Varanus Island Compression Project

Section 38 Environmental Referral under the Environmental Protection Act 1986

EA-00-RI-217

December 2012

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REVISION HISTORY

1	21/12/12	Resubmission to EPA	LGO	SM	HW	LH
0	28/11/12	Submitted to EPA	LGO	SM	HW	LH
A	08/11/12	Issued for Review	LGO	SM	HW	LH
REV	**DATE**	**DESCRIPTION**	**BY**	**CHK**	**ENG**	**EM/PM**

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ABBREVIATIONS

AHD	Australian Height Datum
ALARP	As Low as Reasonably Practicable
APPEA	Australian Petroleum Production Association
CALM	WA Department of Conversation and Land Management (now the DEC)
CEMP	Construction Environmental Management Plan
DEC	WA Department of Environment and Conservation
DIA	WA Department of Indigenous Affairs
DMP	WA Department of Mines and Petroleum
EH&S	Environmental, Health, and Safety
EP	Environment Plan
ESJV	East Spar Joint Venture
HAZID	Hazard Identification
HDPE	High Density Polyethylene
IUCN	International Union for Conservation of Nature
KMCR	Kitchen/Mess and Cyclone Refuge
MARPOL 73/78	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MSDS	Material Safety and Data Sheet
NWS	North West Shelf
SEWPaC	Commonwealth Department of Sustainability, Environment, Water, people and Community
SRE	Short-range Endemic
VICP	Varanus Island Compression Project

1. INTRODUCTION

Apache Northwest Pty Ltd (Apache), on behalf of its joint venture participants, operates oil and gas production and infrastructure facilities located on Varanus Island (VI) (VI facilities). VI is within the Shire of Ashburton (Shire) boundaries and is part of the Lowendal group of islands, located approximately 20 kilometres (km) northeast of Barrow Island and 15 km south of the Montebello Islands on the North West Shelf (NWS) of Western Australia (WA). A regional overview of VI is shown in Figure 1-1.

VI is a declared Nature Conservation Reserve (33902) managed by the Department of Environment and Conservation (DEC) for the protection of flora and fauna.

Since 1986, Apache has leased a 29.31 hectares (ha) portion of Reserve 33902 (Apache lease) for the operation of petroleum receiving, processing and loading/export facilities and associated infrastructure. The Apache lease is discussed in Section 1.1.

Apache intends to install additional gas compression equipment and supporting infrastructure and services to support its on-going operations on VI. The intended works (described in detail in Section 2) are collectively referred to as the “Project”.

The VI facilities are shown on Figure 1-2. A description of the Project is provided in Section 2.

1.1 Land and Tenure

VI is part of the Lowendal group of islands which are vested as Nature Conservation Reserves and are managed by the DEC. In order to operate petroleum activities on VI, a lease was required from the then Department of Conservation and Land Management (CALM) (now the DEC), under the *Conservation and Land Management Act* 1984 (CALM Act).

The CALM Executive Body granted lease 1902/100 over portions of Reserve 33902 to the Harriet Joint Venture (HJV) in 1986 for the operation of petroleum receiving, processing and loading/export facilities. A portion of lease 1902/100 was subsequently annexed as a new lease 2604/100 granted to the East Spar Joint Venture (ESJV). The lease terms expired in 1995 at which time an extension of the leases was granted for a 10 year period, expiring in 2005.

Apache and its JV participants have been granted yearly extensions to the leases since 2005 awaiting final lease renewal conditions from the DEC. These lease conditions have recently been provided as a draft to Apache and are awaiting finalisation. The revised lease conditions will apply for a 19 year period or the day on which the term of the PL12 licence (refer to Section 1.3.2) is renewed or terminated, whichever is the earlier.

The lease conditions require Apache to undertake regular environmental monitoring and annual reporting of results to both the DEC and the Department of Mines and Petroleum (DMP). Apache prepares annual reports, on behalf of its JV participants, which are submitted to the DEC and DMP.

The HJV and ESJV leases, jointly referred to as the ‘Apache lease’, encompass the central portion of VI and occupy an area of approximately 29.32 ha or 34.5% of the land area of VI. The HJV and ESJV leases are shown on Figure 1-2.

The Project, except for the wharves upgrade works, occurs within the Apache lease. Apache has applied to the Department of Transport for a licence to conduct the wharves upgrade works.

1.2 Aboriginal Heritage & Cultural Values

A search of the Department of Indigenous Affairs (DIA) Aboriginal Heritage Inquiry System indicated that no ethnographic or archaeological sites are listed for VI and no records of Aboriginal occupation have been recorded for VI or the surrounding marine waters of the nearby islands. The vesting of VI as a nature reserve under the *Land Act* 1933 extinguishes Native Title over the Island. There are no Native Title claims that exist over VI or the offshore facilities that connect to the VI facilities.

In the unlikely event that any matters of archaeological or heritage significance should be discovered during any development activities on VI or offshore, the DIA will be notified promptly.

Figure 1-1 Regional Overview of Varanus Island

Figure 1-2 Varanus Island General Overview

1.3 Varanus Island Environmental Approvals

1.3.1 Environmental Impact Assessment

Operations on VI within the Apache lease area have been assessed under Part IV of the *Environmental Protection Act* 1986 (EP Act), and the Minister for the Environment has issued a number of Ministerial Statements (MS) including:

- MS 134: Pipeline, Harriet Gas Field to Dampier-Wagerup Pipeline, Dampier – Environment Protection Authority (EPA) Bulletin 473;
- MS 395: East Spar Off-shore Gas Field Development, Varanus Island – EPA Bulletin 787;
- MS 457: Wonnich Gas Development, South-west of the Montebello Islands – EPA Bulletin 856; and
- MS 573: Simpson Oil Field Development, Offshore Abutilon Island, Lowendal Islands – EPA Bulletin 1023.

The Project does not require amendments to the Ministerial statements.

Apache proposes to undertake the Project by way of a Section 38 referral under the EP Act to the DEC (this referral), and an *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act) referral to the Department of Sustainability, Environment, Water, People and Community (Cth) (SEWPaC). The SEWPaC referral is separate to this referral.

1.3.2 Works Approvals and Operating Licences

Under Part V of the EP Act, industries with emissions that have the potential to pollute the environment require a works approval to construct and a licence to operate. Licences are imposed on prescribed premises under the EP Act. Apache has an operating licence (L6284/1992/9) issued by the DEC. The VI facilities are classed as a 'Prescribed Premise' under the EP Act based on the following licence categories:

- Category 10: oil or gas production from wells;
- Category 73: bulk storage of chemicals, etc.; and
- Category 85: sewage treatment facility.

The production throughputs approved for the VI facilities under the operating licence are:

- Quantity of oil produced: 2 million tonnes per annum;
- Quantity of sales gas produced: 5,050,000 tonnes per annum;
- Bulk crude product storage capacity: 120,000 m^3; and
- Quantity of treated sewage: greater than 20 m^3 but less than 100 m^3 per day.

The Project does not alter or modify the production throughputs currently approved under the operating licence. The Project does not require an amendment to the VI operating licence.

Within the Apache lease, Apache also holds, on behalf of its joint venture participants, Pipeline Licences (PL12 and PL29) granted by the DMP pursuant to the *Petroleum Pipelines Act* 1969.

The Project requires a Works Approval for the compression equipment (section 2.1). The Project will also require variations to Licence PL12 and PL29. The Works Approval, and licence amendments are separate processes to this referral.

1.3.3 Vegetation Clearing Permit

Within the Apache lease, Apache holds two vegetation clearing permits issued by the DMP:

- CPS 1359/1: Permit to Clear Native Vegetation under the EP Act, Apache Northwest Pty Ltd – Construction and Maintenance of Buildings and Infrastructure; and
- CPS 997/1: Permit to Clear Native Vegetation under the EP Act, Apache Northwest Pty Ltd – Fire Risk Reduction and Maintenance.

CPS 1359/1 provides for the clearing of up to 24.93 ha of native vegetation within the Apache lease, subject to the conditions in the permit.

The required clearing of vegetation for the Project is within the CPS 1359/1 permit area.

1.4 Stakeholder Consultation

Apache has consulted with the relevant stakeholders and regulatory authorities regarding the Project, including:

- DEC;
- DMP; and
- SEWPaC.

Table 1.1 summarises the issues discussed with the various stakeholders, how Apache has addressed the issues, and the proposed management of those issues.

Table 1.1 Summary of Stakeholder Consultation Issues and Management

Stakeholder	Issues Raised	Apache Action/Management
DMP	None.	The DMP was satisfied the proposed Project and associated clearing can be conducted under the existing vegetation clearing permits.
DEC	Apache must demonstrate that project alternatives have been considered, and the vegetation clearing is minimised.	The basis for site selection is discussed in Section 3. The layout of the kitchen/mess cyclone refuge has been modified to minimise disturbance area and clearing required. The Project requires clearing of approximately 0.75 ha (approximately 9.5% of remnant vegetation within the Apache lease).
SEWPaC	Apache must demonstrate avoidance or minimal disturbance to the Wedge-tailed shearwater colonies and turtle nesting beaches.	The proposed earthworks have potential to impact on the Wedge-tailed shearwater and turtles through noise and vibration. Noise impacts are not expected to have a significant impact on the Wedge-tailed shearwater. These are discussed in detail in Sections 7.2.2 and 8.2.2. In relation to vibration, should drilling and blasting activities be required, this is contingency, they will be conducted outside of the nesting season. A drilling and blasting procedure will be prepared prior to drilling and blasting works. This is discussed in Section 9.3.

2. PROJECT DESCRIPTION

2.1 Varanus Island Compression Project (VICP)

Presently gas and associated liquids flow under natural pressure from the John Brookes (JB) wellhead platform through the slug catcher (ESJV) to the inlet of the amine trains on VI. Declining reservoir pressure means that in the future there will no longer be sufficient natural pressure to maintain the required production flow rate. The VICP will compensate for the future decline in reservoir pressures, and avoids the immediate need for modifications to the VI facilities to accommodate the declining reservoir pressures.

As the reservoir pressure declines further, currently anticipated around January 2019, further additional equipment installation will be required including the installation of condensate pumps on the liquid outlet of the existing plant JB slug catcher, inlet compression inter stage cooling, inlet compression re-wheeling and new offshore well production chokes. These future activities are not part of this referral. However, currently scheduled earthworks and land use planning described in this referral do make allowance for these future activities.

The VICP involves the planning, design, construction/installation, pre-commissioning, commissioning and operation of a natural gas compression equipment and ancillary facilities (New Plant) extending from the existing East Spar Joint Venture (ESJV) infrastructure. The New Plant intended for the VICP includes:

- 2 x Solar Mars 100 gas turbine driven compressors, module based and including scrubbers, air cooled heat exchangers, gas/gas exchanger and Joule-Thompson (JT) gas cooling valve;
- 1 x Centaur 40 gas turbine driven electrical power generator;
- 1 x pipe rack module;
- 1 x electrical switch room;
- 1 x transformer compound and battery room;
- Utilities upgrades including instrument air, polished water etc.

The compressors will discharge gas at temperatures in excess of 100°C. Initial cooling of the gas will be achieved via air cooled heat exchangers which will typically drop gas stream temperatures to between 35°C and 55°C depending on the ambient air temperature which has considerable seasonal variation.

Additional cooling of the gas stream is required for the downstream Tri Ethylene Glycol (TEG) dehydration packages, and is achieved by two means:

- A gas/gas heat exchanger that cools the compressor discharge stream through the incoming gas stream from the slug catcher, and
- Expansion of the over-pressurised compressor discharge stream through the JT valve nozzle thereby decreasing its temperature.

Following cooling, the gas stream may enter the TEG contactor column for dehydration to achieve sales gas specification.

The New Plant includes an electric power generator to meet the New Plant load and sufficient spinning reserve to be shared with the existing plant such that the existing plant generators can effectively backup New Plant generators and vice versa.

The proposed VICP facilities including the required tie-ins to the ESJV gas plant will be located to the south of the existing ES facilities, and requires the realignment of the existing bund wall that provides secondary containment for the three bulk liquid petroleum storage tanks on VI. The VICP works area is bounded:

- To the north by the existing East Spar gas plant;
- To the east and south by the existing VI storage tank containment bund, and
- To the west by the existing bund wall and ES pipeline infrastructure beyond.

The VICP includes other ancillary and support infrastructure and services described in Section 2.2, and the project staging is discussed in Section 2.3. Figure 2-1 shows the layout of the VICP.

2.1.1 Operations – Description of the VICP in Operation

The JB gas field, as a depletion field with no aquifer drive, has shown a steady and predictable decline over the first 6 years of operation. A reduced arrival pressure at VI will potentially allow for significant additional recovery of gas from the JB gas field. However any significant reduction in arrival pressure will require booster compression at the inlet to the VI gas processing trains to maintain the current gas export capacity across the VI facilities. Apache has identified additional facilities on VI that when installed will maximise the recovery and the deliverability from the JB gas field by allowing for a reduction in the arrival pressure of the gas at VI.

JB produced fluids arrive at VI and are first processed by the JB slug catcher which is part of the existing plant. The gas phase outlet of this slug catcher will be re-routed and instead of going to the CO_2 removal plants (amine plant) located in the existing plant the gas will go to inlet compressors located within the New Plant.

To assist in temperature control, the sea bed cooled gas arriving from the existing plant JB slug catcher then flows into a gas-gas exchanger (compressor suction to compressor discharge exchanger) located in the New Plant. This helps to cool the discharged wet gas from the compressors inside the New Plant.

Within the New Plant, wet gas from the slug catcher then has further liquids knocked out by inlet compressor scrubbers before then being compressed by inlet compressors and subsequently cooled by the compressor discharge coolers and then cooled further by the previously mentioned gas-gas exchanger and compressor discharge coolers. After the gas-gas exchanger the compressed gas is cooled further again by letting it down across a JT valve. This last stage of JT cooling is only enabled as required by an automatic control algorithm, otherwise it is effectively bypassed.

The compressed, cooled wet JB gas is then sent via a compressed gas discharge header back to the CO_2 removal (amine) plants in the existing plant.

The VICP has no requirement for additional produced liquid handling facilities. Produced water will be tied into the existing plant produced water treatment. All water liquids knocked out of the gas in the New Plant are piped into the produced water treatment system located within the existing plant. The New Plant blowdown and pressure relief systems will be connected to the existing plant flare.

The New Plant essentially operates between two parts of the existing plant, JB onshore arrival and amine facilities.

The VICP function is to simply boost the pressure of the arriving JB wet gas so that the downstream amine, gas treatment and sales gas compression plants can all operate without modification.

The VICP will not generate a hot oil service from the new gas turbine driven inlet compressors. Hot oil tie-ins to the existing plant will not be provided.

The New Plant utilises spare capacity in the existing plant closed drainage system, flare system, fire water system and all other utilities services, however, the New Plant equipment shall be self-contained for instrument air and uninterrupted power supply.

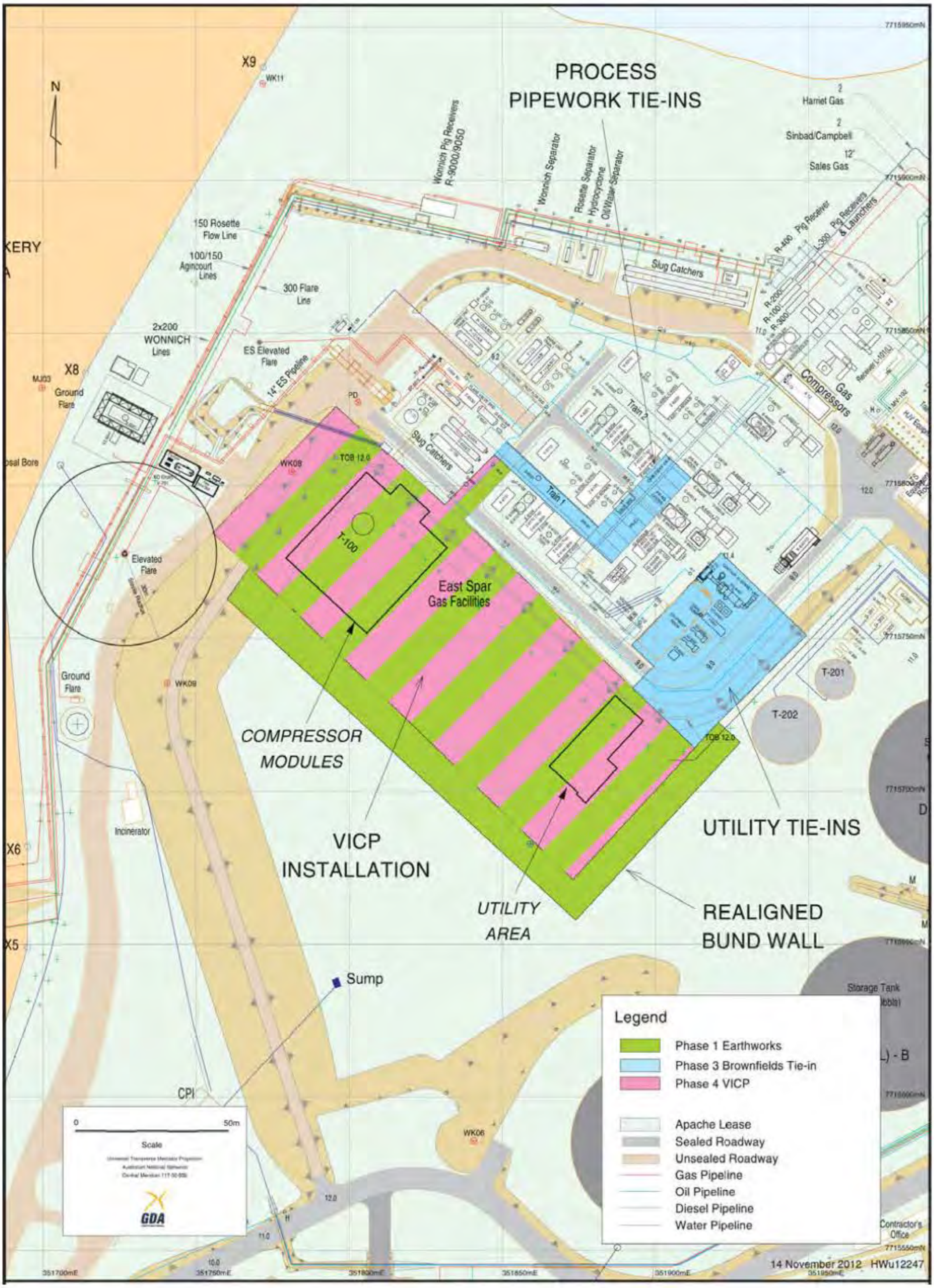

Figure 2-1 VICP General Arrangement

2.2 Support Services and Utilities

2.2.1 West Wharf and East Wharf Upgrade

The proposed wharf upgrades are required as part of infrastructure maintenance, including for the safe use of the wharves for on-going operations of the VI facilities, as well as, in relation to the West Wharf, to allow for the barging of the accommodation upgrade modules and the VICP maxi-modules. The wharves upgrade area is shown on Figure 2-2. The wharf upgrade works involves:

- During low tides, investigative works and ground truthing of the seabed immediately adjacent to the existing wharf structure (extending approximately 6 m from the existing wharves edge) which will involve some excavation and removal of rock (less than 100 m^3) in the intertidal seabed utilising a long reach excavator operating from the existing wharves;
- During low tides, clean-up (recover for Project reuse) construction debris using a small rubber tracked excavator to provide a better keying surface for under caisson connection to scabbled rock;
- During low tides, placement of wharf caisson in-situ cast concrete foundation elements in the prepared seabed;
- Installation by a wharf based crane of pre-cast concrete caissons (extending approximately 4 m from existing wharves edge), grout sealing of joints, followed by infill of the caissons with rubble recovered from bulk earthworks as part of the Project;
- Installation of pre-cast concrete wharf deck sections;
- Installation of rubble mound revetment wing walls; and
- Installation of wharf appurtenances.

The indicative work proposed for the wharves is shown in Figure 2-2. The construction sequence for the wharf upgrade works are shown in Appendix 1.

The west wharf works were previously referred to the DEC in February 2011, and no works approval was required for the proposed works.

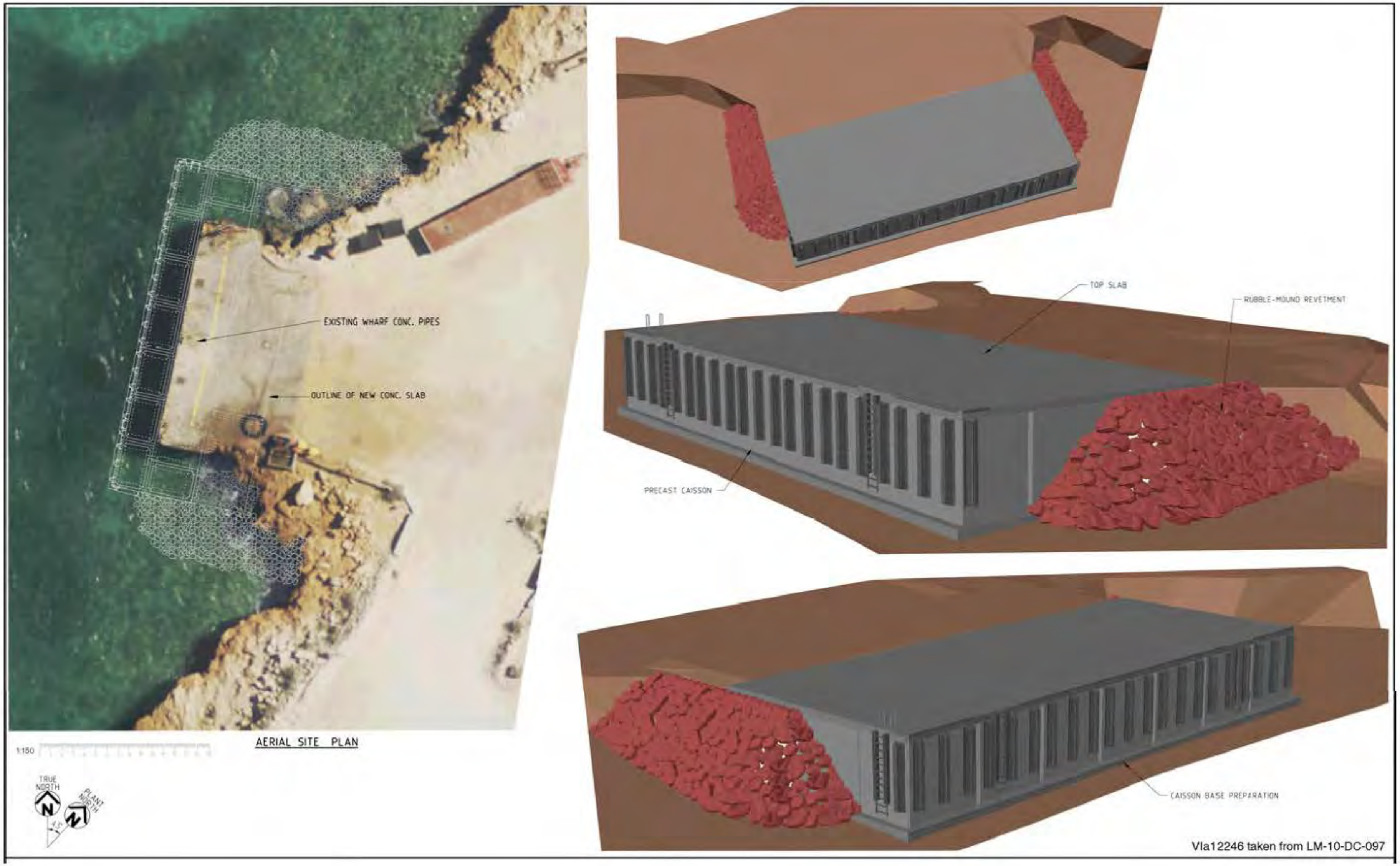

Figure 2-2 Indicative Wharves Works

2.2.2 Accommodation Camp Upgrade

Existing accommodation units that will be decommissioned and replaced consists of four and six-person modules. The accommodation camp upgrade involves the removal of sixteen existing four and six-person accommodation modules, and the installation of twenty new four-person en-suite accommodation units, gymnasium facility, and services including phone, internet and cable TV to each accommodation space. The camp upgrade is required as part of general maintenance works, as well as to support the construction workforce for the Project.

The new build accommodation facilities have been designed and will be constructed in accordance with the Shire's conditions particular to planning approval and subsequent building permits applicable to the buildings required for the Project.

The existing accommodation camp has a capacity to accommodate 240 personnel. The proposed upgrade works do not alter the current capacity of the accommodation camp.

Figure 2-3 shows the indicative general arrangement of the camp upgrade works.

2.2.3 Kitchen/Mess Cyclone Refuge (KMCR)

The Project workforce as well as VI operations personnel operate on a fly-in fly-out basis from Perth via Barrow Island, and are transported to and from Barrow Island to VI by helicopter. The KMCR building is intended to provide contingency cyclone refuge to personnel on VI where personnel are unable to be transferred off the island in a timely manner at the time of an impending cyclone event due to logistical or other difficulties.

The KMCR building, comprising fourteen individual modules, which will be complexed on site into a single structure. The indicative KMCR general arrangement is shown on Figure 2-3.

With respect to the KMCR and the accommodation camp upgrade described in Section 2.2.2, Apache will seek amendment to the existing certificate of Registration of Lodging House in accordance with the *Health Act* 1911 and local health laws in respect of the KMCR including:

- En-suite accommodation for 80 personnel, replacing existing non-industry standard habitation units and including a new gymnasium;
- Kitchen and dry mess building to cater for up to 138 personnel;
- Approved cyclone refuge capability for Project and other VI based personnel (190 person capacity);
- Upgraded power reticulation; and
- Vehicle roadways, parking and site external lighting in accordance with approval requirements.

The amendment to the housing certificate is separate to this referral. Figure 2-3 shows the general arrangement of the KMCR.

2.2.4 Water Supply and Demand

Approximately 11 ML of potable water is required to support the construction workforce throughout the Project (December 2012 to March 2015). This will be supplied from the existing reverse osmosis and distillation units on VI.

Approximately 13 ML of water will be required for the Project construction works. This will be supplied by a temporary mobile reverse osmosis treatment unit as the existing reverse osmosis and distillation units on VI do not have adequate capacity to meet the estimated construction water needs for the Project.

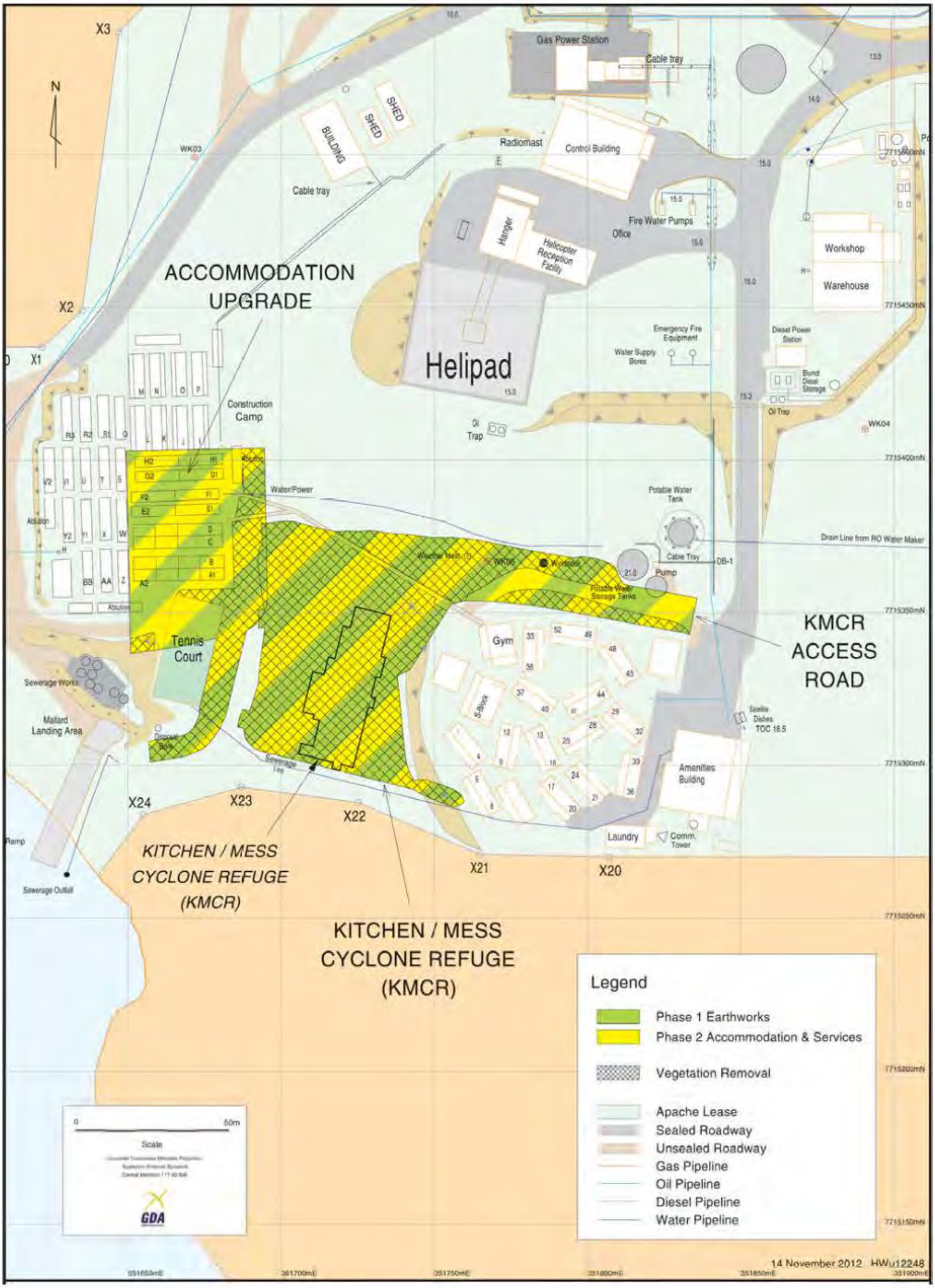

Figure 2-3 Indicative Accommodation Camp and KMCR General Arrangement

2.2.5 Construction Workforce

It is estimated that a combined workforce of between 10 and 100 Project personnel will be required on VI for the Project works including; earthworks, construction/installation, brown-fields tie-in work, testing and pre-commissioning.

All Project personnel will be accommodated on VI within the upgraded accommodation camp.

2.2.6 Concrete Batching Plant Upgrade

The current concrete batching plant on VI is used for small scale works required for the maintenance of facilities and infrastructure. As part of Apache’s dust mitigation strategy and quarantine management, precast concrete sections are to be used in the Project where possible, for instance the East and West Wharf caissons, as well as foundation and retaining wall elements required for the VICP works. However, on-site concrete and grout batching will be required for works where precast concrete is not feasible such as minor foundations, footpaths and blindings etc.

To further reduce potential cement dust and wash down product management issues, the existing concrete batching plant will be upgraded to be consistent with the *Environmental Protection (Concrete batching and Cement Product Manufacturing) Regulations* 1998, and will include:

- A silo and integrated delivery chute for bulk cement handling to allow cement bulker bags to slide over a cylinder and be encapsulated within the silo;
- An elevator chute to dispense dry cement from the silo directly into the batching plant hopper;
- Mist spays over the sand and aggregate premix storage bay to reduce dust during materials transfer into the batching hopper; and
- HDPE (2 mm thickness) lined slurry pits for the retention and settling out of agitator-truck wash down products. The pits will enable clarified water to be periodically drawn off and transferred to a bulk water tank to be used for dust suppression. Solidified concrete waste will be recovered by bob-cat and reused via the VICP’s mobile crushing plant to be used for the processing of infill materials.

2.2.7 Access Roads and Laydown Area

The existing plant access road through the west lay down area will be upgraded to facilitate access for earthworks and to allow delivery of the VICP maxi-modules (compressors and power generators). Areas adjacent to the upgraded access road will be used as lay down areas for work items for the Project including closed and open top containers, bulk materials, pallets, pipe spools, cable reels, light fabrication areas, site offices, accommodation and KMCR module holding area, muster area for back-load items, waste bins, batching plant, concrete materials.

The access road upgrade works and lay down area is shown on Figure 2-5.

2.2.8 Power Supply and Demand

Power needs for the New Plant will be provided by the new power generator described in Section 2.1. Existing power supply at VI is adequate and will provide for all power needs for the support services and utilities.

New feeder cables will be installed within the existing common services trench for power supply to the KMCR.

2.2.9 Temporary Construction Facilities

Other temporary equipment and facilities to support the Project include crushing plant, mobile plant such as generators, welders, crusher, excavator and trucks etc.

Rock crushing and earthworks conditioning (for the bund realignment works) will be undertaken within the existing bund area.

The temporary reverse-osmosis plant for construction water needs will be located in the adjacent area to the helipad (Figure 2-5).

2.3 Ground Disturbance

Within the Apache lease, the current disturbed/non-vegetated area is approximately 21.62 ha. Non-vegetated areas include beaches and rock outcrops. Remnant vegetation within the Apache lease is approximately 7.81 ha.

The development of the Project requires approximately 3.2 ha of area within the Apache lease. The majority of the areas required are within current operations or previously disturbed areas. A breakdown of the areas required is presented in Table 2.1.

Table 2.1 Breakdown of Ground Disturbance Areas

Proposed Works	Area (ha)
VICP (including realigned bund wall)	1.2370
East Wharf upgrade	0.0139
West Wharf upgrade	0.0249
Accommodation camp upgrade	0.2813
KMCR	0.5704
Access Road and Lay Down Area	0.7634
Soil and rock recovery area	0.2472
Temporary reverse osmosis unit	0.0629
Concrete batching plant	-
Total (approximately):	3.2

The Project requires clearing of vegetation at the lay down area and access road upgrade, as well as the accommodation camp upgrade and the KMCR area. Approximately 0.75 ha (or approximately 9.6% of remaining vegetation within the Apache lease) of vegetation will be cleared. The basis for site selection of the KMCR is discussed in Section 3; and potential impacts and management of flora and vegetation are discussed in Section 8.1.

The additional clearing will bring total clearing within the Apache lease to 22.37 ha. This is within the 24.93 ha limit under clearing permit CS1359/1.

The VICP (refer Figure 2-1) and other items of work do not require clearing of vegetation as they occur within disturbed areas.

2.4 Bulk Earthworks

As part of the realignment of the bund, the VICP and access road earthworks involve:

- In the VICP area, the removal and adjacent stockpiling within the existing bund of between 1,500 m^3 and 3,000 m^3 of contaminated soil over-lying the HDPE liner using a bobcat. The contaminated soil will be relocated and managed within the bund and the HDPE liner folded back and anchored in the (new) realigned bund wall (refer to Section 9.1);

- For the new bund wall, soil blending (of the recovered contaminated soil if possible) and water conditioning with crushed material derived from the KMCR and accommodation camp area (with contingent use of material from the pipeline beach stockpile area) (Figure 2-5);
- Bulk excavation using an excavator with a hydraulic milling head, with contingency use of a D10 bulldozer or precision explosives;
- Precision milling of deep foundation pockets (including within the bulk excavation area) to approximately RL 8m, which will be filled to the design sub-grade level of RL 9 m;
- Material crushing, screening and conditioning within the bund;
- Material infill and compaction at the VICP area of 6,500 m^3 using vibratory roller;
- Material infill and compaction using a vibratory roller on the access road and west laydown area of between 10,000 m^3 and 13,000 m^3 subject to detailed design.

The KMCR & Accommodation area earthworks involve:

- Bulk excavation using an excavator with a hydraulic milling head, with contingency use of a D10 bulldozer or precision explosives;
- Material crushing, screening and conditioning within the existing bund;
- Material infill and compaction using vibratory roller, and
- Rip-rap rock placement and mortaring for stabilisation on batters and drainage lines.

Drilling and blasting, and the use of explosives are discussed in Section 9.3.

The East wharf and West wharf upgrades require minor excavations in the intertidal seabed for the in-situ casting of concrete foundations for the pre-cast caissons. The wharves also require the use approximately 100 m^3 of blue metal for the caisson sub-grade, which will be sourced from the WA mainland and delivered to VI in bulker bags.

The concrete batching plant upgrade does not involve earthworks or soil reclamation.

Table 2.2 summarises the indicative cut and fill volumes for the Project.

Table 2.2 Indicative Earthworks for the Project

Description of Work	Indicative Cut Volume	Indicative Fill Volume
VICP and access road	15,700 m^3	6,500 m^3
Realigned bund wall	780 m^3	-
Access road upgrade & laydown area	-	10,000 m^3 to 13,000 m^3
KMCR	8,730 m^3	2,170 m^3
Accommodation Camp upgrade	1,800 m^3	800 m^3
West Wharf (with rock armour wing wall fill)	200 m^3	600 m^3
East Wharf (with rock armour wing wall fill)	200 m^3	600 m^3
Total:	27,510 m^3	20,720 m^3 to 23,720 m^3

The soil and rock recovery area (Figure 2-5) will provide rock material for the wharves stabilisation wing walls. If required, soil material from this area will also be used for the Project works, e.g. for the bund realignment works. Management of excess materials is discussed in Section 9.7.

2.4.1 Haulage Routes and Number of Trucks

Excavated soil/rock will be loaded onto tippers by the excavators/loader. The recovered materials will be transferred via existing sealed and unsealed roads and temporary access ways to each of the Project locations where the materials will be re-used. In general:

- Materials recovered from the KMCR and accommodation camp area will be used for the bund realignment works, as well as the access road. Crushing and processing of materials for the bund realignment works will be undertaken within the existing bund area. Figure 2-4 shows the indicative designated truck movements and material storage areas within the main bund;
- Materials from the soil and rock recovery area will be used for the wharf upgrade works for caisson infilling and wing walls; and
- Contaminated soil from the VICP area will be removed and relocated utilising a bobcat excavator with rubber tracks to avoid damage to the underlying liner. Contaminated soil will be retained within the bund.

2.4.2 Material Crushing, Screening and Conditioning

An access road (approximately 400 mm thickness) will be constructed using clean materials such that trucks delivering recovered material to the bund will always operate on clean soil. The trucks will reverse into the bund area and offload the material in designated areas.

Crushing, screening and conditioning of materials are required to construct the new realigned bund.

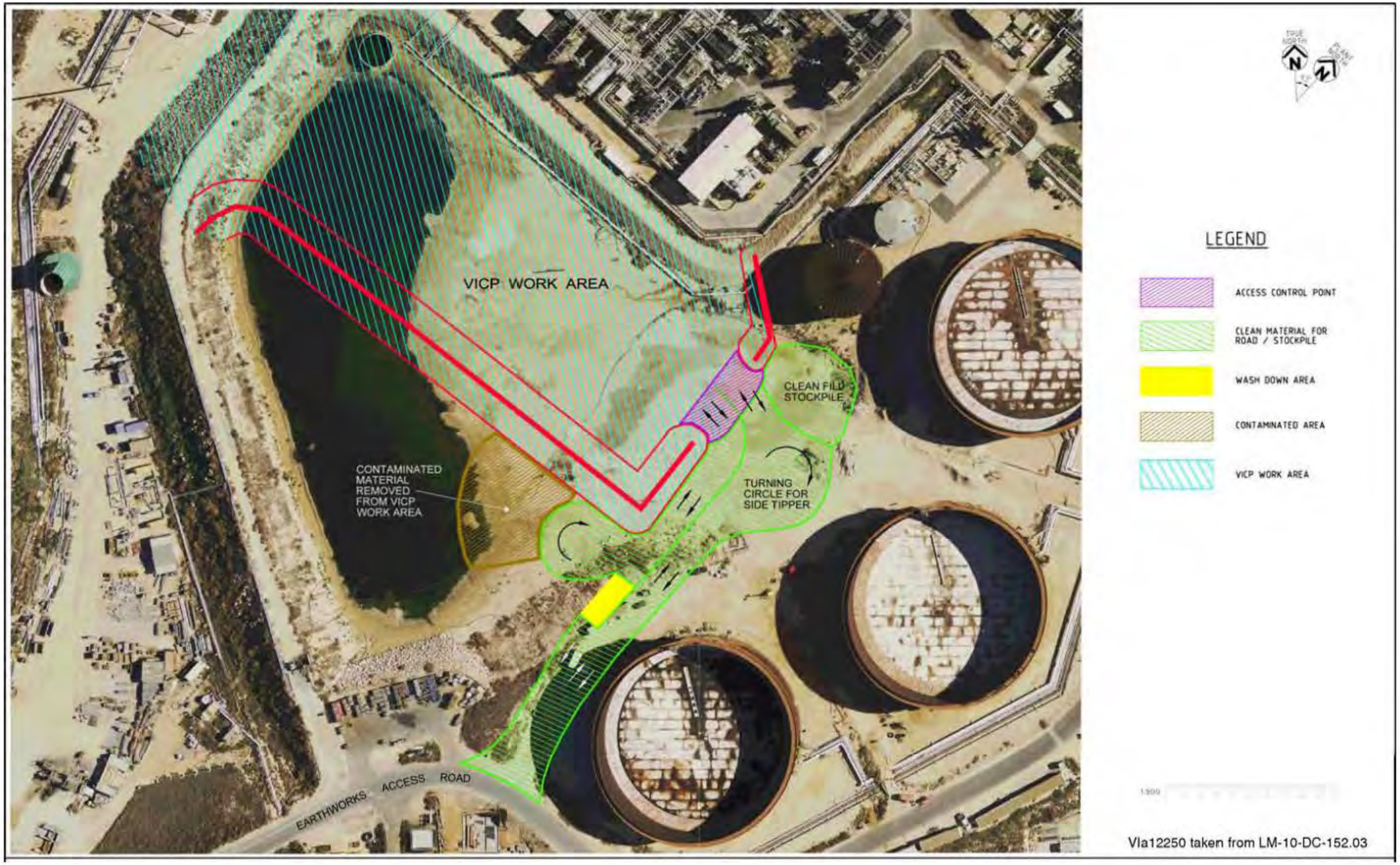

Figure 2-4 Indicative Earthworks Transfer and Processing within Main Bund

2.5 Project Staging

The Project will be undertaken in four phases, described below. Indicative schedule for the construction stages is discussed in Section 2.6.

Figure 2-5 shows the Project general arrangement and staging.

2.5.1 Phase One: Earthworks

Phase One of the Project involves bulk earthworks and site preparation across the construction sites including:

- Earth and rock excavation, crushing, carting, placement, compaction and below ground service installations as necessary to support Phases Two & Three works;
- Investigative works, ground truthing and the preparation of the seabed adjacent to the existing wharves to facilitate caisson installation as part of Phase Two works;
- Removal of existing accommodation modules and below-ground services, and
- Excavation, segregation, blending of soil (if appropriate, re-use of contaminated soil) for the construction of the realigned bund wall within the existing HDPE lined secondary containment bund.

Construction works in Phase One involve:

- Realignment of the existing bund wall using the blended material to support Phase Three works;
- Installation and anchoring of the HDPE liner in the realigned bund wall;
- Installation of precast concrete retaining walls and drainage within the VICP works area to support Phase Three works;
- Access road and lay-down area as necessary to support Phases Two & Three works; and
- Upgrade of the concrete batching plant.

2.5.2 Phase Two: Accommodation Camp, Wharves Upgrades and Services

Site preparation in Phase Two involves the installation of local foundation and excavation works, as well as services including power, water, communications & fire water runs. Sewer line interconnections and contractor's facilities establishment (site offices etc.) also form part of Phase Two preparation works.

Construction works in Phase Two involve:

- Construction of extensions to the existing east and west wharves that service VI;
- installation of a KMCR module comprising 14 individual modules complexed into a single building;
- Replacement of sixteen existing four and six-person accommodation modules with twenty new four-person accommodation modules and associated support steelwork; and
- Installation of additional power feed and fibre optic communications cables to service the new KMCR and local cabling for the replacement and additional accommodation units.

2.5.3 Phase Three: Brownfields VICP Tie-In Works

Phase Three of the Project involves the brownfields tie-in works at ESJV in preparation of the VICP compressor modules and equipment installations in Phase Four.

2.5.4 Phase Four: VICP Installation and Setup

Phase Four of the Project involves the construction and installation of the VICP modules and associated infrastructure including:

- Two Solar Mars 100 gas turbine powered compressor units;
- One Centaur40 gas turbine powered generator unit;
- Local interconnection of gas processing pipework and associated packages;
- An electrical switch room, and
- Control and power cabling, instrumentation, fire water mains and ancillary services.

2.6 Indicative Project Schedule and Regional Ecological Aspects Timing

An indicative schedule for the Project and regional ecological aspects timing are provided in Table 2.3.

Table 2.3 Indicative Project Schedule and Regional Ecological Aspects Timing

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ecological Activity on the Montebello/Lowendal islands												
Dugongs breeding												
Turtle nesting												
Turtle hatchling emergence												
Migratory Birds nesting												
Project Activity												
Ecologist survey/burrow check (avifauna) (2012)												
Ecologist survey (flora and vegetation) (2012/13)												
Bulk earthworks and clearing (2013)												
Drilling and blasting (if required)												
VICP and bund realignment (2013)												
Concrete batching plant upgrade (2012/13)												
Wharves upgrade (2012/13)												
KMCR and Accommodation module delivery (2013)												
VICP module delivery (2013/14)												
Instrumentation works (2014/15)												
VICP Commissioning and Completion (2014/15)												

Key to activity

- Peak of ecological activity, presence reliable and predictable
- Low level of abundance/activity/presence
- No proposed activity
- Proposed Project activity

2.7 Design Life

All above ground instrument, electrical, rotating, piping and static equipment are designed for a 25 year life.

All roads, civil works, equipment buildings, structures or below ground installations design are designed for a 25 year life.

All works associated with the accommodation re-arrangements and the KMCR have a design life of 20 years.

Life extension of the East wharf and West Wharf is for 25 years.

2.8 Project Deliveries to VI

The prefabricated project modules (compressors, power generator, wharf caissons, accommodation camp, KMCR, temporary reverse osmosis unit etc.) will be manufactured off VI and delivered to VI via barges. The modules will either be installed directly upon delivery or will be temporarily held within the designated Project lay down area until required. Approximately six barge deliveries are expected for the Project.

Apache has a Quarantine Procedure (refer to Section 4.3.2) in place to manage quarantine risks. Quarantine controls associated with movement of all freight to VI include inspections and, where required, cleaning, baiting and/or fumigation to treat potential quarantine risks to verify the freight is vermin and insect free.

Apache has a number of plans in place to manage operations of vessels and barges transporting and travelling towards and leaving VI, including an Environmental Requirements for Offshore Marine Vessels procedure which seeks to minimise activity impacts on the land, sea and air; and a Whale Interaction and Sighting Procedure which describes the procedure to follow with regards to the interaction with, and sighting of, marine mammals.

These plans have been prepared to satisfy relevant regulatory requirements including Australian Quarantine and Inspection Service and the International Convention for the Prevention of Pollution from Ships 1973, as modified by Protocol 1978 (MARPOL 73/78) requirements.

Figure 2-5 Indicative VICP and Support Infrastructure Phases and General Arrangement

3. KMCR BASIS OF SITE SELECTION AND ALTERNATIVES

The requirement for a KMCR building is considered to be an essential safety element for the Project as well as for VI operations personnel to provide contingency refuge during cyclonic conditions in the event that evacuation of personnel cannot be achieved on a timely basis due to logistical or other difficulties arising from the increased project activity in the northwest of WA.

Apache has considered a number of alternatives for the potential siting of the KMCR building within the Apache lease. The site selection process involved the consideration of selection criteria, as well as multiple configurations of the KMCR to reduce ground disturbance and clearing. The locations considered include:

- The proposed location;
- Alternative 1: north of bottom camp; and
- Alternative 2: upgrade of existing mess.

The selection criteria for the KMCR include the following:

- The KMCR must be located within the Apache lease;
- The KMCR needs to be in close proximity to the existing accommodation facilities (top and bottom camps) for personnel accessibility and safety (muster) reasons;
- Ideally, the KMCR building should be set back into an excavated hillside such that the design Shielding Multiplier (Ms) as per AS1170.2 – Wind Actions Standard (2011) is minimised. The Ms is a measure of wind loadings on the KMCR. Lower Ms indicates greater protection to the building, and higher Ms may involve greater design and construction costs;
- The KMCR needs to be offset from the helicopter flight path;
- The KMCR needs to be above the 1:10,000 year cyclone surge level;
- The KMCR needs to be remote from potential airborne dust sources for safety and hygiene;
- The KMCR building location should allow the implementation of acceptable management practices for the protection of existing flora and fauna both during construction and operations; and
- Opportunity for winning of infill material as required for the VICP earthworks.

The proposed KMCR, and alternative locations are shown in Figure 3-1. Within the Apache lease, Figure 3-1 shows that there is very limited available and suitable area for new infrastructure, in this case the KMCR.

Table 3.1 discusses the alternative locations considering the site selection criteria described above. The management of vegetation clearing in the KMCR area is discussed in Section 8.1.4.

The proposed location for the KMCR is preferred as it is centrally located and meets all of the site selection criteria.

Table 3.1 Consideration of Altrnative KMCR Locations

Selection Criteria	Proposed KMCR Location	Alternative 1: north of bottom camp	Alternative 2: upgrade existing mess
Close proximity for personal accessibility and safety reasons	The proposed location is in a central location in close proximity to the top and bottom camps.	Alternative 1 is in close proximity to the bottom camp, but is less accessible to personnel at the top camp.	Alternative 2 is in close proximity to the top camp, but is less accessible to personnel at the bottom camp.
Low Shielding Multiplier (Ms)	The proposed location is shielded by topography to the east and north, and has an Ms of 1.0.	Alternative 1 is more exposed to wind, and has an expected Ms of 1.1.	Alternative 2 is more exposed to wind, and has an expected Ms of > 1.1
Outside of helicopter flight path	The proposed location is acceptably offset from the helicopter flight path.	Alternative 1 is not appropriate as it does not provide offset from the helicopter flight path.	Alternative 2 is outside of the helicopter flight path.
Above cyclone surge level	All three options are above the cyclone surge level.		
Remote from potential dust sources	All three options are at similar distances to the primary sources of dust, i.e. the ESJV and HJV process plants.		
Allow the implementation of flora and fauna management practices	The Project includes the stabilisation, rehabilitation and re-vegetation of the batter between the KMCR and the bottom camp. This is discussed in Section 8.1.4. The KMCR layout has also been revised to reduce disturbance to the Wedge-tailed shearwater rookery to the south. Potential noise and vibration impacts are discussed in Section 9.3.	The alternative location does not require additional flora and fauna management measures.	Upgrade of the existing mess does not require additional flora and fauna management measures.
Opportunity for winning of material	The preferred location provides significant volumes of material for use in other components of the Project (Section 2.4).	Alternative 1 provides very little or no soil infill material for use in the Project.	Alternative 2 provides no soil infill material for use in the Project.
Overall comment	The proposed location is preferred as it meets all selection criteria.	Alternative 1 is ruled out as it is not sufficiently offset from the helicopter flight path.	Alternative 2 is ruled out because it requires the existing mess to be shut down for 3 months or more, involving cost and safety implications to Apache operations.

Figure 3-1 KMCR and Alternative Locations

4. APACHE ENVIRONMENTAL MANAGEMENT FRAMEWORK

4.1 Apache Regional Environmental Management Policy and Corporate Environmental, Health and Safety Standards

Apache's activities on VI are required to be planned and conducted in accordance with Apache's Regional Environmental Management Policy. Apache's Environmental Management Policy provides broad guidelines for the environmental responsibilities of all Company personnel and the conduct of Company activities.

Apache also has Worldwide Environmental, Health and Safety (EH&S) Standards. The EH&S Standards represent the Company's minimum requirements for environmental management across its global operations. The EH&S Standards afford each Region the opportunity to determine how they accomplish and implement the Standards which are an Apache mandatory requirement for operation. The EH&S Standards are audited against by Apache Corporate EH&S team with the results reported to Apache's Australian Executive Management.

4.2 Australian Petroleum Production and Exploration Association Code of Environmental Practice

The Australian petroleum exploration and production industry operates within an industry code of practice. The industry and Apache corporate standards provide guidelines for activities that are not formally regulated and have evolved from the collective knowledge and experience of the oil and gas industry both nationally and internationally.

The Australian Petroleum Production Association (APPEA) has recently revised its 1996 Code of Environmental Practice. The revised APPEA Code of Environmental Practice 2008 provides an outline of environmental objectives which represent guidance to affiliated companies on key aspects of good environmental practice in the petroleum industry. Apache has a commitment in its Environmental Management Policy of implementing the APPEA Code.

4.3 Existing Management Plans

4.3.1 VI facilities Operations Environmental Plan

Apache prepared and submitted to the Government an Environmental Management Plan (EMP) in November 1986 as a requirement of the Apache lease condition from the then CALM (now the DEC). In December 1997, the original EMP was updated to incorporate all the expansion projects and new developments that had been undertaken on VI including the Harriet Gas Gathering Project, Tanami, Alkimos, Agincourt and East Spar.

As part of an application to the DMP as the Designated Authority for the renewal of the production licence TL1 and pipeline licence PL12 for VI in 2006, the DMP requested Apache submit a revised Environment Plan (EP) to reflect the status of environmental management of the facilities covered by the licences. DMP requested that the revised EP be prepared to satisfy the requirements of the *Commonwealth Petroleum (Submerged Lands) (Management of the Environment) Regulations* 1999 (now replaced by the *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations* 2009 (OPGGS (Env) Regulations) as no stage regulations were in place under the WA *Petroleum (Submerged Lands) Act* 1982.

Apache undertakes periodic reviews of the EP to ensure it remains appropriate for operations on VI including the Project. The EP covers all infrastructure and operational activities on VI, associated offshore platforms/monopods and subsea tie-backs, the subsea pipelines, flow lines and umbilicals between VI and the offshore facilities, the pipelines between VI and the WA mainland metering station and the pipeline from VI to the marine load-out terminal.

The EP addresses the management of routine and non-routine (or accidental) events identified from an environmental hazard assessment undertaken for the VI facilities as well as historical hazard identifications (HAZID) undertaken for each new project undertaken by Apache. Environmental risk management is discussed in Section 4.4 below.

4.3.2 Other Management Plans

In addition to the EP, there are a number of other management plans in place in relation to operations on VI. Management plans and procedures that are relevant to the Project include:

- Varanus Island Lighting Management Plan (EA-60-RI-153) (October, 2012);
- Varanus Island Vegetation Management Plan (EA-60-RI-172) (April 2006);
- Quarantine Procedure (AE-91-IQ-189) (October, 2012);
- Vermin Management Plan (EA-60-RI-131) (June, 2007);
- Refuelling and Chemical Transfer Management Procedure (AE-91-IQ-098) (April, 2012);
- Environmental Requirements for Offshore Marine Vessels (AE-91-IQ-202) (July, 2012);
- Environmental Auditing and Inspection Procedure (EA-91-IG-003) (July, 2012);
- Whale Interaction and Sighting Procedure (EA-91-II-003) (August, 2012);
- Controlled Waste Procedure EA-00-II-003) (June, 2012);
- Procedure for Mobilising Contractors to Site (AE-00-ZF-012) (December, 2007);
- VICP Drilling and Blasting Procedure (LM-10-IG-198) (to be finalised if required – refer to Section 9.3);
- Hazard Reporting, Incident Notification and Investigation Procedure (AE-91-IF-002) (March, 2012);
- Fire Control Philosophy Varanus Island (AE-10-ZF-001) (May 2001);
- HAZID Procedure (Af-91-IF-038);
- VICP Construction Environmental Management Plan (JB-10-RI-002) (being prepared); and
- VICP Construction Audit Plan (JB-10-RF-059).

The EP and the VI Vegetation Management Plan are being reviewed to reflect recent changes in regulatory requirements, Project requirements, as well the as on-going environmental management requirements of VI.

Environmental management requirements and measures described in this referral are included in the project-specific CEMP.

4.3.3 Contractor Management

The Project will be managed and conducted in accordance with the management plans described in Section 4.3.2, and contractors will be required to conduct their operations in accordance with the management plans.

Contractors are required to demonstrate their ability to meet the relevant legislative requirements as well as the relevant management plans. Apache will conduct routine audits and inspections during the Project to ensure the contractors meet the relevant standards and practice. A project-specific Construction Audit Plan has been prepared to address auditing requirements for the Project.

Contractors for the Project will be managed under the Procedure for Mobilising Contractors to Site, which:

- Summarises the requirements contractors need to fulfil prior to mobilising personnel and equipment; and
- Provides a mechanism for contractors to demonstrate appropriate due diligence prior to arriving at a work site.

In addition, Apache has also prepared a project-specific CEMP which describes the performance objectives, standards, criteria, management measures and monitoring requirements for environmental aspects relevant to the Project, including:

- Flora and fauna;
- Lighting;
- Air (dust);
- Noise and vibration;
- Surface water;
- Waste;
- Vessel movements; and
- Incidents and emergency response.

The CEMP also sets out the implementation strategy to ensure potential environmental impacts are appropriately and adequately addressed throughout the Project. As part of the Project, the CEMP will also be audited in accordance with the Construction Audit Plan.

4.4 Environmental Risk Assessment and Management

Environmental risk assessment refers to a process where hazards and events from an activity are quantitatively and/or qualitatively assessed for their potential impact on the environment (including physical, biological, and socio-economic environments).

The environmental risk assessment methodology is detailed in the HAZID Procedure. The risk assessment process is an integral part of Apache's operations in analysing the known and potential environmental, engineering, safety and social hazards and events.

Environmental risk assessment consists of four steps:

- Risk identification;
- Risk analysis;
- Risk evaluation; and
- Risk treatment.

Apache adopts the As Low As Reasonably Practicable (ALARP) principle in its environmental risk management. The ALARP principle recognises that no industrial activity is entirely risk-free and that there is a level of risk with any activity. The ALARP principle is based on criteria which segregate risk into the following zones:

- Unacceptable (above ALARP and deemed unacceptable);
- ALARP (within the ALARP region such that measures should be considered to reduce the risk); and

- Tolerable (below the ALARP region and deemed Tolerable).

The main components of the ALARP demonstration are as follows:

- Application of design and construction codes and standards and good industry practice,
- Early identification of hazards and implementation of the recommendations to eliminate risk through design, procedures and practices;
- Identification of the key risk drivers qualitatively or quantitatively;
- Identification of risk reduction measures; and
- Assessment of the practicability and cost benefit of each risk reduction measure.

Apache's management and mitigation actions aim to reduce the environmental risks of the Project.

Applying the ALARP principle to Apache's risk assessment matrix means that residual risks that were ranked as Tolerable are considered below the ALARP range and require no further risk reduction measures. At the other end of the scale, those residual risks that are ranked unacceptable means that the activity cannot go ahead as currently proposed. In between these are activities where ALARP must be demonstrated.

4.4.1 Environmental Risk Assessment for the Project

Risk Assessment Methodology

The risk assessment was conducted using an objective approach, however Apache's working knowledge of the NWS gained over many years of oil and gas exploration and development was also drawn upon for the overall assigning of likelihood and consequence to a particular hazard and event to consider appropriate contextual and site specific factors.

The workshops considered the following operations and activities:

- General construction activities including dust, dust suppression, vegetation clearing, hydraulic and chemical spills, light spill, waste management etc.;
- General construction activities involving potential interaction with terrestrial marine fauna, seabed disturbance, quarantine requirements;
- Noise and vibration resulting from construction activities, runoff and erosion, bund capacity, contaminated soil handling and management;
- Potential events during installation of prefabricated modules; and
- Potential on-going events as part of operations during and after commissioning of the Project.

The risk assessment process concluded that the majority of potential impacts would arise from the earthworks and construction activities as a result of ground disturbance and clearing (Stage 1 of the Project). Stages 2 and 3 have comparatively lesser potential environmental impacts as much of the Project components/modules are prefabricated off VI, and installation works involves positioning of the modules and minor tie-in works only.

The risk assessment considered existing mitigation controls and measures in place, and assessed the residual risks of those events. Environmental risks which were rated ALARP are summarised in Table 4.1. No unacceptable risks were identified from the workshops.

Risk Assessment Workshops

Two workshops were conducted to assess environmental risks relevant to the Project on 12 July and 19 September 2012 respectively. Using a brainstorming method to systematically identify environmental hazards and impacts, a number of risks, recommendations and actions were identified from the first workshop.

These risks, recommendations and actions were reviewed and incorporated into the Project design, to substitute or reduce the risks to ALARP level. For example, the first workshop identified:

- The need to stabilise the batter between the KMCR and the bottom camp. Apache redesigned the batter to include geosynthetic material (geoweb);
- Locally significant flora in the KMCR area. Apache engaged Astron Environmental Services to develop a rehabilitation plan which includes a trial for the re-vegetation of the locally significant flora species; and
- Potential noise and vibration impacts associated with earthworks equipment. Alternative equipment (the Erkat rotary cutter) was subsequently considered and included as an alternative equipment to reduce noise and vibration impacts.

