absorb visual impacts especially if low screening vegetation is damaged or removed.

A large proportion of the proposed pipeline corridor is located in this landscape character unit.

Figure 2.10 - View westerly from terminal tanks towards the central uplands showing main oil distributor pipe. Views along the pipe easement are in contrast to views adjacent the pipeline easement where low vegetation can screen pipeline views.

Unit 5 – Creek or Seasonal Drainage Lines

This landscape unit occurs generally in the broad valleys and flats of limestone ridges and is located slightly in from the coastal fringes. This landscape has deeper alluvial soil structure and in conjointly a denser, taller vegetation character. The vegetation in this unit type is described as Mixed Hummock Grassland of *Triodia angusta* with pockets of dense shrubs along major creek lines.

Figure 2.11 - View easterly in the vicinity of the proposed LNG Plant showing taller vegetation communities within the drainage line landscape.

Out of the earlier landscape character units discussed this has the greatest capacity to absorb visual impacts due to the following factors:

- Low-lying topography in an undulating landscape may assist in lessoning a structures potential view shed;
- Vegetation height will potentially be the greatest in this landscape unit making it easier to absorb above ground pipe infrastructure.
- Due to greater soil depth and vegetation type rehabilitation has the best opportunity to be achieved.
- The local vegetation community has a greater capacity for rehabilitation using the 'Direst Topsoil Placement' procedure.
- The proposed LNG Plant is located within this Landscape unit.

Onshore Mainland Landscape Character Units

Unit 1 – Coastal Mangrove Zone

Unlike the western exposed shoreline of Barrow Island, the mainland shoreline has a low-lying approach. Adjacent the shoreline a wide spreading zone of Mangroves inhabit the shallow coastal waters.

Figure 2.13. illustrates rehabilitation technique (fenced structure) used to shelter and encourage new Mangrove growth. This break in the Mangrove stand has occurred due to the existing gas easement.

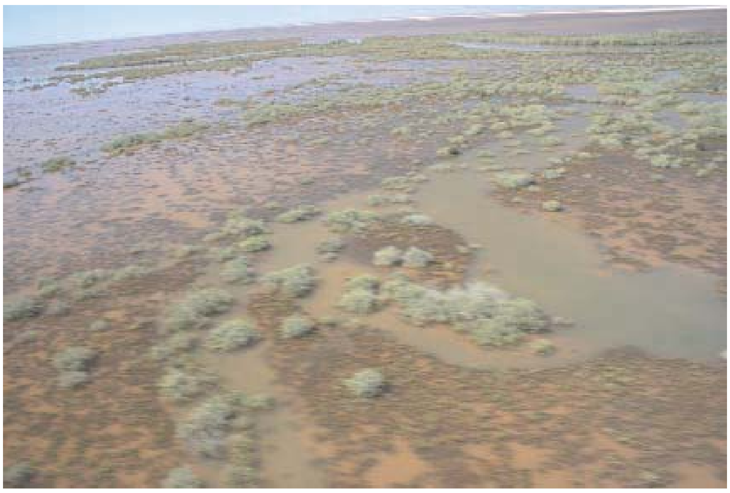


Figure 2.12 – Aerial view east towards shoreline showing extent of mangrove zone.

Figure 2.13 - View west showing existing pipeline easement through the shoreline vegetation and rehabilitation works involved with mangrove re-establishment.

Unit 2 – Red/Grey Non–vegetated Salt Flats

These salt flats are tidal and occur directly adjacent the shoreline and traverse east into the mainland to eventually dissolve into the slightly higher lying shrub and grasslands.

While this landscape has no capacity to absorb above ground structure in contrast it has a great capacity to disguise ground disturbance due to the moving tidal sands and sediment.

Figure 2.14 – Aerial view showing expanse of non-vegetated salt flats adjacent and west of shoreline.

Unit 3 – Vegetated Hummocks within Salt Flats

Increasingly as you move east from the shoreline vegetated hummocks are dispersed within the salt flats. These hummocks are vegetated with low sparse grassland/spinifex vegetation. This hummock landscape unit has limited capacity to absorb visual impacts especially if low screening vegetation is damaged or removed.

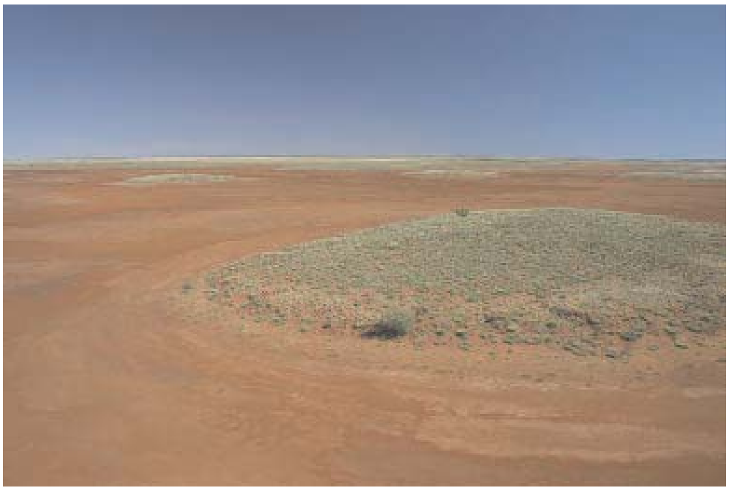


Figure 2.15 – Aerial view of vegetated hummocks within the salt flats.

Figure 2.16 – Aerial viewing west near Compressor Station One. This view shows existing pipeline easement within the low lying shrub and grassland landscape.

Unit 4 – Low Lying Shrub and Grasslands

As the pipeling easement moves east towards Compressor Station One, the vegetated hummocks join to develop a low lying shrub and grassland plain.

This landscape unit has limited capacity to absorb visual impacts especially if low screening vegetation is damaged or removed and the underlying red soil is exposed.

On the mainland a large proportion of the proposed pipeline corridor is located in this landscape character unit.

Baseline Landscape Character – Shore Crossing Options

This section describes the visual landscape character within the Barrow Island proposed Gorgon components local study area.

North White's Beach - Option

The proposed pipeline shore crossing at this site enters at right angles to the coastline. Steep cliffs with limestone rocky headlands occur to the south and north of the corridor. To the east, the grade reduces as the land approaches a sandy beach.

Fig 2.17 Viewing north across the headlands of White's Beach

Apart from the coastal fringe and limestone headlands the area east leading into the shoreline could be described as a 'Valley Slope and Escarpments' landscape unit.

Fig 2.18 Viewing westerly down a slight grade into White's Beach showing typical landform leading to shore line.

From this point in the landscape, with exception an existing red dirt track that falls in and out of view as it winds its way through the undulating limestone ridges, no man-made structures or 'unnatural' disturbances can be viewed.

Vegetation in this unit type is described as open low shrubland with dominant species of *Triodia wiseana* .

Also mixed emergent lower growing shrub species such as *Acacia bivenosa/Petalostylis labicheiodes* as shown in Figure 2.18 previous page.

Flacourt Bay - Option

The proposed shore crossing would also enter at right angles to the shoreline. High steep sided headlands occur to the south and north of the beach corridor as shown in Figure 2.19 below.

Figure 2.19 Viewing southerly across Flacourt Bay.

To the east, the grade reduces through a windy, relatively narrow, steep sided valley and as indicated in earlier Figure 2.8, the land drainage line snakes its way to an open sandy beach.

Views into the bay remain 'natural' with no man-made visual disturbance.

The sandy beach line is larger at Flacourt Bay, however as noted before, the dominant landscape snaking from the east into the shore line can be described as a 'Valley Slope and Escarpments' landscape unit with the common species being *Triodia wiseana*.

Baseline Landscape Character – Pipeline Corridor Options

North White's Beach Gas Pipeline Option – Barrow Island

An overview of North White's Beach Gas pipeline option indicates that after the shore crossing the corridor continues south east to meet the north-south T-Tree Road & Howards Harbour Barge Landing Service roads. The pipeline then continues due south to meet up with the main east-west road. At this point the pipeline would join the Flacourt Bay proposed route and continue due east to the LNG Plant. The overall distance from shore crossing to LNG Plant Site is approximately 10.5km.

In more detail, upon leaving the beach line, the pipeline corridor climbs a gentle drainage line and valley slope for approximately 600m to ascend to the western upland area. From this point until meeting up with the major east west road, the landscape character that the pipeline corridor runs through is gently undulating as it dips into thickly vegetated creek and seasonal drainage lines and rises over the sparsely vegetated stony limestone ridges as shown below in Figure 2.20.

Ascending from the western beach complex the pipeline corridor runs approximately 3km to meet up with the north-south road that gives access the north Island T-Tree area (Indicted as point A on Figure 2.1 Location Map). The North White's Beach pipeline option then changes course to continue due south along this road.

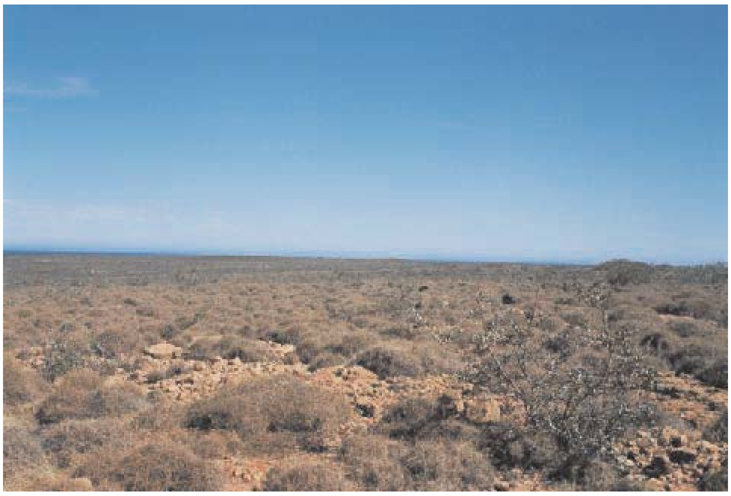


Figure 2.20 Showing typical limestone ridge landscape.

This feeder pipeline corridor option follows adjacent to this road for approximately 1.7km upon where the road and pipeline corridor divert. The road detours east to service Howards Harbour and the barge landing.

For 3.2km the easement crosses south over natural ground, apart from any road easement, until it joins the Howards Landing service road again on its southern approach.

From this point the easement runs adjacent with the road another 1.8km until meeting up with the major east-west access road that links with Town Point, The Terminal Tanks and the LNG Gas Plant site (Indicated as point B on Figure 2.1 Location Map).

Not until approaching this east-west road to Town Point has the pipeline corridor shared other main existing infrastructure easements. Whereas in this area there are a number of existing oil pipe and power easements snaking there way through the landscape often visually obstructed by slightly undulating land or existing vegetation. It is not until the viewer is aligned with one of these easements that a clear view of the infrastructure corridor is apparent as seen in Figure 2.22.

Flacourt Bay Gas Pipeline Corridor – Barrow Island

Flacourt Bay is due west of the LNG Plant Site and is the option with the least travel distance being approximately 9km from coast to LNG Plant.

An overview of this pipeline option indicates that following the shore crossing the gas pipeline corridor continues west mostly adjacent the east/west road to terminate at the LNG Plant Site.

In more detail, upon leaving a wide beach line, the easement climbs approximately 500m up a gentle sloped drainage line, which then narrows into a winding valley for approximately 2km to ascend to the limestone uplands as indicated in Figure 2.21 below.

Fig 2.21 Viewing west from shore line into Flacourt Bay Showing drainage line and winding valley beyond.

As discussed earlier in the Barrow Islands Landscape Overview, valleys and ridgelines tend to be more defined on the western coastline. Views from within the valleys are restricted whereas once ascending upon the ridgeline it is possible to view west across the headlands to the Indian Ocean, also down through tight winding valleys with glimpses of sandy beaches and the shore line beyond.

Continuing along the pipeline corridor oil well heads appear irregularly as you approach the central uplands. The well structures meld into the landscape and only at a reasonable close distance, approximately 1-1.5km, possibly a little further with the sun angle behind the viewer, can this structure be visually discerned from the surrounding landscape. Oil well infrastructure stands out as a small black vertical T-shape when viewed on a ridgeline with a blue sky background. Scattered oil, power and water pipeline infrastructure intersects the ground plane in the upland area. Assuming a pipeline easement is viewed from a vehicle on a service road these low infrastructure easements are visually prominent in the following instances:

- when a long lineal intrusion contrasts the natural landscape visual norm.
- when the pipeline is aligned with the road and there is a break in vegetation easement between the alignments or the vegetation becomes particularly low and sparse;

- when the pipeline angle is misaligned with the viewer on relatively flat ground the visual obtrusion becomes greater the further you can see along the easement. This is mostly experienced when the pipe easement crosses the road as seen in Figure 2.22 below;

Fig 2.22 Viewing south showing typical pipeline and power easement at junction of north south and east west roads

Fig 2.23 Viewing east along the east west road showing proposed pipeline corridor and existing power easement in a typical 'Limestone Ridges' landscape unit.

The roadside vegetation on the uplands becomes increasingly sparse on the limestone ridges this allows filtered views to the aligned corridor as the viewer travels along the east west road.

The alignment continues in a westerly direction adjacent to the east west road where the landscape unit type of the upland 'Limestone Ridges' are typical from this point on until terminating at the seasonal drainage flat of the LNG Plant site.

The rolling topography in the west becomes more gradual as it moves east from the uplands and wide views to Barrow Islands central east lands and coastline open up as the landscape levels towards the eastern coast and terminates at the lowland level of the LNG Plant Site.

Baseline Landscape Character – LNG Plant Site & Port Facilities

The LNG Plant Site & Port Facilities are located on the central eastern coastal flank of Barrow Island approximately 1km west of Town Point and 3.5km north of the Chevron Camp. The proposed plant will be located on the land sloping away to the right of the image below and will be visible from this location.

From the existing Chevron Camp looking north as indicated in Figure 2.24 below, the LNG Plant Site sits within a 'Creek or Existing Drainage Line' landscape unit. Limestone ridges to the north, south and west border the broad low-lying flat, with the land sloping gently down to the shoreline bordering to the east.

The landscape continues to be characterised by gently undulating topography. Expansive views across the landscape can be gained from the fringing ridgeline, however your views are limited within the drainage line flat.

Fig 2.24 Viewing north from Chevron Camp towards proposed LNG Plant Site The view shows a large open flat bordered by the Chevron Camp ridgeline and the Terminal Tank ridgeline to the north.

Vegetation on this flat is relatively tall (1-1.5m) and there is a dense cover of spinifex, *Triodia pungens*.

Man made structures that are shared within this view shed are the five large Terminal Tanks to the north, the Communication Tower to the south west and the Chevron Camp accommodation buildings, nestled into the ridge due south.

3 Visual Assessment

3.1 Statements, Policy And Planning Guidelines

Environment Protection and Biodiversity Conservation Act (EPBC Act)

Barrow Island is classified under EPBC Act since 1910 as a Class A Nature Reserve.

In relation to visual amenity The Environmental Protection Authority (EPA) issued a statement on the principal of locating a gas processing complex on Barrow Island. Visual significance is not specifically mentioned, although concern was raised for,

' …adequate attention be given to plant design, appropriate stack heights, avoidance of building effects…'

It should be noted that these recommendations have been incorporated into the amelioration measures recommended for the proposed gas plant and pipeline locations.

Visual Assessment Objectives

This part of the report assesses the visual impact of the:-

- onshore components of the 2 gas pipeline options:
  - North White's Beach
  - and Flacourt Bay
- mainland onshore components of gas pipeline
- LNG Plant, Port Facilities and temporary construction camp site

The proposed methodology for this visual assessment is set out in Appendix A.

The objectives of this report are to:

- Describe how the proposed development would alter the landscape character of the immediate area;
- Examine the visual impacts associated with the pipeline and associate infrastructure from adjacent road easements and road vantage points;
- Examine the visual impact of the LNG Plant from identified viewpoints;
- Assess the visual impacts during the phases of construction and completion and present visual optimisation and impact mitigation recommendations.

Assumptions

Assumptions are made when assessing visual impact. These include:

- The parameters of human vision provide some guide in measuring relative visual impacts.
- Natural landscape characteristics (ie. topography, vegetation cover) and degrees of disturbance (man-made built form) influence the capacity to absorb visual changes.
- As distance increases, visual impacts are reduced, to a point where the visual impact is insignificant. This physical distance can be calculated and defines the extent of the view shed for a particular development.
- Vegetation can screen or filter views (in relation to pipeline easements).
- Topography can screen views.
- Perception of beauty and what is visually intrusive can vary.

Visual Impact Mitigation

Visual impact can be lessoned through vegetative and topographic screening, maximising the separation distance to viewpoints and by selecting environments that are capable of absorbing visual changes in the context of surrounding viewpoints. For pipeline easements the strategic alignment of the route is the most important consideration in minimising visual impacts.

Strategic mitigation measures include:

- Alignment of the route to minimise adverse visual impacts associated with easement clearance;
- Minimal visibility of the easements and associated infrastructure from surrounding viewpoints;
- Selection of the most appropriate infrastructure sites for particular circumstances.

On occasions it is not possible to avoid sensitive viewpoints and it is necessary to balance visual impacts with other conflicting issues such as ecological impacts and cost. On such occasions it is necessary to consider tactical methods of mitigation to reduce visual impact. Tactical mitigation measures are applied at visually critical points in order to reduce visual impact to the practical minimum and include:

- adjusting the route alignment and positioning of infrastructure;
- blending infrastructure colour, materiality to match surrounding landscape character;

- vegetation retention;
- rehabilitation.

Tactical mitigation measures provide a degree of amelioration but rarely provide immediate relief from visual impacts and may not always be appropriate or practical. For example, screen planting can be effective in many landscape characters, however given the height and density of existing vegetation and the unique character of this natural Reserve, the introduction of screening species for the large infrastructure becomes inappropriate.

These limitations reinforce the point that infrastructure integration and route selection for pipeline easements are the most important factor in minimising landscape and visual impact.

Tactical mitigation measures available to further ameliorate impacts are discussed below.

Adjusting the Alignment

Minor modifications of the final alignment may make a major difference to the visual impact of the surrounding landscape. These need to be examined on a case by case basis but are generally readily achieved subject to technical suitability.

Colour Integration

The use of sympathetic colours, which blend with the surrounding landscape or are neutral (not contrasting) can assist to visually merge the infrastructure components with the surrounding landscape particularly when viewed from a distance. Colour also can be appropriated in the design and construction of the port facilities.

Vegetation Retention

The retention of vegetation as close as possible to the pipeline easements and LNG Plant site works will reduce exposure of the visually contrasting red soils and rock associated with this area.

Rehabilitation

Rehabilitation should reflect the landscape characteristics of surrounding areas. The removal and replacement of soil, rock and indigenous planting is to be implemented as follows;

Vegetation

- Before removing vegetation from an area that is to be substantially cleared, ensure local seed collection viability and stockpiling techniques have been explored and implemented if required (at present seed viability in the Pilbara region is as little as 1%).
- Vegetation removed is to be buried in appropriate landfill areas.
- Topsoil, not more than 100-50mm (200mm max.) from top of soil profile, at Barrow Island has been known to contain a viable seed pool and if direct

topsoil placement (without storage stockpiling) from one local area to another is practised there is the highest probability for regenerating vegetation cover.

- If stockpiling of topsoil is to occur and maintain seed viability it has to be stockpiled at a depth of 1.5m, not more than 2m high and ripped monthly for aeration. Stockpiles stored longer than a few years will cease to have viable seed stock.

- When roadways are being rehabilitated one technique used with satisfactory results is called 'equalisation' ripping, the dragging of topsoil containing seed from both sides of the road in a staggered pattern. As well as transporting seed this treatment allows a less uniform disturbance line in the natural landscape setting and in consideration of the soil profile.

Soil Profile

Visual disturbance in the Barrow Island natural setting is most noticeable when the soil profile is altered or new cap rock is brought to the surface. Topsoil has a different colouring and texture to hidden subsoils and rocks. With this in mind when excavation occurs it is important to maintain topsoil and subsoil layers in separate stockpiles and for these to be replaced in their respective soil profiles.

The soil profile on gorgon apart form the sandy coastal fringes generally consists of the following levels:

1. Topsoil (to 200mm, mostly shallow);
2. Granuled Subsoil (approx 200mm to 1m);
3. Limestone Gravel (approx. 1m to 2m); and
4. Cap Rock (at approx 2m).

This profile is a general across the Barrow Island Landscape. There are many instances especially in the Limestone ridges where the cap rock is exposed. However newly exposed rock has a different hue to existing weathered rock.

Ripping

- When ripping or equalising for road revegetation the prevention of bringing up submerged rocks can be avoided by only shallow ripping to150mm, no greater than 200mm depth. This is to be monitored on site.

Note: The implementations of specific tactical mitigation measures are discussed in association with the assessment of individual viewpoints.

Visual Impact Assessment – Shoreline Crossings

North White's Beach

The options of directional drilling or digging in of the pipeline through the narrow beach foredune achieves a none to negligible visual impact shore crossing.

An access road passes a few hundred metres adjacent on the ridgeline east of North White's Beach as seen in Figure 3.1 below. A track would need to be developed to allow construction equipment access down a moderate gradient to the site.

Fig 3.1 Aerial viewing east towards White's Beach showing proposed pipeline corridor and existing road running adjacent to shoreline.

The temporary disruption to the landscape at this location will be visible from vantage points within the surrounding western coastal ridgeline, however this coastal crossing has a viewshed of less than 0.5km.

Reinstatement of sand, soil, exposed rock and vegetation, as soon as practicable will prevent long-term visual impacts. Refer to chapter 3.4 on Visual Mitigation and rehabilitation for recommended reinstatement procedures.

Flacourt Bay

Again, the options of directional drilling or digging in the pipeline through the wide 100m beach have also been discussed to achieve an undersurface, none to negligible visual impact.

The existing road terminates on a ridgeline to the south of Flacourt Bay as seen in Figure 3.2 following page. A track would have to be developed down a steep sided valley to allow construction equipment access to the site.

The temporary disruption to the landscape at this location will be highly visible from vantage points within the surrounding western coast headlands, however this coastal crossing has a viewshed of less than 1km when approached from land.

Suitable reinstatement of sand, soil, exposed rock and vegetation, as soon as practicable will prevent long-term visual impacts. Refer to chapter 3.4 on Visual Mitigation and rehabilitation for recommended reinstatement procedures.

Fig 3.2 Aerial viewing east towards Flacourt Bay showing proposed pipeline corridor and existing road terminating on ridgeline south of beach.

Visual Impact Assessment – Onshore Pipeline Corridors

The majority of the land traversed by the pipeline corridors will follow close to existing road or other pipeline easements. Visual impacts associated with all options are very similar. This is based on visual intrusion of pipeline and for the construction works phase.

Apart from the coastline crossing's all proposed easements pass through gently undulating landscape that has mostly sparse vegetation coverage of low spinifex.

It is therefore possible to align the gas pipeline close to the adjacent road easement and existing pipeline corridors to ensure that there is little vegetation removal required for construction.

It could be argued that a pipe easement adjacent to the road and low in the drivers/passengers visual horizon has a far less visual impact than an alignment that is seen cutting through and contrasting with the open natural setting.

Some visual impacts will be of a temporary nature with vegetation clearing for construction access. Refer to chapter 3.4 on Visual Mitigation and Rehabilitation for recommended reinstatement procedures.

The local visual characteristics, development impacts and mitigation recommendations are summarised for each of the landscape character units within Table 3.1 - Visual Assessment Overview of Onshore Pipeline Options.

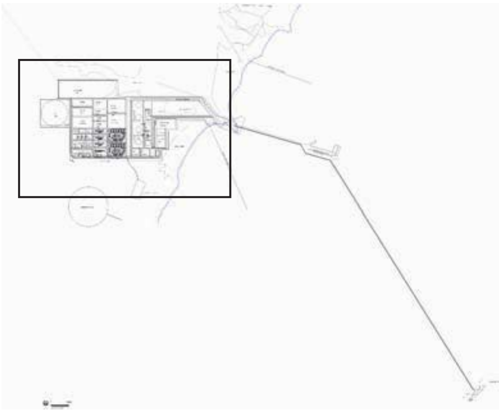
Table 3.1 - Visual Assessment Overview of Barrow Island Onshore Pipeline Corridors.

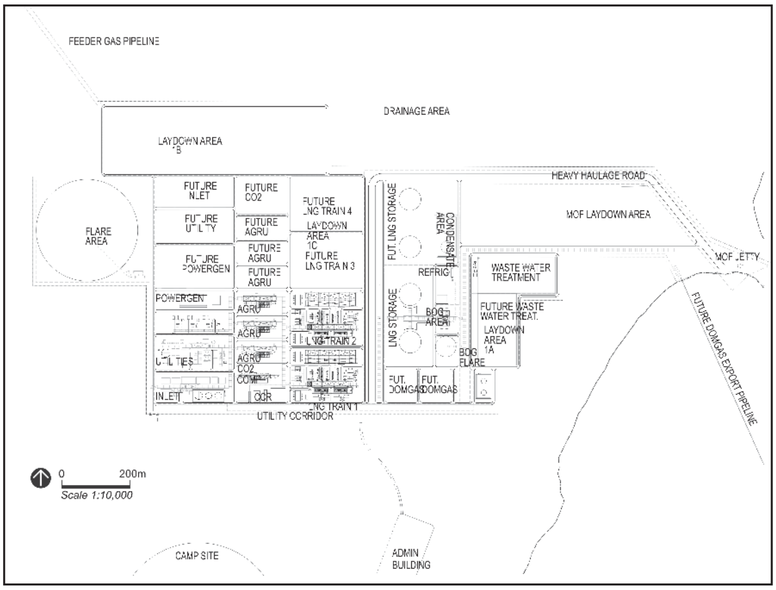
LANDSCAPE UNITS	LOCAL LANDSCAPE CHARACTERISTICS	POTENTIAL VISUAL IMPACTS	MITIGATION MEASURES AND RECOMMENDATIONS
UNIT 1 West Coastal Complex Western Shoreline crossing	Coastal cliffs Sandy beaches with high rocky headlands Open sandy beach line Gentle to medium slopes behind sandy beach line	Negligible to nil* visual impact on shoreline crossing moderate* visual impact from beyond beach line Disturbance of soil profile, possible exposure of rock on sandy beach and behind shoreline Possible views to pipeline from higher vantage points (rocky headlands)	Directional drilling to minimise damage to the foreshore Rectification of works sites and access roads with vegetation rehabilitation, sand, soils and rock profile to match existing Align pipeline easement to take advantage of topography with screening from vantage point views when climbing escarpment within the valleys
UNIT 3 Valley Slopes and Escarpments Most prominent between West Coast and Central Limestone Ridges	Low shrubland with dominant species of *Triodia wiseana* with mixed emergent lower growing shrub species such as *Acacia bivenosa/Petalostylis labicheiodes* and *Petalostylis trichodemoides* situated on the southern escarpments	Slight* visual impact Ground disturbance and vegetation clearance during the construction of access roads and pipeline easement Permanent pipeline easement with vegetation removal within the easement. Possible screening of easement from ridgelines and in contrast overlooking of pipeline easement into valleys Low to Moderate visual impact from adjacent roads	Rectification of works sites and access roads with soil and rock profile to match existing. Align pipeline easement to take advantage of topography with screening vantage point views when pipeline is not adjacent to road easement Align pipeline easement as close to and adjacent to road easement as practicable Reinstate local vegetation with local direct topsoil placement.
UNIT 4 Limestone Ridges Landscape Character Type most dominant in central development area	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 include the sensitive Hummock Grassland of *Triodia wiseana* with low mixed shrubs including *Acacia gregorii* Planting is sparse and has limited rehabilitation capacity	Moderate* visual impact Ground disturbance and vegetation clearance during the construction of access roads and pipeline easement Permanent pipeline easement with vegetation removal within the easement Little screening from adjacent road easement	Align pipeline easement as close to and adjacent to road easement as practicable Rectification of works sites and access roads with soil and rock profile to match existing. Reinstate indigenous vegetation with local direct topsoil placement. Retain as much vegetation as practicable

LANDSCAPE UNITS	LOCAL LANDSCAPE CHARACTERISTICS	POTENTIAL VISUAL IMPACTS	MITIGATION MEASURES AND RECOMMENDATIONS
UNIT 5 Creek or Seasonal Drainage Lines Landscape Character Type that occupies the open valleys between the limestone ridges with large open flats situated on the east side of Barrow Island	The vegetation in this unit type is described as Mixed Hummock Grassland of *Triodia angusta* with pockets of dense shrubs along major creek lines. Low-lying topography in an undulating landscape Vegetation height will potentially be the greatest in this landscape unit making it easier to absorb above ground pipe infrastructure.	Negligible* visual impact Ground disturbance and vegetation clearance during the construction of access roads and pipeline easement Permanent pipeline easement with vegetation removal within the easement Due to soil depth and vegetation type rehabilitation has a greater opportunity to be achieved. **Criteria definitions in Methodology Appendices*	Rectification of works sites and access roads with soil profile to match existing. Align pipeline easement as close to and adjacent to road easement as practicable Reinstate indigenous vegetation with local direct topsoil placement.

LNG Plant Layout & Port Faciliy Layout

Figure 3.3 below illustrates the proposed LNG Plant that is to be located at Barrow Island. The elements listed are common for all plants, however their configuration varies relative to site constraints.





The major visual components of the gas plant are:

- The LNG Trains which are made up of columns, pipes and steel platforms, and has a mass height of approximately 20m above ground level; and
- The bulk Compressor and Storage tanks. Each tank is approximately 20m high and 20 metres in diameter. Therefore the comprehensive height of the LNG Plant can be ascertained at 20m above bench level (approximately 38.5m AHD).

The Emergency flare height at 150m high contrasts with the other Plant structures. This structure is tall and thin and although has potentially a wide viewshed it can be argued to have a negotiable visual impact on the surrounding landscape. (Refer Cha. 3.5.4 – Flare & Illumination).

Although the development area on whole will be approximately 300 hectares the LNG Plant is not constructed or viewed as a single mass. The Plant will be viewed as a mixture of steel structural elements of varying size, width and height combining to give the development an "airy" feeling.

In general the development has been sited in a low-lying are to minimise visual impact within the surrounding landscape.

The Port facilities consist of a larger Materials Offloading Ramp (MOF) approximately 1km in length and a lighter structured offshore ship gas loading jetty of approximately 3km 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.

LNG Plant Viewshed

The viewshed for the LNG Plant site has been calculated assuming radii's of 5km, 7.5km and 10km.

A viewshed diagram (Figure 3.4 below) has been created using Global Positioning System (GPS) combined with 3D topographic information (ArcView) to determine their visibility from surrounding areas.

