Volume 2

Technical Appendices FA to FI

Final Environmental Impact Statement/Response to Submissions on the Environmental Review and Management Programme for the Proposed Wheatstone Project

February 2011

Wheatstone Project

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Underwater Environmental Noise Assessment:
Wheatstone Piling

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. An underwater noise assessment for the piling activities associated with the Project was undertaken as a validation activity, following a review that concluded that observation and suspension zones provided in the Draft EIS/ERMP (Chapter 8, Section 8.4.5.8) were appropriate and conservative.

This noise assessment focused on pile driving (piling), as the activity with the greatest potential to generate noise-related impacts, and turtles as the key fauna group likely to occur within the area of this activity.

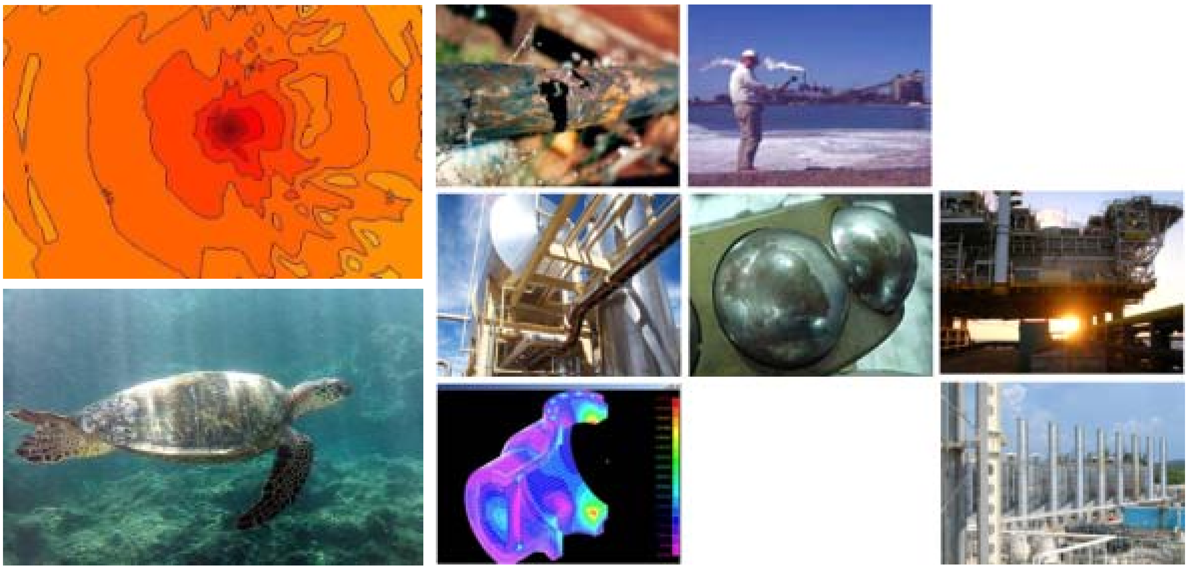
Possible physical injury and possible behavioural disturbance were the two scenarios considered in the assessment. The Zone of Possible Physical Injury is defined as 'the zone where there is a possibility that the animal may suffer physical injury and/or permanent hearing damage'. The Zone of Possible Behavioural Disturbance is defined as 'the zone where there is a possibility that the animal may experience masking and/or behavioural change and/or avoid the area'. Each scenario was modelled using a Highest Astronomical Tide of 3 m, and was based on a sandy substrate which causes noise to propagate further, resulting in conservative zones of influence.

The model results suggest that physical injury or hearing damage of turtles could occur within a 10 m range of piling activities and that behavioural disturbance for adult turtles could occur within a 700 m range. This is a highly conservative estimate as it includes behavioural responses such as avoidance of the area.

Within a 25 m range, piling activities will likely induce physical injury or hearing damage to turtle hatchlings. Behavioural disturbance for turtle hatchlings was not considered, as hatchling movements in the nearshore area are predominately determined by tides and currents. However, as a precautionary approach it is recommended that the zone of behavioural disturbance estimated for adult turtles is applied to turtle hatchlings. Consideration should also be given to the fact that turtle beaches are not located in close proximity to the piling activities.

SVT ENGINEERING CONSULTANTS

UNDERWATER ENVIRONMENTAL NOISE ASSESSMENT: WHEATSTONE PILING



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EXECUTIVE SUMMARY

SVT was commissioned by RPS to perform an underwater noise assessment for the piling activities associated with the Wheatstone port facility development. This report documents the outcomes of the underwater noise model and the assessed impact on adult turtles and turtle hatchlings from the piling activities associated with the development.

Assessment Criteria

Possible physical injury and possible behavioural disturbance by marine fauna are the two environmental impacts of underwater noise that were considered in the assessment. These two effects result in the determination of two areas or zones of interest. These areas or zones are as follows:

1. **Zone of Possible Physical Injury**. In this zone there is a possibility that the animal may suffer physical injury and/or permanent hearing damage.
2. **Zone of Possible Behavioural Disturbance**. In this zone there is a possibility that the animal may experience masking and/or behavioural change and/or avoid the area.

The marine fauna under this study include adult turtles and turtle hatchlings.

Table E-1 provides the noise assessment criteria that were used to determine impacts on adult turtles and turtle hatchlings. Note the criteria are based on a single hammer strike.

Table E-1 Received threshold levels for peak pressure level (SPL peak), RMS sound pressure level (SPL(rms)) and sound exposure level (SEL) above which there would be a possibility of physical injury or behavioural effect for adult turtles and turtle hatchlings as a result of a single hammer strike.

Metric	Possible Physical Injury		Possible Behavioural Disturbance	
	Adult Turtles	Turtle Hatchlings	Adult turtles	Turtle Hatchlings
SPL peak (dB re 1μPa)	222	208	No data available	No data available
SPL (rms) (dB re 1μPa)	No data available	No data available	175	No data available
SEL (dB re 1μPa^2.s)	No data available	187	164[1]	No data available

Modelling Results

Two modelling scenarios were modelled in this study. Each scenario was modelled using Highest Astronomical Tide (HAT) of 3 meters.

Table E-2 summarises the maximum distances between noise source and the zone of possible behavioural disturbance and possible physical injury for both adult turtles and turtle hatchlings.

[1] SEL for turtle behavioural disturbance was calculated from the SPL (rms) assuming that the pulse length to be 90ms.

Table E-2 Furthest distance to zones of behavioural disturbance and possible physical injury

Modelling Scenarios	Furthest Distance from Source to Zone of Physical Injury (m)		Furthest Distance from Source to Zone of Behavioural disturbance (m)	
	Adult Turtles	Tutle Hachlings	Adult tutles	Turtle Hatchlings
Pile Driving – Wheatstone port facility development	10	25	700	Not applicable

It can be seen from the table that in the range of 10 m it is likely that the piling activities in the proposed Wheatstone port facility area could induce physical injury or hearing damage to adult turtles, and the piling activities could also cause behavioural disturbance for adult turtles within a 700 m range. Within 25 m range, piling activities will likely induce physical injury or hearing damage to turtle hatchlings. Behavioural disturbance for turtle hatchlings was not considered as hatchling movements in the near shore water which are predominately determined by tides and currents. However as a precautionary approach it is recommended that the zone of behavioural disturbance estimated for adult turtles is applied to turtle hatchlings. Consideration should also be given to the fact that turtle beaches are not located in close proximity to the piling activities.

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APPENDIX A : ACRONYMS A-1

1. INTRODUCTION

SVT was commissioned by RPS to undertake an underwater environmental noise impact assessment for the piling activities associated with the jetty and wharf construction of the proposed Wheatstone port facility development. This report documents the outcomes of the underwater noise model and the expected impact on adult turtles and turtle hatchlings as a result of piling activities for the port facility development.

1.1 Background

The proposed Wheatstone port facility development is located at Ashburton North, approximately 12 km south-west of Onslow, Western Australia. The facility forms part of the downstream component of the Wheatstone LNG development, as shown in Figure 1-1. The facility development will consist of the wharf and access jetty construction, for which piling activities will be involved.

1.2 Aim

The aim of this study was to assess the impact of underwater noise on turtle and turtle hatchlings, as a result of the piling activities associated with the jetty and wharf construction of the proposed Wheatstone port facility development.

1.3 Scope

The scope of this work covers the modelling of the underwater noise from the piling activities associated with the Wheatstone port construction activities as well as the assessment of the impact on turtles and turtle hatchlings as a result of the piling activities.

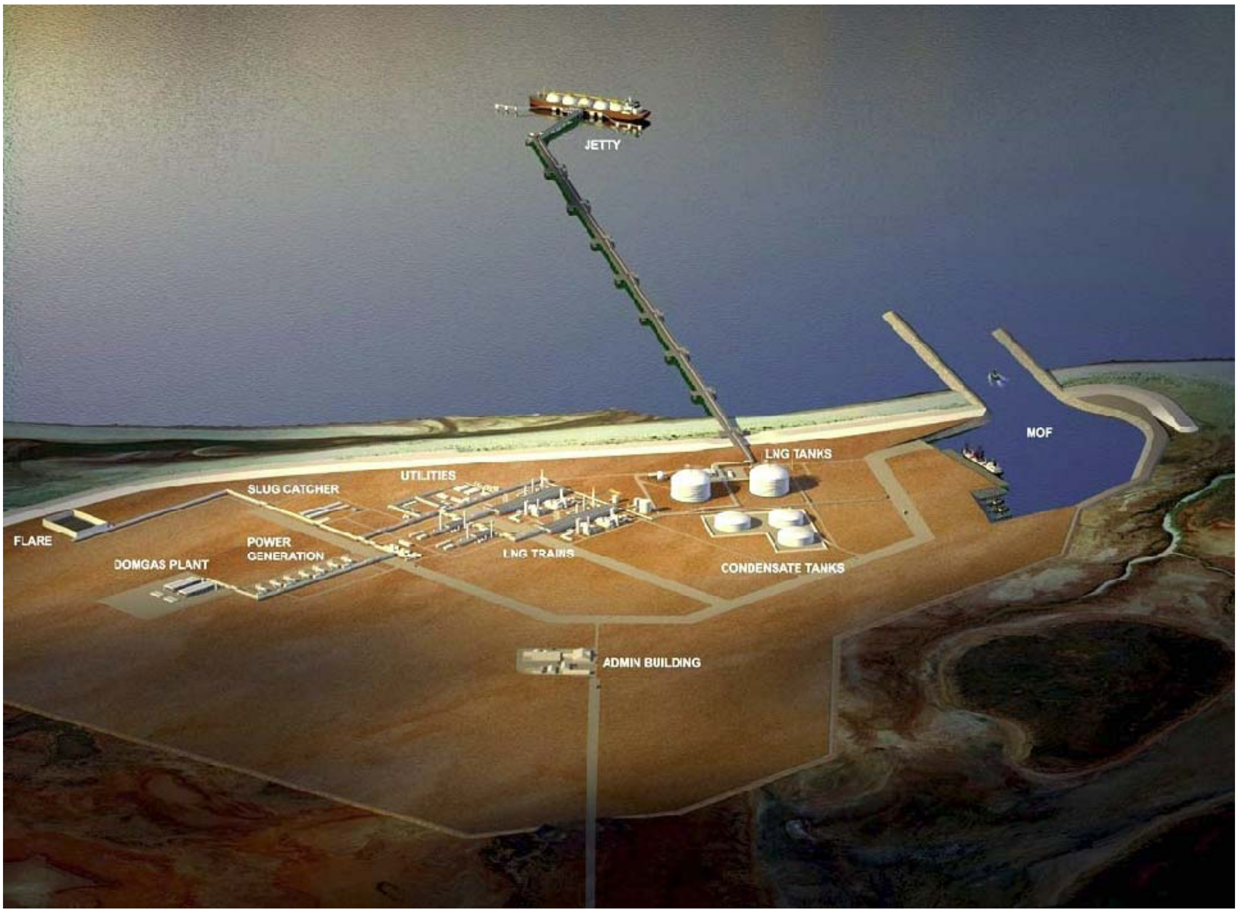

Figure 1-1 Illustrative representation of downstream infrastructure[2] (Note: this is illustrative only and does not represent final layout of facilities).

[2] Wheatstone Project – Environmental Scoping Document. Chevron Australia Pty Ltd. 2nd June 2009.

2. NOISE SOURCES

2.1 Pile Driving

Pile driving operations involve hammering a pile into the seabed. The noise emanating from a pile during a piling operation is a function of its material type, its size, the force applied to it and the characteristics of the substrate into which it is being driven.

The action of hammering a pile into the sea bed (Figure 2-1) will excite bendy waves[3] in the pile that will propagate along the length of the pile and then into the seabed. The transverse component of the wave will create compressional waves that will propagate into the ocean while the compressional component of the bendy wave will propagate into the seabed. There will also be some transmission of the airborne acoustic wave into the sea.

It can be expected that most of the energy from the hammering action of the pile driver will transfer into the seabed. Once in the seabed, the energy will then propagate outwards as compressional and shear waves. Some of the energy may be transferred into Rayleigh waves, which are seismic waves that form on the water/seabed interface, but it is expected that this will be a small portion of the total wave energy.

Piles can be driven using various methods such as vibration, gravity and hammer. The method that is used is dependent on the size of the pile and the substrate into which the pile is being driven. It is planned that hydraulic impact hammers with diameters of between 915 mm and 1200 mm will be used for pile driving operations in this development project. It is expected that one pile driving evolution will take up to 3 hours. The noise that is generated by an impact hammer hitting the top of the pile is short in duration lasting approximately 90 ms and can therefore be described as impulsive noise.

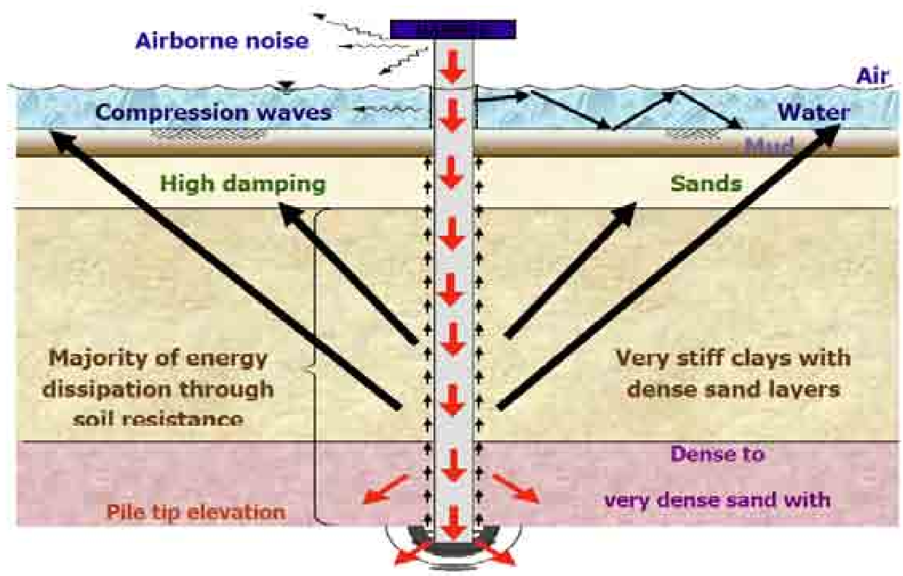

Figure 2-1 Energy transfer modes which occur when a pile is being driven into the seabed[4]

[3] Bendy wave is a wave that comprises of a compression wave and a transverse wave.

[4] S. Theiss, "Development of Guidance on the effects of Pile Driving on Fish', TRB ACD40, 2006

3. ASSESSMENT CRITERIA

Unlike airborne noise, where impact levels on humans have been regulated, assessment criteria levels for underwater environmental noise impacts have not been defined in regulation except in the case of underwater noise impacts on cetaceans from seismic surveys, where the EPBC Act Policy Statement 2.1 applies. As a result, assessment levels in this report are determined from peer reviewed and widely accepted literature.

A variety of units are used in underwater acoustics to define steady-state and impulsive signals. Some of the important definitions are as follows:

- Sound Pressure Level (SPL) Root Mean Square (RMS) units dB re 1 µPa. The rms pressure is the decibel value of the root mean of the squared pressure over a defined period of a signal.
- Sound Pressure Level Peak units dB re 1 µPa (0-Pk). Peak pressure is the maximum recorded pressure and is measured from the mean of the signal to the maximum excursion from the mean.
- Sound Pressure Level Peak to Peak units dB re 1 µPa (Pk-Pk). Peak to Peak sound pressure is the algebraic difference between the maximum positive and maximum negative instantaneous peak pressure.
- Sound Exposure Level (SEL) units dB re 1 $\mu Pa^2.s$. Sound exposure level is a measure of energy with the dB level of the time integral of the squared-instantaneous sound pressure normalized to a 1-s period. For impulsive signals, such as pile driving noise and marine blasting noise, the averaging time is a significant consideration. Impulsive signals are better described by a measure of Sound Exposure Level (SEL) and a measure of the signal peak pressure.

3.1 Zones of Interest

For underwater noise impacts on marine fauna, two effects are of interest, namely physical injury and behavioural disturbance. These two effects result in the determination of two areas or zones of interest for underwater noise assessments. These areas or zones are as follows:

1) **Zone of Possible Physical Injury**. In this area there is a possibility that the animal may suffer physical/auditory injury and/ or permanent hearing damage or hearing threshold shift (PTS).

2) **Zone of Possible Behavioural Disturbance.** In this area there is a possibility that the animal may experience hearing masking/temporal threshold shift (TTS) and/or behavioural change and/or avoid the area.

   Behavioural responses of marine animals to underwater noise encompass all behavioural reactions and responses. Here are some different levels of responses to the underwater noise that marine animals have: 1) some of these responses will be reflex responses that an animal would exhibit regardless of the noise stimulus; 2) some of these responses (such as alert responses or some avoidance) reflect an animal's awareness, and animals might experience hearing masking or temporal hearing threshold shift (TTS) at this response level; 3) sub-lethal responses encompass the full range of observable symptoms of acute or chronic stress in individual animals that can disable an individual animal but do not kill the animal. Sub-lethal responses include increased respiration (for example, increased surfacing rates in aquatic mammals), reductions in an animal's foraging activity and foraging success, reduced body condition and reduced growth rates (which can result from reduced foraging success, but can also indicate physiological stress), reduced fecundity and reduced reproductive success (which can result from any of the other sub-lethal responses). The behavioural disturbance concerned in this study is based on animals' behavioural responses to underwater noise at some stages of the second response level.

3.2 Turtles

3.2.1 Auditory Sensitivity

The sea turtle's auditory canal consists of cutaneous plates underlain by fatty material at the side of the head which serves the same function as the tympanic membrane in the human ear. Vibrations are transmitted through the cutaneous plates and underlying fatty tissue to the extracolumella. The extracolumella has a mushroom-shaped head which is loosely attached to the outer middle ear cavity. The extracolumella has a long shaft-like shape which extends through the middle ear and is responsible for transmitting the sound to the stapes in the auditory canal. The footplate of the stapes in turn is responsible for transmitting the acoustic energy through the oval window into the otic cavity which performs a similar function to that of the human cochlea.

Measurements on the cochlea potentials of giant sea turtles have shown their upper auditory limit to be approximately 2 kHz and their maximum sensitivity is between 300 and 400 Hz[5]. Studies using auditory brainstem responses[6] of juvenile Green and Ridley's turtles and sub-adult Green turtles showed that juvenile turtles have a 100 to 800 Hz (Figure 3-1) bandwidth, with best sensitivity between 600 and 700 Hz, while adults have a bandwidth of 100 to 500 Hz (Figure 3-2), with the greatest sensitivity between 200 and 400 Hz[7,8]. This indicates that a turtle's frequency and sensitivity bandwidth decreases with age.

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[5] Ridgway *et al*, 'Hearing in the Giant Sea Turtle, Chelonia mydas', Proc N.A.S, Vol 64, 1969

[6] Some uncertainties regarding Auditory Brainstem Response (ABR) and behavioural audiograms are as follows. The temporal summation influences sensitivity to sound (i.e. sounds shorter than some critical value are generally less detectable than longer signals). For mammals, this may vary between 30 and 800ms.These long pulse lengths cannot be created in a tank that is limited in size without reverberation. If a reference hydrophone is not placed in close proximity to the subjects head then the received levels will be unknown as reverberation has not been considered. SVT is unable to confirm if the sound field is measured at the head of the subject. Some other issues concerning ABR are that the subjects are often drugged. From the reviewed papers it appears that some of the drugs may affect hearing. Another issue is that the number of subjects tested is small and therefore the statistics of the sample size are not stable. Considering all the above, and knowing that there are inaccuracies in the ABR technique, SVT determined the optimum approach was to take the widest bandwidth of the known audiogram with no weighting added to it (i.e. it was assumed that the audiogram frequency response was flat and that there was no attenuation). This is equivalent to taking a linear weighting and not an A-weighting for the human case. This is considered a conservative approach and it is felt that it is reasonable under the circumstances.

[7] Ketten and Bartol,' Functional Measures of Sea Turtle Hearing', doc no. 20060509038, Sept 2005.

[8] S Bartol. *"Turtle and Tuna Hearing",* Woods Hole Oceanographic Institute, MA, USA, as part of NOAA Technical Memorandum NMFS-PIFSC-7, December 2007.

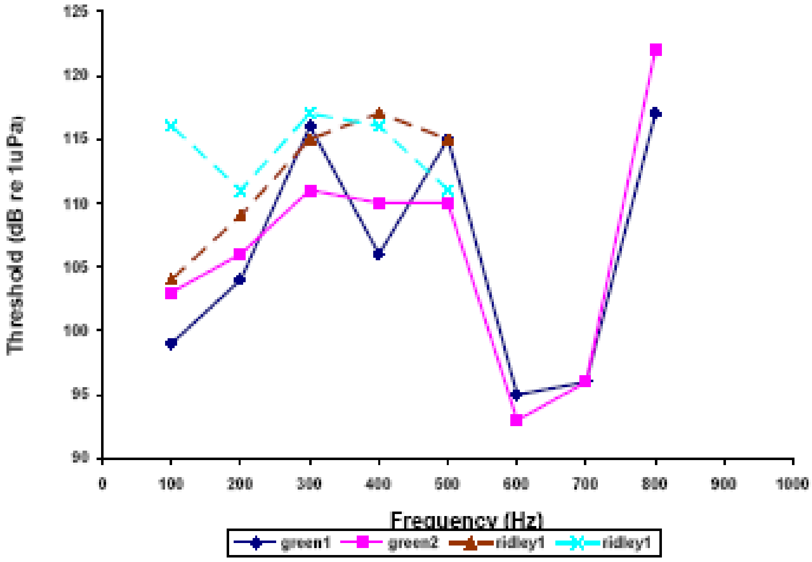

Figure 3-1 Audiograms of two juvenile green turtles and two juvenile Ridley's turtles[9].

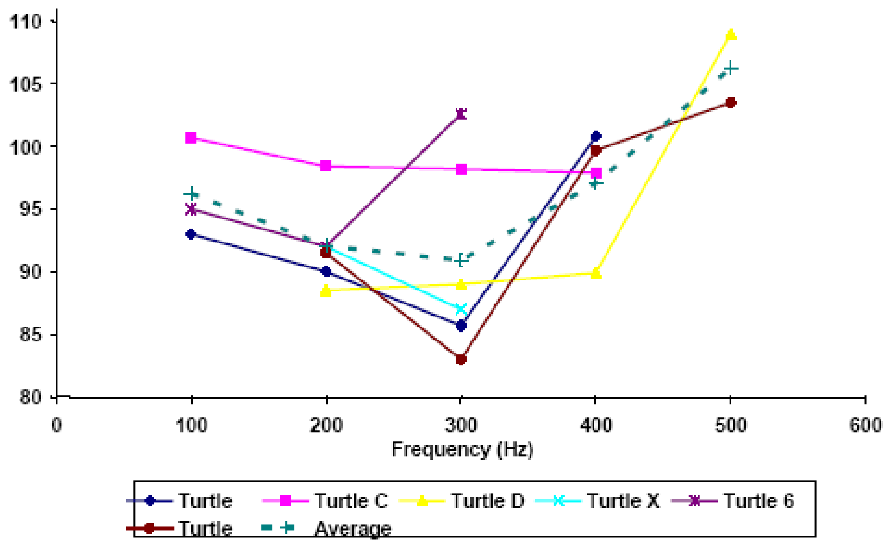

Figure 3-2 Audiograms of six sub-adult Green turtles[10]

3.2.2 Physical injury

Little is known about the source levels and associated frequencies that cause physical injury to a turtle. Some studies on the effects of explosions on turtles recommend that an empirically-based

[9] S Bartol. "*Turtle and Tuna Hearing",* Woods Hole Oceanographic Institute, MA, USA, as part of NOAA Technical Memorandum NMFS-PIFSC-7, December 2007.

[10] S Bartol. "*Turtle and Tuna Hearing",* Woods Hole Oceanographic Institute, MA, USA, as part of NOAA Technical Memorandum NMFS-PIFSC-7, December 2007.

safety range be used for guidance[11]. Using the safety range formula as noted[12] and converting back to peak SPL using Ross formula[13], a value of 222 dB re 1µPa is obtained. Based on this peak SPL, a value of 222 dB re 1µPa should not be exceeded for adult turtles to avoid physical injury for any single hammer strike. It is important to note, however, that the pulse duration and pulse rise time for piling noise is longer than that of an explosion. As a result, the effect of a pile driving pulse on a marine animal is not expected to be as damaging as a pulse from an explosion of equal peak SPL. Therefore, the value this study takes for physical injury assessment is conservative.

Due to the lack of scientific data availability, turtle hatchlings will be evaluated using both SEL and peak sound pressure level for fish[14]. Assuming that hatchlings will suffer the same effects as fish when exposed to piling noise, the following conservative interim dual criteria recommended by Popper[15] will be used. Popper recommended that for a **single hammer strike** that a SEL level of 187 dB re 1µPa^2.s and a peak sound pressure level of 208 dB re 1µPa not be exceeded. Note the criteria are based on a single hammer strike.

3.2.3 Behavioural Change

Only limited literature could be found showing what SPL will affect the turtles' behavioural patterns or mask their communications. Two trials conducted on the response of a green and loggerhead turtle to pulsive signals (air-gun) showed that at a levels of 175 dB (rms) re 1 µPa the turtle behaviour became more erratic which was presumed to be avoidance response[16]. This value can be converted to an SEL of 164 dB re 1µPa^2.s, where it is assumed that a pulse length of 90ms was used during the experiment.

3.2.4 Turtle Habitats

Tutle studies undertaken by RPS[17] indentified that the beach directly adjacent to Ashburton North is unsuitable for marine turtle nesting. The studies also showed the project footprint has no reef habitat, while the turtle densities are greater in the offshore reef habitats than non-reef hatitats.

The Environment Protection and Biodiversity Conservation (EPBC) search result displayed six endangered or vulnerable species of marine turtle that may be present within the proposed project footprint[18]. These marine turtle species may potentially be exposed to the underwater noise from the piling activities.

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[11] Young, G.A. 1991. Concise methods for predicting the effects of underwater explosions on marine life. NAVSWC No. 91-22. Naval Surface Warfare Centre, Silverspring, Maryland, USA.

[12] Keevan and Hempen,' THE ENVIRONMENTAL EFFECTS OF UNDERWATER EXPLOSIONS WITH METHODS TO MITIGATE IMPACTS, U.S. Army Corps of Engineers, Aug 1997.

[13] D. Ross. Mechanics of underwater noise. Penisula Publishing. Los Altos. California, USA.

[14] The physiology of turtle hatchling is different from fish. However, the air filled cavities such as lungs of turtle hatchlings and swimbladders of fish have been found to be most acceptable for physical injury assessment from impulsive wave such as pile driving signal. Therefore it is reasonable to correlate physical injury criteria for turtle hatchlings with that for fish.

[15] Popper *et al.* Interim Criteria for Injury of Fish to Pile Driving Operations: A White Paper. 2006.

[16] McCauley RD, *et al* ,2000,'Marine Seismic Surveys: analysis and propagation of air-gun signals; and effects of exposure on humpback whales , sea turtles, fishes and squid'. R99-15, Perth Western Australia.

[17] RPS 2010. Technical Appendix – Marine Turtles Wheatstone Project EIS/ERMP. Report to Chevron Australia.

[18] Wheatstone Project – Environmental Scoping Document. Chevron Australia Pty Ltd. 2nd June 2009.

3.2.5 Summary of Levels of Possible Physical Injury and Behavioural Change

Based on information in the preceding sections, the sound pressure (peak and rms) and SEL values are of interest with regard to their effects of noise on turtles and turtle hatchlings are given in Table 3-1.

Table 3-1 Estimated received levels at which there is a possibility of physical injury or behavioural effect for Turtles.

Metric	Possible Physical Injury		Possible Behavioural Disturbance	
	Adult Turtles	Turtle Hatchlings	Adult turtles	Turtle Hatchlings
SPL peak (dB re 1µPa)	222	208	No data available	No data available
SPL (rms) (dB re 1µPa)	No data available	No data available	175	No data available
SEL (dB re 1µPa^2.s)	No data available	187	164[19]	No data available

[19] SEL for turtle behavioural disturbance was calculated from the SPL (rms) assuming that the pulse length to be 90ms.

4. METHODOLOGY

4.1 Underwater Noise Modelling

Underwater noise propagation models use bathymetric data, geoacoustic information and oceanographic parameters as inputs to produce estimates of the acoustic field in the water column at any depth and distance from the source. The accuracy of the environmental information used in the model is critical for the modelling prediction. For example, the geoacoustic parameters of the seabed, particularly the seabed layer structure, the compressional and shear sound velocities for each layer material, and the corresponding sound attenuation coefficients can significantly affect the acoustic propagation and can therefore affect the accuracy of the model predictions.

4.1.1 Model Selection

Various numerical techniques are used for the development of underwater acoustic propagation models, including wavenumber integration, ray theory, normal modes, parabolic equation (PE) and finite differences/finite elements. When determining which model is to be used for the modelling prediction, it is necessary to define the application for which it is to be used and the type of underwater environment it is going to model. For this model, the underwater environment has the following characteristics:

- strong range dependence
- shallow water ocean environment
- differing bottom types.

Parabolic Equation (PE) models are by nature capable of making predictions in environmental conditions that are range dependent, in shallow water and have changing bottom types. As a result, a PE model called the Monterey Miami Parabolic Equation (MMPE) model was selected. This model was selected because it has been benchmark tested for shallow water environment[20].

4.1.2 Data and Model Limitations

The following data and model limitations need to be noted:

1. **Rough Surface Scattering**. Acoustics wave scattering due to the roughness of sea surface and seabed is not accounted for in the model.
2. **Salinity and Sound Speed Profiles**. The water depth in the modelling area is relatively shallow. It can therefore be assumed that the water column is isothermal. Additionally, salinity will have negligible effect on the sound speed profile. Variation in the model's sound speed profile has been limited to the effects of water column pressure.

[20] Shallow Water Acoustic Modelling (SWAM 99) Workshop.

3. **Seabed**. The seabed was taken as half-space in the model, and its properties were taken as the same as the top layer sediment properties.

4.1.3 Model Environmental Inputs

The following environmental conditions were inputted into the model:

Tide level

In this study, the Highest Astronomical Tide (HAT) was used for the coastal area of Ashburton North, south-west of Onslow, representing the worst case scenario. HAT was 3 m higher than the Lowest Astronomical Tide (LAT) (i.e. chart datum)[21].

Seabed Types

Based on geophysical survey data supplied to SVT by RPS, the seabed in the nearshore survey area off Ashburton North is predominantly covered by soft sediment, assumably uncemented shelly sandy silts of various thickness with limestone base. Small patches of hard substrate, most likely limestone or hard rock, randomly distribute in the area. In terms of the seabed types for the modelling a sandy seabed type was entered to represent the soft sediment from the geophysical surveys. For the small patches of hard rock and inland area, basalt was selected to represent the seabed type. The geoacoustic properties of the seabed types used in the model are as described in Table 4-1.

Table 4-1 Geoacoustic properties used in the model for each seabed type

Type	Sound speed (m/s)	Density (g/cm^3)	Compressional Attenuation (dB/m/kHz)	Shear Attenuation (dB/m/kHz)	Shear Speed (m/s)
Fine to medium sand	1774.0	2.050	0.374	0	0
Bassalt	5250.0	2.700	0.1	0.2	1500

Sound Speed Profile

The sound speed profile in the near shore of Ashburton North is assumed to be isothermal with a constant temperature of 23 C and a constant salinity of 35 ppt. This is estimated to be representative of the water temperature in the shallow water environment of the Pilbara area.

4.1.4 Model Contour Depth

The model produces horizontal contours for any depth as well as vertical plots showing depth versus range for any bearing. It is not practical to provide plots for each depth and for each bearing (i.e. 360 for each scenario). As a result only a selected number of graphs are provided in this report.

[21] Macedon Gas Development Subtidal Marine Ecology Survey, URS, 26 March 2010

5. MODEL INPUT

5.1 Noise Source Locations

Figure 5-1 presents the locations of various Work Points (WP) for the proposed Wheatstone port facility development. Pile driving barges are expected to be operating at WPs in the proposed development area as shown in the figure, and two piling barges are assumed to be operating simultaneously. Four source locations were selected to represent two piling operational scenarios: piling with source locations WP114 and WP106 and piling with WP103 and WP102 (see Table 5-1 for detailed locations).

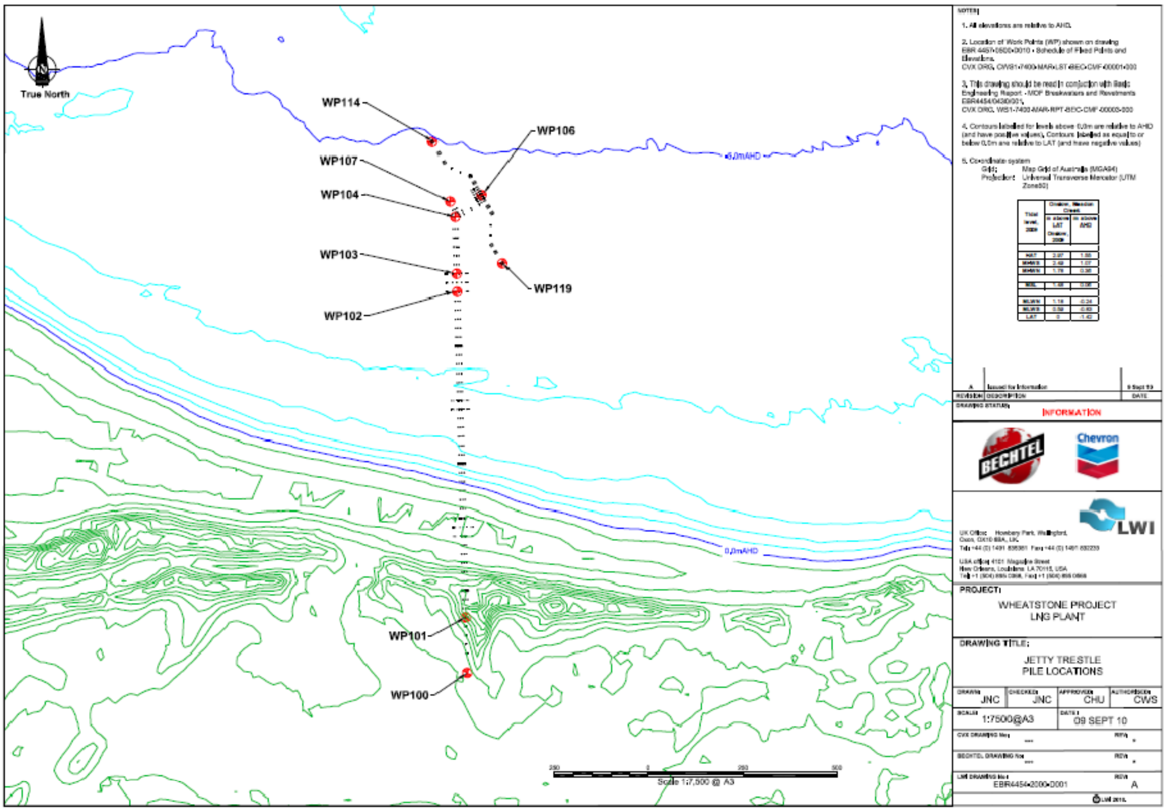


Figure 5-1 Locations of Work Points (WP) in the proposed Wheatstone port facility development.

Table 5-1 Noise sources and their locations

Source	Easting (m)	Northing (m)
Pile Driving 1 – WP114	293604.67	7601859.88
Pile Driving 2 – WP106	293735.27	7601718.63
Pile Driving 3 – WP103	293692.47	7600598.39
Pile Driving 1 – WP102	293696.34	7600451.77

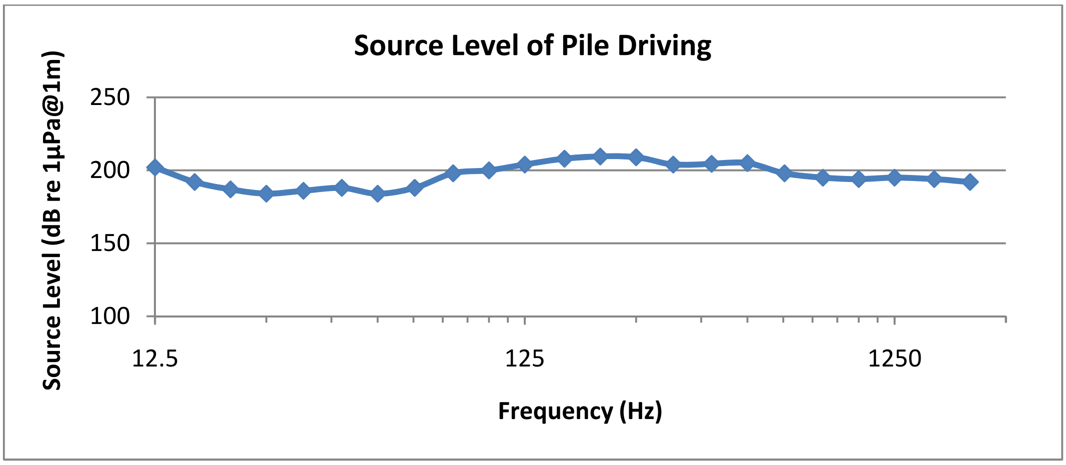
5.2 Modelling Source Depths and Characteristics

The depths of piling noise sources were determined by estimating their acoustic centre, as listed in Table 5-2. The source spectrum level of the piling noise source used in the model are given in Figure 5-2. The frequency range used in the model was from 63 Hz to 2 kHz, which covers the expected frequency range of the major noise energy produced by the construction activities and auditory frequency ranges of adult turtles and turtle hatchlings.

Table 5-2 Noise source depths.

Source	Water Depth (Chart datum + 3 m for HAT)	Source Depth
Pile Driving 1 – WP114	9.3 m	4.65 m above seabed
Pile Driving 2 – WP106	9.2 m	4.6 m above seabed
Pile Driving 3 – WP103	8.6 m	4.3 m above seabed
Pile Driving 1 – WP102	8.5 m	4.25 m above seabed

Figure 5-2 Source characteristics of Pile Driving



6. MODELLING RESULTS

The contour plots shown in this section are for a receiver depth of 2 m below the sea surface. The scenarios under the Highest Astronomical Tide (HAT) were modelled as it represents the worst case scenario.

6.1 SEL Contours for Piling Noise Sources

It is expected that 2 pile barges will be operating simultaneously in the proposed Wheatstone port facility development area, and the maximum separation of the two pile barges are assumed to be a minimum distance of 1 km apart.

Figure 6-1 and Figure 6-2 show the contours of predicted SEL of 1 pile pulse or hammer strike for the two modelling scenarios (i.e. two piling operations occurring simultaneously at locations of WP114 and WP106, and two piling operations occurring simultaneously at WP103 and WP102).

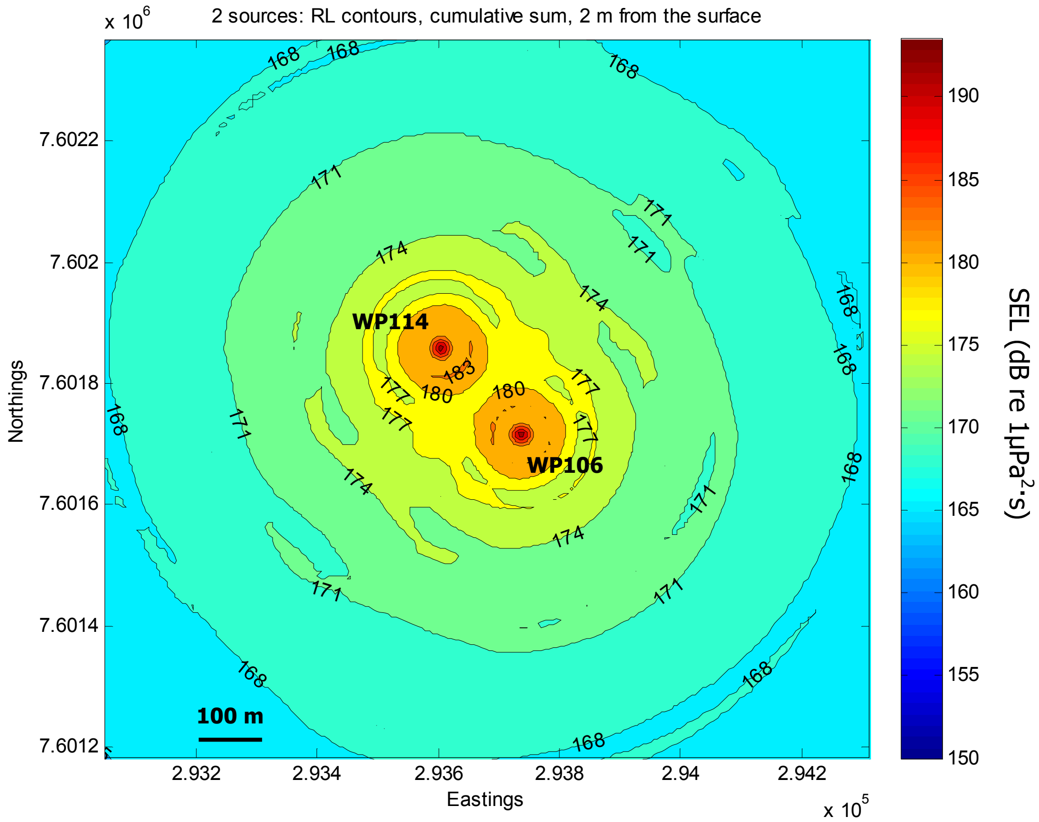


Figure 6-1 Contours showing predicted SEL of one piling strike from 2 piling barges operating simutaneously at WP114 and WP106. The noise contour is 2 m below the sea surface

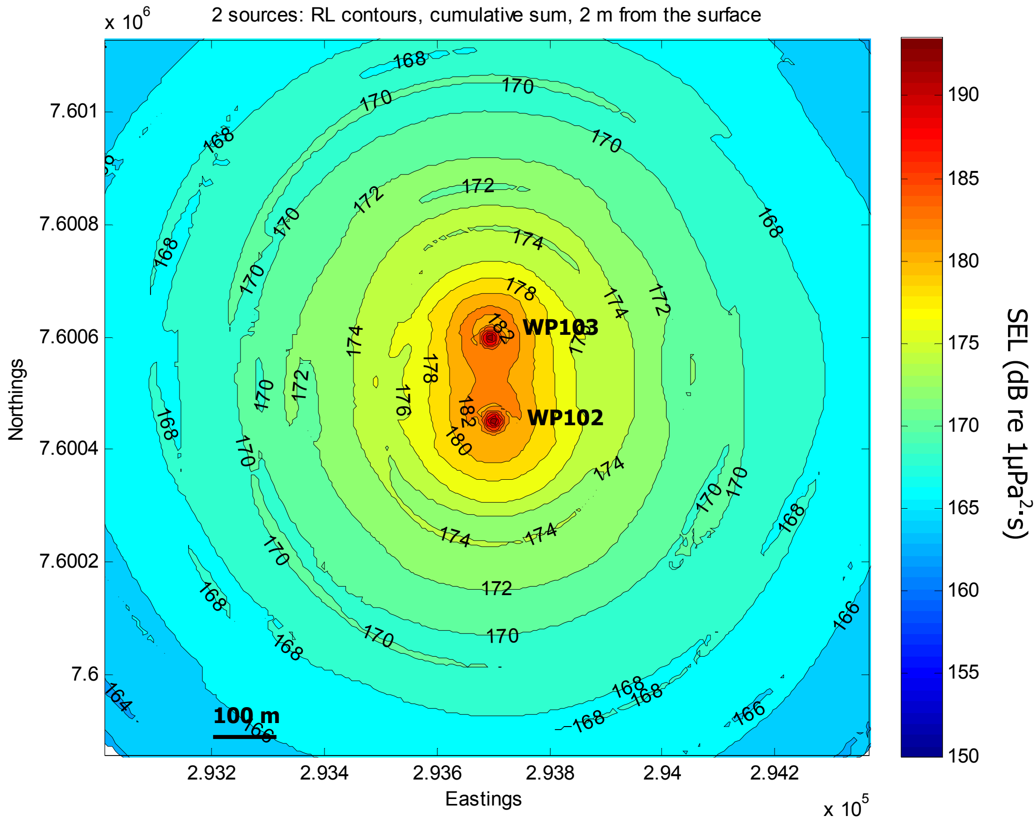


Figure 6-2 Contours showing predicted SEL of one piling strike from 2 piling barges operating simultaneously at WP103 and WP102. The noise contour is 2 m below the sea surface

6.2 Zones of Possible Behavioural Disturbance and Possible Physical Injury

Zones of behavioural disturbance and possible physical injury for both adult turtles and turtle hatchlings were assessed based on criteria listed in Table 3-1. Peak pressure levels for pile driving noise were estimated using an empirical formula[22].

The two modelling scenarios have similar noise propagation environmental conditions, and therefore the modelling outcomes are similar for the estimate of the two zones. Table 6-1 summarises the maximum distances for the two scenarios modelled and the zones of behavioural disturbance and possible injury for adult turtles and turtle hatchlings. It can be seen that in the range of 10 m it is likely that the piling activities in the proposed Wheatstone port facility area could induce physical injury or hearing damage to adult turtles, and the piling activities could also cause behavioural disturbance for adult turtles within a 700 m range. Within 25 m range, piling activities could likely induce physical injury or hearing damage to turtle hatchlings. Behavioural disturbance for turtle hatchlings was not considered as hatchling movements in the near shore water are predominately determined by tides and currents. However as a precautionary approach it is recommended that the zone of behavioural disturbance estimated for adult turtles is applied to

[22] $SPL_{peak}=SEL+10*\log(T_1/T_2)+18$, where T_1=1s and T_2=duration of impulsive signal. This empirical formula was obtained by SVT from another source via private conversation.

turtle hatchlings. Consideration should also be given to the fact that turtle beaches are not located in close proximity to the piling activities.

Table 6-1 Furthest distance to zones of behavioural disturbance and possible injury at sea level of HAT.

Modelling Scenarios	Furthest Distance from Source to Zone of Physical Injury (m)		Furthest Distance from Source to Zone of Behavioural disturbance (m)	
	Adult Turtles	Turtle Hatchlings	Adult turtles	Turtle Hatchlings
Pile Driving – Wheatstone port facility development	10	25	700	Not applicable

APPENDIX A : ACRONYMS

Acronym	Definition
EPBC	The Environment Protection and Biodiversity Conservation
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
LNG	Liquified Natural Gas
MMPE	Monterey Miami Parabolic Equation
PE	Parabolic Equation
RMS	Root Mean Square
SEL	Sound Exposure Level
SPL	Sound Pressure Level
WP	Work Points

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Appendix FB

Biomass Attributes of Intertidal Habitats in the Hooley Creek Area

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. Avoidance of mangroves and their associated high-tidal mudflat habitats has been a key design constraint for the Project. In the current design, benthic primary producer habitats within the Ashburton River Delta are avoided; however, there are areas of benthic primary producer habitats (mangroves, bioturbated mud flats and algal mats) that may be impacted upon in the upper reaches of Hooley Creek West. The loss of some intertidal benthic primary producer habitats from the Project may potentially exceed the allowable Cumulative Loss Guideline of 10 per cent in development areas (Environmental Protection Authority Environmental Assessment Guideline No. 3) in the Hooley Creek area. Therefore, additional data of selected biomass attributes for each of the intertidal benthic primary producer habitats types was collected to:

- Demonstrate a level of scientific understanding or assessment of ecological value that is beyond a purely "area" based loss assessment
- Use the biomass attributes at representative sites as a surrogate for "ecological value" to help confirm that the ecological value of each habitat type in the Project area is similar to that occurring at other areas within the Hooley Creek-Four Mile Creek system, which will not be impacted.

Field surveys were undertaken in January and May 2010 to provide information on biomass attributes and crab densities of the three intertidal benthic primary producer habitats types (mangrove, bioturbated mud flat and algal mat) that occur in the Hooley Creek tidal system. The relative ecological values (as represented by biomass attribute data) of the three benthic primary producer habitats units in the Hooley Creek West area are similar to those found outside of, but adjacent to, the area of direct impact (i.e. Hooley Creek East and Middle Creek). The biomass data confirms that the significant modifications to the Project layout made during the design phase resulted in the avoidance of impacts to the more productive, closed canopy mangroves occurring along the mid to lower reaches of Hooley Creek West. The direct impacts to mangroves were confined to the upper reaches of Hooley Creek West, in an open shrubland mangrove habitat. Mangrove structure and biomass estimates determined from this study for mangroves in the Onslow area are comparable with values recorded elsewhere along the Pilbara coast. Finally, variation in crab burrow density within mangrove habitats made it a less useful indicator compared to the mangrove structure-based estimates of biomass.

Report

Biomass Attributes of Intertidal Habitats in the Hooley Creek Area

12 JANUARY 2011

Prepared for

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Executive Summary

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future yet-to-be determined gas fields. The Project will require the installation of gas-gathering, export and processing facilities in Commonwealth and State Waters, and on land. The LNG plant will have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Wheatstone Project is currently being assessed by the Western Australia Environmental Protection Authority (EPA) following submission of the Environmental Review and Management Programme (ERMP). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

Avoidance of mangroves and their associated high tidal mudflat habitats has been a key design constraint for the Wheatstone Project. The current design avoids any direct impact to intertidal Benthic Primary Producer Habitats (BPPH) within the Ashburton River Delta, however, due to the orientation of coastal landforms, there are areas of BPPH (mangroves, bioturbated mud flats, algal mats) that may be impacted upon in the upper reaches of Hooley Creek West.

As required by the EPA guidance (Environmental Assessment Guidelines, No 3: Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment GS 3. December 2009) (EPA 2009) the extent of loss of intertidal BPPH has been assessed within the ERMP. Due to the extent of loss of some intertidal BPPH from the Wheatstone Project potentially exceeding the 10% guidance (as per the above EPA 2009 document) in the Hooley Creek area it was suggested that additional data of selected biomass attributes for each of the intertidal BPPH types be collected to:

- Demonstrate a level of scientific understanding or assessment of ecological value that is beyond a purely "area" based loss assessment.
- Use the biomass attributes at representative sites as a surrogate for "ecological value" to help confirm that the ecological value of each habitat type under the project footprint is similar to that occurring at other areas within the Hooley Creek-Four Mile Creek system that will not be impacted. This helps to confirm (at a secondary level) that the area based loss assessment is indicative of the actual loss in terms of ecological value.

Field surveys were undertaken in January and May 2010 to provide information on biomass attributes of the three intertidal BPPH types that occur in the Hooley Creek tidal system. A series of sites were chosen that was representative of the mangrove, bioturbated mud flat and algal mat habitats at the three tidal creek systems of Hooley Creek West, Hooley Creek East and Middle Creek. Within mangrove areas, sites were included in both of the two main mangrove communities that occur in the study area - closed canopy *Avicennia marina* shrubland (Am2) and open shrubland *Avicennia marina* (Am3). Data was collected on the following attributes:

- mangrove structure (stem density, stem thickness, species composition, ground projection area, tree height) - these data were used to determine above-ground biomass and leaf canopy biomass using allometric relationships derived previously for Pilbara mangroves
- crab burrow density as an indicator of crab density
- thickness and organic matter content of algal mats

Based on these data collected the main findings of the study are:

- The relative ecological values (as represented by biomass attribute data) of the three BPPH units in the Hooley Creek West area (i.e. those areas under the plant footprint) are similar to those found outside of, but adjacent to, the area of direct impact (i.e. Hooley Creek East and Middle Creek).
- In terms of productivity of mangrove communities, the biomass data confirm statements made in the Wheatstone ERMP (Appendix N1 BPPH Loss Assessment) that the significant modifications to the project layout made during the design phase resulted in the avoidance of impacts to the more productive closed canopy mangroves occurring along the mid to lower reaches of Hooley Creek West. Direct impacts to mangroves have been confined to the upper reaches of Hooley Creek West that support an open shrubland mangrove habitat which contributes a much lower biomass that the closed canopy mangrove habitat.
- Mangrove structure and biomass estimates determined from this study for mangroves in the Onslow area are comparable with values recorded elsewhere along the Pilbara coast.
- Within mangrove habitats there was large variation in crab burrow density making it a less useful indicator compared to the mangrove structure based estimates of biomass. This variation is likely to be due to the range of factors that may vary on the local scale (these factors include substrate type, sediment grain size and other microscale chemical and climatic conditions).

Introduction

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future yet-to-be determined gas fields. The Project is referred to as the Wheatstone Project and "Ashburton North" is the proposed site for the LNG and Domgas plants. The Project will require the installation of gas-gathering, export and processing facilities in Commonwealth and State Waters, and on land. The LNG plant will have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Wheatstone Project is currently being assessed by the Western Australia Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) following submission of the ERMP. The investigations outlined in this report have been conducted to support the environmental impact assessment process.

Intertidal habitat surveys conducted for the Wheatstone Project have visited a range of sites in the Tubridgi Point to Coolgra Point area to document the intertidal habitats and associated biological communities and collect information on the distribution and conservation significance of intertidal habitats. Particular focus was placed on the two main intertidal systems located adjacent to the proposed Wheatstone North development site, these being the Hooley Creek tidal embayment and the Ashburton River Delta. The results of these surveys are provided in URS (2010a).

Intertidal habitat mapping of the Hooley Creek system and aerial photo analysis has delineated the distribution of intertidal Benthic Primary Producer Habitat (BPPH) (URS 2010a). As required by the EPA guidance (Environmental Assessment Guidelines, No 3: Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment GS 3. December 2009) (EPA 2009) the extent of loss of those habitats can be assessed at the primary level based on area (ha and %). Due to the extent of loss of some intertidal BPPH from the Wheatstone Project potentially exceeding the 10% guidance (as per the above EPA 2009 document) in the Hooley Creek area it was suggested that additional data of selected biomass attributes for each BPPH types be collected to:

- Demonstrate a level of scientific understanding or assessment of ecological value that is beyond a purely "area" based loss assessment.
- Use the biomass attributes at representative sites as a surrogate for "ecological value" to help confirm that the ecological value of each habitat type under the project footprint is similar to that occurring at other areas within the Hooley Creek-Four Mile Creek system that will not be impacted. This helps to confirm (at a secondary level) that the area based loss assessment is indicative of the actual loss in terms of ecological value.

The report below provides the results of two surveys undertaken in January and May 2010 to collect data on selected biomass attributes and includes an assessment of the relative ecological value of those areas of intertidal BPPH that are potentially impacted by the project.

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Intertidal BPPH in the Hooley Creek - Four Mile Creek Tidal Embayment

The tidal embayment comprises a very broad tidal flat area on the eastern side of the Project site that includes narrow tidal creeks with fringing mangroves and extensive mud flats. The embayment occupies an area of approximately 70 km^2, protected from the sea by a barrier beach/dune system. It is drained to the sea by the west and east arms of Hooley Creek and Middle Creek which have a common entrance, and Four Mile Creek which enters the sea separately further to the east. Due to the dynamic nature of coastal processes operating along the ocean-facing shoreline, the orientation of sand spits and creek entrances has undergone considerable change.

The arrangement of intertidal habitat types within the tidal embayment is a pattern from tidal creek – mangroves – samphire and bioturbated high tidal mud flat – algal mat-covered high tidal flat – salt flat – hinterland margin (i.e. the beginning of the surrounding dunes). A similar geomorphology and pattern or sequence of intertidal habitats also occurs within the extensive tidal flat embayment systems at Tubridgi Point (Urala Creek) and east of Onslow from Beadon to Coolgra Point (Beadon Creek, Second Creek, Third Creek and Coolgra Creek). The main geomorphic features of the Hooley Creek area are shown in Figure 2-1.

The distribution of the various intertidal habitats and adjacent supratidal areas has been mapped and is provided in Figure 2-2. The three intertidal Benthic Primary Producer Habitat types that occur in the Hooley Creek tidal system and the area they occupy are:

- Mangroves (83 ha)
- Bioturbated mudflats with samphire communities (high tidal mud flats which occur landward of the mangrove fringed tidal creeks) (637 ha)
- Algal mats (815 ha).

Figure 2-1 The main features of the eastern section of the Hooley Creek - Four Mile Creek tidal embayment

A: Sand spit, sand bars and shoals and alluvial fan at mouth of Hooley and Middle Creek

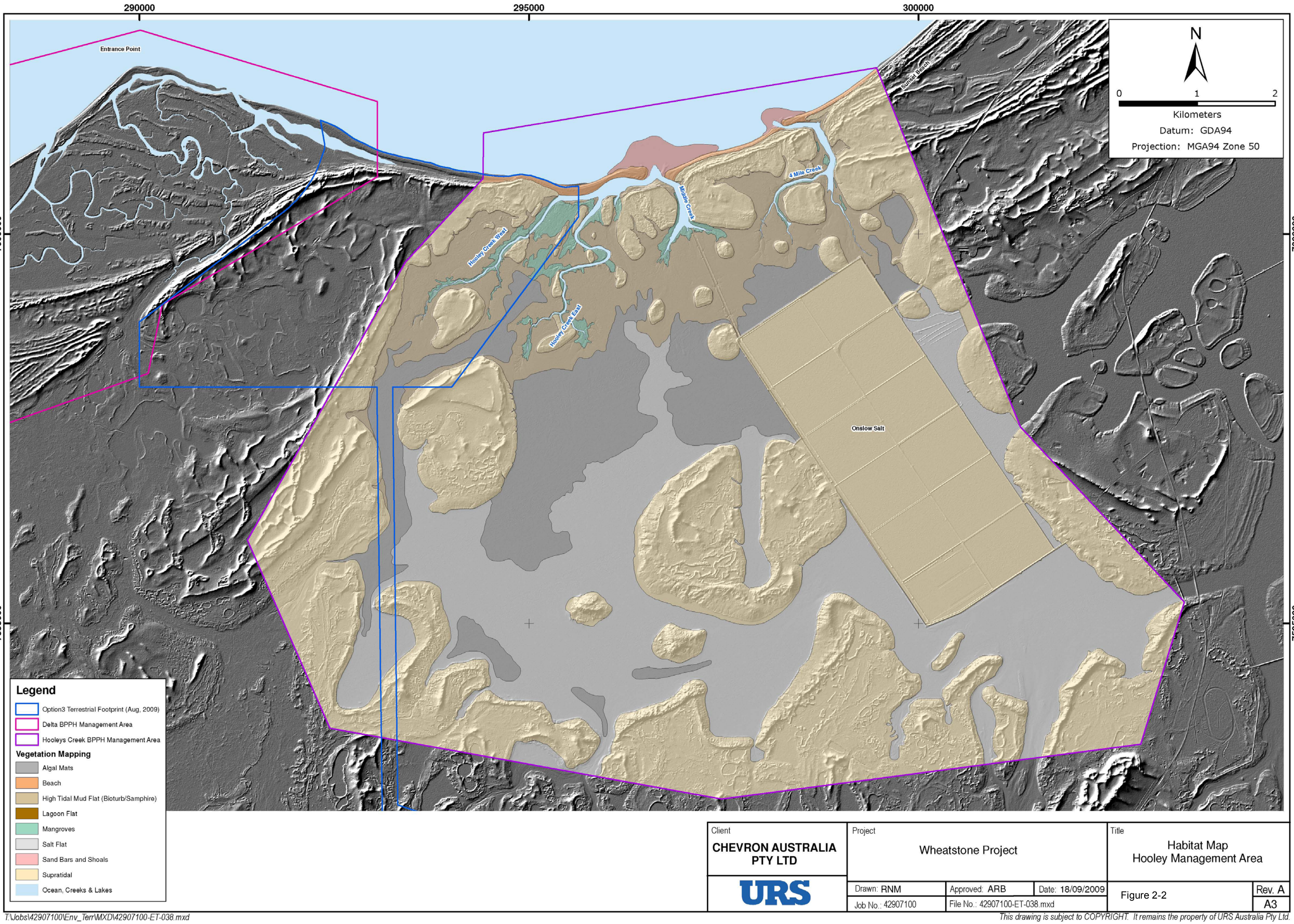
B: Sand spit and confluence of Hooley Creek West and East Arms.

C: Narrow mangrove zone fringing Hooley Creek West Arm.

D: High tidal mud flats adjacent to Hooley Creek West Arm.

E: Algal mat (dark colour) and samphire communities landward of the upper reaches of Hooley Creek West Arm.

Figure 2-2 Habitat Map of the Hooley Creek-Four Mile Creek Area



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2 Intertidal BPPH in the Hooley Creek - Four Mile Creek Tidal Embayment

2.1 Mangroves

Mangroves are confined to fringing the tidal creek channels where they typically occur as a narrow band only 10-20 m wide (see Figure 2-1). Within the study area, *Avicennia marina* is a widespread and dominant species. It commonly was found growing monospecifically and in a range of structural forms (e.g. from dense to open shrubland), but also occurred in association with the other mangrove species. The local dominance of *A. marina* reflects the broader regional pattern with this species being the most widespread and abundant mangrove species in the Pilbara coastal region (Semeniuk 1993).

Groundwater and sediment salinity gradients are established across the tidal flats in response to decreasing frequencies of seawater (tidal) recharge with increasing tidal flat elevation. These gradients have produced recognisable structural and physiognomic zones or associations within the mangroves (URS 2010a). The distribution of mangrove associations in Hooley Creek is shown in Figure 3-1 and the two main associations are described below. Codes used in the mapping denoted for the various associations reflect the dominant mangrove species.

Low to moderate height, dense Avicennia marina shrubland (Am2)

Together with the more open shrubland unit (Am3), this association is the most widespread in the Hooley Creek – Four Mile Creek tidal embayment (Am2 occupies 35 ha and Am3 occupies 47 ha). It occurs as a fringe along the lower-mid reaches of the tidal creek systems. This association is predominantly monospecific *A. marina*, approximately to 2-3 m in height and with a variable moderate to dense canopy cover. It is often backed by, and intergrades with, the open scrub unit (Am3) described below.

Low, open to very open Avicennia marina scrub on the landward margins (Am3)

Extensive areas of this unit occur along the uppermost reaches of the tidal creeks and at the landward extent of the mangrove zone on tidal flat areas. As tidal elevation increases and the frequency of inundation decreases, the density of trees within these areas becomes generally low to scattered and they grow in a stunted, recumbent form due to high soil salinities that are approaching (or at) the threshold level tolerated by mangroves. Areas of low open *A. marina* scrub mangroves are often interspersed with the high tidal mud flat habitat (samphire and bioturbated mud flat zone) described below.

2.2 Bioturbated Mud Flats

Landward of the mangrove zone, areas of bioturbated mud flats with samphire communities typically extend across the tidal flats either to the hinterland margin or to algal mat areas. These high tidal mud flat areas occur in the upper or higher sections of the intertidal zone and hence were not regularly inundated by tides.

Together with the mangrove and algal mat habitats, this habitat was been considered as Benthic Primary Producer Habitat (BPPH) for the purposes of the Wheatstone environmental assessment (URS 2010b). The samphire plants and algal mats, like mangrove trees, are primary producers in the strict sense while the bioturbated mud flats are areas of high secondary production essential to the output of nutrients by the plants in the ecosystem. The bioturbated/samphire zone was a mappable habitat, however, the boundaries between samphire communities and bioturbated areas were often indistinct (or often interspersed within the same area) and hence they have been mapped together (URS 2010a).

At locations where the extent of mud flat development was limited or truncated by the hinterland or low islands, the bioturbated/samphire mud flat habitat occupied the full extent of the mud flat zone between the landward edge of the mangroves and the hinterland margin. During both ground and helicopter-based

2 Intertidal BPPH in the Hooley Creek - Four Mile Creek Tidal Embayment

surveys it was noted that high tides above 2.2 m Chart Datum (0.7 m Australian Height Datum) were required to inundate these areas. In many locations this habitat was hundreds of metres wide, while in others the bioturbated/samphire mud flat habitat zone was only a few metres wide and abutted the base of supratidal sandy cheniers or dunes with a well-defined high tide mark.

Within the bioturbated/samphire mud flat habitat a patchy and often complex zonation or mosaic was evident in the following sub-habitats:

- bioturbated mud flats - devoid of macro-vegetation but heavily worked over by burrowing crabs, typically ocypodid (fiddler crabs - genus *Uca*) and sesarmids (marsh crabs – genera *Neosarmatium, Perisesarma, Parasesarma*) (Plates 2-1 and 2-2).
- samphire flats and/or discrete patches of samphires - dominated by halophytic shrubs but with some crab burrows.

Vegetation communities within samphire areas were dominated by two species, *Halosarcia halocnemoides* and *H. pruinosa*. Other species that were commonly found in areas where the samphire flats abutted the hinterland or low islands located amongst the tidal mud flats were *Muellerolimon salicorniaceum*, *Frankenia ambita*, *Noebassia astrocarpa*, *Hemichroa diandra* and the perennial grass *Sporobolus virginicus* (marine couch).

Plate 2-1 Bioturbated mud flats showing numerous crab burrows

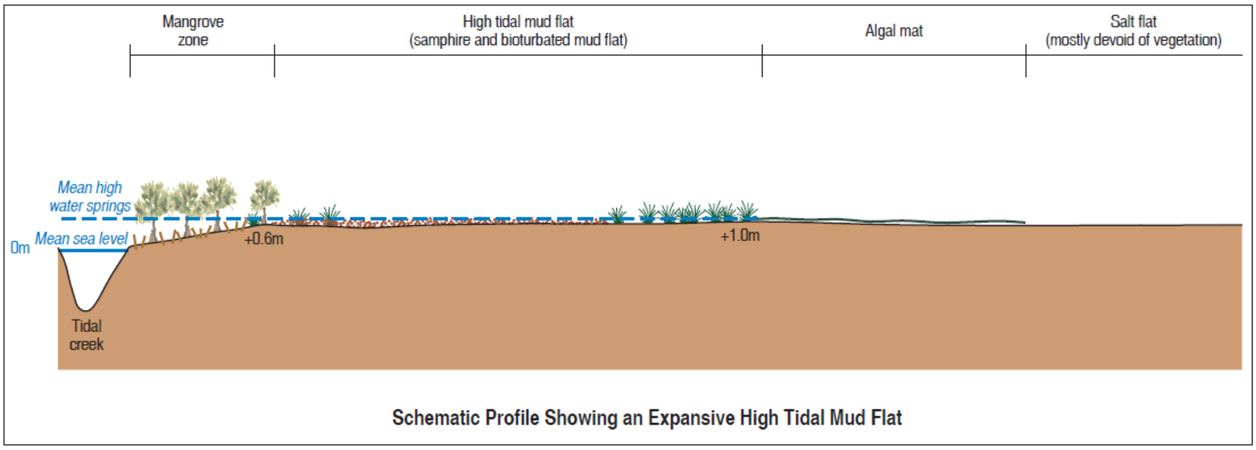
2 Intertidal BPPH in the Hooley Creek - Four Mile Creek Tidal Embayment

Plate 2-2 The fiddler crab species (*Uca elegans*) is the dominant crab occurring within the bioturbated mud flat habitat

2.3 Algal Mats

In the Hooley Creek – Four Mile Creek tidal embayment expansive of cyanobacterial mats, also referred to as algal mats, occurred on mud flats further landward of the bioturbated/samphire habitat. The schematic profile shown in Figure 2-3 presents this scenario. Algal mat areas are only rarely inundated by the largest of the spring tides and, during helicopter flights over the area, it was observed that high tides (2.6 m CD) partly inundate the algal mat areas (Plate 2-3).

Figure 2-3 Schematic profile showing an expansive mud flats with algal mats



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2 Intertidal BPPH in the Hooley Creek - Four Mile Creek Tidal Embayment

Plate 2-3 Partial inundation during spring tides of algal mats (dark colour on photo) on tidal flats landward of Hooley Creek East

The algal mats varied from a sheet form to a pustular or crinkled form. In the most commonly observed sheet form, the mat was typically 5-10 mm in thickness and could be easily rolled and peeled back from the underlying mud flat surface (see Plate 2-5). Where the algal mats still retained moisture, they took on a dark colouring and texture that made them readily identifiable from a distance.

The algal mats of the coastline near Onslow have been examined and described previously as part of the Onslow Solar Salt Project environmental assessment (Paling 1990) and more recently a detailed investigation of algal mats within a similar coastal setting was undertaken along the east side of Exmouth Gulf for the Yannarie Salt Project ERMP (Biota 2005). Analysis of algal mat samples collected in May 2009 in the Hooley Creek – Four Mile Creek tidal flat area and observations on algal mat distribution made during surveys in the Tubridgi Point to Coolgra Point area were consistent with the findings of the previous studies, as summarised below:

- Algal mats consisted of dehydrated algal material on the surface with a moister layer below consisting of tangled filaments, mostly *Oscillatoria* sp.
- The upper limits or elevation of algal mat distribution were likely to be controlled by dehydration and high salinity due to low frequency of tidal inundation. Biota (2005) estimated that algal mats are only submerged by tides for between 1-3% of the time.
- The lower limits or elevation may be related to a greater frequency of tidal inundation (and hence exposure to greater tidal currents) and grazing by invertebrates such as the extensive crustacean populations that occurred in the high tidal mud flat habitat (i.e. this being the next habitat located at lower elevation adjoining algal mat areas).

2 Intertidal BPPH in the Hooley Creek - Four Mile Creek Tidal Embayment

Cyanobacterial mats have been demonstrated to fill an important ecological function in coastal arid zone systems, fixing atmospheric nitrogen into biologically available forms (Paling et al. 1989). Crabs are absent or rare in these areas but insects and insect larvae are sometimes seen under the algal mats.

Plate 2-4 Algal mat peeling back from the underlying mud flat

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Field Surveys and Location of Sites

Field surveys were undertaken in January and May 2010 to provide information on biomass attributes of the three intertidal Benthic Primary Producer Habitats that occur in the Hooley Creek tidal system. A series of sites were chosen that was representative of the mangrove, bioturbated mud flat and algal mat habitats at the three creek systems of Hooley Creek West, Hooley Creek East and Middle Creek. Within mangrove areas, sites were included in both of the two main mangrove communities that occur in the study area - closed canopy *Avicennia marina* shrubland (Am2) and open shrubland *Avicennia marina* (Am3).

Access to the sites located close to the tidal creek channels was via the vessel King Diver and associated tenders while tidal flat areas located further landward of the tidal creeks were accessed by vehicle and foot. The selection of sites was made of the basis of:

- representativeness of habitat type
- access constraints
- health and safety considerations
- inclusion of some sites in areas proposed to be directly impacted by the Wheatstone Project (i.e. the upper reaches of Hooley Creek West and adjacent tidal flats)

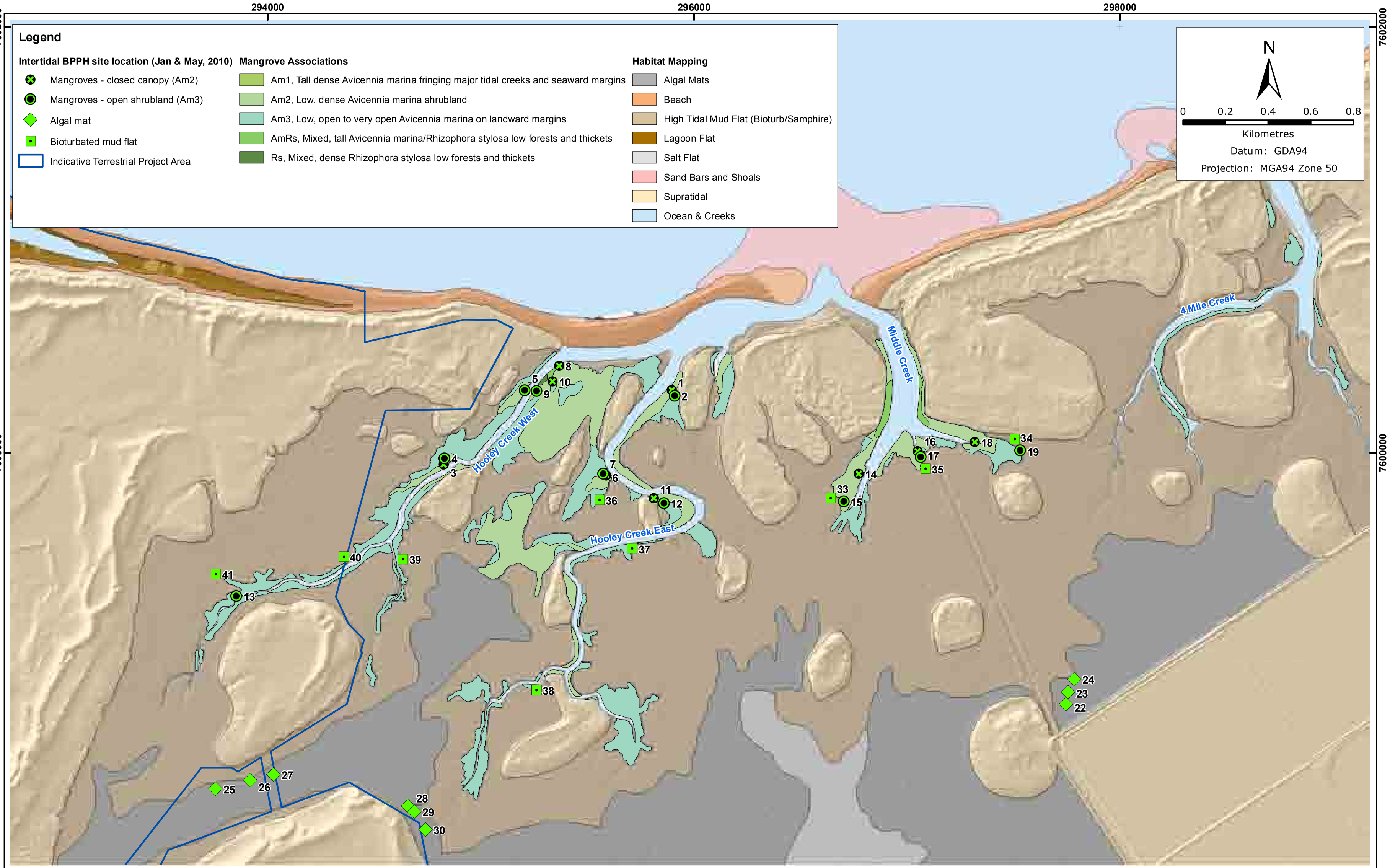
Table 3-1 provides the site location information and Figure 3-1 shows the location of the sites together with the habitat distribution and the Indicative Terrestrial Project Area (i.e. the blue line on Figure 3-1 represents the proposed eastern limit of direct impact from the Ashburton North project site).

Table 3-1 Survey Sites - Location and Habitat Type

Site	Northings	Eastings	Intertidal BPPH Type	Location
1	295896	7600294	Mangroves - closed canopy (Am2)	Hooley Ck East
2	295910	7600267	Mangroves - open shrubland (Am3)	Hooley Ck East
3	294826	7599945	Mangroves - closed canopy (Am2)	Hooley Ck West
4	294829	7599974	Mangroves - open shrubland (Am3)	Hooley Ck West
5	295206	7600293	Mangroves - open shrubland (Am3)	Hooley Ck West
6	295588	7599894	Mangroves - closed canopy (Am2)	Hooley Ck East
7	295573	7599902	Mangroves - open shrubland (Am3)	Hooley Ck East
8	295367	7600409	Mangroves - closed canopy (Am2)	Hooley Ck West
9	295262	7600290	Mangroves - open shrubland (Am3)	Hooley Ck West
10	295337	7600335	Mangroves - closed canopy (Am2)	Hooley Ck West
11	295812	7599786	Mangroves - closed canopy (Am2)	Hooley Ck East
12	295859	7599764	Mangroves - open shrubland (Am3)	Hooley Ck East
13	293852	7599328	Mangroves - open shrubland (Am3)	Hooley Ck West
14	296774	7599902	Mangroves - closed canopy (Am2)	Middle Ck
15	296703	7599772	Mangroves - open shrubland (Am3)	Middle Ck
16	297050	7600008	Mangroves - closed canopy (Am2)	Middle Ck
17	297063	7599980	Mangroves - open shrubland (Am3)	Middle Ck
18	297318	7600051	Mangroves - closed canopy (Am2)	Middle Ck
19	297531	7600012	Mangroves - open shrubland (Am3)	Middle Ck
22	297747	7598820	Algal mat	Middle Ck
23	297756	7598876	Algal mat	Middle Ck
24	297785	7598937	Algal mat	Middle Ck

3 Field Surveys and Location of Sites

Site	Northings	Eastings	Intertidal BPPH Type	Location
25	293754	7598423	Algal mat	Hooley Ck West
26	293918	7598463	Algal mat	Hooley Ck West
27	294026	7598490	Algal mat	Hooley Ck West
28	294658	7598343	Algal mat	Hooley Ck East
29	294688	7598315	Algal mat	Hooley Ck East
30	294740	7598231	Algal mat	Hooley Ck East
33	296642	7599787	Bioturbated mud flat	Middle Ck
34	297505	7600064	Bioturbated mud flat	Middle Ck
35	297088	7599925	Bioturbated mud flat	Middle Ck
36	295557	7599778	Bioturbated mud flat	Hooley Ck East
37	295711	7599551	Bioturbated mud flat	Hooley Ck East
38	295260	7598886	Bioturbated mud flat	Hooley Ck East
39	294635	7599501	Bioturbated mud flat	Hooley Ck West
40	294357	7599512	Bioturbated mud flat	Hooley Ck West
41	293756	7599431	Bioturbated mud flat	Hooley Ck West



Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project	Hooley Creek Area Intertidal BPPH Assessment Sites
URS	Drawn: MR · Approved: ARB · Date: 31/05/2010 Job No.: 42907466 · File No.: 42907466-EM-006.mxd	Figure 3-1 · Rev A · A3

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Mangrove Structure – Biomass Estimates

4.1 Methods

A standard technique for estimating above-ground biomass in mangroves is to determine allometric relationships between the stem diameter at breast height (DBH) and biomass. This has been determined mostly from tropical mangroves where the trees are tall (3-15 m high) and typically only have a single trunk (Clough & Scott 1989, Ong *et al*. 1985). Due to the arid and highly saline conditions that are experienced along the Pilbara coastlines the mangroves are low (mostly less than 4 m high) and have a growth form that consists of multiple stems or branches arising close to the ground from a base (similar to a mallee growth form). This growth form is characteristic of *Avicennia marina*, the commonly occurring mangrove species on the Pilbara coastline (and in the Hooley Creek area) (see Plate 4-1).

Plate 4-1 Typical growth form of *Avicennia marina* mangroves in the study area. Note the multiple stems branching close to the ground.

Hence the estimation of biomass using conventional allometric relationships between biomass and stem diameter (at breast height) based on a single trunk is not applicable to the low, multi-stemmed Pilbara mangroves. Two different biomass estimates are used in this study, both of which have been developed for Pilbara mangroves. These are:

- Above-ground biomass (i.e. dry weight of trunks, stems, leaves combined) based on allometric relationships between stem diameter and biomass where individual stems are treated as individual trees. The approach, methodology and derived allometric relationships follow that used previously in the Pilbara by Clough *et al.* (1997).

- Leaf canopy biomass (i.e. dry weight of leaves) is based on allometric relationships between mangrove stand structure (tree height, ground projection area of canopy) and leaf biomass. The methodology and derived allometric relationships follow that used previously in multi-stemmed, low mangrove trees in the Pilbara by LeProvost Environmental Consultants (LEC) (1992).

With both of the above techniques in mind, sampling was undertaken in the two main mangrove associations or zones that occur in the area. These are an open shrubland of *Avicennia marina* (mangrove association Am3 in Figure 3-1) and closed canopy *Avicennia marina* (mangrove association Am2 in Figure 3-1). In each of the open shrubland and closed canopy mangrove sites in Hooley Creek West, Hooley Creek East and Middle Creek, a 25 m^2 quadrat was delineated temporarily by laying out a fibreglass tape and the following data were recorded:

- mangrove species (identification of species in quadrat);
- tree and stem density (count of trees in quadrat, stem density is obtained while recording stem thickness – see below);
- percentage canopy cover (visual estimate);
- tree height and canopy dimensions – breadth, width (using a survey staff)
- stem thickness (as per the technique described in Clough *et al.* (1997) – measured using vernier callipers.

Using the allometric relationships provided in Clough *et al.* (1997) and LEC (1992) the data collected from the surveys were used to calculate above-ground biomass and leaf canopy biomass for each site.

4.2 Results

Appendix A provides the field data collected from each site. Tables 4-1 and 4-2 provide the results of data analysis using the existing allometric relationships to calculate above-ground biomass (dry weight: kg per quadrat or per 25 m^2 of mangrove habitat) at each site (with a mean and standard error also shown for each location).

In summary these data show:

- considerable variation between sites within each mangrove community type that reflect the complexity and differences in tree/stem architecture that was evident upon examination of individual shrubs/trees in the field
- far greater above-ground biomass values (by approximately four times) were derived from the closed canopy mangrove communities, this supporting the visually evident differences observed in the field and as shown by the examples in Plates 4-2 and 4-3.
- similar above-ground biomass values within the open shrubland mangroves at the three locations
- greater above-ground biomass values within the closed canopy mangroves at Hooley Creek West and East by comparison with Middle Creek

4 Mangrove Structure – Biomass Estimates

Table 4-1 Above-ground biomass for open shrubland mangrove sites

	Location (Open Shrubland)		
	Hooley Ck West (kg/25 m^2)	**Hooley Ck East (kg/25 m^2)**	**Middle Ck (kg/25 m^2)**
	106 (Site 4)	125 (Site 2)	70 (Site 15)
	43 (Site 5)	128 (Site 7)	117 (Site 17)
	95 (Site 9)	151 (Site 12)	51 (Site 19)
	118 (Site 13)		
Mean & SE	**90 ± 16**	**135 ± 8**	**79 ± 20**

Table 4-2 Above-ground biomass for closed canopy mangrove sites

	Location (Closed Canopy)		
	Hooley Ck West (kg/25 m^2)	**Hooley Ck East (kg/25 m^2)**	**Middle Ck (kg/25 m^2)**
	333 (Site 3)	292 (Site 1)	334 (Site 14)
	537 (Site 8)	499 (Site 6)	328 (Site 16)
	383 (Site 10)	454 (Site 11)	298 (Site 18)
Mean & SE	**418 ± 61**	**415 ± 63**	**320 ± 11**

The above-ground biomass data from this study have been summarised to provide estimates for the Onslow area and in Table 4-3 these are compared to above-ground biomass values determined by Alongi *et al*. (2000) from other locations in the Pilbara (stem density and stem diameter - DBH is also provided) where *Avicennia* dominated mangrove occur. These data illustrate that the range of biomass estimates obtained from the Hooley Creek area are similar to those recorded elsewhere on the Pilbara coast.

Table 4-3 Above-ground biomass - Pilbara *Avicennia marina* mangroves comparison (tonnes/ha)

Location	Stem Density (stems/ha)	DBH (cm)	Above ground Biomass (tonnes dry weight/ha)
Hooley Creek, Onslow (open shrubland)	10,000	3.3	40.4
Hooley Creek, Onslow (closed canopy)	10,044	5.7	153.6
Dampier [1]	11,300	3.9	45.8
Port Hedland [1]	5,600	8.8	147.6
North West Cape[1]	4,400	7.9	90.5

[1] Data source (Alongi *et al.* 2000)

4 Mangrove Structure – Biomass Estimates

Plate 4-2 Open shrubland mangroves dominated by *Avicennia marina* at Site 13, Hooley Creek West

Plate 4-3 Closed canopy mangroves at Site 18, Middle Creek

4 Mangrove Structure – Biomass Estimates

Tables 4-4 and 4-5 provide the results of data analysis using the existing allometric relationships to calculate leaf canopy biomass at each site (with a mean and standard error also shown for each location).

In summary these data show:

- considerable variation between sites within the open shrubland mangrove community type and far less variation between sites within the closed canopy community type. This reflects the more uniform canopies observed at the closed canopy sites
- greater leaf canopy biomass values (by approximately 5-7 times) were derived from the closed canopy mangrove communities. Again this supports the visually evident differences observed in the field and as shown by the examples in Plates 4-2 and 4-3
- similar leaf canopy biomass values within the closed canopy mangroves at the three locations. Differences between the leaf canopy biomass values from the open shrubland mangroves at the three locations are difficult to interpret due to the extent of variation between sites.

Table 4-4 Leaf canopy biomass for open shrubland mangroves sites

	Location (Open Shrubland)		
	Hooley Ck West (kg/25 m^2)	**Hooley Ck East (kg/25 m^2)**	**Middle Ck (kg/25 m^2)**
	2.08 (Site 4)	4.44 (Site 2)	3.60 (Site 15)
	1.91 (Site 5)	0.91 (Site 7)	5.96 (Site 17)
	1.44 (Site 9)	1.74 (Site 12)	1.69 (Site 19)
	5.00 (Site 13)		
Mean & SE	**2.61 ± 0.81**	**2.36 ± 1.07**	**3.75 ± 1.24**

Table 4-5 Leaf canopy biomass for closed canopy mangrove sites

	Location (Closed Canopy)		
	Hooley Ck West (kg/25 m^2)	**Hooley Ck East (kg/25 m^2)**	**Middle Ck (kg/25 m^2)**
	14.18 (Site 3)	21.77 (Site 1)	12.70 (Site 14)
	19.51 (Site 8)	14.23 (Site 6)	17.48 (Site 16)
	21.64 (Site 10)	15.12 (Site 11)	20.15 (Site 18)
Mean & SE	**18.44 ± 2.22**	**17.04 ± 2.38**	**16.78 ± 2.18**

The leaf canopy biomass data from this study have been summarised to provide estimates for the Onslow area. In Table 4-6 these are compared to leaf canopy biomass values determined from similar mangrove communities at Port Hedland (LEC 1992). These data illustrate that the leaf canopy biomass estimates obtained from the Hooley Creek area are similar to those recorded at Port Hedland and, given the extensive distribution of these mangrove communities along the Pilbara coast, these values are likely to be representative on a regional scale.

4 Mangrove Structure – Biomass Estimates

Table 4-6 Leaf canopy biomass - Pilbara *Avicennia marina* mangroves comparison (dry weight, tonnes/ha)

	Open Shrubland Mangroves (tonnes/ha)	Closed Canopy Mangroves (tonnes/ha)
Onslow, Hooley Creek Area	1.16	6.97
Port Hedland[2]	1.36	4.21

[2] Data source (LEC 1992)

Burrowing Crab Density

Invertebrates perform a critical ecological role in converting the mangrove primary productivity into secondary productivity that is used not only by themselves but by higher levels in the mangrove food chains such as fish. As crabs are the most common and widely distributed invertebrates in the Hooley Creek system, crab density was measured as a proxy for secondary productivity.

5.1 Methods

The density of crab burrows has been used by Skov *et al*. (2002) and Penha-Lopes *et al*. (2009) to assess fiddler crab density and a similar approach was taken during the Hooley Creek survey work by counting crab burrow density in three 1 m^2 quadrats located immediately adjacent to each of the mangrove quadrats described above. Additional observations were made on surface fauna diversity. At each of the open shrubland and closed canopy mangrove sites where mangrove structure was measured, crab burrow density was also measured in three 1 x 1 m quadrats near, but outside the mangrove quadrat to minimise disturbance to the crabs and maximise the numbers of individuals outside their burrows. Counts were made of the number of burrows as not all crabs were emergent.

The crab density measure described above also formed the biomass attribute in the bioturbated mud flat zone (Plate 5-1). Again, three 1 m^2 quadrats were located at each site in areas assessed to be representative of this habitat. Bioturbated mudflat sites were located in areas landward of the mangroves at Hooley Creek (both west and east arms) as well as Middle Creek (see Figure 3-1).

While, on initial observation, it appears as though most burrows contain one crab per burrow, most crabs rapidly retreat to their burrows when disturbed and hence it is difficult to test this assumption. A study specifically undertaken to quantify the density of mangrove crabs counted the number of active burrows and the number of active crabs on the surface in a standard area under a series of conditions including periods when there was the maximum number of active crabs outside their burrows (Skov *et al*. 2002). This study estimated that 81% of all burrows were inhabited.

Plate 5-1 Fiddler crab holes in bioturbated mud flat near Site 41, Hooley Creek West.

5.2 Results

Table 5-1 shows the results obtained for crab burrow densities. Table 5-2 summarises the data by habitat in each of the three creeks.

Table 5-1 Density of crab burrows in mangrove and bioturbated mudflat habitats in the Hooley Creek system (Means ± 1 standard error are shown).

Station number	Location	Habitat	Mean density (burrows/m^2)
1	Hooley Creek East	Closed canopy mangroves	0±0
2	Hooley Creek East	Open shrubland mangroves	0±0
3	Hooley Creek West	Closed canopy mangroves	0±0
4	Hooley Creek West	Open shrubland mangroves	9.3±4.3
5	Hooley Creek West	Open shrubland mangroves	5.0±1.7
6	Hooley Creek East	Closed canopy mangroves	4.0±0.6
7	Hooley Creek East	Open shrubland mangroves	6.3±2.4
8	Hooley Creek West	Closed canopy mangroves	0±0
9	Hooley Creek West	Open shrubland mangroves	5.0±1.5
10	Hooley Creek West	Closed canopy mangroves	3.7±0.6
11	Hooley Creek East	Closed canopy mangroves	1.0±1.0
12	Hooley Creek East	Open shrubland mangroves	0.7±0.7
13	Hooley Creek West	Open shrubland mangroves	11.8±7.6
14	Middle Creek	Closed canopy mangroves	76.3±5.8
15	Middle Creek	Open shrubland mangroves	61.0±1.7
16	Middle Creek	Closed canopy mangroves	90.3±17.4
17	Middle Creek	Open shrubland mangroves	65.0±1.5
18	Middle Creek	Closed canopy mangroves	130.7±5.9
19	Middle Creek	Open shrubland mangroves	104.7±24.0
33	Middle Creek	Bioturbated mudflat	67.0±15.0
34	Middle Creek	Bioturbated mudflat	99.3±14.2
35	Middle Creek	Bioturbated mudflat	93.7±27.8
36	Hooley Creek East	Bioturbated mudflat	31.0±3.5
37	Hooley Creek East	Bioturbated mudflat	61.7±5.1
38	Hooley Creek East	Bioturbated mudflat	29.3±2.3
39	Hooley Creek West	Bioturbated mudflat	36.3±6.8
40	Hooley Creek West	Bioturbated mudflat	33.0±3.6
41	Hooley Creek West	Bioturbated mudflat	53.7±13.9

5 Burrowing Crab Density

Table 5-2 Comparison of crab burrow density in the tidal creek areas and adjacent mudflats (Means ± standard deviation are shown).

Habitat	Location		
	Hooley Creek West (burrows/m^2)	Hooley Creek East (burrows/m^2)	Middle Creek (burrows/m^2)
Closed canopy mangroves	1.2±1.9	1.7±2.1	99.1±29.6
Open shrubland mangroves	10.9±9.0	2.3±3.7	76.9±29.5
Bioturbated mudflat	41.0±16.8	40.7±17.5	75.5±33.5

Density of crab burrows varied considerably between quadrats, habitats and systems (Tables 5-1 and 5-2). The high standard errors at individual stations in Table 5-1 indicate the within site variation.

The density of crab burrows showed considerable variation, much of which could be explained by variation in local conditions. For example, the closed canopy sites on Hooley Creek East and Hooley Creek West had a sandy substrate with very low density of crab burrows (1.7 and 1.2 burrows/m^2 respectively). In contrast, the same habitat at Middle Creek had a muddy substrate and a substantially greater density of crab burrows (99 burrows/m^2). This localised variation is not unusual.

For example, a similar pattern of small scale variation in substrate conditions also causes substantial variations in the density of snails of the genus *Terebralia*, which are common invertebrates in many Pilbara mangroves. In particular, only isolated individuals of the large (up to 12 cm) *T. palustris* are found in most areas of the Bay of Rest on Exmouth Gulf. However, small dense (> 100/m^2) are found where conditions are favourable (Wells 1980).

Density of crab burrows varied by habitat, ranging from low at some mangrove sites to consistently high densities on the bioturbated mudflat (Table 5-2). The greatest density at both Hooley Creek West and Hooley Creek East occurred in this habitat. All of the habitats proximal to mangroves at Middle Creek had much greater densities of crab burrows than either of the Hooley Creek areas. The greatest density of crab burrows occurred in the closed canopy.

Because of the considerable variability in density of crab burrows within the mangrove habitats, it is concluded that mangrove biomass is a better indicator of ecological value in the mangroves in the study area than the density of crab burrows. However, the data on crab burrows clearly do not show that the crab biota at Hooley Creek West, near the proposed plant site is of greater value than on Hooley Creek East or Middle Creek. On the contrary, it could be argued that the high density of crab burrows on Middle Creek indicates this is the most important of the three creeks for crabs. Within the bioturbated mudflat habitat the variability in crab burrow density was considerable less than that recorded from the mangrove habitats.

Because burrows were counted, most of the crabs could not be identified. However, those that could be identified by sight demonstrated that there were distinct patterns to the crabs. Sesarmids were common in closed canopy and less so in open shrubland. They were absent on the bioturbated mudflat and algal mat. Fiddler crabs (*Uca*) were more widely distributed. Several species (e.g. *U. capricorneus*, *U. pavo*, *U. polita*) can occur in shaded areas of the tree zones. *Uca flammula* occurs along the creek banks and *U. elegans* in the bioturbated zones of the open mudflat landward of the mangroves (George & Jones 1982). However, these are generalised patterns and the actual species composition at a site is likely to reflect a complex

5 Burrowing Crab Density

range of factors that vary on the local scale (these factors include substrate type, sediment grain size and other microscale chemical and climatic conditions).

Algal Mats

6.1 Methods

Algal mats are areas of cyanobacterial mat that grow on the surface of high tidal mudflats. Algal mats were sampled at three sites landward of each of the three tidal creeks, Middle Creek (sites 22-24), and Hooley Creek west arm (sites 25-27) and Hooley Creek east arm (sites 28-30) see Figure 3-1. At each site, five 50 cm^2 samples were collected and algal mat thickness were measured on site using vernier callipers.

Samples were collected by a mini-corer (depth of 30 mm) that typically collected both the surface veneer of algal mat (~4-6 mm thick) and the underlying sediment to which the algal mat adhered (see Plate 6-1). These samples were frozen and sent to the Marine and Freshwater Research Laboratories (MAFRL) at Murdoch University for determination of dry weight and the % Loss of Ignition at 550°C. Organic matter begins to ignite at 200°C and is completely ignited at 550°C and hence the % Loss of Ignition method can be used to calculate the proportion of the overall dry weight of each sample that was composed of organic matter (Dean 1972, Marchant & Williams 1977). The organic matter proportion is used here as a measure of algal mat weight per sample (i.e. the unit of measure being dry weight of organic matter: grams per 50 cm^2, also standardised to grams/m^2).

It should, however, be noted that minor amounts of other organic matter apart from algal mat may also have been present within the algal mat/adhered sediment samples collected (e.g. broken down plant detritus or dead bodies of zooplankton) and hence the unit/term “grams/m^2 organic matter” is used as the biomass attribute for the algal mat habitat.

Plate 6-1 Thin veneer of algal mat adhered to the underlying sediment

6.2 Results

Table 6-1 below provides a summary of the algal mat thickness data for each site. While there were some differences observed between the sites regarding the extent of surface water on the tidal flats, surface micro-topography and algal mat structure, the algal mat thickness was similar between sites.

Table 6-1 Algal mat thickness (mm)

Site	Location	Algal Mat Thickness (mm) (mean and range)
22	Middle Creek	5.0mm (4-6mm)
23	Middle Creek	4.2mm (3-5mm)
24	Middle Creek	4.8mm (4-6mm)
25	Hooley Creek West	4.8mm (4-6mm
26	Hooley Creek West	5.0mm (4-6mm)
27	Hooley Creek West	4.8mm (4-5mm)
28	Hooley Creek East	5.4mm (5-6mm)
29	Hooley Creek East	4.2mm (4-5mm)
30	Hooley Creek East	4.8mm (4-6mm)

Appendix B provides the results of the dry weight and % loss of ignition analysis undertaken by MAFRL for each sample. These data have been transformed to calculate the dry weight of organic matter per m^2 at each site. These values are shown below in Table 6-2 together with the mean and standard error for each of the three locations.

Table 6-2 Algal mat samples - dry weight of organic matter

	Location		
	Hooley Creek West (kg/m^2)	Hooley Creek East (kg/m2)	Middle Creek (kg/m2)
	1.56 (Site 25)	1.76 (Site 28)	1.36 (Site 22)
	1.73 (Site 26)	1.59 (Site 29)	1.14 (Site 23)
	1.96 (Site 27)	1.56 (Site 30)	1.29 (Site 24)
Mean & SE	**1.75 ± 0.12**	**1.64 ± 0.06**	**1.26 ± 0.06**

These data show comparable organic matter values between the three locations. This is to be expected given the high tidal flat areas supporting the algal mats can be considered to be contained with the one tidal embayment (i.e. Hooley Creek – Four Mile Creek system) and are subject to the same tidal inundation regime. By comparison, lower values of organic matter content were recorded from algal mat areas at the Dampier (0.76 ± 0.03 kg/m^2 at King Bay) and Karratha (0.55 ± 0.04 kg/m^2 at Dampier Salt) by Dr Eric Paling (pers, comm.). Advice received from Dr Paling suggests that the higher values recorded from the Onslow area may reflect the lower tidal variation at Onslow (~ 2 m at Onslow; ~ 3.5 m at Dampier/Karratha) which could allow for better growth of the algal mats.

7 Discussion

Avoidance of mangroves and their associated high tidal mudflat habitats has been a key design constraint for the Wheatstone Project. The current design avoids any direct impact to intertidal BPPH within the Ashburton River Delta, however, due to the orientation of coastal landforms, there are areas of BPPH (mangroves, bioturbated mud flats, algal mats) that may be impacted upon in the upper reaches of Hooley Creek West.

The original layout plan for the Project was predicted to result in the destruction of 36 ha of mangroves in the Hooley Creek from direct impacts. During the design phase, significant modifications to the proposed Project footprint were made to reduce the scale of potential direct impacts to mangroves and other intertidal BPPH in the Hooley Creek area. These modifications to the proposed footprint result in:

- a reduction in potential mangrove loss by direct impacts from 36 ha to 4 ha; and
- avoidance of potential direct impacts to the mid to lower reaches of Hooley Creek, which contain the more productive closed canopy mangroves. Impacts to mangroves are now proposed to be confined to the upper reaches of Hooley Creek West that support an open shrubland mangrove habitat.

The assessment of loss of intertidal habitats undertaken for the Wheatstone ERMP conformed to the requirements of Environmental Assessment Guidelines, No 3: Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment GS 3 (EPA 2009) by determining the extent of loss of intertidal BPPH at the primary level based on area (ha and %). For the Hooley Creek – Four Mile Creek area, the proposed total loss of mangrove is less than the Cumulative Loss Guideline (CLG) indicated in EPA (2009), while the loss of high tidal mud flat (bioturbated mud flat/samphires) and algal mat exceeds the 10% CLG threshold. EPA (2009) indicates that the CLG's should not be considered to be rigid limits, but notes that the acceptability of such losses will be a judgement of the EPA based on its consideration of the overall risk to the ecological integrity of the remainder of the ecosystem within the defined Loss Assessment Units (LAU).

In this context, the data on selected biomass attributes provided in this report have helped to confirm the relative "ecological value" value of each habitat type under the project footprint by using selected biomass attributes as surrogate measures. Based on these data the main findings of the study are:

- The relative ecological values (as represented by biomass attribute data) of the three BPPH units in the Hooley Creek West area (i.e. those areas under the plant footprint) are similar to those found outside of, but adjacent to, the area of direct impact (i.e. Hooley Creek East and Middle Creek).
- In terms of productivity of mangrove communities, the biomass data confirm statements made in the Wheatstone ERMP (Appendix N1 BPPH Loss Assessment) that the significant modifications to the project layout made during the design phase resulted in the avoidance of impacts to the more productive closed canopy mangroves occurring along the mid to lower reaches of Hooley Creek West. Direct impacts to mangroves have been confined to the upper reaches of Hooley Creek West that support an open shrubland mangrove habitat which contributes a much lower biomass that the closed canopy mangrove habitat.
- Mangrove structure and biomass estimates determined from this study for mangroves in the Onslow area are comparable with values recorded elsewhere along the Pilbara coast.
- Within mangrove habitats there was large variation in crab burrow density making it a less useful indicator compared to the mangrove structure based estimates of biomass. This variation is likely to be due to the range of factors that may vary on the local scale (these factors include substrate type, sediment grain size and other microscale chemical and climatic conditions).

URS

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Glossary

Terminology	Definition
Allometric relationships	In the context of this report this term means a derived mathematical formula that quantifies the relationship between a parameter of mangrove structure (e.g. stem diameter) and the biomass of a tree or part thereof.
Benthic Primary Producer communities	Are biological communities, including the plants and animals, within which benthic primary producers are the more prominent components.
Benthic Primary Producer Habitats (BPPH)	Are both the BPP communities described above as well as the areas of substratum that can and/or does support these communities.
Benthic Primary Producers (BPP)	Are predominantly photosynthetic marine autotrophs, mainly plants and algae (some examples include seagrasses, mangroves, attached macroalgae), but also include scleractinian corals and some other filter feeding invertebrates such as some sponges and soft corals, which obtain a proportion of their energy requirements from photosynthetic symbiotic microalgae that live in animal tissues. All BPP organisms grow on the seabed either subtidally or intertidally, or as epiphytes.
Bioturbation	Turnover of substrate by fauna from burrowing, excavation and other activities.
Chenier	Detached shoestring or sinuous sand deposit built to high tidal or supratidal levels surrounded by muddy tidal-lands.
Halophytic shrubs	Plants that are adapted to living in saline conditions. Some of these plants survive by excreting salt through the leaves; others rely on storage capacity and high salt content (e.g. samphires).
Intertidal	Environment between the high and low levels of spring tides.
Mangrove	A plant that grows in sediments regularly inundated by seawater.
Nitrogen fixation	The conversion of atmospheric nitrogen into organic nitrogen compounds. This enriches the soil and is carried out by certain bacteria and blue-green algae.
Supratidal	Areas located above the influence of tides.
Terriginous	Refers to sediments derived from the land.

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Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 27 February 2010.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between June and September 2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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A

Appendix A Mangrove Structure Data

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Mangrove Structure Data From Closed Canopy Mangrove Associations (Am2)

Date	Easting	Northing	Site 1: Hooley Ck East - Lower Reaches - Closed Canopy Mangroves
21/01/2010	295896	7600294	
Time			
1230hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	3.2	2.7	2	20	57	90	52									4
2	Ceriops	0.7	0.8	0.4	28	27											4
3	Ceriops	1.3	0.6	0.6	16												4
4	Avicennia	3.3	3.4	2.2	56	53	80	72									4
5	Ceriops	1.8	0.6	1	23	11											4
6	Avicennia	3.1	2.6	1.4	44	53											4
7	Avicennia	3.4	1.1	1.2	50												4
8	Avicennia	3.4	2.5	1.1	71												4
9	Avicennia	3.8	2.2	3.7	80	62	49										4
10	Ceriops	1.7	1.5	1	43	19	21	19	21	33							4
11	Ceriops	1.9	0.7	0.9	28												4
12	Ceriops	1.1	0.6	0.5	24												4
13	Avicennia	3.8	2.2	1	59												3
14	Avicennia	3.3	2.4	2.4	24	90	92										3
15	Avicennia	3.4	2.1	2.1	72												4
16	Avicennia	3.7	1.7	1.4	53												4

Date	Easting	Northing	Site 3: Hooley Ck West - Mid Reaches - Closed Canopy Mangroves
23/01/2010	294826	7599945	
Time			
0745hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	1	0.5	0.4	23												4
2	Avicennia	1	1.6	0.4	29	35	22	27									4
3	Avicennia	0.7	0.8	0.7	19												4
4	Avicennia	1.4	0.7	0.8	32												3
5	Avicennia	1.3	1.5	0.8	30	25	32										4
6	Avicennia	2.7	3.1	3.1	66	74	35	62									4
7	Avicennia	1.2	0.5	0.2	37												4
8	Avicennia	1.4	0.9	0.6	33												4
9	Avicennia	2.5	5	5	25	71	93	94	61	65	21	51	57	93	50		4
9 (contd)					54	31	29	23	54	87	89						4
10	Avicennia	2	0.9	0.7	21	17	25	54									4
11	Avicennia	0.9	1.2	0.5	34												4
12	Avicennia	1.5	2.2	1.4	57												4
13	Avicennia	1.2	1.2	0.9	36												4

Date	Easting	Northing	Site 6: Hooley Ck East - Mid Reaches - Closed Canopy Mangroves
23/01/2010	295588	7599894	
Time			
1030hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	2.7	0.9	0.5	25												4
2	Avicennia	2.8	2	1.2	60												4
3	Avicennia	2.8	2.3	2.2	193												4
4	Avicennia	2.3	2.2	1.2	57												4
5	Avicennia	2.9	3.2	2.8	65	49	80	30	37	44	49						4
6	Avicennia	1.8	2	1.5	41	39											4
7	Avicennia	2	0.9	0.9	43												1
8	Avicennia	2.2	1.7	0.8	50												4
9	Avicennia	3.2	2.1	2.7	101	52											4
10	Avicennia	3.4	2.8	2.5	79	109	66	111	105	32	14	35	19	52	59		3
11	Avicennia	1.2	1.2	0.8	31	35											4

Date	Easting	Northing	Site 8: Hooley Ck West - Lower Reaches - Closed Canopy Shrubland Mangroves
23/01/2010	295367	7600409	
Time			
1230hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	2.5	2.6	1.1	54	52	49										4
2	Ceriops	2	1.1	1	18	70	27										4
3	Avicennia	4	3.4	2.6	151	71	71	119									4
4	Avicennia	3.8	4	1.8	193												4
5	Avicennia	3	4	1.3	62	29	42	122									4
6	Ceriops	2.6	1	1	13	23	54	30	15								3
7	Avicennia	3.7	3.6	2.4	137	115	199	120	115	122							4
8	Ceriops	2.1	1.2	1.2	50	25	54	23	21								4
9	Ceriops	1.5	0.7	0.5	21	20											4
10	Avicennia	1.6	1.1	1	42	15	12	45									4
11	Avicennia	2.2	1.4	1.1	61	33	127										4

Date	Easting	Northing	Site 10: Hooley Ck West - Lower Reaches - Closed Canopy Shrubland Mangroves
23/01/2010	295337	7600335	
Time			
1400hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	3.2	7	7	54	50	109	90	61	60	31	69	45	24	37		
					20	139	93	121	84	54	20	45	113				4

Date	Easting	Northing	Site 11: Hooley Ck East - Mid to Upper Reaches - Closed Canopy Mangroves
23/01/2010	295812	7599786	
Time			
1425hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	3.3	7	4	87	100	54	163	142	49	112	55	120	110			4
2	Avicennia	2.4	1	1.8	42	51											4
3	Avicennia	2.6	1.9	1.3	50	15	17										4
4	Avicennia	2.6	1.5	1.5	35	49	49										4

Date	Easting	Northing	Site 14: Middle Creek - West Branch - Closed Canopy Mangroves
21/05/2010	296774	7599902	
Time			
1017hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	3.3	5	5.5	81	97	42	101	52	26	78	81	107	84	96	92	4
1 (contd)					99	86											
2	Avicennia	1.1	0.5	0.6	17												4
3	Avicennia	1.1	0.5	0.3	15												4
4	Avicennia	1.2	0.4	0.3	14												4

Date	Easting	Northing	Site 16: Middle Creek - Central Section - Closed Canopy Mangroves
21/05/2010	296774	7599902	
Time			
0950hrs			

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	2.9	3.9	3.1	44	151	101	72	27	22							4
2	Avicennia	3.3	3.6	3.9	61	33	40	32	55	104	34	41	63				4
3	Avicennia	3.3	4	3.4	107	41	40	36	24	78	63						4

Date 21/05/2010 **Easting** 297318 **Northing** 7600051 **Site 18: Middle Creek - East Branch - Closed Canopy Mangroves**

Time 1115hrs

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	2.7	1.4	1.8	80												2
2	Avicennia	3.3	4.2	3.5	41	92	101										4
3	Avicennia	3.4	4.2	3.2	64	89	109										4
4	Avicennia	1.9	1.5	1.4	92	21	18										3
5	Avicennia	2.9	1.1	1.3	82												4
6	Avicennia	3.3	3.5	3.2	77	39	104										4
7	Rhizophora	2.2	1.1	0.9	34												3
8	Rhizophora	1.9	1.1	0.9	34												3

Mangrove Structure Data From Open Shrubland Mangrove Associations (Am3)

Date 21/01/2010 **Time** 1330hrs | **Easting** 295910 | **Northing** 7600267 | **Site 2: Hooley Ck East - Lower Reaches - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	2	4	4	30	40	59	37	44	46	30	59	46	25	31	46	4
					50	18	18	48	43	52	46	45	83	31			

Date 23/01/2010 **Time** 0900hrs | **Easting** 294829 | **Northing** 7599974 | **Site 4: Hooley Ck West - Mid Reaches - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	1.1	1.9	1.4	34	30	50	22	33	35	20						4
2	Avicennia	0.6	1.2	1.1	33	22	22										3
3	Avicennia	1.2	2.6	2.2	24	49	34	31	24	54	34	69	25	31	20		3
4	Avicennia	0.8	1.1	0.5	22	17	23										4
5	Avicennia	0.8	1.5	1.1	54	31	18	18									4
6	Avicennia	1.2	2	1.5	50	40	29	32	24	25							4

Date 23/01/2010 **Time** 0930hrs | **Easting** 295206 | **Northing** 7600293 | **Site 5: Hooley Ck West - Lower Reaches - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Ceriops	0.9	0.5	0.6	33												3
2	Avicennia	0.9	2	1	22	19	23	13									4
3	Avicennia	1.3	2.2	2.1	31	29	32	33	27	45	32						4
4	Avicennia	1.1	1	0.7	11	19											4
5	Avicennia	1.4	1.6	1.8	31	14	44	41	24	29							4

Date 23/01/2010 **Time** 1115hrs | **Easting** 295573 | **Northing** 7599902 | **Site 7: Hooley Ck East - Mid Reaches - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Ceriops	1.5	1.5	1.1	173												4
2	Avicennia	0.7	0.7	0.7	18	14											4
3	Avicennia	0.7	0.7	0.6	30												4

Date 23/01/2010 **Time** 1330hrs | **Easting** 295262 | **Northing** 7600290 | **Site 9: Hooley Ck West - Lower Reaches - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	1	1.2	0.8	20	32	16	51									3
2	Avicennia	1.1	1.3	1.1	31	30	23	17	14	15							4
3	Avicennia	1.2	1.4	1.1	55	43											4
4	Avicennia	0.9	0.9	0.5	14	21	10										4
5	Avicennia	1.3	1.8	1.4	50	27	50	11	33	35	72	69					4
6	Avicennia	1	1	0.9	32	21	16	13									4
7	Avicennia	0.8	0.9	0.7	23	19											4

Date 23/01/2010 **Time** 1500hrs | **Easting** 295859 | **Northing** 7599764 | **Site 12: Hooley Ck East - Mid to Upper Reaches - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	1.5	2	1.8	49	62	61	21	23	15	20	21	40	61	40	62	
1 (contd)					30	28	25	34									3
2	Avicennia	1.1	1.3	0.9	42	15	40	42	27								4
3	Avicennia	1.2	1.1	1	50	30	21	26	21	14	15	17					4

4	Avicennia	1.3	2	1.9	60	19	27	41	14	34	14	15	32	51	42	40	
4 (contd)					41												4

Date 22/05/2010 **Time** 0815hrs | **Easting** 293852 | **Northing** 7599328 | **Site 13: Hooley Ck West - Upper Reaches - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	1.8	3.1	3.6	72	52	31	87									4
2	Avicennia	1.1	2.7	2.6	61	42	51	30	33	52							4
3	Avicennia	1.1	1.9	1.2	51	38											4
4	Avicennia	1.1	1.9	2.5	49	42	35	31									4

Date 21/05/2010 **Time** 1035hrs | **Easting** 296703 | **Northing** 7599772 | **Site 15: Middle Creek - West Branch - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	1.3	1.1	0.7	23	9	12	22									4
2	Avicennia	0.8	0.4	0.2	14												4
3	Avicennia	0.6	0.5	0.3	21												4
4	Avicennia	1.5	2.9	2.9	11	69	51	45	16	52	47						4
5	Avicennia	1.4	2.4	2.5	32	57	51										4
6	Avicennia	0.8	0.9	0.5	31												4
7	Avicennia	0.9	0.7	0.6	25												4
8	Avicennia	1	1.1	0.8	12	13	12	18									4
9	Avicennia	1.2	1	0.6	41												4

Date 21/05/2010 **Time** 0925hrs | **Easting** 297063 | **Northing** 7599980 | **Site 17: Middle Creek - Central Section - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	0.9	1.3	0.9	27	17	31	18	17	22							4
2	Avicennia	1.7	2.6	3.3	48	37	31	43	41	32	20	15	13	12	13		4
3	Avicennia	1.9	3.1	2.8	27	57	51	24	58	27	28						4
4	Avicennia	1.3	2.2	2.4	20	19	15	63	31	41	42	48	32				4
5	Avicennia	0.8	0.7	0.6	16	12	8	7	11								4
6	Avicennia	0.9	1.5	1.2	18	28	21	9	22	18	20	15	31				4
7	Avicennia	1	1.3	1.1	31	18	11										3

Date 21/05/2010 **Time** 1141hrs | **Easting** 297531 | **Northing** 7600012 | **Site 19: Middle Creek - East Branch - Open Shrubland Mangroves**

Tree Number	Species	Tree Height (m)	Breadth (m)	Width (m)	Stem Diameter (mm)												Defoliation
1	Avicennia	0.7	0.9	0.7	25												4
2	Avicennia	0.9	0.8	0.9	32												4
3	Avicennia	0.5	0.7	0.7	10	23											4
4	Avicennia	0.8	0.8	0.7	21												4
5	Avicennia	0.6	1	1	29												4
6	Avicennia	0.8	1	0.8	27												4
7	Avicennia	0.6	0.5	0.4	19												4
8	Avicennia	0.9	1.4	1.5	58												4
9	Avicennia	0.8	0.7	0.6	27												4
10	Avicennia	0.5	0.8	0.6	68												4
11	Avicennia	0.7	0.8	0.5	31												4
12	Avicennia	0.5	0.5	0.3	17												4
13	Avicennia	1.5	1.9	1.4	59												4

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B

Appendix B Algal mat samples - data from sample analysis (MAFRL)

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Marine and Freshwater Research Laboratory
Environmental Science

Telephone: (08) 9360 2907 Facsimile: (08) 9360 6613

Accreditation Number: 10603
This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025.