The second workshop reconsidered the improvements made to the Project design, and this referral describes the residual risks in relation to the environmental aspects. These are discussed in Table 4.1.

Subsequent to the workshop, during the finalisation of design, construction through to completion of the Project, additional risks and hazards associated with the Project will continue to be assessed using the assessment methodology described in section 4.4.1. A Project risk register will be prepared prior to the commencement of the Project. Risks and hazards additional or different to those identified in the HAZID workshops will be added to the risk register. If appropriate, the CEMP will be revised to include the additional management measure(s) associated with the additional risk or hazard.

Table 4.1 Summary of Environmental Risk Assessment

Aspect	Risk Rating	Relevance to Project
Clearing of native vegetation: loss of potential fauna habitat	ALARP	Native vegetation will be cleared in the accommodation camp and KMCR works area. ***Apache action:*** The footprint of the KMCR has been optimised to reduce the amount of clearing required. Potential impacts associated with clearing activities are discussed in Section 8.1.
Clearing of native vegetation: reduction in locally significant flora	ALARP	Native vegetation will be cleared in the accommodation camp and KMCR works area. ***Apache action:*** The batter between the KMCR and the accommodation camp will be designed to allow rehabilitation and re-vegetation with local (significant) endemic species. This is discussed further in Section 8.1.
Potential release of hydrocarbons: vessel collision with Agincourt platform	ALARP	Potential vessel collision with the platform for project deliveries to the West Wharf on VI. ***Apache action:*** Apache conducted a marine survey and modified the vessel route to avoid the Agincourt platform. Potential vessel collision with the platform is low and unlikely.

Aspect	Risk Rating	Relevance to Project
Quarantine: introduction of non-endemic marine species of concern	ALARP	There is a risk of foreign fauna being introduced to VI through deliveries and workforce transport. ***Apache action:*** Apache has a Environmental Requirements for Offshore Marine Vessels procedure in place which describes the requirements in relation to vessel quarantine risks including invasive marine pest species and ballast water management. International vessels are required to adhere to AQIS requirements; and all vessels are required to be risk assessed prior to departing for VI. The risk assessment will identify further actions required including cleaning and inspection.
Quarantine: introduction of non-endemic, non-native flora and fauna pest species	ALARP	There is a risk of foreign fauna being introduced to VI through deliveries and workforce transport. ***Apache action:*** Apache has a Environmental Requirements for Offshore Marine Vessels procedure in place which describes the requirements in relation to vessel quarantine risks including invasive marine pest species and ballast water management. International vessels are required to adhere to AQIS requirements; and all vessels are required to be risk assessed prior to departing for VI. The risk assessment will identify further actions required including cleaning and inspection.
Earthworks noise: changes in fauna behaviour/ movement	ALARP	Potential noise impacts to the Wedge-tailed shearwater and turtles from construction equipment and operational noise. ***Apache action:*** Routine noise monitoring in the past has not identified noise related disturbance to avifauna or turtles.
Drilling and blasting: noise and vibration impacts on avifauna	ALARP	Potential impacts on the Wedge-tailed shearwater due to drill and blast activities as part of the earthworks. ***Apache action:*** Drilling and blasting activities is a contingency only, in the event that the excavators and bulldozer are unable to break the hard rock in the project areas. If required, drilling and blasting will be undertaken outside of peak Wedge-tailed shearwater and turtle nesting season. A project-specific Drilling and Blasting Procedure will be finalised prior to blasting activities commencing. No drilling and blasting impacts to Wedge-tailed shearwater or turtles are likely. This is discussed further in Sections 7.2.2, 8.2.2, and 9.3.
Surface runoff during heavy rainfall	ALARP	Surface runoff should not impact on the Wedge-tailed shearwater rookery south of the KMCR. ***Apache action:*** Silt traps will be provided for earthworks in the KMCR area to minimise runoff impacts beyond the project area. Earthworks in the area will also be conducted such that runoff within the project area is diverted away from the rookery.

Aspect	Risk Rating	Relevance to Project
Bund realignment: maintenance of secondary containment	ALARP	Secondary containment for the bulk crude oil storage tanks must be maintained throughout the Project. ***Apache action:*** The VICP earthworks will be scheduled to occur during period when hydrocarbon volumes in the storage tanks are minimised, e.g. the tanks will be emptied prior to works commencing. During the works, on-going crude oil production will be distributed across the three tanks. At all times, the bund will provide secondary containment for a volume of 110% of a single storage tank. This is discussed in Section 9.6.3.
Bund realignment: contamination of clean soils and area	ALARP	There is potential for contamination in the vicinity of the work area through leaching or surface runoff from the contaminated soil to areas beyond the contaminated soil area. ***Apache action:*** The existing bund will be maintained throughout the VICP works, and be partially removed after the new bund is established. In addition, the existing HDPE lining will be maintained and pulled back to 'wrap' around and anchored at the top of the new bund, providing containment for potentially contaminated runoff throughout the works. This is discussed in Section 9.1.
Bund realignment: damage to existing liner	ALARP	There is potential for damage to the existing liner during earthworks excavation. ***Apache action:*** Care will be taken to ensure the existing liner will not be damaged during earthworks. Appropriate equipment will be used to minimise damage during works, e.g. use of bobcat excavator fitted with rubber tracks. If the existing liner is damaged, the damaged area will be patched or replaced, as appropriate.
Air emissions: reduction in air quality	ALARP	There is potential for dust impacts (particularly on mangrove); and emissions (air pollutants) from the VICP during operations needs to be assessed. ***Apache action:*** Apache will conduct quarterly monitoring of mangrove during the Project to manage dust emission and deposition. This is discussed in Section 8.1.5. Apache has also undertaken dispersion modelling to assess potential increase in air pollutant emissions. This is discussed in Section 9.2.

Aspect	Risk Rating	Relevance to Project
Light spill: changes in fauna behaviour/movement	ALARP	Construction activities for the Project will be undertaken as daylight operations. There are potential light spill impacts from the operations of, and activities associated with, the Project post-completion. ***Apache action:*** Apache has updated the Lighting Management Plan to incorporate the DEC Environmental Assessment Guideline No.5 *Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts* (DEC EACG No.5) requirements. Apache has also updated the VI Lighting Design Specification for Projects to be consistent with DEC EAG No. 5. The specification guides the selection and setups of lighting equipment for the Project. Potential impacts on marine fauna are discussed further in Section 7.2.2.

5. PHYSICAL ENVIRONMENT

5.1 Climate

The climate of the region is arid subtropical with hot summer temperatures and low and unpredictable rainfall, high evaporation, occasional cyclones and associated summer rainfall. The annual average rainfall of the Lowendal Islands is approximately 300mm, mostly as a result of tropical cyclones.

The summer and winter seasons fall into the periods October-March and May-July, respectively. Winters are characterized by clear skies, fine weather, predominantly strong east to south-east winds and infrequent rain. Summer winds are more variable, with strong south-westerly's dominating. Three to four cyclones per year are typical, primarily between December and March (WNI, 1995). The months of April and September are considered transitional between summer and winter.

Average surface air temperatures range from 34.2°C (maximum) and 24.8°C (minimum) in summer (December to February) to 25.2°C (maximum) and 17.1°C (minimum) in winter (June to August).

Climatic data is monitored and recorded at a Bureau of Meteorology automatic weather station on VI.

The winds in the area show a marked seasonal variation. During winter (May to August), moderate to strong south-easterlies and north-easterlies to easterlies prevail, while during summer (October to March) moderate southerly, south-westerly and westerly winds dominate. April and September are transitional months where the wind can blow from the south-west to south-east.

Extreme wind conditions may be generated in the area by tropical cyclones, strong easterly pressure gradients, squalls, tornadoes and waterspouts. Tropical cyclones generate the most significant storm conditions on the North West Shelf (SSE, 1993). These clockwise-spiralling storms have generated wind speeds of 50 to 120 knots within the region (SSE, 1991). Since recordings began in 1960/61, tropical cyclones have approached the area from the north-west through to east, with the most frequent directions being from the north (34%) and east (36%). However, due to the circular wind patterns involved, winds can approach from any direction during the passage of the storm.

The frequency of occurrence of tropical cyclones is an important physical environmental factor influencing the marine fauna, particularly corals, in shallow water at the Lowendal Islands.

5.2 Geomorphology

The Lowendal group of islands are low lying limestone rock, some covered in vegetation, others being rock with few plants to be found. The formation is comprised of lime-cemented dune sand that was deposited during the Pleistocene.

Shoreline profiles for the Lowendal group of islands are typically steep, and contain relatively narrow low intertidal zones, which dip onto the extensive shallow sub-tidal platform that characterises the area. Both the lower intertidal and shallow sub-tidal zones comprise semi-planar limestone pavement (DEC, 2007).

The topography of Varanus Island is flat to undulating low dunes. The elevation ranges from sea level to a maximum of 18 m Australian Height Datum (AHD). Outcropping occurs over much of the lease area at VI, particularly in the eastern and south-eastern areas (Parsons Brinckerhoff, 2005).

5.3 Groundwater

Parsons Brinckerhoff (PB) conducted a soil and groundwater investigation in the main bund area on VI in 2012 (PB, 2012). The groundwater table over most of the Apache lease is present at an elevation of 1.8 m AHD at low tide and 2.6 m AHD at high tide (PB, 2012). Groundwater contours prepared by PB (2012) shows that groundwater levels around the VICP range between 1.8 to 1.9 m AHD. The design sub-grade level for the VICP is approximately 9 m AHD.

As such, there will be no interaction with groundwater, and no potential impacts to groundwater are likely.

6. RELEVANT ENVIRONMENT ASPECTS

Based on the environmental risk assessment described in Section 4.4, environmental aspects relevant to the Project are summarised in Table 6.1. Apache has undertaken recent surveys and assessments in relation to the Project where appropriate. The results from the surveys and assessments, and proposed management measures for the relevant environmental aspects have been incorporated into this referral.

Table 6.1 Environmental Aspect relevant to the Project

Environmental Aspects	Relevance to Project	Section
Marine Environment		
Macroalgae and Seagrass	Potential clearing as part of wharves upgrade works	7.1
Turtles	Potential disturbance of habitat, and potential impacts to hatchlings via light spill	7.2
Whales, Dolphins and Dugongs	General overview	7.3
Biological Environment		
Terrestrial Vegetation (including rehabilitation and re-vegetation)	Clearing of flora and vegetation; potential clearing of fauna habitat	8.1
Terrestrial Fauna	Fauna including mammals, vermin, avifauna and reptiles	8.2
Short-Range Endemics	Potential impacts to short-range endemics through ground disturbance and clearing	8.3
Subterranean Fauna	Potential impacts to subterranean fauna through ground disturbance and clearing	8.4
Other Environmental Aspects		
Contaminated Soil	Relocation of contaminated soil as part of bund realignment	9.1
Air Emissions	Emissions from compressors stacks; and potential increase in dust generation	9.2
Noise and Vibration	Ground disturbance and noise during earthworks	9.3
Greenhouse Gas	Greenhouse gas emissions associated with Project components.	9.4
Surface Water	Stormwater runoff and potentially contaminated runoff management	9.5
Hazardous Materials and Chemicals	Potential soil and groundwater contamination through chemical storage and use	9.6
Waste Management	Management of Project wastes	9.7

7. MARINE ENVIRONMENT

Shoreline/intertidal habitats surrounding VI are described as rocky undercut cliffs and intertidal limestone platforms, large sandy beaches with back dunes and Mangroves (on the western beaches). Shallow sub-tidal habitats surrounding VI are described as limestone pavements and reefs, isolated corals and coral bommies offshore.

The Project involves land based construction works except for the East and West Wharves upgrade which involves ground truthing immediately adjacent to the existing wharves.

As described in Section 2.2.1, the wharves upgrade construction works will occur in the intertidal seabed utilising a long reach excavator operating from the existing wharves, followed by debris clean-up using a small excavator, in-situ casting concrete foundations, installation of pre-cast concrete caissons, infilling and deck sections, and rubble mound revetment wing walls.

Broad marine habitat types at VI and its surrounding marine environment are shown in Figure 7-1. In general around the East and West Wharves, as well as well around VI generally, the primary marine habitat is sub-tidal sand and macroalgal communities.

A number of avifauna and marine turtles nests on VI. The region also supports migratory, transient and resident marine mammals such as whales, dolphins and dugong.

7.1 Macroalgae and Seagrasses

7.1.1 Regional Environment

Macroalgae and seagrasses are most prolific over the shallow pavement limestone reefs adjacent to VI. Seagrasses in the Montebello/Lowendal/Barrow Island region do not form extensive meadows but rather are sparsely interspersed between the macroalgae. Six species have been recorded to date; *Cymodocea angustata*, *Halophila ovalis*, *Halophila spinulosa*, *Halodule uninervis*, *Thalassia hemprichii* and *Syringodium isoetifolium* (DEC, 2007). The main seagrasses of the Barrow Island region are small, ephemeral species that grow on soft sediments on subtidal sands and in intertidal pools. The most common species are *Halophila ovalis* on the deeper subtidal sand and *Halophila*, *Syringodium isoetifolium* and *Halodule uninervis* in the rock pools (Chevron, 2005).

Macroalgae and seagrasses are important primary producers in tropical inshore waters. Seagrasses are directly grazed by dugongs (Prince, 1986), and both seagrasses and macroalgae are grazed by green turtles. Few tropical fish species graze directly on seagrass or macroalgae. However, both vegetation types support a diverse and abundant fauna of small invertebrates that are the principal food source for many inshore fish species (Blaber & Blaber, 1980). Small crustaceans, such as amphipods, copepods and isopods that emerge from this vegetation at night are fed upon by planktivorous fish, such as herring, sardine and anchovy. Dense schools of these fish are, in turn, fed upon by both predatory fish, such as tuna and mackerel, and diving birds, such as shearwater and terns. Beds of both seagrasses and macroalgae support the juvenile stages of prawn species that are commercially important in the region (Loneragan *et al*., 1994).

Macroalgae are the dominant macrophyte in the Montebello/Lowendal/Barrow Island region, occupying approximately 40% of the benthic habitat area of the region (DEC, 2007). The most numerically abundant macroalgae are the species of *Sargassum* that cover the shallow sub-tidal rock platforms around the islands. Seasonally *Sargassum* grows large foliose thalli that generally produce reproductive structures and then senesce each winter. Consequently, the biomass of the macroalgal beds varies greatly with these seasonal changes. Other abundant taxa include *Halimeda*, *Caulerpa*, *Dictyopterus*, *Dictyota*, *Cystoseira*, *Padina*, *Codium* and *Laurencia*).

7.1.2 Seabed Surveys around Varanus Island

Apache has conducted a number of seabed surveys in the waters surrounding VI for developments associated with operations on the island, including the JB Gas Development, the 'String of Pearls' fields and Harriet (Bambra) Bravo Development.

Seabed surveys undertaken in the vicinity of VI for the JB development, located in surrounding waters west of VI, showed a gradually deepening limestone pavement, mostly covered by sand veneers. This habitat type extended from VI west along the plateau surrounding the Lowendal Group. Sands were generally bare of benthic organisms, except for minor occurrences of seagrasses from the genera *Halophila* and *Syringodium* in the shallower waters closer to VI.

A transect of the seabed from the eastern side of VI to the deeper waters surrounding Harriet Bravo consists of macro algae-rubble dominated community in the shallow intertidal waters. This gives way to a limestone pavement gradually increasing in water depth with occasional hard corals in the form of individual bommies, including the massive *Porites*, becoming more abundant.

7.1.3 Potential Impacts

Potential marine environment impacts relevant to the Project include:

- Clearing of foraging habitat via disturbance to macroalgal communities as part of the wharves upgrade site preparation works; and
- Light spill impacts both during construction and operations to foraging turtles and turtle hatchlings.

7.1.4 Management Measures for Marine Fauna

The East and West Wharf upgrades will occur in the intertidal seabed during low tides. Recent inspections of the wharf areas confirm that the area is absent of macroalgae communities and seagrasses (Figure 7-2).

In relation to the concrete blinding and cast in-situ foundation works as required for the wharf upgrade works, silt fencing will be installed to contain plume development. Steel frames for the concrete in-situ cast foundations will be filled from the bottom up using appropriate sluices or tremie pipes. No dropping of concrete through the water column will be permitted unless silt screens are in place.

A small rubber tracked excavator will be used to clean-up construction debris from the wharf works for Project re-use.

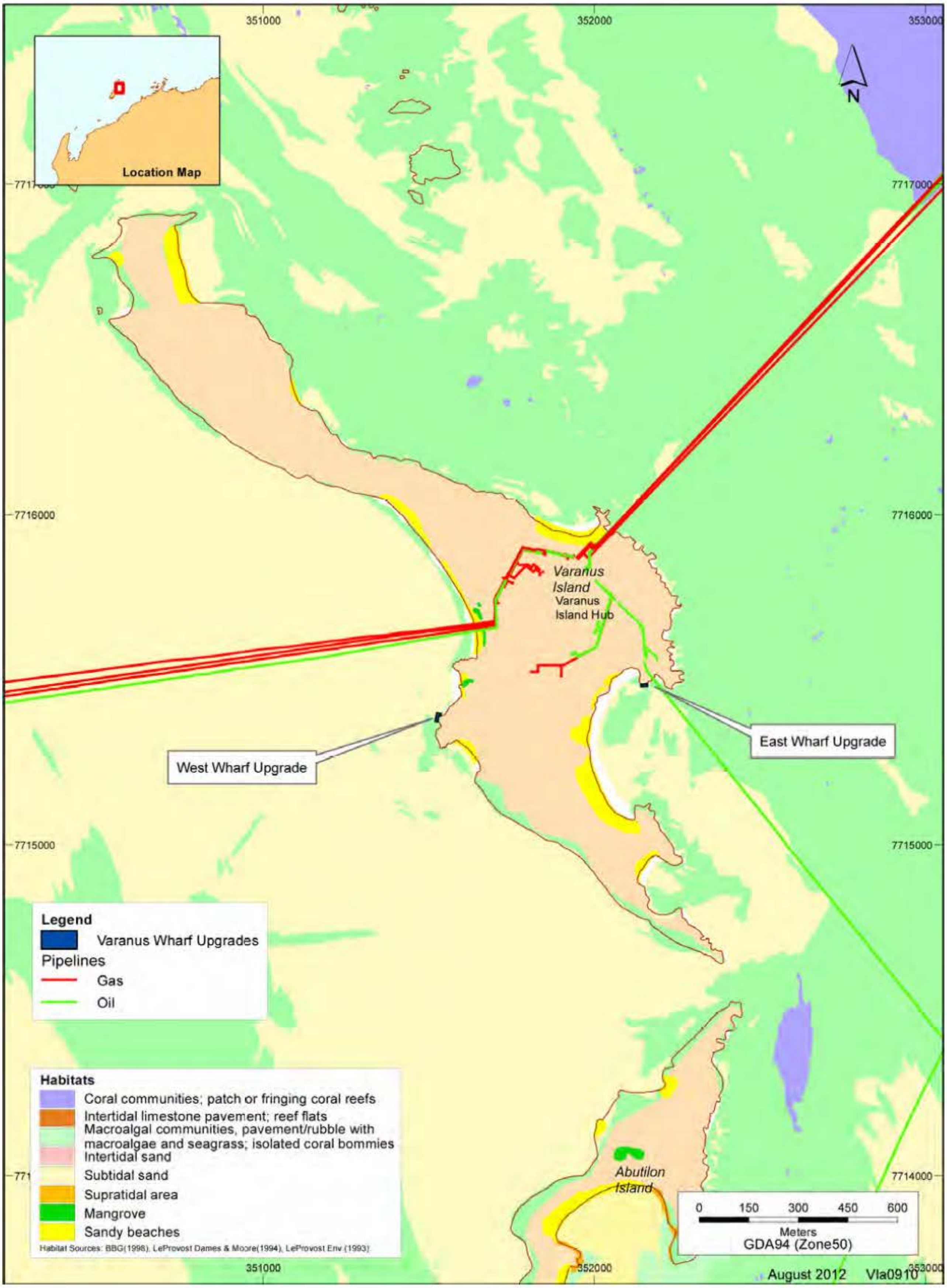

Figure 7-1 Marine Habitats for Varanus Island

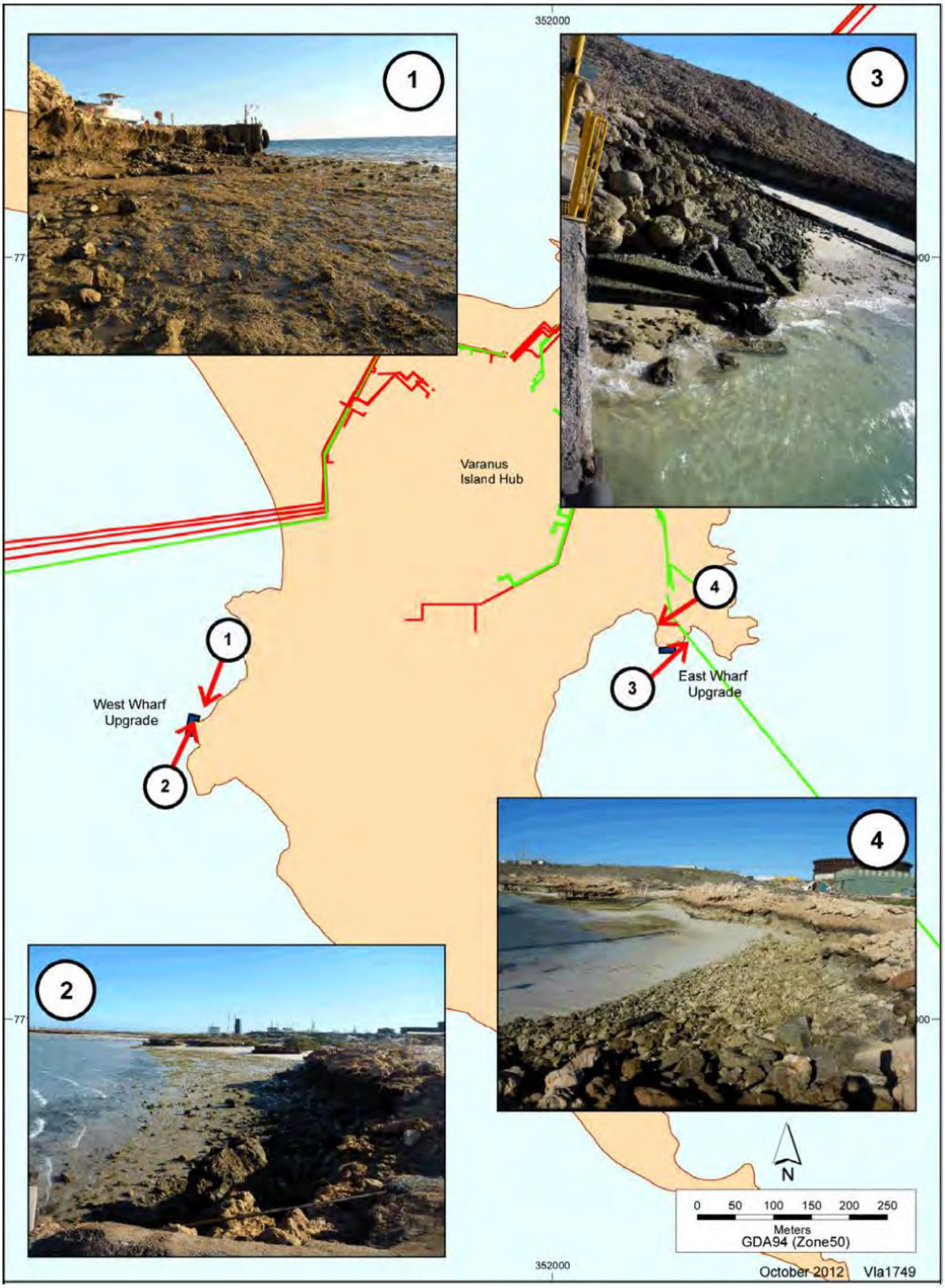

Figure 7-2 East and West Wharves Works Area

7.2 Turtles

7.2.1 Existing Environment

Five species of marine turtle nest on sandy shore sites of the Dampier Archipelago, Montebello Islands, Lowendal Islands, Barrow Island, Airlie Island, Thevenard Island, other coastal islands and the Exmouth region. These are the:

- Hawksbill turtle (Eretmochelys imbricata);
- Flatback turtle (*Natator depressus*);
- Green turtle (*Chelonia mydas*); and
- Loggerhead turtle (*Caretta caretta*) and
- Leatherback turtle (*Dermochelys coriacea*).

The most common species of turtle nesting on VI is the hawksbill turtle. Flatback turtles are seen frequently whilst green turtles are the least common. The leatherback turtle may visit the open waters around VI.

The protection status of the turtles under the *Wildlife Conservation Act* 1950 (WC Act), the EPBC Act and the International Union for Conservation of Nature (IUCN) red list are summarized inTable 7.1.

Table 7.1 Protection Status of Turtles

Species	WC Act*	EPBC Act*	IUCN
Hawks bill turtle (*Eretmochelys imbricata*)	S1	V	Critically endangered
Flatback turtle (*Natator depressus*)	S1	V	Data deficient
Loggerhead turtle (*Caretta caretta*)	S1	En; M	Endangered
Green turtle (*Chelonia mydas*)	S1	V	Endangered
Leatherback turtle (*Dermochelys coriacea*)	S1	En; M	Critically endangered

* S1: Schedule 1 – fauna that is rare or likely to become extinct; V: Vulnerable; En: Endangered; M: Migratory.

Figure 7-3 shows the beach locations on VI.

Flatback Turtles

The major nesting beaches on VI for Flatback turtles are Pipeline, Tanny's, North Mangrove, Mangrove, Amenity, Harriet's and Andersons Beaches. Flatback turtles have been observed to nest on VI between November and February. Tagging studies on VI suggests nesting season for Flatback turtles peaks in December and January with subsequent peak hatchling emergence in February and March.

Hawksbill Turtles

Tanny's Beach on the west coast of Varanus is the main Flatback turtle nesting beach in the Lowendal Group (Pendoley Environmental [Pendoley], 2012). On VI, hawksbills tend to nest in greater numbers on the eastern Pipeline Beach, Harriet Beach, and Anderson's Beach. Hawksbills have been observed breeding on the NWS between July and March with peak nesting activity around the Lowendal Islands between October and December.

Figure 7-3 Beaches on Varanus Island

7.2.2 Potential Impacts on Turtles

Pendoley Environmental (Pendoley) assessed potential lighting, and noise and vibration impacts arising from the Project (in particular the KMCR) (Pendoley, 2012) (Appendix 2).

The Project construction works will be undertaken as daylight operations. However, there is potential for light spill from the operations of the installed infrastructure at Mangrove Beach, Tanny's Beach and possibly North Mangrove Beach.

There is potential for noise and vibration impacts arising from the Project earthworks.

Potential Lighting Impacts

Pendoley (2012) considered that the size and scale of lighting from the KMCR is limited relative to light emissions from the existing plant lighting, flares and facilities on VI. However, the Project should be managed to minimise light spill.

There is potential for lighting impact from the VICP area. However, lighting plan for the VICP is not currently available and cannot be assessed.

Potential Noise and Vibration Impacts

It is unlikely that noise and vibrations from the KMCR area will affect nesting turtles at Mangrove Beach, incubating clutches or turtle hatchlings as the KMCR is greater than 200 m from the beach (Pendoley, 2012).

Earthworks at the VICP may have noise and vibration impacts on Mangrove Beach. Pendoley (2012) noted that eggs and buried pipped hatchlings in the nest are exposed to the natural noise and vibration of breaking waves. However, the importance of these vibrations for development and sea finding and consequently the potential interference of artificial sources of noise and vibrations has not been formally tested but is recognised as a potential risk factor for nesting beaches near petroleum infrastructure. Noise monitoring on WA nesting beaches has also shown beach locations to be noisier than inland locations at all times of the day due to wave action.

In Section 2.6, the regional ecological aspects timing show earthworks will commence in March 2013 which is towards the end of turtle nesting season. There may be low level of turtle activity in the months of March and April. However, Mangrove Beach is not a major nesting site on VI (Pendoley, 2012). Past surveys of turtle activity on VI show that Pipeline Beach is the most visited beach on VI. On the western shoreline, turtle emergences have been recorded on Mangrove beach and Tanny's Beach but typically up to early-mid February.

The Project is not considered to have significant noise impacts on turtles.

7.2.3 Management of Potential Impacts to Turtles

Lighting Management

Apache has updated the Lighting Management Plan to incorporate DEC EAG No.5 requirements including the consideration of light types, light wavelengths, elevation and illumination directions etc.

Apache has also updated the VI Lighting Design Specification for Projects to be consistent with DEC EAG No. 5. The specification guides the selection and setups of lighting equipment for the Project.

Apache will undertake baseline lighting studies prior to the commencement of the Project to assist the periodic assessment of potential lighting impacts on VI.

The selection of lighting equipment at the VICP will be designed and selected with reference to the Lighting Management Plan and the VI Lighting Design Specifications for Projects. The lighting plan for the VICP, when available, will also be provided to Pendoley for review and comment.

Noise and Vibration Management

Drilling and blasting will be undertaken outside of peak turtle nesting season (May to August). Potential impacts to turtle on VI will also be managed through the routine survey on VI which is conducted typically through the months of January and February.

Management of drilling and blasting activities is further discussed in Section 9.3.

7.3 Whales, Dolphins and Dugongs

7.3.1 Existing Environment

Whales

Whale species that may occasionally visit the Montebello/Barrow/Lowendal islands region include the:

- Humpback whale (Megaptera novaeangliae);
- Short-finned pilot whale *(Globicephala macrorhynchus*);
- False killer whale (*Pseudorca crassidens*);
- Killer whale (*Orcinus orca*);
- Minke whale (Balaenoptera acutorostrata);
- Bryde’s whale (Balaenoptera edeni);
- Sei whale (Balaenoptera borealis);
- Pygmy blue whale (Balaenoptera musculus brevicauda);
- Fin whale (Balaenoptera physalus);
- Melon-headed whale (*Peponocephala electra*);
- Sperm whale (Physeter macrocephalus); and
- Blue whale (Balaenoptera musculus musculus).

Among the whale species, only the humpback whale is a regular visitor to the area (Chevron, 2005; DEC, 2007) and is the most commonly sighted whale in the Pilbara region. This species migrates between the Antarctica waters and the Kimberly region of Western Australia. The peak of the northerly migration occurs around June to July, while the southerly return migration peaks around September to October.

Dolphins

Bottlenose dolphins (*Tursiops truncatus*) and Indo-Pacific humpback dolphins (*Sousa chinensis*) are resident throughout the shallow waters of the inner Rowley Shelf (Chevron, 2005; DEC, 2007). Other dolphins known from the region include:

- Common dolphins (*Delphinus delphis*);
- Striped dolphins (Stenella coeruleoalba);
- Spinner dolphins (Stenella longirostris);
- Risso's dolphins (*Grampus griseus*);
- Spotted dolphins (*Stella attenuata*); and
- Rough-toothed dolphins (*Steno bredanensis*).

Dugongs

Dugongs (*Dugong dugon*) occur across the tropical coastal waters of Australia form Shark Bay to Queensland and are protected under national legislation and international agreements. Dugongs are herbivores and are generally associated with seagrass beds, upon which they feed. They are commonly found in shallow (less than 5m deep) sheltered areas, often near islands or large bays.

Dugongs are known to occur in the shallow, warm waters around the Rowley Shelf such as Barrow Island, the Lowendal Islands and the Montebello Islands, although not in the large concentrations seen further south in the Exmouth Gulf or Shark Bay (Prince, 1989; Chevron, 2005; DEC, 2007). Current knowledge on the size and distribution of dugong populations and their migratory habits in the region between North West Cape and the Dampier Archipelago is limited. Recent aerial surveys of dugong distribution have found the animals occur around Barrow Island, Airlie Island, Lowendal Islands and the Montebello Islands further offshore (Prince, 2001). Dugongs have been sighted around VI in the past.

7.3.2 Potential Impacts on Whales, Dolphins and Dugongs

Potential impacts on whales, dolphins and dugongs include:

- Loss of foraging habitat (in relation to dugongs specifically);
- Vessel interaction and collision; and
- Behavioural change to fauna through light and noise.

Loss of habitat

The Project occurs largely within or adjacent to disturbed areas on VI. The wharves upgrades occur in intertidal seabed adjacent to the existing wharves absent of seagrass and macroalgal communities. As such, no foraging habitat (seagrass) is expected to be removed.

Vessel interaction and collision

The regional distribution of many whale species is not well understood and while many species may occur in the Pilbara region, most are likely to be transients or occasional visitors.

Apache has a Whale Interaction and Sighting Procedure in place to minimise disturbance to marine mammals and whale sharks, including sighting and reporting requirements.

Behavioural change

The Whale Interaction and Sighting Procedure requires vessels to be maintained in good condition to minimise transfer of noise into the water.

8. BIOLOGICAL ENVIRONMENT

8.1 Terrestrial Vegetation

8.1.1 Existing Environment

The vegetation assemblages that occur on VI have been described as coastal. Six broad vegetation assemblages, distinguished on the basis of the relative abundance of species and/or vegetation structure, have been described by Semeniuk (1992). The assemblages are:

- A Low (to 20cm) open herbland of *Frankenia pauciflora* on exposed limestone, which is exposed to wind and sea spray and has poorly developed soil;
- B Low (to 50cm) open shrubland of *Scaevola spinscens*, *Rhagodia preissii* and *Sarcostemma viminale* subsp*. australe* (formerly S. australe) on limestone plains and ridges inland from the exposed coastal limestone;
- C Low (to 50cm) open shrubland of *Sarcostemma viminale* subsp*. australe*, *Capparis spinosa* and *Pittosporum phylliraeoides* on more sheltered and inland parts of undulating limestone terrain;
- D Open grassland of *Spinifex longifolius* on white sands of coastal dunes;
- E Closed mixed grassland/herbland of *Setaria dielsii* and *Amaranthus pallidiflorus* on the deeper orange sands of inland plains; and
- F Low (to 50 cm) open shrubland of *Sarcostemma viminale* subsp. *australe* with mixed grassland on orange sand particularly where it is shallow over limestone.
- Dis Disturbed vegetation within the DEC lease area.

All vegetation assemblages (A to F) are also found on Bridled Island.

In 2003, eight flora species were recorded to have very restricted distribution on VI, and Astron Environmental Services (Astron) considered these to be locally significant to VI. These species are not listed for protection, and are not declared rare species. These flora species include:

- *Capparis umbonata* (wild orange); found at one location within the lease – does not occur outside the lease;
- *Lepidium platypetalum* (slender peppercress); found in small populations at two locations within the lease – does not occur outside the lease;
- *Dicladanthera forrestii*; found at two locations within the lease – does not occur outside the lease;
- *Abutilon indicum* var. *australiense* (Indian lantern flower); found at just two locations; one within the lease and a second single plant outside the lease;
- *Jasminum calcarium*; found at one location outside the lease;
- *Jasminum didymum*; found at one location outside the lease;
- *Acanthocarpus verticillatus*; found at one location outside the lease; and
- *Striga curviflora*; found at one location outside the lease.

Figure 8-1 shows the locations of the locally significant flora species.

Astron conducted an annual vegetation monitoring of twenty-nine previously established transects in December 2011 (Astron, 2011). The transects cover a range of disturbed and undisturbed sites within, near and remote from the Apache lease. Each transect is 25 m in length and 1 m wide and have been selected to provide a representative sample of plant communities for that particular association. The transects are shown on Figure 8-3.

The 2011 vegetation monitoring was conducted outside of the optimal survey period, and perennial vegetation (in particular perennial grasses) was largely dormant. However, most species were still able to be identified although a number of grass species were reduced to rootstock making identification difficult. No Declared Rare Flora or Priority Flora was recorded during the survey (Astron, 2011).

A total of 72 plant taxa (including subspecies and varieties) were recorded in the transects. An additional 21 taxa were recorded outside the transects. All taxa recorded had been previously recorded on VI (Astron, 2011).

Astron (2011) compared the survey results with 2010 survey results, and concluded that the variations in the number of families, genera and taxa in the transects between surveys were not related to the habitat type or the contrast between disturbed and undisturbed areas but were possibly related to individualistic responses of each species to between-year variation in rainfall.

8.1.2 Weeds and Introduced Species

Fourteen environmental weed species and eight introduced mainland species have been recorded on VI (Astron, 2011) since 2000. These are summarised in Table 8.1.

Table 8.1 Weeds and Introduced Species on Varanus Island (Astron, 2011)

Scientific Name	Common Name	DEC Rating	Occurrence (Since 2000)
Environmental Weed Species			
**Cenchrus ciliaris*	Buffel Grass	High	Continues to persist; occurrence increased.
**Cenchrus setiger*	Birdwood Grass	High	Continues to persist; occurrence increased.
**Aerva javanica*	Kapok	High	Continues to persist; occurrence increased.
**Sonchus oleraceus*	Milk Thistle	Moderate	Continues to persist; occurrence variable depending on rainfall.
**Sonchus asper*	Prickly Sow Thistle	Moderate	Continues to persist.
**Chloris barbata*	Purple Top Chloris	Moderate	Appears eradicated.
**Tridax procumbens*	Tridax Daisy	Moderate	Continues to persist; occurrence increased.
**Malvastrum americanum*	Spiked Malvastrum	Moderate	Continues to persist; occurrence increased.
**Digitaria ciliaris*	Summer Grass	Low	Not recorded since 2003.
**Taraxacum officinale*	Dandelion	Low	Continues to persist; occurrence increased.
**Conyza sumatrensis*	Tall Fleabane	Low	Not recorded since 2001.
**Euphorbia sp.*	Spurge	-	Eradicated.
**Lycopersicon esculentum*	Tomato (Garden variety)	Low	Occasional occurrence; last recorded in 2010.
**Flaveria trinervia*	Speedy Weed	Naturalised.	Naturalised.
Introduced Mainland Species			
Ipomoea muelleri	Poison Morning Glory	-	Continues to persist.
Acacia ampliceps	Salk Wattle	-	Continues to persist.
Acacia coriacea	Leather Leaved Wattle, Wirewood	-	Garden area only.
Eucalyptus camaldulensis	River Gum	-	Garden area only.
Callistemon sp.	Identification to be confirmed	-	2009 stump regenerated in 2010.
**Cynodon dactylon*	Couch Grass	-	Recorded in 2000 within lawn area. Plants found in 2010 after removal of lawn.
Austrostipa sp.	Spear Grass	-	One record in 2002; presumed eradicated.
Sesbania cannabina	Sesbania Pea	-	One record in 2003; presumed eradicated.

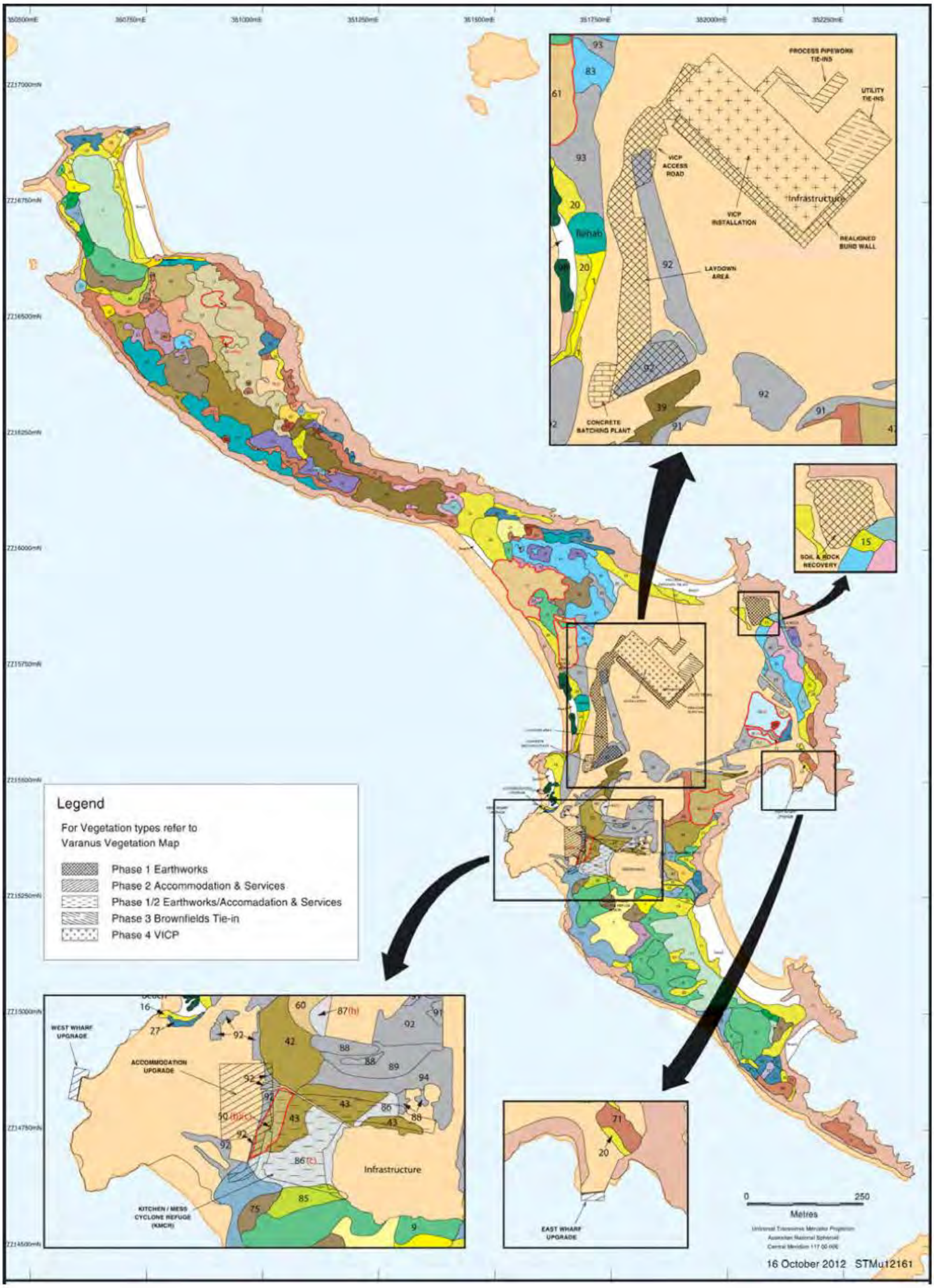

Figure 8-1 Vegetation Map of Varanus Island

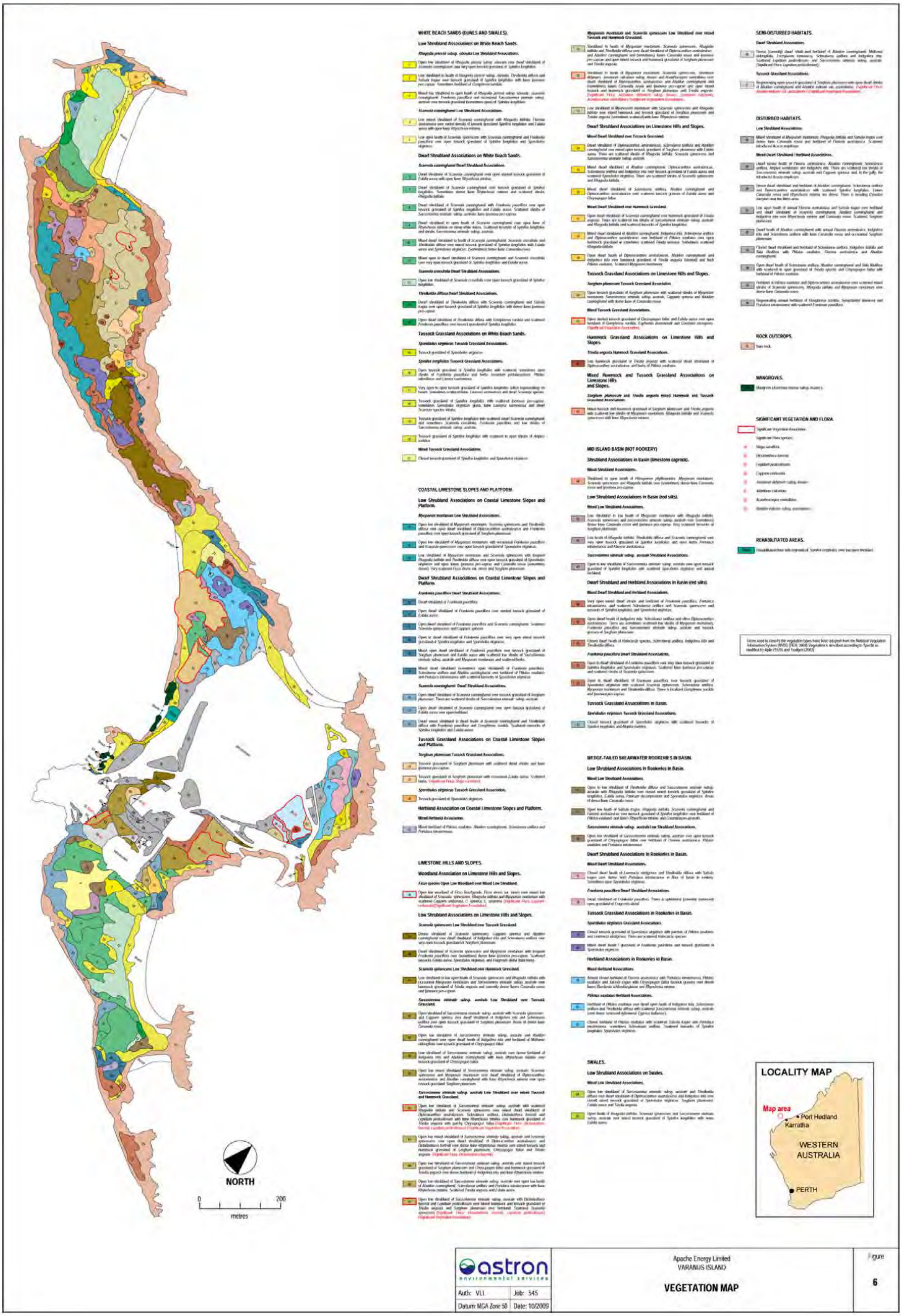

Figure 8-2 Vegetation Association Legend

Figure 8-3 Vegetation Monitoring Transects

8.1.3 Potential Impacts on Vegetation

The Project may have the following potential impacts on vegetation:

- Direct impact through clearing;
- Spread of weeds through movement of equipment and vehicle; and
- Introduction of foreign flora species.

Vegetation clearing

The KMCR and accommodation camp upgrade involves clearing of some locally significant vegetation association (*Sarcostemma viminale* subsp. *Austral* Low Shrubland over mixed Tussock and Hummock Grassland), within which locally significant flora *Dicladanthera forrestii* and *Lepidium pedicellosum* are recorded.

While the vegetation association and flora species identified are considered to be locally significant, they are not listed or protected species, and are not of State significance. The two identified locally significant flora species (*Dicladanthera forrestii* and *Lepidium pedicellosum*) have been recorded elsewhere within the Apache lease, although recorded numbers are low.

Weeds and introduced species

There is potential for the introduction of weed and foreign species to VI through Project freight and personnel arriving at VI, as well as equipment and personnel moving across different areas of VI.

8.1.4 Terrestrial Vegetation Management Measures

The Project will be undertaken in accordance with the CEMP, which among other things requires:

- All vehicles and mobile equipment to travel on designated routes only; and
- Wash-down of vehicles and equipment (other than oversized equipment) if the equipment is to move between different work areas.

Prior to the locally significant vegetation being cleared, Apache will develop in consultation with Astron a plan for rehabilitation of the batter between the KMCR and the accommodation camp, which will include:

- A program to trial the propagation of the locally significant flora species.
- Requirements for the removal and stockpiling of topsoil in the area for use in rehabilitation works;
- Specifications for the use of geosynthetic product, e.g. the geoweb, for the batter rehabilitation to support possible re-vegetation efforts; and

The rehabilitation plan will be incorporated into the VI Vegetation Management Plan.

Apache has a Quarantine Procedure in place to manage quarantine risks associated with activities on VI. Quarantine controls associated with all freight to VI include inspections and, where required, cleaning, baiting and/or fumigation to treat potential quarantine risks to verify the freight is vermin and insect free.

Apache has a Vegetation Management Plan in place for the management of flora and vegetation (including weed control) on VI including the identification of flora and vegetation, weed management, and other relevant management practices. The Vegetation Management Plan will be revised to include the KMCR area in relation to vegetation and weed management during construction and ongoing operations.

As part of the construction activities for the Project, weed control will be conducted in the Project areas prior to work (earthworks) commencing.

Rehabilitation and Revegetation

The Project disturbed and cleared areas will form part of the total disturbed areas within the Apache lease.

The Vegetation Management Plan provides measures for the management of weeds, requirements of the existing vegetation clearing permit for the island, restrictions to personnel access and the requirements for the progressive rehabilitation of disturbed or cleared areas where practicable. A plant nursery has been established on the island to assist with on-going rehabilitation works.

8.1.5 Mangroves

Existing Environment

Mangroves on VI are restricted to a disjoint population of white mangrove (*Avicennia marina*) along the southern portion of a sandy beach on the west coast of the Island, occupying only a thin strip along the high water mark, and being separated by a series of small rocky headlands (vegetation association 98 in Figure 8-1).

Potential Impacts on Mangroves

Similar to existing operations on VI, the Project has a potential to impact on mangroves through dust deposition. Aspects of the Project which may generate dust include earthworks, soil and rock transport and site preparation activities including concrete batching. The operation of the New Plant is not expected to generate dust emissions.

Dust Management Measures

As part of Apache's dust mitigation strategy, a number of initiatives have been incorporated into the Project to eliminate or minimise dust generation including:

- The use of precast concrete sections where possible. In-situ concrete batching is used where it is not possible to prefabricate the required concrete sections such as blindings, retaining walls, footpaths, minor foundations and the use of cement grout etc.;
- Upgrading the concrete batching plant to include integrated cement delivery chute, mist spays over the sand and aggregate premix storage bay to reduce dust during materials transfer into the batching hopper, and HDPE lined slurry pits for the retention and settling out of agitator-truck wash down products; and
- Provision of a temporary reverse-osmosis unit to supply water during the Project for soil conditioning as well as dust suppression.

In general, water suppression will be implemented where required to control dust emissions including Project areas, as well as during soil and rock transfer between the Project areas.

In addition, chemical suppressant (Heavy Water Dynamic) will also be used to control dust. The suppressant is not expected to pose environmental risks, and is suitable for sensitive use for example near mangrove communities. The suppressant will break down in days and is not expected to bio-accumulate.

Based on the above, potential dust impacts to mangroves are not considered to be significant, and are not likely to be additional to existing operations on VI. During the Project, Apache will conduct quarterly surveys of the mangroves to ensure there is no increased risk of impact through dust deposition as a result of the Project.

8.2 Terrestrial Vertebrate Fauna

8.2.1 Existing Environment

Mammals

There are no native mammals endemic or introduced to VI.

Vermin

Apache undertakes annual vermin monitoring on VI to validate VI is free of vermin such as rodents, as well as active monitoring via use of bait stations and flour trays in the areas where freight is inspected and checked on arrival to VI. Vermin monitoring also occurs post-completion of major projects that are considered to have the potential to increase the risk of vermin introductions.

Monitoring to date confirms that vermin are absent on VI.

Apache has a Vermin Management Plan in place which details the actions to be taken where vermin are sighted or suspected of being present on VI.

Apache has a Quarantine Procedure in place to manage quarantine risks associated with activities on VI. Quarantine controls associated with all freight to VI include inspections and, where required, cleaning, baiting and/or fumigation to treat potential quarantine risks to verify the freight is vermin and insect free.

Avifauna

Five avifauna species breed on VI. The protection status of the birds under the *Wildlife Conservation Act* 1950 (WC Act), the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act) and the International Union for Conservation of Nature (IUCN) red list are summarized in Table 8-2..

Table 8.2 Protection Status of Birds on Varanus Island

Species	WC Act	EPBC Act	IUCN
Crested Terns (*Sterna bergii*)	-	-	-
Bridled Terns (*Onychoprion anaethetus*)	S3	M	-
Wedge-tailed Shearwater (*Puffinus pacificus*)	S3	M	-
Pied Cormorants	-	-	-
Ospreys (*Pandion haliaetus*)	-	M	-

The two avifauna species that are located within or in the vicinity of Project areas are the Wedge-tailed shearwater, and Bridled tern.

<u>Wedge-tailed Shearwaters</u>

The shearwater nests in burrows that are excavated or renovated by the breeding pairs at the start of each nesting season. On islands of the NWS, wedge-tailed shearwaters usually return to their colony areas to resume courtship and re-excavate burrows in August each year. There is an incubation period of 55 days whereupon the newly hatched chicks are brooded for only several days, but are fed nightly by both parents. The young chicks are tended by the parents until late March to early April. Shearwaters typically spend the non-breeding season between May and August feeding in open waters.

On VI, rookeries for the wedge-tailed shearwater are located on the eastern, western and southern sides of the Apache lease (Figure 8-4). Behind the beaches in the shifting sand dunes, wedge-tailed shearwaters dig their burrows into the soft sand, breed and raise their chicks between October and April.

Bridled tern

Bridled terns return to VI in late November and nest between late December and April. There are several Bridled tern nests along coastal cliffs adjacent to the East Wharf, as well as a single nest abutting the West Wharf.

8.2.2 Potential Impacts on Avifauna

Halfmoon Biosciences (Halfmoon) assessed potential Project noise and vibration impacts to avifauna on VI (Halfmoon, 2012) (Appendix 3).

The proposed works involve bulk earthworks which will be undertaken by a D10 bulldozer and/or an excavator with a hydraulic milling head, with contingency use of precision explosives for hard rock removal. The Project may impact on avifauna through:

- Clearing of avifauna habitat;
- Disturbance to avifauna through lighting;
- Disturbance to avifauna through equipment noise during earthworks; and
- Disturbance to avifauna habitat through drilling and blasting noise and vibrations (in particular in the KMCR area).

Clearing of habitat

Two Wedge-tailed shearwater burrows have been found within the KMCR footprint. These burrows will be destroyed during the proposed earthworks. Halfmoon (2012) noted the long-term average burrow occupancy for VI Wedge-tailed shearwaters is 49%, which means one of the two burrows within the KMCR footprint may be occupied.

The single nest at the West Wharf is likely to be displaced by construction activity, however the nests situated west and east of the East Wharf are unlikely to be affected (Halfmoon, 2012).

The impact of construction activities upon the single nest at the West Wharf is dependent upon timing, and whether the nest is occupied at the time of works. If construction activities occur at this location during, but prior to the end of, the breeding season (April) the breeding attempt is likely to be disrupted. However, not all Bridled Terns breed each year, and dependent upon oceanographic conditions there may be no breeding attempt in this nest.

Lighting impacts

Seabirds are attracted to light and may become disorientated and vulnerable when caught within construction sites. In addition, disorientated adult birds may not be able to return to their burrows to relieve their mates or feed their young. Fledgling Wedge-tailed shearwaters are particularly vulnerable to light during the fortnight young birds depart the colony for the first time (Halfmoon, 2012).

Halfmoon (2012) considered that potential light impacts can be greatly reduced following the lighting management measures in relation to turtles. These are discussed in Section 7.2.3.

Noise impact

Project noise levels are unlikely to disturb most nesting seabirds on VI due to existing operational noise levels. However, the Wedge-tailed shearwater – a highly vocal species, if present to the south of the KMCR, is likely to be disturbed (Halfmoon, 2012).

Halfmoon (2012) noted that the Wedge-tailed shearwater returns to nesting sites under the cover of darkness. Halfmoon recommended the avoidance of night works, and conducting invasive Project works (e.g. drilling and blasting) outside of nesting periods to minimise potential impacts on the Wedge-tailed shearwater.

On-going monitoring of the Pipeline Beach colony suggests operational noise does not impact the Wedge-tailed shearwater. It is considered that Project noise is unlikely to have a significant impact on the Wedge-tailed shearwater.

Bridled Tern chicks vocalise to alert feeding parents. However, they usually remain within a small range of the original nesting site.

Drilling and blasting noise and vibration impact

The Wedge-tailed shearwater excavates burrows in the pink limestone sands which is unstable. Vibration from drilling and blasting activities may cause the burrows to collapse.

8.2.3 Avifauna Management Measures

Project activities will be conducted as daylight operations. As such, potential noise impacts to the Wedge-tailed shearwater are considered unlikely. On 29 and 30 November 2012, Apache confirmed that the Wedge-tailed shearwater and Bridled Tern burrows identified at the KMCR area and West Wharf are not occupied this year. The Wedge-tailed shearwater burrows are highly unlikely to be occupied and used to nest this season; and the Bridled Tern nest at the West Wharf will be inspected again in January 2013.

If required, drilling and blasting will be undertaken outside of the avifauna nesting season. Halfmoon (2012) considered that drilling and blasting outside of nesting periods would limit vibration impacts, and collapse of burrows outside of nesting season has little impact on breeding birds as they return to re-excavate burrows prior to laying.

Potential impacts and management measures associated with noise and vibration is discussed further in Section 9.3.

8.2.4 Reptiles

Existing Environment

Phoenix Environmental Services (Phoenix) conducted a vertebrate fauna survey for the Project (Phoenix, 2012a) (Appendix 4).

The Phoenix (2012a) literature search identified thirteen reptile species on VI including:

- Burton's legless lizard (*Lialis burtonis*);
- Blind snake (Ramphotyphlops ammodytes);
- Northwest shovel-nosed snake (*Brachyurophis appoximans*);
- Moon Snake (*Furina ornate*);
- Spiny-tailed Monitor *(Varanus acanthurus*);
- Two-toed skink (North-western sandslider) *(Lerista bipes*);
- Lerista clara;
- Meuller's Lerista (*Lerista muelleri*);
- Rock ctenotus (*Ctenotus saxatilis*);
- Bynoe's gecko (*Heteronotia binoei*);
- Gehyra Pilbara;

- *Eremiascincus isolepis*;
- *Morethia ruficaudaexquisita*; and
- Ta-ta lizard (*Amphibolurus gilberti*).

The Northern bar-lipped skink (*Glaphyromorphus isolepis*) has also been observed on VI.

Burton's legless lizard lives amongst the grass tussocks, rocks and dead vegetative matter. It feeds on insects, small skinks and geckos, and is active during the day and at night.

The blind snake is adapted for life underground, where they burrow with their blunt, projecting snouts. They are rarely found above ground.

The Ta-ta lizard and Rock ctenotus are the most common and easily observed reptiles on VI. Ta-ta lizard can often be found perched on top of a rock or bush where they can survey their territory and gain the most of the sun's rays during the cooler parts of the day.

The North-west shovel nosed snake is uncommon on VI. Like the blind snake, they possess a blunt snout for burrowing through sand and are seldom seen, although they occasionally emerge after rain. They can grow to a length of 0.5m and their diet consists largely of blind snakes.

The Spiny-tailed Monitor is the same species as those found on the mainland, having only slight differences in size. Although smaller than most other species of goanna, the species still possesses the typical characteristics displayed by this group. Their diet consists of insects, other lizards, birds and their eggs and carrion.

Bynoe's gecko is the only species of gecko found on VI. As evening falls, the Bynoe's gecko can be seen scuttling out to seize fallen insects under lights on the paths and walkways of VI.

Skinks on VI are potentially the most diverse group of lizards on the island and they form an important part of the food chain both as consumers of small insects such as ants, and as prey for birds and larger reptiles. There are both nocturnal and diurnal species that are found in a range of habitats on the island. Skinks on the island are small and slender, having smooth, shiny scales and limbs that are often reduced or absent, particularly in burrowing species.

Forty-nine other reptiles (including conservation significant species) were considered to be potentially occurring in the region, but are not considered likely to translocate to VI (Phoenix, 2012a).

Potential Impacts on Reptiles

Potential Project impacts on reptiles include:

- Habitat loss, degradation and fragmentation through clearing;
- Loss of individual fauna;
- Modification of ecosystem through fire;
- Spread of introduced fauna; and
- Pollution.

<u>Habitat loss, degradation and fragmentation</u>

The KMCR and accommodation camp upgrade areas will require clearing of vegetation and potential reptile habitats. However, the habitat that will be cleared/disturbed (limestone hills, slopes and low ridges) is also found elsewhere on VI.

The Project is not considered to have a significant impact on fauna habitats on VI.

Loss of individual fauna

The KMCR and accommodation camp upgrade areas will require clearing of vegetation and potential reptile habitats. However, the habitat that will be cleared/disturbed (limestone hills, slopes and low ridges) is also found elsewhere on VI.

The Project may result in losses in individual fauna which may not be able to move away from the works area.

Fire risks

While fire may occur as natural events, the risk of fire may be increased due to human activities. The Project, in general is considered to pose low fire hazards and risks, except for the VICP which will be connected to the existing process facilities, where fire risks is considered to be the greatest.

The Project is not considered to increase fire risks on reptiles as the Project (and in particular the VICP) occur within the Apache lease, and away from potential reptile habitats.