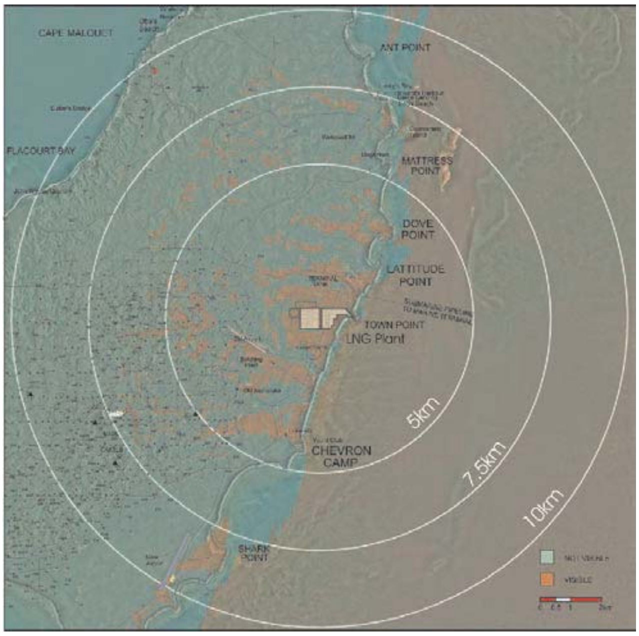


Figure 3.4 - Viewshed of LNG Plant site

The heights of the various infrastructure components have been identified to determine the extent of the viewshed. The viewshed analysis shown in Figure 3.4 above considers structures, which range in height from 10m to 20m and form the comprehensive bulk of the development. It is recommended that Individual stacks and flares may protrude above the comprehensive LNG Plant structure height but their impact is insignificant due to their narrow construction width.

The viewshed quantitative assessment also recognises that the emergency flare exceeds 150m in height, however given its narrow columnar appearance, the disturbance to the field of view is insignificant especially when viewed at a distance. The visual impacts are further tested as part of the qualitative assessment and simulations.

The topography of the LNG Plant Site immediate surrounds is low-lying, flat to gently undulating. This is reflected in the viewshed analysis with the plant being visible from a significant area within the central eastern segment of the Island. The LNG Plant would be visible from the ocean approaching from the east. Viewpoints

The viewpoints identified in the Figure 3.5 below are located within the LNG Plant viewshed. These viewpoints have been selected to illustrate both typical and worst case visual impacts of the proposed development.

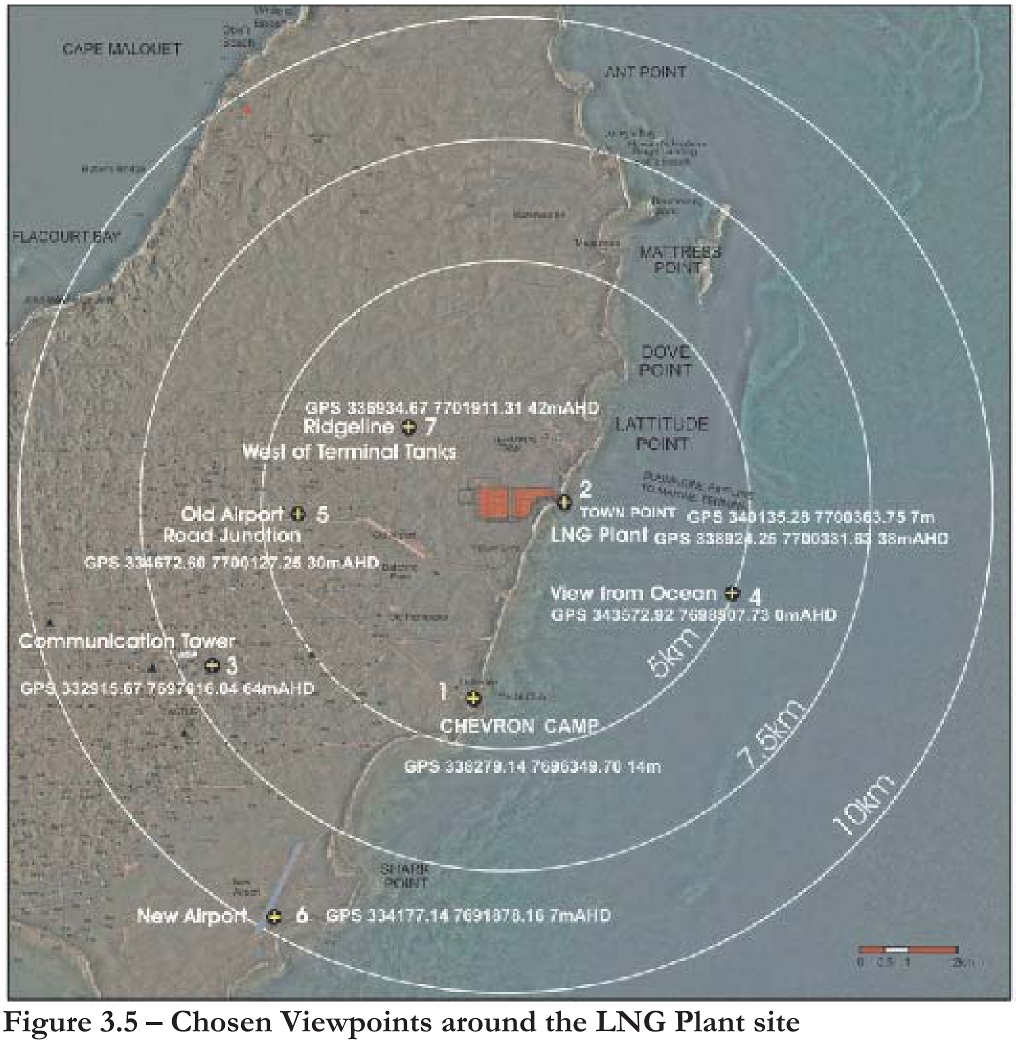


Figure 3.5 – Chosen Viewpoints around the LNG Plant site

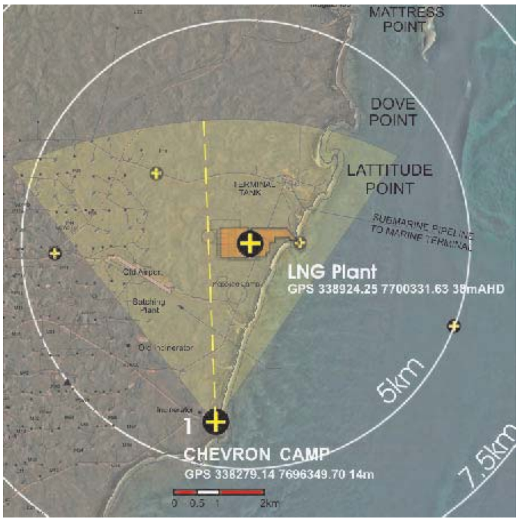


Figure 3.6 – Viewpoint 1

The view is looking north from the Chevron Camp carpark on the southern ridgeline overlooking the drainage line and broad flat. This viewpoint is located due south of the Terminal Tanks and Town Point, approximately 4.3km from the proposed LNG Plant.

Figure 3.7 – Simulation of LNG Plant & Port Facilities at completion of works from Viewpoint 1 – Chevron Camp

This viewpoint was chosen to show the common viewing point for the Chevron Camp workers and as a good overview of the LNG Plant, Port Facilities (MOF) within its landscape character.

The LNG Plant is moderately visible from this viewpoint and continues a low built skyline from the existing terminal tanks as seen situated on the right of the LNG Plant model.

From this distance the flare structure and low lying port facilities become of negligible visual impact and has very little effect on the overall scene.

Viewpoint 2 – Town Point

The view is looking west from Town Point. This viewpoint is located south east approximately 1.8km of the Terminal Tanks and approximately 1.2km due east from the centre of the proposed LNG Plant.

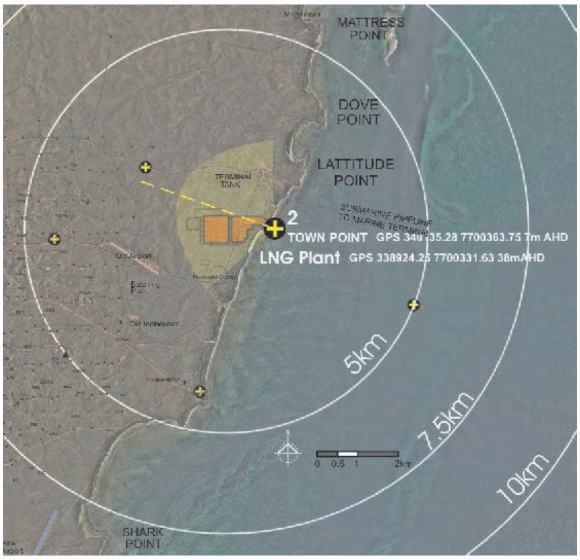


Figure 3.8 – Viewpoint 2

Figure 3.9 – Simulation of LNG Plant at completion of works from Viewpoint 2 – Town Point

This viewpoint was chosen to illustrate an immediate view of the development and to contrast the existing terminal tanks shown on the far right of photo.

The LNG Plant is substantially visible from this close viewpoint and adds to the built skyline of the existing terminal tanks.

This model simulation also shows proposed earth benching that contrasts the natural landscape this is before vegetation rehabilitation of the bench slopes.

Viewpoint 3 – Communication Tower, Base Castle

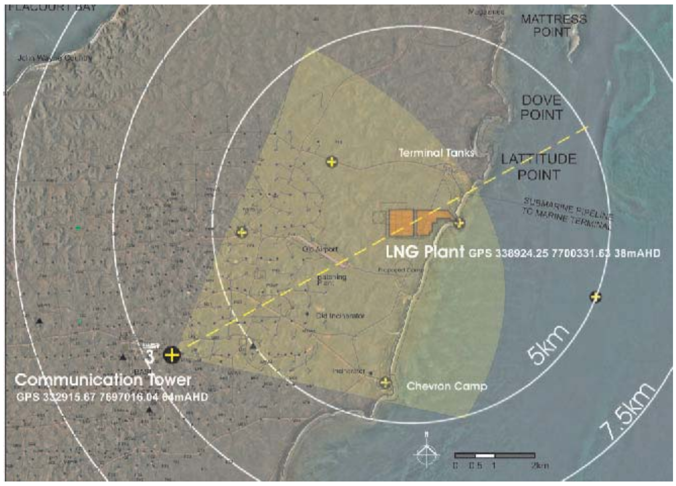


Figure 3.10 – Viewpoint 3

The view is looking north east from the Communication Tower, at 63m the highest central point on Barrow Island. This viewpoint is located 5.2km due west of the Chevron Camp site and approximately 6.8km south west of the proposed LNG Plant.

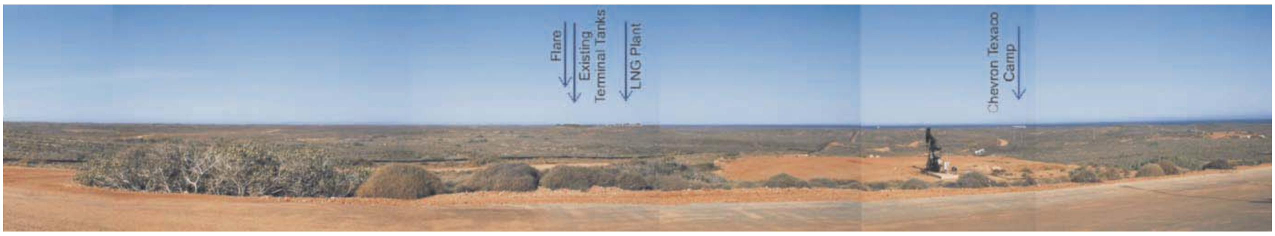


Figure 3.11 – Simulation of LNG Plant at completion of works from Viewpoint 3 – Communication Tower, Base Castle

This viewpoint was chosen to illustrate views from the highest central point in the island (63m AHD). From this view the Plant site is partially hidden due to a ridgeline and its position on a low-lying flat.

The LNG Plant has negligible visual impact and the view indicates how the LNG Plant at this distance melds into the landscape.

The flare structure at this point becomes less discernible and has virtually no visual impact to the broader scene.

Viewpoint 4 – Ocean View at 5km East of LNG Plant

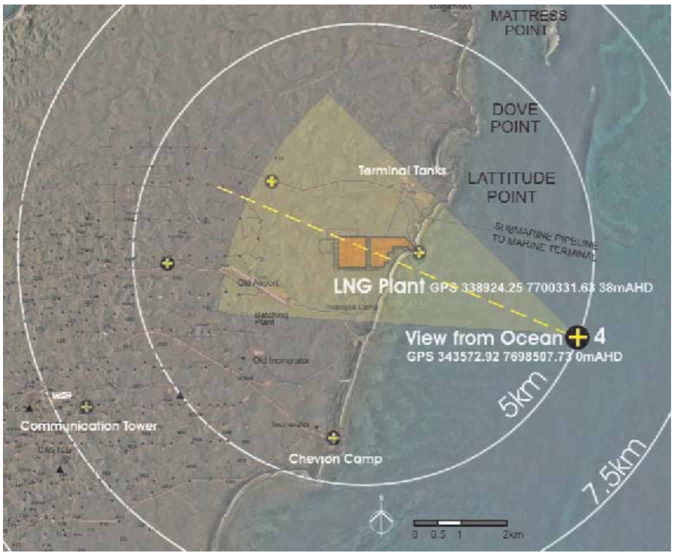


Figure 3.12 – Viewpoint 4

The view is looking west from 5km east of the proposed LNG Plant.

This viewpoint was chosen to account for the view while approaching the development site within a water vessel.

Figure 3.13 – Simulation of LNG Plant at completion of works from Viewpoint 4 – Ocean View at 5km east of LNG Plant. View at left of figure shows extent of Ship Gas Loading facility.

From this viewpoint the LNG Plant has a moderate to substantial visual impact and the view indicates how the LNG Plant and Port Facilities form a recognisable new element within the landscape.

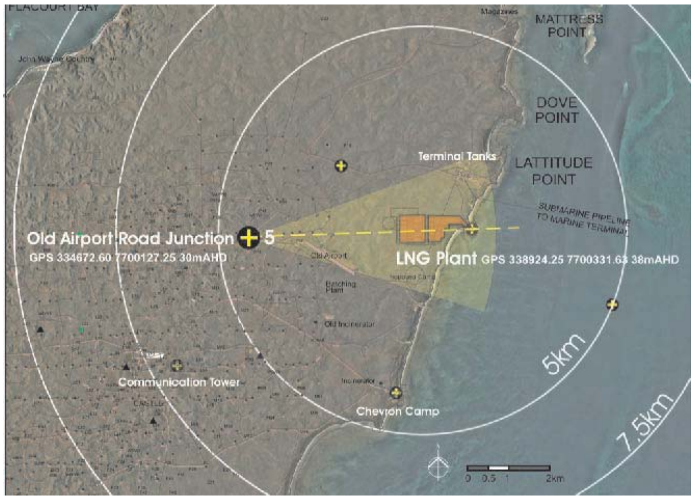


Figure 3.14 – Viewpoint 5

This view is looking due east from a major road junction 1.5km west of the old Airport and 4.9km due west of the Proposed LNG Plant site.

Figure 3.15 – Simulation of LNG Plant at completion of works from Viewpoint 5 – Road Junction, Old Airport

This viewpoint was chosen to illustrate one of the few visible views beyond the development sites low-lying, drainage flat landscape. The junction is situated in a shallow east west valley that aligns, when looking east, with the proposed Plant site.

From this viewpoint the Plant bulk is partially hidden due to a ridgeline however the development dominates the skyline and is seen to have a substantial change to the natural landscape.

Viewpoint 6 – Passenger Terminal, New Airport

This viewpoint was chosen to illustrate the only ground view passengers would

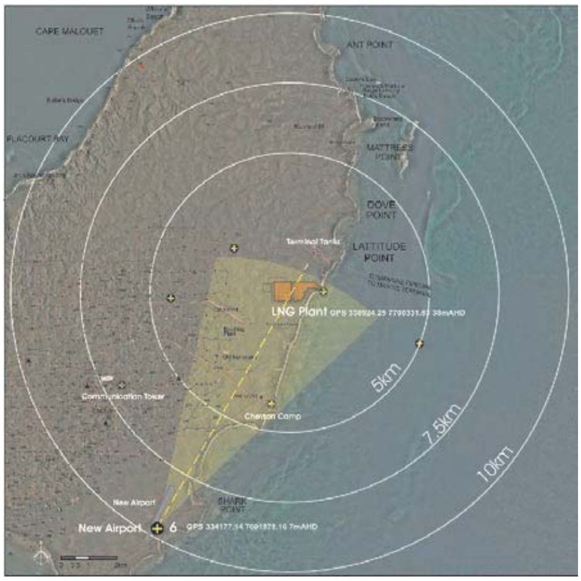


Figure 3.16 – Viewpoint 5

Figure 3.17 – This view is looking north north-east from the New Airport passenger terminal at Barrow Island 9.7km south west of the of the Proposed LNG Plant site.

have of the development site. From this viewpoint the bulk of the development sits behind the helicopter hanger and the flare is the only structure that can be faintly seen. The bulk of the plant sits below a ridgeline and structures that sit above form, from this distance, part of the landform.

The visual impact of the development from the New Airport passenger terminal would be described as negligible to none.

Viewpoint 7 – Ridgeline West of Terminal Tanks

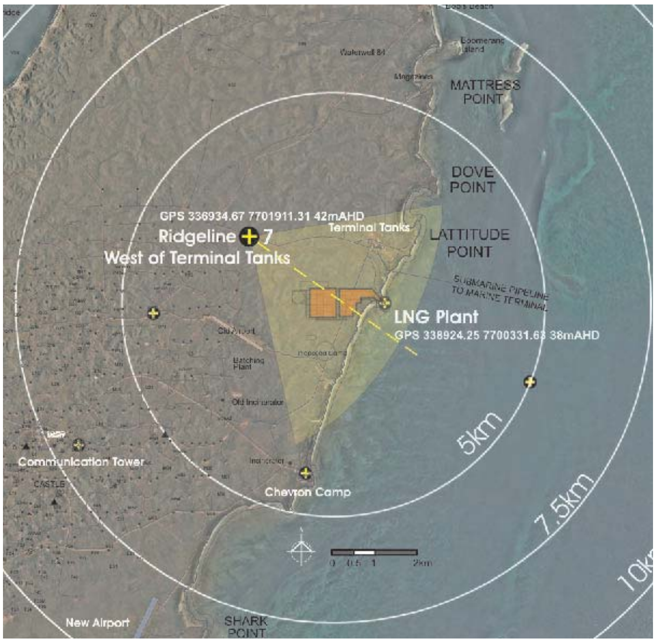


Figure 3.18 – Viewpoint 7

This view is looking south east from a main road that leads west from the existing Terminal Tanks. This view is from the highest point of the ridgeline that surrounds the development site. It is situated 3km west of the Terminal Tanks and 2.5km north west of the development site.

Figure 3.19 – Simulation of LNG Plant at completion of works from Viewpoint 7 – Ridgeline West of Terminal Tanks

This viewpoint was chosen to illustrate a worse case scenario of the highest and closest point that a worker will view the entire development.

From this viewpoint the Plant bulk is totally exposed and the development will dominate the landscape and skyline. Within this broad flat and surrounding ridgeline the development is seen to have a substantial change to the natural landscape.

Flare and Illumination

Foreground active activity is more prominent.

Bench marking 5 – 9km integrate with the landscape

The emergency flare stack of the gas plant is 150 metres in height and has an internal diameter of 0.5m. It is proposed for emergency discharges only, which will be of short duration and infrequent occurrence. The emergency flare will normally operate a pilot flame only, automatically igniting when required for pressure relief. If an emergency situation arises and the flare needs to be used the flame of the flare will extend approximately 30-40 metres above the top of the stack.

The flare will be visible from long distances. However due to the relative infrequency (due to the design of the plants shutdown system) of the purge, the visual impacts are not considered significant.

The lighting of this facility would be designed to ensure that light levels are minimal required for safety and plant operations. Plant and Port Facility lighting will be visible from adjacent ridgelines and roads' where vegetation and topography does not screen or filter views.

Quantitative Assessment – LNG Plant Site

The following Table 3.2 following page show the distances to the proposed gas plant from nominated viewpoints. Also measured are the developments horizontal and vertical line of sight angles (vertical bulk height of 20m). Further described is the likely visibility of the ancillary lighting at night.

Table 3.2 - Distances and viewing angles from identified viewpoints to Centre of Proposed LNG Plant **Note: LNG Plant Site Centre GPS 338924.24 – 7700331.63 38m AHD**

VIEWPOINTS	Distance to gas plant	Horizontal angle of view	Potential impact	Vertical angle of view	Potential impact	Night time Lighting
1. Chevron Camp GPS 338279.14 – 7696349.70 14m AHD	4033m	14°	Potentially noticeable	0.3°	Insignificant	Noticeable glow
Town Point GPS 340135.28 – 7700363.75 7m AHD	1100m	40°	Potentially visually dominant	1.5°	Potentially noticeable	Glow in foreground
Coms. Tower GPS 332915.67 – 7697016.04 64m AHD	6862m	6°	Potentially visually dominant	0.24°	Insignificant	Dull glow in distance
Ocean View GPS 343572.92 – 7698507.73 2m AHD	4993m	10°	Potentially visually dominant	0.5°	Potentially noticeable	Noticeable glow
Old Airport GPS 334672.60 – 7700127.25 30m AHD	4256m	26°	Potentially noticeable	0.11°	Insignificant	Noticeable glow
New Airport GPS 334177.14 – 7691878.16 7m AHD	9695m	5°	Insignificant Disregarding view screened by helicopter hanger	0.02°	Insignificant Disregarding view screened by helicopter hanger	Dull glow in distance
Ridgeline GPS 336934.67 – 7701911.31 7m AHD	2540m	40°	Potentially visually dominant	0.5°	Potentially noticeable	Glow in foreground

The quantitative assessment recognises that isolated structures within the gas plant exceed 20m, however their dimensions are such that their narrow columnar appearance will not provide a significant visual impact when viewed at a distance providing the remaining structure is hidden from view. The visual impacts are further tested as part of the qualitative assessment and simulations.

4 Conclusion

4.1 Pipeline Corridor - Shoreline Crossings

The **Visual Impact** of the alternative shoreline crossings at 'North White's Beach' and 'Flacourt Bay' are considered as none to negligible due to their underground construction and works temporary nature.

Reinstatement of sand, soil, exposed rock and vegetation, as soon as practicable will prevent long-term visual impacts. Refer to chapter 3.4 on Visual Mitigation and rehabilitation for recommended reinstatement procedures.

Onshore Pipeline Corridor(s)

The construction and form of the proposed pipeline easements for Barrow Island will have similar visual implications for all landscape character units with the exception of the underground shoreline crossings. The visual impacts can be summarised as follows:

- When viewed, a long lineal form that will contrast with natural environment;
- Visual gaps in landscape from removal of vegetation and soil;
- Colour change in soil profile disturbance; and
- Additional access roads.

Achieving the following will reduce visual impact for all the proposed pipeline easements on Barrow Island and the Mainland:

- Limiting the removal of vegetation within the pipeline easement;
- Limiting duration of disturbance;
- Replacing disturbed areas as soon as practicable with local direct topsoil replacement;
- Replacing disturbed soil and rock back to existing soil profile;
- Limiting construction access roads;
- Aligning pipeline corridors adjacent and as close to existing road easements as practicable; and
- When a pipeline corridor is not adjacent to road easement designing the pipeline to fit into the topography of the landscape where practicable.

LNG Plant Site

The siting of the LNG Plant has the potential to significantly alter the landscape character without appropriate siting and mitigation treatment applied.

The visual assessment recognises that the regional landscape character surrounding the proposed LNG Plant has the greatest **Landscape Absorptive Capability** ability to incorporate the visual impact of this type of infrastructure.

The **Visual Amenity** of the proposed LNG Plant site adjacent Town Point would be considered negligible to human visual perception and significance.

However, according to the viewers position within the LNG Plant's viewshed the **Visual Impact** ranges from negligible to substantial as the development bulk height is screened from most of Barrow Island by surrounding ridgelines and its tactical positioning within a low-lying landscape.

Visual Impact Mitigation

Given the lack of substantial indigenous vegetation and inappropriate within this landscape character to use exotic species, the visual impact level of the LNG Plant or ancillary and other lighting would not significantly reduce over time.

It is important that the lower infrastructure to 20m (including the temporary construction camp) is coloured not to contrast surrounding spinifex vegetation where practicable and benching slopes (unused roads, benches) are revegetated to blend effectively into the landscape. The extent of vegetation removed is to be minimised and rehabilitation by direct soil placement is to take place as soon as practicable.

Figure 4.1 – Proposed aerial view simulation of LNG Plant at completion of works. View shows LNG Plant & extent of Port Facilities. Chevron Camp can be viewed on the lower right hand corner of the simulation.

5 Appendices

5.1 Methodology

Quantitative Assessment

An analysis of the parameters of human vision makes it possible to establish guidelines for defining the viewshed within which potential visual impacts associated with a development may occur. Within this viewshed it is possible to identify specific locations with potential views to the infrastructure or easement clearing associated with the gas pipeline.

The visual impact of a development can be quantified by reference to the degree of influence on a person's field of vision. The diagrams on the following pages illustrate the typical parameters of human vision. These provide a basis for assessing and interpreting the impact of a development by comparing the extent to which the development would intrude into the central field of vision.

These parameters also allow a comparative analysis of the visual impacts relative to other elements within the landscape such as tall trees.

It should be noted that the quantitative assessment determines the relative scale of a development from a viewpoint. The quantitative assessment assumes that distance is the only modifier of visual impact, and if considered in isolation, does not allow for local landscape characteristics, which may influence the visibility of a development. As such the quantitative assessment should be interpreted in association with the qualitative assessment.

Horizontal Line of Sight

The central field of vision for most people covers an angle of between 50° degrees to 60°. Within this angle, both eyes observe an object simultaneously. This creates a central field of greater magnitude than that possible by each eye separately. This central field of vision is termed the 'binocular field' and within this field images are sharp, depth of perception occurs and colour discrimination is possible.

The visual impact of a development will vary according to the proportion in which a development impacts on the central field of vision. Being evaluation on this measurable parameter allows the rating of potential impact.

These physical parameters are illustrated in Figure A1.1

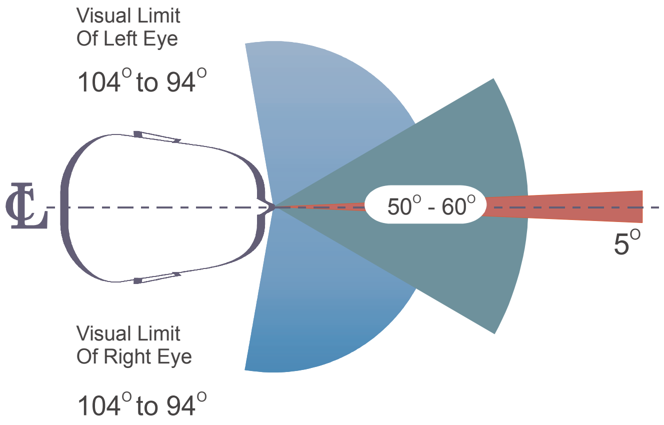


Figure A1.1 Horizontal Field of View

Table A1.1 below list assumptions, which determine whether the impact of a development is:

- Insignificant;
- Potentially noticeable; or
- Potentially visually dominant.

Once potential visual impacts are rated one may direct remedial action to those viewpoints that are most impacted.

Horizontal Field of View	***Impact***
<5° of view	Insignificant The development will take up less than 5 percent of the central field of view. The development, unless particularly conspicuous against the background, will not intrude significantly into the view. The extent of the vertical angle will also affect the visual impact.
5° – 30° of view	Potentially noticeable The development may be noticeable and its degree of visual intrusion will depend greatly on its ability to blend in with its surroundings.
>30° of view	Potentially visually dominant Developments that fill more than 30 percent of the central field of vision will always be noticed and only sympathetic treatments will mitigate visual effects.

Table A1.1 Impact within the horizontal field of view

Vertical Line of Sight

A similar analysis can be undertaken based upon the vertical line of sight for human vision.

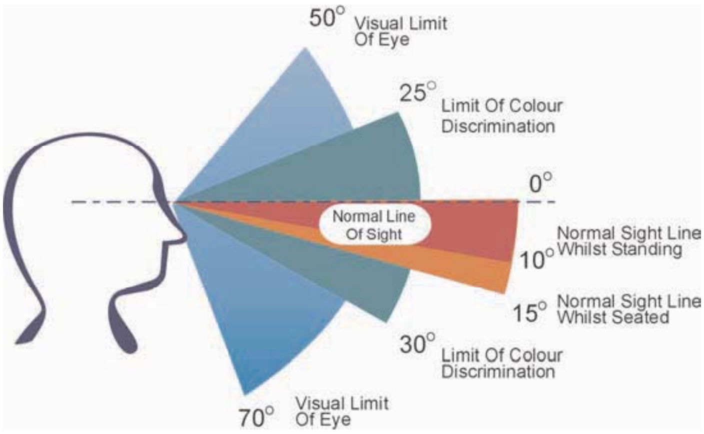


Figure A1.2 Vertical Line of Sight

As can be seen in Figure A1.2, the typical line of sight is considered to be horizontal or 0°. A person's natural or normal line of sight is below the horizontal. It varies slightly from person to person and depends on whether they are standing or sitting. If standing, the normal line of sight is approximately 10° below the horizontal and if sitting, approximately 15°

This situation is similar when looking across a disturbed landscape. Objects, which take up a small proportion of the vertical field of view, are visible when one focuses on them directly. However, they are not dominant, nor do they create a significant change to the existing environment when short objects are placed within a landscape.

Table A1.2 Shows the relationship between the impact and the proportion that the development occupies within the vertical line of sight.

Vertical Line of Sight	Impact
<0.5° of vertical angle	Insignificant A thin line in the landscape.
0.5° – 2.5° of vertical angle	Potentially noticeable The degree of visual intrusion will depend on the development's ability to blend in with the surroundings.
>2.5° of vertical angle	Visually evident Usually visible, however the degree of visual intrusion will depend of the width of the object and its placement within the landscape.

Table A1.2 Impact within the Vertical Line of Sight

Qualitative Assessment

The qualitative analysis is achieved by observation, description of existing conditions (supported by simulations, photographs, sketches etc.) and interpretation of the changes to the landscape associated with the proposed development

Computer Simulations

Computer imagery makes it possible to accurately simulate the visual changes associated with the proposed development. The visual modelling process enables people to observe the typical changes to the landscape associated with the construction of the proposed gas pipeline from particular viewpoints at the completion of construction and once mitigation measures such as trees have established.

- Photographs were taken from the selected viewpoints towards the proposed corridor, using a 50mm lens to most accurately simulate the human eye. GIS Co-ordinates (satellite positioning) were recorded to determine the location at which the photographs were taken;

- 3-D models were constructed of the infrastructure to accurately represent their form in terms of height and construction;

- A 3-D, wire frame model of the terrain was then created from digital contour information. The 3-D models of the infrastructure were accurately positioned within this terrain model, again using GIS Co-ordinates to determine their location and height;

- Cameras were created within the 3-D model to simulate the camera used on site. The simulated camera view was then overlayed onto the original photos;

- The visual modelling software then rendered the proposed alignment over the scanned site photo to demonstrate how the infrastructure would appear along the corridor;

- Photo-montaging techniques were utilised to modify the final view to represent proposed view in its' altered condition

The accuracy of simulations is dependent on the available base information and may be subject to change during the development of the project.