MURDOCH UNIVERSITY
PERTH, WESTERN AUSTRALIA

SEDIMENT DATA

Contact: Anthony Bougher
Customer: URS Australia
Address: Level 3, 20 Terrace Rd, East Perth WA 6004

Date of Issue: 9/08/2010
Date Received: 5/07/2010
Our Reference:URS10-6
Your Reference: 42907466

METHOD SAMPLE CODE	Sampling Date	TOTAL Dry Weight (g)	5400 % LOSS ON IGNITION AT 550°C
Reporting Limit			
File		100720	100728
22.1	20/05/2010	40.6	18.1
22.2	20/05/2010	33.5	21.6
22.3	20/05/2010	35.7	19.4
22.4	20/05/2010	27.8	22.3
22.5	20/05/2010	34.8	18.3
23.1	20/05/2010	14.6	23.8
23.2	20/05/2010	15.4	27.5
23.3	20/05/2010	39.4	17.0
23.4	20/05/2010	51.4	17.5
23.5	20/05/2010	26.7	19.2
24.1	20/05/2010	50.7	15.9
24.2	20/05/2010	34.9	19.8
24.3	20/05/2010	40.6	20.7
24.4	20/05/2010	22.7	21.3
24.5	20/05/2010	22.8	17.7
25.1	20/05/2010	78.4	10.0
25.2	20/05/2010	110	8.2
25.3	20/05/2010	120	7.6
25.4	20/05/2010	70.9	9.1
25.5	20/05/2010	63.7	10.4

Signatory: [signature]
Date: 9/8/2010

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science

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SEDIMENT DATA

Contact: Anthony Bougher
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Date of Issue: 9/08/2010
Date Received: 5/07/2010
Our Reference:URS10-6
Your Reference: 42907466

METHOD SAMPLE CODE	Sampling Date	TOTAL Dry Weight (g)	5400 % LOSS ON IGNITION AT 550°C
Reporting Limit			
File		100720	100728
26.1	20/05/2010	120	8.1
26.2	20/05/2010	70.9	13.1
26.3	20/05/2010	52.8	12.2
26.4	20/05/2010	74.8	9.9
26.5	20/05/2010	103	10.2
27.1	20/05/2010	71.0	12.9
27.2	20/05/2010	78.2	10.4
27.3	20/05/2010	92.7	11.1
27.4	20/05/2010	109	11.3
27.5	20/05/2010	86.2	10.7
28.1	20/05/2010	48.8	16.8
28.2	20/05/2010	59.7	16.2
28.3	20/05/2010	62.8	15.2
28.4	20/05/2010	53.4	15.8
28.5	20/05/2010	47.5	17.0
29.1	20/05/2010	50.8	17.1
29.2	20/05/2010	66.2	14.9
29.3	20/05/2010	17.2	18.8
29.4	20/05/2010	58.8	15.4
29.5	20/05/2010	56.1	16.1

Signatory:
Date: 9/8/2010

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science

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METHOD SAMPLE CODE Reporting Limit	Sampling Date	TOTAL Dry Weight (g)	5400 % LOSS ON IGNITION AT 550°C
File		100720	100728
30.1	20/05/2010	52.8	14.7
30.2	20/05/2010	60.6	14.2
30.3	20/05/2010	73.9	10.5
30.4	20/05/2010	67.0	12.7
30.5	20/05/2010	50.8	12.6

Note: This testing is outside the scope of accreditation.

Signatory: [signature]
Date: 9/8/2010





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Appendix FC

Geological Heritage Features of the Onslow Embayment:
Coastal Landforms, Coral Reefs & Wrack Lines

This report has been provided as part of the supplementary information for the Final Response to Submissions on the Draft EIS/ERMP. Features of geological heritage are not protected under State or Commonwealth legislation. The aims of the field survey were to:

- Identify and describe localised geoheritage features within and immediately adjacent to the Wheatstone Project (the Project) area that are likely to be of national or higher geoheritage value, such as the old shoreline and fossil coral reef site found at Big Island near Hooley Creek and the wrack line at Casugrina Point
- Describe areas where there is evidence of tsunami and storm surge inundation
- Estimate the potential geoheritage value of all sites examined
- Indicate areas of potentially high geoheritage value that may need preservation.

A total of 29 sites were surveyed and described in notes and with photographs, with coral and shell samples collected for radiometric dating and collection of sediment cores, from a backflow delta within the Hooley Creek floodplain, for isotope analysis of the sedimentary layers. Rock types varied across the Project area. One complete sequence of an old shoreline and coral reef was surveyed (Big Island) and exhibited a rock platform supporting in-situ corals, a narrow beach ramp (overlain by colluvial boulders, eolianite outcrops and dune ridges), a low bluff (overlain by colluvial boulders, eolianite outcrops and dune ridges), and sandstone and weakly cemented eolianite, overlain by dune sands. It is possible that other similar features exist in the greater regional area. Two levels of inundation were represented by elevated wrack lines commonly found on the Ashburton River Delta. These may indicate that different processes affect extreme water levels in the region.

Coral samples taken from multiple features have been forwarded to the Australian National University for chronologic interpretation to confirm the estimated 120 000 years before present age. Shells taken from wrack lines at Casugrina Point and Urala Station (deposition age), as well as live shells taken from Second Creek (reservoir effects) have also been forwarded to the Australian Nuclear Science and Technology Organisation for analysis.

GEOHERITAGE FEATURES OF THE ONSLOW EMBAYMENT:
Coastal Landforms, Coral Reefs & Wrack Lines

Damara WA Pty Ltd
October 2010

Report 82-04-Rev 0

I.Eliot & J.Dodson

Document Control

Index	Author	Date	Review	Date	Comment
Draft A	I.Eliot	15.8.2010	J.Dodson	17.8.2010	Figures to come.
Draft B	I.Eliot	17.8.2010	J.Dodson	18.8.2010	
Draft C					
Rev A	I.Eliot	20.8.2010	M.Eliot	20.8.2010	Client Review.
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Investigation of coastal geoheritage features on the Onslow Coast required the assistance of several people in addition to the generous resource support from URS Australia Pty Ltd and Chevron Australia Pty Ltd. The authors are pleased to thank Damian Ogburn for his encouragement and direction; as well as Richard Morup and Brooke Hay for their unstinting assistance in the field. Report production was aided by some timely editing by Matt Eliot and GIS contributions by Simon Mouchemore.

At Onslow we were provided with access to areas of interest, advice concerning what we might observe and guidance in our travels. In approximate order of their involvement we are pleased to thank James Redmond for his liaison with the Traditional Owners as well as Glenys Hayes, Meecham Kelly, Delwyn and Marlon for direction on Thalanyji lands; Robert Lund and Wade Stevenson for introducing us to lands bordering the Onslow Salt Ponds and clarifying our thinking about some of the sites we had intended to visit; and Joe Armstrong for providing access to Urala Station and showing us the Two Wells.

Citation

Eliot I and Dodson J (2010). *Geoheritage Features of the Onslow Embayment: Coastal landforms, coral reefs and wrack lines*. Damara WA Pty Ltd, Innaloo, Western Australia.

Executive Summary

The aims of the field survey were to:

1. Identify and describe localised geoheritage features within and immediately adjacent to the Wheatstone Project (the Project) area that are likely to be of national or higher geoheritage value, such as the old shoreline and fossil coral reef site found at Big Island near Hooley Creek and the wrack line at Casugrina Point;
2. Describe areas where there is evidence of tsunami and storm surge inundation;
3. Estimate the potential geoheritage value of all sites examined; and
4. Indicate areas of potentially high geoheritage value that may need preservation.

Excluding return trips to Casugrina Point (Site 5) and the Backflow Delta (Sites 8 & 9), 29 sites were visited and descriptions of the sites recorded photographically and in notes. The results were collated and the sites classified according to their geologic and geomorphic features. The sites were then grouped according to criteria listed for geoheritage purposes by Brocx & Semeniuk (2010) and individually assigned a geoheritage value according to the number of categories represented at the site and the degree to which each might contribute to a scientific understanding of the geology or geomorphology of the wider region.

Outcomes relating to the principal aims of the field work, with particular reference to Aims 1 & 2, are as follows:

(1) In an upward sequence the old shoreline features and coral reef apparent on the NE shore of Big Island (Site 11) included:
- rock platform supporting in-situ corals
- a narrow beach ramp (overlain by colluvial boulders, eolianite outcrops and dune ridges);
- a low bluff (overlain by colluvial boulders, eolianite outcrops and dune ridges); and
- sandstone and weakly cemented eolianite, overlain by dune sands

(2) The full sequence of shoreline features on Big Island (Site 11) was not observed at any other site visited;

(3) A more limited sequence of beach ramp, rock platform and in-situ corals were observed at (Site 16) on the eastern margin of the Onslow Salt ponds but this had been disturbed by excavation. The find suggests that sites equivalent to that on Big Island may occur elsewhere in the region should a wider survey be conducted.

(4) Two levels of inundation are represented by elevated wrack lines commonly found on the Ashburton River Delta. These may indicate that different processes affect extreme water levels in the region: a two metre storm surge level and a seven metre tsunami level are postulated; and

(5) Wrack lines were present at seven metres above High Water Level (HWL) on Casugrina Point and along the southern shore of an extensive mudflat on Urala Station. The species assemblage in wrack at Casugrina Point differs from that at Urala site in that it includes a mixture of species from the inner continental shelf and is not dominated by large oysters.

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1. INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is seeking to develop coastal infrastructure at the Ashburton North Strategic Industrial Area (Ashburton North SIA) to support the development of offshore gas fields. The proposed site lies west of Onslow, near the eastern end of the low-lying Ashburton deltaic system. Geomorphic investigations undertaken by Damara WA Pty Ltd (Damara WA; 2010) as part of the Project's environmental assessment identified two features on the site with potential geoheritage value:

- A section of well preserved ancient shoreline, with radiometric dating indicating an age of 120,000 years Before Present (BP), corresponding to the last Interglacial period;
- Several high level wrack deposits, indicative of modern sea level fluctuations, believed to be generated by either cyclones or tsunami.

URS Australia Pty Ltd (URS), on behalf of Chevron, commissioned a survey to assess the potential geoheritage value of these sites and whether they were more widely distributed in the vicinity of the Ashburton River Delta. Potential sites were identified by interpretation of aerial photography and their potential geoheritage values established in the field survey. The field program, sites examined and their likely geoheritage values are described in this report.

2. AIMS

The aims of the field survey were to:

1. identify and describe localised geoheritage features within and immediately adjacent to the Project area that are likely to be of national or higher geoheritage value, such as the old shoreline and fossil coral reef site found near Hooley Creek and the wrack line at Casugrina Point;
2. estimate the potential geoheritage value of all sites examined;
3. describe areas where there is evidence of tsunami and storm surge inundation; and
4. indicate areas of high value that may need preservation.

2.1. RATIONALE

Geoheritage relates to geological and geomorphological areas or features with potential listing for conservation under land management decisions as set out in the Australian Natural Heritage Charter (Environment Australia 1997). A list of features from the Ashburton area, including some within the Project area, may be developed and required as part of the environmental review and management process implemented by the State Environmental Protection Authority (EPA). The process for geoheritage identification and registration is not well defined. The significance of the features relate to the degree to which the landforms: (a) collectively and individually provide essential life services; and/or (b) are recognised by experts within the geological disciplines for inclusion within the Register of the National Estate (Australian Heritage Commission 1990).

The following comments from Brocx (2008: 126-127) identify the broad geoheritage attributes of the Ashburton region:

- *The Pilbara coast in northwestern Australia is the most arid coast in Australia, and globally it is one of the few arid coasts that consists of wide riverine lowlands fronting Precambrian uplands in a non-tectonic setting (Semeniuk 1993).*
- *Semeniuk (1996) emphasized that the Pilbara Coast is special in comparison to other coasts in Australia and worldwide. This is because the Pilbara Coast portrays distinctive coastal forms, chemical products and stratigraphy, all of which reflect a Pleistocene to Holocene history of sedimentation, aridity, and frequent cyclonic storms. As a result, the coastal zone is distinguished by a range of features such as construction of arid-zone deltas, delta destruction and sediment redistribution during times of sediment depletion, cyclone-induced erosion and sedimentation, growth of mangroves and their associated deposits, evolution of coastal groundwater hypersalinity, and cementation to form beachrock, high-tidal crusts and gypsum precipitates, amongst others.*

In this context,

- *Semeniuk (1996) considers that the Pilbara Coast provides a globally important model or classroom, unparalleled elsewhere in the world, for the development of a range of megascale landforms through to microscale geomorphic, sedimentary and stratigraphic products that develop within a coastal alluvial plain in an arid climate, and also provides for the Earth Sciences an important and unique global model of arid zone coastal sedimentation, diagenesis, and stratigraphic evolution.*

While the wider investigation may not be relevant or necessary without an EPA request, the aims and objectives of the field work focus on specific sites and their potential geoheritage value. The fossil coral outcrops and shore platforms on Big Island identified by Damara WA (2010) are unusual features for their age and completeness of structure. However, the degree to which they are of geoheritage significance is a function of the geographic distribution of similar forms elsewhere in the region and remains open to question. Although Interglacial features have been described from the Ningaloo Coast (Stirling *et al.*, 1995, 1998), the assemblage of shorelines and islands along the Ashburton Coast are significantly different and will attract geoheritage interest. The question of whether there is a similar site outside the Project area is a matter investigated under the aims of the field program. However, Chevron may have other, more immediate interests in having the geoheritage work done.

2.2. FIELD PROGRAM – AUGUST 2010

The scope of the field survey was divided into two components including:

1. identification and assessment of existing major coastal impact features due to geologically recent storm surge and tsunami events; and
2. identification, description and assessment of geologically older geoheritage sites on the Project area and adjoining coastal areas of the Onslow Mudflats and Urala Station.

The field survey program is outlined in TABLE 1 and site locations are identified in Appendix A.

2.2.1. Component 1: Recent Geological Features

The work scope was designed to confirm identification of geologically recent major coastal impacts due to tsunami and storm surge in the vicinity of Casugrina Point (Site 5) as well as on an apparent backflow delta in a floodway palaeochannel within the Project area (Sites 8 & 9). The areas of interest were accessed by 4WD vehicle and are described below.

Assessment of the impacts have been based on site description and photography, sampling of shell from wrack line deposits in the foredunes at Casugrina Point, and shallow (hand) coring of sediments on the backflow delta. The shells recovered in this work will be used for radiometric dating of material from the foredunes; and the shallow cores from the deltaic feature for isotopic analysis of sedimentary layers. Radiometric dating requires completion: hence the results of these analyses will be presented as an addendum to this report at a later date.

The activities for Component 1 include:

- GPS and photographic survey of the high level wrack (shell) line in the foredunes on the western part of the coastal dune ridge at Casugrina Point (Site 5) has been completed. Detailed contour information from LiDAR imagery was used to determine the frontal dune slope. The foredune and beach shape were identified to establish the height of the wrack line with reference to HWL; and
- Photographic survey, hand coring and shell sampling of a backflow delta (Sites 8 & 9) on the south eastern boundary of the Saddle Hill dune system.

2.2.2. Component 2: Older Geological Features

In-situ outcrops of fossil corals on rock platforms and former fringing reefs on islands of the mudflats within the Project area and sites of their possible distribution on the Onslow Mudflats in close proximity to the Project area have been examined. Assessment of these potential geoheritage sites included a photographic survey of rock platforms possibly adjoining islands on mudflats between Urala Station and along the northern shore of the Onslow Salt eastern salt ponds.

Results of the field survey outline the field program, describe sites surveyed and discuss the implications of island sites and their setting within the Onslow Interglacial embayment from a geological heritage perspective.

TABLE 1: FIELD PROGRAM

Day	August	Activity	No. Sites
Tuesday	3	am: Travel Perth to Onslow via Karratha pm: Planning session with Onslow Salt (Robert Lund & Wade Stevenson)	n/a
Wednesday	4	am: Site induction; Ian to Backflow Delta with James Redmond, Meecham Kelly and Delwyn John, Brooke & Richard to islands of Onslow Salt western salt ponds. pm: Casugrina Point and chenier (Eastern) delta	1 5
Thursday	5	am: Casugrina Point and Chenier delta pm: Backflow Delta & coring Ian & Brooke to Hooley Creek Islands on Argo	3 2 2
Friday	6	am: Onslow Salt – Eastern Ponds pm: Onslow Salt – Second Creek (Reservoir shell sample & high stand wrack line Sunset Beach (near Four Mile Beach Lookout)	5 2 1
Saturday	7	am: Urala Station pm: Urala Station & west bank of Ashburton River	7 3
Sunday	8	am: Travel – Return to Perth	n/a

Total sites visited: 29 (Excluding return trips to Casugrina Point & the Backflow Delta)

2.3. CATEGORIES OF GEOHERITAGE SITES

Geoheritage is appropriately considered at a range of scales. At the broadest scale the deltaic coast of the Ashburton River, between Locker Point and Coolgra Point combines the attributes of Types 6, 10 and 11 as defined by Brocx & Semeniuk (2010: 99-101). It comprises landforms constructed by sedimentary coastal processes that have been active during the Holocene although the Holocene component is surficial and commonly overlies platforms, ramps and pavements cut into Pleistocene sandstones and calcarenite. In places, it also includes sedimentary records from which sea level history, particularly indicators of the last Interglacial High-stand, can be deduced. These attributes, together with the climatic setting and oceanographic process peculiar to the region indicate the Ashburton Coast has high, international geoheritage values of the wider region, as has been recognised by Brocx (2008) and Brocx & Semeniuk (2010). However, the assessment reported below is based on an appraisal of local sites and is not a full geoheritage assessment. Following Brocx & Semeniuk (2010: 106), consideration of the site attributes facilitates comparison of sites within a consistent framework and provides an indication of the range of geoheritage values found in the area examined.

Four categories of geoheritage site recognised by Brocx & Semeniuk (2010: 83) are:

1. *Type examples, reference sites or locations for stratigraphy, fossils, soil reference profiles, mineral sites and geomorphic sites, including locations for teaching, research and reference;*
2. *Cultural sites where classic locations have been described;*
3. *Geohistorical sites where there are classic exposures in cliff and outcrops where the history of the Earth can be reconstructed, or the processes within the Earth in the past can be reconstructed; and*
4. *Modern, active landscapes where dynamic processes are operating.*

The categories provide a convenient first order classification of sites examined on the dunes and coastal lowlands of the Ashburton River Delta.

The potential geoheritage values of each site were identified according to whether the site was of international, national, regional, local or low significance. Ranging from highest to lowest geoheritage value, this was done according to the number of categories which were represented at the site and the degree to which each site may contribute to a scientific understanding of the geology or geomorphology of the wider region. The procedure is loosely based on that described by Brocx & Semeniuk (2007). Herein the term '*low significance*' refers to a feature that is common within the Pilbara Region or more generally; whereas 'national or higher significance' refers to one that previously has not been described in the scientific literature and/or adds to a national or global understanding of the geological history of the Earth. Key features of the sites visited as part of the field project are described in Section 3 (TABLE 2). The geoheritage categories and potential geoheritage values are listed in Section 4 (TABLE 3).

3. SITES VISITED: LOCATION, KEY FEATURES AND GENERAL SETTING

TABLE 2: SITES VISITED IN DAILY SURVEYS

No.	DAY	SITE & LOCATION	KEY FEATURES	GENERAL SETTING
	WED 4	**ONSLOW SALT – WESTERN PONDS**		
1		Horseshoe Island (Sites originally nominated)	The original sites selected for examination on Horseshoe Island comprised disturbed areas of dune sand which graded to salt and mudflat. They were of no significance as local geoheritage sites. The original locations were shown as: (1) 0298077 E & 7597339 N (2) 0297311 E & 7595715 N	
2		Horseshoe Island (West) 0296294 E 7595798 N	The Western Arm of Horseshoe Island includes a low level wrack line with shell and coral approximately 2m above HWL. A number of cultural heritage items were also apparent.	

3		Horseshoe Island (East) 0298039 E 7596909 N	Banks of coral, mainly fragmentary but with some that appears to be in-situ are located on Horseshoe Island (East) near the salt ponds. The corals are mixed with fragments of eolianite. The coral on this site is not as extensive or as well preserved as that on Big Island.	
4		Little Island N of Horseshoe 0297505 E 7598621 N	The site visited was disturbed by construction work and was inconsequential for geoheritage purposes.	
	THU 5	**CASUGRINA POINT**		
5		Casugrina Point (M1) 0292728 E 7600881 N	View N from the crest of the coastal dune, down the eroded face of the dunes across a foredune to the coastal lagoon and spit. High wrack lines with shelly deposits are close to the crest, at approximately 7m above HWL.	

6		Richard's Rock 0291928 E 7600641 N	A low cliff (1m) and pavement was apparent in sandstone beach rock on the west facing side of the dunes along the Project area. Coastal dunes overlie the sandstone.	
7		Chenier Delta (3P) 0291334 E 7600438 N	This point on the eastern, chenier delta of the Ashburton River was examined for evidence of the calcarenite pavement, common in the area. The pavement was not discernable but may have been covered with silty sand to an elevation of approximately 3m above HWL. There was evidence of tidal creek incursion which would occur in response to low recurrence fluctuations in sea level.	
		BACKFLOW DELTA		
8		SW Flood delta 0291906 E 7595184 N	View SW along the Backflow Delta towards its flood tide component. The water body is at the SW limit of the gorge. An undisturbed sediment sequence on the flood tide delta was of interest.	

9		NE Ebb delta 0292639 E 7595733 N	View NE from the end of the tidal gorge across the ebb tide delta. A potentially undisturbed sediment sequence was of interest.	
		HOOLEY ISLANDS		
10		Little Island (4S, 8-5) 0294430 E 7599058 N	Cliff and ramp grades to mudflat on the NE flank of Little Island. It was anticipated that this may have similar features to those on Saddle Hill Big Island.	

11		Big Island (Saddle Hill Island) (5P; 8-6) 0294601 E 7598274 N	This is the **main area of geoheritage interest** because it includes a full coastal sequence comprised of a cliff, ramp, rock platform and in-situ corals. The corals have previously been dated at approximately 120,000 years BP.	
	FRI 6	**ONSLOW SALT – EASTERN POND**		
12		Onslow Town Quarry 0306381 E 7604816 N	The photograph shows the sandstone face in the Department of Transport Quarry at Onslow. The sandstone is described as the Tantabiddy Member of the Bundera Calcarenite, a Pleistocene sedimentary rock. It sits on an older calcarenite pavement. Such pavements are common throughout the region.	

13		Mouth of Second Creek 0310013 E 7607248 N	Photograph shows a view N to the mouth of Second Creek. An extensive low wrack line at approximately 2m above HWL, and corresponding with the top of the mangroves occurs in the lower reaches of the creek. The wrack line includes woody debris as well as a variety of shell species. A sample of recently living *Anadara* spp was obtained from the beach at the mouth of the creek to provide an updated estimate of the carbon reservoir effect for dating purposes.	
14		Salt Pond Site 2 0312112 E 7605580 N	Limestone quarry in Lower to Middle Miocene Limestone of the Cape Range Group. Here the limestone basement is well above HWL and underlies sand dunes.	
15		Salt Pond Site 5 0316680 E 7609098 N	A low cliff has been eroded in the Pindan dune soils adjoining salt and mud flats at Site 5.	

16		Salt Pond Site 7 0319744 E 7608643 N	An extensive pavement abuts the shore on the NE side of the small island at Site 7. Shell and corals are embedded in the pavement.	
17		Salt Pond Site 8 0319683 E 7607001 N	Localised erosion has cut a small cliff in the dune sands at the end of a constructed causeway near site 8.	
18		**SUNSET BEACH** 299477 E 7601929N	A high wrack line approximately 7m above the HWL is located along the steep face of the dune near the Lookout at Sunset Beach. The westerly view shows the steep face of the hind dune fronted by a low terrace and foredune to seaward.	

	SAT 7	URALA STATION		
19		Two wells (Soaks) 0273392 E 7589958 N	Two wells on Urala Station mark an old shoreline at approximately 2m above HWL. The landward shore shown here is comprised of coarse gravels and shell mixed with sand. At the second well also in sand was comprised of finer gravels and shell.	
20		Urala Key Site 1 (1P) 0280154 E 7590563 N	The view south from the lower slope to the dune crest shows a sandstone cliff & ramp overtopped by desert dune. A wrack line is located on the lagoonal floodplain below the ramp at an elevation approximately 7m above HWL.	
21		Urala Site A 0280514 E 7590716 N	The view W along the ramp is a continuation of Site 20, above. The area includes sandstone cliff & ramp but without overtopping by desert dune; The 7m wrack line is continuous along the southern side of the lagoon.	

22		Urala Key Site 2 (2S) Site A –Quarry 0281105 E 7590913 N	The view S shows a sandstone ridge abutted by beachrock below. It indicates an old shoreline. The 7m wrack line is continuous along the southern side of the lagoon immediately S of the site.	
23		Urala Site B – Middens 0281698 E 7591133 N	Middens in the dunes skirting the cliff line are linked to the lagoon shore indicated by the wrack line at approximately 7m above HWL. The middens are located the lower part of the rise to the ramp and cliff. The 7m wrack line is continuous along the southern side of the lagoon immediately S of the site.	

24		Urala Site C – Quarry 0282103 E 7591338 N	The cliff and ramp formations continue along the ridge. Here the ridge has not been overridden by longitudinal dunes. The difference between sites indicates an older Pleistocene or early Holocene age for the beach features comprising it, with the dunes overtopping them more recently in places. The view is to the south from the shore of the mudflat.	
25		Urala Key Site (3S) 0282597 E 7592310 N	The site is located at a change in the orientation of the dune ridge and shoreline from a NW to a WNW aspect and is an area of sediment accumulation from the lagoon and the Ashburton River. A sequence of beach ridges forms part of the Ashburton River Delta.	
26		Urala Site D – Middens 0283816 E 7592809 N	Cultural heritage features are apparent along the dune ridge and were linked to the lagoon shore as a source of food, mainly *Anadara* spp.	

27		Urala Site E – River Mouth 0284678 E 7597504 N	A wrack line is located at approximately 2m above the HWL along the western shore of the Ashburton River. The wrack line is composed of woody and shelly material.	
28		Urala Key Site 4 (4P) 0285265 E 7594289 N	Cultural heritage features were apparent high in the dune ridge, at the head of a gully debouching onto a fan low on the dune slope. *Anadara* spp shells in the midden indicate a link between the site and the lagoon in the coastal plain to the north at a time there was water in the lagoon.	
29		Urala Rocky outcrop near 4P 0286279 E 7593591 N	Site 29 is on a NNE facing arm of the dune ridge, where it parallels palaeo channels of the Ashburton River. The core of the dune ridge is apparent as a sandstone cliff and colluvial ramp. It is capped by the dune sands.	

4. POTENTIAL GEOHERITAGE SIGNIFICANCE OF THE SITES VISITED

The potential geoheritage significance of each of the sites visited is listed in Table 3. Significance was determined by examining the features at each site, assigning the site to one of the geoheritage categories described by Brocx & Semeniuk (2010) and determining the level of potential significance on a nominal scale.

TABLE 3: INTERPRETATION OF POTENTIAL GEOHERITAGE SIGNIFICANCE OF SITES

	SITE	GEOHERITAGE CATEGORY (After Brocx & Semeniuk, 2010: 83)	POTENTIAL SIGNIFICANCE	FEATURES
	ONSLOW SALT – WESTERN PONDS			
1	Horseshoe Island (original)	Disturbed sites on modern, active landscapes where dynamic processes are operating.	Low significance	

2	Horseshoe Island (West)	Modern, active landscapes where dynamic processes are operating.	Local Significance	
3	Horseshoe Island (East)	Modern, active landscape where dynamic processes are operating.	Local Significance	
4	Little Island N of Horseshoe	Disturbed site on modern, active landscape where dynamic processes are operating.	Low Significance	No photograph

	CASUGRINA POINT			
5	Casugrina Point (M1)	1. Geohistorical site where the history of the Earth can be reconstructed 2. Modern, active landscapes where dynamic processes are operating.	**National Significance**	
6	Richard's Rock	Type example, location for stratigraphy, fossils	Local Significance	
7	Chenier Delta (3P)	Modern, active landscapes where dynamic processes are operating and indicate recent fluctuations in sea level	Regional Significance	

	BACKFLOW DELTA			
8	SW Flood delta	1. Geohistorical sites where the history of past processes can be reconstructed. 2. Modern, active landscapes where dynamic processes are operating	Regional Significance	
9	NE Ebb delta	1. Geohistorical sites where the history of past processes can be reconstructed. 2. Modern, active landscapes where dynamic processes are operating	Regional Significance	
	HOOLEY ISLANDS			
10	Little Island (4S, 8-5)	Modern, active landscapes where dynamic processes are operating	Local Significance	

11	Big Island (Saddle Hill Island) (5P; 8-6)	1. Type examples, location for stratigraphy, fossils, and geomorphology, including location for teaching, research and reference. 2. Geohistorical site where there is classic exposure in cliff and outcrops where the history of the Earth can be reconstructed. 3. Modern, active landscape where dynamic processes are operating.	**National or higher significance**	
	ONSLOW SALT – EASTERN POND			
12	Onslow Town Quarry	Type example location for stratigraphy and fossils, including location for teaching, research and reference.	Local Significance	
13	Mouth of Second Creek	Modern, active landscape where dynamic processes are operating.	Local Significance	

14	Salt Pond Site 2	Type example location for stratigraphy and fossils.	Regional Significance	
15	Salt Pond Site 5	Modern, active landscape where dynamic processes are operating.	Local Significance	
16	Pond Site 7	1. Type example location for stratigraphy and fossils 2. Modern, active landscape where dynamic processes are operating.	Regional Significance	

17	Pond Site 8	Modern, active landscape where dynamic processes are operating.	Low significance	
18	**SUNSET BEACH**	Modern, active landscape where dynamic processes are operating. Extends understanding of the distribution of high level wrack deposits and changes to the shoreline following this depositional event.	Regional Significance	

	URALA STATION			
19	Two wells (Soaks)	Type example location for stratigraphy and fossils	Regional Significance	
20	Urala Key Site 1 (1P)	1. Type example location for stratigraphy and fossils 2. Geohistorical sites where the history of past processes can be reconstructed. 3. Modern, active landscape where dynamic processes are operating.	Regional & Higher Significance	
21	Urala Key Site 2 (2S)	1. Type example location for stratigraphy and fossils 2. Geohistorical sites where the history of past processes can be reconstructed. 3. Modern, active landscape where dynamic processes are operating.	Regional & Higher Significance	

22	Urala Site A –Quarry	1. Type example location for stratigraphy and fossils 2. Geohistorical site where the history of past processes can be reconstructed. 3. Modern, active landscape where dynamic processes are operating.	Regional Significance	
23	Urala Site B – Middens	Modern, active landscape where dynamic processes are operating. Heritage indicates changes in coastal resource availability.	Regional Significance	
24	Urala Site C - Quarry	1. Type example location for commonly occurring stratigraphy and fossils 2. Geohistorical site where the history of past processes can be reconstructed.	Local Significance	

25	Urala Key Site (3S)	Modern, active landscape where dynamic processes are operating, particularly closure of the coastal lagoon and development of the mudflats since deposition of high level wrack deposits.	Regional Significance.	
26	Urala Site D - Middens	Modern, active landscape where dynamic processes are operating. Heritage indicates changes in coastal resource availability.	Regional Significance	

27	Urala Site E – River Mouth	Modern, active landscape where dynamic processes are operating.	Local & Regional Significance	
28	Urala Key Site 4 (4P)	Modern, active landscape where dynamic processes are operating, particularly closure of the coastal lagoon and development of the mudflats since deposition of high level wrack deposits.	Regional Significance	

29	Urala Rocky outcrop near 4P	Modern, active landscape where dynamic processes are operating.	Local Significance	

5. TYPE OF SITE

Four sets of geologic and geomorphic features were the focus of the field survey (TABLE 4). Two included sites associated with rock platforms and pavements likely to be linked to abandoned shores and potential coral reef systems as indicated by in-situ coral assemblages.

The major coastal impact features due to geologically-recent storm surge and tsunami events were wrack lines deposited above HWL. Additionally, a number of cultural heritage sites likely to be associated with the high-level wrack line and an abandoned lagoon shore immediately north of the dune ridge on Urala Station were observed and their positions along the dune ridge on Urala Station noted.

Quarry sites were also visited to determine any evidence of old shoreline deposits and to increase knowledge of the geology of the area.

Only sites that could be accessed by vehicle or walking on the Project area and adjoining coastal areas of the Onslow Mudflats and Urala Station were examined for their geoheritage potential.

TABLE 4: TYPES OF SITE

Features	Site Number
Old shores (Rocky cliff, ramp, beach & pavement)	3, 6, 10, 11, 16, 19, 20, 21, 25
In-situ corals	3, 11
Coastal inundation (wrack lines, back-flow delta)	2, 7, 8 , 9, 13, 18, 20, 21, 27
Cultural sites linked to old shorelines	23, 26, 28
Quarries & rock outcrops	12, 14, 22, 24, 29
Miscellaneous (dunes, sand cliffs, disturbed sites)	1, 4, 7, 15, 18

5.1. OLD SHORES AND ROCK PAVEMENTS

Fossil shores are common features in the region, either as sandy beaches now well away from oceanic or lagoonal coast or features cut in coastal sandstone. At least two large dune ridges abut abandoned shorelines: the western flank of the Saddle Hill dune ridge running south west from Casugrina Point in the Project area; and the Pleistocene dune ridge abutting the mudflats southeast of Rocky Point on Urala Station. Both dune fields overlie sandstone and calcarenite, including beachrock formations, which outcrop in places where the dunes have been eroded by shore processes.

There are also a variety of rock pavements in the region. These have not been examined in detail but would provide evidence of landscape evolution.

5.2. OLD SHORELINES AND REEF SYSTEMS

The shoreline and reef features of Site 11 on Big Island, Saddle Hill are unique amongst those examined and the site has at least National geoheritage value. In an upward sequence the old shoreline features and coral reef apparent on the NE shore of Big Island included:

- A Pleistocene rock platform supporting 120,000 year-old in-situ corals
- a narrow beach ramp (overlain by colluvial boulders, eolianite outcrops and dune ridges);
- a low bluff (overlain by colluvial boulders, eolianite outcrops and dune ridges); and
- sandstone and weakly cemented eolianite, overlain by dune sands

Although not fully investigated, it is likely that the alignment of the dune ridges and the dune stratigraphy will provide further information on the geological history of the site and hence has potential to add to its substantial geoheritage significance.

The coral beds and ancient shoreline on Saddle Hill, Big Island (FIGURE 1) are a very well preserved example of what is otherwise poorly represented part of Australia's geological heritage. Other locations with features related to the 120,000 year BP sea level are known to exist in Western Australia (Stirling *et al*. 1995, 1998) but initial inspection suggests the features on Big Island are highly significant for their combination of coral reef on pre-existing rocky shoreline features.

The full sequence was not observed at any other sites visited a more limited sequence of beach ramp, rock platform and in-situ corals was observed at (Site 16) on the eastern margin of the Onslow Salt ponds. Unfortunately, this had been disturbed by excavation.

The find suggests that sites equivalent to that on Big Island may occur elsewhere in the region should a wider survey be conducted. The local geology and landforms indicate there may be similar sites on other mudflat islands that are extremely difficult to access. There also is potential for other components of the ancient shorelines to be found along the outer edge of the mudflats. The level of preservation as well as the extent and diversity of geological and geomorphic features would determine the geoheritage value of any other site identified.

FIGURE 1: SADDLE HILL, BIG ISLAND

5.3. WRACK LINES

Fluctuations in water along the coast, in the lower reaches of tidal creeks and along the shores of estuaries and coastal lagoons are marked by wrack lines, or debris lines. These linear features commonly mark the upper reach of water level and wave action on a beach and are left at an elevated water level in sheltered environments inundated by storm surge or river flooding. Two types of marine wrack line are observable in the Ashburton region. The first is a low-level line of debris that includes a mixture of shell species as well as a variety of debris of marine and terrestrial origin (FIGURE 2a). Such wrack lines occur at a height of approximately two metres above HWL. They are observable near the mouths of tidal creeks and may be linked to storm surge associated with Tropical Cyclones Vance (March 1999), Dominic (January 2009) or older cyclones. They are significant indicators of recent inundation levels likely to affect the Project area.

The second wrack line is mainly oyster shell in a discrete band along the shores of mudflats and the open coast, although other shell may be present in small quantities (FIGURE 2b). The secondary species includes *Anadara* spp. suitable for radiometric dating. The oyster wrack lines are high, commonly close to seven metres and higher above HWL on coastal dunes and along landforms bordering mudflat basins (coastal lagoons). Two high-level wrack lines have been described from Casugrina Point, and further sampling of shell material from that site has been carried out to confirm its radiometric age, estimated to be approximately 700 years BP.

(a) Low level wrack line comprised of woody debris as well as shell near the mouth of Second Creek

(b) High level wrack line comprised of mainly of oyster shell near Site 21 on Urala Station

FIGURE 2: WRACK LINES IN THE ASHBURTON RIVER REGION

5.4. CULTURAL HERITAGE SITES LINKED TO THE URALA LAGOON

The significance of the cultural sites is that they indicate use of natural resources at a time when the mudflat was a coastal lagoon and open to the sea. *Anadara* spp were apparently taken from the lagoon and transported to areas just below the crest of the dune ridge, the flesh consumed and the shells discarded in mounds which now form the middens. During the field survey, *Anadara* spp were taken from the wrack line at approximately seven metres above HWL, while the middens are higher on the dune ridge at approximately 15 metres. No shell samples were taken from the middens although it would be useful to date shell material from them in order to establish temporal links between the shellfish harvesting and the high water event or events.

5.5. THE BACKFLOW DELTA

Overflow water from marine inundation and river flooding potentially is delivered separately to a small palaeochannel basin (FIGURE 3). The basin is offset from and slightly higher than the main mudflat south of Hooley Creek so that water has to push upslope to enter the basin. Temporal variation in flow into and out of the basin has resulted in formation of a backflow delta with geomorphic components similar to those of a tidal delta at the mouth of a coastal lagoon. The channel or gorge leading from the main mudflat into the basin separates distinct ebb and flood tide deltaic forms. Although they may be part of a palaeochannel, the gorge and basin are enclosed by low dunes. These indicate the basin may not be overwhelmed by river floods except under extreme river floods and storm surge events.

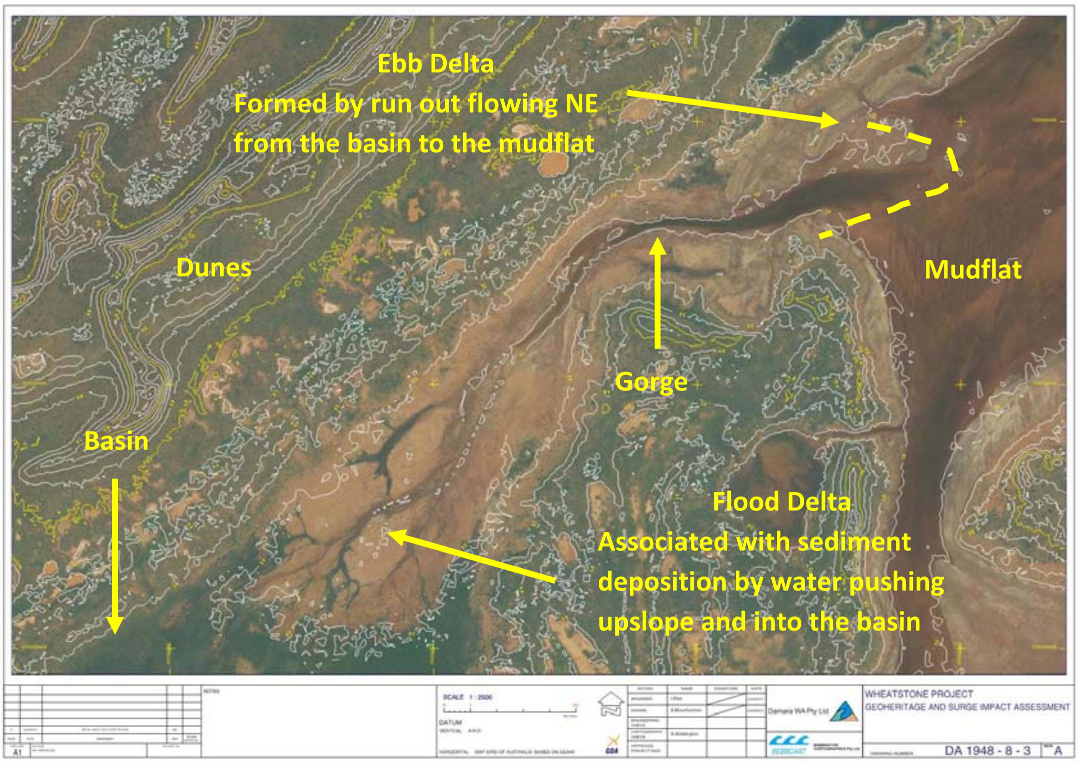

FIGURE 3: COMPONENTS OF THE BACKFLOW DELTA

It was anticipated the different inundation regimes will leave a stratigraphic imprint either as layers of different sediment and/or isotopic signals. Hence shallow cores approximately one metre deep were extracted; two from the flood delta and one from the ebb delta component. The cores have been submitted to the Australian Nuclear Science and Technology Organisation (ANSTO) for determination of the isotopic profile and radiometric dating of its age structure.

6. GEOCHRONOLOGY & OTHER LABORATORY ANALYSES

Ten shell samples have been submitted to ANSTO for radiocarbon dating to establish the ages of the wrack lines and their possible relationships, as well as to determine reservoir effects for calibration purposes. The shell samples have been listed for priority treatment and results from the analyses are anticipated to be available in approximately six weeks.

The three cores taken from the back-flow delta also have been delivered to ANSTO for potential isotopic determination of major marine inundation and river flooding events. It is anticipated this phase of the investigations will take approximately six weeks.

Four coral samples have been forwarded to Tezer Esat at the Australian National University for U-Th determination of their ages. It is anticipated the analysis will contribute to a closer definition of sea level in the region during the Last Interglacial Period, approximately 120,000 years BP.

All results from the laboratory investigations will be presented as addenda to this report as they become available.

7. SUMMARY

1. Rock types vary significantly across the area, with Miocene Limestone outcropping well above sea level on the north coast of the salt ponds. Outcrops of weakly lithified Pleistocene sandstone and calcrete, as well as Holocene calcarenite were apparent at Onslow and as islands and rocky pavements in the mudflats of the Project area. More strongly lithified and apparently older Pleistocene sandstones underpinned the dune ridge and old shoreline on Urala Station. Rock pavement was commonly tied to the sandstone islands, outcropped close to the surface in parts of the mudflats and occasionally supported in-situ corals. The composition and stratigraphy of rock forming the pavements is diverse and suggests a range of origins that have not been investigated.

2. The Interglacial shoreline and coral reef on Saddle Hill, Big Island (Site 11) in the Project area was the most complete site of its type of all sites visited. No other site had a full range of shoreline features together with an in-situ coral reef. Coral samples were taken from in-situ formations at Big Island, Horseshoe Island and a rock platform bordering the shore of the eastern salt ponds, at Site16. These samples have been forwarded to Tezer Esat at the Australian National University for chronologic interpretation to confirm the estimated 120,000 year BP age.

3. The full sequence of shoreline features on Big Island (Site 11) was not observed at any other site visited.

4. Identification and assessment of existing major coastal impact features due to geologically recent storm surge and tsunami events was undertaken at Second Creek, along the old shoreline on Urala Station and at Casugrina Point. The results indicated a variety of HWLs with the most common at approximately two metres and seven metres above HWL. The levels were determined by GPS and checked on the LiDAR derived topography.

5. An extensive wrack line comprised substantially of oyster shell was located parallel to the mudflat shore, at seven metres above HWL immediately north of the Urala dune shoreline and seaward of Sites 20 to 25. Cultural material in shell middens was distributed along the ridge in the dunes backing the shore. Shell material in the middens apparently came from the mudflat at the time it was connected to the sea and formed a coastal lagoon. Although it is outside the Project area, the dune ridge south of the mudflats at Rocky Point on Urala Station, together with its associated landforms, wrack line and cultural sites is an area of regional, if not broader, geoheritage and cultural heritage significance;

6. Shells were taken from Casugrina Point and the old shoreline on Urala Station to confirm the age of deposition. Other samples of recently live shells were taken from the beach at Second Creek to determine reservoir effects. All samples have been

submitted to the radiocarbon laboratory at ANSTO for analysis, the results of which will be presented as an addendum to this report.

7. A further attempt to establish an inundation chronology for the area involved extraction of three shallow cores. Two cores were taken from the flood and one from the ebb tide components of the backflow delta (Sites 8 and 9). The cores have been delivered to ANSTO for isotope analysis. It is anticipated these may assist identification of extreme marine incursion and river flood events over a long time span (yet to be determined) and it is hoped they will show some connection with the seven metre surge event of approximately 700 years BP.

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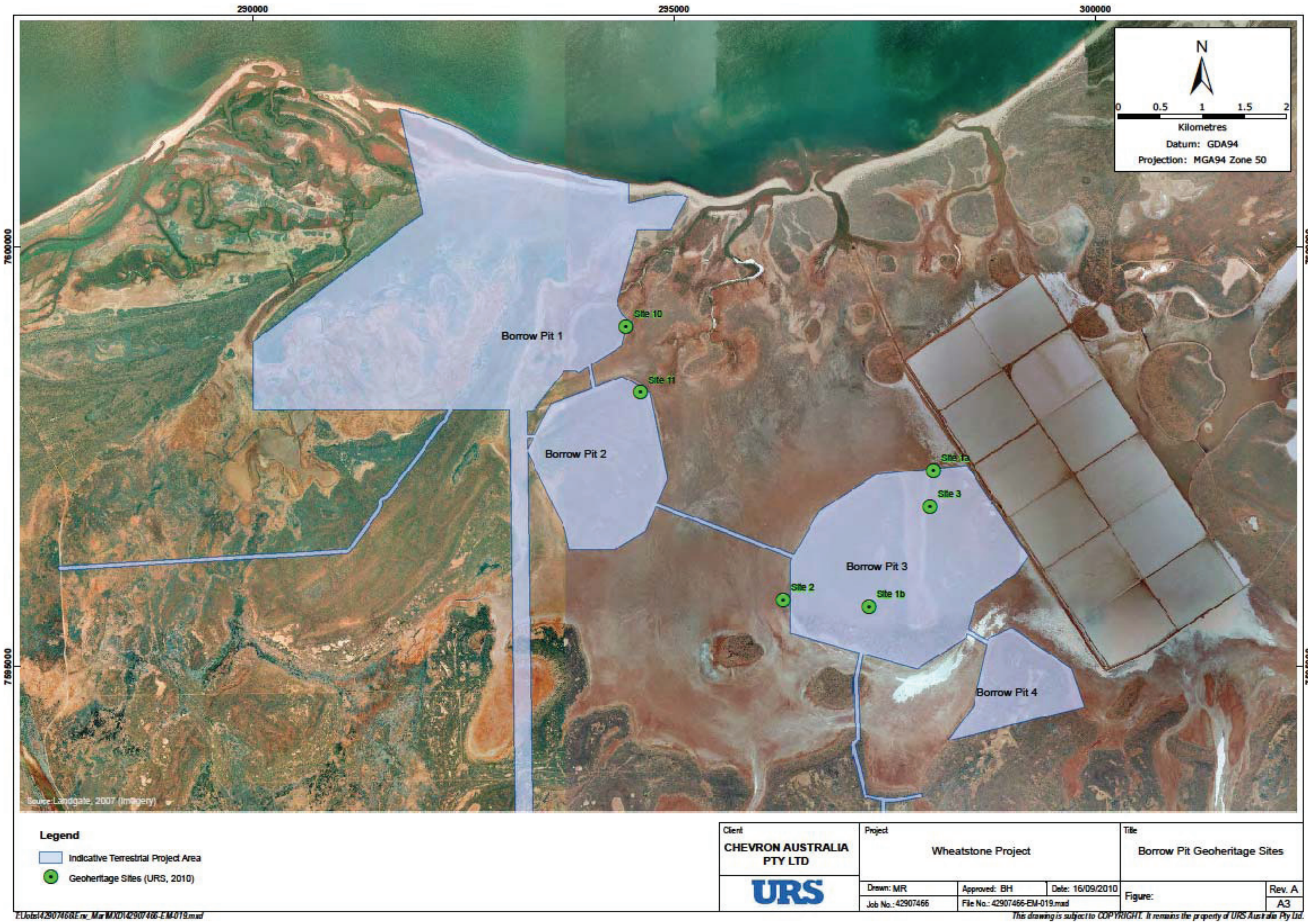
Appendix A Field Sites and Their Locations

APPENDIX A (1): FIELD SITES AND THEIR MGA ZONE 50 COORDINATES

Site number	Site Name	Easting	Northing
1a	Horseshoe Island (1)	298077	7597339
1b	Horseshoe Island (2)	297311	7595715
2	Horseshoe Island (West)	296294	7595798
3	Horseshoe Island (East)	298039	7596909
4	Little Island	297505	7598621
5	Casugrina Point	292728	7600881
6	Richard's Rock	291928	7600641
7	Chenier Delta (3P)	291334	7600438
8	SW Flood delta	291906	7595184
9	NE Ebb delta	292639	7595733
10	Little Island	294430	7599058
11	Big Island	294601	7598274
12	Onslow Town Quarry	306381	7604816
13	Mouth of Second Creek	310013	7607248
14	Pond Site 2	312112	7605580
15	Pond Site 5	316680	7609098
16	Pond Site 7	319744	7608643
17	Pond Site 8	319683	7607001
18	Sunset Beach	299477	7601929
19	Two wells (Soaks)	273392	7589958
20	Urala Key Site 1	280154	7590563
21	Urala Site A	280514	7590716
22	Urala Key Site2 A Quarry	281105	7590913
23	Urala Site B – Middens	281698	7591133
24	Urala Site C – Quarry	282103	7591338
25	Urala Key Site (3S)	282597	7592310
26	Urala Site D – Middens	283816	7592809
27	Urala Site E – River Mouth	284678	7597504
28	Urala Key Site 4 (4P)	285265	7594289
29	Rocky outcrop near 4P	286279	7593591

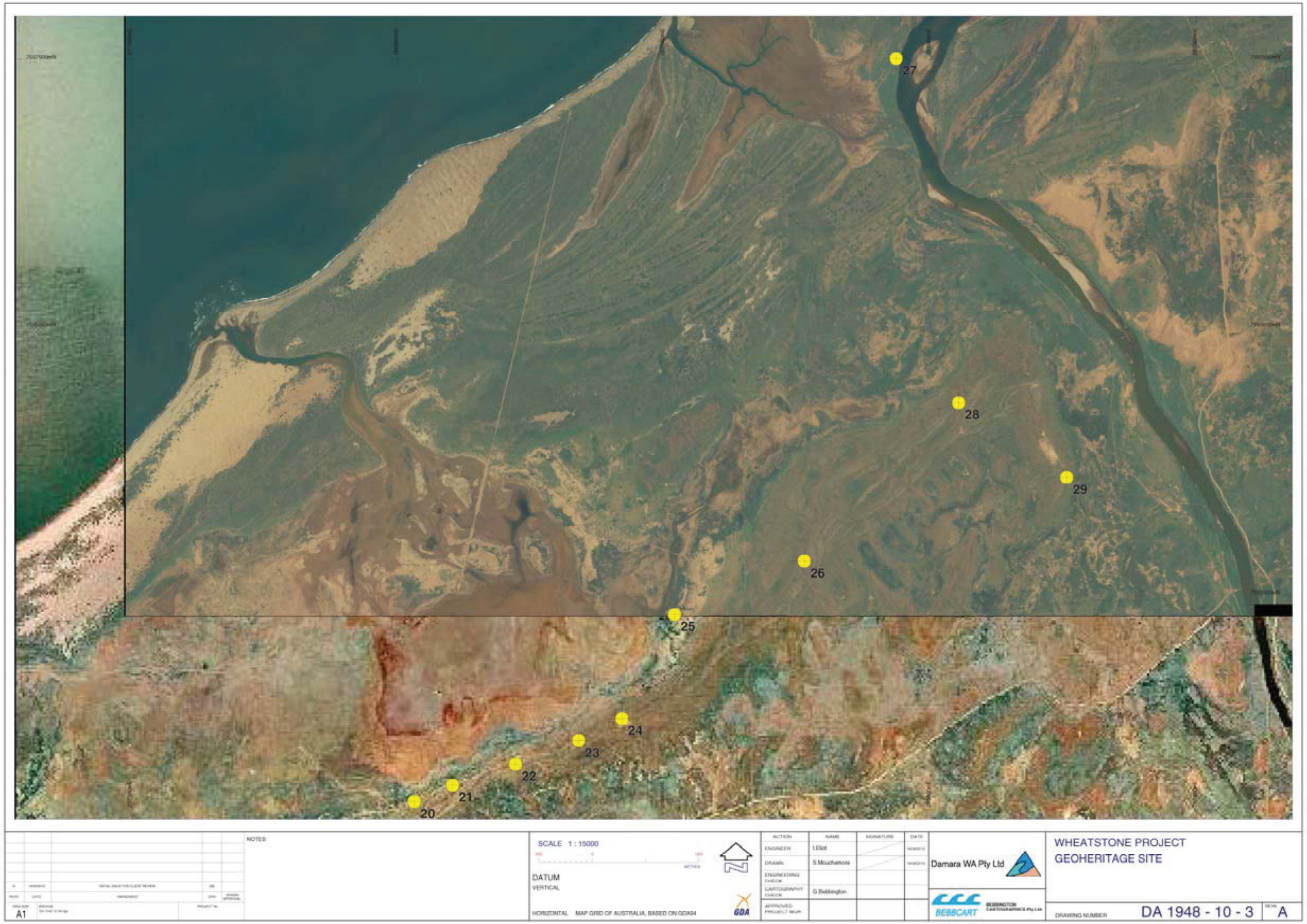
NOTE: With the exception of the Two Wells (Site 19) on Urala Station the all sites listed are illustrated on the maps below and available as GIS files for expansion. The Two Wells site was immediately west of imagery made available for the report.

APPENDIX A (2): SITES VISITED IN THE PROJECT AREA AND HOOLEY CREEK MUDFLATS



APPENDIX A (3): SITES VISITED ON PROPOSED BORROW PITS IN THE PROJECT AREA

APPENDIX A (4): SITES VISITED IN THE ONSLOW SALT EASTERN POND AREA



APPENDIX A (5): SITES VISITED ON URALA STATION

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Appendix FD

A Description of Megafauna Distribution and Abundance in the SW Pilbara Using Aerial and Acoustic Surveys – Final Report 2010

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. It is the final report of the aerial survey program, with two previous reports being submitted as Appendix O3 and O4 of the Draft EIS/ERMP. A series of aerial and acoustic surveys were completed near the proposed Project trunkline in order to determine megafauna distribution and abundance in this area and to relate encountered species populations in a broader regional context. A total of 1221 humpback whales were sighted in 26 aerial surveys over the south-west Pilbara offshore region between May 2009 and May 2010. Nearshore waters (5-50 m depths) recorded lower densities of humpback whales than offshore waters (50- 950 m depths), perhaps due to annual water temperature profiles. Pygmy blue whales, sperm whales, killer whales, minke whales and pilot whales were also sighted during the aerial surveys. Acoustic surveys conducted between May 2009 and December 2009 identified the presence of humpback whales, pygmy blue whales, Brydes' whales and dwarf minke whales in the study area. Pygmy blue whales and dwarf minke whales are present in deeper waters of the offshore study area from mid-May onwards although, in the 2009 season, these species were recorded in lesser numbers (based on call rates) than in previous seasons. Nearshore aerial surveys (depths less than 50 m) reported regular sightings of dugongs, dolphins, manta rays and turtles throughout the period of the survey. No high-density concentrations of megafauna were identified between May and December near the Ashburton North Strategic Industrial Area, where proposed nearshore and offshore infrastructure will be located.

A Description of Megafauna Distribution and Abundance in the SW Pilbara Using Aerial and Acoustic Surveys – Final Report 2010

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1. Abstract

A series of aerial and acoustic surveys have been initiated near to the proposed Wheatstone Project (Project) trunkline in order to determine megafauna distribution and abundance in this area and to relate encountered species populations to the broader regional context. A total of 1221 humpback whales were sighted in 26 aerial surveys over the South West Pilbara offshore region during May 2009 to May 2010. Nearshore waters (5-50m depths) have lower densities of humpback whales than offshore waters (50-950m depths) perhaps due to annual water temperature profiles. Pygmy blue whales, sperm whales, killer whales, minke whales and pilot whales were also sighted during the aerial surveys. Acoustic surveys conducted over the May 2009 to December 2009 time period identified the presence of humpback whales, pygmy blue whales, Brydes' whales and dwarf minke whales in the study area. Pygmy blue whales and dwarf minke whales are present in deeper waters of the offshore study area from mid May onwards, although in the 2009 season these species were apparently in lesser numbers (based on call rates) than in previous seasons. Nearshore legs of the aerial surveys (depths less than 50m) reported regular sightings of dugongs, dolphins, manta rays and turtles throughout the period of the survey. No high-density concentrations of megafauna have been identified during the May to December time period near the Ashburton North Strategic Industrial Area (SIA), where an onshore LNG Plant, Product Loading Facility (PLF) and Material Offloading Facility (MOF) are proposed to be developed.

2. Scope of Work

The primary purpose of this study is to determine the seasonal distribution and relative abundance of great whales and other megafauna along the South West Pilbara coast, and offshore over the proposed trunkline route, during a 12 month period. The Centre for Whale Research (CWR) and Curtin University were commissioned by URS Australia Pty. Ltd. in April 2009 to design, conduct and analyse a series of aerial and acoustic surveys that would best compliment existing datasets and fill knowledge gaps in great whale and other megafauna distribution and abundance along the nearshore and offshore South West Pilbara coastline and in particular near to the proponents proposed trunkline. The new aerial survey program was to be consistent with existing CWR survey data collected near North West Cape (NWC) between 2000 and 2008 (Figure 1). The acoustic component of the survey is ongoing at the time of this report and will be reported on separately.

The combination of aerial and passive acoustic surveys were considered the most effective means of detecting spatial and temporal species clusters in the time window assigned, and which could be used for preliminary environmental assessment for the Project. Using a combination of acoustic and aerial survey techniques results in a reduction of knowledge gaps that typically arise using just one or the other technique. Aerial surveys alone generally suffer from lack of temporal detail and are unable to sample at night, while acoustic surveys generally suffer from lack of spatial (in shallow water) and species (for non-vocalising species) detail. Documenting the existing levels of vessel activity and coastal infrastructure was also considered to be an important part of baseline data collection so that "before and after" style analyses of megafauna patterns accurately reflects change.

Aerial surveys were to be conducted in two phases such that a preliminary analysis of a three-month (approx.) subset of the data could be used to inform an environmental approvals process for the Project. A second interim report was requested to be delivered in January 2010 that included all flights in 2009 and the complete humpback whale migratory cycle. This document represents the final report for the aerial survey component of the study and documents a complete 12 month monitoring program (total 26 aerial surveys). A contextual interpretation of the results for future management purposes is also provided.

This report also includes a preliminary analysis of the combined aerial/acoustic datasets for the first three months of acoustic data. Acoustic surveys began in mid-April, 2009 and spanned 78 days at an offshore site and 94 days at a nearshore site. This combined part of the report should be considered preliminary as the data collection period spanned only part of a season for some species discussed below, and data analysis was not completed for all species acoustically detected due to limited analysis time from the time of logger recovery.

3. Background - Humpback whales at Exmouth Gulf and North West Cape

Humpback whales are expected to be the most frequently encountered protected species in this study area. Furthermore, there is a relatively large wealth of knowledge on humpback whale ecology and behaviour. CWR has been conducting independent studies into the population dynamics and migratory habits of humpback whales in Western Australia since 1990 (Jenner & Jenner, 1994; Jenner *et al.*, 2001). Through this work, CWR has confirmed Chittleborough's (1953) theory that Exmouth Gulf, located southwest of the study area, is a nursery area for humpback whales (Jenner *et. al*. 2001). Hence, a variety of boat and aerial-based survey studies have been conducted in Exmouth Gulf since 1995.

Chittleborough (1953) first described Exmouth Gulf as a possible "nursery" for humpback whales based on aerial surveys over the area in 1951 and 1952. These flights were a regular part of an exploratory process designed to maximise returns for the commercial whaling industry. A whaling station operated at Norwegian Bay near Pt. Cloates (Lat S 22° 36') from 1912 to 1916 and then from 1922 to 1928, and finally from 1949 to 1955. By 1963, when a moratorium on humpback whaling was passed, there was thought to be less than 800 whales left in Breeding Population "D", or Western Australian population (Chittleborough, 1965).

Now, over 40 years since the cessation of whaling, this population of whales is thought to have been recovering at an annual rate of between 7 and 12% (Bannister and Hedley, 2001). Recent (2008) estimates of this population report that the population has increased to 26,100 individuals (CI = 20,152-33,272) (Salgado Kent *et al.*, 2010). If, as suggested, approximately 10% of this population is represented by cow/calf pairs (Bannister and Hedley, 2001), then as many as 3,000 pairs could use nursing areas like Exmouth Gulf by 2010. How this population increase is progressing and how it relates to the use and significance of areas adjacent to nursing or resting areas (such as the location of the proposed Project northeast of Exmouth Gulf) is of great interest to managers and importance to the Project.

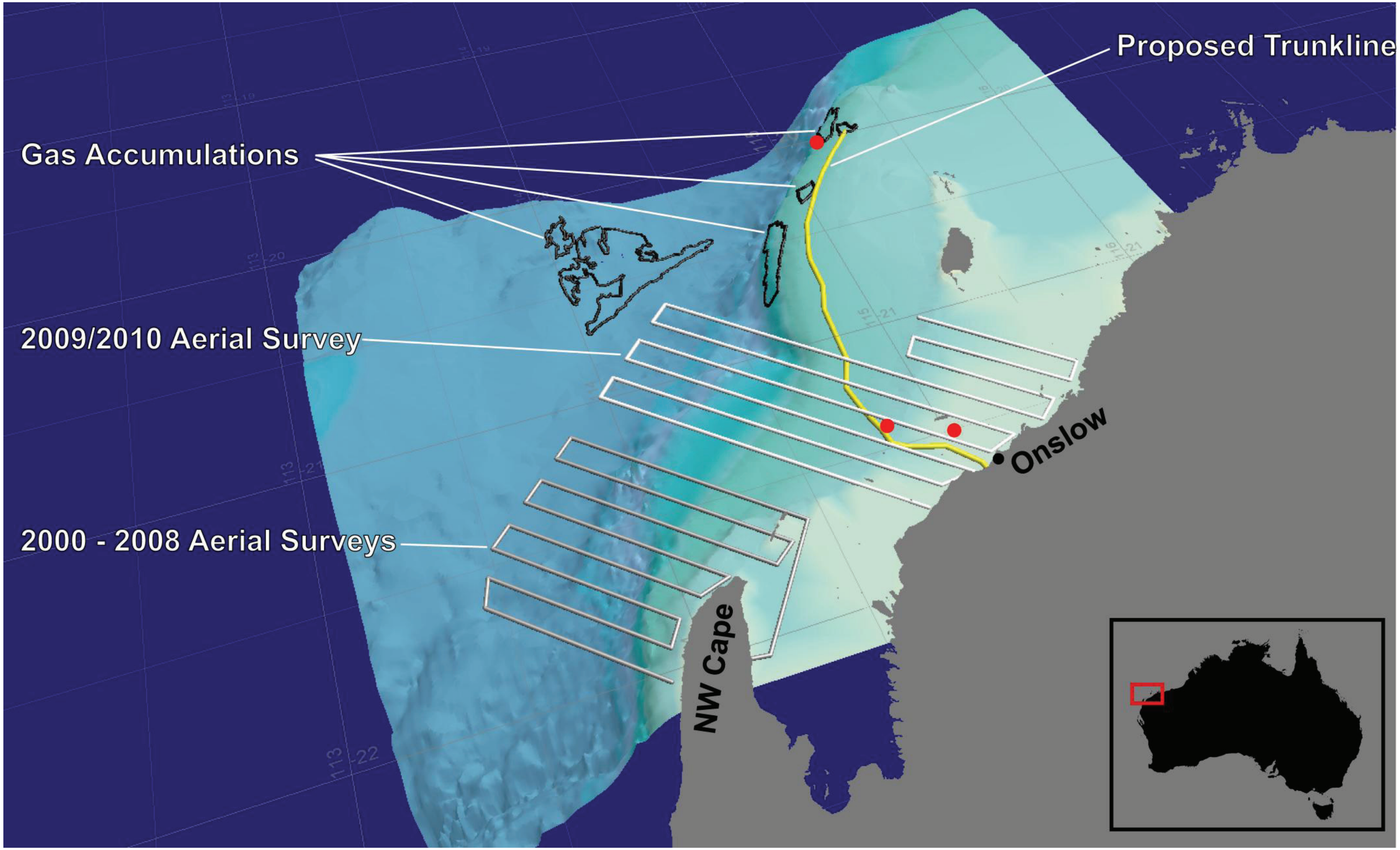

Figure 1. Aerial survey flight paths for the 2009/2010 study period showing proximity to the 2000 – 2008 CWR aerial survey flight path near North West Cape and 2009 acoustic logger positions (red dots). Continental Slope and Continental Shelf depth contours (>500m) are shades of green.

The migration of humpback whales both north and south past Exmouth Gulf follows a predictable but complicated progression of age and sex classes north and south along the coast each season. The northern migration of this species near Albany, Western Australia, has been described by Chittleborough (1965) as being segregated by age and sex class. It is likely that this same pattern where subadults and mature females terminating lactation are in the vanguard of the northern migration, followed by mature males and females and then later pregnant females (carrying near term foetuses), is present off NWC and the broader South West Pilbara offshore region.

The southern migration follows a similar order, with cows with their newly born calves appearing at the tail end of the migration. It is the cow/calf portion of the migration that congregate in greatest numbers inside Exmouth Gulf and that may have an overlap of spatial /temporal distribution in nearshore portions of the study area.

Spatially, the northern migratory path appears to be consistent in its location (CWR unpubl. data) for all age and sex classes off NWC, and is centred between the 150m and 350 depth contours (Figure 2). Whales rarely enter Exmouth Gulf during the northern migration (June to early August), perhaps due to the three degree or more temperature difference between the open ocean and the shallow Gulf during that time period. A transition phase between the northern and southern migrations occurs from early August to early September (Figure 3). This time period is consistent with peak numbers of whales each season (Figure 5) and results in the migratory path spreading to include a much wider depth range than is observed during the northern or southern migration. Sightings of whales inside the warmer northern part of Exmouth Gulf increase during early September and by mid-late September the main southbound migratory peak passes west of NWC with many animals entering the Gulf (Figure 4).

It is likely that water temperature plays a role in determining when whales, particularly cow/calf pairs trying to minimise metabolic expenditures, enter Exmouth Gulf. Cow/calf numbers inside Exmouth Gulf peak during the last 2 weeks of September and the first 2 weeks of October, at a similar time annually, as the sea surface temperature inside the Gulf becomes equal to that found offshore at the same latitude. In months preceding the water temperatures are much cooler (approx 4^{o} C) and may not be metabolically ideal for nursing calves (Figures 6 & 7).

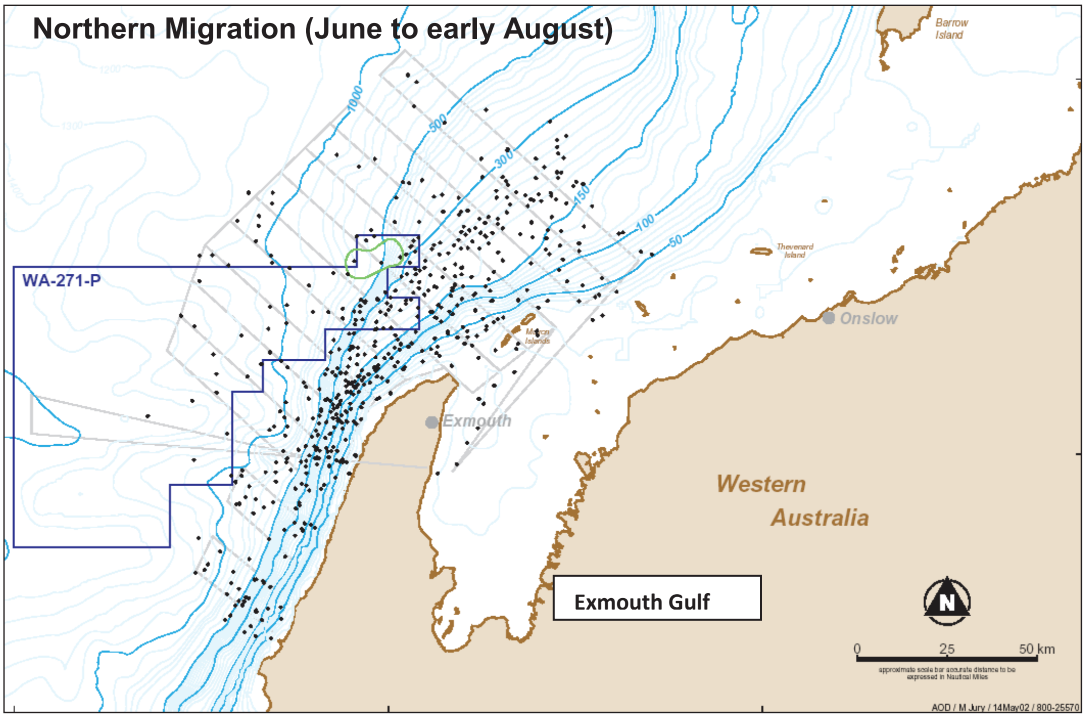

Figure 2. Aerial survey sightings of humpback whales during the northern migratory period (June to early August) in 2000 and 2001 (historical data from CWR aerial surveys in Woodside Energy EIS Document (2002) section 2.3.2.5.)

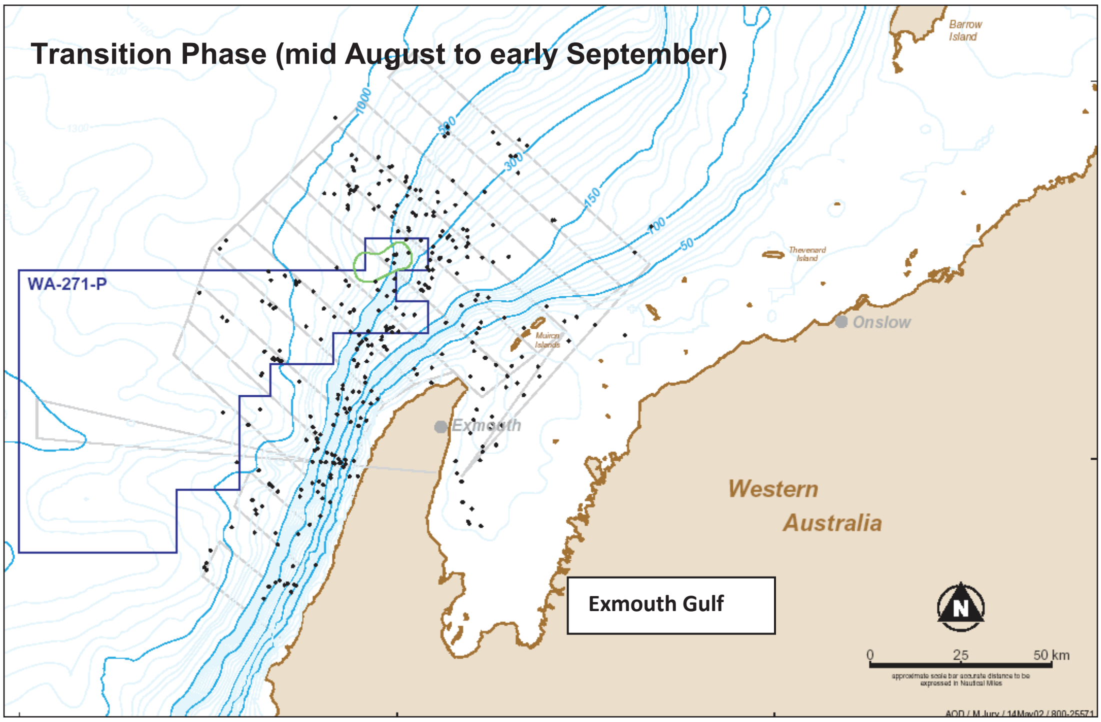

Figure 3. Aerial survey sightings of humpback whales during the peak of migration, or "Transition Phase" (mid Audust to early September), in 2000 and 2001 (historical data from CWR aerial surveys in Woodside Energy EIS Document (2002) section 2.3.2.5.)

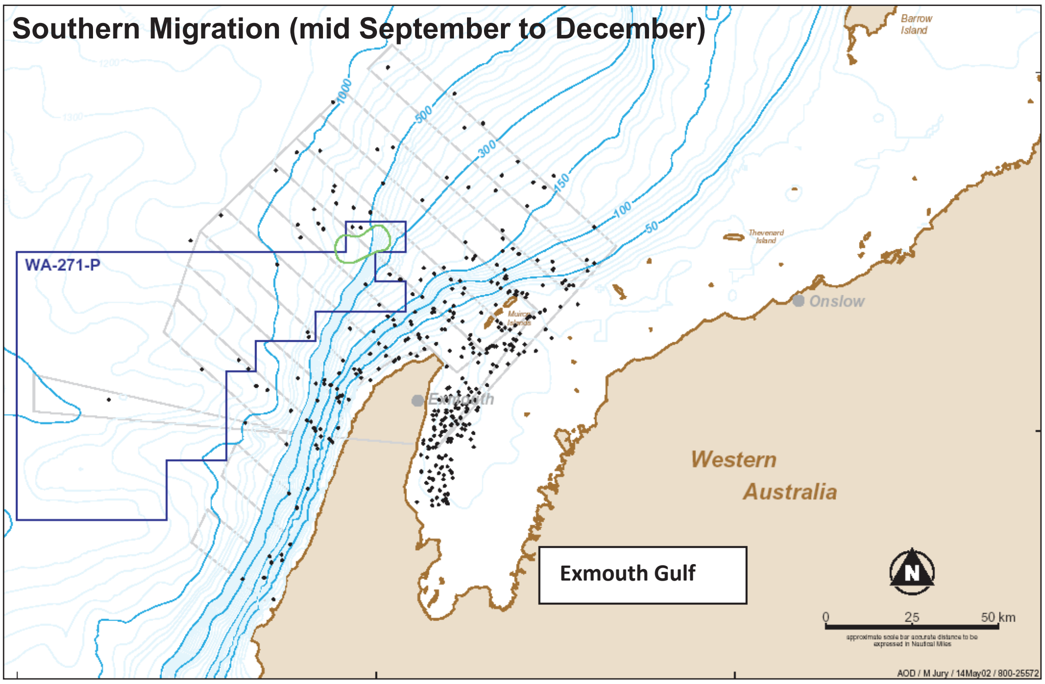

Figure 4. Aerial survey sightings of humpback whales during the southern migratory period (mid September to December) in 2000 and 2001 (historical data from CWR aerial surveys in Woodside Energy EIS Document (2002) section 2.3.2.5.)

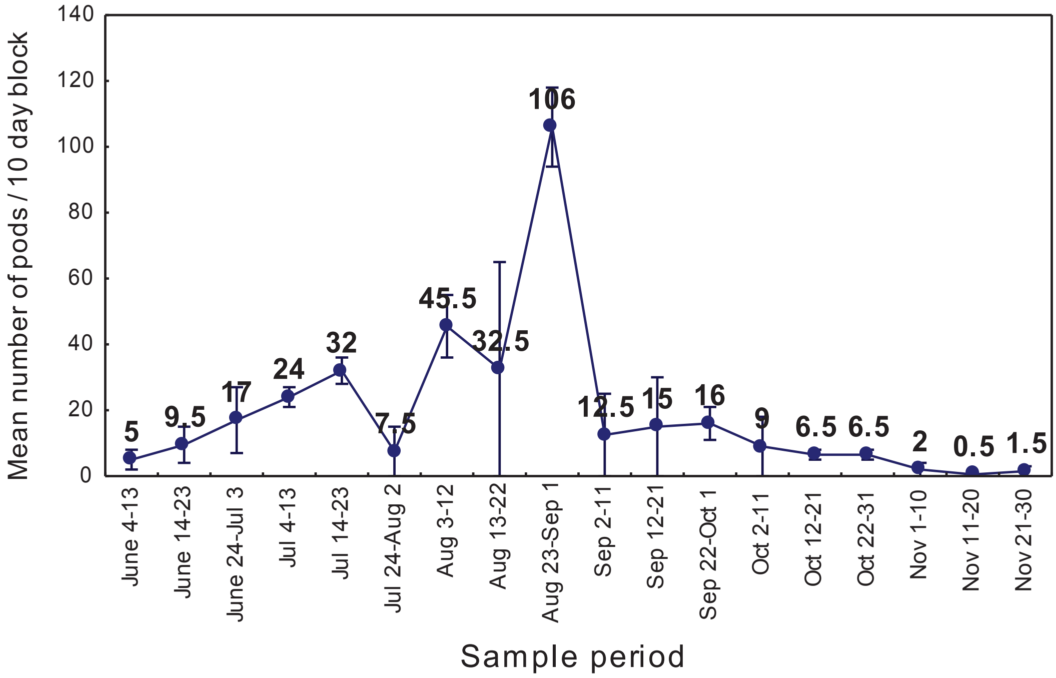

Figure 5. Mean number of humpback whale pods recorded during aerial surveys in 10-day sample blocks during the months of June to October during 2000 and 2001 ($\bar{x}$ ± 1 SE). Historical data from CWR aerial surveys west of, and not including, Exmouth Gulf for Woodside Energy 2000/2001, EIS document.

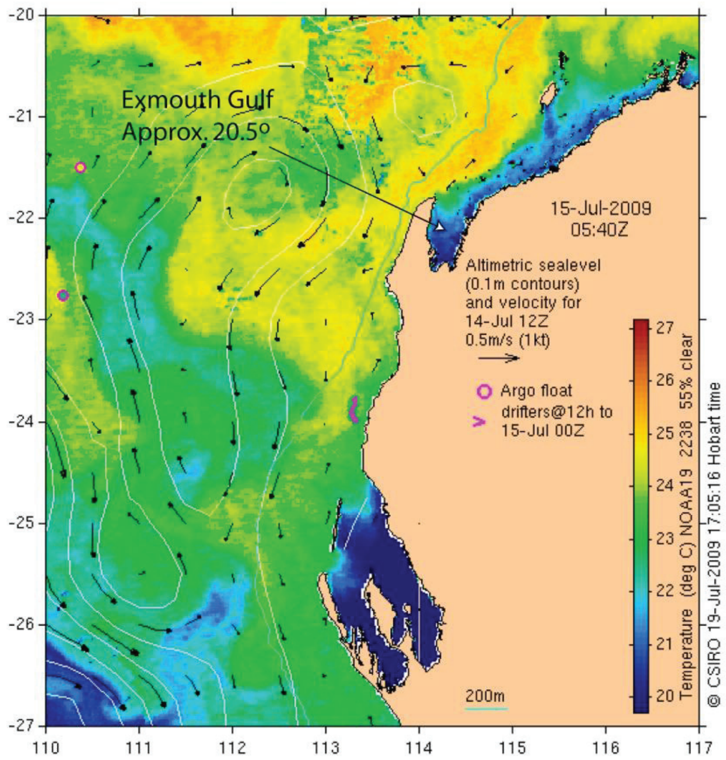

Figure 6. Sea surface temperature map for mid July, 2009, showing the cooler water inside Exmouth Gulf and the nearshore South West Pilbara region.

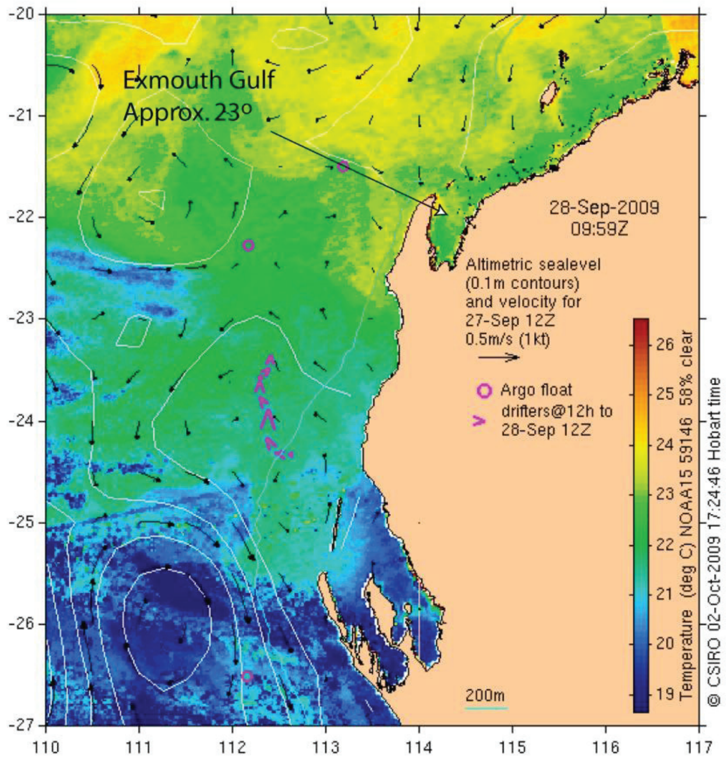

Figure 7. Sea surface temperature map for late September, 2009, showing the increase in temperature inside Exmouth Gulf.

4. Methods

4.1 Acoustic Surveys

A series of five sea noise loggers were deployed nearshore, west of Onslow between April and July 2009, and three in a 2 km triangle on the continental shelf break north of the Montebello Islands between May and July 2009 (offshore site) (see Figure 1). Near shore logger depths ranged from 10m to 43m while offshore logger depths were 200 to 225m. The offshore logger positions were located within 20km of a similar system deployed by Curtin University in 2006. Details of the passive acoustic survey methodology are presented in a separate report (McCauley and Kent, 2009).

4.2 Aerial Surveys

4.2.1 Design

The offshore area between Exmouth Gulf and Barrow Island was systematically examined using aerial surveys for megafauna from mid-May, 2009, to late April, 2010 in two week time blocks. Transects were designed to be consistent, comparable and a logical extension to transects described in Jenner and Jenner (2008). The transects covered an area which included the main humpback whale migratory body (Jenner *et al.*, 2001). A total of 26 samples of all transects were collected at 14 day intervals with the precise dates within these time blocks (intervals) dependant on "good" weather conditions (winds less than 18 knots) for detecting humpback whales or other large cetaceans (the primary target species). It is recognised that these conditions may not be optimal for spotting other smaller species however this study is designed to provide baseline spatial and temporal data that can be investigated in more detail in future.

The design of the survey followed protocols defined in the Distance ver. 5.1 software program (Buckland *et al.,* 2001, Buckland *et al.*, 2004). This program specifically allows users to design line transect surveys and analyse data resulting from these surveys for the purpose of estimating density and abundance. Using the principles of this system, transects were drawn over the study area in order to maximise coverage probability during a single flight. Although parallel line transect designs are disadvantaged because the time spent in between transects is "off survey", this technique results in a more even probability of coverage for non-rectangular survey areas such as the current study area (Buckland *et al.,* 2001). Furthermore, this system is consistent with previous CWR aerial surveys from both offshore near NWC (20 km southwest of the study area) and Exmouth Gulf (40 km southwest of the study area) (Figure 1).

The timing of the first six surveys was planned to coincide with the bulk of the northern migration of humpback whales through this region (see Figure 8, trends in humpback swim direction).

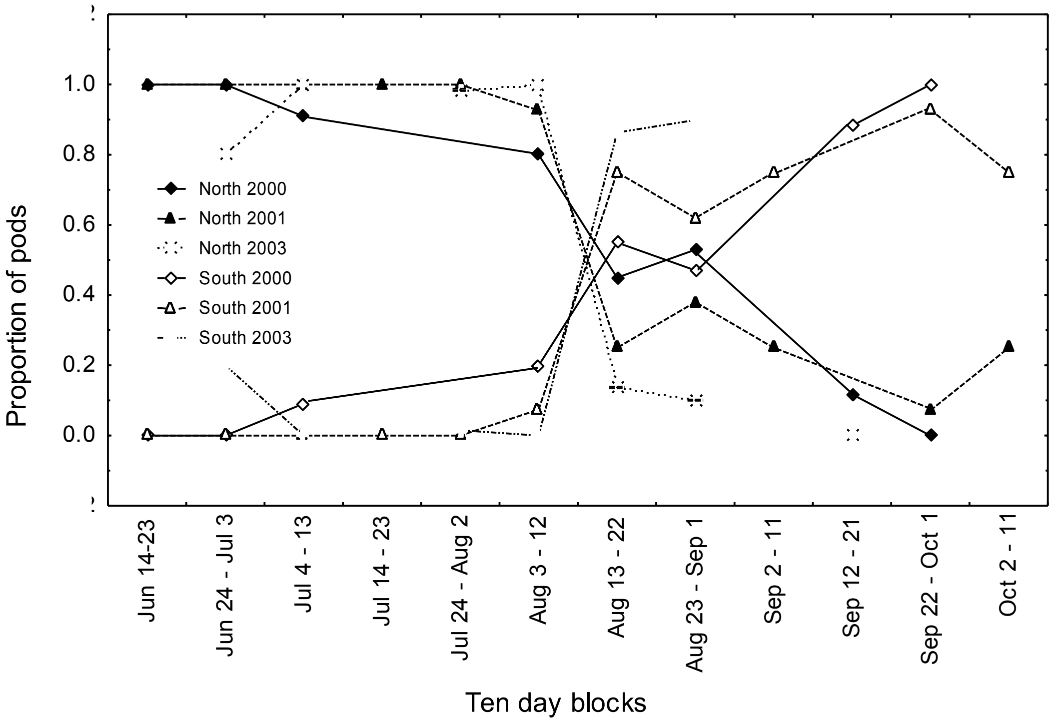

Figure 8. Migratory direction of humpback whale pods recorded during aerial surveys at North West Cape, showing June and July as a northern migration period (from Jenner *et al.*, in prep.). Non-migrating whales (i.e. resting or milling) are not plotted.

4.2.2 Methodology

Aerial surveys were conducted at an altitude of 305 m (1000 ft) and a speed of 222 km/hr (120 knots) using a twin-engine, over-head wing aircraft (Cessna 337). The plane followed line transects which were surveyed in passing mode (e.g. the plane did not deviate from the flight path). Surveys were only initiated in wind speeds less than 33 km h^{-1} (18 knots, or Beaufort Sea State less than 5, Appendix 1), which has been shown to be adequate for spotting whales (Jenner *et al.* in prep). Each flight was of approximately 5.5 to 6 hours duration and take-off times varied between 8:40 and 10:55 so that the mid-day period was consistently sampled and glare would be a consistent factor for all flights. Flights during the expected northern migration period where flown from north to south to minimize the possibility of double counting pods of whales on successive transects. Similarly, the flights during the southern migratory period were flown from south to north.

Personnel for each of the 26 surveys included four people; two pilots and two observers. The observer team consisted of four trained personnel. One person (Lyn Irvine) flew 22 flights, one person (Jane Kennedy) flew 18 flights, one person (Jennifer Thompson) flew 8 flights, one person (Emily Wilson) flew 3 flights and one person (Dani Rob) flew 1 flight. The pilots were not responsible for spotting, and were separated acoustically from the two observers. The pilots were responsible for recording the planes' angle of drift on each transect, so that angles reported from the compass boards could be corrected relative to the flight path. The observers were linked via a separate intercom system which was logged to a Sony Mini Disk Recorder NH900 and allowed the observers to search continuously and voice record all sightings to a time code which was synchronized to the Global Positioning System (GPS) before each flight. A Garmin III Pilot aeronautical GPS was used to log sightings (as waypoints) and coordinates of the flight path, including altitude, for every second of the flight.

Observers sighted and recorded positions of whales by measured vertical and horizontal angles from the aircraft to the whales (using Suunto PM-5/360PC clinometers, and a compass board). The location (latitude and longitude) of each sighted whale was later plotted by projecting a new GPS waypoint from the waypoint recorded at the time of sighting (using Oziexplorer ver. 3.95 GPS software) from the calculated angle and distance of the aircraft to the whale. The angle was calculated with the following formulae: Angle to starboard = $AC + (MHA + DA)$, and Angle to port = $AC + (MHA - DA)$, where *AC* was the aircraft course, *MHA* was the measured horizontal angle and *DA* was the angle of drift of the aircraft. Distances were calculated using formulae in Lerczak and Hobbs (1998).

No vertical or horizontal angles were recorded for any other species (i.e. dolphins, dugongs, rays sharks or turtles) and it was assumed for plotting purposes that sighting positions were the same as the waypoint marked (i.e. directly under the plane). However vertical and horizontal angles were measured for vessels and other man-made objects, and, where possible, direction of travel was also recorded.

The sighting information that was recorded for whales included the direction of migration (north, south, resting/milling, or undetermined) of each pod observed. Northbound pods were those sighted steadily swimming parallel to the coast in a northerly direction. Likewise, southbound whales were those sighted swimming parallel to the coast in a southerly direction. Pods reported as “milling” were swimming perpendicular to the coast (not northbound or southbound) or surface lying at the time of sighting with no obvious signs of swimming (i.e. resting whales). Pods recorded as “undetermined” were sighted too far from the aircraft, or for too short a time period, to assess swim direction.

The intensity and direction of glare (scale 1-3) for each observer was recorded for each transect as well as environmental variables such as Beaufort sea-state (scale 0 -12), associated wind speed (estimated in knots) and direction (from wave patterns), cloud cover below 1000 feet (percentage) and overall visibility (scale 1-3).

4.2.3 Analysis (Humpback Whales)

The GIS program Arcview 3.2, with extensions Spatial Analyst and Animal Movement (Hooge and Eichenlaub, 1997), was used to analyze the distribution of cetaceans and all other encountered wildlife. Complete spatial randomness (CSR) of cetacean sightings was tested to determine if sightings data were spatially structured (i.e. whether sightings were clustered, random or uniformly distributed) within the flight path study area. Other smaller species (dugongs, dolphins, turtles etc.) were not tested for CSR since they could not be reliably sighted away from the track line. Nearest neighbor routines were run in Arcview to test for CSR and a Kernel “home range” estimator was used to compute locations of clusters (indicating higher relative densities and possible a migratory corridor or resting area) for cetaceans within the study area. Apparent clustering of humpback whales around the track line has been assumed, for the purposes of this report, to have minimal effect on the results given an effective half strip width of 5 km (Bannister and Hedley, 2001).

The mean distance of whale pods on each flight from the nearest section of coastline was measured using a GIS "Spider Distance" tool to establish spatial and temporal patterns in clustered data. Probability contour maps were generated for each flight that display relative density contours on the day of the survey and across all surveys reporting humpback whales.

A smoothing factor ("*h*" statistic) controls the size of the home range reported and has been shown to be inconsistent for different sample sizes (Hooge and Eichenlaub, 1997). For this reason a second technique, the minimum convex polygon (MCP) method was used to first confirm sightings range extent. The MCP was considered to be the minimum extent of the sightings range and the smoothing factor was adjusted until the area of an unbroken 95% kernel contour for the entire dataset completely included the area of the MCP. This provides an objective method for selecting the smoothing factor (Hooge and Eichenlaub, 1997) and creates a baseline for relative density comparisons between flights.

The "*h*" statistic was used to calculate 50%, 75% and 95% probability density contours for each flight day where the 50% contour represents the highest density of whale pods (not whales) and the 95% contour represents the likely extent of all pods. A single "*h*" statistic was used as a basis for comparison for each flight and was calculated using the maximum density in the entire study area over the entire study period.

5. Results

5.1 General Description – Acoustic Loggers

A general description of preliminary results from the passive acoustic surveys is presented here, however a detailed description of these results is presented in McCauley and Kent (2009) and a further acoustic report will follow the retrieval of the loggers in late 2010.

The noise loggers detected various whale species including: pygmy blue, dwarf minke, Brydes, and humpback whales. The recording period is currently too short to correctly delineate seasonal patterns in whale trends. The offshore noise loggers were dominated by seismic survey noise and vessel noise during the entire recording period. At times three seismic survey sources could be detected at the offshore location. These are believed to be associated with two surveys running in deep waters adjacent to the shelf to the south. Vessel noise was prominent at the offshore location, presumably from vessels involved in site works at the proposed Pluto gas field.

Pygmy blue whales were present offshore over most of the May to July period. These are believed northbound pygmy blue whales returning to low latitudes after spending summers feeding in temperate waters (Branch *et al.,* 2007). The time integrated count of individual calling pygmy blue whales from the offshore site from a nearby, but unrelated, data set made in 2006 was compared with the similar count made in 2009 over the matching time period in Julian days. Six times fewer whales passed in 2009 compared with 2006.

Dwarf minke whales were detected and counted at the offshore site. Dwarf minke whales were present persistently across the April to July period with a slight tendency for more whales in June-

July. The time integrated counts of individual calling dwarf minke whales in 2009 were compared with the same calculation for the nearby site made in 2006 and seven times fewer dwarf minke whale detections were made in 2009(McCauley, unpubl. data). It is currently not clear why counts of pygmy blue and dwarf minke whales are lower in 2009 than in 2006 at the offshore site.

Brydes whales were detected on one day only in April at a site in 43 m of water west of Onslow.

Humpback whales were present at the 43 m depth nearshore site and at the offshore site but the counts have not yet been analysed for trends or timing.

Regular evening fish choruses were heard at the 43 m depth nearshore site (expected regular demersal species) but not at a 10 m depth site. Expected fish choruses from the offshore site (i.e. globally dispersed deep water myctophid species) were not detected.

5.2 General Description – Aerial Surveys

A total of 26 flights at approximately two week intervals from 17 May 2009, to 29 April 2010, totalling 179.65 survey hours over the south western Pilbara offshore region resulted in 5424 megafauna sightings and 771 vessel/manmade object sightings (Table 1). A total of five species of great whale (humpback, blue, killer, minke and sperm whales) were sighted. Humpback whales were the most commonly sighted large cetaceans while small cetacean sightings of pilot whales and dolphin species were also reported.

Table 1. Megafauna and vessel sightings during the 26 flight series.

SIGHTING	1 - May 17, 2009	2- May 31, 2009	3- Jun 12, 2009	4- Jun 26, 2009	5 - Jul 11, 2009	6 - Jul 23, 2009	7 - Aug 5, 2009	8 - Aug 20, 2009	9 - Sep 3, 2009	10 - Sep 17, 2009	11 - Oct 2, 2009	12 - Oct 15, 2009	13 - Nov 2, 2009	14 - Nov 12, 2009	15 - Nov 28, 2009	16 - Dec 13, 2009	17 - Dec 24, 2009	18 - Jan 7, 2010	19 - Jan 23, 2010	20 - Feb 6, 2010	21 - Feb 19, 2010	22 - Mar 6, 2010	23 - Mar 19, 2010	24 - Apr 4, 2010	25 - Apr 15, 2010	26 - Apr 29, 2010	TOTAL
Humpback whale:	0	0	6	50	75	97	169	231	145	218	119	87	16	4	2	0	2	0	0	0	0	0	0	0	0	0	1221
Blue whale:	0	0	0	0	0	0	0	0	0	0	0	0	2	0	6	3	0	0	0	0	0	0	0	0	0	4	15
Killer whale:	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Minke whale:	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pilot whale:	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Sperm whale:	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	14
Other whales (unidentified):	0	0	0	0	2	0	2	0	0	2	0	0	0	5	1	1	0	0	0	0	0	0	0	0	0	0	13
Dolphin spp.:	40	203	8	68	47	78	71	31	36	171	84	99	7	102	150	174	0	0	0	71	12	9	52	0	0	168	1681
Dugong:	13	3	12	31	2	25	18	13	14	6	2	2	0	2	5	0	0	2	1	0	0	1	5	0	4	8	169
Whale Shark:	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	4
Manta ray:	2	0	4	12	1	3	21	3	9	4	4	3	4	5	11	5	1	0	0	15	3	0	1	1	0	1	113
Turtle spp:	53	101	32	122	14	100	261	31	159	112	14	174	61	134	140	50	33	4	3	35	35	159	122	5	9	189	2152
Krill Ball:	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	3	0	1	0	0	0	0	4	10
Aquaculture Net:	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	22
Warning Beacon:	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
Buoy:	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	1	0	0	0	0	0	0	0	0	0	0	6
Vessel:	50	46	36	50	48	55	32	27	37	22	33	15	9	16	25	20	5	11	18	23	11	13	19	31	30	56	738

5.3 Humpback Whales

A total of 801 humpback whale pods containing 1221 individual whales were sighted during the mid-June to late December time period (Table 2). A total of 95 cows with calves were sighted, peaking in numbers during mid-September to mid-October. Humpback whale sightings increased steadily after the June 12, 2009, flight and peaked during the August 20, 2009, flight (Figure 9).

Table 2. Humpback whale sightings for the 26 flights.

Flight Date	Number of Pods	Number of Whales	Number of Calves	Number Whales Migrating	Number Whales Resting/Milling	Number Undetermined
17/05/2009	0	0	0	0	0	0
31/05/2009	0	0	0	0	0	0
12/06/2009	4	6	0	6	0	0
26/06/2009	28	50	0	41	6	3
11/07/2009	46	75	0	23	24	28
23/07/2009	66	97	3	61	17	19
05/08/2009	113	169	10	87	46	36
20/08/2009	152	231	10	103	70	58
03/09/2009	100	145	10	52	79	14
17/09/2009	138	218	22	41	155	22
02/10/2009	87	119	11	35	61	23
15/10/2009	52	87	19	20	66	1
02/11/2009	11	16	6	10	5	1
12/11/2009	2	4	2	0	4	0
28/11/2009	1	2	1	2	0	0
13/12/2009	0	0	0	0	0	0
24/12/2009	1	2	1	0	2	0
07/01/2010	0	0	0	0	0	0
23/01/2010	0	0	0	0	0	0
06/02/2010	0	0	0	0	0	0
19/02/2010	0	0	0	0	0	0
06/03/2010	0	0	0	0	0	0
19/03/2010	0	0	0	0	0	0
04/04/2010	0	0	0	0	0	0
15/04/2010	0	0	0	0	0	0
29/04/2010	0	0	0	0	0	0
TOTAL	**801**	**1221**	**95**	**481**	**535**	**205**

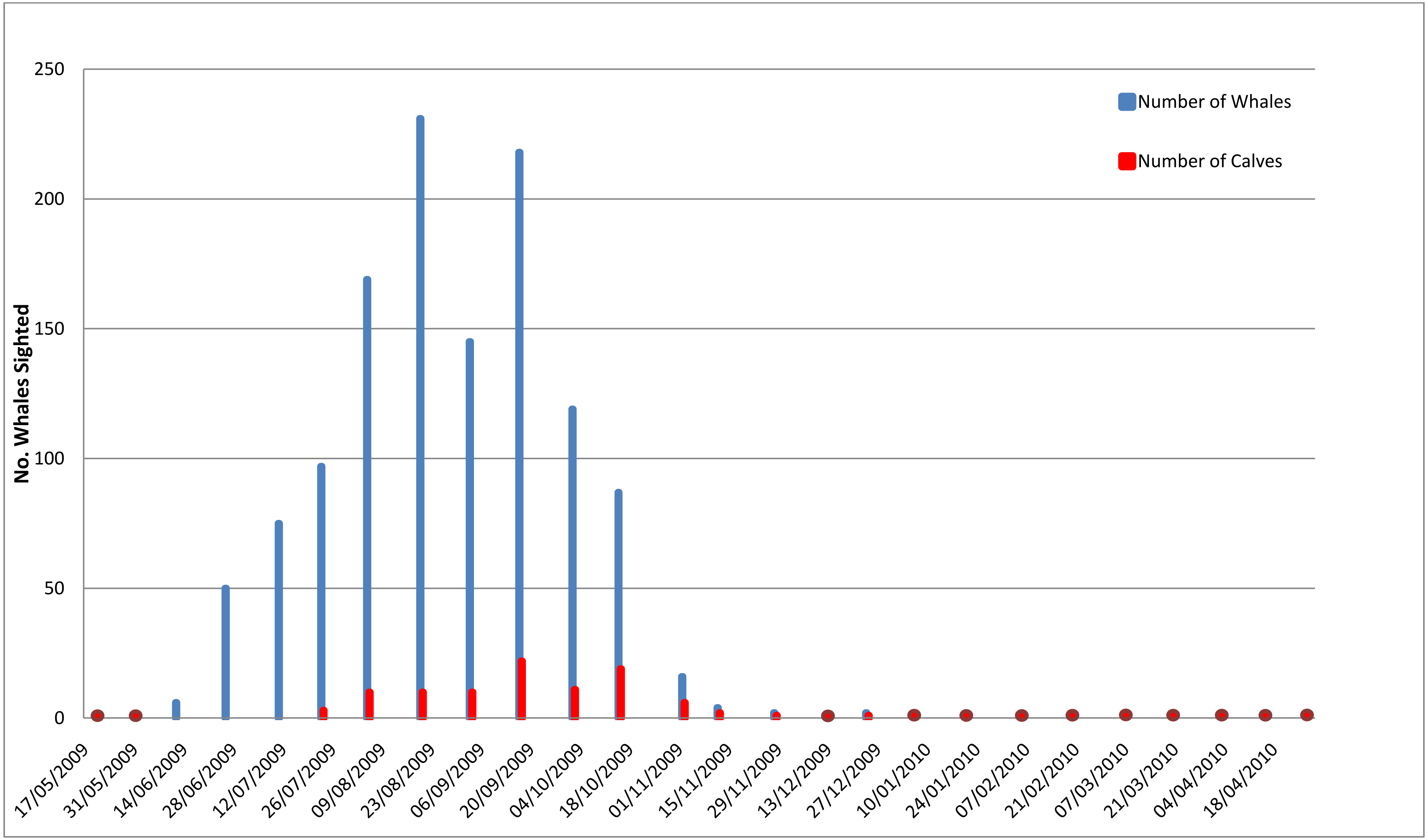

Figure 9. Numbers of humpback whales and numbers of calves sighted per flight for each of the 26 flights (red dot indicates a flight but no sighting).

As a means of initially exploring the spatial datasets, tests for CSR of humpback whale pod distribution for each flight were conducted to test the hypothesis that distribution within the study area was random. The nearest neighbour analysis in Animal Movement (v.2.0) was used to test for CSR using a polygon encompassing the flight path area as a boundary.

Assumptions for the test are as follows:

1) If the resulting value of R from the nearest neighbour analysis equals 1 for an observed data set then the data is randomly distributed, since the observed distribution does not deviate from the expected random model.
2) If $R < 1$, the data is clustered where the observed mean nearest neighbour distance is less than what is expected with the random model, thereby resulting in clusters.
3) If $R > 1$, the data is uniformly distributed because the mean observed nearest neighbour distance is greater on average than the expected.

CSR analysis using the nearest neighbour technique resulted in the data points on all flights during June 26 to November 2 being designated "clustered" (R values all less than 1, Table 3). There were too few sightings on June 12, November 12, November 28 and December 24 to run the test effectively.

Table 3. Values of R indicating clustered distribution of humpback whale pods during each flight. Meaningful values could not be calculated for flights with low sightings numbers (*) or for the 13/12/2009 flight (-) when no whales were sighted.

Flight	"R" Value
12/06/2009	*
26/06/2009	4.73E-06
11/07/2009	5.88E-06
23/07/2009	6.70E-06
5/08/2009	7.12E-06
20/08/2009	7.11E-06
3/09/2009	7.72E-06
17/09/2009	6.56E-06
2/10/2009	8.14E-06
15/10/2009	7.60E-06
2/11/2009	8.91E-06
12/11/2009	*
28/11/2009	*
13/12/2009	-
24/12/2009	*

Having established that there is clustering of the data points, the next step in spatial analysis was to determine if there is any evidence of site fidelity among flights, bearing in mind variables such as migratory direction which may influence distribution. We assume here, and confirm below, that the majority of pods sighted in surveys in June, July and early August are likely to be part of the northern migratory phase and those sighted after late August are likely to be part of the southern migration.

The GIS tool Animal Movement 2.0 (Hooge and Eichenlaub*,* 1997) was used to calculate probabilistic contours of equal utilization distributions. This is also known as a Kernel home range calculator. The Kernel home range is considered one of the most robust of the probabilistic techniques for spatial analysis of point data (Worton 1989). The Kernel is essentially a grid of equal utilisation areas that has smoothed edges. The smoothing can be done automatically by a GIS program or adjusted manually, using an "*h*" statistic, which is fit to the dataset with a MCP. For the current dataset, the latter more precise technique was used where points from all flights were combined to define the maximum boundary for the MCP (Figure 10). An "*h*" value of 0.056538 was selected based on the visual fit of the 95% probability contour which results in a maximum envelope around a single point equal to the half strip width of the line transects (five km).

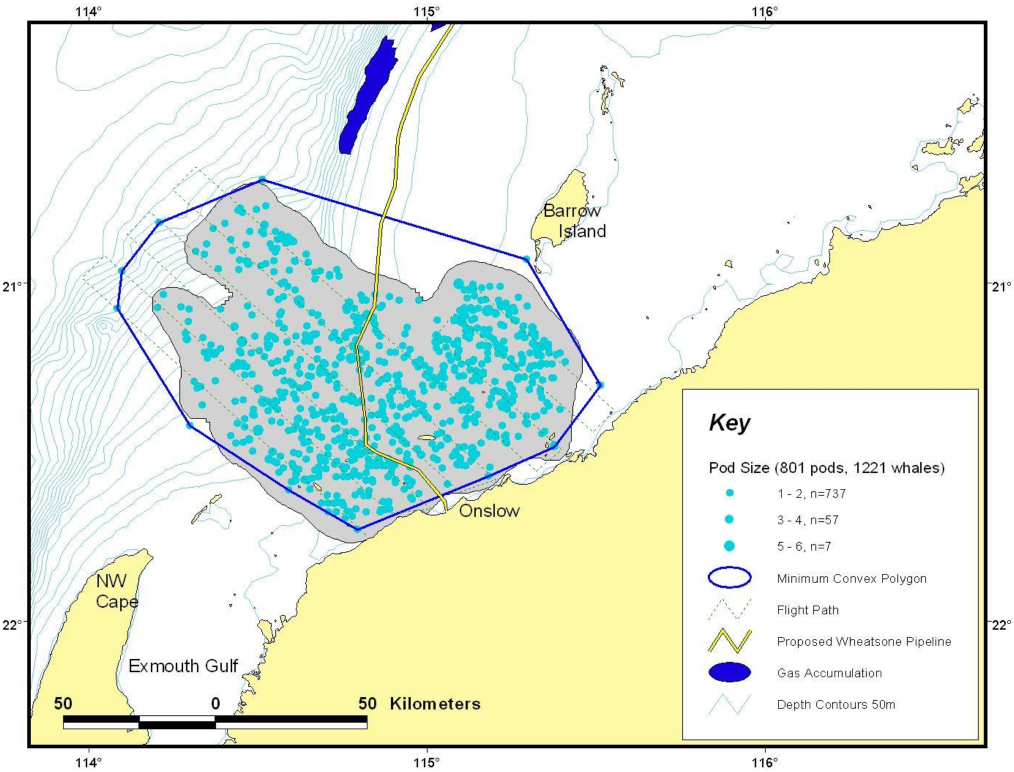

Figure 10. The Minimum Convex Polygon used to select the smoothing factor for the June to December humpback whale dataset (h=0.056538) and the resulting 95% Kernel contour for all sightings. Positions of all pods (n=1221) are shown.

Maps showing ranked Kernel density polygons (highest to lowest) for flights 4 to 21 (June 26 to November 2) using the same "*h*" value (0. 0.056538) are presented in Figures 12 to 21, and show a comparative relative density and range of migrating humpback whales across all flights. Similar Kernel plots for flights on June 12, November 12, November 28, December 13 and December 24 were not constructed as there were too few data points (all less than 5) to perform the calculations (Figures 11, 22, 23, and 24).

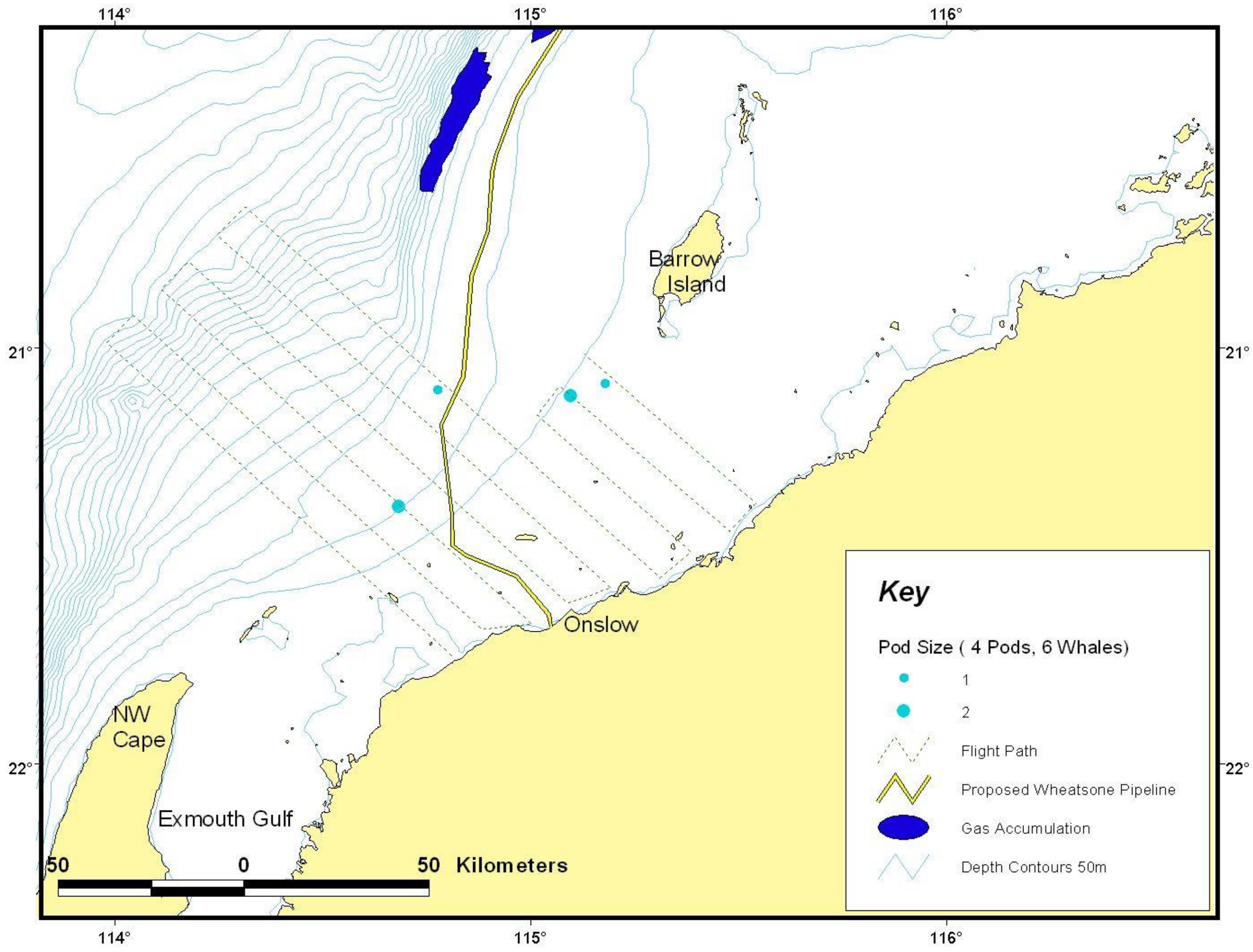

Figure 11. Positions of humpback whale pods sighted on June 12, 2009.