Spread of introduced fauna

The Project is not considered to increase quarantine risks at VI. Quarantine management and requirements are discussed in Section 2.8.

Pollution

There will be no bulk storage of hazardous materials and chemicals within the Project area. Potential impacts within the Project area may arise from minor spills and leakages from mobile refuel tanks and may include localised soil and potential groundwater contamination.

Reptiles Management Measures

Potential impacts to reptiles will be managed by:

- Minimising clearing of vegetated areas where possible;
- Progressive rehabilitation of cleared areas where the area is no longer needed;
- On-going education of staff in relation to conservation significant species and their habitats;
- Clearly demarcating clearing areas to avoid unnecessary additional clearing;
- Review of the quarantine management procedure to identify potential new pathways for species introduction and the identification of appropriate management measures to manage the risk; and
- Provide adequate clean-up and containment equipment and suitable staff training to respond to pollution events.

Reptile monitoring on Varanus Island is completed annually as part of the vermin monitoring program.

Handling and management of hazardous materials and chemicals are discussed in Section 9.6.2.

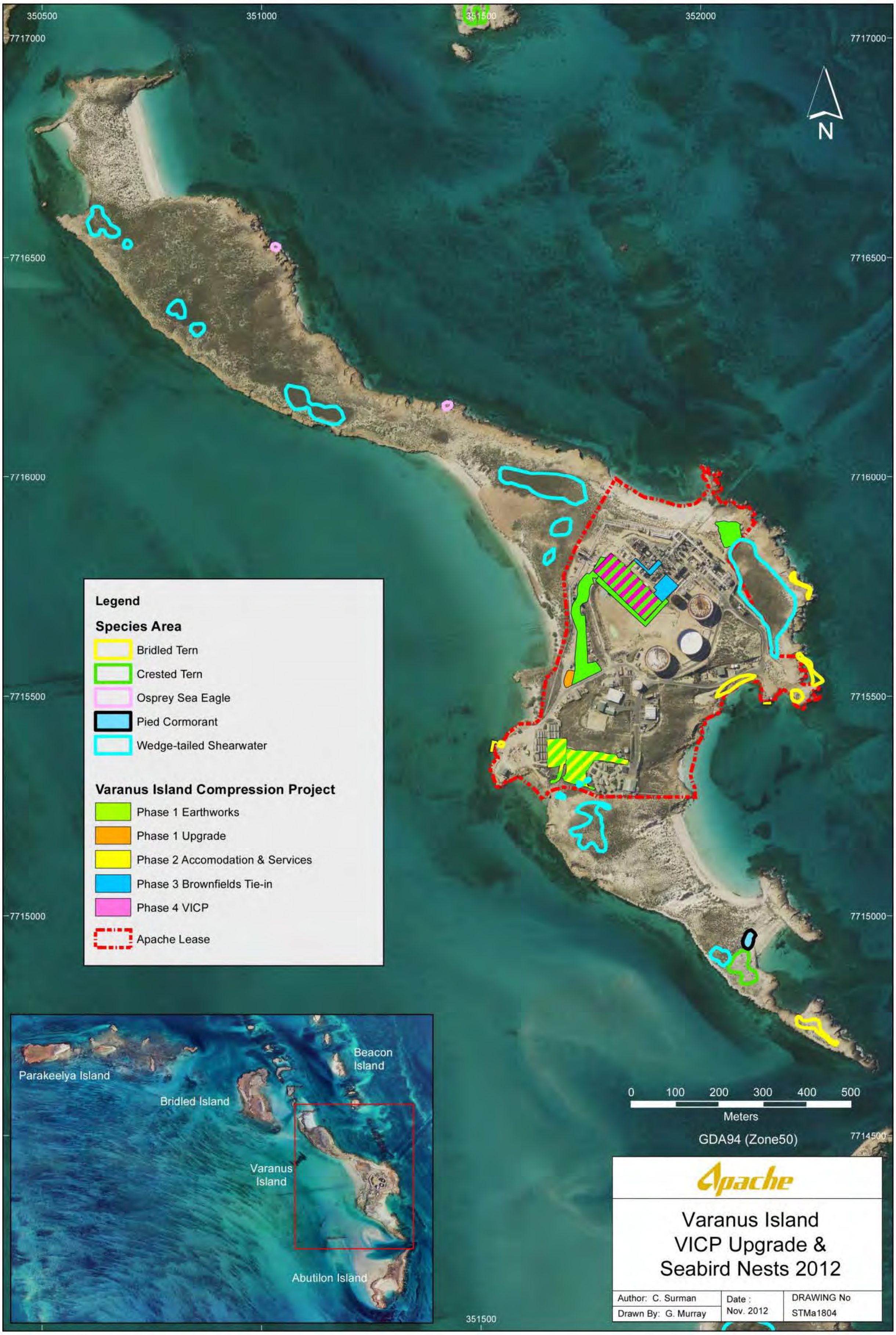

Figure 8-4 Seabird Colonies and Nesting Sites on Varanus Island

8.3 Short-Range Endemic Invertebrate Fauna

8.3.1 Existing Environment

Phoenix conducted a short-range endemics (SREs) study (Phoenix, 2012b) (Appendix 5) to identify potential terrestrial and subterranean records, and actual terrestrial short-range endemics (SREs) species records with particular focus on land snails, as well as identifying potential Project impacts on SRE and subterranean fauna, in particular troglofauna. The study consisted of a comprehensive desktop review as well as field survey of 11 survey sites on VI.

VI is thought to share a considerable proportion of its invertebrate fauna with Barrow Island due to its similar geological history and proximity (Phoenix, 2012b). The study used a three tier categorisation for SREs due to uncertainties in determining the range-restrictions of invertebrates due to lack of surveys, lack of taxanomic resolutions within target taxa and problems in identifying certain life stages: confirmed SRE, likely SRE and potential SRE.

The desktop review identified a total of 68 terrestrial SRE taxa in at least 22 families and 40 genera. Three of the terrestrial SRE taxa were from VI, including the trapdoor spider *Aname* sp. indet. (Nemesiidae), and the land snails *Rhagada plicata* and *Quistrachia barrowensis* (both Camaenidae).

During the field survey, a total of 11 sites were surveyed across VI. A total of 960 individual specimens of terrestrial SREs were collected during the SRE survey. Of these, 350 specimens (36.5% of total catch) from eight taxa are considered to include species from the three SRE categories (Phoenix, 2012b).

The flatrock spider *Karaops burbidgei* (family Selenopdidae) and the land snails *Quistrachia montebelloensis* (shown to be a senior synonym of *Quistrachia barrowensis*) and *Rhagada plicata* (Camaenidae) are confirmed SREs. The trapdoor spider *Aname* 'MYG079' (Nemesiidae) and the slater Armadillidae 'varanus island' are considered likely SREs. The centipedes *Cryptops* sp. indet. (Cryptopidae), and the slaters *Barrowdillo pseudopyrgoniscus* and Spherillo 'varanus island' (both Armadillidae) are considered potential SREs (Phoenix, 2102b).

Figure 8-5 shows the survey sites across VI.

8.3.2 Potential Impacts

Within the Project disturbance areas, a confirmed SRE *Rhagada plicata*, and a likely SRE *Aname* 'MYG079', were recorded within the KMCR area. Other invertebrate fauna recorded within the KMCR area include *Euryolpium* sp. Indet., *Olpiidae* sp. Indet., *Buddelundia* '60', *Quistrachia montebelloensis*, , *Gastrocopta mussoni* and *Pupoides contrarius* (Phoenix, 2012b).

Rhagada plicata is a confirmed SRE. However, this species is known throughout the Barrow/Montebello/Lowendal archipelagos (Phoenix, 2012b). On VI, the species was recorded at two other survey sites – one within and another outside of the Apache lease.

Aname 'MYG079'is a likely SRE. The species has been recorded previously on Barrow Island, and some species of the *Aname mainae*-group (similar to *Aname* 'MYG079' have been recorded on the Pilbara region and may be conspecific with *Aname* 'MYG079'. On VI, the species was recorded at three other survey sites outside of the Apache lease (Phoenix, 2012b).

Euryolpium sp. Indet. was the most dominant Olpiidae species collected, and was recorded at 10 of the 11 survey sites on VI. *Olpiidae* sp. Indet. was recorded at one other survey site on VI.

Buddelundia '60' occurs throughout the north-west Pilbara and on Barrow Island. On VI, the species was recorded at six other survey sites (Phoenix, 2012b).

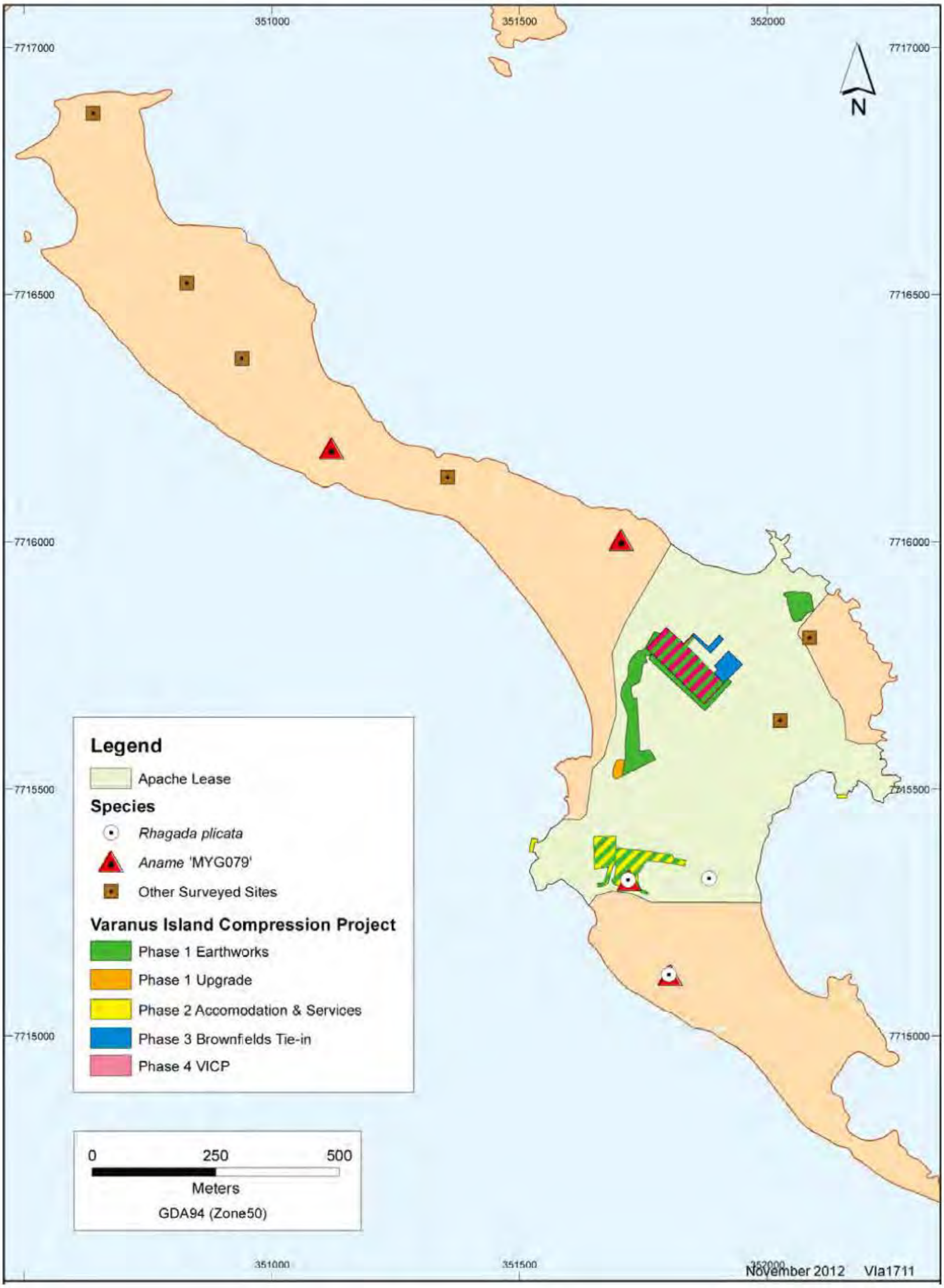

Figure 8-5 SRE Survey Sites across Varanus Island

Quistrachia montebelloensis was the most commonly collected snail, and is known throughout the Barrow/Montebello/Lowendal archipelagos. Results from molecular analysis show that this species is a senior synonym of *Quistrachia barrowensis* which is a confirmed SRE. *Quistrachia montebelloensis* was recorded at 10 of 11 survey sites on VI (Phoenix, 2012b); and *Quistrachia barrowensis* has previously been recorded on other islands in the region (especially Barrow Island). This species is not considered likely to be impacted.

Gastrocopta mussoni is widespread and is found throughout the northern half of Australia into Queensland. On VI, the species was recorded at four other survey sites (Phoenix, 2012b).

Pupoides contrarius is widespread along the north-western WA coastline, and was recorded at 9 of the 11 survey sites on VI.

Phoenix (2012b) concluded that there were no major limitations affecting the field survey, and species richness estimators suggest most invertebrate species within the SRE target groups were collected, with the possible exception of pseudoscorpions. Phoenix (2012b) considered the Project has a low impact on the SREs.

No management measures are considered required as part of the Project in relation to SRE.

8.4 Subterranean Fauna

8.4.1 Troglofauna

The Phoenix (2012b) desktop review did not reveal any records of troglofauna on VI. However, Phoenix considered the extent of potential impact to troglofauna would be proportionate to the depth of which rock will be extracted. VI is comprised of a single geological type, i.e. Pleistocene coastal limestone covered by lime-cemented shelly sand, dune sand, and beach conglomerate. This geology is well represented on the eastern side of Barrow Island where extensive subterranean fauna, both troglofauna and stygofauna, has been recorded. It is therefore very likely that troglofauna, in addition to stygofauna, is present on VI including the impact area. The potential extent of troglofauna habitat is believed to correspond with the extent of the island because of the uniformity in geology across the island (Phoenix, 2012b).

Potential Impacts

Potential impacts from the Project include:

- Primary (direct) impact from removal of troglofauna habitat; and
- Secondary (indirect) impact from removal of surface vegetation.

Phoenix (2012b) considered that if troglofauna are present within the Project disturbance areas, it is also likely to be present elsewhere on VI due to the island's geological uniformity. Phoenix (2012b) concluded that the Project is unlikely to threaten troglofauna species to the point of extinction.

8.4.2 Stygofauna

In the absence of systematic subterranean fauna surveys, the likelihood of the presence of stygofauna was based on an assessment of the geology of VI and corresponding geologies on Barrow Island, which support a rich diversity of subterranean fauna (Phoenix, 2012b). Phoenix considered that while no troglofauna were recorded, the desktop review suggests stygofauna is present.

The Project does not involve works at or below the groundwater table. As such, potential stygofauna impacts are considered unlikely (Phoenix, 2012b).

9. OTHER ENVIRONMENTAL ASPECTS

9.1 Contaminated Soils

9.1.1 Existing Soil Environment within the Bund and Potential Impacts

A soil and groundwater investigation was conducted within the VI's main bund area in 2012 (PB, 2012). The investigation found the soil within the containment bund to contain barium (Ba), lead (Pb), mercury (Hg), zinc (Zn) and Total Recoverable Hydrocarbons (TRHs) in exceedance of DEC *Landfill Waste Classification and Waste Definitions* (1996) guideline and Contaminated Sites Management Series *Assessment Levels for Soils, Sedijent and Water guideline* levels.

9.1.2 Potential Impacts in relation to Contaminated Soil

It is estimated that up to 3,000 m^3 of contaminated soil may be relocated as part of the bund re-alignment works to accommodate the New Plant.

9.1.3 Contaminated Soil Management Measures

The bund realignment works will be conducted so that the contaminated soil is relocated and managed within the existing bund at all times. The contaminated soil may be used for the construction for the new realigned bund wall if it meets design specifications. If used, the contaminated soil will be contained within HDPE lining. Equipment working with contaminated soil will be washed down prior to leaving the bund area. No contaminated soil will be used for other Project works.

Figure 9-1 shows the indicative sequence of bund realignment works. The works will be undertaken in a sequence which maintains the existing HDPE lining throughout the bund realignment works such that contaminated runoff or leaching will be contained, and the risk of contamination to clean soils and operations area is reduced to ALARP. The HDPE liner will be patched or replaced, as appropriate, if found to be damaged or if it is damaged during the project works.

9.2 Air

Apache is preparing an air dispersion modelling and assessment to support a Works Approval application for the installation of the two new compressors as part of the VICP works. The addition of the two compressors is not expected to affect the National Environment Protection Measure long or short term maximum concentrations discernibly.

Potential dust impacts are primarily associated with mangroves on VI. These are discussed in Section 8.1.5.

9.3 Noise and Vibration

9.3.1 Existing Environment

There are avifauna (including Wedge-tailed shearwater and Bridled tern) rookeries in close proximity to the Apache lease (refer to Figure 8-4). Marine turtles also nests on beaches on VI. The Project may occur during nesting season where the species may nest and inhabit the area, and may be impacted by the Project activities.

9.3.2 Potential Noise and Vibration Impacts

The proposed works involve bulk earthworks which will be undertaken by either: a D10 bulldozer and/or an excavator with a hydraulic milling head, with contingency use of precision explosives for hard rock removal.

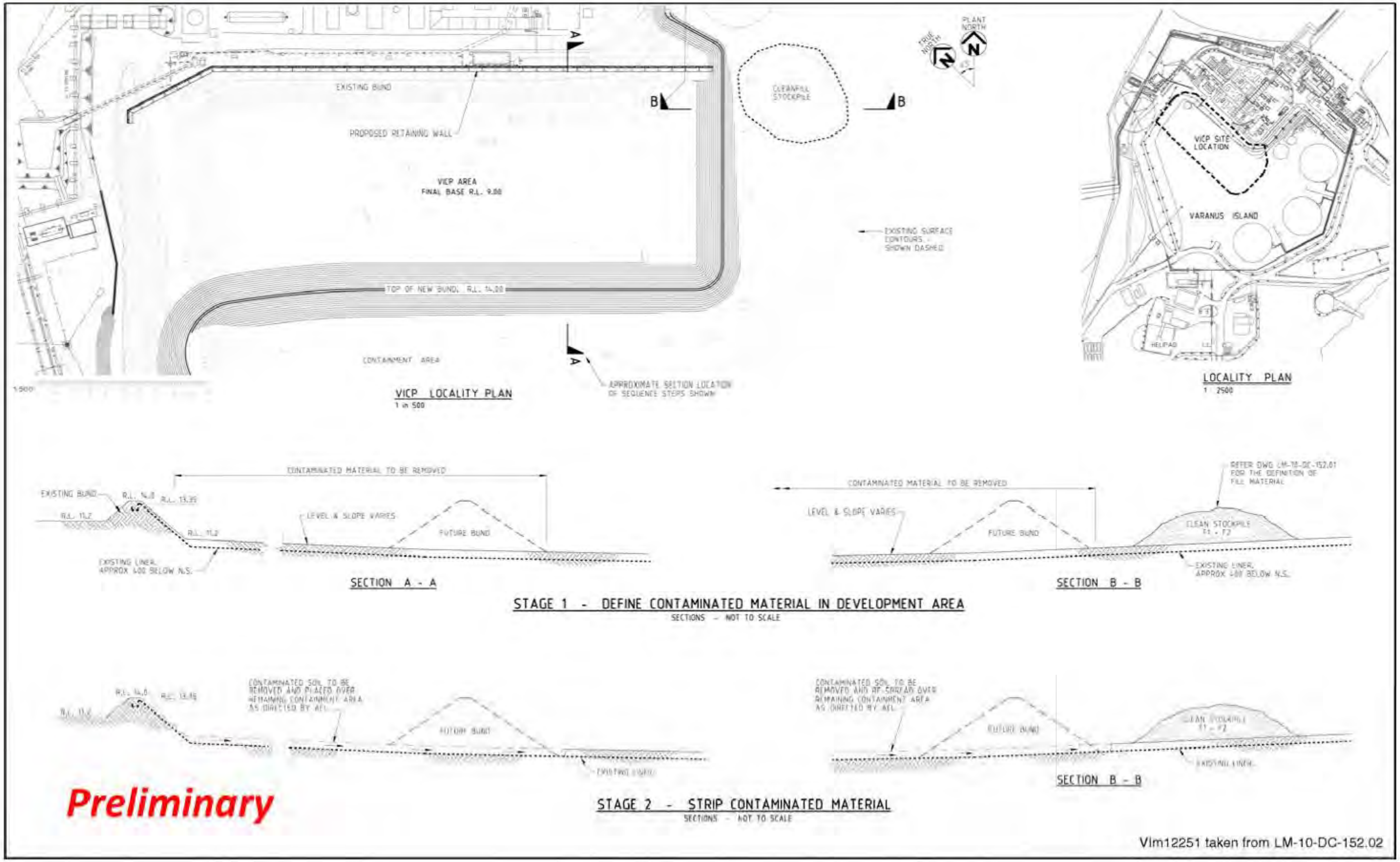

Figure 9-1 Indicative Sequence of Bund Realignment Works

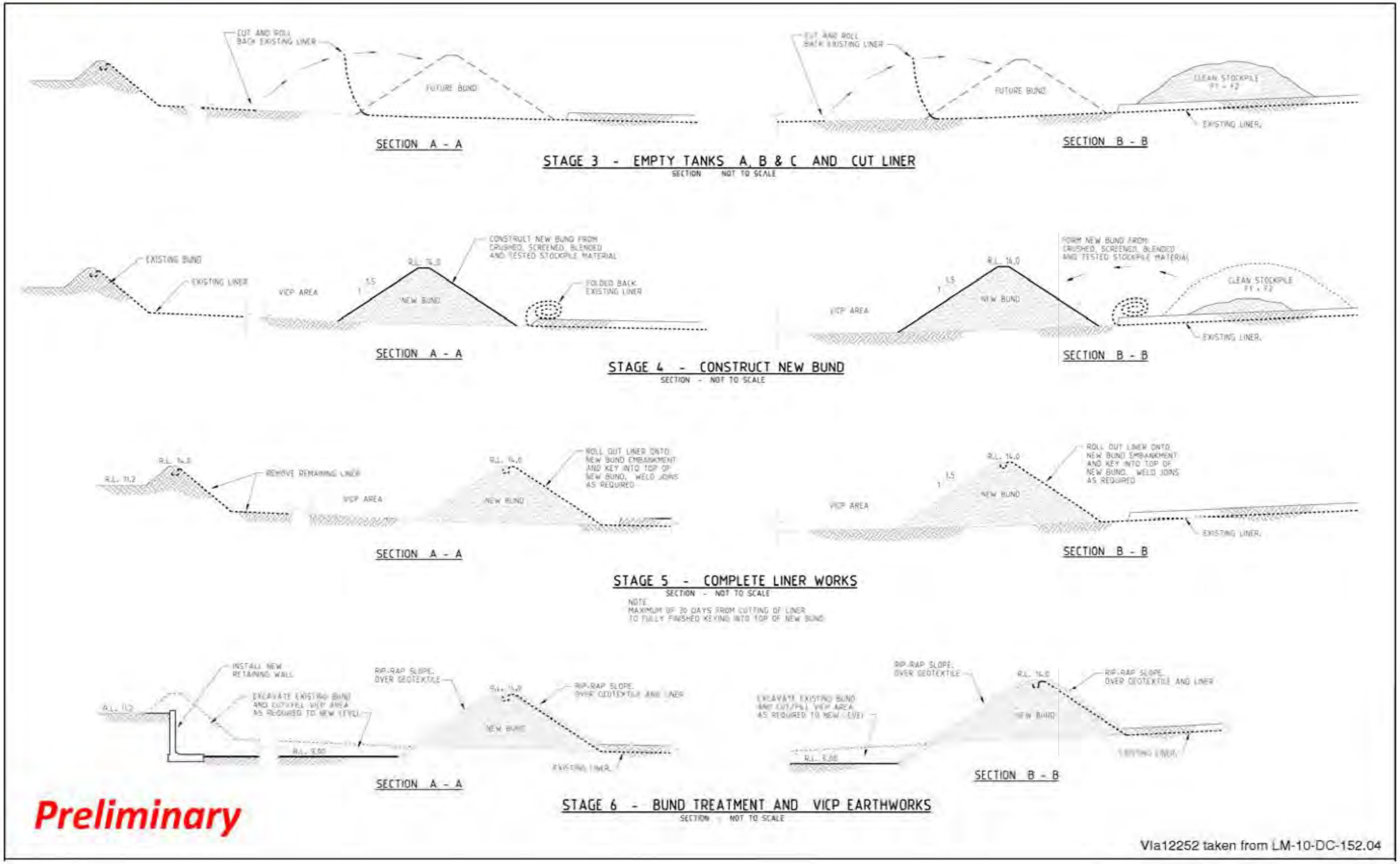

Figure 9-1 Indicative Sequence of Bund Realignment Works (cont.)

The Project may impact on avifauna and marine turtles through:

- Disturbance to the species through excessive noise levels; and
- Disturbance to the species through ground vibration from drilling and blasting activities.

SVT Engineering Consultants (SVT) assessed potential noise and ground-borne vibration impacts associated with the Project (SVT, 2012) (Appendix 6). SVT adopted the guidance limit of 10 mm/s in ground vibration which will result in minor structural damage (e.g. shattering windows and cracks), as the guidance limit which may cause damage to fauna nests and burrows (e.g. collapse of burrows).

SVT (2012) concluded that earthworks activities will result in noise levels exceeding fauna weighted (for avifauna and turtles) noise levels; and drilling and blasting will result in ground-borne vibration levels in exceedence of the 10 mm/s guidance limit at fauna rookeries and nesting sites.

Potential noise and vibration impacts on turtles have been discussed in Section 7.2.2; potential noise impacts on avifauna have been discussed in Section 8.2.2.

9.3.3 Noise and Vibration Management Measures

As noted in Section 2.4, drilling is blasting for infill materials recovery is a contingency only, and may be required for minor areas of disturbance where the bulldozer or rotary cutter is inadequate to remove hard rock.

If required, drilling and blasting will be undertaken outside of peak avifauna and turtle nesting season (May to August). Prior to undertaking drilling and blasting, Apache will develop a project-specific Drilling and Blasting Procedure for the contingency use of explosives. The procedure outlines the management practices that will be implemented during the proposed works including:

- Delivery of explosives to VI by a licensed supplier in accordance with the *Dangerous Goods safety Act* 2004;
- Drill patterns and charging;
- Blast hole stemming and tying in;
- Detonation and notification procedures; and
- Clearing and demobilisation.

The drill and blast operations will be undertaken by a licensed contractor in accordance with the *Dangerous Goods safety Act* 2004.

9.4 Greenhouse Gas

Apache will continue to report its greenhouse gas emissions under the *National Greenhouse and Energy Reporting Act* 2007, including emissions from the Project.

It is not expected that the Project will have a significant contribution of greenhouse gas emissions to the VI facilities.

9.5 Surface Water

9.5.1 Existing Surface Water Management

There are no natural freshwater receiving water bodies on VI and therefore any runoff from rainfall or storm water predominantly infiltrates the soils.

In relation to clean water drainage:

- Rainwater from roadways and minor areas of the facility drains to local low points such as constructed drains and natural low lying areas which eventually infiltrate to an unconfined shallow groundwater mound or under heavy rainfall or cyclonic conditions to the marine environment;
- Uncontaminated stormwater runoff from the process areas is directed to an unlined basin (via an oily water separator) located on the western side of the lease area near the elevated flare; and
- Water from localised air conditioning units drains freely to the ground.

Storm water collected in the drainage basin will either evaporate or infiltrate through the basin. A spillway constructed on the basins southern side discharges to the natural ground surface.

In relation to potentially contaminated water drainage:

- Areas and process skids that may contain hydrocarbon or chemicals in the HJV and ESJV plants drain into local constructed metal or concrete sumps within bunded areas or to Humeceptors. Runoff from the shipping pump areas and part of the HJV plant outside of the bunded areas, drains into a triple trap and then into a Humeceptor; and
- Rain and wash down water from external hardstand areas of the maintenance workshop and wash-down pad, chemical and fuel storage areas, water maker areas, and roof of the bulk crude storage tanks drain to the lined crude oil tank bund. Water from the bund is pumped to the corrugated plate interceptor (CPI) for removal of hydrocarbons and then disposal in the injection bores. The bulk crude storage tank bund is lined with a HDPE liner. The vehicle washdown area was upgraded in 2003 with HDPE lining underneath the paved area. The chemical and fuel storage areas as well as the potable water maker areas are on hardstand with culverts draining to the tank bund.

9.5.2 Surface Water Management for the Project

Surface water management for the Project is similar to existing surface water management measures.

Surface water run-off originating from facility roofs and the building sites will be adequately drained so that surface pooling of water will not occur. In particular, diversion drainage will ensure that surface water will not be able to pool under the installed buildings.

All stormwater run-off (including potentially contaminated runoff) will be suitably channelled within the facilities area via sub-surface pipework or surface spoon drains which are directed to new Humeceptors. All installed stormwater hardware designed to manage water run-off are suitably sized to allow for deluge conditions associated with cyclone downpours and to minimise soil erosion. Drainage design within the building sites have a design capacity based on the 20 year ARI.

The accommodation modules will be connected into the existing sewer line draining to the WWTP.

The KMCR building will be connected by a new branch main into the existing sewer line to the south of the site which drains to the WWTP. Immediately downstream of the KMCR kitchen, the sewer line will fall to a 1,000 L pre-cast concrete thermal cooling pit and thence to a 2,000 L industrial grade PVC grease trap before tying into the new branch main.

Surface water around the KMCR will be diverted and directed to local sumps and drainage lines (Figure 2-3). Figure 2-3 shows the layout of an existing drainage line that will be upgraded. Water flow from the drainage line will follow natural elevations, and will discharge south into the ocean.

A refuse bin clean-out and wash down area is to be provided within the sealed area to the northeast of the KMCR building. The wash down area will provide a silt sump and sewer interconnection via the adjacent industrial rated grease trap that will also service the kitchen / mess facility.

Grease pit evacuation will be undertaken periodically by a licensed waste management contractor.

9.6 Hazardous Materials and Chemicals

Chemical storage at VI and offshore facilities include hazardous substances and dangerous goods. The main concern with chemical storage is their accidental loss through a spill and/or uncontrolled release and their potential to enter the environment. Whilst chemicals are generally stored within durable vessels, there remains the potential for spills and leaks to occur as a result of accidental damage and/or failure of these vessels. The potential for a chemical spill to enter the environment is considered to be higher in areas in close proximity to the lease boundaries at VI where there is no built containment.

9.6.1 Potential Hazardous Material Impact

There will be no bulk storage of hazardous materials and chemicals within the Project area. Potential impacts within the Project area may arise from minor spills and leakages from mobile refuel tanks and may include localised soil and potential groundwater contamination.

9.6.2 Hazardous Material Management Measures

Apache has adopted the National Code of Practice for the Storage and Handling of Workplace Dangerous Goods (2001) as a Company standard for workplace control. This standard is applied to all Apache work sites to the extent that prevailing regulations are not contradicted.

The primary mitigation measure to avoid the release of stored chemicals in the environment is to ensure these chemicals are stored in suitable containers within a bunded area (or temporary bunding such as pallet bunds) and hardstand areas. Storing chemicals in bunded and hardstand ensures that spills or leaks from chemical storage areas can be contained or isolated and thus their entry into the environment can be restricted.

Equipment within the New Plant is equipped with skids, providing secondary containment to chemicals and hazardous materials within the installed plant and equipment. Apache has a Refuelling and Chemical Transfer Management Procedure in place to manage refuelling activities. Spill kits are available and strategically located to allow easy access and clean-up of minor spills and leaks.

In addition to the above, dangerous goods must be stored in compliance with the Australian Dangerous Goods Code (ADG) and the relevant segregation charts. Incompatible chemicals are segregated to reduce the risks associated with reactions that may occur between non-compatible chemicals. If explosives is required as part of earthworks, storage (if required) of explosives (Class 1 Dangerous Goods) will be conducted in compliance with the Australian Explosives Code.

Apache conducts regular inspections and checks to ensure the integrity of bunding and storage vessels are maintained and repairs undertaken for leakages observed. In addition, Apache also maintains relevant records response equipment including material safety data sheets (MSDSs) database and spill kits.

9.6.3 Maintenance of Secondary Containment for Bulk Hydrocarbon Storage Tanks

The sequence of works is shown in Figure 9-1. For the works in the VICP area, the existing bund will be removed only after the new bund is constructed and bund lining established, thereby ensuring provision of secondary containment (110% of largest storage tank) throughout the works.

The excavation, filling and new bund construction works will be scheduled to be undertaken when the bulk storage tanks have minimal stored hydrocarbon, e.g. they will be emptied prior to works commencing in the area. The produced formation water tank will also be emptied prior to earthworks commencing in the VICP area. During the works, crude oil production will also be distributed across the three storage tanks to minimise the volume stored in the tanks in the event of leakage or spill.

9.7 Waste Management

9.7.1 Existing Waste Management

All wastes generated from the VI facilities are disposed of in accordance with the VI site environmental licence (L6284/1992/9) which requires hazardous solid wastes to be exported offsite for disposal to an approved facility, no waste grease or other hydrocarbons to be incinerated and where practicable, to separate and recycle solid wastes prior to disposal to an approved landfill.

Toxic and hazardous liquid wastes generated on VI are disposed of via the CPIs where the hydrocarbon are transferred to the bulk crude storage tanks and other liquids are disposed of via injection wells. Cooking oils/grease are separated and disposed on the mainland.

Sewage and grey water on VI are treated in sewage treatment plants, and treated effluent is discharged via an ocean outfall under the VI site licence.

Food scraps and other organic waste, paper, cardboard and wood are incinerated on VI.

9.7.2 Waste Management in relation to the Project

Project wastes and on-going wastes as part of the operations will be managed in accordance with the site environmental licence. Primary waste streams from the Project include:

- Potential excess in earthworks;
- For quarantine purposes, packaging of the prefabricated modules for the Project;
- Other packaging materials such as concrete waste, seafastening steel and transportation steel brackets etc.; and
- Brine from the temporary reverse-osmosis unit required to meet Project water needs.

Excess material from earthworks will be stockpiled at the soil and rock recovery area (Figure 2-5) for on-going operational use and future VI facility expansion works.

The prefabricated modules will be inspected and unwrapped within the lay down area, wrappers and packaging materials, and other Project wastes, will be retained within the lay down area and for disposal on the mainland.

Reject water and brine from the temporary reverse-osmosis unit is expected to range between 0.16 to 2.58 ML per month, and will be discharged through the existing brine discharge point north of the East Wharf.

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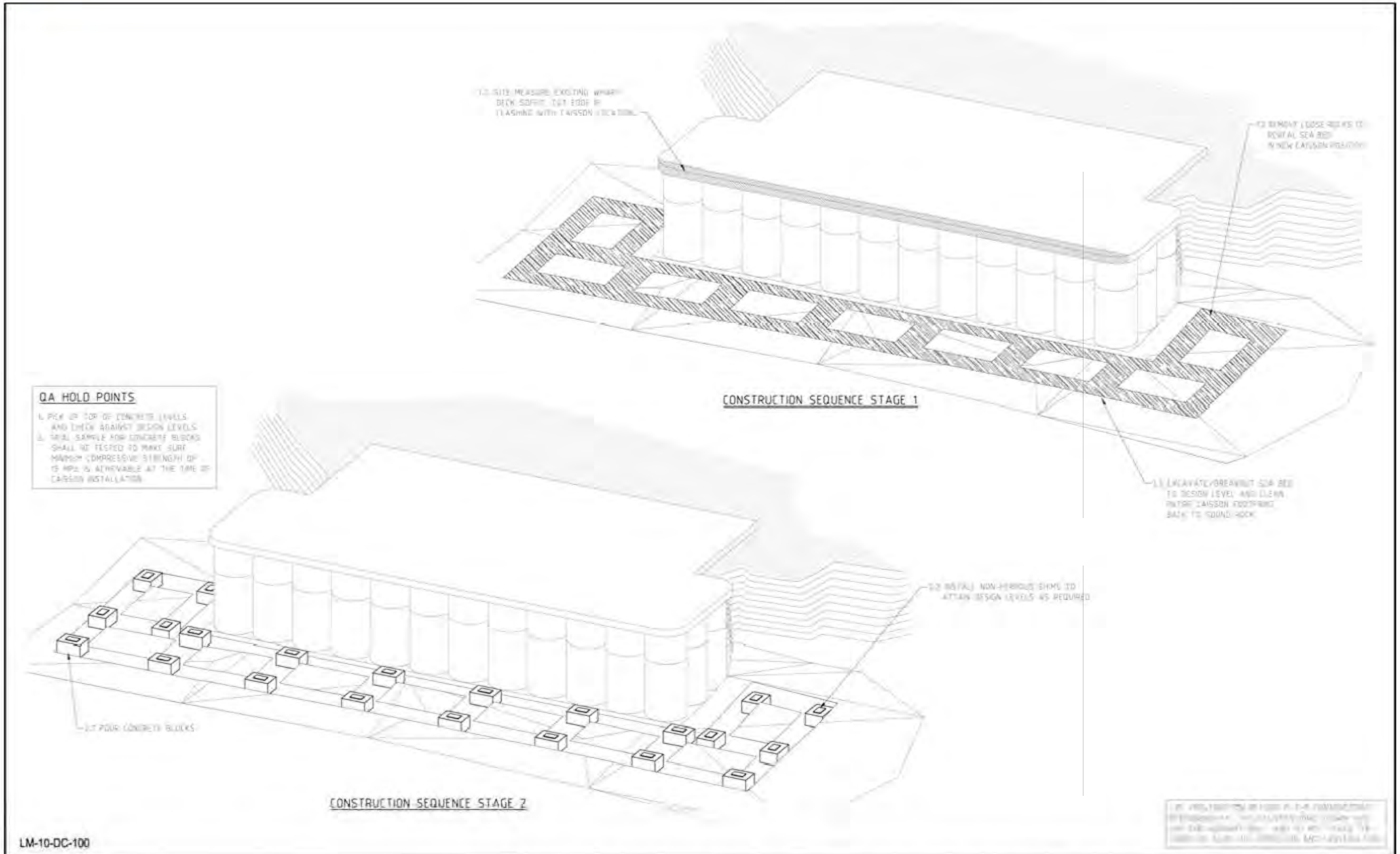
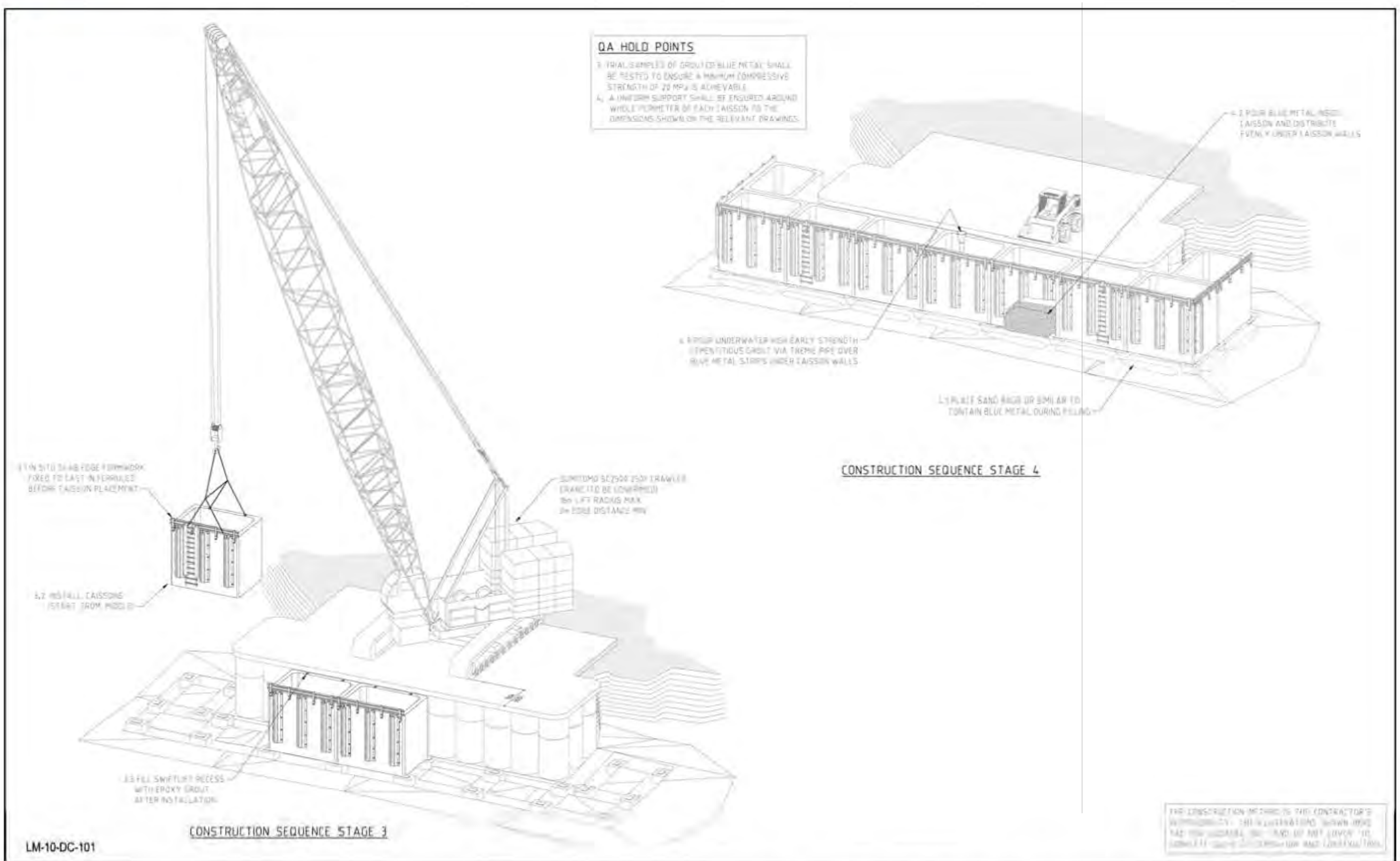
APPENDIX 1 – INDICATIVE WHARF UPGRADES CONSTRUCTION SEQUENCE



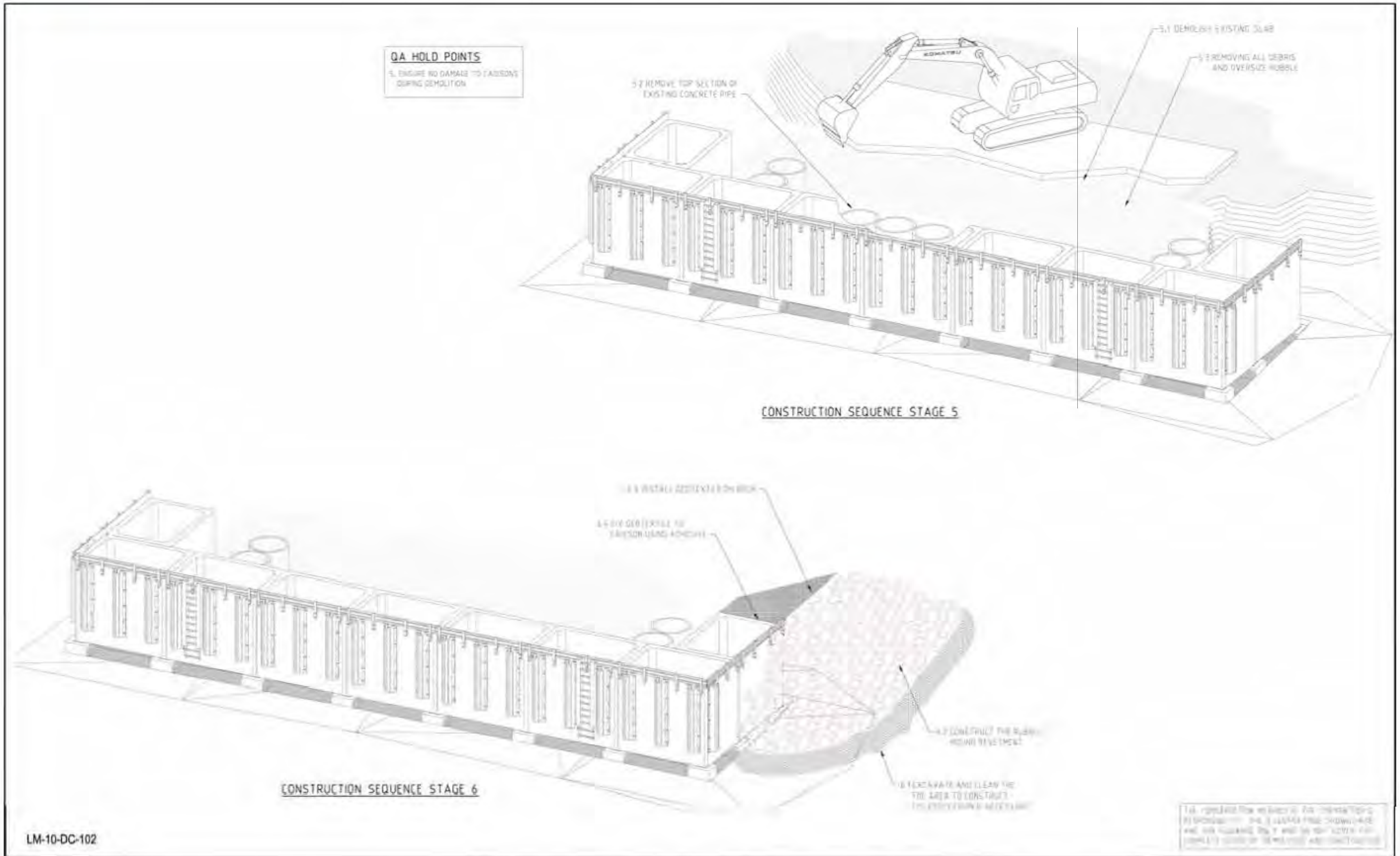
VARANUS ISLAND COMPRESSION PROJECT

WEST WHARF UPGRADE AND RECTIFICATION CONSTRUCTION SEQUENCE - SHEET 1



VARANUS ISLAND COMPRESSION PROJECT

WEST WHARF UPGRADE AND RECTIFICATION CONSTRUCTION SEQUENCE - SHEET 2



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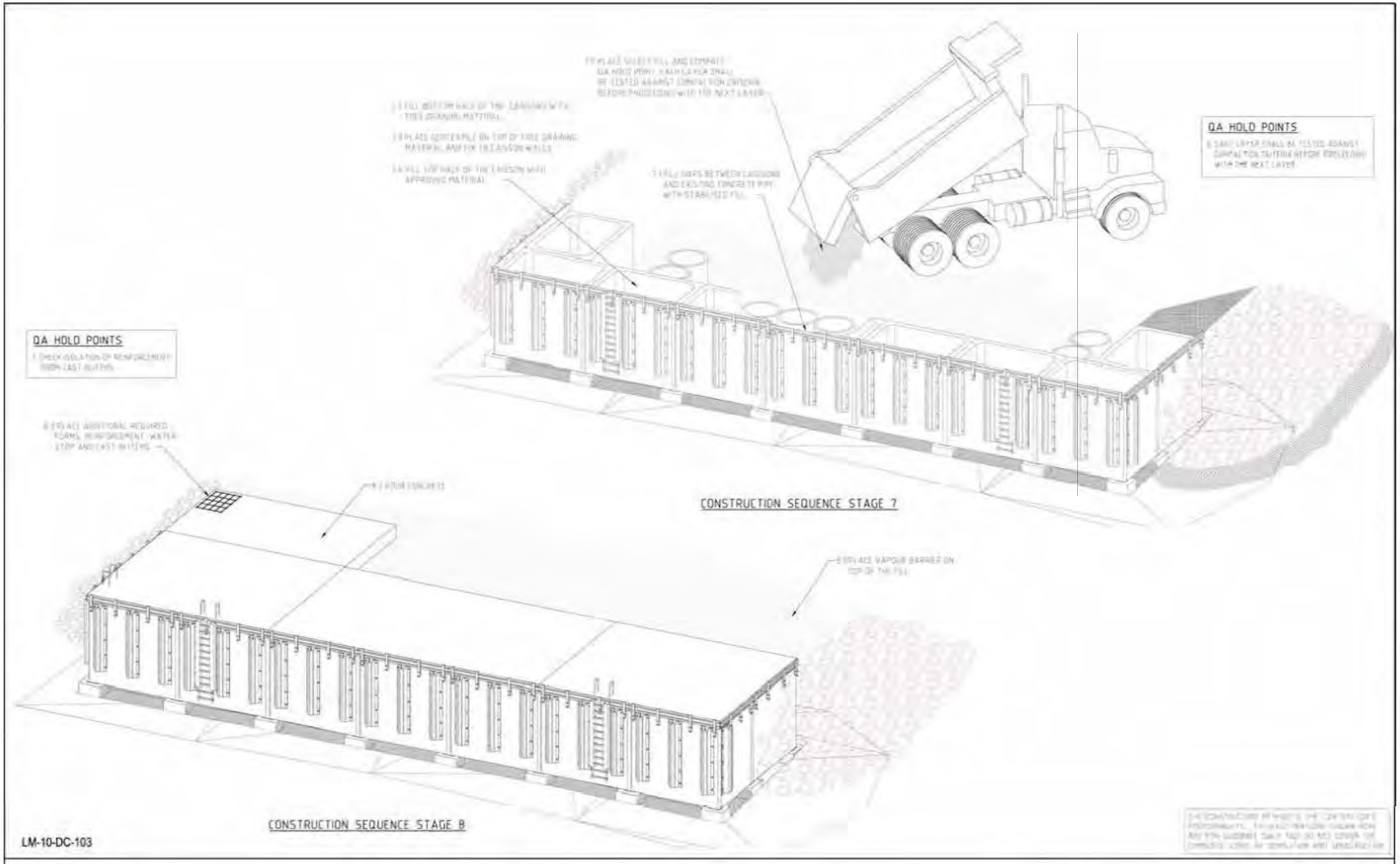
WEST WHARF UPGRADE AND RECTIFICATION CONSTRUCTION SEQUENCE - SHEET 3



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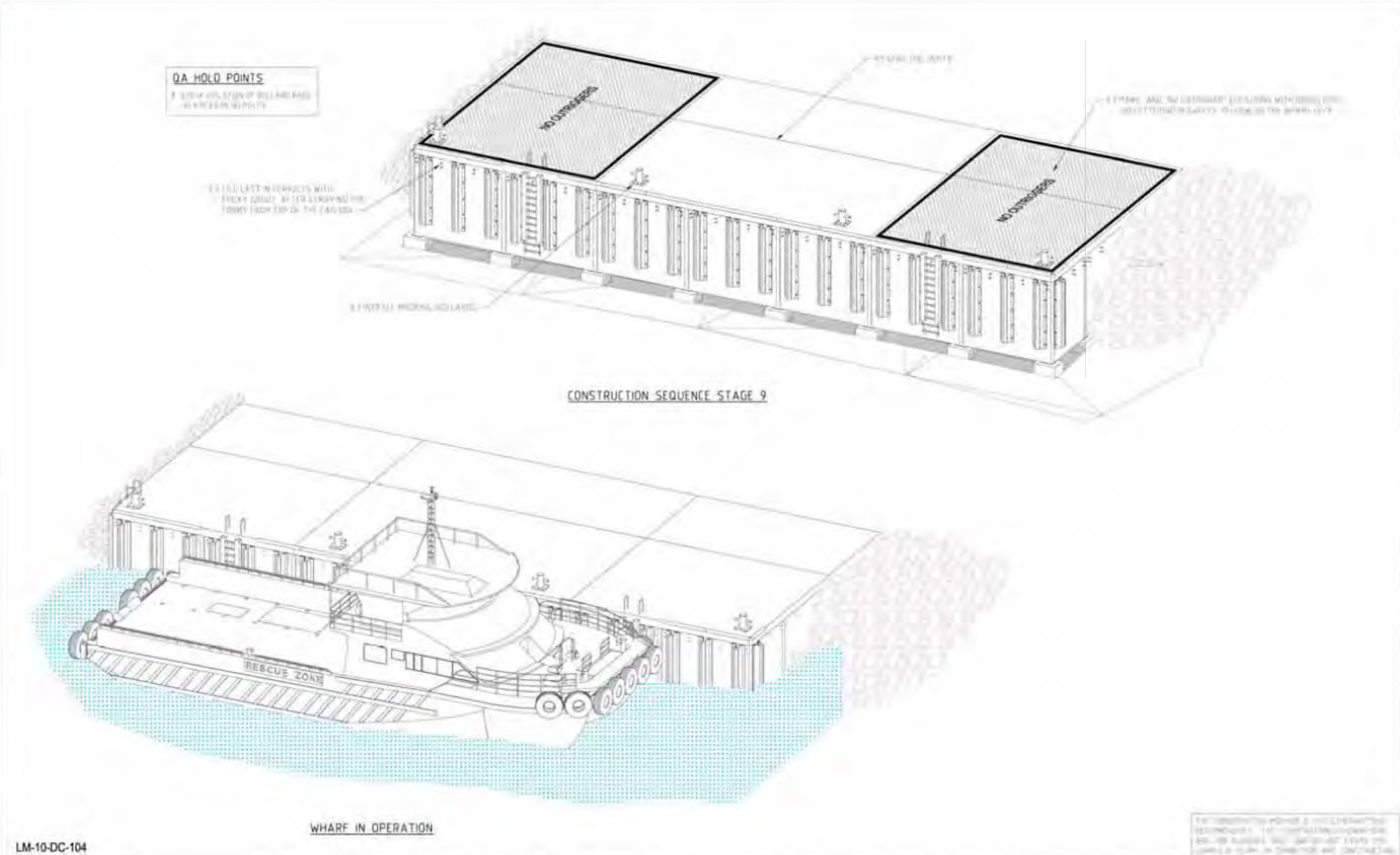
WEST WHARF UPGRADE AND RECTIFICATION CONSTRUCTION SEQUENCE - SHEET 4



VARANUS ISLAND COMPRESSION PROJECT

WEST WHARF UPGRADE AND RECTIFICATION CONSTRUCTION SEQUENCE - SHEET 5

APPENDIX 2 – PENDOLEY ENVIRONMENTAL VARANUS ISLAND UPGRADE DESKTOP ASSESSMENT OF POTENTIAL IMPACTS TO MARINE TURTLES DRAFT REPORT (2012)

Apache Energy Ltd

Varanus Island Facility Upgrade Desktop Assessment of Potential Impacts to Marine Turtles

Prepared by

Pendoley Environmental Pty Ltd

For

Apache Energy Ltd

15 October 2012

DOCUMENT CONTROL INFORMATION

TITLE: VARANUS ISLAND FACILITY UPGRADE DESKTOP ASSESSMENT OF POTENTIAL IMPACTS TO MARINE TURTLES

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Document History

Revision	Description	Date issued	Date received	Personnel
Draft	Report Draft			A. Lewis
Rev A	Internal Review	13/10/2012	15/10/2012	Dr K. Pendoley
Rev B	Client review	15/10/2012		
Rev 0	Final report issued			

Printed:	28 November 2012
Last saved:	26 November 2012 09:06 AM
File name:	P:\06 Projects\J06 Apache Energy (ACH)\2012_2013 Varanus Island\05 Programs\J06013 Varanus Island Facility Upgrade (Light)\05 Technical Reports\J06013 Apache Desktop Assessment_Facility Upgrade_RevC.docx
Author:	Anna Lewis
Project manager:	Anna Lewis
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	Varanus Island Facility Upgrade: Turtles, Desktop Assessment
Client	Apache Energy Ltd
Client representative:	Sonja Mavrick
Report number:	J06013
Cover photo:	Flatback hatchlings (Kayleigh Jones)

TABLE OF CONTENTS

1 PROJECT OVERVIEW

Apache Energy Ltd (Apache) has requested Pendoley Environmental conduct an assessment on the biological impacts of a proposed facility upgrade on Varanus Island. The assessment focuses on proposed light placement and possible effects related to the new Kitchen/Mess Cyclone Refuge (KMCR) facility upgrade on marine turtles. The construction of these facilities, planned for Q2 2013, will be located on Cardiac Hill between the existing accommodation camps on Varanus Island. This assessment specifically addresses the potential impacts of increased noise, vibration and light on marine turtles.

2 LEGISLATION REGARDING MARINE TURTLE PROTECTION AND CONSERVATION

Six species of marine turtles from two families (*Cheloniidae, Dermochelyidae*) inhabit Western Australian waters (**Table 1**). All six species are considered endangered or vulnerable and are protected by state and federal legislation and international organisations (**Table 1**). The two most abundant species of marine turtle nesting on Varanus Island are the hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) turtles.

Table 1: Relevant legislation and level of protection afforded each species. Wildlife Conservation Act 1950 (WCA) Schedule 1: Fauna that is rare or likely to become extinct; Environment Protection and Biodiversity Conservation 1999 (EPBC); Convention on Migratory Species (CMS) (as at May 2012); Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (as at May 2012; International Union for Conservation of Nature (IUCN) (as at May 2012)

Turtle Species	WCA	EPBC	CMS	CITES	IUCN
Flatback (*Natator depressus)*	Schedule 1	Vulnerable	Not listed	I	Data Deficient
Green (*Chelonia mydas)*	Schedule 1	Vulnerable	I & II	I	Endangered
Hawksbill (*Eretmochelys imbricata)*	Schedule 1	Vulnerable	I & II	I	Critically Endangered
Loggerhead (*Caretta caretta*)	Schedule 1	Endangered	I & II	I	Endangered
Olive Ridley (*Lepidochelys olivacea)*	Schedule 1	Endangered	I & II	I	Vulnerable
Leatherback (*Dermochelys coriacea)*	Schedule 1	Vulnerable	I & II	I	Critically Endangered

3 ACTIVITY ASSOCIATED WITH THE PROPOSED FACILITY UPGRADE

Oil and gas processing facilities are typically operated 24 hours a day. Lights planned for use in the facility upgrade include 50 to 70 WHPS bollard lights and Pierlite 18 W bulkhead lights. The 50WHPS bollard lights have external louvres which reduce light glow. The bulkhead lights contain internal prisms for optimum light distribution. Illuminance is between 27 Lux four meters and 48 Lux at three meters high.

4 EXISTING ENVIRONMENT

4.1 Artificial Light

Pipeline Beach on Varanus Island is the second largest hawksbill turtle rookery in the Lowendal Group after Beacon Island (Pendoley 2005). Tanny's Beach on the west coast of Varanus is the main flatback turtle nesting beach in the Lowendal Group and flatback, hawksbill and green turtles also nest on the other beaches of Varanus Island. A recent opportunistic light study undertaken on Varanus Island by Pendoley Environmental during the 2011/12 reproductive season (Pendoley 2012) confirmed the findings of Pendoley (2005) which found evidence of misorientation and disorientation of hatchlings during sea-finding and attraction of hatchlings toward land following departure from the natal beach. Facility lights and glow are visible from both the western and eastern beaches of Varanus, Cooks Beach on the north east side of Varanus Island and the south facing beach on Beacon Island.

Recommendations for managing the visible light included changing light orientation away from the coast, shielding lights, installing motion sensors and closing blinds at night to minimise light spill.

Subsequent modifications to lights on Varanus have reduced the visibility of some lights however further work is required. Apache plans to collect qualitative and quantitative data on current light emissions from Varanus Island marine turtle nesting beaches in December 2012.

4.2 Noise and Vibration

Current noise and vibration patterns on Varanus Island are not known but have been modelled by SVT contractors and are described in Section 8.2

5 MODIFICATIONS ASSOCIATED WITH THE FACILITIES UPGRADE

5.1 Proposed Positioning and Timing of Lighting

Lights facing north and west have potential to cause most impact to nesting turtles and hatchlings on Mangrove and Tanny's beaches. These include four (4) Pierlight 18W bulkhead lights mounted two metres off the ground, two (2) Pierlight 70 WHPS bulkhead lights mounted approximately two metres off the ground and six (6) Al Fresco area bollard lights at 50 WHPS located low to the ground. The 70 WHPS bulkhead mounted lights and bollard lights will be switched off between 21:00 and 0400 hrs.

5.2 Predicted Noise and Vibration

Predicted filtered noise levels (dB) resulting from the KMCR Facility Upgrade range from 39.8 dB and 88.4 dB at various locations.

6 POTENTIAL ENVIRONMENTAL IMPACTS

6.1 Artificial Light

The many properties of colour, intensity, proximity and direction of a light source are all thought to play a role in marine turtles hatchling orientation (Environmental Protection Authority 2010). While marine turtle hatchlings see all visible light, when given a choice they will select a lower wavelength light statistically more often that a higher wavelength (Witherington & Bjorndal 1991; Pendoley 2005). Overall, bright light that has high directivity causes the greatest disruption. The greatest problems for turtle hatchling orientation are caused by bright, highly directive white lights containing short (blue-green) wavelengths (<400 nm). However, even long wavelength lights (orange-red, >700 nm) that are intense enough and direct enough will disrupt hatchling orientation, especially in the absence of sun or moon light. The operational implications of this are that *any* artificial light may misorient hatchlings on their natal beaches, particularly on nights of the new moon. Furthermore in the absence of moonlight the artificial lights are relatively brighter and more visible and potentially more disruptive to hatchling orientation. The visibility of light to turtles coming to the beach to lay eggs is dependent on a wide range of parameters, including turtle life stage, light type, light intensity, light emission wavelength, distance between the turtle and the light source, the proportion of sky or horizon illuminated, lunar cycle, cloud cover and aerosol concentration.