In the first instance, the digital wire frame simulation is overlaid on the photograph to demonstrate the accuracy of the modelling process. By relating the 3-D contours with the terrain and landscape features within the photograph, it is possible to accurately position the infrastructure in the landscape. The pipeline alignment and infrastructure are clearly identified in yellow so that they clearly stand out from the landscape.

The final visual simulation is intended to accurately reflect the colours and form of the gas plant or associated infrastructure and easement clearing.

Interpretation

The existing landscape character plays an important role in determining the impact of a proposed development. The background setting and surrounding natural/built environment can help to absorb changes brought about by developments such as linear infrastructure developments. Alternatively, a development may contrast significantly with the existing environment making its integration more difficult.

There are four major elements of landscape character, which affect the extent to which the proposed developments impact on a landscape. These are:

- Vegetation cover;
- Topography;
- Degree of human modification to 'the natural' landscape and dominance of man made elements; and
- Distance

Vegetation Cover

The height and density of vegetation can contribute to the visual quality of the landscape. However the removal of vegetation to accommodate infrastructure in the Barrow Island Landscape presents a significant change to the landscape character by exposing the contrasting red soils and in some cases contrasting unexposed rock that is deeper in colour to the sun bleached extracted rock. The visual impact is relative to the significance of the viewpoints.

Topography

Topography can play an important role in determining the visibility of a development within the landscape, depending on elevation of viewpoints and their relationship with the proposed development, and surrounding vegetation and structures.

Flat Landscapes

Changes in the vertical field of view may not be apparent within flat landscapes if foreground vegetation screens views. If views are not screened, vertical development above the scale of the surrounding landscape becomes very apparent from longerdistances.

Undulating Landscapes

Landscapes with topographical variations have greater capacity to partially screen views to a development, however, this is largely dependent on the viewing location. At lower elevations topography may help to screen foreground views, whereas at higher elevations views may be exposed.

Degree of Human Modification

The potential impact of the proposed pipeline easement and associated infrastructure is less when man modifies the surrounding landscape. Viewers perceive the first change to a natural landscape with greater sensitivity than subsequent changes.

Distance

As distance increases, the impacts associated with development decrease due to the relative reduction in scale. As the scale of a development reduces, the capacity for screening is increased.

Sensitive Viewpoints

The location and frequency of viewing are important considerations when assessing visual impact. As the Barrow Island Visual Assessment is unique due to the lack of sensitive human receptors visual impact within the context of this study, will be assessed from a number of viewpoints that are considered important to represent the potential changes in the landscape character. These viewpoints are from:

- the Chevron Camp site;
- Town Point;
- The base of the Communication Tower highest land point located centrally on the Island;
- from 5km offshore looking towards the LNG Plant site;
- A main road junction directly west of the development site;
- The new Airport, in regard to passengers passing through; and
- Worst case scenario of highest closest point to view whole of construction (Ridgeline directly west of Terminal Tanks.

Major, Secondary Roads and Access Tracks

In regard to the Barrow Island, workers alone will be viewing changes to the landscape from roads. Roads themselves are part of man-modified landscapes.

Generally, the visual impact of easement clearing and infrastructure construction on motorists varies according to distance and surrounding landscape character. In vegetated areas, changes to the landscape resulting from easement clearing or construction works may be seen for only a short period in the context of a journey. Therefore vegetated areas easement clearing is preferable at right angles to existing roads, as the view along the easement may be visible for only a very short period.

When easement clearing occurs adjacent to the road edge, the change to the landscape character is more apparent for longer periods to the motorist.

However in the Barrow Island context, as stated earlier, this structure will be inspected and viewed by gas and oil workers, a pipeline easement that becomes part of the road easement would be in this scenario viewed in favour of an easement cutting through the natural landscape.

Easement clearing can be viewed at a further distance on Barrow Island due to the to low and sparse vegetation habit and as noted with the existing seismic lines.

Visual Impact Definitions

Table A1.3 explains the visual impact definitions used within this study.

Visual Impact	Definition
None	No part of the development, or work or activity associate with it, is discernible.
Negligible	Only a very small part of the proposals is discernible and/or they are at such a distance that they are scarcely appreciated, Consequently they have very little effect on the scene.
Slight	The proposals constitute only a minor component of the wider view, which might be missed by the casual observer or receptor. Awareness of the proposals would not have a marked effect on the overall quality of the scene.
Moderate	The proposal may form a visible and recognisable new element within the overall scene and may be readily noticed by the observer or receptor.
Substantial	The proposals form a significant and immediately apparent part of the scene that affects and changes its overall character.
Severe	The proposals become the dominant feature of the scene to which other elements become subordinate and they significantly affect and change its character.

Table A1.3 Visual Impact Definitions

Note: That these definitions can apply to either existing or proposed situation and that visual impacts need not be necessary detrimental. For example, a proposed prominent group of trees might have a 'substantial' impact, however the effect on the landscape and views would be beneficial.

Landscape Visual Assessment - Glossary

Analysis	(Landscape) The process of breaking the landscape down into its component parts to understand how it is made up.
Assessment	(Landscape) An umbrella term for description, classification and analysis for landscape.
Enhancement	Landscape improvement through restoration, reconstruction or creation.
Environment	Our physical surroundings including air, water and land.
Landform	Combinations of slope and elevation that produce the shape landform of the land.
Landscape	Human perception of the land conditioned by knowledge and identity with a place.
L. absorptive capacity	The degree to which a particular landscape character type or area is able to accommodate change without unacceptable adverse affects on its character. Capacity is likely to vary according to the type and nature of change being proposed.
Landscape character	The distinct and recognisable pattern of elements that occur consistently in a particular type of landscape, and how this is perceived by people. It reflects particular combinations of geology, landform, soils, vegetation, land use and human settlement. It creates the particular sense of place of different areas of the landscape.
L. character type	A landscape type will have broadly similar patterns of geology, landform, sols, vegetation, land use , settlement and field pattern discernible in maps and field survey records.
Landscape effects	Change in the elements, characteristics, character and qualities of the landscape as a result of development. These effects can be positive or negative.
Landscape perception	The psychology of seeing and possibly attaching value and/or meaning to landscape.
Landscape sensitivity	The extent to which a landscape can accept change of a particular type and scale without unacceptable adverse effects on its character.
Landscape value	The relative value or importance attached to a landscape which expresses national or local consensus, because of its quality, special qualities

	including perceptual aspects such as scenic beauty, tranquillity or wildness, cultural associations other conservation issues.
Receptor	Special interest of viewer group that will experience the landscape effect.
Sense of place	The essential character or spirit of an area. The *genius loci* meaning the spirit of a place.
Visual amenity	The value of the landscape character, a particular area in terms of what is seen.
Visual effect	Change in appearance of the landscape as a result of development. This can be positive(ie. beneficial, improvement) or negative (ie. adverse or a detraction).
Visual impact	The measure of visual effect in the landscape being quantitative or qualitatively assessed.
Visual Mitigation	Measure, including any process, activity or design to avoid, reduce remedy or compensate for adverse landscape and visual effects of a development project.
Viewshed	Extent of potential visibility to or from a specific area or feature.
Methodology	The specific approach and techniques used for a given study.

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Technical Appendix E3

Public Risk Assessment

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CHEVRONTEXACO

GORGON DEVELOPMENT

PUBLIC RISK ASSESSMENT TECHNICAL APPENDIX: E3

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REVISION RECORD

Rev	Date	Description	Prepared	Reviewed	Approved
0	8/07/04	Issued to client	S Robertson	K Cheney	K Berry
1	29/09/04	Aircraft Hazard included	S Robertson	G Penno	K Berry
2	09/11/04	BOD Rev 1 incorporated	S Robertson	G Penno	K Berry
Title	**CHEVRONTEXACO AUSTRALIA, GORGON DEVELOPMENT, PUBLIC RISK ASSESSMENT**		**QA Verified**	M Grosvenor	

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ABBREVIATIONS

^oC	degrees Celsius
^0F	degrees Fahrenheit
/kmy	per kilometre year
AGRU	Acid Gas Removal Unit
aMDEA	Activated Methyldiethanolamine
APCI	Air Products and Chemicals Inc
AS	Australian Standards
bara	bar atmosphere
barg	bar gauge
BLEVE	Boiling Liquid Expanding Vapour Explosion
CASA	Civil Aviation Safety Authority
C3MR	Propane Mixed Refrigerant
CO_2	Carbon Dioxide
CS1	Compressor Station 1
CVX	ChevronTexaco
Dom Gas	Domestic Gas
EIS/ERMP	Environmental Impact Statement/Environmental Review and Management Programme
EPA	Environmental Protection Authority
ERS	Environmental Risk Solutions
FEED	Front End Engineering Design
GRE	Glass Reinforced Epoxy
GV	Gorgon Venture
H_2S	Hydrogen Sulphide
HAT	Highest Astronomical Tide
Hg	mercury
HHV	High Heating Value
HP	High Pressure
HW	High Water
ID	inside diameter
kg/s	kilograms per second
km	kilometre
KP	Kilometre Point
Kv	Kilovolt
LAT	Lowest Astronomical Tide
LNG	Liquefied Natural Gas
LOC	Loss of Containment
LP	Low Pressure
m^3	cubic metres
m^3/h	cubic metres per hour

m	meter
mm	millimetre
MCHE	Main Cryogenic Heat Exchanger
MEG	Monoethylene glycol
MOF	Materials Offloading Facility
MR	mixed refrigerant
MTPA	million tonnes per annum
MW	megawatt
NSW	New South Wales
NWS	North West Shelf
pa	Per annum
PJ/a	Peta-joule per annum
QRA	Quantitative Risk Assessment
R1	Rural Land Use
STP	Standard Temperature and Pressure
T1	Suburban
T2	High Rise
t	tonnes
TEG	triethylene glycol
TJ	terrajoule
TJ/d	terrajoules per day
T/T	tangent to tangent
v	volts
WA	Western Australia
WAPET	Western Australian Petroleum
wt	weight
y	year

1. SUMMARY

The Gorgon Venture (GV) proposes to construct and operate a number of pipelines and onshore gas plant as part of the Gorgon Development which is located off North Western Australia. A gas processing facility (i.e. a Liquefied Natural Gas Plant) (LNG) of two trains each with a nominal capacity of five million tonnes per annum (MTPA) and Domestic Gas (Dom Gas) plant) with a 60PJ/a to 100PJ/a capacity, located on the central-east coast of Barrow Island would process the gas. Reservoir carbon dioxide would be removed and re-injected into deep saline reservoirs beneath the island. The liquid hydrocarbon product would then be transported by ship to international markets. Compressed domestic gas would be delivered via a sub-sea pipeline to the Western Australian mainland for use in the industrial and domestic gas markets.

The scope of this study includes the five pipelines and the onshore plant facilities for the Gorgon Development. The pipelines include:

- Sub–sea flow lines from well clusters via four manifolds and Export Flowline to onshore facilities on Barrow Island
- LNG Export Pipeline from LNG tanks to ship loading facility
- Condensate Export Pipeline from condensate storage tanks to existing crude export loading line
- Carbon Dioxide Pipeline for the re-injection of carbon dioxide from the on-shore plant to north end of Barrow Island
- Domestic Gas (Dom Gas) Export Pipeline from the Barrow Island onshore plant to Compressor Station 1 (CS1) which is located on the mainland.

The plant, located on Barrow Island, consists of:

LNG

- Inlet Separator
- Acid Gas Removal
- Carbon Dioxide Reinjection
- Dehydration and Mercury Removal
- Liquefication
- Condensate Handling
- Storage

Domestic Gas

- Acid Gas Removal
- Carbon Dioxide Reinjection
- Dehydration
- Compression

The scope of the study is to determine the level of offsite risk to human life that would be imposed on surrounding environs of the proposed Gorgon Development Barrow Island

plant. It is recognised that at this early stage of the Gorgon Development, the plant's detailed design has not been undertaken. Therefore the risk assessment will reflect the current design stage. No consideration is given to pipeline ancillaries such as compressor stations, valve pits and branch/lateral lines it is considered unwarranted at this stage of an Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP).

The risk assessment aims to:

- demonstrate that the offsite risks resulting from the Gorgon Development Onshore Plant are tolerable and meet the EPA criteria for industrial developments (Reference 2); and
- assess the risks and identify the safeguards associated with the operation of the proposed pipelines for the Gorgon Development. The focus of this study is on public risk and assessment of the level of risk to the public will be made against the criteria provided by AS2885 and EPA Public Risk Criteria (References 15 and 3 respectively).

The methodology used in this study is outlined in the NSW Department of Planning's Hazardous Industry Planning Advisory Paper No.6 (Reference 7), which is a classical risk assessment, a systematic approach to the analysis of what can go wrong in hazardous industrial facilities. This approach is consistent with that provided in AS4360 (Reference 1).

One approach to establish the likelihood of a hazardous event occuring is to review generic data that is published in the public domain in various data bases. One such data base is the E & P Forum; as reported by CMPT, that provides frequencies for leaks from pipelines and process equipment based largely on UK offshore experience but combined with onshore data where necessary. Therefore it is appropriate for this study to determine applicable frequencies. This data source has been augmented by other publically available documents such as PARLOC which is prepared for the UK Health and Safety Executive. Although it is practicable for the failure cases to be dependant on the major equipment items, other smaller plant items such as pipework, pumps, valves, fittings etc; together with their contribution to offsite risk are excluded. To address this issue, and to ensure that a true representation of the level of offsite risk is determined, a conservative approach of increasing all onshore plant failure case frequencies by a factor of 5 was applied. Jet and pool fires have been assumed to represent wost case off-site effects for the materials of methane and condensate.

The QRA modelling was undertaken using "TNO's Effects 4" and "Riskcurves" packages. The TNO tools are internationally recognised by industry and government authorities, including WA's Department of Industry and Resources.

There have been two methodologies used in undertaking the pipelines risk assessment; AS2885 and QRA. The AS2885 risk assessment was undertaken for:

- Export Flowline – both Flacourt Bay and North White's Beach route options:
- LNG Export Pipeline for both the Jetty and Cryogenic options;
- Condensate Export Pipeline; and
- Dom Gas Pipeline.

The level of risk for the above 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 with or exceeding the controls criteria specified by AS2885 (Reference 15).

The CO_2 Reinjection Pipeline will be located above ground on Barrow Island with little, if any, obstructions to natural ventilation. A release of CO_2 from the worst case scenario of catastrophic failure of the pipeline would not displace the oxygen content within the air to a degree where asphyxiation could occur. Therefore this hazard was not considered further.

The applicable risk criteria as published by the EPA (Reference 6) is the level of individual risk in residential areas of one in a million per year is not exceeded by the pipeline routes. The applicable residential area on Barrow Island are deemed to be the Gorgon Development Construction Village (due to personnel being housed in this village during commissioning and plant start-up) and the existing Chevron Village, both of which are not affected by individual risk levels greater than one in a million per year due to the pipelines.

The results of the risk assessment for the plant are provided in Appendix E as iso-risk contours that reflect the current stage of the plant's design. The one in a million per year individual risk contour extends 150m outside the site's southern boundary. This iso-contour does not encroach on the proposed for the Construction Village with the contour being approximately 250m from the Construction Village. The major risk contributor being the propane and ethane storage vessel BLEVEs and jet fires from plant equipment. Therefore, compliance with the EPA Criteria for residential areas (Reference 2) is expected.

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2. INTRODUCTION

2.1 Background

The Gorgon Venture (GV), the participants being ChevronTexaco Australia, Shell Developments Australia and Exxon Mobil Australia Resources Pty Ltd, proposes to construct and operate an onshore gas plant and a number of pipelines as part of the Gorgon Development which is located off North Western Australia. A gas processing facility (ie a Liquefied Natural Gas (LNG) and Domestic Gas (Dom Gas) plant) located on the central-east coast of Barrow Island would process the gas. Reservoir carbon dioxide would be removed and re-injected into deep saline aquifers beneath the island. The LNG product will then be transported by ship to international markets. Compressed domestic gas would be delivered via a sub-sea pipeline to the Western Australian mainland for use in the industrial and domestic gas markets.

Environmental Risk Solutions Pty Ltd (ERS) has been commissioned to undertake a public risk assessment on the proposed facilities and pipelines as an element of the Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) for the Gorgon Development. This document reports the findings of the risk assessment.

2.2 Study Scope

The scope of this study includes the five pipelines and the onshore plant facilities for the Gorgon Development. The pipelines are:

- Sub–sea flow lines from well clusters via four manifolds and Export Flowline to onshore facilities on Barrow Island
- LNG Export Pipeline from LNG tanks to ship loading facility
- Condensate Export Pipeline from condensate storage tanks to existing crude export loading line
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The plant, located on Barrow Island, consists of:

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- Condensate Handling
- Storage

Domestic Gas

- Acid Gas Removal
- Carbon Dioxide Reinjection
- Dehydration
- Compression

The scope of the study is to determine the level of offsite risk to human life that would be imposed on surrounding environs of the proposed Gorgon Development Barrow Island plant and the level of risk to human life due to the pipeline. It is recognised that at this early stage of the Gorgon Development, the plant's detailed design has not been undertaken. Therefore the risk assessment will reflect the current design stage. No consideration is given to pipeline ancillaries such as compressor stations, valve pits and branch/lateral lines it is considered unwarranted at this stage of an EIS/ERMP.

The risk assessment is to consider the risks due to pipeline and plant operations including storage and unloading of export shipments.

2.3 Objectives

The risk assessment aims to:

- demonstrate that the offsite risks resulting from the Gorgon Development Onshore Plant are tolerable and meet the EPA criteria for industrial developments (Reference 2); and
- assess the risks and identify the safeguards associated with the operation of the proposed pipelines for the Gorgon Development. The focus of this study is on public risk and assessment of the level of risk to the public will be made against the criteria provided by AS2885 and EPA Public Risk Criteria (References 15 and 3 respectively).

3. METHODOLOGY

3.1 General

The methodology used in this study is outlined in the NSW Department of Planning's Hazardous Industry Planning Advisory Paper No.6 (Reference 7), which is a classical risk assessment, a systematic approach to the analysis of what can go wrong in hazardous industrial facilities. This approach is consistent with that provided in AS4360 (Reference 1). The normal conditions of operation of the system are defined and then the following questions asked:

- What accidental events can occur in the system?
- How frequently would each event occur?
- What are the consequences of each event?
- What are the total risks (frequencies x consequences) from the system?
- What is the significance of the calculated risk levels?

These questions correspond to the basic components of a risk assessment. Once a system has been analysed, if the risks are assessed to be too high according to some criteria, the system can be modified in various ways to attempt to reduce the risks to an acceptable level, and the risk levels recalculated. The process may therefore be viewed as iterative, where the design of the system may be changed until it complies with the needs of society. By objectively quantifying the risks from each part of the system, the QRA enables the most effective measures to reduce risks to be identified. Figure 3.1 illustrates all these tasks in the context of QRA methodology.

Figure 3-1 QRA Methodology

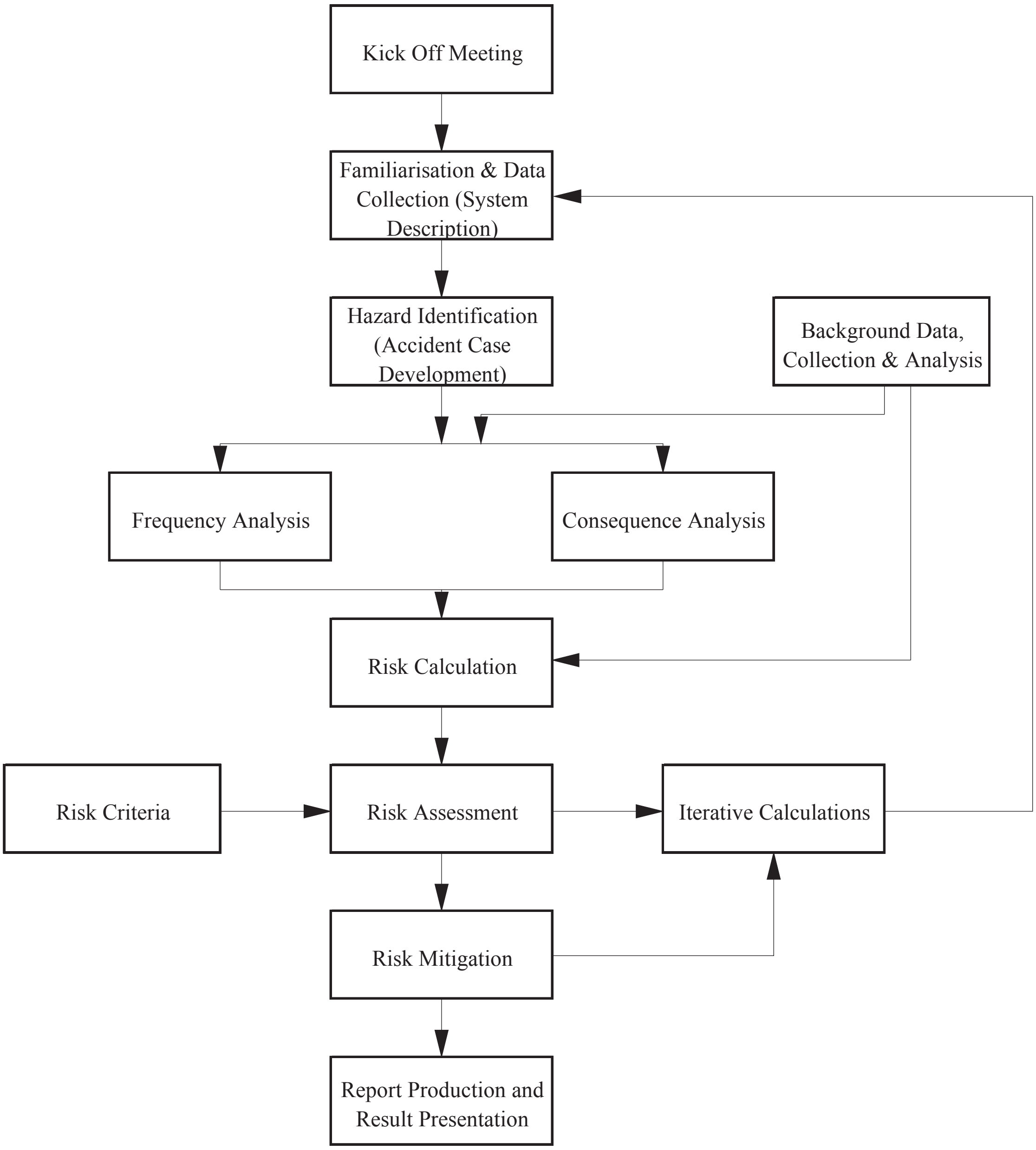


Table 3.1 reproduces the EPA's risk criteria that are detailed in their publication 'Risk Assessment and Management: 'Offsite Individual Risk from Hazardous Industrial Plant No. 2 Interim' (Reference 2).

Table 3-1 WA EPA Individual Fatality Risk Criteria

"a)	A risk level in residential zones of one in a million per year or less, is so small as to be acceptable to the Environmental Protection Authority.
b)	A risk level in "sensitive developments", such as hospitals, schools, child care facilities and aged care housing developments of between one half and one in a million per year is so small as to be acceptable to the Environmental Protection Authority. In the case of risk generators within the grounds of the "sensitive development" necessary for the amenity of the residents, the risk level can exceed the risk level of one half in a million per year up to a maximum of one in a million per year, for areas that are intermittently occupied, such as garden areas and car parks.
c)	Risk levels from industrial facilities should not exceed a target of fifty in a million per year at the site boundary for each individual industry, and the cumulative risk level imposed upon an industry should not exceed a target of one hundred in a million per year.
d)	A risk level for any non-industrial activity located in buffer zones between industrial facilities and residential zones of ten in a million per year or lower, is so small as to be acceptable to the Environmental Protection Authority.
e)	A risk level for commercial developments, including offices, retail centres and showrooms located in buffer zones between industrial facilities and residential zones, of five in a million per year or less, is so small as to be acceptable to the Environmental Protection Authority."

3.2 Pipeline Risk Assessment

The overall purpose of this risk assessment is to determine the level of risk to the public from the external pipelines associated with the Gorgon Development. To this end, two methods of assessment has been used to determine the overall level of risk.

The method in accordance with AS2885 is applicable for hydrocarbon pipelines, i.e.:

- Export Flowline;
- LNG Export Pipeline;
- Condensate Export Pipeline; and
- Dom Gas Export Pipeline.

Details of this method are provided in Section 3.2.1.

All pipelines will be the subject of a QRA whose results will include individual risk contours to address the EPA's Public Risk Criteria (Reference 3). Details of the QRA Methodology are provided in Section 3.1. The results from both risk assessment methodologies have been used to determine if compliance with government authorities' risk criteria is achieved.

3.2.1 AS 2885 Risk Assessment

For hydrocarbon pipelines, public risk and safety has been addressed using the guidance provided by AS2885.1 – 1997 (Reference 15) . The definitions of terms and categorisations used in those documents have been used in this study.

In undertaking this assessment, the following parameters have been considered:

- Location Analysis – the purpose of which is to provide the basis for the identification of the areas that are appropriate to the land use and activities along the pipeline route.
- Threat Analysis which develops a list of threats to the pipeline at each location. It should be noted that not all threats are location specific.
- External Interference Protection provides controls for many of the threats and is a combination of physical and procedural measures.
- Threats prevented by Design and/or Procedures apply to those threats that are not controlled by external interference protection
- Failure Analysis is undertaken for those threats that cannot be controlled by design and/or procedures. Failure analysis determines the potential damage that an identified threat may cause to the pipeline and allow assessment of the consequence.
- Hazard Events use those threats that cannot be effectively controlled by either external interference protection or by design or by appropriate procedure, and which are determined by the failure analysis to result in a loss of integrity. Each hazardous event is carried through to risk evaluation.

The risk assessment methodology provided in AS2885.1 (Reference 15) combines an estimate of the frequency of occurrence of each hazardous event with the estimated severity of the hazardous event to produce a risk class. The relevant tables in AS2885.1 (Reference 1) are reproduced below.

Table 3-2 Frequency of Occurrence for Hazardous Events

Frequency of Occurrence	Description
Frequent	Expected to occur typically once per year or more.
Occasional	Expected to occur several times in the life of the pipeline.
Unlikely	Not likely to occur within the life of the pipeline, but possible.
Remote	Very unlikely to occur within the life of the pipeline.
Improbable	Examples of this type of event have historically occurred, but not anticipated for the pipeline in this location.
Hypothetical	Theoretically possible, but has never occurred on a similar pipeline.

Table 3-3 Typical Severity Classes for Pipelines for use in Risk Matrix

Severity Class	Description
Catastrophic	Applicable only in location classes T1 and T2 where the number of humans within the range of influence of the pipeline would result in many fatalities.
Major	Event causing few fatalities or loss of continuity of supply or major environmental damage.
Severe	Event causing hospitalising injuries or restrictions of supply.
Minor	Event causes no injuries and no loss or restriction of supply.

Note: T1 and T2 refers to the classificationof locations where T1 is Suburban which is areas developed for residential, commercial or industrial use, and T2 is High Rise which is areas as per T1 with the majority of buildings having four or more floors.

Table 3-4 Risk Matrix

	Risk Class			
Frequency of occurrence	**Severity Class**			
	Catastrophic	**Major**	**Severe**	**Minor**
Frequent	H	H	H	I
Occasional	H	H	I	L
Unlikely	H	H	L	L
Remote	H	I	L	L
Improbable	H	I	L	N
Hypothetical	I	L	N	N

Legend: H = High risk, I = Intermediate risk, L = Low risk, N = Negligible

For each hazardous event, the risk class determines the risk management actions that are required (see Table 3.5).

Table 3-5 Risk Management Actions

Risk Class	Action Required
High	Modify the hazardous event, the frequency or the consequence to ensure the risk class is reduced to intermediate or lower.
Intermediate	Repeat the risk identification and risk evaluation processes to verify and, where possible to quantify, the risk estimation. Determine the accuracy and uncertainty of the estimation. Where the risk class is confirmed to be intermediate, modify the hazardous event, the frequency or the consequence to ensure that the risk class is reduced to low or negligible.
Low	Determine the management plan for the hazardous event to prevent occurrence and to monitor changes which could affect the classification.
Negligible	Review at the next review interval.

4. LOCATION DESCRIPTION

4.1 General

The Gas Fields are located approximately 70km north west of Barrow Island in North Western Australia. Barrow Island is approximately north of Onslow. Figure 4.1 provides an indication of the location of the Gorgon Gas Fields and Barrow Island to the North West Australian Mainland. Figure 4.2 provides the general map for Barrow Island.

Petroleum interest in Barrow Island dates back to June 1947 when the first exploration permit was issued The Barrow Island oilfield was originally envisaged to have a 30 year life but as a result of proper reservoir management, the field life is expected to last through until the 2020's.

A strict environmental program, which protects the island's unique flora and fauna, has enabled the petroleum activities to successfully coexist with the island's Class A Nature Reserve status. This successful coexistence is world renowned.

Figure 4-1 Location of Barrow Island from Mainland, Western Australia

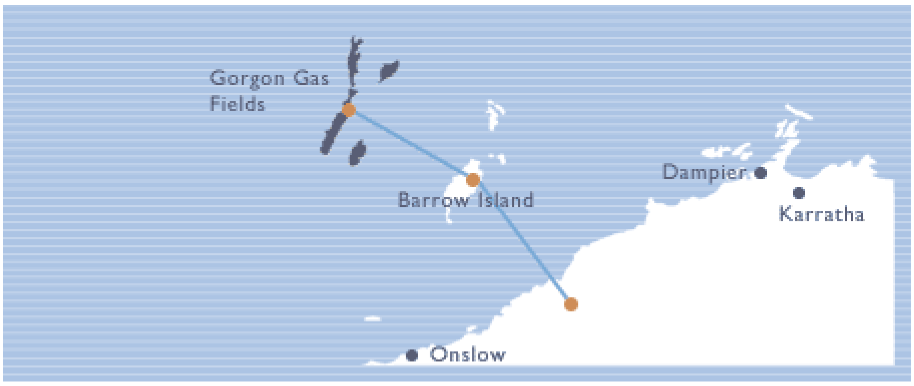


Figure 4-2 Barrow Island

4.2 Climate

4.2.1 General

The sea surrounding Barrow Island provides a moderate influence on the harsh climate generally experienced in the north-west of Australia, characterised by a mild to dry winter (June to August) and a mild to hot summer with cyclonic activity (October to March).

Prevailing summer winds are typically from the south west due to the heat low over the Pilbara region lingering into the night. The normal winter wind patterns are more variable with northerly through easterlies to southerlies predominating. The autumn months of April and May indicate a transitional period, where the winds are more variable in direction and lighter in speed, while the Spring month of September shows a pattern similar to Summer.

4.2.2 Meteorological Conditions

Barrow Island is located in a region considered to have the highest wind risk in Australia (Region D – AS 1170.4) (Reference 10). This is primarily influenced by the occurrence of tropical cyclones in the area, which occur at an average of about twice per year. Maximum wind conditions are tabulated in Table 4.1. Figure 4.3 provides wind roses for Barrow Island.