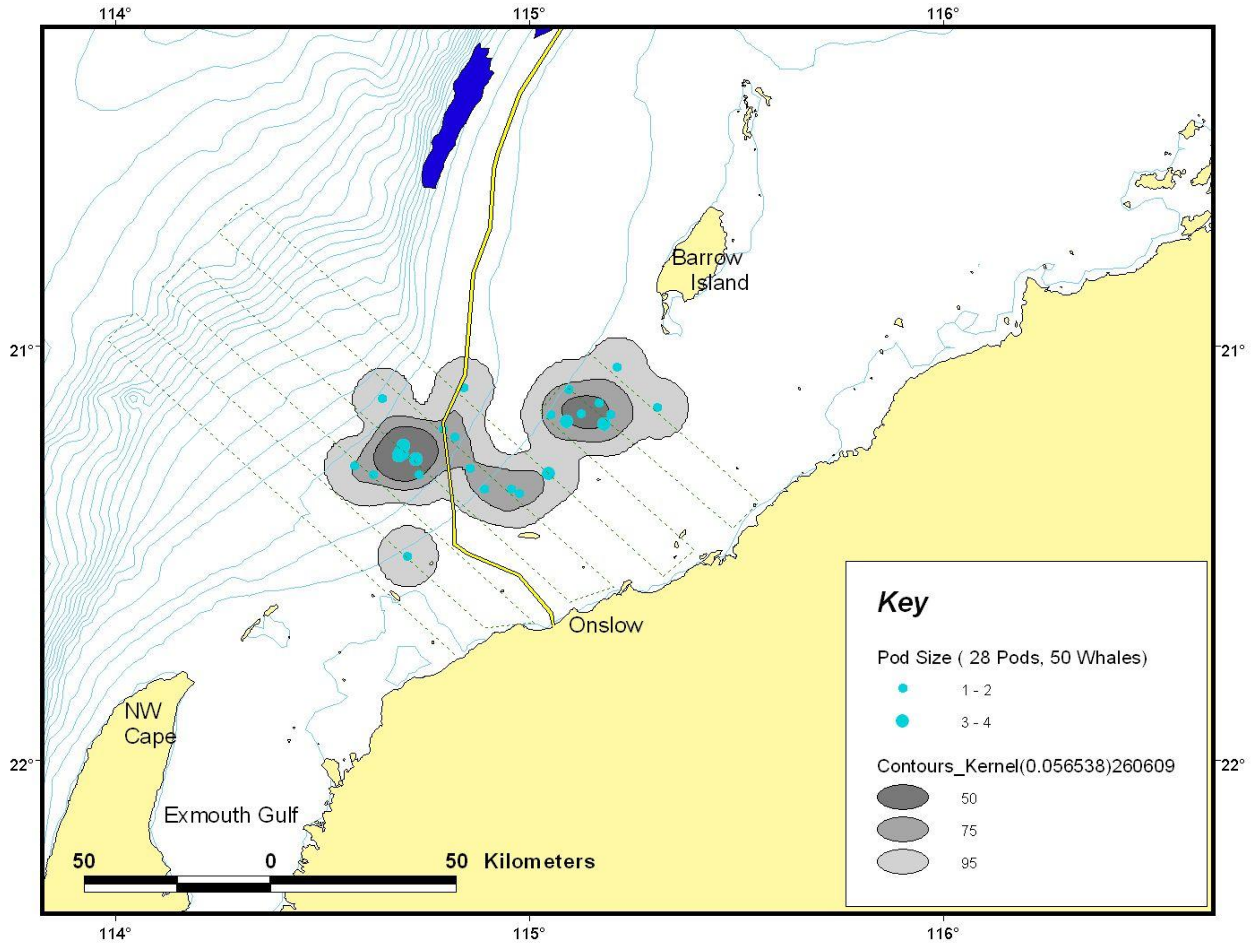

Figure 12. Positions of humpback whale pods sighted on June 26, 2009, with relative density distribution polygons.

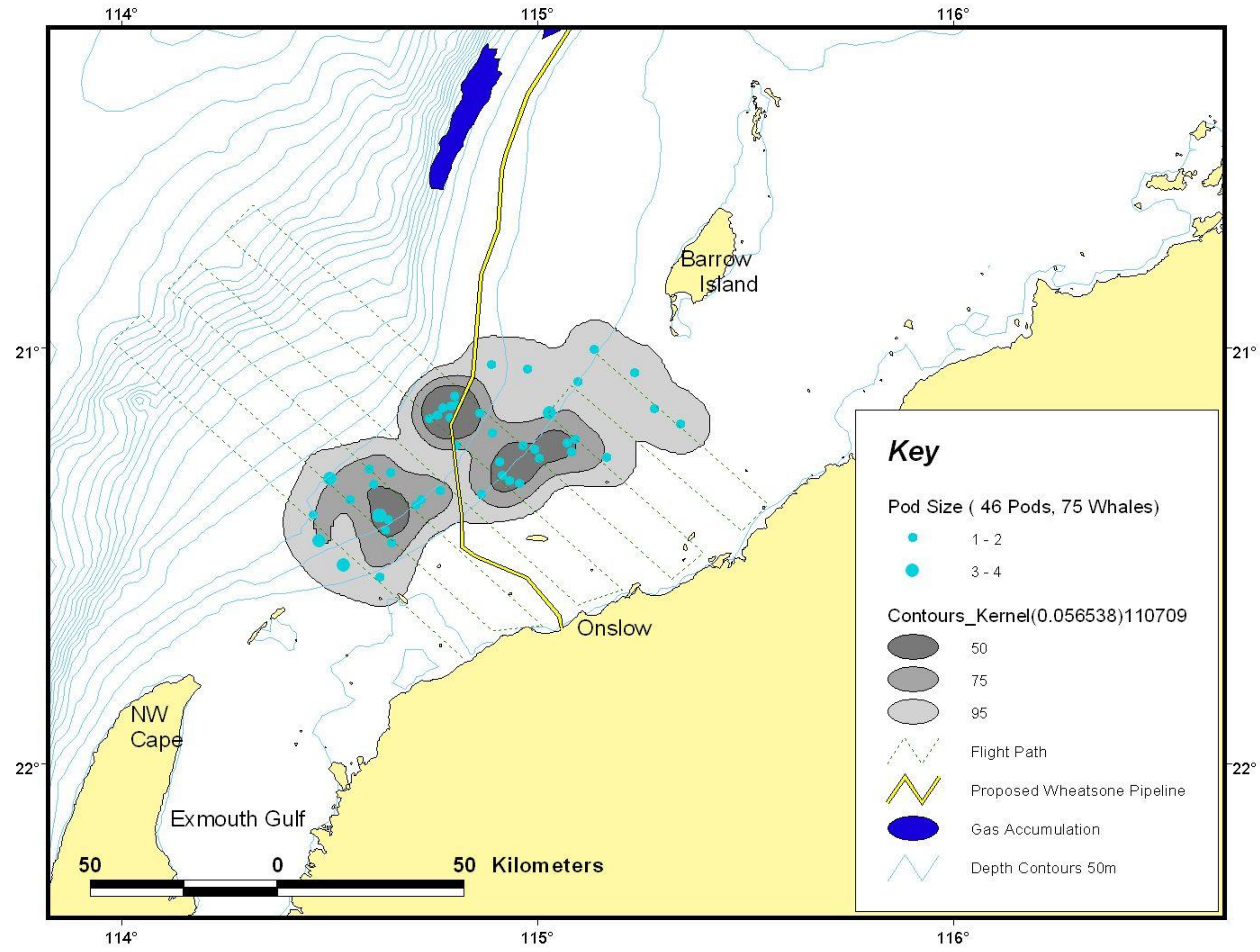

Figure 13. Positions of humpback whale pods sighted on July 11, 2009, with relative density distribution polygons.

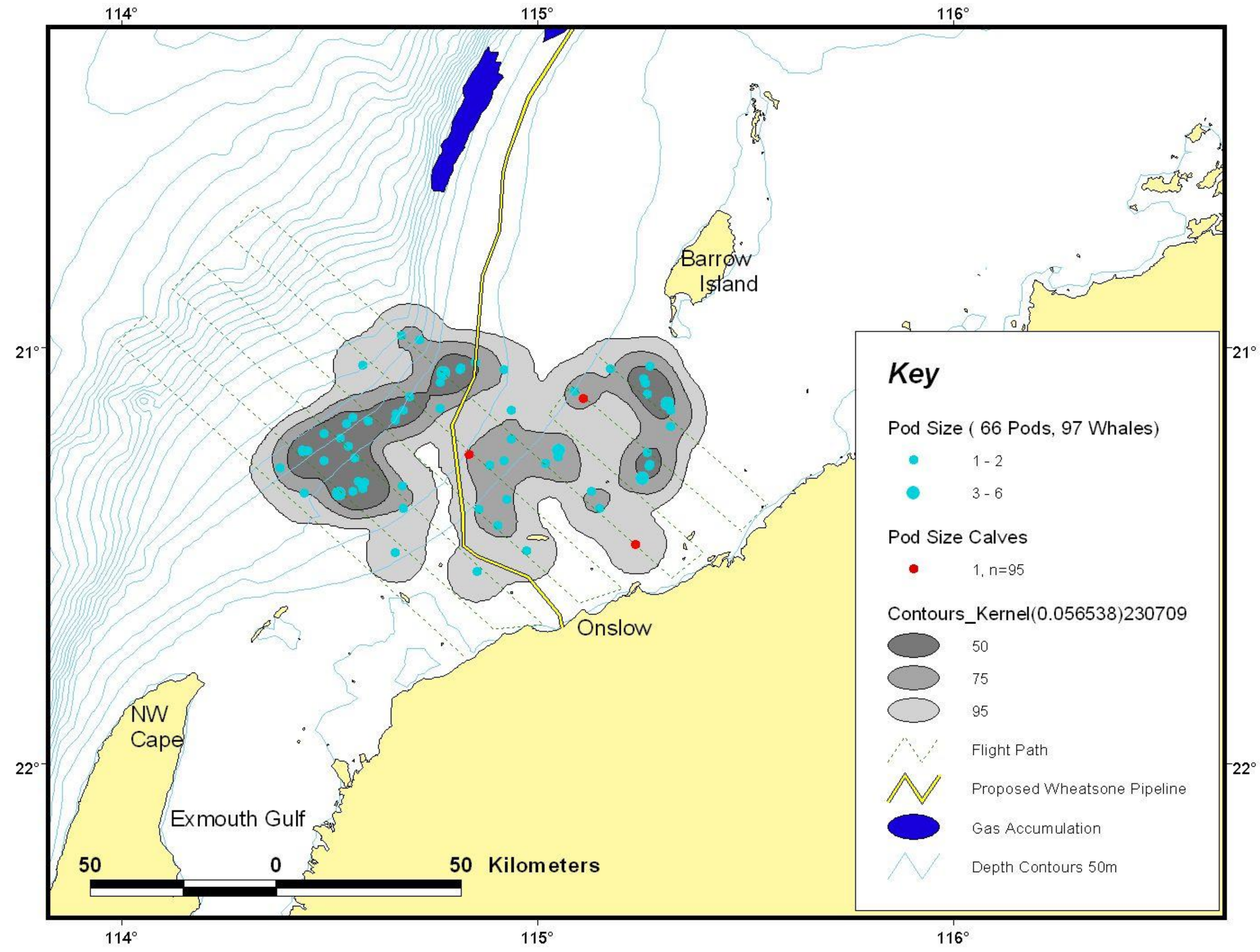

Figure 14. Positions of humpback whale pods sighted on July 23, 2009, with relative density distribution polygons.

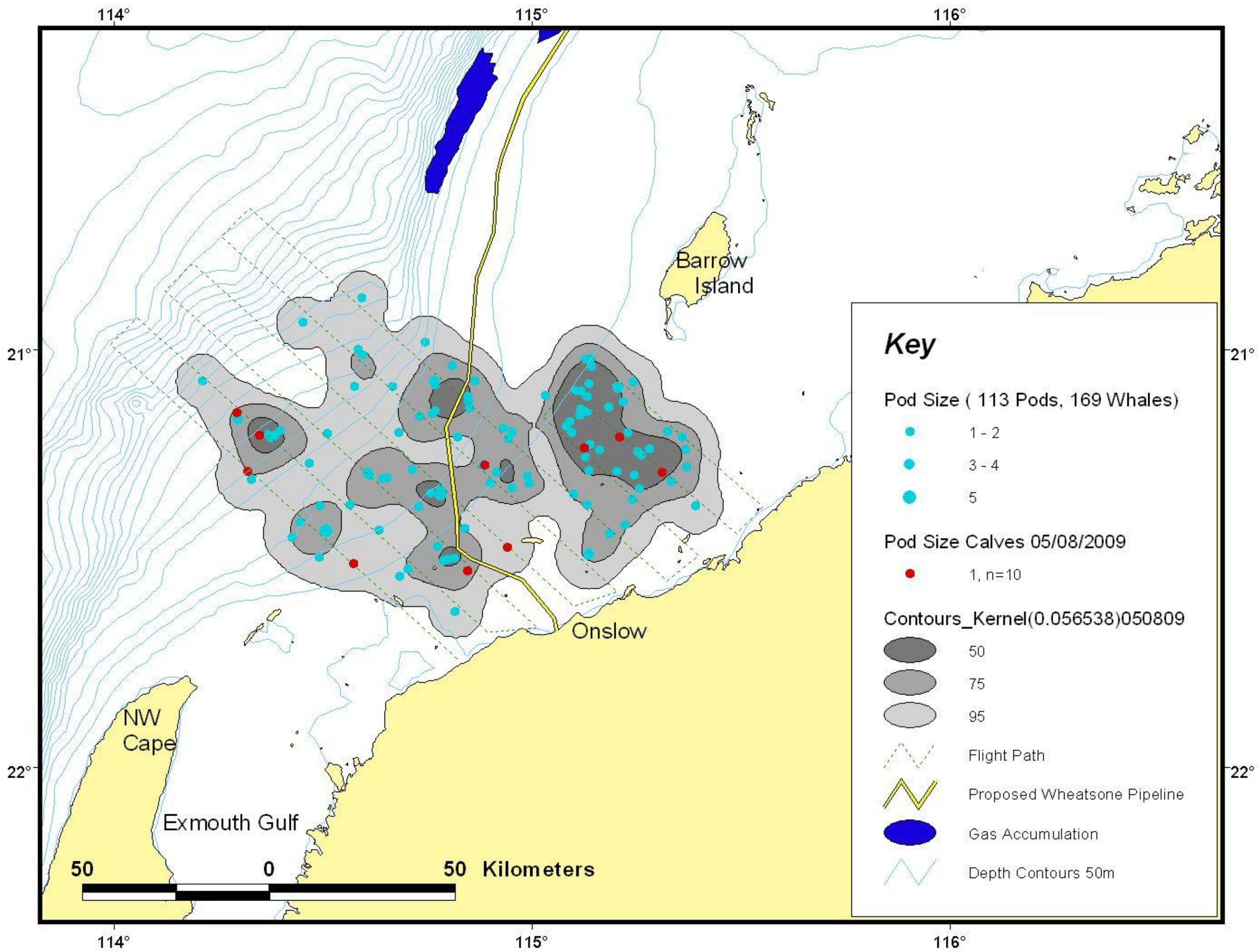

Figure 15. Positions of humpback whale pods sighted on August 5, 2009, with relative density distribution polygons.

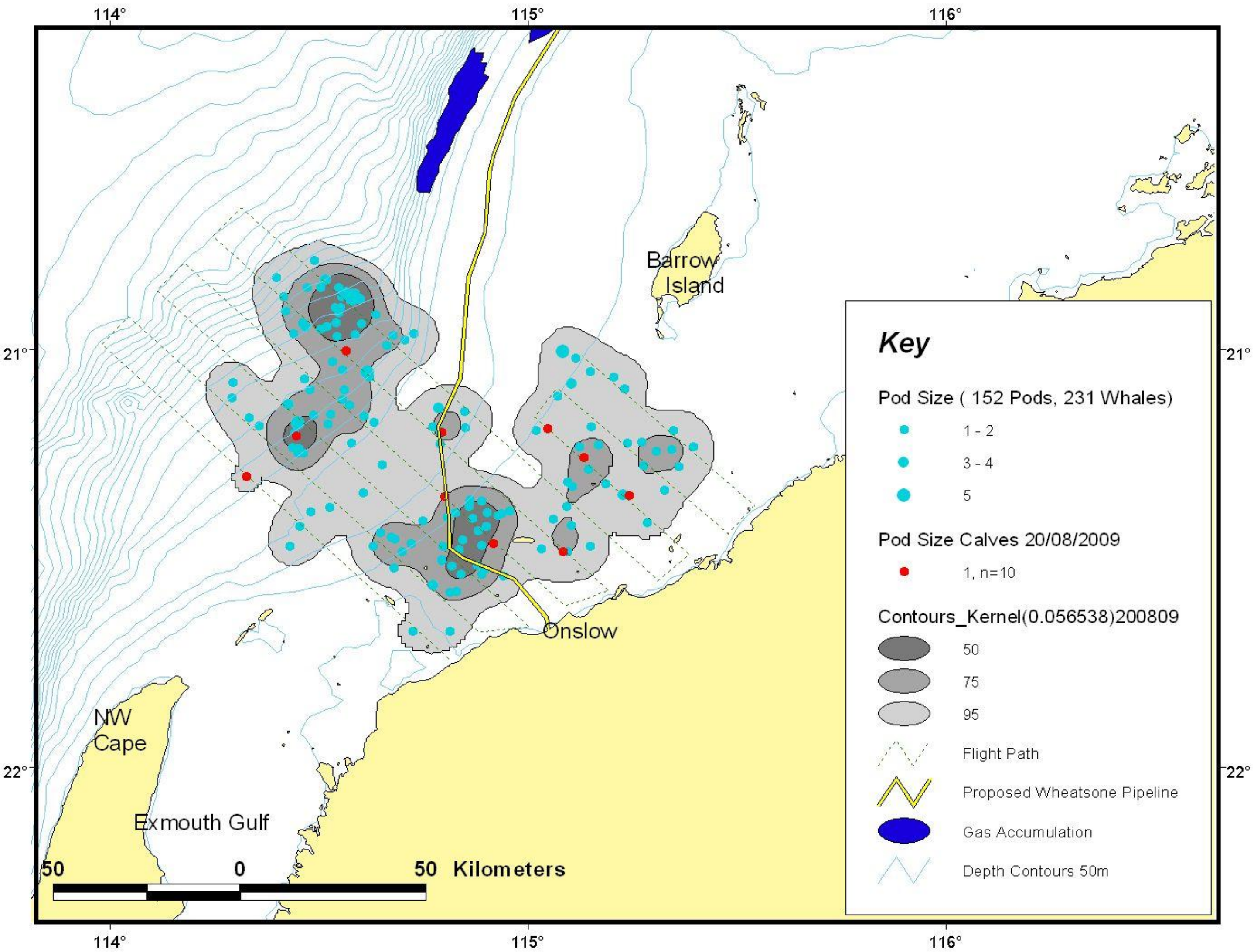

Figure 16. Positions of humpback whale pods sighted on August 20, 2009, with relative density distribution polygons.

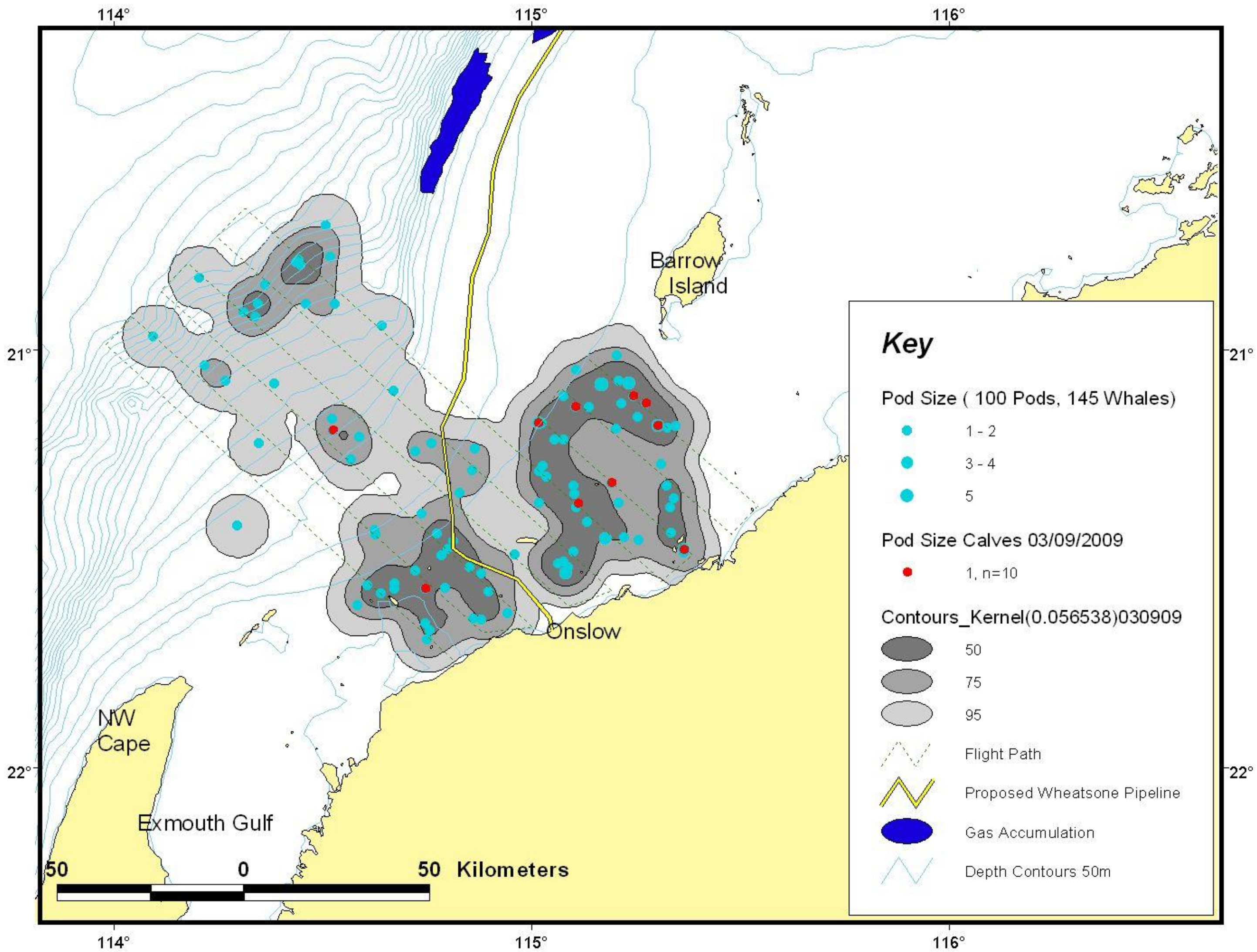

Figure 17. Positions of humpback whale pods sighted on September 3, 2009, with relative density distribution polygons.

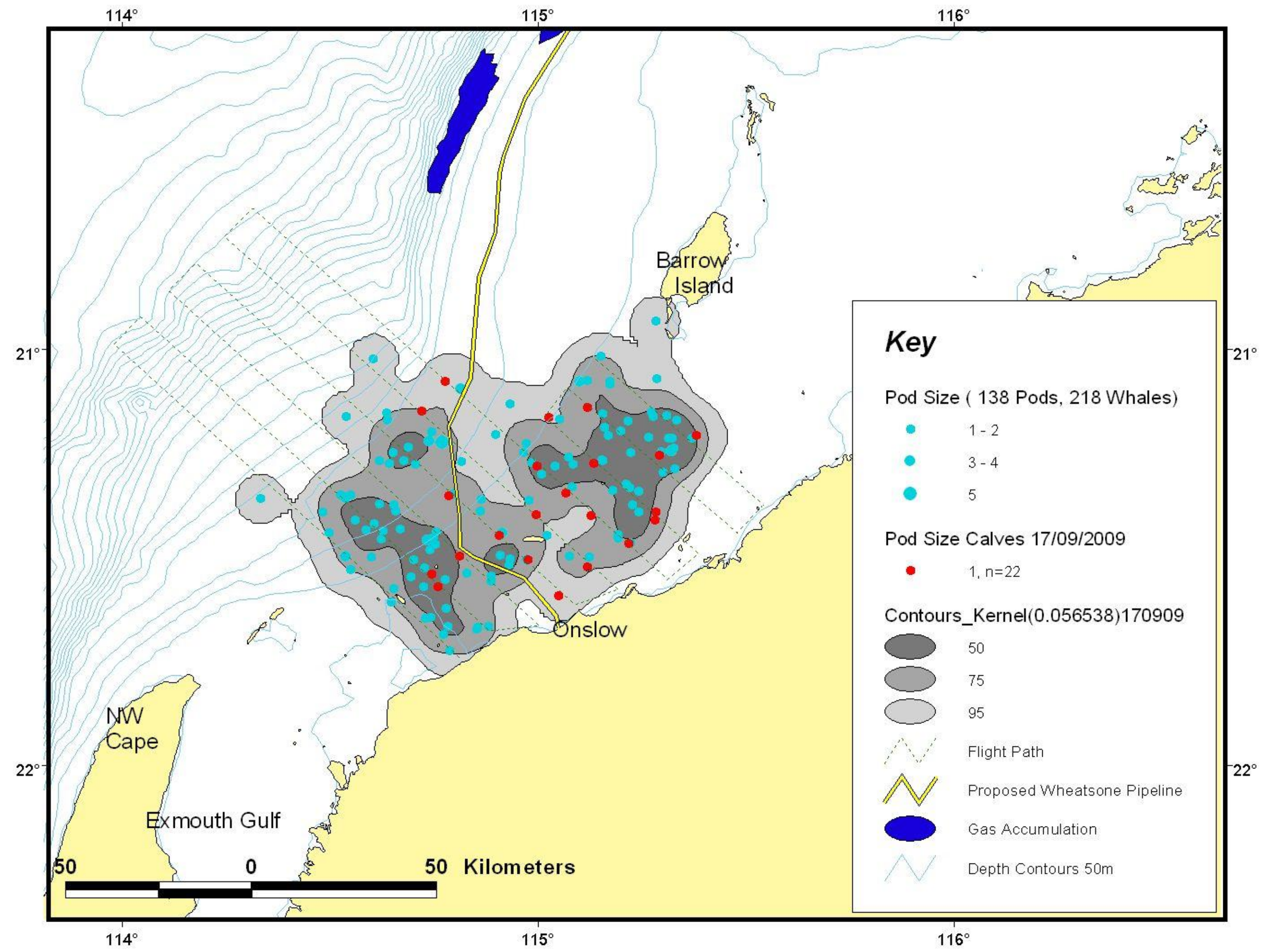

Figure 18. Positions of humpback whale pods sighted on September 17, 2009, with relative density distribution polygons.

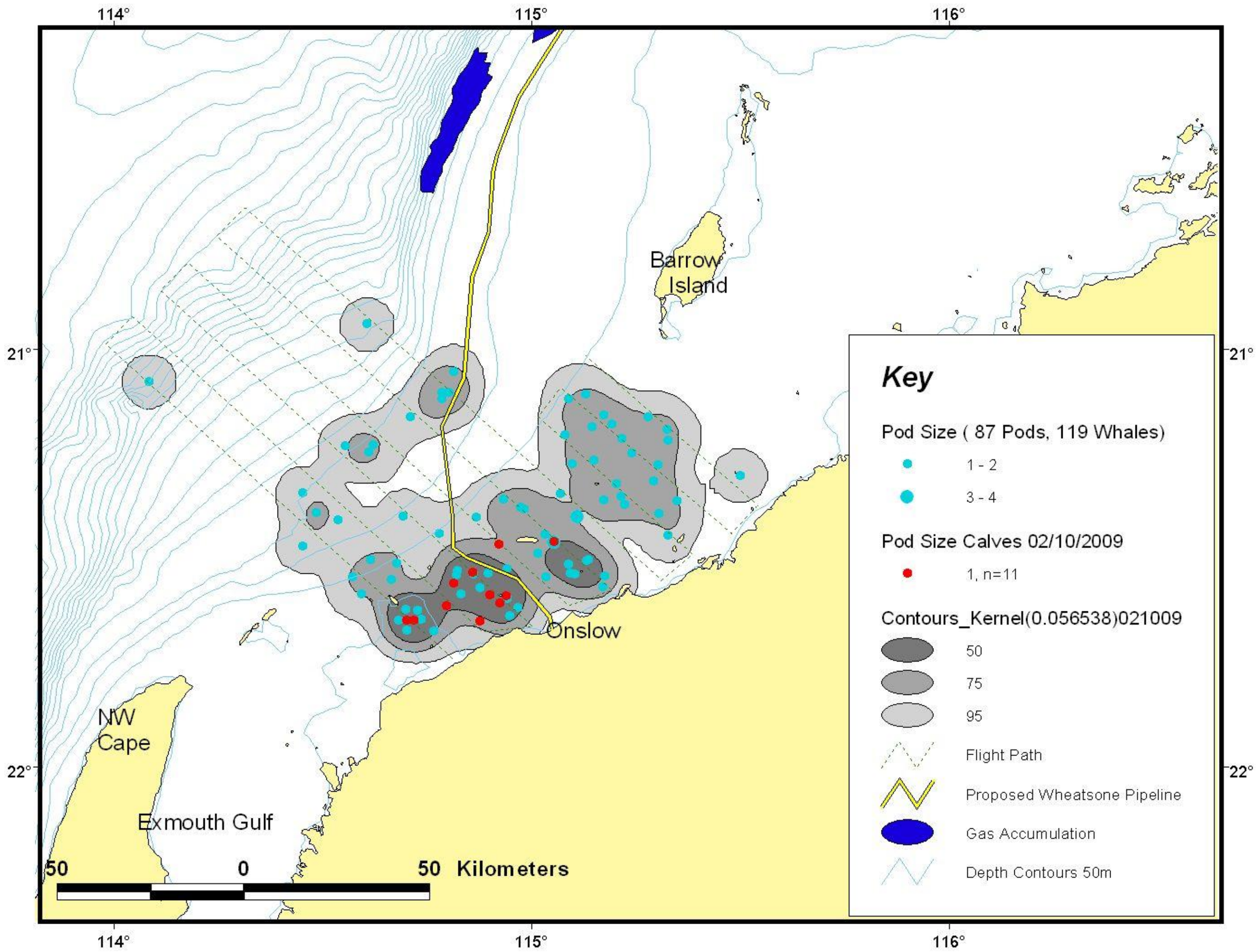

Figure 19. Positions of humpback whale pods sighted on October 2, 2009, with relative density distribution polygons.

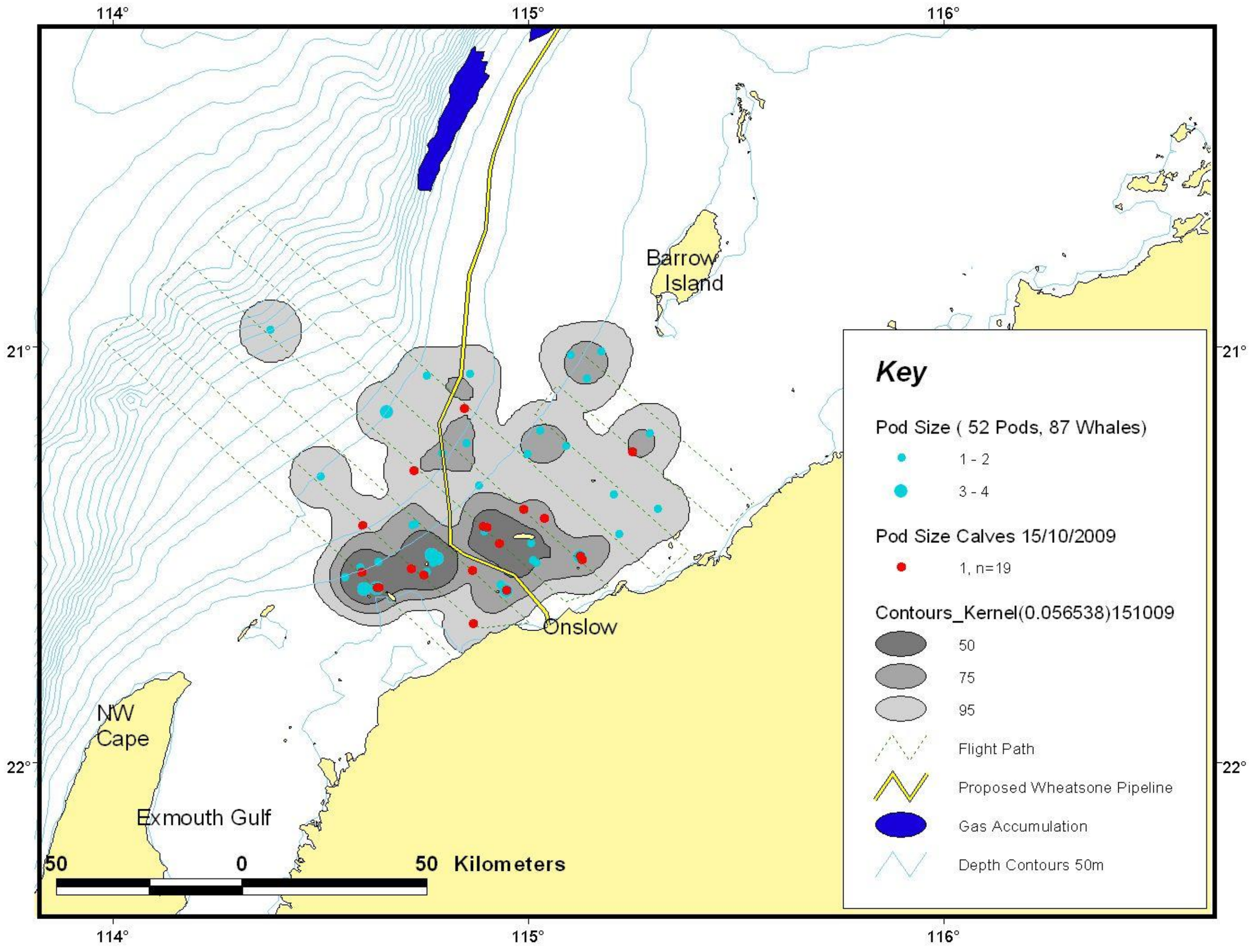

Figure 20. Positions of humpback whale pods sighted on October 15, 2009, with relative density distribution polygons.

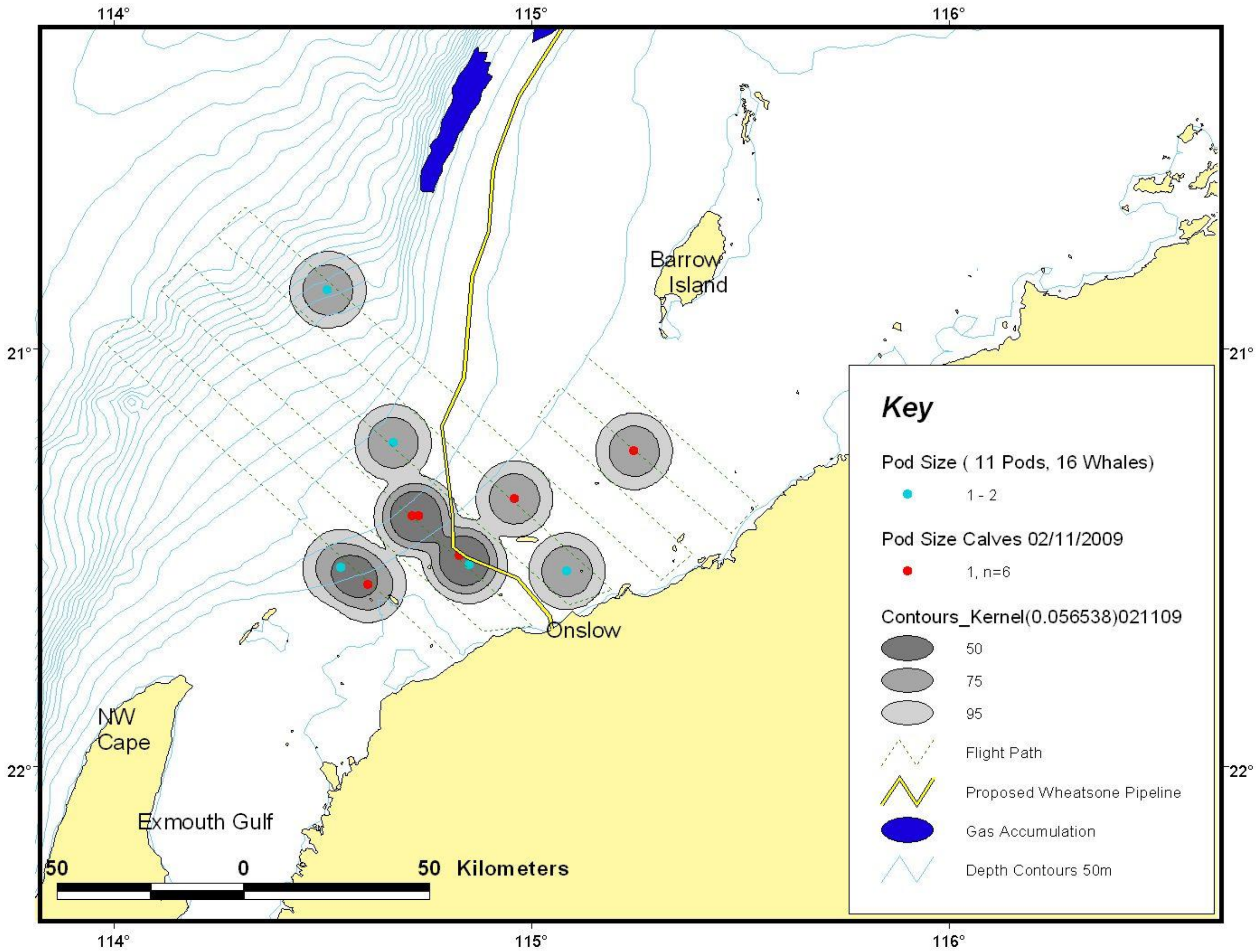

Figure 21. Positions of humpback whale pods sighted on November 2, 2009, with relative density distribution polygons.

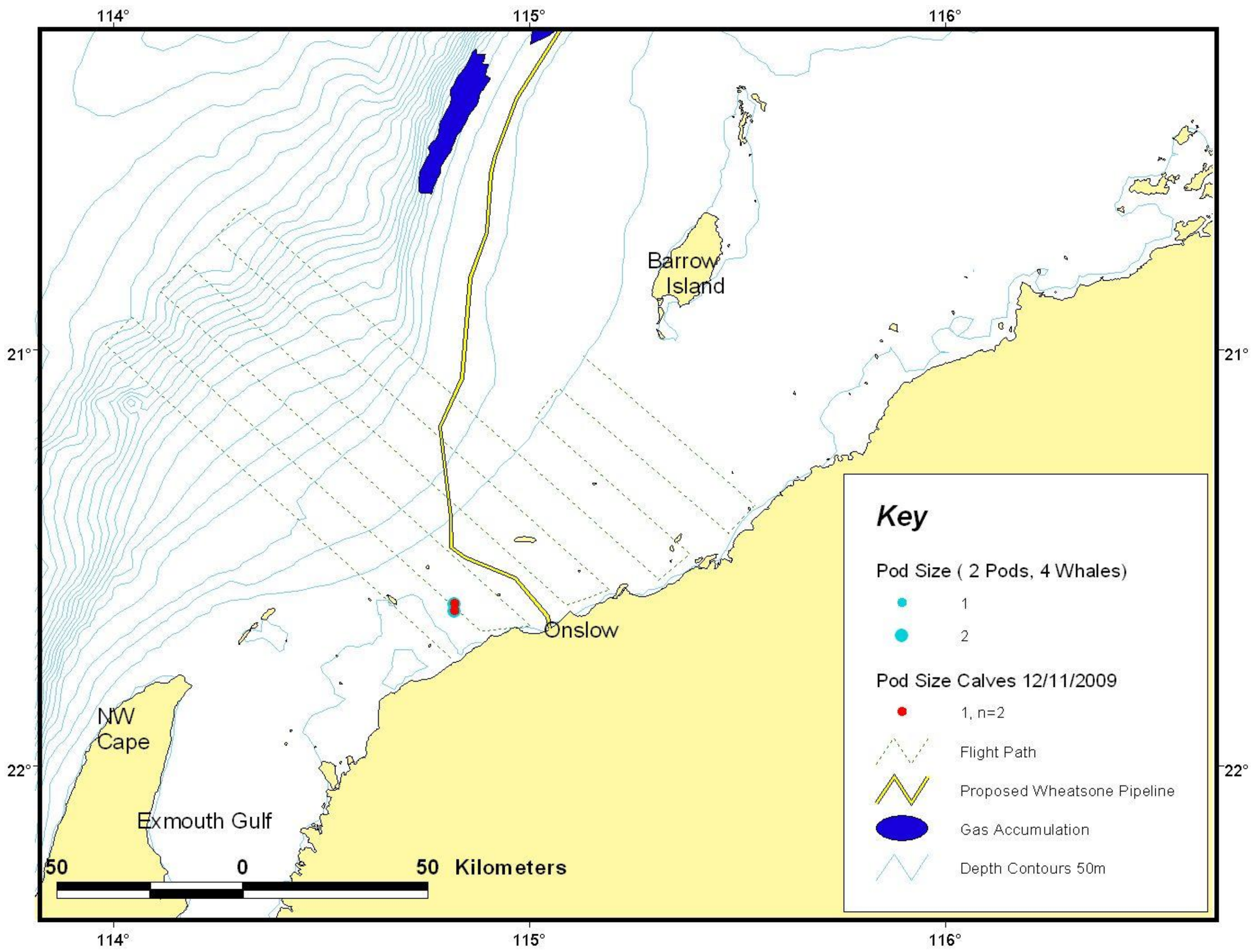

Figure 22. Positions of humpback whale pods sighted on November 12, 2009.

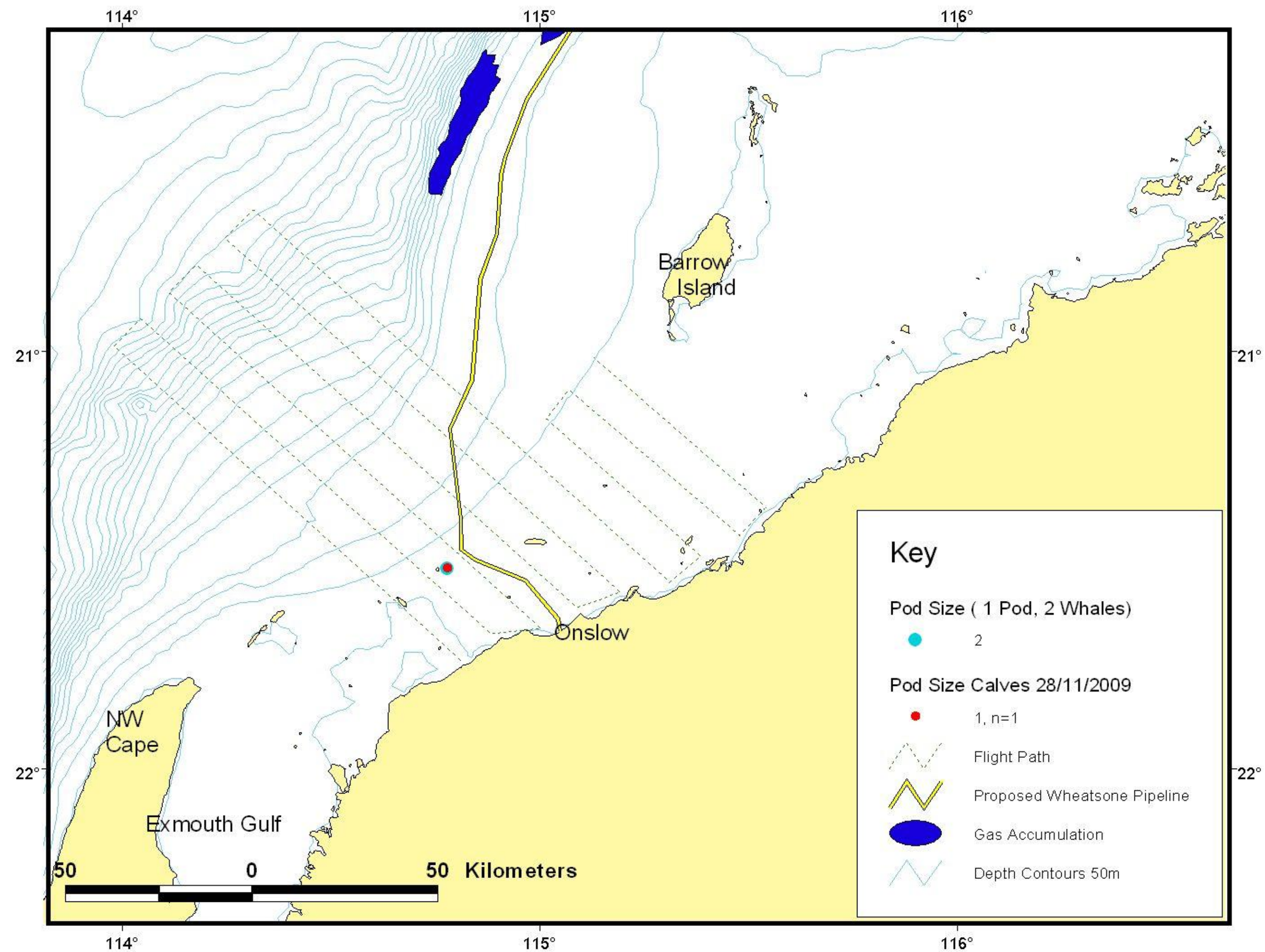

Figure 23. Positions of humpback whale pods sighted on November 28, 2009.

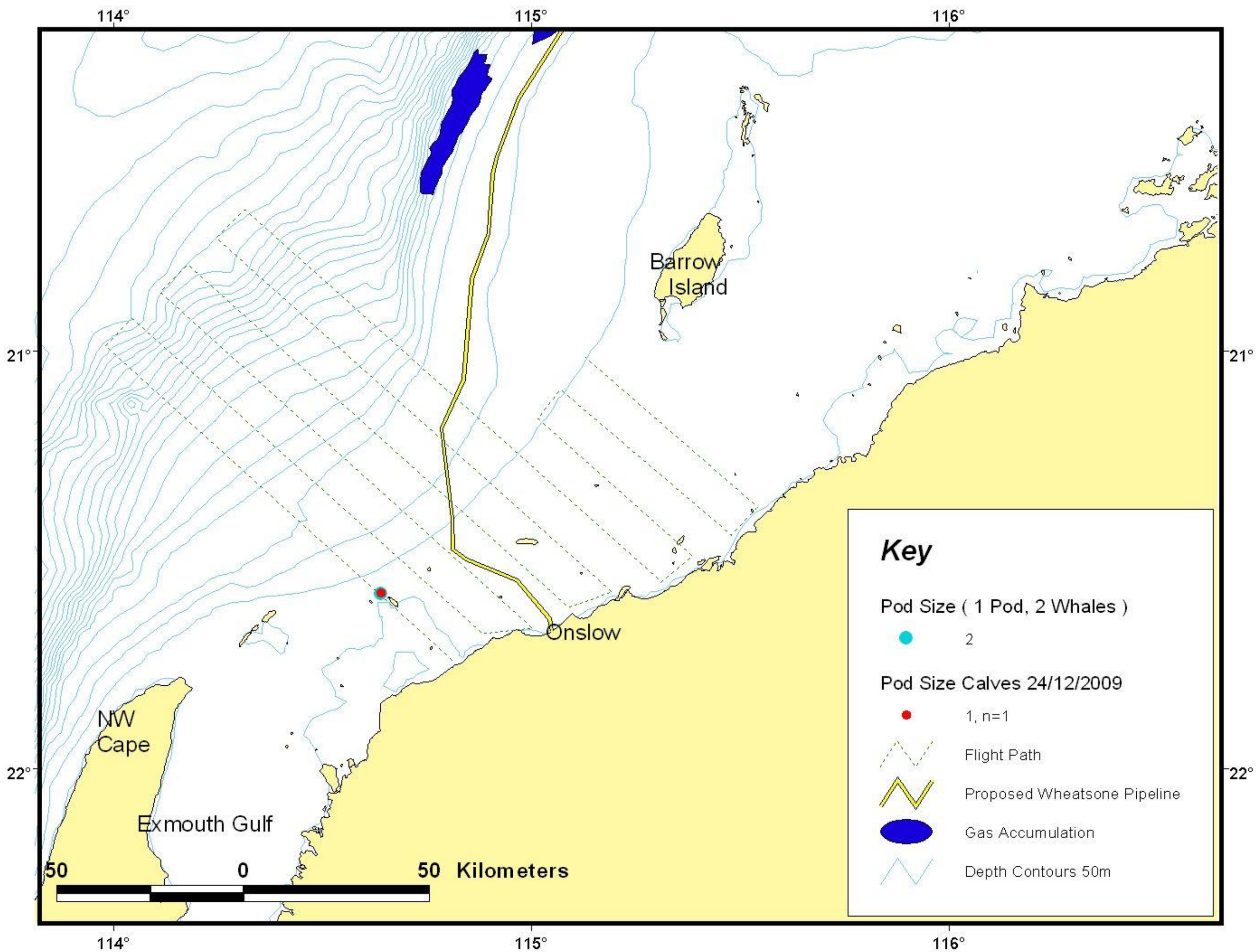

Figure 24. Positions of humpback whale pods sighted on December 24, 2009.

Migratory direction changed from being predominantly northbound in the study area, to predominantly southbound, in mid August between flights on the 5th and 20th of August 2009 (Figure 25). Higher proportions of resting/milling pods were sighted during the southern migratory phase than during the northern phase.

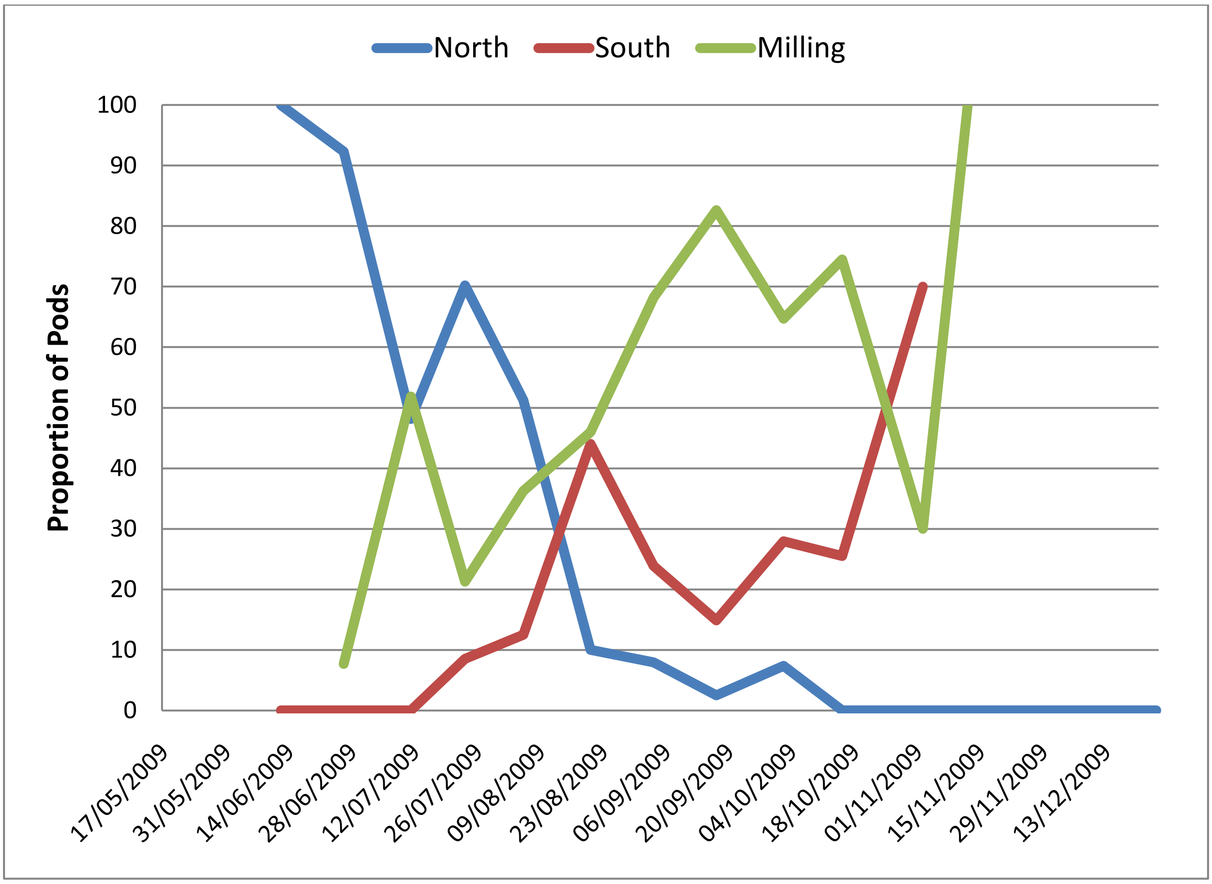

Figure 25. Proportion of humpback whale pods sighted swimming northbound, southbound or milling during the June 12 to December 24, 2009, time period.

Whales sighted during the northern migration period (prior to August 20, 2009) were sighted an average of 49.1 km (±1.0 SE, n=257) offshore while during the southern migration (after August 20, 2009) whales were an average of 35.9 km (±1.2, n=392) offshore. Whales sighted on August 20, the peak of season in terms of sightings numbers, were significantly further offshore than during both the northern or southern phases (mean = 55.6 km ±2.4 SE, n=152).

Swim direction during the northern migratory phase was consistently northbound while peak of season contained approximately equal proportions of southbound and milling whales (Figures 26 and 27). The southern migration was mostly made up of milling/resting pods (Figure 28). Cow/calf pods were also mostly resting and in less than 50m water depth (Figure 29).

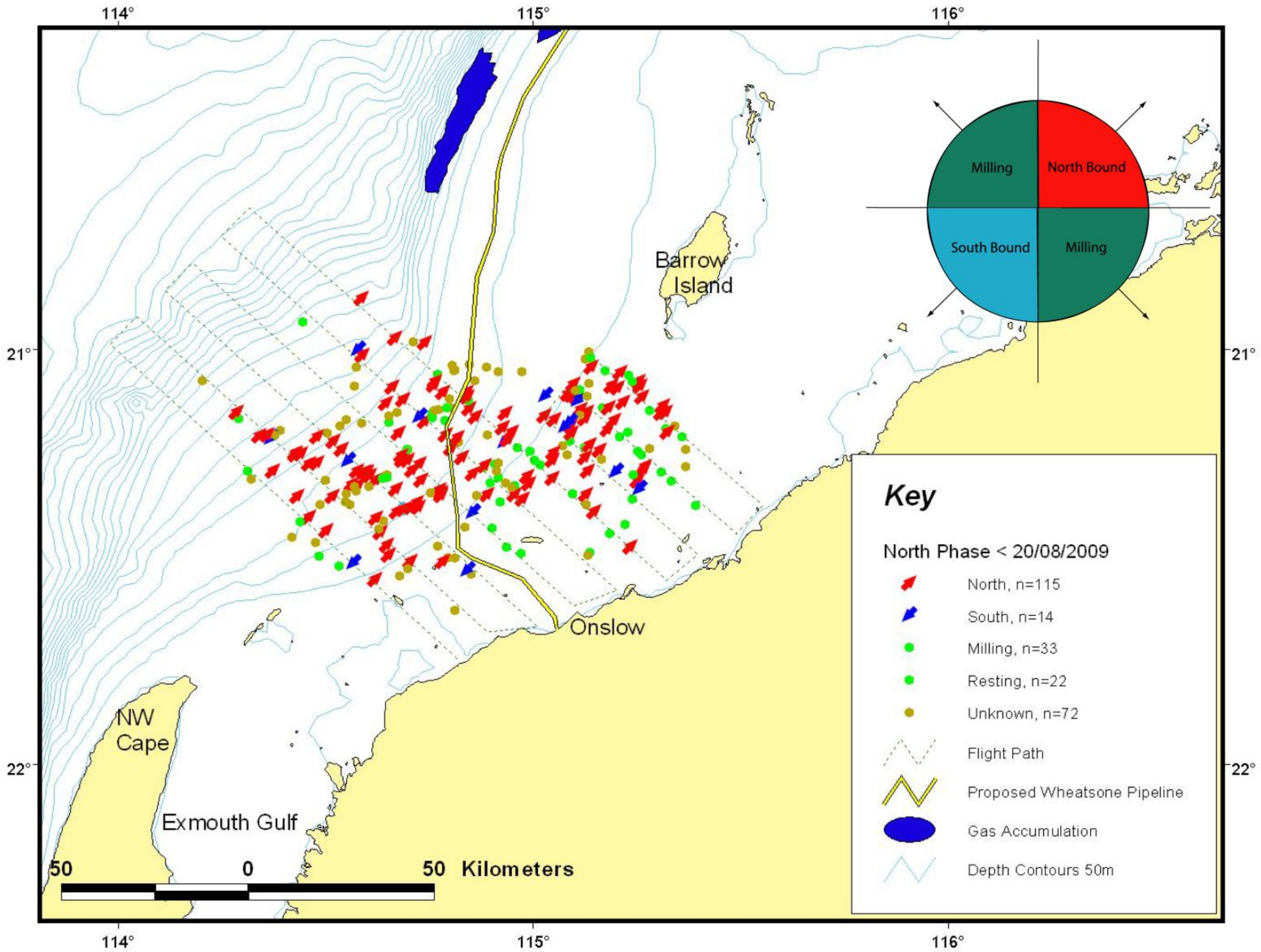

Figure 26. Swim direction with proportions reported for humpback whale pods sighted during the northern migratory phase (June 12 – August 5, 2009)

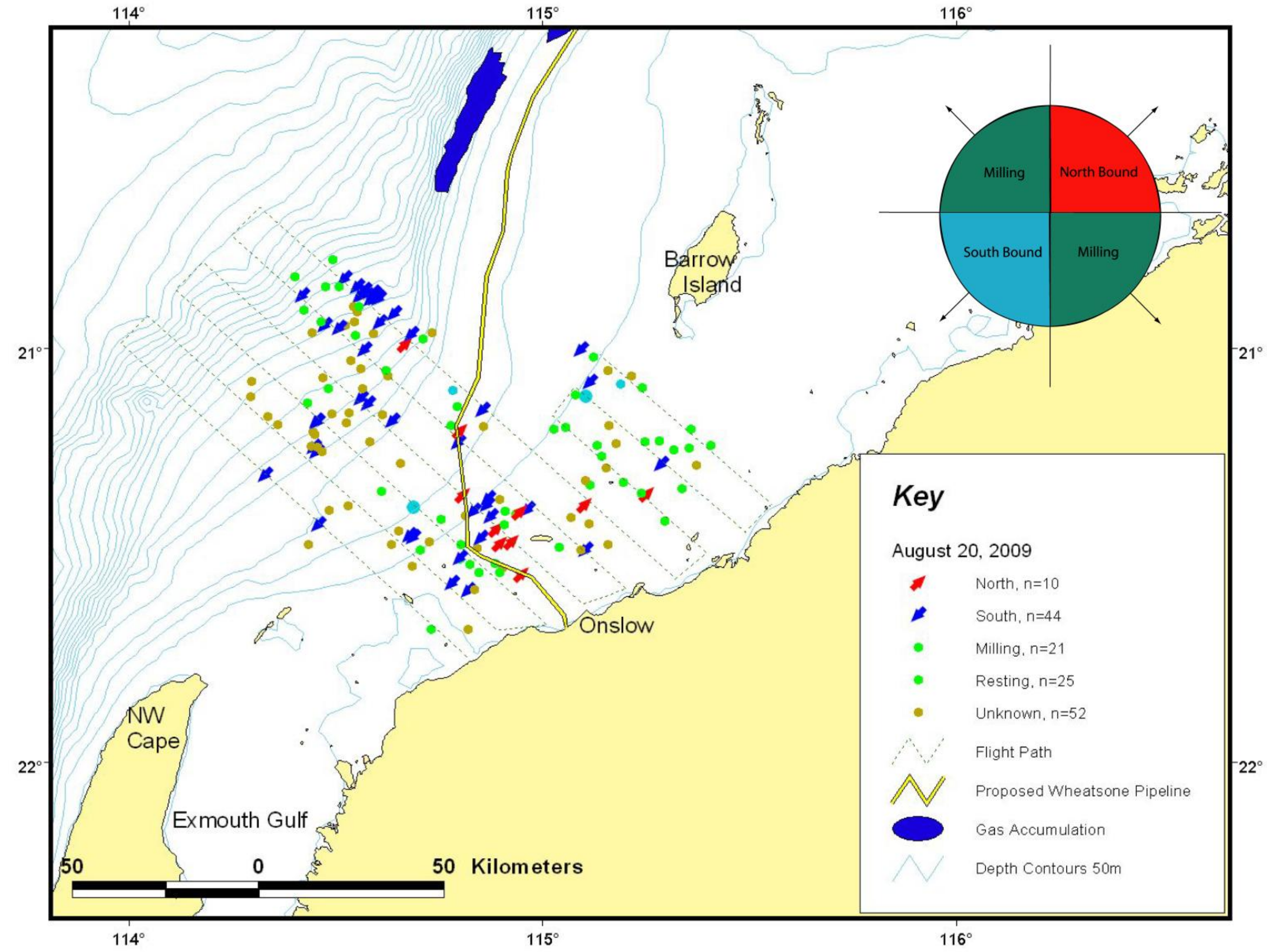

Figure 27. Swim direction reported for humpback whale pods sighted during the peak of migration (August 20, 2009)

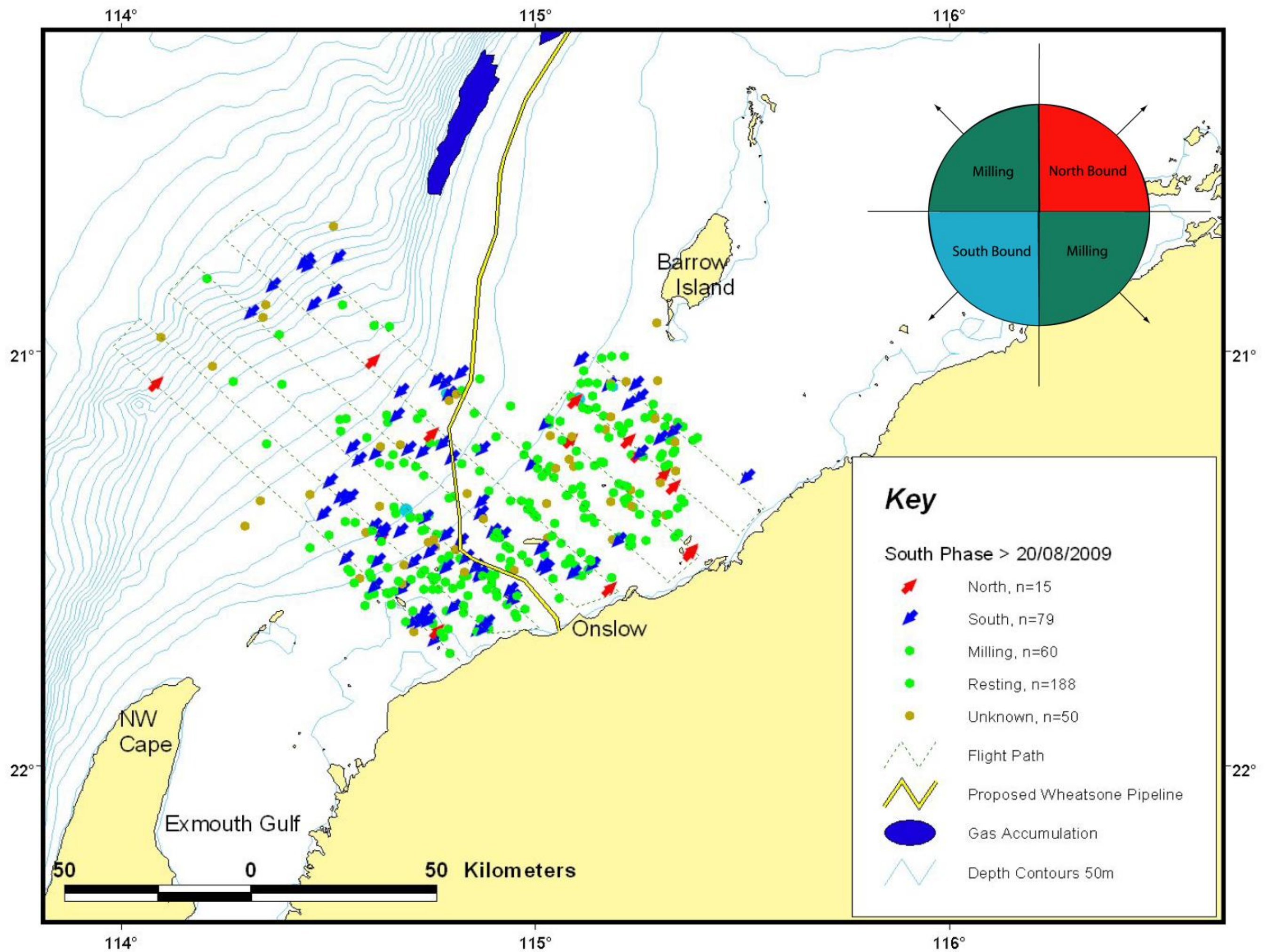

Figure 28. Swim direction reported for humpback whale pods sighted during the southern migratory phase (September 3 to December 24, 2009)

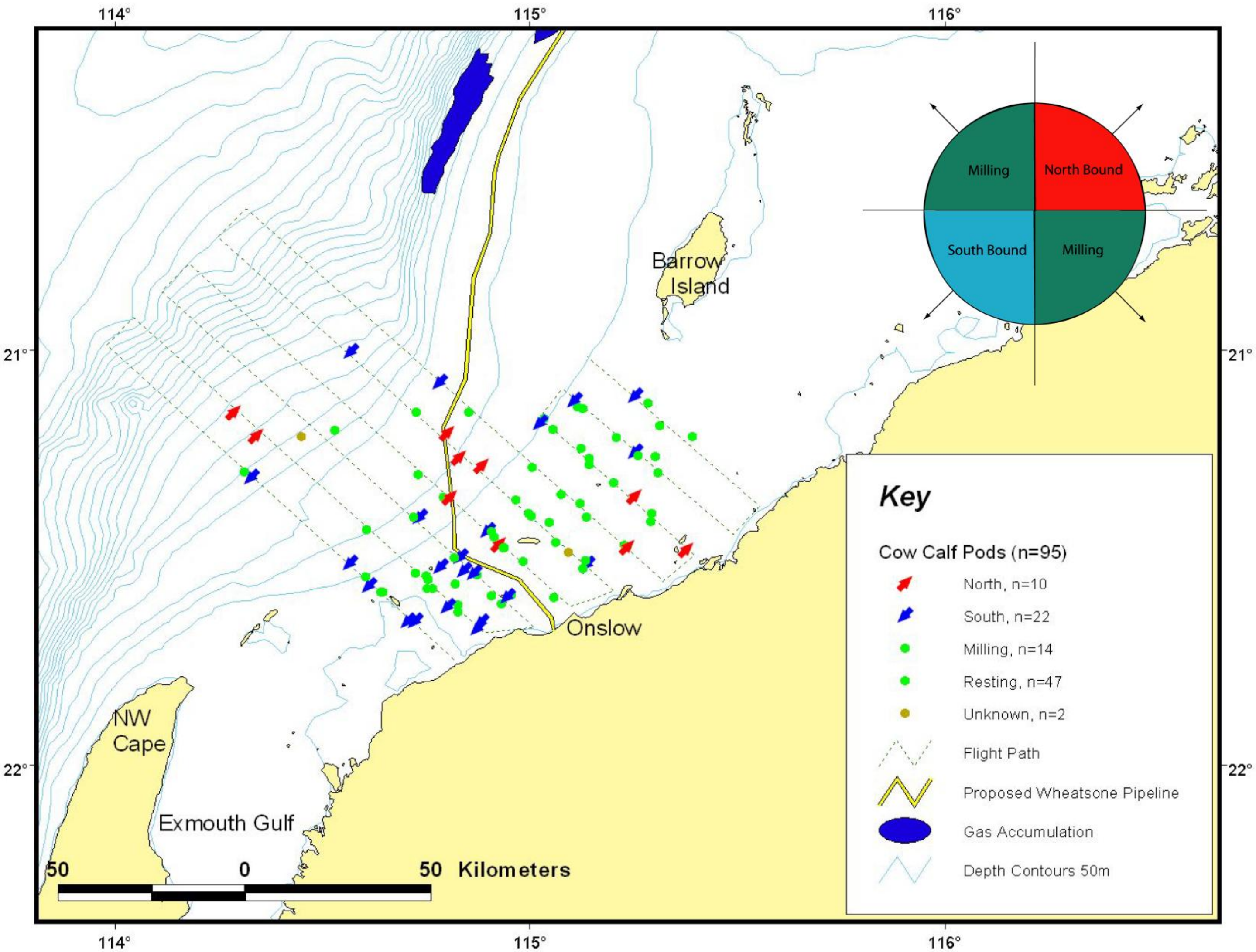

Figure 29. Swim direction reported for humpback whale pods with calves sighted during all flights from June 12 to December 24, 2009

5.4 Other Megafauna

5.4.1 Dugongs

Dugongs were sighted throughout the study period and peaked in late June (Figure 30). A total of 169 dugongs were sighted over the May 17, 2009 to April 29, 2010, time period. Herds containing cow/calf pairs accounted for approximately 12% (12/98) of all sightings (Appendix 3). Dugongs were predominantly sighted in the southwestern portion of the study area in water depths less than 10m (Figure 31).

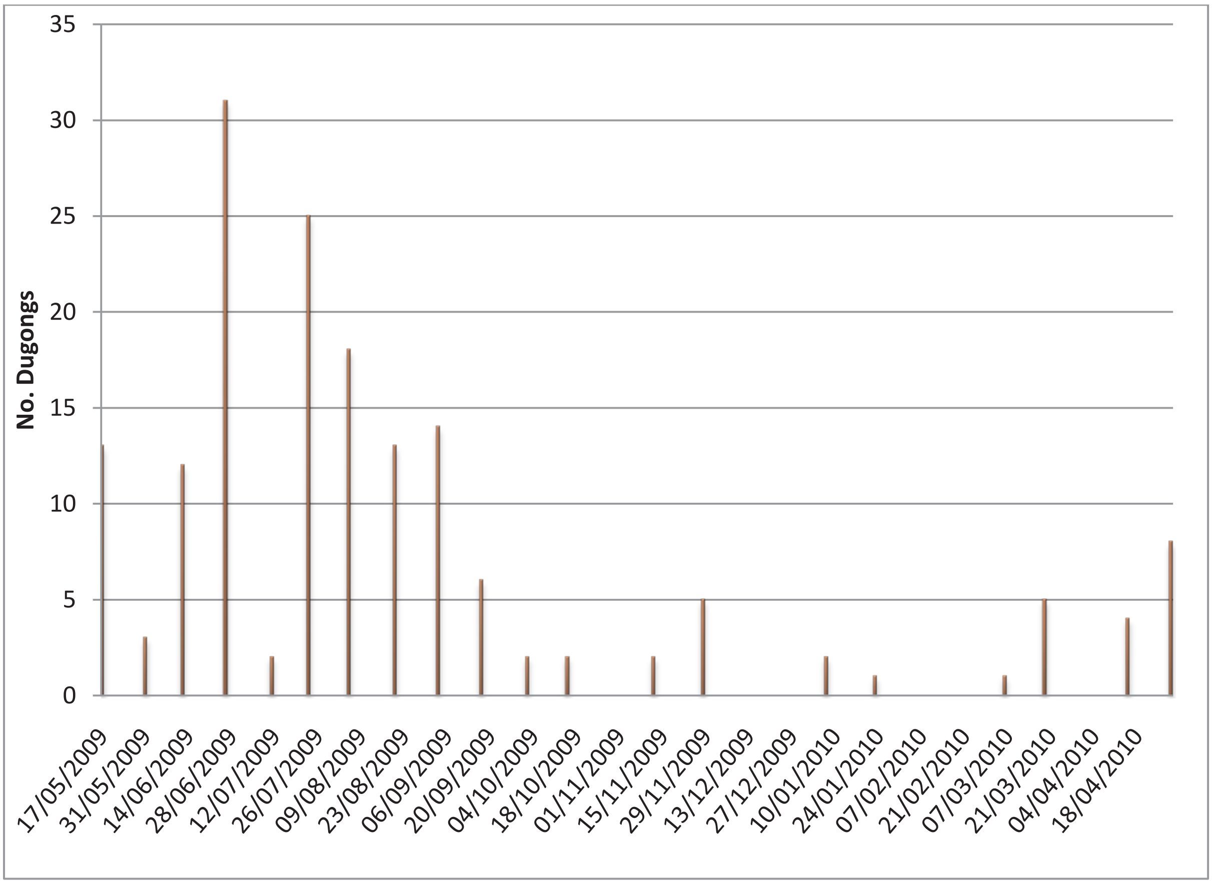

Figure 30. Numbers of Dugongs sighted during each flight from May 17, 2009 to April 29, 2010.

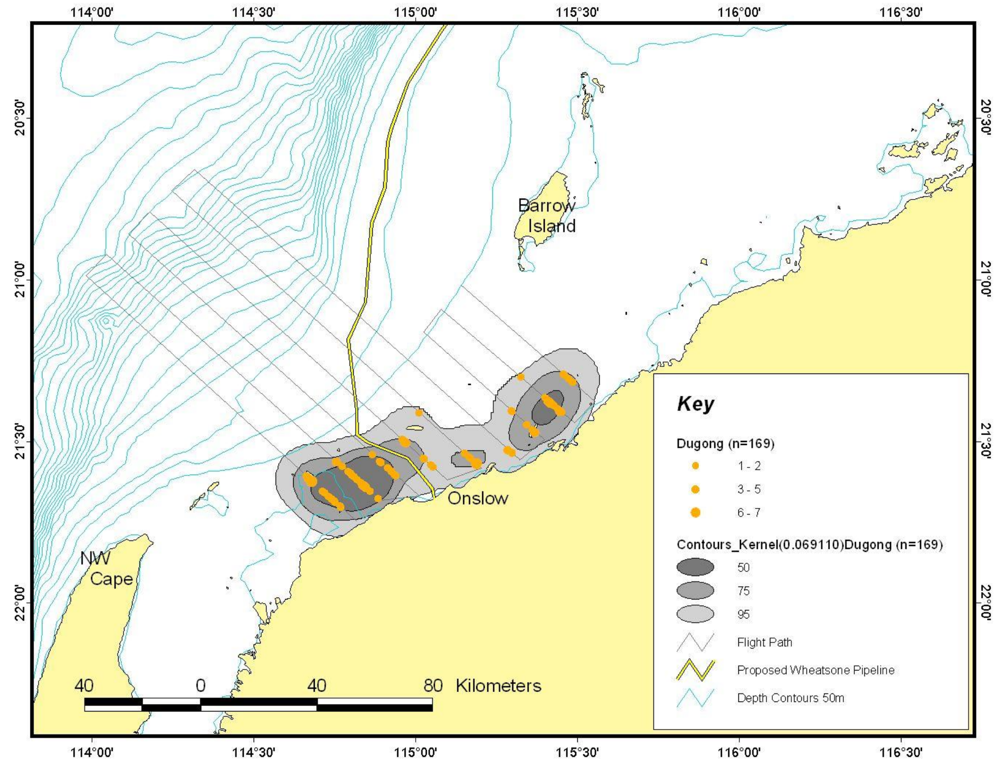

Figure 31. Distribution and relative density of Dugong herds sighted from May 17, 2009 to April 29, 2010.

5.4.2 Dolphins

Dolphins are likely to either be nearshore (< 50m) species including *Tursiops spp*., *Sousa chinensis or Orcaella spp.* and the offshore species may include *Tursiops spp.* and *Stenella spp. (*Jenner and Jenner, unpublished data), however sightings were not identified to species level due to difficulty in identification. Dolphins were sighted during each flight during the May 2009, to April 2010 period except during three flights spanning late December to late January and during two flights in early to mid April (Appendix 3). A total of 1681 dolphins were sighted with a peak numbers observed during the May 31 flight (Figure 32). Only 16 calves were sighted throughout the survey period although sightings of dolphin calves must be considered to be difficult in all but ideal conditions. Spatially, dolphins were predominantly sighted in the southwestern portion of the study area in water depths less than 50 m, although larger pods (>100 individuals) were sighted offshore (Figure 33).

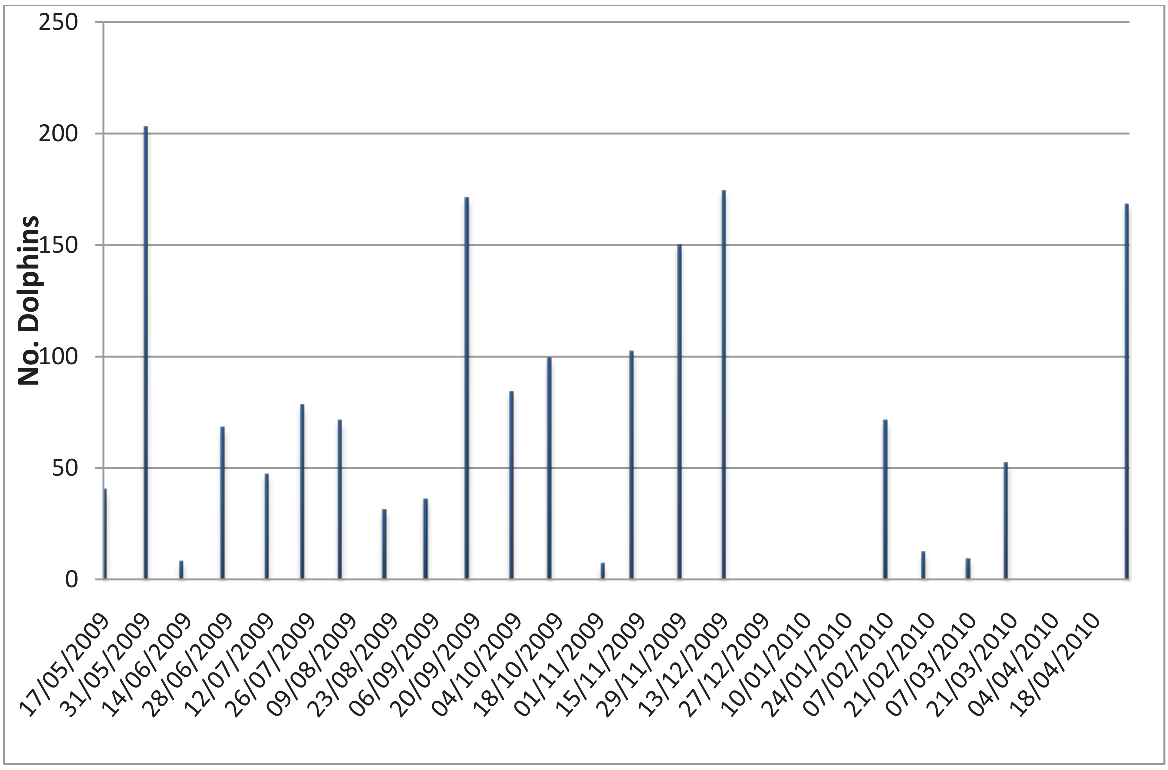

Figure 32. Numbers of dolphins sighted during each flight from May 17 to July 23, 2009.

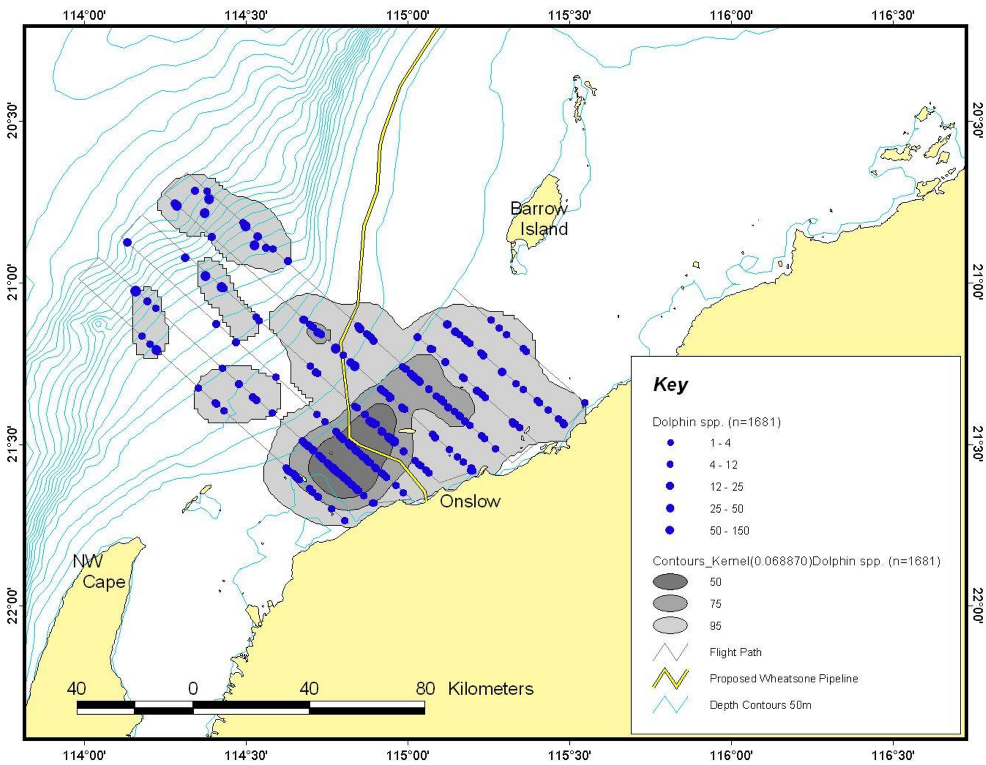

Figure 33. Distribution and relative density of dolphin species sighted from May 17, 2009 to April 29, 2010.

5.4.3 Other Cetaceans

Other cetacean species sighted included pygmy blue whales, killer whales, sperm whales, pilot whales and minke whales (Figure 34). Pygmy blue whales were sighted in two distinct time periods, November and December, 2009, (11 whales)and in April, 2010, (four whales) (Table 1) in depths between 250m and 900m. A pair of fast swimming unidentified whales, possibly Brydes' or minke whales, were sighted in July, 2009, and five large unidentified whales were sighted in mid-November, 2009. Sperm whales (n=14) were logging at the surface when sighted over the continental slope, as were the pilot whales (n=25). Dwarf minke whale sighted on June 26 and August 5, 2009, were swimming steadily northeast.

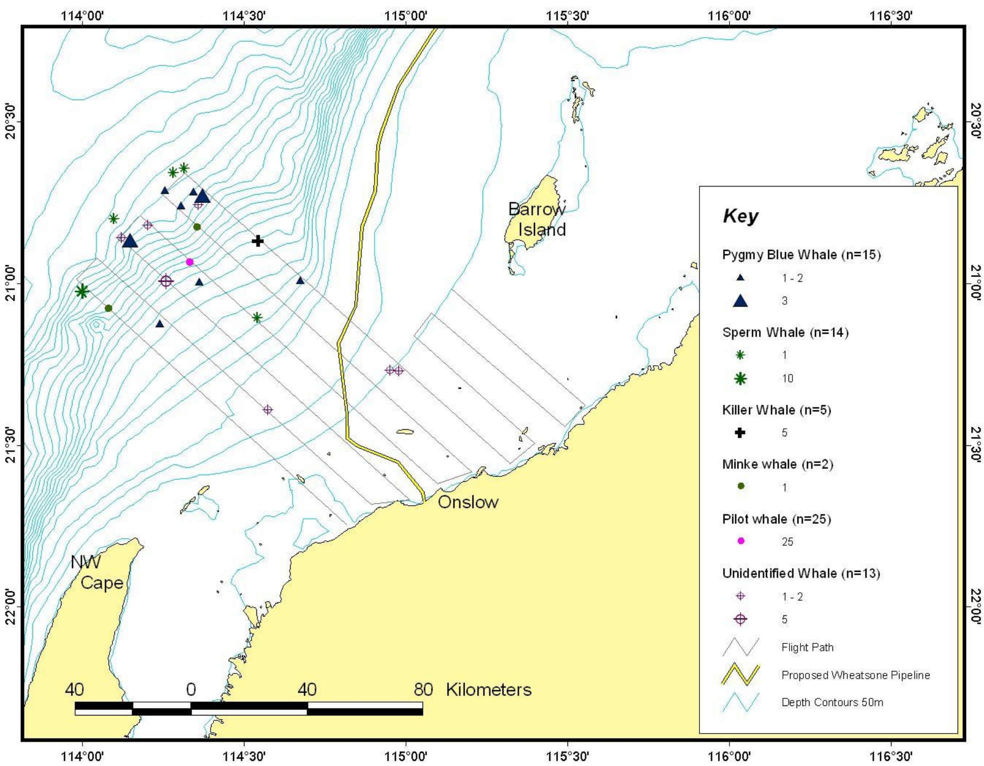

Figure 34. Distribution of other cetacean species sighted from May 17, 2009 to April 29, 2010.

5.4.4 Turtles, Rays and Whale sharks and Krill

Turtles could not be identified to species level at the time of sighting. Boat based sightings by CWR from previous surveys suggest that the principle turtle species in the near shore Exmouth Gulf region during the May to November period is the green turtle (*Chelonia mydas)*. However, hawksbill turtles (*Eretmochelys imbricata*) are frequently sighted in mangrove creeks and loggerhead (*Caretta caretta*) and flatback (*Natator depressus*) turtles have also been sighted in CWR surveys between 2000 and 2009 (CWR unpublished data). Manta rays (*Manta birostris*) were distinguished from other rays by their distinctive shape although it is possible that other species of bottom dwelling rays were mistaken for mantas along the mangrove creek areas. Whale sharks (*Rhincodon typus*) are unique in shape and size and are commonly sighted and identified using aerial surveys (i.e. Ningaloo whale shark tourist industry) so misidentification is considered unlikely.

Turtles were sighted during each of the 26 flights while manta rays were sighted during 21 of the 26 flights (Table1). A single whale shark was sighted during the May 17, 2009, flight and no further whale sharks were sighted until mid November when two animals were sighted, followed by another single animal in mid December.

Turtles were predominantly located inside the 50m bathymetry line (Figure 35). Manta rays were more broadly and sparsely distributed and were sighted in highest densities near the 50m depth contour as well as nearshore, in the eastern-most section of the flight path, at an area known as the Mangrove Islands (Figure 36).

Krill swarms were sighted in shallow waters (<50m) during several months and at times in association with krill predators such as whale sharks and manta rays (Figure 36).

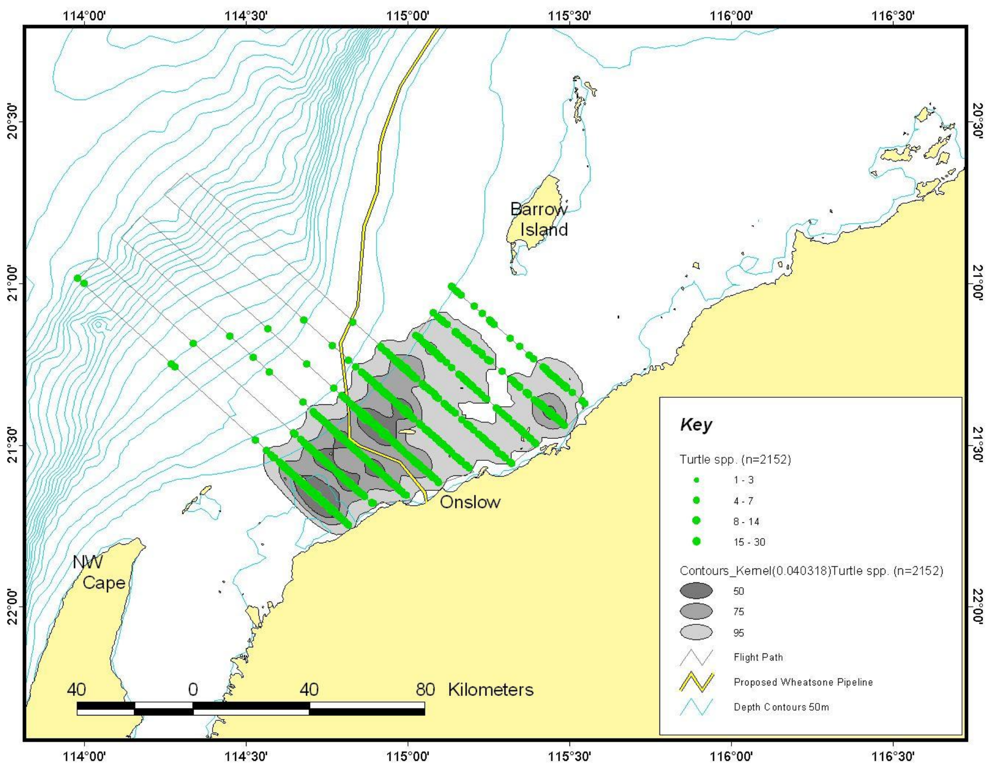

Figure 35. Distribution and relative abundance of turtle species sighted from May 17, 2009 to April 29, 2010.

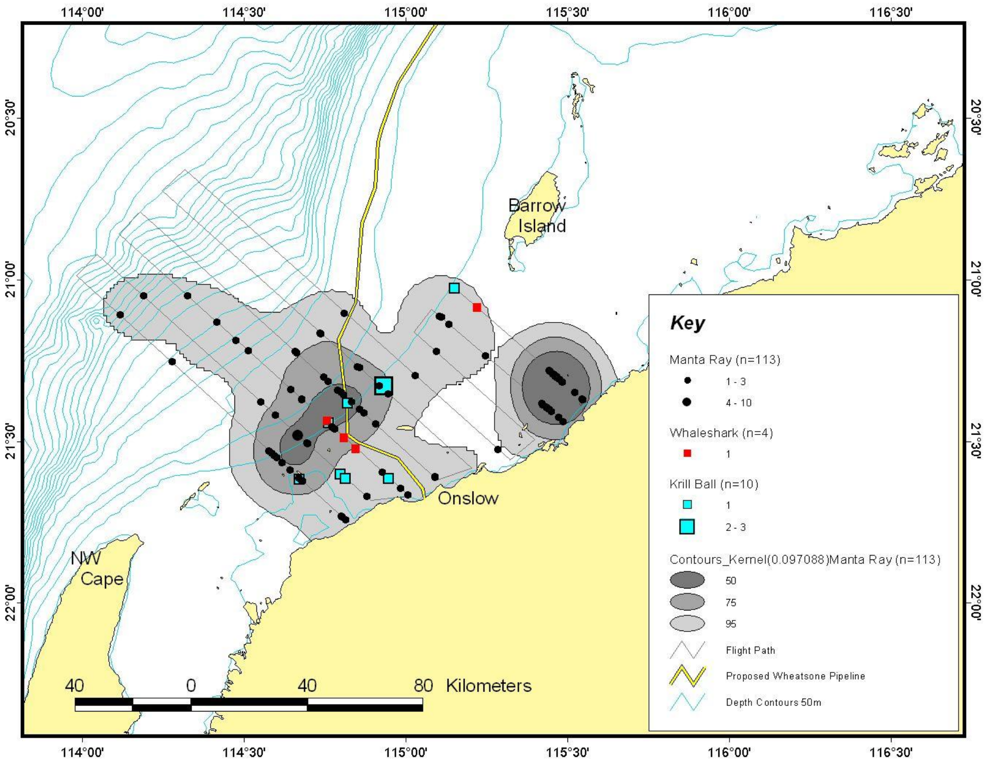

Figure 36. Distribution and relative abundance of manta rays and distribution of whale sharks and krill swarms sighted from May 17, 2009 to April 29, 2010.

5.4.6 Vessels

A total of 728 vessels and other man-made structures (drill rigs, storage platforms, ships, small vessels, aqua culture nets, etc.) were sighted during the mid May to late April 2010 period (Table 1). Although “home range” calculations for vessels are not biologically meaningful, the application of consistent density distribution mapping techniques to demonstrate high usage areas justifies its use here. The majority of vessels were sighted in water depths less than 50m and focussed around the Thevenard Island area where a large number of oil and gas production and storage facilities are located (Figure 37). Of note was a seismic survey that was ongoing from mid-June until late July, 2009. In general there was more vessel activity during winter months than summer months (Figure 38).

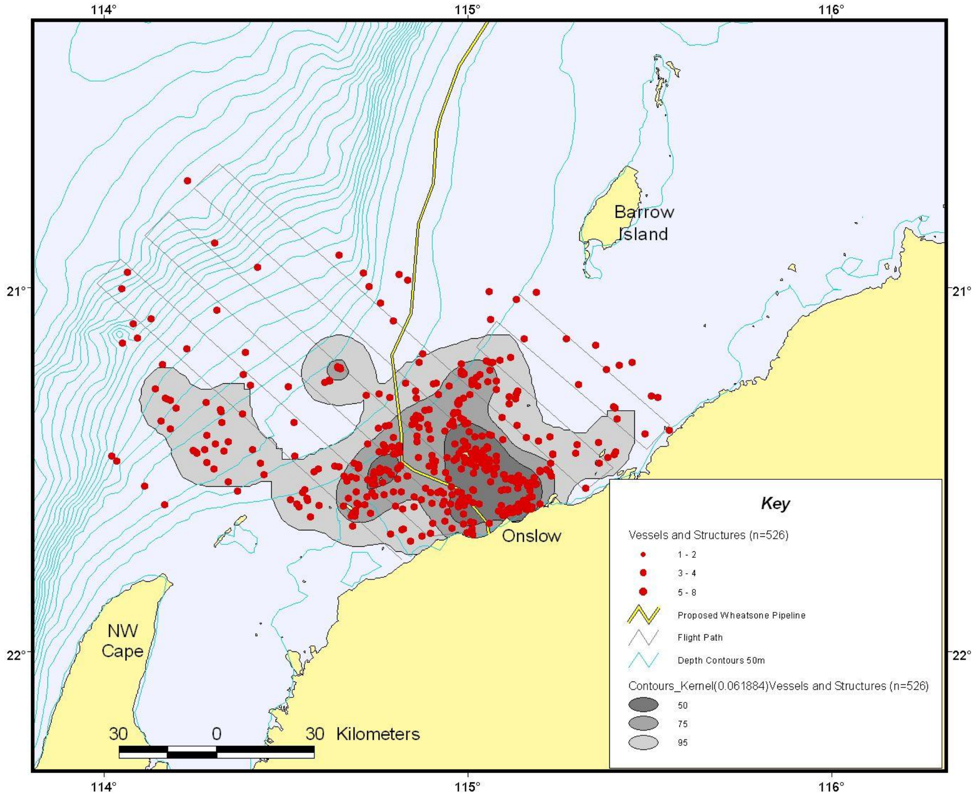

Figure 37. Distribution and relative abundance of vessels and man-made structures during the May 17 to December 24, 2009 period.

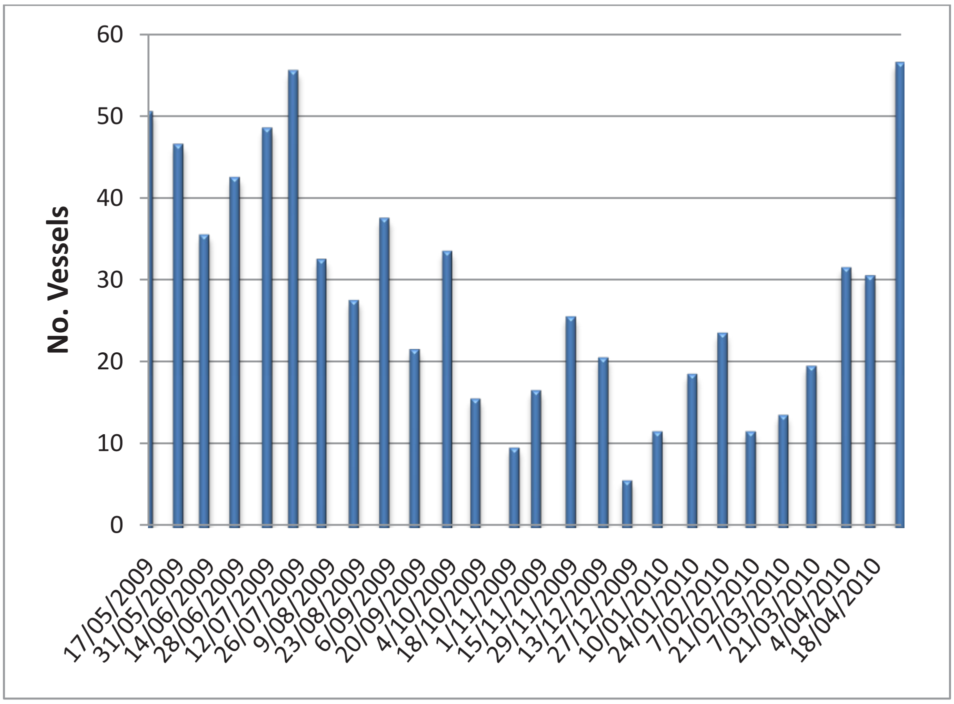

Figure 38. Numbers of vessels and man-made structures sighted per flight from May 17, 2009 to April 29, 2010.

6. Discussion

This report summarises a study program carried out from May 17, 2009 to April 29, 2010, in the South West Pilbara offshore region using aerial surveys at approximately 14-day intervals and acoustic surveys (McCauley and Kent, 2009) from bottom mounted sea noise loggers. The results presented in this document and McCauley and Kent (2009) represent eight months of an acoustic study and a 12 month of aerial survey study period. Temporal and spatial pattern analysis for both survey types will benefit from comparisons of the complete twelve month dataset, however some useful comments can be made regarding the data collected thus far.

Detection of cetacean species using a combination of acoustic and aerial survey techniques has resulted in a reduction of knowledge gaps that typically arise using just one or the other technique. Aerial surveys alone generally suffer from lack of temporal detail and are unable to sample at night, while acoustic surveys generally suffer from lack of spatial (in shallow water) and species detail (for non-vocalising species). Here we discuss the combined datasets in the survey area during the May to December period, which substantially mitigate the short fallings of each other.

A total of seven cetacean species were identified from the study area over the 12 month study period, seven by aerial survey and four by acoustic survey. Importantly, from a management perspective, pygmy blue whales and Brydes' whales, which were not sighted in the aerial surveys in May to July, were detected in the acoustic surveys. It is useful confirmation to have positive identification of Brydes' whales from the acoustic dataset as an "unidentified cetacean" sighting on July 11 during the aerial survey was reported as either "minke or Brydes", making the classification of Brydes' more plausible. Both species are tropical baleen whale species that do not migrate to polar waters and have been identified in previous surveys in the area (Jenner and Jenner, 2005; CWR unpubl. data). Conversely, sperm whales and pilot whales were sighted in the aerial surveys but not detected in the acoustic surveys, either due to proximity or because the loggers are designed to receive predominantly low frequency sounds (higher frequency sounds such as those made by toothed whales do not propagate over long distances).

Both the acoustic surveys and the aerial surveys detected numerous seismic operations over the 12 month period. Seismic survey noise dominated the offshore acoustic dataset making species detection and identification more difficult. Previous studies have shown behavioural reactions of individual baleen whales to seismic survey (air gun) sounds (summarised in Richardson *et al.* 1995; McCauley *et al.*, 2003) however there is no information available regarding the impacts of seismic surveys on migratory herds of these animals.

The aerial survey program between May and December, 2009, has captured the complete northern and southern migratory cycle of humpback whales in this area. A northern migration changing in mid-August to a southern migration was consistent with historical datasets. The peak of season was observed during the cross-over between northern and southern migrations as has been previously described by Jenner *et al.* (in prep).

During the aerial surveys, 22% and 48% of sightings in July were reported to be resting and without migratory direction (milling), while only 28% to 9% were migrating northwards. This is an unexpected high proportion of resting and milling whales during the July time period. CWR aerial survey data from 2000 to 2005 from NWC (immediately to the southwest of the study area) indicate that 80 to 100% of sightings are typically northbound at this time of year (Jenner *et al.*, in prep). Furthermore, swim speeds are expected to be relatively high (5.1 to 7.9 km/hr for June/July, versus 4.1 to 4.5km/hr in Aug/Sept/Oct, Jenner *et al.*, in prep) at this time of year. Hence few whales are expected to be resting at this time of the year contrary to what has been observed. When viewed with similar surveys near NWC this season, the general spatial distribution of the migratory herd in this region during 2009 was compressed near NWC and focused inshore (>150m) in the Exmouth Gulf to Barrow Island area (Figure 39).

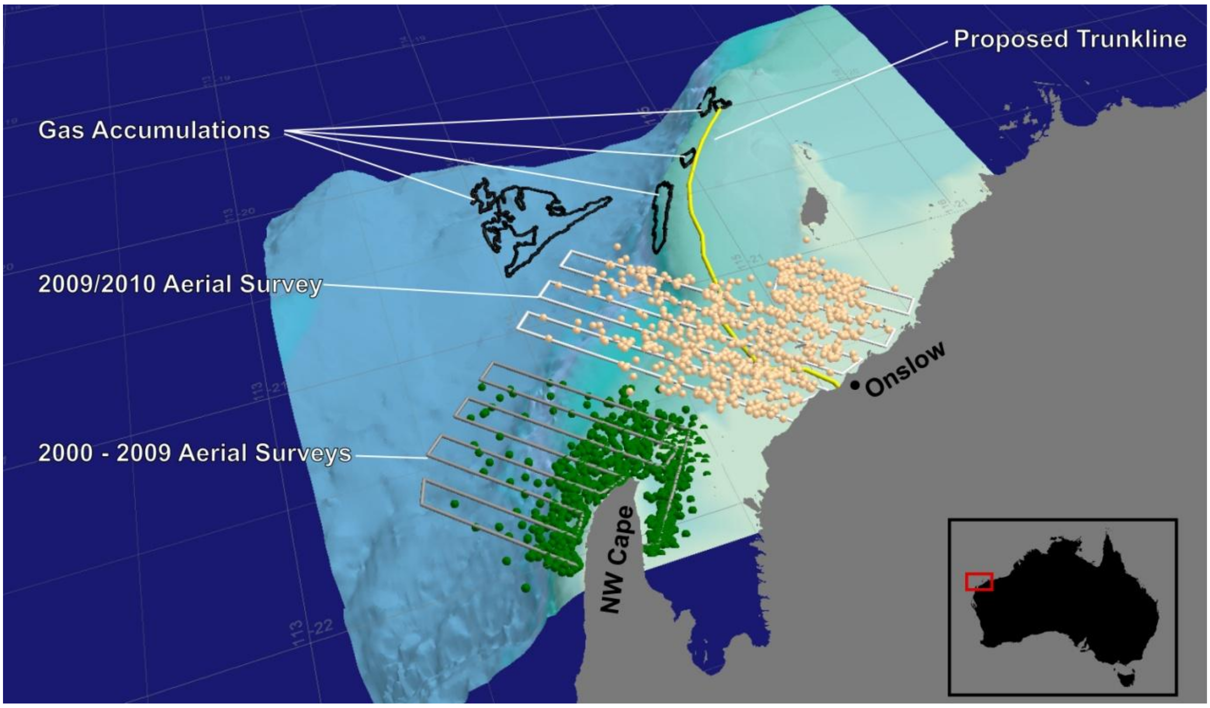

Figure 39. The 2009 humpback whale dataset (BHP Billiton green, Chevron white, CWR, unpubl. data). Note: Surveys for BHP Billiton and Woodside Energy have also been conducted along the grey transects during five seasons between 2000 and 2008 (Salgado *et al.*, 2010).

Possible causes for this apparent change in migratory behaviour during the 2009 season are currently being investigated and will include environmental and anthropogenic possibilities. Initial investigation of the acoustic dataset indicate that at the shelf edge air gun signals were clear and at the 100-200m bathymetry contours where the majority of humpback whale pods were sighted, air gun signals would have been audible. Near the nearshore logger positions (45 m and 10 m depth) there were no air gun signals detected. However, slightly stronger wind conditions on 11 July 2009 may have contributed to the higher number of "unknown" migratory direction pods reported (50% of sightings) and therefore contributed to the lower sightings of northbound humpback whales. Further investigation shows that approximately 65% (15 of 23) of pods sighted and reported with unknown swim direction were breaching or exhibiting other splash behaviours, an association (wind and splashing behaviours) supported by Dunlop *et al.* (2008), while only a small number of pods (8 of 23) were sighted for too short a time to determine swim direction, indicating that perhaps sea conditions were not the most important factor in the reported swim directions. Also of interest is what appears to be comparatively low numbers of acoustic detections of pygmy blue and dwarf minke whales compared with a similar data set collected in 2006 (McCauley and Kent, 2009).

Increasing numbers of resting and milling whales were sighted after the cross-over period and this observation class dominated the period of the southern migration. This behaviour pattern appears to be typical of this species and results in a slower southern migration and possibly greater opportunities for mating. Also influencing the rate of travel of the southern migratory body are cows moving south from the Kimberley Calving Grounds with newborn calves. Feeding intervals may be regular en route and it is unclear whether this species migrates steadily between resting areas or, instead, rests at regular intervals along the migratory path. The high densities of resting whales inside the 50m depth contour between Barrow Island and Exmouth Gulf could be due to either of these possibilities, or others and will form the basis for ongoing studies.

In a previous CWR survey (2004/2005) in which the entire Exmouth Gulf area was surveyed at three week intervals over 12 months, no humpback whales were sighted inside the Gulf during the June/July period (Jenner and Jenner, 2005). It was suggested by Jenner and Jenner (2005) that this was largely due to cooler water temperatures in the nearshore waters at this time of year.

Similarly, during the 2009 surveys, the nearshore waters were significantly cooler than the offshore waters and a similar paucity of whales in this region was reported in this study. Water temperatures nearshore of the 50m depth contour increase during August and September (Figure 6; Figure 7), coinciding with the arrival of the southern migratory body.

The nearshore legs of the aerial survey area (within the 50m bathymetry) had the highest densities of dugongs, dolphins, turtles, manta rays, whale sharks and vessels. Dugong and dolphin densities were highest near the Exmouth Gulf side of the survey study area, suggesting a link to known populations, and possibly food sources, in that area (Jenner and Jenner, 2005). Variation in numbers of dugongs, manta rays, dolphins and turtles and less visible species is likely attributable to weather conditions (Appendix 2). Such sightings of other megafauna reported here are of limited use in determining actual densities of these species and should rather be used to infer presence (not absence, nor density) during a particular temporal period. However it is interesting to note that at this stage of the study program, there were no high-density contours for any megafauna species that overlapped the nearshore position of the proposed Project trunkline, and the proposed MOF and PLF.

It is likely relevant to the above observation that the area nearshore of the 50m contour, in the vicinity of Onslow and the proposed trunkline, is already a relatively high-density vessel traffic area.

7. Conclusions

The following conclusions can be drawn from this study,

- Humpback whales are present in the study area in increasing numbers from early to mid-June onwards to mid August when a peak occurs, after which numbers steadily decrease to end of December
- Spatial distribution of humpback whales is clustered indicating a likely northern migratory corridor centred 50 km offshore and a southern corridor 35 km offshore.
- Cow/calf humpback whale pods are found in highest numbers inside the 50m depth contour in the study area.

- Cow/calf pods are predominantly resting in the area nearshore of the 50m bathymetry, although for unknown lengths of time.
- Nearshore waters have lower densities of humpback whales than offshore waters (deeper than 50m) in June and July perhaps due to annual water temperature profiles.
- Pygmy blue whales and dwarf minke whales are present in deeper waters of the offshore study area from mid May onwards, possibly as part of an annual north/south migration, although in the 2009 season apparently in lesser numbers (based on call rates) than in previous seasons (McCauley and Kent, 2009).
- Brydes' whales, sperm whales and pilot whales are present in the study area in deep water areas at undetermined frequencies and densities.
- Dugongs, dolphins and turtles are found predominantly inside the 50m depth contour with detection rates likely linked to sea state (and other visibility conditions).
- Manta rays are found predominantly in depths of 50-150m and sightings rates are also likely linked to sea state conditions.

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Appendix 1 – Beaufort Sea State for all transects during each flight – darker shades indicate stronger wind.

Flight Number	Flight Date	TRANSECT 1	TRANSECT 2	TRANSECT 3	TRANSECT 4	TRANSECT 5	TRANSECT 6	TRANSECT 7	TRANSECT 8	TRANSECT 9
Flight 1	17/05/2009	3	3	3	3	2	2	2	2	2
Flight 2	31/05/2009	3	2/ 3	2	3	2	2	2	2	2
Flight 3	12/06/2009	4	3	3	3	2	3	3	2	2
Flight 4	26/06/2009	1/ 2	1	1	2	2	1/ 3	3	3	2
Flight 5	11/07/2009	3	2	3	3	3	3	3	3	3
Flight 6	23/07/2009	2	2	2	2	2	2	2	2	2
Flight 7	05/08/2009	1	1	1	1	1	1	2	1/ 2	2
Flight 8	20/08/2009	1/ 2	1	1	2	2	1/ 3	3	3	2
Flight 9	03/09/2009	3	2/ 3	2	2	2	1/ 2	0	0	0
Flight 10	17/09/2009	2	2	2	2	2	2	2	2	2
Flight 11	02/10/2009	2	2	3	3	3	3	3	3	3
Flight 12	15/10/2009	1	1	1	2	1	3	3	3	2
Flight 13	02/11/2009	2	2	2	3	3	3	3/ 4	4	3
Flight 14	12/11/2009	2	1	2	2	3	1	3	2	3
Flight 15	28/11/2009	2	1	1	1	3	3	3	3	3
Flight 16	13/12/2009	2	2	2	1	2	2	3	3	3
Flight 17	24/12/2009	2	2	2	2	2	2	2	2	2
Flight 18	07/01/2010	3/ 5	4	5	5	5	5	4/ 5	4	5
Flight 19	23/01/2010	3	3/ 4	3	3	3	3	3	3	3
Flight 20	06/02/2010	2	2	3	2	2	2/ 3	3	3	2/ 3
Flight 21	19/02/2010	3	2	3	3	3	3	3	3	3
Flight 22	06/03/2010	3	2	2	2	2	2	2/ 3	3	3
Flight 23	19/03/2010	3	2	2	2	2	2	3	3	3
Flight 24	04/04/2010	3	3	3	2	2	4	3	3	3
Flight 25	15/04/2010	4	4/ 5	3	3	3	3	3	3	3
Flight 26	29/04/2010	2	3	1	1	1	2	1	1	2

Appendix 2 – Sea State as a sighting variable. Peak values per species/object in yellow for May, 2009 to April, 2010.

Flight Date	Blue whale	Killer whale	Minke whale	Pilot whale	Sperm whale	Unidentified whale	Dolphins	Dolphin Pods	Dugongs	Krill Ball	Manta Ray	Turtle spp.	Vessels	Whale Shark	Mean Sea State
17/05/2009	0	0	0	0	0	0	40	10	13	0	2	53	50	1	2.4
31/05/2009	0	0	0	0	0	0	203	18	3	0	0	101	46	0	2.3
12/06/2009	0	0	0	25	0	0	8	4	12	0	4	32	35	0	2.8
26/06/2009	0	0	1	0	0	0	68	28	31	0	12	122	42	0	2.1
11/07/2009	0	0	0	0	10	2	47	10	2	0	1	14	48	0	2.9
23/07/2009	0	0	0	0	0	0	78	0	25	0	3	100	55	0	2.0
05/08/2009	0	0	1	0	0	2	71	19	18	0	21	261	32	0	1.3
20/08/2009	0	0	0	0	0	0	31	4	13	0	3	31	27	0	2.1
03/09/2009	0	0	0	0	0	0	36	17	14	0	9	159	37	0	1.6
17/09/2009	0	0	0	0	0	2	171	34	6	1	4	112	21	0	2.0
02/10/2009	0	0	0	0	0	0	84	4	2	0	4	14	33	0	2.8
15/10/2009	0	0	0	0	0	0	99	14	2	0	3	174	15	0	1.9
02/11/2009	2	5	0	0	0	0	7	1	0	0	4	61	9	0	2.9
12/11/2009	0	0	0	0	0	5	102	12	2	1	5	134	16	2	2.1
28/11/2009	6	0	0	0	0	1	150	17	5	0	11	140	25	0	2.2
13/12/2009	3	0	0	0	0	1	174	10	0	0	5	50	20	1	2.2
24/12/2009	0	0	0	0	0	0	0	0	0	0	1	33	5	0	2.0
07/01/2010	0	0	0	0	0	0	0	0	2	0	0	4	11	0	4.8
23/01/2010	0	0	0	0	0	0	0	0	1	3	0	3	18	0	3.1
06/02/2010	0	0	0	0	2	0	71	7	0	0	15	35	23	0	2.6
19/02/2010	0	0	0	0	0	0	12	1	0	1	3	35	11	0	2.9
06/03/2010	0	0	0	0	0	0	9	6	1	0	0	159	13	0	2.4
19/03/2010	0	0	0	0	0	0	52	6	5	0	1	122	19	0	2.4
04/04/2010	0	0	0	0	0	0	0	0	0	0	1	5	31	0	2.9
15/04/2010	0	0	0	0	0	0	0	0	4	0	0	9	30	0	3.3
29/04/2010	4	0	0	0	2	0	168	28	8	4	1	189	56	0	1.6
TOTAL	**15**	**5**	**2**	**25**	**14**	**13**	**1681**	**250**	**169**	**10**	**113**	**2152**	**728**	**4**	

Appendix 3. Table of Species other than humpback whales

Dugong herd details per flight.

Flight Date	Dugong Herds	No. Dugongs	Dugong Calves
17/05/2009	3	13	0
31/05/2009	2	3	0
12/06/2009	7	12	2
26/06/2009	19	31	3
11/07/2009	2	2	0
23/07/2009	11	25	0
05/08/2009	12	18	1
20/08/2009	8	13	1
03/09/2009	10	14	0
17/09/2009	5	6	1
02/10/2009	2	2	0
15/10/2009	1	2	0
02/11/2009	0	0	0
12/11/2009	1	2	1
28/11/2009	3	5	0
13/12/2009	0	0	0
24/12/2009	0	0	0
07/01/2010	1	2	1
23/01/2010	1	1	0
06/02/2010	0	0	0
19/02/2010	0	0	0
06/03/2010	1	1	0
19/03/2010	3	5	0
04/04/2010	0	0	0
15/04/2010	2	4	1
29/04/2010	4	8	1
TOTAL	**98**	**169**	**12**

Dolphin pod details per flight.