The orientation or sea-finding ability of hatchlings can be affected by the presence of artificial lighting on beaches (Salmon 2003; Tuxbury & Salmon 2005; Verheijn 1985; Witherington & Martin 1996) and flares (Pendoley 2005). Artificial lighting may adversely affect hatchling sea-finding behaviour in two ways; disorientation, where hatchlings crawl on circuitous paths; or misorientation, where they move landward, possibly attracted to artificial lights (Salmon 2005; Witherington & Martin 1996). The consequences of this disruption to sea-finding are mortality resulting from increased exposure to predation, dehydration and exhaustion (Salmon 2005; Witherington & Martin 1996). Studies to date indicate that artificial night lighting on or near marine turtle nesting beaches may disrupt the nesting behaviour of females (Salmon 2005; Salmon *et al.* 1995). Nesting densities are typically lower at beaches exposed to artificial night light, although this may not be the only, or even primary cause (Salmon *et al.* 1995). Furthermore, on beaches exposed to urban lighting shielded by tall buildings or tall trees, nest placement was positively correlated with object elevation. Higher density nesting occurred in the shadow of the buildings or trees than in the lit areas between the buildings or trees.

6.2 Noise and Vibration

Eggs and buried pipped hatchlings in the nest are exposed to the natural noise and vibration of breaking waves. The importance of these vibrations for development and sea finding and consequently the potential interference of artificial sources of noise and vibrations has not been formally tested but is recognised as a potential risk factor for nesting beaches near petroleum infrastructure. While movement of developing eggs has been implicated in embryo mortality, the scale of movement (e.g. fine scale vibrations versus physically shaking the egg back and forth) that affects development has not been defined. Fine scale vibrations therefore remain a potential source of impact on the success of egg development and hatchling emergence on nesting beaches near petroleum facilities. The few papers addressing these issues are summarised below.

Nests of sea turtle eggs buried in a beach are exposed to natural sound and vibrations from breaking waves on the shore line. These physical characteristics have been proposed as a possible cue used by hatchlings to locate the direction of the ocean while inside the nest (Lohmann, 1991). While attempting to explain the results of laboratory studies on hatchling orientation, Lohmann (1991) suggested hatchlings might calibrate a magnetic compass using a directional reference, such as sound or vibration, which is available to them inside the nest.

7 UPGRADE PROJECT IMPACT ASSESSMENT

7.1 Artificial Light

The size and scale of the lighting regime proposed for the upgrade project is limited relative to light emissions from the existing plant lighting, flares and facilities on Varanus Island. While it is likely the impact of the additional lights will be undetectable over the effects from the current light emissions from the camps, offices, mess and warehouses on Varanus, it is strongly recommended that the new lighting be managed to minimise light spill. This is particularly important as the elevated location of the KMCR facilities will increase the visibility of all lights from west coast nesting beaches (i.e. Tanny's and Mangrove). Light management should focus not only on shielding light sources but also on reducing light glow.

7.2 Noise and Vibration

Neither noise nor vibration data was collected from nesting beaches during the noise survey. The location of marine turtle nesting beaches relative to the KMCR facility exceeds approximately 200 metres. Beaches closest to the project sites include Amenity Beach and Mangrove Beach and neither are major nesting beaches. It is therefore unlikely that noise or vibrations from the proposed facility upgrade will affect nesting turtles, incubating clutches or turtle hatchlings over this distance.

Baseline vibration measurements for Varanus Island beaches are available based on modeled profiles and are therefore approximate. Baseline levels considered to be low and typical of levels measured at beaches in the north west of Western Australia at surface is <0.07 mm/s at the surface and <0.06 mm/s at 50 cm depth (Chevron Australia 2010). Vibration levels greater than 10 mm/s would require the unlikely blast force of greater than 162.43 kg to be felt at Amity Beach, which may have potential to cause structural damage.

8 RECOMMENDATIONS FOR MANAGEMENT

The Environmental Protection Authority recommends steps to avoid, reduce, manage and mitigate light, noise and vibration impacts on marine turtles, particularly for new developments. (Environmental Protection Authority 2010)

8.1 Artificial Light

Satisfactory resolution of lighting design near marine turtle nesting beaches requires the accommodation of public and employee safely and utility while ensuring no significant disruption to marine turtle behaviour.

To reduce lighting impacts on marine turtles, the Environmental Protection Authority (2010) recommends simple guidelines that include:

- Keep it off (keep light off the beach and lights off when not needed);
- Keep it low (mount lights low down with lowest intensity for the job);
- Keep it shielded (stop all light escaping upwards and outwards; and
- Keep it long (use long wavelength lights).

The lighting plan provided by Apache has taken these guidelines into consideration when creating the lighting plan for the Facility Upgrade, with both lights considered to support EPA requirements.

The Pierlight 18 WHPS and 70 WHPS bulkhead lights should be shielded from view beyond the boundary of the facility buildings. Consideration should be given to locating outside Al Fresco area and lights on the south or east side of the buildings so as to provide shielding by buildings and topography from Varanus nesting beaches. The proposed bollard lights at 50 WHPS are suitable for marine turtles as they are located low to the ground and are shielded however a follow-up inspection and audit of all newly installed lighting is recommended to ensure visibility of lights from nesting beaches is minimised.

Recommendations made in the 2010/11 Marine Turtle Tagging Program report to Apache (Pendoley 2011), provide direction for management of existing facility lighting and should be during implementation of lighting associated with Facilities Upgrade.

8.2 Noise and Vibration

Noise monitoring on Western Australian nesting beaches (Chevron 2010), has shown that all beach locations to be noisier than inland locations at all times of the day due to wave action. There are currently no specific noise emission targets with regard to impacts on turtles; however we advise that noise standards comply with Australian standards and where necessary appropriate noise management measures are implemented. Monitoring of noise and vibration levels throughout construction to detect changes is recommended.

8.3 Monitoring Programs

Apache proposes a number of marine turtle surveys to support this assessment. A pre-construction baseline light monitoring survey will be carried out in December 2012 to provide quantitative and qualitative data regarding artificial light profiles visible from marine turtle nesting beaches on Varanus Island. These data will be analysed in conjunction with findings from a hatching orientation monitoring program (scheduled to occur during the annual Turtle Tagging Program) to assess the impact of current light emissions on hatchling orientation. A nest success survey is also planned for the 2012/13 nesting season to assess the hatching and emergence success of hawksbill turtles on Pipeline beach.

9 REFERENCES

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APPENDIX 3 – HALFMOON BIOSCIENCES SEABIRD IMPACT ASSESSMENT FOR VI WORKS REPORT (2012)

Seabird Impact Assessment for the Varanus Island Works

Apache Energy Ltd.

October 2012

Contents

Date	Description	Prepared by	Reviewed by
16 October 2012	Draft issued for internal review	C.A. Surman & L.W. Nicholson	LWN
18 October 2012	Draft issued for client review	C.A. Surman & L.W. Nicholson	SM
6 November 2012	Final issued	C.A. Surman & L.W. Nicholson	LWN

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1 Introduction.

This is an impact assessment on seabird fauna nesting within areas proposed for facility upgrades during the Varanus Island Works program.

Halfmoon Biosciences was engaged by Apache Energy Ltd (AEL) to search and assess any nesting activity of seabirds within the areas earmarked for construction activity, as well as to advise on any potential impacts to seabird nesting colonies adjacent to the areas planned for the VI Works program.

There are three main species of seabirds breeding on Varanus Island, the burrow-nesting Wedge-tailed Shearwater *Ardenna pacifica* (annually, approximately 1000 pairs), the concealed-nesting Bridled Tern *Onychoprion anaethetus* (annually, approximately 20 pairs) and the open surface-nesting Crested Tern *Thalasseus bergii* (intermittently, 5550 pairs). The Crested Tern has bred on Varanus Island three times since 1996 (Surman and Nicholson 2012).

2 Methods.

Varanus Island was visited on 13-14 September 2012. Visual ground searches were conducted in areas to be impacted during the VI works program, with particular attention given to those areas adjacent to known nesting colonies. In addition, a literature search was conducted to find any reported impacts upon seabird colonies elsewhere from sound, vibration or light associated with construction activities.

Baseline data on the presence of seabirds and their breeding sites has been reported in *Monitoring of annual variation in seabird breeding colonies throughout the Lowendal Group of islands: 2012 Annual Report* (Nicholson and Surman 2012). Baseline data has been collected by Halfmoon Biosciences on behalf of Apache Energy Ltd since 2005.

3 Results and Discussion.

Seabird nest sites were observed at two locations within the proposed facility upgrade areas. These were the West Wharf Upgrade and Kitchen Mess Cyclone Refuge area. A single Bridled Tern nest site was located under limestone rocks immediately to the east of the West Wharf, abutting the northern edge of the existing wharf. Two Wedge-tailed Shearwater burrows, both active, were located at the base of a rock spill pile from earlier earthworks associated with the development of the VI Top Camp (see Figure 1 - blue/black circles). Three more Wedge-tailed Shearwater burrows were located immediately adjacent to the VI boundary rope, 14m west of the other burrows (Figure 1 – blue/black circles).

3.1 Potential Impacts Upon Seabirds

The major potential impacts upon nesting seabirds are

- Noise
- Vibration
- Lighting

There were no published precedents found during the literature search on the impact of construction activities upon seabird breeding colonies. However, surface nesting birds are known to withstand up to 85 db from aircraft passing overhead (Burger 1981). It has been observed that Crested Terns, Silver Gulls, Osprey and Bridled Terns, appear to adapt to some disturbances, as they do not alight on the approach of helicopters over regular flights paths at Varanus Island (Surman *pers obs*.). However it is difficult to surmise the potential impacts of construction activities upon nesting seabirds in close proximity.

3.1.1 Noise Impacts

The hearing sensitivity of birds is thought to lie between that of reptiles and mammals, within the range of 1 to 5 kHz. Their hearing sensitivity is similar to that of the more sensitive mammals (Dooling 1978), however in contrast to mammals, bird sensitivity falls off at a greater rate with increasing and decreasing frequencies.

A study on the effects of noise on Herring Gulls *Larus argentatus* that nested less than 1 km from JFK Airport in New York (Burger 1981), found that noise levels at the nesting colony were between 85 to 100 db during the approach of an aircraft, and between 94 to 105 db during takeoff. There were no adverse effects of subsonic aircraft noise on these ground-nesting Herring Gulls reported.

Noise effects also appeared to have negligible impacts on a breeding population of burrow-nesting Snow Petrels *Pagodroma nivea* at Casey Station, Antarctica (J. Creuwels *pers. comm*.). Over a twenty year period the duration of the noise sources were short term (explosions) and longer term (excavations) at a quarry adjacent to the nesting colony.

3.2 Wedge-tailed Shearwaters

The two burrows located within the proposed KMCR area (Figure 2) will be affected by earthworks, as they are likely to be directly impacted (destroyed) as part of the construction process. Three WTS burrows nearby fall outside the lease boundary, however they are directly adjacent the KMCR area, and may be impacted by construction activities (Figure 2).

Noise impacts upon seabirds are unclear, apart from the studies cited above. Wedge-tailed Shearwaters are highly vocal during courtship and breeding, particularly when they return to their burrows after dusk. Vocalisation is particularly important during the prelaying period (August- October) and to a lesser extent during the remainder of their breeding period (to early April).

Whilst vocalisations are important to Wedge-tailed Shearwaters, it is during the hours of darkness (when presumably construction noise will have ceased) that the parents locate and feed young at the burrow. The chick remains at the burrow throughout the nesting period until it fledges. A four year study of the VRS-A Wedge-tailed Shearwater colony on Varanus Island found that those burrows located closest to the gas plant facility (and 24 hour noise source), had the same breeding participation and breeding success as those burrows which did not have a noise source nearby (Nicholson 2002).

Whilst the levels of noise within burrows may be mitigated to a degree from the surrounding sand, high levels of vibration may increase the risk of burrow collapse. Burrows on Varanus Island are excavated in pink limestone sands. These are highly unstable. For example, during moderate-heavy rainfall burrows often collapse. The SVT assessment states.

> "*The ground borne vibration levels of 1mm/s and 10mm/s have been used to determine charge size at which the vibration levels will be reached at each receiver. As a guide 10mm/s will result in structural damage to buildings (and therefore possibly structural damage to burrows). So for example at receiver SR3 in the table below which is 16.4 m away from the blast modelled a 10 mm/s vibration level will be achieved using 0.72 kg of explosive. Ground borne vibration modelling has been undertaken for each area.*"

The likely impacts of predicted noise and vibration levels (as indicated by the SVT assessment) for the main Wedge-tailed Shearwater colonies are listed below.

- The "football field" colony would be unaffected by noise or vibration, given that most of the nesting shearwaters are located at the far end of this colony, 100 NE of the NW R1-6 receptors in the SVT assessment.

- The main VRS A shearwater colony could be affected by vibration affects. A minimum charge of 25kg at the VICP NE site is likely to produce vibrations in excess of 3 mm/s at most NE R sites. However, if construction activity is managed so that vibration levels during the breeding season (November to early April) are 1mm/s or less, then impacts to breeding shearwaters are likely to be negligible. Noise impacts at this site are also likely to be negligible as the colony is located adjacent to the Gas Plant facility which already generates significant noise (as mentioned in 3.2).

- The smaller Dune colony to the south of the KMCR site (Figure 2) could be affected by both noise and vibration given its proximity to the construction activity. All sites, except SR 6, triggered greater than 10 mm/s vibration levels using charges of less than 25 kg at the KMCR source, and in 2 cases at the Accommodation source (SR 1 and SR 2). This level of vibration could collapse the 5 burrows located within the immediate area, but may also impact burrows in the main part of this colony situated 40 m further south.

3.3 Bridled Terns

Bridled Terns return to the island in late November and breed from late December until April (Surman and Nicholson 2012). Bridled Tern nesting sites on Varanus

Island are shown in Figure 1. There are several Bridled Tern nests along coastal cliffs adjacent to the East Wharf, as well as a single nest abutting the West Wharf. Bridled Terns nest under the cover of rocks, or within holes in limestone cliffs.

This species already nests in association with regular disturbance from activities on Varanus Island. The single nest at the West Wharf may be displaced by construction activity, however the nests situated west and east of the East Wharf are unlikely to be affected by either vibration, noise or light beyond existing levels found in these areas.

Noise impacts are unlikely to disrupt breeding behaviour of this species, except any breeding attempts adjacent to the West Wharf. Bridled Tern chicks do vocalise to alert feeding parents, as they are sheltered under cover, however they usually remain within a small range of the original nesting site.

4 Management of Impacts

4.1 Noise

As discussed above, noise levels are unlikely to disturb most nesting seabirds on Varanus Island. This is due to the level of noise that already exists within the lease area that is adjacent to colony areas. The southern colony of Wedge-tailed Shearwaters is the most likely to be disturbed from noise as it is has been the least exposed to facility noise. .

To reduce potential impacts, limiting noise levels at the KMCR site, particularly at night, or undertaking works outside of the breeding season, would limit any impact.

4.2 Vibration

SVT have found that vibration levels of 1mm/s are negligible, but levels of 10mm/s may result in collapse of Wedge-tailed Shearwater burrows. Based on SVT modelling, those burrows adjacent to the KMCR area are the most likely to be impacted by higher vibration levels.

To reduce this impact, it is recommended that the works be undertaken outside of the breeding season. Collapse or erosion of burrows outside of the breeding season has little impact upon breeding birds, as when they return in August they re-excavate burrows prior to laying (Nicholson 2002).

4.3 Light

Light impacts breeding seabirds in much the same way as it does marine turtles. Seabirds, particularly fledglings, are “attracted” to light, which disorientates them, and become vulnerable when caught within construction infrastructure. In addition, disoriented adult birds may not be able to return to their burrows to relieve their mates or feed their young. Fledgling Wedge-tailed Shearwaters are particularly vulnerable to light during the fortnight young birds depart the colony for the first time (late March early April)(Nicholson 2002).

Light impacts can be greatly reduced following guidelines established on Varanus Island for marine turtles.

4.4 Displacement of Two Wedge-tailed Shearwater Burrows Within the KMCR

The two Wedge-tailed Shearwater burrows located within the proposed KMCR site will be displaced by construction activity. The long-term average burrow occupancy for Varanus Island Wedge-tailed Shearwaters is 49% (Nicholson and Surman 2012). Therefore we could expect one of the two burrows to be occupied during the 2012/13 season. Several approaches may be undertaken to reduce impact to the adult birds prior to construction commencing. These burrows will be inspected in late November 2012 to see if they have been occupied.

- Avoid construction activity during the breeding season, between late November and April.
- Block off burrows prior to laying (late November) to prevent adults accessing the site. There is some risk adults will re-excavate nearby.
- Remove any egg laid and block burrow to discourage adults from returning to site during the current season. However, there is some risk adults will re-excavate nearby.
- Offset this impact by the introduction of artificial nest boxes in habitat adjacent to the KMCR site, post completion of works and prior to the next breeding season.

4.5 Displacement of the Single Bridled Tern Nest at the West Wharf.

The impact of construction activities upon the single Bridled Tern nest at the West Wharf is dependent upon timing, and whether the nest is occupied during the 2012/13 season.

If construction commences prior to egg laying in late December, the adults will relocate due to ongoing disturbance. If construction activities occur at this location after this date, but prior to the end of the breeding season (April) then the breeding attempt will be disrupted. However not all Bridled Terns breed each year, dependent upon oceanographic conditions (Surman and Nicholson 2012), so there may be no breeding attempt in this nest.

Techniques for reducing the impact upon adult Bridled Terns are similar to that proposed for Wedge-tailed Shearwaters:

- Limit access to this nesting site under limestone rock prior to the breeding season (Halfmoon Biosciences can undertake this during a visit planned in November 2012)

5 References

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Figure 1: Aerial view of the Varanus Island showing the main seabird nesting areas located adjacent to proposed to Facilities Upgrades.
Of note are the two Wedge-tailed Shearwater (WTS) burrows (see Figure 2) within the Kitchen Mess Cyclone Refuge (KMCR) area, and the single Bridled Tern nest site at the West Wharf. The WTS colony to the south of the KMCR site is approximately 40 m from the KMCR. Wedge-tailed Shearwater nesting burrows or habitat are shown in blue, and Bridled Tern habitat in yellow. The total numbers of nests/burrows at each location are given in parenthesis.

	Apache Energy	Drawn by: C. Surman
		Date: 21 September 2012

HALFMOON Biosciences

Figure 2: Aerial view of the Varanus Island top and bottom camps, showing (A) the Kitchen Mess Cyclone Refuge (KMCR) area of proposed earthworks, with areas searched for seabird nesting activity marked in yellow, and the lease area boundary marked in red. (B) Detail aerial view of Wedge-tailed Shearwater burrows within the proposed earthworks. Wedge-tailed Shearwater nesting burrows or habitat are shown in blue, individual burrows are marked as blue circles.

Apache Energy	Drawn by: C. Surman
	Date: 21 September 2012

APPENDIX 4 – PHOENIX ENVIROMENTAL SERVICES VERTEBRATE FAUNA SURVEY FOR VARANUS ISLAND FILL PROJECT REPORT (2012a)

PHOENIX
ENVIRONMENTAL SCIENCES

Vertebrate fauna desktop review for the Varanus Island Fill Project

Prepared for Apache Energy Ltd

November 2012

Final Report

Vertebrate fauna desktop review for the Varanus Island Fill Project

Prepared for Apache Energy Ltd

Final Report

Author/s: Guillaume Bouteloup, Jarrad Clark

Reviewer/s: Volker Framenau, Melanie White

Date: 21 November 2012

Submitted to: Sonja Mavrick, Apache Energy Ltd

Chain of authorship and review			
Name	**Task**	**Version**	**Date**
Guillaume Bouteloup	Draft for technical review	1.0	21 September 2012
Jarrad Clark	Draft for technical review	1.1	23 September 2012
Volker Framenau	Technical review	1.2	23 September 2012
Melanie White	Editorial review	1.3	24 September 2012
Jarrad Clark	Draft for client comments	1.4	26 September 2012
Volker Framenau	Final submitted to client	2.0	21 November 2012

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EXECUTIVE SUMMARY

Varanus Island is the largest island in the Lowendal archipelago and is located approximately 14 km east-northeast from the northern tip of Barrow Island. The island's oil and gas facilities have been operated by Apache Energy Ltd (Apache) since 1993 and now, Apache is planning to further develop the infrastructure on Varanus Island. The development will require fill material comprising rock, soil and sand, which will be sourced from several locations within the current 29 ha tenement on Varanus Island.

In August 2012, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned to undertake a vertebrate fauna desktop review for the Varanus Island Fill Project (the Project), excluding marine mammals and marine reptiles. The review encompasses Varanus Island (the study area), and the neighbouring Barrow and Montebello island complexes which provide a regional context and for which more comprehensive data are available. The aims of the review were to:

- summarise the vertebrate fauna of the study area, including likely fauna assemblages, conservation significant fauna and associated habitat values
- assess potential impacts of the Project on vertebrate fauna, including recommendations for management and mitigation of impacts where applicable.

The desktop review of the Barrow, Montebello and Lowendal island groups identified a wealth of information for the Barrow and Montebello islands but relatively few, less-reliable fauna data for the Lowendal islands. Therefore, availability of adequate data was a key limitation of the desktop review. The key source of information, a 1986 systemic vertebrate fauna survey report, was not accessible.

It was deemed appropriate to identify and discuss the *potential* occurrence of conservation significant species of the study area, because:

- there were limited fauna data for Varanus Island
- the islands of the Lowendal Island group together form an 'C' Class Nature Reserve, and are recognised as an IBA (Important Bird Area) for several species of seabird
- birds represented more than 60% of total fauna records for the three island groups and, given their mobility and ranges, most have been recorded or are likely to occur on Varanus Island
- the majority of conservation significant birds recorded for the three island groups are migratory birds.

A total of 25 mammals, 49 reptiles and three amphibians were recorded as potentially occurring in the study area. Of these, Varanus Island recorded:

- a single (introduced) mammal, the House Mouse (*Mus musculus*)
- 13 reptiles (possibly one endemic) (only ten of these were recorded in the most recent targeted reptile survey in 2002).

A total of 150 bird species were recorded on the Barrow, Montebello and Lowendal island groups, and of these:

- 89 have previously been recorded on Varanus Island
- 66 are terrestrial
- 84 are littoral and/or seabird species.

Up to 36 species of conservation significance may potentially occur in the study area, primarily migratory species and breeding seabirds. This desktop review determined that the Project has the potential to impact several conservation significant species:

- the Water-rat (*Hydromys chrysogaster*). The only conservation significant mammal that can potentially occur on Varanus Island, based on the database searches that comprise the desktop review. Disturbance risks for this species associated with the project are relatively low, as it is generally not expected to take up residence close to human activities and therefore is unlikely to be found within or near the impact area.
- Barrow Island Blind Snake *(Ramphotyphlops longissimus)* – this subterranean blind snake has not been recorded on Varanus Island but could occur, given that the cavernous limestone that forms the island is a continuation of the same geological unit as that of Barrow Island and given that subterranean fauna (stygobitic amphipods) are known from Varanus Island. Not much is known about this species that has so far only been found on Barrow Island, but given the nature of the project (i.e. surface scraping) direct impacts (should it occur) are unlikely to be significant. Secondary impacts such as sub-surface contamination are more likely to impact subterranean voids. Any future subterranean fauna surveys should attempt to target this species.
- the Wedge-tailed Shearwater (*Puffinus apacificus*) colonies, with >1000 breeding pairs returning annually to a large area within the Project footprint
- terns and especially, the Fairy Tern (*Sternula nereis*, EPBC Vulnerable, last recorded breeding on Lowendal Islands in 2005).

The majority of the remaining conservation significant species that potentially occur on the Varanus Island, are unlikely to occur in the Fill Project footprint.

With respect to the overall non-avian vertebrate assemblage (mammals, reptiles and bats), no comprehensive systemic survey has been undertaken since 1986 (indeed a systematic bat survey may never have been undertaken) and these data could not be accessed. This is a major gap in the knowledge base required to adequately assess the environmental impacts of the Project.

In the context of the potential impacts to conservation significant fauna of Varanus Island, key management recommendations include:

- review the existing Quarantine Management Plan before commencement of the Project in order to identify any new pathways for species introduction
- review the on-going Vermin Trapping Program in line with the Project construction and operation phases

- conduct a systematic terrestrial vertebrate fauna survey (Level 2, targeting the main fauna habitats present), with emphasis on potential endemics (e.g. a potential subspecies of *Gehyra pilbara*) and bat echolocation recordings; if a Level 2 surveys is undertaken
    - collect tissue samples or voucher specimens for comparison with WA Museum specimens in order to gauge the degree of endemism on Varanus Island
    - if deemed necessary, develop a Vertebrate Fauna Management Plan (VFMP) for the Project
- avoid seabird colonies, especially the Wedge-tailed Shearwater to minimise direct mortality and habitat loss
- conduct pre-clearing surveys to relocate the conservation significant species at risk
- undertake Project earthworks outside the breeding season of key species
- maintain annual seabird monitoring in the Lowendal Islands.

1 INTRODUCTION

In August 2012, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Apache Energy Ltd (Apache) to undertake a vertebrate fauna desktop review for the Varanus Island Fill Project ('the Project'). This report describes the results of this desktop review.

1.1 BACKGROUND

Varanus Island is located approximately 14 km east-northeast from the northern tip of Barrow Island (Figure 1-1). Bond Corporation developed the original Varanus Island oil and gas facilities in 1987. Since 1993, the Department of Environment and Conservation (DEC) has leased 29 ha of the 83 ha 'C' Class Nature Reserve to Apache Energy for oil and gas production. Apache is planning to further develop the infrastructure on Varanus Island which will require fill material comprising rock, soil and sand. Apache has proposed to source the fill material from several locations within the confines of the current 29 ha tenement on Varanus Island (Figure 1-2).

For this development, Apache requested a vertebrate fauna desktop review to summarise the current knowledge of the vertebrate fauna values of Varanus Island (the study area).

Varanus Island is part of the Lowendal Islands, an archipelago comprising more than 30 islands that are located approximately 14 km east-northeast of the northern end of Barrow Island and 15 km south of the Montebello Islands off the north-western coast of Western Australia. Varanus Island is the largest of the Lowendal Islands and is 2.5 km long and 600 m wide (approximately 85 ha).

Varanus Island is a twisted, linear limestone outcrop with recent sand dunes. The Island is formed from a marine basement beneath a marine calcarenite, which is overlain by a well cemented dune limestone (Astron 2009). The highest point of the island is approximately 30 m above sea level (a.s.l.) (DMP 2011).

The vegetation of the islands of the Lowendal group (including Varanus, Abutilon, Bridled, and Parakeelya Islands) consists of coastal species (*Spinifex longifolius* and *Acacia coriacea*), with some *Triodia angusta, Ficus platypoda* and *Pittosporum phylliraeoides* inland on Varanus (Kendrick & Mau 2001). One hundred and twenty-two plant taxa have been recorded on Varanus Island and Bridled Island, including 12 weed species and six introduced mainland species (Astron 2009).

The Lowendal group is recognised as an important nesting ground for several species of seabird and marine turtle. For example, the Lowendal Islands archipelago regularly supports more than 1% of the global population of several species of terns (Birdlife Australia 2005–2007b).

Important sea turtle nesting occurs throughout the Lowendal group. Hawksbills (*Eretmochelys imbricate*) and Greens Turtles (*Chelonia mydas*) nest on Varanus, Abutilon and Bridled Islands. Flatback Turtles (*Natator depressus*) are known to also nest on Varanus Island in low numbers and occasional nesting by Loggerheads has been recorded. Dugongs are present in surrounding waters (Kendrick & Mau 2001).

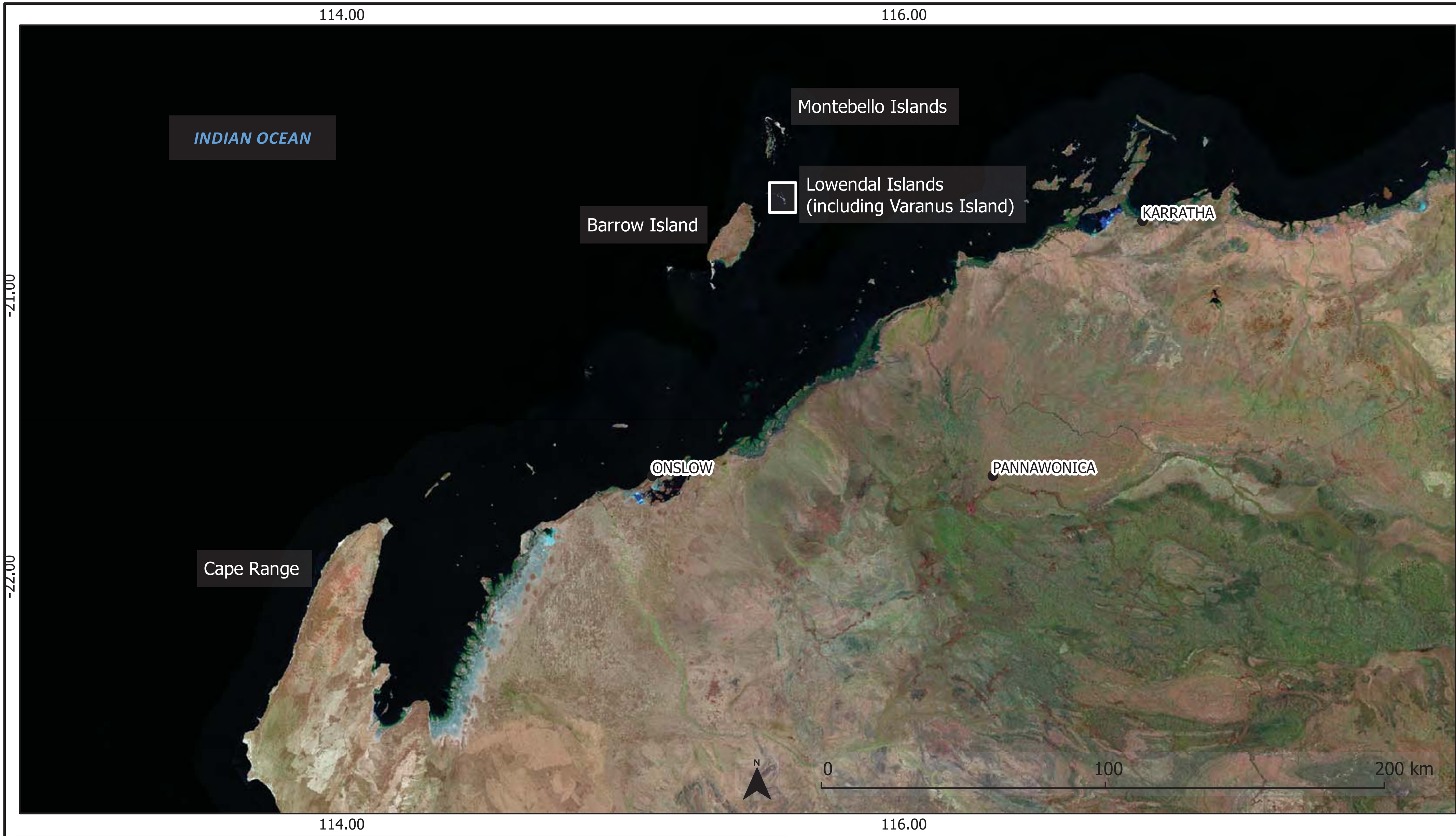

Figure 1-1
Location of Varanus Island

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:1550000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PHOENIX ENVIRONMENTAL SCIENCES

PROJECT: Varanus Island Fill Project

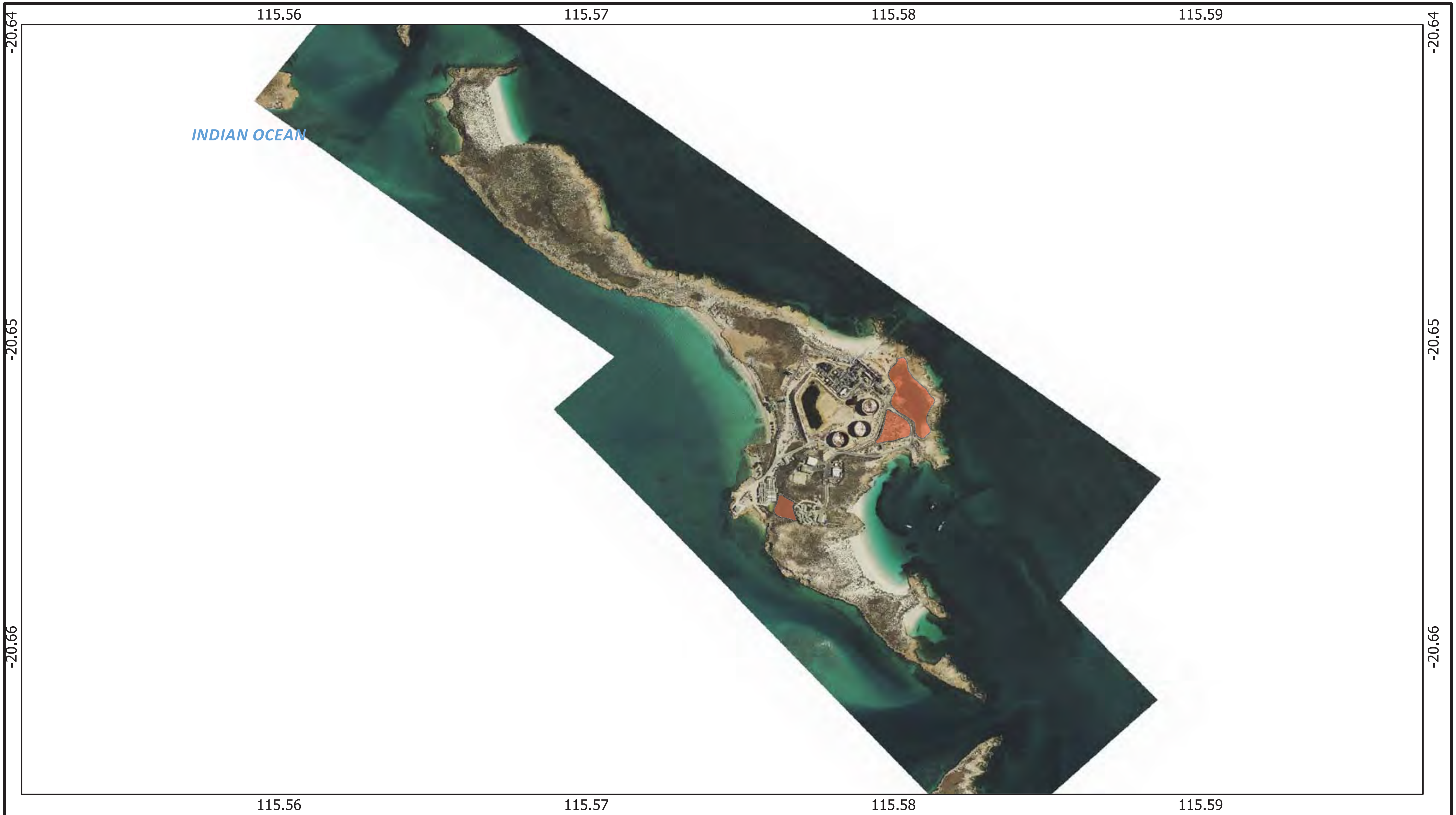

Figure 1-2
Proposed impact area for the Varanus Island Fill Project (August 2012)

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:14000
PROJECT: Varanus Island Fill Project	
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

1.2 SCOPE OF WORK AND SURVEY OBJECTIVES

The scope of work is as follows:

- review all available technical reports on vertebrate fauna from Varanus Island and conduct database searches to collate a list of the likely vertebrate assemblage of the study area
- identify any potential vertebrate fauna of conservation significance on the island
- undertake a desktop habitat assessment, with consideration to the value of this area to conservation significant species
- prepare maps showing conservation significant species records and habitats in the study area, if possible
- prepare a technical report outlining methods, results, assessment of potential impacts on vertebrate fauna by the Project and, if applicable, recommendations for management and mitigation of impacts.

On the request of Apache, marine mammals and the marine reptiles (turtles, sea-snakes) have been excluded from this report. In relation to avifauna, a high-level summary only was requested (S. Mavrick 2012, email to Volker Framenau, 4 September).

2 EXISTING ENVIRONMENT

2.1 INTERIM BIOGEOGRAPHIC REGIONALISATION OF AUSTRALIA (IBRA) REGION

The Interim Biogeographic Regionalisation of Australia (IBRA) defines 'bioregions' as large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems (DSEWPC 2012; Thackway & Cresswell 1995). Their purpose is to record and categorise the large-scale geophysical patterns that occur across the Australian continent. The identified patterns in the landscape are linked to fauna and flora assemblages and processes at the ecosystem scale. They are a useful means for simplifying and reporting on more complex patterns of biodiversity (Thackway & Cresswell 1995).

Western Australia contains 26 IBRA bioregions and 53 subregions. By combining information for an IBRA region with information on protected areas within the region and its sub-regions, the level of protection of Australia's various landscapes can be established. IBRA is therefore a dynamic tool for monitoring progress towards building a comprehensive, adequate and representative reserve system (DSEWPC 2012).

Similar to Barrow Island, Varanus Island represents a natural extension of Cape Range and therefore falls within the Carnarvon region; however, these islands are geographically closer to the Pilbara bioregion and share many floristic and faunistic elements with the Pilbara (e.g. (Astron 2009; Eberhard *et al.* 2005; Karanovic 2006; RPS & Mattiske 2005).

The Carnarvon region covers an area of 83,747 km^2 and is divided into two subregions (DSEWPC 2012)

- Cape Range (CAR01): northern part of the Carnarvon Basin; includes Exmouth Gulf, and the islands of the Barrow group, Lowendal group, Montebello group and Muiron group
- Wooramel (CAR02): southern and central parts of the Carnarvon Basin; includes Lake MacLeod, the Kennedy Range and the islands of Shark Bay.

The Project is situated in the Cape Range subregion (Figure 2-1). Characteristics of this subregion include (Kendrick & Mau 2001):

- saline alluvial plains with samphire and saltbush low shrublands
- Bowgada low woodland on sandy ridges and plains
- Snakewood scrub on clay flats
- tree to shrub steppe over hummock grasslands on and between red sand dune fields
- limestone strata with *Acacia stuartii* or *Acacia bivenosa* shrubland outcrop in the north, where extensive tidal flats in sheltered embayments support mangel
- islands which are important for sea turtle and seabird breeding
- karst systems supporting unique and diverse troglofauna and stygofauna.

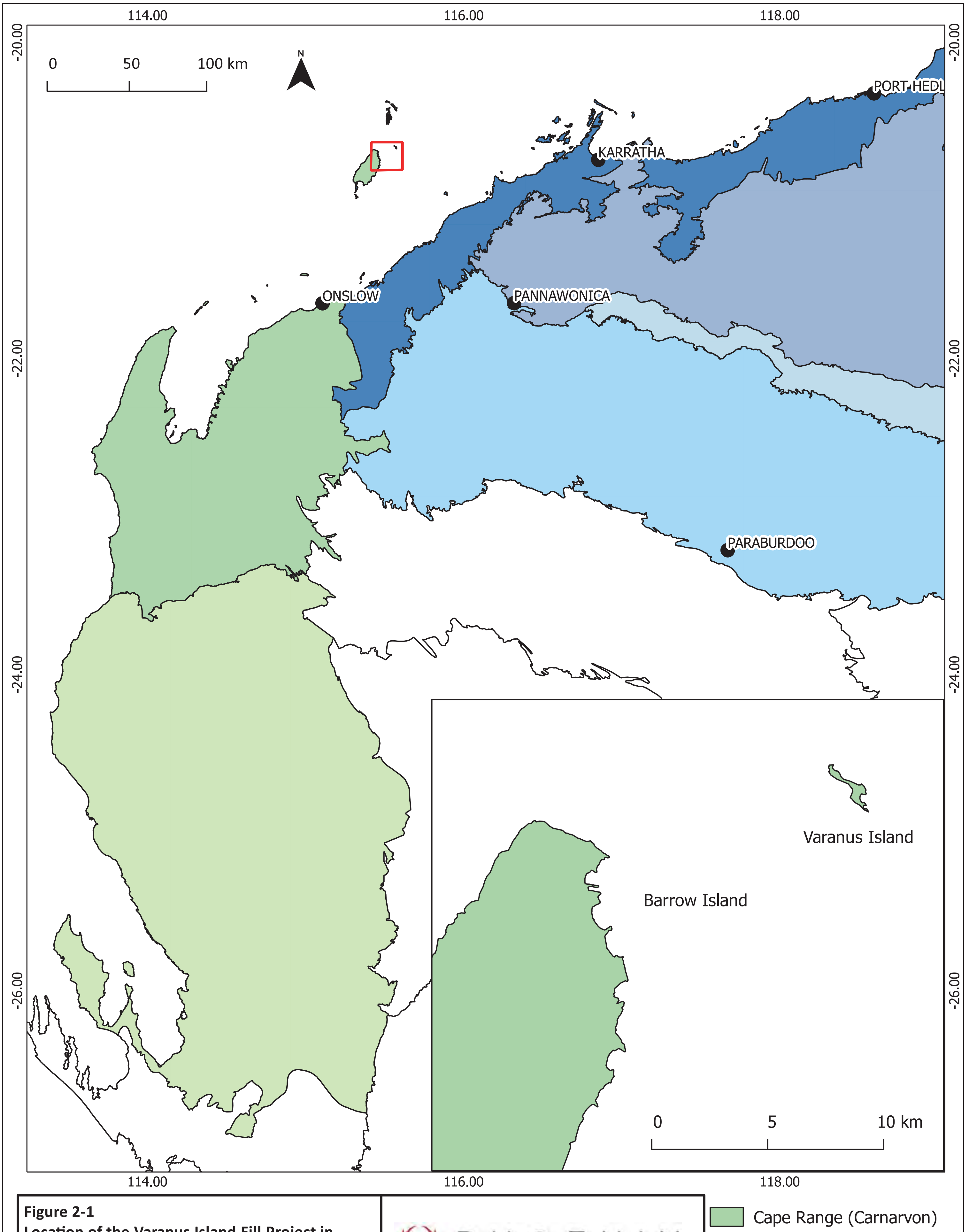

Figure 2-1
Location of the Varanus Island Fill Project in relation to IBRA regions and sub-regions

AUTHOR: A.E. Leung	**CLIENT: Apache Energy Ltd**
DATE: August 2012	**Scale: 1:2500000**
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PHOENIX ENVIRONMENTAL SCIENCES

PROJECT: Varanus Island Fill Project

2.2 GEOLOGY AND HYDROLOGY

The Barrow Island group, the Montebello Islands and the Lowendal Islands are the furthest offshore islands of the southern Rowley Shelf islands. The Rowley Shelf is a large sedimentary shelf 80 km from the west Pilbara coast, largely in the geological province of the Carnarvon Basin. These islands are separated from the inner part of the Rowley Shelf by the Flinders Fault and collectively form the Barrow-Montebello Complex. This complex, including Varanus Island, emerges as a north-tending promontory extension of the Rowley Shelf. This island system comprises Trealla limestone, flanked and veneered by Pleistocene and Holocene sediment deposits (RPS 2005; Wilson *et al.* 1994).

The Lowendal Island group contains more than 30 limestone islands, islets and rocky stacks with typically steep shorelines. The larger islands have dunes of white sand, while the smaller islands consist mostly of low lying, bare rocky islets and stacks (DEC & MPRA 2006).

2.3 CLIMATE

The Carnarvon bioregion has a semi-arid to arid climate with average maximum temperatures of about 32°C in summer and higher rainfall in the winter (DEWHA 2008). However, Varanus Island is geographically closer to the Pilbara bioregion which experiences high summer temperatures over 40°C and rainfall that is highly variable but more prevalent in summer where cyclonic activity is common (McKenzie *et al.* 2009).

The nearest Bureau of Meteorology (BOM) weather station is located at Barrow Island Airport (20.80°S, 115.41°E) approximately 14 km west-southwest of Varanus Island. Barrow Island weather station records the highest maximum mean monthly temperature (33.2°C) in January, February and March, and the lowest maximum mean annual temperature (17.7°C) in July and an average annual rainfall of 305.2 mm (BOM 2012)(Figure 2-2).

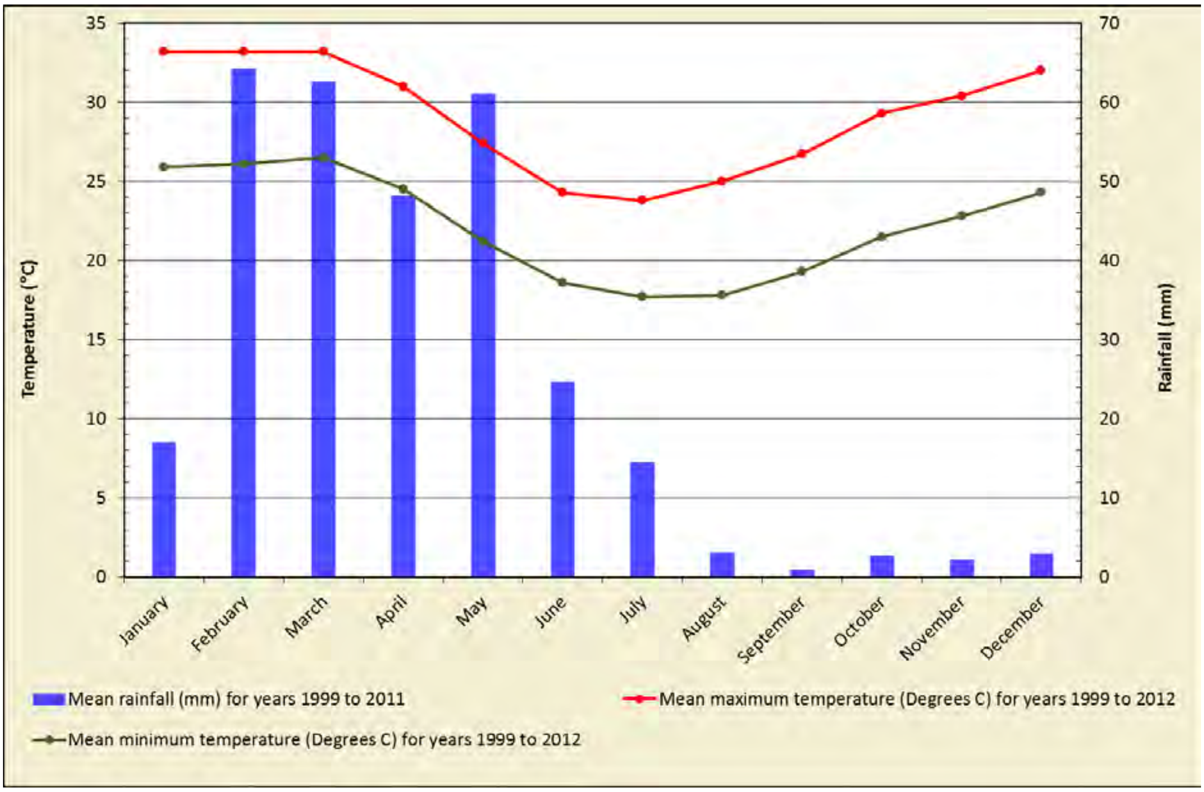

Figure 2-2 **Climate data (average monthly temperatures and rainfall records) for Barrow Island (BOM 2012)**

2.4 LAND USE

As part of the Lowendal Islands Nature Reserve, Varanus Island has largely been set aside for conservation purposes. Apache holds a lease of approximately 29 ha of the island which has been used for a gas processing plant and habitation infrastructure for employees since 1987 (Figure 1-2).

2.5 CONSERVATION RESERVES

The Barrow-Montebello complex contains a number of islands that are managed for the purpose of conservation (DEC & MPRA 2006). These include the Montebello Islands Conservation Park, Barrow Island Nature Reserve, Boodie, Double and Middle Islands Nature Reserve, and the Lowendal Islands Nature Reserve (Figure 2-3). Nature reserves are established for wildlife and landscape conservation, scientific study and preservation of features of archaeological, historic or scientific interest (EDO 2011).

The Montebello Islands are also managed to allow a level of recreation that is consistent with protecting the natural values or features of archaeological, historic or scientific interest. The boundary of the majority of the island reserves extends to the low water mark and therefore the intertidal communities are part of these terrestrial reserves. The exception is the Lowendal Islands Nature Reserve, which extends to the high water mark (DEC & MPRA 2006).

Barrow Island Nature Reserve is an 'A' Class Nature Reserve and one of the most important conservation reserves in the State (DEC & MPRA 2006). It is Western Australia's second largest island and an important biological refuge due to its isolation from the mainland with a number of endemic species and low incidence of introduced species. Barrow Island supports regionally and nationally significant rookeries for threatened Green and Flatback turtles and flora species that are geographically restricted, priority-listed and at the limits of their range. Important ecosystems include an extensive karst system, intertidal mudflats, rock platforms, mangroves, rock piles, cliffs, clay pans and caves (DEC 2012a).

Varanus Island is managed by DEC as part of the 179 ha Lowendal Islands Nature Reserve ('C' Class) (Reserve No. 3350). The Environmental Protection Authority (EPA) recognises the Lowendal and nearby islands as reserves for the conservation of flora and fauna, including recognised breeding grounds of a number of sea bird species which are listed in the National List of Threatened Species under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. There are at least 78 listed species of particular conservation significance potentially found on, and in the vicinity of, the Lowendal Islands (EPA 2001).

Three marine conservation reserves surround the islands of the Barrow, Montebello and Lowendal archipelagos, i.e. Montebello Islands Marine Park (58,331 ha), Barrow Island Marine Park (4,169 ha) and Barrow Island Marine Management Area (114,693 ha) (Figure 2-3).

The Montebello and Barrow islands marine conservation reserves have very complex seabed and island topography including sheltered lagoons, channels, beaches and cliffs. This complexity is thought to have resulted in a high diversity of habitats in the reserves supported by high sediment and water quality. The mangrove communities are made of up six species and are considered globally significant because they occur in lagoons of offshore islands. The reserves are important breeding areas for several species of marine turtles and seabirds, which use the undisturbed sandy beaches for nesting. Humpback whales migrate through the reserves and dugongs occur in the shallow warm waters (DEC & MPRA 2006).

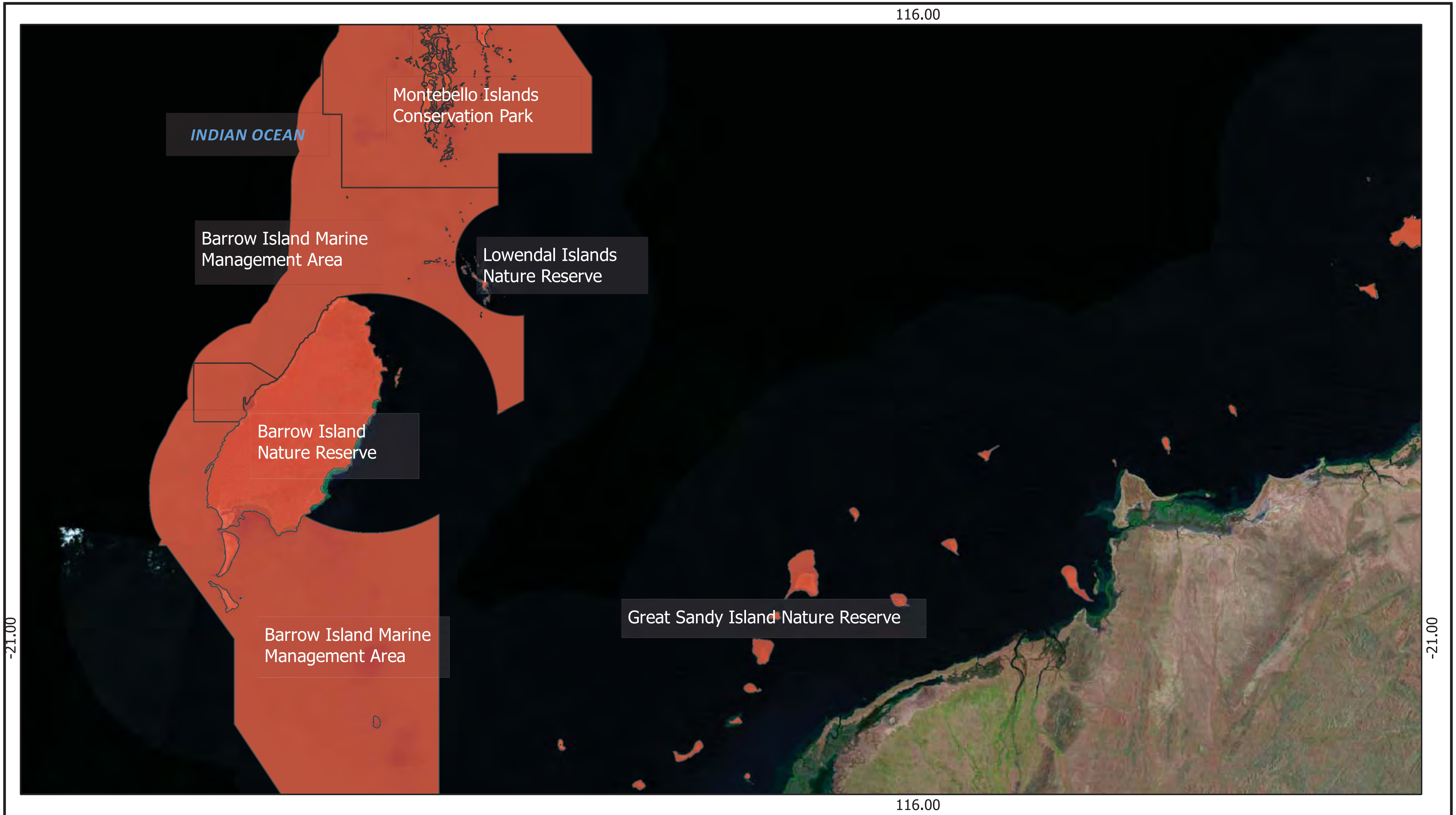

Figure 2-3
Conservation areas in the Barrow Island/Montebello Islands/Lowendal Islands archipelagos

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	**CLIENT:** Apache Energy Ltd
DATE: August 2012	**Scale:** 1:420000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	**PROJECT:** Varanus Island Fill Project

2.6 Biological Context

2.6.1 Vertebrate fauna

Several publications provide information on the vertebrate fauna of the Barrow /Montebello/Lowendal island archipelagos. Each group of islands are usually treated separately in the literature.

The scientific literature provides limited information on the Lowendal Islands compared to nearby archipelagos. Most information for the Lowendal island group is available through unpublished reports, primarily prepared for Apache for Varanus Island. Given that Varanus Island (and, more broadly, the Lowendal islands) is the main subject of this report, the fauna of the islands are described in more detail in Section 4.

The most extensively studied area is Barrow Island, due to its size, it's elevated conservation status ('A' Class Nature Reserve), and the recent development of the Gorgon Project. The vertebrate fauna of the island is a combination of terrestrial vertebrates that remain permanently on the island (with several being endemic) and marine and migratory species that only come to the island to breed or overwinter as part of their annual migration pattern (Smith *et al.* 2006) (Table 2-1).

No native endemic bird species are currently known from the Montebello Islands; however, recent translocation programs resulted in the introduction of the Barrow Island White-winged Fairy-wren (*Malurus leucopterus edouardi*) and the Spinifexbird (*Eremiornis carteri*) to the Montebello Islands.

Table 2-1 Endemic vertebrate fauna species of the Barrow/Montebello/Lowendal island archipelagos

Scientific name	Common name
Reptiles	
Ctenotus pantherinus acripes	No common name (subspecies of Leopard Ctenotus)
Ramphotyphlops longissimus	No common name (a blind snake)
Birds	
Malurus leucopterus edouardi	White-winged Fairy-wren (Barrow Island, recently translocated to Montebello Islands)
Mammals	
Isoodon auratus barrowensis	Barrow Island Golden Bandicoot
Bettonggia lesueur ssp.	Boodie (Barrow Island)
Lagorchestes conspicillatus conspicillatus	Barrow Island Spectacled Hare-wallaby
Macropus robustus isabellinus	Barrow Island Euro

2.6.2 Threatening processes

There are several threatening processes to the flora and fauna of the Carnarvon bioregion (Kendrick & Mau 2001), but not all are relevant to insular fauna:

- human disturbance
- introduced feral animals
- grazing pressure

- pathogens.

Human activities include the development of the Chevron Australia Gorgon Project on Barrow Island, the current Project under the responsibility of Apache and the lease of a pearl farm.

These activities can potentially increase the level of threat, especially the introduction of feral animals and pathogens that can be brought onto the islands through the transportation of people, equipment and the import of building material. Introduced animals can then spread to neighbouring islands as happened between 1993 and 1997 with the spread of the House Mouse from Varanus Island to Bridled and Beacon islands (Burbidge & Morris 2002). All the current projects enforce strict quarantine procedures to avoid such unwanted events. Despite all precautionary measures undertaken there is still potential for them to occur (e.g. Apache 2011).

2.7 RELEVANT LEGISLATION AND AGREEMENTS

International

The list of migratory species established under section 209 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) comprises:

- migratory species which are native to Australia and are included in the appendices to the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals Appendices I and II)
- migratory species included in annexes established under the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA)
- native, migratory species identified in a list established under, or an instrument made under, an international agreement approved by the Minister for the Environment, Water, Heritage and the Arts (the Minister), such as the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

Commonwealth

Under the EPBC Act, actions that have, or are likely to have, significant impacts on a matter of national environmental significance (NES) require approval from the Minister. The EPBC Act provides for the listing of nationally threatened native species as matters of NES.

Fauna species of national conservation significance may be classified as 'critically endangered', 'endangered', 'vulnerable' or 'conservation dependent'.

- **EX (Extinct):** no reasonable doubt that the last member of the species has died.
- **EW (Extinct in the Wild):** it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
- **CR (Critically Endangered):** A native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
- **EN (Endangered):** it is not critically endangered and it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.

- **VU (Vulnerable):** it is not critically endangered or endangered; and it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
- **CD (Conservation Dependent):** the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or the following subparagraphs are satisfied:
  - o the species is a species of fish
- the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of the species so that its chances of long term survival in nature are maximised
  - o the plan of management is in force under a law of the Commonwealth or of a State or Territory
  - o cessation of the plan of management would adversely affect the conservation status of the species.

The EPBC Act is also the enabling legislation for protection of migratory species under the international agreements listed above.

Native species in Western Australia which are under identifiable threat of extinction are protected under the Western Australian *Wildlife Conservation Act 1950* (WC Act). Under the WC Act, the *Wildlife Conservation (Specially Protected Fauna) Notice 2012 (2)* (Western Australian Government 2012) recognises four classifications of rare and endangered fauna:

- **Schedule 1:** Fauna that is rare or is likely to become extinct
- **Schedule 2:** Fauna presumed to be extinct
- **Schedule 3:** birds that are subject to an agreement between the government of Australia and the governments of Japan, China and the Republic of Korea relating to the protection of migratory birds
- **Schedule 4:** Other specially protected fauna.

In addition, the Department of Environment and Conservation (DEC) produces a list of Priority species (last update: 23 February 2012) (DEC 2012c) that have not been assigned statutory protection under the WC Act. Species on this list are considered to be of conservation priority because there is insufficient information to assess their conservation status or they are considered rare but not threatened and are in need of monitoring. The DEC list categories are:

- **Priority 1:** Taxa with few, poorly known populations on threatened lands
- **Priority 2:** Taxa with few, poorly known populations on conservation lands
- **Priority 3:** Taxa with several, poorly known populations, some on conservation lands
- **Priority 4:** Taxa in need of monitoring – considered not currently threatened but could be if present circumstances change
- **Priority 5:** Taxa in need of monitoring – considered not currently threatened but subject to a conservation program, the cessation of which could result in the species becoming threatened.

The DEC also produces a declared threatened fauna list. This list provides details on the conservation status of species listed as Schedule 1 under the WC Act. The level of threat is based on the International Union for Conservation of Nature (IUCN) criteria:

- **EX: Extinct** - there is no reasonable doubt that the last individual has died.
- **EW: Extinct in the Wild** - is known only to survive in captivity or as a naturalized population (or populations) well outside the past range.
- **CR: Critically Endangered** - considered to be facing an extremely high risk of extinction in the wild.
- **EN: Endangered** - considered to be facing a very high risk of extinction in the wild.
- **VU: Vulnerable** - considered to be facing a high risk of extinction in the wild.