Table 4-1 Maximum Wind Speeds for Barrow Island

Condition	1 YEAR (non-cyclonic)	50 YEAR (extreme)
3 - second gust	28.6 m/s	68.2 m/s
1 minute mean	24.0 m/s	57.3 m/s
10 - minute mean	20.0 m/s	48.4 m/s

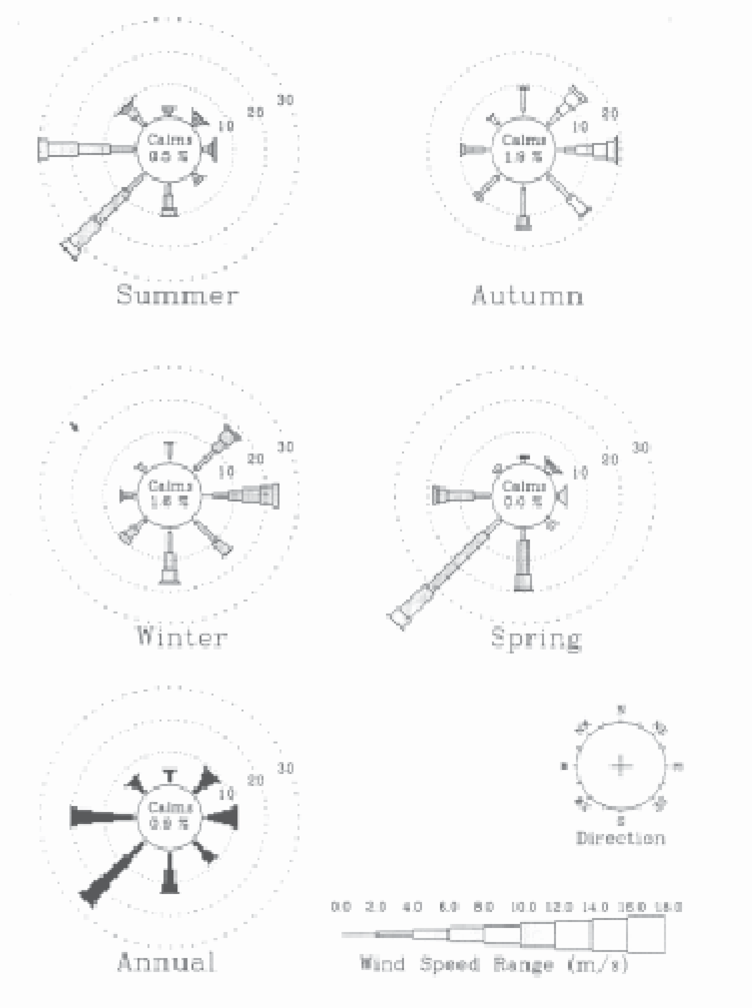
Air temperatures at Barrow Island typically vary between 15.8 °C and 42.0 °C. In 1994, there were 228 days where the temperature rose above 30 °C and 2 days where the temperature rose above 40 °C.

Table 4.2 provides a summary of rainfall and humidity statistics for Barrow Island.

Table 4-2 Rainfall and Humidity Statistics for Barrow Island.

Condition	Value
Rainfall (mm)	
Mean Annual	329 mm
Median Annual	312 mm
Mean Raindays	27 per year
Humidity	
Maximum	100 %
Maximum (monthly average)	72.2 %
Minimum (monthly average)	55.9 %

Figure 4-3 Wind Rose Diagrams for Barrow Island



4.2.3 Oceanographic Conditions

The seawater temperature varied between 19^{0}C and 31^{0}C. Tables 4.3 and 4.4 show the annual minimum, maximum and mean significant swell wave heights and the maximum wave heights and return periods for 2 year non cyclonic return periods and 50 year extreme at the Barrow Island Marine Terminal.

Table 4-3 Significant Swell Wave Heights for Barrow Island.

	Minimum	Maximum	Mean
Swell Wave Height (metres)	0.00	0.29	0.07
Swell Wave Period (seconds)	9.37	19.06	13.44

Table 4-4 Maximum Wave Heights and Return Periods

	Height (m)	Period (sec)
1 year storm	4.7	7.4
50 year storm	11.4	12.9

The highest astronomical tide (HAT) is 3.68m above the lowest astronomical tide (LAT) measured at WAPET landing. The directions of the tidal stream is approximately 245º on flood and 065º on ebb and attains a rate of 1.0 knot during Spring tides.

Due to the shallow water depth (less than 10 m), channelled bathymetry and strong semi diurnal tides, all the current data is dominated by tides and direction is dominated by bathymetry.

4.2.4 Seismic Activity

Barrow Island is located in an area which is considered to have a 10% probability of experiencing an earthquake resulting in ground acceleration in excess of 0.11g (AS 1170.4).

Tsunamis have previously not been considered important for the North West Shelf (NWS) due to the long distance from significant earthquake risk areas and the barrier provided by the NWS. Furthermore, the shallow reef area surrounding the island provides better protection than for other areas on the NWS.

However, recent incidents on the NWS, one involving sudden lateral movement of a moored tanker, have raised the possibility of Tsunami effects also on the NWS. The Bureau of Meteorology is currently managing a research program on Tsunamis in the NWS area.

5. FACILITIES DESCRIPTION

5.1 Pipeline Description

The details of each of the five pipelines are provided in this section.

A Kilometre Point (KP) system has been used to indicate the length of pipelines, and the location of features that may influence the pipelines design or operation. The KPs begin at 0.00 at a point which is 2m hihg water (HW) mark on Barrow Island, and positively increase as the Pipeline traverses offshore. Negative KPs are used for pipelines on Barrow Island. The exception to this is the CO_2 Pipeline which does not have a shore crossing, and therefore, the KP 0.00 is at the isolation valve at the Plant. For the Dom Gas Pipeline, the KP0.00 is defined as a point 2m above the HW mark on Barrow Island, and the KPs increase positively towards the mainland, and onto CS1.

5.1.1 Export Flowline

As the pipeline's identity suggests, this is the export flow line from the subsea wells and manifolds to the on-shore plant facilities located on the east side of Barrow Island.

The flow line consists of two lines, each of an internal diameter of 697 mm, and an outlet pressure of 77 bara. There are two route options for the flow line, i.e.:

- Flacourt Bay; and
- North White's Beach.

The submerged Export Flowline will be designed and constructed in accordance with international standards and the onshore section will be above ground with the line supported on purpose built supports.

The Export Flowline is a gas gathering system that is used for the transport of production fluids and gases from the well heads and manifolds to the onshore plant facilities on Barrow Island.

Option A – Flacourt Bay

A 66km submerged line from the field subsea manifold to Barrow Island with shore crossing at Flacourt Bay. From Flacourt Bay, Export Flowline will traverse in a easterly direction across Barrow Island towards the plant facilities for a distance of 9.2km. At KP13.5, the Export Flowline will cross the existing East Spar pipeline.

The onshore route will be selected to minimise environmental impact by following an existing road where feasible. It includes seven road crossings at KP -2, -3.7, -4, -4.9, -5.7, -6 and –6.3. It is proposed that the Export Flowline will be buried and protected at the seven road crossings.

There are five locations where the Export Flowline crosses ephemeral water crossings at KP -1, -3, -4.2, -5.3 and -6.9. These ephemeral waterways are dependant on large quantities of rainfall, is typical of extreme cyclones.

The route passes 6 existing wells that are within 100 m of the Export Flowline route, and are located at KP -3.1, -4, -4.9, -5.3, -5.7 & -6.4.

The route includes the following crossings, all of which are constructed above ground. It is proposed that the Export Flowline will be protected at these crossings.

- 5 crossings of existing flowlines at KP -3.6, -3.9, -4.6, -6.3, and -6.5;
- 3 crude pipeline crossings at KP-5.9 and -6.6 (known on site as Glass Reinforced Epoxy (GRE) highways) and -8.5 for the Shipping Line; and
- 2 crossings of the 1000 volt (v) also known as 1 Kilovolt (Kv)) cable at KP -5.8 and -6.9.

5.1.1.1 Option B – North White's Beach

From North White's Beach, the Export Flowline will initially traverse in a easterly direction across Barrow Island towards the carbon dioxide re-injection pipeline; will traverse in a southerly direction parallel with the carbon dioxide re-injection pipeline until it is west of the plant facilities; and then traverse in a easterly direction to the plant facilities, again parallel with the carbon dioxide re-injection pipeline. The onshore section is approximately 12.80 km in length.

The route from North White's Beach will be selected to minimise environmental impact by following an existing road where feasible. This route is parallel with the CO_2. Reinjection Pipeline. It includes eight road crossings at KP -0.6, -0.9, -5.1, -6.3, -8.5, -9.1, -10.4 and -10.9. It is proposed that the Export Flowline will be buried and protected at the eight crossings.

There are nine locations where the Export Flowline crosses ephemeral water crossings at KP-2.5, -4.5, -5.2, -6.2, -7.3, -8.3, -8.7, -9.2, and –12.5 These ephemeral waterways are dependant on large quantities of rainfall, is typical of extreme cyclones.

The route passes 3 existing wells that are within 135 m of the Export Flowline route; 2 are located at KP –0.9 and the other at KP-10.4

The route includes the following crossings, all of which are constructed above ground. It is proposed that the Export Flowline will be protected at these crossings.

- 4 crossings of existing flowlines at KP –0.8, -10.2, -10.3, and –10.8;
- 1 crude pipeline crossing at KP-12.2 for the Shipping Line; and
- 2 crossings of the 1Kv cable at KP –10.1 and –10.5.

5.1.2 LNG Export Pipeline

There are two options being considered for the transfer of Liquefied Natural Gas (LNG) from the plant to ship: the Jetty Option and Submerged Cryogenic Pipeline Option. Ship loading will occur approximately every three days, with the day either side of loading being scheduled for ship berthing and other ship activities.

5.1.2.1 Jetty Option

Liquefied natural gas (LNG) from the plant will be transported via a 915 mm diameter pipeline to the LNG ship loading jetty operating at 1.5 bara. The approximate length of this pipeline is 1 km for the onshore section, and 4.2 km for the pipeline running along the jetty.

The onshore route for both options is located within the plant area and there are no crossings of waterways and vehicle access routes.

5.1.2.2 Submerged Cryogenic Pipeline Option

This option consists of 2 x 609 mm internal diameter pipelines operating at 16 bara. The route incorporates a 1 km onshore section, and an 8 km offshore pipeline loop. (i.e. 2 x 8 km)

5.1.3 Condensate Export Pipeline

Condensate recovered from the production wells will be loaded onto ships for export. The loading will be effected by a pipeline that is 508 mm internal diameter and operating at 19 bara. This pipeline will traverse from the plant to the existing Barrow Island Oil Pipeline for product transfer to ship loading.

The new 1.45 km pipeline will be constructed from the storage tank to the load out pump used for current operations. This will connect to the 9.8 km pipeline with 300,000 bbls shipments of condensate scheduled 1 per month with ship loading requiring 24 hours.

The 1.45 km pipeline route between the storage site tank and load out pump is located as follows:

- Within the plant area the pipeline traverses northerly for 300 m from the storage tank and then for 400 m in a easterly directions; and
- From the plant area, the pipeline will traverse 750 m in a north easterly direction towards the existing load out pumps, and will be located within a designated plant area in a pipeline corridor.

Both sections do not cross any vehicle access routes and waterways.

5.1.4 Carbon Dioxide Re-injection Pipeline

Carbon dioxide (CO_2) from the field stripped at the plant will be piped and reinjected into the Dupuy saline reservoir which is located at the north end of Barrow Island. This pipeline will have an operation pressure of 300 bara, and 305 mm internal diameter.

The pipeline route of 19 km has been selected to minimise the impact to the environment and for much of the route, the pipeline follows existing vehicle access ways. The pipeline crosses fourteen ephemeral water crossings at KP 0.6, 0.9, 2.4, 2.7, 3.1, 3.9, 5.9, 6.6, 7.6, 8.7, 9.7, 10.1, 10.6, and 13.9**.** These ephemeral waterways are dependant on large quantities of rainfall that is typical of extreme cyclones.

The pipeline route includes eleven road crossings at KP1.0, 2.7, 3.2, 6.1, 6.4, 10.6, 11.8, 14, 14.6, 15.9, and 16.4. It is proposed that the pipeline will be buried and protected at these crossings.

The route passes 3 existing wells that are within 100 m of the Export Flowline route, and are located at KP 0, 4.4, and 12.

The route includes the following crossings, all of which are constructed above ground. It is proposed that the Export Flowline will be protected at these crossings.

- 4 crossings of existing flowlines at KP 6.3, -15.7, 15.8, and 16.3;
- 1 crude pipeline crossing at KP17.7 for the Shipping Line; and
- 2 crossings of the 1000 volt (v) cable at KP 15.6 and 16.

5.1.5 Dom Gas Export Pipeline

The Dom Gas will be supplied to the Western Australian mainland via a 430 mm internal diameter pipeline. It is envisaged this pipeline will connect to the existing Dampier to Bunbury Natural Gas Pipeline at CS1. The outlet pressure of the pipeline will be 65 bara, and consists of 3 sections:

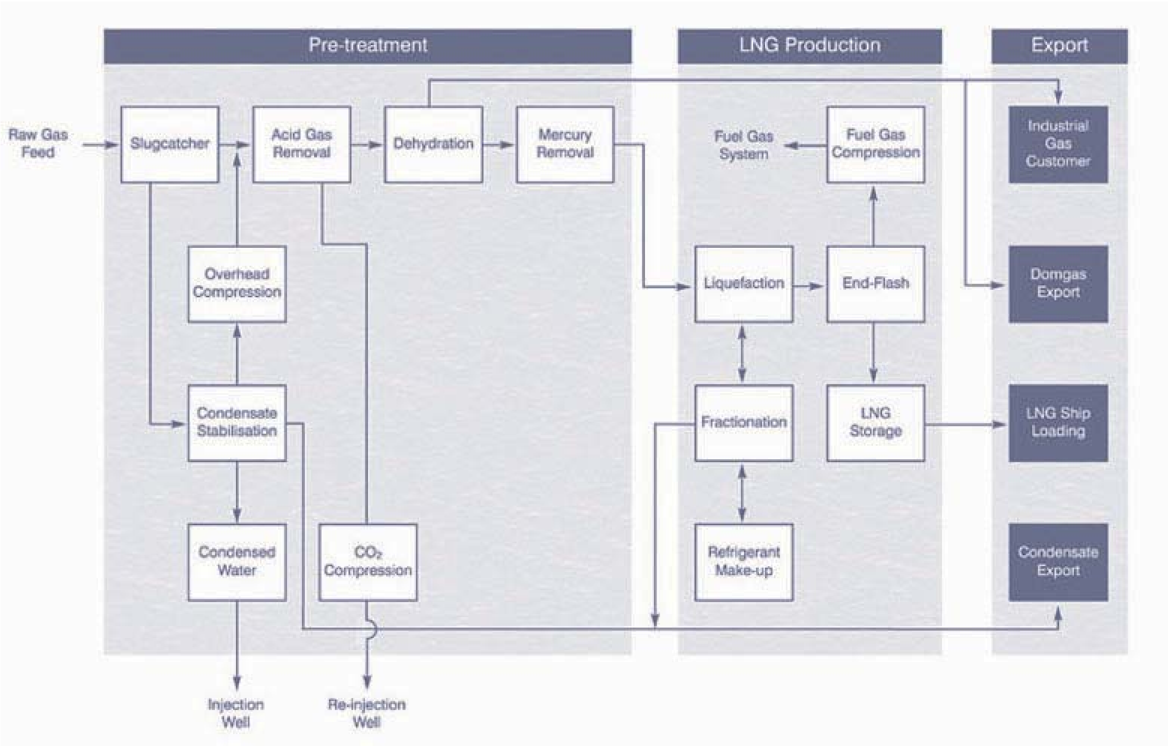
- Barrow Island onshore section where the pipe will run from the Dom Gas Plant for 1.11 km to the shore crossing. This pipeline will be within the plant boundary and there are no crossings with vehicle access routes and waterways;
- A 61.32 km submarine pipeline between Barrow Island and the mainland; and
- A 29.64 km buried pipeline from the mainland shore crossing to CS1. The shore crossing is approx 150 km south west of Karratha and this route will follow the existing gas pipeline operated by Apache Energy, with a 30 m separation distance being established between the two pipelines. This route incorporates the crossing of:
    - a wet land area between KP 61.32 and 72.0 that is typical of the North Western Australian mainland consisting of tidal flats and mangroves;
    - ephemeral water crossing at KP 76.12 ;
    - 3 minor road crossings at KP 76.2, 77.76 and 84.77;
    - an ephemeral water lake is passed between KP 85.15 and 85.34 (note that this is not crossed by the pipeline); and
    - 2 crossings of Seismic Survey Information Lines at KP 73.22 and 74.92.

5.2 Description

5.2.1 Processing Facilities Overview

The facility would separate gas and condensate (light oil) received from the gas fields. After separation from the gas, the condensate will be stabilised prior to shipping to market. The gas component of the stream will then be treated to remove carbon dioxide (CO_2), hydrogen sulfide (H_2S), trace amounts of mercury (Hg) and water vapour. At this point the gas can be either liquefied for export as LNG, compressed and exported as domestic gas (once the domestic gas export pipeline is installed) or utilised as feed gas for other gas processing facilities. An illustration of the process is provided in Figure 5.1.

Figure 5-1 Plant Process Summary



The configuration of the onshore plant in terms of major equipment is summarised in Table 5.1. The following sections provide an overview of the proposed plant.

Table 5-1 Plant Configuration Summary

Area	Train Configuration	Comments
Inlet Separator	1 x 100%	1 x 100% handles Gorgon feed for LNG and Dom Gas production.
Acid Gas Removal Unit (AGRU)	2 x 50%	Size limited by proven amine licensor experience. Each Gorgon absorber handles half of the combined LNG /Dom Gas production.
Liquefaction trains	2 x 50%	5 MTPA each. Includes Dehydration and Hg removal.
LNG Storage Tanks	2 x 50%	135,000 m^3 per tank.

5.2.2 Gas Reception and Liquid Stabilisation

Raw production is received from the Export Flowline by 1 x 100% Inlet Separator approximately 74 barg. There is one separator for each of the 2 Export Flowlines. The overhead vapour from the separator is sent to the Feed Gas Separator; a Knockout drum which protects downstream units from liquid and solids carry-over. Inlet Separator liquids pass to the three phase Stabilisers Feed Separator (6.5 m ID x 32.7 m long) at 25 barg where the aqueous water/MEG phase is separated and sent to MEG recovery. The MEG regeneration and reclamation package is designed for 120 m^3 of rich MEG (40% MEG by wt.) and produces lean MEG (80% by wt.) for reuse. MEG is used in upstream operations to assist in the control of hydrates formation.

The hydrocarbon stream from the three phase Stabiliser Feed Separator is sent to the Stabiliser process. Stabilised condensate (RVP:11 psia at 100 F) is sent to condensate storage.

5.2.3 Acid Gas Removal

Wet gas at 70 barg is passed to 2 x 50% AGRU trains for CO_2 and H_2S removal via the aMDEA process. Each AGRU train contains an amine absorber column (5.5 m ID x 25 m T/T), flash drum (6.1 m ID x 14 m T/T), amine regenerator column (6.8 m ID x 25 T/T) and four shell and tube reboilers. The reboiler duty is 144 MW per train, or 432 MW for the total which represents approximately 80% of the heating medium load for the plant. All of the AGRU sweetened gas is recombined before being split again to feed the 2 x 4.88 MTPA LNG trains.

5.2.4 CO2 Reinjection

The wet CO_2 from the AGRU trains is compressed to 45 barg, dehydrated by TEG, further compressed to approximately 135 barg, cooled, then compressed supercritically to 300 barg and exported to the reinjection wells. This unit comprises of 2 x 50% compression/dehydration trains and a single 100% accumulator/supercritical liquid pump set. Each 37 MW compressor operates on a single shaft, has four stages and a fixed speed electric motor driver. The interstage pressures, export pressure and pipeline size are to be optimised during FEED. The CO_2 will be reinjected down several wells in the Dupuy reservoir. The wells are to be located in the north of Barrow Island, approximately 15 km from the LNG Plant.

5.2.5 Dehydration and Mercury Removal

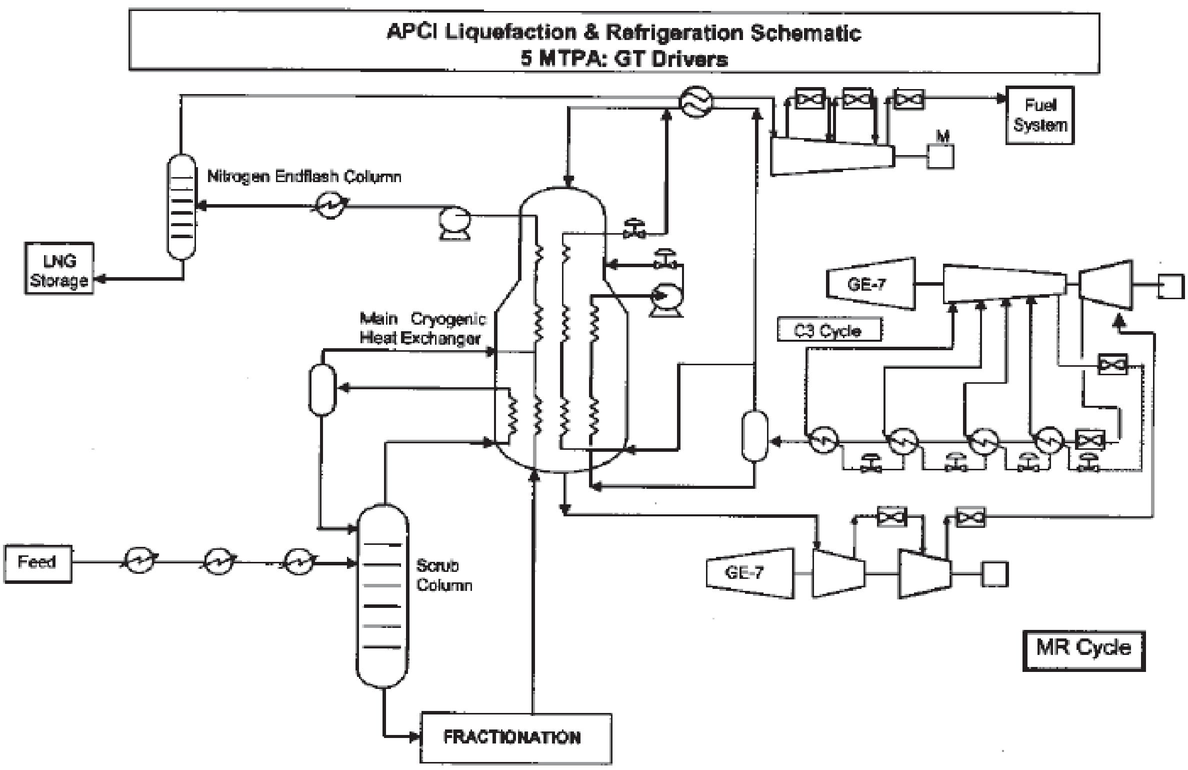
Prior to entering the liquefaction trains, the process gas is dried by 3 x 50% mole sieve vessels (each, 4m ID x 5.5 m T/T). Regeneration of the mole sieve beds is a batch process. Typically, two of the vessels are in service while the 3rd vessel is being regenerated. The mole sieve material is regenerated at approximately 55 barg and 290^0C by heated dry gas from downstream of the mercury removal beds. Regeneration gas is heated by waste heat from the refrigerant compressor gas turbine drivers. The spent regeneration gas is recompressed and recycled to the onshore plant inlet feed stream. The dry gas is passed through 2 x 50% mercury absorbers (3.5 m ID x 4.2 m T/T) to remove mercury.

5.2.6 Liquefaction

Each 5 MTPA liquefaction train is based on "Split C3MR APCI technology (See Figure 5.1 of the APCI train configuration). The design is based on achieving the desired cooling and liquefaction of natural gas with two refrigerant circuits, propane and mixed refrigerant. The summary is as follows:

- The feed gas from the mercury absorbers is cooled by the propane refrigerant to minus 34^{o}C and passed to the scrubber column (4.3m ID x 20m T/T) at approximately 67 barg.
- Recovered liquids from the scrub column are sent to fractionation.
- Overhead gas from the scrub column is further cooled to minus 148^{0}C and partially condensed in the Main Cryogenic Heat Exchanger (MCHE) (4.6m ID x 54m high).
- 3 mol% nitrogen in the LNG is removed in the nitrogen endflash column (4.3 ID x 15m T/T)
- Final condensation and chilling is achieved by the liquids expander and nitrogen endflash. LNG leaves the bottom of the nitrogen column at minus 158^{o}C and 1.3 barg. Rundown pumps repressurize the stream to 6.3 barg to move the LNG to the storage tanks.
- Endflash gas is recompressed and used for HP fuel gas.

Figure 5-2 APCI 5 MTPA Refrigeration Cycle



Pre-cooling duty and cooling of mixed refrigerant is provided by the propane circuit which consists of a 4 stage, single casing compressor and 10 propane kettles operating at 2 to 17.6 barg and down to -36 ^{o}C. The propane refrigerant compressor flowrate is 2.1 million kg/hr of propane. Major equipment in the propane circuit includes the propane condender (aircooler, 173 MW, 15.5 m x 203 m long) and LLP Propane suction drum (7.4 m ID x 9.8 m T/T).

The Mixed Refrigerant (MR) circuit is a 3-casing compressor, LP, MP and HP, over cover 5 to 65 barg and down to -160 ^{o}C. 1.2 million kg/hr of MR is circulate through the compressors and the MCHE. Major equipment includes the MP MR suction drum (7.8 m ID x 9.8 m T/T). The LP MR suction drum (6.5 ID x 8.7 m T/T) has been sized with vane pack internals. Without internals the calculated diameter required exceeds current manufacturing limits of 8 m (24ft).

The MR and propance compressor drivers in each train will be Frame 7 gas turbines configured as follows (refer to Figure 5.2).

All LPGs extracted by fractionation will be injected back into the condensate except as required to supply make-up refrigerant. Due to the low LPG content of inlet gas it is not economically attractive to store and sell LPGs separately. LPG fractionation includes a deethaniser, depropaniser and debutaniser columns.

5.2.7 Product Storage and Loading

LNG storage consists of 2 x 135,000 m^3 tanks with double containment design. Each tank contains 4 submerged loading pumps and the design loading rate is 10,000 m^3/h. Storage tank boil off gas will be compressed and sent to HP fuel gas. Boil off gas from loading operations will be separately compressed and recombined with dry feed from Mercury removal. Loading will be via two loading arms.

Condensate will be stored in 2 x 35,000 m3 floating roof tanks. 2 x 50% loading pumps have been assumed. Pumps will tie into existing oilfield loadout subsea pipelines.

5.2.8 Domestic Gas

Domestic gas (Dom Gas) facilities are incorporated into the plant design based on 300TJ/d derived from Gorgon feed gas. The Dom Gas processing facilities are integrated with LNG gas through the AGRUs. At this point, a stream of sweetened gas is sent to stand alone facilities including:

- Dehydration
- Dew Point Control
- Export Compression.

6. ASSUMPTIONS

The following is a list of the assumptions made in undertaking this risk assessment, together.

1. The LNG Plant is designed to operate an average of 336 days per year, with the other days being for shutdowns and maintenance. It is assumed that the Dom Gas plant will have a similar operating philosophy. However, it is unlikely that both LNG trains and/or the Dom Gas plant will be shutdown simultaneously. Therefore a conservative approach is adopted where it is assumed the plant will operate continually throughout the year.

2. In undertaking the AS2885 risk assessment, it is assumed that internal corrosion is not a valid threat for the LNG and Dom Gas pipelines as water moisture is removed in the plant by the Mole Sieves and therefore the gas is considered to be dry. Internal corrosion for the Condensate Export Line is not considered in the AS2885 risk assessment as the pipeline contents do not include water (i.e. condensate only).

3. Although it is recognised that additional safety mechanisms are likely to be included in the plants' design, they have not been incorporated into this risk assessment as the details of such options are not available at the time of this study.

4. A risk assessment, probably in the form of a Hazard Identification Study, will be undertaken for the construction of the plant and pipelines. It is assumed that this construction risk assessment will cover all the hazards to the environment, the plant and other infrastructure such as roads, and other pipelines. Therefore these hazards are not included in this risk assessment.

5. It is assumed that the plant will be provided with a system whereby any losses of containment of gas and liquid hydrocarbons and other hazardous materials such as CO_2 and H_2S will be detected. The detection system will activate mechanisms that will place the section of plant and/or the entire plant if warranted, in a safe condition (e.g. vent to flare) and isolate inventory so as to minimise the level of risk. It is assumed that detection and isolation within the plant will require up to 15 minutes for the inventory to be isolated by high integrity devices such as Emergency Shutdown Valves. It is also assumed that the inventory for a failure case will be the maximum inventory.

6. Given that the ship loading of LNG and Condensate will take place at a considerable distance from the shore line (i.e. the shortest distance is for the LNG Export Pipeline via the Jetty Option that has the ship loading approximately 4.2km from the shoreline), then it is assumed that the risks from these activities will not influence the onshore risk levels due to the plant. This risk level will not be determined.

7. The operation of the 3 Mole Sieves in the Dehydration and Mercury Removal circuit is assumed to be one on line, one being regenerated, and one on standby. Therefore in determining the frequency of failure cases, it is assumed that 2 Mole Sieves are in operation mode (i.e. at operating pressure and temperature) and one is on standby. This is a conservative assumption that is in line with good practice.

8. The size and operating conditions for equipment in the Dom Gas circuit is assumed to be the same as that in the LNG trains. This assumption is made in lieu of plant specific data being available at the time of this study.

9. There will be 338.1 operating days per year for the LNG and Dom Gas Plants. Therefore, the CO_2 pipeline will not be required to operate at full capacity for 365 days per year. It is unlikely that both plants will be shut down simultaneously, and therefore, the CO_2 pipeline will be required for a reduced duty. A conservative approach is taken in this risk assessment for the duty of the CO_2 pipeline is that it will be assumed and assessed at full duty of 365 days per year.

10. In the immediate vicinity of the mainland shore crossing for the Dom Gas Export Pipeline, it is assumed that an isolation valve will be provided.

11. Where pipelines enter and/or exit the plant area, an isolation valve will be provided to isolate the pipeline.

12. The onshore sections of LNG Export Pipelines, Condensate Pipelines and the Dom Gas Pipe (i.e. Barrow Island) are assumed to be located within the on shore gas plant area.

13. Regular visual inspections of the above ground sections of the on-shore pipelines will be undertaken.

14. Although both the condensate export and LNG export pipelines (both options for the latter) are scheduled to operate monthly and every 3 days respectively, it is assumed that continuous operation will occur. This conservative approach accommodates the potential scenario when the pipeline is rested with product, albeit at a lower pressure

15. The Dom Gas pipeline located on the mainland will be buried with a minimum depth of cover of 1200mm.

16. The time to affect the closure of isolation valve for all pipelines in this study will be dependant on their location. For those pipeline sections with the plant and operating areas including the jetty, it is expected that detection and closure for leaks will be effected within 120 seconds. For other valve locations, such as shore crossing isolation valves, the time interval will vary. A conservative approach is adopted for modelling a loss of containment, in that all releases will be modelled as a continuous leak instead of a decaying leak.