Flight Date	Dolphin Pods	No. Dolphins	Dolphin Calves
17/05/2009	10	40	0
31/05/2009	18	203	0
12/06/2009	4	8	0
26/06/2009	28	68	0
11/07/2009	10	47	1
23/07/2009	29	78	1
05/08/2009	19	71	1
20/08/2009	4	31	1
03/09/2009	17	36	0
17/09/2009	34	171	0
02/10/2009	4	84	0
15/10/2009	14	99	0
02/11/2009	1	7	0
12/11/2009	12	102	1
28/11/2009	17	150	2
13/12/2009	10	174	2
24/12/2009	0	0	0
07/01/2010	0	0	0
23/01/2010	0	0	0
06/02/2010	7	71	0
19/02/2010	1	12	0
06/03/2010	6	9	0
19/03/2010	6	52	0
04/04/2010	0	0	0
15/04/2010	0	0	0
29/04/2010	28	168	7
TOTAL	**250**	**1681**	**16**

Appendix FE

Dugong Aerial Survey Report

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. A dugong aerial survey was completed to obtain data to validate the risk assessment presented in the Draft EIS/ERMP, and to inform the development of management measures for dugongs. This dugong-specific aerial survey was to complement data collected by the Centre for Whale Research which was designed for humpback whales, and obtained useful spatial and temporal distribution data on dugongs. The survey did not enable quantification of dugong absolute abundance or density.

The survey objectives were to:

- Quantify dugong abundance and distribution within the Project area, and in Exmouth Gulf as a regional comparison
- Identify any aggregation areas
- Collect opportunistic data, including foraging behaviour and group size.

The survey also compared the Project area with other areas of the Western Australian coastline, known to support dugongs, including Shark Bay and the Ningaloo Marine Park.

The dugong aerial survey was completed based on standardised methods and was undertaken during winter (August 2010) as winter was the season in which previously-undertaken fauna surveys recorded the highest relative abundance of dugongs.

The key findings from the survey indicate that a larger dugong population estimate and density existed in Exmouth Gulf, in comparison with the Project area. There were no aggregation areas or calves recorded within the Project area. An apparent aggregation of dugong was recorded approximately 7 km east of Tubridgi Point, within Exmouth Gulf, and six calves in total were observed within Exmouth Gulf.

Within the Project area, dugongs were primarily found in the north-west, close to the coast, near previously recorded seagrass areas or in the lee of reef fringed islands. The estimated population size, within the Project area at the time of the survey, was 287 animals (95% CI: 176–340), which is the lowest recorded on the Western Australian coastline, apart from recordings made in Exmouth Gulf when the population was temporarily displaced due to Tropical Cyclone Vance in 1999.

RPS

DUGONG AERIAL SURVEY REPORT

Wheatstone Project





DUGONG AERIAL SURVEY REPORT

Wheatstone Project

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Disclaimer

GLOSSARY, ACRONYMS AND DEFINITIONS

Term/Abbreviation	Definition
Absolute abundance	The actual (true) number of individuals present in one place at one time.
Adaptive management	An approach to environmental management which defines triggers and responsive management practices, should it be found that the pre-existing measures are not adequate or appropriate.
Aggregation	An apparent grouping of individuals and / or herds of animals.
Availability bias	A bias in the data affected by an animal being concealed by an environmental factor so that it is not visible to the observer.
BO	Both observers
BSS	Beaufort Sea State
CALM*	Department of Conservation and Land Management (WA). *Superseded by DEC in 2007.
CAMRIS	Coastal and Marine Resources Information System
CI	Confidence Interval
Confidence Interval	A way of estimating the precision with which a sample is likely to estimate a population parameter. Constructing a 95% confidence interval should contain the true population parameter 95% of the time.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CWR	Centre for Whale Research
DEC*	Department of Environment and Conservation (WA). *Formed in 2007 to replace CALM.
Density	Number of individuals within a unit area (e.g. animals per km^2).
DEWHA*	Department of the Environment, Water, Heritage and the Arts (Commonwealth). *Superseded by DSEWPC in September 2010
Domgas	Domestic gas
Double platform	A sampling method using two observers to sample a given species in the same in area at the same time. The two observers must be independent of each other and isolated visually and acoustically. On aerial surveys the two observers are normally arranged as a front and rear observer. (Refer to 'platform'.)
DSEWPC*	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth). *Formed in September 2010 to replace DEWHA.
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency (Western Australia)
EPBC Act	*Environmental Protection and Biodiversity Conservation Act (1999)*
Ephemeral	Short period of occurrence or short-lived.
ERMP	Environmental Review and Management Programme
FO	Front observer
GIS	Geographic Information System
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
km/h	Kilometres per hour
Knots	Nautical miles per hour

Term/Abbreviation	Definition
Lek	An event where an aggregation of males engages in sexual displays in order to attract females.
LNG	Liquefied Natural Gas
Metapopulation	A grouping of organisms within which separate populations are distributed in an area, but with some interaction of individuals occurring between them.
MNES	Matter of National Environmental Significance
MTPA	Million tonnes per annum
N	Number
Neap tide	Corresponding to the lunar cycle, neap tides are those with the smallest and least variable tidal range, having minimal effect on turbidity (and therefore visibility). They occur every two weeks during the first and third quarter moons.
Perception bias	A bias in the data caused by an observer not seeing an animal despite it being visible.
Platform	The location or position of an observer, for example the bridge deck of a vessel or the seats of an aircraft.
Population estimate	An estimate of the number of individual animals living in one place at one time.
RAN	Royal Australian Navy
Recapture	The event of one individual or group of animals being counted (and thus recorded) a subsequent time, usually by a rear observer.
RO	Rear observer
SE	Standard error
Spring tides	Corresponding to the lunar cycle, spring tides are those with the largest and most variable tidal range, having the greatest effect on turbidity (and therefore visibility). They occur every two weeks during the new and full moons.
Standard error	The accuracy of the sample mean, giving a measure of how well a sample represents the population.
T	Transect
TSS	Total suspended solids
WA	Western Australia

SUMMARY

Chevron Australia Pty Ltd (Chevron), the proponent of the Wheatstone Project, proposes to construct and operate a multi-train LNG plant and domestic gas (Domgas) plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast of Western Australia (WA). As part of the environmental approvals process, Chevron has prepared and submitted a Draft EIS/ERMP to the EPA and DSEWPC (formerly DEWHA). The Draft EIS/ERMP was released for public comment in July 2010.

The draft EIS/ERMP incorporated information from previous marine megafauna aerial surveys undertaken in the western Pilbara and Exmouth Gulf by Prince (2001) and Centre for Whale Research (CWR) (Jenner and Jenner 2010; Jenner and Jenner 2005). Prince (2001) obtained dugong (*Dugong dugon)* population estimates for the Pilbara coastline and offshore waters from Exmouth Gulf to Barrow Island (2046: SE±376), and for Exmouth Gulf (95: SE±62) in 2000 (Table 1). The small population recorded in Exmouth Gulf in 2000 was attributed to the effects of Cyclone Vance in 1999 (Prince 2001; Gales et al. 2004).

CWR undertook fortnightly aerial surveys for 12 months from May 2009 over nearshore and offshore waters near the Wheatstone Project Area, focussing on humpback whales, but also targeting smaller marine fauna species including dugongs. A fluctuation of dugongs sightings throughout the year was recorded, with numbers peaking in late June 2009. Most dugongs were sighted within the 10 m isobath and, over time, there appeared to be a higher density in the south-west portion of the survey area (Jenner and Jenner 2010). Although designed to sample for larger species, such as humpback whales, the survey obtained useful spatial and temporal distribution data on dugongs, but did not enable quantification of dugong absolute abundance or density.

Chevron commissioned RPS to undertake a dugong aerial survey in both the immediate vicinity of the coastal site of the Wheatstone Project Area (Wheatstone Survey Area) and in Exmouth Gulf (as a comparison site) in 2010. The aim was to obtain data that would increase the certainty of the EIS/ERMP risk assessments and to inform the development of management measures in relation to dugongs. The survey was undertaken during winter (August) because that was the season in which CWR recorded highest relative abundance of dugongs. This is the best time of year to survey for marine megafauna in north-west WA because of least windy conditions that produce a low Beaufort Sea State (BSS) rating and therefore provide the best potential for animal detection.

The objectives of the study were to:

1. Quantify the absolute abundance and distribution of dugongs (including calves) within both the Wheatstone Survey Area and Exmouth Gulf.

2. Compare the absolute abundance of dugongs in the vicinity of the Wheatstone Survey Area with other areas of the WA coastline known to support dugongs (Shark Bay, Ningaloo Reef and Exmouth Gulf), using historical datasets collected for these area through other surveys.

3. Identify dugong aggregation areas during the survey period within both the Wheatstone Survey Area and Exmouth Gulf.

4. Collect incidental data (such as foraging behaviour and group size) within the survey areas to assist understanding of the dugong abundance and distribution results.

Key survey findings were:

1. The absolute abundance of dugongs within the Wheatstone Survey Area was less than one-sixth of that in the Exmouth Gulf, with population estimates of 287 (95% CI: 176–340) and 1760 (95% CI: 1,369–2,088) respectively.

2. The density of dugongs in the Wheatstone Survey Area was found to be approximately one-fifth of that in Exmouth Gulf, with densities of 0.11(95% CI: 0.07–0.13) and 0.59 (95% CI: 0.46–0.70) dugongs per km^2 respectively.

3. No calves were recorded within the Wheatstone Survey Area, while six calves were recorded within Exmouth Gulf.

4. Within the Wheatstone Survey Area, dugongs were primarily found in the north-west portion, often close to the coast or in the lee of reef-fringed islands and sometimes near areas where seagrass has previously been recorded.

5. Within Exmouth Gulf, most dugongs were distributed in the intertidal area of the gulf's eastern coast, but were also associated with offshore reef habitat further north.

6. The estimated population size of the Wheatstone Survey Area is only 287 animals, the lowest recorded on the WA coastline, apart from Exmouth Gulf in 1999 when the population temporarily moved away from the area after Cyclone Vance (Table 1).

7. The density of dugongs within the Wheatstone Survey Area (0.11 dugongs / km^2) was found to be the lowest recorded on the WA coastline (apart from in Exmouth Gulf in 1999 when the dugong population temporarily moved away from the area after Cyclone Vance).

8. No dugong aggregations were observed within the Wheatstone Survey Area.

9. There was an apparent aggregation of dugongs approximately 7 km east of Tubridgi Point within Exmouth Gulf, in the area between Brown Island, Fly Island and Rocky Island and the associated offshore reef habitat.

10. The number of dugongs recorded as foraging was much lower in the Wheatstone Survey Area (n=10) than in Exmouth Gulf (n=39), while the proportion of feeding dugongs compared with the total number of animals observed was not as varied (71% and 79%, respectively).

11. Within both survey areas, dugongs were primarily foraging in waters less than 10 m deep, and within 5 km of the coast or islands.

12. The highest level of foraging activity was observed within Exmouth Gulf, at Hope Point, Brown Island and Giralia Bay.

13. Solitary animals made up the majority of size classes observed in both survey areas, with most herds consisting of two animals.

14. Herds of only two animals were recorded within the Wheatstone Survey Area, while herds of up to eight animals were recorded within Exmouth Gulf.

When assessing the potential impact of the Wheatstone Project on dugongs, it can be concluded from the data obtained in this and previous surveys that the location of the Project is not an area heavily occupied by dugongs and the area is unlikely to represent important habitat for these animals.

Sufficient information has been obtained to support the assumptions underlying the risk rankings presented in the Wheatstone Project EIS/ERMP. It is unlikely that dugongs in high densities or at sensitive life stages, such as calving, will be present within the Wheatstone Project's areas of high construction or operational activity.

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1.0 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast of Western Australia (WA) (Figure 1). The plant will initially process gas from the Wheatstone natural gas fields, approximately 200 km offshore from Onslow in the West Carnarvon Basin. The Wheatstone Project will require the installation of gas gathering, exporting and processing facilities in Commonwealth and state waters and in the Shire of Ashburton. The LNG plant will be located in the Ashburton North Strategic Industrial Area and have a combined maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Wheatstone Project is currently subject to an environmental approvals process, and is being assessed by the WA Environmental Protection Authority (EPA) and the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPC, formerly DEWHA) via a joint Environmental Impact Statement/Environmental Review and Management Program (EIS/ERMP) document (Chevron 2010). Chevron submitted the draft EIS/ERMP to the EPA and DEWHA in June 2010 and it was released for public comment in July 2010.

Chevron commissioned RPS to undertake a dugong aerial survey in the winter of 2010 (August) to obtain data that would increase the certainty of the EIS/ERMP risk assessments and to inform the development of management measures in relation to dugongs (*Dugong dugon)*.

1.1 Survey Aim and Objectives

The aim of this survey was to achieve a better understanding of the dugong population and distribution within both the Wheatstone Survey Area and Exmouth Gulf, as a regional comparison site (Figure 1).

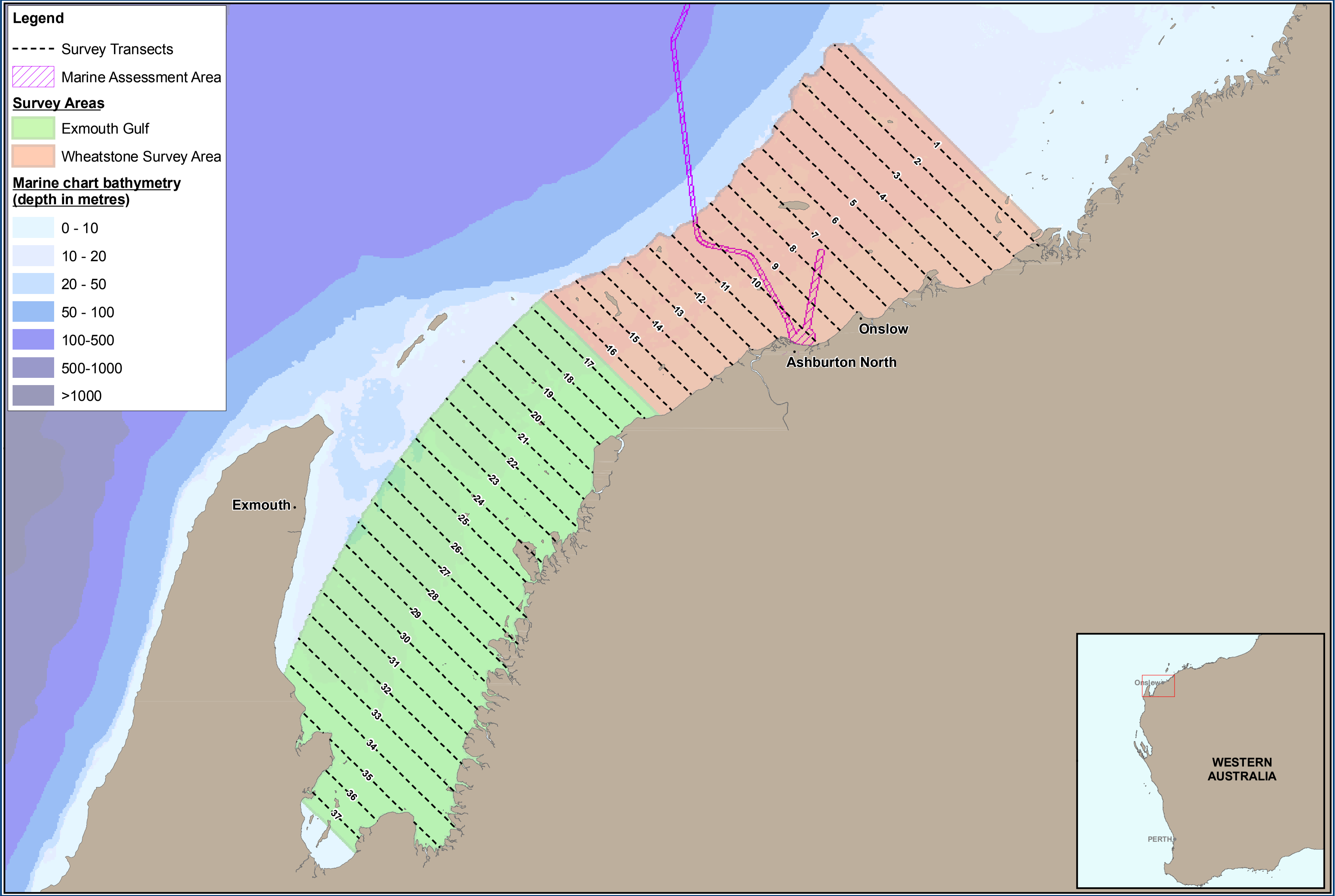
The objectives of the study were to:

1. Quantify the absolute abundance and distribution of dugongs (including calves) within both the Wheatstone Survey Area and Exmouth Gulf.

2. Compare the absolute abundance of dugongs within the Wheatstone Survey Area with other areas of the WA coastline known to support dugongs (Shark Bay, Ningaloo Reef and Exmouth Gulf), using historical datasets collected for these areas through other surveys.

3. Identify dugong aggregation areas during the survey period within both the Wheatstone Survey Area and Exmouth Gulf.

4. Collect incidental data (such as foraging behaviour and group size) within the survey areas to assist understanding of dugong abundance and distribution results.



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Revision: A
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Figure 1: Survey Areas

2.0 BACKGROUND

2.1 Conservation Significance

The dugong is the only extant member of its taxonomic family, Dugongidae. The species is listed as Vulnerable by the International Union for Conservation of Nature (IUCN), and its viability potentially is threatened globally by effects of coastal development, pollution, shipping corridors, human intrusion, direct hunting, and commercial fishing (Marsh and Saalfeld 2004; IUCN 2010).

In Australia, the species is listed as Migratory and therefore afforded protection as a Matter of National Environmental Significance (MNES) under the Commonwealth *Environment Protection and Biodiversity Act 1999* (EPBC Act). In WA, the species is specially protected under the *Wildlife Conservation Act (1950).*

2.2 Dugong Ecology

The information presented here is an annotated version of that provided within the Wheatstone Project Marine Mammal Technical Appendix (RPS 2010), outlining the key aspects of dugong ecology relevant to its conservation and management. Refer to RPS (2010b) for a more detailed species description.

2.2.1 Seagrass Foraging and Habitat

Dugongs inhabit tropical coastal waters, favouring water temperatures in the range of 21–27 °C (Sleeman et al. 2007). A herbivorous marine mammal, dugongs forage selectively on seagrass, favouring tropical species such as *Halodule* and *Halophyla,* which are low in fibre but high in nitrogen availability and digestibility (Lanyon 2007; Aragones et al. 2006). These tropical seagrass species often grow in low densities and are ephemeral, their distribution shaped by changes in seasonal tidal patterns, rainfall, nutrient availability and cyclonic activity (URS 2010).

This is true in the Pilbara, including Exmouth Gulf, where tropical species occur as low-density patches, with biomass highest in November to March and lowest in August to September (URS 2010; URS 2009b; Oceanica 2008). Intensive grazing by dugongs, foraging the same small area for up to four weeks, (Anderson 1981) possibly increases the nitrogen content of the plants by up to 35% (Aragones et al. 2006).

Dugongs begin to forage on seagrass shortly after birth while they are being weaned off milk (Marsh 1995). As adults, dugongs spend much of their day at the sea floor foraging, eating up to 40 kg of seagrass a day (Marsh and Saalfeld 2004). Based on behavioural studies undertaken in Shark Bay, the Gulf of Carpentaria and Shoalwater Bay, Chilvers et al. (2004) found that the diving behaviour of dugongs is dominated by "square and U-shaped" feeding dives, indicating that these animals dive straight to the sea floor, graze for some time and then return to the surface to breathe.

Dugongs will often feed on seagrass rhizomes and new meristems, creating a long and sinuous furrow known as a feeding trail (Anderson 1981; Marsh and Saalfeld 2004). This action stirs up the surrounding sediment, creating an obvious sandy plume in the water column, which can be seen during aerial surveys in good weather conditions.

2.2.2 Reproduction

With a very slow and highly inconsistent reproductive rate (Lanyon 2007), the dugong has low fecundity. The gestation period is approximately 14 months, the litter is usually only of one calf and the calving interval varies from three to seven years (Marsh 1995). Calving is believed to occur from late August to November in northern Queensland (Marsh 1995), but the season is unconfirmed within WA. Calving occurs in protected shallow waters such as tidal sandbanks and estuaries (Marsh et al. 1999).

Dugongs have a long breeding season (Anderson 2002), with mating behaviour varying throughout Australia. Scramble promiscuity, where up to 20 males pursue individual oestrous females, occurs in densely populated areas of north-eastern Australia, while leks, aggregations of males engaging in sexual displays in order to attract females, have been observed in Shark Bay during the springs of 1988 and 1989 (Anderson 1997; Anderson 2002).

2.2.3 Migration

Although dugong migratory patterns are not well known, they appear not to follow well-defined pathways but are not undertaken by all individuals in a population. From a satellite tracking study of 70 dugongs in the Northern Territory and Queensland, Sheppard et al. (2006) found that 37% of animals moved less than 15 km, 40% moved between 15 and 100 km, while approximately 23% moved further than 100 km (the furthest distance being 560 km). A recent satellite tagging project in the Kimberley involving four tagged dugongs recorded three animals with high site fidelity, while the fourth travelled almost 500 km south to east of Port Hedland (Campbell, R. pers. com. 2010). Migratory movements have not been found to reflect animal gender or size (Sheppard et al. 2006), nor has a relationship between movement and breeding season been verified.

Local and regional dugong movement occurs in response to changes in water temperature or seagrass availability (Marsh et al. 2002; Holley 2006; Gales et al. 2004; Prince 2001). Dugongs have been recorded moving from coastal waters at a trigger point of approximately 18 °C into warmer, deeper waters during winter months (Marsh et al. 2002; Holley 2006). Gales et al. (2004) suggested that dugongs migrated to Shark Bay from Exmouth Gulf following the removal of seagrass foraging habitat by Category 1 Tropical Cyclone Vance in 1999.

2.3 Dugong Distribution and Abundance in WA

Shark Bay supports the largest and most stable population of dugong in Australia (Table 1) due to its expansive seagrass meadows, low level of habitat disturbance and presence of critical habitat for mating and calving (Preen et al. 1997). These features of Shark Bay have contributed to its World Heritage Area Status. Exmouth Gulf has also been identified as an important area for dugongs. Table 1 presents dugong population estimates obtained from aerial surveys undertaken in Ningaloo Reef, Exmouth Gulf and the Pilbara coastline. The high density of dugongs at Ningaloo Reef is significant, with more than one animal per km^2.

Table 1: Dugong Population Estimates, Survey Area Size and Densities of dugong at Shark Bay, Ningaloo Reef, Exmouth Gulf and the Western Pilbara Coastline

Date	Shark Bay	Ningaloo Reef	Exmouth Gulf	Western Pilbara Coast	Reference
4–11.07.1989	10,146 (SE±1,665)	634 (SE±127)	1,062 (SE±321)		*Preen et al. (1997) *cited in* Hodgson (2007)
	14,906 km^2	555 km^2	3,180 km^2		
	0.68 / km^2	1.14 / km^2	0.33 / km^2		
1–30.06.1994	10,529 (SE±1,464)	968 (SE±320)	1,006 (SE±494)		*Preen et al. (1997) *cited in* Hodgson (2007)
	14,906 km^2	869 km^2	3,180 km^2		
	0.70 / km^2	1.11 / km^2	0.31 / km^2		
8–16.07.1999	13,929 (SE±1,652)	163 (SE±148)	174 (SE±82)		*Gales et al. (2004) *cited in* Hodgson (2007)
	14,239km^2	869 km^2	3,180 km^2		
	0.98 / km^2	1.18 / km^2	0.05 / km^2		
6–16.04.2000			95 (SE±62)	2046 (SE±376)	*Prince (2001)
			3,755 km^2	19,949 km^2	
			0.025 / km^2	0.10 / km^2	
4–10.02.2004	11,021 (SE±1,357)				*Holley et al. (2006) *cited in* Hodgson (2007)
	14, 906km^2				
	0.74 / km^2				
30.03 –16.06.2007	14,022 (SE±1,230)		1,411 (SE±561)		*Hodgson (2007)
	14,694 km^2		2,898 km^2		
	0.95 / km^2		0.48 / km^2		

Date	Shark Bay	Ningaloo Reef	Exmouth Gulf	Western Pilbara Coast	Reference
30.03 – 16.06.2007	9,347 (SE±1204)		704 (SE±354)		#Hodgson (2007)
	14,694 km^2		2,898 km^2		
	0.63 / km^2		0.24 / km^2		

*Marsh and Sinclair (1989) method
Marsh and Sinclair (1989) as refined by Pollock et al. (2006) method
Shaded boxes denote an absence of survey data

Note: The precision of sample estimates is described in different ways among studies: SE = standard errors, 95% CI = confidence intervals (refer to glossary).

2.3.1 Dugongs of the Western Pilbara

2.3.1.1 Previous Survey Results

Prince (2001) estimated dugong population sizes for Exmouth Gulf at 95 animals (SE±62) and the Pilbara coastline at 2046 (SE±376) in 2000 (Table 1). Only two dugongs were recorded within the Exmouth Gulf area, the low number being attributed to the removal of seagrass by Cyclone Vance, causing animals to move to Shark Bay in search of new foraging ground (Prince 2001; Gales et al. 2004). Prince's (2001) Pilbara survey block encompassed coastal waters to the 20 m isobath as far north as the Montebello Islands, eastward to approximately 20 km east of Robe River and westward to approximately 10 km west of Serrurier Island. Within this survey block, most dugongs were found to be distributed to the east of Barrow Island, within close proximity to islands in the area, as well as the Mary Anne Passage (Prince 2001).

The Centre for Whale Research (CWR) undertook fortnightly aerial surveys over 12 months from May 2009 to record marine megafauna distribution and abundance, specifically targeting larger species such as humpback whales, but also recording observations of dugongs. The survey block targeted the nearshore waters of the Wheatstone Project Area, referred to as being in the "south-west Pilbara". CWR (2010) recorded a variation in the number of dugongs observed throughout the year, with numbers peaking in late June 2009. Most dugongs were sighted within the 10 m bathymetry and, over time, there appeared to be a higher density in the south-west portion of the survey area (CWR 2010). While the survey obtained useful spatial and temporal distribution data, the design did not enable quantification of dugong abundance or density.

2.3.1.2 Anecdotal Evidence

Anecdotal evidence was obtained during the scoping phase of the Wheatstone Project EIA and in the planning of baseline surveys. However, this information has limited application due to a lack of scientific basis. It cannot be used quantitatively or be relied on to provide a true representation of distribution or population size.

According to CALM (2002), dugongs are believed to be relatively common in the shallow waters of islands near Onslow. Based on a series of community interviews in 2009, dugongs have been seen around Coolgra Point, Montebello Islands (including calves), the south-east end of Middle Mangrove Island and in very shallow coastal waters away from any islands. Serrurier (Long) Island is recognised by the Shire of Ashburton in its Town Planning Scheme as having habitat for dugong (WAPC 2003).

Reports of stranded or dead animals washed ashore can be valuable indicators of seasonal occurrence of a species, but depend on systematic data collection to extract useful and reliable information. Such data are not collected as a matter of routine in WA. Although a dead dugong was recorded in Beadon Creek in December 2009 (M. Johnson pers. comm. 2009), it provides no more information than an indication that dugongs occur in the general area.

3.0 METHODS

3.1 Survey Area

The overall aerial survey area covered a total of 5,614.76 km^2 and encompassed nearshore waters of the south-west Pilbara from the coastline to the 20 m isobath, eastward to North Mangrove Island and westward down into Exmouth Gulf. This area was divided into two smaller survey areas based on the survey objectives: the Wheatstone Survey Area and Exmouth Gulf (Figure 1).

The Wheatstone Survey Area boundaries were based on the Dugong Management Area depicted in Chapter 12 of the Wheatstone EIS/ERMP, but excluded the terrestrial area and extended only to the 20 m isobath. Deeper water was excluded because CWR reported that most dugongs were observed between the coastline and the 10 m isobath (Jenner and Jenner 2010).

In the interest of survey efficiency, the Exmouth Gulf survey area was delineated by continuing the seaward boundary of the Wheatstone Survey Area into the gulf, rather than extending it to the North West Cape coastline. This decision was based on aerial survey results indicating that the vast majority of dugongs within the gulf were distributed within the south-east section (Jenner and Jenner 2005). The western boundary, coincidently, matches that of the DEC's Pilbara Dugong Management Unit at the Ashburton River (DEC 2008).

3.2 Survey Timing

Marsh and Sinclair (1989a) stipulate that BSS must be four or below during dugong surveys to maximise the potential to detect dugongs. The survey was undertaken in winter on 7–8 August 2010, when winds were consistently light in the western Pilbara. This is consistent with most other dugong aerial surveys undertaken in north-west WA (Table 1). Only those surveys specifically undertaken to sample for variation between the summer and winter months, such as Holley et al. 2006, have been implemented in summer.

To maximise detectability, the aerial surveys occurred as close to the period of neap tide (6 August) as possible to avoid tidally-influenced turbidity. Surveys were undertaken after midday to avoid high glare conditions, which could also impede dugong detectability.

3.3 Strip Width Transect Design

Aerial survey is the most commonly employed method to sample for marine megafauna distribution and abundance because regional spatial scales can be surveyed in a short time frame (Marsh and Sinclair 1989a), and disturbance of the targeted species is minimal. A strip width transect design, as described by Marsh and Sinclair (1989a) and refined by Pollock et al. (2006), was employed and conducted from a CASA 212-400 fixed-wing aircraft. The survey was flown at an altitude of 900 feet (274 m) and at a constant speed of 110 knots (204 km/h).

Parallel transects were established 4.65 km apart and on a diagonal north-west to south-east alignment, perpendicular to local bathymetry that intersects ecological axes of the Pilbara nearshore area (Prince 2001). This also followed the transect orientation of Jenner and Jenner 2010, improving suitability for data comparison. This alignment was continued into Exmouth Gulf so that there would be consistency in the glare angle, a potential environmental variable in detecting dugongs. The Wheatstone Survey Area included transects 1 to 16, while transects 17 to 37 were included within the Exmouth Gulf survey area (Figure 1).

A strip width of 400 m was surveyed from each side of the aircraft along each transect. Each 100 m width within this area was demarcated as low, middle, high and very high zones on the each of the observers' windows, following the procedure prescribed by Marsh and Sinclair (1989a). Observers focused solely in the sampling strip and animals outside of the survey area were not recorded.

3.4 Data Collection

3.4.1 Dugong Observations

To ensure that the survey objectives and sampling protocol were understood, and to enable the acquisition of robust records and reliable transcription of audio records into the project Access database, all survey personnel undertook an office-based training session and a trial flight over Shark Bay prior to survey mobilisation.

A "double platform" approach was employed to allow a recapture method of data analysis. A team of tandem observers (one front, one rear) was placed on each side of the aircraft (port and starboard) (Figure 2), so that perception bias could be accounted for when calculating population estimates. The members of each tandem team were visually separated by a curtain and acoustically separated through an eight track audio recording system. The front observer (FO), being the most experienced, obtained the primary dugong observations, while the rear observer (RO) recorded animals for a second time (i.e. recapture sightings), and those not seen by the front observer.

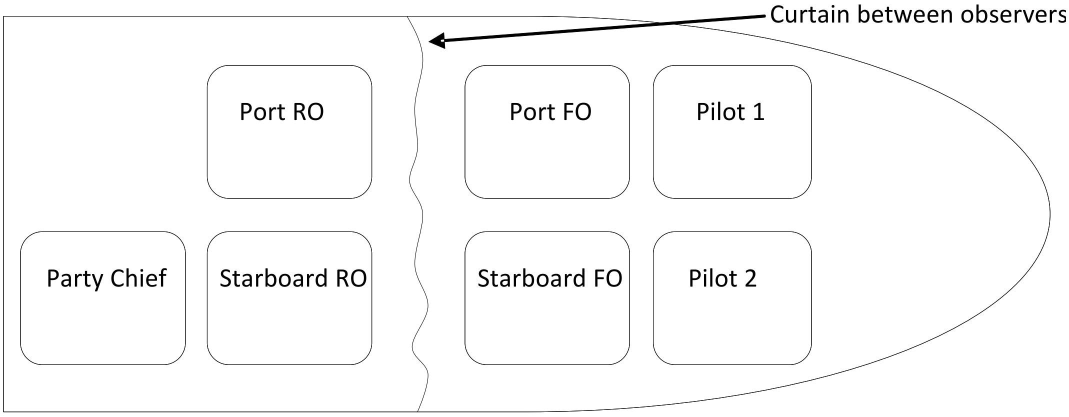

Figure 2: **Configuration of Survey Personnel**

Using the audio recording system, observations from each observer were recorded onto separate audio tracks. Fauna observations were targeted in the following priority order:

1. Dugongs.
2. Turtles*.
3. Coastal dolphins*.

*These fauna were recorded as incidental observations. The distribution of these records is presented and described in Appendix 3.

The following information was recorded for each observation:

- Number of animals / number of calves.
- Zone.
- Behaviour (and direction of travel if swimming).
- Reliability.
- Turbidity / glare.

Dugong feeding was primarily inferred by the presence of an obvious long, sandy plume indicating a feeding trail, but also by observation of a stationary dugong on the sea floor. Feeding plumes were also included as a surrogate for individual animals, due to their conspicuous shape and size and because they were confirmed as feeding trails by observers during other surveys when dugongs could be seen.

3.4.2 Environmental Data and Spatial Projection

In addition to the four observers on the aircraft, there were two pilots and a dedicated Party Chief. The role of the Party Chief during the flights was to monitor survey progress and oversee data collection, operate and troubleshoot survey equipment, record environmental conditions through the survey period and liaise between the observers and pilots.

The Party Chief monitored survey progress in-flight by tracking the aircraft's movements using a Global Positioning System (GPS) and laptop computer loaded with OziExplorer. He was responsible for recording the following environmental data:

- Wind speed (knots) and direction (degrees).
- Cloud cover (okta).
- BSS (1–12).
- Turbidity (1–4).
- Visibility (1–9).
- Other weather conditions (e.g. rain).
- Transect start and finish time.
- Angle of drift of the aircraft and whether to port or starboard.

Position fixes were obtained and downloaded every second from a Garmin GPSMAP 60CSx to a laptop. The GPS was fitted with an external antenna located in the cockpit of the aircraft. A backup GPS in the cockpit also recorded fixes every second to its internal memory. The audio system, GPSs and Party Chief's watch were synchronised prior to every flight so that all records (observational and environmental) could later be allocated their unique spatial position within a customised database.

3.5 Data Processing and Analysis

All data were transcribed from the audio system into an Access database upon return from the field. The database contained forms featuring drop-down menus and look-up tables to control the wording, fields and feature classes being entered, to reduce the risk of error during data entry. Transcription was undertaken by each team of tandem observers and overseen by the Party Chief, which allowed for quality assurance and control. Observations recorded between transects were later removed from the database.

Prior to analysis, the data were processed to establish recapture records so that the double counting of animals was avoided. Recaptures were identified through plotting the location of all observations in a Geographical Information System (GIS) application (ArcMap 9.3.1) to pinpoint overlapping records of similar information that were recorded by both the front and rear observers. The similarities of these records were double-checked against the attributes of each record within the Access database, including strip width zone, time, group size and behaviour. Time similarity was dependant on the zone in which the animal / s were observed, and loosely followed these criteria:

- Very high zone: recapture could occur within 60 seconds.
- High zone: recapture could occur within 30 seconds.
- Medium zone: recapture could occur within 20 seconds.
- Low zone: recapture could occur within 14 seconds.

Each observation record was then identified as a BO recapture (recorded by both observers), a front observer only record or a rear observer only record. For each BO pair of records, the record made by the front observer was retained, and the record made by the rear observer was removed.

Where applicable, the data then underwent correction for perception bias and availability bias (Figure 3). As described in Section 3.4.1, perception bias was removed using the recapture approach devised by Marsh and Sinclair (1989b). Correction for availability bias followed Pollock et al. (2006) to account for animals being concealed in turbid or windswept waters, allowing a population estimate based on absolute abundance to be obtained. Perception and availability bias were not applied to dugong herds of 10 or more animals because the probability of detection is high enough for large herds to always be seen. The process is summarised in Figure 3.

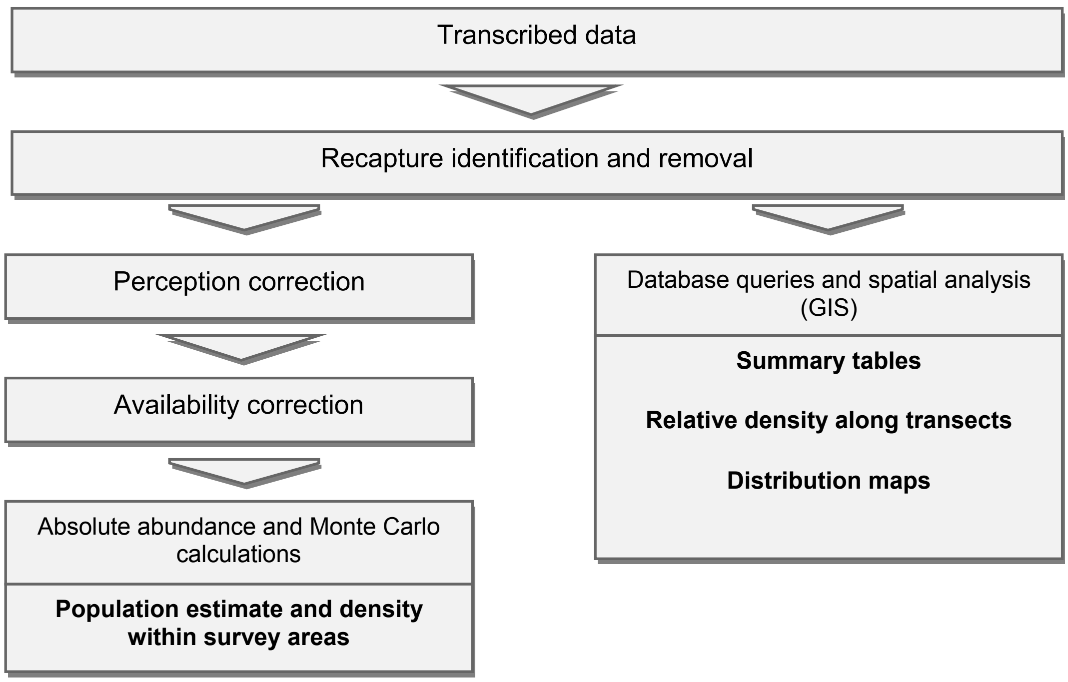

Figure 3: **Data Processing and Analysis Flowchart (Outputs are in Bold)**

Summary tables of survey effort and dugong observations were produced using the Access database query builder. Data presented in the results and interpreted in the discussion were extracted from the database under the following parameters:

- Include unique records collected by both the front and rear platforms.
- Exclude recaptures.
- Use the maximum recorded number of individuals in a group (rather than averaging the minimum and maximum best estimate).

Population estimates for each of the survey areas were calculated after correcting for perception and availability biases and then multiplying the density of animals recorded within the strip width areas to the whole survey area. To calculate confidence intervals for each survey area, Monte Carlo re-sampling analysis was performed on 1,000 simulations to estimate confidence intervals around the population estimate.

The relative abundance of dugongs recorded along each transect was calculated so that variation in density across the survey area could be quantified. This was based on data from both platforms, but excluding recaptures.

Distribution maps of observed dugongs and calves were plotted using ArcMap 9.3.1 to project records within the Access database to their estimated spatial position based on the central distance of the strip width zone (refer to Section 3.3) in which they were observed (port or starboard). The indicative distribution of known seagrass was also mapped, using shapefiles created by URS (2009) based on benthic habitat surveys in nearshore waters of the Wheatstone Project Area and collated surveys held within the Coastal and Marine Resources Information System (CAMRIS) (CSIRO 1996). Reef habitat was digitised from the Royal Australian Navy (RAN) admiralty chart, following the method used by URS (2009a), but grouping reef, patches, rock, shoals and bombora (bommies) as one consolidated layer.

4.0 RESULTS

4.1 Survey Effort

The aerial survey was undertaken on 7–8 August 2010. A total of 124 linear kilometres were flown over a total of 6 hours 26 minutes on transect, amounting to an area of 994.96 km² sampled within an overall survey area of 5614.76 km² (Table 2). The survey was divided into two survey areas, the Wheatstone Survey Area and Exmouth Gulf. There were 16 transects in the Wheatstone Survey Area and 21 transects in Exmouth Gulf, culminating in a survey effort of 576.5 and 669 km respectively. Survey conditions and visibility remained good throughout the survey, with BSS ≤ 4 and mostly at 2 and 3.

Transects 37 to 25 within Exmouth Gulf were flown on the afternoon of 7 August as this was the area most sheltered from the light winds experienced on the day. Transects 1 to 26 were flown on the afternoon of 8 August, taking advantage of excellent surveying conditions (very light winds and clear skies) over the entire Wheatstone Survey Area and the northern section of the Exmouth Gulf survey area.

Table 2: Summary of Survey Effort (both Port and Starboard)

	Wheatstone Survey Area	Exmouth Gulf	Total
Length of transects	576.47 km	668.98 km	124.25 km
Sampled area	461.04 km²	533.92 km²	994.96 km²
Overall survey area	2613.67 km²	3001.09 km²	5614.76km²
Proportion surveyed	17.63%	17.79%	17.72%
Survey Duration	3 hrs 13 mins 10 secs	3 hrs 13 mins 31 secs	6 hrs 26 mins 41 secs

4.1.1 Recapture Rate

A summary of recapture rates by each tandem team is given in Table 3, with the workings presented in Appendix 1. The recapture rate for the starboard side of the aircraft was 18.2%, significantly lower than that of the port side of 45% recapture. The number of observations recorded by the front observer only and the rear observer only on the starboard side also differed considerably, at 74% and 7.8% respectively. In contrast, the percentage of observations recorded by the front and rear observer only on the port side were relatively close, at 32% and 23% respectively.

Because a high percentage of recaptures provides a more accurate and precise population estimation than those with low recapture rates, it was decided to progress the subsequent analysis with port data only. This reduced the proportion of the surveyed area from 17.7% to 8.85%, but strengthened the reliability of the population estimate.

Table 3: Recapture Rate of Dugong Observations

Observation Type	Starboard	Port
Recapture (both platforms)	18.2%	45%
Front observer only	74%	31.65%
Rear observer only	7.8%	23.35%

4.2 Summary Statistics

A summary of the dugong sightings, number of individuals, calves, the group sizes and distance from land (coast and islands) and the mainland is given in Table 4. Sixty dugong observations (including groups) were recorded during the aerial surveys, comprising 99 adults and six calves (excluding recaptures and off-transect sightings). Of the 60 sightings, 72% were recorded as certain dugong sightings. The remaining 17% were recorded as probable dugong sightings. Probable dugong sightings were often associated with an observed feeding plume in clear and shallow waters, but with the dugong thought to be concealed by suspended sediment.

Table 4: Summary of Dugongs Recorded within each Survey Area

	Wheatstone Survey Area	Exmouth Gulf	Total
Number of observations*	11	49	60
Number of animals	14	85	99
Number of calves	0	6	6
Number of animals feeding	10	39	49
Mean group size	1.27	1.74	1.5
Median group size	1	1	1
Maximum group size	2	7	7
Mean distance from land (km)	3.11	3.38	
Mean distance from mainland (km)	10.4	6.10	

* Observation records include solitary animals and groups.

Both the number of observations and of individual animals was far higher in Exmouth Gulf than in the Wheatstone Survey Area (Table 4). No calves were recorded within the Wheatstone Survey Area, while six were recorded within Exmouth Gulf. The number of feeding dugongs was also much lower in the Wheatstone Survey Area (n=10) than in Exmouth Gulf (n=39), while the proportion of feeding dugongs compared the total number of animals observed was not as varied (71% and 79%, respectively) (Table 4).

Figure 4 depicts the frequency of each group size class within each survey area. The majority of sightings throughout both survey areas consisted of one to two individuals, with larger groups only observed within Exmouth Gulf; one group comprising of eight individuals. However, the mean group size is only slightly higher for the Exmouth Gulf than the Wheatstone Survey Area due to the high frequency of individual dugong sightings in Exmouth Gulf.

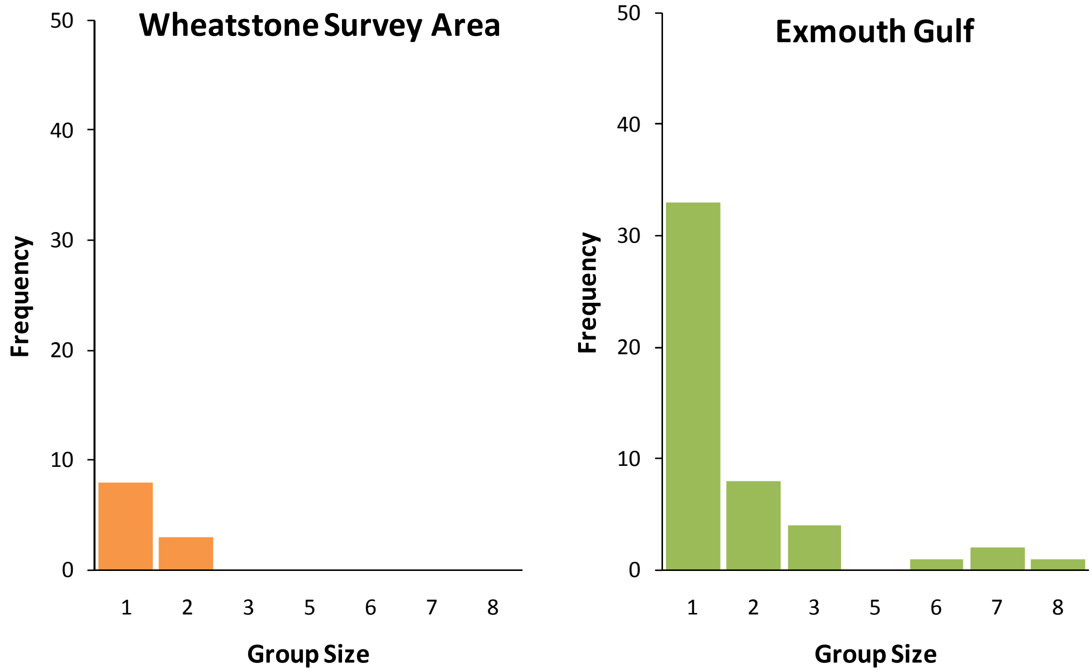

Figure 4: Frequency of Group Size Classes within the Wheatstone Survey Area and Exmouth Gulf

4.3 Abundance

4.3.1 Population Estimate

The population of dugongs within each survey area was estimated after correction for perception and availability biases, as described in Section 3.5, and is shown in Table 5. The estimated number of dugongs in Exmouth Gulf was found to be six times greater than that estimated in the Wheatstone Survey Area (Table 5; Figure 5), with population estimates of 1760 and 287 individuals respectively.

The Monte Carlo analysis estimated that the population of dugongs in the Wheatstone Survey Area is likely to fall between 176 and 340 individuals, while the Exmouth Gulf population is likely to fall between 1,369 and 2,088 individuals. These confidence intervals are relatively narrow, indicating a fairly precise population estimate.

Table 5: Estimated Dugong Population (and Confidence Intervals) within each Survey Area during the Survey Period

		Wheatstone Survey Area	Exmouth Gulf
Population estimate		287	1760
Confidence interval	Upper:	340	2088
	Lower:	176	1369

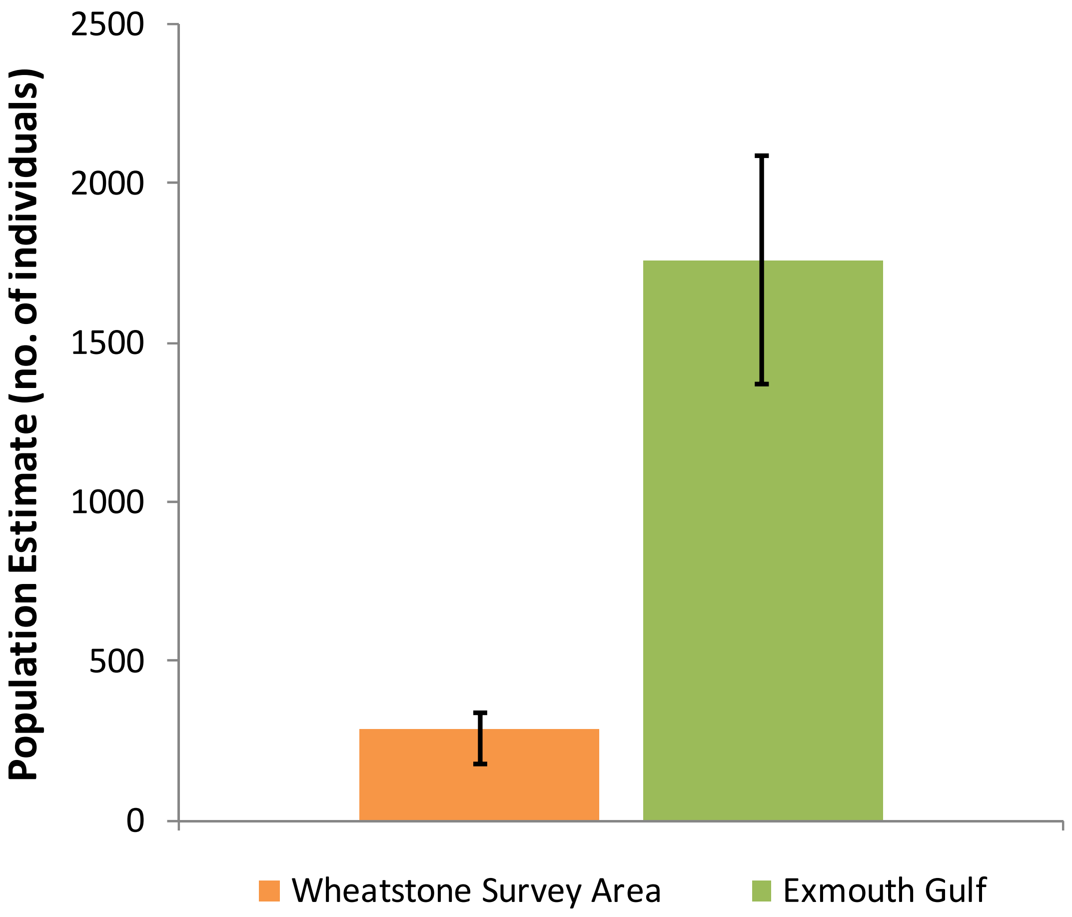

Figure 5: Population Estimates including Confidence Intervals for the Wheatstone Survey Area and Exmouth Gulf

4.3.2 Absolute Density

The population estimates for each survey area were used to calculate the absolute density of dugongs within each survey area (Table 6). The Exmouth Gulf survey area was found to support a much greater density of animals (0.59 dugongs per km^2, 95% CI: 0.46–0.70), than the Wheatstone Survey Area (0.11 dugongs per km^2, 95% CI: 0.07–0.13). The mean estimate of dugong density is therefore approximately 5.4 times greater in Exmouth Gulf than in the Wheatstone Survey Area.

Table 6: Absolute Density of Dugongs within Each Survey Area

	Wheatstone Survey Area	**Exmouth Gulf**
Total area (km^2)	2613.67	3001.09
Density (dugongs / km^2)	0.11	0.59
Density - Upper CI	0.13	0.70
Density - Lower CI	0.07	0.46

4.3.3 Relative Density

The relative density of dugongs was calculated per unit of survey effort (kilometre transect flown) for individual transect (Table 7).

The relative density of dugongs in the Wheatstone Survey Area was consistently low for each transect, with the highest relative abundance of 0.11 dugong / km^2 for T6.

The highest relative density for the Exmouth Gulf was of 0.74 dugongs / km^2 for T21, and 0.35 dugongs / km^2 on T20. Transects in the southern reaches of the Exmouth Gulf, from T34 to T37, also supported high relative densities, from 0.16 to 0.29 dugongs / km^2. Larger groups of six to eight individuals were recorded on T29, T21 and T34, resulting in high relative densities for these transects.

Table 7: Relative Density of Dugongs per Transect

	Transect (T)	Transect Length (km)	Number of Dugongs	Relative Density (dugongs / km^2)
Wheatstone Survey Area	1	51.80	0	0
	2	48.92	1	0.02
	3	48.97	3	0.06
	4	45.56	4	0.09
	5	40.04	0	0
	6	37.67	4	0.11
	7	37.25	0	0
	8	32.76	1	0.03
	9	32.88	0	0
	10	31.68	0	0
	11	26.71	1	0.04
	12	26.83	0	0
	13	27.42	0	0
	14	28.03	0	0
	15	29.28	0	0
	16	30.66	0	0
Exmouth Gulf	17	28.69	1	0.03
	18	27.51	0	0
	19	26.32	3	0.15
	20	28.96	8	0.35
	21	30.89	21	0.74
	22	33.49	0	0
	23	32.21	0	0
	24	32.39	0	0
	25	31.88	0	0
	26	35.68	2	0.06
	27	37.03	1	0.03
	28	37.94	6	0.16

	Transect (T)	Transect Length (km)	Number of Dugongs	Relative Density (dugongs / km^2)
	29	35.69	10	0.28
	30	36.70	1	0.03
	31	37.13	0	0
	32	38.58	7	0.18
	33	39.34	3	0.10
	34	42.09	11	0.26
	35	30.78	5	0.16
	36	13.81	4	0.29
	37	11.90	2	0.17

4.4 Distribution

4.4.1 Dugong Distribution within the Wheatstone Survey Area

A total of 11 observations were recorded in the Wheatstone Survey Area, comprising 14 individuals (Table 4). The distribution of these records is shown in Figure 6. Most observations were recorded in the north-west section of the Wheatstone Survey Area, and in water depths of less than 10 m. With a mean distance of 3.11 km from any land, many animals were in close proximity to the mainland, or in lee of offshore islands, such as Direction and Thevenard islands. A total of 64% of all sightings in the Wheatstone Survey Area were distributed within approximately 10 km of the mainland coast. A number of dugongs were recorded near the coastal reef habitat between Coolgra Point and South Mangrove Island, and also in shallow waters between Beadon Bay, Coolgra Point and Direction Island, which has previously been found to support patchy seagrass habitat of 5–12% density (URS 2009b).

4.4.1.1 Locations of Observed Feeding within the Wheatstone Survey Area

Dugongs were recorded as feeding at the following locations (Figure 6):

- Approximately 1 and 2 km from reef approximately 5 km from the coast (T3).
- Within 1 km of the coast, close to reef habitat, on T4.
- Approximately 5 km north-west of Twin Islands in waters 10–20 m deep (T4).
- At two points near Direction Island over reef habitat (T6).
- Approximately 1 km east of Thevenard Island, over reef habitat and close to previously mapped seagrass habitat (CSIRO 1996) (T6).

4.4.2 Dugong Distribution within Exmouth Gulf

A total of 49 observations were recorded in Exmouth Gulf, comprising 85 individuals, including six calves (Figure 7). All calf sightings were of one calf only, accompanied by one or more other animals and in water depths of less than 10 m.

Of the 49 observations, 94% were located in water depths of less than 10 m. Many dugong observations recorded within Exmouth Gulf were located in the south-east region of the gulf, from transect 26 to 37. In the northern portion of the gulf, observations were concentrated at a location approximately 7 km from Tubridgi Point, in the area between Brown Island, Fly Island and Rocky Island and the associated offshore reef habitat. Five of the six calf sightings were observed in this area. Of interest were several sightings of patrolling sharks recorded on the edge of this area.

4.4.2.1 Locations of Observed Feeding within Exmouth Gulf

Within Exmouth Gulf, dugongs were observed to be feeding at a number of locations (Figure 7):

- Approximately 7 km north-west of Tubridgi Point (T19).
- At Fly Island Reef (T20; T21).
- At Tubridge Reef, with a herd of at least six feeding dugongs observed (T21).
- Approximately 1 km north-west of Brown Island over reef habitat, with a herd of at least seven feeding dugongs observed, including one calf (T21).
- Approximately 1.5 km and 2.5 km south-west of Brown Island (T21).
- Within sheltered waters south of Hope Point (several herds observed) (T28).
- Approximately 8 km north-west of Islam Islands, with a herd of eight dugongs feeding and several other animals swimming towards them (T29).
- Within Giralia Bay, from the coast to 5 km out (T34; T35).
- Approximately 2.5 km north-east of Roberts Island (T36).

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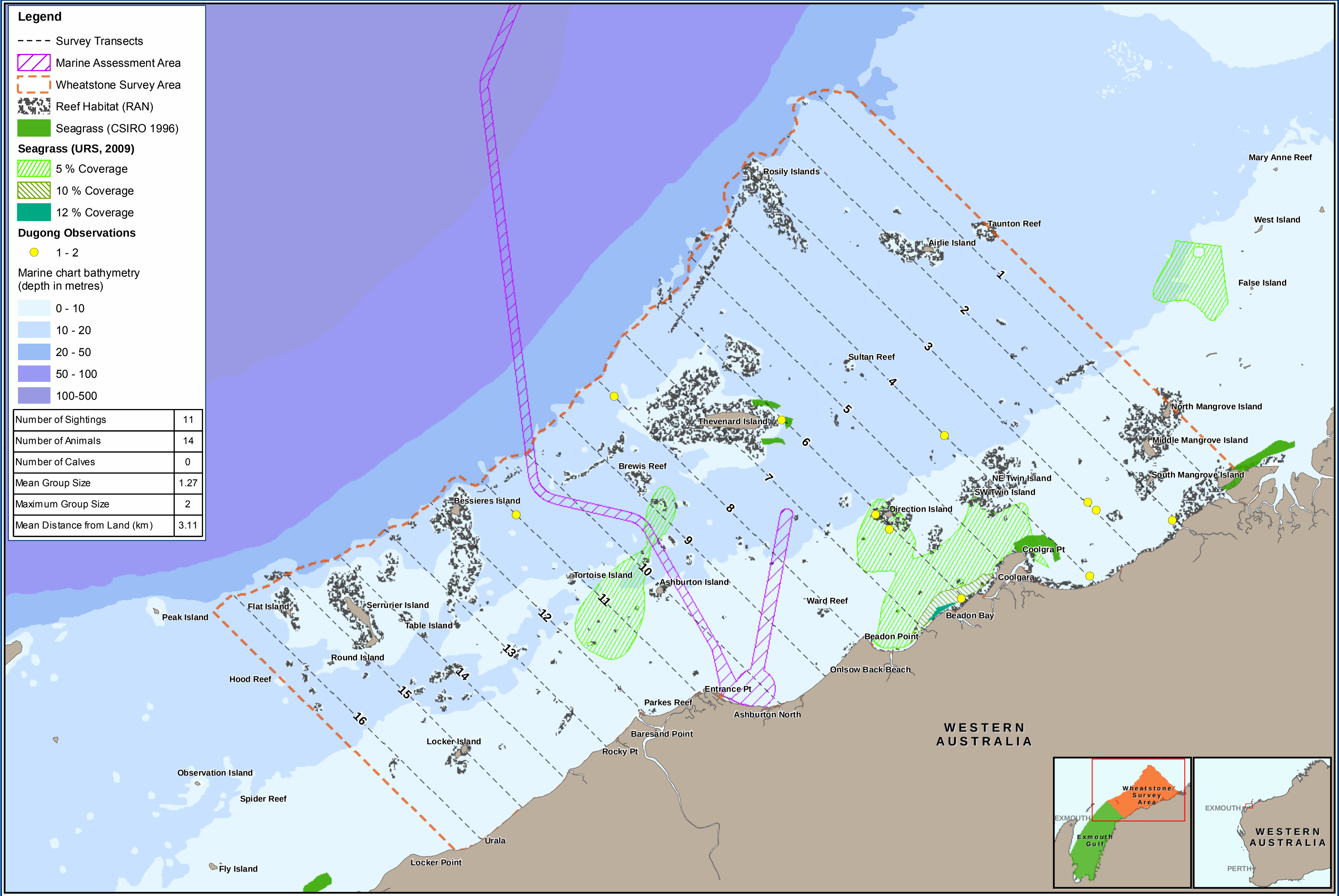

Number of Sightings	11
Number of Animals	14
Number of Calves	0
Mean Group Size	1.27
Maximum Group Size	2
Mean Distance from Land (km)	3.11

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Date: 12/10/2010
Revision: C
Scale @ A3: 1:300,000
Drafted by: M Angove
Source: Wheatstone Data Sphere

Figure 6: Dugong Observations within the Wheatstone Survey Area

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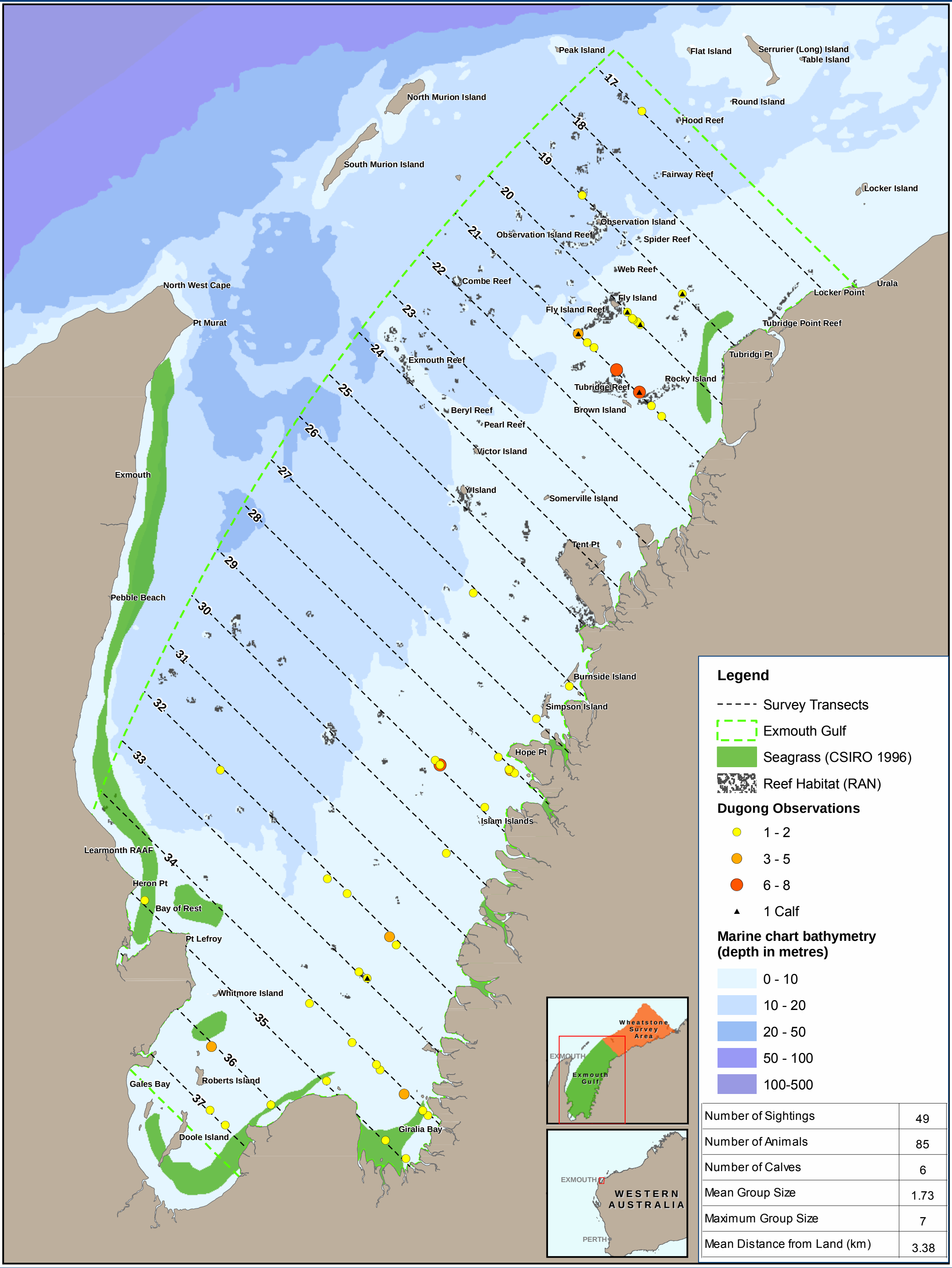


Number of Sightings	49
Number of Animals	85
Number of Calves	6
Mean Group Size	1.73
Maximum Group Size	7
Mean Distance from Land (km)	3.38

RPS

Dwg Number : M10612-003
Date: 12-10-2010
Revision: C
Scale @ A3: 1: 300,000
Drafted by: M Angove
Source: Wheatstone Data Sphere

0 2.5 5 10 km

Figure 7: Dugong Observations within Exmouth Gulf

5.0 DISCUSSION

5.1 Survey Reliability

The environmental conditions remained suitable throughout the survey, enabling successful collection of survey data. There was, however, variability between the observations recorded by the tandem observers on the starboard side, where the front observer recorded a far greater number of animals than the rear observer. As there was also a disproportionately higher number of dugong sightings recorded by the front starboard observer than those recorded by those on the port side, it was decided to omit the starboard records from the data analysis. It is believed that this has not significantly affected the population estimate, as Marsh and Sinclair (1989b) suggest that a single tandem team could be used instead of two tandem teams where space on an aircraft or resources is limited. It is likely that the distribution maps depict an underestimation of the animals present during the survey, but reliable and consistent effort between the survey areas has been achieved.

The southern coastal section (out to approximately 4 km) of the survey area, that from Entrance Point, experiences high turbidity of 20 mg/L total suspended solids (TSS) during winter (Figure 8). This level of turbidity impedes the detectability of dugongs, reducing the chance of seeing a dugong to low. While the correction for availability bias enables this to be accounted for in calculating absolute abundance, it was not taken into account when producing the maps. For this reason, the maps may be affected by negative bias in areas affected by high levels of turbidity.

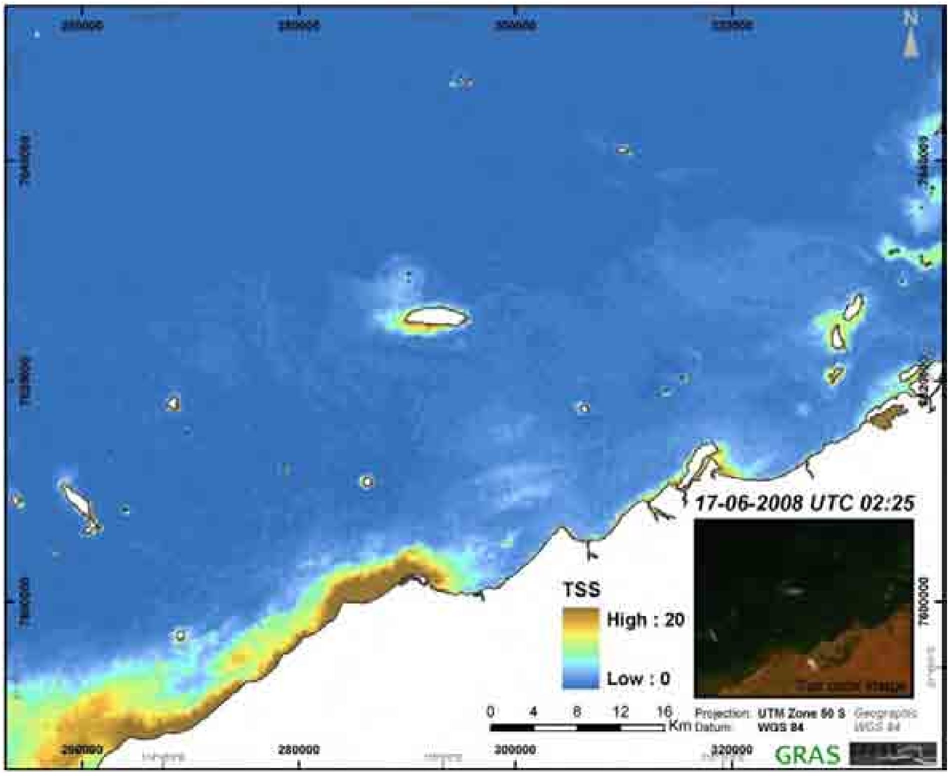


Figure 8: Turbidity of the Survey Area during Winter (DHI 2010)

Given the ephemeral nature of tropical seagrasses, and that the data contained within CAMRIS is more than 10 years old, it is possible that the seagrass distribution at the time of the survey was different to that presented in the figures. Thus, the seagrass maps are indicative, showing the potential locations of seagrass occurrence.

5.2 Population Size and Density

5.2.1 Comparison between the Wheatstone Survey Area and Exmouth Gulf

The Wheatstone Survey Area was found to support far fewer dugongs than Exmouth Gulf. This is not surprising because Exmouth Gulf has long been recognised as providing important dugong habitat (DEWHA 2008).

With an estimated population of 287 dugongs, the Wheatstone Survey Area was found to support only one-sixth of the dugong population that was estimated in Exmouth Gulf (1760 dugongs). Correspondingly, the density of dugongs was five times less in the Wheatstone Survey Area (0.11 dugongs per km^2) than in Exmouth Gulf (0.59 dugongs per km^2). The density recorded for the Wheatstone Survey Area is consistent with that found by Prince (2001) for the wider western Pilbara area.

The population estimate calculated for Exmouth Gulf is largely comparable to previous studies in the same area that have recorded up to 1,400 animals (Table 1), with the exception of Prince's (2001) 1999 Exmouth Gulf population estimate of only 95 dugongs at a density of 0.025 animals per km^2. This anomaly is attributed to animals migrating to Shark Bay in response to the impact of Cyclone Vance. The population has since recovered, with the fast growing seagrass species having recolonised (Oceanica 2008) and attracting dugongs back to the area.

Solitary animals made up the majority of size classes observed in both survey areas. By far the most commonly recorded herd size was two animals. While only group sizes of one to two animals were recorded within the Wheatstone Survey Area, there were five groups of three to five animals and three groups of six to eight animals in Exmouth Gulf. Although it is not unusual to observe groups of such sizes (Anderson 1981), it is not possible to infer what type of social structures these observations represent as only the cow-calf family group has so far been found to exist within dugongs (Anderson 1981).

5.2.2 Comparison between the Wheatstone Survey Area and Other Areas in WA

The Wheatstone Survey Area is of low dugong habitat significance on a regional scale, based on the comparison of results from this survey and of those collected from the various surveys presented in Table 1[1]. At only 287 animals, the density of dugongs

[1] It should be noted that this is a comparison of general trends as absolute abundance is somewhat hindered through temporal disparity. Also, not all of the past surveys were based on standardised methods following Marsh and Sinclair

within the Wheatstone Survey Area (0.11 dugongs / km^2) was found to be the lowest recorded on the WA coastline, apart from 1999 when dugongs were temporarily displaced from Exmouth Gulf (Prince 2001).

Shark Bay, consistently found to support the highest number of dugongs in WA, supports as many as 50 times more dugongs than in the Wheatstone Survey Area. Shark Bay is known to be of importance due to the expansive seagrass meadows of both tropical and temperate species, enabling dugongs to have access to an abundant year round supply of foraging habitat (Holley 2006; DEWHA 2008). Ningaloo Reef has the highest density of dugongs along the WA coastline, with a density 10 times greater than the Wheatstone Survey Area (Table 1).

5.3 Distribution

5.3.1 General Distribution Patterns

Most dugongs were recorded in waters less than 10 m deep and often near the coast, reefs, or in the lee of islands throughout both survey areas. This is not surprising as dugongs are known to frequent such protected areas (Marsh and Saalfeld 2004; Marsh et al. 1999).

At the time of this survey, there appeared to be a stronger association between dugongs and reef habitat than with dugongs and (historical) seagrass distribution (Figure 6). Also, dugongs were commonly observed foraging in areas that did not correspond to the plotted seagrass maps obtained from CSIRO (1996) or URS (2009b). This implies that the presence or absence of tropical seagrass based on historical mapping cannot be used as an indicator for the presence or absence of dugongs, especially with the ephemeral nature of seagrass.

More animals were distributed within Exmouth Gulf than within the Wheatstone Survey Area, as discussed in Section 5.2.1 above, with potential aggregations of dugongs identified, while there was none within the Wheatstone Survey Area.

5.3.2 Dugong Distribution within the Wheatstone Survey Area

Within the Wheatstone Survey Area, dugongs were primarily found in the north-west portion, often close to the coast or in the lee of reef-fringed islands and sometimes near areas where seagrass has previously been recorded. Correspondingly, it was also these shallow water areas where dugongs were primarily found to be feeding. As foraging is the largest component of a dugong's daily activities, (Marsh and Saalfeld 2004) it is not surprising that most dugongs were observed to be feeding.

(1989b) and Pollock et al. (2006), therefore having the potential for perception and availability bias to lead to an underestimate of animal numbers (Caughley et al. 1976 *cited in* Marsh and Sinclair, 1989a).

The dominant distribution of dugongs in the north-west contrasts with the findings of the CWR survey, as dugongs were more often recorded towards the south-west portion of the survey area over the full temporal extent of that survey (Jenner and Jenner 2010) (Appendix 2, Figure 1). This could suggest that there is no strong preference by dugongs for any particular area within the Wheatstone Survey Area over an extended period of time.

No dugongs were recorded in close proximity to the mainland near Entrance Point during this survey (Figure 2), or during any of the survey flights undertaken by CWR (Jenner and Jenner 2010) (Figure 5 of Appendix 2), which could be a product of highly turbid water conditions that could reduce the detectability of dugongs. However, given the combined survey effort over this area by CWR and RPS, if dugongs do frequent the area, it is likely a small number would have been detected during the surveys. It is also possible that dugongs avoid this area during winter months due to the high turbidity. If this is so, it would more likely be a result of a possible lack of seagrass habitat due to very low light attenuation rather than poor visibility conditions, as dugongs rely on other senses than their eyesight, which is poor (Marsh and Saalfeld 2004).

5.3.3 Dugong Distribution within Exmouth Gulf

Within Exmouth Gulf, most dugongs were distributed in the intertidal area of the gulf's eastern coast, but were also associated with offshore reef habitat further north. During the survey, water depths appeared to be very low, providing good foraging conditions for dugongs. According to Anderson (1981), dugongs forage at depths to 3 or 4 m in both sublittoral and intertidal areas. Targeted studies in this area have indicated that seagrass is supported within this extensive shallow water environment, with vegetated habitat abundant in waters less than 2.5 m deep (Oceanica 2008). Foraging was the dominant behaviour observed.

The eastern portion of Exmouth Gulf is listed as a wetland of national importance, supporting seagrass beds, extensive mangal communities, well developed tidal creeks and broad saline coastal flats, and is acknowledged to support large numbers of dugongs (DEWHA 2008). The vast majority of dugongs were within this area during this survey, with high relative densities recorded along the southern transects of Exmouth Gulf, from Hope Point to Giralia Bay, largely attributable to several groups of six to eight individuals. This pattern is clearly consistent with that found by Jenner and Jenner (2010), where the vast majority of dugongs were observed in the southern section of Exmouth Gulf (Appendix 2, Figure 2), reflecting the importance of this intertidal area as dugong habitat.

Dugongs are often found around areas where there is ready access to both shallower and deeper waters (Anderson 1981). This was seen in the north of the survey area on T20 and T21, where a number of dugongs, including five of the six calves that were recorded, were observed at the edge of the Fly Island Reef, near to where the bathymetry drops to below 10 m. This was identified as a potential aggregation, with these transects having twice the relative density of that recorded on transects further south (Figure 7; Table 7). Most of these animals were observed to be on the bottom, feeding. All animals within the large groups observed approximately 5 to 10 km offshore from the coast on T21 were foraging, with a number of feeding plumes recorded.

The CSIRO (1996) seagrass map confirms that seagrass has the potential to exist in this area, as it has been recorded in very near locations in the past. It is possible that using this shallow location enabled dugongs to forage while remaining protected from several sharks observed in deeper waters nearby. Also, by being positioned near the edge of a drop-off, the dugongs would be able to move quickly into deeper waters when the tide fell, preventing them from becoming stranded on shallow sandbars.

The aggregations that have been identified during this survey are unlikely to be static because the distribution is expected to vary across the survey area over time as the size and composition of dugong herds change as they move between feeding sites (Anderson 1981). This was seen approximately 8 km north-west of Islam Islands, where several solitary dugongs appeared to be swimming towards a herd of eight foraging dugongs. However, Anderson (1981) asserts that dugongs tend to forage persistently on the same seagrass area, even as it becomes sparse or depleted.

5.3.4 Distribution of Calves

Overall, the proportion of calves to other dugongs was recorded to be very low. This is likely to reflect the low fecundity of dugongs (Marsh 1995), but it is also possible that calves were less visible to observers when they were directly over their mother's body, a strategy employed to cover them from potential predators (Anderson 1981).

While there were no calves recorded within the Wheatstone Survey Area, six were recorded within Exmouth Gulf, five of these between Brown and Fly islands. These calves were recorded within the aggregations, where feeding appeared to be the dominant activity. At the time of the survey, this area was inundated by shallow tidal water. Shallow waters such as tidal sandbanks and wide shallow bays may be preferred sites to avoid sharks (Marsh et al. 1999).

While noting the temporal variability between CWR's surveys in Exmouth Gulf (2004/5) and south-west Pilbara (2009/10), and this survey, some patterns are evident. CWR recorded only one or no calves during 24 of the 26 survey flights within the Wheatstone Survey Area (Jenner and Jenner 2010) (Appendix 2, Figure 2). Conversely, during CWR's 17 survey flights undertaken for the Yannarie Salt Project, a total of 86 calves were recorded within Exmouth Gulf (Jenner and Jenner 2005). There has been little research into the existence of a definitive calving season in WA, but these data suggest that Exmouth Gulf provides a more important habitat for dugong cows with calves than the coastal waters of the Wheatstone Project Area.

5.4 Temporal Trends and Movement

5.4.1 Movement within the Wheatstone Survey Area

This survey can only provide a snapshot in time as the distribution of dugongs within the Wheatstone Survey Area is expected to change in response to the growth or reduction of their preferred forage areas (Anderson 1981).

While temporal trends cannot be reported from this survey, it can be surmised that some seasonal change in dugong distribution occurs within the Wheatstone Survey Area, as shown by the fluctuation and changing distribution of dugong observations recorded by CWR over the 12-month survey period (Jenner and Jenner 2010). The highest number of animals and sightings was recorded by CWR in winter, followed by spring (Figure 5 of Appendix 2). Observations appeared to be distributed most evenly across the survey area during autumn and spring. During winter, most dugongs were recorded in the south-west section of the survey area. In contrast, dugongs were only seen on one survey flight during summer, and only in the northern section of the survey area (n=27). This could be an adaptive movement in relation to seasonal seagrass availability, which is of high spatial and temporal variability (Gales et al. 2004; Marsh and Saalfeld 2004; McDonald 2005).

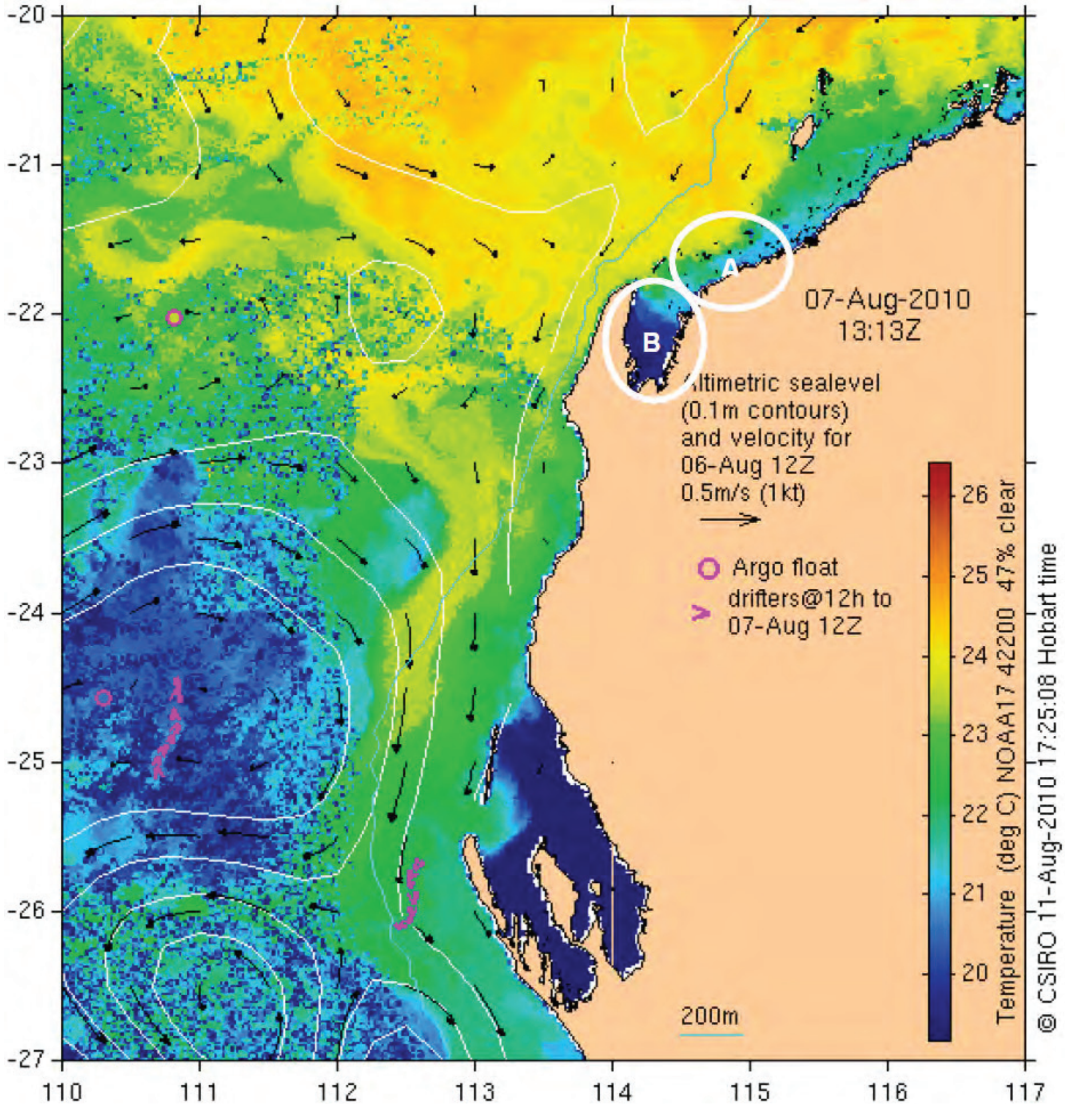
5.4.2 Migration of Individuals Outside Survey Areas

The level of migration varies between dugong populations and individuals (Sheppard et al. 2006). The temporal variation in dugong numbers recorded by CWR throughout its 12-month survey period (Jenner and Jenner 2010) may suggest that animals move between the Wheatstone Survey Area and other areas off the WA coast. A study on dugong population genetics in Australia has indicated that there is a high level of gene flow between Australia and nearby countries to the north, and between populations on the WA coastline (McDonald 2005). A migrating dugong that was tracked from the Kimberley to the Pilbara supports this hypothesis (Campbell, R. pers. com. 2010). It is likely that north-west WA supports a dugong metapopulation in which occupancy of an area changes over time (Burgman & Lindenmayer 1998), with some individuals remaining resident in a given area, but others undertaking regional scale migrations.

5.4.3 Mass Migration outside Survey Areas

Dugongs move in response to seasonal changes in water temperature and seagrass availability (Anderson 1981; Marsh et al. 2002; Holley 2006; Gales et al. 2004; Prince 2001). A decrease in water temperature is a strong driver of dugong migration, with dugongs recorded to move at a trigger point of approximately 18 °C to 19 °C into a warmer location (Preen et al. 1997; Marsh et al. 2002; Holley 2006). Mass migration is known to occur in Shark Bay during winter months, when dugongs move from the cooled coastal waters within the shallow section of the bay to the deeper, warmer waters outside of the bay, which experience mixing with the warm Leeuwin Current flowing down from the north (Preen et al. 1997; Holley 2006).

Unlike the inner waters of Shark Bay, waters of the south-west Pilbara coast are exposed to mixing and do not experience a dramatic reduction in water temperature, remaining at about 21 °C during winter (Figure 9). Therefore, the driver for dugongs to migrate into deeper waters during winter does not occur within the Wheatstone Survey Area. In contrast, there is the potential for dugongs to migrate out of, or towards the top of, Exmouth Gulf as the water temperature cools to be below 20 °C in the southern end of the gulf (Figure 9). However, as this survey was undertaken when the water was at this temperature, and dugongs were still recorded within the southernmost reaches of the gulf, it is unlikely that mass migration occurs here in a similar way to what happens in Shark Bay.



A= approximate location of the Wheatstone Survey Area
B= approximate location of Exmouth Gulf

Figure 9: Satellite Imagery of Water Temperatures on 7 August 2010 (CSIRO 2010)

6.0 CONCLUSION

Marine mammals utilising nearshore habitats or foraging areas are the most likely to be impacted by habitat modification because most marine development occurs in coastal areas. These species are, therefore, more susceptible to fragmentation and displacement than the larger deep water species.

When assessing the potential impact of the Wheatstone Project on dugongs, it can be concluded from the data obtained in this and previous surveys that, the location of the Project is not an area heavily occupied by dugongs and is unlikely to represent important habitat for these animals. This conclusion is based on the following survey findings:

1. The absolute abundance of dugongs within the Wheatstone Survey Area was less than one-sixth of that in the Exmouth Gulf, with population estimates of 287 (95% CI: 176–340) and 1760 (95% CI: 1,369–2,088) respectively.

2. The density of dugongs in the Wheatstone Survey Area was found to be less than one-fifth of the density in Exmouth Gulf, with densities of 0.11(95% CI: 0.07–0.13) and 0.59 (95% CI: 0.46–0.70) dugongs per km^2 respectively.

3. The estimated dugong population size of the Wheatstone Survey Area is only 287 animals, the lowest recorded on the WA coastline (apart from Exmouth Gulf in 1999 when the population temporarily moved away from the area after Cyclone Vance).

4. The density of dugongs within the Wheatstone Survey Area (0.11 dugongs / km^2) was found to be the lowest recorded on the WA coastline (apart from Exmouth Gulf in 1999 when dugongs temporarily moved away from the area after Cyclone Vance).

5. The number of dugongs recorded as foraging was much lower in the Wheatstone Survey Area (n=10) than in Exmouth Gulf (n=39), with the highest level of foraging activity observed at Hope Point, Brown Island and Giralia Bay in Exmouth Gulf.

6. No dugong aggregations were observed within the Wheatstone Survey Area.

7. No calves were observed within the Wheatstone Survey Area, while six calves were recorded within Exmouth Gulf.

Sufficient information has been obtained to support the assumptions underlying the risk rankings presented in the Wheatstone Project EIS/ERMP. It is unlikely that dugongs in high densities or at sensitive life stages, such as calving, will be present within the Wheatstone Project's areas of high construction or operational activity.

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APPENDIX 1

Survey Recapture Workings

APPENDIX 1: Survey Recapture Workings

Transect	Starboard			Groups >10?	Transect	Port			Groups >10?
	Recaptures	FO	RO			Recaptures	FO	RO	
1	0	1	1	—	1	0	0	0	—
2	0	1	0	—	2	0	1	0	—
3	1	5	1	—	3	2	0	0	—
4	1	2	0	—	4	1	1	0	—
5	1	1	0	—	5	0	0	0	—
6	0	0	0	—	6	1	2	1	—
7	0	0	1	—	7	0	0	0	—
8	0	3	0	—	8	1	0	0	—
9	0	0	0	—	9	0	0	0	—
10	1	0	0	—	10	0	0	0	—
11	1	0	0	—	11	0	1	0	—
12	0	0	0	—	12	0	0	0	—
13	0	0	1	—	13	0	0	0	—
14	0	0	0	—	14	0	0	0	—
15	0	0	0	—	15	0	0	0	—
16	0	0	0	—	16	0	0	0	—
17	0	0	0	—	17	1	0	0	—
18	0	0	0	—	18	0	0	0	—
19	0	0	0	—	19	1	0	1	—
20	0	2	0	—	20	2	3	0	—
21	1	3	0	—	21	5	1	1	—
22	0	6	0	22	22	0	0	0	—
23	1	1	0	24	23	0	0	0	—
24	1	2	0	—	24	0	0	0	—
25	0	2	0	—	25	0	0	0	—
26	0	0	0	—	26	0	0	2	—
27	0	1	0	—	27	1	0	0	—
28	0	4	0	—	28	1	0	3	—
29	0	4	0	—	29	1	2	1	—
30	0	4	0	—	30	1	0	0	—
31	0	1	0	—	31	0	0	0	—
32	2	4	0	—	32	2	3	0	—
33	0	4	0	—	33	1	1	0	—
34	0	5	1	—	34	3	0	4	—
35	4	1	1	—	35	1	2	1	—
36	0	2	0	—	36	1	1	0	—
37	0	0	0	—	37	1	1	0	—
TOTAL	14	59	6	2	TOTAL	27	19	14	0
TOTAL RECORDS			79		TOTAL RECORDS			60	
GROUPS > 10			2		GROUPS > 10			0	
FINAL TOTAL RECORDS			77		FINAL TOTAL RECORDS			60	

Figure 1-1: Number of Recaptured, Front Only and Port Only Dugong Observations Recorded per Survey Transect

APPENDIX 2

Dugongs Recorded in the Survey Areas by CWR

APPENDIX 2: Dugongs Recorded in the Survey Areas by CWR

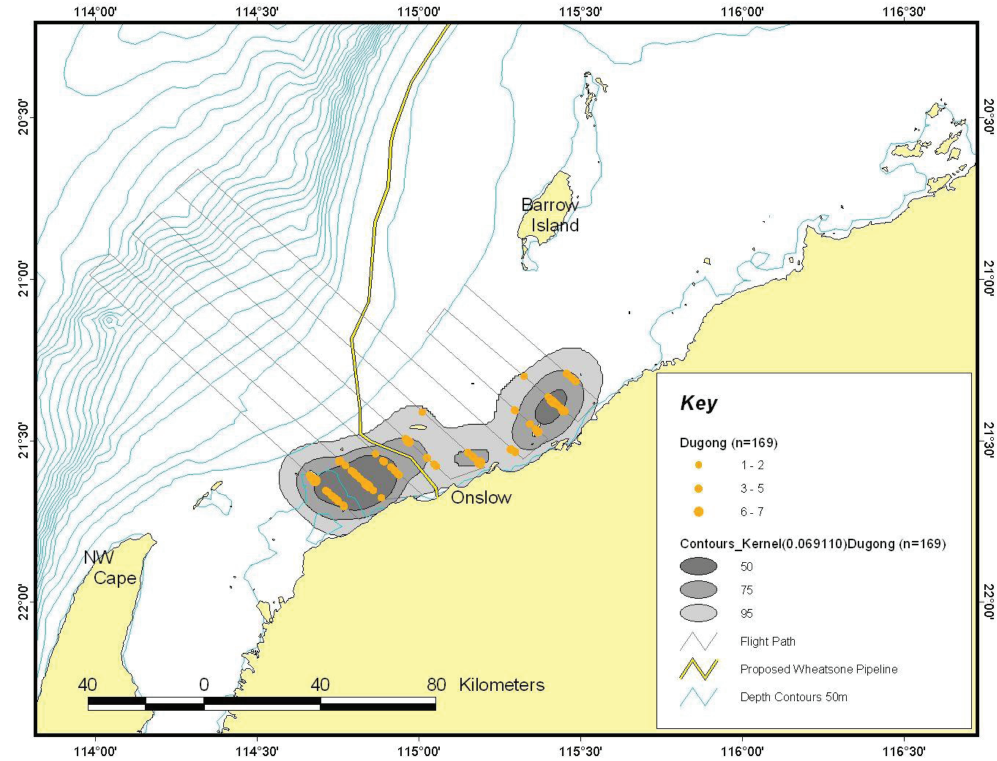


Figure 2-1: **Distribution of Dugongs Recorded in Waters surrounding the Wheatstone Project Area from 17 May 2009 to 29 April 2010 (Jenner and Jenner 2010)**

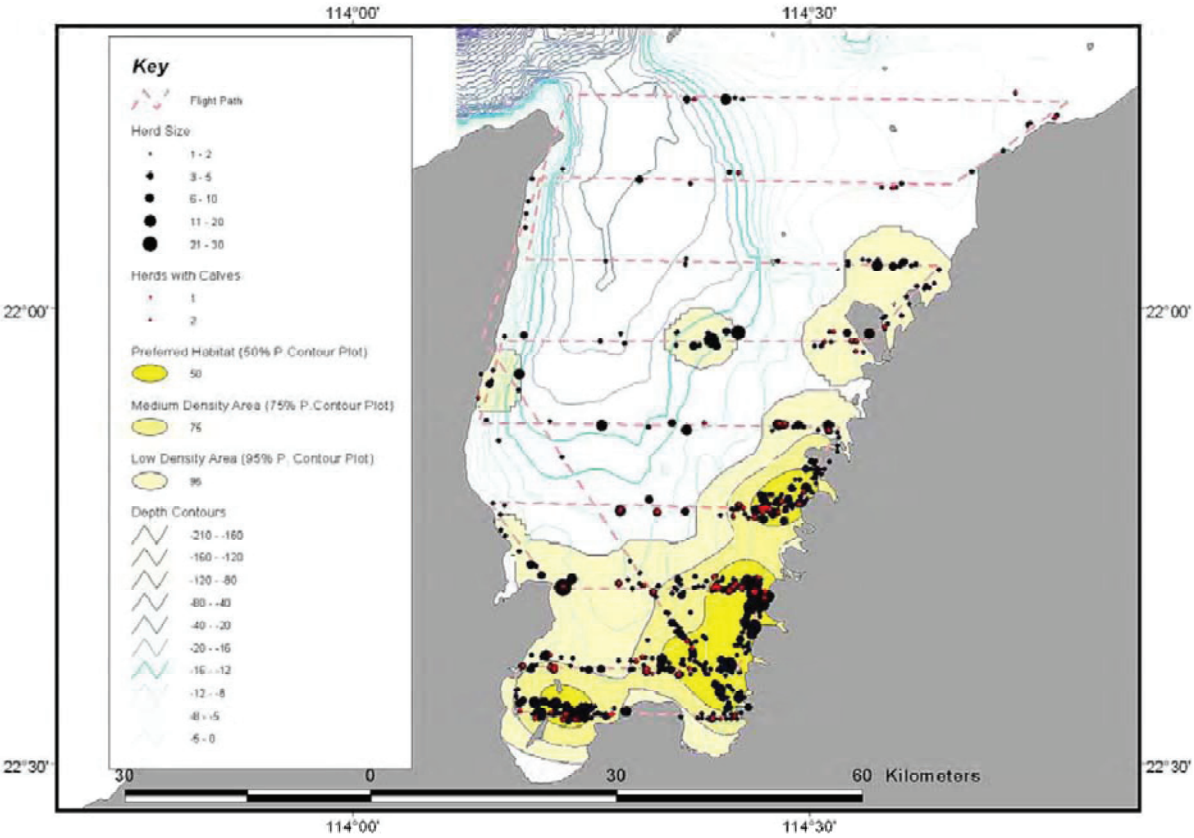
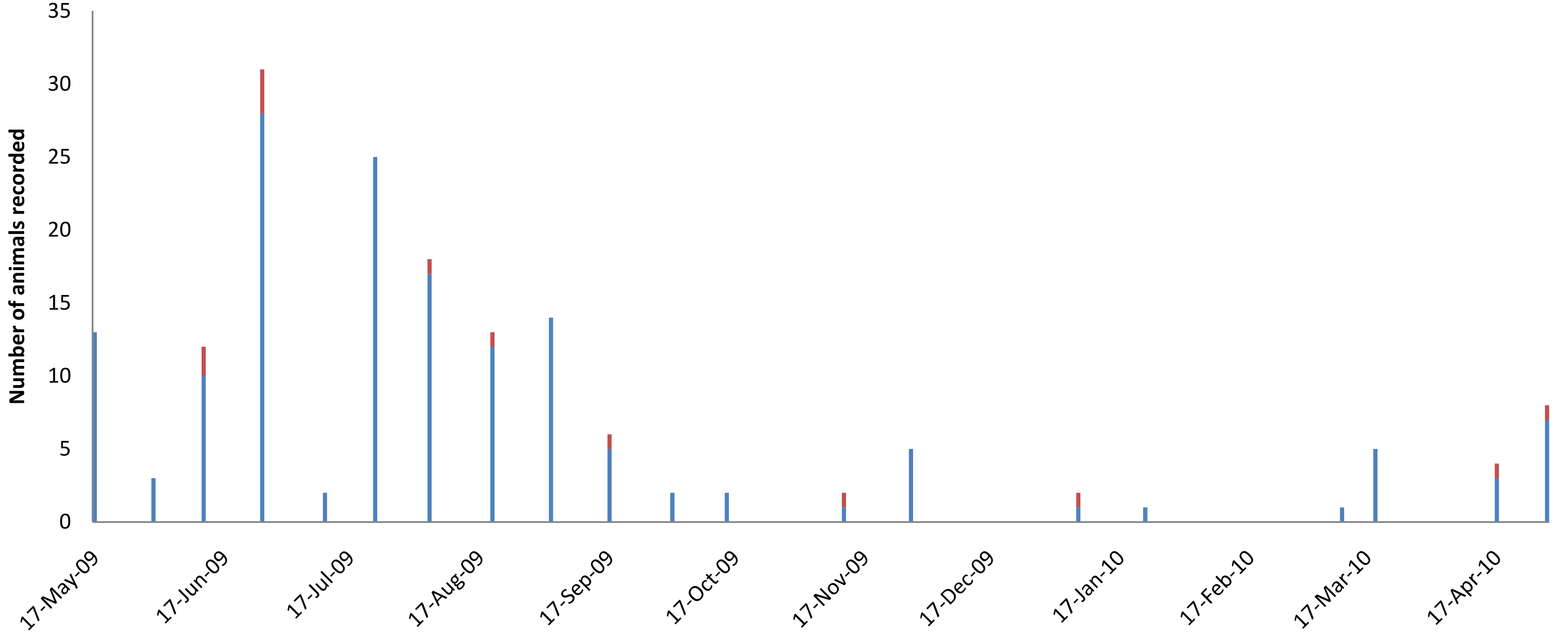
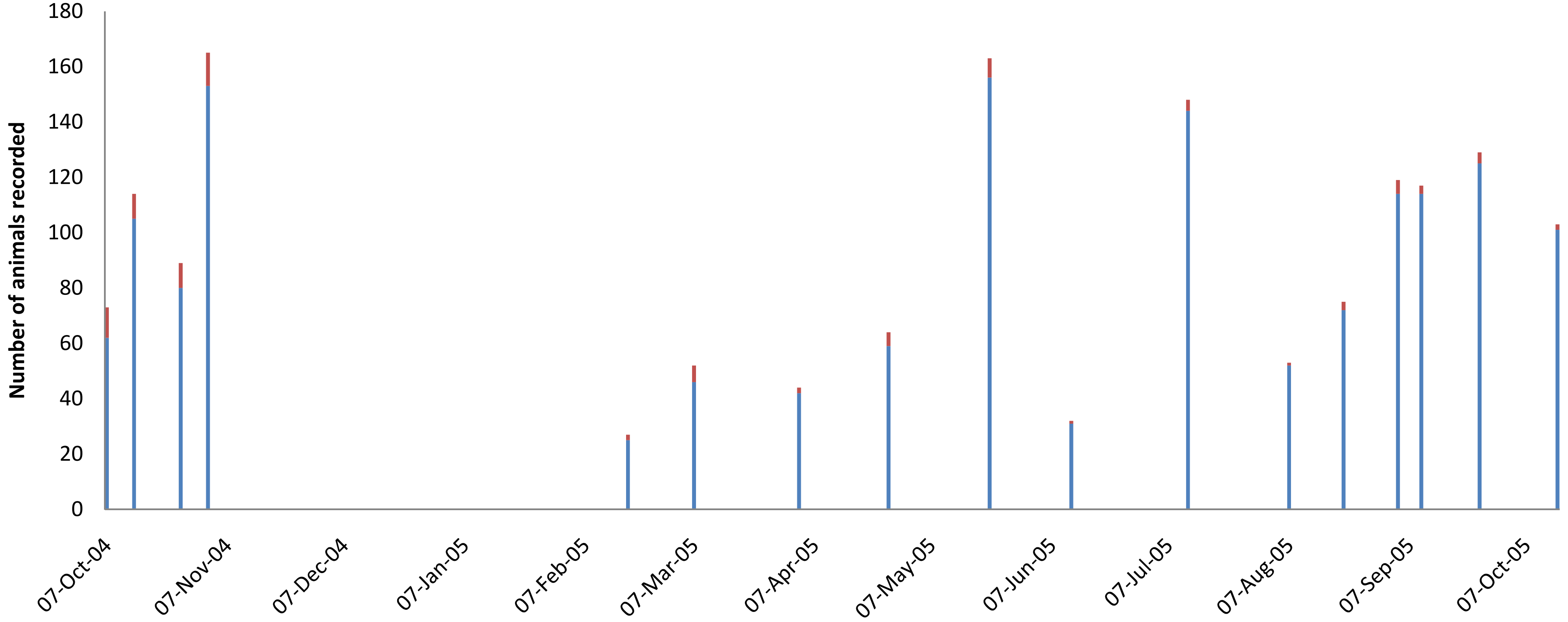


Figure 2-2: Distribution of Dugongs Recorded in Exmouth Gulf from 7 October 2004 to 15 October 2005 (Jenner and Jenner 2005)



	17-May-09	31-May-09	12-Jun-09	26-Jun-09	11-Jul-09	23-Jul-09	05-Aug-09	20-Aug-09	03-Sep-09	17-Sep-09	02-Oct-09	15-Oct-09	02-Nov-09	12-Nov-09	28-Nov-09	13-Dec-09	24-Dec-09	07-Jan-10	23-Jan-10	06-Feb-10	19-Feb-10	11-Mar-10	19-Mar-10	04-Apr-10	17-Apr-10	29-Apr-10
Calves	0	0	2	3	0	0	1	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1
Adults	13	3	10	28	2	25	17	12	14	5	2	2	0	1	5	0	0	1	1	0	0	1	5	0	3	7

Figure 2-3: **Dugong Adults and Calves Recorded in Waters surrounding the Wheatstone Project Area (Jenner and Jenner 2010)**



	07-Oct-04	14-Oct-04	26-Oct-04	02-Nov-04	18-Feb-05	07-Mar-05	03-Apr-05	26-Apr-05	22-May-05	12-Jun-05	12-Jul-05	07-Aug-05	21-Aug-05	04-Sep-05	10-Sep-05	25-Sep-05	15-Oct-05
Calves	11	9	9	12	2	6	2	5	7	1	4	1	3	5	3	4	2
Adults	62	105	80	153	25	46	42	59	156	31	144	52	72	114	114	125	101

Figure 2-4: Dugong Adults and Calves Recorded in Exmouth Gulf (Jenner and Jenner 2005)

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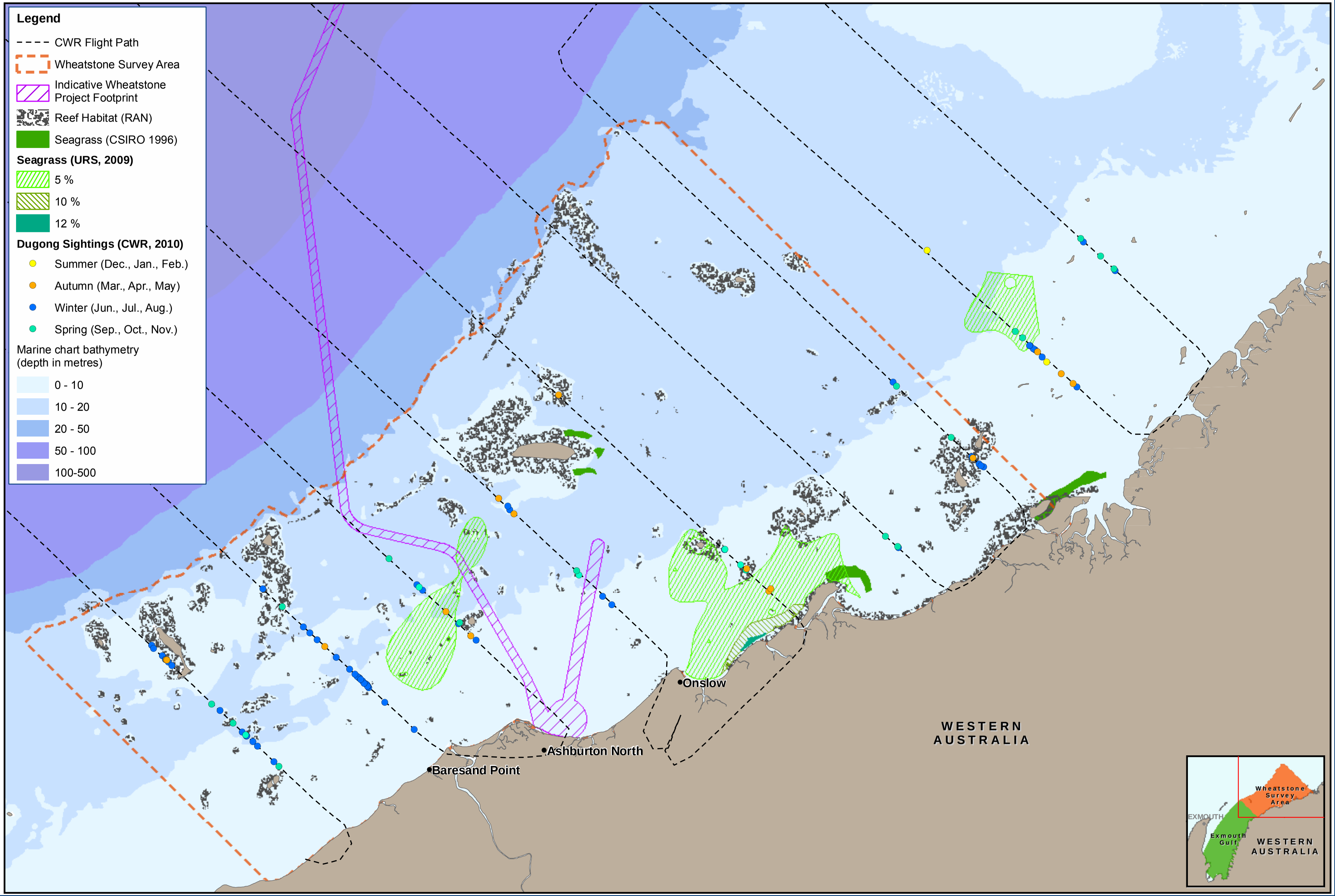

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Date: 14-10-2010
Revision: B
Scale @ A3: 1: 300,000
Drafted by: M Angove
Source: Wheatstone Data Sphere

Figure 5: Seasonal distribution of dugong observations within the Wheatstone Survey Area, as collected by CWR

APPENDIX 3

Distribution of Incidental Turtle and Coastal Dolphin Observations

APPENDIX 3: Distribution of Incidental Turtle and Coastal Dolphin Observations

1.0 PREFACE

RPS undertook a dugong strip-width aerial survey in August 2010 around the coastal site of the Wheatstone Project Area and in Exmouth Gulf, on behalf of Chevron Australia. Whilst dugongs were the primary marine megafauna species targeted, incidental observations of sea turtles and coastal dolphins were also recorded. This document presents maps and a brief description of the distribution these records.

1.1 Caveat

As this survey was designed to target dugongs using a double platform arrangement, turtles and dolphins were recorded incidentally and as a low priority. The methods employed for the dugong aerial survey were at too high an altitude to enable turtle or dolphin species identification. As it was not within the scope of this survey to undertake abundance or density analysis for data collected for these fauna groups, no correction for perception or availability bias has been undertaken. Rather than identifying and removing recaptures, only the data collected by the front observers were used in order to avoid the double counting of animals within each tandem team. In essence, a single platform approach was used.

1.2 Mapping Method

Data were plotted using ArcMap 9.3.1 to project records within the Access database to their estimated spatial position based on the central distance of the strip width zone in which they were observed (port or starboard). The data were extracted directly from the Access database under the following parameters:

- Include observations recorded by front observers.
- Exclude observations recorded by rear observers.
- Use the maximum recorded number of individuals in a group (rather than averaging the minimum and maximum best estimate).

2.0 TURTLE OBSERVATIONS

2.1 Turtles within the Wheatstone Survey Area

A total of 103 turtle sightings, consisting of 170 individual turtles, were recorded within the Wheatstone Survey Area (Figure 1), mainly milling on the sea surface. The group sizes varied greatly, from one animal to 20, with the mean group size comprising of 1.65 animals. Very few turtles were observed close to the coast, with only one turtle recorded within the Wheatstone marine assessment area. The vast majority of turtles were further than five kilometres from the mainland, (at a mean distance of 22.05 km from the coast) and past the 10 m isobath. Within the 10–20 m isobath however, turtles were commonly observed near reefs; both fringing and submerged. Of particular note is the large number of turtles, including one group of 11 individuals and another of 20 individuals, observed around the reef habitat fringing Thevenard Island which, although not displayed by the figures. A high number of turtle observations were also recorded over the 20 m isobath, at the most seaward end of T2, T3, T5, T14 and T16.

2.2 Turtles within the Exmouth Gulf

Fewer turtles were seen within Exmouth Gulf than within the Wheatstone Survey Area (Figure 2), 54 turtle observations recorded and 134 individual turtles recorded. The mean group size of turtles within Exmouth Gulf was 2.48 animals. This is likely to be attributed to the large groups of six to ten turtles on T20, T21, T22 and T24 and the group of 25 animals on T20, representing a potential “hot spot”. Almost three quarters of the turtle observations within Exmouth Gulf were recorded in this northern portion (north of Tent Island), with some relation to the distribution of submerged and fringing reef habitat. Turtle observations were confined to water depths of zero to ten metres deep within the southern reaches of the gulf.

3.0 DOLPHIN OBSERVATIONS

3.1 Dolphins within the Wheatstone Survey Area

Dolphins were present throughout the Wheatstone Survey Area during the survey, with a number of 26 observations of 111 individual animals recorded (Figure 3). Group size varied from one or two animals to large pods of up to 20 dolphins. All pod size categories were distributed in all water depths but at a mean distance of 4.72 km from land (including islands), dolphins were closer to the coastline or islands more often than not. There did not appear to be any relationship between dolphin distribution and reef habitat within the Wheatstone Survey Area.

3.2 Dolphins within the Exmouth Gulf

Eleven dolphin observations, consisting of 26 individuals, were recorded within Exmouth Gulf. Group size ranged from one to 12 dolphins, the mean group size being 3.91. The mean distance from land was 4.68 km. There were too few data collected to indicate any strong patterns of dolphin distribution within Exmouth Gulf.