A taxon listed under the DEC Priority list is not be listed under the DEC declared threatened fauna list. There is therefore no overlap between these lists and both are merged and presented in the current report under the “DEC” label.

3 METHODS

3.1 DESKTOP REVIEW

The desktop review was completed using available local and regional published and unpublished reports, databases and spatial data. Four databases were reviewed to identify significant species that may occur within the study area (all using the rectangle polygon defined by the coordinates 115°15'39''E, 20°17'04''S and 115°42'21''E, 21°00'00''S):

- EPBC Act Protected Matters database (DEWHA 2011)
- DEC Threatened Fauna database (DEC 2012d)
- DEC/WA Museum NatureMap (DEC 2012b)
- Birds Australia Birdata (Birdlife Australia 2005–2007a).

A literature search was conducted for any available reports on vertebrate fauna surveys conducted within the vicinity of the study area to build on the species list developed from the database searches. These reports include Barrow Island, the Montebello and Lowendal archipelagos (in chronological order):

- Dinara (1991). Harriet field development, second triennal environmental report. Appendix 1A, annual environmental report for Varanus Island terminal development. Terrestrial activities. Dinara Pty Ltd. Unpublished report prepared for Hadson Energy Ltd
- Burbidge, A. A., Blyth, J. D., Fuller, P. J., Kendrick, P. G., Stanley, F. J. & Smith, L. A. (2000). The terrestrial vertebrate fauna of the Montebello Islands, Western Australia. CALMScience 3: 95–107
- Apache (2002). Varanus and Abutilon Island mammal monitoring program report, June/July 2002. Apache Energy Ltd
- Cullen, P. P. (2002). Terrestrial herpetofauna survey - Varanus and Abutilon Islands. Unpublished report prepared for Apache Energy Ltd
- Apache (2003). Varanus and Abutilon Island mammal monitoring program report, June 2003. Apache Energy Ltd
- Apache (2004). Varanus Island mammal monitoring program report, July 2004. Apache Energy Ltd
- Apache (2005). Varanus Island vermin monitoring program report, July 28 – August 11 2005. Apache Energy Ltd
- Bamford, Biota & RPS (2005). Gorgon development on Barrow Island. Technical report - Mammals and reptiles. Bamford Consulting Ecologists, Biota Environmental Sciences, RPS Bowman Bishaw Gorham. Unpublished report prepared for ChevronTexaco Australia Pty Ltd
- Bamford & RPS (2005). Gorgon development on Barrow Island. Technical report - Avifauna. Bamford Consulting Ecologists, RPS Bowman Bishaw Gorham. Unpublished report prepared for ChevronTexaco Australia Pty Ltd
- Apache (2006). Varanus Island vermin monitoring program, 4th – 18th July 2006. Apache Energy Ltd
- Richardson, J., Watson, G. & Kregor, G. (2006). The distribution of terrestrial fauna in the Montebello Islands. Conservation Science Western Australia 5: 269 –271

- Apache (2008). Varanus Island vermin monitoring program, 23rd June – 7th July 2008. Apache Energy Ltd
- Burbidge, A., Hamilton, N., Comer, S., Blythman, M., Caton, W., Pridham, J. & Danks, A. (2010). New and interesting bird records from Barrow Island. Western Australian Bird Notes 135: 25–26
- Surman, C. A. & Nicholson, L. W. (2010b). Monitoring of annual variation in seabird breeding colonies throughout the Lowendal group of islands: 2010 Annual Report. Halfmoon Biosciences. Unpublished report prepared for Apache Energy Ltd
- Apache (2011). Varanus Island vermin monitoring program, 19th – 30th June 2011. Apache Energy Ltd
- Surman, C. A. & Nicholson, L. W. (2011). Monitoring of annual variation in seabird breeding colonies throughout the Lowendal group of islands: 2011 Annual Report. Halfmoon Biosciences Unpublished report prepared for Apache Energy Ltd
- Moro, D. & MacAulay, I. (no date-a). A guide to the birds of Barrow Island. Chevron Australia
- Moro, D. & MacAulay, I. (no date-b). A guide to the mammals of Barrow Island. Chevron Australia
- Moro, D. & MacAulay, I. (no date-c). A guide to the reptiles and amphibians of Barrow Island. Chevron Australia.

One report could not be accessed. This report included the results of a terrestrial vertebrate fauna survey from 1986. Due to changes in the names, owners and holders of land on Varanus Island, no copy (hard copy or electronic) could be obtained (S. Mavrick 2012, email to G. Bouteloup, 4 September).

3.2 TAXONOMY AND NOMENCLATURE

The taxonomy and nomenclature used in this report follows several sources, depending on the fauna group:

- amphibians (Tyler & Doughty 2009)
- birds (Christidis & Boles 2008)
- reptiles (Wilson & Swan 2010)
- mammals (Menkhorst & Knight 2011).

3.3 PERSONNEL AND ACKNOWLEDGEMENTS

The desktop review for vertebrate fauna was conducted by experienced zoologists (Table 3-1).

Table 3-1 Project team

Name	Qualifications	Role/s
Mr Jarrad Clark	B.Sc. (Env. Mgmt)	Project Manager, report writing
Mr Guillaume M. Bouteloup	B.Sc. (Land Cons. Mgmt)	Report writing, GIS
Mrs Melanie White	B.Sc. (Env. Biol.) (Hons)	Report review
Dr Volker Framenau	M.Sc. (Cons. Biol.), Ph.D. (Zool.)	Report review

4 RESULTS

4.1 DESKTOP REVIEW

A total of 227 vertebrate fauna species were identified in the desktop review as potentially occurring in the Barrow/Montebello/Lowendal archipelago (Appendix 1). Some of these may potentially occur in the study area (Varanus Island).

The potentially occurring fauna comprise 25 mammals (22 native and 3 introduced), 49 reptiles and three amphibians, the majority of which were recorded on the Barrow and/or Montebello Islands and are unlikely to translocate to Varanus Island.

A total of 150 bird species or subspecies were recorded, and although some records were for the Barrow and Montebello Islands, most bird species of particular conservation significance could also be found on and in the vicinity of the Lowendal Islands (EPA 2001).

As some of the database records are historical (prior to 1999), and because much of the data originates from neighbouring islands, the search results are likely to overestimate the number of vertebrate species that may currently use the study area.

A total of 14 species listed as threatened under the EPBC Act and/or the WC Act were identified as potentially occurring in the study area (Table 6-1). A further six species listed as Priority (DEC list) and 54 species of birds listed as 'Migratory' under the EPBC Act were identified as potentially occurring in the study area (Table 6-1).

4.2 HABITAT DESCRIPTIONS

Initial habitat characterisation is based on the survey conducted by Astron (2009). The habitat map has been modified to represent the main fauna habitats found on the island based on habitat features generally selected by vertebrates (e.g. vegetation structure, substrate).

Eight broad fauna habitat types were identified on Varanus Island (Figure 4-1):

- white beach sands on dunes and in swales (15 ha, 23 % of the habitat of Varanus Island): the largest patch of this habitat is found across the southern end of the island. Several patches compose the central part of the island with some overlapping the Wedge-tailed Shearwater colony. Towards the north of the island, a large patch dominates the landscape. This habitat partially overlaps with the project.
- rocky outcrop (13 ha, 21 % of the habitat of Varanus Island): this habitat fringes almost the entire island. It alternates with another habitat (white sandy beach). Reptiles can shelter in small caves. Seabirds can also potentially breed on some cliffs but most species would prefer the plateaux at the top of the more sheltered cliffs. The mixed tern species colony is located on the small peninsula at the southern end of the island.
- limestone hills, slopes and low ridges (12 ha, 19 % of the habitat of Varanus Island): the limestone hills are present across northern two thirds of Varanus Island. This habitat is almost exclusively found inland rather than on the coast. This habitat can support vertebrate species than can shelter during the day but burrowing species are likely to be absent due to the hardness of the sediment.
- mid-island basin with red brown slits (11 ha, 17 % of the habitat of Varanus Island): this habitat is found across the entire island but the majority of it is present in the northern and central sections. It largely overlaps with the Wedge-tailed Shearwater colony. Digging is potentially easy for reptiles, seabirds and potentially mammals. The Project largely overlaps

this habitat which is probably the going to be the most impacted of all. The impacted section is in the eastern central part of the island and includes land occupied by a large colony of Wedge-tailed Shearwaters.

- coastal limestone slopes and platform (5 ha, 8 % of the habitat of Varanus Island): this habitat acts as a buffer between other habitats located “inland” and the rocky outcrops that fringe Varanus Island.
- disturbed habitats on lease (4 ha, 6 % of the habitat of Varanus Island): this habitat does not include the infrastructures present on the island but includes areas where the ground the vegetation has been disturbed by human activity. This habitat partially overlaps with the project.
- white sandy beach (3 ha, 5 % of the habitat of Varanus Island): this habitat can support most of the shorebirds and other migratory species. This habitat type is likely to present limited opportunities for small reptiles and mammals as it is regularly immersed.
- mangroves (0.2 ha, 0.3 % of the habitat of the study area): mangroves are very restricted in size. They can potentially support a number of conservation significant species, especially birds, but the limited size of this habitat within the study area means the carrying capacity is likely to be low.

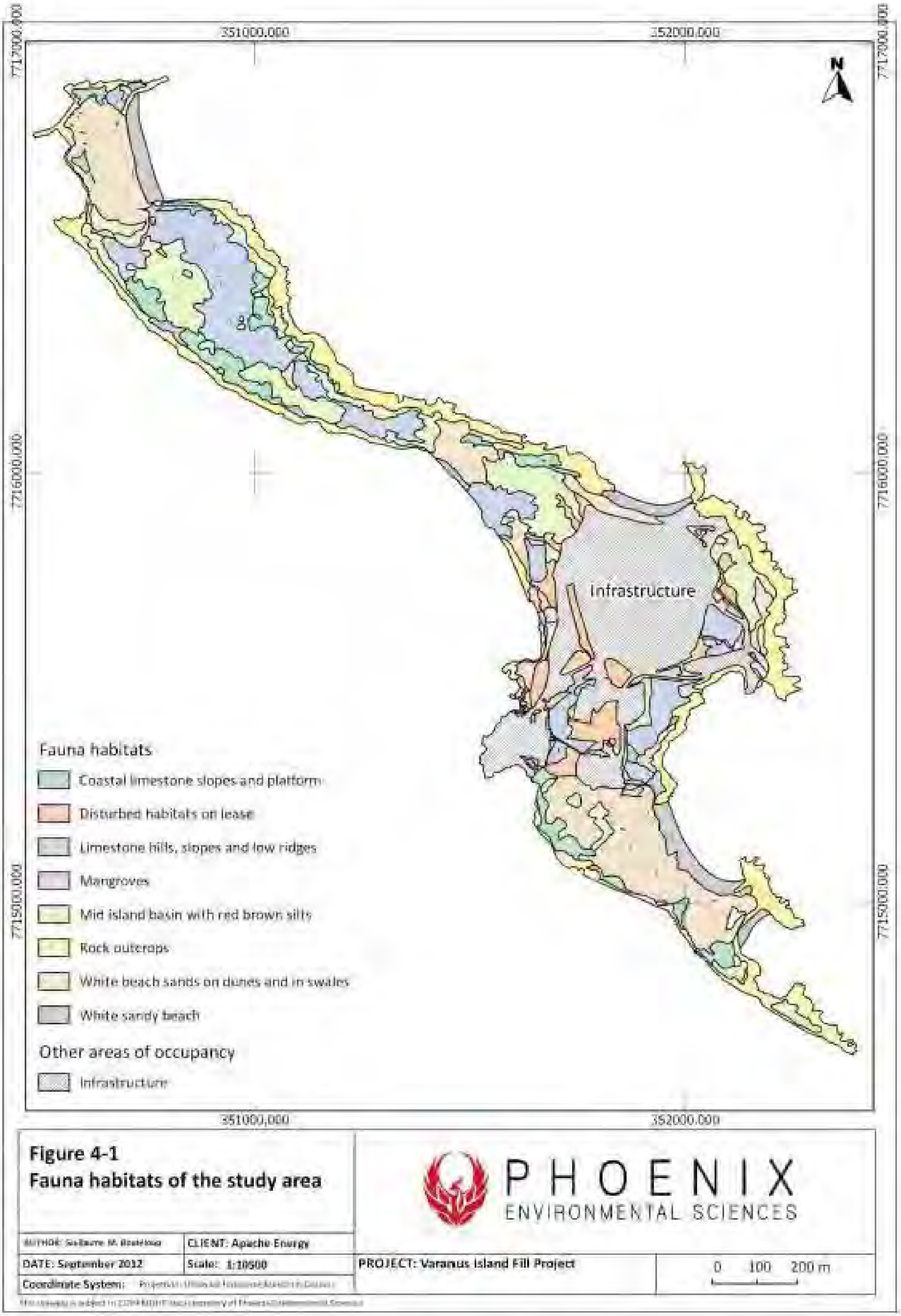

Figure 4-1 Fauna habitats of the study area (based on Astron 2009)

4.2.1 Amphibians

Three species of frogs were returned from the database search and one species from a report (Moro & MacAulay no date-c), which is one of the three returned in the database search. None of these are of conservation significance or endemic to the Barrow/Montebello/Lowendal complex. No frog has so far been reported from Varanus Island.

4.2.2 Reptiles

A total of 49 terrestrial reptile species have been recorded in the desktop review. Cullen (2002) provides the only systematic list of reptiles known from Varanus Island with 13 species. The record of one species listed once in the text of the report, *Amphibolurus longirostris*, seems to be an error. This record appears to refer to *Amphibolurus gilberti* which is listed several times in the report. *Amphibolurus. longirostris* is currently only known from the mainland. The assemblage includes a number of skinks, geckos and snakes; none of which are proven to be endemic to the island but Cullen (2002) indicates that *Gehyra pilbara* found on Varanus Island may be a subspecies or even a separate species given its coloration and the habitats found on the island.

Two species of reptiles of conservation significance have been recorded in the desktop review. Only one, the subterranean Barrow Island Blind Snake may potentially occur on Varanus Island.

4.2.3 Avifauna

Up to 150 species of birds can potentially occur on Varanus Island based on the database and literature search. Of these, 89 have already been recorded on the Lowendal Islands (Dinara 1991). Dinara's (1991) list is probably the most comprehensive of all the vertebrate surveys conducted on the Lowendal Islands. Some records are probably erroneous or attributed to the wrong species. They are the Magpie Goose, *Anseranas semipalmata* and the Streaked Shearwater *Calonectris leucomelas*. Both are extremely rare in the region.

Some records are noteworthy from a biogeographical perspective with no particular significance for the Project. For example, the record of the Hooded Pitta (*Pitta sordida*) on Barrow Island in 2010 was the first time this species has been recorded in WA. It was previously known from Southeast Asia only.

Birds can broadly be divided into two main groups: landbirds and seabirds/littoral birds (Bamford & RPS 2005).

Landbirds (66 species recorded in desktop review) are the species that live on the land their whole life. These species are not able to survive at sea or in an aquatic environment.

Littoral and seabird species (84 species) rely on coastal and/or pelagic environments to survive at some stage of their annual biological cycle. These species only come ashore to breed (seabirds) or to breed and forage at some stage throughout the year.

Most of the landbirds of Varanus Island are vagrants with few being resident there. These include mainly passerines: Yellow White-eye (*Zosterops luteus*), Welcome Swallow (*Hirundo neoxena*), White-breasted Woodswallow (*Artamus leucorhynchus*), Australasian Pipit (*Anthus novaeseelandiae*), Zebra Finch (*Taeniopygia guttata*), Bar Shouldered Dove (*Geopelia humeralis*), Nankeen Kestrel (*Falco cenchroides*), White-bellied Sea-eagle (*Haliaeetus leucogaster*), Spotted Harrier (*Circus assimilis*) and Black Shouldered Kite (*Elanus axillaris*) (Dinara 1991).

The majority of shorebirds are migratory under the EPBC Act, although some are resident (e.g. Pied Oystercatcher, *Haematopus longirostris,* and Sooty Oystercatcher, *Haematopus fuliginosus ophtalmicus*).

Breeding seabirds draw most of the attention in terms of conservation significance and numbers. The Lowendal islands are an Important Bird Area (IBA based on criteria defined in Dutson *et al.* (2009)) and supports several globally-important bird populations of seabirds, especially (Birdlife Australia 2005–2007a):

- Crested Tern (4000–9097 breeding pairs)
- Bridled Tern (3000–5000 breeding pairs).

The latest breeding numbers available for these species, 552 and 946 breeding pairs respectively (Surman & Nicholson 2011) are, however, far lower than given as minimum for to represent an IBA.

Other species of seabirds breeding in large numbers on the Lowendal islands are (Surman & Nicholson 2011):

- Wedge-tailed Shearwater (*Puffinus pacificus*, 2437 pairs, 1015 on Varanus Island)
- Silver Gull (*Chroicocephalus novaehollandiae*, 653 pairs, none on Varanus Island)
- Pied Cormorant (*Phalacrocorax varius*, 316 pairs, none on Varanus Island).

Numbers have decreased since 2010 with at least two potential explanations (Surman & Nicholson 2011):

- a shift in space for some species that relocate their colonies every year across the Barrow/Montebello/Lowendal islands
- environmental conditions (e.g. *La Niña*).

The five islands that support the largest seabird numbers within the Lowendal Islands are also the largest of the archipelago: Abutilon, Bridled, Parakeelya, Varanus and Beacon Islands.

4.2.4 Mammals

According to the database and literature search, the House Mouse (*Mus musculus*) is the only mammal species that has been recorded on Varanus Island to date. The last capture is from January 2011 and was shortly followed by a trapping session that secured no further captures. There is no additional evidence for the presence of the species on the island since.

No other introduced species of mammals are known on the island. The Black Rat (*Rattus rattus*) and the Feral Cat (*Felis catus*) are exclusively known from the neighbouring islands. A “baby rat” (Apache 2002) was also found on board of one of the barges stationed near the island in 2002.

To date there is no known endemic mammal on Varanus Island.

The desktop review has identified 25 species of mammal as potentially occurring. Of these, the large majority are unlikely to be present on Varanus Island; a reasonable number are endemic to Barrow Island and some are species introduced from the mainland for conservation.

No species of bat is known from the island. At least two species can potentially occur, the Common Sheath-tail Bat (*Taphozous georgianus*) and Finlayson's Cave Bat (*Vespadelus finlaysoni*), but neither is of conservation significance.

The Water-rat (*Hydromys chrysogaster*, Priority 4) can potentially occur on Varanus Island as it has the ability to disperse by sea (Chapman & Chuwen 2010). It is known from both the Montebello and Barrow islands (DEC 2012b).

In addition to the Water-rat, eight mammal species of conservation significance were recorded in the desktop review; details on the likelihood of occurrence for these species are given in section 5.

5 CONSERVATION SIGNIFICANT SPECIES

This section provides an overview of all the conservation significant species recorded in the desktop review, some of which may potentially occur on Varanus Island.

Seventy-two species listed as threatened (EPBC Act; WC Act), priority or threatened (DEC) or migratory (EPBC Act) were recorded in the desktop review. Many of these species are unlikely to occur within the study area. Based on the literature, the biology of these species, their capacity for dispersal, their regularity of occurrence in a broader region, the habitats known within the study area and other criteria (e.g. detectability) each species' potential for occurring in the study area is assessed but not measured (Table 5-1).

Fifty-four of these species are listed under the EPBC Act as migratory. Therefore, they only occur at certain times of year, mostly during the northern hemisphere winter. Some individuals can occasionally stay for a year or more on wintering grounds, but these cases are rare and isolated.

Table 5-1 Likelihood of occurrence of the conservation significant vertebrate fauna species recorded in the desktop review

Taxonomy		Conservation status				Likelihood of occurrence on Varanus Island
Scientific name	Common name	EPBC Threatened species	EPBC Migratory	WC Act	DEC	
REPTILES						
Aprasia rostrata	Hermit Island Worm-lizard	VU		S1	VU	Unlikely , endemic to Hermite Island with only one specimen collected in 1952, cryptic and hard to survey, possibly subject to predation by introduced species (e.g. Feral Cats) (Burbidge *et al.* 2000)
Ramphotyphlops longissimus	Barrow Island Blind Snake				P2	Possible, endemic to Barrow Island but potentially troglobitic (Wilson & Swan 2010) and could therefore extend from Barrow to Varanus given the geology (Phoenix 2012). Requires access to subterranean environment.
BIRDS						
Phaethon lepturus lepturus	White-tailed Tropicbird		●	S3		Unlikely, rare vagrant
Hirundapus caudacutus	White-throated Needletail		●	S3		Unlikely, irregular vagrant
Apus pacificus	Fork-tailed Swift		●	S3		Recorded on Varanus Island
Oceanites oceanicus	Wilson's Storm-Petrel		●	S3		Unlikely, offshore only
Thalassarche chlororhynchos	Yellow-nosed Albatross	VU	●	S1	VU	Unlikely vagrant, offshore only
Macronectes giganteus	Southern Giant-Petrel	EN	●	S1	EN	Unlikely vagrant, offshore only
Puffinus apacificus	Wedge-tailed Shearwater		●	S3		Annual breeder present in large number on Varanus Island (>1000 pairs)
Calonectris leucomelas	Streaked Shearwater		●	S3		Unlikely, rare vagrant
Fregata ariel	Lesser Frigatebird		●	S3		Unlikely, vagrant
Sula dactylatra bedouti	Masked Booby (eastern		●	S1/S	VU	Unlikely, vagrant

Taxonomy		Conservation status				Likelihood of occurrence on Varanus Island
Scientific name	Common name	EPBC Threatened species	EPBC Migratory	WC Act	DEC	
	Indian Ocean)			3		
Sula leucogaster	Brown Booby		●	S3		Unlikely, vagrant
Ardea modesta	Eastern Great Egret		●	S3		Unlikely, vagrant
Egretta sacra	Eastern Reef Egret		●	S3		Recorded on Varanus Island
Pandion cristatus	Eastern Osprey		●			Recorded on Varanus Island
Haliaeetus leucogaster	White-bellied Sea-Eagle		●	S3		Recorded on Varanus Island
Falco peregrinus	Peregrine Falcon			S4		Recorded on Varanus, recent sighting on Barrow Island (Burbidge *et al.* 2010)
Ardeotis australis	Australian Bustard				P4	Unlikely, vagrant
Burhinus grallarius	Bush Stone-curlew				P4	Unlikely, vagrant
Pluvialis fulva	Pacific Golden Plover		●	S3		Recorded on Varanus Island
Pluvialis squatarola	Grey Plover		●	S3		Recorded on Varanus Island
Charadrius mongolus	Lesser Sand Plover		●	S3		Recorded on Varanus Island
Charadrius leschenaultii	Greater Sand Plover		●	S3		Recorded on Varanus Island
Charadrius veredus	Oriental Plover		●	S3		Recorded on Varanus Island
Limosa limosa	Black-tailed Godwit		●	S3		Recorded on Varanus Island
Limosa lapponica	Bar-tailed Godwit		●	S3		Recorded on Varanus Island
Numenius minutus	Little Curlew		●	S3		Recorded on Varanus Island
Numenius phaeopus	Whimbrel		●	S3		Recorded on Varanus Island
Numenius madagascariensis	Eastern Curlew		●	S3	P4	Recorded on Varanus Island
Xenus cinereus	Terek Sandpiper		●	S3		Recorded on Varanus Island
Actitis hypoleucos	Common Sandpiper		●	S3		Recorded on Varanus Island
Heteroscelus brevipes	Grey-tailed Tattler		●	S3		Recorded on Varanus Island
Tringa nebularia	Common Greenshank		●	S3		Recorded on Varanus Island
Tringa stagnatilis	Marsh Sandpiper		●	S3		Recorded on Varanus Island
Tringa glareola	Wood Sandpiper		●	S3		Unlikely, vagrant
Arenaria interpres	Ruddy Turnstone		●	S3		Recorded on Varanus Island
Calidris tenuirostris	Great Knot		●	S3		Likely, not recorded on Varanus Island
Calidris canutus	Red Knot		●	S3		Recorded on Varanus Island
Calidris alba	Sanderling		●	S3		Recorded on Varanus Island
Calidris minuta	Little Stint		●	S3		Vagrant recorded on Varanus Island
Calidris ruficollis	Red-necked Stint		●	S3		Likely, never recorded on Varanus Island
Calidris acuminata	Sharp-tailed Sandpiper		●	S3		Recorded on Varanus Island
Calidris ferruginea	Curlew Sandpiper		●	S3		Unlikely, vagrant
Philomachus pugnax	Ruff		●	S3		Recorded on Varanus Island
Glareola maldivarum	Oriental Pratincole		●	S3		Unlikely, even if previously recorded on Varanus Island

Taxonomy		Conservation status				Likelihood of occurrence on Varanus Island
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**WC Act**	**DEC**	
Stercorarius pomarinus	Pomarine Jaeger		●	S3		Unlikely, even if previously recorded on (or near) Varanus Island
Anous stolidus	Common Noddy		●	S3		Unlikely, even if previously recorded on Varanus Island
Anous tenuirostris melanops	Lesser Noddy	VU		S1	VU	Unlikely, not previously recorded on Varanus Island
Sterna anaethetus	Bridled Tern		●	S3		Breeds on the Lowendal Islands
Sternula albifrons	Little Tern		●	S3		Breeds on the Lowendal Islands
Sternula nereis	Fairy Tern	VU		S1	VU	Occasionally breed (last 2005) on the Lowendal Islands
Sterna caspia	Caspian Tern		●	S3		Occasionally breed on the Lowendal Islands
Chlidonias leucopterus	White-winged Black Tern		●	S3		Recorded on Varanus Island
Sterna dougallii	Roseate Tern		●	S3		Breeds on the Lowendal Islands
Sterna hirundo	Common Tern		●	S3		Recorded on the Lowendal Islands
Thalasseus bengalensis	Lesser Crested Tern		●	S3		Breeds on the Lowendal Islands
Cuculus optatus	Oriental Cuckoo		●	S3		Unlikely, vagrant
Merops ornatus	Rainbow Bee-eater		●	S3		Unlikely, vagrant even if previously recorded on Varanus Island
Malurus leucopterus edouardi	White-winged Fairy-wren (Barrow Island)	VU		S1	VU	Unlikely, only recorded from Barrow Island with some individuals translocated to the Montebello Islands over the last five years
Hirundo rustica	Barn Swallow		●	S3		Unlikely, vagrant offshore
Neochmia ruficauda subclarescens	Star Finch				P4	Unlikely, no habitat, vagrant, mainland species
Motacilla flava	Yellow Wagtail		●	S3		Unlikely, vagrant
MAMMALS						
Isoodon auratus barrowensis	Barrow Island Golden Bandicoot	VU		S1	VU	Unlikely, endemic to Barrow Island
Bettonggia lesueur ssp.	Boodie (Barrow Island)	VU		S1	VU	Unlikely, endemic to Barrow Island
Bettongia lesueur lesueur	Shark Bay Burrowing Bettong	VU		S1	VU	Unlikely
Lagorchestes conspicillatus conspicillatus	Barrow Is. Spectacled Hare-wallaby	VU		S1	VU	Unlikely, endemic to Barrow Island
Lagorchestes hirsutus ssp.	Rufous Hare-wallaby, Mala (NT ssp.)	EN		S1	EN	Unlikely, not recorded on Varanus Island
Macropus robustus isabellinus	Barrow Island Euro	VU		S1	VU	Unlikely, endemic to Barrow Island
Petrogale lateralis lateralis	Black-footed Rock-wallaby, Warru	VU		S1	VU	Unlikely, endemic to Barrow Island
Hydromys chrysogaster	Water-rat, Rakali				P4	Likely, capacity to disperse, known from nearby islands
Pseudomys fieldi	Shark Bay Mouse	VU		S1	VU	Unlikely

6 DISCUSSION

This section presents an assessment of impacts to vertebrate fauna from the Project. In assessing development proposals, the EPA's broad objective for vertebrate fauna is to maintain the abundance, diversity, geographic distribution and productivity of fauna at the species and ecosystem level, through the avoidance or management of adverse impacts and improvement in knowledge.

Accordingly, the main aim of this assessment was to determine whether the Project will result in the decline of faunal abundance, diversity, distribution or productivity, with particular emphasis on conservation significant species.

Potential impacts of the project are described, followed by the implications for conservation significant fauna, and management recommendations to mitigate potential impacts, as relevant to Varanus Island.

6.1 POTENTIAL IMPACTS

6.1.1 Habitat loss, degradation and fragmentation

Habitat loss is the total and physical removal of a habitat. This is often achieved using heavy machinery, occasionally chemicals. The Project will include vegetation clearing and topsoil removal.

Habitat loss may reduce resource and shelter for native fauna. Recent studies indicate that ground-dwelling mammals are more exposed to predation when the ground vegetation cover is removed or reduced (Arthur *et al.* 2005; Körtner *et al.* 2007). In addition, a number of species use trees and shrubs for diurnal sheltering (microbats, reptiles and nocturnal birds) or for nesting on rocky substrates a number of species require crevices and cavities to survive. Loss of individual fauna is therefore highly likely during vegetation clearing (Gleeson & Gleeson 2012). Details on the loss of individual fauna are given in Section 6.1.2.

The concept of habitat degradation is more subjective than that of habitat loss. It is often the secondary result of a primary stress, such as fire. Depending on the nature of the cause, habitat degradation is likely to affect a guild of species or a single species.

Habitat fragmentation is also a secondary impact caused by primary disturbances. After vegetation clearing a previously continuous habitat can be divided into several disconnected remnant patches. This can result in more predation (May & Norton 1996), genetic isolation of populations (Brooker & Brooker 1994), dispersal of individuals (Brooker *et al.* 1999) or reduced access to resource habitats (Gleeson & Gleeson 2012).

6.1.2 Loss of individual fauna

Loss of individual fauna can occur directly or indirectly. Vehicles or machinery in movement can kill or injure animals. This impact can be increased by factors such as roadside vegetation or time of day (Kölcker *et al.* 2006; Rowden *et al.* 2008).

Animals are also likely to be killed during habitat clearing (Gleeson & Gleeson 2012). The species at risk during habitat clearing are mostly the ones with no or little opportunity to escape during the clearing. This is especially true for most mammals and reptiles (burrows, cavities) but also resident bird species (e.g. ground nesting species).

Static infrastructures such as power lines, cables or barbwire can also cause death or injury of native fauna. Power lines are a threat to birds, particularly large birds such as bustards (Martin & Shaw

2010). Fence with barbwire can kill bats and birds; this includes conservation significant species such as the Peregrine Falcon (*Falco peregrinus*) (Booth 2007).

6.1.3 Displacement of individuals

Displacement of fauna is often the result of a primary disturbance (e.g. light spill, habitat loss, noise, etc.). Animals can be deterred by activities temporarily or permanently depending on the species and the nature of the disturbance. Some groups of species are more easily disturbed than others (Ruddock & Whitfield 2007).

6.1.4 Modification and interruption of ecosystem processes

Ecosystem processes are the dynamic (spatial and temporal) relationships between several components (e.g. species communities) of an ecosystem that sustain its functionalities (Gleeson & Gleeson 2012). As an example, the removal or recalibration of a drainage channel will modify the local primary productivity, change the flux and movements of the local fauna or the nature of the vegetation. A number of complex relationships are involved in these processes and most are difficult to quantify or anticipate accurately.

Fire is an ecosystem process altered following most human activities. Native Australian reptiles, birds and mammals respond to fire differently (Leavesley 2008; Letnic & Dickman 2005; Pianka & Goodyear 2012), but not all have adaptively evolved to fire on islands. A modification of fire regimes can have short term as well as long-term effects on the fauna and flora communities. The use of machinery, tools, equipment and chemicals increases the risk of an accidental fire. The fact that the project is located within the close proximity of an oil field development adds to these factors.

6.1.5 Spread of introduced fauna and flora

The introduction of fauna and flora species to Australia has caused great harm to native ecosystems, especially over the last 200 years. In the arid interior of Western Australia 90% of the medium-sized mammals are extinct or have experienced a significant range contraction since the 1920s (Burbidge & McKenzie 1989). The introduction of several herbivores (James 2003) and carnivores (Kinnear *et al.* 2002) by humans has played a major role in this decline, both directly and indirectly (McKenzie *et al.* 2007). The total or local extinction of native mammal species may have had impacts on several arid ecosystem processes, for example on seed dispersal (James & Elridge 2007). In addition to the loss of biodiversity, this has also affected the Australian economy (McLeod 2004). The impact of introduced fauna and flora are worsened by insularity (e.g. limited possibility to escape, disperse, shelter) in island environments.

The combined effect of both introduced flora and fauna species can potentially be severe, as hypothesised by Burbidge & McKenzie (1989). Human activities can facilitate the spread of non-native species (Gleeson & Gleeson 2012). For instance, weed seeds can be carried by vehicles (e.g. underparts, tyres), humans (e.g. footwear and clothing) or machinery (e.g. diggers) (Gleeson & Gleeson 2012).

The trapping of a House Mouse in January 2011 (Apache 2011) highlights the permanent risk of introducing new fauna species on Varanus Island and the need to conduct permanent trapping and monitoring for feral species as part of the ongoing quarantine procedures.

6.1.6 Pollution

Pollution events can potentially occur at every stage of project operations (ICMM 2006). Pollution events can be small and localised (e.g. an oil spill under a car caused a by damaged hose), but also much more significant (large scale pollution of a surface or ground water body, failure of contaminant facilities during a cyclone) (Environment Australia 2002).

The effects in time and space of pollution on fauna will depend on the nature of the contaminant and the amount released, the magnitude and type of incident, the habitat and nature of the receiving environment (Lloyd *et al.* 2002). Seabirds and shorebirds are known to be at particular risk in the event of an oil spill, especially if it occurs during or before the breeding season.

6.1.7 Artificial lighting

Artificial lighting is used in the construction industry to allow nocturnal work and also for health and safety reasons. Depending on the nature and amount of light used, the effects can vary. Gleeson & Gleeson (2012) summarise the main effects of artificial lighting on the different biological cycles of fauna: foraging, breeding, predation, movement and circadian rhythm.

Most of the studies documenting the effect of artificial lights on wildlife have been conducted in coastal urban environments, with few in Australia. The impacts on coastal species are now well known and have been proven to potentially have significant impacts. In the context of the Project lighting is most likely to impact the Wedge-tailed Shearwater (Surman & Nicholson 2010a). The most critical times are during the breeding season, when chicks are fledging or during the migratory period. Therefore, this not only relates to seabirds, but any other birds at risk (e.g. shorebirds).

6.1.8 Dust

Soil particles can be blown by natural winds but also by vehicles and machinery. The nature of the Project involves a high risk of increased dust for a short period. Several authors have demonstrated the detrimental effect of dust on plants in general (Farmer 1993; Gleason *et al.* 2007). Overall the impacts vary depending on the species and the nature of the dust. Main effects include reduced rates of photosynthesis, respiration and transpiration. There is no evidence that dust itself can affect vertebrate fauna in arid environments; instead, fauna are indirectly affected due to changes in vegetation diversity, structure and cover.

6.1.9 Noise and vibration

Birds are likely to be more prone to noise disturbances than mammals or reptiles. Acoustics play a major role in bird communication, mostly for breeding (territory defence, mate choice, predation). Phoenix (2010) provides a summary of the effect of noise on birds in the literature. The main known aspects are:

- Lowest bird densities are found near noise sources, independently of the habitat.
- Terrestrial birds forage in noisy areas but don't breed or breed in lower numbers.
- Birds that communicate at a frequency higher than the noise source are less affected than birds that communicate at the same or at an inferior frequency.

Most of the literature available on this subject is based on road traffic noise, not earthworks operation; however, these studies provide a good background to anticipate and understand the effect of artificial noise on birds in general. Burrow-dwelling seabirds use acoustics a lot to locate their young and/or their partner among the numerous burrows of a colony. Significant increases in noise should therefore occur outside of the breeding season for relevant species.

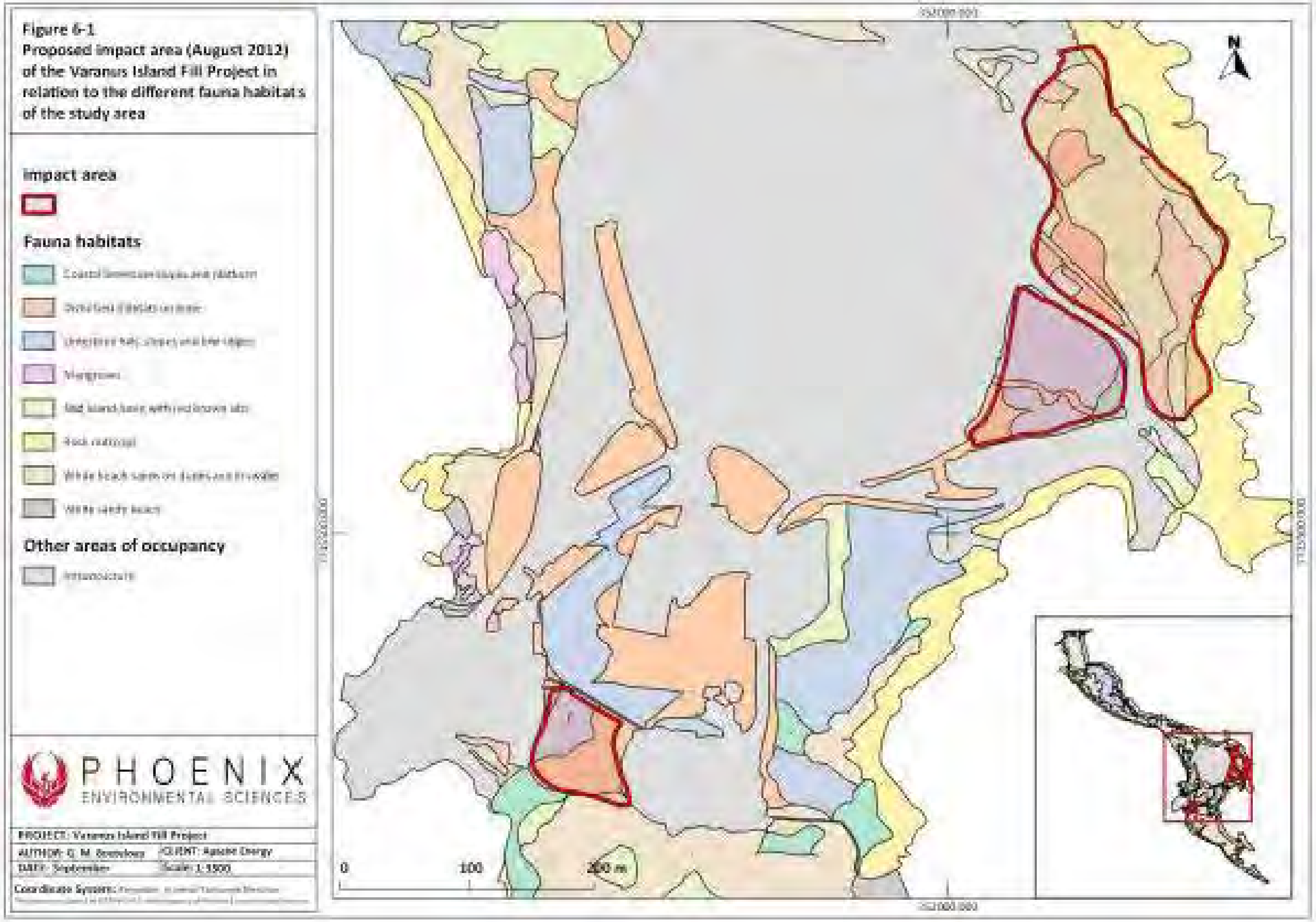

Figure 6-1 **Proposed impact area (August 2012) of the Varanus Island Fill Project in relation to the different fauna habitats of the study area**

6.1.10 Impacts to conservation significant species

Up to 36 species of conservation significance may potentially occur in the study area (Table 6-1). The study area contains important habitat for:

- the Water-rat (*Hydromys chrysogaster*). The only conservation significant mammal that can potentially occur on Varanus Island, based on the database searches that comprise the desktop review. Disturbance risks for this species associated with the project are relatively low as the species is not expected to take up residence close to human activities and therefore is unlikely to be found within or near the impact area.
- Barrow Island Blind Snake *(Ramphotyphlops longissimus).* This subterranean blind snake has not been recorded on Varanus Island but could occur given that the cavernous limestone that forms the island is a continuation of the same geological unit as that of Barrow Island and given that subterranean fauna (stygobitic amphipods) are known from Varanus Island (Bradbury & Williams 1997). Not much is known about this species that has so far only been found on Barrow Island, but given the nature of the project (i.e. surface scraping) direct impacts (should it occur) are unlikely to be significant. Secondary impacts such as sub-surface contamination are more likely to affect this species. Any future subterranean fauna surveys should attempt to target the Barrow Island Blind Snake.
- Fairy Tern (*Sternula nereis,* EPBC Vulnerable). The only species listed as Vulnerable likely to occur within the study area[1].
- Breeding seabirds in general. One of the Wedge-tailed Shearwater colonies is located within the largest polygon of the impact area[1].
- Migratory species. These species are mostly shorebirds and some are non-resident seabirds. These species are likely to be found along the white sandy beaches, located 200-300 m north and south of the impact area, and not within[1].

[1] A detailed impact assessment in relation to avifauna was not part of the scope of this review and will be undertaken by Halfmoon Bioscience on behalf of Apache (S. Mavrick 2012, email to Volker Framenau, 4 September).

Table 6-1 Summary of conservation significant species likely to occur on Varanus Island and potential impacts by the Varanus Island Fill Project

Taxonomy		Conservation status				Potential impacts								
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**WC Act**	**DEC**	**Habitat loss, degradation and fragmentation**	**Loss of individual fauna**	**Displacement of individuals**	**Modification and interruption of ecosystem processes**	**Spread of introduced fauna and flora**	**Pollution**	**Artificial lighting**	**Dust**	**Noise and vibration**
BIRDS														
Apus pacificus	Fork-tailed Swift		●	S3										
Puffinus apacificus	Wedge-tailed Shearwater		●	S3		●	●	●	●	●	●	●	●	●
Egretta sacra	Eastern Reef Egret		●	S3							●			
Pandion cristatus	Eastern Osprey		●								●	●		
Haliaeetus leucogaster	White-bellied Sea-Eagle		●	S3							●	●		
Pluvialis fulva	Pacific Golden Plover		●	S3							●	●		
Pluvialis squatarola	Grey Plover		●	S3							●	●		
Charadrius mongolus	Lesser Sand Plover		●	S3							●	●		
Charadrius leschenaultii	Greater Sand Plover		●	S3							●	●		
Charadrius veredus	Oriental Plover		●	S3							●	●		
Limosa limosa	Black-tailed Godwit		●	S3							●	●		
Limosa lapponica	Bar-tailed Godwit		●	S3							●	●		
Numenius minutus	Little Curlew		●	S3							●	●		
Numenius phaeopus	Whimbrel		●	S3							●	●		
Numenius madagascariensis	Eastern Curlew		●	S3	P4						●	●		

Taxonomy		Conservation status				Potential impacts								
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**WC Act**	**DEC**	**Habitat loss, degradation and fragmentation**	**Loss of individual fauna**	**Displacement of individuals**	**Modification and interruption of ecosystem processes**	**Spread of introduced fauna and flora**	**Pollution**	**Artificial lighting**	**Dust**	**Noise and vibration**
Xenus cinereus	Terek Sandpiper		●	S3							●	●		
Actitis hypoleucos	Common Sandpiper		●	S3							●	●		
Heteroscelus brevipes	Grey-tailed Tattler		●	S3							●	●		
Tringa nebularia	Common Greenshank		●	S3							●	●		
Tringa stagnatilis	Marsh Sandpiper		●	S3							●	●		
Arenaria interpres	Ruddy Turnstone		●	S3							●	●		
Calidris tenuirostris	Great Knot		●	S3							●	●		
Calidris canutus	Red Knot		●	S3							●	●		
Calidris alba	Sanderling		●	S3							●	●		
Calidris ruficollis	Red-necked Stint		●	S3							●	●		
Calidris acuminata	Sharp-tailed Sandpiper		●	S3							●	●		
Sterna anaethetus	Bridled Tern		●	S3						●	●	●		
Sternula albifrons	Little Tern		●	S3						●	●	●		
Sternula nereis	Fairy Tern	VU		S1	VU					●	●	●		
Sterna caspia	Caspian Tern		●	S3						●	●	●		
Chlidonias leucopterus	White-winged Black Tern		●	S3							●			
Sterna dougallii	Roseate Tern		●	S3						●	●	●		

Taxonomy		Conservation status				Potential impacts								
Scientific name	Common name	EPBC Threatened species	EPBC Migratory	WC Act	DEC	Habitat loss, degradation and fragmentation	Loss of individual fauna	Displacement of individuals	Modification and interruption of ecosystem processes	Spread of introduced fauna and flora	Pollution	Artificial lighting	Dust	Noise and vibration
Sterna hirundo	Common Tern		●	S3							●			
Thalasseus bengalensis	Lesser Crested Tern		●	S3						●	●	●		
REPTILES														
Ramphotyphlops longissimus	Barrow Island Blind Snake				P2	●	●	●	●		●			●
MAMMALS														
Hydromys chrysogaster	Water-rat, Rakali				P4					●	●			

VU – Vulnerable (EPBC Act); S1 – Schedule 1 (WC Act); S3 – Schedule 3 (WC Act) P4 – Priority 4 (DEC); Migratory species (EPBC Act).

6.2 Recommendations

Central to conservation strategies for threatened species is the protection of habitat (EPA 2002). Protection of habitat for conservation significant species has the added benefit of protecting broader species assemblages and helping to maintain whole of ecosystem functions. This concept is equally relevant at the Project level and the focus should be on avoiding or minimising impacts to important habitat as much as individual animals.

There is little literature available on the fauna of the Varanus Island. The previously conducted vermin surveys trapped introduced species but were not designed to census the vertebrate ground-dwelling fauna of Varanus Island.

A Level 2 survey is required to provide an adequate and current inventory of the vertebrate fauna found on Varanus Island. This survey would utilise a range of trapping techniques (and include bat echolocation recordings) across the range of vertebrate fauna habitats. Collecting tissue samples and appropriately voucher specimens would help to determine if some species are endemic to the island, as suggested for reptiles by Cullen (2002).

Results of the survey would give greater clarity and conclusiveness to the impact assessment for the Project, particularly for species in need of protection (e.g. ground-dwelling reptiles), and would demonstrate a pro-active and conservation-focussed approach.

It is critical to avoid seabird colonies that are under potentially impacted by the Project, especially the Wedge-tailed Shearwater colony which overlaps with the Project. In addition, it is advised to maintain the monitoring of the Wedge-tailed Shearwater colonies across the Lowendal Islands (as well as the annual seabird monitoring).

Table 6-2 below cross-references potential impacts with recommendations to avoid and minimise impacts, in line with the EPA hierarchy of mitigation (avoid, minimise, rectify, reduce) (EPA 2006).

Table 6-2 Summary of potential impacts to vertebrate fauna

Impact	Recommendation
Habitat loss, degradation and fragmentation	Conduct a Level 2 survey to adequately understand the ground-dwelling vertebrate fauna of Varanus Island and the potential for impact. The surveys would aim to provide adequate information to address the scale and nature of the Project design specifics. Such a survey would provide baseline data as well as an up-to-date inventory of the complete vertebrate fauna of Varanus Island (including bats). The collection of voucher specimens for comparison with WA Museum specimens in order to gauge the degree of endemism should be considered.
	Avoidance of seabird colonies potentially impacted by the Project, especially the Wedge-tailed Shearwater colony which overlaps with the Project.
	Use cleared and/or disturbed habitats as much as possible rather than clearing new areas.
	Rehabilitate and restore habitats once cleared areas no longer required for the Project (e.g. tracks).
	Strictly control and minimise vegetation and soil clearing, by clearly

Impact	Recommendation
	demarcating boundaries and putting clearing approval procedures in place (if they do not exist already).
Loss of individual fauna	Conduct pre-clearing surveys to relocate the conservation significant species at risk. At this stage this is solely related to the Wedge-tailed Shearwater and tern colonies. A Level 2 terrestrial fauna survey may uncover additional species of concern.
	Ensure on-going and tailored education of staff in relation to conservation significant species and their habitats.
Displacement of individuals	Strictly control and minimise vegetation and soil clearing, by clearly demarcating boundaries and putting clearing approval procedures in place (if they do not exist already).
Modification of ecosystem processes	Develop a fire management plan.
	Provide adequate fire equipment and staff training.
	Review the existing Quarantine Management Plan before commencement of the Project in order to identify any new pathways for species introduction.
	Review the on-going Vermin Trapping Program in line with the Project construction and operation phases.
Pollution	Provide adequate clean-up and containment equipment and suitable staff training to respond appropriately to pollution events.
Artificial lighting	Minimise artificial lighting as much as possible, especially in the vicinity of important seabird colonies, such as that of the Wedge-tailed Shearwater. Lighting can have detrimental impacts on bat species, but as no systemic bat surveys have been undertaken, no impact assessment can be completed at this stage.
Dust	Review existing dust management procedures with respect to the Fill Project, to ensure that existing procedures are sufficient to minimise impacts to ground dwelling fauna, including nesting seabirds, such as the Wedge-tailed Shearwater.
Noise	Consider the erection of acoustic barriers between the impact area and Wedge-tail Shearwater colony in the event that noise is considered to be significant, especially during the breeding season. Nesting seabirds rely heavily on acoustic communication with fledglings.
General	Following the outcomes of the Level 2 terrestrial fauna survey, if necessary, develop a Vertebrate Fauna Management Plan (VFMP) for the Project into the future.

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Appendix 1 Species records from desktop review and field surveys

Taxomony		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
AMPHIBIANS (3 species)																												
Cyclorana maini	Sheep Frog						●																		●			
Cyclorana platycephala	Water-holding Frog						●																					
Litoria rubella	Little Red Tree Frog						●																					
REPTILES (49 species)																												
Amphibolurus gilberti	Ta-Ta or Gilbert's Dragon						●				●	●	●	●	●	●	●	●			●				●		●	●
Ctenophorus caudicinctus caudicinctus	Ring-tailed Dragon						●														●				●		●	
Pogona minor minor	No Common Name						●														●				●			
Lucasium stenodactylum	No Common Name						●														●				●			
Strophurus jeanae	No Common Name						●														●				●		●	●
Gehyra pilbara	No Common Name						●					●			●		●				●				●		●	●
Gehyra punctata	No Common Name						●																				●	●
Gehyra variegata	No Common Name						●														●				●			
Heteronotia binoei	Bynoe's Gecko						●					●	●			●	●				●				●		●	●
Aprasia rostrata	Hermit Island Worm-lizard	VU			S1	VU	●	●		●																	●	●
Delma borea	No Common Name						●														●				●		●	●
Delma nasuta	No Common Name						●														●				●		●	●
Delma tincta	No Common Name						●														●				●			
Lialis burtonis	No Common Name						●					●									●				●		●	●
Pygopus nigriceps	No Common Name						●														●				●			
Carlia munda	No Common Name						●																					

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	Common name	EPBC Threatened species	EPBC Migratory	EPBC Marine	WC Act	DEC	Naturemap	EPBC Protected matters	Birdata	DEC Threatened Fauna base	Dinara (1991)	Cullen (2002)	Apache Energy (2003)	Apache Energy (2004)	Apache Energy (2005)	Apache Energy (2006)	Apache Energy (2008)	Apache Energy (2011)	Surman and Nicholson (2010)	Surman and Nicholson (2011)	Bamford RPS (2005)	Bamford & al. (2005)	Moro & MacAulay (no date a)	Moro & MacAulay (no date b)	Moro & MacAulay (no date c)	Burbidge & al. (2010)	Burbidge & al. (2000)	Richardson et al. (2006)
Carlia triacantha	No Common Name						●														●				●			
Cryptoblepharus plagiocephalus	No Common Name						●														●				●			
Ctenotus duricola	No Common Name						●														●				●			
Ctenotus grandis	No Common Name						●														●				●			
Ctenotus hanloni	No Common Name						●														●				●			
Ctenotus pantherinus acripes	No Common Name						●														●				●			
Ctenotus saxatilis	Rock Ctenotus						●				●	●	●	●	●	●	●	●			●				●		●	●
Ctenotus serventyi	No Common Name						●														●				●			
Cyclodomorphus melanops	Slender Blue-tongue						●														●				●			
Eremiascincus isolepis	No Common Name						●					●	●	●	●	●	●	●			●				●		●	●
Eremiascincus richardsonii	Broad-banded Sand Swimmer						●														●				●			
Lerista bipes	No Common Name						●					●	●	●	●	●	●				●				●		●	●
Lerista clara	No Common Name						●					●																
Lerista elegans	No Common Name						●														●				●		●	●
Lerista muelleri	No Common Name											●				●					●				●		●	
Menetia greyii	No Common Name						●														●				●			
Morethia lineoocellata	No Common Name						●														●				●			
Morethia ruficauda exquisita	No Common Name						●					●	●								●				●		●	●
Notoscincus ornatus ornatus	No Common Name						●														●				●			
Proablepharus reginae	No Common Name						●														●				●			
Varanus acanthurus	Spiny-tailed Monitor						●					●			●	●	●	●			●				●		●	●
Varanus brevicauda	Short-tailed Pygmy Monitor						●														●				●			
Varanus giganteus	Perentie						●														●				●			

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Varanus gouldii	Bungarra or Sand Monitor						●																				●	●
Ramphotyphlops ammodytes	No Common Name						●					●									●				●		●	●
Ramphotyphlops grypus	No Common Name						●														●				●			
Ramphotyphlops longissimus	Barrow Island Blind Snake					P2	●			●											●				●			
Antaresia stimsoni stimsoni	No Common Name						●														●				●		●	●
Brachyurophis approximans	No Common Name						●					●									●				●			
Demansia rufescens	Rufous Whipsnake						●														●				●		●	●
Furina ornata	Moon Snake						●					●															●	●
Parasuta monachus	No Common Name																								●			
Pseudechis australis	Mulga Snake						●														●							
BIRDS (149 species)																												
Coturnix pectoralis	Stubble Quail			●			●		●																			
Coturnix ypsilophora	Brown Quail						●		●		●								●	●		●	●				●	
Anseranas semipalmata	Magpie Goose			●							●																	
Cygnus atratus	Black Swan																					●	●					
Chenonetta jubata	Australian Wood Duck																					●	●					
Anas gracilis	Grey Teal																					●	●					
Phaethon lepturus lepturus	White-tailed Tropicbird		●	●	S3						●																	
Tachybaptus novaehollandiae	Australasian Grebe																					●	●					
Columba livia	Rock Dove										●																	
Ocyphaps lophotes	Crested Pigeon																					●	●					
Geopelia striata	Peaceful Dove																					●	●					
Geopelia humeralis	Bar-shouldered Dove						●		●		●		●	●	●	●	●	●	●	●		●	●				●	
Hirundapus caudacutus	White-throated Needletail		●	●	S3				●													●	●					

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Apus pacificus	Fork-tailed Swift		●	●	S3			●		●	●											●	●					
Oceanites oceanicus	Wilson's Storm-Petrel		●	●	S3		●		●	●	●											●	●					
Thalassarche chlororhynchos	Yellow-nosed Albatross	VU	●	●	S1	VU																●	●					
Macronectes giganteus	Southern Giant-Petrel	EN	●	●	S1	EN		●																				
Daption capense	Cape Petrel			●			●																					
Puffinus apacificus	Wedge-tailed Shearwater		●	●	S3		●	●	●	●	●						●		●	●		●	●				●	
Calonectris leucomelas	Streaked Shearwater		●	●	S3						●																	
Puffinus huttoni	Hutton's Shearwater			●			●																				●	
Fregata ariel	Lesser Frigatebird		●	●	S3				●	●	●											●	●				●	
Morus serrator	Australasian Gannet			●			●																					
Sula dactylatra bedouti	Masked Booby (eastern Indian Ocean)		●	●	S1/S3	VU																●	●					
Sula leucogaster	Brown Booby		●	●	S3		●		●	●	●						●					●	●				●	
Anhinga novaehollandiae	Australasian Darter																					●	●					
Microcarbo melanoleucos	Little Pied Cormorant																					●	●					
Phalacrocorax carbo	Great Cormorant																					●	●				●	
Phalacrocorax sulcirostris	Little Black Cormorant																			●		●	●					
Phalacrocorax varius	Pied Cormorant						●		●		●		●	●	●		●		●	●			●				●	
Pelecanus conspicillatus	Australian Pelican			●							●											●	●				●	
Ardea modesta	Eastern Great Egret		●	●	S3																	●	●				●	
Butorides striata	Striated Heron																					●	●				●	
Egretta novaehollandiae	White-faced Heron										●											●	●				●	
Egretta garzetta	Little Egret			●													●					●	●					

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Egretta sacra	Eastern Reef Egret		●	●	S3		●		●	●	●				●	●	●	●	●	●		●	●				●	
Nycticorax caledonicus	Nankeen Night-Heron			●							●											●	●				●	
Pandion cristatus	Eastern Osprey		●	●			●	●	●		●		●	●	●	●	●	●	●	●		●	●				●	
Elanus axillaris	Black-shouldered Kite						●		●		●								●			●	●				●	
Lophoictinia isura	Square-tailed Kite																					●	●					
Hamirostra melanosternon	Black-breasted Buzzard										●											●	●				●	
Haliaeetus leucogaster	White-bellied Sea-Eagle		●	●	S3		●	●	●	●	●				●				●	●		●	●				●	
Haliastur sphenurus	Whistling Kite			●			●				●											●	●				●	
Haliastur indus	Brahminy Kite			●			●		●		●											●	●				●	
Accipiter cirrocephalus	Collared Sparrowhawk										●																	
Circus assimilis	Spotted Harrier						●		●		●									●		●	●				●	
Circus approximans	Swamp Harrier			●																							●	
Aquila audax	Wedge-tailed Eagle																					●	●					
Falco cenchroides	Nankeen Kestrel			●			●		●		●							●	●	●		●	●				●	
Falco berigora	Brown Falcon										●											●	●					
Falco longipennis	Australian Hobby										●											●	●				●	
Falco peregrinus	Peregrine Falcon				S4						●															●	●	
Ardeotis australis	Australian Bustard					P4	●			●												●	●					
Burhinus grallarius	Bush Stone-curlew					P4																				●		
Esacus magnirostris	Beach Stone-curlew			●			●		●		●		●			●			●	●		●	●				●	
Haematopus longirostris	Australian Pied Oystercatcher						●		●		●		●	●	●	●	●	●	●	●		●	●				●	
Haematopus fuliginosus ophtalmicus	Sooty Oystercatcher						●		●		●			●				●	●	●		●	●				●	
Himantopus himantopus	Black-winged Stilt			●																		●	●					

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Cladorhynchus leucocephalus	Banded Stilt						●															●	●					
Pluvialis fulva	Pacific Golden Plover		●	●	S3		●		●	●	●								●			●	●					
Pluvialis squatarola	Grey Plover		●	●	S3		●		●	●	●											●	●				●	
Charadrius ruficapillus	Red-capped Plover			●			●		●		●		●	●					●			●	●				●	
Charadrius mongolus	Lesser Sand Plover		●	●	S3		●		●	●	●								●			●	●				●	
Charadrius leschenaultii	Greater Sand Plover		●	●	S3		●		●	●	●								●	●		●	●				●	
Charadrius veredus	Oriental Plover		●	●	S3		●	●		●	●											●	●					
Limosa limosa	Black-tailed Godwit		●	●	S3						●											●	●					
Limosa lapponica	Bar-tailed Godwit		●	●	S3		●		●	●	●								●	●		●	●				●	
Numenius minutus	Little Curlew		●	●	S3						●											●	●					
Numenius phaeopus	Whimbrel		●	●	S3		●		●	●	●								●	●		●	●				●	
Numenius madagascariensis	Eastern Curlew		●	●	S3	P4	●			●	●											●	●				●	
Xenus cinereus	Terek Sandpiper		●	●	S3						●											●	●					
Actitis hypoleucos	Common Sandpiper		●	●	S3		●		●	●	●								●			●	●				●	
Heteroscelus brevipes	Grey-tailed Tattler		●	●	S3		●		●	●	●								●	●		●	●				●	
Tringa nebularia	Common Greenshank		●	●	S3		●		●	●	●									●		●					●	
Tringa stagnatilis	Marsh Sandpiper		●	●	S3						●											●	●					
Tringa glareola	Wood Sandpiper		●	●	S3																	●	●					
Arenaria interpres	Ruddy Turnstone		●	●	S3		●		●	●	●								●	●		●	●				●	
Calidris tenuirostris	Great Knot		●	●	S3					●												●	●					
Calidris canutus	Red Knot		●	●	S3					●	●											●	●				●	
Calidris alba	Sanderling		●	●	S3		●		●	●	●											●	●					
Calidris minuta	Little Stint		●	●	S3						●																	
Calidris ruficollis	Red-necked Stint		●	●	S3		●		●	●									●			●	●				●	