17. The end of the existing runway for Barrow Island Airport is between 7.1 and 8.5 km from the proposed Gorgon Development. The northern extension of the runway centreline is aligned with the proposed LNG Process Plant and there is a potential for aircraft to over-fly the Plant and flare area. The operation of the flare is non-continuous. There exists the possibility of an aircraft on the flight path overflying the flare simultaneously as the activation of the flare. Further, there is the risk to aircraft due to tall structures. Both of these hazards could result in damage to the aircraft and a possible impact with ground and/or the on-shore plant.

    Given the low frequency of scheduled flights (i.e. a maximum of 2 flights per day or 14 flights per week at peak), it is considered that the contribution to the overall level of risk from/to aircraft approaching or taking off from the BWI airfield during construction, is negligible. Once operation commences the number of flights will diminish to a very low frequency, until or unless further construction is planned. However, this potential risk will be incorporated into the Safety Case risk assessment that will be undertaken during the detailed design phase of the project. All risks will be revisited during detailed design to validate original assumptions, to obtain Civil Aviation Safety Authority (CASA) approval to implement aerodrome design changes or to publish safety notifications.

18. Barrow Island is located in an area whose weather patterns include cyclones. The hazards to facilities due to cyclones are acknowledged and as such, engineering design incorporates a number of safeguards and as such these hazards are not considered further.

CASA has established regulations for the safety of aircraft movements, some of which pertain to the flight path of aircraft in the vicinity of aerodromes. In particular, CASA advisory circular AC 139-05(0) (Reference 20) provides guidelines for conducting Plume Rise Assessments, and draft advisory circular AC130-08(0) (Reference 21) provides guidelines for Reporting Tall Structures

The need to assess potential hazards to aviation where tall obstructions and gas efflux may cause damage to airframes and/or affect the handling characteristics of an aircraft in flight will be addressed in compliance with CASA requirements. A detailed plume analysis will be undertaken to determine the risk to aircraft. Should CASA consider that safety is compromised, risk will be mitigated by any one of a number of methods including deviation of the approach path, re-alignment of the runway or possibly relocation of the flare. Therefore, this hazard will not be considered further in this study.

7. HAZARD ID

7.1 Material Hazard Identification

7.1.1 LNG

Natural gas is composed primarily of methane, with some ethane and minor quantities of other light hydrocarbons and CO_2. Liquefied natural gas (LNG), when released to the atmosphere, condenses moisture from the air and thus appears as a white cloud or fog, at the point of discharge. A litre of liquid methane will vapourise at an expansion ratio of about 600 to 1 at standard temperature and pressure (STP) atmospheric pressure. Natural gas is lighter than air and may travel long distances to a point of ignition and flash back.

Natural gas is largely composed of methane, with the balance being mainly higher alkanes and inerts such as carbon dioxide. In terms of this analysis the properties of methane are assumed to represent the natural gas.

Methane is a colourless and odourless gas. It is not toxic but is flammable and may form mixtures with air that are flammable or explosive. Methane is violently reactive with oxidisers, halogens, and some halogen compounds. The combustion products of methane and air are water and carbon dioxide. Under some conditions, carbon monoxide may also be produced.

Methane is an asphyxiant and may displace oxygen in a workplace atmosphere. The concentrations at which flammable or explosive mixtures form are much lower than the concentration at which asphyxiation risk is significant.

The principal hazard associated with a release of methane to the atmosphere from pipelines or vessels is the potential for fire and explosion if ignited. The molcular weight of methane is 16.04, its boiling point is -161.5°C, its auto ignition temperature is 537°C, and the flammable limits in air are 5.3% - 15%.

7.1.2 Dom Gas

Dom Gas is the natural gas that is used in the domestic market. It is primarily composed of methane, with some ethane and minor qualities of other light hydrocarbons and CO_2. Dom Gas is compressed and transported via a pipeline. Natural gas is lighter than air and is flammable.

7.1.3 Condensate

This is a volatile liquid consisting of the heavier hydrocarbon fractions that condense out of the gas as it leaves the well. It is a mixture of pentanes and higher hydrocarbons and is flammable. Condensate is a light crude oil which condenses from natural gas with temperature and pressure changes. Condensate is primarily used in oil refineries as it is rich in gasoline (naptha), diesel and kerosene (middle distillate).

7.1.4 Export Flowline Contents

The contents of the Export Flowline will be the production fluids and gases from the production wells. This includes water, sand, CO_2, gases which are primarily methane and ethane with minor quantities of other light hydrocarbons, and condensate. The material is flammable.

7.1.5 Carbon Dioxide

Carbon Dioxide (CO_2) is an inert gas that is widely used in the chemical, food and beverage, petrochemical and metal industries. CO_2 is normally present in the air at a concentration of 340ppm by volume. Where the quantity of CO_2 dilutes the oxygen concentration below the level that can support life, then CO_2 can act as an asphyxiant. Concentration in the order of 10% can cause respiratory paralysis.

The CO_2 facilities are located on Barrow Island in the open air with little, if any, obstructions to natural ventilation. Therefore it is unlikely that a release of CO_2 from the worst case scenario of catastrophic failure of the facilities would displace the oxygen content within the air to a degree where asphyxiation would occur without alarms and visual effects being obvious to personnel. Therefore this hazard will not be considered further.

7.2 Frequency Analysis

One approach to establish the likelihood of a hazardous event occurring is to review generic data that is published in the public domain in various data bases. One such data base is the E & P Forum as reported by CMPT (Reference 9); that frequencies for leaks from process equipment based largely on UK offshore experience but combined with onshore data where necessary. Therefore it is appropriate for this study to determine applicable frequencies.

In determining the failure case for this study, the focus is on major plant equipment that is identified at this stage of the Gorgon Development i.e. slug catchers, feed separators, Absorber Columns, flash drums, reboilers, compressors, scrubber columns, heat exchangers, tanks, etc. The failure cases where by offsite risk will be incurred is expected to originate from significant leaks (i.e. not pinhole type leaks). Therefore two hole sizes of 50 mm and 150 mm have been selected as representatives of holes between 10 mm and 80 mm, and greater than 80 mm including rupture, respectively. These hole sizes are appropriate, and can be viewed as conservative in terms of effects of a Loss of Containment (LOC), given the size of plant equipment.

The leak frequencies and the hole distribution as reported by CMPT (Reference 9) were used to develop the generic failure case frequencies.

The material involved in any LOC has been taken to be the dominant material for that section of plant. The selection of materials has adopted a conservative approach in that the material that has the potential to incur the worst-case effects has been selected. For example, the separator will contain a mixture of gases primarily methane, ethane and minor quantities of other light hydrocarbons, condensate, water, sand, some CO_2 and Hydrogen Sulphide (H_2S). It is expected that 80% to 90% of the material will be gas-predominantly methane. Methane, in terms of off site effects has the potential to cause personal injury. Therefore, for the failure case of the slugcatchers, methane is the selected material to be modelled. A similar process was applied to the other failure cases, which provides for a conservative model.

Although it is practicable for the failure cases to be dependant on the major equipment items, other smaller plant items such as pipework, pumps, valves, fittings etc; together with their contribution to offsite risk are excluded. To address this issue, and to ensure that a true representation of the level of offsite risk is determined, a conservative approach of increasing all failure case frequencies by a factor of 5 was undertaken.

One failure case scenario that is applicable to gas storage (ie propane and ethane) is a Boiling Liquid Expanding Vapour Explosion (BLEVE). Work undertaken by Sooby & Tolchard (Reference 12) considered a vessel population of the exposure of an estimated 2,113,000 vessel years up to 1998 and determined the frequency of a BLEVE to be 5×10^{-7} per vessel year. Given that a BLEVE involves the ancillary pipework and fittings in the incident and the determination of the frequency, then the frequency will not be ammended by a factor of 5.

With regards to pipelines the E & P Forum QRA Data Directory (Reference 19) and its reference studies for onshore gas and oil pipelines in Western Europe for the periods 1970-92 and 1984-88 respectively provides generic data. The likelihood of a LOC is expressed in terms of per kilometer year (/kmy) and the E & P Forum data provides the total leak frequency from all causes as 0.58×10^{-4} /kmy for both gas and oil pipelines.

The E&P Forum also reports data for onshore pipelines within the US as compiled by the US Department of Transport. The failure rates for all causes for the US Pipelines is 5.52×10^{-4} /kmy, however this does not differentiate between gas and oil pipelines.

The E & P Forum data does not differentiate between pipeline sizes such as the PARLOC data (Reference 11) which report offshore pipeline incidents and indicates pipeline leak frequencies in the order of 10^{-5} and 10^{-6} kmy.

For this study, a conservative approach, was used given the early stage of this Gorgon Development, and the number of unknown parameters such as corrosion, sand content of production fluids, etc; the most conservative data is adopted (5.52×10^{-4} /kmy).

PARLOC does provide guidance for various hole sizes distribution for different pipe sizes, and is the only publically available reference that does. However the population for this data is relatively small with only 6 recorded LOCs for the size pipes used in the Gorgon Development. This is likely to be due to the comparative recent introduction of large diameter pipe that have included inherent safety within their design. Although PARLOC is foccussed on submarine pipelines, which by their location are remote, the Gorgon Development pipelines are equally remote. Therefore this data will be used to determine the distribution of hole sizes.. The hole distribution reflects small, medium and large holes with the latter including total pipeline rupture.

Table 8.1 provides the details of the failure cases, the materials and operating conditions to be modelled, and the frequency used in the risk assessment.

7.3 Ignition Probabilities

There are a number of potential sources of ignition including:

- welding, cutting, grinding;
- engines and exhausts;
- hot surfaces other than engines and exhausts;
- electrical, including lights, instrumentation, switch gear motors, mobile phones, radios;
- static;
- lightning strikes;
- flames, e.g. fuel fired equipment, matches, cigarette lighters, bushfires;
- arson.
- drilling, and
- blasting

Most potential ignition sources are controlled by engineering and management procedures. Therefore, in a plant area, the probability of ignition as provided by CMPT (Reference 9) are relevant and are provided in Table 7.1. For this study, medium size release as per the failure cases are equivalent to the Minor and Major Release Rate Categories, and large release are equivalent to Massive Release Rate Category.

Table 7-1 Ignition Probabilities

Release Rate Category	Release Rate (kg/s)	Gas Leak	Oil Leak
Minor	< 1	0.01	0.01
Major	1 to 50	0.07	0.03
Massive	> 50	0.3	0.08

In developing failure cases, another aspect to be considered is delayed ignition which could be caused by:

- The drifting of a gas cloud towards and ignition source. In the Longford Incident, it took the gas cloud 30-60 seconds to reach an ignition source (Reference 11).
- Intermittent ignition sources whereas ignition is most likely from a constant source.
- Delayed ignition can be cased by an introduced ignition source.
- The change in gas concentration towards the gases flammable limits.

CMPT Report (Reference 9) that process leak experience as documented by the UK Health and Safety Executive (HSE) suggests that most events that ignited did so immediately. However this is in conflict with offshore ignition delay probabilities (as provided by CMPT (Reference 9) which are recognised by CMPT as being judgemental. CMPT (Reference 9) also records that other studies have resolved ignition delay probabilities by means of simple judgements with Technica assuming 50% of ignited events were delayed by approximately 5 minutes or more, but this conclusion was applicable for offshore facilities. Given the standing of the UK HSE and its findings in relation to process leaks, this study will use 90% of ignited events being immediate and 10% being delayed by up to 5 minutes.

With regards to onshore pipelines, the work done by Lees (Reference 12) provides ignition probabilities for massive LPG release and flammable liquids. The reference of LPG is used as the most applicable data for the pipeline gases, LNG and Dom Gas that is available in the public domain. Table 7.2 includes the identification of the pipelines for which these ignition probabilities apply. The LPG data is applied to the LNG pipelines the Export Flowline and the Condensate Export Pipeline as this is most applicable to the materials in these pipelines given that the material is cold and in the event of a LOC would run along the ground.

Table 7-2 Probability of Ignition

MATERIAL	PROBABILITY OF IGNITION	APPLICABLE PIPELINES
Massive LPG Release	0.1	LNG Export Pipeline – both Jetty and Cryogenic options Dom Gas Pipeline for 1.11 km section on Barrow Island Export Flowline on Barrow Island and within 1km of an operating well
Flammable liquid with flashpoint below 110^0F	0.01	Condensate Export Pipeline

For the Export Flowline on Barrow Island, and the Dom Gas Pipeline on the mainland, there is limited infrastructure in the immediate area and activities are limited to a few road vehicles movement per day, resulting in less likelihood of ignition sources to be present. The probability of ignition is reduced by one order of magnitude to reflect these site conditions, and left unchanged where the Export Flowline on Barrow Island, where it passes existing wells and crosses the 1Kv power cables, the ignition probability is not reduced to reflect the increased likelihood of an ignition source being present.

7.4 AS 2885 Risk Assessment

The analysis will be undertaken as per AS2885 Risk Assessment methodology and QRA Methodology, the details of which are provided in Section 3.2.1. This section reports the analysis for each methodology.

This methodology applies to the hydrocarbons pipelines, i.e.:

- Export Flowline;
- LNG Export Pipeline;
- Condensate Export Pipeline; and
- Dom Gas Pipeline.

7.4.1 Location Analysis

The proposed routes for the four pipelines traverse the broad rural land use class. This is typified by location in underdeveloped areas on broadly farmed areas that are sparsely populated where the average allotment is typically greater than 5 hectares.

Barrow Island is a Class A Reserve, and populated areas are controlled and limited to CVX personnel. The areas on the mainland where the route for the Dom Gas Pipeline is proposed is sparsely populated and rural in development. For the onshore areas where a pipeline route is proposed, there are no sensitive developments such as schools, hospitals and aged and child centres.

Where the pipelines are submarine, there could be fishing activities undertaken – predominantly recreational. Therefore, a land use of R1 which is used for broad rural land use, is applicable.

For each pipeline, a Location Analysis is provided in:

- Appendix A – Export Flowline;
- Appendix B – LNG Export Pipeline;
- Appendix C – Condensate Pipeline; and
- Appendix D – Dom Gas Pipeline.

7.4.2 Threat Analysis

For the four pipelines, the common threats are:

- Seismic event;
- Internal Corrosion;
- Overpressure;
- Design defects;
- Material defects; and
- Construction defects.

Other threats that are location specific (e.g. road crossings) are included in the Threat Analysis Tables.

The Threat Analysis undertaken for each pipeline (see Appendix 1 to 4) includes details on the controls that will be applied to each pipeline to address each of the threats. These controls are a combination of physical and procedural controls that will be implemented during design, construction and operation of each pipeline. Given the location class of R1 for all four pipelines, at least one physical and two procedural controls are required for each threat.

For each of the four pipelines, the number of physical and procedural controls that are incorporated into the pipelines design, construction and operation, comply or exceed the controls criteria required by AS 2885. Therefore, further analysis as per AS2885 is not warranted.

8. CONSEQUENCE ANALYSIS

8.1 Effects Modelled

Consequence analysis was undertaken using the TNO Quantitative Risk Assessment program "Riskcurves".

Potential consequences associated with high pressure gases (methane), LNG and condensate include:

- jet fires;
- pool fires;
- vapour cloud explosions;
- flash fires; and
- BLEVEs.

Jet fires tend to have relatively small areas of impact. Pool fires are where the liquid (i.e. condensate) forms a pool in the immediate vicinity of the LOC. These are modelled as unconfined circular pool. Given the topography of the plant, the condensate would flow as per the local gradient and streams would be more likely to form. Ignition of a stream of flammable materials would flow back to the source of the LOC. Vapour cloud explosions may result in overpressure effects that become more significant as the degree of confinement increases. Flash fires result from the release of flammable gas and formation of a vapour cloud, and possibly from a pool of flammable liquid. Flash fires have the potential for offsite impact as the vapour clouds can travel downwind of the source. However, these tend to be instantaneous in terms of effects and in terms of fan field effects, are considered not to incur fatalities given the high probability for dispersion by weather conditions. Therefore, flash fires are not considered further. Instead pool and jet fires are modelled. A BLEVE can occur when the vessel wall surrounding the vapour space is subject to extreme heat radiation, normally as a result of a jet fire. BLEVE failure cases are modelled for the ethane and propane storages. A BLEVE is not considered to be a credible scenario for any of the pipelines as there is no storage above the pipeline routes.

For the materials that are processed by this plant there is potential for a combination of effects to occur; for example, a LOC of condensate can result in either a pool or jet fire. A jet fire's effect are limited to the immediate area of the jet fire, whereas the effects are greater with a large diameter pool fire as would be expected to occur given the operating conditions of this equipment. Therefore, a pool fire is modelled for failure cases of condensate.

For most of the plant, the material that is being processed is methane. At each stage of the process, the concentration of methane increases from the slug catchers. A conservative approach is adapted in that all failure cases are modelled as 100% methane. In terms of off-site effects, jet fires from LOCs are modelled as the worst case as other effects such as vapour cloud explosions for methane are highly unlikely.

Similarly, with regards to the failure cases with propane and ethane as the material, the jet fire effects are modelled although there is an increased likelihood of vapour cloud explosions. However these are considered to have minimal effect on the off-site risk levels given the small inventories and the plant layout not being congested.

Table 8.1 summarises the failure cases, together with their frequency and the effects to be modelled.

Table 8-1 Failure Cases and Model Effects

Failure Case ID	Failure Case Description		Volume (m3)	Hole Size (mm)	Failure Case Frequency	QRA Failure Case Frequency	Probability of Ignition	Material	Pressure	Temp ºC	Location North	Location East
ISC01M	No 1 Inlet Separator	medium leak		50	1.34E-04	6.68E-04	0.08	Methane	74 barg	26	7700000	338425
ISC01L	No 1 Inlet Separator	large leak		150	1.65E-05	8.25E-05	0.3	Methane	74 barg	26	7700000	338425
ISC02M	No 2 Inlet Separator	medium leak		50	1.34E-04	6.68E-04	0.08	Methane	74 barg	26	7700050	338425
ISC02L	No 2 Inlet Separator	large leak		150	1.65E-05	8.25E-05	0.3	Methane	74 barg	26	7700050	338425
SFS01M	Stabiliser Feed Separator	medium leak	1085.09	50	1.34E-04	6.68E-04	0.04	Condensate	25barg	26	7699950	338500
SFC01L	Stabiliser Feed Separator	large leak	1085.09	150	1.65E-05	8.25E-05	0.08	Condensate	25barg	26	7699950	338500
AGR Train 1												
AGR01M	Amine Absorber Column	medium leak	593.96	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700150	338625
AGR01L	Amine Absorber Column	large leak	593.96	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700150	338625
AGR02M	Flash Drum	medium leak	478.97	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700150	338625
AGR02L	Flash Drum	large leak	478.97	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700150	338625
AGR03M	Amine Regenerator Column	medium leak	907.92	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700150	338625
AGR03L	Amine Regenerator Column	large leak	907.92	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700150	338625
AGR04M	Reboilers	medium leak	144MW	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700150	338625
AGR04L	Reboilers	large leak	144MW	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700150	338625
AGR Train 2												
AGR05M	Amine Absorber Column	medium leak	593.96	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700240	338625
AGR05L	Amine Absorber Column	large leak	593.96	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700240	338625
AGR06M	Flash Drum	medium leak	478.97	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700240	338625
AGR06L	Flash Drum	large leak	478.97	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700240	338625
AGR07M	Amine Regenerator Column	medium leak	907.92	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700240	338625

Failure Case ID	Failure Case Description		Volume (m3)	Hole Size (mm)	Failure Case Frequency	QRA Failure Case Frequency	Probability of Ignition	Material	Pressure	Temp ºC	Location North	Location East
AGR07L	Amine Regenerator Column	large leak	907.92	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700240	338625
AGR08M	Reboilers	medium leak	144MW	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700240	338625
AGR08L	Reboilers	large leak	144MW	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700240	338625
AGR Train 3												
AGR09M	Amine Absorber Column	medium leak	593.96	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700300	338625
AGR09L	Amine Absorber Column	large leak	593.96	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700300	338625
AGR10M	Flash Drum	medium leak	478.97	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700300	338625
AGR10L	Flash Drum	large leak	478.97	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700300	338625
AGR11M	Amine Regenerator Column	medium leak	907.92	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700300	338625
AGR11L	Amine Regenerator Column	large leak	907.92	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700300	338625
AGR12M	Reboilers	medium leak	144MW	50	1.34E-04	6.68E-04	0.08	Methane	70 bara	25.2	7700300	338625
AGR12L	Reboilers	large leak	144MW	150	1.65E-05	8.25E-05	0.3	Methane	70 bara	25.2	7700300	338625
LNG Train 1												
Dehydration & Mercury Removal												
DM101M	Mole Sieve	medium leak	69.12	50	4.45E-05	2.23E-04	0.08	Methane	65 bara	20	7700000	338725
DM101L	Mole Sieve	large leak	69.12	150	5.50E-06	2.75E-05	0.3	Methane	65 bara	20	7700000	338725
DM102M	Mole Sieve	medium leak	69.12	50	4.45E-05	2.23E-04	0.08	Methane	65 bara	20	7700000	338775
DM102L	Mole Sieve	large leak	69.12	150	5.50E-06	2.75E-05	0.3	Methane	65 bara	20	7700000	338775
DM103M	Mole Sieve	medium leak	69.12	50	4.45E-05	2.23E-04	0.08	Methane	65 bara	20	7700000	338825
DM103L	Mole Sieve	large leak	69.12	150	5.50E-06	2.75E-05	0.3	Methane	65 bara	20	7700000	338825
DM104M	Mercury Absorber	medium leak	40.41	50	6.68E-05	3.34E-04	0.08	Methane	65 bara	20	7700000	338850
DM104L	Mercury Absorber	large leak	40.41	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700000	338850
DM105M	Mercury Absorber	medium leak	40.41	50	6.68E-05	3.34E-04	0.08	Methane	65 bara	20	7700000	338875
DM105L	Mercury Absorber	large leak	40.41	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700000	338875

Failure Case ID	Failure Case Description		Volume (m3)	Hole Size (mm)	Failure Case Frequency	QRA Failure Case Frequency	Probability of Ignition	Material	Pressure	Temp ºC	Location North	Location East
Liquefaction												
LQ101M	Main Cryogenic Heat Exchanger	medium leak	897.43	50	6.68E-05	3.34E-04	0.08	Methane	65 bara	20	7700100	338725
LQ101L	Main Cryogenic Heat Exchanger	large leak	897.43	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700100	338725
LQ102M	Scrubber Column	medium leak	290.44	50	1.34E-04	6.68E-04	0.08	Methane	67 barg	-34	7700100	338775
LQ102L	Scrubber Column	large leak	290.44	150	1.65E-05	8.25E-05	0.3	Methane	67 barg	-34	7700100	338775
LQ103M	Nitrogen Endflash Column	medium leak	217.83	50	1.34E-04	6.68E-04	0.08	Methane	1.32 bara	-158.3	7700100	338825
LQ103L	Nitrogen Endflash Column	large leak	217.83	150	1.65E-05	8.25E-05	0.3	Methane	1.32 bara	-158.3	7700100	338825
LQ104M	Propane Accumulator	medium leak	421.48	50	1.34E-04	6.68E-04	0.08	Propane	16.04 bara	47	7700100	338850
LQ1O4L	Propane Accumulator	large leak	421.48	150	1.65E-05	8.25E-05	0.3	Propane	16.04 bara	47	7700100	338850
LQ105M	Fuel Gas Compressor	medium leak		50	1.39E-02	6.93E-02	0.08	Methane	1.24 bara	-163.5	7700100	338900
LQ105L	Fuel Gas Compressor	large leak		150	1.40E-04	7.00E-04	0.3	Methane	1.24 bara	-163.5	7700100	338900
LNG Train 2												
Dehydration & Mercury Removal												
DM201M	Mole Sieve	medium leak	69.12	50	4.45E-05	2.23E-04	0.08	Methane	65 bara	20	7700200	338725
DM201L	Mole Sieve	large leak	69.12	150	5.50E-06	2.75E-05	0.3	Methane	65 bara	20	7700200	338725
DM202M	Mole Sieve	medium leak	69.12	50	4.45E-05	2.23E-04	0.08	Methane	65 bara	20	7700200	338775
DM202L	Mole Sieve	large leak	69.12	150	5.50E-06	2.75E-05	0.3	Methane	65 bara	20	7700200	338775
DM203M	Mole Sieve	medium leak	69.12	50	4.45E-05	2.23E-04	0.08	Methane	65 bara	20	7700200	338825
DM203L	Mole Sieve	large leak	69.12	150	5.50E-06	2.75E-05	0.3	Methane	65 bara	20	7700200	338825
DM204M	Mercury Absorber	medium leak	40.41	50	6.68E-05	3.34E-04	0.08	Methane	65 bara	20	7700200	338850
DM204L	Mercury Absorber	large leak	40.41	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700200	338850
DM205M	Mercury Absorber	medium leak	40.41	50	6.68E-05	3.34E-04	0.08	Methane	65 bara	20	7700200	338875
DM205L	Mercury Absorber	large leak	40.41	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700200	338875
Liquefaction												
LQ201M	Main Cryogenic Heat Exchanger	medium	897.43	50	6.68E-05	3.34E-04	0.08	Methane	65 bara	20	7700350	338725

Failure Case ID	Failure Case Description		Volume (m3)	Hole Size (mm)	Failure Case Frequency	QRA Failure Case Frequency	Probability of Ignition	Material	Pressure	Temp ºC	Location North	Location East
		leak										
LQ201L	Main Cryogenic Heat Exchanger	large leak	897.43	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700350	338725
LQ202M	Scrubber Column	medium leak	290.44	50	1.34E-04	6.68E-04	0.08	Methane	67 barg	-34	7700350	338775
LQ202L	Scrubber Column	large leak	290.44	150	1.65E-05	8.25E-05	0.3	Methane	67 barg	-34	7700350	338775
LQ203M	Nitrogen Endflash Column	medium leak	217.83	50	1.34E-04	6.68E-04	0.08	Methane	1.32 bara	-158.3	7700350	338825
LQ203L	Nitrogen Endflash Column	large leak	217.83	150	1.65E-05	8.25E-05	0.3	Methane	1.32 bara	-158.3	7700350	338825
LQ204M	Propane Accumulator	medium leak	421.48	50	1.34E-04	6.68E-04	0.08	Propane	16.04 bara	47	7700350	338850
LQ2O4L	Propane Accumulator	large leak	421.48	150	1.65E-05	8.25E-05	0.3	Propane	16.04 bara	47	7700350	338850
LQ205M	Fuel Gas Compressor	medium leak		50	1.39E-02	6.93E-02	0.08	Methane	1.24 bara	-163.5	7700350	338900
LQ205L	Fuel Gas Compressor	large leak		150	1.40E-04	7.00E-04	0.3	Methane	1.24 bara	-163.5	7700350	338900
LNG Tanks												
TKS01M	LNG Tank	medium leak	135000	50	1.00E-05	5.00E-05	0.08	Methane	1.17 bara	-165	7700180	339090
TKS01L	LNG Tank	large leak	135000	150	6.00E-07	3.00E-06	0.3	Methane	1.17 bara	-165	7700180	339090
TKS02M	LNG Tank	medium leak	135000	50	1.00E-05	5.00E-05	0.08	Methane	1.17 bara	-165	7700300	339090
TKS02L	LNG Tank	large leak	135000	150	6.00E-07	3.00E-06	0.3	Methane	1.17 bara	-165	7700300	339090
TKS03M	Propane Sphere	medium leak	1800	50	1.00E-05	5.00E-05	0.08	Propane	15 bara	43	7700160	339165
TKS03L	Propane Sphere	large leak	1800	150	1.00E-06	5.00E-06	0.3	Propane	15 bara	43	7700160	339165
TKS03B	Propane Sphere	BLEVE	1800		1.34E-07	6.70E-07		Propane	15 bara	43	7700160	339165
TKS04M	Ethane Bullet	medium leak	500	50	1.00E-05	5.00E-05	0.08	Ethane	26 bara	-30	7700250	339165
TKS04L	Ethane Bullet	large leak	500	150	1.00E-06	5.00E-06	0.3	Ethane	26 bara	-30	7700250	339165
THS04B	Ethane Bullet	BLEVE	500		1.34E-07	6.70E-07		Ethane	26 bara	-30	7700250	339165
TKS05M	Condensate Tank	medium leak	35000	50	1.00E-05	5.00E-05	0.04	Condensate	5.89 bara	39.6	7700460	339165
TKS05L	Condensate Tank	large leak	35000	150	6.00E-07	3.00E-06	0.08	Condensate	5.89 bara	39.6	7700460	339165
TKS06M	Condensate Tank	medium leak	35000	50	1.00E-05	5.00E-05	0.04	Condensate	5.89 bara	39.6	7700540	339165
TKS06L	Condensate Tank	large leak	35000	150	6.00E-07	3.00E-06	0.08	Condensate	5.89 bara	39.6	7700540	339165

Failure Case ID	Failure Case Description		Volume (m3)	Hole Size (mm)	Failure Case Frequency	QRA Failure Case Frequency	Probability of Ignition	Material	Pressure	Temp ºC	Location North	Location East
Dom Gas												
DMS1M	Mole Sieve	medium leak	69.12	50	1.34E-04	6.68E-04	0.08	Methane	65 bara	20	7700100	339155
DMS01L	Mole Sieve	large leak	69.12	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700100	339155
DMS02M	Mole Sieve	medium leak	69.12	50	6.68E-05	3.34E-04	0.08	Methane	65 bara	20	7700100	339180
DMS02L	Mole Sieve	large leak	69.12	150	8.25E-06	4.13E-05	0.3	Methane	65 bara	20	7700100	339180
DGC03M	Compressor	medium leak		50	1.39E-02	6.93E-02	0.08	Methane	65 bara	20	7700000	339200
DGC03L	Compressor	large leak		150	1.40E-04	7.00E-04	0.3	Methane	65 bara	20	7700000	339200

8.2 Modelling

The QRA modelling was undertaken using "TNO's Effects 4" and "Riskcurves" packages. The TNO tools are internationally recognised by industry and government authorities, including WA's Department of Industry and Resources.