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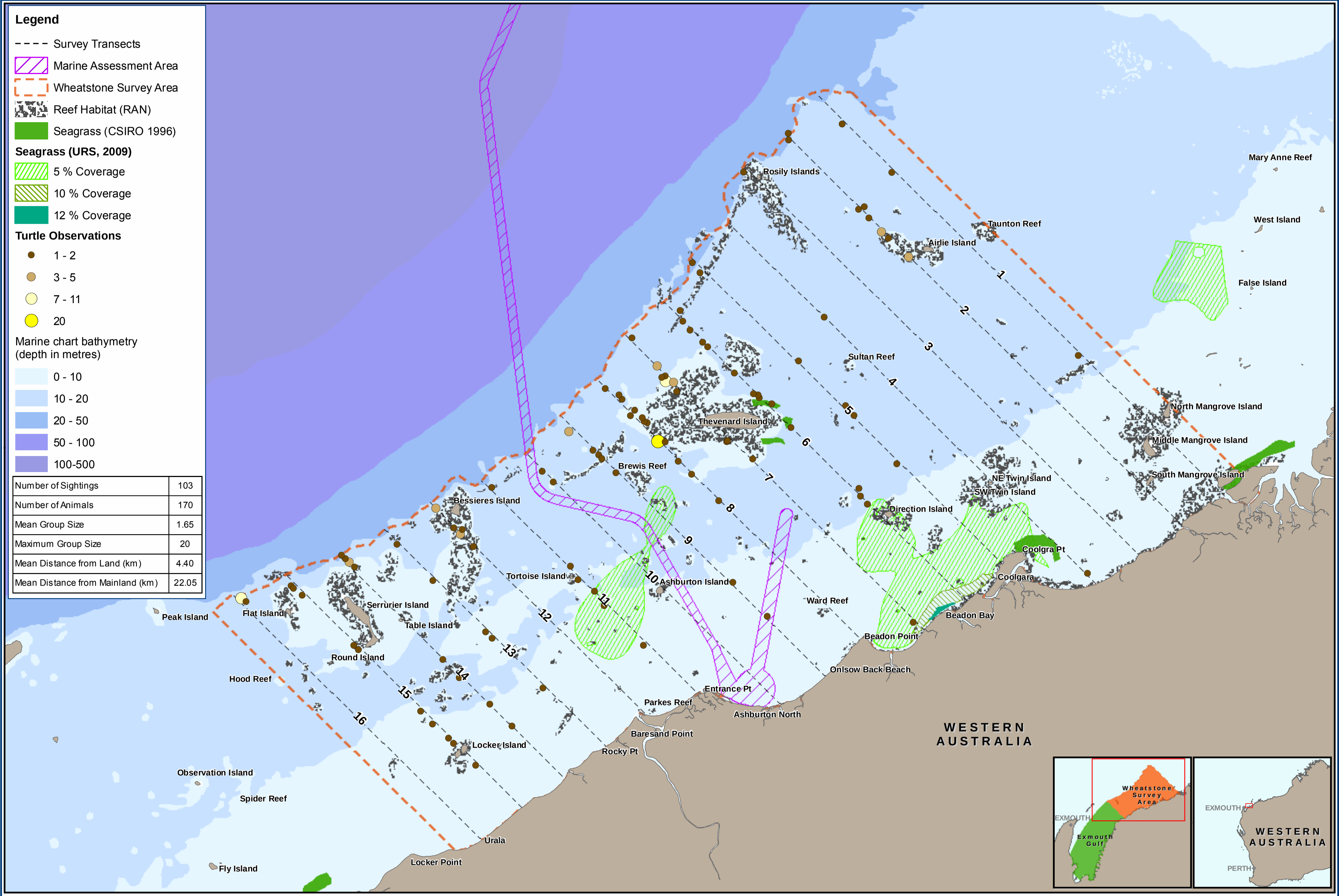

Number of Sightings	103
Number of Animals	170
Mean Group Size	1.65
Maximum Group Size	20
Mean Distance from Land (km)	4.40
Mean Distance from Mainland (km)	22.05

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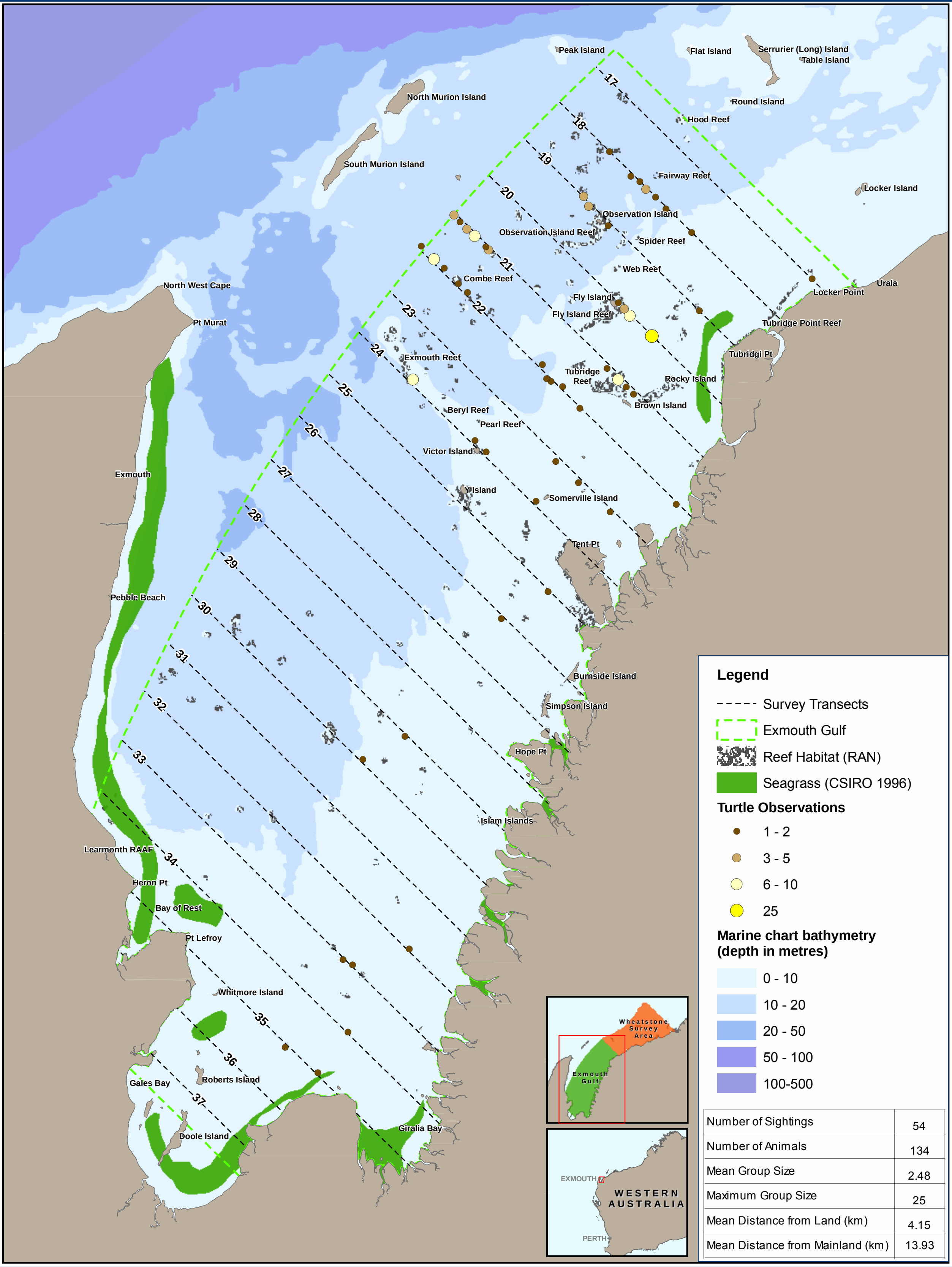
Scale @ A3: 1: 300,000
Drafted by: M Angove
Source: Wheatstone Data Sphere

Figure 1: Turtle Observations within the Wheatstone Survey Area



Number of Sightings	54
Number of Animals	134
Mean Group Size	2.48
Maximum Group Size	25
Mean Distance from Land (km)	4.15
Mean Distance from Mainland (km)	13.93

RPS

Dwg Number : M10612-007
Date: 12-10-2010
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Scale @ A3: 1: 300,000
Drafted by: M Angove
Source: Wheatstone Data Sphere

0 2.5 5 10 km

Figure 2: Turtle Observations within Exmouth Gulf

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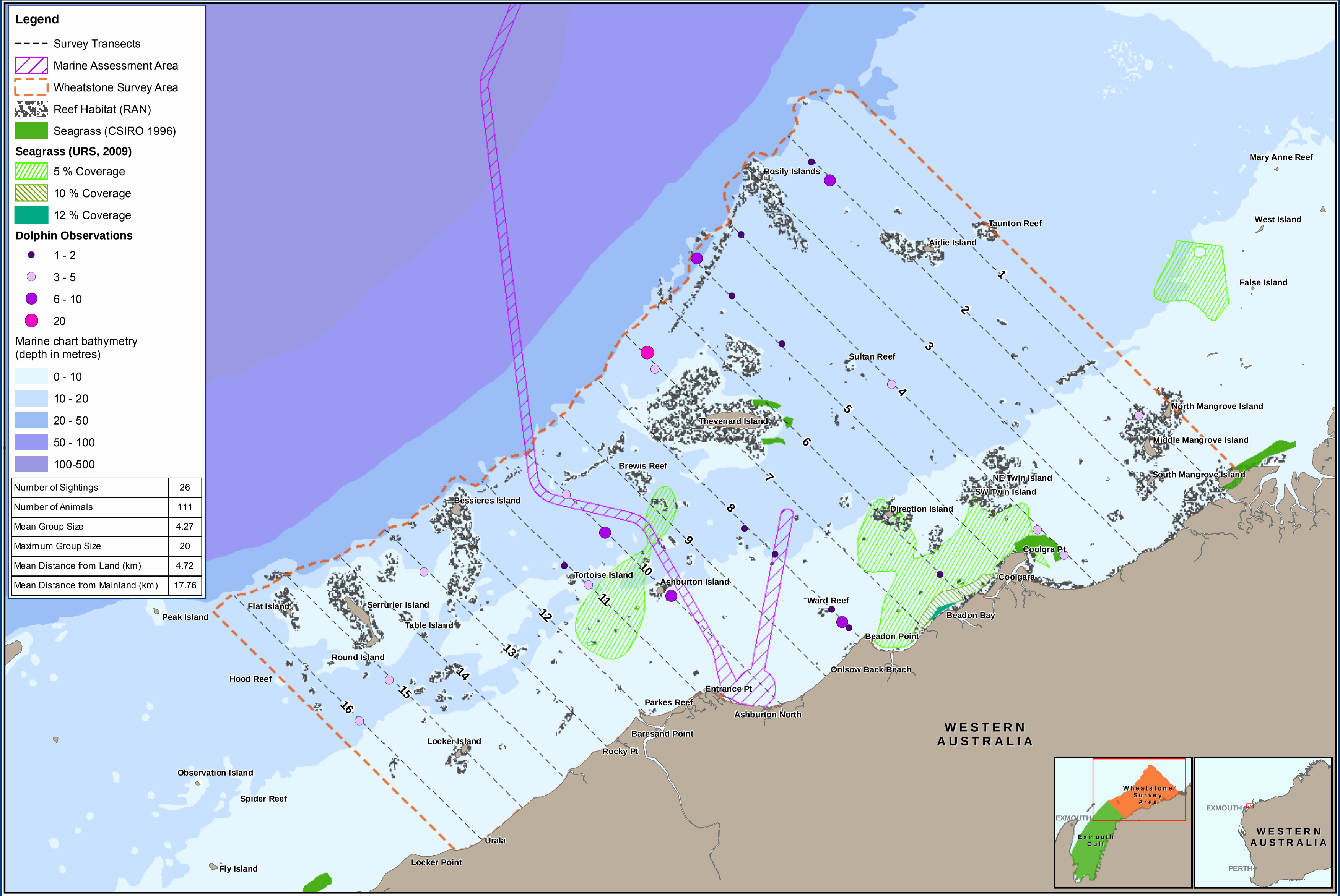

Number of Sightings	26
Number of Animals	111
Mean Group Size	4.27
Maximum Group Size	20
Mean Distance from Land (km)	4.72
Mean Distance from Mainland (km)	17.76

RPS

Dwg Number: M10612-004
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Revision: 0
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Source: Wheatstone Data Sphere

0 2.5 5 10 km

Figure 3: Dolphin Observations within the Wheatstone Survey Area

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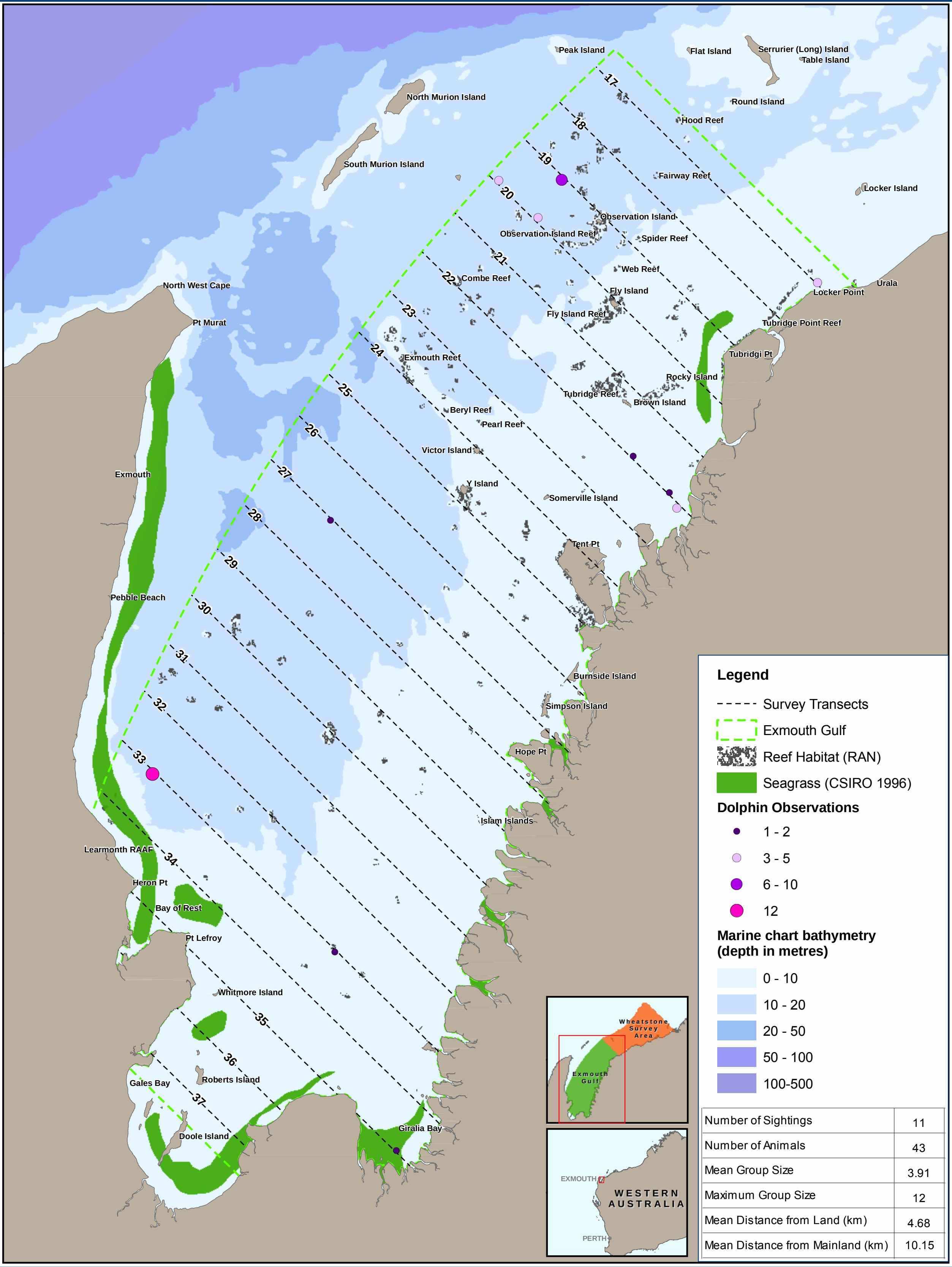

Number of Sightings	11
Number of Animals	43
Mean Group Size	3.91
Maximum Group Size	12
Mean Distance from Land (km)	4.68
Mean Distance from Mainland (km)	10.15

RPS

Dwg Number : M10612-005
Date: 12-10-2010
Revision: 0
Scale @ A3: 1: 300,000
Drafted by: M Angove
Source: Wheatstone Data Sphere

0 2.5 5 10 km

Figure 4: Dolphin Observations within Exmouth Gulf

Appendix FF

Identification and Risk Assessment of Marine Matters of National Environmental Significance

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. This report summarises Matters of National Environmental Significance and incorporates new information acquired by Chevron from ecological surveys since submission of the Draft EIS/ERMP. This report supersedes the review of listed marine fauna presented in the Draft EIS/ERMP (Appendix O7). Matters of National Environmental Significance include *Environment Protection and Biodiversity Conservation Act 1999*-listed Threatened and Migratory species and Commonwealth Marine Areas.

Marine fauna surveys completed as part of the assessment of Matters of National Environmental Significance included:

- A Protected Matters Search
- A desktop literature review
- A dugong aerial survey
- A satellite study of nesting flatback turtles
- A vessel-based survey of foraging marine turtles
- A turtle nesting survey of mainland and island beaches in the vicinity of the Ashburton North Strategic Industrial Area
- An underwater acoustic survey
- A report on turtle nesting and hatchling orientation surveys of mainland and island beaches around Ashburton North
- A survey and report on migratory waterbirds.

A total of 64 Threatened and Migratory marine species have the potential to occur in the Project area, including 10 marine mammal species, six marine reptile species, five elasmobranch species and 43 bird species. Some offshore components of the Project will be located in a Commonwealth Marine Area and potential impacts on the Commonwealth Marine Area have been considered as a Matter of National Environmental Significance. The Protected Matters Search identified nine Matters of National Environmental Significance species with the potential to experience Significant Impact including: the humpback whale, Indo-Pacific humpback dolphin, spotted bottlenose dolphin (Arafura/Timor Sea population only), dugong, flatback turtle, green turtle, hawksbill turtle, loggerhead turtle and sawfish species. Further assessment of potential interaction of these species with nearshore and offshore components of the Project, in line with the Significant Impact criteria, determined that Significant Impact is unlikely. This is because large populations of these species are not restricted to the Project Area, nor is critical habitat for these species located in the Project area. Further, cumulative impacts to these species, arising from the Project-attributable and other planned developments in the area, were considered to be insignificant or manageable through the implementation of appropriate management and mitigation measures.

IDENTIFICATION AND RISK ASSESSMENT OF MARINE MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

Wheatstone Project

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IDENTIFICATION AND RISK ASSESSMENT OF MARINE MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

Wheatstone Project

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Draft B	*Draft for Client Review*	*TraEyr*	*DanHan*	*18.10.10*	*DC 22.10.10*		
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Disclaimer

SUMMARY

Chevron Australia Pty Ltd (Chevron), the proponent of the Wheatstone project, proposes to construct and operate a multi-train LNG plant and domestic gas (Domgas) plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast of Western Australia (WA). As part of the environmental approvals process, Chevron has prepared and submitted a Draft EIS/ERMP to the EPA and DSEWPC (formerly DEWHA). The Draft EIS/ERMP was released for public comment in July 2010

Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), proposed actions are assessed based on whether they will be likely to have a Significant Impact on a matter of National Environmental Significance (NES). The Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) (formerly known as the Department of Environment, Water, Heritage and the Arts (DEWHA) provides guidance on the criteria that should be used to determine whether certain activities are likely to have a Significant Impact on matters of NES.

RPS was commissioned by Chevron to undertake an analysis of the relevant matters of NES for the project. This report summarises these matters of NES and incorporates new information acquired by Chevron from ecological surveys since submission of the Draft EIS/ERMP. This report supersedes the review of listed marine fauna presented in Appendix 07 of the Wheatstone EIS/ERMP (URS 2010a).

The matters of NES relevant to the Wheatstone project are listed Threatened species, listed Migratory species and Commonwealth Marine Areas (CMAs). A total of 64 Threatened and Migratory marine species may occur in the Project Area. These consist of ten marine mammal species, six marine reptile species, five species of sharks and rays and 43 species of birds. Given that some of the upstream components of the project such as the offshore platform and parts of the subsea pipeline will be located in a CMA, potential impacts on the CMA also have been considered as a matter of NES in this report. While 67 species listed as either Marine or Cetacean under the EPBC Act were identified in a Protected Matters search, only a few are likely occur in the vicinity of the Project Area (i.e. the minke whale, bottlenose dolphin and dugong among others).

The search identified nine NES-listed species with the potential to experience Significant Impact: humpback whale, Indo-Pacific humpback dolphin, spotted bottlenose dolphin (Arafura/Timor Sea population only), dugong, flatback turtle, green turtle, hawksbill turtle, loggerhead turtle and sawfish species.

However, further assessment of potential interaction with onshore and offshore components of the project in line with with the Significant Impact criteria determined that Significant Impact is unlikely. The bases of this conclusion were that, although the species are of high conservation status and are likely to be present in or near the Project Area at some time, long-term population decrease is unlikely because large populations are not restricted to the Project Area, nor are critical habitats present in the Project Area.

ABBREVIATIONS

CAMBA	China–Australia Migratory Bird Agreement
CMA	Commonwealth Marine Area
Cth	Commonwealth
DEC	Department of Environment and Conservation (WA)
DEWHA	Department of the Environment, Water, Heritage and the Arts (Cth) (Superseded by DSWPC in September 2010)
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities (Cth)
Domgas	Domestic gas
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ERMP	Environmental Review and Management Programme
JAMBA	Japan–Australia Migratory Bird Agreement
LNG	Liquefied Natural Gas
MPA	Marine Protected Area
MTPA	Million Tonnes per Annum
NES	National Environmental Significance
SIA	Strategic Industrial Area
WA	Western Australia

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Figure 1: Location of Wheatstone project (Chevron 2010).. 3

APPENDICES

APPENDIX 1: EPBC Act Protected Matters Report

APPENDIX 2: Threatened and Migratory Marine Fauna at Risk of Significant Impact

1.0 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast of Western Australia (WA) (Figure 1). The plant will initially process gas from the Wheatstone natural gas fields, approximately 200 km offshore from Onslow in the West Carnarvon Basin. The Wheatstone project will require the installation of gas gathering, exporting and processing facilities in Commonwealth and state waters and in the Shire of Ashburton. The LNG plant will be located in the Ashburton North Strategic Industrial Area and have a combined maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Wheatstone project is currently subject to an environmental approvals process, and is being assessed by the WA Environmental Protection Authority (EPA) and the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPC, formerly DEWHA) via a joint Environmental Impact Statement/Environmental Review and Management Program (EIS/ERMP) document (Chevron 2010). Chevron submitted the draft EIS/ERMP to the EPA and DEWHA in June 2010 and it was released for public comment in July 2010.

The purpose of this report is to identify the marine matters of National Environmental Significance (NES) that are potentially present in areas and may coincide with project activities and infrastructure within the Project Area (referred to as the Indicative Wheatstone Footprint, depicted in Figure 1), and to assess the potential for Significant Impact under the Commonwealth *Environment Protection and Biodiversity Act 1999* (EPBC Act) on the NES matters identified.

This report will be incorporated in the final EIS/ERMP package and supersedes the review of listed marine fauna presented in Appendix 07 of the Wheatstone EIS/ERMP (URS 2009) because it contains new information on listed fauna derived from recent ecological surveys commissioned by Chevron. The full suite of baseline marine fauna surveys commissioned by Chevron and which provide a basis for this report are:

- Protected Matters Search for marine fauna species listed under the EPBC Act that could occur within, or migrate through, the Project Area.
- Detailed desktop literature review on marine mammals potentially occurring in the Project Area (RPS 2010a).
- Dugong aerial survey (RPS 2010b).
- Satellite study of nesting flatback turtles in the vicinity of the Ashburton North SIA (RPS 2010c).

- Vessel-based survey of foraging marine turtles in the vicinity of the Ashburton North SIA (RPS 2010c).

- Turtle nesting survey of mainland and island beaches in the vicinity of the Ashburton North SIA (Pendoley Environmental 2009 described in RPS 2010c).

- Aerial surveys of the abundance and distribution of humpback whales, dugongs, dolphins, whale sharks and turtles in the Project Area (12 month dataset) being undertaken by the Centre for Whale Research (CWR) (Jenner et al. 2010).

- Underwater acoustic surveys of whales and other marine organisms in the Project Area (12 month dataset) undertaken by CMST (Jenner et al. 2009).

- Report on turtle nesting and hatchling orientation surveys of mainland and island beaches around Ashburton North for API in January–March 2009 (Pendoley Environmental 2009a; Appendix O).

- Survey and report on migratory waterbirds present in the vicinity of the Ashburton North SIA (Bamford et al. 2009).

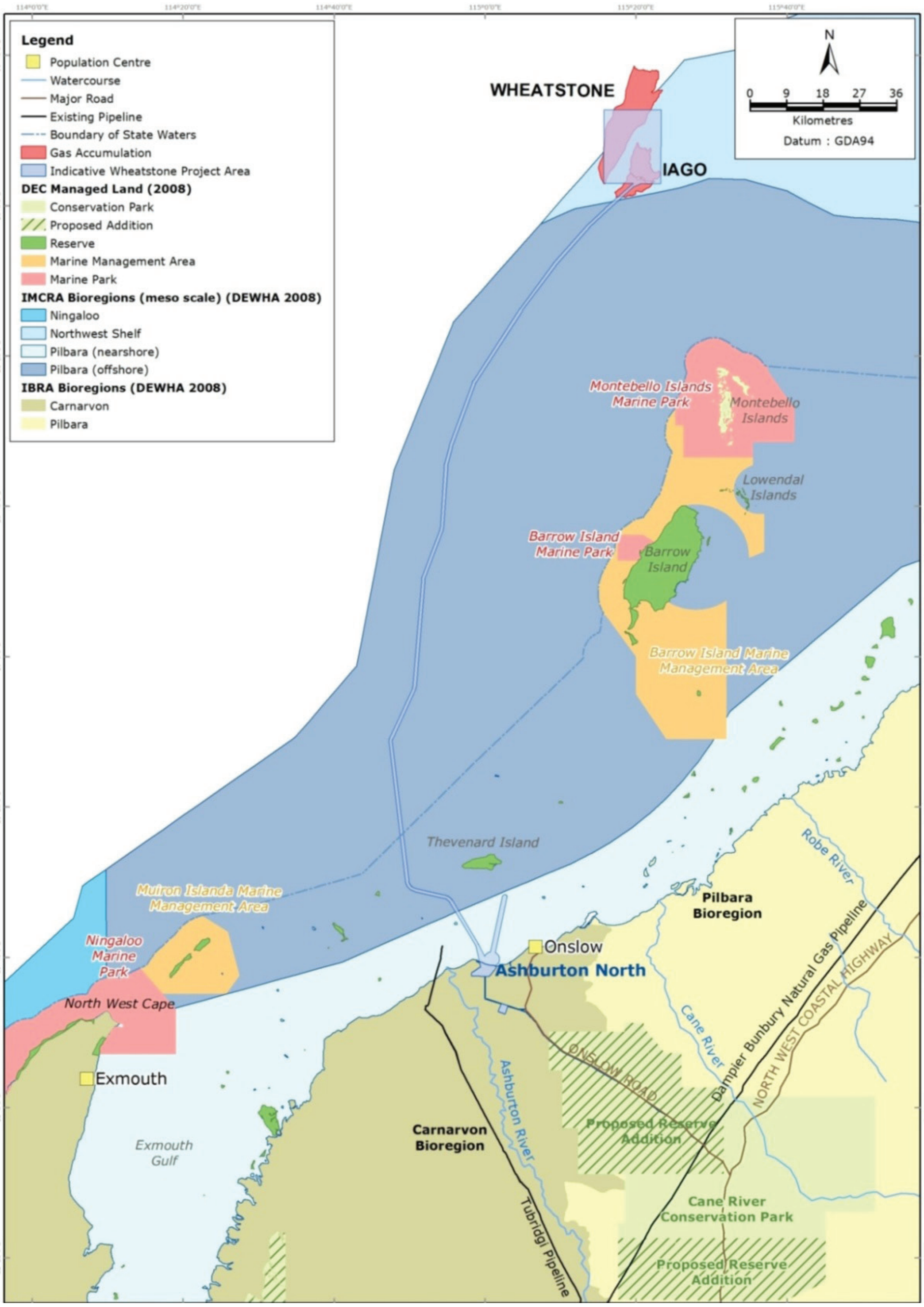

Figure 1: Location of Wheatstone project (Chevron 2010)

2.0 IDENTIFICATION OF MARINE MATTERS OF NES RELEVANT TO THE PROJECT

2.1 Overview of Matters of NES

Under the EPBC Act, proposed actions are assessed based on whether they will be likely to have a Significant Impact on a matter of NES (DEWHA 2009). There are eight matters of NES under the EPBC Act:

- World Heritage properties
- National Heritage places
- Wetlands of International importance
- Listed Threatened species and ecological communities
- Listed Migratory species
- Commonwealth Marine Areas
- Great Barrier Reef Marine Park
- Nuclear actions.

An EPBC Act Protected Matters search of the Project Area and the adjacent waters was conducted and the results are provided in Appendix 1.

There are no World Heritage properties, no National Heritage places, no Wetlands of International importance and no listed Threatened ecological communities within or near the Project Area. The Great Barrier Reef Marine Park is not located within WA and no nuclear actions are proposed as part of the project.

The only marine matters of NES relevant to the Wheatstone project are listed Threatened species, listed Migratory species and Commonwealth Marine Areas (CMAs). They are the focus of this report.

2.2 Threatened and Migratory Species

Threatened and Migratory species that are likely to occur within marine areas (including islands) of, or adjacent to, the Project Area at some time are listed in Table 1. The list has been compiled based on the EPBC Act Protected Matters search result (Appendix 1), as well as from literature reviews and ecological surveys that have been conducted for the project. In summary, a total of 64 Threatened and Migratory marine species may occur in these areas. These consist of ten marine mammal species, six marine reptile species, five species of sharks and rays, and 43 species of birds.

Threatened species categories are defined in section 179 of the EPBC Act as:

- Extinct
- Extinct in the wild
- Critically Endangered
- Endangered
- Vulnerable
- Conservation Dependent.

Migratory species are defined in section 209 of the EPBC Act. Migratory species include native species that either migrate to, or transit through, Australian waters from other territories and are listed under the Bonn Convention, the China–Australia Migratory Bird Agreement (CAMBA), the Japan–Australia Migratory Bird Agreement (JAMBA), and any other international agreement approved under the EPBC Act by the Commonwealth Minister responsible for DSEWPC.

Some species that were listed in the EPBC Act Protected Matters search results (Appendix 1) are not included in Table 1: because the species was either not a marine species (e.g. the mulgara), or because the distribution of the species does not coincide with the Project Area and the species is not known to occur in the Onslow coastal or offshore area. The species distribution information within the EPBC search engine is conservative and based on information from a variety of sources including survey data, literature review and expert opinion. These marine fauna groups are described in more detail in Section 2.2.1 (mammals), Section 2.2.1.2 (reptiles), Section 2.2.2.1 (sharks and rays) and Section 2.2.4 (birds).

Table 1: Threatened and Migratory Marine Fauna that May Occur within Marine Areas (including Islands) of or adjacent to the Project Area

Species Name		EPBC Act Status E: Endangered V: Vulnerable M: Migratory
Mammals		
Blue whale [1] (includes pygmy blue whale)	*Balaenoptera musculus intermedia (and B. m. brevicauda)*	E M
Southern right whale	*Eubalaena australis*	E M
Humpback whale[1]	*Megaptera novaeangliae*	V M
Antarctic minke whale	*Balaenoptera bonaerensis*	M
Bryde's whale	*Balaenoptera edeni*	M
Killer whale[1]	*Orcinus orca*	M
Sperm whale	*Physeter macrocephalus*	M
Indo-Pacific humpback dolphin	*Sousa chinensis*	M
Spotted / Indo-Pacific bottlenose dolphin[2]	*Tursiops aduncus*	M
Dugong[1]	*Dugong dugon*	M

Species Name		EPBC Act Status E: Endangered V: Vulnerable M: Migratory
Reptiles		
Loggerhead turtle[1]	*Caretta caretta*	E M
Green turtle[1]	*Chelonia mydas*	V M
Leatherback turtle	*Dermochelys coriacea*	E M
Hawksbill turtle[1]	*Eretmochelys imbricata*	V M
Flatback turtle[1]	*Natator depressus*	V M
Saltwater Crocodile[1]	*Crocodylus porosus*	M
Sharks and Rays		
Dwarf sawfish[1]	*Pristis clavata*	V
Green sawfish[1]	*Pristis zijsron*	V
Whale shark[1]	*Rhincodon typus*	V M
Shortfin mako	*Isurus oxyrinchus*	M
Longfin mako	*Isurus paucus*	M
Birds		
Accipitridae		
White-bellied sea eagle[1]	*Haliaeetus leucogaster*	M
Eastern osprey[1]	*Pandion cristatus*	M
Osprey[3]	*Pandion haliaetus*	M
Ardeidae		
Cattle egret	*Ardea ibis*	M
Eastern great egret[1]	*Ardea modesta*	M
Eastern reef egret[1]	*Egretta sacra*	M
Charadriidae		
Oriental plover[1]	*Charadrius veredus*	M
Grey plover[1]	*Pluvialis squatarola*	M
Pacific golden plover[1]	*Pluvialis fulva*	M
Lesser sand plover[1]	*Charadrius mongolus*	M
Greater sand plover[1]	*Charadrius leschenaultia*	M
Glareolidae		
Oriental pratincole[1]	*Glareola maldivarum*	M
Laridae		
Caspian tern[1]	*Sterna caspia*	M
Lesser-crested tern[1]	*Sterna bengalensis*	M
Common tern[1]	*Sterna hirundo*	M
Little tern[1]	*Sterna albifrons*	M
White-winged black tern[1]	*Chlidonias leucopterus*	M
Roseate tern[1]	*Sterna dougallii*	M
Bridled tern[1]	*Sterna anaethetus*	M
Procellariidae		
Southern giant-petrel	*Macronectes giganteus*	E M
Wedge-tailed shearwater[3]	*Puffinus pacificus*	M

Species Name		EPBC Act Status E: Endangered V: Vulnerable M: Migratory
Scolopacidae		
Pin-tailed snipe[1]	*Gallinago stenura*	M
Black-tailed godwit[1]	*Limosa limosa*	M
Bar-tailed godwit[1]	*Limosa lapponica*	M
Little curlew[1]	*Numenius minutus*	M
Whimbrel[1]	*Numenius phaeopus*	M
Eastern curlew[1]	*Numenius Madagascariensis*	M
Marsh sandpiper[1]	*Tringa stagnatilis*	M
Common greenshank[1]	*Tringa nebularia*	M
Wood sandpiper[1]	*Tringa glareola*	M
Terek sandpiper[1]	*Xenus cinereus (Tringa terek)*	M
Common sandpiper[1]	*Tringa hypoleucos*	M
Grey-tailed tattler[1]	*Tringa brevipes*	M
Ruddy turnstone[1]	*Arenaria interpres*	M
Red knot[1]	*Calidris canutus*	M
Great knot[1]	*Calidris tenuirostris*	M
Sanderling[1]	*Calidris alba*	M
Red-necked stint[1]	*Calidris ruficollis*	M
Long-toed stint[1]	*Calidris subminuta*	M
Sharp-tailed sandpiper[1]	*Calidris acuminata*	M
Curlew sandpiper[1]	*Calidris ferruginea*	M
Broad-billed sandpiper[1]	*Limicola falcinellus*	M
Threskionithidae		
Glossy ibis [3]	*Plegadis falcinellus*	M

1. Species has been recorded within or near the Project Area during surveys.
2. Arafura/Timor Sea populations only. This dolphin has been referred to as the 'spotted bottlenose dolphin' rather than 'Indo-Pacific bottlenose dolphin' in this report for consistency with the EPBC Act Protected Matters search results.
3. Species is expected to occur in the Onslow region and may therefore occur in the Project Area from time to time.
Note: While the fork-tailed swift *(Apus pacificus)*, the barn swallow *(Hirundo rustica)* and the rainbow bee-eater *(Merops ornatus)* were identified in the EPBC Act Protected Matters search (Appendix 1), they have not been included in this table and are not covered in this report due to their strong terrestrial affinities. Birds are described in greater detail in Section 2.2.4.

2.2.1 Threatened and Migratory Marine Mammals and their Habitat

2.2.1.1 Baleen Whales

A total of five baleen whale species have been identified as potentially occurring in or adjacent to the Project Area: the blue whale *(Balaenoptera musculus)*, southern right whale *(Eubalaena australis)*, humpback whale *(Megaptera novaeangliae)*, Antarctic minke whale *(Balaenoptera bonaerensis)* and Bryde's whale *(Balaenoptera edeni)*. All five species are listed as Migratory under the EPBC Act. The blue whale and the southern right whale are also listed as Endangered, and the humpback whale is listed as Vulnerable under the EPBC Act.

There are two recognised subspecies of blue whale in Australian waters, the southern blue whale *(B. musculus intermedia)* and the pygmy blue whale *(B. musculus brevicauda)* (DEH 2005; DEWHA 2010). Both subspecies of blue whale may be found in all waters around Australia, and in the waters off Australia's Antarctic Territory (Bannister et al. 1996). However the two key feeding and aggregation localities for blue whales in Australia are the Bonney Upwelling in South Australia/Victoria, where southern blue whales aggregate, and the Perth Canyon to the west of Rottnest Island near Perth in WA, where pygmy blue whales aggregate (DEWHA 2010).

Blue whale migration is expected to occur in deep waters offshore and over the continental shelf edge of the Project Area between May and August (northward) and October and January (southward) (RPS 2010a). Aerial surveys conducted in the Project Area to date have recorded very few blue whales, suggesting that numbers are relatively low in the area (Jenner et al. 2010).

Southern right whales that inhabit Australian waters are primarily distributed along the southern coastline of Australia and are occasionally observed in Perth waters between May and October. Sightings in more northern waters are relatively rare, but they have been recorded near Exmouth (DEWHA 2010). No southern right whales have been detected in the Project Area during baseline surveys conducted to date (Jenner et al. 2010).

Humpback whales generally pass through the Onslow area on their northward migration from June onwards. Aerial surveys have found that northbound humpback whales first passed through the Project Area from early to mid-June (Jenner et al. 2010). During the northward migration, whales were generally concentrated seaward of Thevenard Island and over the continental slope. Humpback whales start their southward journey from mid-August (Jenner et al. 2010; RPS 2010a). During their southbound migration, cows and calves predominantly rest inshore of the 50 m isobath (Jenner et al. 2010), with some whales, including cows and calves, recorded in water less than 10 m deep during the latter part of the migration. Generally, all humpback whales have passed Onslow by November (Jenner 2008).

The majority of calving for humpback whales is thought to occur in sheltered areas of the Kimberley region, including Camden Sound, approximately 1200 km north-east of Onslow (DEWHA 2010). During the southward migration, Exmouth Gulf, Shark Bay, Geographe Bay and waters adjacent to the Houtman Abrolhos Islands are used as resting areas (DEWHA 2010). Humpback whales fulfil most of their annual nutritional needs in Antarctic waters during the Austral summer where they feed on krill and in particular *Euphausia superb.*

Antarctic minke whales are often present in deep waters along the edge of the continental shelf of southern Australia (DEWHA 2010). This species has not been recorded within the Project Area during surveys conducted to date and is unlikely to be present due to the species' preference for very cold waters.

Bryde's whales occur in waters around Australia and along the edge of the continental shelf. The nearest known aggregation areas for Bryde's whales in WA are the Abrolhos Islands and north of Shark Bay (Bannister et al. 1996). Bryde's whales were detected during noise logger surveys in waters approximately 40 m deep west of Onslow on a single day in April 2009 (McCauley 2009). Data suggest that Bryde's whales transit through deep-water areas in the Project Area and over the continental shelf in low to very low numbers (RPS 2010a).

2.2.1.2 Toothed Whales (including Dolphins)

Four Threatened or Migratory toothed whale species have been identified as potentially occurring within the Project Area: the sperm whale *(Physeter macrocephalus)*, killer whale *(Orcinus orca),* Indo-Pacific humpback dolphin *(Sousa chinensis)* and the Arafura/Timor Sea populations of spotted bottlenose dolphin *(Tursiops aduncus)*. All of these species are listed as Migratory under the EPBC Act.

Sperm whales may migrate through waters along the entire Australian coastline, although their distribution in the northern most coastal regions is limited (DEH 1999). A pod of ten sperm whales was recorded on the 830 m isobath during the CWR aerial surveys (Jenner et al. 2010). This suggests that sperm whales may be present in the deeper oceanic waters in the vicinity of the gas field locations from time to time (RPS 2010a).

Killer whales are known to be distributed from polar to tropical marine regions during all seasons and are therefore considered widespread (DEWHA 2010). They have been sighted often in Exmouth Gulf (Jenner and Jenner 2005) and in the Barrow Island area (Butler 1975). A pod of five killer whales was recorded in waters 400 m deep during aerial surveys in the Project Area in November 2009. Corkeron and Connor (1999) suggest that killer whale migration is closely linked to the availability of their smaller marine mammal prey. Given the pod of killer whales was recorded close to a humpback whale pair, presumed to be travelling southward, it is possible that killer whales will move through the Project Area at certain times of the year in predatory pursuit of humpback whale calves (Jenner, C., pers. comm., cited in Chevron 2010).

The Indo-Pacific humpback dolphin *(Sousa chinensis)* and the Arafura/Timor Sea populations of spotted bottlenose dolphin *(Tursiops aduncus)* are listed as Migratory under the EPBC Act and have been identified as potentially occurring within the Project Area.

Indo-Pacific humpback dolphins are found along the northern coastline of Western Australia as far south as Shark Bay (Jenner 2008). The Indo-Pacific humpback dolphin is a nearshore species that generally inhabits shallow coastal waters, embayments and estuaries, and has resident populations within the shallow waters of the inner Rowley Shelf, to the north of Exmouth Gulf (DEWHA 2010). The species is considered to be sensitive to habitat degradation, noise pollution and harassment (DEWHA 2010). Although the Project Area is towards the southern limit of Indo-Pacific humpback dolphin distribution in Australia, it is believed that this dolphin species was recorded during aerial surveys (although accurate identification was not possible for small dolphin species) (Jenner et al. 2010). The Indo-Pacific humpback dolphin is likely to be present in coastal areas, including those that coincide with Project Area.

Aerial surveys conducted to date identified dolphins between the 10–20 m depth contours, some of which are likely to be the spotted bottlenose dolphin. There are at least two populations of spotted bottlenose dolphin in Australia, including the Arafura/Timor Sea population, which is listed as Migratory under the EPBC Act and therefore a matter of NES. The migratory Arafura/Timor Sea populations may traverse the area, but are less likely to be encountered in the Project Area than the resident individuals of the local coastal population. These animals generally inhabit warmer nearshore coastal areas (<10 m water depth) and are distributed along the north-west coast of the Northern Territory and northern coast of WA (Bannister et al. 1996). These dolphins should not be confused with common bottlenose dolphins (*T. truncatus*), which are neither Threatened nor Migratory and so are not discussed within this report.

2.2.1.3 Dugong

Dugongs are generally spread across the northern half of Australia in coastal waters off the NT, Queensland and Torres Strait, and northern WA. Important dugong habitats in WA include Shark Bay, Exmouth Gulf, Ningaloo Reef, the Kimberley coast and Ashmore Reef (DEWHA 2008). Dugongs were consistently sighted throughout aerial surveys of the Project Area, at times with calves, and the majority of the recordings were in water less than 10 m deep. Areas of higher densities of dugong were recorded to the north-east and to the south-west of the Project Area (Jenner et al. 2010). However, data showed that dugongs do occur within areas proposed for marine infrastructure (Jenner et al. 2010; RPS 2010a).

A dedicated dugong survey was undertaken by RPS in August 2010. This survey confirmed that the Project Area does not have the same importance for dugongs as Exmouth Gulf or Shark Bay. The absolute abundance of dugongs within the Wheatstone Survey Area, which encompassed the Project Area, was less than one-sixth of that in Exmouth Gulf, and no calves were recorded within the Wheatstone Survey Area. However, dugongs are likely to be present in coastal waters throughout the year (RPS 2010a; Jenner et al. 2009). The 2010 survey confirmed that dugongs were often close to the coast or in the lee of reef-fringed islands and areas where seagrass has been recorded. It remains unclear whether they are resident or migratory, or a mixture of the two (RPS 2010a).

2.2.2 Threatened and Migratory Marine Reptiles and their Habitat

2.2.2.1 Marine Turtles

A total of five marine turtle species have been identified as potentially occurring within the Project Area at some time: the green turtle *(Chelonia mydas)*, flatback turtle *(Natator* *depressus)*, loggerhead turtle *(Eretmochelys imbricata)*, hawksbill turtle *(Caretta caretta)* and leatherback turtle *(Dermochelys coriacea)*. All of these species are listed as Migratory under the EPBC Act. The loggerhead turtle and leatherback turtle are also listed as Endangered, and the green turtle, hawksbill turtle and flatback turtle are listed as Vulnerable under the EPBC Act.

Green turtles and flatback turtles are known to occur in the Project Area during sensitive life-history phases (mating, nesting and inter-nesting), and may be present in the area year-round (RPS 2010c). Loggerhead turtles and hawksbill turtles are less abundant and their distribution in the vicinity of the Project Area is not well known (RPS 2010a). Leatherback turtles have not been recorded in the Project Area, and they are not known to nest in the area (RPS 2010c).

In general, turtle nesting activity is generally higher on the offshore islands than on the mainland. On the islands, nesting activity by a combination of flatback and green turtles was recorded on the large (Serrurier and Thevenard) and moderate sized (Bessieres, Locker and Ashburton) islands (Pendoley Environmental 2009a). These islands appear to support regionally significant nesting rookeries for green turtles; however, none of these rookeries approach the size of the rookeries at Barrow Island or the Dampier Archipelago (60 km to the north and 200 km to the north-east, respectively) (Pendoley Environmental 2009a). Low density hawksbill and loggerhead turtle nesting has also been recorded on some of these islands (Mau and Balcazar 2007; Pendoley Environmental 2009a, 2009b). Little or no nesting activity has been recorded on mainland beaches.

The peak nesting periods in the area are December–February (green turtles), December–January (flatback turtles and loggerhead turtles) and October–December (hawksbill turtles) (Pendoley Environmental 2005). Inter-nesting activity occurs during peak nesting periods. Most marine turtle species spend the inter-nesting period near their nesting beach, although flatback turtles nesting at Barrow Island have been recorded along the Pilbara mainland coast during the inter-nesting season (Chevron 2009). Satellite telemetry studies on flatback turtles demonstrated that inter-nesting habitat for flatback turtles nesting at Ashburton Island comprised approximately 1500 km^2 (RPS 2010d). The turtles regularly moved through the Project Area, but spent relatively little time in this area.

Green, loggerhead and hawksbill turtles generally mate in areas adjacent to their nesting beaches. Flatback turtle mating areas are not known. Peak periods for marine turtle mating are not confirmed, but are thought to be October–December (green turtles), November–December (flatback turtles and loggerhead turtles) and September–October (hawksbill turtles).

Green, loggerhead and hawksbill turtle hatchlings travel from the beaches where they hatch to offshore deep water areas. The peak hatching seasons are not confirmed for all species, but are thought to be February–April (green turtles), January–March (flatback and loggerhead turtles) and November-February (hawksbill turtles).

Six Mk10-AF Platform Terminal Transmitter (PTTs) were attached to nesting flatback turtles at Ashburton Island in December 2009. Five of the PTTs provided location and dive information on inter-nesting movements and all six PTTs provided information on post-nesting migratory movements. The inter-nesting habitat for flatback turtles nesting at Ashburton Island comprised approximately 1,500 km^2 covering areas between Baresand Point, Bessieres Island, Airlie Island and Coolgra Point. The turtles regularly moved through the Wheatstone project footprint, but spent relatively little time in this area (RPS 2010e). Flatback turtles spent large proportions of their time at the seabed and less time near the sea surface (RPS 2010c). There were no obvious areas where the turtles were more or less likely to spend time on the sea floor or near the sea surface (RPS 2010e).

The reef habitats surrounding the islands offshore from Ashburton North appear to be important foraging habitat for juvenile and adult green turtles. Aerial surveys have revealed that the highest densities of turtle sightings are generally around the 40 m isobath in the vicinity of Brewis Reef, Bowers Ledge and north of Onslow.

Foraging studies indicate that marine turtles appear to favour the shallow reef habitats surrounding offshore islands (RPS 2010e). The majority of foraging turtles identified during the foraging studies were juvenile green turtles, which were considered likely to be resident. Foraging green turtles are likely to be found in seagrass and algal habitats near the Project Area, and may utilise coastal mangrove habitats (Pendoley Environmental 2009a). A resident population of adult green turtles was found to forage in the reef habitats surrounding islands. Based on the recent and existing satellite telemetry studies in the region, the area between Barrow Island and the Muiron Islands (between the 20–100 m bathymetric contours) appears to be an important flatback turtle foraging area, particularly to the west of the Project Area (RPS 2010d).

2.2.2.2 Saltwater Crocodiles

The saltwater crocodile *(Crocodylus porosus)* is listed as Migratory under the EPBC Act. It is the most widely distributed crocodilian species, occurring in Northern Australia, throughout Southeast Asia, Southern India and Palau (Kay 2004; URS 2010a). The saltwater crocodile is considered common and locally abundant in WA, particularly in the Kimberley region, where it is known to nest in rivers (URS 2010a). DEC (2009) states that lone male crocodiles have been recorded as resident in isolated rivers in the Pilbara region, and that vagrant crocodiles have been recorded as far south as Carnarvon. There have been recent sightings of several vagrant saltwater crocodiles in coastal waters in the vicinity of the Project Area; an individual in the Ashburton River Mouth, a smaller one further up the Ashburton River and a third at Three Mile Creek (URS 2010a). These animals are monitored by the Shire of Ashburton and Department of Environment and Conservation (DEC) in the interest of public safety and are not likely to be present in any greater numbers within the area.

2.2.3 Threatened and Migratory Sharks and Rays and their Habitat

2.2.3.1 Sharks

Three listed species of shark have been identified as potentially occurring in the Project Area: the whale shark *(Rhincodon typus)*, shortfin mako *(Isurus oxyrinchus)* and the longfin mako *(Isurus paucus)*. These species are all listed as Migratory under the EPBC Act. The whale shark is also listed as Vulnerable under the EPBC Act.

The nearest known aggregation site for whale sharks is at Ningaloo Reef, which is located approximately 100 km west of the Project Area. A recent study found that whale sharks depart Ningaloo Reef between May and June and most travel north-east along the continental shelf before moving offshore into the north-eastern Indian Ocean (Wilson et al. 2006). This migration takes the whale sharks past the Project Area along the offshore continental slope. Four whale sharks were sighted during aerial surveys conducted in May–December 2009 (Jenner et al. 2009); therefore, it is likely that whale sharks will be present in Project Area from time to time, but probably in low numbers.

The shortfin mako shark is considered widespread in temperate and tropical waters of all oceans (Cailliet et al. 2004). In Australia, it is recorded from the marine waters of all states, excluding the Northern Territory (McGrouther 2009). This species is considered highly migratory and can be found from the surface down to at least 500 m water depth (Cailliet et al. 2004). There is little information available on the presence of this species in the Pilbara region, and it has not been recorded in the Project Area during surveys conducted to date.

The longfin mako shark is widely distributed in tropical and warm temperate waters (Reardon et al. 2006). The complete distribution of this species remains unclear and its occurrence is very poorly known in Australian waters (Stevens and Scott 1995). In general, this species is rarely encountered and it has not been recorded in the Project Area during surveys conducted to date.

2.2.3.2 Rays

Two listed species of ray have been identified as potentially occurring in the Project Area: the dwarf sawfish *(Pristis clavata)* and the green sawfish *(Pristis zijsron)*. Both species are listed as Vulnerable under the EPBC Act.

While few surveys have been conducted specifically for these species, the distribution of the dwarf sawfish is generally considered to extend north from Cairns around the Cape York Peninsula in Queensland, and across northern Australia to the Pilbara coast in WA (Last and Stevens 1994; Stevens et al. 2008). There are no confirmed records of the dwarf sawfish outside of Australian waters, which suggests that the Australian population of the species is likely to comprise the majority of the total global population (Stevens et al. 2005; Thorburn et al. 2004). The dwarf sawfish usually inhabits shallow coastal waters (2–3 m) and estuarine habitats (DEWHA 2010). Thorburn et al. (2007) found that this species uses estuarine habitats as nursery areas, with juveniles remaining for up to three years in such areas.

Green sawfish inhabit marine waters, estuaries, river mouths, embankments and waters along sandy and muddy beaches (Peverell et al. 2004; Stevens et al. 2005; Thorburn et al. 2004), and have been recorded in very shallow water (<1 m) to water depths of over 70 m (Stevens et al. 2005). Green sawfish have been recorded in coastal waters off Broome in WA, around northern Australia and down the east coast as far as Jervis Bay, in New South Wales (Stevens et al. 2005). While Last and Stevens (2009) note that the southward range of the green sawfish has been restricted due to population effects from fishing, the species is found south to Coral Bay and could occur as far south as Perth.

Sawfish (*Pristis* spp.) have reportedly been sighted in the lower section of West Hooley Creek and the north-eastern Ashburton Lagoon during surveys conducted in November and December 2009 (Fred Wells, pers. comm., cited in Chevron 2010). However, no sawfish were recorded during netting surveys conducted in April 2010. A dedicated sawfish survey is planned for November 2010 and is expected to confirm the presence of this species of sawfish within the Project Area.

2.2.4 Threatened and Migratory Marine Birds and their Habitat

A total of 43 birds listed as Migratory under the EPBC Act have been identified as potentially occurring in the Project Area (listed in Table 1). Of these species, the southern giant-petrel *(Macronectes giganteus)* is also listed as Endangered under the EPBC Act.

It should be noted that the bird species listed in Table 1 are seabirds that inhabit predominantly marine habitats (gulls, terns, albatrosses, etc.) and waterbirds that inhabit mostly freshwater habitats (waders, ibises, etc.). Waterbirds are considered in this report because many have been observed in coastal areas on the mainland and on offshore islands in the vicinity of the Project Area. In addition, some species that could be considered seabirds (such as terns) were included in the survey conducted on migratory waterbirds (Bamford et al. 2009). As a result, and given that both seabirds and waterbirds are known to inhabit coastal areas in the Pilbara region, these two groups are generally not distinguished in this report. Instead, they are generally referred to as "migratory birds".

The Pilbara region is part of the East Asian–Australasian Flyway, which means millions of migratory birds transit through the region on their way from their breeding grounds in the northern hemisphere to spend part of the southern hemisphere summer in Australia (DEWHA 2008). Offshore islands provide important staging or stopover sites for migratory birds (DEWHA 2008). Significant breeding sites in the Pilbara region include locations such as Eighty Mile Beach, the Lacepede Islands and the Montebello/Barrow Islands (DEWHA 2008). Some of the nearshore islands in the vicinity of the Project Area are also known to support migratory bird nesting (DEWHA 2008).

The southern giant petrel is highly mobile, but favours temperate waters in the Southern Ocean, where they are widespread (DEWHA 2010). They are known to breed on Macquarie Heard, McDonald, Giganteus and Hawker islands in the Australian Antarctic Territories (Environment Australia 2001; Patterson et al. 2008; Woehler et al. 2001). The Project Area is towards the northern limit of their distribution in Australia, therefore this species would rarely be encountered. There are no major breeding or feeding areas for the southern giant petrel in the vicinity of the Project Area.

Migratory species that have been recorded on nearshore islands in the vicinity of Onslow include Caspian terns, white-bellied sea eagles, ospreys, eastern reef egrets and wedge-tailed shearwaters. While these species could be present at times in the vicinity of the Project Area, they are generally considered widespread in the Pilbara region. Overall, surveys conducted to date for the project have found that the Project Area does not support significant numbers of migratory birds (Bamford et al. 2009).

In the Pilbara region, the Dampier Saltworks and Barrow Island are considered important sites for some migratory birds (Bamford et al. 2009). Barrow Island supports 20,000 migratory birds regularly, and the red-necked stint, ruddy turnstone and grey-tailed tattler are present in internationally significant numbers on the island (Bamford et al. 2009). Exmouth Gulf is also known to support large numbers of migratory birds, including grey-tailed tattlers (Yannarie Solar 2006; Bamford et al. 2009). When compared to maximum counts from Barrow Island and Exmouth Gulf, the maximum counts around Onslow can be considered very low (Bamford et al. 2009).

Sites are recognised as being internationally important for migratory birds if they support 20,000 waterbirds or more, one per cent of a species' population, or 0.25 % of a migratory species' population on passage (Ramsar Convention Bureau 2000). Bamford et al. (2009) state that the counts for waterbird species from surveys conducted in 2008 and 2009 are all well below any criterion of international significance, with the exception of the common tern. Scott and Delaney (2002) provide a regional population estimate for the common tern of 25,000–1,000,000. Therefore, the count of 285 on Town Beach in 2008 represents slightly more than one per cent of the lower limit of Delaney and Scott's estimate (Bamford et al. 2009). However, Bamford et al. (2009) note that, given the calculation is based on the lower limit of the population range (25,000), and given the uncertainty associated with the population range estimated, the Onslow count is likely to be less significant.

The common tern has a widespread and largely continuous breeding distribution through much of Europe, Asia and in North America, but is not known to breed in Australia (DEWHA 2010). In Australia, common terns are mainly found along the eastern coast, where they are widespread and common from south-eastern Queensland to eastern Victoria (DEWHA 2010). In northern Australia, they are widespread in the Top End of the Northern Territory, and also in the Gulf of Carpentaria and along the western side of Cape York Peninsula (DEWHA 2010). They are less widespread in WA, with scattered populations north of 30°S to the Kimberley region.

Bamford et al. (2008) provide regional population estimates for the Pilbara and Gascoyne coastline. Generally, numbers of migratory birds in the Onslow area were very low when compared to regional population estimates. The exceptions are the whimbrel, the eastern curlew and the sanderling. The counts of these species recorded during project surveys could be considered regionally important (Bamford et al. 2009). However, the regional estimates provided by Bamford et al. (2008) are based on very few data (Bamford et al. 2009) and therefore have a large amount of uncertainty associated with them. Furthermore, these species are considered widespread in Australia, generally occurring in all states, and none are known to breed in Australia (DEWHA 2010).

There are no important feeding areas for migratory birds in the vicinity of the Project Area. The shorelines in the Project Area are mostly composed of a coarse, sandy substrate, rather than the fine silts that typically support the high densities of invertebrates upon which migratory waterbirds feed (Bamford et al. 2009). Surveys conducted in marine intertidal habitats in the vicinity of the Project Area found the invertebrate fauna to be extremely limited on the seaward beach slopes and low tidal sand flats (URS Australia 2008, 2009). The mangrove habitat and adjacent high tidal mud flats were found to be more productive and supported dense crab populations (URS Australia 2008, 2009). However, with the exception of whimbrels, migratory waterbirds tend to avoid mangrove habitats (Bamford et al. 2009).

Many migratory birds were observed roosting or foraging at the existing Tubridgi Gas Plant, and between the Project Area and the Onslow salt ponds during surveys conducted in 2008 and 2009 (Bamford et al. 2009). However, the near-coastal claypans and tidal flat habitats associated with these areas are extensive in the Onslow region (Bamford et al. 2009).

2.3 Commonwealth Marine Area

The CMA is a matter of NES under the EPBC Act. Under section 24 of the EPBC Act, the CMA covers any part of the sea, including the waters, seabed and airspace, within Australia's Exclusive Economic Zone (EEZ), with the exception of state or territorial waters. Most of the upstream components of the project, such as the offshore platform and parts of the subsea pipeline, will be located in the CMA. Within the CMA, listed flora and fauna species are included as matters of NES.

A significant impact on the CMA may result if an aspect of the project has a substantial adverse effect on a listed Marine or Cetacean species populations, life cycles (for example, breeding, feeding, migration behaviour, life expectancy) or spatial distributions that occurs within the CMA. A number of species listed as Marine or Cetacean under the EPBC Act may be present in the Project Area. This includes many of the species listed in Table 1, as well as additional species identified in the EPBC Act Protected Matters search (Appendix 1). Results from the EPBC Protected Matters search (Appendix 1) suggest that 67 species (other than those also listed as Threatened and Migratory) could occur within the Project Area. This includes:

- seventeen species listed as Cetacean (which are not also listed as Threatened or Migratory)
- fourteen sea snake species listed as Marine
- thirty-three syngnathids (seahorses, seadragons, pipefish and pipehorses) listed as Marine and one solenostomid (ghost pipefish) listed as Marine
- two bird species listed as Marine (which are not also listed as Threatened or Migratory).

Of the cetacean species, the minke whale *(Balaenoptera* sp.*)* and the bottlenose dolphin (*Tursiops* sp.) are the only Listed Cetacean species (in addition to those listed in Table 1) that have been recorded in the Project Area. A number of other cetaceans have been observed during aerial surveys; however, identification of species level was not always achievable (Jenner et al. 2009). It is therefore possible that other cetaceans could be present in the Project Area from time to time. Minke whales and bottlenose dolphins are widespread in Australia, and the remaining cetacean species identified in the EPBC Act Protected Matters search have not been recorded, and are not known to breed, feed or aggregate in large numbers within the Project Area.

No sea snakes have been recorded during surveys conducted to date for the project. Sea snakes generally have a tropical and subtropical distribution and inhabit shallow waters along the coast, around islands and at river mouths (DEWHA 2008). While little is known about sea snake distribution in the marine areas of north-western Australia, they are known to generally occupy three broad habitat types (DEWHA 2008):

- Shallow water, coral reef and seagrass habitats.
- Deep water, soft bottom habitats away from reefs.
- Surface water pelagic habitat.

These habitats are common and widespread in northern WA and are not restricted to the Project Area.

Syngnathids and solenostomids mainly inhabit nearshore and inner shelf waters in north-western Australia, but some species have also been recorded in deeper shelf waters (DEWHA 2008), mainly around coral reefs in tropical waters (Foster and Vincent 2004, cited in DEWHA 2008). A number of species have been recorded in north-western Australia; however, very little information is available on their distribution, abundance and ecology (DEWHA 2008). Syngnathids are considered to have diverse characteristics and inhabit a variety of marine habitats in both tropical and temperate waters (DEWHA 2008). No significant aggregations of syngnathids or solenostomids have been observed during marine benthic habitat surveys conducted to date for the project.

The sooty tern *(Sterna fuscata)* and the fairy tern *(Sterna nereis)* are the two bird species that are listed as Marine under the EPBC Act (but are not also listed as Threatened or Migratory). Only the fairy tern has been recorded in surveys conducted to date in the Project Area (Bamford et al. 2009). The distribution of the fairy tern in Australia extends from the Kimberley region, south along the WA coastline and east to Victoria and Tasmania (DEWHA 2010). The population is considered stable in WA (BirdLife International 2010), and this species is not known to breed or nest within the Project Area. The sooty tern may occur in the Project Area; however, this species is widely distributed in most tropical oceans and population estimates for this species are large (21–22 million) (BirdLife International 2010).

Commonwealth Marine Protected Areas (MPAs) represent areas of higher conservation value, which are declared as Commonwealth Reserves under the EPBC Act. There are no Commonwealth MPAs in the vicinity of the project. The closest Commonwealth MPA is the Ningaloo Marine Park, part of which falls within Commonwealth waters off the WA coastline between Coral Bay and Exmouth.

3.0 SIGNIFICANT IMPACT ASSESSMENT

3.1 Methodology

A Significant Impact is defined as "an impact that is important, notable or of consequence, having regard to its context or intensity" (DEWHA 2009). The Department of Sustainability, Environment, Water, Population and Communities (DSEWPC, formerly DEWHA) provides guidance on the criteria used in determining whether certain activities are likely to have a Significant Impact on EPBC Act listed species (DEWHA 2009). The Significant Impact criteria for the listed Threatened and Migratory species that are relevant to this report are provided in Table 2, along with the criteria for the CMA. These Significant Impact criteria were considered in conjunction with the impact assessment conducted for the draft EIS/ERMP in order to determine whether the Threatened or Migratory species identified in Table 1, or the CMA, are at risk of Significant Impact due to construction and operation of the project.

Table 2: Summary of Significant Impact Criteria for Matters of NES Relevant to Wheatstone project (DEWHA 2009)

Matter of NES	Significant Impact Criteria
Threatened (Endangered) Species	A possibility of any of the following occurring to the species in question: ▪ Long-term population decrease. ▪ Reduced occupancy area. ▪ Population fragmentation. ▪ Critical habitat is adversely affected. ▪ Disruption of a population's breeding cycle. ▪ Decline due to loss or modification of habitat availability or quality. ▪ Establishment of harmful invasive species within the habitat. ▪ Decline due to introduced disease. ▪ Interference with species recovery.
Threatened (Vulnerable) Species	A possibility of any of the following occurring to the species in question: ▪ Long-term decrease of an important population. ▪ Reduced occupancy area of an important population. ▪ Fragmentation of an important population. ▪ Adverse effect on critical habitat. ▪ Disruption of an important population's breeding cycle. ▪ Decline due to loss or modification of habitat availability or quality. ▪ Establishment of harmful invasive species within the habitat. ▪ Decline due to introduced disease. ▪ Substantial interference with species recovery.
Migratory Species	A possibility of any of the following occurring to the species in question: ▪ Substantial modification, destruction or isolation of an important habitat. ▪ Establishment of harmful invasive species within the important habitat. ▪ Serious disruption of an ecologically significant proportion of the population's life cycle (breeding, feeding, migration or resting).

Matter of NES	Significant Impact Criteria
CMA	A possibility of any of the following occurring in the CMA: ▪ Establishment of a pest species. ▪ Loss of an important or substantial area of habitat, potentially damaging marine ecosystem functioning or integrity. ▪ Substantial adverse effect on an EPBC listed “marine species” or cetaceans (e.g. life cycle or spatial distribution). ▪ Substantial change in air or water quality, potentially damaging biodiversity, ecological integrity, social amenity or human health. ▪ Accumulation of persistent potentially harmful chemicals, potentially damaging biodiversity, ecological integrity, social amenity or human health. ▪ Substantially adverse impacts to heritage values.

3.2 Threatened and Migratory Species

The impact assessment undertaken as part of the draft EIS/ERMP process focussed on “key receptors”. Key receptors are species of conservation or ecological significance, especially those considered Migratory, Vulnerable or Endangered, whose distributions overlap with the Project Area. The key receptors that are also marine matters of NES are listed in Table 3, along with the reasons why they were selected as key receptors. Given the status of these species as key receptors, they were included in the assessment of Significant Impact conducted as part of this report.

In addition to key receptors, the assessment of Significant Impact considered the following:

- Spatial distribution of species within the project footprint (i.e. is it likely to occur in the Project Area?).
- Spatial distribution of species within the regional and international context (i.e. is it considered widespread regionally or internationally?).
- Presence of critical habitats within the project footprint (i.e. are there habitats within the Project Area that support large numbers of these species?).
- Presence within the project footprint during sensitive life history stages (i.e. do these species breed in the Project Area?).
- Cumulative impacts to key receptors from the project, and from other past, present and reasonably foreseeable future actions (or projects).

A table summarising the results of the assessment of Significant Impact for Threatened and Migratory marine fauna is provided in Appendix 2 of this report. In summary, it was found that only the nine key receptors identified in Table 3 are possibly at risk of Significant Impact from project activities and infrastructure. The remaining species of Threatened and Migratory marine fauna were considered unlikely to occur in the

Project Area or, if present, were known to occur in low numbers and were regionally or internationally widespread. Furthermore, none of the other species was dependent on the Project Area for breeding, foraging or resting.

Table 3: Key Receptors that are also Marine Matters of NES

Key Receptor	Reason for Selection as a Key Receptor
Humpback whale	Present in coastal waters during southward migration; cows and calves may rest within the Project Area in spring.
Indo-Pacific humpback dolphin	Likely to be present in coastal waters (<20 m deep) throughout year.
Spotted bottlenose dolphin (Arafura/Timor Sea populations only)	Spotted bottlenose dolphins have been identified within the Project Area. It is uncertain (although less likely) whether individuals or groups of the Arafura/Timor Sea population were observed.
Dugong	Present in coastal waters adjacent to the Project Area.
Flatback turtle	Nests and forages in coastal waters of the Project Area.
Green turtle	Nests and forages in coastal waters of the Project Area.
Hawksbill turtle	Nests in region encompassing the Project Area.
Loggerhead turtle	Nests in region encompassing the Project Area.
Sawfish	Recorded in inshore waters near the Project Area and may live in creeks near the Project Area.

3.2.1 Risk Assessment of Threatened and Migratory Species at Risk of Significant Impact

Chevron conducted a series of environmental risk assessments in 2009 during the preparation of the draft EIS/ERMP for the project (Chevron 2010). The risk assessments were conducted in accordance with the following standards and guidelines:

- EPA draft guidelines, *Application of risk-based assessment in EIA* (EPA 2009).
- *AS/NZS ISO 31000:2009: Risk management – Principles and guidelines* (Standards Australia/ Standards New Zealand 2009).

Chapter 7 of the draft EIS/ERMP (Chevron 2010) provides detailed information on the methodology applied during the risk assessment process, including the consequence categories and definitions of likelihood that were used. Table 4 shows the risk matrix used for the risk assessments. Using the risk matrix, the identified risks were categorised into five groups that ranged from Very Low Risk to Extreme Risk (Table 4).

A total of one Medium, 26 Low and eight Very Low risks have been identified for the Threatened and Migratory species that have the potential to be exposed to Significant Impact. No High or Extreme risks were identified for these species. A summary of the risks that are relevant to these species is presented in Table 5. Also included in the table is the stressor, the potential impacts (and scenarios) and the residual risk ranking. The following sections describe whether Significant Impact to these species is considered *likely*, from the risks identified (Table 5). Cumulative impacts to key receptors were also considered in assessing the likelihood of Significant Impact.

Table 4: Risk Matrix (EPA 2009)

		Consequence category					
		6 Negligible	5 Minor	4 Moderate	3 Major	2 Massive	1 Catastrophic
Likelihood category	1. Almost certain	Low	Medium	High	Extreme	Extreme	Extreme
	2. Likely	Low	Low	Medium	High	Extreme	Extreme
	3. Possible	Very Low	Low	Low	Medium	High	Extreme
	4. Unlikely	Very Low	Very Low	Low	Low	Medium	High
	5. Remote	Very Low	Very Low	Very Low	Low	Low	Medium

Table 5: Potential Risks Identified for Threatened and Migratory Species at Risk of Significant Impact from project*

Marine Fauna	Stressor	Potential Impacts and Scenarios	Residual Risk Ranking
Humpback whale	Noise and Vibration	▪ Behavioural changes, injury or mortality during construction. ▪ Behavioural changes during operations activities.	Low
	Leaks and Spills	▪ Toxic effects in the event of leaks and spills. ▪ Potential smothering and/or oiling of fauna leading to injury or mortality.	Low
	Vessel Movements	▪ Injury or mortality due to vessel collision. ▪ Disturbance from vessel movements.	Low
	Construction Activities-marine	▪ Entanglement or ingestion of debris.	Low
	Physical Presence of Marine Infrastructure	▪ Disturbance of normal movements/migration.	Low
	Discharges	▪ Toxic effects from discharges.	Very Low
Indo-Pacific humpback dolphin	Noise and Vibration	▪ Behavioural changes, injury or mortality or construction. ▪ Behavioural changes during operations.	Low
	Leaks and Spills	▪ Toxic effects from leaks and spills. ▪ Potential smothering and/or oiling leading to injury or mortality.	Low
	Vessel Movements	▪ Injury or mortality due to vessel collision. ▪ Disturbance from vessel movements.	Low
	Physical Presence of Marine Infrastructure	▪ Disruption of normal movements/migration.	Low
	Construction Activities-marine	▪ Entanglement or ingestion of debris.	Low
	Discharges	▪ Toxic effects from discharges.	Very Low
Spotted bottlenose dolphin (Arafura/ Timor Sea populations)	Noise and Vibration	▪ Behavioural changes, injury or mortality during construction. ▪ Behavioural changes during operations.	Low
	Leaks and Spills	▪ Toxic effects from leaks and spills. ▪ Potential smothering and/or oiling leading to injury or mortality.	Low
	Vessel Movements	▪ Injury or mortality due to vessel collision. ▪ Disturbance from vessel movements.	Low
	Construction Activities-marine	▪ Entanglement or ingestion of debris.	Low
	Discharges	▪ Toxic effects from discharges.	Very Low

Marine Fauna	Stressor	Potential Impacts and Scenarios	Residual Risk Ranking
Dugong	Noise and Vibration	▪ Behavioural changes, injury or mortality during construction. ▪ Behavioural changes during operations.	**Low**
	Leaks and Spills	▪ Toxic effects from leaks and spills. ▪ Potential smothering and/or oiling leading to injury or mortality.	**Low**
	Vessel Movements	▪ Injury or mortality due to vessel collision.	**Low**
	Increased Recreational Pressure (boating)	▪ Disturbance of vessel movements.	**Medium**
	Discharges	▪ Toxic effects from discharges.	**Very Low**
	Dredging	▪ Loss of critical habitat due to dredging and dredge material placement.	**Very Low**
Flatback turtle, green turtle, hawksbill turtle, loggerhead turtle	Noise and Vibration	▪ Behavioural changes, injury or mortality during construction. ▪ Behavioural changes during operations	**Low**
	Leaks and Spills	▪ Toxic effects from leaks and spills. ▪ Potential smothering and/or oiling of fauna leading to injury or mortality.	**Low**
	Vessel Movements	▪ Injury or mortality due to vessel collision. ▪ Disturbance from vessel movements.	**Low**
	Construction Activities-marine	▪ Entanglement or ingestion of debris.	**Low**
	Discharges	▪ Toxic effects from discharges.	**Very Low**
	Dredging	▪ Loss of critical habitat due to dredging and dredge material placement.	**Very Low**
	Light Emissions	▪ Attraction and interference with sea-finding behaviour. ▪ Disturbance to behaviours and migratory patterns.	**Low**
	Physical Presence of Marine Infrastructure	▪ Behavioural changes, injury or mortality to marine fauna during construction and operations activities.	**Low**
Sawfish	Noise and Vibration	▪ Behavioural changes, injury or mortality during construction. ▪ Behavioural changes during operations	**Low**
	Leaks and Spills	▪ Toxic effects from leaks and spills. ▪ Potential smothering and/or oiling of fauna leading to injury or mortality.	**Low**
	Vessel Movements	▪ Injury or mortality due to vessel collision.	**Low**
	Discharges	▪ Toxic effects from discharges.	**Very Low**

* NOTE: Risk rankings include the application of sufficient and appropriate management measures.

3.2.2 Marine Mammals and their Habitat at Risk of Significant Impact

The humpback whale, Indo-Pacific humpback dolphin, spotted bottlenose dolphin (Arafura/Timor Sea population) and dugong are not at risk of Significant Impact from the stressors and associated risks identified in Table 5. These species are all listed as Migratory species under the EPBC Act, with the exception of the humpback whale, which is also listed as Vulnerable under the EPBC Act.

When considering the Significant Impact criteria in Table 2 in conjunction with the risks in Table 5, and in light of management measures that have been/will be committed to, Significant Impacts are considered unlikely from:

- noise and vibration emissions generated during marine construction and operations activities
- smothering or toxic effects from leaks and spills
- disturbance from vessel movements
- entanglement or ingestion of debris
- the physical presence of permanent marine infrastructure
- toxic effects of marine discharges associated with the offshore installation.

These risks were all ranked as Medium to Very Low after consideration of the management measures that will be adopted. The first four risks are associated with temporary construction and operational activities, and are anticipated to have generally short-term and localised impacts.

Noise and vibration emissions may interfere with acoustic perception and communication in humpback whales. However, impacts are expected to be temporary, short-term and localised.

Major leaks and spills of hydrocarbons that are large enough to have an effect on population viability of humpback whales are rare. While minor leaks and spills are considered more likely, they are unlikely to result in toxic effects, or disrupt migration patterns, given this species is highly mobile.

Humpback whales also have a relatively quick avoidance response. Therefore, any impacts associated with vessel movements will most likely be limited to localised displacement of a small proportion of the migrating population and is unlikely to affect the success of the migrations.

Entanglement or ingestion of debris by humpback whales is also considered a Low risk, given the project plans to implement conservation and awareness programs focused on responsible waste disposal, particularly during recreational boating.

The ongoing (planned) marine discharges associated with the offshore installation and the presence of permanent marine infrastructure are longer-term stressors that have the potential to impact humpback whales. However, these discharges would be controlled under relevant permits and the majority of offshore production facilities will be located on the seabed, and structures above the sea surface can be avoided by humpback whales, given their mobility. Contaminants associated with marine discharges from the offshore platform are expected to dilute rapidly in the deep, oceanic waters, therefore the risk of toxic effects to humpback whales is considered Very Low.

The cumulative impact associated with vessel movements from the project and other actions in the Onslow area could further increase the risk to humpback whales, Indo-Pacific humpback dolphins, spotted bottlenose dolphins (individuals of the Arafura/Timor Sea population) and dugongs. Vessel activity, particularly relating to construction and recreational activities, will occur mainly in nearshore waters and therefore away from the majority of the humpback whale population. In addition, the lower speeds at which larger vessels travel is not expected to cause significant risk to humpback whales. None of these species or their habitats is restricted to or concentrated within the areas of highest construction vessel activity.

During operations of the project or the other proposed actions considered, the vessel departure routes do not intersect any known critical resting, feeding or breeding habitats of these species. Commercial fishing vessels in the region are also thought not to pose a significant threat to dugongs due to the low volume of vessels operating in the area where dugongs may be concentrated. Currently, the number and management of workers from the project and other activities who will utilise the area for recreational fishing are largely unknown. Therefore, the cumulative impacts associated with recreational boating are uncertain. However, with appropriate controls in place, the impacts to these species can be managed.

Therefore, the risks presented in Table 5 are unlikely to result in any long-term decreases in the size of humpback whale populations, and are not predicted to fragment the existing populations or reduce the area of occupancy of the species because it is a highly mobile species. There is no habitat critical to the survival of humpback whales located within or near the Project Area, and the potential impacts are not anticipated to disrupt the breeding cycle of humpback whales. Furthermore, these risks are unlikely to result in the introduction of invasive species or diseases that would result in adverse impacts to this species. The risks presented in Table 5 are also unlikely to interfere with the recovery of the humpback whale population.

The Indo-Pacific humpback dolphin, spotted bottlenose dolphin (Arafura/Timor Sea population only) and dugong are listed as Migratory under the EPBC Act. When considering the Significant Impact criteria for Migratory species (Table 2), in conjunction with the risks identified in Table 5, Significant Impacts to these three species is also considered unlikely. The marine habitats located within the Project Area are not known to represent important habitat for these species. The Project Area has been found to support only a low dugong density and population. The risks identified in Table 5 are also unlikely to result in the introduction of invasive species or diseases that would result in adverse impacts to these three species. The populations of these species that are likely to be present in the Project Area do not represent ecologically significant proportions, and therefore any impacts to breeding, feeding, migration or resting behaviours would be limited to individuals of these species.

3.2.3 Marine Turtles and their Habitat at Risk of Significant Impact

Of the four species of marine turtle, the loggerhead turtle is listed as Endangered under the EPBC Act and the green, hawksbill and flatback turtles are listed as Vulnerable. All four species of marine turtle are also listed as Migratory under the EPBC Act. Green turtles and flatback turtles are known to nest on some of the offshore islands as well as on mainland beaches. While the rookeries on offshore islands support lower abundances of nesting turtles than those on Barrow Island, they are still considered regionally important (CALM 2002, cited in RPS 2010c). The majority of nesting in the vicinity of the Project Area is by flatback turtles at Ashburton Island and at the Ashburton River Delta (Chevron 2010). Nesting activity observed on mainland beaches in the vicinity of the Project Area is very low density and the area is not considered important habitat for these species (RPS 2010c).

When considering the Significant Impact criteria in Table 2 in conjunction with the risks in Table 5, Significant Impacts to marine turtles are considered unlikely from:

- noise and vibration emissions generated during marine construction and operations activities
- smothering or toxic effects from leaks and spills
- disturbance from vessel movements
- entanglement or ingestion of debris
- entrainment in the dredge
- loss of habitat due to dredging and dredge material placement
- the physical presence of permanent marine infrastructure

- toxic effects of authorised marine discharges associated with the ocean outfall in nearshore waters

- artificial light spill associated with the project

- presence of the workforce on offshore islands during recreational activities.

These risks were all ranked as Low to Very Low. The first five risks are associated with temporary construction and operational activities, and are anticipated to have generally short-term and localised impacts.

Noise and vibration emissions may interfere with turtle nesting activities; however, the closest nesting sites to the Project Area are Ashburton River Delta and Ashburton Island. Given the distance of these rookeries from the Project Area, noise impacts are expected to be temporary, short-term and localised.

Major leaks and spills of hydrocarbons that are large enough to have an effect on population viability of marine turtles are rare. While minor leaks and spills are considered more likely, they are unlikely to have an effect on turtle nesting.

Impacts associated with vessel movements will most likely be limited to localised displacement of individuals, but will not affect nesting activity, given the shipping channel is approximately 14 km from the nearest important turtle rookery.

Entanglement or ingestion of debris by turtles is considered a Low risk since the project plans to implement conservation and awareness programs focused on responsible waste disposal, particularly during recreational boating.

Marine turtles that are resting or foraging on the seabed have the potential to be entrained in the dredging program. However, impacts would be limited to individuals and are unlikely to have a significant effect on population sizes.

The remaining five risks listed above are longer-term stressors that have the potential to impact marine turtles. Dredge modelling outputs indicate that no critical habitat for marine turtles will be impacted by dredging and dredge material placement, which is why the loss of habitat from dredging is considered a Low risk.

The permanent marine infrastructure can be avoided by turtles given their mobility and is unlikely to affect migration patterns. Contaminants associated with marine discharges in nearshore waters will be treated and discharged in accordance with regulations; therefore, the risk of toxic effects is considered Very Low.

While the presence of the workforce on offshore islands during recreational activities has the potential to affect turtle nesting behaviour, such disturbance is unlikely to have long-term effects on population sizes or distribution.

Artificial light spill associated with the project (particularly the onshore infrastructure) has the potential to interfere with the sea-finding ability of turtle hatchlings and could also disturb adult marine turtle behaviour (including feeding, mating and nesting). However, the mainland beaches in the vicinity of, and adjacent to, the onshore infrastructure are not considered major nesting sites for turtles. Disorientation of hatchlings is expected to be limited to those hatching at Ashburton River Delta. However, the dune system on the Ashburton River Delta beach reaches up to 10 m and will shield a large section of the nesting beach from illumination, therefore reducing possible impacts to hatchlings (Chevron 2010).

Nesting by flatback turtles and green turtles on offshore islands is unlikely to be affected by light spill, given the large distance between the closest rookeries and the onshore infrastructure. Light spill modelling suggests that offshore islands in the vicinity of Ashburton North will experience only very low level luminance from operational lighting associated with onshore infrastructure (URS 2010b). Therefore operational lighting is not expected to deter turtles from nesting (Chevron 2010). Light emissions from within the Project Area are unlikely to affect the foraging or mating behaviour of adult turtles as the nearshore waters adjacent to the Project Area are not known to support important habitat for these activities.

In terms of cumulative impacts to turtles, the proposed Scarborough and Macedon facilities at the Ashburton North SIA will create light emissions that could increase the risk of potential impact. However, the distance from the shoreline of these actions will greatly reduce this impact. It is thought that the light emissions from Onslow town have not greatly impacted marine turtles due to their limited nature, although no studies have been conducted to date to confirm this.

Therefore, the risks presented in Table 5 are unlikely to result in any long-term decreases in the size of marine turtle populations, and are not predicted to fragment the existing populations or reduce the area of occupancy of the species because they are a mobile species. There is no habitat critical to the survival of marine turtles located within the Project Area, and the potential impacts are not anticipated to disrupt their breeding cycle over the longer term.

Furthermore, these risks are unlikely to result in the introduction of invasive species or diseases that would result in adverse impacts to this species. The risks identified are unlikely to interfere with the recovery of marine turtles, and would not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically-significant proportion of their populations in WA.

3.2.4 Sharks and Rays and their Habitat at Risk of Significant Impact

Species of sawfish are listed as Vulnerable under the EPBC Act. While there is limited data available on the population and distribution of sawfish sp. in the Pilbara region, they have been observed in low numbers in the vicinity of the Project Area. However, when considering the Significant Impact criteria for Vulnerable species (Table 2), in conjunction with the risks identified in Table 5, Significant Impacts to sawfish are considered unlikely.

The Project Area is not known to support important populations of sawfish, so the risks identified are unlikely to result in any long-term decreases in the size of their populations. The activities and infrastructure associated with the project will not fragment the existing populations or reduce the area of occupancy of sawfish. There is no habitat that is considered critical to the survival of sawfish located within the Project Area, and the potential impacts identified in Table 5 are not anticipated to disrupt the sawfish breeding cycle. Furthermore, these risks are unlikely to result in the introduction of invasive species or diseases that would result in adverse impacts to this species. The risks presented in Table 5 are also highly unlikely to interfere with the recovery of sawfish in Australia.

3.3 Commonwealth Marine Area

Despite some of the project infrastructure being located within the CMA, none of the Project Area is a Commonwealth MPA. Furthermore, while a number of species listed as either Marine or Cetacean were identified in the EPBC Act Protected Matters search, only a few are actually known to occur in the vicinity of the Project Area (i.e. the minke whale, bottlenose dolphin and fairy tern).

When considering the Significant Impact criteria (Table 2), the marine environment within the CMA is not at risk of Significant Impact. Project activities are unlikely to result in a known or potential pest species becoming established in the Commonwealth marine environment. Australian and International quarantine measures will apply to the project, and include risk assessments and biosecurity checks, which will reduce the likelihood that a species is introduced.

The modification, destruction, fragmentation or disturbance of important habitat within the Commonwealth marine environment is not planned as part of project activities, unless approved under the EPBC Act or other relevant legislation. Substantial adverse effects on a population of a species listed as Marine or Cetacean is considered unlikely given such species are generally widespread either regionally or within Australia, and given the lack of important habitat, feeding, breeding or nesting areas present within the Project Area.

While there are emissions (air, noise, etc.) associated with the project, they will not result in a substantial change in air quality or water quality to the extent that biodiversity, ecological integrity, social amenity or human health within the Commonwealth marine environment is adversely impacted. While there are some marine discharges associated with the project, they are not expected to result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating such that biodiversity, ecological integrity, social amenity or human health is adversely affected.

Finally, the project will not have an adverse impact on heritage values such as historic shipwrecks as there is none present within the Project Area.

3.4 Conclusion

Nine species of NES were identified as having potential to experience Significant Impact from the Wheatstone project, based on the Significant Impact Guidelines (DEWHA 2009). These were the humpback whale, Indo-Pacific humpback dolphin, spotted bottlenose dolphin (individuals of the Arafura/Timor Sea population), dugong, flatback turtle, green turtle, hawksbill turtle, loggerhead turtle and sawfish species.

Following further assessment of potential interaction with onshore and offshore components of the project, in conjunction with the Significant Impact criteria (Table 2), it was determined that the likelihood of Significant Impact is unlikely. The bases of this were that, although the species are of high conservation status and are likely to be present in or near the Project Area at some time, long-term population decrease is not predicted because large populations are not restricted to the Project Area, nor are critical habitats present.

Furthermore, the cumulative impacts to these species arising from the project and other existing or foreseeable actions in the area are considered to be either not significant or manageable through the incorporation of appropriate mitigation measures. The CMA is not at risk of Significant Impact since there are no Commonwealth MPAs located within or near the Project Area. Of the listed Marine or Cetacean species known to actually occur in the vicinity of the Project Area (e.g. the minke whale, fairy tern), none is restricted to the Project Area, and all are known to occur elsewhere in the region.

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APPENDIX 1

EPBC Act Protected Matters Report

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APPENDIX 1: EPBC Act Protected Matters Report

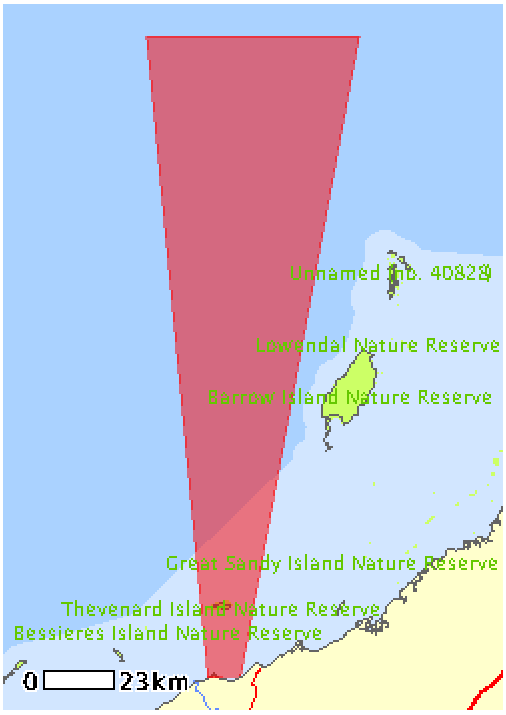
EPBC Act Protected Matters Report

22 March 2010 18:19

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

You may wish to print this report for reference before moving to other pages or websites.

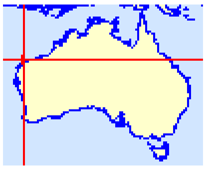
The Australian Natural Resources Atlas at http://www.environment.gov.au/atlas may provide further environmental information relevant to your selected area. Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html



Search Type: Area (approximately 8,723 km^2)

Buffer: 0 km

Coordinates: -19.6918,115.4245, -19.6918,114.7659, -21.6804,114.9559, -21.6741,115.0572



Report Contents:
Summary
Details
- Matters of NES
- Other matters protected by the EPBC Act
- Extra Information

Caveat
Acknowledgments

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Significance: (Ramsar Sites)	None
Commonwealth Marine Areas:	Relevant
Threatened Ecological Communities:	None
Threatened Species:	13
Migratory Species:	30

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html.

Please note that the current dataset on Commonwealth land is not complete. Further information on Commonwealth land would need to be obtained from relevant sources including Commonwealth agencies, local agencies, and land tenure maps.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.au/epbc/permits/index.html.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Places on the RNE:	1
Listed Marine Species:	67
Whales and Other Cetaceans:	27
Critical Habitats:	None
Commonwealth Reserves:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	1
Other Commonwealth Reserves:	None
Regional Forest Agreements:	None

Details

Matters of National Environmental Significance

Commonwealth Marine Areas [Dataset Information]

Approval may be required for a proposed activity that is likely to have a significant impact on the environment in a Commonwealth Marine Area, when the action is outside the Commonwealth Marine Area, or the environment anywhere when the action is taken within the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

EEZ and Territorial Sea

Threatened Species [Dataset Information]	Status	Type of Presence
Birds		
Macronectes giganteus Southern Giant-Petrel	Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera musculus Blue Whale	Endangered	Species or species habitat may occur within area
Dasycercus cristicauda Mulgara	Vulnerable	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll	Endangered	Species or species habitat likely to occur within area
Eubalaena australis Southern Right Whale	Endangered	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale	Vulnerable	Congregation or aggregation known to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Endangered	Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle	Vulnerable	Species or species habitat may occur within area
Natator depressus Flatback Turtle	Vulnerable	Breeding known to occur within area

Sharks		
Pristis clavata Dwarf Sawfish, Queensland Sawfish	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark	Vulnerable	Species or species habitat may occur within area
Migratory Species [Dataset Information]	Status	Type of Presence
Migratory Terrestrial Species		
Birds		
Haliaeetus leucogaster White-bellied Sea-Eagle	Migratory	Species or species habitat likely to occur within area
Hirundo rustica Barn Swallow	Migratory	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater	Migratory	Species or species habitat may occur within area
Migratory Wetland Species		
Birds		
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel	Migratory	Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole	Migratory	Species or species habitat may occur within area
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift	Migratory	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel	Migratory	Species or species habitat may occur within area
Sterna caspia Caspian Tern	Migratory	Breeding known to occur within area
Migratory Marine Species		
Mammals		
Balaenoptera bonaerensis	Migratory	Species or species habitat may

Antarctic Minke Whale, Dark-shoulder Minke Whale		occur within area
Balaenoptera edeni Bryde's Whale	Migratory	Species or species habitat may occur within area
Balaenoptera musculus Blue Whale	Migratory	Species or species habitat may occur within area
Dugong dugon Dugong	Migratory	Species or species habitat likely to occur within area
Eubalaena australis Southern Right Whale	Migratory	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale	Migratory	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca	Migratory	Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale	Migratory	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin	Migratory	Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations)	Migratory	Species or species habitat likely to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle	Migratory	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle	Migratory	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Migratory	Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle	Migratory	Species or species habitat may occur within area
Natator depressus Flatback Turtle	Migratory	Breeding known to occur within area
Sharks		
Isurus oxyrinchus Shortfin Mako, Mako Shark	Migratory	Species or species habitat likely to occur within area
Isurus paucus Longfin Mako	Migratory	Species or species habitat likely to occur within area
Rhincodon typus Whale Shark	Migratory	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Dataset Information]	Status	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift	Listed - overfly marine area	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Listed - overfly marine area	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Listed - overfly marine area	Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel	Listed - overfly marine area	Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole	Listed - overfly marine area	Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle	Listed	Species or species habitat likely to occur within area
Hirundo rustica Barn Swallow	Listed - overfly marine area	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel	Listed	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater	Listed - overfly marine area	Species or species habitat may occur within area
Pandion haliaetus Osprey	Listed	Breeding known to occur within area
Sterna caspia Caspian Tern	Listed	Breeding known to occur within area
Sterna fuscata	Listed	Breeding known to occur within

Sooty Tern		area
Sterna nereis Fairy Tern	Listed	Breeding known to occur within area
Mammals		
Dugong dugon Dugong	Listed	Species or species habitat likely to occur within area
Ray-finned fishes		
Acentronura larsonae Helen's Pygmy Pipehorse	Listed	Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish	Listed	Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish	Listed	Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish	Listed	Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish	Listed	Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish	Listed	Species or species habitat may occur within area
Corythoichthys flavofasciatus Yellow-banded Pipefish, Network Pipefish	Listed	Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish	Listed	Species or species habitat may occur within area
Doryrhamphus dactyliophorus Ringed Pipefish	Listed	Species or species habitat may occur within area
Doryrhamphus excisus Indian Blue-stripe Pipefish, Blue-stripe Pipefish	Listed	Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish	Listed	Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish	Listed	Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Negros Pipefish	Listed	Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish	Listed	Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish	Listed	Species or species habitat may occur within area

Halicampus brocki Brock's Pipefish	Listed	Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish	Listed	Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish	Listed	Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish	Listed	Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Seadragon, Ribboned Pipefish	Listed	Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish	Listed	Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse	Listed	Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse	Listed	Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse	Listed	Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse	Listed	Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse	Listed	Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish	Listed	Species or species habitat may occur within area
Phoxocampus belcheri Rock Pipefish	Listed	Species or species habitat may occur within area
Solegnathus hardwickii Pipehorse	Listed	Species or species habitat may occur within area
Solegnathus lettiensis Indonesian Pipefish, Gunther's Pipehorse	Listed	Species or species habitat may occur within area
Solenostomus cyanopterus Blue-finned Ghost Pipefish, Robust Ghost Pipefish	Listed	Species or species habitat may occur within area
Syngnathoides biaculeatus Double-ended Pipehorse, Alligator Pipefish	Listed	Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bend Stick Pipefish, Short-tailed Pipefish	Listed	Species or species habitat may occur within area
Trachyrhamphus longirostris Long-nosed Pipefish, Straight Stick Pipefish	Listed	Species or species habitat may occur within area

Reptiles

Acalyptophis peronii Horned Seasnake	Listed	Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake	Listed	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake	Listed	Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake	Listed	Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake	Listed	Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake	Listed	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle	Listed	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle	Listed	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth	Listed	Species or species habitat may occur within area
Disteira kingii Spectacled Seasnake	Listed	Species or species habitat may occur within area
Disteira major Olive-headed Seasnake	Listed	Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake	Listed	Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake	Listed	Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle	Listed	Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake	Listed	Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake	Listed	Species or species habitat may occur within area
Hydrophis ornatus a seasnake	Listed	Species or species habitat may occur within area
Natator depressus Flatback Turtle	Listed	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake	Listed	Species or species habitat may occur within area

Whales and Other Cetaceans [Dataset Information]	Status	Type of Presence
Balaenoptera acutorostrata Minke Whale	Cetacean	Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale	Cetacean	Species or species habitat may occur within area
Balaenoptera edeni Bryde's Whale	Cetacean	Species or species habitat may occur within area
Balaenoptera musculus Blue Whale	Cetacean	Species or species habitat may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin	Cetacean	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale	Cetacean	Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale	Cetacean	Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale	Cetacean	Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus	Cetacean	Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale	Cetacean	Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale	Cetacean	Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin	Cetacean	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale	Cetacean	Congregation or aggregation known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale	Cetacean	Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca	Cetacean	Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale	Cetacean	Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale	Cetacean	Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale	Cetacean	Species or species habitat may occur within area

Sousa chinensis Indo-Pacific Humpback Dolphin	Cetacean	Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin	Cetacean	Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin	Cetacean	Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin	Cetacean	Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin	Cetacean	Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations)	Cetacean	Species or species habitat likely to occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin	Cetacean	Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin	Cetacean	Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale	Cetacean	Species or species habitat may occur within area

Places on the RNE [Dataset Information]
Note that not all Indigenous sites may be listed.

Natural

Islands Exmouth Gulf and Rowley Shelf WA

Extra Information

State and Territory Reserves [Dataset Information]

Thevenard Island Nature Reserve, WA

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the *Environment Protection and Biodiversity*

Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under "type of presence". For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the migratory and marine provisions of the Act have been mapped.

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites;
- seals which have only been mapped for breeding sites near the Australian continent.

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

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APPENDIX 2

Threatened and Migratory Marine Fauna at Risk of Significant Impact

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APPENDIX 2: Threatened and Migratory Marine Fauna Likely to be at Risk of Significant Impact

Common Name	Species Name	Identified as a Key Receptor?	Likely to occur in Project Area?	Is Significant Impact Possible?	Is Significant Impact Likely?
Mammals					
Blue whale[1]	*Balaenoptera musculus*	No	Yes	No (low numbers in offshore areas only, no key habitat, feeding or breeding areas).	No.
Southern right whale	*Eubalaena australis*	No	No	No (unlikely to occur in Project Area).	No.
Humpback whale[1]	*Megaptera novaeangliae*	Yes	Yes	Yes (present in coastal waters during southward migration, cows and calves may rest within Project Area in spring).	No. Refer to assessment in Section 3.2.2.
Antarctic minke whale	*Balaenoptera bonaerensis*	No	No	No (unlikely to occur in Project Area).	No.
Bryde's whale	*Balaenoptera edeni*	No	Yes	No (low numbers in offshore areas only, no key habitat, feeding or breeding areas).	No.
Killer whale[1]	*Orcinus orca*	No	Yes	No (low numbers, no key habitat, feeding or breeding areas).	No.
Sperm whale	*Physeter macrocephalus*	No	Yes	No (no key habitat, feeding or breeding areas).	No.
Indo-Pacific humpback dolphin	*Sousa chinensis*	Yes	Yes	Yes (likely to be present in coastal waters [<20 m deep] throughout year).	No. Refer to assessment in Section 3.2.2.
Spotted bottlenose dolphin[2]	*Tursiops aduncus*	Yes	Yes	Yes (likely to be present in coastal waters throughout year).	No. Refer to assessment in Section 3.2.2.
Dugong[1]	*Dugong dugon*	Yes	Yes	Yes (present in coastal waters adjacent Project Area).	No. Refer to assessment in Section 3.2.2.
Reptiles					
Loggerhead turtle[1]	*Caretta caretta*	Yes	Yes	Yes (nests in region encompassing Project Area).	No. Refer to assessment in Section 3.2.3.
Green turtle[1]	*Chelonia mydas*	Yes	Yes	Yes (nests and forages in coastal waters of Project Area).	No. Refer to assessment in Section 3.2.3.
Leatherback turtle	*Dermochelys coriacea*	No	No	No (unlikely to occur in Project Area, no key habitat, feeding or breeding areas).	No.
Hawksbill turtle[1]	*Eretmochelys imbricata*	Yes	Yes	Yes (nests in region encompassing Project Area).	No. Refer to assessment in Section 3.2.3.
Flatback turtle[1]	*Natator depressus*	Yes	Yes	Yes (nests and forages in coastal waters of Project areas).	No. Refer to assessment in Section 3.2.3.

Common Name	Species Name	Identified as a Key Receptor?	Likely to occur in Project Area?	Is Significant Impact Possible?	Is Significant Impact Likely?
Saltwater Crocodile[1]	*Crocodylus porosus*	No	Yes	No (unlikely to occur in Project Area in large numbers, as this is the southern extent of their range. It is believed that the individuals anecdotally recorded are displaced vagrants).	No.
Sharks and rays					
Dwarf sawfish[1]	*Pristis clavata*	Yes	Yes	Refer to risk assessments conducted.	No. Refer to assessment in Section 3.2.4.
Green sawfish[1]	*Pristis zijsron*	Yes	Uncertain	Refer to risk assessments conducted.	No. Refer to assessment in Section 3.2.4.
Whale shark[1]	*Rhincodon typus*	No	Yes	No (unlikely to occur in Project Area in large numbers, no key habitat, feeding or breeding areas).	No.
Shortfin mako	*Isurus oxyrinchus*	No	No	No (unlikely to occur in Project Area).	No.
Longfin mako	*Isurus paucus*	No	No	No (unlikely to occur in Project Area).	No.
Birds					
Accipitridae					
White-bellied sea eagle[1]	*Haliaeetus leucogaster*	No	Yes	No (considered widespread in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Eastern osprey[1]	*Pandion cristatus*	No	Yes	No (low numbers, no key habitat, feeding or breeding areas).	No.
Osprey[3]	*Pandion haliaetus*	No	Yes	No (considered widespread in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Ardeidae					
Cattle egret	*Ardea ibis*	No	Yes	No (widespread distribution in Australia, no key habitat, feeding or breeding areas).	No.
Eastern great egret[1]	*Ardea modesta*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
Eastern reef egret[1]	*Egretta sacra*	No	Yes	No (considered widespread in the Pilbara region, no key habitat, feeding or breeding areas).	No.

Common Name	Species Name	Identified as a Key Receptor?	Likely to occur in Project Area?	Is Significant Impact Possible?	Is Significant Impact Likely?
Charadriidae					
Oriental plover[1]	*Charadrius veredus*	No	Yes	No (not recorded in Project Area during surveys, considered widespread, no key habitat, feeding or breeding areas).	No.
Grey plover[1]	*Pluvialis squatarola*	No	Yes	No (considered widespread, no key habitat, feeding or breeding areas).	No.
Pacific golden plover[1]	*Pluvialis fulva*	No	Yes	No (considered widespread, no key habitat, feeding or breeding areas).	No.
Lesser sand plover[1]	*Charadrius mongolus*	No	Yes	No (considered widespread, no key habitat, feeding or breeding areas).	No.
Greater sand plover[1]	*Charadrius leschenaultia*	No	Yes	No (considered widespread, no key habitat, feeding or breeding areas).	No.
Glareolidae					
Oriental pratincole[1]	*Glareola maldivarum*	No	Yes	No (considered widespread in northern Australia, no key habitat, feeding or breeding areas).	No.
Laridae					
Caspian tern[1]	*Sterna caspia*	No	Yes	No (considered widespread in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Lesser-crested tern[1]	*Sterna bengalensis*	No	Yes	No (low numbers, no key habitat, feeding or breeding areas).	No.
Common tern[1]	*Sterna hirundo*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
Little tern[1]	*Sterna albifrons*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
White-winged black tern[1]	*Chlidonias leucoptera*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
Roseate tern[1]	*Sterna dougallii*	No	Yes	No (low numbers, no key habitat, feeding or breeding areas).	No.
Bridled tern[1]	*Sterna anaethetus*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
Procellariidae					
Southern giant-petrel	*Macronectes giganteus*	No	No	No (unlikely to occur in Project Area).	No.

Common Name	Species Name	Identified as a Key Receptor?	Likely to occur in Project Area?	Is Significant Impact Possible?	Is Significant Impact Likely?
Wedge-tailed shearwater[3]	*Puffinus pacificus*	No	Yes	No (considered widespread in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Scolopacidae					
Pin-tailed snipe[1]	*Gallinago stenura*	No	Yes	No (not recorded in Project Area during surveys, considered widespread, no key habitat, feeding or breeding areas).	No.
Black-tailed godwit[1]	*Limosa limosa*	No	Yes	No (widespread distribution in Australia, low numbers recorded, no key habitat, feeding or breeding areas).	No.
Bar-tailed godwit[1]	*Limosa lapponica*	No	Yes	No (widespread distribution in Australia, low numbers recorded, no key habitat, feeding or breeding areas).	No.
Little curlew[1]	*Numenius minutus*	No	Yes	No (not recorded in Project Area during surveys, widespread distribution in Australia, no key habitat, feeding or breeding areas).	No.
Whimbrel[1]	*Numenius phaeopus*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
Eastern curlew[1]	*Numenius Madagascariensis*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
Marsh sandpiper[1]	*Tringa stagnatilis*	No	Yes	No (not recorded in Project Area during surveys, widespread distribution in Australia, no key habitat, feeding or breeding areas).	No.
Common greenshank[1]	*Tringa nebularia*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Wood sandpiper[1]	*Tringa glareola*	No	Yes	No (widespread distribution in Australia, no key habitat, feeding or breeding areas).	No.
Terek sandpiper[1]	*Xenus cinereus (Tringa terek)*	No	Yes	No (widespread distribution in Australia, no key habitat, feeding or breeding areas).	No.
Common sandpiper[1]	*Tringa hypoleucos*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Grey-tailed tattler[1]	*Tringa brevipes*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.

Common Name	Species Name	Identified as a Key Receptor?	Likely to occur in Project Area?	Is Significant Impact Possible?	Is Significant Impact Likely?
Ruddy turnstone[1]	*Arenaria interpres*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Red knot[1]	*Calidris canutus*	No	Yes	No (not recorded in Project Area during surveys, widespread distribution in Australia, no key habitat, feeding or breeding areas).	No.
Great knot[1]	*Calidris tenuirostris*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Sanderling[1]	*Calidris alba*	No	Yes	No (considered widespread in Australia, no key habitat, feeding or breeding areas).	No.
Red-necked stint[1]	*Calidris ruficollis*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Long-toed stint[1]	*Calidris subminuta*	No	Yes	No (not recorded in Project Area during surveys, no key habitat, feeding or breeding areas).	No.
Sharp-tailed sandpiper[1]	*Calidris acuminata*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Curlew sandpiper[1]	*Calidris ferruginea*	No	Yes	No (low numbers relative to other areas in the Pilbara region, no key habitat, feeding or breeding areas).	No.
Broad-billed sandpiper[1]	*Limicola falcinellus*	No	Yes	No (not recorded in Project Area during surveys, widespread distribution in Australia, no key habitat, feeding or breeding areas)’	No.
Threskionithidae					
Glossy ibis[3]	*Plegadis falcinellus*	No	Yes	No (not recorded in Project Area during surveys, considered widespread, no key habitat, feeding or breeding areas)’	No.

Sources: Bamford et al. 2009; DEWHA 2010; BirdLife International 2010.
1. Species has been observed or recorded within or near Project Area during surveys.
2. Arafura/Timor Sea populations only.
3. Species is expected to occur in the Onslow region and may therefore occur in Project Area from time to time.

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Appendix FG

Satellite Telemetry of Nesting Flatback Turtles from Ashburton Island

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. A satellite telemetry study of flatback turtles nesting at Ashburton Island was completed to verify the environmental impact assessment relating to the potential for turtle entrainment from dredging, as well as to inform the development of management measures. The study focused on flatback turtles nesting at Ashburton Island due to the proximity of the island nesting beaches to dredging activities.

Six satellite transmitters with time-depth recording capabilities were attached to nesting flatback turtles at Ashburton Island in December 2009 to determine their spatial movements during the nesting season and post-nesting migration. Five of the transmitters provided location and dive information on inter-nesting movements and all six transmitters provided information on post-nesting migratory movements.

The inter-nesting habitat for flatback turtles nesting at Ashburton Island was approximately 1500 km^2 in size and ranged between Baresand Point, Bessieres Island, Airlie Island and Coolgra Point. Two of the six turtles were recorded nesting on islands up to 20 km away from Ashburton Island and it is possible that flatback turtles regularly move between different beaches within their inter-nesting habitat to nest.

The turtles regularly moved through the Project area, but spent relatively little time in this area during the inter-nesting period. Inter-nesting flatback turtles spent large proportions of their time on the sea floor and less time near the sea surface. There were no obvious areas where the turtles were more or less likely to spend time on the sea floor or near the sea surface.

Following their final nesting event for the season, the turtles spent up to three weeks within the inter-nesting habitat before commencing their post-nesting migration. These movements are possibly associated with foraging or attempting to locate new foraging areas. Following post-nesting circling, the flatback turtles either migrated to the Kimberley or remained within the Pilbara region.

The area between Barrow Island and the Muiron Islands (20–100 m) appears to be an important flatback turtle foraging area, with turtles from several nesting locations in the Pilbara migrating to this area. Two of the six turtles were recorded nesting on nearby islands up to 20 km away within the same nesting season.

Given that flatback turtle tracks have been recorded on most of the islands surrounding the Project area and on sections of the adjacent mainland, it is possible that flatback turtles regularly move between different beaches in the region to nest.

RPS

SATELLITE TELEMETRY OF NESTING FLATBACK TURTLES FROM ASHBURTON ISLAND

Wheatstone Project EIS/ERMP





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SATELLITE TELEMETRY OF NESTING FLATBACK TURTLES FROM ASHBURTON ISLAND

Wheatstone Project EIS/ERMP

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ACRONYMS AND DEFINITIONS

Term/Acronym	Definition
Chelonid	Hard-shelled marine turtles of the family Cheloniidae. Extant species are green, flatback, hawksbill, loggerhead, olive ridley and Kemp's ridley turtles
CSV	Comma-separated value
DEC	Department of Environment and Conservation (Western Australia)
DEWHA	Department of the Environment, Water, Heritage and the Arts (Commonwealth)
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority
ERMP	Environmental Review and Management Programme
GIS	Geographic Information System
GPS	Global Positioning System
Inter-nesting	The time between consecutive clutches of eggs laid by an individual turtle during a nesting season
LADS	Laser Airborne Depth Sounder
LNG	Liquid Natural Gas
MTPA	Million Tonnes Per Annum
Neritic zone	Inshore marine environment where water depth is less than 200 m – generally includes the continental shelf
PBT	Proportion bottom time (proportion of time spent on the sea floor)
Post-nesting	The period between completion of the final nest for the season and the commencement of the subsequent breeding season
Project footprint	Potential marine and terrestrial construction areas, including the LNG plant, shipping channel, pipeline route, MOF and jetty
PST	Proportion surface time (proportion of time spent near the sea surface)
PTT	Platform Terminal Transmitter
Re-emergence interval	The time between a successful nesting event and the next nesting attempt by an individual turtle during a nesting season, whether successful or not
Re-nesting interval	The time between two consecutive nesting events within a nesting season
SE	Standard error
TAD	Time at depth
TDR	Time depth recorder

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SUMMARY

Chevron Australia, as part of the Wheatstone project, proposes to construct and operate a multi-train LNG plant and Domgas plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast of Western Australia (Figure 1). As part of the environmental approvals process, Chevron Australia have prepared and submitted a Draft EIS/ERMP to the EPA and DEWHA. The Draft EIS/ERMP was released for public comment in July 2010.

To support the EIS/ERMP, RPS were commissioned to undertake satellite telemetry and time – depth recording studies on flatback turtles nesting at Ashburton Island, approximately 12 km to the north-west of Ashburton North (Figure 1). Preliminary results of these studies were presented in a Marine Turtle Technical Appendix to the Draft EIS/ERMP and the full dataset is reported here.

Six Mk10-AF PTTs were attached to nesting flatback turtles at Ashburton Island in December 2009. Five of the PTTs provided location and dive information on inter-nesting movements and all six PTTs provided information on post-nesting migratory movements.

The inter-nesting habitat for flatback turtles nesting at Ashburton Island comprised approximately 1,500 km^2 covering the area between Baresand Point, Bessieres Island, Airlie Island and Coolgra Point. The turtles regularly moved through the Wheatstone project footprint, but spent relatively little time in this area.

Inter-nesting flatback turtles spent large proportions of their time at the sea floor and less time near the sea surface. There were no obvious areas where the turtles were more or less likely to spend time on the sea floor or near the sea surface.

Although flatback turtles are generally thought to have high nesting beach fidelity, two of the six turtles tracked from Ashburton Island were recorded nesting on nearby islands up to 20 km away within the same nesting season. Given that flatback turtle tracks have been recorded on most of the islands surrounding the Wheatstone project footprint and on sections of the adjacent mainland, it is possible that flatback turtles regularly move between different beaches in the region to nest.

Following their final nesting event for the season, the tracked turtles spent up to three weeks within the inter-nesting habitat before commencing their post-nesting migration. These movements after nesting but before migration are known as "post-nesting circling movements" and are thought to be associated with foraging or attempting to locate new foraging areas.

Following post-nesting circling, the flatback turtles either migrated to the Kimberley or remained within the Pilbara region. The area between Barrow Island and the Muiron Islands (20–100 m) appears to be an important flatback turtle foraging area, with turtles from several nesting locations in the Pilbara migrating to this area.

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Movements of Individual Turtles during Inter- and Post-nesting

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1.0 INTRODUCTION

Chevron Australia Pty Ltd (Chevron Australia) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast. These plants will initially process gas from the Wheatstone natural gas fields, approximately 200 km offshore from Onslow in the West Carnarvon Basin. The Wheatstone project will require the installation of gas gathering, exporting and processing facilities in commonwealth and state waters and in the Shire of Ashburton. The LNG plant will be part of the Ashburton North Strategic Industrial Area with a combined maximum capacity of 25 Million Tonnes Per Annum (MTPA) of LNG.

The Wheatstone project was referred to the Western Australian Environmental Protection Authority (EPA) and the Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA), with the assessment level set at Environmental Impact Statement/Environmental Review and Management Plan (EIS/ERMP). Chevron Australia submitted the draft EIS/ERMP to the EPA and DEWHA in June 2010 and it was released for public comment in July 2010.

To support the environmental impact assessment for the EIS/ERMP, Chevron Australia commissioned a series of marine turtle investigations, including satellite telemetry of inter- and post-nesting movements of flatback turtles (*Natator depressus*). Preliminary results of turtle movements during inter-nesting were provided in the Marine Turtle Technical Appendix to the EIS/ERMP. The current report adds to the data presented in the EIS/ERMP and examines all inter- and post-nesting location data and dive records for all Platform Terminal Transmitters (PTTs) deployed on flatback turtles at Ashburton Island.

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2.0 BACKGROUND INFORMATION ON FLATBACK TURTLES

2.1 Nesting Activity in the Wheatstone Project Footprint

The nesting season for flatback turtles in the Pilbara region extends from October to March and peaks in December and January (Pendoley 2005; RPS 2010). Although no flatback turtle rookeries have been identified within the Wheatstone project footprint, flatback turtles tracks have been recorded on both mainland and island beaches adjacent to the project footprint, including at the Ashburton River Delta, Ashburton Island, Direction Island, Thevenard Island, Locker Island and Bessieres Island (RPS 2010; Figure 1). The greatest numbers of tracks recorded on these beaches were recorded at Ashburton Island (42 tracks/night) and the Ashburton River Delta (21–35 tracks/night), during the peak of the 2009–2010 nesting season (RPS 2010).