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Calidris acuminata	Sharp-tailed Sandpiper		●	●	S3						●											●	●				●	
Calidris ferruginea	Curlew Sandpiper		●	●	S3					●												●	●				●	
Philomachus pugnax	Ruff		●	●	S3						●																	
Glareola maldivarum	Oriental Pratincole		●	●	S3			●	●		●																	
Stiltia isabella	Australian Pratincole			●																		●	●					
Stercorarius pomarinus	Pomarine Jaeger		●	●	S3						●																	
Anous stolidus	Common Noddy		●	●	S3		●		●	●	●																●	
Anous tenuirostris melanops	Lesser Noddy	VU		●	S1	VU														●		●	●					
Sterna anaethetus	Bridled Tern		●	●	S3			●	●	●	●								●	●		●	●				●	
Sterna fuscata	Sooty Tern			●			●	●	●																		●	
Sternula albifrons	Little Tern		●	●	S3														●	●		●	●					
Sternula nereis	Fairy Tern	VU		●	S1	VU	●	●	●	●	●								●	●		●	●				●	
Gelochelidon nilotica	Gull-billed Tern			●																		●	●					
Sterna caspia	Caspian Tern		●	●	S3		●	●	●		●								●	●		●	●				●	
Chlidonias leucopterus	White-winged Black Tern		●	●	S3				●	●	●											●	●					
Sterna dougallii	Roseate Tern		●	●	S3		●	●	●	●	●								●	●		●	●				●	
Sterna hirundo	Common Tern		●	●	S3		●			●									●	●		●	●					
Sterna paradisaea	Arctic Tern			●							●																	
Thalasseus bengalensis	Lesser Crested Tern		●	●	S3		●	●	●	●	●								●	●		●	●				●	
Thalasseus bergii	Crested Tern			●			●	●	●		●						●	●	●	●		●	●				●	
Larus pacificus georgii	Pacific Gull			●												●												
Chroicocephalus novaehollandiae	Silver Gull			●			●	●	●		●		●	●	●	●	●	●	●	●		●	●				●	

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Eolophus roseicapillus	Galah																					●	●					
Cacatua sanguinea	Little Corella										●											●	●					
Nymphicus hollandicus	Cockatiel																					●	●					
Melopsittacus undulatus	Budgerigar										●											●	●					
Chalcites basalis	Horsfield's Bronze-Cuckoo			●					●		●											●	●				●	
Chalcites osculans	Black-eared Cuckoo			●																		●	●					
Cacomantis pallidus	Pallid Cuckoo			●																		●	●				●	
Cuculus optatus	Oriental Cuckoo		●	●	S3																	●	●					
Ninox novaeseelandiae	Southern Boobook			●																		●	●					
Tyto javanica	Eastern Barn Owl																					●	●					
Todiramphus pyrrhopygius	Red-backed Kingfisher										●											●	●					
Todiramphus sanctus	Sacred Kingfisher			●			●		●		●											●	●				●	
Todiramphus chloris	Collared Kingfisher																										●	
Merops ornatus	Rainbow Bee-eater		●	●	S3			●			●															●		
Pitta sordida	Hooded Pitta																									●		
Malurus leucopterus edouardi	White-winged Fairy-wren (Barrow Island)	VU			S1	VU	●	●		●												●	●				●	
Gerygone fusca	Western Gerygone																									●		
Lichenostomus virescens	Singing Honeyeater						●		●		●											●	●					
Purnella albifrons	White-fronted Honeyeater										●																	
Acanthagenys rufogularis	Spiny-cheeked Honeyeater																					●	●					
Epthianura tricolor	Crimson Chat										●											●	●				●	
Lichmera indistincta	Brown Honeyeater						●		●		●											●	●				●	
Coracina novaehollandiae	Black-faced Cuckoo-shrike			●							●											●	●					

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Lalage sueurii	White-winged Triller										●											●	●				●	
Pachycephala rufiventris	Rufous Whistler																										●	
Artamus leucorhynchus	White-breasted Woodswallow						●		●		●		●						●	●		●	●				●	
Artamus cinereus	Black-faced Woodswallow						●															●	●					
Rhipidura albiscapa	Grey Fantail										●																	
Rhipidura leucophrys	Willie Wagtail										●											●	●				●	
Corvus bennetti	Little Crow						●				●											●	●					
Grallina cyanoleuca	Magpie-lark			●							●											●	●				●	
Cisticola exilis	Golden-headed Cisticola										●																	
Cincloramphus mathewsi	Rufous Songlark										●															●		
Cincloramphus cruralis	Brown Songlark										●											●	●					
Eremiornis carteri	Spinifexbird						●		●													●	●				●	
Zosterops luteus	Yellow White-eye						●		●		●		●	●	●	●	●	●		●		●	●				●	
Zosterops lateralis	Silvereye			●																								
Hirundo rustica	Barn Swallow		●	●	S3			●																				
Hirundo neoxena	Welcome Swallow			●			●		●		●		●	●	●	●	●	●	●	●		●	●				●	
Petrochelidon ariel	Fairy Martin																					●	●					
Petrochelidon nigricans	Tree Martin			●							●											●	●				●	
Taeniopygia guttata	Zebra Finch						●		●								●	●				●	●				●	
Neochmia ruficauda subclarescens	Star Finch					P4																				●		
Emblema pictum	Painted Finch																					●	●					
Anthus novaeseelandiae	Australasian Pipit			●					●		●		●	●	●	●	●	●	●	●		●	●				●	
Motacilla flava	Yellow Wagtail		●	●	S3																		●					

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
MAMMALS (25 species)																												
Planigale ingrami	Long-tailed Planigale						●																					
Planigale maculata	Common Planigale																				●							
Planigale sp.	Planigale sp.																				●			●				
Pseudantechinus sp.	Pseudantechinus sp.																							●				
Pseudantechinus roryi	Rory's Pseudantechinus						●																					
Isoodon auratus barrowensis	Barrow Island Golden Bandicoot	VU			S1	VU		●		●											●			●			●	
Bettonggia lesueur ssp.	Boodie (Barrow Island)	VU			S1	VU	●	●													●			●			●	
Bettongia lesueur lesueur	Shark Bay Burrowing Bettong	VU			S1	VU				●																		
Lagorchestes conspicillatus conspicillatus	Barrow Is. Spectacled Hare-wallaby	VU			S1	VU	●	●		●											●			●			●	
Lagorchestes hirsutus ssp.	Rufous Hare-wallaby, Mala (NT subsp)	EN			S1	EN	●			●																	●	
Macropus robustus isabellinus	Barrow Island Euro	VU			S1	VU	●	●		●											●			●				
Petrogale lateralis lateralis	Black-footed Rock-wallaby, Warru	VU			S1	VU	●	●		●											●			●				
Petrogale rothschildi	Rothschild's Rock-wallaby						●																					
Trichosurus vulpecula arnhemensis	Northern Brushtail Possum						●														●			●				
Pteropus alecto	Black Flying-fox																				●							
Taphozous georgianus	Common Sheathtail-bat						●														●			●				
Vespadelus finlaysoni	Finlayson's Cave Bat						●														●			●			●	

Taxonomy		Conservation status					Database search				Varanus and/or Lowendal records										Other references							
Scientific name	**Common name**	**EPBC Threatened species**	**EPBC Migratory**	**EPBC Marine**	**WC Act**	**DEC**	**Naturemap**	**EPBC Protected matters**	**Birdata**	**DEC Threatened Fauna base**	**Dinara (1991)**	**Cullen (2002)**	**Apache Energy (2003)**	**Apache Energy (2004)**	**Apache Energy (2005)**	**Apache Energy (2006)**	**Apache Energy (2008)**	**Apache Energy (2011)**	**Surman and Nicholson (2010)**	**Surman and Nicholson (2011)**	**Bamford RPS (2005)**	**Bamford & al. (2005)**	**Moro & MacAulay (no date a)**	**Moro & MacAulay (no date b)**	**Moro & MacAulay (no date c)**	**Burbidge & al. (2010)**	**Burbidge & al. (2000)**	**Richardson et al. (2006)**
Tadarida australis	White-striped Freetail-bat						●														●							
Hydromys chrysogaster	Water-rat, Rakali					P4	●			●											●			●			●	
Mus musculus	House Mouse						●											●									●	●
Pseudomys fieldi	Shark Bay Mouse	VU			S1	VU	●			●																		
Pseudomys nanus	Western Chestnut Mouse						●														●			●				
Rattus rattus	Black Rat						●																				●	
Zyzomys argurus	Common Rock-rat						●														●			●				
Felis catus	Cat						●																				●	

Vertebrate fauna desktop review for the Varanus Island Fill Project

Prepared for Apache Energy Ltd

Phoenix Environmental Sciences Pty Ltd

APPENDIX 5 – PHOENIX ENVIROMENTAL SERVICES SHORT-RANGE ENDEMIC INVERTEBRATE FAUNA SURVEY AND SUBTERRANEAN FAUNA DESKTOP REVIEW OF THE VARANUS ISLAND FILL PROJECT REPORT (2012b)

PHOENIX
ENVIRONMENTAL SCIENCES

Short-range endemic invertebrate fauna survey and subterranean fauna desktop review of the Varanus Island Fill Project

Prepared for Apache Energy Ltd

November 2012

Final Report

Short-range endemic invertebrate fauna survey and subterranean fauna desktop review of the Varanus Island Fill Project

Prepared for Apache Energy Ltd

Final Report

Authors: Anna Leung, Volker Framenau, Erich S. Volschenk

Reviewers: Melanie White

Date: 21 November 2012

Submitted to: Sonja Mavrick, Apache Energy Ltd

Chain of authorship and review			
Name	Task	Version	Date
Anna Leung	Draft for technical review	0.1	16 August 2012
Volker Framenau	Draft for editorial review	0.2	24 August 2012
Erich S. Volschenk	Final for technical review	0.3	30 August 2012
Melanie White	Editorial review	0.4	31 August 2012
Volker Framenau	Draft for client comments	1.0	31 August 2012
Volker Framenau	Final submitted to client	2.0	21 November 2012

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EXECUTIVE SUMMARY

Apache Energy Ltd (Apache) is operating facilities for piping oil and gas from various locations within the Harriet and East Spar oilfield, on a lease of approximately 29 ha on Varanus Island. Apache is planning to further develop the infrastructure on Varanus Island. This will require fill material (rock, soil and sand) to be sourced by surface scrapes from locations within the current tenement.

Varanus Island is part of the Lowendal Islands, an archipelago comprising more than 30 islands located approximately 11 km east/north-east of Barrow Island, 15 km south of the Montebello Islands and 60 km from the Pilbara coast of Western Australia. At 2.5 km long and 600 wide (approximately 85 ha), Varanus Island is the largest of the Lowendal Islands. It is part of the C-class Lowendal Islands Nature Reserve.

Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Apache to undertake a short-range endemic (SRE) invertebrate fauna survey and a subterranean invertebrate fauna desktop review for the Varanus Island Fill Project ('the Project'), with the aims of:

- identifying potential terrestrial and subterranean records, and actual terrestrial SRE species records for the Project, with a particular focus on land snails
- identifying potential impacts on SRE and subterranean, in particular troglofauna, and recommend management and mitigation measures.

The comprehensive desktop review preceded the terrestrial SRE field survey and paid particular reference to Barrow Island. Due to its similar recent geological history and close proximity, Barrow Island is thought to share a considerable proportion of its invertebrate fauna with Varanus Island. The terrestrial and subterranean invertebrate fauna of Barrow Island, an A-class nature reserve, are the most thoroughly investigated in Western Australia through ongoing survey work for Chevron Australia's Gorgon Project. Barrow Island, together with Cape Range (a natural geological extension), is one of the biodiversity hotspots for subterranean fauna in Western Australia.

There are uncertainties in determining the range-restrictions of many invertebrates in Western Australia due to lack of surveys, lack of taxonomic resolutions within target taxa and problems in identifying certain life stages. To account for these uncertainties Phoenix uses a three-tier categorisation for short-range endemism: confirmed SRE, likely SRE and potential SRE.

Terrestrial Invertebrate Fauna

The desktop review identified a total of 68 terrestrial SRE taxa in at least 22 families and 40 genera; 50% of these were only recorded from Barrow Island. Only three of the terrestrial SRE taxa were from Varanus Island, including the trapdoor spider *Aname* sp. indet. (Nemesiidae), and the land snails *Rhagada plicata* and *Quistrachia barrowensis* (both Camaenidae).

Field surveys for terrestrial SREs consisted of foraging and combined soil/leaf litter sifting. A total 11 sites were surveyed along Varanus Island of which three were located in the proposed impact area of the Project. The sites were surveyed between 18 and 22 June 2012.

A total of 960 individual specimens of terrestrial SREs were collected during the SRE survey on Varanus Island, representing 21 individually-recognised taxa from seven orders in 13 families and at least 21 genera. Of these, 350 specimens (36.5% of total catch) from eight taxa are considered to include species from the three SRE categories. SRE records and locations were as follows:

The flatrock spider *Karaops burbidgei* (family Selenopdidae) and the land snails *Quistrachia montebelloensis* (here shown to be a senior synonym of *Quistrachia barrowensis*) and *Rhagada plicata* (Camaenidae) are confirmed SREs, the trapdoor spider *Aname* 'MYG079' (Nemesiidae) and the slater Armadillidae 'varanus island' are considered likely SREs and the centipede *Cryptops* sp. indet. (Cryptopidae), and the slaters *Barrowdillo pseudopyrgoniscus* and *Spherillo* 'varanus island' (both Armadillidae) are considered potential SREs.

Five of these SREs, including all confirmed SREs, the likely SRE *Aname* 'MYG079' and the potential SRE *Barrowdillo pseudopyrgoniscus*, have been found outside Varanus Island, in particular on Barrow Island. Poor taxonomic knowledge does not allow detailed assessment of the wider distribution of the two additional SREs *Cryptops* sp. indet. and *Spherillo* 'varanus island' outside Varanus Island, although their occurrence on Barrow Island is likely. Both have been found across Varanus Island, including reference sites. Therefore, the impact of the Project on seven SREs is considered very low.

The likely SRE Armadillidae 'varanus island' is the only SRE that has exclusively been found in the impact area in mid-island basin habitat. Based on the occurrence of this habitat throughout the island, it is likely that the species also occurs outside the impact area (risk-based approach). An impact on the species by the project is therefore considered low.

No major limitation affected the survey. Species richness estimators suggest that most species within the SRE target groups were collected, possibly with the exception of pseudoscorpions.

With respect to terrestrial SREs it is recommended to:

- avoid or minimize disturbance at and near site 02, where Armadillidae 'varanus island' was found
- conduct targeted surveys for Armadillidae 'varanus island' on Varanus Island and possibly Barrow Island to better understand the impact of habitat loss on the species.

Subterreanan Fauna

No troglofauna was recorded from Varanus Island in the desktop review. The desktop review identified 15 SRE troglofauna taxa in at least ten families and 11 genera. Twelve of these (= 80%) are recorded only from Barrow Island. Two of these are listed on Schedule 1 of the WA Act, the schizomid *Draculoides bramstokeri* (Hubbardiidae) and the millipede *Speleostrophus nesiotes* (Trigoniulidae).

Amphipod stygofauna has been recorded from Varanus Island; however, details of these records were not accessible for the desktop review. The desktop review also identified 36 SRE stygofauna taxa in at least 14 families and 21 genera. All taxa were recorded from Barrow Island, with seven also occurring on the mainland. Nine species, all amphipods, are listed on Schedule 1 of the WA Act, seven of ten Barrow Island *Nedsia* species (Melitidae), *Bogidomma australis* (Bogidiellidae) and *Hadzia subthalassica* (Hadziidae).

Varanus Island is comprised of a single geological type i.e. Pleistocene coastal limestone covered by lime-cemented shelly sand, dune sand, and beach conglomerate. This geology is well represented on the eastern side of Barrow Island where extensive subterranean fauna, both troglofauna and stygofauna, has been recorded. It is therefore very likely that troglofauna, in addition to stygofauna, is present on Varanus Island including the impact area. The potential extent of troglofauna habitat is believed to correspond with the extent of the island.

Based on results of the desktop study information, the extent of potential primary impact to troglofauna would be proportional to the depth to which rock will be extracted. Phoenix has recorded troglofauna from less than one metre depth and therefore, there is potential for direct impact on the troglofauna. However, if troglofauna are present in the proposed disturbance area, they are also likely to be present elsewhere on the island, because of the uniformity in geology across the island.

It is therefore unlikely that the proposed project would threaten species to the point of extinction. Due to the shallow disturbance it is unlikely that stygofauna is majorly impacted by the Project.

With respect to subterranean fauna it is recommended to conduct baseline subterranean fauna surveys to accurately assess the effects of the Project.

1 INTRODUCTION

In June 2012, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Apache Energy Ltd (Apache) to undertake a short-range endemic (SRE) invertebrate fauna survey and a subterranean fauna desktop review for the Varanus Island Fill Project ('the Project'). This report describes the terrestrial and subterranean invertebrate desktop reviews in addition to the SRE survey undertaken in June 2012 on Varanus Island.

1.1 BACKGROUND

Varanus Island is located approximately 14 km east-northeast from the northern tip of Barrow Island (Figure 1-1). Bond Corporation developed the original Varanus Island facilities in 1987, and since 1993 Apache has been operating and developing these facilities. Apache is planning to further develop the infrastructure on Varanus Island which will require fill material comprising rock, soil and sand. Apache has proposed to source the fill material at several locations within the confines of the current tenement on Varanus Island (Figure 1-2).

For approval of this development, The Department of Environment and Conservation (DEC) has indicated the need for an SRE survey, with a focus on snails. A preliminary assessment of the Mollusca and Arachnology/Myriapodology databases of the WA Museum (C. Whisson and M. Castalanelli 2012, email to V.W. Framenau) has identified at least two groups of potential SREs, *Quistrachia* land snails (family Camaenidae) and *Aname* trapdoor spiders (family Nemesiidae).

Varanus Island is part of the Lowendal Islands, an archipelago comprising more than 30 islands that is located approximately 11 km east/north-east of the northern end of Barrow Island and 15 km south of the Montebello Islands off the north-western coast of Western Australia. Varanus Island is the largest of the Lowendal Islands and is 2.5 km long and 600 m wide (approximately 85 ha).

Varanus Island is a twisted, linear limestone outcrop with recent sand dunes. The Island is formed from a marine basement beneath a marine calcarenite, which is overlain by a well cemented dune limestone (Astron 2009). The highest point of the island is approximately 30 m a.s.l. (DMP 2011).

The vegetation of the islands of the Lowendal group (including Varanus, Abutilon, Bridled, and Parakeelya Islands) consists of coastal species (*Spinifex longifolius* and *Acacia coriacea*), with some *Triodia angusta, Ficus platypoda* and *Pittosporum phylliraeoides* inland on Varanus Island (Kendrick & Mau 2001). One hundred and twenty-two plant taxa have been recorded on Varanus Island and Bridled Island, including 12 weed species and six introduced mainland species (Astron 2009).

The Lowendal group is recognised as an important nesting ground for several species of seabird and marine turtle. For example, the Lowendal Islands Archipelago regularly supports more than 1% of the global population of Crested Tern and Bridled Tern (Birdlife Australia 2005–2007). Thirteen species of terrestrial herpetofauna in twelve genera and seven families have been recorded from Varanus Island (Cullen 2002). House mice were introduced onto Varanus Island in 1993 but were eradicated by 1997 (Burbidge & Morris 2002).

Important sea turtle nesting occurs throughout the Lowendal group. Hawksbills and Greens Turtles nest on Varanus, Abutilon and Bridled Islands. Flatback Turtles are known to also nest on Varanus Island in low numbers and occasional nesting by Loggerheads has been recorded. Dugongs are present in surrounding waters (Kendrick & Mau 2001).

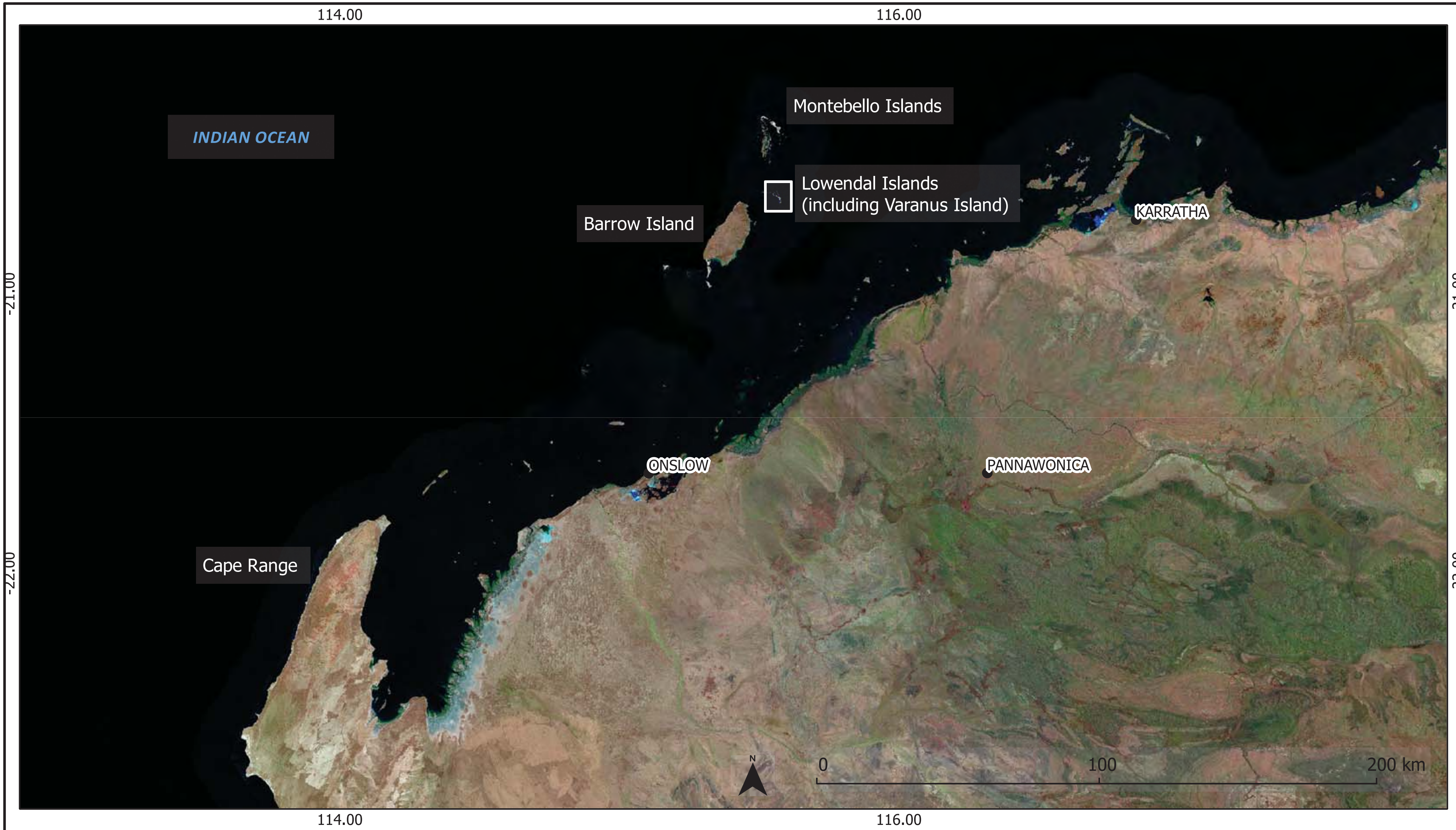


Figure 1-1
Location of Varanus Island

AUTHOR: A.E. Leung	**CLIENT: Apache Energy Ltd**
DATE: August 2012	**Scale: 1:1550000**
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PHOENIX ENVIRONMENTAL SCIENCES

PROJECT: Varanus Island Fill Project

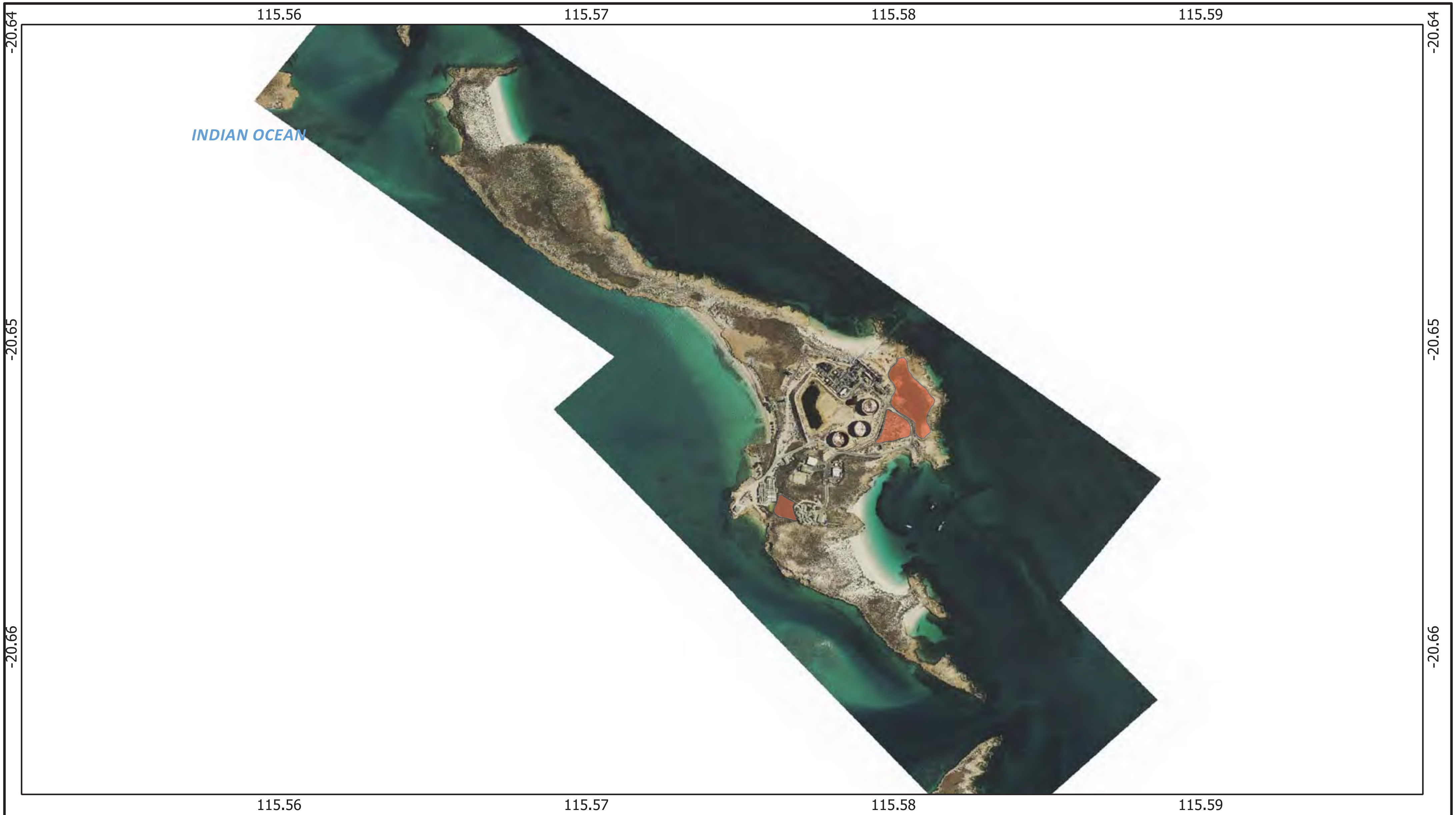


Figure 1-2
Proposed impact area for the Varanus Island Fill Project (August 2012)

PHOENIX ENVIRONMENTAL SCIENCES

impact area

0 0.25 0.5 km

N

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd	
DATE: August 2012	Scale: 1:14000	PROJECT: Varanus Island Fill Project
Coordinate System: Projection: Transverse Mercator; Datum: GDA94		

1.2 SCOPE OF WORK AND SURVEY OBJECTIVES

The main objective of the survey was to assess the level of impact from the proposed development on terrestrial SRE species or habitats.

The scope of works undertaken to achieve these objectives was as follows:

- conduct a desktop review of available technical reports and relevant databases to determine the potential SRE species and habitats within the study area
- prepare a desktop assessment for the potential of the project to impact on short-range endemic, including subterranean invertebrates)
- conduct a field survey for SRE taxa on Varanus Island concentrating on the area proposed for fill sourcing
- undertake data analyses, sample processing and species identifications (including molecular identification) for samples collected during the field survey
- prepare maps showing potential SRE species records and habitats in the study area
- prepare a technical report outlining survey methods, results, assessment of potential SRE species and habitats, assessment of potential impacts on SRE species from the Project and recommendations for management and mitigation of impacts.

This SRE survey adhered to the principles and practices of the Environmental Protection Authority's (EPA) Guidance Statement No. 20: *Sampling of short-range endemic invertebrate fauna for environmental impact assessment (EIA) in Western Australia* (EPA 2009), which outlines preferred methods for the surveying and assessment of SREs in the context of EIA.

The survey has also been designed in accordance with the EPA Guidance Statement No. 56: *Terrestrial fauna surveys for environmental impact assessment in Western Australia* (EPA 2004) and EPA Position Statement No. 3: *Terrestrial biological surveys as an element of biodiversity protection* (EPA 2002).

The subterranean fauna desktop review complied with the Environmental Protection Authority's (EPA's) requirements for an environmental impact assessment (EIA) of subterranean invertebrates as outlined in Guidance Statement 54 (EPA 2003), Guidance Statement 54a, (EPA 2007).

The limitations of the survey with respect to Guidance Statement 56 (EPA 2004) are discussed in Section 4.12.

2 EXISTING ENVIRONMENT

2.1 INTERIM BIOGEOGRAPHIC REGIONALISATION OF AUSTRALIA

The Interim Biogeographic Regionalisation of Australia (IBRA) defines ‘bioregions’ as large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems (DSEWPC 2011; Thackway & Cresswell 1995). Their purpose is to record and categorise the large-scale geophysical patterns that occur across the Australian continent. The identified patterns in the landscape are linked to fauna and flora assemblages and processes at the ecosystem scale. They are a useful means for simplifying and reporting on more complex patterns of biodiversity (Thackway & Cresswell 1995).

Western Australia contains 26 IBRA bioregions and 53 subregions. By combining information for an IBRA region with information on protected areas within the region and its sub-regions, the level of protection of Australia's various landscapes can be established. IBRA is therefore a dynamic tool for monitoring progress towards building a comprehensive, adequate and representative reserve system (DSEWPC 2012).

Similar to Barrow Island, Varanus Island represents natural extension of Cape Range and therefore falls within the Carnarvon region; however, these islands are geographically closer to the Pilbara bioregion and also share floristic and faunistic elements with the Pilbara (e.g. Astron 2009; Eberhard *et al.* 2005; Karanovic 2006; RPS & Mattiske 2005).

The Carnarvon region covers an area of 83,747 km^2 and is divided into two subregions (DSEWPC 2012):

- Cape Range (CAR01): northern part of the Carnarvon Basin; includes Exmouth Gulf, and the islands of the Barrow group, Lowendal group, Montebello group and Muiron group
- Wooramel (CAR02): southern and central parts of the Carnarvon Basin; includes Lake MacLeod, the Kennedy Range and the islands of Shark Bay.

The Project is situated in the Cape Range subregion (Figure 2-1). Characteristics of this subregion include (Kendrick & Mau 2001):

- saline alluvial plains with samphire and saltbush low shrublands
- Bowgada low woodland on sandy ridges and plains
- Snakewood scrub on clay flats
- tree to shrub steppe over hummock grasslands on and between red sand dune fields
- limestone strata with *Acacia stuartii* or *Acacia bivenosa* shrubland outcrop in the north, where extensive tidal flats in sheltered embayments support mangel
- islands which are important for sea turtle and seabird breeding
- karst systems supporting unique and diverse troglofauna and stygofauna.

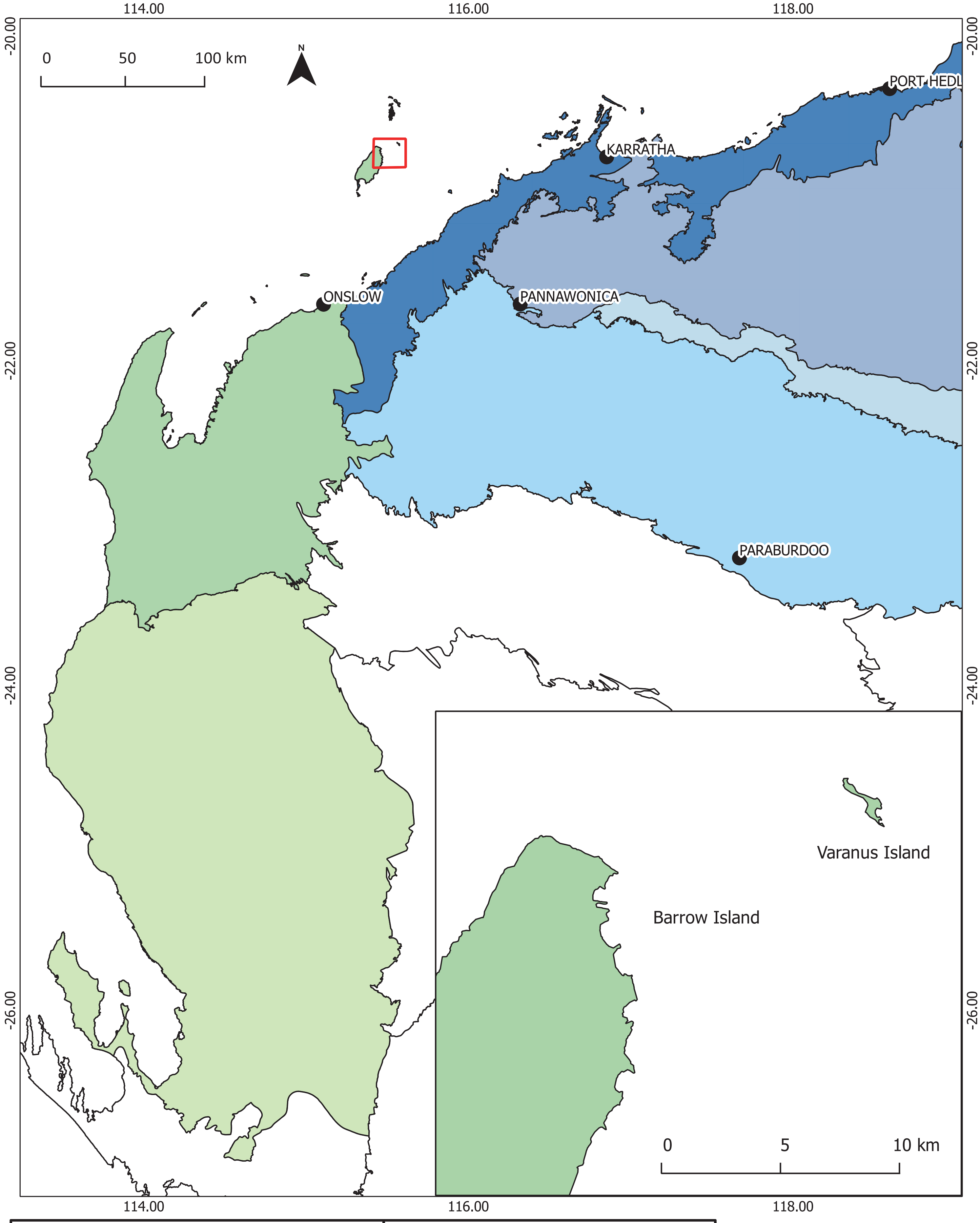


Figure 2-1
Location of the Varanus Island Fill Project in relation to IBRA regions and sub-regions

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:2500000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PROJECT: Varanus Island Fill Project

2.2 GEOLOGY AND HYDROLOGY

Barrow Island, the Montebello Islands and the Lowendal Islands are the most offshore of the southern Rowley Shelf islands. The Rowley Shelf is a large sedimentary shelf 80 km from the West Pilbara coast, to a large extent in the geological province of the Carnarvon Basin. These islands are separated from the inner part of the Rowley Shelf by the Flinders Fault and collectively form the Barrow-Montebello Complex. This complex, including Varanus Island, emerges as a north-tending promontory extension of the Rowley Shelf. This island system comprises Trealla limestone, flanked and veneered by Pleistocene and Holocene sediment deposits (RPS 2005; Wilson *et al.* 1994).

The Lowendal Island group contains more than 30 limestone islands, islets and rocky stacks with typically steep shorelines. The larger islands have dunes of white sand, while the smaller islands consist mostly of low lying, bare rocky islets and stacks (DEC & MPRA 2006).

2.3 CLIMATE AND WEATHER

The Carnarvon bioregion has a semi-arid to arid climate with average maximum temperatures of about 32°C in summer and higher rainfall in the winter (DEWHA 2008). However, Varanus Island is geographically closer to the Pilbara bioregion which experiences high summer temperatures over 40°C and rainfall that is highly variable but more prevalent in summer where cyclonic activity is common (McKenzie *et al.* 2009).

The nearest Bureau of Meteorology (BOM) weather station is located at Barrow Island Airport (20.80°S, 115.41°E) approximately 12 km west-southwest of Varanus Island. Barrow Island Airport weather station records the highest maximum mean monthly temperature (33.2°C) in January, February and March, and the lowest maximum mean annual temperature (17.7°C) in July and an average annual rainfall of 305.2 mm (BOM 2012) (Figure 2-2).

Records from Barrow Island Airport weather station between from January 2012 recorded above average rainfall for that month (Figure 2-2), possibly attributed to tropical cyclone activity which brought large amounts of rainfall during the cyclone season (BOM 2012). However, subsequent months (February to May 2012) recorded below average rainfall preceding the survey. The mean daily maximum and minimum temperatures from January to June 2012, were close to average (BOM 2012).

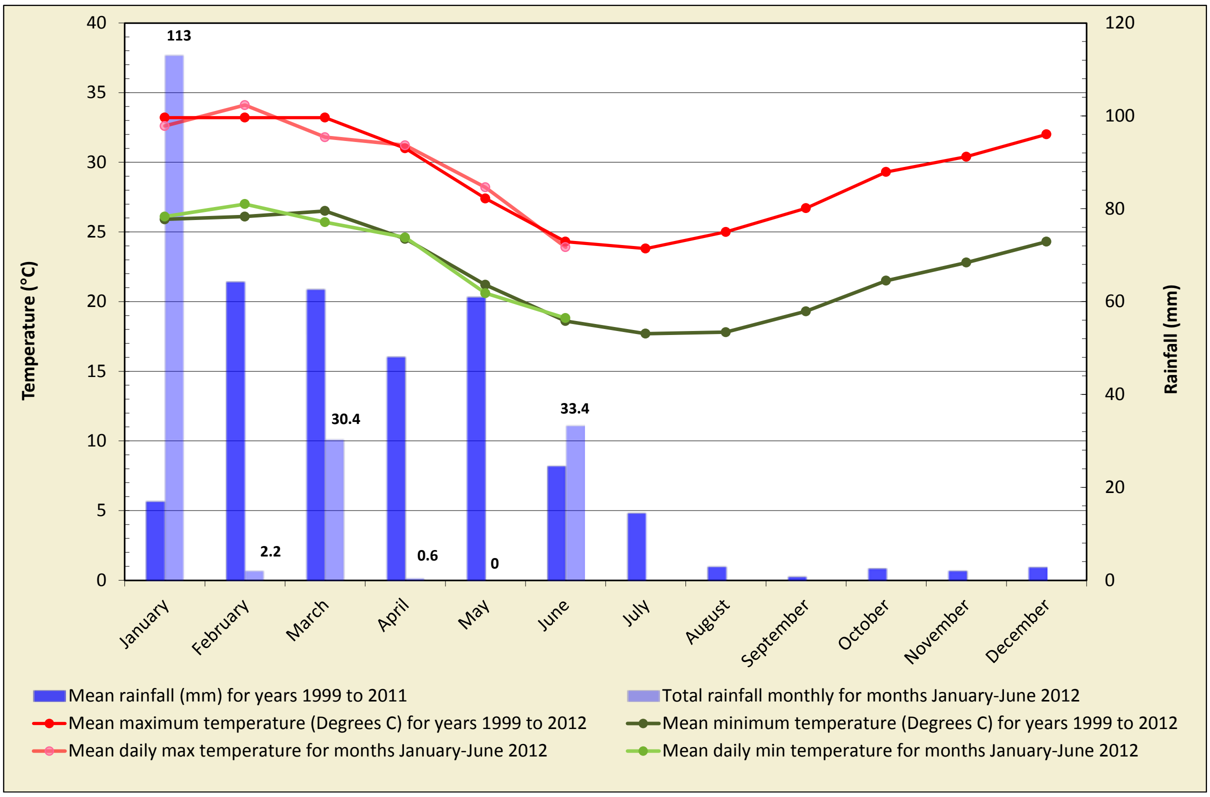


Figure 2-2 **Climate data (average monthly temperatures and rainfall records) and weather (temperature and rainfall preceding survey) for Barrow Island (BOM 2012)**

2.4 LAND USE

As part of the Lowendal Islands Nature Reserve, Varanus Island has largely been set aside for conservation purposes. However, Apache's holds a lease of approximately 29 ha of the island which is used for gas processing plant and habitation infrastructure for employees (Figure 1-2).

2.4.1 Conservation Reserves

The Barrow-Montebello complex contains a number of islands that are managed for the purpose of conservation (DEC & MPRA 2006). These include the Montebello Islands Conservation Park, Barrow Island Nature Reserve, Boodie, Double and Middle Islands Nature Reserve, and the Lowendal Islands Nature Reserve (Figure 2-3). The Montebello Islands are also managed to allow a level of recreation that is consistent with protecting the natural values or features of archaeological, historic or scientific interest. The boundary of the majority of the island reserves extends to the low water mark and therefore the intertidal communities are part of these terrestrial reserves. The exception is the Lowendal Islands Nature Reserve, which extends to the high water mark (DEC & MPRA 2006).

Barrow Island Nature Reserve is an A-class reserve and one of the most important conservation reserves in the State (DEC & MPRA 2006). It is Western Australia's second largest island and an important biological refuge due to its isolation from the mainland with a number of endemic species and low incidence of introduced species. Barrow Island supports regionally and nationally significant rookeries for threatened green and flatback turtles and flora species that are geographically restricted, priority-listed and at the limits of their range. Important ecosystems include an extensive karst system, intertidal mudflats, rock platforms, mangroves, rock piles, cliffs, clay pans and caves (DEC 2012a).

Three marine conservation reserves surround the islands of the Barrow, Montebello and Lowendal archipelagos, i.e. Montebello Islands Marine Park (58,331 ha), Barrow Island Marine Park (4,169 ha) and Barrow Island Marine Management Area (114,693 ha) (Figure 2-3). The Montebello/Barrow islands marine conservation reserves have very complex seabed and island topography including sheltered lagoons, channels, beaches and cliffs. This complexity is thought to have resulted in a high diversity of habitats in the reserves supported by high sediment and water quality. The mangrove communities are made of up six species and are considered to be globally significant because they occur in lagoons of offshore islands. The reserves are important breeding areas for several species of marine turtles and seabirds, which use the undisturbed sandy beaches for nesting. Humpback whales migrate through the reserves and dugongs occur in the shallow warm waters (DEC & MPRA 2006).

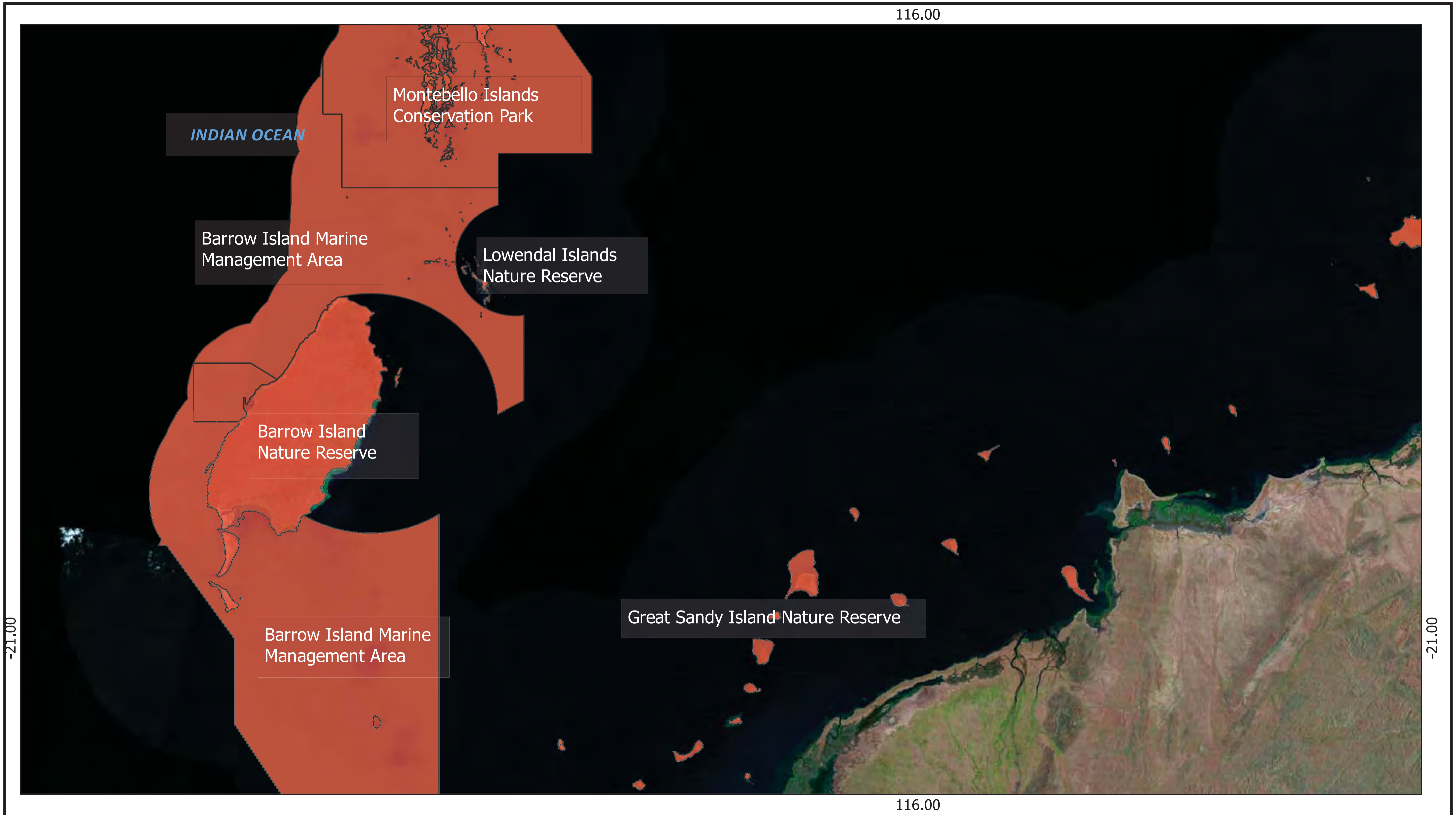


Figure 2-3
Conservation areas in the Barrow Island/Montebello Islands/Lowendal Islands archipelagos

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:420000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	PROJECT: Varanus Island Fill Project

2.4.2 Threatening processes

2.4.2.1 Terrestrial fauna

The restricted ranges of SREs in combination with often very specific habitat preferences make them particularly vulnerable to adverse effects (Harvey 2002). The main threatening processes for island SRE taxa are:

- **Introduced species**: Introduced vertebrate and invertebrate species can have severe effects on island fauna (e.g. Framenau & Thomas 2008; Surman & Nicholson 2011). House mice were introduced to Varanus Island in 1993 but eradicated by 1997 (Burbidge & Morris 2002). Consequently, Chevron has developed a comprehensive non-indigenous species management plan for Barrow Island (Chevron 2009).
- **Spread of weeds**: A total of 16 weed species have been identified on Varanus Island, including 12 environmental weed species and six introduced native species from the mainland (Astron 2009).
- **Habitat destruction through mining and associated infrastructure:** Clearing land for infrastructure developments such as processing plants, ports, and pipelines potentially impact flora and fauna species and assemblages.
- **Climate change**: Current predictions suggest that the north-west region may become warmer with more hot days and fewer cold nights and may experience less annual rainfall. Droughts may be more severe and storm events become more common (McKenzie *et al.* 2009). These effects may enhance the effects of other threatening processes, in particular the likelihood of fire and the introduction of more species from the tropics.

2.4.2.2 Subterranean fauna

Impacts to subterranean fauna can be classed as either:

- **primary impacts** – impacts that physically destroy the subterranean void networks
- **secondary impacts** – impacts that change the physicochemical nature of subterranean habitat without physically destroying the void networks.

Primary impacts are obvious, whereas secondary impacts tend to be cumulative and may affect a far greater area than that being developed (Hamilton-Smith & Eberhard 2000). There are commonly two key threatening processes from mining activities that impact subterranean fauna through the direct loss of habitat:

- **Development of mine pits:** The most obvious primary impact to subterranean habitats occurs as a result of their physical removal during mining. Troglofauna require air-filled void networks which are typically destroyed during pit construction and/or mining. Similarly, direct loss of stygofauna habitat may be caused by the removal of geological formations if any aquifers are associated with these formations.
- **Depletion of an aquifer leading to loss of stygofauna habitat:** Depletion of an aquifer that is identified as suitable for stygofauna represents a direct loss of stygofauna habitat. The significance of the impact is dependent on the depth of drawdown, the size and extent of the aquifer and the connectivity of the aquifer with adjacent habitat for stygofauna. The EPA typically considers a lowering of the water table by more than 10 m to be a significant impact. Anchialine systems (connected to the ocean) are often characterised by highly stratified salinity gradients, with surface waters being freshest and becoming saltier with

increasing depth**.** Removal of the freshwater lense can also have detrimental impact to stygofauna that are intolerant of high salinity.

Secondary impacts are those that affect the physicochemical properties of subterranean habitats. The nature of these changes can be difficult to measure and there is limited empirical evidence to support or refute these putative impacts. There are four secondary impacts that may be relevant to the Project:

- **Depletion of an aquifer leading to altered relative humidity:** Troglofauna are dependent on high relative humidity (Barr 1968; Humphreys 1991; Humphreys 2000a). Dewatering may impact troglofauna habitat in unsaturated strata above the water table by lowering relative humidity.
- **Nutrient starvation:** Surface vegetation is the primary source of nutrients entering subterranean systems. Large-scale clearing of vegetation may result in the localised nutrient starvation of underlying subterranean habitat. Smothering of these nutrient sources on which subterranean systems depend, in the form of waste and overburden stockpiles and tailings ponds, may reduce inflow of nutrients to subterranean systems and lead to nutrient deficient habitats.
- **Vibration:** Propagation of shock waves through subterranean strata from blasting or heavy vehicle traffic may result in the collapse of less-consolidated void spaces and also impact physically on subterranean fauna. There is little data to challenge or corroborate these observations and impacts are generally thought to be localised.
- **Contamination:** Contamination of subterranean habitats from spills, such as diesel fuel, may degrade the quality of subterranean habitats. Such impacts would generally be highly localised and minor in scale.

2.5 BIOLOGICAL CONTEXT

2.5.1 Terrestrial short-range endemic invertebrates

Short-range endemic terrestrial fauna are defined as animals that display restricted geographic distributions, nominally less than 10,000 km^2, that may also be disjunct and highly localised (Harvey 2002; Ponder & Colgan 2002). The most appropriate analogy is that of an island, where the movement of fauna is restricted by the surrounding marine waters, therefore isolating the fauna from other terrestrial populations. Isolating mechanisms and features such as roads, urban infrastructure, large creek lines and ridges can act to prevent the dispersal and gene flow of the less mobile invertebrate species.

Short-range endemism in terrestrial invertebrates is believed to have evolved through two primary processes (Harvey 2002):

- **Relictual short-range endemism**: relictual SREs are thought to have had wider distributions during more mesic geological periods. Australia's aridification over the last 60 million years resulted in a contraction of the ranges of these species into relatively small habitat pockets where moist conditions persist (relictual Gondwanan habitats). Evolutionary processes over long periods of isolation typically resulted in each population developing into a distinctive species. Millipedes and slaters are typical relictual SREs and they are generally found in deep gullies often on the south-facing slopes of mountains, hills and ridges. Relictual SREs often inhabit areas with: high rainfall, areas where topography induces fog, areas with permanent water (swamps, creek lines and river systems) or deep litter beds. Sometimes habitats have various combinations of these features.

- **Habitat specialisation**: habitat specialist SREs may have settled in particular isolated habitat types by means of dispersal or phoresy (transport of one organism by another) and evolved in isolation into distinct species. Such habitat islands include rocky outcrops (pseudoscorpions in the genus *Synsphyronus* or spiders in the family Selenopidae are typical examples) or salt lakes (e.g. wolf spiders of the genus *Tetralycosa*). Unlike relictual SREs in mesic habitats, habitat specialist SREs are restricted by environmental parameters other than humidity and are often found in arid environments such as the Pilbara.

Invertebrate groups that contain terrestrial SRE taxa are generally well distributed across the Australian landscape and well adapted to semi-arid environments due to a variety of behavioural and morphological features that have developed to avoid desiccation and predation. They generally possess (Harvey 2002):

- poor powers of dispersal
- confinement to discontinuous habitats
- seasonality, i.e. only active in cooler or wetter months
- slow growth
- low levels of fecundity.

In the Carnarvon bioregion, the current knowledge of terrestrial SREs is relatively poor and the rarity of collections from certain areas makes it difficult to assess the distribution and likely occurrence of SRE species. However, intense invertebrate surveys on Barrow Island provide a good reference for the invertebrate fauna of Varanus Island. Potential terrestrial SRE taxa of the Carnarvon bioregion include the following groups that represent the target invertebrates of this survey (EPA 2009):

- spiders and relatives (Arachnida)
    - spiders (Araneae), in particular trapdoor spiders (Mygalomorphae) and selected modern spiders (Araneomorphae) (here mainly Flat Rock Spiders, family Selenopidae)
    - harvestmen (Opiliones)
    - false scorpions (Pseudoscorpiones)
    - true scorpions (Scorpiones)
    - whip spiders (Schizomida) (the majority of SREs in this order are troglobites (Harvey *et al.* 2008; Harvey *et al.* 2011)
- multipedes (Myriapoda)
    - centipedes (Chilopoda), mainly the order Geophilomorpha and the Cryptopidae in the order Scolopendromorpha; other Scolopendromorpha are generally widespread and are not considered target taxa (e. g. (Colloff *et al.* 2005; Koch 1982, 1983a, b, c)
    - millipedes (Diplopoda)
- crustaceans (Crustacea)
    - slaters (Isopoda)
- snails and relatives (Mollusca)
    - land snails (Eupulmonata, Gastropoda).

Whilst other invertebrate groups have recently been proposed to contain a substantial proportion of range-restricted species, e.g. epigaeic (ground-dwelling), often wingless beetles in the Pilbara (Guthrie *et al.* 2010), these are currently not targeted in SRE invertebrate surveys (EPA 2009).

In the context of subterranean fauna it has been argued that the nominal range of short-range endemism as applied to terrestrial fauna is too large. For stygofauna, a reduced area of less than 1000 km^2 has been proposed (Eberhard *et al.* 2009). Even this may need further refinement as groundwater calcrete aquifers of the southern Western Shield (Yilgarn) each have unique fauna largely comprising endemic species. Of 77 unique calcrete faunas listed as 'priority communities' by the DEC, the mean area of each calcrete is 90.8 km^2 (range 0.89–2205 km^2) (Harvey *et al.* 2011).

2.5.2 Subterranean fauna

Subterranean fauna are organisms (almost exclusively invertebrates) that live beneath the surface of the ground. Subterranean organisms can exist within a variety of subterranean void networks, including solution cavities within calcrete and karst, fractured rock and course sediments such as cobble or gravel strata (Howarth 1983; Humphreys 2008; Subterranean Ecology 2010). The energy and nutrient resources for subterranean habitats are almost exclusively sourced from allochthonous materials. Tree roots and water form the most important transport routes that move energy and nutrients into subterranean networks (Howarth 1983; Humphreys 2000a; Poulson & Lavoie 2000).

Subterranean fauna live within air- or water-filled underground networks. They are predominantly invertebrates. Organisms specialised for living in air-filled subterranean networks are referred to as troglofauna, while those inhabiting water-filled subterranean networks are referred to as stygofauna (Howarth 1983; Humphreys 2000a).

Subterranean habitats are perpetually dark, are extremely constant in temperature and humidity (air-filled networks) and very low in nutrients and energy that are required to support organisms (Howarth 1993). Evolution under such conditions has resulted in much specialised organisms that are restricted to the void networks in which they have evolved (Harvey 2002; Holsinger 2000; Howarth 1993; Ponder & Colgan 2002; Volschenk & Prendini 2008). Such species are obligated to living in subterranean networks and cannot live in epigean (surface) environments.

For this reason, organisms specialised to live in subterranean networks are likely to represent short-range endemics (SREs) with extremely limited capabilities of dispersal (Harvey 2002; Ponder & Colgan 2002; Volschenk & Prendini 2008). It is these subterranean species that are considered to be of conservation significance because they are at greatest risk of extinction from development projects.

In Western Australia, and particularly in the Pilbara region, there has been a recent renaissance in the study of subterranean biodiversity (Humphreys 2008), driven by the growth of the mineral resources industry and mining environmental impact assessment (EPA 2003, 2007). Despite the extensive survey work undertaken in the Pilbara, relatively little knowledge on SRE diversity and biology has emerged from the primary literature. The biology, diversity and distributions of most of Western Australia's subterranean fauna are still poorly understood.

2.5.2.1 Troglofauna

Troglofauna are typically divided into three categories of specialisation to subterranean life:

- troglobites, that are restricted to subterranean habitats and usually perish on exposure to the surface environment (Barr 1968; Howarth 1983; Humphreys 2000a)
- troglophiles, which facultatively use subterranean habitats but are not reliant on them for survival (Barr 1968; Howarth 1983; Humphreys 2000a)
- trogloxenes, which use subterranean systems for specific purposes, such as roosts for reproduction (bats and swiftlets).

Both troglobites and troglophiles may be SRE's and therefore, conservation significant.

Troglobites are organisms that have adapted to exploit the special characteristics of air-filled subterranean networks. They are often characterised by much specialised adaptations to subterranean life, such as:

- lack or reduction of eyes
- lack or reduction of wings (for species that are normally winged)
- lack or reduction of body pigmentation
- heightened chemosensory and mechano-sensory systems
- loss of circadian rhythms
- very low metabolic rate.

These adaptations allow troglobites to exploit the dark, humid, nutrient-poor subterranean void networks (Howarth 1983, 1993; Humphreys 2000a; Poulson & Lavoie 2000). Several soil and litter dwelling groups are blind and pale, making determination of troglobitic status extremely difficult. In these instances, DNA sequencing is used in order to obtain regional context for such finds (Subterranean Ecology 2010); that is to determine if any records are conspecific with other recorded specimens.

Troglophiles are species that can live and reproduce in subterranean networks, but are not restricted to them. These species are usually very tiny and exist within the soil. Some troglophiles appear to be widespread species, while others, like diplurans and cryptopids, are often SREs (Phoenix unpublished data). This limits any comments regarding species distribution outside of the study area.

2.5.2.2 Stygofauna

Stygofauna represent the fauna living within subterranean water bodies or aquifers (Humphreys 2000a). They typically show similar traits to troglobites in their specialisation to subterranean life, including loss of body pigment, eyes and heightened mechano-sensory systems. Stygofauna are similarly termed to troglofauna:

- stygobites, that are restricted to subterranean habitats and usually perish on exposure to the surface environment
- stygophiles, which facultatively use subterranean habitats but are not reliant on them for survival (Humphreys 2008).

Aquifers are often connected to surface water bodies and some surface species may also be able to freely move from surface to subterranean systems and back. Such species are referred to as stygoxenes (Humphreys 2000a) and represent non-obligatory stygofauna. Short-range endemic stygofauna are only represented by stygobitic species.

2.5.2.3 Identifying troglofauna and stygofauna

The characterisation of subterranean fauna into troglobites or stygobites is largely based on an understanding of species habitat requirements. The recognition and identification of these species are usually limited to the presence of troglomorphies, such as reduction or loss of eyes or wings etc. Troglomorphies are used to infer a species that have become specialised to subterranean existence over many generations of confinement to subterranean habitats.

The use of troglomorphies may be justified when a species being identified belongs to a genus (or other higher taxonomic rank) in which epigean species do not exhibit troglomorphic characteristics. Some groups, such as diplurans, cryptopid centipedes and atelurine silverfish, are more difficult to assess since all members of these groups, whether subterranean or not, lack eyes and are generally pale.