9. RISK ASSESSMENT AND CONCLUSIONS

There have been two methodologies used in undertaking the pipelines risk assessment; AS2885 and QRA. The AS2885 risk assessment was undertaken for:

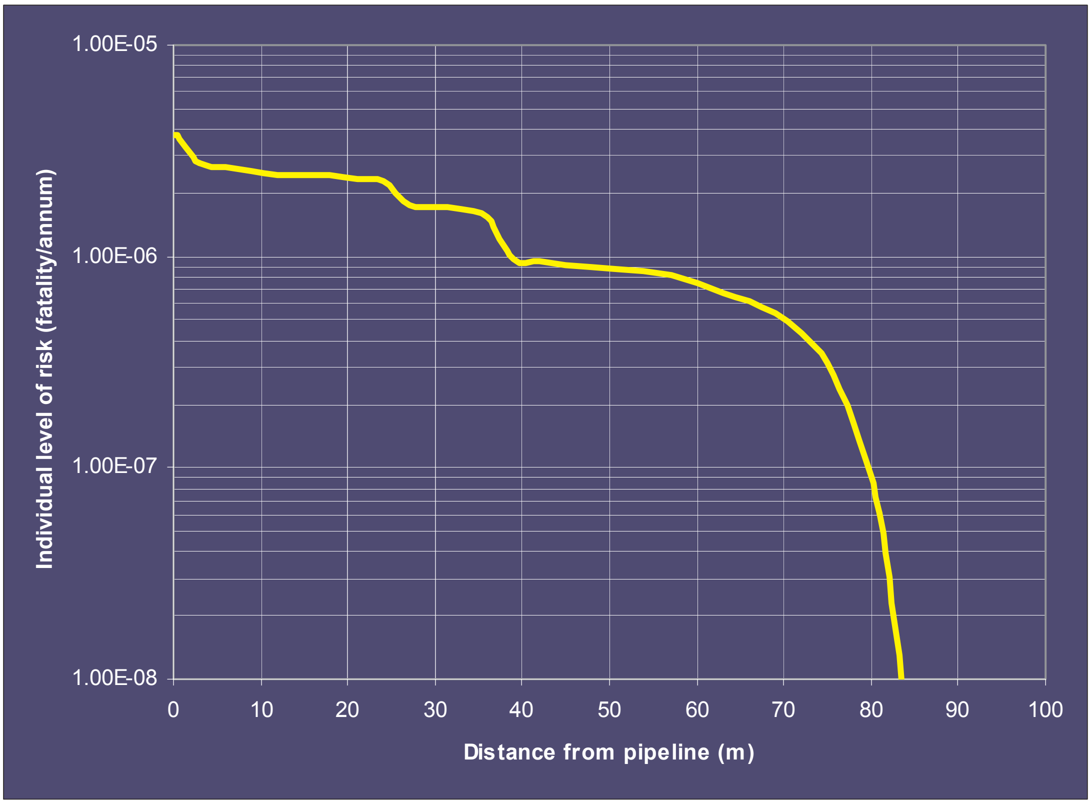
- Export Flowline – both Flacourt Bay and North White's Beach route options:
- LNG Export Pipeline for both the Jetty and Cryogenic options;
- Condensate Export Pipeline; and
- Dom Gas Pipeline.

The level of risk for the above 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 (Reference 15).

The CO_2 Reinjection Pipeline will be located above ground on Barrow Island in the open air with little, if any, obstructions to natural ventilation. A release of CO_2 from the worst case scenario of catastrophic failure of the pipeline would not displace the oxygen content within the air to a degree where asphyxiation would occur. Therefore this hazard was not considered further.

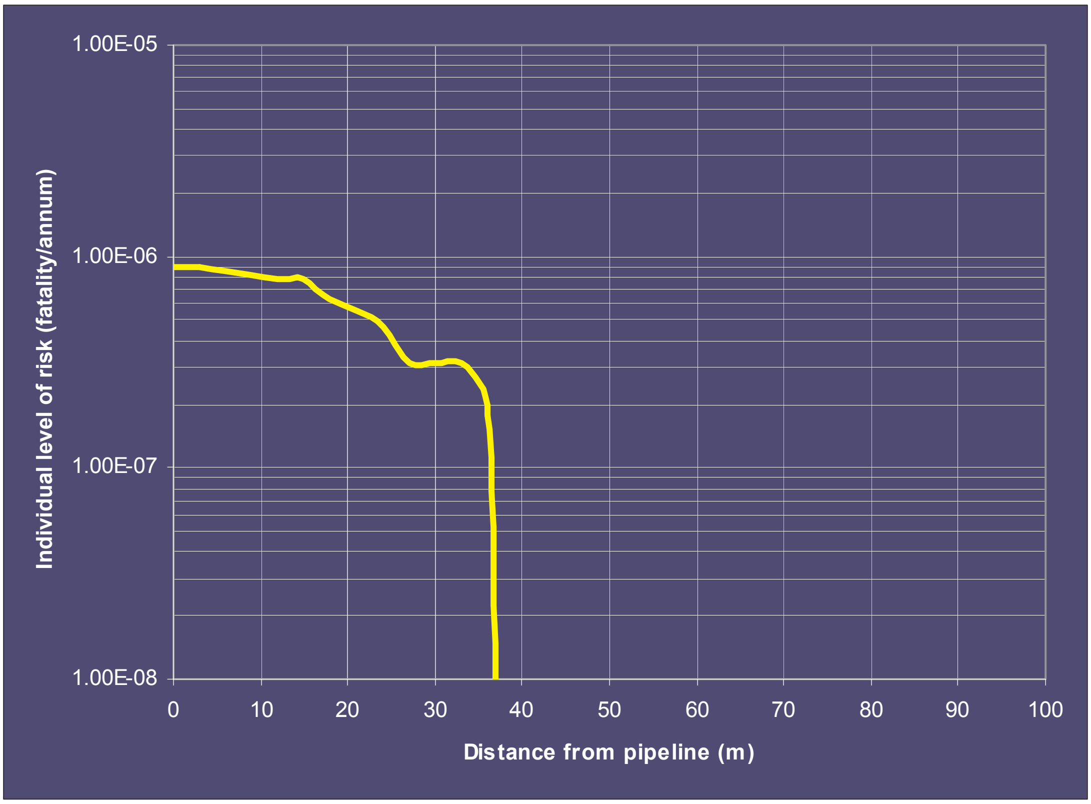
The QRA methodology was applied to all hydrocarbon pipelines with individual risk transects for each pipeline provided in Figures 9.1 to 9.4.

Figure 9-1 Export Flowline Risk Transect



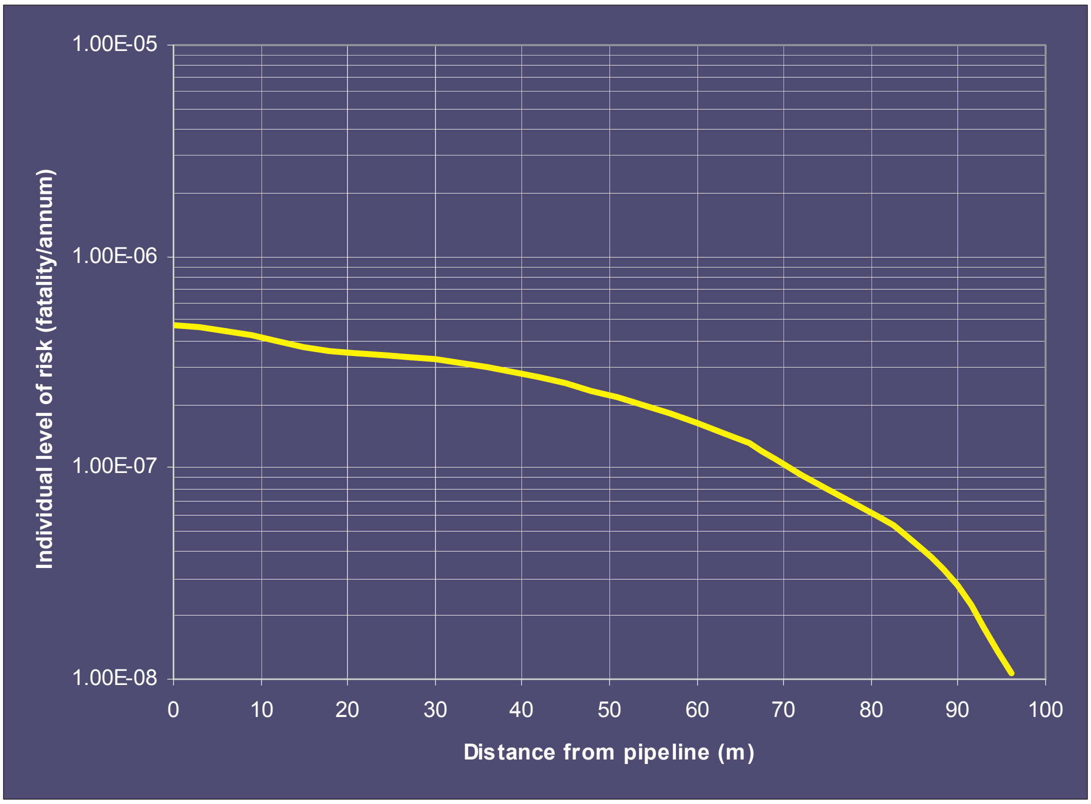
The level of individual risk is approximately 4 x 10^{-6} pa at the centreline for the Export Flowline and decreases to 1 x 10^{-6} pa over a distance of 40m either side of the Export Flowline route. The EPA's individual fatality risk criterion (Reference 2) for residential areas is 1 x 10^{-6} pa. As both routes for the Export Flowline do not pass within 40m of a residential area (i.e. the construction village), then compliance is achieved. These results are indicative for both routes given that the material modelled is methane as jet fires.

Figure 9-2 LNG Export Pipeline Risk Transect



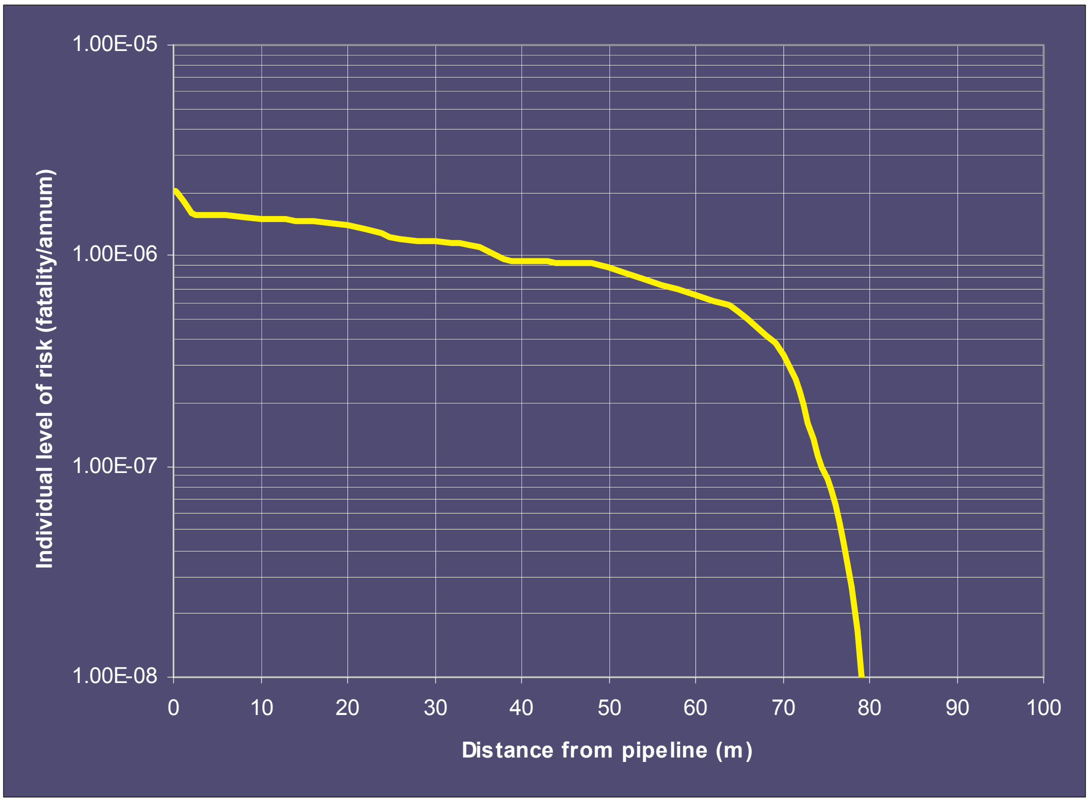
The level of individual risk is approximately 1 x 10^{-6} pa at the centreline for the LNG Export route and decreases to 2 x 10^{-7} pa over a distance of approximately 40m either side of the pipeline. This level of risk is less than the EPA individual fatality risk criteria (Reference 2) and therefore compliance is achieved. These results reflect modelling as methane for jet fires for the Jetty Option. These results are indicative for both options for planning purposes.

Figure 9-3 Condensate Pipeline Risk Transect



The level of individual risk is approximately 4 x 10^{-7} pa at the centreline for the Condensate Export Pipeline and decreases to 1 x 10^{-8} pa over a distance of approximately 100m either side of the pipeline. This level of risk is less than the EPA individual fatality risk criteria (Reference 2) and therefore compliance is achieved. These results are indicative that the material modelled is condensate as pool fires.

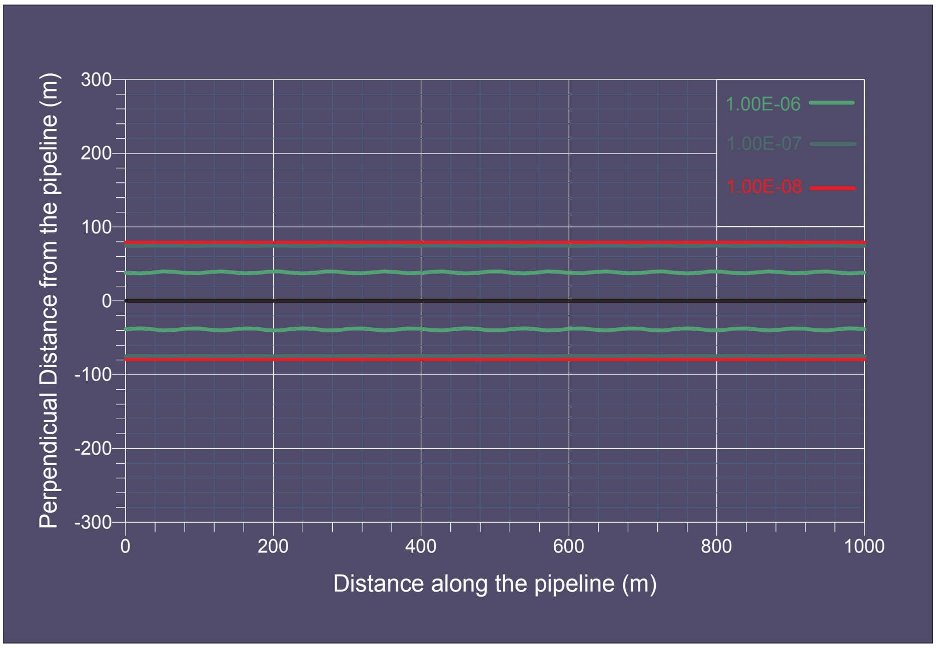
Figure 9-4 Dom Gas Pipeline Risk Transect



The level of individual risk is approximately 2 x 10^{-6} pa at the centreline for the Dom Gas Pipeline and decreases to 1 x 10^{-6} pa over a distance of approximately 40m either side of the pipeline. The EPA's individual fatality risk criterion (Reference 2) for residential areas is 1 x 10^{-6} pa. As both routes for the Dom Gas pipeline do not pass within 40m of a residential area (i.e. the construction village), then compliance is achieved. These results are indicative given that the material modelled is methane as jet fires.

Figure 9-5 provides an illustration of the iso-risk contours for a 1 km section of the Dom Gas Pipeline. The black line in the centre represents the centreline of the pipeline and illustrates the 1 x 10^{-6} per year iso-risk contour is approximately 40m either side of the pipeline.

Figure 9-5 Dom Gas Pipeline Iso-Risk Contours



The applicable risk criteria as published by the EPA (Reference 6) is the level of individual risk in residential areas of one in a million per year is not exceeded by the pipeline routes. The applicable residential area on Barrow Island are deemed to be the Gorgon Development Construction Village (due to personnel being housed in this village during commissioning and plant start-up) and the existing Chevron Village, both of which are not affected by individual risk levels greater than one in a million per year due to the pipelines.

The results of the risk assessment for the plant are provided in Appendix E as iso-risk contours that reflect the current stage of the plant's design. The one in a million per year individual risk contour extends 150m outside the site's southern boundary. This iso-contour does not encroach on any residential areas such as the area that is proposed for the Village with the contour being approximately 250m from the Village. The major risk contributors being the propane and ethane storage vessel BLEVEs and jet fires from process eqipment. Therefore, compliance with the EPA Criteria for residential areas (Reference 2) is achieved.

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APPENDIX A

THREAT ANALYSIS OF PROPOSED EXPORT FLOWLINE – FLACOURT BAY OPTION & NORTH WHITE'S BEACH

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Table AP A.1 : Threat Analysis of Proposed Export Flowline – Flacourt Bay Option

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-9.2 to 0.00	R1	Class 1 Nature Reserve	Export Flowline runs approximately 8.2 km over gentle undulating plateau, and 1km wide dune foreshore.	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
-2 ,-3.7, -4, -4.9, -5.7, -6, & -6.3	R1	Road Crossings	The Export Flowline intersects several tracks	Potential damage by grading of track and earth movement by heavy vehicles. Potential damage in the event that a vehicle runs of the road/track	Physical: Depth of cover (to 1200mm) in road reserves and in road crossings. Concrete slabs over pipeline under drainage ditches. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly	1 Physical, 2 Procedural	1 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-1, -3, -4.2, -5.3 & -6.9	R1	Ephemeral Water Crossings	The Export Flowline crosses several ephemeral waterways	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
-3.6, -3.9, -4.6, -6.3, & -6.5	R1	Export Flowline crossings	The Export Flowline crosses existing flowlines associated with current Barrow Island operations	Excessive wear/erosion of Export Flowline wall thickness due to pipe movement	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. All crossings of existing flowlines will be designed and constructed to eliminate contact between Export Flowlines. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly	1 Physical, 2 Procedural	2 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-3.1, -4, -4.9, -5.3, -5.7, & -6.4	R1	Infrastructure Passing	The Export Flowline passes up to six existing wells	Operating, housekeeping and maintenance activities could cause damage to the Export Flowline.	Physical: Clearance by at least 100m. A coating of either Fusion Binded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	2 Physical, 3 Procedural
-5.9, -6.6, & -8.5	R1	Pipeline crossings	This Export Flowline crosses existing pipelines (i.e. 2 GRE Highways and the Shipping Line) associated with current Barrow Island operations	Excessive wear/erosion of Export flowline wall thickness due to pipe movement	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. All crossings of existing pipelines will be designed and constructed to eliminate contact between the Export Flowlines and pipelines. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route.	1 Physical, 2 Procedural	2 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The route will be patrolled regularly		
-5.8, & -6.9	R1	1000v power cable crossings	This Export Flowline crosses existing 1000v power cable that are associated with current Barrow Island operations.	Excessive wear/erosion of Export Flowline wall thickness due to pipe movement	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. All crossings of existing power cables will be designed and constructed to eliminate contact between the Export Flowlines and cables. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly	1 Physical, 2 Procedural	2 Physical, 3 Procedural
0.00 to 66.0	R1	Marine	Vessels (ships/boats) crossing submarine Export Flowline	A sinking vessel could impact the Export Flowline, an anchor being dragged or a dropped object (i.e. an anchor) could damage the Export Flowline	Physical: The Export Flowline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks.	1 Physical, 2 Procedural	1 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The Export Flowline location will be included on all admiralty charts will be marked with signs for its entire route.		
0.00 to 66.0	R1	Marine	Fishing	Fishing activities (i.e. trawling) could damage the Export Flowline	Physical: The Export Flowline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks. The Export Flowline location will be included on all admiralty charts will be marked with signs for its entire route.	1 Physical, 2 Procedural	1 Physical, 2 Procedural
0.00 to 66.0	R1	Marine	Pipeline crossing	An existing submarine pipeline is to be crossed. Excessive wear/erosion of Export Flowline wall thickness due to pipe movement	Physical: The Export Flowline will be provided with stabilisation that will limit Export Flowline movement This pipeline crossing will be designed and constructed to eliminate contact. Procedural: Regular pipeline integrity checks.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The Export Flowline location will be included on all admiralty charts will be marked with signs for its entire route.		
NON-LOCATION SPECIFIC							
All	R1			Design Defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning.	1 Physical, 2 Procedural	2 Physical, 2 Procedural
All	R1			Material defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Steel mill verification of pipe material in accordance with material specification. Pressure testing during	1 Physical, 2 Procedural	2 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					commissioning.		
All	R1			Defects introduced during construction.	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning	1 Physical, 2 Procedural	2 Physical, 2 Procedural
All	R1			Internal Corrosion	Physical: Corrosion inhibitors to be added at well heads Procedural: A comprehensive corrosion analysis will be carried out at the detailed design stage to ensure that the pipeline is protected against corrosion. Regular pipeline integrity checks.	1 Physical, 2 Procedural	1 Physical, 2 Procedural
All	R1			Overpressure	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. Procedural:	1 Physical, 2 Procedural	1 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					Pipeline design pressure is greater than well shut-in pressure. Regular pipeline integrity checks		
All	R1			Seismic activity	Physical Pipeline to be designed and constructed in accordance with Australian Standard 2885. The pipeline lies in a low seismic activity risk area. Procedural: Emergency shutdown systems to close off supply of gas in event of rupture. Regular pipeline integrity checks	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Table AP A.2 : Threat Analysis of Proposed Export Flowline – North Whites Beach Option

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-12.8 to 0.00	R1	Class 1 Nature Reserve	Export Flowline runs approximately 12.8 km over gentle undulating plateau, and 1km wide dune foreshore.	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
-0.6, -0.9, -5.1, -6.3, -8.5, -9.1, -10.4, & -10.9	R1	Road Crossings	The Export Flowline intersects eight tracks	Potential damage by grading of track and earth movement by heavy vehicles. Potential damage in the event that a vehicle runs of the road/track	Physical: Depth of cover (to 1200mm) in road reserves and in road crossings. Concrete slabs over pipeline under drainage ditches. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly	1 Physical, 2 Procedural	1 Physical, 3 Procedural
-2.5, -4.5, -5.2, -6.2, -7.3, -8.3, -8.7, -9.2, & -12.5	R1	Ephemeral Water Crossings	The Export Flowline crosses nine ephemeral waterways	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural:	1 Physical, 2 Procedural	1 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.		
-0.8, -10.2, -10.3, &-10.8	R1	Export Flowline crossings	This Export Flowline crosses existing flowlines associated with current Barrow Island operations	Excessive wear/erosion of Export Flowline wall thickness due to pipe movement	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. All crossings of existing flowlines will be designed and constructed to eliminate contact between Export Flowlines. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly	1 Physical, 2 Procedural	2 Physical, 3 Procedural
-0.9, & -10.4	R1	Infrastructure Passing	The Export Flowline passes up to three existing wells	Operating, housekeeping and maintenance activities could cause damage to the Export Flowline.	Physical: Clearance by at least 100m. A coating of either Fusion Binded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route.	1 Physical, 2 Procedural	2 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The route will be patrolled regularly.		
-12.2	R1	Pipeline crossings	This Export Flowline crosses existing pipeline (i.e. the Shipping Line) associated with current Barrow Island operations	Excessive wear/erosion of Export Flowline wall thickness due to pipe movement	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. All crossings of existing pipelines will be designed and constructed to eliminate contact between the Export Flowlines and pipelines. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly	1 Physical, 2 Procedural	2 Physical, 3 Procedural
-10.1, & -10.5	R1	1000v power cable crossings	This Export Flowline crosses existing 1000v power cable that are associated with current Barrow Island operations.	Excessive wear/erosion of Export Flowline wall thickness due to pipe movement	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. All crossings of existing power cables will be designed and constructed to eliminate contact between the Export Flowlines and cables. Procedural: Regular pipeline integrity checks.	1 Physical, 2 Procedural	2 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The pipeline will be marked with signs for its entire route. The route will be patrolled regularly		
0.00 to 66.37	R1	Marine	Vessels (ships/boats) crossing submarine Export Flowline	A sinking vessel could impact the Export Flowline, an anchor being dragged or a dropped object (i.e. an anchor) could damage the Export Flowline	Physical: The Export Flowline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks. The Export Flowline location will be included on all admiralty charts will be marked with signs for its entire route.	1 Physical, 2 Procedural	1 Physical, 2 Procedural
0.00 to 66.37	R1	Marine	Fishing	Fishing activities (i.e. trawling) could damage the Export Flowline	Physical: The Export Flowline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks. The Export Flowline location will be included on all admiralty charts will be marked with signs for its entire route.	1 Physical, 2 Procedural	1 Physical, 2 Procedural
0.00 to 66.37	R1	Marine	Pipeline crossing	An existing submarine pipeline is to be crossed. Excessive wear/erosion of	Physical: The Export Flowline will be provided with stabilisation that will limit Export Flowline movement	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
				Export Flowline wall thickness due to pipe movement	This pipeline crossing will be designed and constructed to eliminate contact. Procedural: Regular pipeline integrity checks. The Export Flowline location will be included on all admiralty charts will be marked with signs for its entire route.		
Non-Location Specific							
All	R1			Design Defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning.	1 Physical, 2 Procedural	2 Physical, 2 Procedural
All	R1			Material defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and	1 Physical, 2 Procedural	2 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					design checked. Steel mill verification of pipe material in accordance with material specification. Pressure testing during commissioning.		
All	R1			Defects introduced during construction.	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning	1 Physical, 2 Procedural	2 Physical, 2 Procedural
All	R1			Internal Corrosion	Physical: Corrosion inhibitors to be added at well heads and on corrosion resistant alloys will be used Procedural: A comprehensive corrosion analysis will be carried out at the detailed design stage to ensure that the pipeline is protected against corrosion. Regular pipeline integrity checks.	1 Physical, 2 Procedural	1 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
All	R1			Overpressure	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. Procedural: Pipeline design pressure is greater than well shut-in pressure. Regular pressure testing. Regular pipeline integrity checks	1 Physical, 2 Procedural	1 Physical, 3 Procedural
All	R1			Seismic activity	Physical Pipeline to be designed and constructed in accordance with Australian Standard 2885. The pipeline lies in a low seismic activity risk area. Procedural: Emergency shutdown systems to close off supply of gas in event of rupture. Regular pipeline integrity checks	1 Physical, 2 Procedural	2 Physical, 2 Procedural

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APPENDIX B

THREAT ANALYSIS OF PROPOSED LNG EXPORT LINE – JETTY OPTION & CRYOGENIC SUBMERGED OPTION

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Table AP B.1 : Threat Analysis of Proposed LNG Export Line - Jetty Option

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-1.00 to 0.00	R1	Plant area	Pipeline runs from plant LNG tanks to marine jetty.	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
0.00 to 4.2	R1	**Marine jetty**	Pipeline runs along jetty above water	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
0.00 to 4.2	R1	Marine jetty	Jetty operations	Jetty operations such as vehicle movements and equipment handling may impact pipeline, leading to damage	Physical: The pipeline will be protected by being located outside the normal work area. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly	1 Physical, 2 Procedural	1 Physical, 3 Procedural
0.00 to 4.2	R1	Marine jetty	Jetty operations	Impact with ships may lead to pipeline damage	Physical: The pipeline route will be outside normal ship movement area. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
Non-Location Specific							
All	R1			Design Defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning.		
All	R1			Material defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Steel mill verification of pipe material in accordance with material specification. Pressure testing during commissioning.	1 Physical, 2 Procedural	2 Physical, 3 Procedural
All	R1			Defects introduced during construction.	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					Pressure testing during commissioning		
All	R1			External Corrosion	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
All	R1			Overpressure	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. Procedural: Pipeline design pressure is greater than well shut-in pressure. Regular pressure testing. Regular pipeline integrity checks	1 Physical, 2 Procedural	1 Physical, 3 Procedural
All	R1			Seismic activity	Physical Pipeline to be	1 Physical,	2 Physical,

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					designed and constructed in accordance with Australian Standard 2885. The pipeline lies in a low seismic activity risk area. Procedural: Emergency shutdown systems to close off supply of gas in event of rupture. Regular pipeline integrity checks	2 Procedural	2 Procedural

Table AP B.2 : Threat Analysis of Proposed LNG Export Line - Cryogenic Option

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-1.00 to 0.00	R1	Plant area	Pipeline runs from plant LNG tanks to marine jetty.	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
0.00 to 8.00	R1	Marine	Vessels (ships/boats) crossing submarine pipeline	A sinking vessel could impact the pipeline, an anchor being dragged or a dropped object (i.e. an anchor) could damage the pipeline	Physical: The pipeline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks. The pipeline location will be included on all admiralty charts will be marked with signs for its entire route.	1 Physical, 2 Procedural	1 Physical, 2 Procedural
0.00 to 8.00	R1	Marine	Fishing	Fishing activities (i.e. trawling) could damage the pipeline	Physical: The pipeline will be provided with stabilisation that will provide protection to impact.	1 Physical, 2 Procedural	1 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					Procedural: Regular pipeline integrity checks. The pipeline location will be included on all admiralty charts will be marked with signs for its entire route.		
0.00 to 8.00	R1	Marine jetty	Jetty operations	Impact with ships may lead to pipeline damage	Physical: The pipeline route will be outside normal ship movement area. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
Non-Location Specific							
All	R1			Design Defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					Pressure testing during commissioning.		
All	R1			Material defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Steel mill verification of pipe material in accordance with material specification. Pressure testing during commissioning.	1 Physical, 2 Procedural	2 Physical, 3 Procedural
All	R1			Defects introduced during construction.	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
All	R1			External Corrosion	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
All	R1			Overpressure	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. Procedural: Pipeline design pressure is greater than well shut-in pressure. Regular pressure testing. Regular pipeline integrity checks	1 Physical, 2 Procedural	1 Physical, 3 Procedural
All	R1			Seismic activity	Physical Pipeline to be designed and constructed in accordance with Australian Standard 2885.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Loc. (approx. km)	Loc. Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The pipeline lies in a low seismic activity risk area. Procedural: Emergency shutdown systems to close off supply of gas in event of rupture. Regular pipeline integrity checks		

APPENDIX C

THREAT ANALYSIS OF PROPOSED CONDENSATE EXPORT PIPELINE

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Table AP C.1 : Threat Analysis of Proposed Condensate Export Pipeline

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-1.45 to 0.00	R1	Plant area	Pipeline runs from plant condensate tank to the existing loud out pump that is used for current operations.	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
0.00 to 9.80	R1	Marine operations	Vessels (ships/boats) crossing submarine pipeline	A sinking vessel could impact the pipeline, an anchor being dragged or a dropped object (i.e. an anchor) could damage the pipeline	Physical: The pipeline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks. The pipeline location will be included on all admiralty charts will be marked with signs for its entire route.	1 Physical, 2 Procedural	1 Physical, 2 Procedural
Non-Location Specific							
All	R1			Design Defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
All	R1			Material defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Steel mill verification of pipe material in accordance with material specification. Pressure testing during commissioning.	1 Physical, 2 Procedural	2 Physical, 3 Procedural
All	R1			Defects introduced during construction.	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning	1 Physical, 2 Procedural	2 Physical, 2 Procedural
All	R1			External Corrosion	Physical:	1 Physical,	1 Physical,

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	2 Procedural	3 Procedural
All	R1			Overpressure	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. Procedural: Pipeline design pressure is greater than well shut-in pressure. Regular pressure testing. Regular pipeline integrity checks	1 Physical, 2 Procedural	1 Physical, 3 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
All	R1			Seismic activity	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. The pipeline lies in a low seismic activity risk area. Procedural: Emergency shutdown systems to close off supply of gas in event of rupture. Regular pipeline integrity checks	1 Physical, 2 Procedural	2 Physical, 2 Procedural