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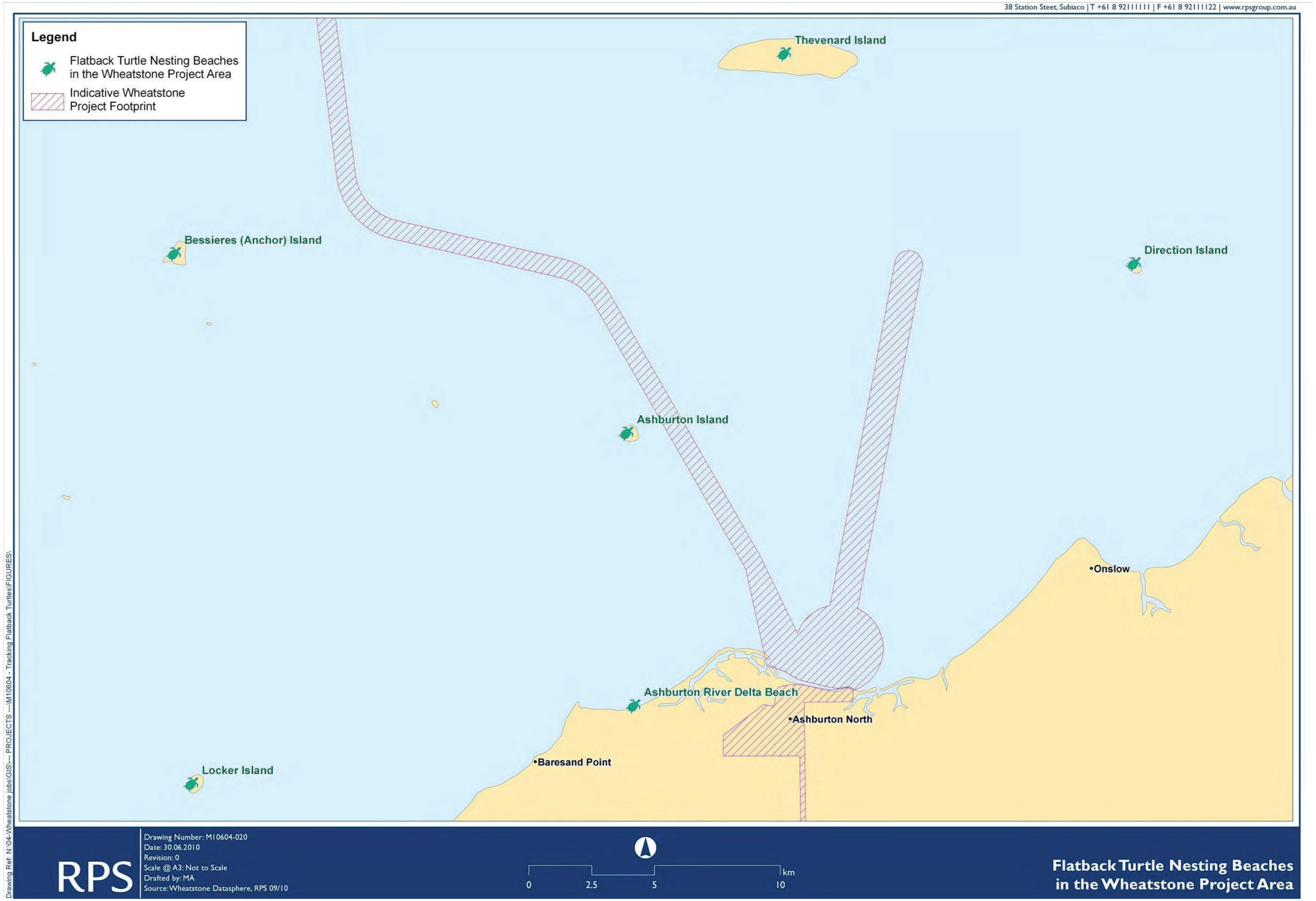

Figure 1: Flatback Turtle Nesting Beaches adjacent to the Wheatstone Project Footprint

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2.2 Inter-nesting Behaviour

2.2.1 Distribution

Available literature relating to the distribution of inter-nesting flatback turtles is limited to a few isolated satellite telemetry studies from Curtis Island in Queensland (Sperling 2007), Bare Sand Island in the Northern Territory (Sperling 2007) and Barrow Island and Mundabullangana Station in Western Australia (Pendoley Environmental 2006; Chevron Australia 2009) (Figure 2). Satellite telemetry studies of nesting flatback turtles have also been undertaken at the Port Hedland, Maret Islands, Lacepede Islands and Roebuck Bay rookeries (Figure 2), but the results of these studies are not yet publicly available.

The first satellite telemetry study of flatback turtles was by Sperling (2007), who tracked three nesting flatback turtles from Curtis Island in Queensland and four nesting flatback turtles from Bare Sand Island in the Northern Territory for a single re-emergence interval [1] (i.e. the time between a successful nesting event and the next nesting attempt, whether successful or not).

Unlike other species of hard-shelled turtle (e.g. green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles), which generally remain close to their nesting beach during the nesting season (Godley et al. 2008), the flatback turtles from both Curtis Island and Bare Sand Island were observed to travel between 20 and 30 km from their nesting beach during the inter-nesting period (Sperling 2007).

While low numbers of satellite transmissions precluded detailed analyses for the Bare Sand Island turtles, the three turtles tracked from Curtis Island all spent the majority of the inter-nesting period south of their nesting beach in the Gladstone port and harbour area. The three turtles each travelled extensively throughout the port and harbour area before returning to Curtis Island to nest. Both the Curtis Island and Bare Sand Island turtles returned to the waters surrounding the nesting beach between 12 and 72 hours prior to the next nesting event.

Flatback turtles nesting at Barrow Island were tracked via satellite telemetry as part of environmental research and monitoring for the Gorgon Gas Development (Chevron Australia 2009), however the results for most of these turtles are not publicly available. The Gorgon Gas Development Revised Proposal Draft Public Environmental Review (Chevron Australia 2009) reports that flatback turtles from Barrow Island displayed two distribution patterns during the inter-nesting period, with some turtles remaining in shallow (0–10 m) water adjacent to the nesting beach and others travelling up to 70 km from their nesting beach to shallow nearshore waters off the Western Australian mainland coast (Chevron Australia 2009).

[1] Some authors refer to the inter-nesting interval/period as "the time between a successful nesting event and the next nesting attempt, whether successful or not" (e.g. Sperling 2007; Whiting et al. 2007) while others refer to it as "the time between laying successive clutches of eggs" (e.g. Godley et al. 2002). For the purposes of this study, the time between a successful nesting event and the next nesting attempt, whether successful or not is referred to as the re-emergence interval, and the time between two consecutive nesting events is the re-nesting interval.

Preliminary analysis of inter-nesting data for two flatback turtles tagged on their nesting beach at Eco Beach in Roebuck Bay in November 2009 suggests that these turtles remained within Roebuck Bay during the inter-nesting period, travelling a maximum of 30 km to the Port of Broome (McFarlane pers. comm. 2 March 2010). Further data analysis is required before the results from this study are published (McFarlane pers. comm. 2 March 2010).

2.2.2 Re-nesting and Re-emergence Intervals

Average re-emergence intervals for flatback turtles from Curtis Island and Bare Sand Island were 15.3 days (range = 15–16 days) and 16.25 days (range = 15–17 days), respectively (Sperling 2007).

The average re-nesting interval (i.e. the time between laying successive clutches of eggs) for flatback turtles at Barrow Island has been inferred from intensive flipper tagging between 2005 and 2008. Flatback turtles at Barrow Island lay a minimum of three clutches per season, at an average interval of 14.7 days (range = 12–16 days) (Pendoley Environmental 2009).

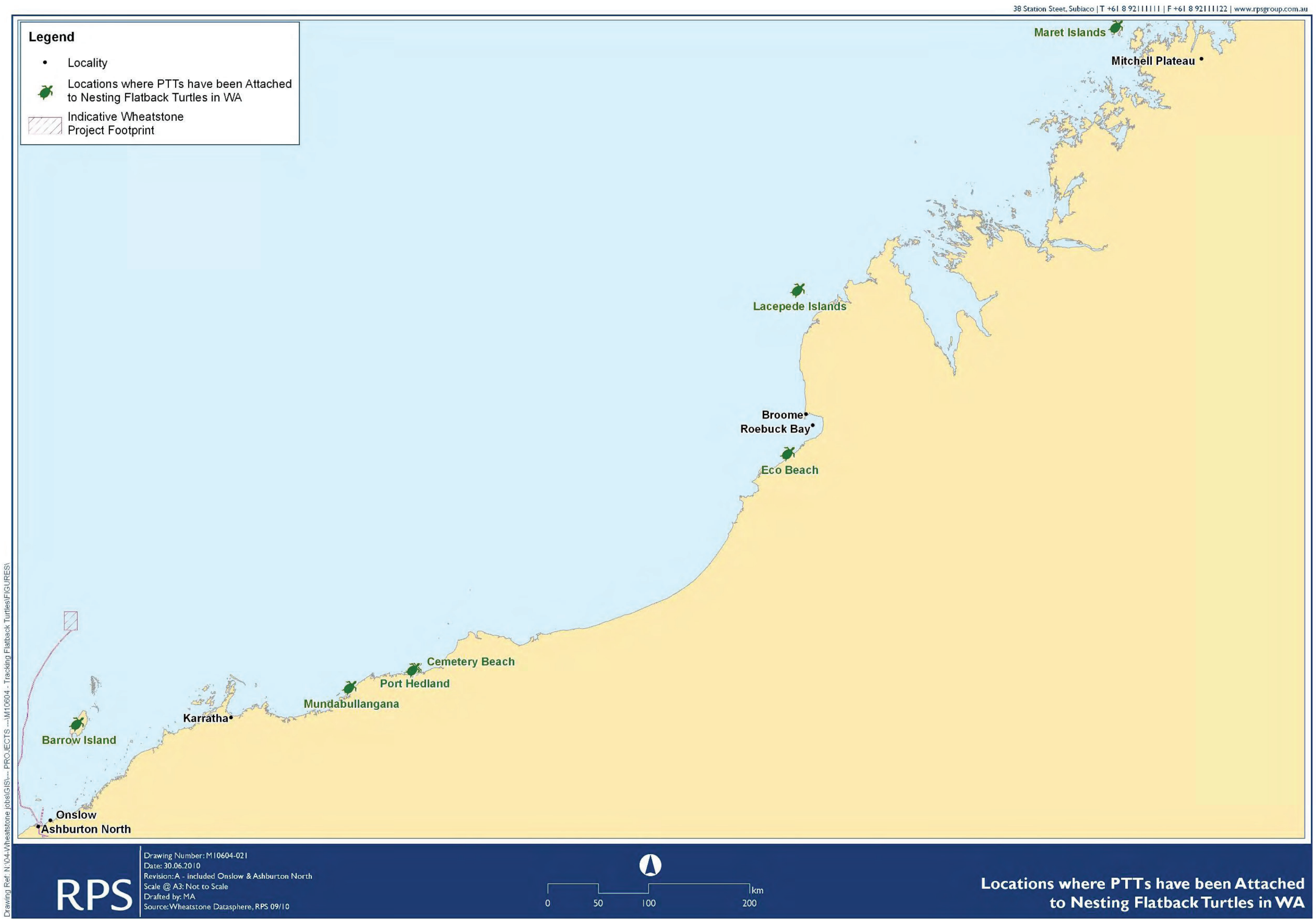

Figure 2: Locations in Western Australia where PTTs have been attached to Flatback Turtles

Note: There are additional flatback turtle rookeries in Western Australia where PTTs have not been attached to flatback turtles

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2.2.3 Dive Patterns

Eight different dive types have been identified for inter-nesting flatback turtles based on studies conducted at Curtis Island and Bare Sand Island (Table 1; Figure 3). Many of these dive types have been described for other marine turtle species, but dive types s4 and 1-4 are thought to be exclusive to flatback turtles (Sperling 2007).

Dive patterns of inter-nesting flatback turtles have not been studied in Western Australia, however, time-depth studies at Curtis Island and Bare Sand Island indicate that flatback turtles spend the majority of time (91.5% and 88.3%, respectively) sub-surface (Sperling 2007). Average surface time between dives ranged from 1.9–2.4 minutes with about half of dives presenting type 1a dive profiles (Sperling 2007).

Type 1a dives were most prevalent in the middle of the re-emergence interval, whereas shallow dives were commonly recorded towards the beginning and end of the re-emergence interval (Sperling 2007). Sperling (2007) suggests that this pattern indicates the turtles are relatively active when travelling to and from their inter-nesting area, but are relatively inactive whilst in the inter-nesting area. Short, shallow dives were especially prevalent in the last three to four days of the re-emergence interval, when they were in close proximity to their nesting beach (Sperling 2007).

Table 2 shows the overall percentage of dive time that the turtles spent engaged in the different dive types. Dive type 1a was by far the most common dive type for turtles from both Curtis Island and Bare Sand Island, followed by dive type 1b.

Table 1: Dive Types of Inter-nesting Flatback Turtles

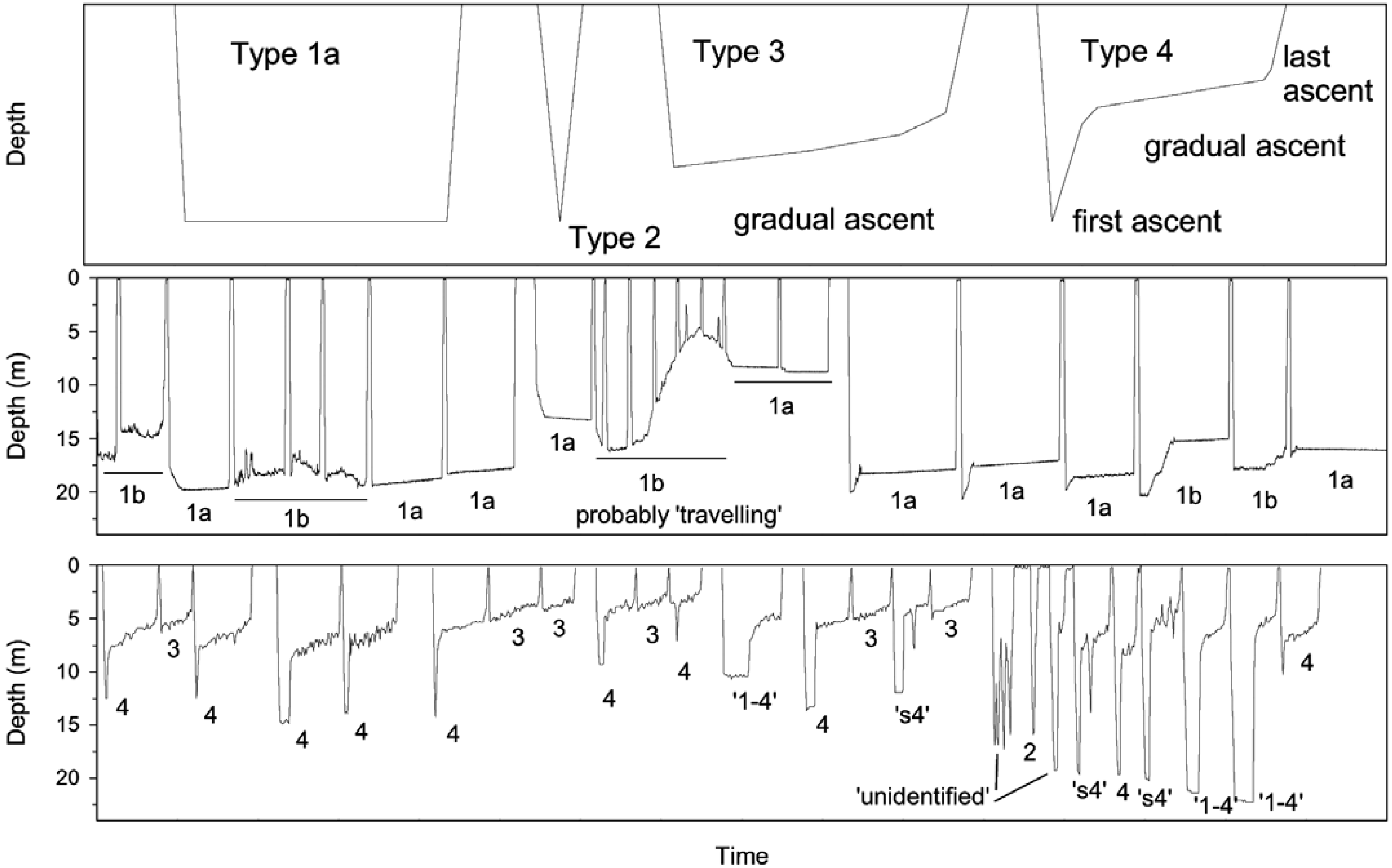
Dive Type	Description of Dive Type	Expected Turtle Behaviour
1a	Rapid descent, followed by long bottom time and rapid ascent	Resting on sea floor
1b	Similar to dive type 1a but with changes of depth during the bottom time	Foraging on sea floor
2	Steep descent followed immediately by steep ascent	Exploratory dive
3	Quick descent followed by gradual ascent, then quick final ascent	Energy conserving dive while travelling
4	Quick descent followed by quick partial ascent, then gradual partial ascent, then quick final ascent	Resting on sea floor in deep water
s4	Hybrid of dive type 4, with “spikes” in the gradual partial ascent where the turtle dives/ascends to deeper/shallower water	Surveying the water column or catching prey
1-4	Hybrid of dive types 1a and 4. Involves a rapid descent, followed by long bottom time, then gradual partial ascent, then quick final ascent	Resting on the sea floor, following by energy conserving ascent
5	Dives to 3 m or less that do not fit any of the above categories	No hypothesis provided

Source: Sperling (2007)

Table 2: Percentage of Dive Time Spent Engaged in Different Dive Types at Curtis Island and Bare Sand Island

Dive Type	% of Dive Time Spent Engaged in Dive Type	
	Curtis Island	**Bare Sand Island**
1a	61.0	54.0
1b	19.1	11.5
2	0.8	0.7
3	1.0	0.8
4	2.8	9.7
s4	1.9	4.6
1-4	1.7	6.6
5	0.3	1.2
Unidentified	11.3	10.9

Source: Sperling (2007)



Source: Sperling (2007

Figure 3: Dive Types for Inter-nesting Flatback Turtles, based on Recorded Dive Profiles)

2.3 Post-Nesting Migratory Behaviour

2.3.1 Distribution

The majority of post-nesting satellite telemetry studies for flatback turtles have not been published or are not publicly available and the post-nesting migratory behaviour of flatback turtles is largely unknown (Godley et al. 2008).

Godley et al. (2008) identified two general post-nesting migration patterns, for all species of marine turtle.

1. Type A: turtle swims directly from the breeding area to a fixed feeding area (generally in the neritic zone). This can be further categorised as follows

   – type A1 – oceanic and/or coastal movements to neritic foraging grounds
   – type A2 – coastal movements between summer and winter foraging sites
   – type A3 – local residence

2. Type B: turtle swims to oceanic habitat then performs long-distance wandering movements.

Most chelonid turtles (i.e. hard-shelled species such as green, flatback and hawksbill (*Eretmochelys imbricata*) turtles) exhibit a type A migration pattern, although some individuals undertake type B migrations (Godley et al. 2008). Leatherback (*Dermochelys coriacea*) turtles typically exhibit type B migration patterns (Godley et al. 2008).

Limited information on the post-nesting migratory pathways for flatback turtles tracked from Barrow Island, Cemetery Beach and Mundabullangana rookeries suggests that these turtles either travel along the Western Australian coastline to foraging areas in the Kimberley or remain in the Pilbara in an area between the Muiron Islands and the Montebello Islands (Pendoley Environmental 2006; Chevron Australia 2009; Howlett pers. comm. 15 June 2010).

Flatback turtles tracked from Eco Beach in Roebuck Bay in November 2009 were noted to have migrated northwards along the Western Australian coastline to the Timor Sea at the conclusion of the nesting season (McFarlane pers. comm. 2 March 2010).

2.3.2 Dive Patterns

Dive patterns of post-nesting flatback turtles have not been studied. However, as turtles experience greater drag when swimming at the surface than when swimming below the surface, migrating turtles are generally expected to spend the majority of their time submerged and very little time at the sea surface (Godley et al. 2002). This behaviour pattern has been observed in time-depth studies of migrating turtles of other species (Hays et al. 2001; Whiting et al. 2007).

Green turtles that were tracked after being captured at their nesting beach and released 60–270 km away were found to have a bimodal distribution of dive depth, peaking at 0.9–1.5 m and 10–20 m (Hays et al. 2001).

Olive ridley turtles (*Lepidochelys olivacea*) tracked from their nesting beach at Melville Island in the Northern Territory dived to a maximum of 200 m during their post-nesting migrations, with the majority of dives being 50–80 m in depth (Whiting et al. 2007). The majority of time was spent at depths of between 50 and 100 m (Whiting et al. 2007). The greatest proportions of dives were 1–5 or 20–80 minutes in duration (Whiting et al. 2007).

2.4 Foraging Behaviour

There have been no targeted studies investigating flatback turtle foraging areas in Western Australia. As a result, flatback turtle feeding grounds in Western Australia have not been confirmed.

As mentioned in the previous section, satellite telemetry data suggest that flatback turtles from Barrow Island, Cemetery Beach and Mundabullangana rookeries migrate to foraging areas in the northern Kimberley and Pilbara regions (Pendoley Environmental 2006; Howlett pers. comm. 15 June 2010). Recent data from flatback turtles tracked from Barrow Island indicate that post-nesting flatback turtles in Western Australia inhabit waters of 25–100 m depth and spend large amounts of time in clear deep water (Chevron Australia 2008). It appears that post-nesting flatback turtles do not migrate to a single foraging area, but may move between several feeding grounds (Chevron Australia 2008), which means that turtle densities at foraging areas may vary over time.

In north-eastern Australia and the Gulf of Carpentaria, flatback turtles are thought to forage in turbid, shallow, inshore waters in depths between 5 and 20 m (Bjorndal 1997) and are rarely found foraging in intertidal seagrass meadows or coral reef habitats (Limpus 2009). Flatback turtles are regularly reported in prawn trawl catches in the Gulf of Carpentaria and the Great Barrier Reef region and are recognised as a regular inhabitant of shallow inshore turbid waters and bays in these potential foraging areas (Limpus et al. 1983). Flatback turtles have been captured during trawl fishery activities in soft bottomed habitats of 6–35 m water depth within the Great Barrier Reef region and 11–40 m water depth within the Torres Strait (Limpus 2009). It was postulated that these turtles were in their foraging habitat (Limpus 2009).

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3.0 RESEARCH AIM AND OBJECTIVES

The aim of the current research is to determine the distribution and dive patterns of flatback turtles in the vicinity of the project footprint. This information will be used to inform the assessment of risks to flatback turtles from dredging and vessel movements associated with the Wheatstone project and for the development of mitigation and management measures.

The primary objectives of the study were to:

- identify the spatial distribution of inter-nesting flatback turtles from the Ashburton Island rookery
- determine the proportion of time that inter-nesting flatback turtles spend on the sea floor
- determine the proportion of time that inter-nesting flatback turtles spend near the sea surface
- identify patterns in flatback turtle distribution and diving behaviour during the inter-nesting period.

Secondary objectives of the study were to:

- identify flatback turtle post-nesting migration pathways and end points
- compare flatback turtle dive patterns during inter-nesting and post-nesting.

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4.0 METHODS

4.1 Survey Design

Six Mk10-AF (Wildlife Computers Inc.) Platform Terminal Transmitters (PTTs) were attached to flatback turtles nesting at Ashburton Island in December 2009. The Mk10-AF is specifically designed to collect high accuracy location and time-depth data for animals that spend the majority of time under the water.

4.1.1 Location Data

Once the PTT is attached and deployed, its location is determined through two satellite systems:

1. Argos-linked satellites.
2. Global Positioning System (GPS).

Positions acquired by the Argos-linked satellites are transmitted to receiving stations, which then forward the information to processing centres. Positions acquired by the GPS are transmitted from the PTT to the Argos-linked satellites, before being transmitted to the receiving stations and forwarded to the processing centres (CLS, 2008).

The acquisition of GPS positions relies on relatively new Fastloc™ technology which allows GPS positions to be acquired in a very short time frame. Positions acquired through the GPS are generally more accurate than positions acquired through the Argos system; however, they use more battery power than Argos transmissions and can significantly shorten the operational life of the PTT. The Mk10-AF PTTs are programmable, allowing researchers to select how often the PTTs should attempt to acquire GPS positions and how often they should transmit data to the Argos-linked satellite, thus allowing for a balance between the number of acquired positions and the required operational life of the PTT.

The position acquisition and transmission settings for this study were selected to achieve two aims. The first aim was to collect high accuracy location data during the inter-nesting period when there is a greater chance that the turtles will be moving within the project footprint. The second aim was that the batteries in the PTTs would last long enough to determine the migration end-points for tracked turtles.

The PTTs were programmed to collect and transmit location data only on certain days, as follows:

- December–February (inter-nesting period) – every day
- March–May (migration period) – every second day
- June–November (post-migration) – every fourth day.

On these days, Argos transmissions were attempted every 45 seconds but the number of GPS location acquisitions was limited to a maximum of three per hour (maximum of 72 locations per day) to increase battery life.

The Mk10-AF PTTs are fitted with wet/dry sensors that identify when the turtles are out of the water (i.e. on the beach attempting to nest). In order to identify subsequent nesting events and false crawls (and thus be able to determine the re-nesting and re-emergence intervals), the PTTs were programmed to enter "haul-out" mode after 10 consecutive "dry minutes", with a dry minute defined by the wet/dry sensor being dry for 60 seconds in a minute. The PTTs were programmed to exit haul-out mode if the wet/dry sensor was wet for 10 (not necessarily consecutive) seconds in a minute.

4.1.2 Time-depth Data

Although the Mk10-AF PTTs are capable of recording depth every second, the limited bandwidth of the Argos system means that full dive profiles are too large to be transmitted (Myers et al. 2006). To reduce the data to a size small enough to be transmitted via the Argos system, the Mk10-AF PTTs group the data into histograms of a user-specified duration. For this study the PTTs were programmed to collect data every 10 seconds and then group the data into hourly histograms.

The Mk-10AF PTTs collect three types of dive histogram data:

- maximum dive depth
- time at depth (TAD)
- dive duration.

For each of these types of data, 14 bins were selected, as detailed in Table 3. The depth bins (for maximum dive depth and TAD) were chosen to provide high resolution at shallow depths, as water depths in vicinity of Ashburton Island rarely exceed 10 m. The time bins (for dive duration) were also selected to provide high resolution.

The data reported through the Argos system for each hourly histogram included:

- maximum depth bin achieved for each dive
- proportion of time spent within each depth bin
- number of dives within each dive duration bin.

Dive profiling commenced once the turtle dived below 0.5 m. To account for the effects of swell and wind-waves, a dive was only logged if it was deeper than 1 m and longer than 20 seconds.

Table 3: Programmed Dive Profile Bins for the Mk10-AF PTTs

Bin	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dive maximum depth (m)	2	4	6	8	10	12	14	16	18	20	50	100	150	>150
Time at depth (m)	2	4	6	8	10	12	14	16	18	20	50	100	150	>150
Dive duration (minutes)	1	2	3	4	5	10	15	20	25	30	40	50	60	>60

4.2 Field Survey Techniques

PTTs were attached to the turtles using harnesses developed specifically for flatback turtles (Sperling and Guinea 2004; Pendoley 2005) (Plate 1).

Turtles were selected opportunistically for inclusion in the study. Researchers patrolled the nesting beach until a turtle was located then waited for the turtle to complete her nesting attempt before attaching the PTT. If a second turtle was seen returning to the ocean nearby while the team was already tagging a turtle, the second turtle was restrained in a wooden pen (150 cm x 150 cm x 60 cm) for up to an hour until the survey team had finished with the first turtle (Plate 2). Two turtles were released without a PTT as their carapaces were too large for the harnesses.

Plate 1: PTT and Harness being attached to a Flatback Turtle

Plate 2: Turtle Restrained in the Holding Pen

4.3 Data Analysis

4.3.1 Location Data

Text files supplied by Argos were processed through Wildlife Computers Data Analysis Program software (version 2.0) and converted into comma-separated value (CSV) files for analysis. The analyses include location data up to 31 May 2010.

Locations generated by the Argos satellite system are categorised into Location Classes according to the number of messages received per satellite pass and the error associated with the location calculation (Table 4). Location Classes 3 and 2 are the highest accuracy, with <500 m estimated error.

The accuracy of GPS positions also varies with the number of satellites used to obtain a location (Table 5). The highest accuracy locations are those attained from ten or more satellites however, field studies have shown that most locations are acquired with four satellites and very few positions are acquired with eight or more satellites (Hazel 2009).

Table 4: Argos Location Class Categories

Location Class	No. of Messages Received per Satellite Pass	Estimated Error
3	≥ 4	< 250 m
2	≥ 4	250 < 500 m
1	≥ 4	500 < 1500 m
0	≥ 4	> 1500 m
A	3	No accuracy estimation
B	2	No accuracy estimation
Z	–	Invalid location

Table 5: GPS Location Accuracy

No. of Satellites	95% Location Accuracy (m)
4	630.0
5	140.0
6	70.0
7	50.0
8	39.6
9	35.3
10	30.8
>10	29.8

Source: Bryant (2007)

To ensure high accuracy results, location data were filtered to only include Location Class 3 and 2 and GPS positions. Clearly erroneous data (i.e. data points that were far inland or would have required the turtle to swim >5 km/h) were also removed (cf. Luschi et al. 1998). The remaining data were plotted in a Geographic Information System (GIS) to produce maps showing the movements of the turtles.

Each location was then assigned to one of the following activity categories based on the turtles' spatial movements:

- nesting
- false crawl
- inter-nesting
- post-nesting.

As the haul-out function of the Mk10-AF PTTs did not provide reliable information on nesting attempts, nesting events and false crawls were identified by applying a series of data filters (Table 6). Very high accuracy location data is required to identify nesting events and false crawls as it is necessary to determine whether or not the turtle is on land. Although the highest accuracy GPS positions are attained with 10 or more satellites (Table 5), only a very small proportion (approximately 0.02) of locations were attained with 10 or more satellites in the present study during the inter-nesting period. To achieve a balance between location accuracy and the number of locations received, only positions acquired with ≥5 satellites were used during the inter-nesting period (Table 6). Experiments have shown that 95% of locations acquired from ≥5 satellites are within 140 m of the actual location (Bryant 2007; Table 5).

Table 6: Filters applied to Data to Determine Nesting Events and False Crawls

Turtle Activity	Filter 1	Filter 2	Filter 3 (applied only if >12 Days between Consecutive Nesting Events after Filter 2)
Nesting Event	Turtle observed nesting by the researchers when the PTT was attached	GPS position obtained from ≥5 satellites that was recorded: a) on land b) between 4.00 pm and 8.00 am c) six or more days prior to next nesting attempt[2]	GPS position obtained from ≥5 satellites that was recorded: a) within 140 m of land b) between 4.00 pm and 8.00 am c) six or more days prior to next nesting attempt
False crawl	Turtle observed not nesting by the researchers when the PTT was attached	GPS position obtained from ≥5 satellites that was recorded: a) on land b) between 4.00 pm and 8.00 am c) less than six days prior to next nesting attempt	GPS position obtained from ≥5 satellites that was recorded: a) within 140 m of land d) between 4.00 pm and 8.00 am b) less than six days prior to next nesting attempt

Positions acquired between nesting events were categorised as "inter-nesting" and positions acquired after the final nesting event for the season were categorised as "post-nesting".

Inter-nesting data were analysed to determine the mean numbers of:

- nesting events for all turtles
- days per re-nesting interval
- days per re-emergence interval
- days between a false crawl and the next nesting attempt.

Post-nesting movements were further classified as follows:

a) Post-nesting circular movement

  – Circular movements in the vicinity of the inter-nesting habitat prior to the commencement of the post-nesting migration (Cheng 2000; Troëng et al. 2005; Blumenthal et al. 2006).

[2] Turtles are physiologically unable to produce a clutch of eggs in less than six days (Miller 1997). Therefore nesting events cannot be less than six days apart.

b) Travelling

- The post-nesting migration (i.e. period after the final nesting for the season, when the turtle leaves the inter-nesting area and travels consistently in a purposeful direction over a number of days/weeks).

- Travel time between periods of milling (McMahon et al. 2007; Whiting et al. 2007).

c) Milling

- Periods of days or weeks where the turtle is not travelling consistently in a purposeful direction, but travels back and forth throughout an area (McMahon et al. 2007; Whiting et al. 2007).

Straight line distances travelled from Ashburton Island and the total distances travelled during the inter-nesting period were also calculated for each turtle.

Post-nesting data were plotted in a GIS and analysed to determine:

- the number of days spent undertaking post-nesting circular movements
- distance travelled from the nesting beach during post-nesting circular movements
- distance travelled from the nesting beach during post-nesting migrations
- duration of post-nesting migration
- location and activity at last transmission.

4.3.2 Time-depth Data

The time – depth analyses include data up to 30 April 2010.

One of three activity types (inter-nesting, travelling and milling) was ascribed to each hourly histogram based on the turtles' spatial patterns of movement at the time of data collection (refer Section 4.3.1). As post-nesting circular movements also occurred in the area of the project footprint, post-nesting circular movements were categorized as "inter-nesting" for the purposes of the time-data analyses.

In order to explore variation in maximum dive depth and dive duration amongst the turtles, these parameters were plotted for each turtle for each activity type (i.e. inter-nesting, travelling and milling), using the value of the midpoint of the bin.

Overall mean proportions were also calculated for each activity type for the following parameters:

- dives to each maximum dive depth bin
- time spent within each depth bin
- dives within each dive duration bin.

These data are presented in frequency histograms.

Given that the majority of dives by inter-nesting flatback turtles in Queensland and the Northern Territory were to the sea floor (Sperling 2007) and that hydrographic charts for the Onslow area indicate that the bathymetry is relatively uniform, the proportion of time spent on the sea floor was determined as being the proportion of time spent at the deepest recorded bin of each TAD histogram.

The proportion of time spent near the sea surface (PST) was determined using the TAD histogram data from the first bin (0–2 m). This calculation does not include time spent at the sea surface between dives.

Diurnal dive patterns were examined by presenting the mean values of PST and PBT for all turtles for each hour of the day for each activity type. The mean values of PST and PBT during the inter-nesting period were also presented spatially for each turtle using ArcGIS.

4.4 Limitations

While the six PTTs deployed for this study have provided insights into the distribution and dive patterns of flatback turtles from Ashburton Island during inter-nesting and post-nesting, it cannot be assumed that all flatback turtles that nest at Ashburton Island will behave the same way. More than 40 flatback turtle tracks were recorded on Ashburton Island the night that the PTTs were attached (RPS 2010). Given that only six PTTs were deployed, only a very small proportion of the total population of flatback turtles that nest at Ashburton Island have been tracked. While some general behavioural patterns are evident, it is not possible to determine if the turtles tracked during the present study are representative on the entire population due to the small sample size.

4.4.1 Location Data

Although Argos transmissions and GPS position acquisitions were attempted every 45 seconds and 20 minutes respectively, typically <10 useable locations (i.e. locations that were retained after data filtering; refer Section 4.3.1) were received each day. The movements of the turtles between the transmitted locations are not known therefore, distances between transmitted locations represent minimum distances travelled.

Additionally, as the Argos antennae must break the surface of the water in order to transmit data, the location data are biased towards time when the turtles are on the sea surface.

These limitations are common to all tracking studies of marine turtles.

4.4.2 Proportion of Dive Data Received

Marine turtles are only at the sea surface for limited periods of time, therefore there is limited opportunity for the PTTs to transmit dive data through the Argos system, as the Argos antenna needs to break the sea surface in order to transmit data. (Myers et al. 2006). Consequently, the PTTs are unable to transmit all of the collected data through the Argos system (Myers et al. 2006). Instead, the PTT transmits a proportion of the histograms collected over the preceding week. The proportion of dive data transmitted through the Argos system for each turtle for each activity is shown in Table 7.

The proportion of dive data transmitted varied between the activity types, but was relatively similar across the three types of dive data. The proportion of data transmitted during inter-nesting ranged from 0.20–0.30 for dive maximum depth and dive duration and from 0.21–0.30 for TAD. The proportions of data transmitted during travelling and milling ranged from 0.01–0.19 and 0.06–0.20 respectively, for all three types of dive data.

Table 7: Proportion of Dive Data Transmitted through the Argos System

Dive Data Type	Proportion of Dive Data Transmitted					
	52941	52942	52952	52953	52955	52963
Dive Maximum Depth						
Inter-nesting	0.30	0.29	0.27	0.28	0.20	0.26
Travelling	0.19	0.03	0.16	0.19	0.01	0.10
Milling	N/A	0.19	0.06	0.06	0.20	0.11
TAD						
Inter-nesting	0.30	0.30	0.27	0.27	0.21	0.27
Travelling	0.19	0.03	0.16	0.18	0.01	0.10
Milling	N/A	0.19	0.06	0.06	0.20	0.11
Dive Duration						
Inter-nesting	0.30	0.29	0.26	0.28	0.20	0.25
Travelling	0.19	0.03	0.17	0.18	0.01	0.10
Milling	N/A	0.19	0.07	0.06	0.20	0.11

N/A – Not applicable. Turtle was not recorded to undertake this activity

4.4.3 Proportion of Time Spent on the Sea Floor

In order to confirm the assumption that water depth was equivalent to maximum dive depth, high accuracy bathymetry data[3] were used to determine water depth at a number of GPS locations received during the inter-nesting period (Figure 4). The GPS data were then joined with the TDR data using the time-date stamp. If the depth of the dive at the

[3] The high accuracy bathymetry data comprised Laser Airborne Depth Sounder (LADS) data. This data has a horizontal accuracy of 15 m and vertical accuracy >0.3 m (Australian Hydrographic Service 2009). LADS data were only available for a proportion of the turtles' inter-nesting habitat.

next reported histogram was greater than, or within 10% of the depth at the preceding GPS location, then the dives were considered to be to the sea floor (cf. McMahon et al. 2007).

Due to the paucity of accurate bathymetry data outside of the project footprint, this was performed on GPS locations received during the inter-nesting period only, however it was assumed that this method for estimating the proportion of bottom time (PBT) was applicable to the other two activity types.

This estimate of proportion of bottom time represents a minimum estimate as it was not possible to determine if time spent at other depth bins was also on the sea floor (resulting from the turtle moving across regions of changing depth within the one hour reporting period of the histogram TAD data). It is likely that the estimates of the proportion of time spent on the sea floor are an underestimate of the true extent of this variable.

For four of the six turtles, 100% of dives were deeper than or within 10% of the bathymetric depth (Table 8). The average percentage of dives deeper than or within 10% of the sea floor for all six turtles was 97%, confirming the validity of the assumption that all dives were to the sea floor (Table 8).

Table 8: Number and Percentage of Dives that were deeper than or within 10% of the Bathymetric Depth

PTT ID #	No. of Dives in Areas of Accurate Bathymetric Data	No. of Dives deeper than or within 10% of Bathymetric Depth	No. of Dives shallower than 10% of Bathymetric Depth	Percentage of Dives deeper than or within 10% of Bathymetric Depth
52941	14	14	0	100
52942	2	2	0	100
52952	20	20	0	100
52953	60	56	4	93
52955	77	75	2	97
52963	15	15	0	100
Total	**188**	**182**	**6**	**97**

4.4.4 Proportion of Time Spent Near the Sea Surface

The proportion of time spent near the sea surface was determined as the proportion of dive-time spent in the first depth bin (0–2 m; refer Section 4.3.2). However, as dives less than 1 m deep and shorter than 20 seconds in duration were not recorded by the PTTs (refer Section 4.1.2), the proportion does not include time spent at the sea surface between dives.

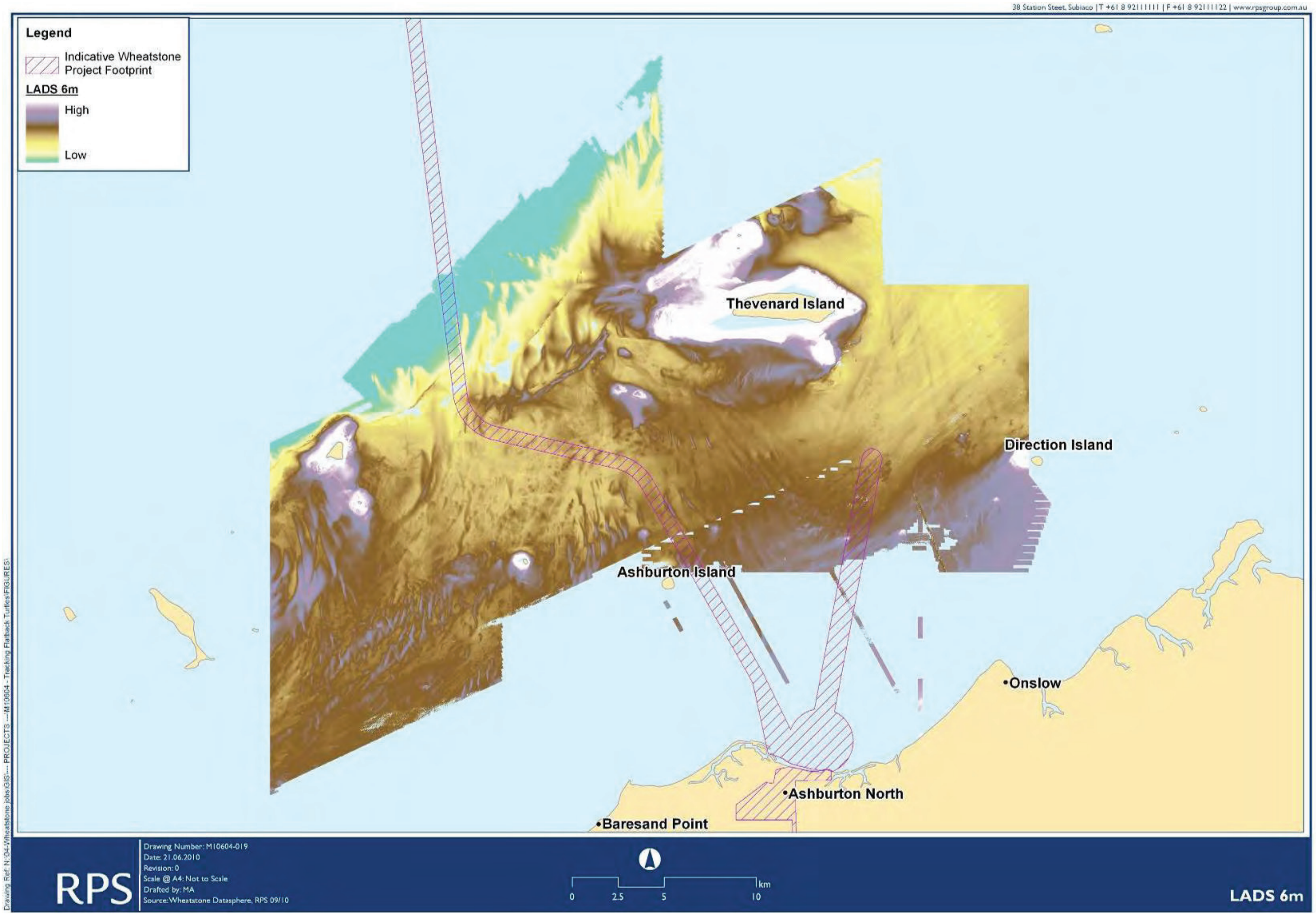

Figure 4: Available LADS Bathymetric Data for the Project Footprint

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5.0 RESULTS

5.1 Location Data

5.1.1 Inter-nesting Movements

Data on inter-nesting movements were received for five out of the six turtles. One turtle (52952) did not nest (or attempt to nest) again after the PTT was attached and consequently no information about this turtle's inter-nesting movements was received.

Two of the transmitters did not provide location data until several days after they were attached. The first locations received for turtles 52952 and 52963 were received 17 December 2009 (three days after the PTT was attached) and 25 December 2009 (11 days after the PTT was attached), respectively.

The dates and locations of nesting events recorded for each turtle are provided in Table 9. The mean number of nesting events was 2.50 (n = 6 turtles; SE = 0.43; range = 1–4). Turtle 52955 had the greatest number of nesting events (n=4), which were all recorded at Ashburton Island. The mean number of false crawls before each nesting event was 1.22 (n = 9 re-nesting intervals; SE = 0.40; range = 0–3).

Two turtles re-nested on islands other than Ashburton Island. Turtle 52942 nested at Ashburton Island and then at Direction Island (20 km north-east of Ashburton Island) 13 days later (Table 9). Turtle 52953 nested at Ashburton Island twice (including the night that the PTT was attached) then laid its final clutch of eggs for the season on the eastern end of Thevenard Island (15 km north-north-east of Ashburton Island).

The mean re-nesting interval (i.e. the interval between laying successive clutches of eggs) was 15.33 days (n = nine re-nesting intervals; SE = 0.93; range = 13–20 days). The mean re-emergence interval (i.e. the number of days between a nesting event and the next nesting attempt whether or not successful) was 14.11 days (n = nine re-emergence intervals; SE = 0.79; range = 11–19). The mean number of days between a false crawl and the next nesting attempt was 0.53 days (n = 15 false crawls; SE = 0.22; range = 0–3) and the mean number of days between the first nesting attempt and a successful nesting[4] was 1.00 days (n = nine re-nesting intervals; SE = 0.41; range = 0–3).

[4] Includes instances where the turtle nested successfully on her first attempt

Table 9: Nesting Activities of Flatback Turtles Tagged at Ashburton Island

PTT ID #	1st Recorded Nesting			2nd Recorded Nesting			Re-nesting Interval #1 (days)	3rd Recorded Nesting			Re-nesting Interval #2 (days)	4th Recorded Nesting			Re-nesting Interval #3 (days)
	Date	Time	Location	Date	Time	Location		Date	Time	Location		Date	Time	Location	
52941	16.12.09	1:55	Ashburton Island	31.12.09	21:04	Ashburton Island	15	–	–	–	–	–	–	–	–
52942	17.12.09	23:06	Ashburton Island	31.12.09	21:31	Direction Island	13	–	–	–	–	–	–	–	–
52952	14.12.09	21:20	Ashburton Island	–	–	–	–	–	–	–	–	–	–	–	–
52953	14.12.09	23:50	Ashburton Island	30.12.09	2:02	Ashburton Island	15	14.01.10	22:15	Thevenard Island	15	–	–	–	–
52955	14.12.09	22:10	Ashburton Island	28.12.09	19:50	Ashburton Island	13	18.01.10	00:17	Ashburton Island	20	7.02.10	16:44	Ashburton Island	20
52963*	14.12.09	18:10	Ashburton Island	27.12.09	21:49	Ashburton Island	13	11.01.10	16:24	Ashburton Island	14	–	–	–	–

*As no location data was received for this turtle for 11 days after the PTT was attached, it is possible that a nesting event was missed. However, as no other turtle had a re-nesting interval of <13 days, this is considered highly unlikely.

The inter-nesting distributions for the five turtles that were tracked during inter-nesting are shown in Figure 5. Distribution maps for the individual turtles are provided in Appendix 1. Whilst there was large variation in the movements of the individual turtles, some common patterns were evident in the data.

The turtles all travelled extensively throughout the inter-nesting period. Given the extent of movements by the five tracked turtles, the "inter-nesting habitat" for turtles nesting at Ashburton Island can be described as the area between Baresand Point, Bessieres Island, Airlie Island and Coolgra Point, an area of approximately 1,500 km^2.

All five turtles travelled through the project footprint at least once during the inter-nesting period (Figure 5). Turtles 52942 and 52963 spent very little time in the project footprint, only moving through the area between nesting events (Figure 5). Turtles 52941, 52953 and 52955 appear to have spent more time in the project footprint with several locations recorded in the project footprint for each of these turtles (Figure 5). Turtle 52955 in particular, spent time in the project footprint during all three re-nesting intervals.

Three of the five turtles travelled through the Onslow Salt navigation channel during the inter-nesting period however, none of the turtles spent significant amounts of time in this area.

All five turtles travelled between Ashburton Island and the mainland during the inter-nesting period. The largest numbers of transmissions near the mainland were between Baresand Point and Onslow, with many transmissions recorded near the Ashburton River Delta beach (Figure 5).

Three turtles (52942, 52953 and 52955) travelled to or past Direction Island, with one (52955) travelling past the island during two separate re-nesting intervals. Turtle 52955 also travelled within 2 km of either side of Thevenard Island during a re-nesting interval (Figure 5).

The greatest straight-line distance travelled from Ashburton Island was approximately 35 km by turtles 52942 and 52955. Turtle 52955 travelled between 140 km and 221 km during each re-nesting interval, which was the maximum distance travelled by any of the turtles (Table 10).

Table 10: Distances Travelled by each Turtle during the Inter-nesting Period

PTT ID #	Re-nesting Interval #1		Re-nesting Interval #2		Re-nesting Interval #3	
	Max. Straight Line Distance Travelled (km)	Total Distance Travelled (km)	Max. Straight Line Distance Travelled (km)	Total Distance Travelled (km)	Max. Straight Line Distance Travelled (km)	Total Distance Travelled (km)
52941	11.5	63	–	–	–	–
52942	35	95	–	–	–	–
52952*	–	–	–	–	–	–
52953	22.5	120	17.5	102	–	–
52955	24	141	32	221	35	210
52963	Unknown	Unknown	13.5	76	–	–

* This turtle did not nest again after the PTT was attached
Unknown: the PTT did not start transmitting until several days after it was attached

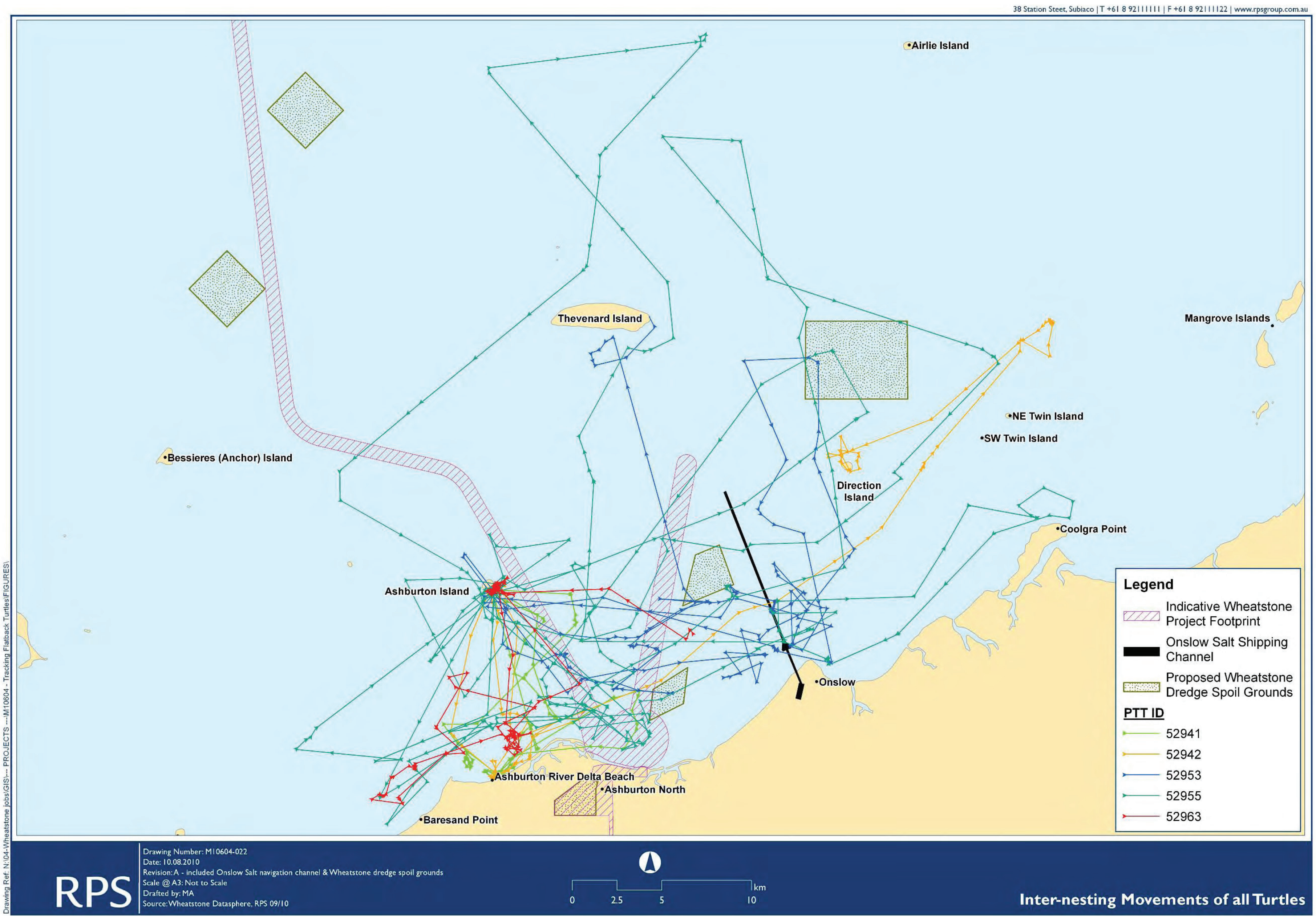

Figure 5: Spatial Distribution of Flatback Turtles during the Inter-nesting Period

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5.1.2 Post-nesting Movements

All six PTTs provided data on the post-nesting movements of flatback turtles up to 31 May 2010 (Figure 6). All six PTTs continued to transmit location data beyond 31 May 2010 however these data have not yet been analysed.

Post-nesting movements comprised three key activities: post-nesting circling; migration/travelling and milling.

5.1.2.1 Circling

All six tracked turtles undertook post-nesting circular movements within the inter-nesting area before commencing their post-nesting migrations. The number of days spent circling ranged from 3–21, with three of the six turtles spending four or less days circling (Table 11). Straight line distances travelled from the nesting beach during post-nesting circling ranged from 1.7–40 km. The total distances travelled ranged from 12–144 km and increased with the straight line distances (Table 11).

Table 11: Number of Days and Distances Travelled during Post-nesting Circular Movements

PTT ID #	No. of Days of Post-Nesting Circular Movements	Straight Line Distance Travelled from Last Nesting Beach during Post-nesting Circular Movements (km)	Total Distance Travelled from Last Nesting Beach during Post-nesting Circular Movements (km)
52941	4	10	27
52942	3	1.7	12
52952	21	Unknown	Unknown
52953	10	40	144
52955	3	11	45
52963	6	18	52

Unknown: this turtle did not nest again after the PTT was attached but the PTT also did not start transmitting until three days after it was attached (refer Section 5.1.1), therefore the distances travelled during post-nesting circular movements is unknown

5.1.2.2 Migration and Milling

Following the completion of post-nesting circling, three of the turtles (52941, 52952 and 52963) migrated north-east along the Western Australian coastline to the Kimberley region (Figure 6). Two of these turtles (52952 and 52963) were last recorded off Eighty Mile Beach, while turtle 52941 was last recorded in the Timor Sea (Figure 6; Table 12).

The other three turtles (52942, 52953 and 52955) remained in the Pilbara region. Two of these turtles (52942 and 52955) were last recorded off the coast of Barrow Island, while turtle 52953 was last recorded to the north of the Dampier Archipelago (Figure 6; Table 12).

All three of the turtles that migrated to the Kimberley region (52941, 52952 and 52963) undertook periods of mid-migration milling between Port Hedland and Pardoo during their post-nesting migrations. Turtles 52941 and 52952 spent several days milling in the Port Hedland area, whereas turtle 52963 spent up to five weeks in this area. Turtle 52941, who migrated to the Timor Sea, also spent approximately 10 days milling roughly 100 km offshore from the Buccaneer Archipelago before continuing on its post-nesting migration.

Table 12: Details of Post-nesting Migrations, including Commencement Dates, Distances Travelled and Turtle Locations at Last Transmission

PTT ID #	Date of Final Nesting	Date Commenced Migration	Distance Travelled from Ashburton Island during Post-nesting (km)	Total Distance Travelled during Post-nesting (km)	Duration of Post-nesting Migration	Date of Last Transmission	Location of Last Transmission	Activity at Last Transmission
52941	31.12.09	5.01.10	1519	2606	3 months	24.05.10	185 km NNW of Cape Bougainville (Timor Sea)	Milling
52942	31.12.09	4.01.10	114	1069	1 day	30.05.10	15 km off the west coast of Barrow Island	Milling
52952	14.12.09	4.01.10	762	2014	2 months	29.05.10	35 km SW of Cape Bossut (Eighty Mile Beach)	Milling
52953	14.01.10	25.01.10	291	1230	Unclear	26.05.10	80 km NNE of Rosemary Island (Dampier Archipelago)	Unclear
52955	7.02.10	7.02.10	73	577	Unclear	28.05.10	20 km SW of Barrow Island	Unclear
52963	11.01.10	18.01.10	755	1747	2 months	29.05.10	28 km SW of Cape Bossut (Eighty Mile Beach)	Milling

Unclear: at this stage it is unclear whether the turtle has completed her post-nesting migration

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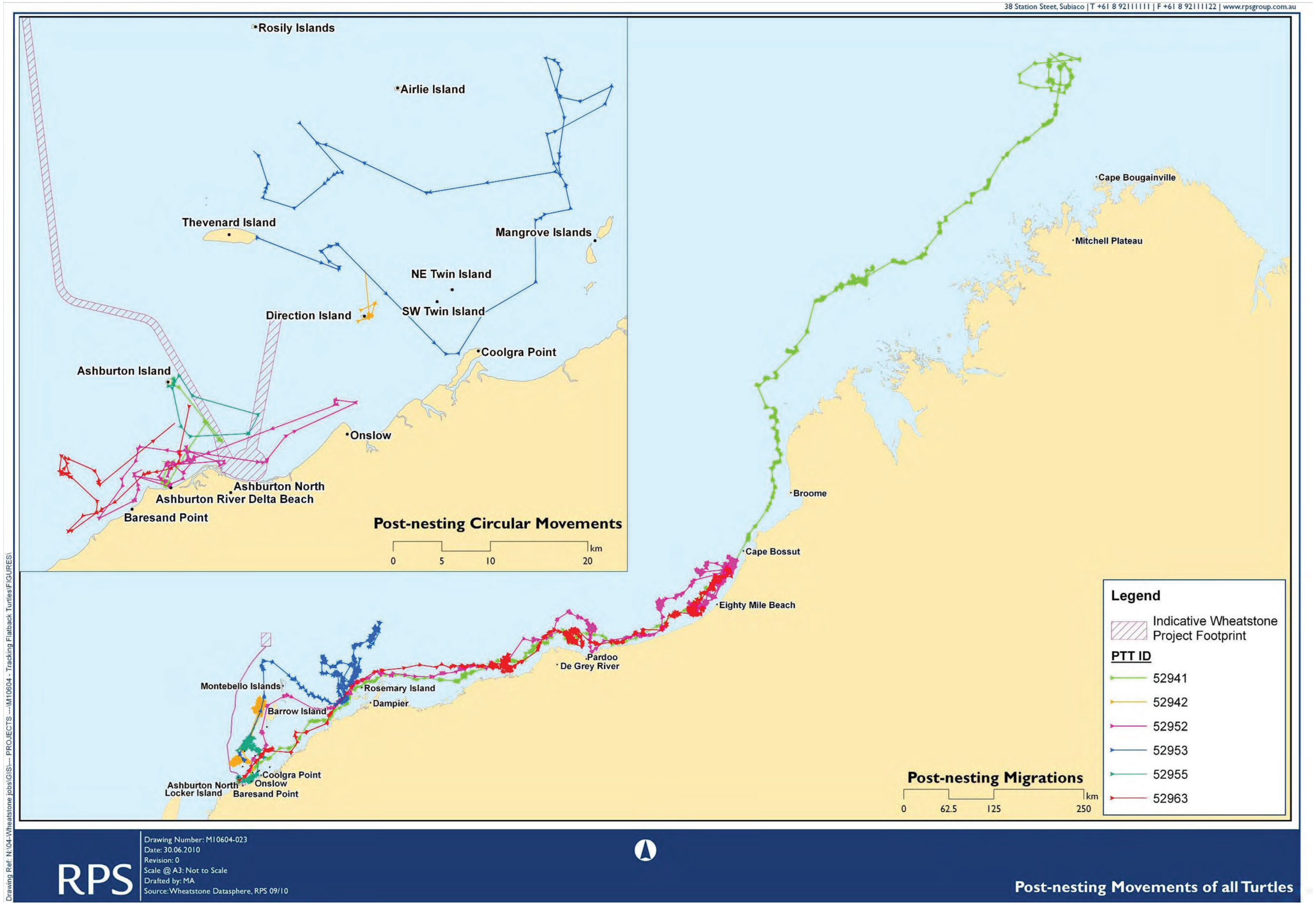

Figure 6: Spatial Distribution of Flatback Turtles during Post-nesting Circling and Migrations

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5.2 Time-depth Data

5.2.1 Dive Depth

Some turtles (e.g. 52942) showed great variation in mean dive depth between activities, whereas other turtles (e.g. 52955 and 52963) had relatively consistent mean dive depths for each activity (Figure 7).

While mean dive depth between turtles was relatively uniform during inter-nesting (ranging from approximately 5–9 m), there was large variation between turtles during travelling and milling. For example, the mean dive depth for turtle 52942 during travelling was approximately 44 m, compared with approximately 9 m for turtle 52955 (Figure 7).

Mean dive depths during inter-nesting did not exceed 10 m and this activity had the shallowest mean dive depth for all turtles. For the majority of turtles, the deepest mean dive depths were recorded during travelling. The exception was turtle 52955 whose mean dive depth was slightly deeper during milling (Figure 7). Mean dive depths during travelling ranged from approximately 9–44 m. Mean dive depths during milling ranged from approximately 9–32 m.

Maximum dives depths during travelling and milling reached 100 m, while the maximum dive depth during inter-nesting was 20 m (Figure 8). The largest proportions of dives during travelling (0.25) and milling (0.33) were to the 20–50 m depth bin, with <0.10 of dives recorded most of the other depth bins. Dive depths were more evenly distributed during inter-nesting with 0.10–0.15 of dives recorded in each of the six lowest depth bins. During inter-nesting 0.75 of all dives were to 10 m or less.

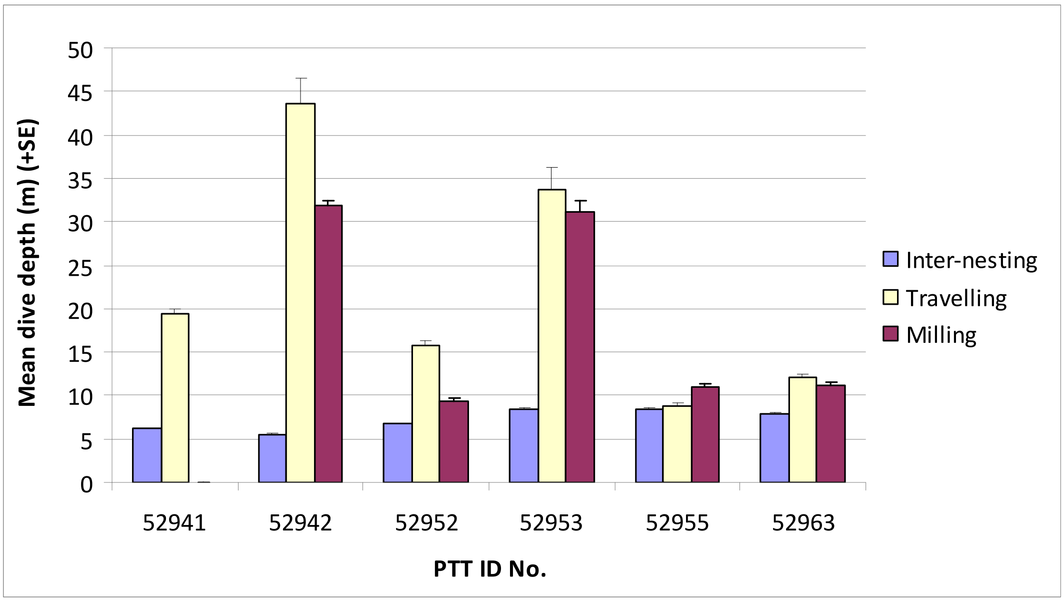

Figure 7: Mean Dive Depth for each Turtle during Inter-nesting, Travelling and Milling

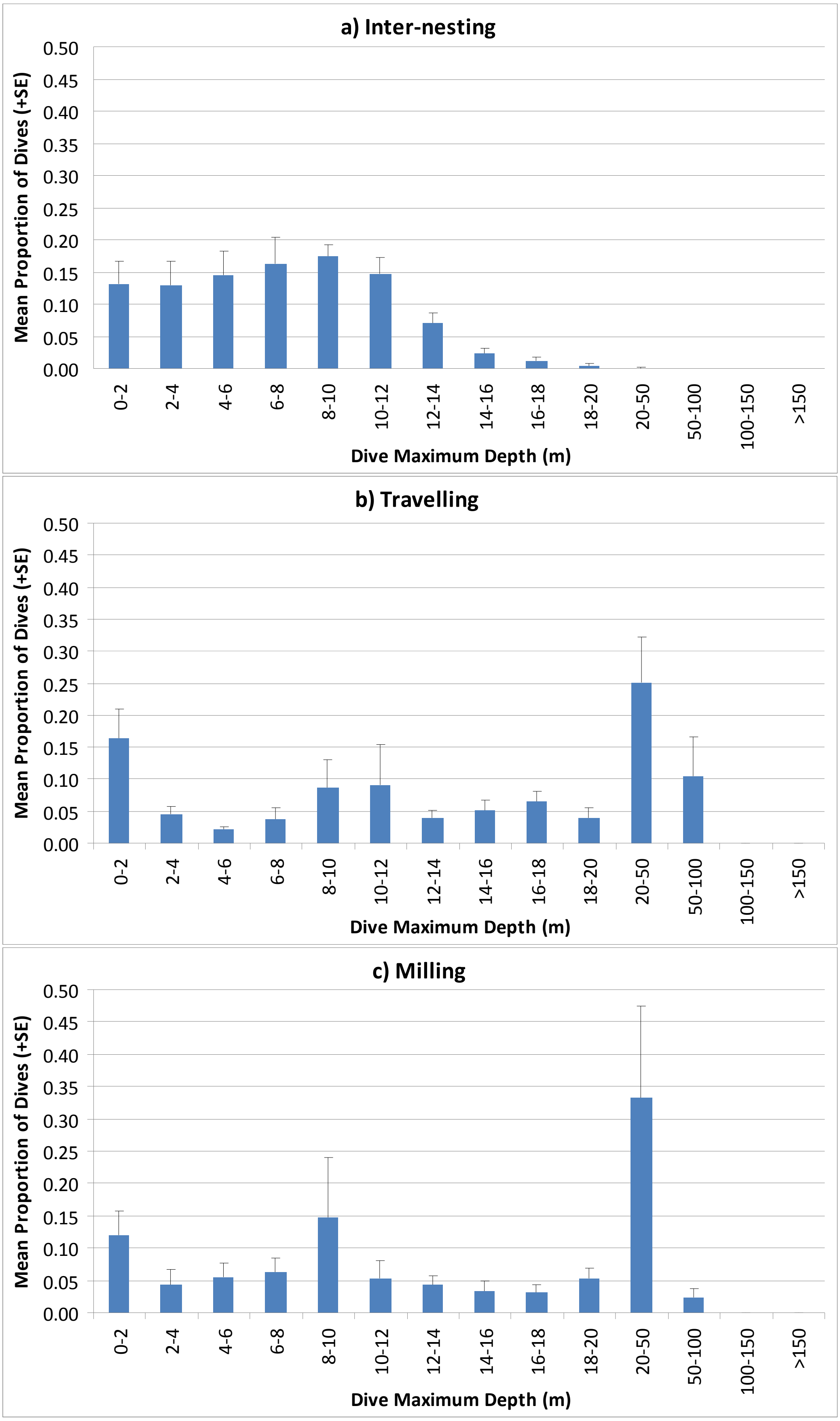

Figure 8: Mean Maximum Dive Depth during a) Inter-nesting, b) Travelling and c) Milling for all Turtles

5.2.2 Time at Depth

The distribution of time at depth during inter-nesting was markedly different to the distributions during travelling and milling. The highest proportions of time during travelling (0.27) and milling (0.32) were spent at 20–50 m, whereas the majority of time (0.57) during inter-nesting was spent at ≤8 m. The maximum depth recorded during inter-nesting was 20 m.

The distribution of time at depth was very similar to the distribution of maximum dive depth for all activity types.

The mean proportion of time spent in each depth bin was generally equivalent to the proportion of dives to that depth bin (Figure 8; Figure 9).

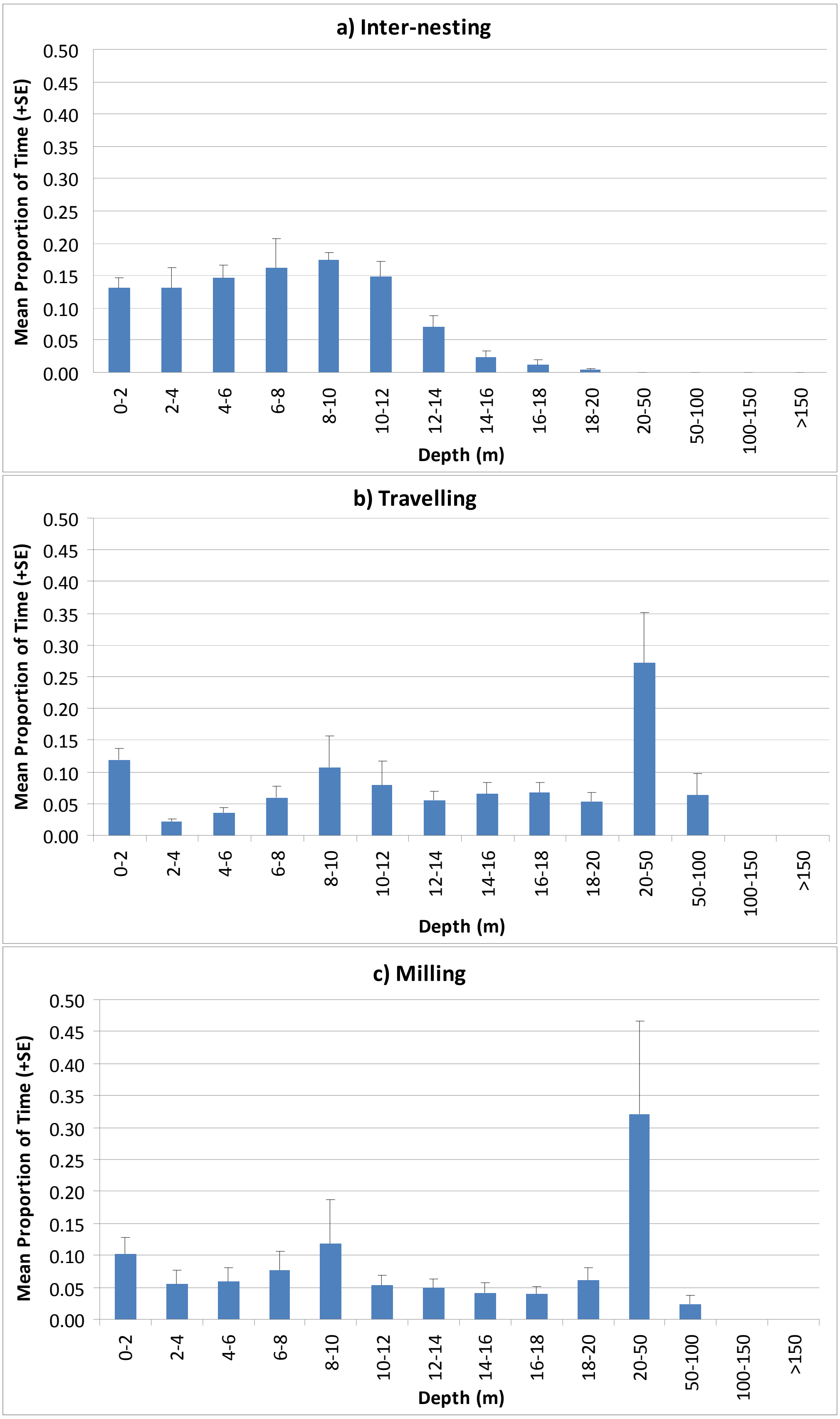

Figure 9: Mean Time at Depth during a) Inter-nesting, b) Travelling and c) Milling for all Turtles

5.2.3 Dive Duration

There was large variation in mean dive duration between turtles and between activities (Figure 10). Mean dive duration ranged from approximately 12–19 minutes during inter-nesting, 13–35 minutes during travelling and 12–33 minutes during milling.

Mean dive durations were similar during travelling and milling. The only obvious difference between the two activities was that >0.10 of dives during milling were >60 minutes in duration compared to <0.05 of dives during travelling.

Dives during the inter-nesting period were generally of short duration. Just over half (0.57) of dives during inter-nesting were ≤15 minutes in duration and approximately one quarter (0.27) of dives were ≤5 minutes in duration. In comparison, around half (0.56) of dives during travelling and milling were ≤20 minutes and ≤25 minutes in duration, respectively.

Only 0.06 of all dives were >40 minutes in duration during inter-nesting, compared with 0.16 of dives during travelling and 0.22 of dives during milling.

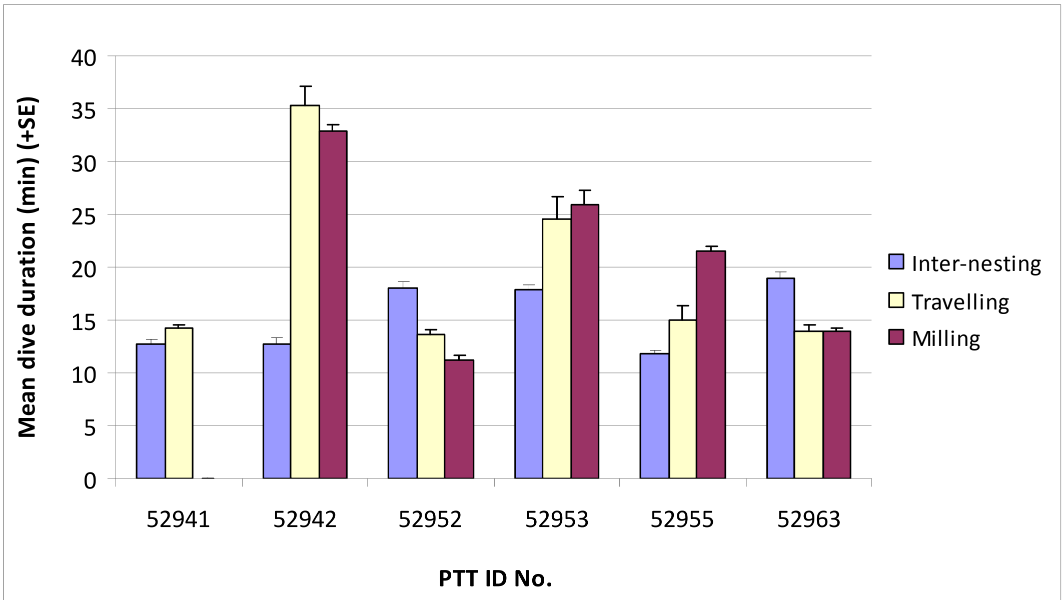

Figure 10: Mean Dive Duration for each Turtle during Inter-nesting, Travelling and Milling

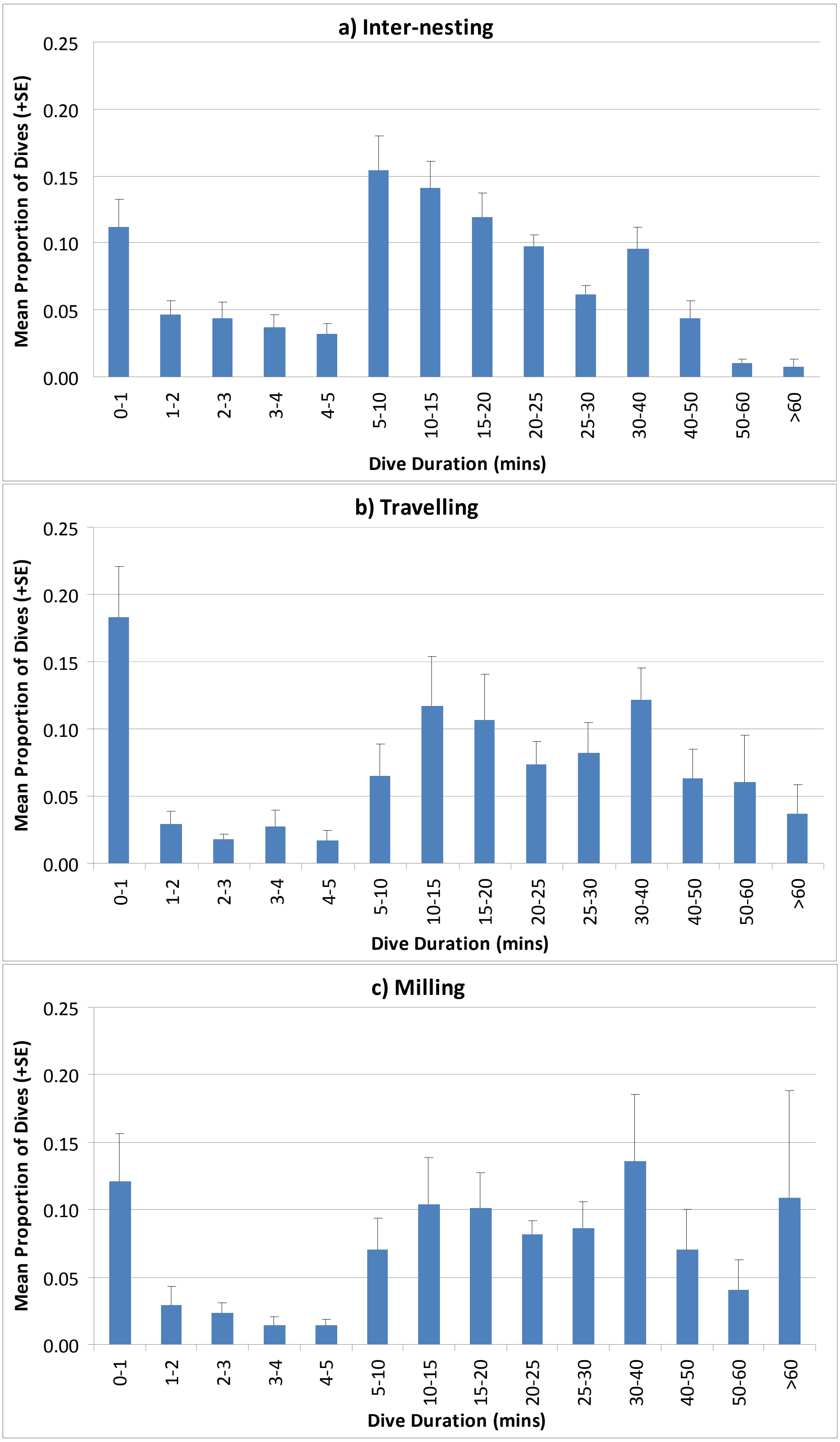

Figure 11: Mean Dive Duration during a) Inter-nesting, b) Travelling and c) Milling for all Turtles

5.2.4 Proportion of Time Spent on the Sea Floor

The turtles spent around half of their time on the sea floor during all three activities (Figure 12). The greatest proportions of time were spent on the sea floor during milling, where the turtles generally spent >0.50 of their time on the sea floor throughout the day (Figure 12).

During the inter-nesting period the turtles spent between 0.33 and 0.55 of their time on the sea floor. There was no clear diurnal pattern during inter-nesting, although the mean proportion of time spent on the sea floor remained below 0.50 between 5.00 pm and 2.00 am and above 0.50 between 7.00 am and 10.00 am.

The mean proportion of time spent on the sea floor during travelling ranged from approximately 0.25–0.65 (Figure 12). Between 9.00 am and 7.00 pm the proportion of time spent on the sea floor was consistently greater than 0.45, whilst generally less than 0.45 of time was spent on the sea floor between 8.00 pm and 8.00 am.

There were no clear patterns in the proportion of time spent on the sea floor in different localities amongst the turtles. The proportion of time spent on the sea floor within the project footprint ranged from 0.00–0.94. Refer to Appendix 2 for spatial representation of the proportion of time that individual turtles spent on the sea floor during the inter-nesting period.

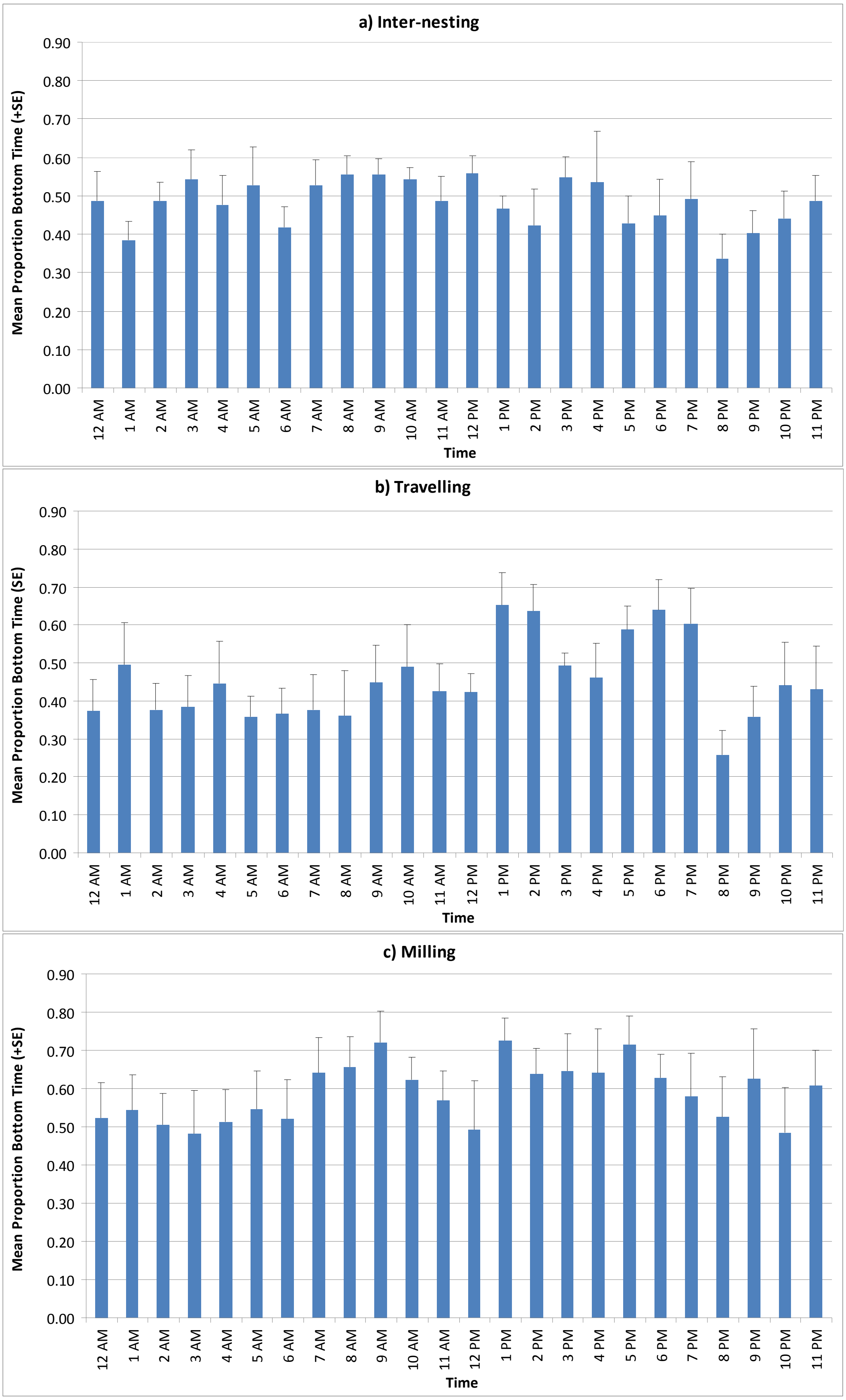

Figure 12: Mean Proportion of Time Spent on the Sea Floor throughout the Day during a) Inter-nesting, b) Travelling and c) Milling for all Turtles

5.2.5 Proportion of Time Spent Near the Sea Surface

The turtles spent very little of their time near the sea surface during all three activities (Figure 13).

The proportion of time spent near the surface during inter-nesting ranged from approximately 0.08–0.19. In all but one time period (12.00 am) the turtles spent ≥0.10 of their time near the sea surface. There were small peaks in the proportion of near-surface time at 6.00 am, 1.00 pm and 8.00 pm. The corresponding troughs in the proportion of near-surface time were at 10.00 am, 4.00 pm and 12.00 am.

The proportion of time spent near the surface during travelling ranged from approximately 0.07–0.26, with ≥0.10 of time spent near the surface for approximately half of all time periods. There was a clear peak in the proportion of time spent near the surface from 9.00 am to 11.00 am, although there was also a high standard error during this period.

There was no clear diurnal pattern in the proportion of time spent near the surface during milling (Figure 13). Proportions of time spent near the surface ranged from approximately 0.07–0.15 throughout the day, with ≥0.10 of time spent near the surface during only one third of the day.

Most turtles spent ≤0.25 of their time near the sea surface for the majority of the inter-nesting period. Generally when the turtles did spend >0.25 of their time near the sea surface they were either travelling from Ashburton Island to the mainland or in the vicinity of the Ashburton River Delta beach. Turtle 52942 also spent >0.25 of its time near the sea surface when in the vicinity of Direction Island.

Within the project footprint, most of the turtles spent ≤0.25 of their time near the sea surface. However, turtles 52953 and 52955 who travelled through the project footprint often, were regularly recorded to spend up to 0.50, and occasionally up to 0.75, of their time near the sea surface in this area. Refer to Appendix 3 for spatial representation of the proportion of time that individual turtles spent near the sea surface during the inter-nesting period.

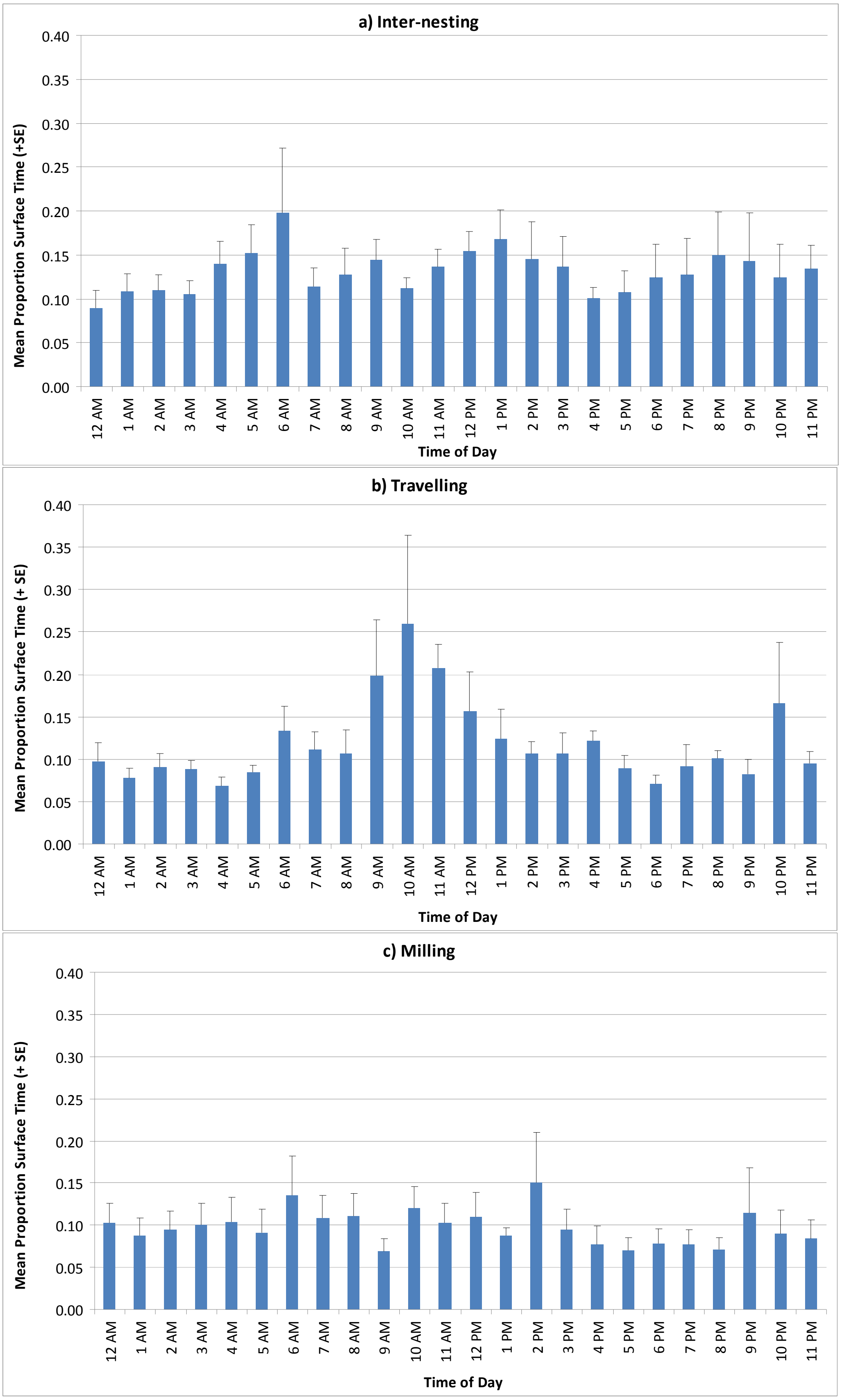

Figure 13: Mean Proportion of Time Spent near the Sea Surface throughout the Day during a) Inter-nesting, b) Travelling and c) Milling for all Turtles

6.0 DISCUSSION

6.1 Inter-nesting movements

6.1.1 Distribution

6.1.1.1 Distance Travelled

The straight line distances that the flatback turtles travelled from Ashburton Island during the inter-nesting period (11.5–35 km) are comparable with the distances travelled by inter-nesting flatback turtles from the Kimberley region of Western Australia (McFarlane pers. comm. 2 March 2010), and from rookeries in Queensland and the Northern Territory (Sperling, 2007), but lower than the distances travelled by some flatback turtles from the Barrow Island rookery (Chevron Australia 2009). Flatback turtles tracked from the southern end of Roebuck Bay travelled up to 30 km from their nesting beach during the inter-nesting period (McFarlane pers. comm. 2 March 2010). Similarly, flatback turtles tracked from Curtis Island in Queensland and from Bare Sand Island in the Northern Territory travelled between 20 and 30 km from their nesting beach during the inter-nesting period (Sperling 2007). Whilst some flatback turtles from the Barrow Island rookery remain within several kilometres of their nesting beach during the inter-nesting period, some turtles have been recorded to travel as far as 70 km from their nesting beach to the Western Australian mainland during the inter-nesting period (Chevron Australia 2009).

6.1.1.2 Extent of Inter-nesting Habitat

Based on the satellite telemetry data from the present study, the inter-nesting habitat for flatback turtles nesting at Ashburton Island covers up to 1,500 km^2. The extent of this habitat is much greater than the extent of the inter-nesting habitat for flatback turtles from the Curtis Island (approximately 250 km^2) and Bare Sand Island (approximately 600 km^2) rookeries (Sperling, 2007), but similar to the extent for flatback turtles from the Barrow Island rookery (approximately 1,100 km^2) (Pendoley Environmental 2006). However, the inter-nesting patterns between islands and the mainland nearshore areas are less defined at Ashburton Island compared to Barrow Island.

As reported at Barrow Island (Pendoley Environmental 2006), turtles from the Ashburton Island rookery travel to the Western Australian mainland during the inter-nesting period, suggesting the nearshore areas support habitat for flatback turtles between nesting events. The slightly larger inter-nesting habitat for turtles from the Ashburton Island rookery, when compared with the Barrow Island rookery, is attributable to the turtles from Ashburton Island travelling to offshore islands such as Direction Island and Thevenard Island whereas the Barrow Island turtles do not.

Although the turtles from Ashburton Island regularly travelled through the project footprint during the inter-nesting period, none of the turtles demonstrated a preference for this area over other areas of the inter-nesting habitat. The benthic habitats within the project footprint (i.e. soft sediments with some areas of sparse macroalgae) are also well represented outside of the project footprint (Chevron Australia 2010), suggesting no reason for turtles being attracted to this area.

6.1.1.3 Re-nesting and Re-emergence Intervals

The mean re-nesting interval for flatback turtles from Ashburton Island (15.33 days; n = nine re-nesting intervals) was higher than for Barrow Island (14.7 days; n = 1529 re-nesting intervals) and Mundabullangana (12.6 days; n = 134 re-nesting intervals) (Pendoley Environmental 2009). Pendoley et al. (2009) suggest that the re-nesting intervals are longer at Barrow Island than at Mundabullangana because they travel a greater distance (up to 70 km) from their nesting beach during the inter-nesting period, whilst flatback turtles at Mundabullangana remain nearshore waters adjacent to the nesting beach (Pendoley et al. 2009). While the Ashburton Island turtles travelled lesser distances from their nesting beach than the Barrow Island turtles, they had a broader extent of distribution, which may account for the longer re-nesting intervals.

The longer re-nesting interval observed in the present study may also be an artefact of the lower sample size. However, it is unlikely that the longer re-nesting intervals reflect a bias towards younger animals with less breeding experience, as, unlike some species of mammals and birds, breeding success of marine turtles is not thought to be related to an individual's breeding experience (Broderick et al. 2003).

The mean re-emergence interval for flatback turtles from Ashburton (14.11 days, n = nine re-emergence intervals) was slightly shorter than for flatback turtles from Curtis Island (15.3 days, n = three re-emergence intervals) and Bare Sand Island (16.25 days, n = four re-emergence intervals). However, the range of re-emergence intervals for flatback turtles at Ashburton Island (11–19 days) was wider than for both Curtis Island (15–16 days) and Bare Sand Island (15–17 days) (Sperling, 2007).

6.1.1.4 Nesting Beach Fidelity

Flatback turtles from Queensland and the Northern Territory generally display high nesting site fidelity both within and between nesting seasons (Limpus 2004; 2009; Limpus et al. 1984), however this was not recorded for the turtles tracked from Ashburton Island. Two of the six turtles from Ashburton Island were recorded nesting at nearby islands during the season. One turtle (52942) nested at Direction Island (20 km north-east of Ashburton Island) and another (52953) nested at Thevenard Island (15 km north-north-east of Ashburton Island).

While there are no known records of flatback turtles moving between islands to nest within a nesting season, there have been infrequent reports of nesting at adjacent beaches. At Barrow Island, flatback turtles have been observed emerging on two different beaches <10 km apart in the same night (Pendoley Environmental 2009). Flatback turtles nesting at Mon Repos (in south-east Queensland) have been recorded nesting about 5 km from the original nesting location (Limpus 2004).

The observations of flatback turtles moving between islands up to 20 km apart to nest within a nesting season are unique to this study. At this stage it is not known how often or what proportion of the total population of turtles from Ashburton Island move to different islands to nest due to the low sample size in this study. Flatback turtle tracks have been recorded on Locker Island (22 km south-west of Ashburton Island), Bessieres Island (18 km north-west of Ashburton Island), North-east Twin Island (30 km north-east of Ashburton Island), Flat Island (32 km west of Ashburton Island), Table Island (22 km west-south-west of Ashburton Island) and Round Island (29 km west-south-west of Ashburton Island) (RPS 2010) and it is possible that flatback turtles may move between some or all of these islands during the nesting season.

6.1.2 Dive Patterns

6.1.2.1 Dive Depth and Duration

The flatback turtles tracked from Ashburton Island conducted shallower dives during the inter-nesting period (mean dive depths <10 m; maximum dive depth 20 m) than those from Curtis Island and Bare Sand Island (mean dive depths <20 m; maximum dive depths 44 m). Maximum dive depths at each location correspond with sea floor depth, indicating that the differences in dive depth are a function of bathymetric gradients (Sperling 2007).

There were also differences in dive duration between the two studies, with the Curtis Island and Bare Sand Island turtles regularly undertaking dives >60 minutes (Sperling 2007) whereas <5% of dives by the Ashburton Island turtles were >50 minutes.

The similarities in the distributions of time at depth and maximum dive depth for the Ashburton Island turtles suggests that these turtles spend the majority of their dives at or near maximum dive depth (i.e. they are undertaking type 1a and/or type 1b dives). This is consistent with Sperling's (2007) study, which found that dive type 1a was the most common dive type for inter-nesting flatback turtles from Curtis Island and Bare Sand Island, followed by dive type 1b.

6.1.2.2 Proportion of Near-surface and Bottom Time

Sperling (2007) found that flatback turtles spend 10–12% of their time within 2 m of the sea surface between dives during the inter-nesting period. She also found that these turtles spend an average of 1.9–2.4 minutes at the surface between dives. While the current study did not measure time at the surface between dives, the amount of time that the Ashburton Island turtles spent near the sea surface (8–19%) was similar to the turtles from Sperling's (2007) study.

Turtles that nested at Ashburton Island spent up to half of their time on the sea floor during the inter-nesting period. There were no obvious locations where the turtles spent more time on the sea floor, indicating a relatively even distribution throughout the inter-nesting habitat. Although Sperling (2007) did not determine the proportion of time that flatback turtles from Curtis Island and Bare Sand Island spent on the sea floor during the inter-nesting period, given that these turtles commonly presented type 1a dive profiles, she suggests that the majority of their time was spent resting on the sea floor (Sperling 2007).

6.2 Post-nesting Movements

6.2.1 Distribution

6.2.1.1 Post-nesting Circular Movements

Post-nesting circular movements have been described for several individuals of other marine turtle species, including green, loggerhead and olive ridley turtles (Cheng 2000; Dodd and Byles 2003; Troëng et al. 2005; Blumenthal et al. 2006; Whiting et al. 2007). It has been suggested that post-nesting circular movements may be spent either foraging or searching for a new foraging area (Blumenthal et al. 2006).

All six turtles tracked from Ashburton Island undertook post-nesting circular movements before commencing their post-nesting migrations. Three of the turtles (52941, 52952 and 52963) undertook post-nesting circular movements in the nearshore area between Ashburton North and Baresand Point, two of which also used this area during inter-nesting.

The nearshore area between Ashburton North and Baresand Point is mostly sand/silt with very small and isolated patches of subtidal coral and subtidal pavement (Chevron Australia 2010), which indicates that the turtles are not using this area to forage on benthic prey. One distinctive feature of the area is the Ashburton River mouth. It is possible that the turtles travel to this area to feed on jellyfish, crustaceans, fish and other pelagic prey that are flushed out of the Ashburton River with the changing tides and/or increased rainfall (e.g. Davis 1988; DoW 2009) that is experienced in the region between January and June (BOM 2010).

6.2.1.2 Migration Pathways

Three of the flatback turtles exhibited a type A1 migration pattern (Godley et al. 2008) as they travelled north-eastwards along the Western Australian coastline to the Kimberley region. They followed a similar migratory pathway to flatback turtles tracked from Barrow Island, Mundabullangana, Roebuck Bay and Cemetery Beach (Pendoley Environmental 2006; Howlett pers. comm. 15 June 2010; McFarlane pers. comm. 2 March 2010). Green turtles tracked from Barrow Island and hawksbill turtles tracked from Varanus Island also followed the same migration pathway (Pendoley 2005). It therefore appears that the coastal areas (<100 km offshore) of the Pilbara and Kimberly regions comprise a northern migratory pathway for a proportion of post-nesting marine turtles in Western Australia.

The other three flatback turtles tracked from Ashburton Island remained within the Pilbara region at the conclusion of the nesting season, migrating between 73 km and 291 km from Ashburton Island. These turtles do not appear to be following a defined migration pathway and are not adhering to any of the migration patterns described by Godley et al. (2008). The only common pattern displayed by these three turtles during their migration is they have all travelled between Barrow Island and Thevenard Island. A flatback turtle tracked from Barrow Island also travelled through this area (Pendoley Environmental 2006), however the relevance of this behaviour is unknown.

6.2.1.3 Mid-migration Milling Areas

Milling during the post-nesting migration has been reported previously for green and loggerhead turtles and is thought to be associated with foraging and/or resting behaviour (Pendoley 2005; Blumenthal et al. 2006; Whiting et al. 2007). Both flatback turtles (the present study) and hawksbill turtles (Pendoley 2005) have been recorded milling in the nearshore areas between Port Hedland and Pardoo. Three rivers flow into the ocean adjacent to this area (Yule River, Turner River and De Grey River), and it is possible that the turtles stopped mid-migration to take advantage of food sources that flush out of these river systems with the changing tides and/or increased rainfall (e.g. Davis 1988; DoW 2009), which is common in the region between January and June (BOM 2010).

The three turtles that exhibited mid-migration milling were the same three turtles that undertook post-nesting circular movements between Ashburton North and Baresand Point. At this stage it is unclear why these turtles displayed such similar behavioural patterns.

6.2.1.4 Post-migration Activities

Of the turtles that migrated north-eastwards to the Kimberley region, two stopped travelling at Eighty Mile Beach and the third ended its migration in the Timor Sea. A green turtle from Barrow Island has also been tracked to Eighty Mile Beach (Pendoley 2005) and nesting flatback turtles from Barrow Island and Cemetery Beach have been tracked to the Timor Sea (Pendoley Environmental 2006; Howlett pers. comm. 15 June 2010), suggesting that these are foraging areas that are shared by turtles from Pilbara rookeries. There do not appear to be any bathymetric features that define the foraging areas. It is unknown whether the turtles remain within a small defined area at their migration end points or if they will continue travelling after a number of weeks or months of milling. Ongoing monitoring of these PTTs will provide additional data that will confirm post-migration activities.

Turtles that remained within the Pilbara region travelled to the Dampier Archipelago and around Barrow Island and Thevenard Island. Green turtles released from Barrow Island and hawksbill turtles released from Rosemary Island have also been reported to migrate to the Dampier Archipelago (Pendoley 2005). Bathymetric charts for the region do not indicate any significant features in the area to the north of the Dampier Archipelago. It is possible that turtle 52953 has not yet completed its post-nesting migration, as it spent March–May moving slowly north-eastwards, following a similar route to the turtles that migrated to the Kimberley region (Figure 6).

Other studies have shown that the area between Barrow Island and the Muiron Islands may be an important foraging area for flatback turtles from nearby Pilbara rookeries. Two nesting turtles tracked from Cemetery Beach also ended their migrations to the west of Thevenard Island and remain within 50 km since ending their migration (Howlett pers. comm. 15 June 2010). Both the Ashburton Island and Cemetery Beach turtles appear to be travelling back and forth along a steep bathymetric gradient where the water depth drops from 20 m to 100 m. According to habitat mapping for the Wheatstone project EIS/ERMP this area is typified by a sand/silt substrate with approximately 10% coverage by filter feeders, including soft corals, sponges and ascidians (Chevron Australia 2010). Given that flatback turtles feed principally on soft-bodied invertebrates including soft corals, sea pens and holothurians (Limpus 2009), it is likely that the area is an important flatback turtle foraging ground.

6.2.2 Dive Patterns

6.2.2.1 Dive Depth and Duration

While green turtles are reported to generally conduct short, shallow dives during their post-nesting migrations, including during oceanic travelling (Hays et al. 1999; Godley et al. 2002), the flatback turtles in the present study were shown to conduct longer dives to deeper depths. During both travelling and milling activities, the greatest proportion of dives were within the 20–50 m depth bin and similar proportions of time were spent at these depths, suggesting that the turtles were diving to the sea floor and remaining there for up to 50% of the time before returning to the surface.

The reason that the flatback turtles were spending the majority of time on the sea floor is unknown, though it could be related to feeding activity (Godley et al. 2002).

7.0 CONCLUSIONS

The nesting season for flatback turtles at Ashburton Island extends from at least mid-December to early February. The inter-nesting habitat for these turtles comprises shallow (<20 m) waters between Baresand Point, Bessieres Island, Airlie Island and Coolgra Point on the Western Australian coast. Flatback turtles regularly travel between their nesting beach and the mainland coast and spend large amounts of time in the nearshore waters adjacent to the Ashburton River Delta beach. Although the turtles travel through the project footprint, they do not typically spend large amounts of time in this area.

Flatback turtles from Ashburton Island undertake short, shallow dives during the inter-nesting period. This pattern is probably due to the uniformly shallow bathymetry of their inter-nesting habitat. The majority of dives appear to be resting dives to the sea floor. The turtles spend up to 50% of their time on the sea floor and up to 20% near the sea surface during the inter-nesting period. There are no obvious areas within the inter-nesting habitat where the turtles are more or less likely to be on the sea floor or near the sea surface.

Flatback turtles in the Ashburton area show relatively low nesting site fidelity and utilise multiple islands for nesting within a nesting season. At present, the turtles have only been recorded nesting on Ashburton Island, Direction Island and Thevenard Island during consecutive nesting events. However, it is possible that they may also nest on other nearby islands or areas of the mainland where flatback tracks have been recorded, such as Locker Island, Bessieres Island and the Ashburton River Delta beach.

Flatback turtles that nest at Ashburton Island undertake post-nesting circular movements within the inter-nesting area for up to three weeks after their final nest. Female flatback turtles can therefore be expected to remain within the inter-nesting habitat for up to three weeks after the conclusion of the nesting season.

Following the post-nesting circling phase, flatback turtles either migrate to the Kimberley or remain within the Pilbara region. Post-nesting migrations to the Kimberley region are within 100 m of the Western Australian coastline and take up to three months. Two foraging areas in the Kimberley have been identified, at Eighty Mile Beach and the Timor Sea.

Flatback turtles from Ashburton Island undertake longer and deeper dives during post-nesting activities than during inter-nesting. This difference is likely to be a function of the deeper water depths available in the post-nesting habitats.

Based on satellite telemetry studies in Western Australia (including this study) and habitat maps (Chevron Australia 2010), the area between Barrow Island and the Muiron Islands (20–100 m) appears to be an important flatback turtle foraging area, with turtles from several nesting locations in the Pilbara migrating to this area.

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APPENDIX 1

Movements of Individual Turtles during Inter- and Post-nesting

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APPENDIX 1: Movements of Individual Turtles during Inter- and Post-nesting

Turtle 52941 travelled from Ashburton Island to the Ashburton River Delta beach following its final nesting for the season. It remained at the Ashburton River Delta beach for four days before commencing its post-nesting migration north-eastwards along the Western Australian coastline. Turtle 52941 remained within approximately 20 km of the mainland until it reached Broome. It then headed further out to sea, remaining within approximately 90 km of the coastline for the remainder of its migration. Turtle 52941 was last recorded approximately 185 km north-north-west of Cape Bougainville, where it has been since early April.

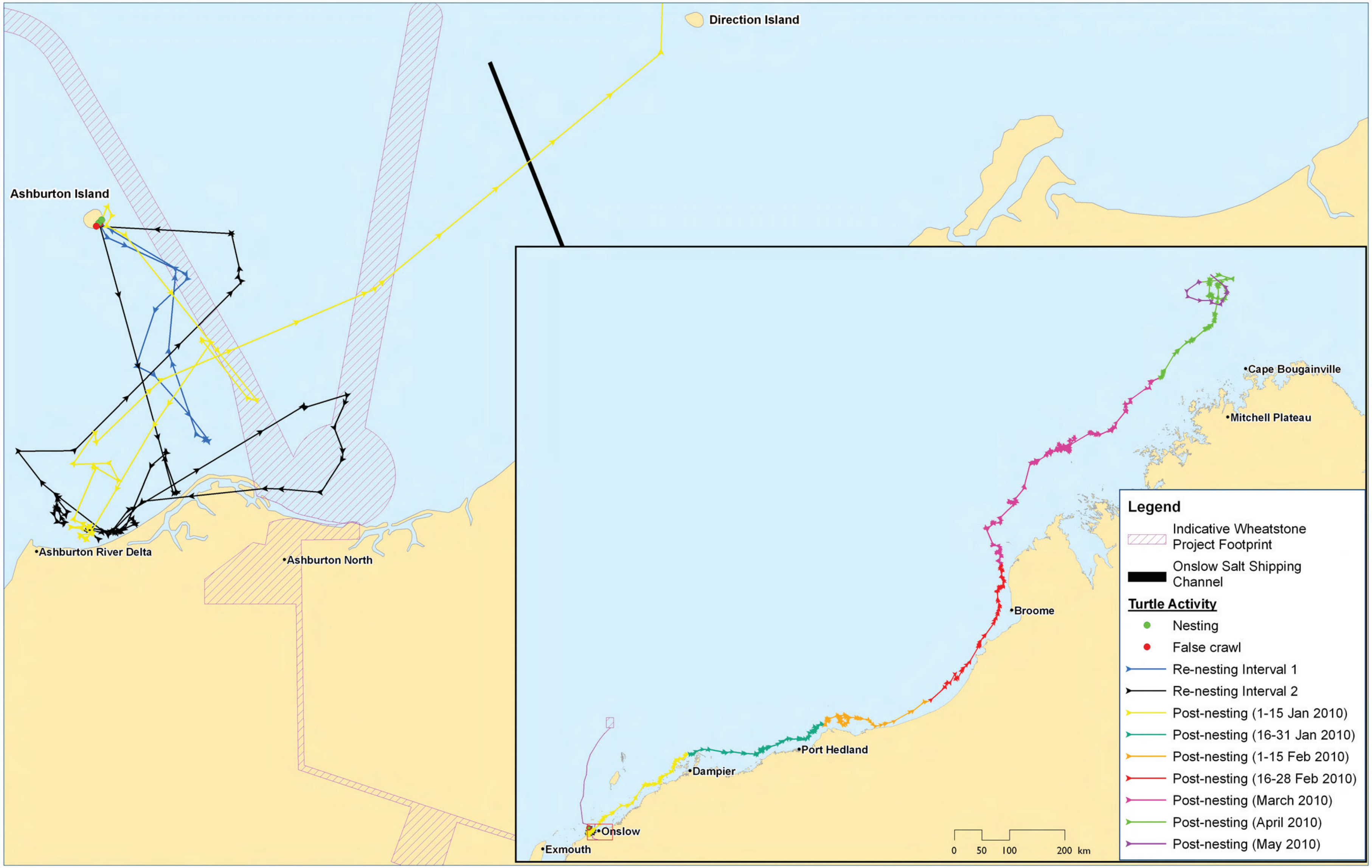
Turtle 52942 remained at Direction Island for three days after completing its final nest for the season. From Direction Island it travelled to an area approximately 10 km north-west of Thevenard Island where it remained for three days. It then travelled north-north-west to an area approximately 15 km west of Barrow Island. Turtle 52942 spent the next four months travelling back and forth between Thevenard Island and Barrow Island, spending several weeks in each area. At the end of May turtle 52942 had been in the Barrow Island area for approximately 10 weeks.

Turtle 52952 remained in the nearshore area between Onslow and Baresand Point for three weeks before commencing its post-nesting migration. It travelled from Baresand Point to the west coast of Barrow, then around the northern side of Barrow Island and past the Montebello Islands. From the Montebello Island turtle 52952 travelled inland to the Dampier Archipelago and began travelling north-eastwards, remaining within approximately 20–40 km of the Western Australian coastline. Upon reaching Pardoo it headed towards the coast, remaining within approximately 10 km of the coastline until it reached the southern end of Eighty Mile Beach. Turtle 52952 reached the northern end of Eighty Mile Beach in early March 2010 and spent March–May travelling up and down Eighty Mile Beach, where it remained at its last transmission.

Turtle 52953 left Thevenard Island immediately after laying its final nest for the season. Over the next 10 days it travelled in a large loop from Thevenard Island to Coolgra Point (on the mainland), past the Mangrove Islands and back to Thevenard Island. Turtle 52953 travelled north from Thevenard Island, past the west coast of Barrow Island and around the northern side of the Montebello Islands. From the Montebello Islands it travelled inland towards the Dampier Archipelago. Turtle 52953 spent February to mid-April travelling through an area approximately 25 km to the north-west of the Dampier Archipelago. It then travelled further to the north-east and spent late April to May in an area approximately 80 km NNE of Rosemary Island, where it remained at its last transmission.

Following its final nesting for the season, turtle 52955 spent three days travelling in a large loop from Ashburton Island towards Ashburton North and back to Ashburton Island. No further transmissions were recorded on or within 150 m of land, indicating that its last nesting was on 7 February 2010. From Ashburton Island turtle 52955 travelled to the coastal waters off Onslow where it remained for approximately one month. It then travelled to an area to the north-east of Rosily Cays and Airlie Island where it remained for approximately 10 weeks. In the last week of May turtle 52955 had commenced travelling in a north-easterly direction and was last recorded approximately 20 km south-west of Barrow Island.

Turtle 52963 spent a week travelling through the coastal waters between Baresand Point and Locker Island before commencing its post-nesting migration north-eastwards along the Western Australian coastline. It stopped for two weeks at Port Hedland and for another two weeks just north of the De Grey River before continuing north-eastwards to Eighty Mile Beach, where it remained for two months until its last transmission.