Taxonomic resolution is difficult to achieve in taxa for which there is no local expertise to provide regional context. The apparently strong evolutionary pressure of subterranean habitats has resulted in highly convergent, morphologically-similar species (Finston *et al.* 2004; Finston & Johnson 2004; Finston *et al.* 2007). Molecular techniques such as 'barcoding' (Hebert *et al.* 2003a; Hebert *et al.* 2003b) are routinely employed to overcome these identification problems. Barcoding methods can also resolve specimen identification where specimens represent taxonomically uninformative life stages or sexes.

2.5.3 Categories of short-range endemism

Currently, there is no accepted system to determine the likelihood that a species is an SRE. The uncertainty in categorising a specimen as SRE originates in a number of factors including:

- **Poor regional survey density** (sometimes taxon-specific): A regional fauna is simply not known well enough to assess the distribution of species. This factor also considers the fact that, simply because a species has not been found regionally, does not mean it is really absent; this confirmation ('negative proof') is almost impossible to obtain ('absence of proof is not proof of absence').
- **Lack of taxonomic resolution**: many potential SRE taxa (based on habitat constraints, SRE status of closely related species, or morphological peculiarities such as troglomorphism) have never been taxonomically treated and identification to species level is very difficult or impossible as species-specific character systems have not been defined. Good taxonomic resolution does not necessarily require a published revision, but generally requires a taxonomist to be actively working on this group or a well-established, preferably publicly available, reference collection (i.e. museum collection).
- **Problems of identification**: SRE surveys often recover life stages of potential SRE taxa that cannot be confidently identified based on morphological characters, even if revisions exist. These include, for example, juvenile or female millipedes, mygalomorph spiders and scorpions. Molecular techniques are increasingly being employed to overcome these identification problems.

Considering these factors of uncertainty, Phoenix currently employs a simple three-tier system to categorise the different probabilities of short-range endemism: confirmed, likely or potential SRE

(Table 2-1). These categories are dynamic and can change with every single survey as knowledge of SRE status is updated. For example, the millipede *Austrostrophus stictopygus* Hoffman, 2003 (order Spirobolida) has been shown widespread in the Pilbara based on material collected as part of environmental assessment studies following its initial description from few localities (Harvey *et al.* 2011; Hoffman 2003).

Life stages of species that cannot be identified at the species level, e.g. some females and juveniles, are assessed based on the knowledge of the higher taxon they belong to, i.e. family or genus. For example, all juvenile or female *Antichiropus* millipedes would be classified as 'confirmed SRE' as all but two of the 120+ known species in this genus are currently considered SREs (Wojcieszek *et al.* 2011).

Although the different categories of 'SRE-likelihood' may help to set conservation priorities, SRE taxa of all categories should be assessed on their merit, in order to determine appropriate conservation measures that adhere to the Precautionary Principle within environmental impact assessments. That is, "*where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason to postpone measures to prevent environmental degradation*" (EPA 2002).

Table 2-1 SRE categories reflecting survey, taxonomic and identification uncertainties

SRE category	Criteria	Typical representative
Confirmed	Confirmed or almost certainly SRE; taxonomy of the group is well known (but not necessarily published); group is well represented in collections, in particular from the region in question; high levels of endemism exists in documented species; inference is often possible from immature specimens	*Antichiropus* millipedes (Paradoxosomatidae); scorpions in the genus *Aops* (Urodacidae)
Likely	Taxonomically poorly resolved group; unusual morphology for the group (e.g. some form of troglomorphism); often singleton in survey and few, if any, regional records	Opiliones in the genus *Dampetrus*; some pseudoscorpions (*Synsphyronus*) and slaters (Philosciidae); araneomorph spiders in the genus *Karaops* (Selenopidae)
Potential	Taxonomically poorly resolved group; often common in certain microhabitats in SRE surveys (i.e. litter dwellers), but no other regional records; congeners (= species in the same genus) often widespread	Many mygalomorph spiders; some centipedes (Cryptopidae; Geophilomorpha)

2.5.4 Previous surveys

No systematic surveys of terrestrial invertebrates have been conducted on Varanus Island. Some opportunistically collected invertebrates are lodged with the WA Museum (M. Castalanelli and C. Whisson 2012, email to Volker Framenau).

Invertebrate surveys of particular relevance to an SRE assessment for Varanus Island include extensive Barrow Island invertebrate surveys (see below) and to some extent, the biological survey of the southern Carnarvon Basin (Burbidge *et al.* 2000) and the Pilbara Biological Survey 2002–2007 (McKenzie *et al.* 2009). The survey of the Carnarvon Basin resulted in published accounts for scorpions (Smith & McKenzie 2000), mygalomorph spiders (Main *et al.* 2000), araneomorph spiders (Harvey *et al.* 2000a), and centipedes and millipedes (Harvey *et al.* 2000b). The Pilbara Biological Survey resulted in reports on selected invertebrate fauna, such as spiders (Durrant *et al.* 2010), scorpions (Volschenk *et al.* 2010) and aquatic invertebrates (Pinder *et al.* 2010).

Systematic collections of *Rhagada* land snails were conducted on Barrow Island, Montebello Islands and the Pilbara coast as part of a molecular study into the evolution of the genus in the Pilbara region (Johnson *et al.* 2012).

Barrow Island has been subject to a number of invertebrate studies, including subterranean surveys, and is claimed to be one of the most completely surveyed islands in relation to its invertebrate fauna (Gunawardene 2011). An annotated bibliography of the natural history of Barrow Island 1622–2004 identified 41 reports and publications on the invertebrate fauna of Barrow Island (Smith *et al.* 2006).

The most recent summary on flora and terrestrial and subterranean fauna of Barrow island was published in May 2012 (Chevron 2012); however, it appears that the data on which this compilation is based are generally more than five years old (Biota 2005, 2007; Biota & RPS 2005a, b). As many taxonomic publications have not been incorporated into Chevron's (2012) document (e.g. Johnson *et al.* 2012; Karanovic 2006; Karanovic *et al.* 2011; Volschenk & Prendini 2008), a critical taxonomic review with reference to original and recent publications became necessary to put the Varanus Island desktop reviews and SRE survey into an appropriate and up-to-date context.

Baseline invertebrate surveys of Barrow Island that commenced in 2005 are being continued as part of the non-indigenous species management plan (Chevron 2009; N. Gunawardene 2012, email to Volker Framenau). Data from these continuing surveys are available through the WA Museum database and Curtin University.

2.6 RELEVANT LEGISLATION

Commonwealth

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), actions that have, or are likely to have, a significant impact on a matter of national environmental significance (NES) require approval from the Australian Government Minister for the Environment, Water, Heritage and the Arts (the Minister). The EPBC Act provides for the listing of nationally threatened native species as matters of NES.

Fauna species of national conservation significance may be classified as 'critically endangered', 'endangered', 'vulnerable' or 'conservation dependent' Few invertebrate taxa from WA are listed as matters of NES and those that are mostly include species that have experienced significant range contractions and populations declines due to habitat loss, for example the Margaret River Marron (*Cherax tenuimanus*) (Critically Endangered) and the Graceful Sun-moth (*Synemon gratiosa*) (Endangered) (DSEWPC 2009).

State

Native species in Western Australia which are under identifiable threat of extinction are protected under the Western Australian *Wildlife Conservation Act 1950* (WC Act). Under the WC Act, the *Wildlife Conservation (Specially Protected Fauna) Notice 2012 (2)* (Western Australian Government 2012) recognises four classifications of rare and endangered fauna:

- **Schedule 1:** Fauna that is rare or is likely to become extinct
- **Schedule 2:** Fauna presumed to be extinct
- **Schedule 3:** Migratory birds protected under an international agreement
- **Schedule 4:** Other specially protected fauna.

In addition, the Department of Environment and Conservation (DEC) produces a list of Priority species (last update: February 2012) (DEC 2012b) that have not been assigned statutory protection under the WC Act. Species on this list are considered to be of conservation priority because there is insufficient information to assess their conservation status or they are considered to be rare but not threatened and are in need of monitoring. The DEC Priority Fauna List categories are:

- **Priority 1:** Taxa with few, poorly known populations on threatened lands
- **Priority 2:** Taxa with few, poorly known populations on conservation lands
- **Priority 3:** Taxa with several, poorly known populations, some on conservation lands
- **Priority 4:** Taxa in need of monitoring – considered not currently threatened but could be if present circumstances change
- **Priority 5:** Taxa in need of monitoring – considered not currently threatened but subject to a conservation program, the cessation of which could result in the species becoming threatened.

Few SRE invertebrate taxa are listed under the WC Act and while there are several invertebrate species on DEC's Priority list (some of which are SRE taxa), these lists cannot be relied on as a complete guide to conservation significant invertebrate taxa within a particular location.

The most up-to-date listings of invertebrates and their distribution is available through database searches of the WA Museum invertebrate databases, including the Arachnology/Myriapodology database of the Department of Terrestrial Zoology and the Mollusca and Crustacea databases of the Department of Aquatic Zoology.

3 METHODS

3.1 DESKTOP REVIEW

The following database searches were requested or undertaken to determine if any SRE taxa have previously been recorded in the study area or its vicinity:

- WA Museum Arachnology and Myriapodology database, WA Museum Mollusca database, WA Museum Crustacea and WA Museum Subterranean Research database – rectangular search grid determined by the proposed maximum range of short-range endemism, i.e. 100 km x 100 km (Harvey 2002). Therefore, the search grid extended ca. 100 km from the study area (NW corner 20°15'S/114°40"E and SE corner 21°30'S/117°08'E).
- EPBC Act Protected Matters database search from a centred point with a 10 km buffer (20°39'9.36"S, 115°34'39.39"E)
- DEC/WA Museum NatureMap search from a centred point (20°39'9.36"S, 115°34'39.39"E) with a 40 km buffer.

Terrestrial and subterranean fauna surveys for the Gorgon Project on Barrow Island provided the most relevant data in relation to the invertebrate assessment on Varanus Island. In addition to the above data sources, invertebrate data was made available through the Curtin University reference collection with permission from Chevron (J. Majer and N. Gunawardene 2012, personal communication to Volker Framenau and Anna Leung).

Few mining developments, for which SRE invertebrate surveys may have been conducted, are being progressed on mainland Pilbara in the area targeted by the desktop review. These projects include in particular:

- Cape Preston (International Minerals Pty Ltd, Mineralogy Pty Ltd and CITIC Pacific Mining Management Pty Ltd): Short-range Endemic Invertebrate Fauna Survey (Phoenix 2009).
- Anketell Point (Australian Premium Iron Management Pty Ltd): Short-range endemic invertebrate baseline survey of the Anketell Point Rail Alignment and Port Projects (Phoenix 2010).

3.2 HABITAT ASSESSMENT AND SITE SELECTION

Ten distinct habitat types were previously identified on Varanus Island (Astron 2009). Three of these potentially harbour SRE invertebrates and were systematically surveyed:

- sand dune – white sand dune with medium to low shrubs
- limestone plain – continuous, exposed limestone bedrock with small to medium sized shrubs
- mid-island basin – lowland depression with grasses and shrubs.

Within these habitats, a total of eleven potential SRE sites were surveyed (Table 3-1; Figure 3-1). Three of these were located in the impact area and eight represented reference sites in the wider study area (Table 3-1; Figure 3-1). Detailed site descriptions including geography, vegetation, soil, rockiness, litter, disturbance and site photographs were recorded (Appendix 1).

Table 3-1 Sites of short-range endemic invertebrate survey and sampling effort of the Varanus Island Fill Project

Site	Habitat type	Impact area	Easting (50K)	Northing (50K)	Collecting techniques[a]	Foraging time (mins)	Litter sifts (no.)
1	Limestone plain	Yes	352026	7715638	FO, LS	120	5
2	Mid-island basin	Yes	352086	7715805	FO, LS	110	5
3	Mid-island basin	No	351703	7716005	FO, LS	110	3
4	Mid-island basin	No	351117	7716189	FO, LS	110	6
5	Sand dune	Yes	351719	7715315	FO, LS	120	4
6	Limestone plain	No	350940	7716370	FO, LS	115	4
7	Limestone plain	No	350639	7716867	FO, LS	110	6
8	Limestone plain	No	350828	7716524	FO, LS	120	6
9	Limestone plain	No	351355	7716130	FO, LS	90	6
10	Sand dune	No	351801	7715124	FO, LS	120	6
11	Sand dune	No	351883	7715319	FO, LS	120	6
Total						**1420**	**57**

FO – foraging; LS – litter and soil sieve.

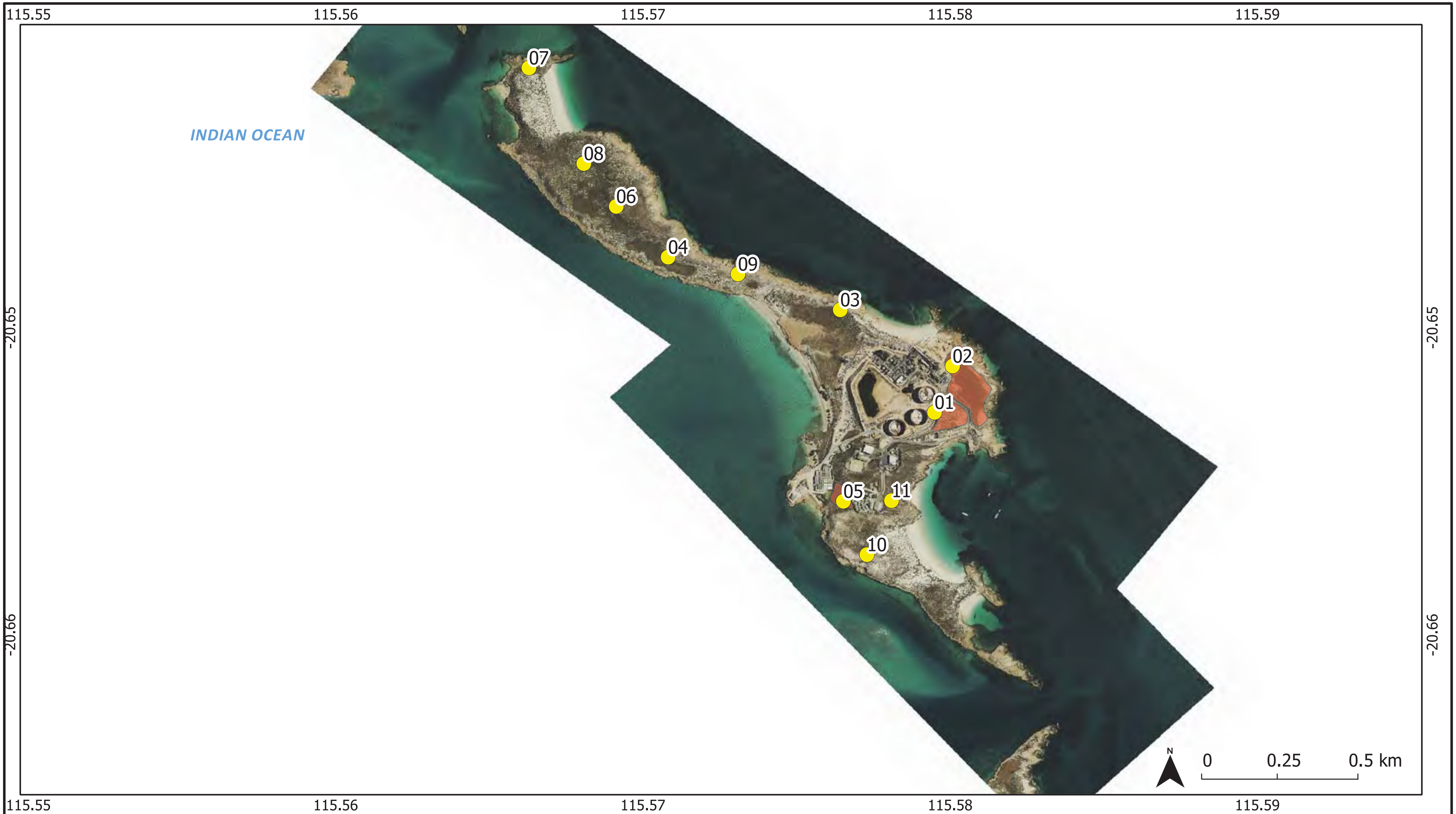


Figure 3-1
Collection sites for the short-range endemic survey of the Varanus Island Fill Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	**CLIENT:** Apache Energy Ltd
DATE: August 2012	**Scale:** 1:14000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PROJECT: Varanus Island Fill Project

3.3 FIELD SURVEY

The field survey was conducted from 18 to 22 June 2012 and utilised two proven, industry-recognised sampling techniques to target SRE taxa: active searches (foraging) and the sieving of combined leaf litter and soil samples (see Table 3-1 for total survey effort).

3.3.1 Foraging

Foraging incorporated the systematic inspection of logs, larger plant debris, the underside of bark of larger trees and the underside of rocks. Methodical searches were conducted amongst the leaf litter of shade-bearing tall shrubs and trees and spinifex bases were inspected thoroughly. Rocks and rock crevices were inspected, particularly for pseudoscorpions.

A temporally standardised approach was undertaken, whereby each site was planned to be sampled for a minimum of two person hours; however, habitat collecting success may have been stopped earlier if no target invertebrates were found for some time (Table 3-1). Trapdoor spider burrows identified during the searches were excavated if they were considered to be inhabited. Excavation involved removing soil from around the burrow to carefully expose the burrow chamber and remove the spider.

3.3.2 Litter/soil sieving

A variable number of combined leaf litter and soil samples were taken at each of the survey sites, depending on the amount of deep leaf litter present. At least three combined litter/soil sifts were undertaken at each site (Table 3-1). The collection of leaf litter samples were standardised volumetrically by the diameter and height (310 mm x 50 mm = 1.55 L) of the sieves which were completely filled with compressed litter and the upper layers of underlying soil.

Samples were sieved through five stages of decreasing mesh size over a round tray and invertebrates were picked from the sieves and tray with forceps or an aspirator.

These samples particularly targeted small spiders (Araneomorphae), pseudoscorpions, buthid scorpions, millipedes, centipedes (in particular Geophilomorpha and Cryptopidae), smaller species of molluscs (e.g. Pupillidae) and slaters.

In situ collecting and sieving is preferred over transporting litter samples to the laboratory. Small invertebrates are best detected when moving and transport to the laboratory can kill a large proportion of the catch. In addition, if litter sieves in the field contain groups of interest, more extensive searches can be conducted, providing greater flexibility in the sampling protocol.

3.4 TAXONOMY AND NOMENCLATURE

3.4.1 Morphological species identification

Phoenix has considerable in-house expertise in the identification of SRE target groups. Senior staff involved in the identification are also Research Associates with a longstanding taxonomic research history at the WA Museum (Table 3-2).

In all cases, identifications relied on direct comparison with reference material from the WA Museum. WA Museum staff were engaged to identify groups in which Phoenix does not have the appropriate expertise (e.g. some pseudoscorpions and all snails).

The single exception was slaters (Isopoda) which were identified by Dr Simon Judd who is the Western Australian authority on slaters (e.g. Judd 2004; Judd & Horwitz 2003), having extensive experience in the identification of isopods of the State. The reliance on the WA Museum reference collections provides the important regional context in the assessment of short-range endemism for unpublished taxa.

Most material collected during the SRE survey, in particular SRE species, has been lodged with the WA Museum, the exception being some representative specimens that remained in the Phoenix reference collection.

Table 3-2 Taxonomic specialists that identified the SRE invertebrates from the survey

Personnel	Taxonomic group/s
Dr Volker W. Framenau[1, 2]	Araneae (Mygalomorphae, Araneomorphae), Diplopoda, Chilopoda
Dr Erich S. Volschenk[1, 2]	Scorpiones, Pseudoscorpiones, Chilopoda (Cryptopidae)
Ms Anna Leung[1]	Pseudoscorpiones, Chilopoda (Geophilomorpha, Scolopendromorpha)
Mr Corey Whisson[3]	Mollusca
Dr Simon Judd[4]	Isopoda

[1]Phoenix Environmental Sciences; [2]Research Associate WA Museum; [3]WA Museum; [4]Freelance taxonomic consultant.

3.4.2 Molecular species identification

Molecular identification for the Project was necessary for the following SRE target groups:

- mygalomorph spiders: only juveniles and females where collected and accurate morphological identification of mygalomorph spiders requires mature males
- camaenid land snails: shell morphology has been shown to be a poor predictor of species identification in some groups, for example *Rhagada* (Stankowski 2011)
- cryptopid centipedes: poorly resolved group taxonomically and morphological characters that can be used for species identification are poorly defined.

The identification of species based on comparisons between DNA sequences is referred to as DNA barcoding. Any gene can be used for barcoding purposes; however, the primary gene targeted by researchers is Cytochrome Oxidase Subunit I (COI or COXI), the 'barcoding gene' (Hebert *et al.* 2003b).

Hebert *et al.* (2003b) examined the percentage differences of over 13,000 species pairs. The study found a mean divergence of 11.3% between species pairs and with the majority of species showing 8% or more sequence divergence. No centipede orders were targeted in that study; however, 1,458 'other orders' of Arthropoda were found to have an average sequence divergence of 10.1% and more than 50% had divergences greater than 8%. For this reason 8% sequence difference was used as a guide for the threshold for discrimination of species, although a number of studies in typical SRE groups show that caution must be applied when using a 'on-size-fits-all' approach, in particular in arachnids and snails (Bond 2004; Boyer *et al.* 2007; Köhler & Johnson 2012).

3.4.2.1 DNA extraction

Nine specimens of mygalomorph spider, six specimens of cryptopid centipede and two specimens each of *Rhagada* and *Quistrachia* land snails from the survey on Varanus Island were sequenced for variation at COI (Table 3-3).

Table 3-3 Specimens sequenced for molecular identification

Species	WAM reg. no.	Locality	Latitude (GDA94)	Longitude (GDA94)
Mygalomorphae (trapdoor spiders)				
Aname sp. indet.	T124702	site 03	-20.649391	115.576497
Aname sp. indet.	T124701	site 03	-20.649391	115.576497
Aname sp. indet.	T124686	site 04	-20.647677	115.570895
Aname sp. indet.	T124691	site 05	-20.65562	115.576599
Aname sp. indet.	T124689	site 05	-20.65562	115.576599
Aname sp. indet.	T124703	site 05	-20.65562	115.576599
Aname sp. indet.	T124688	site 05	-20.65562	115.576599
Aname sp. indet.	T124687	site 10	-20.657357	115.577366

Aname sp. indet.	T124690	site 10	-20.657357	115.577366
Scolopendromorpha (tropical centipedes)				
Cryptops sp. indet.	T124789	Site 01	-20.652728	115.579566
Cryptops sp. indet.	T124781	Site 04	-20.647677	115.570895
Cryptops sp. indet.	T124784	Site 01	-20.652728	115.579566
Cryptops sp. indet.	T124785	Site 11	-20.6556	115.578165
Cryptops sp. indet.	T124783	Site 09	-20.648228	115.573169
Cryptops sp. indet.	T124788	Site 08	-20.644633	115.56815
Gastropoda (land snails)				
Quistrachia sp. indet.	S83644	site 01	-20.652728	115.579566
Quistrachia sp. indet.	S83637	site 04	-20.647677	115.570895
Rhagada sp. indet.	S83636	site 05	-20.65562	115.576599
Rhagada sp. indet.	S83647	site 11	-20.6556	115.578165

A variety of primer combinations were chosen to amplify nucleotides of COI (Table 3-4) (Castalanelli & Harvey 2012; M. Castalanelli personal communication).

Table 3-4 Primers used for molecular analyses

Primer	Sequence	Reference	taxa
LCO1490	GGTCAACAAATCATAAAGATATTGG	Folmer *et al.* (1994)	*Aname*, *Cryptops*, *Quistrachia*, *Rhagada*
HCO2198	TAAACTTCAGGGTGACCAAAAAATCA	Folmer *et al.* (1994)	*Aname*, *Cryptops*, *Quistrachia*, *Rhagada*
LCO1490-Alb	ACTCAACGAATCATAAAGATATTGG	Gittenberger *et al.* (2006)	*Rhagada*, *Quistrachia*
HCO2198-Alb	TATACTTCAGGATGACCAAAAAATCA	Gittenberger *et al.* (2006)	*Rhagada*, *Quistrachia*
C1-J-1718F-mygal	GGAGGATTTGGAAATTGATTAGTTCC	Simon *et al.* (1994)	*Aname*
C1-N-2191	CCCGGTAAAATTAAAATATAAACTTC	Folmer *et al.* (1994)	*Aname*

As the WA Museum holds a large databank of reference sequences for mygalomorph spiders (based on Helix 2012), sequence data for mygalomorph spiders was analysed and compared to their dataset by the WA Museum (Castalanelli & Harvey 2012).

In contrast, the WA Museum does not hold datasets for cryptopid centipedes or snails and analyses of sequences were conducted in-house by Phoenix. Cryptopidae sequences analysed together with six cryptopid sequences from the Pilbara in order to determine similarity (Phoenix unpublished data) and an interpretation of their sequence divergence was limited to an impact vs. non-impact area on Varanus Island. Two out-group specimens were selected from the National Center for Biotechnology Information (NCBI) (http://www.ncbi.nlm.nih.gov/genbank/) ("GenBank") from the order Geophilomorpha (soil centipedes): *Mecistocephalus multidentatus* (accession AB610774) and *M. diversisternus* (accession AB610776) (family Mecistocephalidae).

Searches on GenBank yielded no sequences for *Quistrachia* land snails but reference sequences were be made available through M. Johnson (UWA). Ample reference sequence data was available for *Rhagada* through GenBank which were lodged after recent molecular studies of the genus, including some specimens from Barrow Island: *Rhagada plicata*, *R*. 'barrow small' - MSJ-2012, *R*. 'barrow large' - MSJ-2012 (Johnson *et al.* 2004; Johnson *et al.* 2012). Additional COI sequences were added to further increase robustness of the analysis (Table 3-5).

Table 3-5 COI sequences from GenBank used in the molecular identification of camaenid snails from Varanus Island

Family	Genus and species	GenBank accession no.
Amastridae	*Amastra micans*	AY148558
Amastridae	*Laminella sanguinea*	AY148557
Partulidae	*Eua zebrina*	AY148566
Partulidae	*Partula gibba*	AY148567
Partulidae	*Partula radiolata*	AY148568
Partulidae	*Partula* BSH-2002	AY148570
Partulidae	*Partula thetis*	AY148569
Partulidae	*Samoana thurstoni*	AY148565
Achatinidae	*Achatina fulica*	AY148556
Camaenidae	*Amphidromus* BSH-2002	AY148562
Camaenidae	*Rhagada dominica*	JQ362664
Camaenidae	*Rhagada dringi*	JQ362674
Camaenidae	*Rhagada elachystoma*	JQ362709
Camaenidae	*Rhagada globosa*	JQ362697
Camaenidae	*Rhagada intermedia*	JQ362702
Camaenidae	*Rhagada minima*	JQ362705
Camaenidae	*Rhagada perprima*	JQ362712
Camaenidae	*Rhagada pilbarana*	JQ362683
Camaenidae	*Rhagada plicata*	JQ362721
Camaenidae	*Rhagada plicata*	JQ362722
Camaenidae	*Rhagada primigena*	JQ362668

Family	Genus and species	GenBank accession no.
Camaenidae	*Rhagada radleyi*	JQ362685
Camaenidae	*Rhagada reinga*	JQ362671
Camaenidae	*Rhagada* 'sp. 12' MSJ-2012	JQ362717
Camaenidae	*Rhagada* 'sp. 12' MSJ-2012	JQ362718
Camaenidae	*Rhagada* 'barrow large' MSJ-2012	JQ362725
Camaenidae	*Rhagada* 'barrow large' MSJ-2012	JQ362726
Camaenidae	*Rhagada* 'barrow small' MSJ-2012	JQ362723
Camaenidae	*Rhagada* 'barrow small' MSJ-2012	JQ362724
Euconulidae	*Philonesia harmanni*	AY148563
Euconulidae	*Philonesia* BSH-2002	AY148564
Bradybaenidae	*Bradybaena similaris*	AY148559
Bulimulidae	*Rhabdotus alternatus*	AY148561
Orthalicidae	*Placostylus ambagiosus*	AY148560
Succineidae	*Catinella baldwini*	AY148571
Succineidae	*Catinella rotundata*	AY148574
Succineidae	*Succinea canella*	AY148572
Succineidae	*Succinea modesta*	AY148575
Succineidae	*Succinea rubella*	AY148573

3.4.2.2 Sequence analysis

The Polymerase Chain Reaction (PCR) products were sequenced for both DNA strands at the AGRF node Perth (Western Australian Institute of Medical Research, WA, Australia).

For mygalomorph spiders, the sequences were edited using Geneious Pro 5.5.6 (Drummond *et al.* 2012) and aligned with the reference dataset using Geneious' building in alignment algorithm. Geneious Pro 5.5.6 was used to detect the presence of Nuclear Mitchondrial Genes (Pseudogenes) by translating each *COI* sequence with the standard invertebrate and *Drosophila* codes. Mygalomorph spider sequence data was than compared to the dataset of the WA Museum (Castalanelli & Harvey 2012).

For cryptopid centipedes and land snails, sequences were also edited using Geneious software, but alignment was performed with CLUSTAL X (Thompson *et al.* 1997)). Genetic distances between unique DNA sequences were measured using total percentage of differences between sequences. MODELTEST (Posada & Crandall 1998) and PAUP* (Swofford 2002) software determined that the best model of sequence evolution to fit these data was GTR+I+G. Bayesian analysis was undertaken using MrBayes (Huelsenbeck & Ronquist 2001) through the MrBayes Plugin for Geneious. The analysis involved running two trees simultaneously, each running four simultaneous Markov chain Monte Carlo (MCMC) chains. The analyses were run for 5 million replications with a "burn-in" of 1 million cycles and subsampling every 10,000 replications.

As no reference sequence data for *Quistrachia* land snails was available from GenBank, the Varanus Island sequences were forwarded to M. Johnson (University of Western Australia) for analysis.

3.4.3 Nomenclature

The nomenclature of described invertebrates and higher taxa follows a number of taxon-specific references, most of which are available online (Table 3-6). However, many SRE invertebrate species are currently unnamed and morphospecies designations listed in this report are adopted from the nomenclatural systems developed by the respective taxonomic authorities.

Reference collections generally reside with WA Museum and morphospecies designations generally follow listings developed by the WA Museum (Table 3-6) as expected by the EPA (EPA 2004).

Table 3-6 Nomenclatural references, morphospecies designations and reference collections

Taxonomic group	Taxonomic reference for described species and higher taxa	Morphospecies designation and reference collection
Araneae (Mygalomorphae)	Platnick (2012)	"MYG"-morphospecies designation developed by V.W. Framenau (WAM, Phoenix), reference collection at WAM
Araneae (Araneomorphae: Selenopidae)	Platnick (2012)	Morphospecies designations developed by M. Harvey (WAM) and V.W. Framenau (WAM, Phoenix), reference collection at WAM
Pseudoscorpiones	Harvey (2011a)	"PSE"-morphospecies designations developed by M. Harvey (WAM), reference collection at WAM
Scorpiones	Rein (2011), Fet *et al.* (2000), Glauert (1925), Koch, (1977), Kovařík (1997), Kovařík (2002), Volschenk and Prendini (2008)	Morphospecies designation developed by E.S. Volschenk (WAM, Phoenix), reference collection at WAM
Diplopoda (Polydesmida: *Antichiropus*)	Mesibov (2006)	"DIP"-morphospecies designation developed C. Car and M. Harvey (WAM), reference collection at WAM
Chilopoda (Geophilomorpha, Cryptopidae only)	Colloff *et al.* (2005); Minelli *et al.* (2006 onwards)	Taxonomically poorly studied groups, no reference collection available
Mollusca	Smith (1992); C. Whisson (pers. comm.)	Morphospecies designations developed by C. Whisson and S. Slack-Smith (WAM), reference collection at WAM
Isopoda	Schotte *et al.* (2008)	Morphospecies designations developed by S. Judd, reference material at WAM

3.5 STATISTICAL ANALYSES

Species estimation curves were compiled to obtain an estimate of survey completeness, i.e. whether the collection adequately represents the SRE invertebrate fauna of the study area. Individual-based taxon accumulation curves were plotted in favour of sample-based curves, as they assess species richness rather than density (Gotelli & Colwell 2001).

Analyses were limited to SRE target taxa for the survey, i.e. spiders, pseudoscorpions, selenopid isopods and land snails. Centipedes were not analysed as they could not be identified to species level due to a lack of taxonomic resolution, and scorpions were not analysed due to the lack of specimens collected. The analysis was conducted with the lowest identified taxon rank, i.e. species or morphospecies. If a single morphospecies for a genus was found (e.g. *Laevophiloscia* sp. indet.), indeterminable life stages within this genus such as juveniles or females were assumed to be conspecific and were therefore combined for the analysis. This approach resulted in conservative species estimates, thereby avoiding artificially inflating the number of species with juvenile 'pseudospecies'. In contrast, when multiple morphospecies within a genus were found, indeterminable life stages were excluded from the analyses (e.g. Olpiidae sp. indet.)

Taxon richness from Mao Tau estimates (Colwell *et al.* 2004) was calculated using the software package EstimateS v8.2 (Colwell 2009) with 999 randomizations. In addition, the abundance based, non-parametric species estimators ACE, Chao1 and Jack Knife1 were used to estimate the total number of each taxa group within the study area. These estimators were chosen as they are insensitive to pooling collection data ("grain size") and perform well when tested against real data (Hortal *et al.* 2006; Walther & Moore 2005).

A number of important limitations must be considered when interpreting the species accumulation results. The above analyses do not extrapolate the total species numbers within the study area, but provide estimates for the circumstances under which the data were collected. They reflect potential results for more comprehensive surveys (i.e. more samples), but with the same methods in the same habitats at the same time of the year. Total species numbers for the study area may be higher, when seasonal variations are considered.

The species accumulation data is based on SRE target taxa collected in the survey, not just those species considered to belong to one of the three SRE categories. It is impossible to provide statistically reliable estimates on actual SREs in the study area due to the low number of individuals collected. The likelihood of finding more SREs was based on the estimate for each group and their likelihood to contain SREs.

3.6 SURVEY PERSONNEL

The personnel involved in the survey are presented (Table 3-7).

Table 3-7 Project team

Name	Qualifications	Role/s
Dr Volker W. Framenau	M.Sc. (Cons. Biol.), Ph.D. (Zool.)	Project Manager, taxonomy, report writing
Ms Anna Leung	B.Sc. (Env. Sci.) (Hons)	Field surveys, taxonomy, report writing, GIS
Ms Kate Penwarden	B.Sc. (Zool.) (Hons)	Field surveys, lab work
Dr Erich Volschenk	Ph.D. (Biology)	Taxonomy; report writing, genomic analysis
Mrs Melanie White	B.Sc. (Biology) (Hons)	Report review

4 RESULTS

4.1 DESKTOP REVIEW

No database search results where available from the WA Museum Department of Aquatic Zoology's Crustacea database (A. Hosie 2012, email to Volker Framenau) and WA Museum Subterranean Research database (J. Waldock 2012, email to Volker Framenau). Therefore primary distribution data were not available in particular for some taxa of the troglofauna and the stygofauna desktop review and consequently, stygofauna SRE records could not be mapped. The stygofauna desktop review used Chevron (2012) as initial and most recent reference; however, the taxon lists provided there date back to at least 2007 (Biota 2005, 2007; Biota & RPS 2005b). A critical taxonomic assessment was conducted here to assure that the desktop review for Varanus Island is up-to-date.

Barrow Island has very close biogeographic links with Cape Range, in particular in relation to subterranean fauna (Humphreys 1993b; Humphreys 2000b). With a distance of approximately 150 km south of Varanus Island, Cape Range falls outside the area of the desktop review and the nominal range for short-range endemism; however, invertebrates that can be found only on Barrow Island and Cape Range are here considered SREs. This is consistent with the size of their potential distributional range which does not include the sea in between.

4.1.1 Terrestrial invertebrates

A total of 68 terrestrial SREs taxa in at least 22 families and 40 genera were identified in the desktop review (Table 4-1; Appendix 2). The majority of the search results came from nearby islands; 34 taxa (= 50%) from the review are currently known from Barrow Island only.

Most taxa were reported through the WA Museum Arachnology/Myriapodology and Mollusca database searches, but some records were from other data sources, including a *Barrowdillo* isopod and some *Rhagada* snails (reported in Dalens 1993; Johnson *et al.* 2012).

Only three of the terrestrial SRE taxa recovered in the desktop review were from Varanus Island, including the trapdoor spider *Aname* sp. indet., *Rhagada plicata* and *Quistrachia barrowensis* (Table 4-1; Figures 4-1 - 4-6).

The desktop review returned 21 described species (31%), which represents a comparatively high percentage for the Pilbara and neighbouring regions. This is driven mainly by camaenid snails (12 species) which have been taxonomically treated along the Pilbara coast (Johnson *et al.* 2012; Solem 1997).

The scorpion *Urodacus* 'linnaei' listed as SRE from Barrow Island in Chevron's (2011) monitoring plan has recently been named (*U. butleri*) and reported from a variety of places in the Pilbara (Volschenk *et al.* 2012). It is not an SRE.

Table 4-1 Short-range endemic terrestrial invertebrates identified through the desktop review for the Varanus Island Fill Project

Family	Genus	Species	Locality	SRE category[a]	Data source, remarks
Acari (mites)					
Laelapidae	*Haemolaelaps*	*marsupialis*	Barrow Island	Confirmed	WAM; Biota (2005a)
	Mesolaelaps	*antipodianus*	Barrow Island	Confirmed	WAM; Biota (2005a)
Araneae – Araneomorphae (modern spiders)					
Ammoxenidae	*Barrowammo*	*waldockae*	Barrow Island	Confirmed	WAM; Platnick (2002)
Miturgidae	*Miturga*	'serrata'	Barrow Island	Confirmed	WAM; Biota (2005a)
Oonopidae	*`Orchestina?`*	'Barrow sp. 2'	Barrow Island	Potential	WAM
	Grymeus	'nasutus'	Barrow Island	Potential	WAM
	Orchestina	'barrow'	Barrow Island	Confirmed	WAM; Biota (2005a)
	Pelicinus	*saaristoi*	Barrow Island	Confirmed	WAM; Ott and Harvey (2008)
Selenopidae	*Karaops*	*burbidgei*	Barrow Island	Confirmed	WAM; Crews and Harvey (2011)
Zodariidae	*Spinasteron*	*casuarium*	Enderby Island (near Dampier)	Confirmed	WAM; Baehr and Churchill (2003)
Araneae – Mygalomorphae (trapdoor spiders)					
Actinopodidae	*Missulena*	sp. indet.	Mardie Station; Barrow Island	Potential	WAM; Curtin University collection
Barychelidae	*Aurecocrypta*	'po3'	Mardie	Potential	WAM
		'Barrow sp. 1'	Barrow Island	Potential	WAM
	Idiommata	sp. indet.	Barrow Island	Potential	WAM
	Synothele	'preston'	Mardie	Potential	WAM
		butleri	Barrow Island	Confirmed	WAM; Raven (1994)
Ctenizidae	*Conothele*	'Barrow sp. 1'	Barrow Island	Potential	WAM
		'Barrow sp. 2'	Barrow Island	Potential	WAM
		'Barrow sp. 3'	Barrow Island	Potential	WAM
Idiopidae	*Eucyrtops*	'sp. (juv.)'	Karratha	Potential	WAM
	Euoplos	'MYG081'	Lake Poongkaliyarra	Potential	WAM
		'MYG218'	Barrow Island	Potential	WAM
Nemesiidae	*Aname*	sp. indet.	Barrow Island; Varanus Island;	Potential	WAM; also includes specimens

Family	Genus	Species	Locality	SRE category[a]	Data source, remarks
			Karratha; Dampier		identified as 'Barrow Island', '*mainae* species-group'
		'MYG079'	Barrow Island	Likely	WAM
	Kwonkan	'po2'	Mardie	Potential	WAM
	Yilgarnia	'Barrow sp. 1'	Barrow Island	Potential	WAM
Pseudoscorpiones (pseudoscorpions)					
Garypidae	*Anagarypus*	*heatwolei*	Barrow Island	Confirmed	WAM; Muchmore (1982)
	Synsphyronus	'PSE032'	Barrow Island	Confirmed	WAM; Biota (2005a)
		'sp. B'	Roebourne	Likely	WAM
	Protogarypinus	'sp.'	Barrow Island	Likely	WAM
Scorpiones (scorpions)					
Buthidae	*Isometroides*	'barrow'	Barrow Island	Potential	WAM
	Lychas	'glauteri'	Barrow Island	Confirmed	WAM
Urodacidae	*Aops*	'ops'	Barrow Island	Confirmed	WAM
Diplopoda (millipedes)					
Paradoxosomatidae	*'DIPAAA'*	'DIP020'	NW of Mt Prinsep	Confirmed	WAM
	Antichiropus	'DIP025'	Mt Welcome Station	Confirmed	WAM
		sp. indet.	Karratha Station; Wickham Marda Pool; Mt Roe; Dampier; Mardie station; Mt Roebourne; Karratha-Millstream-Chichester National Park	Confirmed	WAM
	Boreohesperus	'DIP001'	Barrow Island	Confirmed	WAM
		'DIP022'	Marda Pool	Confirmed	WAM
	Antichiropus	sp. indet.	Barrow Island	Confirmed	WAM
Chilopoda (centipedes)					
Lithobiomorpha fam.	*'Barrow gen. 1'*	'Barrow sp. 1'	Barrow Island	Potential	WAM

Family	Genus	Species	Locality	SRE category[a]	Data source, remarks
indet.					
Geophilomorpha fam. indet.	*'Barrow gen. 2'*	'Barrow sp. 1'	Barrow Island	Potential	WAM
	'Barrow gen. 3'	'Barrow sp. 1'	Barrow Island	Potential	WAM
	'Barrow gen. 4'	'Barrow sp. 1'	Barrow Island	Potential	WAM
Cryptopidae	*Cryptops*	sp. indet.	Anketell Rail Corridor, NNW Tom Price, Barrow Island	Potential	WAM; Curtin University collection
Isopoda (slaters)					
Armadillidae	*Barrowdillo*	*pseudopyrgoniscus*	Barrow Island	Likely	Dalens (1993)
Gastropoda (land snails)					
Bithyniidae	*Gabbia*	sp. indet.	Karratha	Potential	WAM
Camaenidae	cf. *Kimboraga*	sp. indet.	Dampier Archipelago	Confirmed	WAM
	Quistrachia	*barrowensis*	Barrow Island; Varanus Island	Confirmed	WAM; possibly conspecific with *Q. montebelloensis* (C. Whisson personal communication)
		herberti	Karratha	Confirmed	WAM
		legendrei	Dampier Archipelago	Confirmed	WAM
		montebelloensis	Montebello Islands	Confirmed	WAM; possibly conspecific with *Q. barrowensis* (C. Whisson personal communication)
		'sp. W'	Karratha	Confirmed	WAM
		'sp. X'	Karratha	Confirmed	WAM
	Rhagada	*angulata*	Dampier Archipelago	Confirmed	WAM; Johnson *et al.* (2012)
		dampierana	Dampier Archipelago	Confirmed	WAM; Johnson *et al.* (2012)
		elachystoma	Dampier Archipelago	Confirmed	WAM; Johnson *et al.* (2012)
		intermedia	Dampier Archipelago	Confirmed	WAM; Johnson *et al.* (2012)
		minima	Dampier Archipelago	Confirmed	WAM; Johnson *et al.* (2012)
		perprima	Dampier Archipelago	Confirmed	WAM; Johnson *et al.* (2012)

Family	Genus	Species	Locality	SRE category[a]	Data source, remarks
		plicata	Montebello Islands; Varanus Island	Confirmed	WAM; Johnson *et al.* (2012)
		pilbarana	Karratha	Confirmed	WAM; Johnson *et al.* (2012)
		'sp. HC', 'sp. HP', 'sp. C' and 'sp. 12'	Dampier Archipelago	Confirmed	Johnson *et al.* (2012)
		'barrow small'	Barrow Island	Confirmed	WAM; Johnson *et al.* (2012); possibly conspecific with *R. plicata* (C. Whisson personal communication)
		'barrow large'	Barrow Island	Confirmed	WAM; Johnson *et al.* (2012)
		'Hearson Cove'	Hearson Cove	Confirmed	WAM
Pupillidae	*Gastrocopta*	'CW1'	Barrow Island	Potential	WAM

a – see section 2.5.3 for explanation of SRE categories.

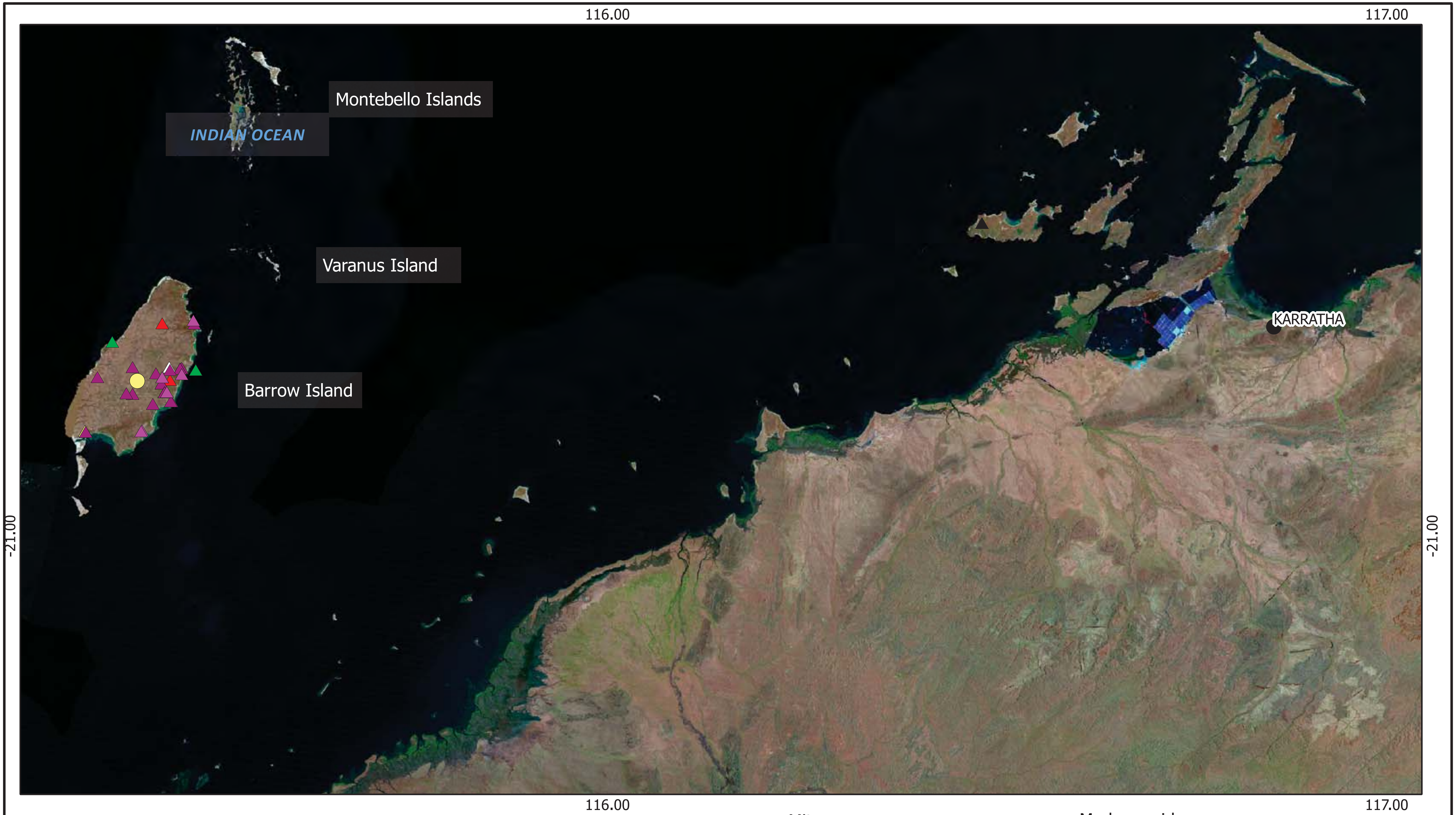


Figure 4-1 **Records of short-range endemic mites (Acari) and modern spiders (Araneomorphae) from the desktop review**	PHOENIX ENVIRONMENTAL SCIENCES
AUTHOR: A.E. Leung	**CLIENT:** Apache Energy Ltd
DATE: August 2012	**Scale:** 1:550000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	**PROJECT:** Varanus Island Fill Project

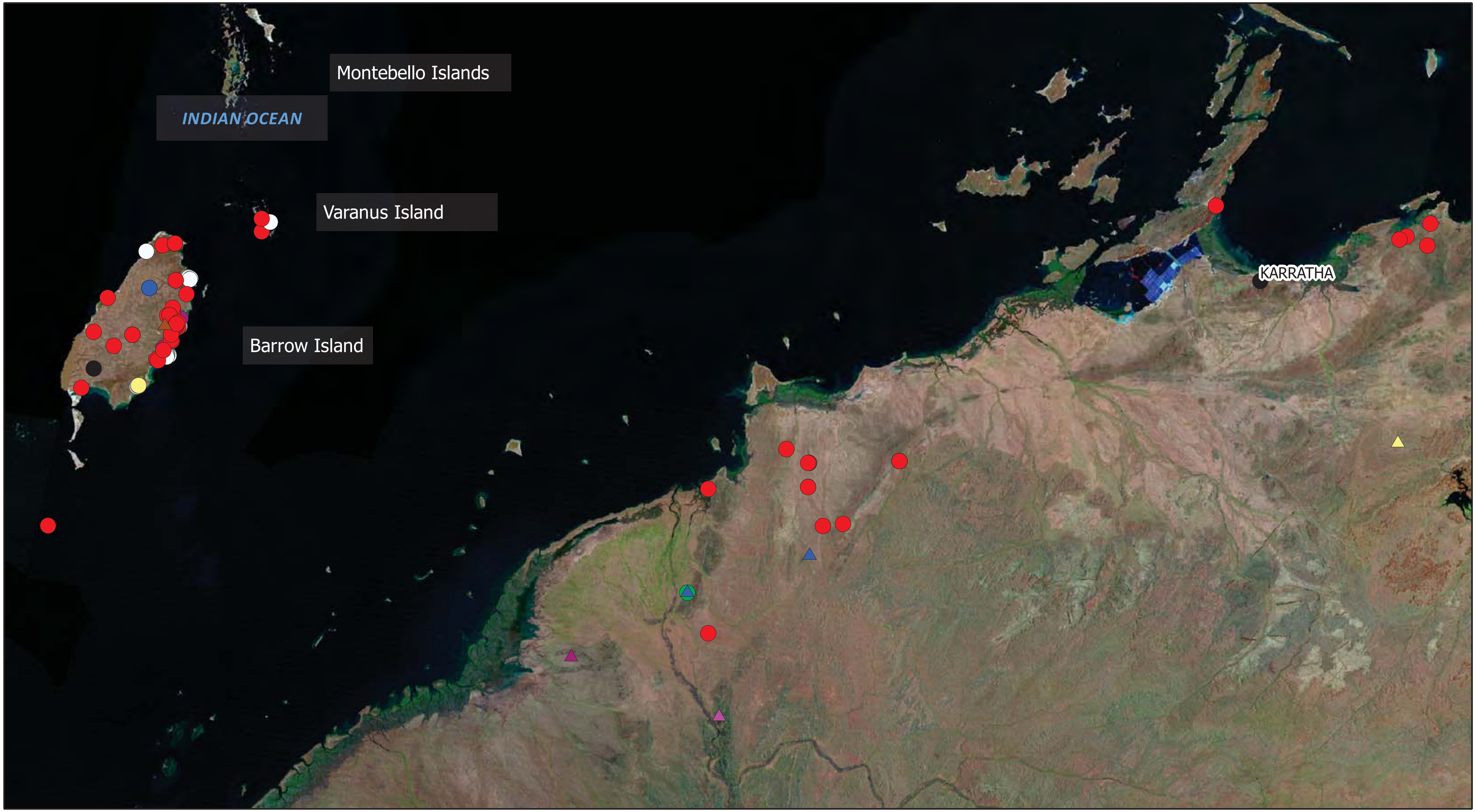
Mites
- Haemolaelaps marsupialis
- Mesolaelaps antipodianus

Modern spiders
- 'Orchestina?' 'Barrow sp. 2'
- Barrowammo waldockae

Modern spiders
- Grymeus 'nasutus'
- Karaops burbidgei
- Miturga 'serrata'
- Orchestina 'barrow'
- Pelicinus saaristoi
- Spinasteron casuarium

0 5 10 km

N



Aname 'MYG079'
Aname 'MYG178'
Aname sp. indet.
Aurecocrypta 'po3'
Aureocrypta 'Barrow sp. 1'
Conothele 'Barrow sp. 1'
Conothele 'Barrow sp. 2'
Conothele 'Barrow sp. 3'
Eucyrtops sp. (juv.)
Euoplos 'MYG081'
Euoplos 'MYG218'
Idiommata sp.
Kwonkan 'po2'
Missulena sp.
Synothele 'preston'
Synothele butleri
Yilgarnia 'Barrow sp. 1'

0 5 10 km

N

Figure 4-2
Records of short-range endemic trapdoor spiders (Mygalomorphae) from the desktop review

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	**CLIENT: Apache Energy Ltd**
DATE: August 2012	**Scale: 1:580000**
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PROJECT: Varanus Island Fill Project

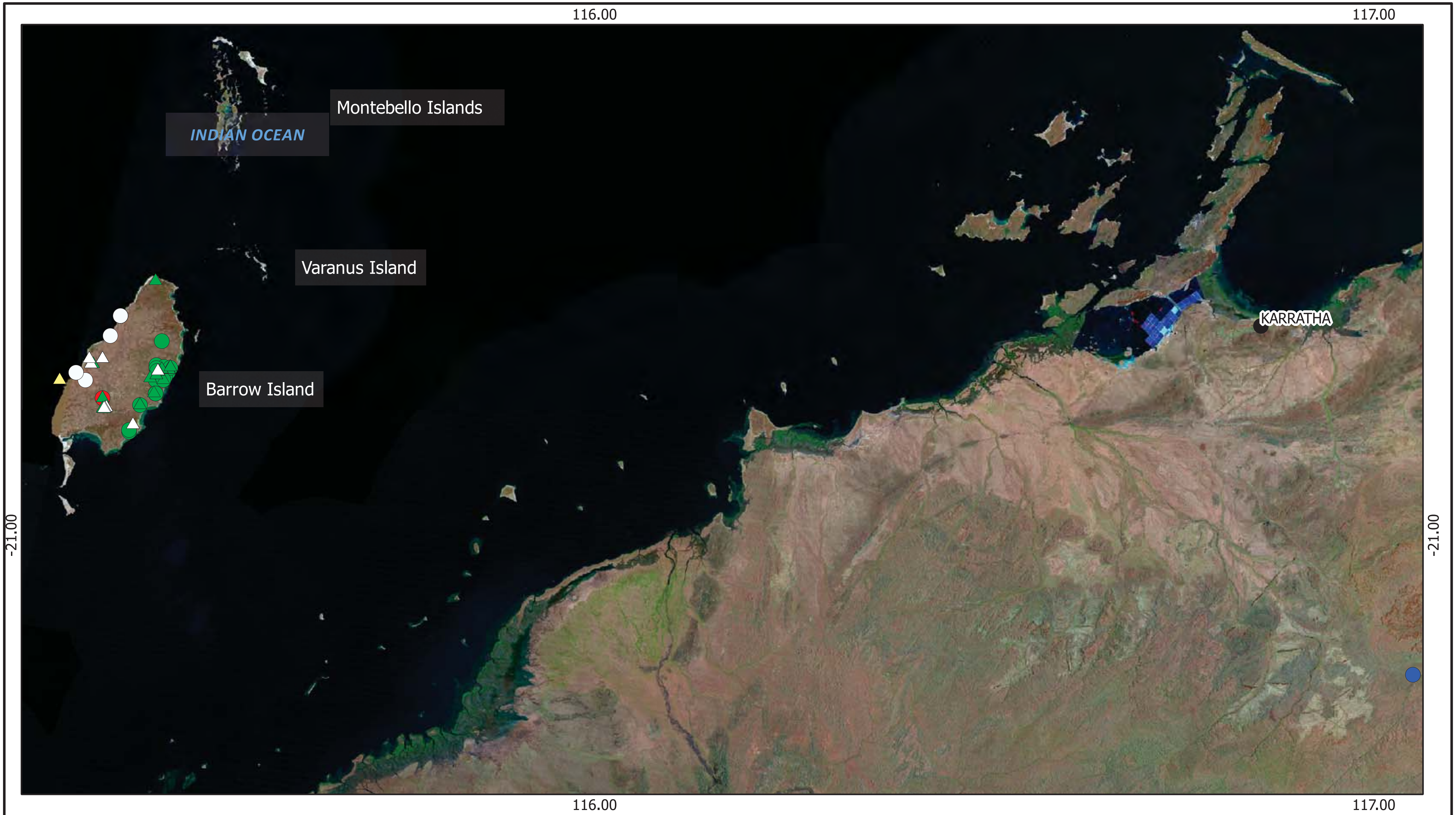
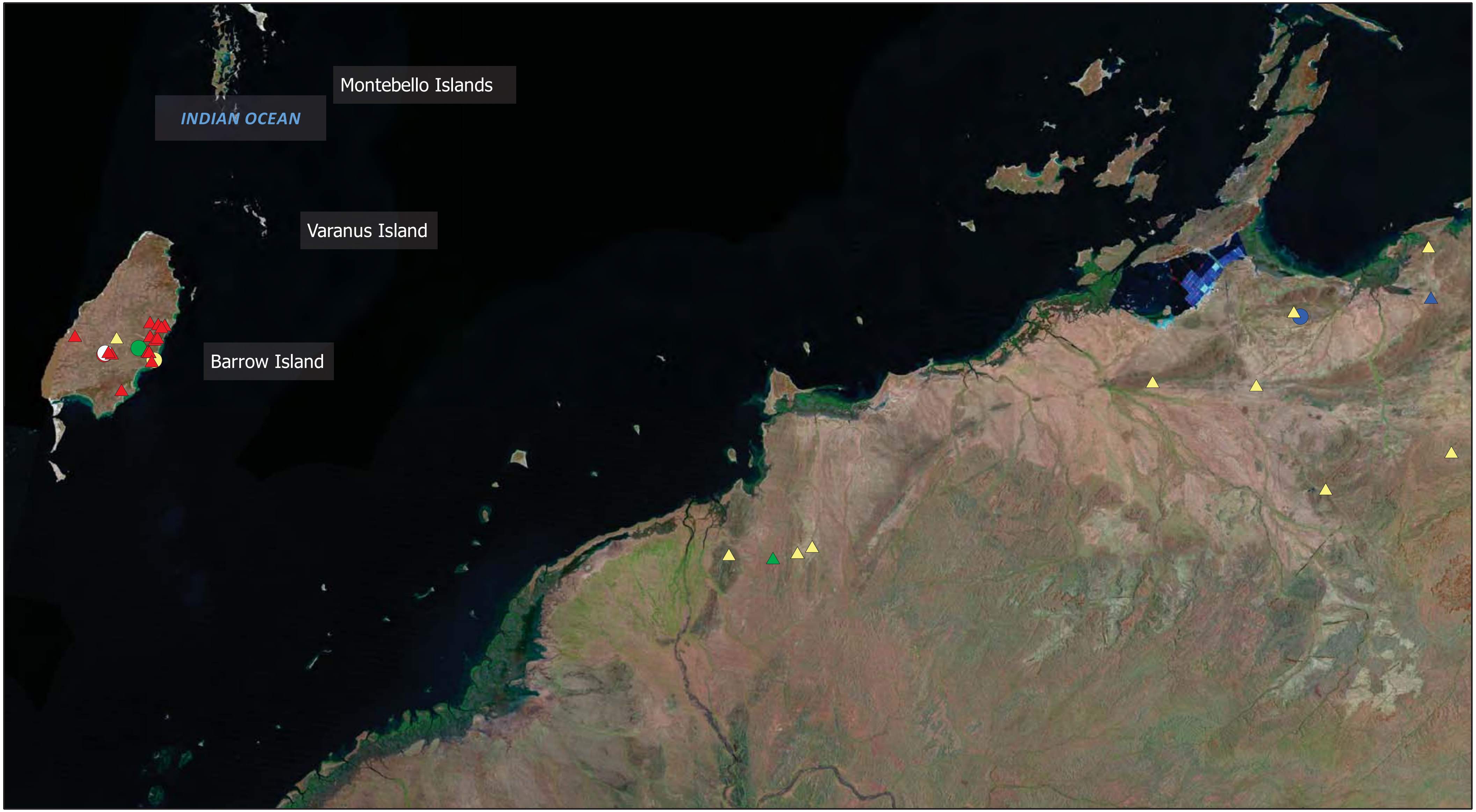


Figure 4-3
Records of short-range endemic pseudo-scorpions (Pseudoscorpiones) and scorpions (Scorpiones) from the desktop review

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	**CLIENT: Apache Energy Ltd**
DATE: August 2012	**Scale: 1:550000**
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PROJECT: Varanus Island Fill Project



Millipedes
- 'Barrow gen. 1' 'Barrow sp. 1'
- 'Barrow gen. 2' 'Barrow sp. 1'
- 'Barrow gen. 3' 'Barrow sp. 1'
- 'Barrow gen. 4' 'Barrow sp. 1'
- 'DIPAAA' 'DIP020'
- Antichiropus 'DIP025'

Millipedes
- Antichiropus sp. indet.
- Boreohesperus 'DIP001'
- Boreohesperus 'DIP022'

Centipedes
- Cryptops sp indet.