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APPENDIX D

THREAT ANALYSIS OF PROPOSED DOM GAS PIPELINE

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Table AP D.1 Threat Analysis of Proposed Dom Gas Pipeline

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
-1.11 to 0.00	R1	Class 1 Nature Reserve	Pipeline runs approximately 1.11 km over gentle undulating plateau, and 1km wide dune foreshore.	External corrosion due to being exposed to wind and other weather conditions	Physical: A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Regular pipeline integrity checks. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly.	1 Physical, 2 Procedural	1 Physical, 3 Procedural
0.00 to 61.32	R1	Marine	Vessels (ships/boats) crossing submarine pipeline	A sinking vessel could impact the pipeline, an anchor being dragged or a dropped object (i.e. an anchor) could damage the pipeline	Physical: The pipeline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks.	1 Physical, 2 Procedural	1 Physical, 2 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The pipeline location will be included on all admiralty charts will be marked with signs for its entire route.		
0.00 to 61.32	R1	Marine	Fishing	Fishing activities (i.e. trawling) could damage the pipeline	Physical: The pipeline will be provided with stabilisation that will provide protection to impact. Procedural: Regular pipeline integrity checks. The pipeline location will be included on all admiralty charts will be marked with signs for its entire route.	1 Physical, 2 Procedural	1 Physical, 2 Procedural
0.00 to 61.32.	R1	Marine	Pipeline crossing	An existing submarine pipeline is to be crossed. Excessive wear/erosion of pipeline wall thickness due to pipe movement	Physical: The pipeline will be provided with stabilisation that will limit pipeline movement This pipeline crossing will be designed and constructed to eliminate contact. Procedural: Regular pipeline integrity checks.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					The pipeline location will be included on all admiralty charts will be marked with signs for its entire route.		
61.32 70 72.0	R1	Tidal Flats	Pipeline runs across tidal flats are and mangrove area	External corrosion due to being exposed to wind and other weather conditions	Physical: Depth of coverage (1200mm) chosen to cater for all reasonable farming activities. A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Buried marker tape will be installed in areas at risk from excavation. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly. There will be regular liaison with the landowners and occupiers. Regular pipeline integrity	1 Physical, 2 Procedural	2 Physical, 5 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					checks.		
72.0 to 90.96	R1	Cattle grazing area	Pipeline runs over gentle undulating plateau	External corrosion due to being exposed to wind and other weather conditions	Physical: Depth of coverage (1200mm) chosen to cater for all reasonable farming activities. A coating of either Fusion Bonded Epoxy (FBE), High Density Polyethylene (HDPE), or polypropylene (PP) will be provided. Procedural: Buried marker tape will be installed in areas at risk from excavation. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly. There will be regular liaison with the landowners and occupiers. Regular pipeline integrity checks.	1 Physical, 2 Procedural	2 Physical, 5 Procedural
76.2, 77.76 & 77.77	R1	Road Crossings	The pipeline intersects several tracks	Potential damage by grading of track and earth movement by	Physical: Depth of cover (to 1200mm) in road reserves	1 Physical, 2 Procedural	2 Physical, 5 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
				heavy vehicles. Potential damage in the event that a vehicle runs of the road/track	and in road crossings. Concrete slabs over pipeline under drainage ditches. Procedural: Buried marker tape will be installed in areas at risk from excavation. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly. There will be regular liaison with the landowners and occupiers. Regular pipeline integrity checks.		
76.12 & 85.15 to 85.34	R1	Ephemeral Water Crossing	The pipeline crosses ephemeral waterway and passes an ephemeral water lake (it does not cross this lake).	External corrosion due to being exposed to wind and other weather conditions	Physical: Depth of cover (to 1200mm) in road reserves and in road crossings. Concrete slabs over pipeline under drainage ditches. Procedural: Buried marker tape will be installed in areas at risk	1 Physical, 2 Procedural	2 Physical, 5 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					from excavation. The pipeline will be marked with signs for its entire route. The route will be patrolled regularly. There will be regular liaison with the landowners and occupiers. Regular pipeline integrity checks.		
All	R1			Design Defects	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning.	1 Physical, 2 Procedural	2 Physical, 2 Procedural
All	R1			Material defects	Physical: Pipeline to be designed and constructed in	1 Physical, 2 Procedural	2 Physical, 3 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Steel mill verification of pipe material in accordance with material specification. Pressure testing during commissioning.		
All	R1			Defects introduced during construction.	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. X-raying of all welds. Procedural: Pipeline design to be verified and design checked. Pressure testing during commissioning	1 Physical, 2 Procedural	2 Physical, 2 Procedural
All	R1			Internal Corrosion	Physical: Corrosion inhibitors to be added at well heads Procedural:	1 Physical, 2 Procedural	1 Physical, 2 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					A comprehensive corrosion analysis will be carried out at the detailed design stage to ensure that the pipeline is protected against corrosion. Regular pipeline integrity checks.		
All	R1			Overpressure	Physical: Pipeline to be designed and constructed in accordance with Australian Standard 2885. Procedural: Pipeline design pressure is greater than well shut-in pressure. Regular pressure testing. Regular pipeline integrity checks	1 Physical, 2 Procedural	1 Physical, 3 Procedural
All	R1			Seismic activity	Physical Pipeline to be designed and constructed in accordance with Australian Standard 2885. The pipeline lies in a low seismic activity risk area.	1 Physical, 2 Procedural	2 Physical, 2 Procedural

Location (approx. km)	Location Class	Predominant Land Use	Environmental Description	Threat Analysis	Protective Measures	Required No. of Protection Measures	Actual No. of Protection Measures
					Procedural: Emergency shutdown systems to close off supply of gas in event of rupture. Regular pipeline integrity checks		

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APPENDIX E

ISO RISK CONTOURS

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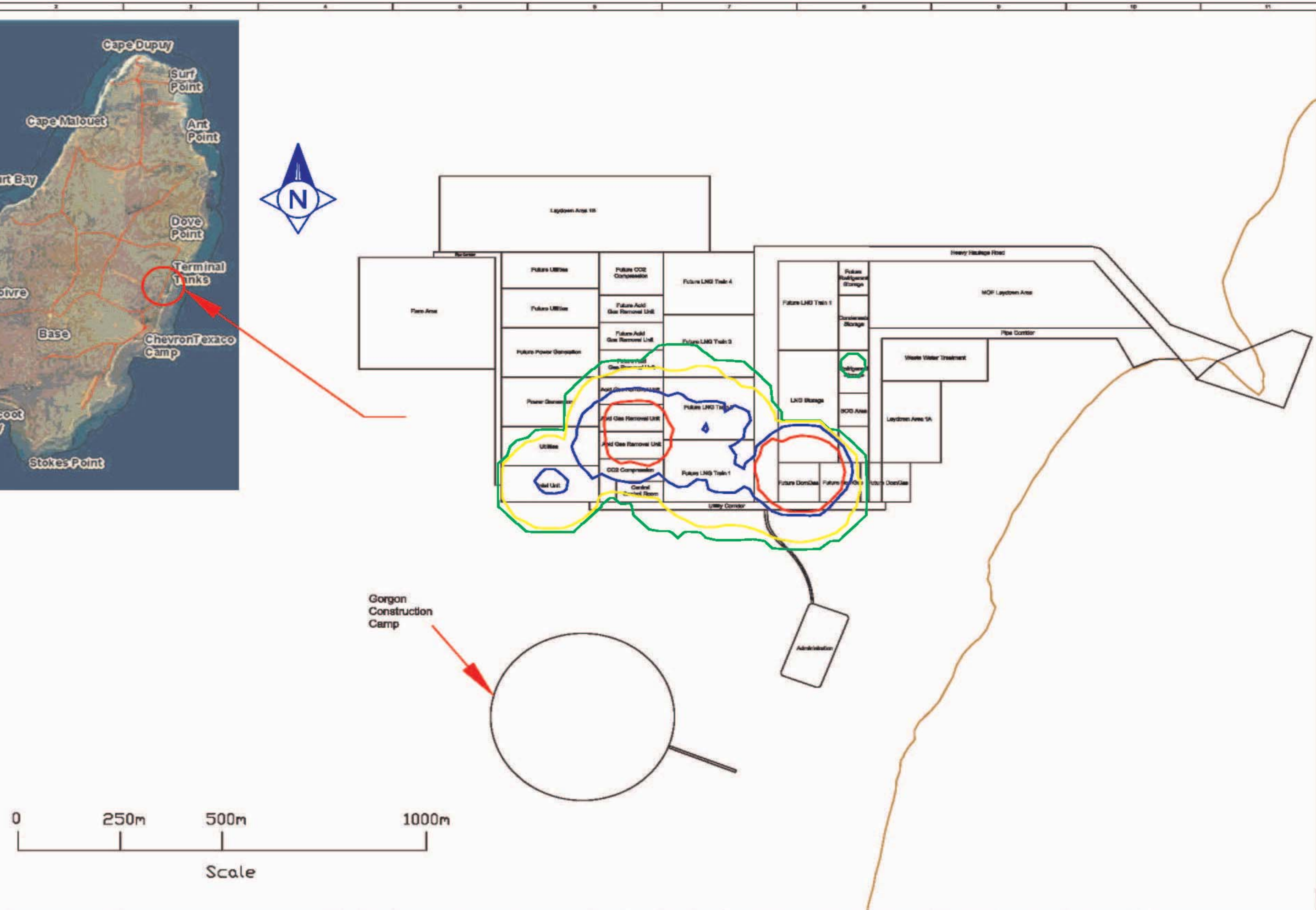

Notes:

Isorisk Contours

- 1X10^-6 pa (green)
- 1X10^-5 pa (yellow)
- 1X10^-4 pa (blue)
- 1X10^-3 pa (red)

THIS DRAWING - REV. HISTORY

REV.	DATE	REVISION DESCRIPTION	DRAWN	CHECKED	APPROVED	CLIENT
3	08/11/2004	Revised Risk Curves	J.Post	G.Penno	S.Robertson	K.Barry
2	29/10/2004	Revised Risk Curves	J.Post	G.Penno	S.Robertson	K.Barry
1	27/09/2004	Revised Risk Curves	J.Post	G.Penno	S.Robertson	K.Barry
0	05/07/2004	Issued For Release	J.Post	G.Penno	S.Robertson	K.Barry
A	17/06/2004	Issued for CVT Review	J.Post	G.Penno	S.Robertson	K.Barry

DRAWING NO.	TITLE

CHEVRON TEXACO AUSTRALIA PTY LTD
L34, QV1, 250 St Georges Terrace
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WA
6000
Tel: (+61 8) 9216 4000
Fax: (+61 8) 9216 4555
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THIS DRAWING - APPROVALS

	SIGNATURES	DATE
DRAWN	J.Post	08/11/2004
CHECKED	G.Penno	08/11/2004
APPROVED	S.Robertson	08/11/2004
CLIENT	K.Barry	08/11/2004

TITLE

CHEVRON TEXACO AUSTRALIA PTY LTD
PLANT QRA

FILE TYPE	SIZE	SCALE	DWG NO	REV
AUTOCAD	A3	1:10	CT-RA-001	3

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Technical Appendix F1

Economic Consequences and Management Measures

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FINAL REPORT

ChevronTexaco Australia Pty Ltd

Gorgon Gas Development: Economic Consequences and Management Measures - *Technical Appendix F1:*

October 2004

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FINAL REPORT

ChevronTexaco Australia Pty Ltd

Gorgon Gas Development: Economic Consequences and Management Measures - *Technical Appendix F1:*

October 2004

Reference: 0013438

For and on behalf of Environmental Resources Management Australia

Approved by: Paul Whincup

Signed:
Position: Project Director
Date: 19 October 2004

TABLE OF CONTENTS

1 Economic Consequences and Management Measures

1.1 Overview

The economic benefits from the Gorgon Development have national, state and regional dimensions. The benefits derive mainly from general economic growth, which result in flow-on effects across the community through businesses, workers and government revenues, and from increased competition in domestic gas markets. There may also be economic costs associated with risks to conservation values and potential regulation of greenhouse gas emissions.

Increases in economic activity are quite well understood, based on empirical evidence. Future impacts are best estimated using economic modelling. For projects of the size of proposed Gorgon Development that have a significant impact on exports and Gross Domestic Product, it is necessary to undertake macro level modelling.

The benefit of modelling is to enable analysis of the possible medium-term macroeconomic impacts of the Development in terms of economic variables such as investment, exports and tax revenues, measured as deviations from a control scenario and long-run growth path without the Development. The focus of the analysis is the aggregate economic response over periods from one to ten years, rather than on the long-run growth path of the overall economy.

1.2 Economic Factors Requiring Assessment

The proposal has the potential to result in impacts at the national, state, regional and local levels. Table 1.1 shows potential impacts against these levels, and makes an assessment of the significance of impact and the need for its management. These impacts are discussed in detail in the following sections.

Table 1.1 Economic Factors Requiring Assessment

Impact Area	Commonwealth	State	Regional / Local
Revenue flows to government	Company tax, PRRT systems already in place	Payroll tax, duty in place. No royalty sharing agreement between state and Commonwealth.	Limited revenue flows to local governments
Employment	Some migration to WA	Significant employment opportunities, managed on FIFO basis	Need to manage expectations with availability of labour
Direct economic activity	Moderately significant, but need to manage opportunities	Significant, but need to manage opportunities	Need to manage expectations with availability of goods and services
Indirect economic activity	Moderate	High	Need to manage expectations with availability of goods and services
Economic assessment of conservation value	Not applicable	Significant, framework set out in State Agreement	Significant, process not yet established
Economic implications of greenhouse	Negligible unless there is national regulation	Current WA Draft Greenhouse Strategy does not impose targets	Need to submit proposals for injection of carbon dioxide

The scoping prepared for the Development, and approved by the Department of Environment and Heritage (DEH) and Environmental Protection Authority (EPA), identifies those factors requiring assessment.

2 National and State Impacts

2.1 Summary of Impacts

The national and state economic consequences of the Gorgon Development have been assessed by two independent macroeconomic models of the Australian economy - AE-MACRO and MMRF-GREEN. AE-MACRO is a dynamic model developed in 1992 by Access Economics[1]. The model has a stable long-term growth path that accords with neoclassical economic theory, together with short-term dynamics derived from the Australian economic experience over the past 25 years.

Results from the AE-MACRO modelling studies have previously been published in Chapter 11 and Appendix K of the *ESE Review*. MMRF-GREEN is operated by the Centre of Policy Studies at Monash University, and is based on the same economic principles as AE-MACRO.

Results from the MMRF-GREEN modelling studies have been included in a report by the Allen Consulting Group[2], which was made available to the government. The results are summarised below. The key finding from the modelling is that the Gorgon Development will produce very substantial economic benefits (refer Tables 2.1 and 2.2).

Table 2.1 Summary of Modelling Results for Australia

Economic Consequences **Net Present Value (NPV) increase over Business As Usual till 2030, unless otherwise indicated**	**AE-MACRO** **A$ million NPV, at 5% discount rate**	**MMRF-GREEN Scenario 1** **A$ million NPV, at 4% discount rate**	**MMRF-GREEN Scenario 2** **A$ million NPV, at 4% discount rate**
Gross Domestic Product	3,600 (in 2030)	21,000	31,200
Business Investment	11,000	-	-
Export Revenues	2,400 per year (2012-2030)	4,000 (in 2020)	5,600 (in 2020)
Commonwealth Revenue	7,000	10,000	10,000
Commonwealth Budget Balance	9,000	11,400	14,300
Employment	6,000 in 2030	100 in 2020[3]	100 in 2020
Private Consumption	1,800	7,100	6,600
Welfare Impact	24,000	-	-
Source: Reports by Access Economics and Allen Consulting			

[1] Access Economics, *National and Western Australian Economic and Fiscal Impacts of the Gorgon Gas Supply and LNG Projects*, Final Report to ChevronTexaco, December 2002.

[2] Allen Consulting Group, *Report on Economic Modelling Outcomes*, June 2003.

[3] The MONASH model does not produce significant impacts at the national level due to treatment of labour. However State level employment is significant.

Table 2.2 Summary of Modelling Results for Western Australia

Economic Consequences **Net Present Value (NPV) increase over Business As Usual till 2030, unless otherwise indicated**	**AE-MACRO** **A$ million NPV, at 5% discount rate**	**MMRF-GREEN Scenario 1** **A$ million NPV, at 4% discount rate**	**MMRF-GREEN Scenario 2** **A$ million NPV, at 4% discount rate**
Gross State Product	2,900 (in 2030)	25,800	43,500
Public Revenues	-	48,000	18,000
State Budget Balance	300	1,000	1,900
Employment	1,700 in 2030	6,600 in 2020	4,500 in 2020
Private Consumption	240	1,700	4,600
Welfare Impact	4,000	-	-
Source: Reports by Access Economics and Allen Consulting			

Differences between the modelling results are due to:

- differences between scenarios modelled, as shown in Table 2.3.
- methodological differences between models.

Table 2.3 Scenarios Modelled

Gorgon Development Details	**AE-MACRO**	**MMRF-GREEN (Scenario 1)**	**MMRF-GREEN (Scenario 2)**
Raw Gas Production	Raw gas production begins at 150 PJ in 2007 and plateaus at 740 PJ annually from 2019-2030.	Not stated	Not stated
Domestic Gas (DOMGAS) Supply	Domestic gas sales begin in 2012, peaking in 2015 at 110 PJ per annum until 2030.	Domestic gas sales begin in 2012, peaking in 2015 at 110 PJ per annum until 2030.	Domestic gas sales begin in 2012, peaking in 2015 at 110 PJ per annum until 2030.
Condensate Export	Condensate export reaches a peak of 5.6 MMSTB/year from 2019-2030.	Condensate export reaches 5.6 million tonnes per annum from 2019-2030	Condensate export reaches 5.6 million tonnes per annum from 2019-2030
First LNG Train	Production from 2007, achieving full throughput from 2012. From this point until 2030, LNG will average 9.85 million tonnes per annum	Production from 2007, achieving full throughput from 2012. From this point until 2030, LNG will average 9.85 million tonnes per annum	Production from 2007, achieving full throughput from 2012. From this point until 2030, LNG will average 9.85 million tonnes per annum
Second LNG Train	Not included	9.85 million tonnes of LNG annually from 2012.	9.85 million tonnes per annum
First GTL Phase	Not included	GTL operation consisting of a quantity of 50,000 Barrels per day.	GTL operation consisting of a quantity of 50,000 barrels per day.
Second GTL Phase	Not included	Not included	GTL operation consisting of a quantity of 50,000 barrels per day.
Regulation of greenhouse gas emissions	No	No	No
Source: Reports by Access Economics and Allen Consulting			

2.2 Model Assumptions and Descriptions

2.2.1 Assumptions

Apart from the assumptions for different scenarios, the models include the following important assumptions:

- PRRT revenues will be returned to taxpayers.
- No assistance or tax concessions by either Commonwealth, state, or local governments.
- Carbon taxes or carbon credits are excluded.
- Australian and international economies develop along steady long-run paths.
- For most assets, depreciation begins when it comes into use, not when capital expenditure is first undertaken. The depreciation values are denominated in constant 2002 prices, while adjustments were made to allow for domestic and overseas inflation.
- The export price of the product 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.

2.2.2 AE-MACRO

In the AE-MACRO model, the best measures of the Development's overall impact on economic welfare the increase in annual flows of private consumption and public sector final expenditures that it allows. Another is the estimated increase in public and private sector wealth at the end of the simulation period.

The analysis involved comparing two long-term simulations of the AE-MACRO model that represented scenarios with and without the Development. The first is a standard long-run projection, based on assumptions about trends in macro-economic variables. In the second, the gas supply and LNG activities are added to the model used in the standard projection. The difference between the two simulations provides an indication of the likely macroeconomic impact of the Development.

For the purposes of the AE-MACRO modelling exercise, the overall Development included:

- Upstream development of the Gorgon gas fields, pipelines and offshore platforms
- Downstream establishment of the LNG preparation facility and all associated infrastructure
- Construction of a hypothetical gas-based resource Development in two phases and its ongoing operation

- Increased competition in the WA domestic gas market.

While it is possible to also use the Gorgon gas as feedstock for a world-scale plant producing low sulphur distillate for the domestic and international markets (GTL facility), this activity has not been included in the AE-MACRO scenarios.

AE-MACRO assumes that most of the Gorgon field gas is converted into LNG at a plant on Barrow Island and then exported. The Development also generates condensate for export, and natural gas piped onshore for the WA domestic market. Natural gas demand and supply projections for the Western Australia indicate a surplus of up to 60 PJ of gas that would be available to allocate to an export oriented gas-based resource project.

The AE-MACRO modelling horizon extends to 2030, which equates to the estimated near depletion point of the Gorgon gas field. While there are significant additional gas resources nearby that might allow the Development to continue operating, this is not considered in the economic study.

The upstream development of the Gorgon gas field includes the collection of natural gas from extraction wells and infield flow-lines, using sub-sea equipment and hardware. Export flow-lines transmit the gas onshore into a slug-catcher, which separates the condensate. Carbon dioxide and inert gases are removed, for pumping underground. The remaining water and hydrocarbons are then removed before the gas passes to further processing.

The economic model assumes that raw gas production begins at 150 PJ in 2007 rising to a plateau of around 740 PJ annually from 2019 to 2030. The LNG plant uses feed gas subject to pre-treatment processes and piped ashore. The LNG plant reaches full operation in 2012 and produces at a constant level.

Condensate, a valuable by-product, is derived from both upstream and downstream production phases, with a greater share produced from the slug-catcher (upstream) than from the LNG liquefaction phase (downstream). The LNG liquefaction phase involves the removal of condensate, water and inert gases, and compression of the raw feed gas. The LNG produced is stored until exported.

The model assumes that the total output of condensate will reach a peak from 2019 to 2030, at around 5.6 million standard barrels per annum (MMSTB/year). The Development is expected to begin producing LNG from 2007, achieving full LNG throughput from 2012. From this point until 2030, LNG will average 9.85 million tonnes per annum (energy content 538 PJ).

The Development also yields natural gas for sale in the domestic market (DOMGAS) for commercial and industrial uses. The gas will be piped to the mainland, compressed and then injected into the Dampier-to-Bunbury gas pipeline. Natural gas will be available for domestic sale from 2012, reaching full production of 110 PJ per annum in 2015.

The gas-based resource Development considered by the AE-MACRO model assumes that the amount of gas available will be on the order of 29 PJ annually from 2016 to 2019, and 61 PJ from 2020 to 2030. This quantity would be sufficient to sustain a petrochemicals facility, constructed in two stages. Capital expenditure is concentrated in two periods, from 2014 to 2015, and from 2018 to 2019. It would export its product, and would rely mainly on gas as a raw material. Total investment is projected at US$200 million, with approximately 40% local content. Employment during the main operational phase would be 70 persons from 2020 to 2030.

To estimate the economic impacts on WA, the state and industry modules of AE-MACRO were used. These models allocated a national simulation of the model to state and industries, in line with projected long run trends in demand structure and industry and state relativities. It therefore allowed an assessment of the implications of a shock to the national economy at the level of an individual state.

2.2.3 MMRF-GREEN

The MMRF-GREEN model expanded the Development considered by the AE-MACRO model in two different scenarios. The analysis involved comparing three long-term simulations - representing scenarios with and without two different gas-based projects (scenario 1 and scenario 2). As in the AE-MACRO model, the base-case without the scenarios was a standard long-run projection, based on assumptions about trends in macro-economic variables.

In scenario 1, an initial development of one LNG train plus DOMGAS was expanded later to include a second LNG train, producing 9.85 million tonnes of LNG annually from 2012. The LNG would all be exported. Condensate would also be produced, building up to 5.6 million tonnes per annum from 2019. DOMGAS sales reach 110 PJ per annum in 2015.

Under scenario 2, the scenario 1 development activities are supplemented by two phases of GTL production. The GTL operation modelled by MMRF-GREEN consists of a quantity of 50,000 Bpd per phase.

The MMRF-GREEN horizon also extends to 2030, and therefore, does not consider additional exploration of gas resources nearby. Net present values for 2030 are derived using a 4% discount rate, instead of a 5% discount rate considered by the AE-MACRO model. The low discount rates in both models were used in order to present results in real terms (constant 2002 prices).

Representation of different scenarios relies heavily on the data and modelling assumptions supplied by the project developers. The results obtained by the modelling approach are a projection, on the assumption that past economic trends and current policies continue. The results are conditional on the various assumptions made, and represent a potential outcome, rather than an exact forecast of the long-term behaviour of the economy.

2.3 Detailed Description of Modelling Results

The following sections describe first, the direct and indirect economic consequences at the Commonwealth and state levels derived from first, the AE-MACRO, and then from the MMRF-GREEN model.

2.3.1 AE-MACRO National Results

The AE-MACRO model implies that the Development's main direct national economic impacts are on business investment, exports and Commonwealth tax revenues. The Development provides a substantial boost to overall business investment until the 2020s, totalling over $11 billion. Once production begins, LNG and condensate sales generate substantial export revenues. Over the period from 2007 to 2030, Development exports average over $2 billion annually. The Development is expected to make additional company tax and PRRT payments to governments (not only the Commonwealth budget sector) projected at around $17 billion, over the life of the Development.

During the investment and initial production phase (2003 to 2009), the Development investment raises aggregate demand economy-wide. While a considerable proportion of the investment is imported, a substantial increase in national output and employment occurs.

As investment reaches its peak in 2006, Gross Domestic Product (GDP) increases by about $1.5 billion and total employment rises to 15.5 thousand at its maximum point. Private consumption reaches $750 million reflecting higher wage incomes.

Higher aggregate demand leads to a $1.7 billion increase in 2006, and a $1.6 billion deterioration in the trade balance. This is financed by capital inflows from the Development's investors.

The sharp rise in total demand leads to a temporary increase in inflation, peaking in 2007. This raises the price of domestic output relative to imports, raising the real exchange rate, resulting in some crowding out of other exports. The Government responds by raising short-term interest rates. Imports rise and interest-sensitive components of demand such as dwelling investment fall.

GDP increases further from 2009 onwards, as the first investment phase increases production while investment in the second phase is at a peak. Domestic final demand and imports reach a second peak in 2009. In that year GDP is some $2 billion, or 0.2% above the level in a scenario without the Development. Employment impact is some 7,000 higher in 2009. There is a further slight rise in inflation.

The economic model estimates that between 2012 and 2030, annual GDP is on average 0.25% - some $3.6 billion - above the level in a scenario without the Development. Private consumption is nearly $1.8 billion higher (a 0.20% increase). Employment raises, on average, by over 6,000.

Higher demand and activity leads to some increase in inflation is not fully offset by higher interest rates and a higher exchange rate. Inflation on average is some 0.05 percentage points higher over the period from 2012 to 2030. The short-term interest rate is on average 0.07 percentage points above the level in a scenario without the Development, while the real exchange rate is up by 0.2% on average.

As mentioned above, the Development and the additional economic growth it stimulates will generate substantial additional revenue for the Australian public sector, which includes the:

- Commonwealth budget sector
- Combined state/territory budget sectors
- Commonwealth and state/territory off-budget authorities
- Local government.

The Development's impacts on the Commonwealth budget were calculated under the assumption that net increases in revenues from the government tax and the PRRT would allow a decrease in tax burdens, and that current policies would be maintained.

Under current tax arrangements, the Gorgon Development (and the associated upstream development) are projected to result in additional company tax and PRRT payments of around $17 billion over the life of the Development. In net present value terms, this comes to $7 billion at a 5% real discount rate.

It is assumed that the Commonwealth and state governments will respond to increased revenues from the Development, and the additional growth this stimulates. It is likely that Government will increase expenditures in line with the growth in the economy, and reduce the average personal income tax rate to keep the ratio of public debt to GDP from falling too rapidly. Income tax reductions in turn stimulate further growth.

The overall public sector gain can be seen as the direct company tax and PRRT payments generated by the Gorgon Development, along with other revenue stimulated by additional economic activity. In turn, that equals the sum of additional outlays by the Commonwealth and State Governments, and their additional net lending to other sectors of the economy, together with revenue the public sector forgoes because it provides a tax cut.

At a discount rate of 5% in real terms, the Development generates an overall net impact of $11.3 billion, of which $5.9 billion takes the form of an assumed cut in income taxes.

The impacts of the Development on the Commonwealth budget can also be isolated. The Commonwealth receives company tax and PRRT payments from the Development's investors. Commonwealth tax receipts benefit from the overall increase in economic activity, while Commonwealth expenditures also rise. At a real discount rate of 5% the net present value of overall Commonwealth budget gains is projected at over $9 billion.

The Development's overall impact on the Australian economic welfare is measured as the increase in annual flows of private consumption and public sector final expenditures that is allows, and the increase in public and private sector wealth at the end of the simulation period.

According to AE-MACRO the welfare impact is mainly on the private sector. At a real discount rate of 5%, the Development results in a total private consumption and wealth of $17,610 million in net present terms, while public expenditure and wealth amounts to $6,420 million. Therefore, the welfare impact is mainly on the private sector, and totals around $24 billion in net present values terms.

In summary, the Development's direct impacts on the national economy include a substantial increase in GDP and net exports. Although the Development generates an offsetting outflow in the invisibles account of the balance of payments to pay dividends, its overall impact is positive. The Development raises government revenues, allowing a cut in personal income taxes. Higher consumer demand reflects in higher imports, but also an increase in Australian production and employment. The Australian economic welfare is improved mainly by an increase in private consumption and wealth over the Development life.

MMRF-GREEN

The MMRF-GREEN modelling national results are similar to those obtained from the AE-MACRO model. The MMRF-GREEN model considered two different scenarios relative to a case without the Development (scenario 1 and 2). Scenario 2 results are always presented inside brackets. Net present values for 2030 are derived using a 4% discount rate.

GDP would be boosted by the Development, to a total of $1.9 billion ($2.9 billion) or 0.21% (0.33%) higher in 2020 than in a scenario without the Development. The fact that the gain in GSP is higher than the gain in GDP reflects the fact that some economic activity is crowded out in other states and territories. In Net Present Value (NPV) terms to 2030, GDP is almost $21 billion ($31.2 billion) higher than it would otherwise have been.

Under both scenarios the Development provides a significant and positive impact on state employment, but does not promote significant employment increases at the national level - around 100 full time equivalent workers (FTE) in 2020 for scenario 1 and 2 as compared to a scenario without the Development.

Under scenario 1, both exports and imports increase in volume at the national level. Australian export volumes in 2020 would be $716 million higher, while import volumes are $414 million higher. In NPV terms, net exports would be around $4.0 billion higher than otherwise.

Under scenario 2, Australian exports and imports both increase in volume as well. However, the volume of exports decreases until 2012, leading to a lower relative impact over the projection period. National export volumes are $1.5 billion higher in 2020, while import volumes are $315 million higher. In NPV terms, net exports at the national level are around -$5.6 billion.

In the MMRF-GREEN model, consumption is used as a proxy to total economic welfare. The Development generates substantial increases in consumption nationally, as compared to the state level. Consumption would be $7.1 billion ($6.6 billion) in NPV terms higher over the entire modelling period. The lower figure under scenario 2 is largely explained by the lag in PRRT payments as compared with the smaller scenario. This implies that many of the gains in economic welfare will be felt beyond 2030.