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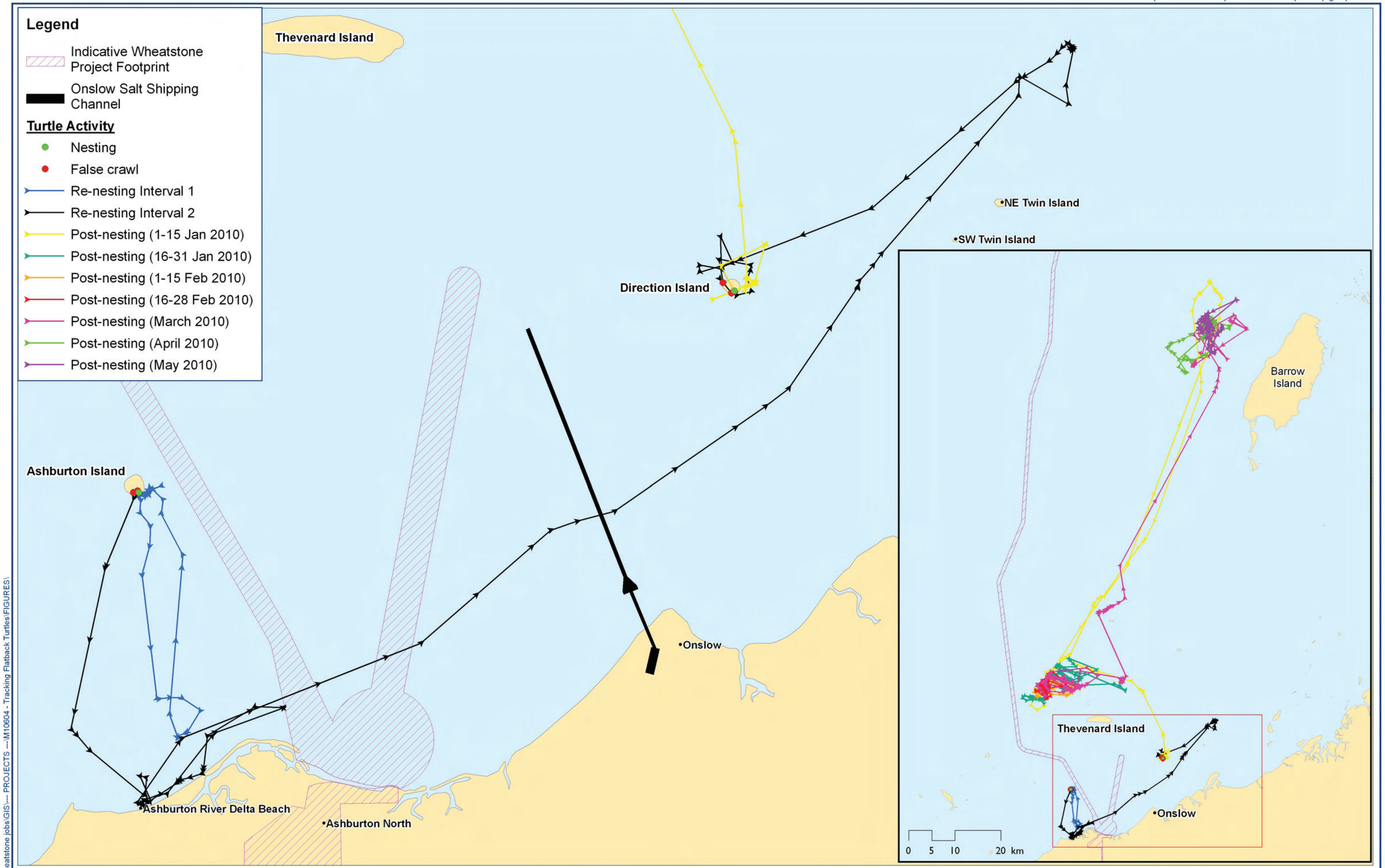

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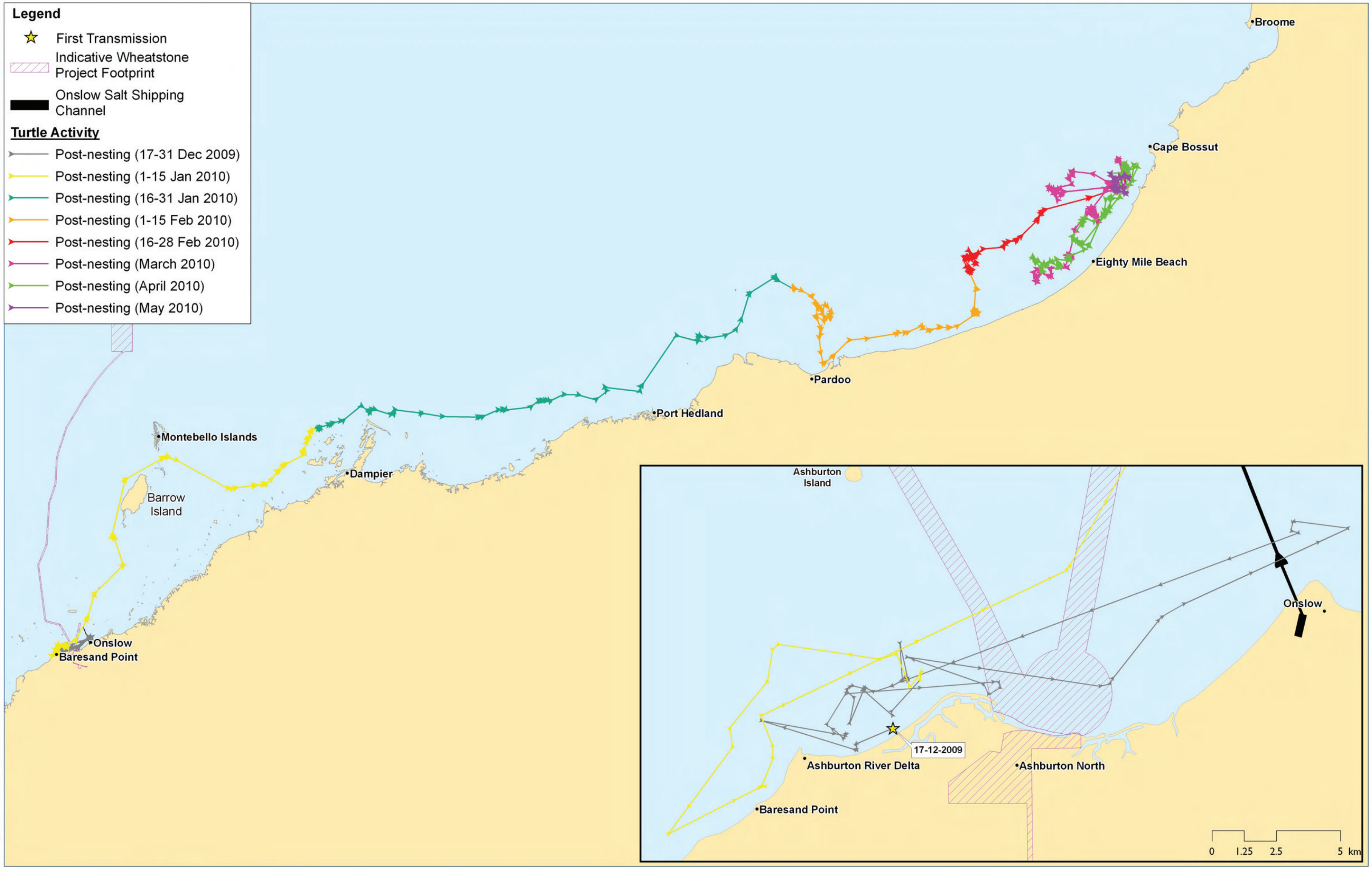

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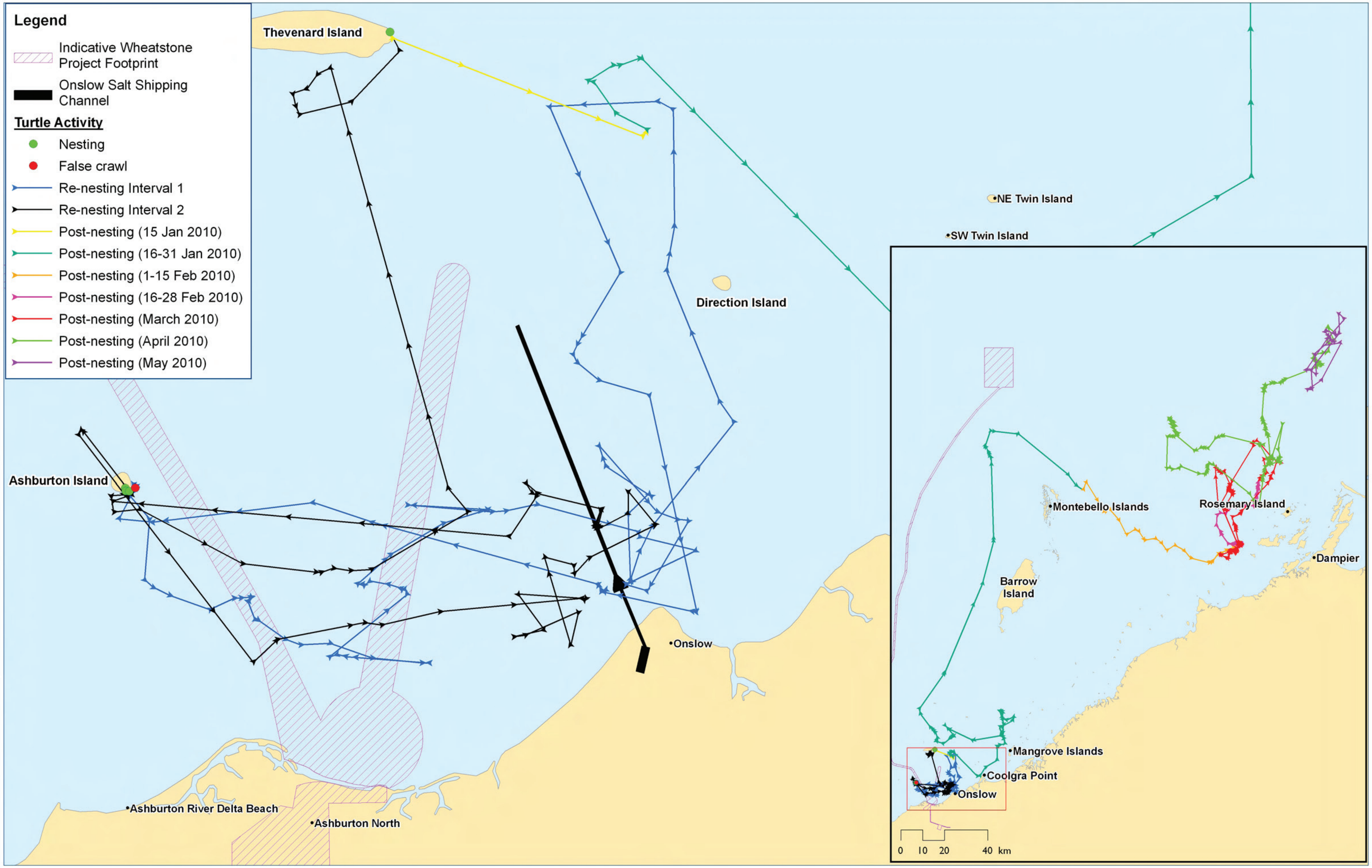

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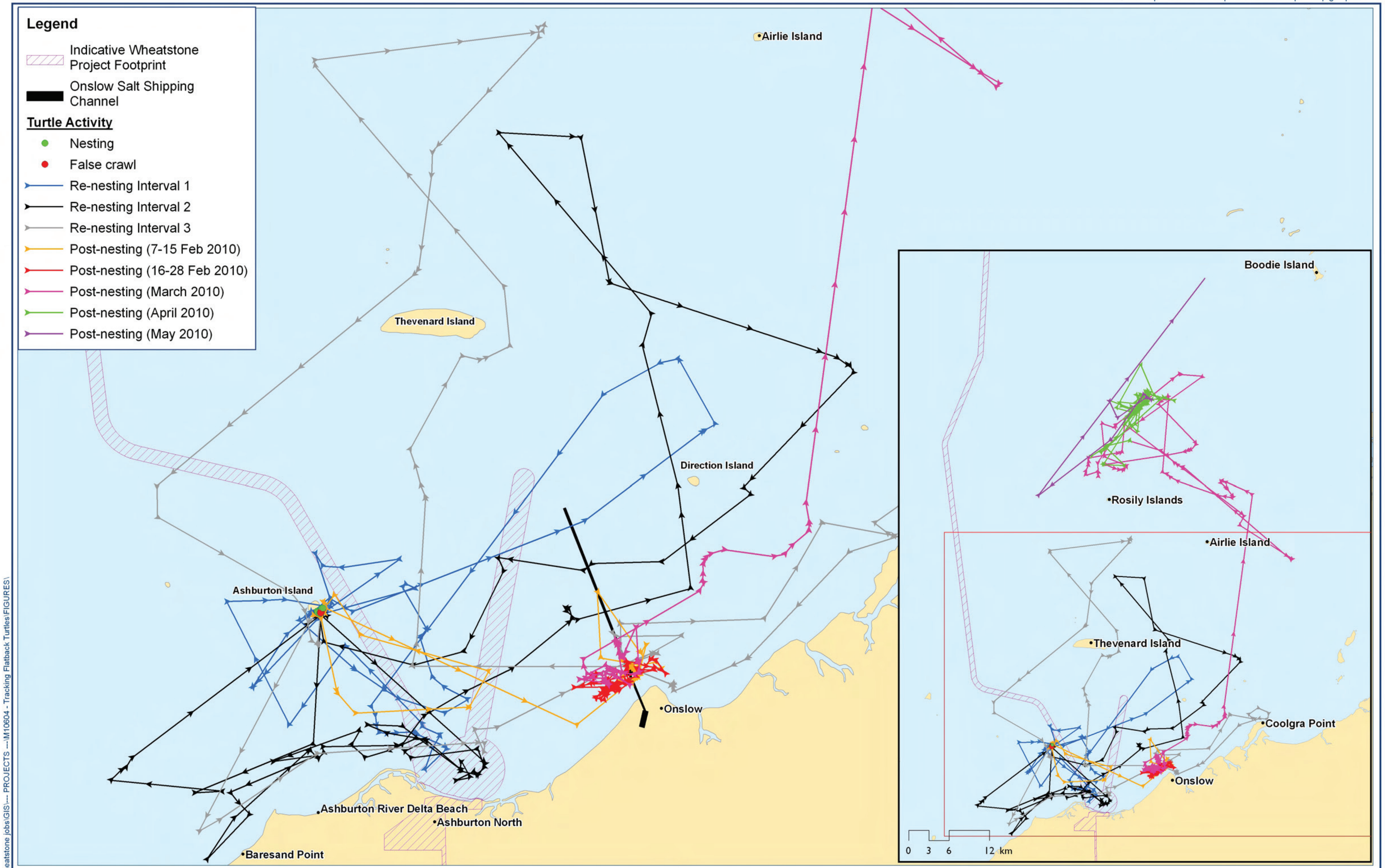

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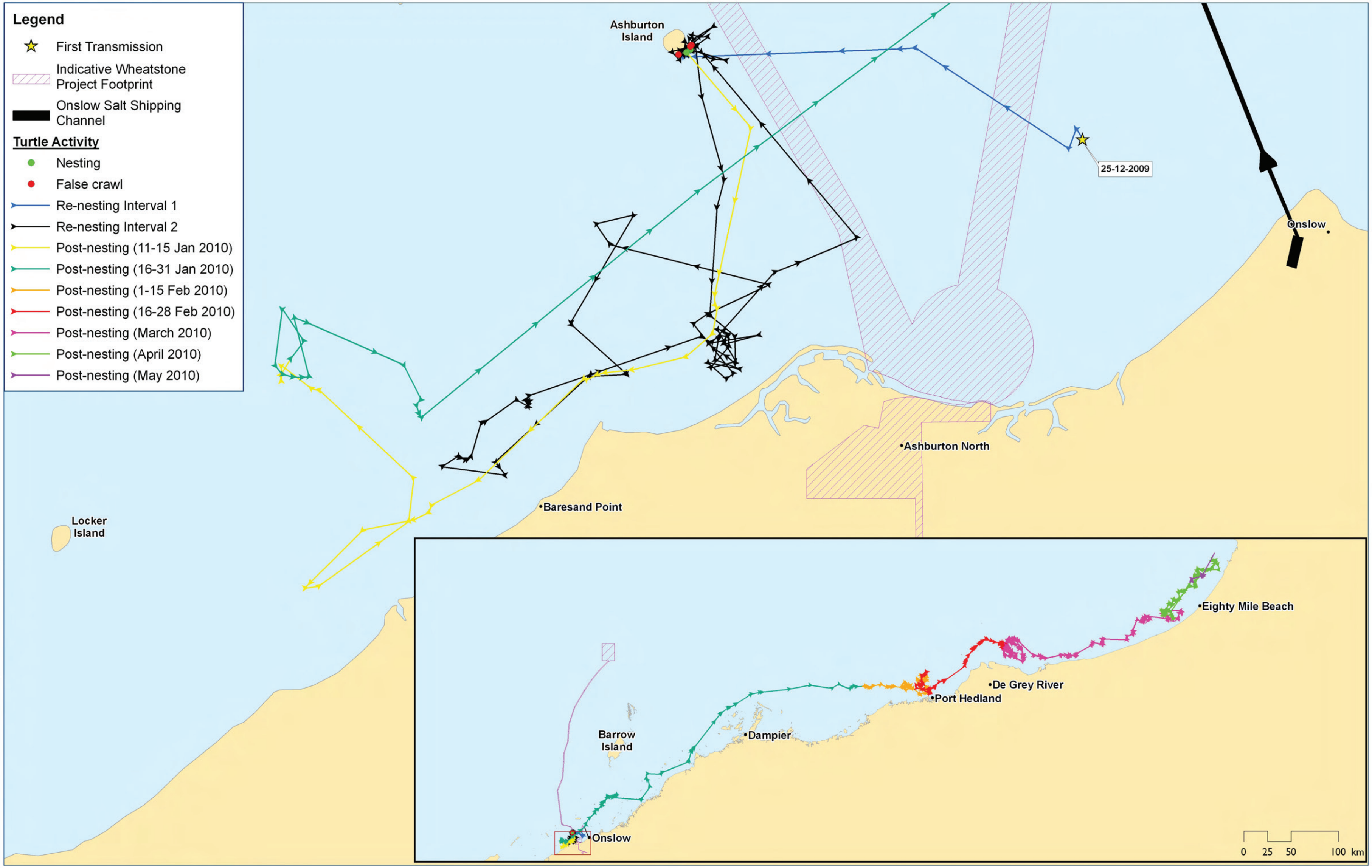

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PTT ID 52963

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APPENDIX 2

Proportion of Time Spent on Sea Floor by Individual Turtles during Inter-nesting Period

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APPENDIX 2: Proportion of Time Spent on Sea Floor by Individual Turtles during Inter-nesting Period

Turtle 52941 spent the greatest amount of time on the sea floor when in the vicinity of the Ashburton River Delta Beach and when returning to Ashburton Island. It spent the least amount of time on the sea floor when travelling from Ashburton Island to the mainland. The behaviour of turtle within the project footprint varied, sometimes spending large proportions of time (>0.75) on the sea floor and sometimes spending very little time (≤0.25) on the sea floor.

Turtle 52942 spent the greatest amount of time on the sea floor when in the vicinity of its nesting beaches and when to the north of NE Twin Island. It spent the least amount of time on the sea floor when in the vicinity of the Ashburton River Delta Beach and when travelling to Direction Island. Turtle 52942 only travelled through the project footprint once, spending between 25% and 50% of its time on the sea floor at this time.

Turtle 52952 spent the greatest amount of time on the sea floor when in the vicinity of the Ashburton River Delta beach and Baresand Point and when travelling from Onslow to the Ashburton River Delta beach. It spent the least amount of time on the sea floor when travelling to Onslow. Turtle 52952 spent between 25% and 75% of its time on the sea floor when in the project footprint.

Turtle 52953 spent the greatest amount of time on the sea floor when off the coast of Onslow, when travelling from Onslow to Ashburton Island and in an area between Thevenard Island and Direction Island. It spent the least amount of time on the sea floor when travelling from Ashburton Island to Onslow and from Thevenard Island to Coolgra Point. Turtle 52953 spent varying amounts of time on the sea floor when in the project footprint, but was recorded to spend >50% of its time on the sea floor on several occasions.

Turtle 52955 spent the greatest amount of time on the sea floor when in the vicinity of Ashburton Island, Baresand Point, Airlie Island and Rosily Cays. It spent the least amount of time on the sea floor when travelling between Ashburton Island and Ashburton North and when travelling past Thevenard Island. Within the project footprint, turtle 52955 generally spent ≤50% of its time on the sea floor.

Turtle 52963 spent >50% of its time on the sea floor in most location. Within the project footprint it spent between 25% and 75% of its time on the sea floor.

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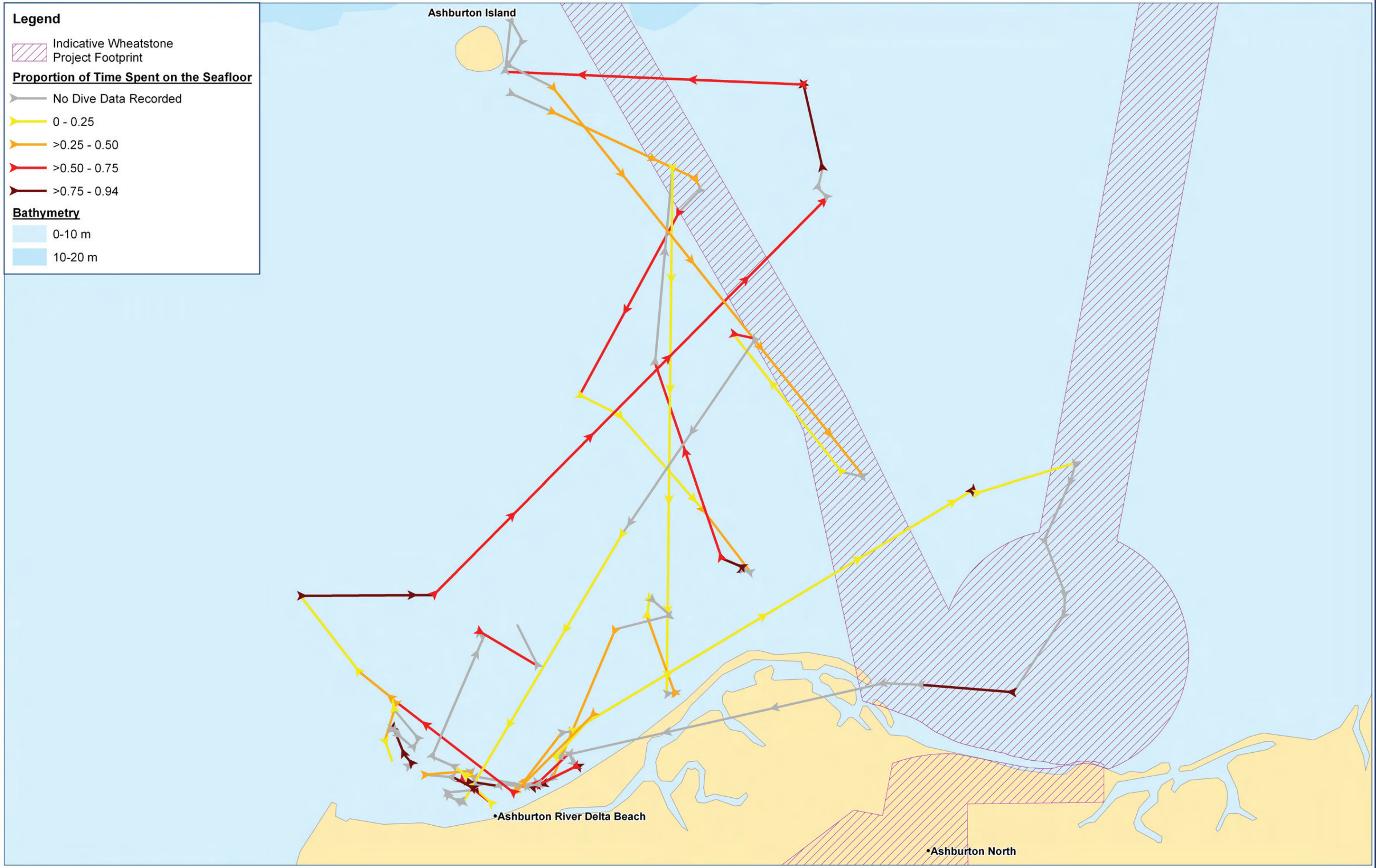

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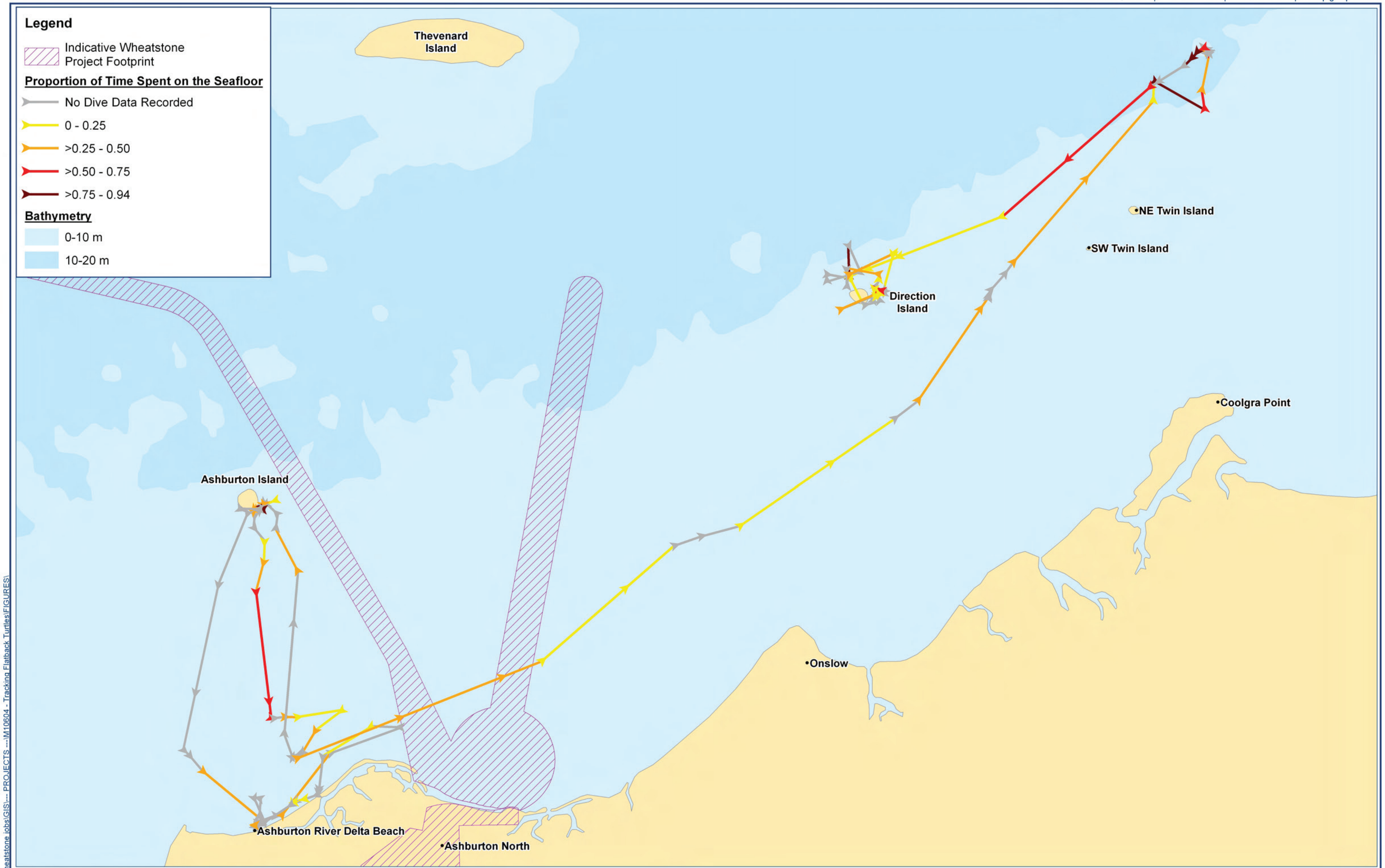

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0 1.25 2.5 5 km

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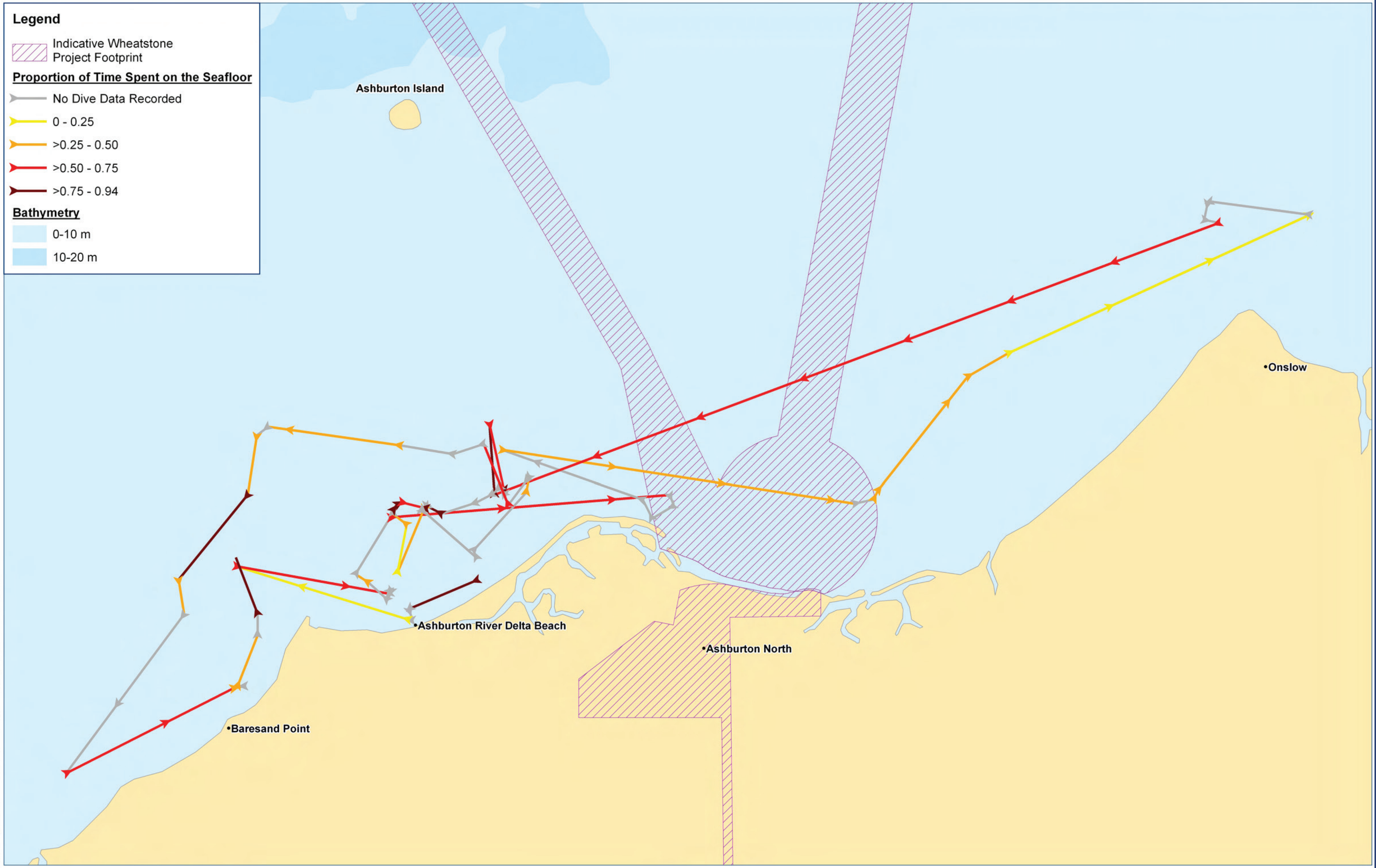

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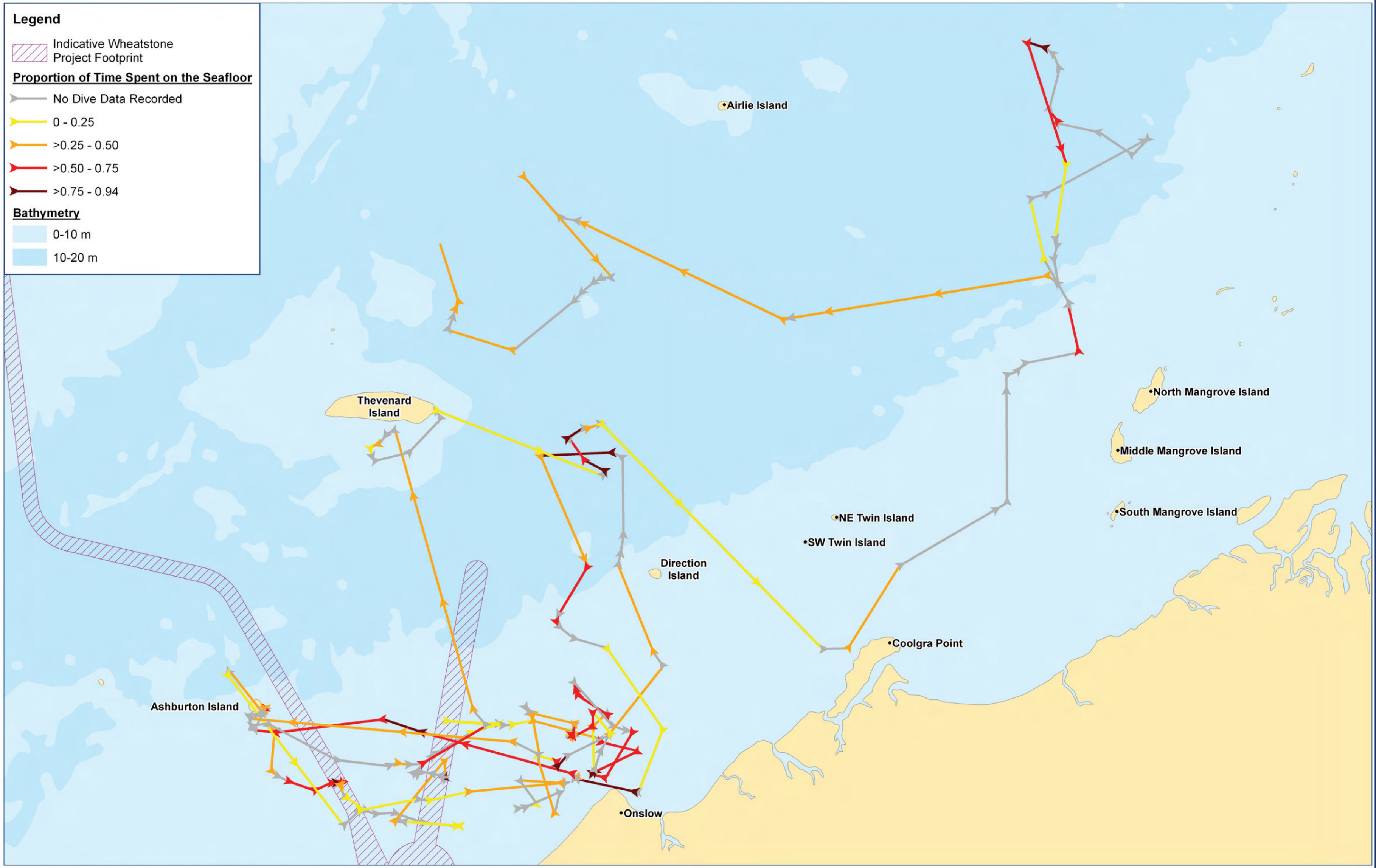

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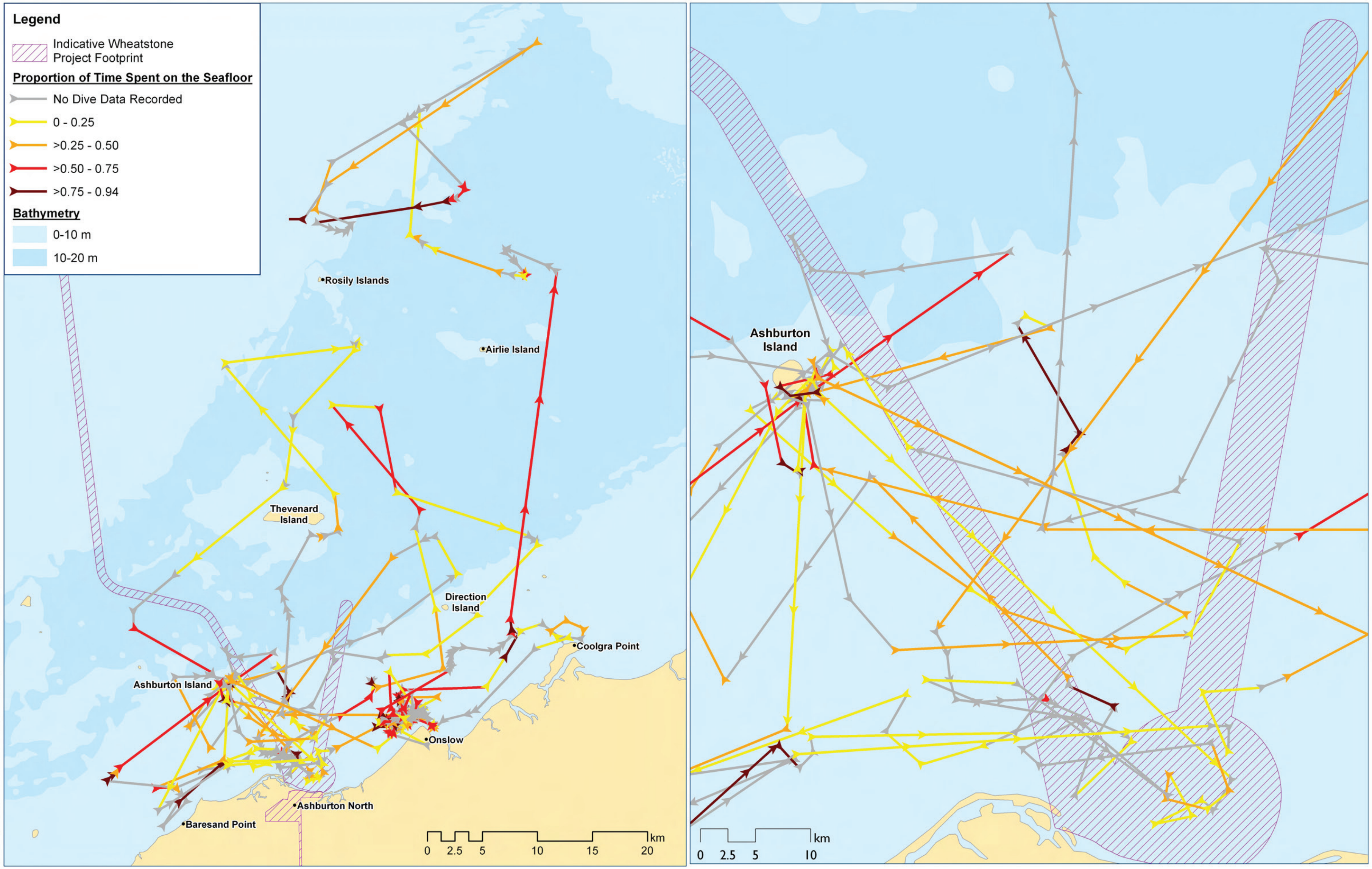

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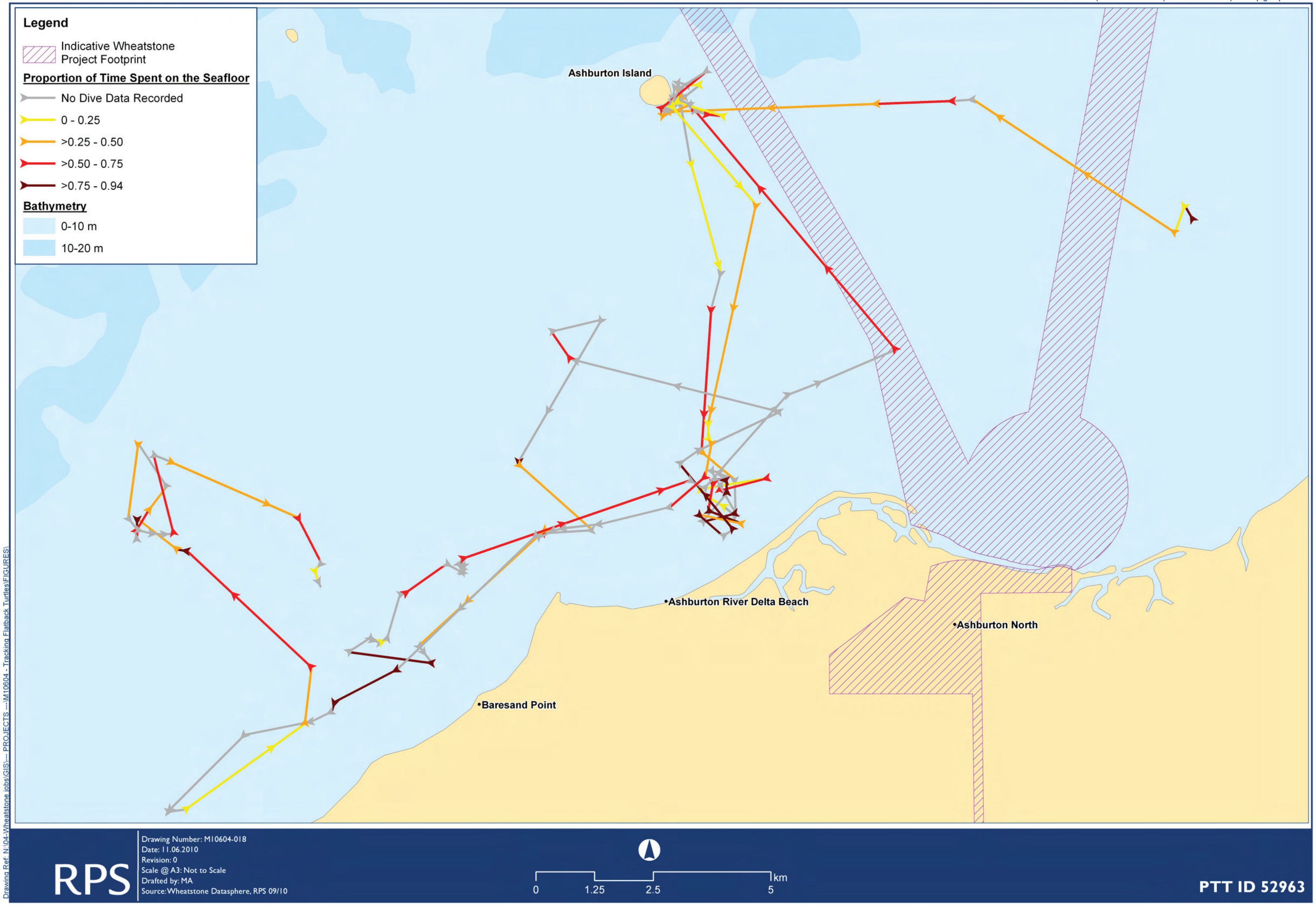

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Legend
Indicative Wheatstone Project Footprint
Proportion of Time Spent on the Seafloor
No Dive Data Recorded
0 - 0.25
>0.25 - 0.50
>0.50 - 0.75
>0.75 - 0.94
Bathymetry
0-10 m
10-20 m
Ashburton Island
•Ashburton River Delta Beach
•Ashburton North
•Baresand Point
0
1.25
2.5
5
km
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APPENDIX 3

Proportion of Time Spent near Sea Surface by Individual Turtles during Inter-nesting Period

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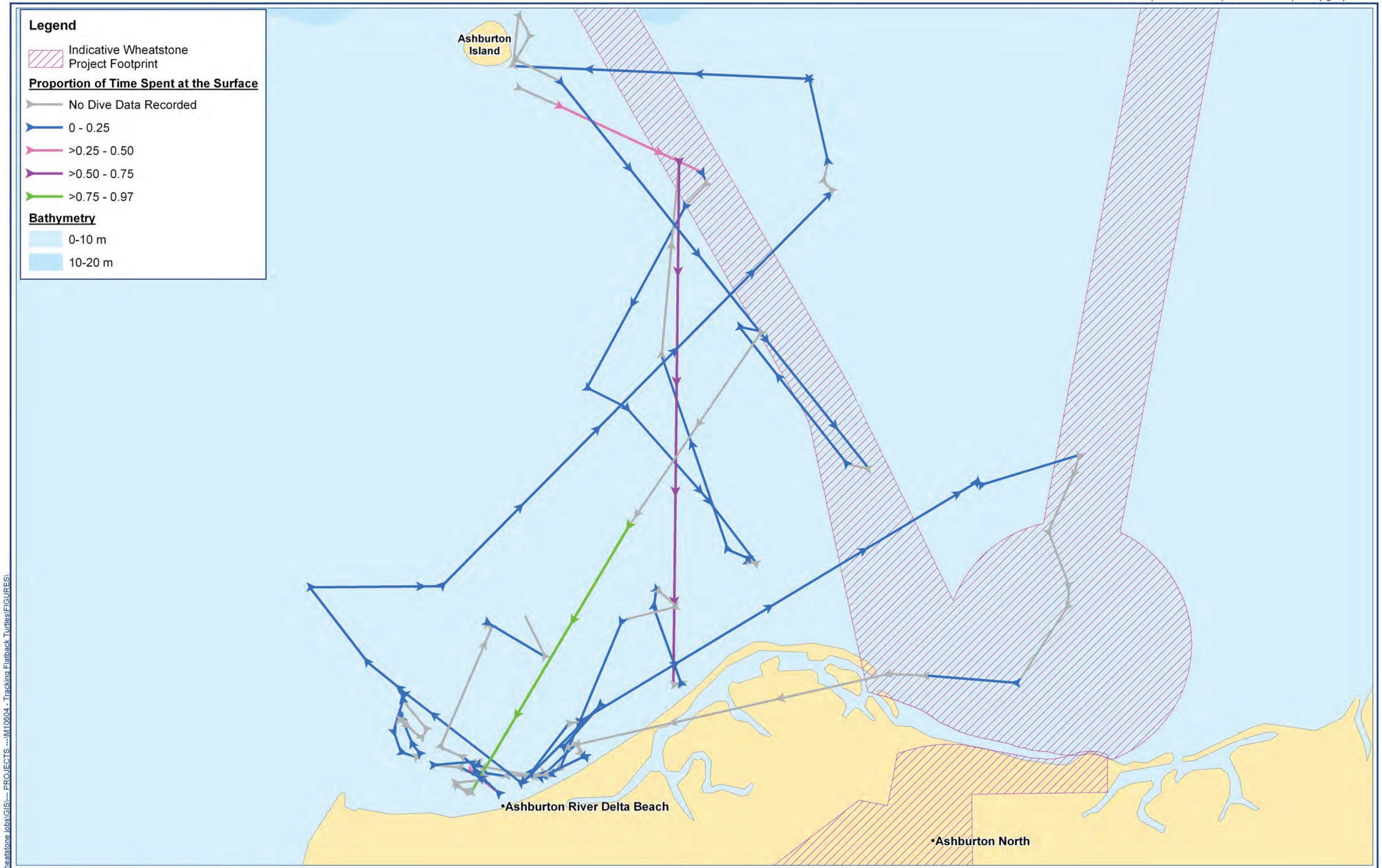

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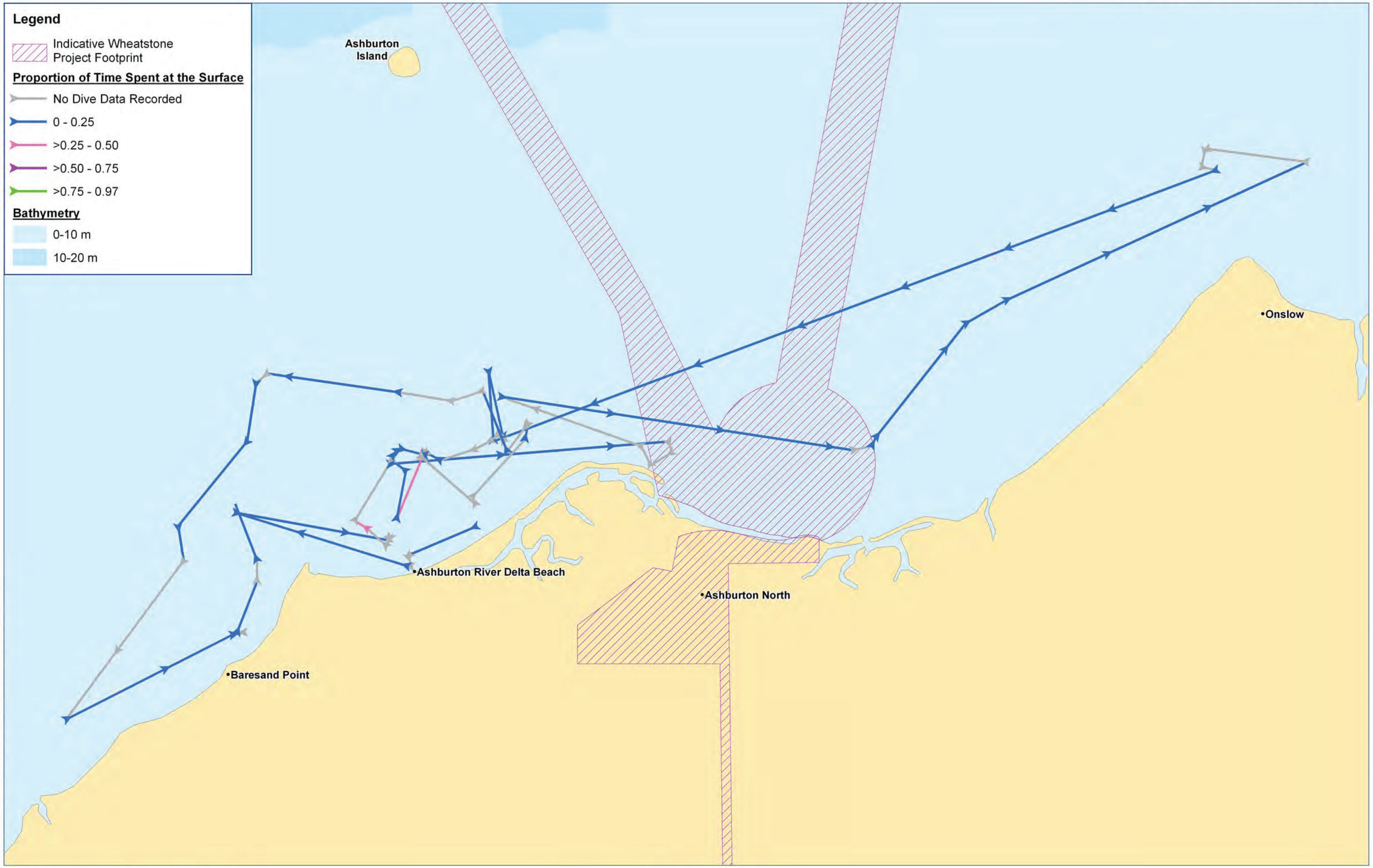

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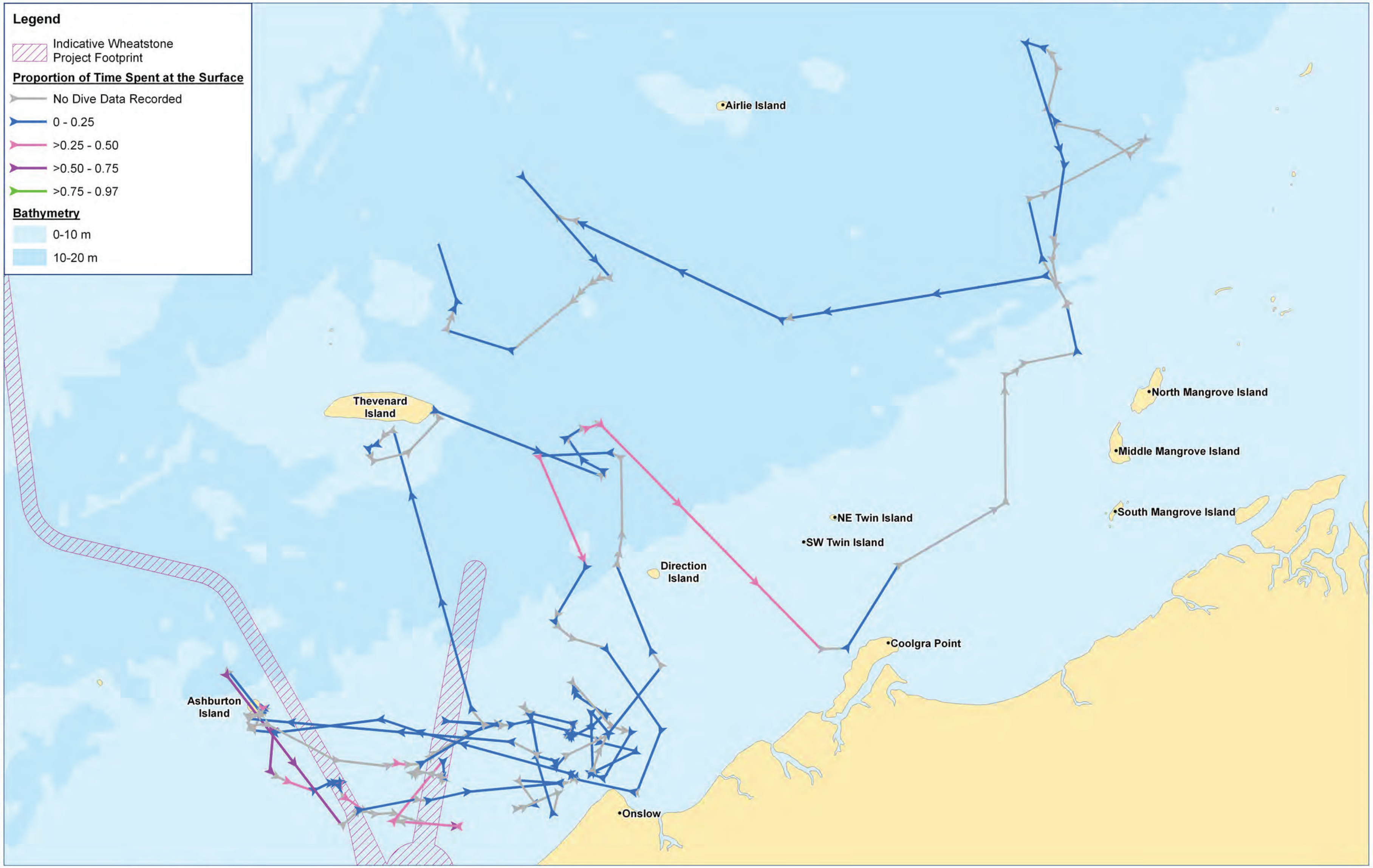

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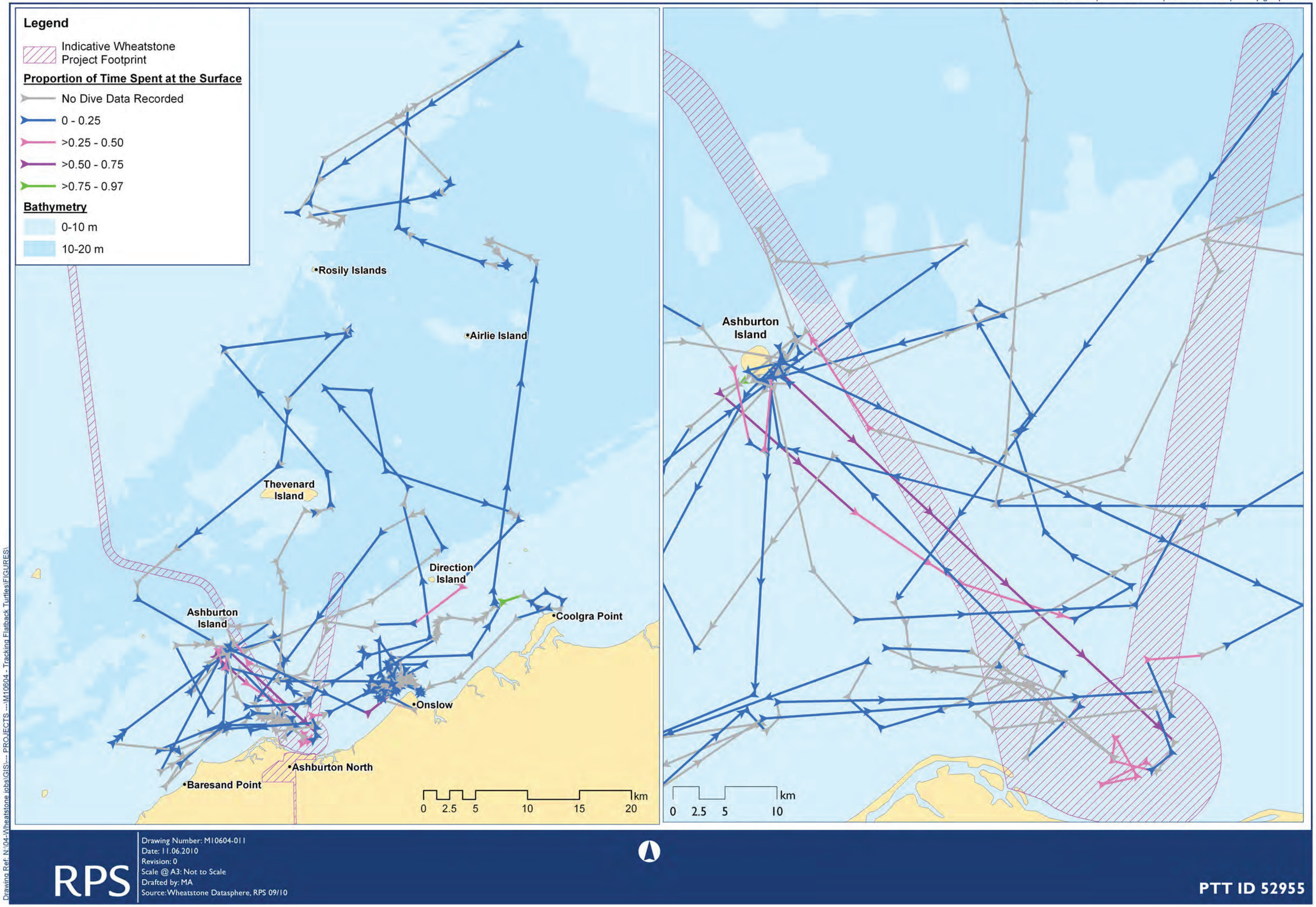

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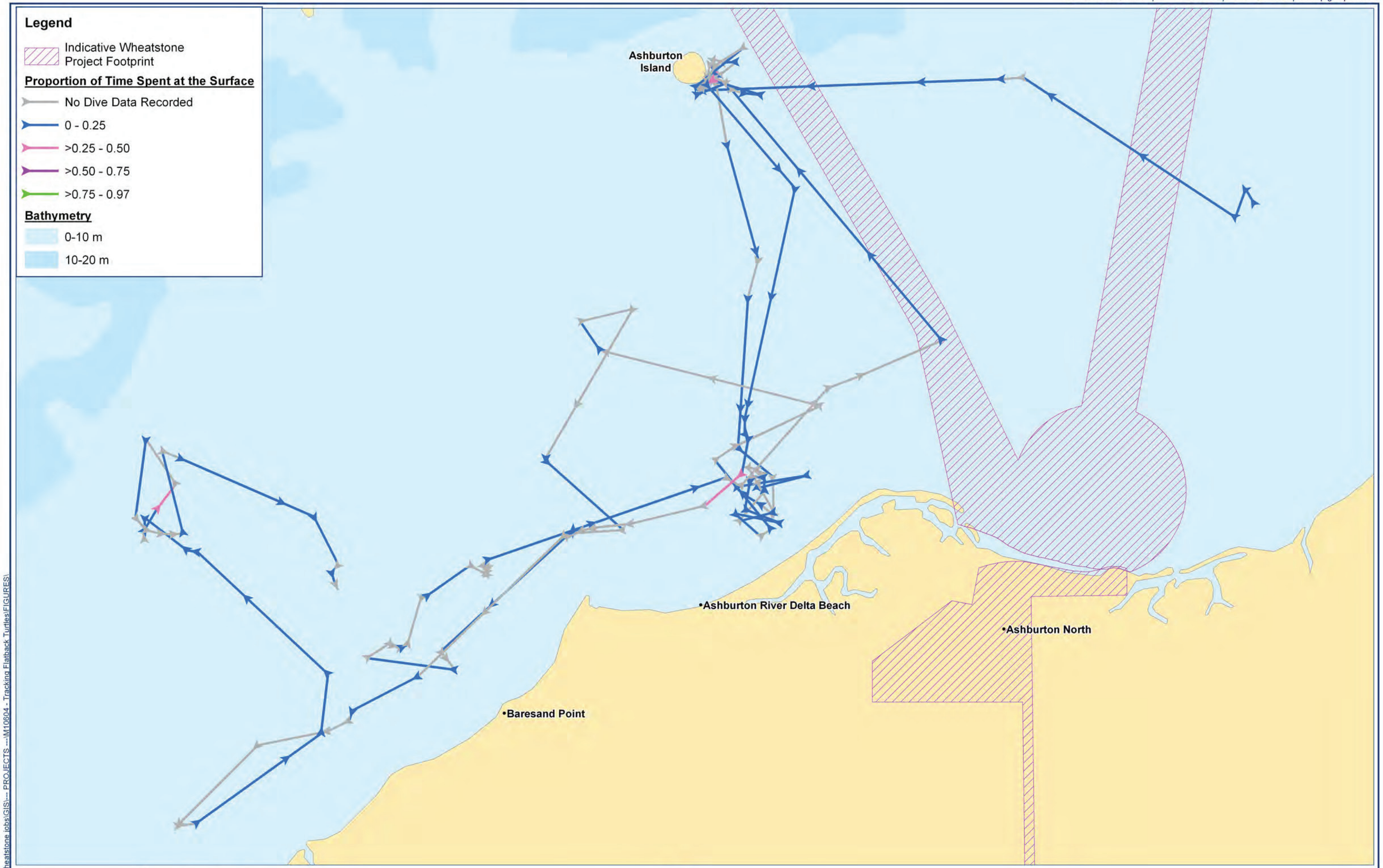

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Appendix FH

Interactions of Onslow Prawn Managed Fishery with Wheatstone Project

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the EIS/ERMP. This document provides information on potential impacts to the Onslow Prawn Managed Fishery that is additional to that provided in the Draft EIS/ERMP (Appendix O10), and to assist in further addressing public submissions on the Draft EIS/ERMP. Revisions to the previous assessment have arisen as a result of:

- Additional field surveys undertaken for the Project since Appendix O10 was prepared
- Analysis of existing habitat data from other surveys
- Updated dredging and coastal impacts modelling for the Project
- Feedback received from public submission during the Public Review period.

Reversible damage to an area of dense seagrass east of Onslow is only anticipated impact during the first two summers of the dredging program. This is predicted to impact less than 15 per cent of the seagrass. No further adverse impacts to seagrass east of Onslow are anticipated from the remainder of the dredging program. Turbidity impacts from maintenance dredging and shipping operations are on a much smaller scale, both in the volume of sediment disturbed and the timeframe of disturbance, and are considered unlikely to adversely affect seagrass growth between six and 10 km away from the proposed navigation channel. A range of prawn species are documented to tolerate high turbidity levels, in excess of those anticipated from the dredging plume. It is likely that prawns will avoid extremely turbid areas (<500 m) close to the dredge area. High turbidity in the Onslow Prawn Managed Fishery occurs periodically. Low levels of dissolved oxygen, a common cause of mass mortality in fish populations, are unlikely to result from dredging operations. Changes to water current speeds as a result of the proposed nearshore infrastructure are predicted to be localised, and mainly confined to the navigation channel, the Materials Offloading Facility and the immediate vicinity of the Materials Offloading Facility. Nearshore infrastructure is anticipated to cause the permanent loss of four per cent of the total available nursery habitat of the Ashburton size management fish grounds, located in Area 1 of the Onslow Prawn Managed Fishery. It is considered unlikely that the permanent removal of habitat for nearshore infrastructure construction will have a significant impact on prawn recruitment in the Onslow Prawn Managed Fishery. Impact to prawn benthic habitat affected by the dredge plume is likely to be short term and limited in spatial extent and duration.

Report

Interactions of Onslow Prawn Managed Fishery with Wheatstone Project

12 JANUARY 2011

Prepared for

Chevron Australia Pty Ltd

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Appendix A Comments from the OPMF

Introduction

This document forms part of the Wheatstone Project EIS/ERMP supplementary documentation and response to submissions received as a result of the public comment process. This document updates the Potential Interactions with the Onslow Prawn Managed Fishery. Technical Appendix O10 from the Wheatstone Project EIS/ERMP to further address the comments submitted in relation to concerns regarding potential impacts to the Onslow Prawn Managed Fishery (OPMF). Revisions to that assessment have arisen as a result of:

- Additional field surveys undertaken for the Project since Appendix O10 was prepared;
- Analysis of existing habitat data from the surveys;
- Results from Dredging and Coastal Process Modelling for the Project; and
- Feedback received from various submissions in the Public Review

1.1 Structure of this Report

The structure of this report is to:

- Describe the OPMF
- Describe the biology of commercial important prawns in the OPMF
- Describe Project related prawn habitat effects
- Describe Project related direct impacts
- Describe Project related relevant mitigation measures
- Assess the overall impacts to prawn populations in the OPMF
- Conclusion

1.2 Onslow Prawn Managed Fishery

Onslow Prawn Managed Fishery, gazetted in 1991, was the last prawn fishery to be declared a managed fishery in WA. Divided into three zones off the coast near Onslow, this fishery harvests mainly tiger prawns from inshore areas, with a lesser catch of king, banana and endeavour prawns further offshore. Environmental factors can also vary catch composition in this fishery: high rainfall years may result in a decline of the tiger prawn catch and a corresponding increase in the banana prawn catch.

The Onslow Prawn Managed Fishery (OPMF) operates in accordance with the Australian Government Guidelines for Ecologically Sustainable Management of Fisheries – 2nd Edition and is considered a well-managed fisheries with a range of management measures to promote the ecologically sustainable harvesting of species from the fishery. These include limited entry, spatial and seasonal closures and gear and boat restrictions (Commonwealth Department Environment and Heritage, 2004). A comprehensive ESD assessment of this fishery has determined that performance should be reported annually against measures relating to the maintenance of breeding stocks of target species (e.g. tiger and king prawns) and secondary target species (Sporer, Kangas and Brown 2006). While economically it is clear that this is a viable fishery in the short term, the exploitation status and breeding stock levels have not been assessed which makes it hard to judge a long term sustainable catch level (Grimbly 2005). The OPMF has a by-catch that historically could reach as high as 6:1 (Penn 2002). By-products including bugs (*Thenus orientalis*), squid and blue swimmer crabs (*Portunus pelagicus*) and cuttlefish and mixed finfish species also form a part of the fishery (Sporer and Kangas 2005). By-catch refers to those animals and plants that are caught by trawling, but not kept by fishers because they have no commercial value or regulations prohibit them from being retained. By-product refers to any commercially valuable species inadvertently caught while targeting the primary species. This by-catch however is thought to have limited impact on other species as the targeted area remains small in comparison to the boundaries of the fishery. This fished area was reported to be less than 5% of the overall fishery (Sporer and Kangas 2005). It is reported that the OPMF has a limited impact on the sea bed as it operates over areas where there is a clean sand or mud bottom that is not easily damaged (Grimbly 2005). The introduction of secondary by-catch reduction devices (square mesh panels) in the cod ends of nets commenced in the 2005 season has further reduced by-catch (Sporer, Kangas and Brown 2006).

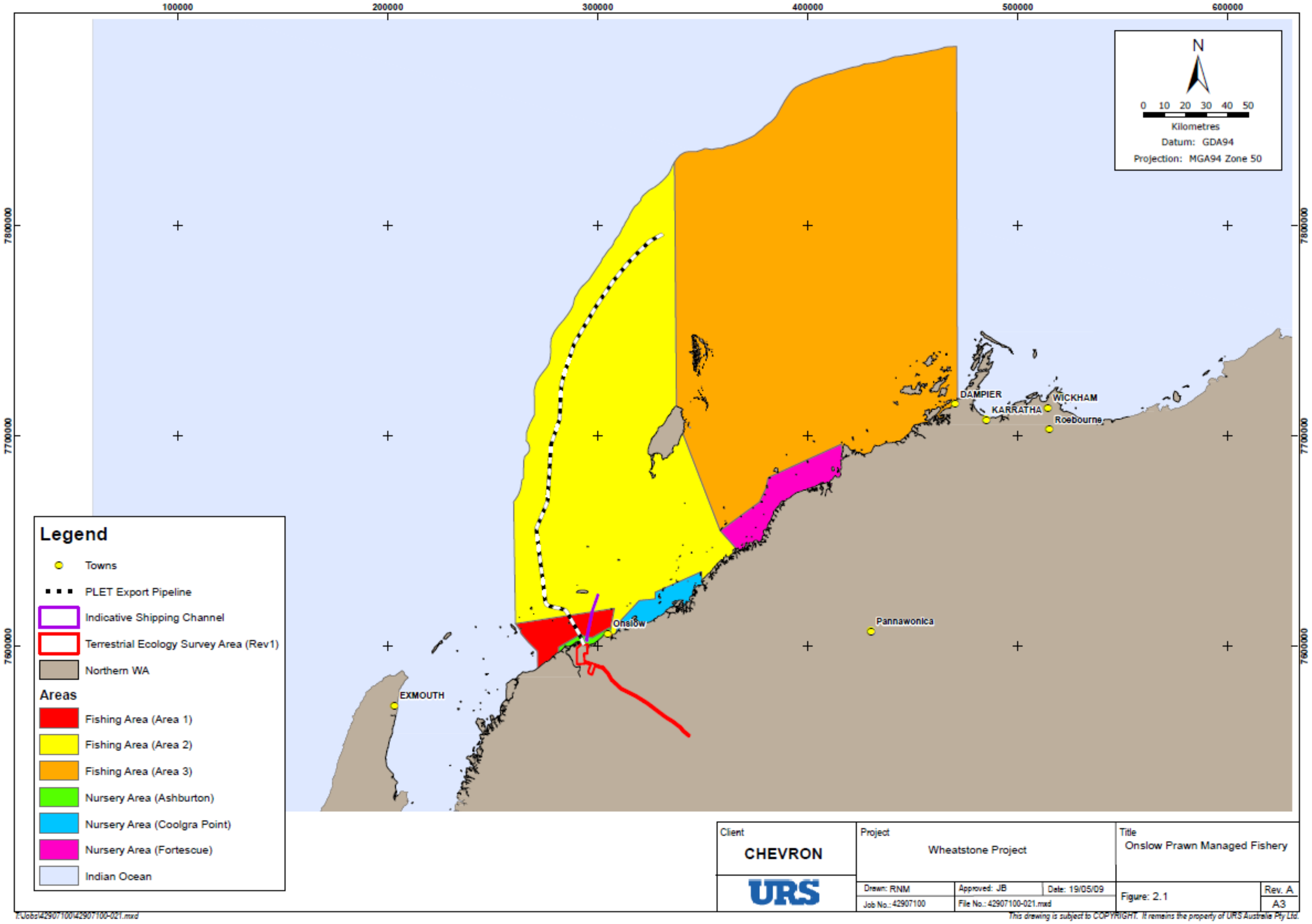
1.3 OPMF Boundaries

The locations of the OPMF fisheries described in the DOF (2004) document are shown in Figure 1-1 and the nursery areas for this fishery are now described as Size Management Fishery Grounds (SMFG). Under agreement with the Commonwealth, DOF manages most fisheries in Commonwealth waters off Western Australia. The licence areas are extremely large because the intent of the legal definition of the fishery limits is to define all available waters as being part of a managed fishery. This means that no additional prawn fisheries can be requested in an “unfished” area.

In reality, the areas fished by each prawn trawl fishery are much smaller than the gazetted area of the fishery; usually less than 10 per cent of the total area. This is because prawn populations are not evenly distributed within each licence area and because of the limited areas that are considered suitable and optimal for prawn trawling.

The 39 748 km^2 OPMF has three areas. Area 1 is a small section in the southwest corner of the fishery centred at the mouth of the Ashburton River and includes the Ashburton SMFG. Area 2 is essentially the western half of the fishery, including most of the shoreline of Barrow Island. Area 3 extends from the eastern shores of Barrow Island east to 116º45' east longitude. Three small nursery areas along the continental coastline are shown in Figure 1-2: Ashburton, Coolgra Point and Fortescue. The Ashburton “prawn nursery” area is approximately 7 450 ha extending 8 km along the coast to Beadon Point. The nursery areas are managed as Size Management Fishery Grounds (SMFG) to allow sections of these areas to be fished on a seasonal basis when the prawns are considered to have grown to an appropriate size and the area deemed suitable. For example, in 2004 the Ashburton SMFG was open 1 June - 31 July 2004 (Sporer and Kangas 2005).

Figure 1-1 Onslow Prawn Managed Fishery licence areas and Size Managed Fishery Grounds (from DOF 2004

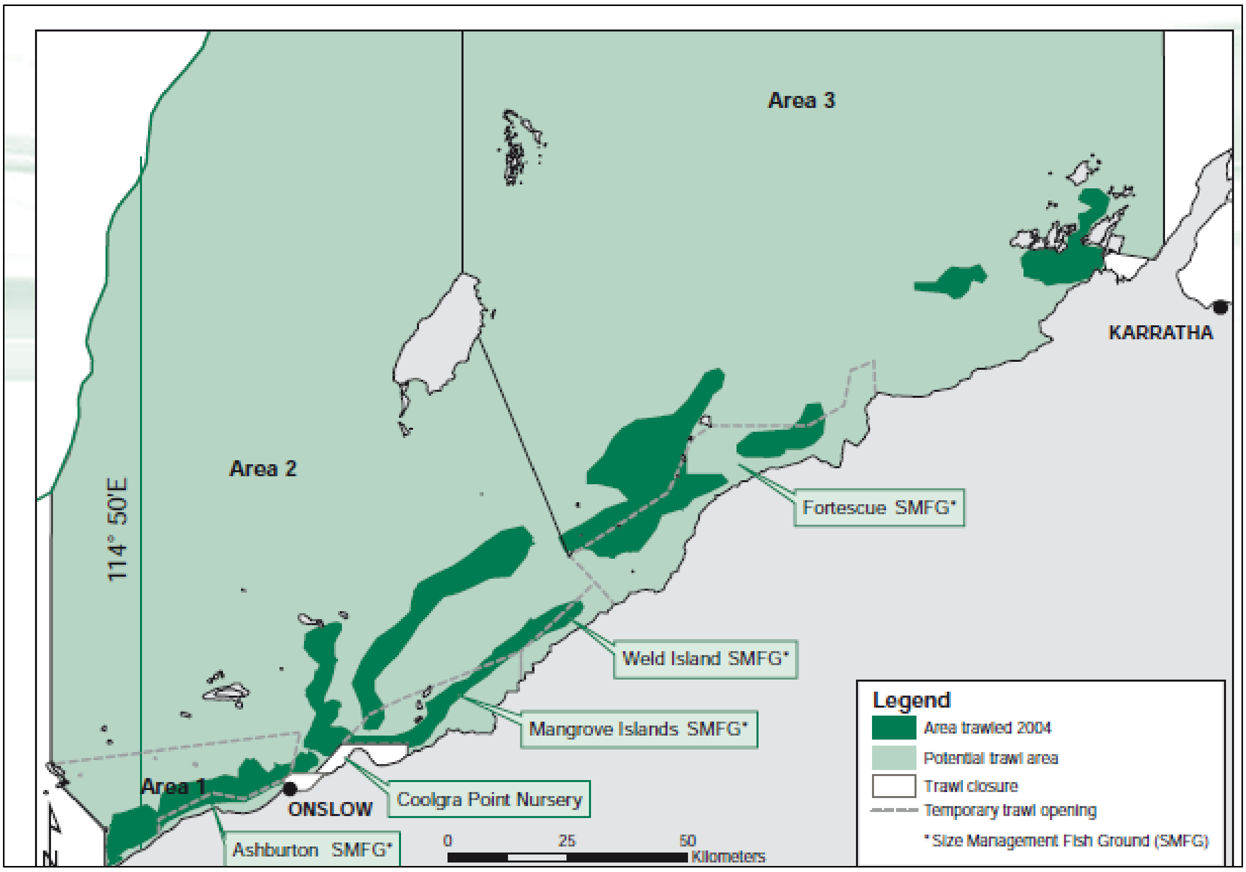


1.4 OPMF Management

The opening and closing dates for the fishery are generally the same each year and are based on advice from the Department of Fisheries Research Division after consultation with industry. Opening dates are typically between the months of March and November. Different areas within the OPMF have different opening and closing dates, which protects smaller prawns and allows access to various target species, primarily tiger and banana prawns at appropriate times. All fishing activities are monitored by Vessel Monitoring Systems (Sporer and Kangas 2005).

Figure 1-2 shows the gazetted boundaries for each area of the OPMF and the sections where trawling is concentrated. Consistent annual effort for banana and king prawns occurs in Area 1 along the shoreline between the mouth of the Ashburton River and Onslow. Approximately half of this region is reported to be consistently fished (Sporer and Kangas 2005). Mangrove Passage in Area 2 is also consistently fished for tiger prawns. King prawn densities are too low in most areas to be economically fished, and trawling occurs over a very small proportion (< 5 percent) of the available areas for these species (Sporer and Kangas 2005).

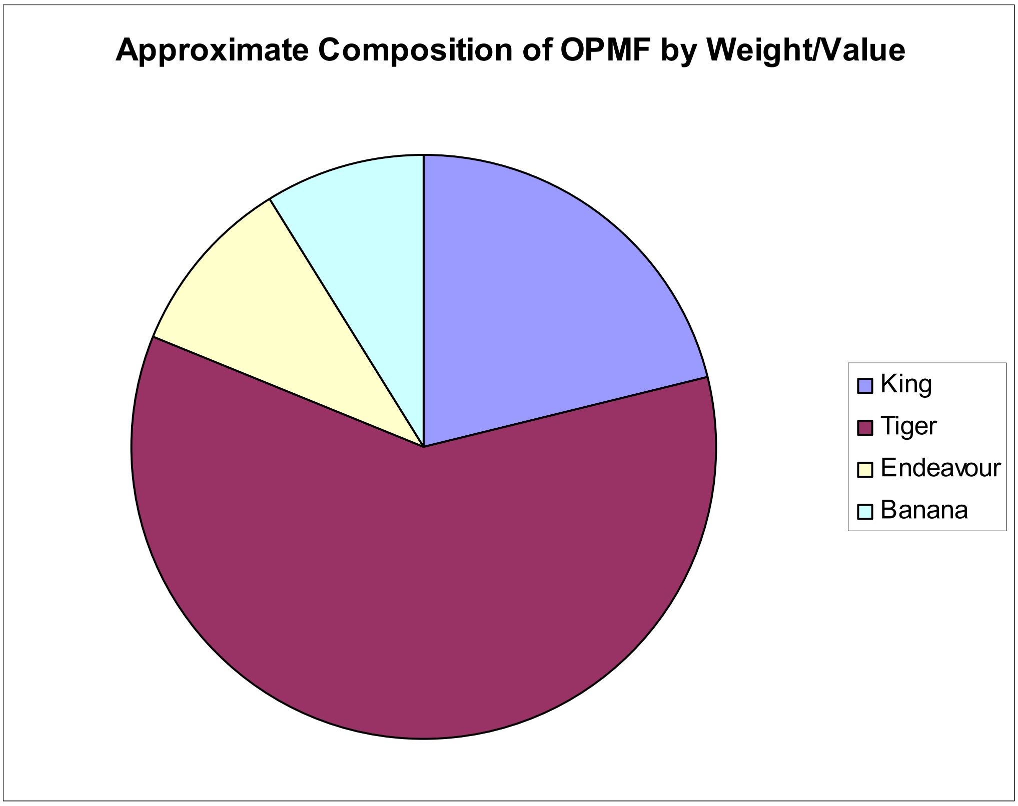
Figure 1-2 Boundaries of the Onslow Prawn Managed Fishery indicating new nursery areas and size management fishery grounds (Sporer and Kangas, 2005).



1.5 Commercial Production in OPMF

The OPMF is a relatively small prawn fishery. Over the ten years from 1998 to 2007, the total catch was 968 tonnes (Table 1-1), with an average of 96.8 tonnes per annum. The catch is dominated by tiger prawns (580 tonnes, 60 per cent) and king prawns (204 tonnes, 21 per cent). Endeavour prawns (97 tonnes, 10 per cent) and banana prawns (86 tonnes, 8.8 per cent) are relatively minor components of the total catch (Figure 1.3). By-product species in the fishery include Moreton bay bugs, squid, blue swimmer crabs, cuttlefish, other prawns such as black tiger (*Penaeus monodon*) and coral prawns, and some finfish species (Sporer and Kangas 2005).

Figure 1-3 Approximate composition by weight and value for OPMF (1998-2006).



1.6 OPMF Catch History

Historical reported catches in the OPMF are shown in Table 1.1. Catches for each species are variable from year to year and the range is shown in Figure 1.4. Tiger prawn catches in seven of the last ten years ranged from 14 to 77 tonnes. There were two excellent years in 2003 and 2004, when 172 and 150 tonnes respectively were caught. There were also good catches in the years before and after, including 2002 and 2005. With the exception of the years 2006 and 2007 when only 2 tonnes and <1 tonne respectively were caught, king prawn catches ranged from 12 to 42 tonnes. Two tonnes of endeavour prawns were also caught in 2006 and < 1 tonne in 2007. In the other years, endeavour prawn catches ranged from 6 to 20 tonnes.

1 Introduction

In 2007, catches of all species were very poor. Only one boat fished and for a total of only 53 days (Sporer *et al*. 2008). The total catch in 2007 was 4 tonnes of all prawn species. With the recent good rains and flooding of the Ashburton River (February 2009), it is anticipated that there will be good banana prawn catches in 2010, with other prawn catches improving in 2011 (Kangas 2009 pers. comm.).

Prawn catches in the OPMF are closely related to environmental conditions. Tiger and endeavour prawns can be negatively impacted by strong storm events, such as cyclones. The effects are particularly severe when juveniles are in shallow seagrass beds. Cyclones can cause major disturbance to benthic habitats including seagrasses (eg Lanyon and Marsh 1995; Duarte et al 1997). In the relatively pristine Gulf of Carpentaria, the site of Australia's major tiger and banana prawn fisheries, a natural decline of around 20% (183 km^2) of prime seagrass habitat as a result of Cyclone Sandy in 1985 resulted in only a 4% (160 t) decline in the total catch of the fishery (Thorogood et al 1990). Cyclone Vance (Category 4) impacted the Onslow area in March 1999 and reported catch from the OPMF for that year and subsequent years did not markedly change the total catch.

King prawn catches are decreased by flooding in the Ashburton River, which disperses the stock and reduces catch rates. In addition, debris from flooding can hamper fishing efforts. Banana prawns can benefit from storm events and the associated high rainfall. There is typically a lag of one year when high summer rainfall is followed by high catches of banana prawns the following year (Sporer and Kangas 2005, Sporer et al. 2006, Sporer et al. 2007).

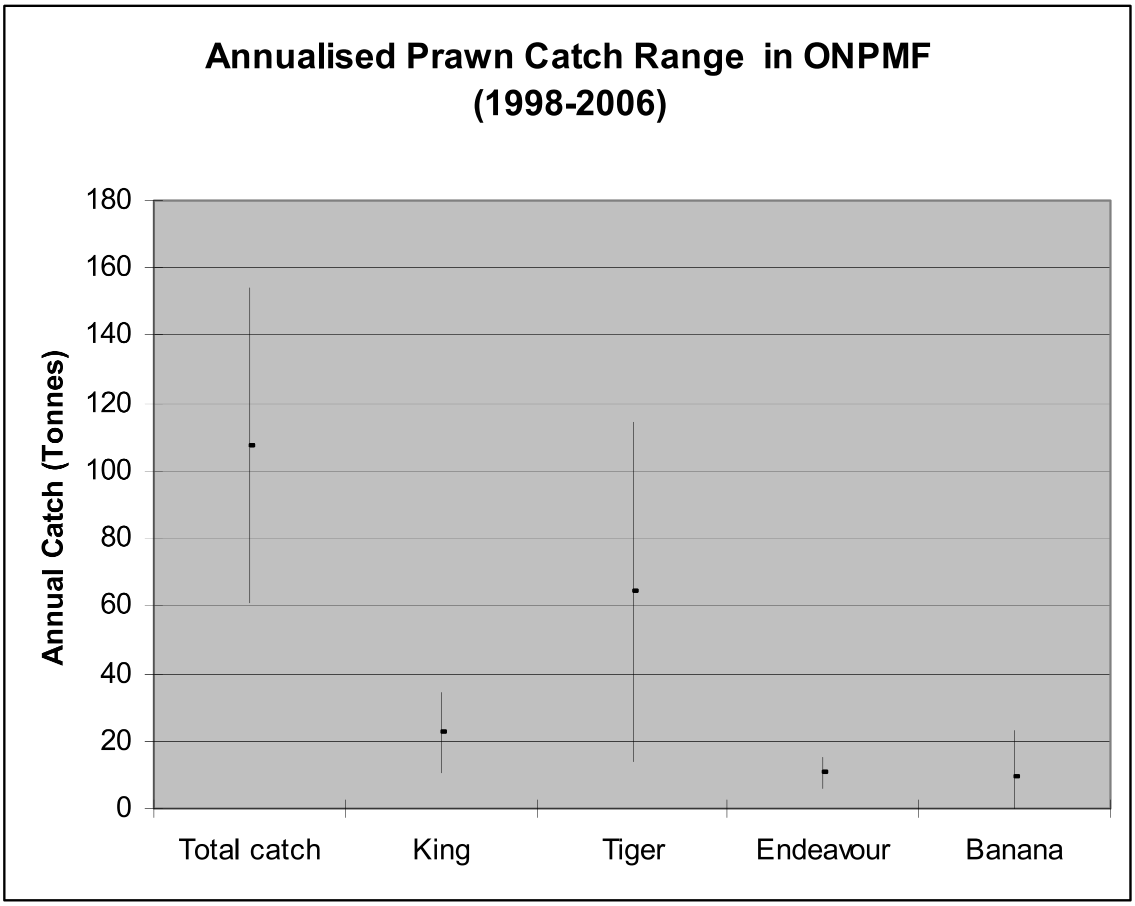
Table 1-1 Catches in the Onslow Prawn Managed Fishery from 1998 to 2007 (DoF 2007).

Year	Total value ($ million)	Banana value ($ million)	Prawn catches (tonnes)				
			Total prawn catch	King	Tiger	Endeavour	Banana
1998	0.9	0.02	62	35	14	11	2
1999	1.4	0.10	93	38	26	20	9
2000	1.5	0.79	87	12	18	6	51
2001	0.9	0.15	63	15	28	7	13
2002	1.7	0.01	135	42	77	14	1
2003	2.4	0.01	194	12	172	9	1
2004	2.2	0.00	194	27	150	17	0
2005	1.0	0.00	85	20	55	10	0
2006	0.65	0.02	51	2	39	2	8
2007	Not recorded	Not recorded	4	<1	<1	<1	<1
Total	**12.65**	**1.10**	**968**	**204**	**580**	**97**	**86**
Average	**1.3**	**0.11**	**96.8**	**20.4**	**58.0**	**9.7**	**8.6**

Note: Values of banana prawn catches are not reported separately by the DOF, so this banana prawn value has been reported by multiplying the reported catch for the year in tonnes by the average value banana prawns obtained for that year as reported by the DOF.

1 Introduction

Figure 1-4 Mean and range of annual catches of individual species in the Onslow Prawn Managed Fishery 1998-2006 (after DoF).



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2

Prawn Biology

2.1 Biology of brown tiger prawns (*Penaeus esculentus*)

Penaeus esculentus (the brown tiger prawn, tiger prawn or common tiger prawn) is a species of prawn which is widely fished for consumption around Australia. It appears to be endemic to Australian waters and is found in warm waters from central New South Wales (near Sydney) to Shark Bay, Western Australia (NSW DPI 2008)

2.1.1 Distribution and stock structure

The brown tiger prawn, *Penaeus esculentus*, has a large distribution throughout northern Australia and although no genetic differences were detected between brown tiger prawn populations, the majority of these operate as functionally independent stocks (DoF cited in Environment Australia 2002). The stocks are associated within relatively sheltered waters and with seagrass habitat, which forms the main juvenile habitat for this species. However, the waters off Onslow and south to Exmouth Gulf generally have less abundant seagrass and macroalgae compared to other parts of Australia where *P. esculentus* occurs (Sporer et al. 2006). Generally, *P. esculentus* are found in coastal waters to approximately 60m (Grey *et al*., 1983) and are commonly caught by trawlers over mud or sandy substrates (Hall and Penn, 1979). While a small fishery and nursery ground is located in the waters adjacent to Onslow, the prawn stock is most abundant in the southern portions of Exmouth Gulf, which is near the southern extremity of its distribution in Western Australia. Adult *P. esculentus* are benthic and nocturnal and require a sandy substrate in which to bury during the day (Keys 2003).

2.1.2 Life history

P. esculentus can live for more than two years although the majority of commercial catches consist of individuals less than two years old. This species matures at six to seven months of age, or a carapace length of approximately 25 to 28 mm, and becomes sexually mature at ten to 12 months of age. As described by Garcia and Le Reste (1981), *P. esculentus* follows the general life cycle of all penaeids, including a juvenile phase that occurs in some regions in a hypersaline marine littoral zone or typical estuarine or lagoon habitat (White, 1975). An overview of the spawning cycles of the *P. esculentus* stock has been reported in White (1975), Penn and Caputi (1985, 1986) and Penn *et al*. (1995). Spawning occurs from August through to March and July/August (peaking in the late winter-spring period), sexually mature female *P. esculentus* aggregate in waters 13 to 20 m deep (Penn and Caputi, 1985). Mature females continue to spawn through the summer months following each successive moult (Penn and Caputi, 1985), while males need to be hard shelled to successfully spawn.

As is generally the case for all penaeid species the larval development from planktonic nauplii to metamorphosis into post larvae generally takes at least two to three weeks. During the planktonic stages the larvae are generally advected (drift) from the spawning grounds to more protected nearshore nursery grounds (e.g. Penn 1975). Once the post larval stage is reached, juveniles resemble the adult form and they become largely benthic in habit on the nursery grounds. During early post larval stages (approximately 10 mm total length), predators are responsible for high mortality. During this stage they typically inhabit nursery grounds in the nearshore waters such as seagrass, macroalgae and estuarine sand flats and may avoid predators by burying in the substrate particularly during neap tides during daylight hours (Vance and Staples 1992).

Juveniles spend approximately three to six months in the nursery grounds as they mature at a size of between 100 and 120 mm total length (Penn and Stalker, 1979). At this size they migrate offshore and enter the trawl fishing grounds.

2.2 Biology of western king prawns (Penaeus latisulcatus)

2.2.1 Distribution and stock structure

The western king prawn (or blue-leg king prawn), *Penaeus latisulcatus*, has a widespread Indo-Pacific distribution and occurs in much of Australian waters from Adelaide in South Australia around the west and north coasts to northern NSW. Richardson (1982) identified genetic differences between western king prawn populations sampled from WA, the Gulf of Carpentaria and South Australia. Stocks of *P. latisulcatus* are generally found in areas associated with the hypersaline waters of marine embayments (Kailola et al. 1993).

2.2.2 Life history

P. latisulcatus become mature at six to seven months of age, or around 25 mm carapace length, and are known to live for up to four years. Average commercial harvest size is 10-16 cm or around 50 g body weight. Juvenile *P. latisulcatus* are generally found inshore where they remain in shallow water nursery grounds for three to six months, and as adults move offshore to mature and spawn to complete the life cycle (Kirkegaard, 1975). Spawning has been reported in the Gulf of Carpentaria to occur during spring (Coles and Long 1985). Planktonic larval stages are transported inshore by tidal currents (Penn 1975) where they metamorphose into juvenile post larvae. During this stage they typically inhabit nursery grounds in the nearshore waters feeding on an omnivorous diet including benthic molluscs and polychaetes. Juvenile western king prawns appear to have a hierarchy of mechanisms for avoiding predators, with burying in sand being the preferred option. If burying is not possible, then seagrass is used for shelter. Active habitat selection to avoid predation appears likely to play a substantial role in determining the distribution of these animals on unvegetated sand- and mud-flats (Tanner and Deakin, 2001). In general, *P. latisulcatus* are found in coastal waters to depths of 80 m and are fished for over hard sediment substrates such as sand, sandy mud or gravel (Dore and Frimodt, 1987).

2.3 Biology of endeavour prawns (Metapenaeus endeavouri)

2.3.1 Distribution and stock structure

The distribution of the endeavour prawn, *Metapenaeus endeavouri*, is restricted to northern Australian waters between northern New South Wales and Shark Bay in Western Australia. (Grey et al.1983). The species is mostly found in coastal waters to 50m deep and fishing effort is mostly targeted at the same fishing grounds as *P. latisulcatus* and *P. esculentus* (Sporer et al. 2006).

2.3.2 Life history

Little is known of the spawning periods and larval development of the *M. endeavouri*. Evidence from other regions in Australia suggests that spawning may occur year round (Courtney et al., 1989) with increased spawning reported to be occurring in the Gulf of Carpentaria in September to December (Coles and Long 1985). Juveniles are mostly associated with seagrass and estuaries (Staples et al., 1985). Juveniles may avoid predators by burying in the substrate particularly during neap tides during daylight hours (Vance and Staples 1992).

Potential effects to prawn habitat in the Pilbara area

3.1 Overview

The Wheatstone EIS/ERMP Chapter 2 provides a Project description and outlines the schedule for the proposed development of the Project. In particular, a major capital works dredging program is planned for the development of a navigation channel, turning basin, materials offloading facility (MOF) and export pipeline at Ashburton North. This dredging program is anticipated to last for up to four years and is likely to result in localised short term exceedance in ANZECC (2000) water quality guidelines; and reversible, short term, localised loss of benthic primary producer habitat. Consequently, this activity has been ranked with **High** residual environmental risk. In addition, the specific risk assessment reported in the draft Wheatstone EIS/ERMP that local medium term impacts to the OPMF prawn nursery located within the Ashburton SMFG are likely to occur resulting in a **Medium** residual risk ranking. In assessing the potential impacts that construction may have to the prawn habitat within the Project area, the issues raised have included:

- Changes in water quality resulting from dredging resulting in high levels of turbidity that causes direct impacts to prawns at the population level in the OPMF
- Large scale and irreversible loss of prawn habitat, in particular seagrass and breeding habitat
- Sedimentation of prawn trawling areas
- Changes to currents in the nearshore area as a result of marine facilities including the MOF and its breakwaters, turning basin and navigation channel
- Changes to coastal littoral transport resulting in abnormal alterations to morphology of delta systems and creek mouths

In assessing risks to these receptors in relation to the OPMF, URS acknowledges some uncertainty in predicting impacts because:

- Limited documented scientific understanding of prawn biology/ecology in the Pilbara
- Limited experimental evidence on prawn habitats derived from Pilbara prawn fisheries
- Prawn abundance and habitat is spatially and temporally variable
- Limited understanding of the impact trawling has on habitat and prawn populations
- Much of our knowledge of biology of prawns in Australia comes from the east and northern coasts so extrapolation to Pilbara is necessary

This latter point in particular is noted; the morphology, habitat, salinity regimes and hydrology of estuaries in the Pilbara are profoundly different from those typically found elsewhere in Australia. These arid estuary systems are a critical habitat component of the life cycle of prawn species commonly fished in the region. The Project development has recognised the need to protect the Ashburton delta and its unique mangrove habitat. This is prescribed as a Priority 1 Area in EPA Guideline 1 "Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline".

3.2 Habitat Impact Assessment

To assess the potential impacts from dredging on key prawn habitat (seagrass and macroalgae) in the Project area, the proponent's consultant Danish Hydrographic Institute (DHI) conducted extensive modelling to predict the size and concentration of sediment plumes under varying dredging and climatic scenarios. Based on an extensive review of available literature (refer to EIS Appendix N3) DHI developed a series of tolerance limits for impacts of suspended sediments on corals and seagrass for the Wheatstone Project area. Some of the reviewed literature deals with experiments where additional (and quantified) suspended sediment or sedimentation loads are added to the ambient environment of

3 Potential effects to prawn habitat in the Pilbara area

particular receptor species, and the effects of these additional environmental loadings are determined. Other papers document the effect of natural turbidity and sedimentation gradients on receptor species composition, and the survival of different species following environmental loading pulse events (such as cyclones or large rainfall events).

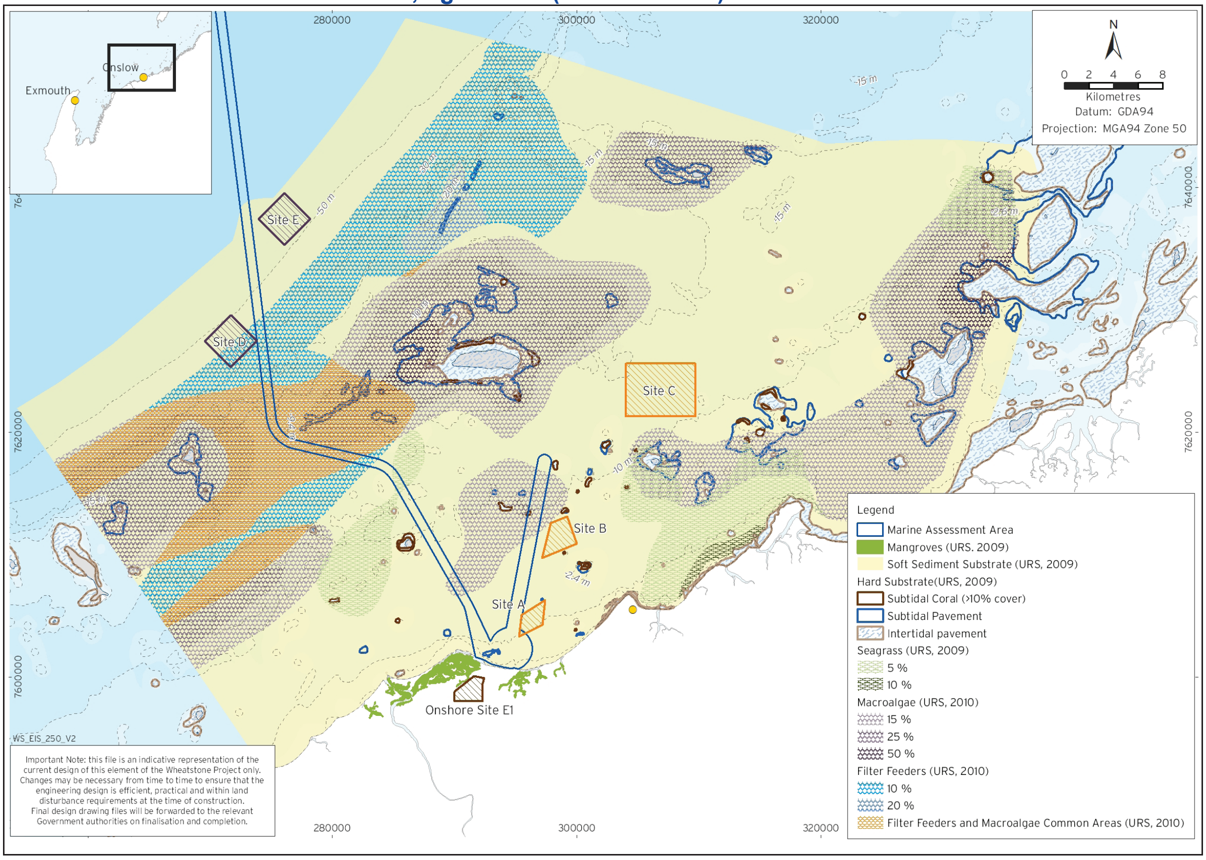
Chevron undertook baseline surveys in the Wheatstone Project area to document these existing water quality conditions, including a review of more than 3 years of MODIS satellite imagery for the area in order to establish the background concentrations and spatial and temporal variability in turbidity; and sediment trap surveys to establish the background sedimentation rates. These have been reported in the EIS and in detail in EIS Appendix Q7. As noted in the EIS, coastal marine waters in the Project area are subject to a wide range of naturally occurring spatial and temporal influences including catchment run-offs, cyclones, tides, winds, currents, seasonal and biotic interaction. As a result water quality can vary markedly through time. The Ashburton nursery area in particular is profoundly influenced by these naturally occurring factors, particularly sediment resuspension during spring tides and windy conditions; and from the catchment run-off from the Ashburton delta. During flood periods up to 5 million tonnes of sediment may be deposited into the ocean from this delta (EIS Appendix Q6).

Using a conservative approach, DHI developed tolerance limits for corals and seagrass (in both cases using the most sensitive species recorded in the Project area) for both suspended sediments and sedimentation, while taking into account the site specific conditions. The tolerance limits were developed using literature values, limits set for previous dredging projects in WA, and DHI's extensive experience of monitoring dredging and reclamation operations around the world (particularly in SE Asia). The tolerance limits were then independently reviewed by Professor Charles Sheppard, an acknowledged expert from Warwick University, and assessed overall to be suitably conservative (Appendix A of EIS Appendix N1).

The distribution of macroalgae and seagrasses in the Project area has been obtained from three surveys conducted over a nine month period and described in EIS Appendix N12 plus an additional survey described in EIS Appendix N8 that looked at deeper water habitats (15-70 m CD). There were no seagrass areas found within the area of the proposed navigation channel. The habitat maps delineate areas of denser seagrass abundance that occur some considerable distance from the channel. Figure 3-1 shows the location of resultant macroalgae and seagrass distribution and % cover in the Project area.

Using the limits of suspended sediment that seagrass and macroalgae can tolerate (tolerance limits) and a habitat map of the Project area it was possible to conservatively predict the potential impacts to these habitats. The proportional loss of seagrass and macro algae has been determined using Local Assessment Units. The findings of this work have been reported in Chapter 8 of the Wheatstone EIS and in detail in EIS Appendix N1.

Figure 3-1 Benthic Primary Producer Habitat (BPPH) distribution map reproduced from Chapter 8 of Wheatstone EIS/ERMP, figure 8.22 (Chevron 2010).



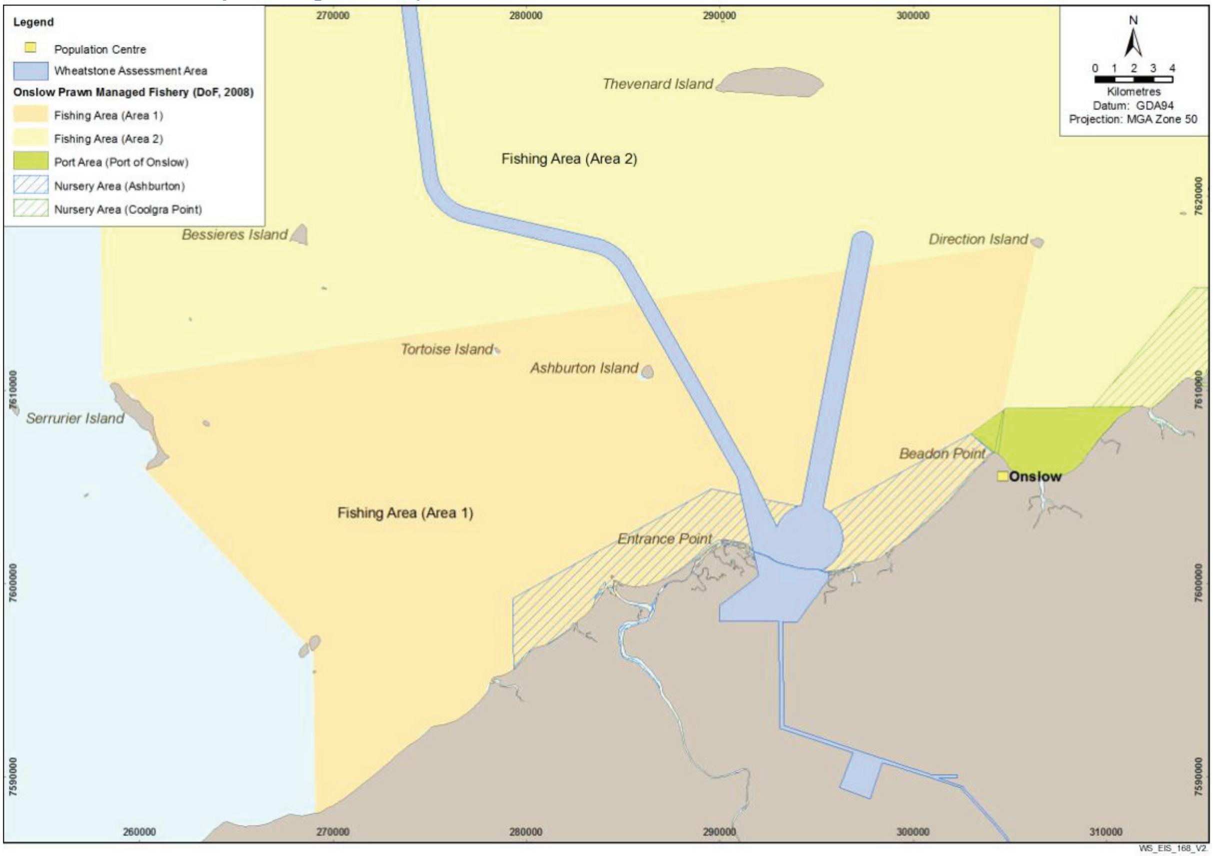
3.3 Potential habitat loss

3.3.1 Permanent loss of macroalgae and seagrass

The Project nearshore infrastructure is anticipated to cause the permanent loss of only four percent of the total available nursery habitat of the Ashburton SMFG located in Area 1 as a result of the footprint of the navigation channel and port facilities (Figure 3-2). It is considered unlikely that the permanent removal of habitat for nearshore infrastructure construction will have a significant impact on prawn production (recruitment) in the Onslow Prawn Managed Fishery. The only other permanent loss is predicted to be two per cent of macroalgae in the Local Assessment Unit (LAU) D1 (see Table 7-1, p117, of Appendix N1).

3 Potential effects to prawn habitat in the Pilbara area

Figure 3-2 Boundaries of the Onslow prawn fishery area showing the Ashburton nursery area (Chevron 2010, p. 568 figure 8.60)

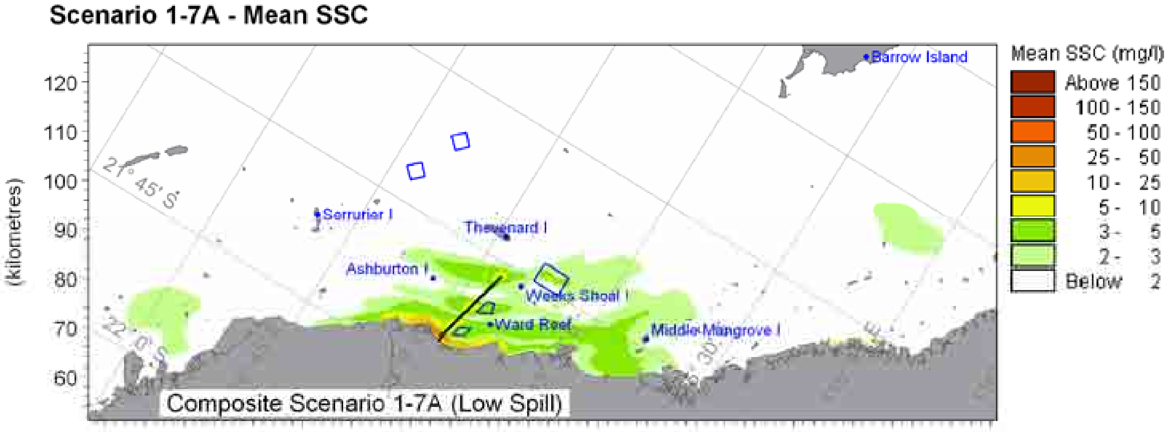


3.3.2 Temporary impacts to macroalgae and seagrass

The predicted dredge plume presented in the EIS/ERMP and shown in Figure 3.3 represents the full dredge log program (FDLP) with all scenarios combined is a compilation of a multiyear dredging campaign using a scenario approach to produce a conservative maximum “envelope” of potential impact. The composite scenario presented in the FDLP provides an overall predicted extent of SSC elevations in marine waters under all scenarios in the Project area due to dredging and dredge material placement. The modelling predicts the most extensive and more intense plumes (>5 mg/L SSC) are anticipated in very nearshore waters between Ashburton River and Onslow depending on the season and dredging operations.

3 Potential effects to prawn habitat in the Pilbara area

Figure 3-3 Mean excess sediment concentrations for the full dredge log program (FDLP)



It should be emphasised that while the dredging programme is expected to extend for four years, impacts to particular seagrass areas are not predicted for this entire four year period. Because the currents run perpendicular to the dredge channel (and parallel to the shore), and the channel will be dredged in distinct sections, impacts will be confined to areas in the direct flow path from those areas, which are also strongly seasonal (i.e. the entire area is not affected continually for the four year dredging programme). Impacts to the seagrass area to the west of the channel are predominantly predicted during winter periods, while impacts to the seagrass area east of the channel, including at Coolgra Point, are predominantly predicted during summer.

Dredge placement at proposed Sites A and B, should that occur, is only anticipated during the first 2 years of dredging. The duration of dredging in each section of the channel is not expected to extend beyond 2 years in total. By comparison, turbidity impacts from maintenance dredging and shipping operations are much smaller scale both in the volume of sediment disturbed and the timeframe of disturbance and considered unlikely to adversely affect seagrass growth some 6 -10 km away from the channel.

The predicted loss of macroalgae and seagrass as a result of increased sedimentation/decreased light attenuation occurs in the zone of partial mortality which covers the area in which more than 50% of these primary producers are expected to survive. Larger areas of seagrasses are potentially more susceptible to the impact of the dredge plume to the east of the channel. As noted, the assessment of BPPH loss presented in the EIS/ERMP is a compilation of loss after a multiyear dredging campaign using a scenario approach to produce a conservative maximum “envelope” of potential impact. The predicted “envelope” does not indicate the timing and duration of that loss for seagrasses and macroalgae. Scenario 6 is the one that has the greatest scale of potential impact on the seagrasses east of Onslow. These works may take some 8 months to complete during the second year of dredging. Reversible damage to the large area of denser seagrass east of Onslow is only anticipated during the first two summers of the dredging campaign and these are predicted to conservatively impact less than 15% of the seagrass in this area. No further adverse impacts to seagrasses east of Onslow are anticipated from the remainder of the dredging program.

No losses are anticipated during other seasons, nor in the last two years of the dredging campaign. Hence the losses are anticipated to be only short term and there is good scope for recovery both seasonally and by the end of the dredging program. As such these predicted seagrass losses are considered to be reversible for the purposes of BPPH Loss assessment. Turbidity impacts from maintenance dredging and shipping operations are much smaller scale both in the volume of sediment disturbed and the timeframe of disturbance and considered unlikely to adversely affect seagrass growth some 6 -10 km away from the channel. Consequently Chevron considers that there will be no irreversible loss of seagrass habitat as a result of the dredging program.

3.3.3 Anticipated recovery of impacted seagrass and macroalgae areas

Macroalgae and seagrass are expected to recover once dredging has ceased as evidenced by recolonisation of Onslow Salt spoil grounds and surrounding dredge areas within the Project area (See Appendix N12 for survey results). The habitat surveys inspected previous dredge spoil grounds established by Onslow Salt and found seagrasses to be growing on the spoil grounds in low abundance and similar to the surrounding seabed areas indicating their potential for recovery. In addition, the dominant genus of seagrass in the Project area is *Halophila* sp., which is a pioneering species, and is expected to recover more rapidly from dredging disturbance compared to other seagrass species. Seagrass habitat primarily inhabits soft sediment substrate in the project area which will not be changed as a result of sediment released by the dredging program. The habitat maps delineate areas of denser seagrass abundance that occur some considerable distance from the channel. There were no seagrass areas found within the area of the proposed navigation channel.

In the Wheatstone EIS Appendix N3 it is reported that Duarte *et al*. (1997) conducted a field study in the Philippines to test the effects of different levels of sediment burial on a range of seagrass species. The findings of the study for the smaller colonising species, such as *Halophila ovalis* (common in the Wheatstone Project area), were quite different from the results for the larger seagrass. Duarte *et al*. (1997) conclude that the smaller seagrass species would probably have suffered partial or total mortality after burial with more than 2-4 cm of sediment, as they would have been completed covered. However, the growth rate of *H. ovalis* in particular, which produces a new rhizome inter-node and leaf pair approximately every four days (Vermaat et al. 1995), meant that by the time the first round of measurements were taken two months after burial, the *H. ovalis* shoot density had fully recovered, and in fact exceeded the original densities (and the control densities) in most instances (Duarte *et al*. 1997). This concurs with the findings of Supanwanid (1996), who recorded full recovery of *H. ovalis* from dugong feeding within two months, and with Longstaff and Dennison (1999), who conclude that the longer-term sedimentation survival strategy for *Halophila* species is the ability to rapidly re-grow from seed and/or vegetative fragments after burial.

It should be noted that the Duarte *et al*. (1997) study involved immediate burial of the seagrass (analogous to an extreme storm event). In the context of dredging and reclamation, such an immediate burial event is likely to be confined to the immediate vicinity (within 100–500 m) of the work area or offshore spoil placement area. For seagrass further away from the immediate work area, sedimentation is better characterised as an accelerated build-up rather than immediate burial. Given the rapid growth rates of most tropical seagrasses (Vermaat et al. 1995) there can be expected to be some capacity to adapt to the risk of accelerated burial due to increased sedimentation rates.

3.4 Direct effects of increased turbidity on prawns

Concerns raised in one submission (see Appendix A) raised the potential of mass mortality for the Area 1 OPMF prawn stock due to dredging. Mass mortality at a population level of prawn stocks has not been documented during dredging programs in WA or elsewhere. The predicted effects on water quality are anticipated to be principally elevated turbidity (suspended sediments) in the vicinity of the dredging operations. The three principal prawn species of interest in the OPMF are documented to tolerate high turbidity levels, well in excess of those anticipated from dredging. Dissolved oxygen, a common cause of mass mortality in fish populations, is unlikely to be adversely affected. Prawns may even avoid areas close (<500 m) to dredging operations.

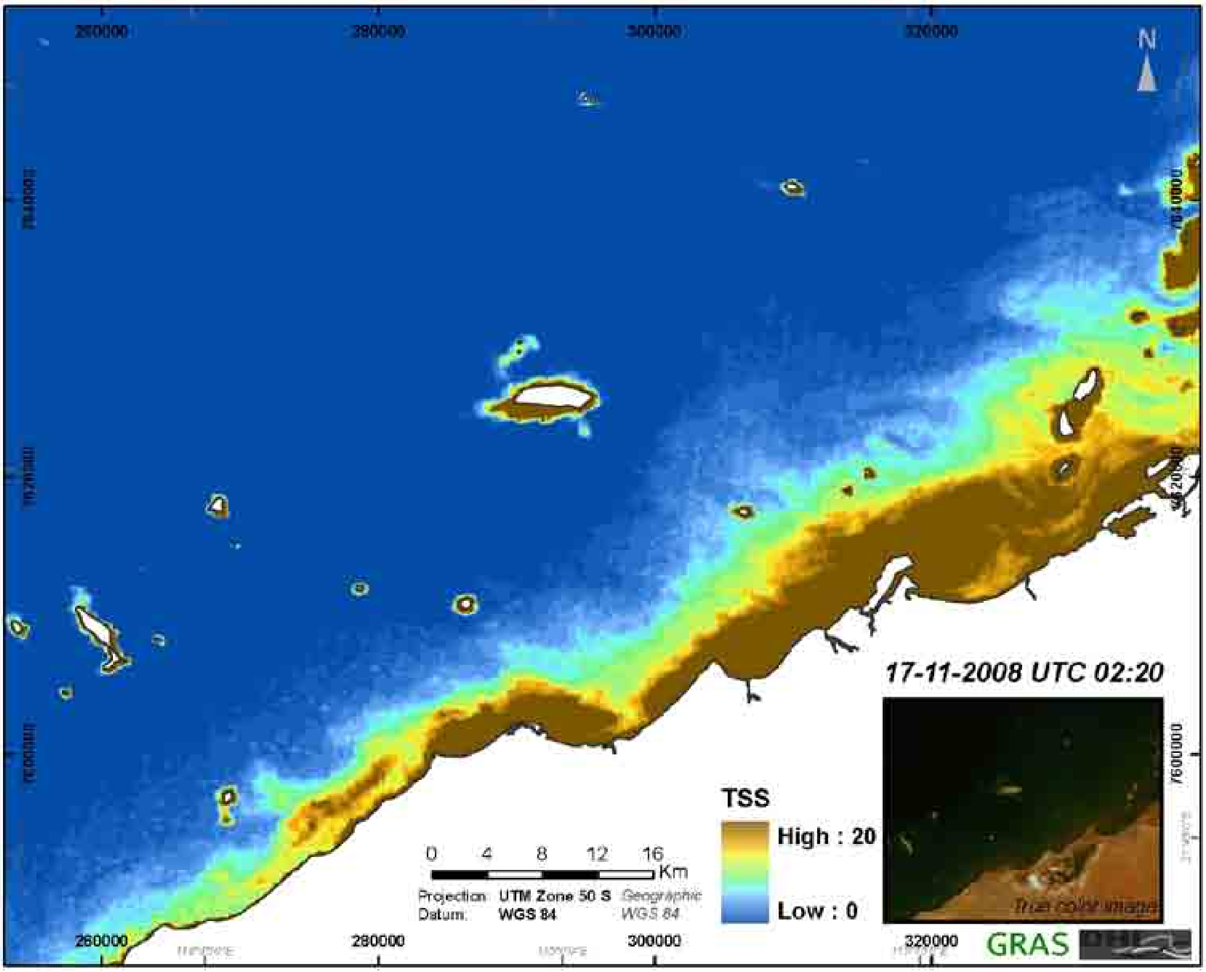
It is acknowledged however that the OPMF occurs within the modelled Zone of Influence of turbid waters from dredging. Under the Wheatstone Dredging and Spoil Disposal Management Plan (DSDMP) reactive management framework (Appendix S1 of the EIS) impacts will be monitored in order to confirm or mange the impacts predicted by the assessment. Monitoring will include relevant water quality parameters and any associated habitat changes related to the dredging programme. The ambient water quality conditions, benthic habit and burrowing activities of prawn species that inhabit the Wheatstone Project area is indicative of their capacity to tolerate turbid conditions. In addition, prawns are benthic dwellers and generally local species have a high tolerance to turbidity in excess of 100 mg/L (Preston et al. 2001). Such high turbidity levels are highly unlikely to be experienced beyond the 500 m "total mortality" impact zone which extends up to 500 metres from where the dredge is operating at any particular time and at the dredge spoil placement site. Ambient turbidity averages for a range of prawn species have been reported in the aquaculture literature and presented in Table 3-1.

Table 3-1 Published turbidity average tolerance values for a range of penaeids

Species	Common name	Turbidity tolerance	Source
P. monodon	Black tiger prawn	105 mg/L	Boyd, 2000; Preston et al 2001
P. monodon	Black tiger prawn	185 mg/L	Briggs et al, 1994; Cowan et al., 1999
P. esculentus	Brown tiger prawn	100 mg/L	Preston et al, 2001
P. latirostris	Pandalus	200 mg/L	Chiba et al, 2004
P. japonicus	Kuruma prawn	65 NTU	Lin et al. 1992
P. merguinesis	Banana prawn	105 mg/L	Preston et al 2001
P. vannamei	White shrimp	90 mg/L	Kinne et al 2001
P. stylirostris	Blue shrimp	145 mg/L	Mendez 2004

The suspended sediment concentrations (SSC) predicted in the Zone of Partial Mortality identified for corals (the most sensitive benthic primary producer receptor identified in the Project area) are only anticipated to exceed 25 mg/L above background turbidity for short durations (<20% time in shallow nearshore areas, and <10% time in offshore areas). Exposure to dredge plumes of this magnitude would only occur in areas down-drift from the particular section of the project area being dredged, which is dependent on the stage of the dredging program and seasonal and tidal conditions. Similar levels of background turbidity are experienced on occasions, particularly during spring tides, across the OPMF as evidenced by the MODIS satellite image analysis presented in Chapter 8.2 of the EIS/ERMP. An example is shown in Figure 3.4. It can be seen that turbidity in excess of 20 mg/L was measured in the Ashburton SMFG on the day this image was taken. The turbidity limits predicted in the FDLP plume are also generally well below that at which the species listed in Table 3-1 are commonly farmed. Evidence also suggests *Penaeus merguiensis* are more abundant in more turbid waters at natural levels (Johnston *et al*, 2007). It is thought that increased turbidity may also offer greater protection to prawns from predators.

Figure 3-4 Total suspended solids concentrations (mg/L) derived from MODS Image Analysis on 17 November 2008.



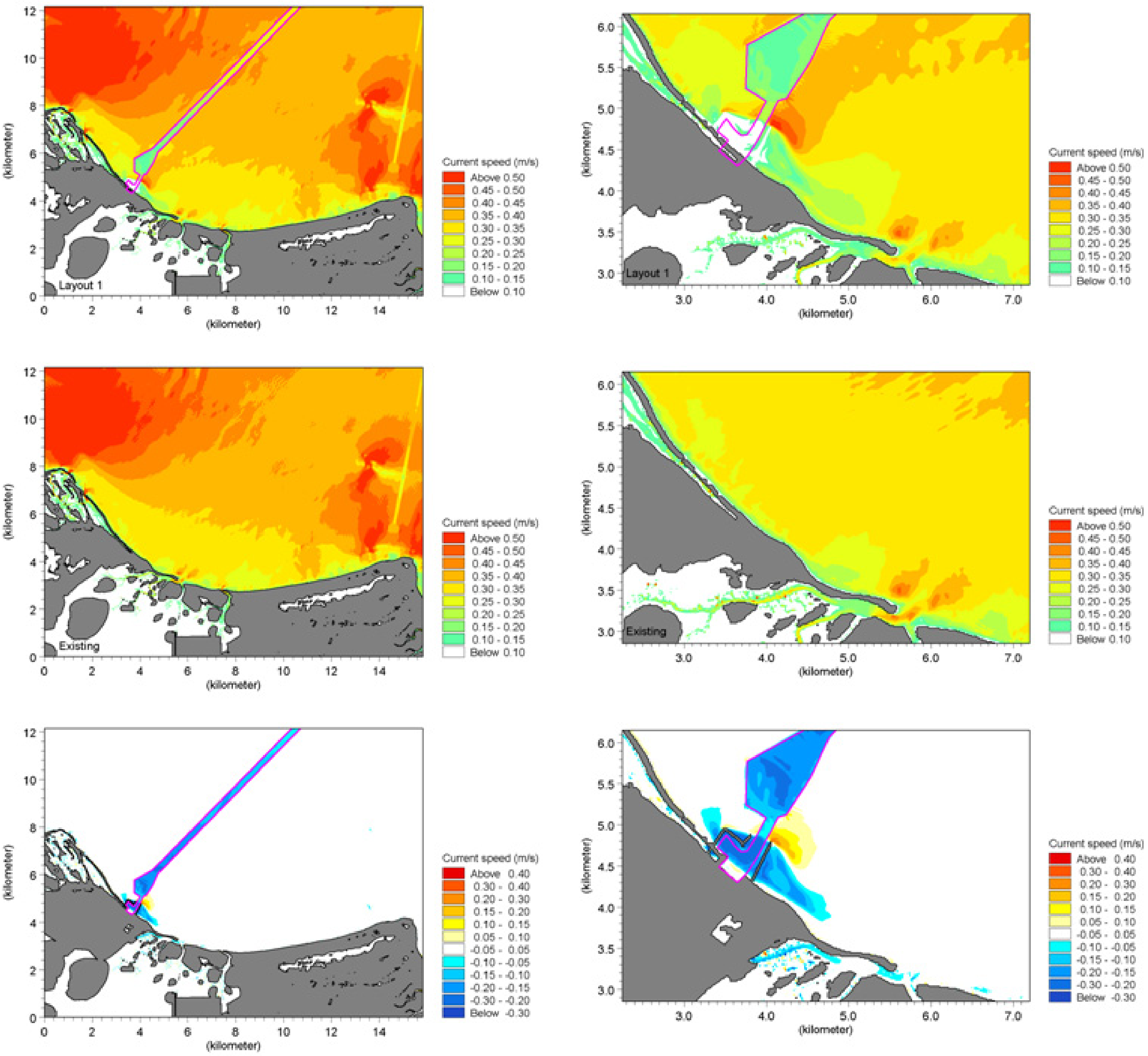
3.5 Potential effects on tidal water flow and currents

Marine currents and tidal flows are crucial for transporting prawn eggs, nauplii, protozoea and mysis larval stages (e.g. Penn 1975) and influence post larvae and prawn movements during their lifecycle. The impact of the proposed development of marine coastal structures and in particular the port facilities including the materials offloading facility (MOF), product loading facility, turning basin and navigation channel described in the Wheatstone EIS on coastal processes including current flows has been assessed through coastal process modelling. This is reported in detail in EIS Appendix P2.

A plot of currents for the entire extent of the navigation channel and another zoomed in on the proposed MOF area at the Ashburton North site is shown in Figure 3-5.

3 Potential effects to prawn habitat in the Pilbara area

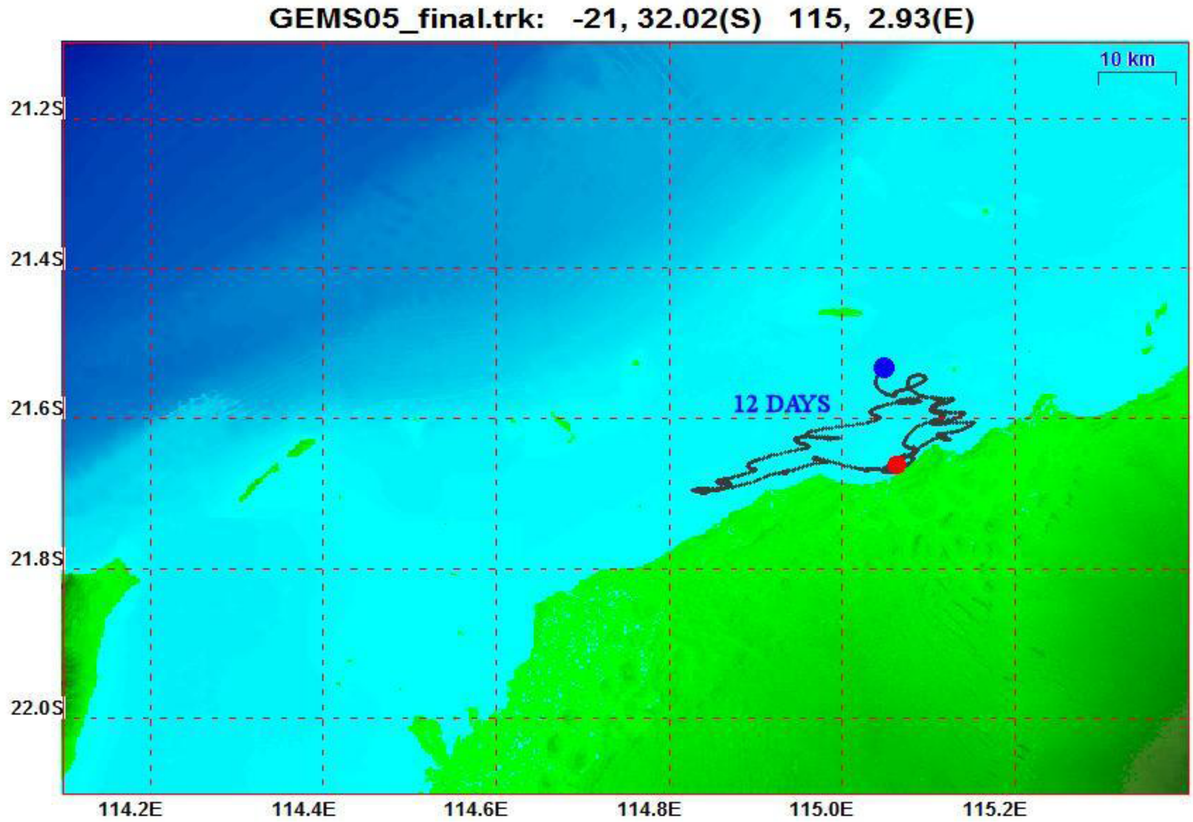
Figure 3-5 Simulated current speeds with and without port infrastructure in the vicinity of the Ashburton North site. Top: max current speed for future situation, with dredging complete Middle: max current speed for existing situation, prior to start of dredging . Bottom: difference plot, showing change in max current speed due to the project (blue is a decrease, yellow/red is an increase).



This simulation represents “average” conditions. Both plots show that changes to current speeds are localized, and mainly confined to the channel, the MOF and the immediate vicinity of the MOF (due to the breakwaters). There are no significant changes to current speeds in any of the seagrass or coral areas. This modification of currents is expected to be minor and unlikely to affect the onshore drift-movement patterns (advection) that are typical of planktonic prawn larval stages (Penn 1975; Rothlisberg *et al*. 1987) following spawning of adult prawns in their life cycle. It is noted the deployment of surface current drogues in the vicinity of the midpoint of the proposed navigation channel, as part of the oceanographic investigations for the Project, demonstrated this onshore drift pattern to the cuspate foreland feature at the mouth of Entrance Point on the Ashburton delta (GEMS, 2010). An example of the drift pattern is shown in Figure 3.6. The channel is not anticipated to markedly alter regional water flows and no adverse impact on the denser areas of seagrass is anticipated.

3 Potential effects to prawn habitat in the Pilbara area

Figure 3-6 Track of Surface Drifter GEMS05 – released (blue) at 14:22 on May 9, 2010 and beached (red) at 17:04 on May 21, 2010.



Proposed mitigation measures

Table 8.48 in Chapter 8 of the EISERMP contain the mitigation measures that will be implemented during dredging to reduce impacts to the prawn fishery. It is noted that under the Wheatstone Dredging and Spoil Disposal Management Plan (DSDMP) reactive management framework (Appendix S1 of the EIS), water quality parameters and any associated habitat changes related to the dredging programme will be monitored, in order to confirm and manage the levels of impact to conform to those predicted in the EIS.

This includes general preventative management and monitoring measures including:

- TSHDs will be fitted with an overflow valve within the overflow pipe
- Where reasonably practical the works will be managed to optimise the TSHD under keel clearance to reduce sediment re-suspension via propeller wash
- Hopper doors on the TSHD and barges will be maintained to ensure minimum loss of sediment during transport
- Well maintained and properly calibrated dredging equipment will be utilised
- A restriction of overflow from the TSHD should occur in the Restricted Overflow Areas when sensitive receptors are at risk. The areas will vary depending on conditions and dredging areas.
- Impacts on BPPH will be limited by limiting anchoring by construction vessels within established
- Water quality monitoring
- Sedimentation monitoring
- Receptor monitoring (coral health)

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Overall Impacts to Prawn Populations in OPMF

Chevron acknowledges that local medium term impacts to the OPMF prawn nursery located within the Ashburton SMFG are likely to occur (Medium Residual Risk in the EIS//ERMP – page 618). This is a result of the construction of the coastal facilities. These medium term impacts are expected to be confined to permanent loss of habitat as a result of the construction of the navigation channel, turning basin and MOF. The area occupies less than 4 percent of the Ashburton SMFG.

Impact to prawn benthic habitat affected by the dredge plume is likely to be short term and limited in spatial extent and duration. The suspended sediment concentrations (SSC) predicted in the Zone of Partial Mortality identified for corals (the most sensitive benthic primary producer receptor identified in the Project area) are not anticipated to exceed 25 mg/L above background turbidity. It should be noted that this is predicted only for short durations (<20% time) and this only occurs at any particular location dependent on the stage during the dredging program and seasonal and tidal conditions. In addition high turbidity is observed in the background levels periodically experienced, particularly during spring tides, across the OPMF nearshore environment.

Given this assessment Chevron is of the view that there will be a viable prawn population in the Onslow Prawn Managed Fishery after the dredging phase.

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Conclusion

The OPMF covers 39 748 km^2 and has three areas. Area 1 is a small section in the southwest corner of the fishery centred at the mouth of the Ashburton River and includes the Ashburton SMFG. Area 2 is essentially the western half of the fishery, including most of the shoreline of Barrow Island. The fished area was reported to be less than 5% of the overall fishery (Sporer and Kangas 2005).

Over the ten years from 1998 to 2007, the total prawn catch in the OPMF was 968 tonnes. The OPMF catch during this period was dominated by tiger prawns (580 tonnes, 60 per cent) and king prawns (204 tonnes, 21 per cent). Endeavour prawns (97 tonnes, 10 per cent) and banana prawns (86 tonnes, 8.8 per cent) are relatively minor components of the total catch. By-product species in the fishery include Moreton bay bugs, squid, blue swimmer crabs, cuttlefish, other prawns such as black tiger (*Penaeus monodon*) and coral prawns, and some finfish species

Reversible damage to the large area of denser seagrass east of Onslow is only anticipated during the first two summers of the dredging campaign and these are predicted to conservatively impact less than 15% of the seagrass in this area. No further adverse impacts to seagrasses east of Onslow are anticipated from the remainder of the dredging program. Hence the losses are anticipated to be only short term and there is good scope for recovery both seasonally and by the end of the dredging program.

Turbidity impacts from maintenance dredging and shipping operations are much smaller scale both in the volume of sediment disturbed and the timeframe of disturbance and considered unlikely to adversely affect seagrass growth some 6 -10 km away from the channel.

A range of prawn species are documented to tolerate high turbidity levels, well in excess of those anticipated from the dredging plume. It is likely that prawns will avoid extremely turbid areas close (<500 m) to dredging operations. Background high level turbidity in the OPMF occurs periodically. Dissolved oxygen, a common cause of mass mortality in fish populations, is unlikely to be adversely affected by dredging operations.

Changes to current speeds as a result of the proposed development are predicted to be localized, and mainly confined to the channel, the MOF and the immediate vicinity of the MOF (due to the breakwaters). There are no significant changes to current speeds in any of the seagrass or coral areas.

The Project nearshore infrastructure is anticipated to cause the permanent loss of four percent of the total available nursery habitat of the Ashburton SMFG located in Area 1 as a result of the footprint of the navigation channel and port facilities. It is considered unlikely that the permanent removal of habitat for nearshore infrastructure construction will have a significant impact on prawn production (recruitment) in the Onslow Prawn Managed Fishery. Impact to prawn benthic habitat affected by the dredge plume is likely to be short term and limited in spatial extent and duration.

URS acknowledges some uncertainty in the impact assessment for the reasons outlined in this report. However, Chevron also confirms the assessment in the Wheatstone EIS/ERMP that local medium term impacts to the OPMF prawn nursery located within the Ashburton SMFG are likely to occur resulting in a **Medium** residual risk ranking.

Given this assessment Chevron is of the view that there will be a viable prawn population in the Onslow Prawn Managed Fishery after the dredging phase.

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Appendix A Comments from the OPMF

Dredging and dredge spoil -

It is noted that much of the analysis that has been done (by DHI Water and Environment) on the dredging, the placing of dredge spoil and the resultant plumes are unpublished. Consequently we can have no confidence that these processes will not cause mass mortality for the Area 1 Onslow Prawn Managed Fishery prawn stocks.

The proposed dredging of the port and channel (variously described to us as 40,000,000 or 44,000,000 cubic metres in meetings with Chevron representatives and 45,000,000cubic metres in the EIS/ERMP) will, over four years:

- Remove part of the prawn habitat.
- Remove areas of prawn breeding habitat.
- Deposit spoil on prawn habitat and trawl grounds.
- Create turbidity that will diffuse sunlight and reduce seagrass growth and could potentially smother the seagrasses outside the proposed spoil dumping grounds. Sea grasses are critical prawn (particularly tiger prawn) habitat.
- Disturb tidal water flows that are crucial for transporting eggs, nauplii, post larvae and prawns during their lifecycle.

The lifespan of prawns is two to three years. It is possible that little or no egg production will occur in the impacted areas from the commencement of dredging. Breeding stock alive at the commencement of dredging will be dead by two to three years into the dredging phase and then there may be little or no egg production for the final years of the dredging program. There is insufficient information or research on the spatial distribution of spawning stock and source sink relationships to provide this Association with any confidence that there will be a viable prawn population in the Onslow Prawn Managed Fishery after the dredging phase. The EIS/ERMP must provide that information and analysis.

In addition to the EIS/ERMP being deficient in providing information on'the turbidity, suspended solids and smothering effects of the proposed dredging program it seems that what little analysis there is in the EIS/ERMP about the effects on prawns is directed to the life-cycle and habitat requirements of banana prawns (Penaeus merguiensis) whereas the mainstay of the Onslow Prawn Managed Fishery are tiger prawns (Penaeus esculentus) and western king prawns (Penaeus latisulcatus). Tiger prawns in particular, and western king prawns to a lesser extent, are strongly dependent upon healthy sea grass or algal habitat unlike banana prawns. How we should interpret this oversight is difficult to know. Either the EISjERMP is so deficient that it failed to focus on the commercial important prawn species in the Onslow Prawn Managed Fishery or its authors focused on an irrelevant species for some inexplicable reason. In either event it is gross deficiency of the draft EIS/ERMP. The EISjERMP must include a complete, detailed and transparent re-assessment of the dredging effects on critical sea grass and .algal habitat and the consequent impacts on the life-cycle of the commercially important species of the Onslow Prawn Managed Fishery.

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Appendix FI

Hydrocarbon Spill Sensitivity Mapping

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. An Environmental Sensitivity Index for the Project was developed to identify areas that are sensitive to a potential spill from the Product Loading Facility and Materials Offloading Facility. The Environmental Sensitivity Index values were overlaid on a coastal resources map to create an environmental sensitivity map. Condensate and diesel spill time-to-exposure plots for the Product Loading Facility and Materials Offloading Facility (Draft EIS/ERMP, Appendix Q2), were then overlaid onto the environmental sensitivity map to determine which environmental receptors are at greatest risk in the event of a spill. Descriptions and explanations of the hydrocarbon spill sensitivity maps were produced to provide an indicative identification (or "go to") of coastal habitats within the Project area (as well as surrounding areas), considered to be vulnerable to the effects of a potential hydrocarbon spill. The hydrocarbon sensitivity map identified a number of sensitive features in the Project area, including corals reefs (Thevenard Island, Ward Reef, Ashburton River, Entrance Point, Hooley Creek, Middle Creeks, Four Mile Creek), and creek and river mouths. These were ranked as sensitive as they provide a pathway for potential spills to come into contact with sensitive BPPH, such as mangrove habitats. Under the hypothetical spill scenarios presented in this study, these features would require protection.

Report

Wheatstone Project

Hydrocarbon Spill Sensitivity Mapping

12 JANUARY 2011

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Appendices

Appendix A Sensitive receptors

Abbreviations

Abbreviation	Description
AMSA	Australian Maritime Safety Authority
DEC	Dept. of Environment and Conservation
EIA	Environmental Impact Assessment
ERMP	Environmental Review and Management Program
ESI	Environmental Sensitivity Index
GA	Geoscience Australia
GIS	Geographic Information System
ITOPF	The International Tanker Owners Pollution Federation Limited
KenSea	Environmental Sensitivity Atlas for Coastal Area of Kenya
MOF	Materials offloading facility
NOAA	National Oceanic and Atmospheric Administration
NWS	North West Shelf
OSSM	Oil spill sensitivity map
PLF	Product loading facility
WP	Wheatstone Platform

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Executive Summary

Chevron Australia Pty Ltd (Chevron) propose to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south-west of Onslow on the Pilbara coast. Chevron has commissioned URS Australia Pty Ltd (URS) to produce a series of oil spill sensitivity maps (OSSM) and an associated report for the Wheatstone Project as mitigation tools in case of a hydrocarbon spill occurring.

An Environmental Sensitivity Index (ESI) for the Wheatstone Project was developed to identify areas that are sensitive to a potential spill from the Loading Jetty and Materials Offloading Facility (MOF). The ESI values were overlaid on a coastal resources map to create an environmental sensitivity map. Condensate and diesel spill time to exposure plots for the Loading Jetty and MOF produced by DHI (2010), previously for the Wheatstone Project, were overlaid onto the environmental sensitivity map to determine which environmental receptors are at greatest risk in the event of a spill.

This report describes and explains the hydrocarbon spill sensitivity maps that have been produced to provide an indicative identification (or "go to") of coastal habitats within the Wheatstone project area (as well as surrounding areas) which are considered vulnerable to the effects of a potential oil spill. Results of the mapping were produced in both A3 (11 in total). Areas of high sensitivity were found to be corals reefs (Thevenard Island, Ward Reef, Ashburton River, Entrance Point, Hooley Creek, Middle Creeks and Four Mile Creek) and river mouths (ranked as sensitive as they are conduits for the potential spill to come into contact with sensitive estuarine features such as mangrove habitats).

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Introduction

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant 12 km south-west of Onslow on the Pilbara coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and anticipated future gas fields. The Project is referred to as the Wheatstone Project (Project) and "Ashburton North" is the proposed site for the LNG and Domgas plants. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

Although hydrocarbon leaks and spills events are considered highly unlikely, emergency response procedures can be aided by planning with respect to identification of sensitive habitats to oil spills. Therefore, Chevron has commissioned URS Australia Pty Ltd (URS) to produce a series of oil spill sensitivity maps and an associated report for the Wheatstone Project as planning tools in case of a hydrocarbon spill occurring. Sensitivity maps were produced using GIS applications to prioritise and rank coastal areas for response management based on environmental and human use areas in the vicinity of the Wheatstone project.

The purpose of a hydrocarbon spill sensitivity map, or an OSSM, is to rank specific areas within a project area in accordance with specific features sensitivity to a hydrocarbon spill. The maps produced are to be utilised as a planning tool in vulnerability assessment to provide hydrocarbon spill responders with sufficient information to prioritise the immediate response and the subsequent clean-up effort. As the information produced is intended for use in planning for potential hydrocarbon spill at the proposed Wheatstone Project site, it is important to note that the report and associated maps are not to be used as management or mitigation tools in the event of a spill.

In the case of the Wheatstone project, the project area is the immediate proposed project area, including onshore and offshore structures. The OSSM mapping area is any area in which a potential spill from the Product loading Facility (PLF) or Materials Offloading Facility (MOF) can reach within 24 hours.

1.1 Hydrocarbon Impacts on the Marine Environment

The behaviour and toxicity of hydrocarbons spilled/released into the marine environment are largely a result of their physical and chemical properties and the prevailing weather conditions during a spill event. Condensate is typically associated with natural gas production and is the hydrocarbon of focus for the Wheatstone Project in conjunction with diesel spills associated with shipping activities. These hydrocarbons are comparatively light and their volatile fractions dissipate more rapidly through weathering compared to heavy crude fractions. However, prior to complete weathering, condensate and diesel are known to be toxic when they come into contact with fauna and flora. Therefore, appropriate mitigation and response strategies in the event of a spill are required to reduce their potential impacts to the marine environment.

The objective of an oil spill sensitivity map is to identify sensitive coastal features potentially at risk in the event of a hydrocarbon spill or leak at a particular location. The OSSM is constructed to provide guidance for targeted emergency response activities to hydrocarbon spills in order to mitigate impacts, thereby decreasing the risk to the environment. An OSSM is produced using GIS applications that incorporate all identified aspects of the marine and coastal environment in the study region. Coastal features are prioritised by ranking areas from least to most susceptible to the effects of a potential oil spill based on physical and biological attributes of those features. Model outputs of hydrocarbon leak and spill scenarios can then be superimposed over the OSSM to predict areas at potentially greatest risk.

Impacts on coastal and marine environments resulting from hydrocarbon spills are multifaceted and spill response teams must always be prepared to incorporate an immense amount of information to achieve an optimal and rapid response action (Carmona et al. 2006). Prioritisation of targeted actions is a vital component for a successful response strategy at any particular location. Specific spatial information is compiled, analysed and published in a comprehensive atlas that can be used in an emergency response plan to a hydrocarbon spill (Tychsen 2006). The compilation of sensitivity maps are key activities in the oil spill contingency planning process that illustrate essential information to spill responders, showing where the different coastal resources are and indicating a ranking of environmentally sensitive areas (Tychsen 2006). It is important that the maps convey the message instantly with clarity and simplicity, without requiring extensive specialised knowledge, (IPIECA 1996a)

1.2 Overview of Oil Spill Modelling

Modelling of hypothetical hydrocarbon spill events in the Project area were conducted to asses the potential hydrocarbon spill dispersal from a potential spill from the PLF and MOF (DHI 2010). Among the potential hydrocarbon spill scenarios identified, the modelling identified a condensate spill at the PLF and a diesel fuel spill at the MOF as potentially causing the greatest exposure of coastal areas to hydrocarbons within the Project area (DHI 2010). These scenarios have been used to develop the geographical extent of the OSSM. The simulation of hydrocarbon spills has been carried out using an oil spill model MIKE 21/3 SA produced by DHI that represented initially buoyant Lagrangian type particles being advected and dispersed while exposed to a range of weathering processes (DHI 2010). The advection (drift) and dispersion of the individual particles is determined by the combined effects of current (tidal and/or wind driven), wind and bed drag. The outputs predicting the 24hr minimum time to exposure of a condensate spill at the PLF and a diesel fuel spill at the MOF will be overlaid on the environmental sensitivity index maps.

1.3 Weathering Processes of Hydrocarbons Specific to this Study

For the purpose of this report, oil or hydrocarbons refer to condensate and diesel rather than crude oil which is traditionally associated with oil spill sensitivity maps. Condensate originating from the North West Shelf (NWS) are typically light hydrocarbons with a low density (Volkman et al. 1994.) and generally a low concentration of aromatic hydrocarbons (between approximately three and six per cent) which are the most toxic components (Neff 1990). Diesel is primarily comprised of cycloparaffins (between 20 and 40%) and, relative to condensate, is more easily entrained in the water column. Diesel contains a higher proportion of aromatic hydrocarbons, at around 24 per cent (DHI 2010). Although the amount of cycloparaffin in diesels makes them “heavier” than condensate, it is still expected that the majority of any spill is likely to evaporate within approximately 48 hours (ITOPF 2002).

In the event of a hydrocarbon leak or spill several physical, chemical, and biological processes operate to jointly weather the hydrocarbons. Weathering results in a change in the physical and chemical properties of the oil thereby influencing its effects on marine ecosystems (Neff et al. 2000). The most significant weathering processes include spreading, evaporation, dissolution, and dispersion into the water column, formation of water-in-oil emulsions, photochemical oxidation, microbial degradation, absorption to suspended particulate matter, and stranding on the shore or sedimentation to the sea floor (Neff et al. 2000).

The effect of weathering processes on subtidal habitats is largely dependent upon the characteristics of the oil and the sea conditions at the time. The rate of weathering processes increases with lower viscosity oils in the presence of breaking waves (ITOPF 2002).

The timing and magnitude of each weathering process is different following an oil spill, however the weathering processes that most affect the chemical and physical properties of the oil are spreading and evaporation. For oils of all densities, about 50 to 70% of the amount of oil that ultimately will be lost by evaporation is lost within the first 10 to 12 hours after a release. Since condensate and diesel are light and volatile compounds large proportions of these hydrocarbons are expected to rapidly evaporate (Neff et al. 2000).

1.4 Sensitivity Features and the Environmental Sensitivity Index (ESI)

An environmental sensitivity index is used to determine and illustrate relative sensitivity of shoreline and offshore areas to the effects of a hydrocarbon spill (Mosbech et al. 2000). Pre-spill ranking allows spill responders and planners to evaluate which areas and environmental components are most susceptible to an oil spill, and provide information to allow priorities to be established. Sensitivity in marine and coastal environments is the extent and scale to which marine features (flora, fauna and habitats) respond to stress. Sensitivity is typically measured using indicators that respond to natural or anthropogenic stress (Zacharias & Gregr 2005).

The most commonly used approach to sensitive area mapping for hydrocarbon spills that is applied to both coastal and inland areas is the Environmental Sensitivity Index (ESI). ESI was first applied in 1979, when prototype ESI maps were prepared following a well blow out from the Ixtoc I oil well in the Gulf of Mexico, maps were produced only days prior to the oil slick arriving in Texas waters (Jensen et al, 1998). Significant effort has since been expended developing sensitivity mapping components of oil spill contingency plans around the world. Over the last 30 years the ESI approach has been implemented in countries such as The United States, Canada, United Arab Emirates, Israel, Jordan, El Salvador, Germany, South Africa, Mauritius, and New Zealand (Jensen et al. 1998).

The ESI identifies sensitive and vulnerable marine areas (Zacharias & Gregr 2005) and ranks them according to their vulnerability to oiling and ecological or social importance using a colour coding system. This provides response teams with an easily interpreted map that facilitates the prioritisation of appropriate resources during an emergency response. Shoreline classifications developed to support ESIs are hierarchical, encompass many types of recourses and are based on human use, coastal type and biological features at high spatial resolution (Zacharias & Gregr 2005).

The principal purpose of oil spill response is to protect resources. This requires information such as an OSSM on the most critical features in a region (Jensen et al. 1998).

The most widely used and accepted ranking system is based on the National Oceanic and Atmospheric Administration (NOAA), 2002 Following an extensive literature review it was decided that the NOAA ranking system would be used in this report due to its international acceptance and relevance to the scope. This report follows Environmental Sensitivity Index Guidelines Version 3.0 with some modifications (changes to benthic features and level of sensitivity) to account for the differences in biological and physical features of the North Western Australian region to that of the United States.

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The ESI is a spatial ranking system comprised of three components (Jensen et al. 1998): human use features, coastal type features and biological features.

- Human-Use Features–specific areas that have added sensitivity and value because of their use, such as beaches, parks and marine sanctuaries, water intakes, and heritage sites.
- Coastal type features–ranked according to a scale (1 – 10) relating to sensitivity, natural persistence of oil, and intensity of required cleanup efforts.
- Biological Features–including sensitive fauna and flora (non-mobile species); and habitats, such as submersed aquatic vegetation and coral reefs. They also include known seabird rookeries and turtle hatching sites (NOAA 2002).

With the ESI ranking system each shoreline and offshore type receive a numeric value, which is reflective of the relative sensitivity of that area to an oil spill (Mosbech et al. 2000).

1.4.1 Human use features

Many human use resources or features such as public beaches can be impacted from oil spill events. In addition, the inclusion of human use features on the OSSM is beneficial to oil spill responders aiming to locate access points to potential affected areas. The ESI method identifies human use features that are of high social and economic importance (NOAA 2002).

In typical ESI mapping systems, there are four types of human-use resources mapped:

❖ Shoreline access and recreational use areas, such as boat ramps, recreational beaches, and recreational-fishing and diving areas.

❖ Natural resource management or protected areas, such as national parks, marine sanctuaries, national wildlife refuges, preserves, and reserves.

❖ Commercial resources, such as commercial fisheries, mining leases, and surface water intakes.

❖ Historical and cultural sites, including lands managed by Aboriginal heritage and communities. Cultural sites located in the intertidal zone or close to the shoreline where they could be damaged by cleanup crews are at particular risk (NOAA 2002).

Examples of human use features on coastal resources maps developed using the NOAA classification system include:

- Towns and settlement
- Historical sites
- Harbours
- Commercial Fishing Zones
- Industrial, mining and port facilities
- Nature Reserves
- Tourism Areas

1.4.2 Coastal features

Coastal and island habitats are at risk during oil spill events. The effect of oil spills on coastal habitats varies extensively depending on the physical features of the coast itself and the metocean conditions to which it is exposed (NOAA 2002). The primary factors that influence the sensitivity of coastal types to an oil spill include the relative exposure to wave and tidal energy, shoreline slope, substrate type

1 Introduction

(grain size, mobility, penetration and/or burial), and biological productivity and sensitivity. The coastal feature types commonly used and types relevant to this study include:

- Sandy Beaches
- Rocky shores
- Mangroves
- High tidal mud flats
- Coral Reefs

For subtidal habitat features, the likelihood of contact with the oil through events such as dispersion is minimal and should be taking into consideration during planning phases for spill response. The processes that can affect subtidal habitats can be found in section 1.3 of this report.
A characterisation of coastal feature types found at the Wheatstone project site is provided in Appendix A.

1.4.3 Biological features

Biological features of the sensitivity map include ecological important habitats, threatened or endangered species, as well as other species and areas of commercial or recreational importance (Jensen, Halls and Michael 1998). To set safeguard strategies and mitigate environmental degradation, the aim of the biological mapping component is to emphasize the locations and areas of highest concentrations, the most sensitive life stages or activities and the most vulnerable species (Jensen et al. 1998).

Overviews of the biological features specific to this study site are provided in Appendix A-2.

1.5 Purpose of this report

In the unlikely event that a hydrocarbon spill occurs as a result of activities at the proposed Wheatstone Project site, the OSSM will become a useful indicative tool for spill responders. The maps produced are created to assist spill responders with decision making by directing resources to those areas most sensitive and vulnerable. The maps are also able to be used for planning to identify locations that are sensitive to potential oil spills and establish protection priorities and identify cleanup strategies (NOAA 2002). The maps indicate sensitive features of the Wheatstone project area and indicate road or vessel access to these features in the case of a spill. The addition of the spill trajectory plots also helps managers predict which sensitive features are most likely to be contacted by a spill originating at the Wheatstone MOF and PLF.

The OSSM maps provide a summary of coastal resources that are sensitive to a potential spill. The objectives of the hydrocarbon spill sensitivity mapping report were;

- To provide Chevron with a planning tool to identify sensitive features of the project area does not include potential management of mitigation.
- Produce a map and associated report highlighting sensitive coastal features that could be potentially threatened in the event of a spill in the project area.

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2

Methodology

2.1 Environmental Sensitivity Index (ESI)

The NOAA classification system was selected as the most suitable methodology to produce the ESI for the oil spill sensitivity map in this report. To produce the ESI, sensitive features were divided into three categories derived from the NOAA ESI, and modified to suit the habitat, human use and biological features appropriate to the Project area and are outlined in Tables 2-1, 2-2 and 2-3 (NOAA 2002). The areas/sites relevant to this study were obtained from the GIS resources outlined in section 2.2.

2.1.1 Human use features

Human use features were identified using the human use groups outlined in the NOAA classification system. The human use features derived for this study are shown in Table 2-1.

Table 2-1 ESI human use classification and ranking

Human Use Group	Areas/Sites Mapped
Management	Marine Management Area Marine Park Nature Reserve Built Up Areas Proposed Conservation Areas (CALM 1994) Onslow Salt Shipping Channel Onslow Prawn Trawled Area 2004-06
Water	Water Dam/Tanks Water Tanks
Emergency/Hospital	Hospital Volunteer Marine and Emergency Service Station
Weather station	Onslow weather station (BOM 2010)
Town	District Hub
Police	Police Station Police Station 24hr
Airports	Major Airport Heliport Minor Airport
Schools	College Tertiary High Primary Special Lighthouses Helicopter Landing Sites Vehicle Parking Sites
Roads	Major Road Minor Road Track Vehicle Parking Sites

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Generalised EIS Marine Facilities	Indicative Jetty Indicative Breakwater MOF Dredge Area Turning Basin Dredge Area Town site Homesteads
Marine Infrastructure Lines	Breakwater Jetty Sea Wall Wharf Line
Pondage Areas	Salt Evaporator Settling Pond Salt Crystalliser Evaporating Ponds
Power	Power Station
Recreational	Caravan Parks/Camping Area Built Up Areas Homesteads Most Popular Fishing Sites Broadcasting Station

2.1.2 Coastal type features

Coastal type features used to develop the ESI have been developed using the NOAA ESI classification system, which ranks coastal types based on their susceptibility to oil spills. The coastal types have been extracted from the GIS resources and ranked according to the modified NOAA ESI system and outlined in section 1.4. The coastal type features used for this study are shown in Table 2-2. Descriptions for each coastal feature and its associated sensitivity index can be found in Appendix A.

Table 2-2 ESI Coastal Type Classification and Ranking from 1 (least sensitive) to 10 (most sensitive).

ESI Ranking	Coastal Type and Classification
1	Man made structures
2	Supratidal
3A	Sandy Beaches
3B	Sand bars and shoals
4A	Bank (sand)
4B	Patch (gravel)
4C	Subtidal sand
5	Lagoon Flat
6	High Tidal Mudflats (Salt flats, bioturbation, Samphire and Algae mat)
7	Rocky Shores
8	Intertidal Rock Platform
9	Shoal Porities/Bommies
10A	Mangroves
10B	Coral Reef and river Mouth

2 Methodology

2.1.3 Biological features

The biological features used to develop the ESI have been developed from the NOAA ESI classification system, which ranks biological features based on their susceptibility to oil spills and ecological importance. The biological features have been derived from the GIS resources outlined in section 2.2 which include extensive marine and terrestrial habitat surveys within the Project area. The biological features have been ranked according to the modified NOAA ESI system and outlined in section 1.4. The biological features derived for this study are shown in Table 2-3.

Table 2-3 ESI Biological Features Classification and Ranking

Biological Group	Biological Sub Groups	Areas/Sites Mapped
Birds	Shore birds Wading birds Diving birds Waterfowl Gulls and Terns	Rookeries Nesting sites Foraging grounds Migratory/feeding concentrations Migratory stopover concentrations
Marine Reptiles	Turtles	Turtle Hatched Nests Turtle Nests High density nesting Medium density nesting Low density nesting
Habitats and Plants	Coral Reefs	Living, reef-building coral areas; rare species
Wetlands	Special/rare wetland, plants or habitats.	Communities

2.2 GIS Methodology

The geospatial analysis input to the hydrocarbon spill sensitivity modelling was based on NOAA Environmental Sensitivity Index Guidelines Version 3.0 (NOAA 2002), ESRI Improving Emergency Planning and Response with Geographic Information Systems, and 'KenSea – Environmental Sensitivity Atlas for Coastal Areas of Kenya' (Tychsen 2006). Other resources that were utilised include Australian Maritime Safety Authority website (AMSA), Geoscience Australia GIS website (GA), the Dept. of Environment and Conservation (DEC) and site specific data collected and validated for the Wheatstone Environmental Impact Statement (EIS)/ Environmental Review and Management Program (ERMP) (Chevron 2010).

The purpose of the GIS analysis is to visualise and delineate coastal, biological and human use features that might be affected by a potential condensate and diesel spill event.

Due to a difference in GIS data scales over a large geographical extent, data has been fused together into a single GIS layer during the modelling phase. Consequently, maps with varying degrees of detail have been amalgamated to form one level of detail at two scales including 1: 100 000 and 1: 55 000.

The Geospatial component was performed in three phases;

- Phase 1 : Coastal Resource Maps
- Phase 2 : Environmental Sensitivity Map (ESM)
- Phase 3 : Overlays for Oil spill Modelling

2 Methodology

2.2.1 Phase 1 Coastal resource maps:

The construction of the Coastal Resources map consist of several GIS layers which are presented as four maps that include:

- Regional Topography map
- Biological Resources Map
- Human Resources Map
- Coastal Features Map

The appropriate data was sourced from previous baseline survey work for the Wheatstone Project along with hydrographical navigation charts that contained Geoscience Australia (GA) GIS data and terrestrial features and any additional known logistical information that could be used to assist emergency planning was also added.

The Regional Topography map's main focus is to illustrate the method selected to accomplish the task which included combing hydrographical navigation charts with GA GIS data showing terrestrial features.

The Biological Resource Map is the second geospatial product, as part of the Coastal Resource Maps series. The maps were produced in the same scales and sizes as the topographic maps. The main purpose of the products is to show the position of permanent locations accessed by fauna that may be affected in the event of a hydrocarbon spill, including turtle nesting locations and seabird nesting locations. There is a possibility that other marine fauna may be in the area, such as Whales, Dolphins and Dugongs, however due to the mobile nature of these marine animals they were not included in the mapping process.

The Human Use Map is the third geospatial product; the main purpose of the product is to show human interaction in the region that could be potentially affected in the event of the spill scenario. The population of Onslow uses the area for many functions including recreational and commercial activities. The information displayed on the maps covers all known activities and uses. This includes population centres, caravan parks, camping sites, broadcasting station, schools, police station, Onslow Salt Company infrastructure, marine parks, fishing spots and a hospital. The information included locations of a police station, a school, a hospital and a power station.

2.2.2 Phase 2 Environmental Sensitivity Map (ESM)

The ESI map was constructed using a data model result. The data model is a construct from geoprocessing of data using ESI ranking (see section 1-4). The GIS data were delineated based on geographical features sensitive to the spill scenario and were differentiated based on varying symbols. The ESI Map has been adapted to suit the project area. Various GIS data was fused into a singular dataset to produce a classification table (Table 2-2).

2.2.3 Phase 3 Overlays of Oil Spill Modelling maps

The final phase of the GIS methodology is to overlay oil spill modelling outputs on the ESM to predict the potential area and sensitive features that could be impacted. Using the area occupied by the 24hr minimum time to exposure of a condensate spill at the PLF and a diesel fuel spill at the MOF for varying seasonal scenarios, the predicted area (ha) of human use, coastal type and biological features were quantified using ARCGIS (ESRI, ARCGIS 9.3.1).

Results

3.1 Project Area Oil Spill Sensitivity Maps

All the oil spill sensitivity mapping outputs have been produced in either an A0 or A3 format. Due to their size and complexity the A0 maps showing the complete geographical extent covered in this study maps are presented separately, outside of the report. The A3 maps showing greater resolution within the Project area are presented in Section 3.3 (Figures 3-1 to 3-5) of this report.

3.1.1 Human Use features

Some human use features were identified as being potentially impacted in the event of an oil spill. These are the Onslow Prawn fishery fishing grounds and several areas used for recreational, environmental or heritage use (Thevenard Island, Locker Island, Round Island and Serrurier Island nature reserves and Ashburton Island and the intertidal areas of Onslow from Baresand Point in the south to Beadon Point and Coolgra Point in the north), the areas surrounding the project area are illustrated in Figure 3-1 and A0 Regional Human use map.

3.1.2 Biological features

The major biological feature at risk is Turtles, a number of important nesting sites exist in the area. High density nesting of turtles has been found to occur at Serrurier Island and Ashburton Islands shown in Figure 3-2 (Full extent of the biological features is shown in the A0 map - Biological Resource Map). Medium and low density turtle nesting has been found to occur at Thevenard, Direction, Bessieres and Locker Islands as well as Onslow Beaches South, between Ashburton River Mouth and Entrance Point. Recorded seabird breeding also occurs on Round, Serrurier, Tortoise, Locker, Ashburton, Thevenard, Direction and North Mangrove Islands.

3.1.3 Coastal type features

Coastal type features that could potentially be affected by an oil spill event is dependant on the time and location of the spill. Spill simulations were run to identify potentially affected areas, the habitats and features affected are detailed below.

MOF Spill Simulation Time of Exposure <24 hours summer

The ESI maps indicate that the area of highest sensitivity during a summer spill from the MOF is the entrance to Hooley Creek and Middle Creek as well as the entrance to Four Mile Creek. This is due to the high value of Mangroves (See Appendix A, Mangroves) found at Hooley Creek, Middle Creek and Four Mile Creek. There is also a potential for the Ward Reef to be affected (Figure 3-6).

MOF Spill Simulation Time of Exposure <24 hours transition between seasons

The area that would be potentially affected would be from Beadon Point to Entrance Point (Figure 3-7). Again the entrance to Hooley Creek, Middle Creek and Four Mile Creek present the greatest risk from suffering the effects of a potential oil spill. Ward Reef is also predicted to be affected if the spill were to reach the east side of the reef. The greatest threat is to Entrance Point, due to the large intertidal and mangrove habitat that occurs within the area if the spill reaches the entrance to the point, it could potentially enter this high value habitat.

MOF Spill Simulation Time of Exposure <24 hours winter

The entrances to Hooley Creek and Middle Creek as well as Entrance Point have the highest ESI ranking for the winter MOF spill simulation. With the spill predicted to encompass the area south of the Project area to Entrance Point and seaward to Curlew and Gravel Banks. The area potentially affected is shown in Figure 3-8.

Loading Jetty Spill Simulation Time of Exposure <24 hours summer

The South eastern area of Ashburton Island will be affected by a summer spill from the Loading Jetty. In addition, coastal areas producing high ESI rankings that can be impacted are the entrances to the Ashburton River, Hooley and Middle Creek, Four Mile Creek and Entrance Point (Figure 3-9).

Loading Jetty Spill Simulation Time of Exposure <24 hours transition between seasons

A summer spill from the Loading jetty results in a North West flow. With Ward Reef, Gorgon Patch, Weeks Shoal and Twin Island all being affected (Figure 3-10). Entrances to creeks and rivers ranging from Entrance Point in the south and Coolgra Point in the North also present high environmental sensitivity.

Loading Jetty Spill Simulation Time of Exposure <24 hours winter

A winter spill will result in a more localised spill area, affecting coastal entrances from Entrance Point to Beadon Point (Figure 3-11). Offshore, the only area of high sensitivity that will be in contact with the spill is Ward Reef.

3.2 Oil Spill Modelling Overlay Maps

The oil spill modelling overlay maps have been produced in either an A0 or A3 format. Due to their size and complexity the AO maps are presented outside of this report (complete geographical extent covered in this study). The A3 maps show greater resolution within the Project area is presented in Section 3.3 (Figures 3-6 to 3-11).

3.3 Predicted Areas of Impact to Sensitive Features

Tables 3-1 to 3-6 list the predicted areas of impact to human use, coastal type and biological features. These areas are based on simulations of hypothetical spill events associated with Project infrastructure.

Table 3-1 Estimated impact areas for MOF Spill Simulation, Time of exposure <24hr - Transition (DHI, 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	18.74
Corals	10	4.32
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	70.10
Intertidal Rock Pavement	7	68.80
Lagoon Flat	5	6.51
Man made structures	1	0.54

3 Results

Mangroves	9	27.96
Sand Bars and Shoals	3	40.90
Sandy Beaches	2	21.03
Shoals	8	8.01
Subtidal Rock Pavement	4C	121.78
Supratidal	N/A	1.43
Total Area (ha)		**390.1**

Table 3-2 Estimated impact areas for MOF Spill Simulation, Time of exposure <24hr - Summer (DHI 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	22.66
Corals	10	4.32
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	114.76
Intertidal Rock Pavement	7	104.51
Lagoon Flat	5	21.71
Man made structures	1	0.57
Mangroves	9	59.14
Sand Bars and Shoals	3	41.89
Sandy Beaches	2	29.42
Shoals	8	8.32
Subtidal Rock Pavement	4C	161.46
Supratidal	N/A	2.01
Total Area (ha)		**570.9**

Table 3-3 Estimated impact areas for MOF Spill Simulation, Time of exposure <24hr - Winter (DHI 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	16.49
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	49.19
Intertidal Rock Pavement	7	8.71
Lagoon Flat	5	20.92
Mangroves	9	16.40
Sand Bars and Shoals	3	14.05
Sandy Beaches	2	9.11
Subtidal Rock Pavement	4C	47.70
Supratidal	N/A	0.22
Total Area (ha)		**182.8**

3 Results

Table 3-4 Estimated impact areas for Loading Jetty Plume Simulation, Time of exposure <24hr - Transition (DHI 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	22.84
Corals	10	34.34
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	77.39
Intertidal Rock Pavement	7	56.19
Lagoon Flat	5	2.68
Man made structures	1	0.51
Mangroves	9	21.08
Sand Bars and Shoals	3	29.03
Sandy Beaches	2	35.99
Shoals	8	82.14
Subtidal Rock Pavement	4C	157.47
Supratidal	N/A	27.96
Total Area (ha)		**547.6**

Table 3-5 Estimated impact areas for Loading Jetty Spill Simulation, Time of exposure <24hr - Summer (DHI 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	22.84
Corals	10	34.34
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	77.39
Intertidal Rock Pavement	7	56.19
Lagoon Flat	5	2.68
Man Made structures	1	0.51
Mangroves	9	21.08
Sand Bars and Shoals	3	29.03
Sandy Beaches	2	35.99
Shoals	8	82.14
Subtidal Rock Pavement	4C	157.47
Supratidal	N/A	27.96
Total Area (ha)		**547.6**

Table 3-6 Estimated impact areas for Loading Jetty Spill Simulation, Time of exposure <24hr - Winter (DHI, 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	55.33
Corals	10	54.83
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	67.13
Intertidal Rock Pavement	7	78.11
Lagoon Flat	5	16.54

3 Results

Mangroves	9	28.05
Patch (gravel)	4B	59.85
Sand Bars and Shoals	3	74.91
Sandy Beaches	2	56.73
Shoals	8	59.89
Subtidal Rock Pavement	4C	134.09
Supratidal	N/a	24.50
Total Area (ha)		**710.0**

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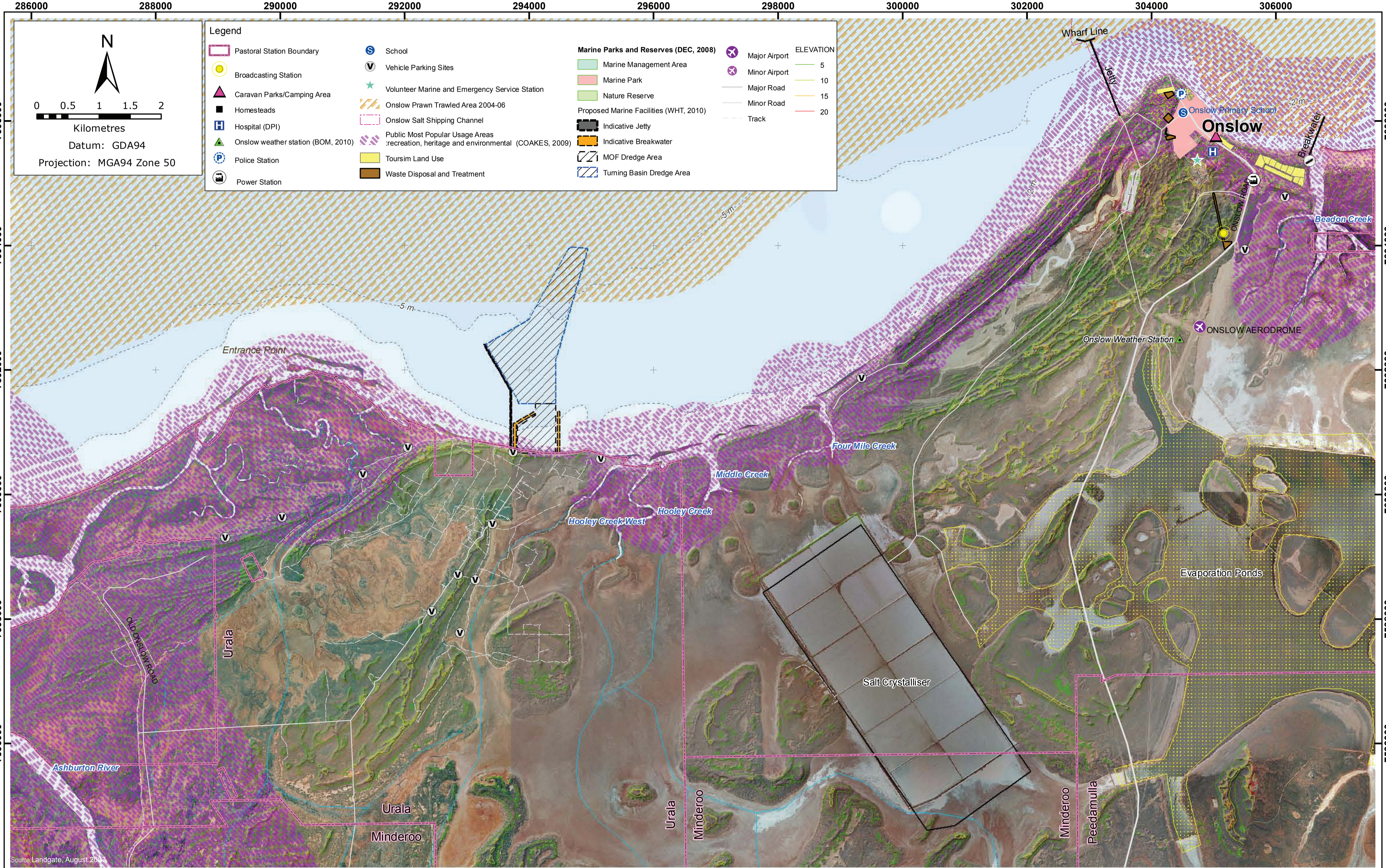

For Hydrocarbon Spill Scenario Briefing Purposes Only.
Map contains best available data at time of analysis.

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Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	Regional Human Use
URS	Drawn: MR / CJT · Approved: DO · Date: 27/10/2010 Job No.: 42907466 · File No.: 42907466-HSSM-001B_RF.mxd	Figure: 3-1 · Rev. F · A3

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Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	Biological Resource Map
URS	Drawn: MR / CJT; Approved: DO; Date: 27/10/2010 Job No.: 42907466; File No.: 42907466-HSSM-002B_RH.mxd	Figure: 3-2; Rev. H; A3

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Map contains best available data at time of analysis.

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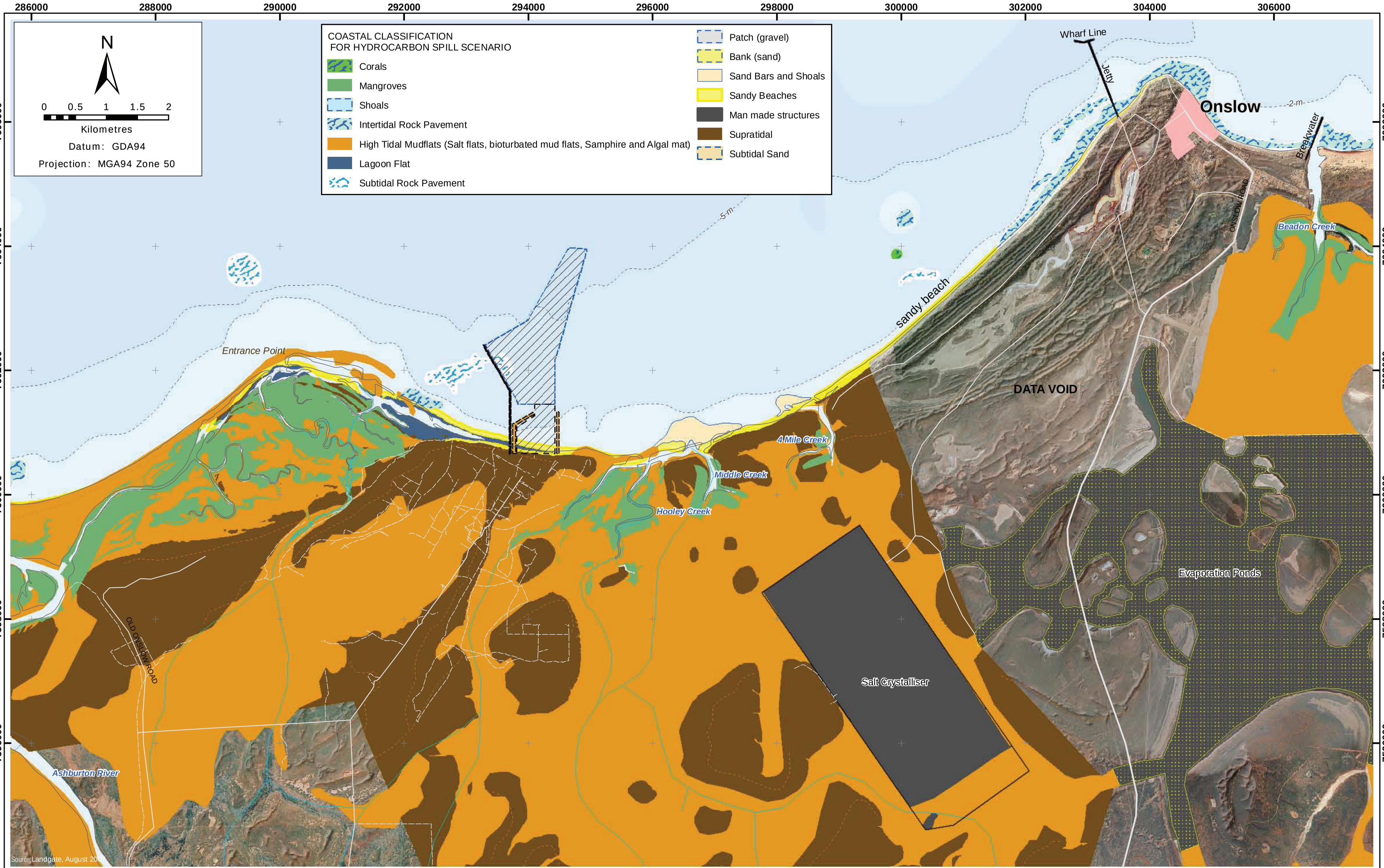

Legend

- Built Up Areas
- Sand Ridges
- Salt Cristaliser
- Evaporating Ponds

Proposed Marine Facilities (WHT, 2010)

- Indicative Jetty
- Indicative Breakwater
- MOF Dredge Area
- Turning Basin Dredge Area

For Hydrocarbon Spill Scenario Briefing Purposes Only.
Map contains best available data at time of analysis.

Client	Project			Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping			Coastal Classification	
URS	Drawn: MR / CJT	Approved: DO	Date: 27/07/2010	Figure: 3-3	Rev. G
	Job No.: 42907466	File No.: 42907466-HSSM-003B_RG.mxd			A3

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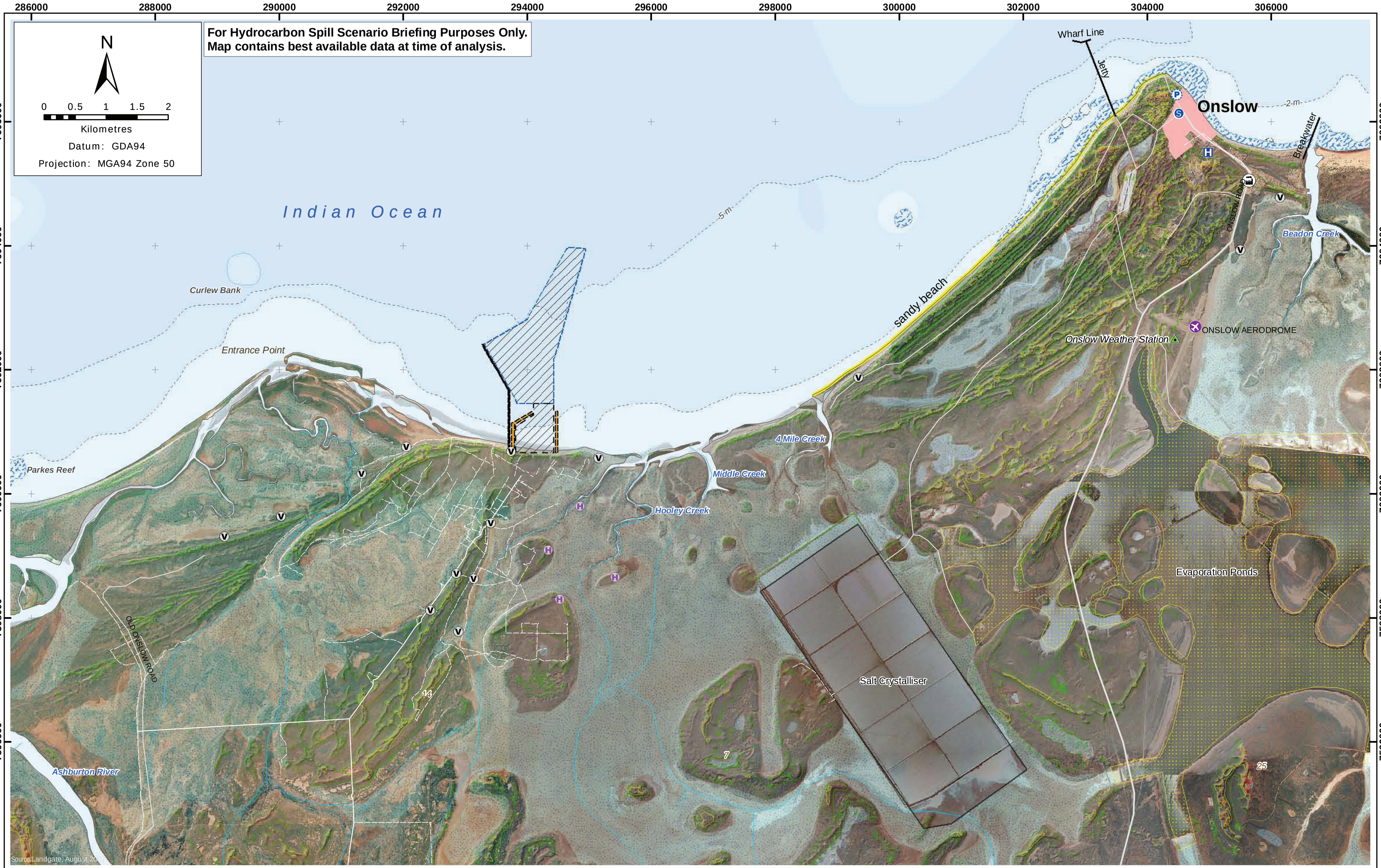

Legend

- Boundary of State Waters (GA, 2006)
- Power Station
- Hospital (DPI)
- Onslow weather station (BOM, 2010)
- Police Station
- School
- Helicopter Landing Sites
- Vehicle Parking Sites
- Major Road
- Minor Road
- Track

Proposed Marine Facilities (WHT, 2010)

- Indicative Jetty
- Indicative Breakwater
- MOF Dredge Area
- Turning Basin Dredge Area
- Salt Cristaliser
- Evaporating Ponds
- Swamp
- Saline Coastal Flat
- Land Subject To Inundation

ELEVATION

- 5
- 10
- 15
- 20

Client	Project	Title	
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	Topography	
URS	Drawn: MR / CJT; Approved: DO; Date: 27/07/2010	Figure: 3-4	Rev. G
	Job No.: 42907466; File No.: 42907466-HSSM-005B_RG.mxd		A3

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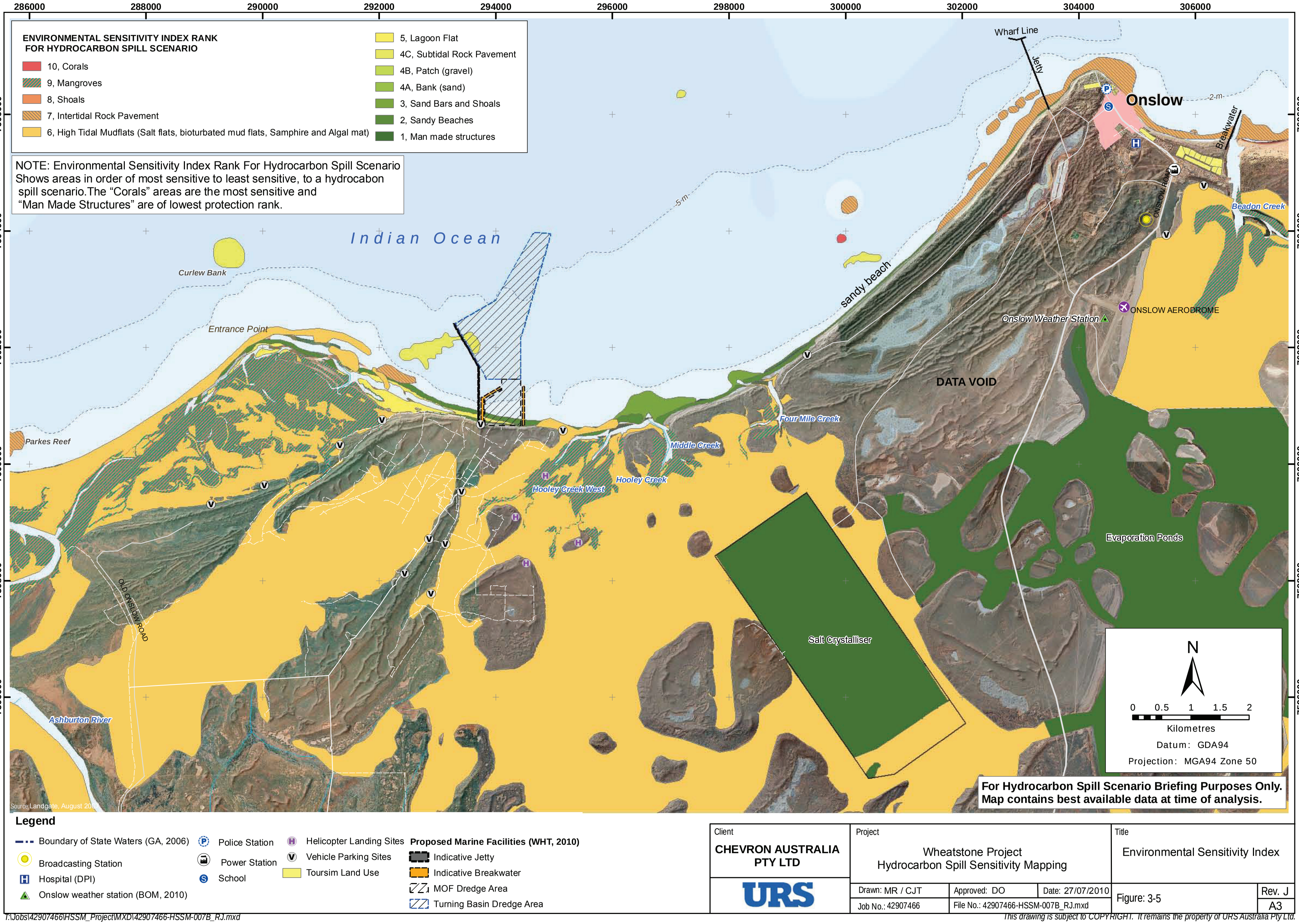

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project Hydrocarbon Spill Sensitivity Mapping		Title: Environmental Sensitivity Index
Drawn: MR / CJT	Approved: DO	Date: 27/07/2010	Figure: 3-5
Job No.: 42907466	File No.: 42907466-HSSM-007B_RJ.mxd		Rev. J / A3

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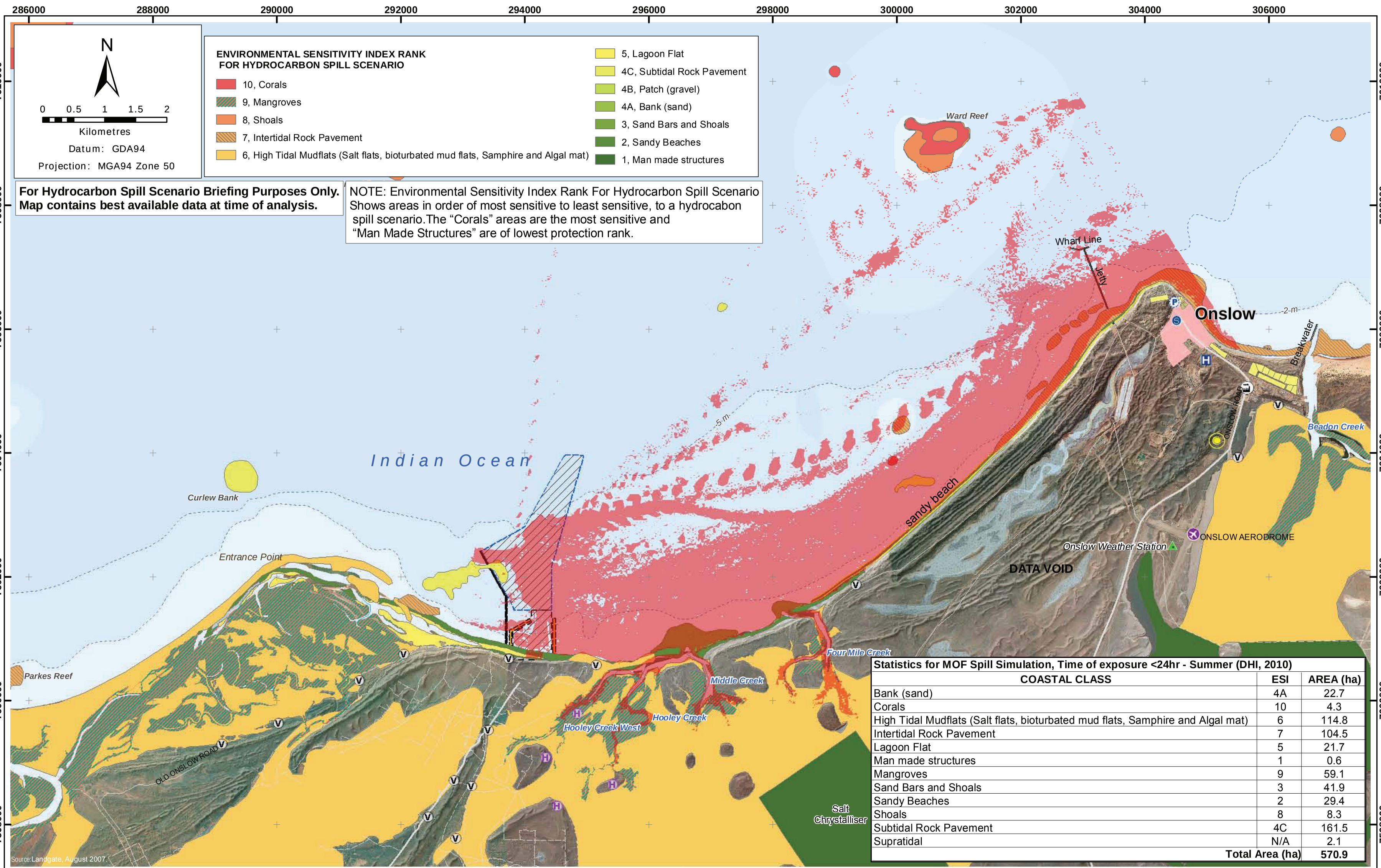

Statistics for MOF Spill Simulation, Time of exposure <24hr - Summer (DHI, 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	22.7
Corals	10	4.3
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	114.8
Intertidal Rock Pavement	7	104.5
Lagoon Flat	5	21.7
Man made structures	1	0.6
Mangroves	9	59.1
Sand Bars and Shoals	3	41.9
Sandy Beaches	2	29.4
Shoals	8	8.3
Subtidal Rock Pavement	4C	161.5
Supratidal	N/A	2.1
	Total Area (ha)	570.9

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	MOF Spill Simulation Time of Exposure <24 hours Summer
URS	Drawn: MR / CJT; Approved: DO; Date: 27/07/2010; Job No.: 42907466; File No.: 42907466-HSSM-008B_RD.mxd	Figure: 3-6; Rev. D; A3

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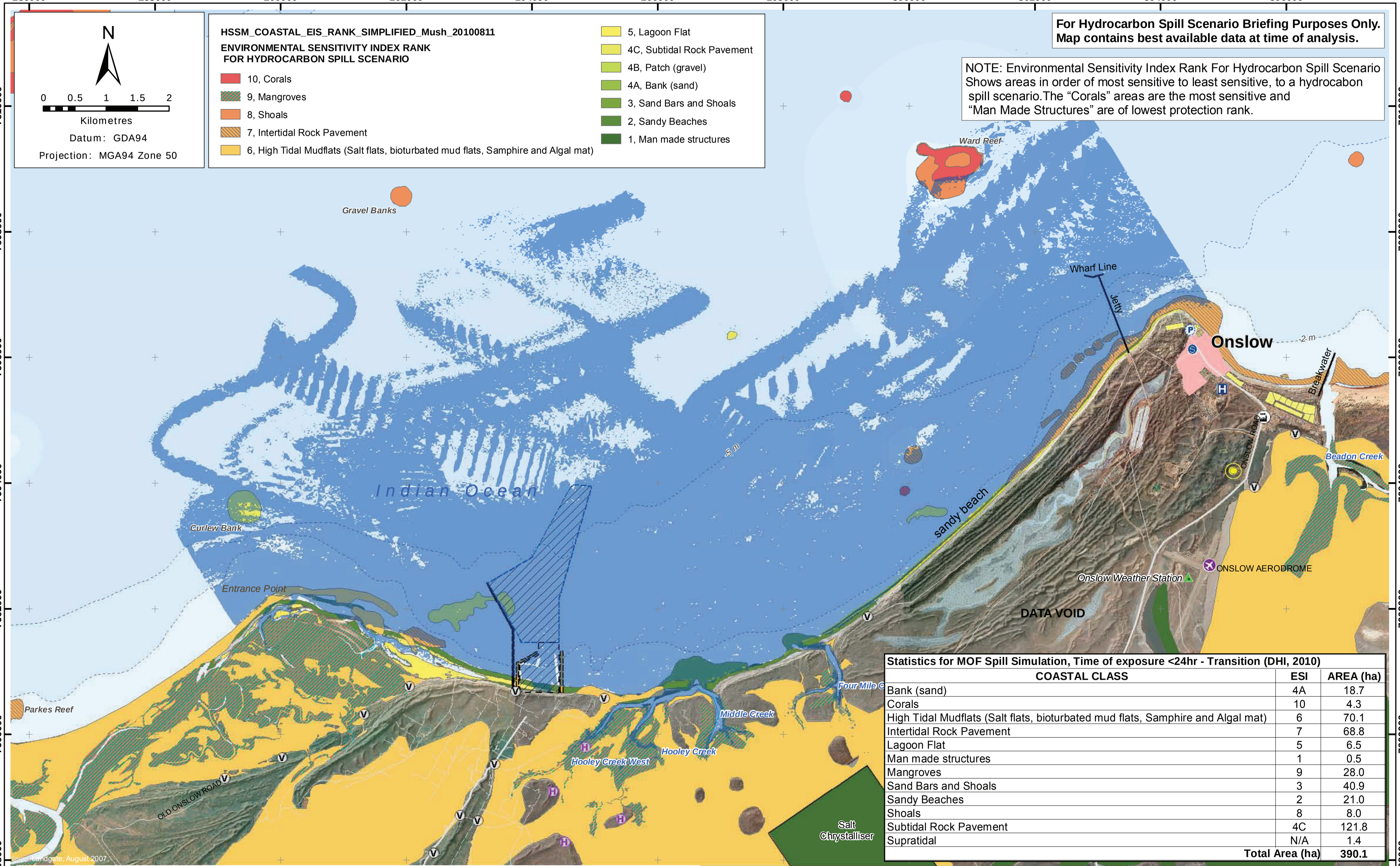

Statistics for MOF Spill Simulation, Time of exposure <24hr - Transition (DHI, 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	18.7
Corals	10	4.3
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	70.1
Intertidal Rock Pavement	7	68.8
Lagoon Flat	5	6.5
Man made structures	1	0.5
Mangroves	9	28.0
Sand Bars and Shoals	3	40.9
Sandy Beaches	2	21.0
Shoals	8	8.0
Subtidal Rock Pavement	4C	121.8
Supratidal	N/A	1.4
	Total Area (ha)	390.1

Legend

MOF,Spill Simulation, Time of exposure <24hr (DHI, 2010)
- Transition Between Seasons Spill Simulation
- Broadcasting Station
- Hospital (DPI)
- Onslow weather station (BOM, 2010)
- Police Station
- Power Station
- School
- Helicopter Landing Sites
- Vehicle Parking Sites
- Toursim Land Use

Proposed Marine Facilities (WHT, 2010)
- Indicative Jetty
- Indicative Breakwater
- MOF Dredge Area
- Turning Basin Dredge Area

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	MOF Spill Simulation Time of Exposure <24 hours Transition Between Season
URS	Drawn: MR / CJT · Approved: DO · Date: 27/07/2010 Job No.: 42907466 · File No.: 42907466-HSSM-009B_RD.mxd	Figure: 3-7 · Rev. D · A3

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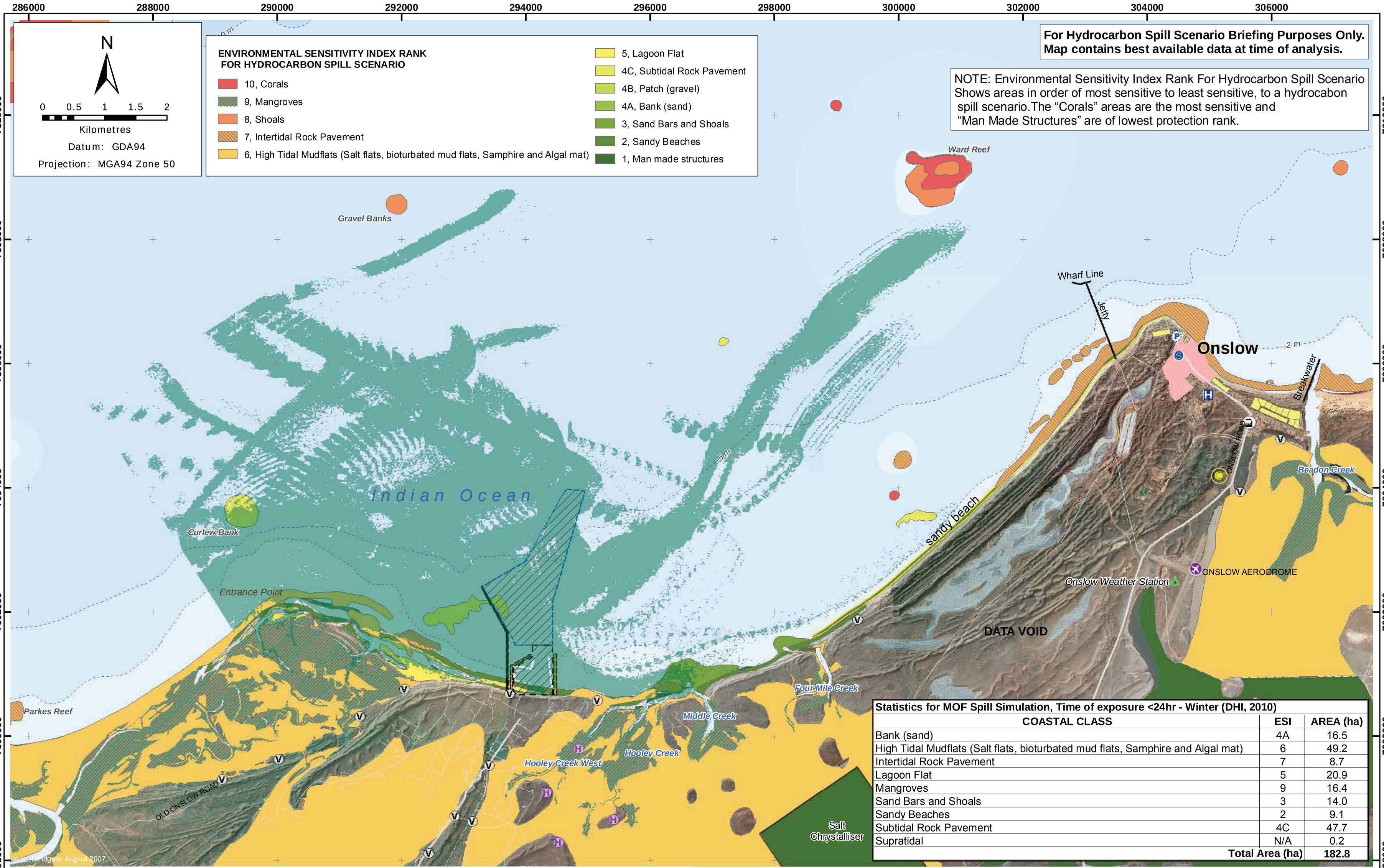

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	16.5
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	49.2
Intertidal Rock Pavement	7	8.7
Lagoon Flat	5	20.9
Mangroves	9	16.4
Sand Bars and Shoals	3	14.0
Sandy Beaches	2	9.1
Subtidal Rock Pavement	4C	47.7
Supratidal	N/A	0.2
	Total Area (ha)	182.8

Statistics for MOF Spill Simulation, Time of exposure <24hr - Winter (DHI, 2010)

Legend

MOF,Spill Simulation, Time of exposure <24hr (DHI, 2010)
- Winter Season Spill Simulation
- Broadcasting Station
- Hospital (DPI)
- Onslow weather station (BOM, 2010)
- Police Station
- Power Station
- School
- Helicopter Landing Sites
- Vehicle Parking Sites
- Toursim Land Use

Proposed Marine Facilities (WHT, 2010)
- Indicative Jetty
- Indicative Breakwater
- MOF Dredge Area
- Turning Basin Dredge Area

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	MOF Spill Simulation Time of Exposure <24 hours Winter
URS	Drawn: MR / CJT; Approved: DO; Date: 27/07/2010; Job No.: 42907466; File No.: 42907466-HSSM-010B_RD.mxd	Figure: 3-8; Rev. D; A3

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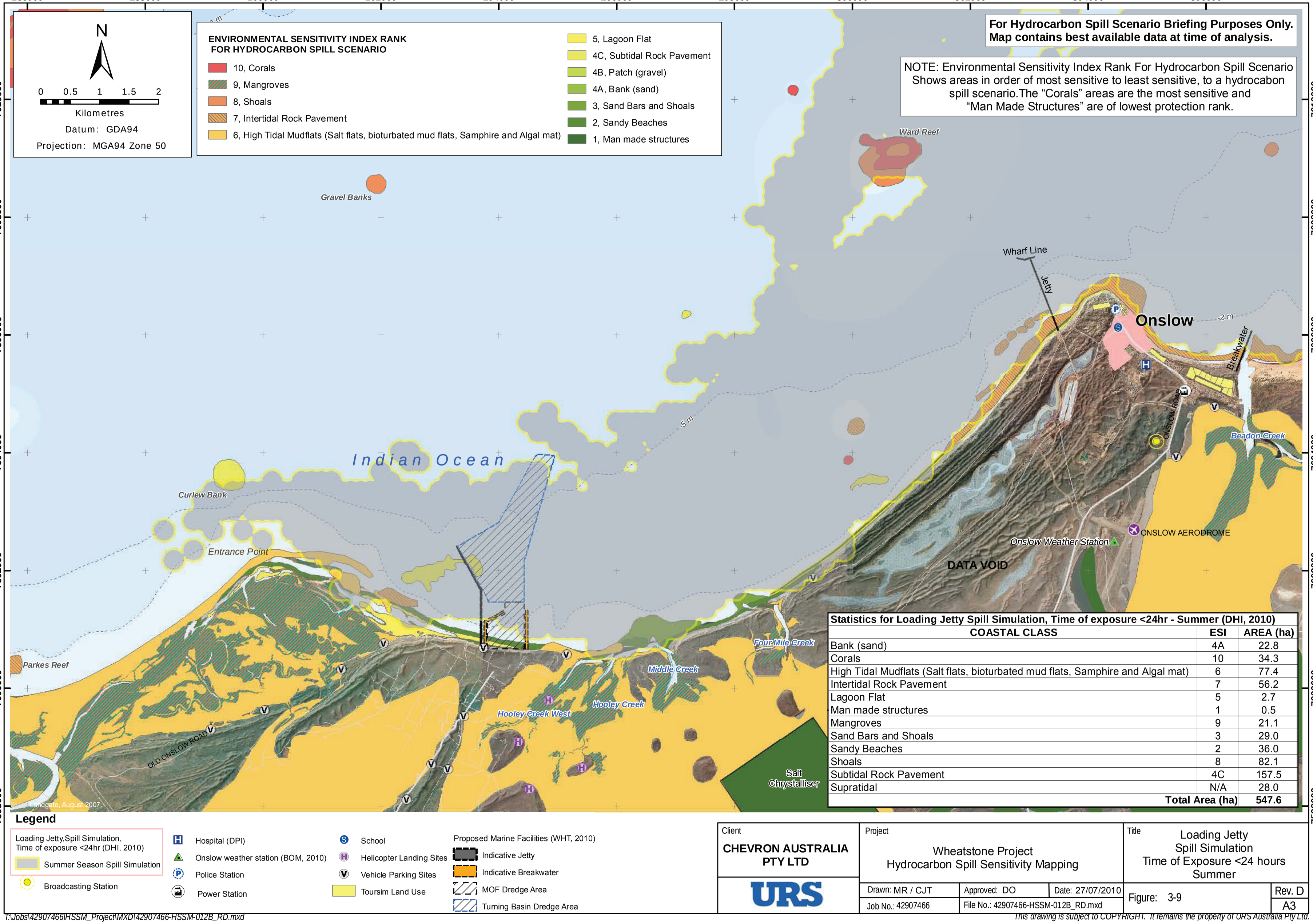

Statistics for Loading Jetty Spill Simulation, Time of exposure <24hr - Summer (DHI, 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	22.8
Corals	10	34.3
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	77.4
Intertidal Rock Pavement	7	56.2
Lagoon Flat	5	2.7
Man made structures	1	0.5
Mangroves	9	21.1
Sand Bars and Shoals	3	29.0
Sandy Beaches	2	36.0
Shoals	8	82.1
Subtidal Rock Pavement	4C	157.5
Supratidal	N/A	28.0
	Total Area (ha)	547.6

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	Loading Jetty Spill Simulation Time of Exposure <24 hours Summer
URS	Drawn: MR / CJT; Approved: DO; Date: 27/07/2010 Job No.: 42907466; File No.: 42907466-HSSM-012B_RD.mxd	Figure: 3-9; Rev. D; A3

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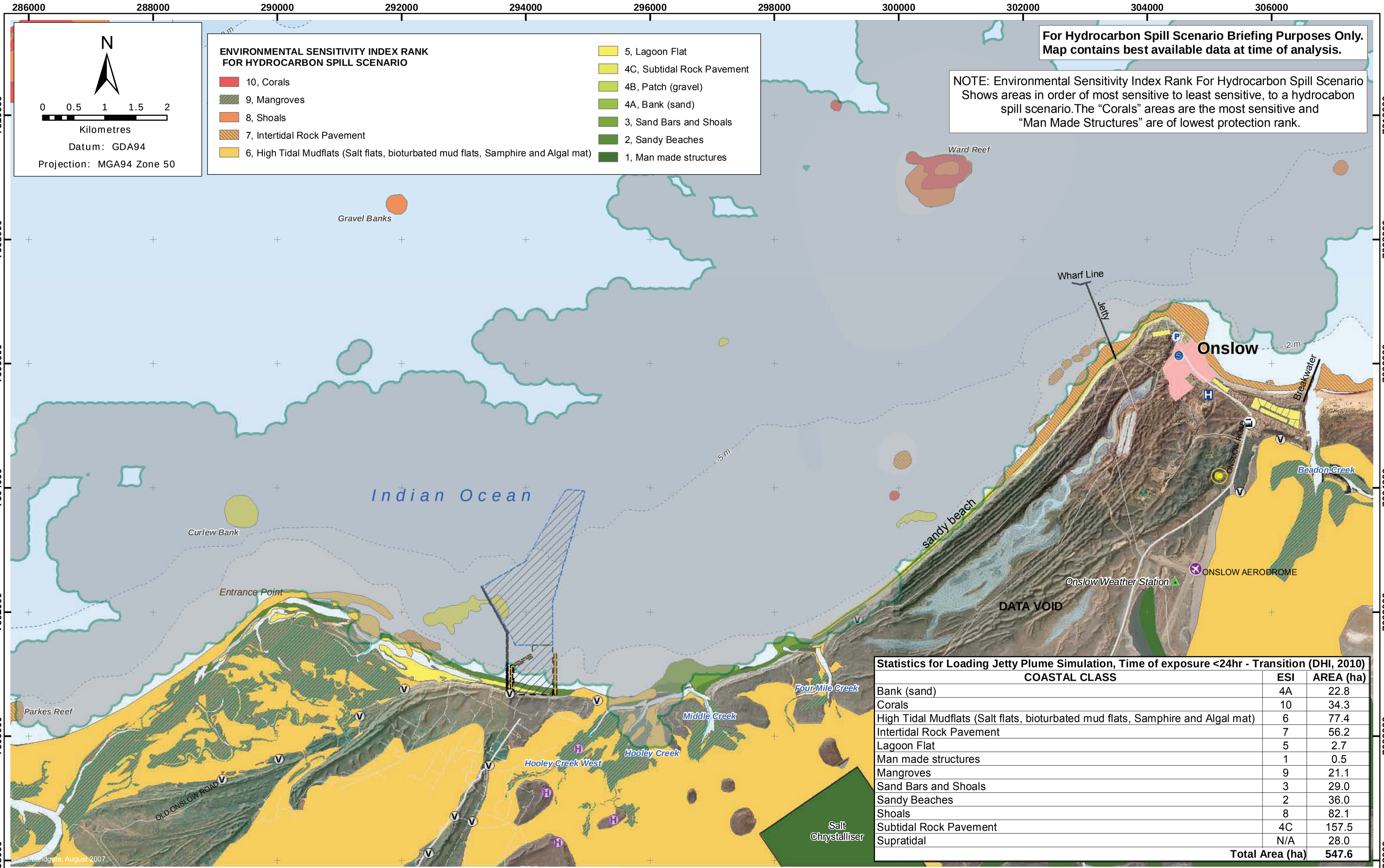

Statistics for Loading Jetty Plume Simulation, Time of exposure <24hr - Transition (DHI, 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	22.8
Corals	10	34.3
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	77.4
Intertidal Rock Pavement	7	56.2
Lagoon Flat	5	2.7
Man made structures	1	0.5
Mangroves	9	21.1
Sand Bars and Shoals	3	29.0
Sandy Beaches	2	36.0
Shoals	8	82.1
Subtidal Rock Pavement	4C	157.5
Supratidal	N/A	28.0
	Total Area (ha)	547.6

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	Loading Jetty Spill Simulation Time of Exposure <24 hours Transition Between Seasons

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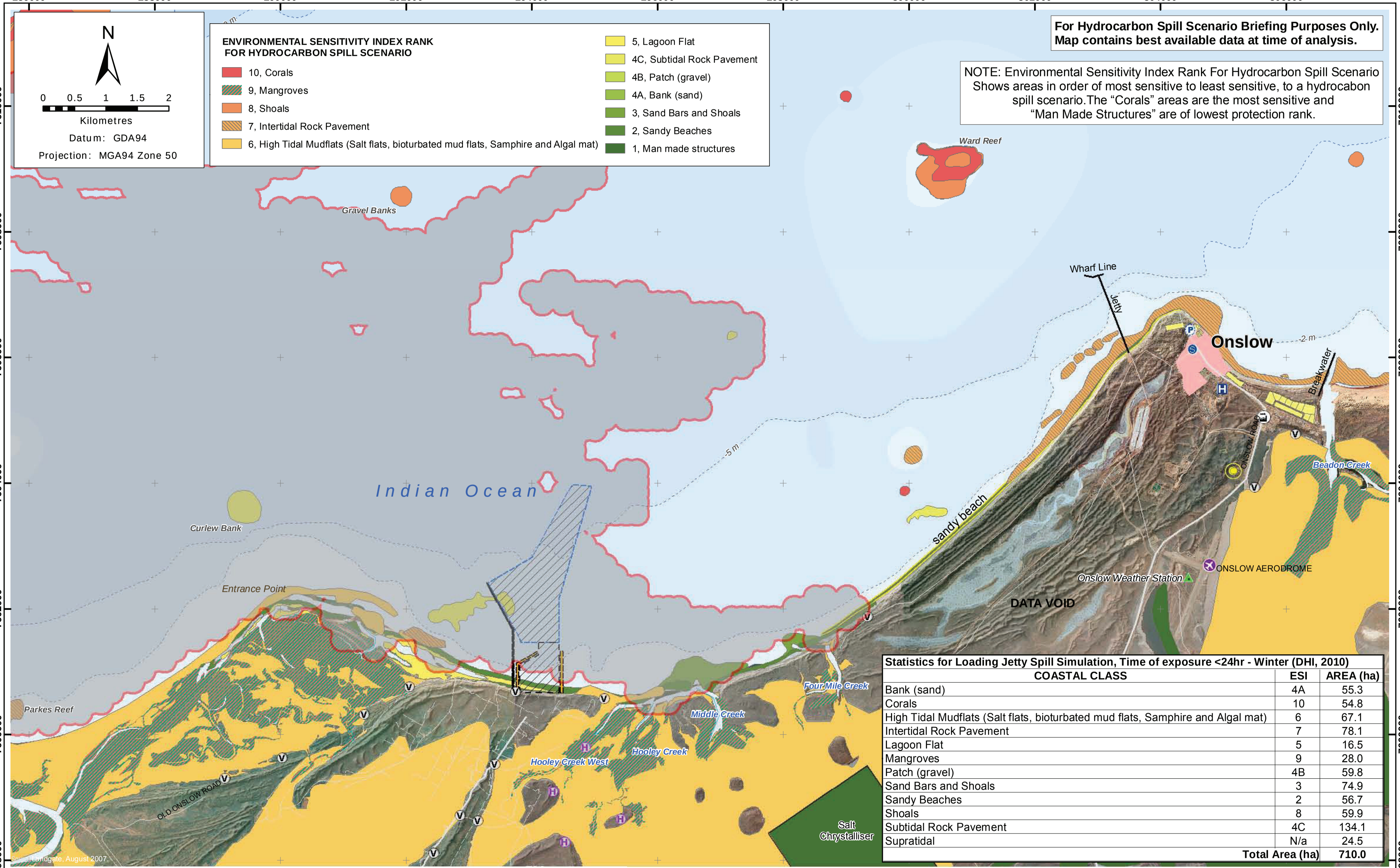

Statistics for Loading Jetty Spill Simulation, Time of exposure <24hr - Winter (DHI, 2010)

COASTAL CLASS	ESI	AREA (ha)
Bank (sand)	4A	55.3
Corals	10	54.8
High Tidal Mudflats (Salt flats, bioturbated mud flats, Samphire and Algal mat)	6	67.1
Intertidal Rock Pavement	7	78.1
Lagoon Flat	5	16.5
Mangroves	9	28.0
Patch (gravel)	4B	59.8
Sand Bars and Shoals	3	74.9
Sandy Beaches	2	56.7
Shoals	8	59.9
Subtidal Rock Pavement	4C	134.1
Supratidal	N/a	24.5
	Total Area (ha)	710.0

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project Hydrocarbon Spill Sensitivity Mapping	Loading Jetty Spill Simulation Time of Exposure <24 hours Winter
URS	Drawn: MR / CJT · Approved: DO · Date: 27/07/2010	Figure: 3-11 · Rev. D
	Job No.: 42907466 · File No.: 42907466-HSSM-011B_RD.mxd	A3

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Discussion

The OSSM produced in this study provides a useful resource for planning and emergency response teams. It is a planning tool to help prioritise resources to restrict oil dispersion and therefore restrict the impact to the environment. For example, the deployment of suitable resources to the entrance of rivers, creeks and tributaries will reduce the impacts to estuarine habitats (mangroves and associated biota) and high tidal mud flats. The Project area contains a number of human use, coastal type and biological features that may potentially be at risk. However under the hydrocarbon spill scenarios considered in this study, only the features in the immediate vicinity of Project infrastructure would be considered to be at risk.

Furthermore, it is to be noted the OSSM's are not static and should be updated with increasing knowledge about the natural resources of an area, this should also include more detailed mapping.

In Summary:

- The Project area contains a range of human use features, coastal type features and biological features that would be susceptible to an oil spill.
- The maps generated in this study depict the locations of coastal and biological features, and sensitive social and economic features, ranking their sensitivity.
- The oil sensitivity map has identified a number of sensitive features in the Project area that would require to be protected under the hypothetical spill scenarios presented in this study.

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Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 4 June 2010.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between June and October 2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Sensitive receptors

A.1 Coastal type features

Sandy Beaches

The beaches of Onslow and neighbouring beaches are remarkably consistent in profile and sediment characteristics and fauna. The beaches comprised fine, well sorted sand with a near-horizontal supratidal ramp and a steep intertidal beach slope. Conspicuous 'black mineral sand' component formed distinct bands on seaward beach slopes and there was very little change of slope from the upper to lower intertidal zones. The surface of the beaches slope is very smooth without bioturbation except for occasional crab burrows. There is no mid-lower littoral sand flat, the beach simply slopes into the sublittoral zone (URS 2010a).

Along the top of the beach ridge there are large numbers of mollusc shells, mostly bivalves. By far the most abundant species is the semi-twisted arc shell *Trisidos semitortus*. While some of the shells were of recent origin derived from living populations in the adjacent subtidal zone, it is believed that the majority are re-worked from the underlying Holocene shell beds, i.e. the deposit is primarily a post-mortem assemblage (URS 2010a).

Sand beaches, composed of medium to coarse-grained calcareous sands and shelly sands, are widespread along the coastline. The beaches are backed by low foredunes (vegetated by coastal species, e.g. *Spinifex longifolius*, *Rhagodia preissii* and *Ipomea brasiliensis*) which front parabolic dune blowouts or vegetated parallel dune systems (e.g. the long curving beach between the Ashburton River mouth and Entrance Point) (URS 2010a).

The fauna of the seaward beach slopes throughout the study area was extremely limited in all the transects and at all sites visited. With the exception of the alluvial fans, sand flats were not developed along this coast and that usually species-rich element of the regional fauna was missing (at least in the intertidal zone). The beach habitat comprised only the steep beach slope covering the entire upper to lower littoral profile (URS 2010a).

Sand and muddy shores have a tube like structures created by the spaces between particles, the capillary effect retains water after the high tide has retreated, thus creating suitable habitats for many burrowing species. The two dominant marine fauna types present are: large animals (>0.5 mm) capable of burrowing into the sediment and meiofauna (0.05–0.5 mm) that live in the spaces created between the particles. As well as the large burrowing species and meiofauna, there are diatoms and bacteria that stick to the surface of sediment particles (IPIECA 1996f).

Sandy shores are also important for the reproduction of a number of species, which are vulnerable to beach degradation (IPIECA 1996f), such as turtles which are discussed in Appendix A.2 Turtle rookeries.

The natural processes and physical characteristics of sandy beaches are key components that determine their susceptibility to an oil spill. Physical features such as relative exposure to tide and wave energy will influence the spread and layering of oil, which in combination with the properties of the sand including grain size and permeability will predict the depth to which hydrocarbons can penetrate. Ultimately, these features will influence the potential effects a spill may have on the natural environment (NOAA 2002).

Appendix A

Rocky shores

Rocky shores are not well-developed along the sandy Onslow Coast, although extensive rock platforms occur around the shores of most of the nearshore islands in the region (URS 2010b) .

West of the Hooley Creek mouth, a short and narrow sloping intertidal limestone ramp is exposed at the base of the beach slope, presumed to be either Holocene beach rock or Pleistocene limestone. This limestone ramp is clearly sand scoured and presents a hostile habitat for the organisms that normally live in a rocky shore habitat. Other small stretches of similar rock platforms are present between Tubridgi and Coolgra Point (URS 2010a). At Beadon Point an intertidal exposure of limestone forms a wide rock platform with a moderately well-developed rocky shore fauna and flora. At Coolgra Point there is also a limestone outcrop in the mid to upper tidal zone, in this case partially mud-covered and with moderately dense growth of mangroves. The invertebrate fauna present are a diverse, mixed assemblage of mangrove and rocky shore species. A extensive area of limestone platform extends along the north-western shoreline of Coolgra Point. Between Hooley Creek and Entrance Point there is a rock bench landward of the current beach/lagoon sequence that is a remnant of a previous rocky shoreline (URS 2010b).

Rocky shores are habitats for a variety of marine flora and fauna, typically microalgae and invertebrate species, these organisms have adapted to high stress levels, with periods of desiccation, predation and sometime strong wave energies. This highly stressful environment creates zonation, especially in high energy environments (IPIECA, 1996e).

The impact of a potential oil spill on a rocky shore environment depends on its topography and flora and fauna communities which inhabit the substrate. Steep or vertical rock faces on a wave exposed coast is unlikely to have any impact from an oil spill event, while a gradually sloping rock platform in low energy environments, sheltered bays and inlets can trap oil. (IPIECA 1996e).

Mangroves

Mangroves in the Pilbara region form small but intricate communities in embayments and on the protected shores of a number of offshore islands. The arid conditions of the Pilbara region are a rare habitat for mangrove communities to occur making the mangroves of the Pilbara and Kimberley of great scientific importance (Human & McDonald 2009).

Mangroves in the Onslow area occur mostly within river mouth and tidal creek systems where they form a nearly continuous ribbon of vegetation fringing and stabilising the creek channels. These mangroves are protected and partially isolated from the sea by barrier dune systems through which tidal creeks have breached narrow channels. Areas of mangroves also occur along the outer, coastal shoreline on the western and northern sides of Coolgra Point (URS 2010a).

At Hooley Creek, Middle Creek, Four Mile Creek, Beadon Creek, and Second and Third Creeks, mangroves are confined to a narrow fringe adjacent to the creek channel that is typically only 10-20 m wide. More expansive mangrove areas occur at the Ashburton River Delta and Coolgra Point where a far greater area and diversity of habitats suitable for mangrove colonisation exists (URS 2010a).

Mangroves of the Pilbara region are generally followed by extensive intertidal flats (landward from the creeks and embayments) and support high species richness and diversity of invertebrates, typically burrowing invertebrates as well as being important foraging ground for migratory birds. There is a strong ecosystem link between the mangrove and intertidal flat communities. Aside from providing a unique habitat for a variety of different creatures, the mangroves also help protect the shoreline from natural forces and act as carbon sinks (Human & McDonald 2009).

Mangroves typically are found in low wave energy ecotones and as a result oil accumulates in these areas after a spill. In addition to low wave energy and the inaccessible nature of mangroves, removal of oil proves very difficult and the fine anaerobic sediment characteristic of these habitats reduces the rate of microbial breakdown of oil (Lewis 1983). The oil is generally deposited on the aerial roots (Pneumatophores) during high incoming tides, often leading to patchy oil distribution. The mangroves can be destroyed by heavy, viscous oil covering the trees' breathing pores thereby suffocating the subsurface roots from which the trees are dependant for oxygen (IPIECA 1996c).

Damage to mangrove forest from oil spills can be severe, killing flora and fauna and having long term effects as a result of degradation of the mangrove habitat (Duke & Burns 1999). If massive mortality occurs in mangrove forest, the structure and cohesion of the mangrove habitat becomes unstable. In addition to direct loss of mangroves, long term effects also transpire as a result of the persistence of residual oil in mangrove sediments, this is known to lessen growth performance in both trees and seedlings (Duke & Burns 1999). Oil can potentially get trapped in mangrove habitats and remain toxic for decades (Duke & Burns 1999). Therefore, the critical zone of impact, and the focus point for response action, is the entrance points to the rivers, creeks and tributaries which serve as bottlenecks for oil impacts. For the purpose of the ESI, the entrance points to mangrove habitat have been ranked with equal importance to the mangrove habitat itself.

High tidal mud flats

Landward of the mangrove zone, areas of bioturbated mud flats with samphire communities typically extend across the tidal flats to the hinterland margin or merge with the extensive cyanobacterial algal mat and salt flat areas. These high tidal mud flat areas occur in the upper or higher sections of the intertidal zone and hence are not regularly inundated by tides (URS 2010b).

At locations where the extent of mud flat development is limited or truncated by the hinterland or low islands, the bioturbated/samphire mud flat habitat occupy the full extent of the mud flat zone between the landward edge of the mangroves and the hinterland margin. During both ground and helicopter-based surveys it was noted that high tides above 2.2 m Chart Datum (0.7 m Australian Height Datum) are required to inundate these areas. In many locations this habitat is hundreds of metres wide, while in others the bioturbated/samphire mud flat habitat zone was only a few metres wide and abutted the base of supratidal sandy cheniers or dunes with a well-defined high tide mark.

Within the bioturbated/samphire mud flat habitat a patchy and often complex zonation or mosaic was evident in the following sub-habitats:

- bioturbated mud flats - devoid of macro-vegetation but heavily worked over by burrowing crabs
- samphire flats and/or discrete patches of samphires - dominated by halophytic shrubs with sparse crab burrows (URS 2010b).

Several locations in the Onslow area exhibit expansive areas of mud flats that extend for several kilometres landward of the mangrove lined tidal creek systems and landward of the bioturbated/samphire mud flat habitat described above. In these more expansive areas there are areas of cyanobacterial mats, also referred to as algal mats. The distribution of algal mats is limited in terms of tidal elevation but, due to the flatness of the tidal flat terrain, they could occupy large spatial areas (as is evident by the dark colouration of this zone on aerial photographs). During intertidal

Appendix A

habitat surveys (URS 2010b) it was observed that tides of 2.6m (CD) are required to inundate algal mat areas. Such expansive areas of mud flats with algal mats are observed at Tubridgi Point (Urala Creek), the Hooley Creek-Four Mile Creek system and the Second Creek-Coolgra Point system. Such expansive areas of mud flats do not occur in the Ashburton Delta and there are no large spatial areas of algal mat detected from the habitat mapping (URS 2010b).

Salt flats form the landward most parts of the high tidal mudflat. Where they occur they do not provide habitat for marine invertebrate fauna due to the hostile conditions produced by high surface temperatures and high evaporation rates. Salt flats are inundated only on rare occasions by either extreme sea levels events (e.g. cyclone-induced storm surges) or by freshwater during flood periods.

Salt flats were predominantly devoid of vegetation; occasional areas of samphire shrubs are present at the interface of salt flats with the hinterland (URS 2010b).

Species occurring in high tidal mudflats are generally found to be zoned according to tidal height. High tidal mud flats often trap oil due to the sheltered conditions; vegetation offers a large surface area for oil absorption. In addition the leaf structure of the samphire and mangroves increases the holding capacity (IPIECA 1996d). Similarly to mangrove habitats, the entrance points to the rivers, creeks and tributaries serve as bottlenecks for oil impacts. Therefore, the entrance points to high tidal mud flats should be ranked with equal importance to the mangrove habitat itself.

Coral Reefs

Coral reefs are well known for their high biological productivity, regarded as the most complex and diverse marine habitats, they play an important role for fisheries, marine ecosystem health, shelter and many other environmental processes (IPIECA1996b).

Studies conducted in the Project area by MScience (2010) found healthy coral communities with low levels of current impacts with coral density varying between 30% and 70% cover. The dominant coral forms found are low relief corals such as *Montipora* inshore or tabulate *Acropora offshore*. Inshore is dominated by species of *Montipora*, to offshore moves to a more *Acropora* species dominated habitats and a zone of mixed communities is found in between. An inverse relationship between the level of coral cover and the community diversity is present, with many sites being entirely dominated by cover of plate *Montipora* corals. The high cover – low diversity nature of many sites may be indicative of low levels of environmental disturbance (MScience 2010).

There are numerous ways that oil can come into contact with coral reefs; as oil is less dense then seawater, it floats over the reefs (except for small amounts lost through dispersion and dissolution into the water column). However, during low tide many parts of the reef can be exposed, particularly during very low spring tides, leading to the coral coming into contact with the oil, causing smothering (IPIECA 1996b). Oil can potentially come into contact with the reef through the creation of oil droplets distributed into the water column as a result of dispersion and crashing waves, corals secrete mucus (particularly when stressed) and the droplets can stick to them easily and may not be shed with the mucus (IPIECA 1996b).

There are several factors that influence the effect of an oil spill on a coral reef, some of these factors include the following (IPIECA 1996b):

- Amount and type of oil that was spilt
- Coral condition prior to the spill
- Seasonal factors such as coral spawning events

- Other stressful factors, such as high levels of total suspended solids
- Coral type
- Weather conditions, tides, storms, currents and rainfall
- The clean-up operation.

A.2 Biological features

The project area is located within the unique Pilbara region, it is the only marine environment neighbouring an arid tropical terrestrial environment in Australia. The Pilbara's marine flora and fauna contribute to the Indo-Pacific assemblage of organisms, although it is not fully understood how much the Indo-Pacific contributes to the genetics on WA marine communities. There are also many endemic species (Human and McDonald 2009).

Some animal and plant species are especially vulnerable to oil spills. The ESI method classifies these species into categories and displays their locations on the maps. Many species and other biological features are vulnerable to potential oil spills and can be especially vulnerable at different spatial and temporal scales (NOAA 2002). Animals and their habitats have increased level of risk from oil spills during early life stages are present in certain areas, such as seabird rookeries or turtle nesting beaches. Oil spills may also affect areas important to specific life stages or important for migration, such as foraging and specific areas are critically important for breeding (NOAA 2002). For the purpose of displaying geospatial information on biological features in this study, only fixed locations of known biological importance have been presented.

Mangrove

See Appendix A.1

Coral reef

See Appendix A.1

Turtle rookeries

Loggerhead, green, hawksbill, olive Ridley, flatback, and leatherback sea turtles are known to occur in the Pilbara and Kimberley regions (Márquez, 1990), and the sandy beaches of the Pilbara region are used by green, hawksbill, and loggerhead turtles as nesting sites (threatened species listed as vulnerable, along with the flatback turtle) (Human and McDonald, 2009).

Following an oil spill in Mexico Bay, Hall (Hall et al, 1983) found the deaths of turtles (Green Turtles *Chelonia mydas* and an Atlantic Ridley Turtle *Lepidochelys kempi*) resulting from the well blowout was caused by ingestion of oil and prolonged exposure to the oil.

A study in Nigeria looking at the effects of oil spills on turtle populations (Luiselli and Akani, 2002) found both direct and indirect effects of oil spills. The primary direct effect was a considerable reduction in the turtle specific diversity, with 50% mortality rate of species after an oil spillage, and overall decline in numbers of turtle species that were able to have some resilience to the event. In addition to the direct loss of adult and juvenile turtles, it was deemed highly probable that the oil contamination would have serious adverse effects also on the eggs as Turtles lay their eggs

Appendix A

seasonally on sandy beaches an oil can either directly wash up on the beach or permeate into environment implying that turtle eggs could easily be destroyed by this contaminant.

Seabird rookeries

The following islands have been listed as recorded seabird breeding sites; Airlie, Ashburton, Bessieres, Direction, Locker, Little Rocky Island, North Mangrove, Mary Anne, Round, Serrurier, Thevenard, Tortoise and West Islands. Airlie and Serrurier islands have recorded colonies of Wedge-tailed Shearwaters (1000-10000 birds) breeding (Burbidge and Fuller, 1996).

Marine Mammals

Marine mammals found in the Pilbara and Kimberley region are composed of whales, dolphins, and dugongs, all of which are protected (CALM, 2005; and DEWHA, 2008). Twenty-seven whale and dolphin species are recorded from the Pilbara and Kimberley region, and there is a single Sirenian species, the dugong (Human and McDonald, 2009).

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