Under scenario 1, the Gorgon Development generates substantial revenue for the Commonwealth Government, raising over $375 million annually in PRRT by 2020 and around $345 million in company taxes relative to the scenario without the Development. As a result, the net financing requirement for the Commonwealth declines from 2004 thus implying a significant positive impact on the Government's fiscal position. The net impact on Australia's net financing requirement over the life of the Development is also positive - that is, the Development will improve the Australian government's budget balance by a NPV of $11.4 billion.

In scenario 2, the Development gives rise to over $688 million in company taxes in 2020, but does not generate PRRT until later in the simulation period because of the higher field development costs associated with the greater production of gas. As a result, the change in net financial requirements (i.e. the need to borrow or raise additional taxes) for the Commonwealth brought about by the Development is negative (implying a positive fiscal impact) from 2003. The Development will improve the Commonwealth's budgetary position (i.e. reduce its net financing requirement) by $14.3 billion in NPV terms.

The economic assessment of major projects needs to consider the ability of "crowding out" the investment potential for other projects. There is a limit to the ability of Australian investors to attract foreign investment from global capital markets, as well as, on the potential labour supply. Aggregate investment at a given period, is determined by macroeconomic variables, impacted by the Gorgon Development. Other potential projects in Australia may suffer consequences from changes in variables such as the exchange rate, the real wage rate, and the level of demand for Australian exports.

Under both models, the Gorgon Development results in limited crowding out. Since it is a capital-intensive project, there is little crowding out as a consequence of changes in real wages. In terms of the exchange rate, while the Development gives rise to significant additional exports (which tends to push the value of A$ relative to other currencies up), there are also high dividend payments to the overseas owners of the capital, which forces the value of A$ relative to other currencies down. Moreover, the more that Governments tax income flows from the Development, however, the more the offsetting downward pressure on the exchange rate is reduced and the greater the crowding out effect. The AE-MACRO model suggests less crowding out than the MMRF-GREEN model.

In the MMRF-GREEN model, the balance of trade effect is influenced by a higher degree of crowding out under scenario 2 than scenario 1, generated by different exchange rate impacts. The high level of exports under scenario 2 contributes to crowding out by pushing the real exchange rate up, and this effect is exacerbated by high levels of inward investment in the Development of a larger scale and over a longer period than in scenario 1. Outward flows of dividends have a lower offsetting effect over this period in scenario 2 as compared to scenario 1.

2.3.2 AE-MACRO State Results

Although tax revenues flow mainly to the Commonwealth, the Developments output and expenditures occur mainly in WA. The State macroeconomic impacts broadly mirror the national results, with some differences occurring through the investment and production phases. In percentage terms, the Development has a much larger impact on the State economy than on the national economy. The peak impact on the GSP, at about 2.2%, is well above the corresponding impact on GDP, 0.25%.

The Development provides a substantial boost to overall business investment until the 2020s, totalling over $11 billion for Australia. This projected investment volume adds directly to the state's final demand, so that almost the entire increase to national investment is reflected in the state outcome. The same holds true for Development exports - the net increase in the state's merchandise exports closely mirrors Development exports. Once production begins, LNG and condensate sales generate substantial export revenues. Over the period from 2007 to 2030, the Development's exports average over $2 billion annually.

During the investment and initial production phase (2003 to 2009), the Development's investment raises aggregate demand to successive peaks, the largest in 2006. A considerable proportion of the investment is imported, but there is still a substantial increase in output and employment. As expenditure on the first production phase reaches its peak in 2006, GSP increases by about $650, and total employment by almost 8,000 jobs. Private consumption is $200 million higher at this point, reflecting higher wage incomes.

Up to 2012, direct impacts on the state accrue mainly through the employment of production workers, payment of payroll tax and expenditure on intermediate inputs. Operation expenditures and employment rise as the Development is implemented. Direct employment by the Gorgon Development is over 600 in 2012. Non-wage operating costs average some $230 million annually.

As the Development reaches full operation in 2012, direct impacts include a substantial contribution to GSP and merchandise exports. Between 2012 and 2030, annual GSP is on average some $2.9 billion above the level in a scenario without the Development. The percentage increase is over 2% in 2012. It then declines mainly because the Development's output remains constant while the state overall experiences strong growth.

Private consumption is on average some $240 million higher over the period from 2012 to 2030. Reflecting the national pattern it shows a gradual increase throughout this period. On average, it is 0.25% higher than in a scenario without the Development. Over this period, state employment is up, on average, by about 1,700 jobs over this period. The Development creates demand for labour through its ongoing investment expenditure, as well as its operational employment. The increase in the State's employment is partly met by increased labour supply from the existing population, and partly met by increase in interstate migration.

The Development would have considerable impacts on state public sector finances. The Development's impacts on the state budget were calculated under the assumption that net increases in revenues from the government tax and PRRT would allow a decrease in tax burdens, and that current policies would be maintained. As an example, revenues from the Commonwealth (in the form of GST and other payments) are assumed to be distributed on the same basis as at present. It also implies no change in state tax rates. The projection of expenditures is consistent with relevant national and state macro-economic determinants. This avoids policy changes that would result in substantial deficits, as well as reductions in tax rates to take advantage of a strong budgetary position.

As compared to the Commonwealth budget sector, the Development has only modest direct impacts on the State public sector finances. On the revenue side, the main impact is the additional payroll tax on the Development's employment. On the expenditure side, it is assumed that there is no state government subsidies. Nor is there a requirement for project-specific investment in infrastructure by state authorities. Indirect effects are more substantial, but still modest as compared to the impacts on the Commonwealth budget.

In the absence of large specific impacts, the net effect on the state budget is highly dependent on the precise assumptions employed. The economic modelling results in an increase in both state revenues and expenditures. Initially, expenditures run ahead of revenues as the state economy expands. As production increases, the position is reversed by the flow of economic resources in the form of higher consumption expenditure and goods and services tax (GST) revenues. The overall increase in state employment results in a positive impact in payroll tax receipts. Also, a slight increase in state population raises the state's share of the GST pool. Revenues reach a peak (in real terms) at around 2010, at the end of the initial investment phase. After 2020, this level is surpassed by further revenue growth, as the Development's wider benefits flow through.

The NPV of the projected revenue gain is approximately $1.1 billion at a 5% real discount rate. The NPV of projected additional current expenses is slightly smaller (at $0.8 billion) resulting in an improvement in NPV of the general government balance. However, taking account of projected capital expenditures and other items, turns this into a slight fall in the NPV of the state's underlying fiscal position (and net lending).

The Gorgon Development would also have considerable impacts on the state's economic welfare. The definition of economic welfare used in the national model is slightly broader than the one used for the state. For the national model, economic welfare includes estimates of the changes in private and public wealth, rather than just the change in net public debt as considered for the State.

The Development's overall impact on the state's economic welfare is measured as the increase in annual flows of private consumption and public sector final expenditures that is allows, and the increase in public and private sector wealth at the end of the simulation period.

According to AE-MACRO the welfare impact affects both private and public sectors. At a real discount rate of 5%, the Development improves state's economic welfare by an estimated $4 billion in net present terms. This estimate is about one sixth of the increase in total Australian economic welfare derived in the national modelling of the Development.

MMRF-GREEN

The MMRF-GREEN modelling state results are similar to those obtained with the AE-MACRO model. As noted above, the MMRF-GREEN model considered two different scenarios relative to a case without the Development (scenario 1 and 2). Scenario 2 results are shown inside brackets. NPV's are calculated using a 4% discount rate till 2030.

GSP would be boosted by the Development, to a total of $ 2.2 billion ($3.3 billion) or 2.1% (3.2%) higher in 2020 than in a scenario without the Development. In NPV terms to 2030, GSP is around $25.8 billion ($43.5 billion) higher. There is a significant and positive impact on employment in WA. The Development leads to an increase in employment of 6,600 FTE (4,500 FTE) persons in 2020 over a scenario without the Development.

In the MMRF-GREEN model, consumption is used as a proxy to total economic welfare. The Development generates less substantial increases in consumption in WA, then nationally. Consumption would be $1.7 billion ($4.6 billion) in NPV terms over the entire modelling period.

Scenario 1 results indicate that the Government budgetary impacts for the State are substantially less than the Commonwealth impacts. The Development generates $70 million in additional revenues for the State by 2020, while the net outlays are lowered by around $22 million. The net impact on the State's net financing requirement over the life of the Development is also positive - that is, the Development will improve the State Government's budget balance by a NPV of $1.0 billion.

The budgetary impacts for WA generated under scenario 2 are substantially less than the Commonwealth impacts. The Development generates $73 million in additional revenues for WA by 2020, while net outlays are lowered by about $55 million. The net financing requirement is reduced from 2003. The Development will reduce the State Government's net financing requirement (ie. improve its budgetary position) by $1.9 billion in NPV terms.

2.3.3 Summary of Results

Overview

The economic modelling available shows the most significant impacts as increase in annual flows of private consumption (spending) and public sector final expenditures. Western Australian benefits from significant economic growth but there are modest impacts on state finances.

The nature, direction and magnitude of economic indicators of these impacts over the modelled period (2002-2030) are summarised in Table 2.4.

Table 2.4 Summary of Economic Indicators

Indicator	National	State
Economic output (GDP)	Results in substantial growth in operational phases adding 0.25% to GDP ($3.6bn). Growth during investment phase is lower.	Gross State Product increases by $650m during investment peak (2006) and very substantial growth in the operational phase adding 2% to state product ($2.9bn). Approximately 1/6 of the increased economic welfare is captured by WA. The major beneficiaries are the construction, logistics and business services sectors.
Imports	$1.7bn (0.4%) increase in investment phase (2006) leading to a large $1.6bn deterioration in balance of trade. Thereafter strongly positive impact on balance of payments despite outflow of dividends.	Imports are substantial lower than the baseline during the investment phase.
Exports	Generates exports from 2007 onward and a nationally significant $2.4bn annually between 2012 and 2030.	Operational phase makes substantial contribution to state product (around 3.7% at peak)
Business investment	Direct investment impacts of $11bn over 20 years with most increase (0.85%) in investment phase.	Substantial boost to 2009 (as high as 6.45% between 2002-06) with investment continuing at lower levels until mid 2020s.
Household disposable income	Higher government revenues over medium term allow cuts in personal income tax resulting in 0.2% rise in the longer term.	Higher employment, wage income and modelled cuts in personal income tax add between 0.4% and 0.55% to after tax income.
Private consumption	$750m higher in 2006 reflecting higher wage incomes. Additional consumer demand between 2012 and 2030 of $1.8bn reflects in higher imports.	$200m higher at 2006 investment peak and $240m higher during operations.
Employment	Additional employment of 15,000 (0.08%) at investment peak and reducing thereafter	Additional employment of 8,000 at investment peak and around 2,000 higher during operations.
Inflation rate	Adds between 0.03% initially, 0.07% in the medium term and 0.06% over the longer term	Adds around 0.5% to inflation consistently throughout the Development
Budget finances	Company tax and PRRT payments of raise $7bn. The overall improvement in public sector finances is $11.3bn of which $9.2bn is the impact on Commonwealth budget finances.	Overall modest impacts despite higher payroll tax revenue and transfers from Commonwealth of higher GST revenue. Initially expenditure runs ahead of revenue. Revenue of $1.1bn is marginally exceeded by outlays.

In summary, results obtained from the AE-MACRO model were confirmed by the second modelling using the MMRF-GREEN model. This second economic model considered the economic consequences of two different Development scenarios as the one considered by AE-MACRO. In scenario 1, an initial development of one LNG train plus DOMGAS is expanded later to include a second LNG train.

In scenario 2, the scenario 1 development activities are supplemented by two phases of GTL production. Thus, the MMRF-GREEN model considers a larger number of activities at Barrow Island.

The MMRF-GREEN model results for scenario 1 (scenario 2 results in brackets) in terms of NPV out to 2030, as compared to a scenario without the Development, are:

- GDP would be $21 billion ($31.2 billion) higher
- The community's economic welfare, as measured by consumption, would be $7.1 billion ($6.6 billion) higher
- Australian exports would be $9.1 billion ($4.7 billion) greater.

In WA, GSP would increase to $25.8 billion ($43.5 billion). As in the case of the AE-MACRO model, the Commonwealth and State Governments would allow the tax burden to be reduced because of increased company tax and PRRT revenues. The net impact on the Commonwealth budget is estimated at $11.4 billion ($14.3 billion) in NPV terms to 2030. The equivalent figure for the WA budget is much lower, at $1.0 billion ($1.9 billion).

In general, the AE-MACRO model generated less crowding out than the MMRF-GREEN model. Crowding out is used here to describe the effect that fierce competition for a finite supply of an input into production (e.g. land, construction materials, skilled labour) has in forcing up the prices for that input and thus making more marginal uses of the input uncommercial. Such competition and inflation is a normal market reaction to scarcity of supply and in the long run is likely to result in inputs being allocated to projects in which they are most productively. However, 'crowding out' could be said to apply in the short term or when demand from a project far outstrips the local capability to supply.

Under both models, the Gorgon Development results in limited crowding out. Since it is a capital-intensive project, there is little crowding out as a consequence of changes in real wages.

Both models suggest that the major impact of the Development in terms of economic activity (GDP/GSP) would be in WA. However, much of the gain at the state level also occurs elsewhere in Australia. This is, in large part, a consequence of the disparity in the budgetary impacts. Since the Development is based on developing a natural resource that lies in the Commonwealth jurisdiction (and therefore pays PRRT) and company taxes are paid at the federal level, the net positive impact on the state's budget is much less significant than the impact on the Commonwealth.

Summary of National Results

AE-MACRO results (in 2002 prices) indicate that the Development's direct economic contribution will include:

- A total of $11 billion of investment expenditure. The data imply direct employment of around 3,000 in the peak investment year (2006), with further employment in subsequent investment phases.

- The generation of exports from 2007 onwards. At full operation, net exports would average $2.4 billion annually over the period from 2012 to 2030. Operational employment would average some 400 persons, with an additional annual average of 200 persons associated with an ongoing investment program.

- A contribution to Commonwealth tax revenues totalling $17 billion (including company tax and PRRT payments) over the life of the Development. In NPV terms this comes to $7 billion at a 5% real discount rate.

According to the AE-MACRO economic modelling, the Development would generate substantial positive national economic impacts divided between the different Development phases.

During the initial investment phase (from 2003 to 2009), the main results are:

- As investment reaches its peak in 2006, GDP increases by about $1.5 billion, and total employment by up to 15.5 thousand jobs. Private consumption is about $750 million higher, reflecting higher wage incomes.

- Higher aggregate demand leads to $1.7 billion increase in imports in 2006, and $1.6 billion deterioration in the trade balance. This is financed by capital inflows from the Development's investors.

During full operation (from 2012 to 2030):

- There is a substantial increase in GDP and net exports, with an offsetting outflow in the invisibles account of the balance of payments to pay dividends to the Development's investors. However, the Development's overall impact on the balance of payments is strongly positive.

- The Development raises government revenues, allowing a cut in personal income taxes. Higher consumer demand reflects in higher imports, but also an increase in Australian production and employment.

- Between 2012 and 2030, annual GDP is on average 0.25% - some $3.6 billion above the level in a scenario without the Development. Private consumption is nearly $1.8 billion higher - a 0.2% increase. Employment is higher on average, by over 6,000 jobs.

The Gorgon Development will also result in positive economic impacts on overall public sector finances, the Commonwealth budget and on national economic welfare. The overall impact on public sector finances is measured as the sum of the model's estimates of additional public sector revenues, plus the revenue foregone through income tax cuts.

According to this definition:

- The NPV of the impact on overall public sector finances is an estimated $11.3 billion at a real discount rate of 5%.

- Using a similar definition of net impact, the NPV of the impact on Commonwealth budget finances is an estimated $9.2 billion in 2002 at a real discount rate of 5%.

In the AE-MACRO model, the best measures of the Development's overall impact on economic welfare is the increase in annual flows of private consumption and public sector final expenditures that it allows, and the increase in public and private sector wealth at the end of the simulation period. As modelled, in NPV terms, the welfare impact is mainly on the private sector. At a real discount rate of 5% the Development improves Australian economic welfare by an estimated $24 billion in NPV terms.

Summary of State Results

The state macro-economic impacts broadly mirror the national results, with some differences. While the Development's output and expenditures occur mainly in WA, the tax revenues flow mainly to the Commonwealth. At a real discount rate of 5% the Development improves the state's economic welfare by about $4 billion. This estimate is about one sixth of the increase in total Australian economic welfare derived in the national modelling of the Development.

AE-MACRO modelling results for WA also indicate that the Development generates a substantial contribution to business investment over the period until 2009 (with further investment continuing until the mid 2020s), and to GSP and merchandise exports once it begins operation.

The projected response of WA business investment closely tracks that of the Development, being slightly higher over the entire Development period. As expenditure on the first production phase reaches its peak in 2006, GSP increases by about $650 million, and total employment by almost 8,000 jobs. Private consumption increases by $200 million, reflecting higher wage incomes.

The consequences of an increase in GSP and exports are mostly felt at the national level, through the real exchange rate and Commonwealth tax revenues. These effects flow back to the state (and to other states/territories) through a rise in real incomes and wealth, a reduction in the average rate of personal income tax and an increase in Commonwealth transfers of GST revenues to the Western Australian Government.

The Development has only modest direct impacts on WA public sector finances. Indirect effects are more substantial, but smaller than the impacts on the Commonwealth budget. Model results indicate that initially expenditures run ahead as the state economy expands. However, as production plateaus and the Development's national economic impacts flow through in the form of higher consumption expenditure and GST revenues, the position is reversed and the state budget benefits. The NPV of the projected revenue gain to WA over the project lifetime is approximately $1.1 billion in NPV terms at a 5% real discount rate.

The Development also has direct impacts on the state through the employment of production workers, payment of payroll tax and expenditure on intermediate inputs. Between 2012 and 2030, annual GSP is on average some $2.9 billion above the level in a scenario without the Development. In percentage terms, the Development has a much larger impact on the Western Australian economy than on the national economy. The peak impact on the GSP (at about 2.2%) is well above the corresponding impact on the GDP (0.25%).

State employment increases, on average, by about 1,700 jobs over the period from 2012 to 2030. The increase in the state's employment is partly met by increased labour supply from the existing population, and partly by a small increase in interstate migration.

3 Regional and Local Impacts

3.1 Introduction

Specific regional modelling has not been undertaken. However modelling using MMRF-GREEN suggests that Gross Regional Product in the Pilbara Region would be 37.1% higher in 2020 under Scenario 1 and 54.6% higher under Scenario 2 than under business-as-usual assumptions. Hence regional impacts may be proportionally greater than state impacts, at least to the extent that the regional economy provides labour and materials.

The extent to which labour and services are provided locally will depend on how the Development is managed. However Development planning and management will not be settled until after detailed design studies have been done, so the following assessment is based on current proposals and expectations.

3.2 Employment

Total employment in the Pilbara region has ranged between 22,000 and 24,000 from 1999 to June 2003[4]. The unemployment rate has ranged between 3% and 5%, which is more than 2% lower than Perth. At its peak, the Gorgon construction workforce is expected to require over 3,300 workers or more than 10% of the entire Pilbara workforce. This means that the Development is so large that the regional economy will not be able to provide all the labour when required.

Interaction with other regional projects will also be very important, as Gorgon Development construction could smooth out demand if it is ramping up when other projects are ramping down. For example, there could be a fifth train constructed for the NWS project by 2008, and possibly the Sunrise project in the Timor Sea in 2009, and the remote Scott Reef on the North-West Shelf could follow in 2012[5]. At the same time, it is

4 *Regional trends and indicators – Pilbara Region*, http://www.regional.wa.gov.au/rti/pirti.pdf, June 2003

5 "Woodside draws up Shelf train No. 5 timetable", *The Age*, March 30, 2004

important to recognise the risk that a significant draw on available labour by the Development could result in labour and skill shortages for other projects.

Each percentage point of unemployment represents about 250 workers, so even if there was a downturn in other project activity, it would not be possible to supply more than 20 per cent of the labour from the current workforce. In the ESE Review it is estimated that "*more than 10 per cent of the construction and operational workforce could be sourced from the Pilbara region*." Even at this level of supply, there could be an increase in wages and/or 'crowding out' of other activities.

The Development proponent is proposing that the project be staffed on a Fly-In Fly-Out (FIFO) basis, with the construction workforce housed on Barrow Island. Flights would generally come from Perth to provide access to a greater source of labour, which will reduce unemployment in the south west of the state. In fact, the state modelling described above suggests that some labour would need to be supplied from interstate.

The *Pilbara Regional Priority Plan*[6] has raised concerns with "*the continued use of fly-in fly-out employment practices which can be seen as a reflection of the lack of social amenity in the region*." However the issue with the Gorgon Development is more that there is insufficient labour available in the short term to meet the demand. The impact of FIFO on social factors is discussed in the social impact assessment.

The Pilbara Regional Priority Plan[7] raises another concern that "*the practice of fly-in fly-out means that local small businesses are not considered for the supply of goods and services. That is, supplies are often flown into the (mine) direct from Perth."* As with labour, there is a significant risk that the increased, short-term, demand for local goods and services will increase prices and/or lead to crowding out of other activities. In a free market economy, businesses ought to be able to anticipate an increased demand for services, and scale up to provide these.

The *Barrow Island Act 2003* requires the Development to use local labour, professional services and materials, "*as far as it is reasonable and economically practicable to do so*"[8]. However the Western Australian Government did not explicitly require local content to be defined in the context of where the Development is located.

The Gorgon Joint Venturers have however committed to an Australian Industry Participation Policy. This Policy addresses potential impediments to establishment of local industries supplying to a major, world-class facility through provision of information, briefings and other factors. It is in the JV Partners' interests to foster sustainable, competitive industries that can provide ongoing services to the Development, such as logistics. However the challenge is to provide positive benefits without adversely affecting the existing economy through price rises and crowding out. The aim is to develop sustainable economic activities that survive the short-term

6 *Pilbara Regional Priority Plan*, Oct 2003, http://www.pdc.wa.gov.au/, p.14

7 *Pilbara Regional Priority Plan*, Oct 2003, http://www.pdc.wa.gov.au/, p.14

8 *Barrow Island Act 2003*. Section 15 of Schedule 1

construction period. This will be difficult to achieve, as demonstrated by the problems of sustainability of staffing in the public sector[9].

4 Other Economic Impacts

4.1 Conservation Values

The Barrow Island Act requires the Joint Venturers to pay to a special state trust account an (indexed) amount of $40 million, for '*ongoing programs that will provide Net Conservation Benefits*'[10]. The WA Conservation Council's submission has criticised the approach of payments to a trust account, saying:

> "The Conservation Council will only consider environmental offsets, as a last resort, if all other options have been exhausted and the project is one that is necessary and brings major undisputed social, economic and environmental benefits…This has not been demonstrated in this case."

However the payment should not be interpreted as an offset, as there may be little or possibly no demonstrable loss of environmental values. No tourists are permitted to visit Barrow Island, so there is no need to compensate for loss of recreation value. There is unlikely to be any significant additional loss of wilderness value, given the presence of oil and gas infrastructure on Barrow Island prior to the proposed Development.

The payment is in fact a provision against a risk of environmental impact, and beyond that offers additional benefit, as made clear in Sustainability Criteria 5.3 – Acceptable legacy[11]. It is very difficult to quantify the risks or to value their impacts, although the proponent is attempting to do so[12]. However, the Conservation Council says[13]:

- "*Nothing could offset the loss of some or all of Barrow's 'evolutionary significant units'.*"
- "*Given the high level of irreplaceability of the biodiversity values of Barrow Island, the extreme difficulty of translocating viable populations to the mainland through a reintroduction program, and a quarantine breach 'virtually certain', in principle approval of this proposal will result in at the least, a loss of biodiversity values and at the most, extinction of species.*"

The Joint Venturers have agreed to an increase in the amount from $10 million as proposed in the ESE Review to $40 million specified in the *Barrow Island Act 2003*. The

9 *Pilbara Regional Priority Plan*, Oct 2003, http://www.pdc.wa.gov.au/, p.13

10 Barrow Island Act, Schedule 1, section 11

11 *Barrow Island Act 2003*, Schedule 1

12 Response to Submissions, April 2003, p. 3

13 *Response from the Conservation Council of Western Australia to the Consideration of access to Barrow Island for Gas Development (July 2003)*

amount of $40 million to be paid into the trust account is likely to exceed reasonable provision against risk, and hence could provide an increase in overall conservation values in WA.

The trust will be managed by government and the allocation of funds to conservation projects will need to be undertaken with care.

4.2 Greenhouse Emissions

There will be two significant contributions to greenhouse gas emissions from the Gorgon Development, namely:

- Carbon dioxide from the gas wells
- Emissions from the energy used to extract and liquefy the gas.

The proponent proposes that carbon dioxide from the reservoir be separated and injected. Such an approach is being used in Norway, and is expected to work here, as discussed in Chapter 13 of the Draft EIS/ERMP. In fact, the State Agreement allows the Minister to decide not to consider complete detailed proposals for activities or infrastructure on Barrow Island unless he has received a proposal for injection of carbon dioxide.

Emissions from combustion in the liquefaction process cannot be readily separated and will presumably be vented as is the case with all other LNG processing plants in the world in 2004. Some may argue that there is an economic cost associated with such emissions, even in the absence of regulatory requirements to manage greenhouse gas emissions. However valuing economic cost in the absence of regulation requires assumptions about the marginal effect of a particular project on climate, and hence production or health impacts.

There will be an economic cost associated with emissions if targets are introduced, namely the economic cost of meeting the target, which can be valued in terms of cost of abating an additional ton of green house gas (GHG) emissions. Hence it is prudent to consider ways to manage emissions.

5 Summary of Consequences

The two independent economic modelling studies show that the Gorgon Development would have significant positive economic consequences for Australia and WA. These benefits are driven by the export income that the Development produces, the amount of money spent in the local economy, and the taxes and royalties paid by the participants, businesses and individuals. These are certain to occur.

The consequences for the regional and local economies in the Pilbara region are very difficult to quantify however it is likely that greater revenues will flow to the nation and the state. Key positive consequences of the development that are likely to occur include:

- Local employment; and
- Procurement from local businesses for goods and services.

This will be derived from the supply base and the development on Barrow Island and will relate to both the construction and operation phase.

The extent to which local expectations about employment and procurement will be met is a separate issue and is discussed in the stakeholder consultation and social impacts sections of the EIS/ERMP.

The regional economy is not large enough to provide all labour, goods and services required for the Gorgon Development, especially given the other project activity already occurring and planned to occur. There is a risk that short-term demand (e.g. labour for construction) will cause price rises and crowd out other activities.

It is unlikely there will be an economic impact on conservation values. Provided that the Development is managed well to reduce risk of loss of conservation values, and funds in the Net Conservation benefit trust account are spent wisely, there may even be an increase overall conservation values in Western Australia.

The risk of economic impact from greenhouse gas emissions on the Development is high, due to the requirement to have proposals for injection of carbon dioxide prior to approvals. This does not have any risk at state, national or regional level.

6 Management and Mitigation Strategies

6.1 Social Impact Management Plan

The State Agreement Act for the Gorgon Gas Development requires the Gorgon Gas Joint Venture to prepare a Social Impact Management Plan (SIMP). The purpose of this Management Plan is to identify management measures specifically aimed at addressing the impacts associated with the Gorgon Gas Development and identified in the impact assessment. It will not be used as a broader policy document but will be focussed on the particular requirements of the Gorgon Development.

The SIMP is required to be prepared during the Proposal stage of the Development, taking into account the outcomes of the impact assessment, stakeholder consultation and the opportunities for local content and procurement identified during the FEED and EPCM stages of the Development. It needs to be approved by the Minister for State Development, Industry and Resources who will seek advice from other Ministers and Government departments as necessary.

An outline of the content and intent of the SIMP is included in Table 6.1 and it is clear this Plan will include consideration of local content, employment and other socio-economic factors.

Table 6.1 Social Impact Management Plan Outline

Component of Plan	Intended Outcome
Introduction: • Development • Purpose • State Agreement Act requirements • Gorgon Social and Economic Commitments	Provides overview of Plan and its purpose.
Process for Preparation of SIMP: • Stakeholder input • Approvals process	Explains how SIMP has been developed.
Management Strategies: • Local content and procurement • Stakeholder engagement • Employment and training • Indigenous people • FIFO • Cultural heritage • Community development	Specific strategies and actions aimed at achieving social and economic management objectives for the Gorgon Gas Development.
Social Investment Strategy	Summary of social investment budget and priorities for Gorgon Gas Development. Linkages to the Industry Participation Policy and local procurement initiatives.
Implementation, Monitoring and Review	Outlines summary list of actions, responsibilities and process for monitoring and review.

The SIMP provides significant opportunities to the Gorgon Joint Venture to make a positive contribution to community development, particularly in the Pilbara Region. In particular, the SIMP will focus on the key elements of:

- Education and training;
- Youth and indigenous employment;
- Research and development; and
- Community engagement with stakeholders in the Pilbara.

6.2 Australian Industry Participation Policy

Strategies for managing economic activity are broadly in place. In particular, these strategies include Clause 11 of the State Agreement and the Australian Industry Participation Policy. This Policy is discussed in detail in Chapter 2.

6.3 Management of Local Content

Management of local content has been identified as a significant issue, as recognised in the State Agreement. The Australian Industry Participation Policy sets out a number of actions to achieve local industry participation. However there are potentially conflicting objectives between local content requirements and commercial drivers.

- The purchaser wants a wide choice of suppliers, so that competition between suppliers keeps prices low and quality high; but
- Mandating local content limits the range of suppliers, so that local suppliers may take advantage of their privileged position to raise prices or reduce quality; and
- Local suppliers may not, at least initially, have the capacity sought by the purchaser. Even if they can supply the purchaser, the increased demand may exceed the capacity of local industry to supply, resulting in 'crowding out' of other activities or price rises.

The commercial tensions between the purchaser and the local suppliers will remain, so it will be important to manage expectations of local supply, for labour, goods and services, and hence indirect impacts.

6.4 Management of Conservation Values

The risk of impacts on conservation values has been highlighted as a significant environmental issue. The State Agreement recognises it as an economic issue as well, by nominating an amount to be paid into a trust account. It will be important to manage the process of deciding where and how to spend funds in the 'Net Conservation Benefits' trust account.

6.5 Management of Greenhouse Gas Emissions

The JV is investigating separation of carbon dioxide from natural gas in flows from the reservoir, and subsequent sequestration underground (refer to Chapter 13 of the Draft EIS/ERMP). The Gorgon JV is required to submit specific proposals for injection of carbon dioxide recovered during gas processing. In addition the Development will be designed to meet NEPM standards and goals for emissions. While these currently have not been implemented in legislation throughout Western Australia, the Department of Environment (DoE) has indicated their intention to implement them through the development of a state-wide Environmental Protection Policy (refer to Chapter 8 of the Draft EIS/ERMP).

Should further emissions reductions be considered, the Joint Venturers may wish to:

- Identify opportunities to reduce greenhouse gas emission by substituting more carbon intensive fuels for Gorgon gas in the Australian energy industry.
- Promote an energy efficiency program during all Development phases in order to minimise energy usage.
- Buy or trade in emission reduction credits.

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