0 5 10 km

N

Figure 4-4
Records of short-range endemic centipedes (Chilopoda) and millipedes (Diplopoda) from the desktop review

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:550000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	PROJECT: Varanus Island Fill Project

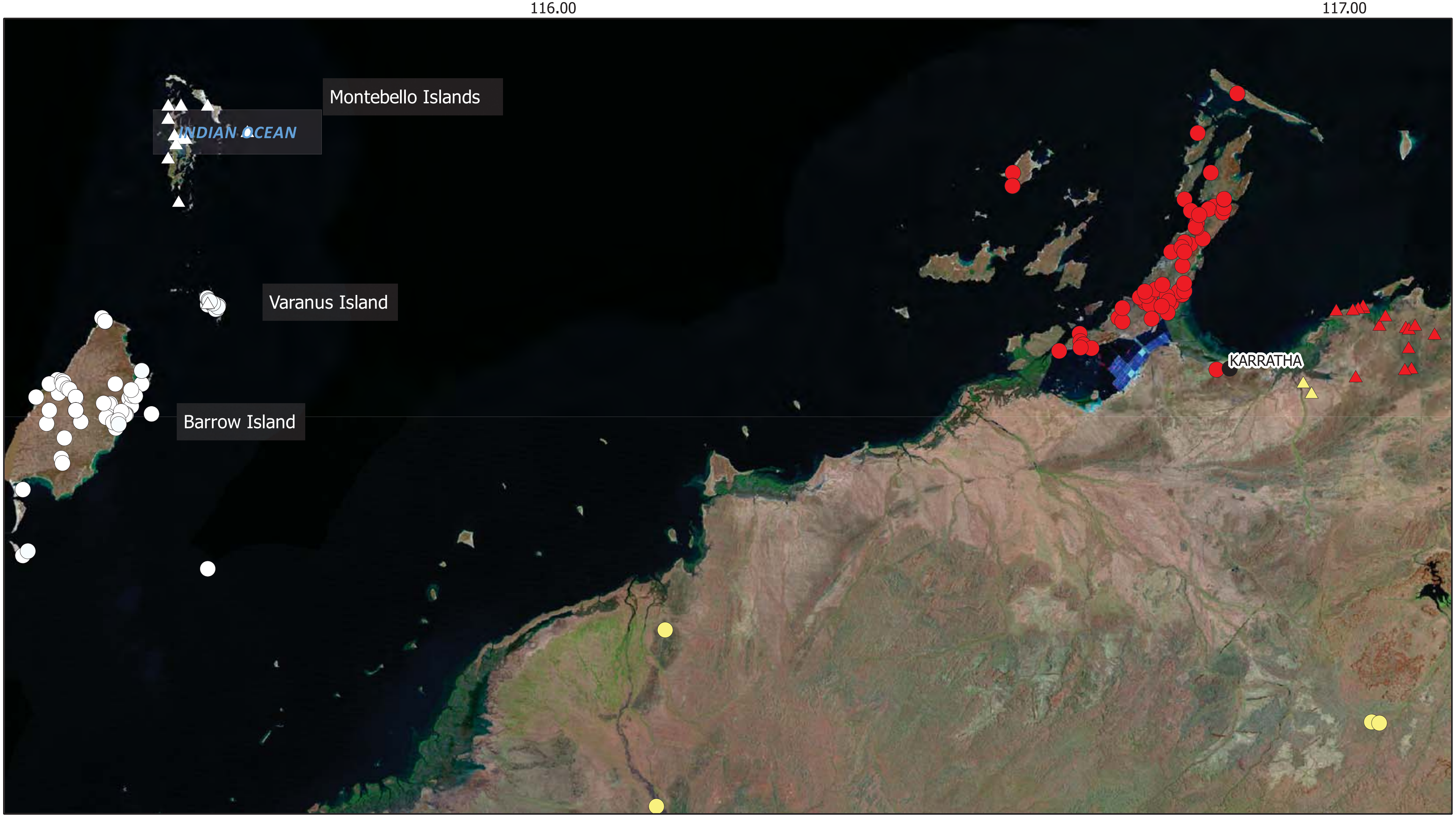


Figure 4-5
Records of short-range endemic Quistrachia snails (Mollusca) from the desktop review

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:560000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PHOENIX ENVIRONMENTAL SCIENCES

PROJECT: Varanus Island Fill Project

- Quistrachia barrowensis
- Quistrachia herberti
- Quistrachia legendrei
- Quistrachia montebelloensis
- Quistrachia 'nov. W'
- Quistrachia 'nov. X'

0 5 10 km

N

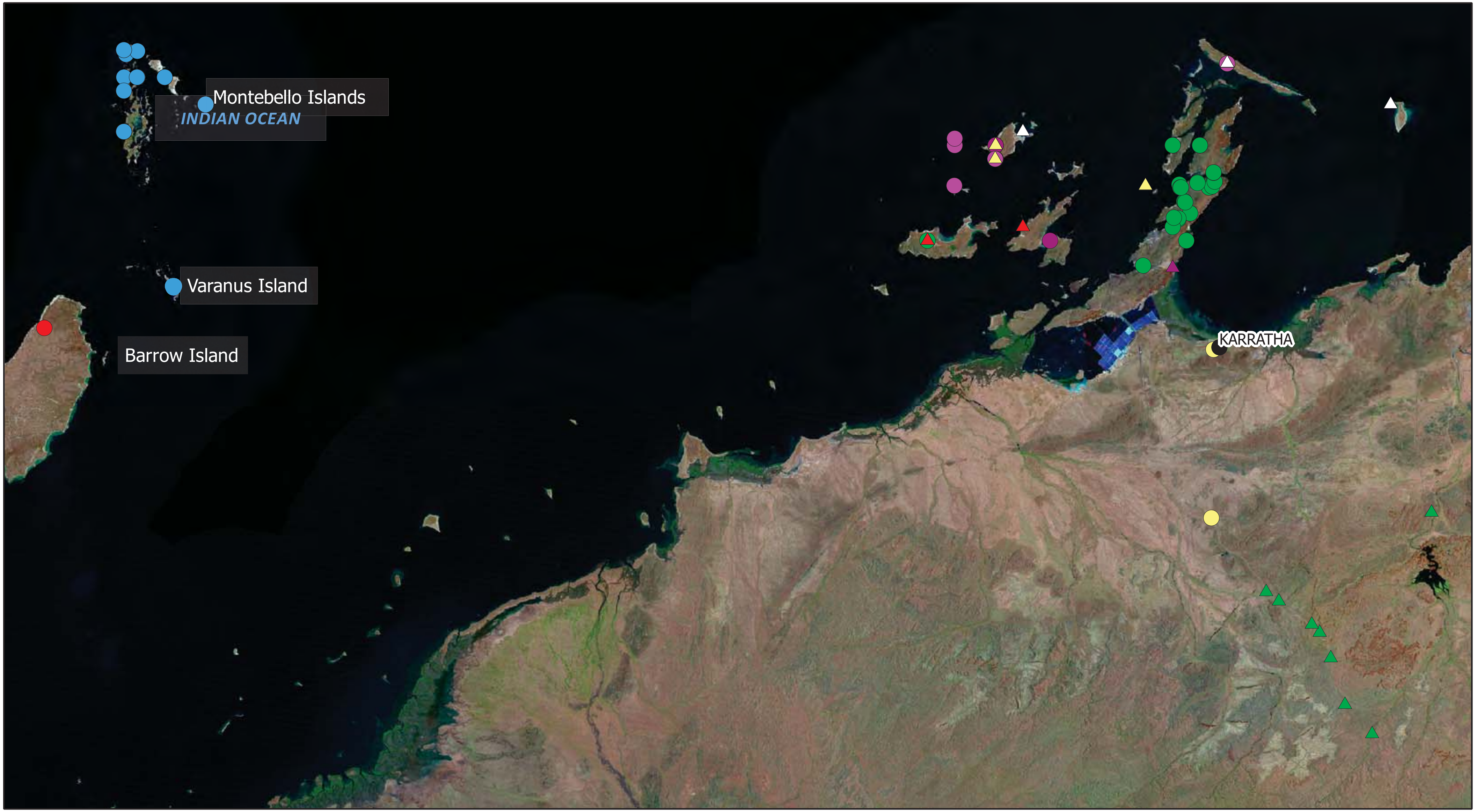


Figure 4-6
Records of short-range endemic Rhagada, Gastrocopta, Gabbia, and Kimboraga snails (Mollusca) from the desktop review

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:550000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PROJECT: Varanus Island Fill Project

- cf. Kimboraga sp.
- Gabbia aff. smithii
- Gastrocopta 'CW1'
- Rhagada angulata
- Rhagada plicata
- Rhagada dampierana
- Rhagada elachystoma
- Rhagada intermedia
- Rhagada minima
- Rhagada perprima
- Rhagada pilbarana
- Rhagada 'Hearson Cove'

0 5 10 km

N

4.1.2 Subterranean invertebrates

4.1.2.1 Troglofauna

No troglobitic SRE taxa were recovered from Varanus Island in the desktop review.

A total of 15 SRE troglofauna taxa were identified in from other sites (Table 4-2) in at least ten families and 11 genera. Twelve of the 15 records (= 80%) are recorded from Barrow Island. Two of these are listed on Schedule 1 of the WA Act, the schizomid *Draculoides bramstokeri* (Hubbardiidae) and the millipede *Speleostrophus nesiotes* (Trigoniulidae) (Table 4-2).

Some of these taxa, i.e. slaters, symphylans, cockroaches and silverfish, could not be mapped as their records were based on reports without exact locality data (mainly Chevron 2012) and not on the review of original collection data, e.g. through the WA Museum database (Figure 4-7).

The desktop review returned six described species (= 40%). This comparatively large percentage mainly reflects ongoing research on troglofauna arachnids and myriapods at the WA Museum which commenced in the Cape Range region of WA in the early 1990s (e.g. Harvey *et al.* 1993; Humphreys 1990; Humphreys & Shear 1993).

The recent troglofauna synopsis of Barrow Island (Chevron 2012) was critically reviewed and some listings are amended as they are at odds with the data obtained by us through the WA Museum:

- "**Arachnida** Scorpiones sp. *bramstokeri*" could not be associated with any subterranean scorpion species on Barrow Island. The only subterranean scorpion known from Barrow Island is *Aops oncodactylus*, described by Volschenk and Prendini (2008) (Table 4-2)
- "**Araneae** Gnaphosidae sp." was excluded as no confirmed subterranean member of this family was returned in the database search of the WA Museum. Gnaphosidae are a mega-diverse epigaeic spider family; the Australian fauna is under revision by V. Ovtsharenko (New York). The Gnaphosidae collection of the WA Museum needs to be critically reviewed if it contains any troglobitic specimens of the Gnaphosidae.
- "**Isopoda** *Oniscidea pseudopyrgoniscus dalens"* most likely refers to *Barrowdillo pseudopyrgoniscus* Dalens, 1993. Although this isopod species was described from specimens collected in caves on Barrow Island, Dalens (1993) in his original description clearly states that "it is not a troglobite and probably also lives outside caves". It is here omitted from the troglofauna desktop review but included within the terrestrial SREs (Table 4-1)
- "**Scolopendrida** Cryptopidae sp." is here also listed as part of the terrestrial SRE fauna desktop review (Table 4-1). It is difficult to establish if these are troglobites as the terrestrial epigean cryptopids posess troglobitic features such as lack of eyes, pale colouration and attenuated legs and antennae.

Table 4-2 Short-range endemic troglobitic invertebrates identified through the desktop review for the Varanus Island Fill Project

Family	Genus	Species	Locality	SRE category[a]	Source, remarks
Pseudoscorpiones (pseudoscorpions)					
Syarinidae	*Ideoblothrus*	*nesotymbus*	Barrow Island	Confirmed	WAM; Harvey and Edward (2007)
		westi	Fortescue River	Confirmed	WAM; Harvey and Edward (2007)
Chthoniidae	*Tyrannochthonius*	*garthhumphreysi*	Barrow Island	Confirmed	WAM; Edward and Harvey (2008)
Schizomida (schizomids)					
Hubbardiidae	*Draculoides*	*bramstrokeri*	Barrow Island, Cape Range	Confirmed	WAM; NatureMap; Harvey and Humphreys (1995); Schedule 1 (Western Australian Government 2012)
	'gen. indet.'	'SCH006'	Pannawonica	Likely	WAM
	'gen. nov.'	'Cape Preston'	Cape Preston	Likely	WAM
Scorpiones (scorpions)					
Urodacidae	*Aops*	*oncodactylus*	Barrow Island	Confirmed	WAM; Volschenk and Prendini (2008)
Diplopoda (millipedes)					
Trigoniulidae	*Speleostrophus*	*nesiotes*	Barrow Island	Confirmed	WAM; NatureMap; (Hoffman 1994); Schedule 1 (Western Australian Government 2012)
		sp.	Barrow Island	Likely	WAM
Symphyla (symphylans)					
	gen. indet.	sp. indet.	Barrow Island	Likely	Chevron (2012); many symphylans are epigean
Isopoda					
Oniscidea	gen. indet.	sp. indet.	Barrow Island	Likely	Chevron (2012); assessment difficult without further taxonomic resolution
Philosciidae	gen. indet.	sp. indet.	Barrow Island	Likely	Chevron (2012)

Family	Genus	Species	Locality	SRE category[a]	Source, remarks
Blattodea (cockroaches)					
	gen. indet.	sp. nov. 1	Barrow Island	Likely	Chevron (2011); Chevron (2012); possibly *Nocticola*?
	Nocticola	sp. nov.	Barrow Island	Likely	Biota and RPS (Biota & RPS 2005b)
Thysanura (silverfish)					
Nicelotiidae	*Trinemura*	sp. nov.	Barrow Island	Likely	Chevron (2012)

a – see section 2.5.3 for explanation of SRE categories.

Schizomids
- 'gen. indet.' 'SCH006'
- 'gen. nov.' 'Cape Preston'
- Draculoides bramstokeri

Millipedes
- Speleostrophus 'sp.'
- Speleostrophus nesiotes

Pseudoscorpions
- Ideoblothrus nesotymbus
- Ideoblothrus westi
- Tyrannochthonius garthhumphreysi

Scorpion
- Aops oncodactylus

N

0 5 10 km

Figure 4-7
Records of troglofauna from the desktop review

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:310000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	PROJECT: Varanus Island Fill Project

4.1.2.2 Stygofauna

The desktop review revealed a single reference to stygofauna from Varanus Island, by Bradbury and Williams (1997, p. 250), who state "Although the taxa described herein significantly increase the already considerable known diversity of subterranean Australian amphipods, still further new taxa await description; material is in our possession or known to us which points to the likelihood of new stygobiont taxa from Queensland *(Chillagoe* sp.), New South Wales, South Australia (north-western, east-central, and southeaster), Tasmania, Western Australia (Barrow Island, Varanus Island, Ashburton River, Nullarbor Plain)."

A total of 36 SRE stygofauna taxa were identified in the desktop review (Table 4-3) in at least 14 families and 21 genera. All taxa were recorded from Barrow Island, although seven also occur on the mainland. Nine amphipods are listed on Schedule 1 of the WA Act, seven of the ten *Nedsia* species (Melitidae), *Bogidomma australis* (Bogidiellidae) and *Hadzia subthalassica* (Hadziidae) (Table 4-3).

No map is supplied for the SRE stygofauna as the records are based on reports and publications often without exact locality data and not on the review of original collection data, e.g. through the WA Museum database.

The desktop review returned 22 described species (= 61%). This comparatively large percentage mainly reflects on ongoing research on stygofauna in Western Australia which commenced in the Cape Range region in the early 1990s (e.g. Humphreys 1993a; Humphreys & Adams 1991; Knott & Humphreys 1993).

Similar to the troglofauna assessment, there are a number of inconsistencies in Chevron's (2012) listing of significant stygofauna from Barrow Island which makes it difficult to use this report as reference for the Varanus Island stygofauna desktop review:

- "**Cyclopoida** *Allocyclops barrowi* n. sp./*A. census*" could not be found in any Copepoda catalogue nor was this treated in Karanovic's (2006) monograph on Pilbara Copepoda that also included Barrow Island. This entry is here presumed to be conspecific with *Dussartcyclops* (*Barrowcyclops*) *consensus*, initially described in the genus *Allocyclops* by Karanovic (2003); only a single female within the subgenus *Barrowcyclops* was ever found on Barrow Island (Karanovic *et al.* 2011).
- **"Cyclopoida** *Halicyclops rochai*" has been excluded from the SRE stygofauna as it one of the most common copepods in the Pilbara (Karanovic 2006); it was initially described from the Robe and Fortescue Rivers (De Laurentiis *et al.* 1999)
- "**Cyclopoida** *Diacyclops* sp." has been excluded as the copepod fauna of Barrow Island has been reviewed and any undescribed species considered to be named (Karanovic 2006)
- "**Cyclopoida** *Diacyclops* aff. *humphreysi*" has similarly been excluded; it is in all likelihood conspecific with *Diacyclops humphreysi unispinosus*, the only species of *Diacyclops* recorded from Barrow Island (Karanovic 2006)
- "**Cyclopoida** species" has been excluded as the copepod fauna of Barrow Island has been reviewed and any undescribed species are considered to be named (Karanovic 2006)
- "**Harpactoida** *Sarsameira* sp." has been excluded as no member of this genus has been reported from Barrow Island (Karanovic 2006)
- "**Harpactoida** *Phyllopodopsyllus* sp. 1" has been excluded as the copepod fauna of Barrow Island has been reviewed and any undescribed species considered to be named (Karanovic 2006)
- "**Harpactoida** *Phyllopodopsyllus thiebaudi*" has been excluded as it is distributed world-wide (Karanovic 2006)

- "**Harpactoida** species" has been excluded as the copepod fauna of Barrow Island has been reviewed and any undescribed species considered to be named (Karanovic 2006)
- "**Harpactoida** Armeiridae sp." is omitted as it is presumed to be *Inermipes humphreysi* or *Biarmeiropsis barrowensis*, the only two armeirid copepod known from Barrow Island (Karanovic 2006).
- **"Copepoda** Calinoida [sic] sp. nov. 1" is omitted as the copepod fauna of Barrow Island has been reviewed and no species of the order Calanoida has been reported from Barrow Island (Karanovic 2006); stygobitic Calanoida, however, are present on Cape Range (Jaume *et al.* 2001)
- **"Amphipoda** *Liagoceradocus subthalassicus*" is here listed in the genus *Hadzia* following proposed synonymy of both genera in Sawicki *et al.* (2004)
- "**Decapoda** *Stygiocaris* sp." was omitted as only one species of *Stygiocaris* has so far been reported from Barrow Island (Page *et al.* 2008).

Table 4-3 Short-range endemic stygofauna invertebrates identified through the desktop review for the Varanus Island Fill Project

Family	Genus	Species	Locality	SRE category[a]	Source, remarks
Crustacea (crustaceans)					
Subclass Copepoda – order Cyclopoida					
Cyclopidae	*Dussartcyclops*	*consensus*	Barrow Island	confirmed	Karanovic *et al.* (2011)
	Halicyclops	*longifurcatus*	Cape Range, Barrow Island	potential	Originally described from Cape Range (Pesce *et al.* 1996); reported from Barrow Island by Biota and RPS (2005b) but not by Karanovic (2006)
	Diacyclops	*humphreysi unispinosus*	Barrow Island, coastal Pilbara	potential	Originally described from Barrow Island by Karanovic (2006); coastal Pilbara in Bennelongia (2007)
Subclass Copepoda – order Harpactoida					
Armeiridae	*Biarmeiropsis*	*barrowensis*	Barrow Island	confirmed	Karanovic (2006)
	Inermipes	*humphreysi*	Barrow Island	confirmed	Lee & Huys (2002)
Tetragonicipidae	*Phyllopodopsyllus*	*wellsi*	Barrow Island, Cape Range	confirmed	Karanovic (2006)
Class Ostracoda - order Podocopida					
Candonidae	*Phlyctenophora*	*mesembria*	Cape Range; Barrow Island	potential	Originally described from Cape Range (Wouters 1999); for Barrow Island in Biota and RPS (2005b); no ostracod listed for Barrow Island in Eberhard *et al.* (2005)
Superorder Syncarida - order Bathynellacea					
Parabathynellidae	*Notobathynella*	sp. nov. 1	Barrow Island	likely	Chevron (2011), Chevron (2012)
	Atopobathynella	sp. nov.	Barrow Island	likely	Eberhard *et al.* (2005)
Superorder Peracarida - order Thermosbaenacea					
Halosbaenidae	*Halosbaena*	*tulki*	Cape Range; Barrow Island	potential	Originally described from Cape Range by Poore and Humphreys (1992); for Barrow Island in Biota and RPS Chevron (2011)

Family	Genus	Species	Locality	SRE category[a]	Source, remarks
Amphipoda (order)					
		Amphipoda sp. 1 and unknown sp. 3	Barrow Island	potential	Chevron (2012)
Melitidae	*Nedsia*	*sculptilis*	Barrow Island, Fortescue, Port Hedland Coast drainage basin	potential	Originally described from Barrow Island by Bradbury and Williams (1996a); from mainland by Bennelongia (2007); Schedule 1 (Western Australian Government 2012)
		humphreysi	Barrow Island	confirmed	All originally described from Bradbury and Williams (1996a); all Schedule 1 (Western Australian Government 2012)
		macrosculptilis	Barrow Island	confirmed	
		straskaba	Barrow Island	confirmed	
		fragilis	Barrow Island	confirmed	
		hurlberti	Barrow Island	confirmed	
		urifimbriata	Barrow Island	confirmed	
		sp. 1	Barrow Island	confirmed	Chevron (2011)
		chevronia	Barrow Island	confirmed	Bradbury (2002); not listed in Chevron (2012)
		stefania	Barrow Island	confirmed	
		halletti	Barrow Island	confirmed	
		unknown sp. 1	Barrow Island		Chevron (2011)
Hadziidae	*Hadzia*	*subthalassica*	Barrow Island	confirmed	Bradbury and Williams (Bradbury & Williams 1996b); Sawicki *et al.* (2004); Schedule 1 (Western Australian Government 2012)
Bogidiellidae	*Bogidomma*	australis	Barrow Island	confirmed	Bradbury and Williams (1996a); Schedule 1 (Western Australian Government 2012)
	?Bogidomma	sp. 1	Barrow Island	confirmed	Chevron (2011)
	Bogidiella	sp.	Barrow Island	Likely	Biota and RPS (2005b)

Family	Genus	Species	Locality	SRE category[a]	Source, remarks
Isopoda (slaters)					
	Oniscoidea	undescribed sp.	Barrow Island	Potential	Chevron (2012)
Cirolanidae	*Haptolana*	*pholeta*	Barrow Island	confirmed	Bruce and Humphreys (1993)
Decapoda					
	Stygiocaris	*stylifera*	Barrow Island; Cape Range	Confirmed	Chevron (2011); Cape Range in Page *et al.* (Page *et al.* 2008)
Oligochaeta (worms)					
Haplotaxida					
Enchytraeidae		sp.	Barrow Island	Potential	Chevron (2012)
Phreodrilidae		sp. 1	Barrow Island	Potential	Chevron (2012)
Polychaeta (worms)					
		sp. 1	Barrow Island	Potential	Chevron (2012)
Nematoda (roundworms)					
		sp. 1	Barrow Island	Potential	Chevron (2012)

a – see section 2.5.3 for explanation of SRE categories.

4.2 FIELD SURVEY

4.2.1 Molecular identification

Mygalomorph spiders in the genus *Aname* (family Nemesiidae), centipedes in the genus *Cryptops* (Cryptopidae) and land snails in the genera *Rhagada* and *Quistrachia* were collected during the surveys on Varanus Island and submitted for molecular sequencing.

All specimens of mygalomorph spiders were conspecific and identified as *Aname* 'MYG079', currently only known from Barrow Island. Sequence similarity within Varanus Island specimens was 99.1–100% and between Varanus and Barrow Island specimens was 96.5–97.2% (Castalanelli & Harvey 2012).

Of the six cryptopid tissues submitted for sequencing, only three yielded sequences. Analysis of these sequences with similarities between 97.0% and 99.8% (Table 4-4) suggests the presence of a single species on Varanus Island. The Varanus Island cryptopids were between 79.8% and 74.3%, similar to other Pilbara representatives of the family (Table 4-4).

Table 4-4 COI sequence similarity of centipedes analysed for the molecular identification of Cryptopidae from Varanus Island

Specimens	**AB610774[a]**	**AB610776[a]**	***Cryptops*_T124783**	***Cryptops*_T124788**	***Cryptops*_T124781**	***Cryptops*_won1_983**	***Cryptops*_MH1**	***Cryptops*_MH1**	***Cryptops*_MH2 2**	***Cryptops*_pilbara1**	***Cryptops*_pilbara2**
AB610774[a]	100										
AB610776[a]	82.5	100									
*Cryptops*_T124783	77.2	77.8	100								
*Cryptops*_T124788	77.1	77.6	**99.8**	100							
*Cryptops*_T124781	76.7	77.2	**97.2**	**97.0**	100						
*Cryptops*_won1_983	76.1	78	79.8	79.6	79.6	99.3					
*Cryptops*_MH1	74.8	74.3	74.3	74.3	75.0	75.0	100				
*Cryptops*_MH1	74.6	74.1	74.4	74.4	75.1	75.4	**99.3**	100			
*Cryptops*_MH2	75.0	75.6	76.8	76.8	77.2	77.1	82.3	82.3	100		
*Cryptops*_pilbara1	74.7	75.6	76.9	76.9	76.9	77.3	79.5	79.5	82.6	99.8	
*Cryptops*_pilbara2	76.4	73.7	75.7	75.7	76.4	75.3	81.0	81.3	81.1	82.7	100

a – outgroup specimens from GenBank (Geophilomorpha)
Specimens from Varanus Island and sequence divergence suggesting conspecifity are shaded gray.

The four gastropods submitted for sequencing all yielded DNA sequences. Analysis of these sequences indicated the presence of two lineages on Varanus Island represent, one corresponding to species within the genus *Rhagada* (Table 4-5), and the other corresponding within *Quistrachia* (M. Johnson 2012, email to Volker Framenau, 14 September).

Within *Rhagada*, the two Varanus Island specimens were most similar to each other (99.8% similarity), to the Barrow Island species, *Rhagada* 'barrow small' (97.6%–97.8% similarity) and *Rhagada plicata* from the Montebello Islands (97.8%–98% similarity). *Rhagada plicata* and *Rhagada* 'barrow small' were found to be 98.1% similar (Table 4-5). The sequence divergence observed between representatives of this group suggests a single species to be present that has previously been named, *Rhagada plicata* even taking into account that there is no clear barcoding threshold in stylommatophoran land snails (Davison *et al.* 2009).

The Varanus Island *Quistrachia* are *Q. montebelloensis.* The average corrected similarity of the Varanus Island sequences from reference *Q. montebelloensis* is 97.6% (range = 99.0% to 96.3%) which support their inclusion within that species (M. Johnson 2012, email to Volker Framenau, 14 September)

Table 4-5 COI sequence similarity of camaenid land snails analysed for the molecular identification of *Rhagada* and *Quistrachia* from Varanus Island

a – outgroup specimens from GenBank
Specimens from Varanus Island and sequence divergence suggesting conspecifity are shaded gray.

(Table 4-5 next page)

Specimens	**R. 12 MSJ-2012.18**	**R. 12 MSJ-2012.17**	***R. reinga***	***R. radleyi***	***R. primig.***	***R. plicata* 22**	***R. plicata* 21**	***R. pilbarana***	***R. perprima***	***R. minima***	***R. interm.***	***R. globosa***	***R. elachystoma***	***R. dringi***	***R. dominica***	**Q._S83637**	**R._S83647**	**Q._S83644**	**R._S83636**	**R. Barrow Small**	**R. Barrow Small**	**R. Barrow Large**	**R. Barrow large**
Rhagada sp. 12 MSJ-2012.18[a]	100																						
Rhagada sp. 12 MSJ-2012.17[a]	100	100																					
Rhagada reinga[a]	79	79	100																				
Rhagada radleyi[a]	83	83	80	100																			
Rhagada primigena[a]	82	82	86	82	100																		
Rhagada plicata 22[a]	90	90	82	84	83	100																	
Rhagada plicata 21[a]	90	90	82	84	83		100																
Rhagada pilbarana[a]	83	83	80	90	81	82.6	82.6	100															
Rhagada perprima[a]	89	89	81	83	83	95.9	95.9	82	100														
Rhagada minima[a]	88	88	82	84	84	95.1	95.1	82	96	100													
Rhagada intermedia[a]	90	90	82	83	83	95.7	95.7	83	96	96	100												
Rhagada globosa[a]	84	84	81	83	82	84.4	84.4	84	84	85	85	100											
Rhagada elachystoma[a]	90	90	82	84	83	93.2	93.2	82	94	94	94	85	100										
Rhagada dringi[a]	84	84	82	87	83	84	84	85	85	85	84	84	85	100									
Rhagada dominica[a]	83	83	87	82	96	82.8	82.8	81	82	83	82	82	83	82	100								
*Quistrachia*_S83637	77	77	78	77	78	78.9	78.9	76	79	78	79	78	77	78	78	100							
*Rhagada*_S83647	90	90	82	84	84	**97.8**	**97.8**	83	95	95	95	85	93	84	83	79	100						
*Quistrachia*_S83644	78	78	78	77	78	79.7	79.7	76	79	78	79	78	78	78	79	**99**	79.4	100					
*Rhagada*_S83636	90	90	82	84	84	**98**	**98**	83	95	95	95	85	93	84	83	79	**99.8**	79	100				
Rhagada sp. BarrowSmall24[a]	90	90	81	83	83	**98.1**	**98.1**	82	96	95	96	84	94	84	82	79	**97.6**	80	**97.8**	100			
Rhagada sp. BarrowSmall23[a]	90	90	81	83	83	**98.1**	**98.1**	82	96	95	96	84	94	84	82	79	**97.6**	80	**97.8**	**100**	100		
Rhagada sp. BarrowLarge26[a]	83	83	81	90	82	83	83	87	82	83	82	84	82	86	82	77	83.5	76	83.5	83.3	83	100	
Rhagada sp. BarrowLarge25	82	82	80	90	82	83.7	83.7	88	83	83	83	85	83	87	82	77	83.7	77	83.7	83.3	83	**97**	100

4.2.2 Survey results

A total of 960 individual specimens in the SRE target groups (see section 2.5.1) were collected from the study area, representing 22 individually-recognised taxa from seven orders in 13 families and at least 21 genera (Appendix 3).

A total of eight taxa in at least seven genera from five families and five orders comprising 350 individuals (36.5% of total catch) are considered to include species from the three SRE categories (Table 4-6; Figures 4-8 - Figure 4-11).

Of these eight SREs, five are known from Barrow or the Montebello Islands, i.e. *Karaops burbidgei*, *Aname* 'MYG079', *Barrowdillo pseudopyrgoniscus*, *Quistrachia montebelloensis* and *Rhagada plicata.*

The taxonomy of the remaining three, *Cryptops* sp. indet., *Spherillo* 'varanus island' and Armadillidae 'varanus island' is too poorly known to assess their distribution outside Varanus Island. *Cryptops* sp. indet. and *Spherillo* 'varanus island' are both found outside the impact area. In contrast, Armadillidae 'varanus island' is only known from a single male from impact site 02.

Detail taxonomic assessments for all SRE taxa recorded from Varanus Island are provided in sections 4.5 to 4.11.

Table 4-6 Short-range endemic invertebrate taxa recorded during the survey

Family	Genus and species	SRE status	Impact sites	Non-impact sites	No. of specimens [impact/non-impact]	Habitat/s
Araneomorphae (modern spiders)						
Selenopidae	*Karaops burbidgei*	Confirmed	01	06–09	1/8	Limestone plain
Mygalomorphae (trapdoor spiders)						
(Nemesiidae)	*Aname* 'MYG079'	Likely	06	03, 04, 10	6/6	Mid-island basin, sand dune
Chilopoda (centipedes)						
Cryptopidae	*Cryptops* sp. indet.	Potential	01	04, 06, 08, 09, 11	2/14	Limestone plain, mid-island basin, sand dune
Isopoda (slaters)						
Armadillidae	*Barrowdillo pseudopyrgoniscus*	Potential	01	06, 08, 09	3/12	Limestone plain
	Spherillo 'varanus island'	Potential	-	03, 08, 11	-/33	Limestone plain, mid-island basin, sand dune

Family	Genus and species	SRE status	Impact sites	Non-impact sites	No. of specimens [impact/non-impact]	Habitat/s
	Armadillidae 'varanus island'	Likely	02	-	1/-	Mid-island basin
Gastropoda (land snails)						
Camaenidae	*Quistrachia montebelloensis*	Confirmed	01, 02, 05	03, 04, 06–09, 11	49/165	Limestone plain, mid-island basin, sand dune
	Rhagada plicata	Confirmed	05	10, 11	5/44	Sand dune
Total					**67/283**	

Figure 4-8 Short-range endemic mygalomorph spider collected for Varanus Island Fill Project. *Aname* 'MYG079' (Nemesiidae).

Figure 4-9 **Short-range endemic taxa collected for Varanus Island Fill Project. a, *Karaops burbidgei* (Selenopidae); b, *Cryptops* sp. indet. (Cryptopidae); c, *Barrowdillo pseudopyrgoniscus* (Armadillidae); d, Armadillidae 'varanus island'; e, *Spherillo* 'varanus island'.**

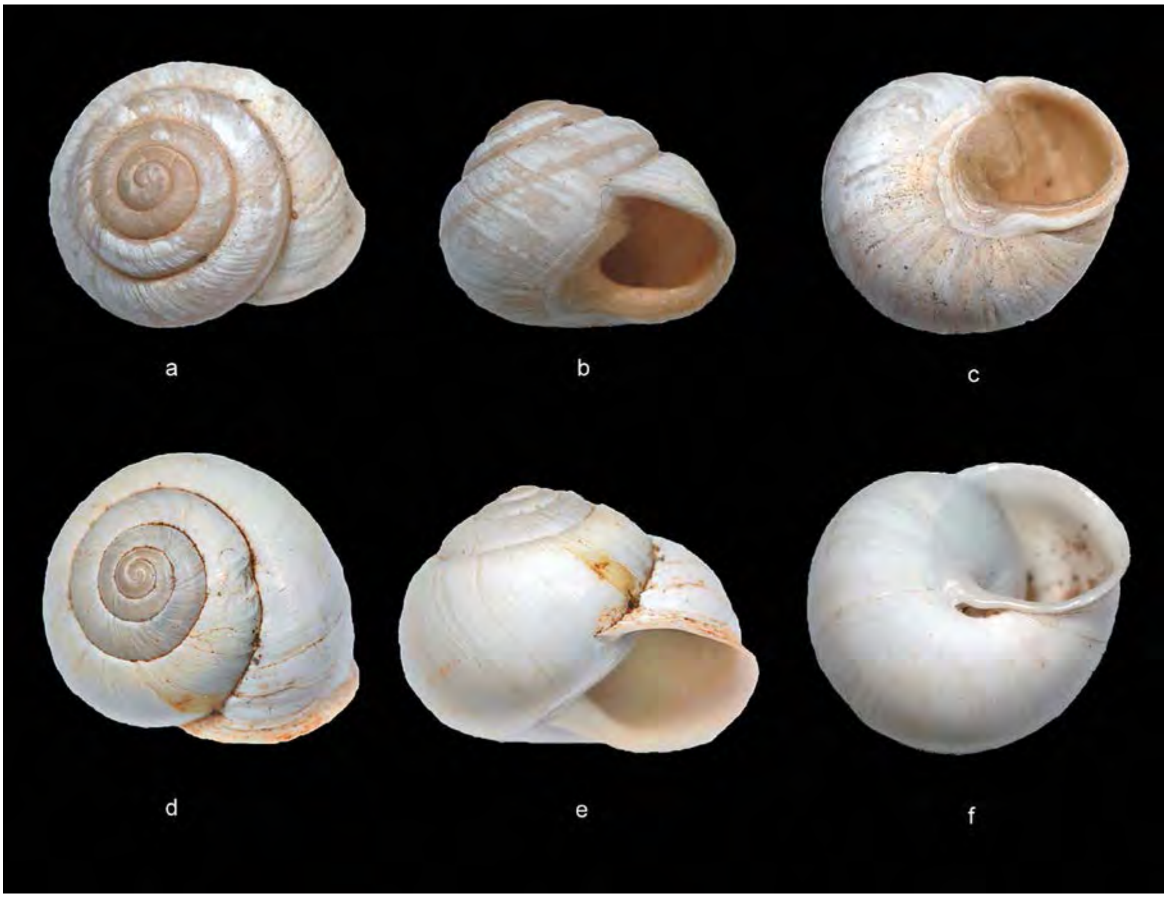


Figure 4-10 Short-range endemic land snails collected for Varanus Island Fill Project. a–c, ***Rhagada plicata*** (Camaenidae), a, dorsal, b, lateral (operculum), c, ventral; d–f, ***Quistrachia montebelloensis*** (Camaenidae), a, dorsal, b, lateral (operculum), c, ventral

Figure 4-11 Short-range endemic land snail collected for Varanus Island Fill Project. ***Quistrachia montebelloensis*** (Camaenidae).

4.3 HABITATS FOR SHORT-RANGE ENDEMIC SPECIES

Short-range endemic invertebrates were recorded from all survey sites and habitat types (Table 4-6). There was some affinity of particular groups for certain habitat types, although centipedes, isopods and land snails were found at every single site. The mygalomorph spiders *Aname* 'MYG079' was only found at sand dune and mid-island basin sites, most likely as this species requires penetrable habitat to construct burrows. In contrast, the flatrock spider *Karaops burbidgei* was only found at limestone plain sites; members of the Selenopidae are adapted to live in crevices under rock and under bark (Crews 2011; Crews & Harvey 2011).

4.4 SPECIES RICHNESS ESTIMATE

Four SRE target groups were collected in sufficient numbers to allow an estimate of species richness on the survey sites: spiders, pseudoscorpions, snails and isopods (Table 4-7, Figure 4-12 - 4-15). Only one species of scorpion, and centipede were collected during the survey which is not sufficient for diversity estimation.

Species richness estimators suggest that the snail and isopod fauna present at the time of the survey was collected exhaustively; in contrast, up to four more species of pseudoscorpion may have been present on Varanus Island.

It should be acknowledged that estimators generally underestimate 'true' species diversity and these should therefore be considered minimum species richness estimates.

Table 4-7 Survey data and species estimators (ACE, Chao1, Jack Knife1 rounded to nearest whole number) for SRE target groups

Taxon[a]	Survey data				Species estimators		
	Number of individuals	Number of singletons per species	Number of doubletons per species	Number of species collected	ACE mean	Chao1 mean	Jack Knife1 mean
Spiders	22	0	0	2	2	2	2
Pseudoscorpions	143	2	0	4	7	6	8
Snails	587	1	1	8	7	7	8
Isopod	103	0	0	4	4	4	4

a – Centipedes were not analysed due to lack of taxonomic resolution. Spiders and scorpions were not analysed due to insufficient numbers of individuals.

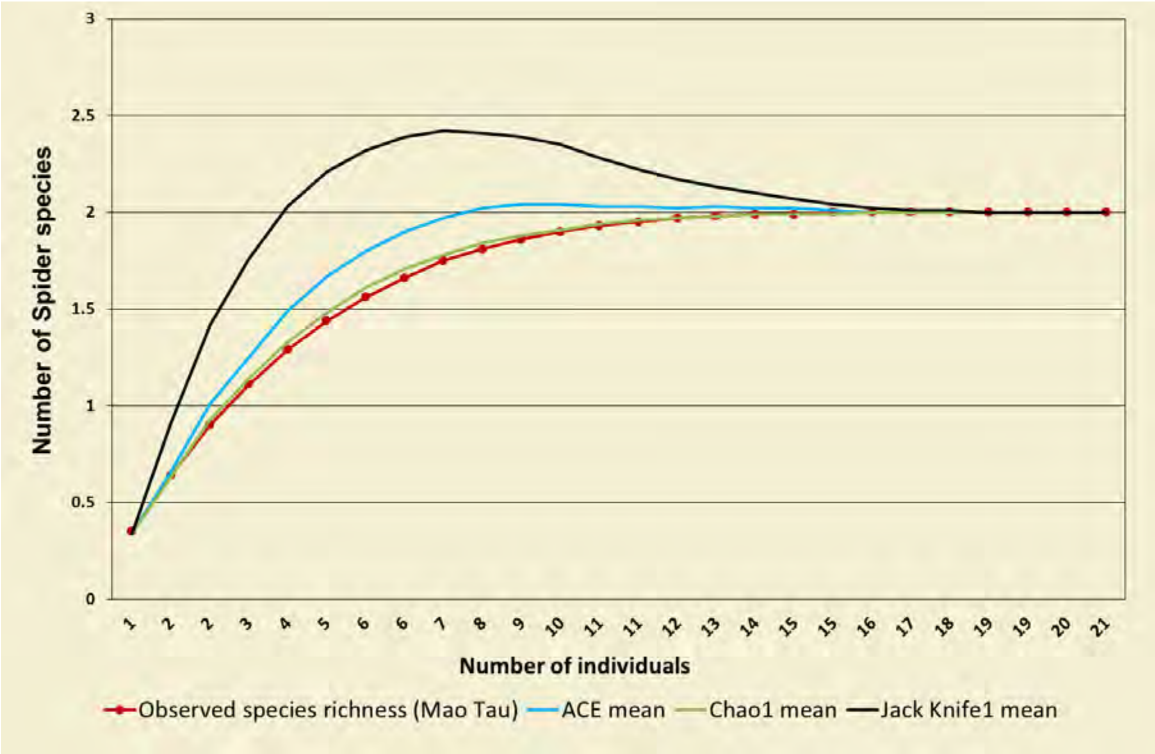


Figure 4-12 Individual based species accumulation curves for spiders, with observed species richness, as well as species estimators (ACE, Chao1 and Jack Knife1)

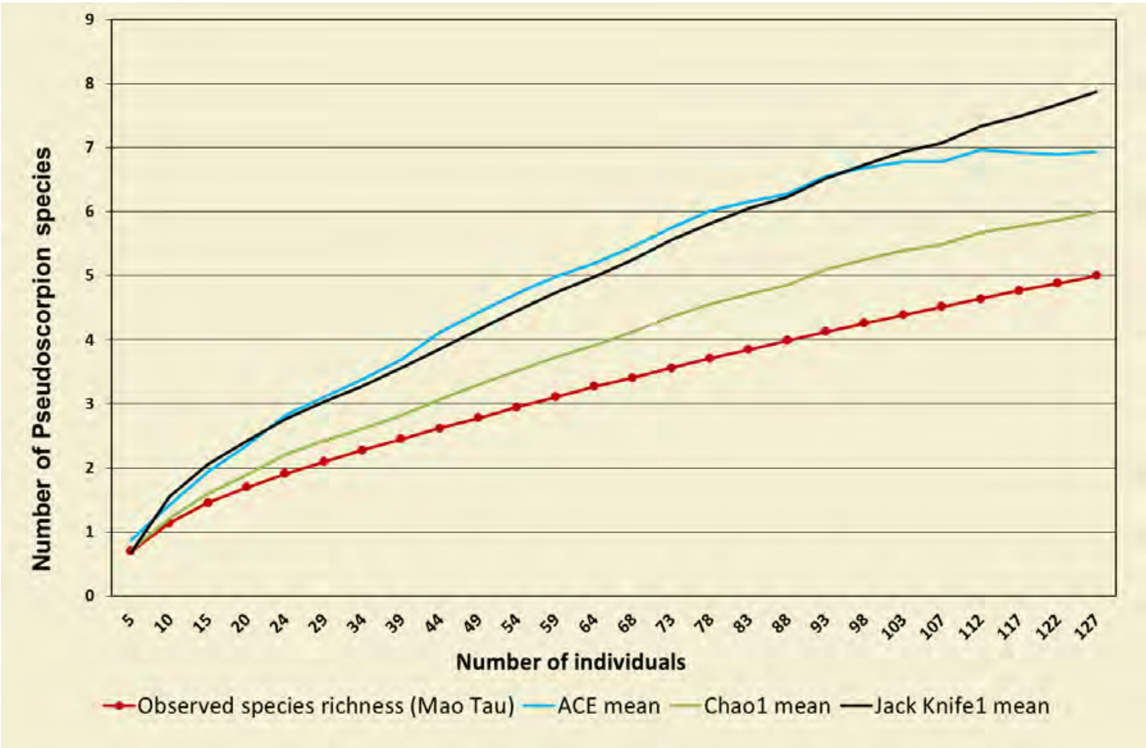


Figure 4-13 Individual based species accumulation curves for pseudoscorpions, with observed species richness, as well as species estimators (ACE, Chao1 and Jack Knife1)

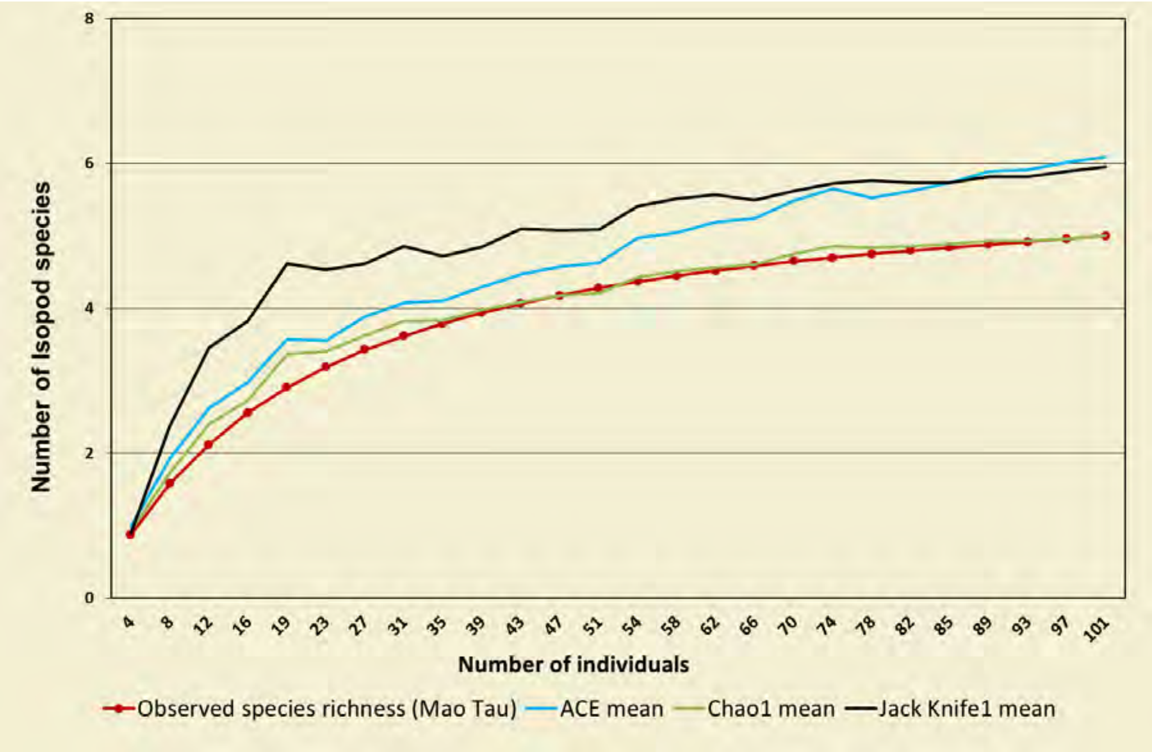


Figure 4-14 **Individual based species accumulation curves for slaters, with observed species richness, as well as species estimators (ACE, Chao1 and Jack Knife1)**

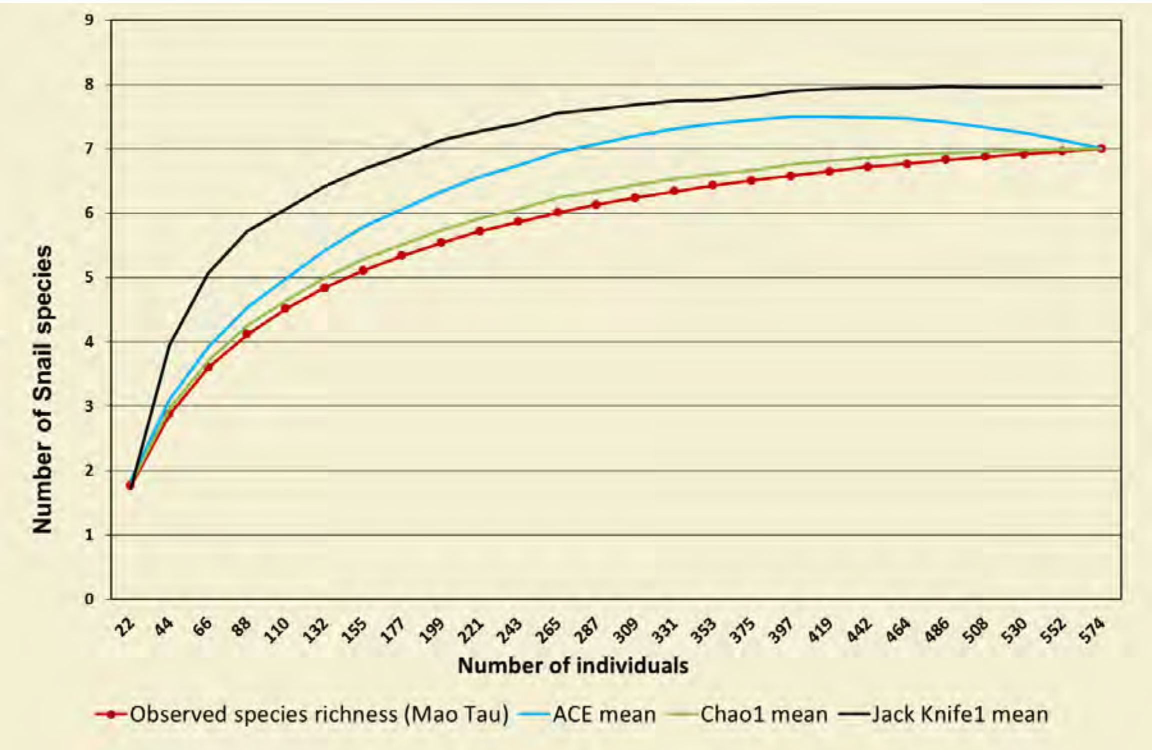


Figure 4-15 **Individual based species accumulation curves for snails, with observed species richness, as well as species estimators (ACE, Chao1 and Jack Knife1)**

4.5 ARANEAE – ARANEOMORPHAE (MODERN SPIDERS)

The Araneae (spiders) are characterised by a number of unique characters, including abdominal appendages modified as spinnerets, silk glands and associated spigots, cheliceral venom glands and male pedipalp tarsi modified as secondary genitalia from sperm transfer (Coddington & Levi 1991). Spiders are one of the largest and most diverse orders of arachnids, more than 40,000 described species worldwide (Platnick 2012), and some 3,400 species named from Australia (Framenau 2012). Few obligatory subterranean spiders are known in Australia, for example in the families Ctenidae, Oonopidae, Styphidiidae, Symphytognathidae, Trochanteriidae and Zoropsidae (Baehr *et al.* 2012; Gray 1973; Gray & Thompson 2001; Harvey 1998; Harvey *et al.* 1993; Platnick 2008).

In contrast to the Mygalomorphae (trapdoor spiders, see section 4.6), Araneomorphae (modern spiders) are rarely targeted in SRE surveys. Araneomorphae often disperse very well, for example by wind-drift on gossamer threads ('ballooning') (e.g. Bell *et al.* 2005) and many species are widely distributed across the Australian landscape (Harvey 2002).

The desktop review recovered eight araneomorph spider taxa that are considered SREs, seven of which are currently known from Barrow Island only (Table 4-1; Figure 4-1). One species, *Spinasteron casuarium* (Zodariidae) is currently known from Enderby Island (Dampier Archipelago) only (Table 4-1; Figure 4-1).

4.5.1 Family Selenopidae (Flat Rock Spiders)

Flat Rock Spiders, or Flatties, are small to medium-sized dorso-ventrally flattened spiders. They are superficially similar to Huntsmen Spiders (family Sparassidae) and Flat Ground Spiders (families Gnaphosidae and Trochanteriidae), but differ by their characteristic eye pattern. Flat Rock Spiders have a light brown mottled colouration and often strongly banded legs (Figure 4-9a). They are extremely fast runners and therefore very difficult to catch. Their flat morphology is a perfect adaptation to a life in narrow crevices and they can typically be found under exfoliating slabs of granite outcrops and under bark of trees (Crews & Harvey 2011). The preference for isolated outcrops or mountain ridges predisposes Selenopidae to short-range endemism. Selenopidae occur in tropical and subtropical regions world-wide. In Australia, a single genus, *Karaops*, is known with 24 described species (Crews & Harvey 2011).

4.5.1.1 Genus *Karaops*

The genus *Karaops* differs from other genera in the family Selenopidae by the spination of the two first pairs of legs and by the absence of scopulae (brushes of dense setae) from their tarsi (Crews & Harvey 2011). *Karaops* is currently known from Australia only. Five species are described from the Pilbara region and its vicinity of which one, *K. martamarta* is fairly widespread. Eleven more species from the Pilbara are currently being described, all of which are known from restricted ranges only (S. Crews personal communication). This supports a high diversity of the genus in the region and suggests restricted ranges for most of its species.

The desktop review revealed one species of SRE selenopid, *Karaops burbidgei* (Table 4-1) which was previously known only from Barrow Island (Crews & Harvey 2011).

The field survey on Varanus Island recovered nine specimens of same species at five of the survey sites (Table 4-8; Figure 4-9a).

Species richness estimators were calculated for araneomorph and mygalomorph spiders combined and showed that all spider species in the SRE target groups present in the study site were collected (Table 4-7; Figure 4-12).

Table 4-8 Selenopid spiders collected during the short-range endemic survey of the Varanus Island Fill Project, by site

	Site[a]											
Taxon[a]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
Selenopidae												
Karaops burbidgei	1					2	2	3	1			**9**
Totals	**1**					**2**	**2**	**3**	**1**			**9**

a – sites located in the impact area and species categorised as potential, likely or Confirmed SREs are shaded in grey.

Karaops burbidgei

One male and eight juveniles of *Karaops burbidgei* were collected from five of the survey sites (Table 4-8; Figure 4-16). Juvenile identification is based on somatic similarities with the male. This species was collected from all of the sites which were categorised as limestone plain. *Karaops burbidgei* is a confirmed SRE based on the well resolved taxonomy and distribution patterns within the genus. Prior to this survey, *Karaops burbidgei* was only known from Barrow Island.

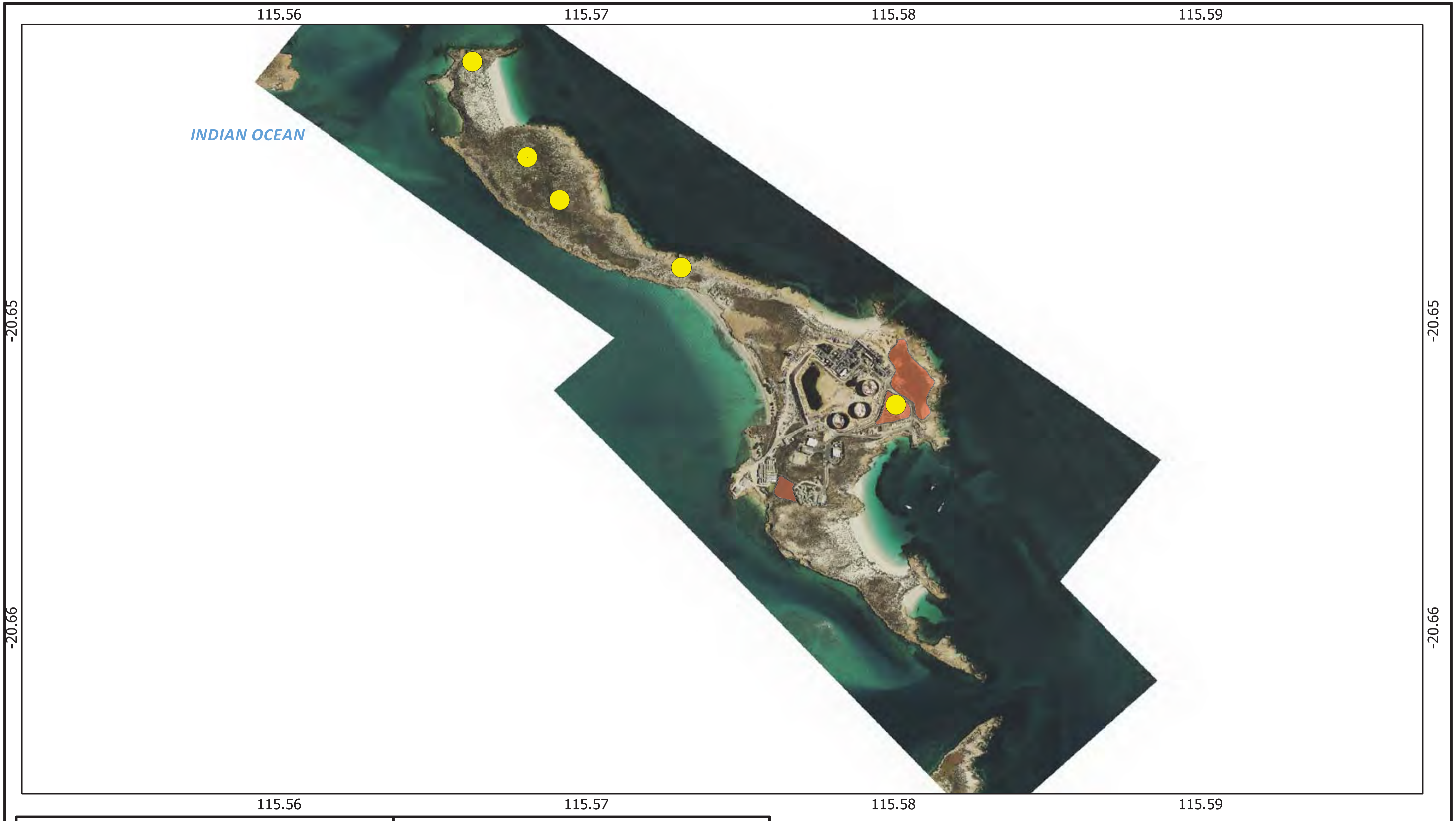


Figure 4-16
Records of Karaops burbidgei (Selenopidae) from the short-range endemic survey of the Varanus Island Fill Project

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AUTHOR: A.E. Leung	**CLIENT:** Apache Energy Ltd
DATE: August 2012	**Scale:** 1:14000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PROJECT: Varanus Island Fill Project

4.6 ARANEAE – MYGALOMORPHAE (TRAPDOOR SPIDERS)

Trapdoor spiders represent one of the focal groups in surveys of SRE taxa (Harvey 2002). A number of mygalomorph spiders, e.g. *Idiosoma nigrum, Kwonkan eboracum* and *Moggridgea tingle* are listed on Schedule 1 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2012 (2)* (Western Australian Government 2012). The Western Australian mygalomorph fauna is vast and many families and genera remain taxonomically poorly known (e.g. Barychelidae: *Idiommata*; Idiopidae: *Aganippe*; Nemesiidae: *Aname*, *Chenistonia*, *Kwonkan*).

Sixteen Mygalomorph spiders were identified from the desktop study of which only one, *Synothele butleri* from Barrow Island, is formally described (Table 4-1; Figure 4-2). Eleven trapdoor spider taxa considered SREs are known from Barrow Island (Table 4-1; Figure 4-2).

Twelve specimens of mygalomorph spiders were collected on Varanus Island from four sites (Table 4-9; Figure 4-17). Molecular identification showed this species to be *Aname* 'MYG079', currently known from Barrow Island only (see section 4.2.1).

Species richness estimators were calculated for araneomorph and mygalomorph spiders combined and showed that all spider species in the SRE target groups present in the study site were adequately collected (Table 4-7; Figure 4-12).

Table 4-9 Trapdoor spiders (Araneae: Mygalomorphae) collected during the short-range endemic survey of the Varanus Island Fill Project, by site

	Site[a]											Total
Taxon[a]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
Nemesiidae												
Aname 'MYG079'			2	2	6					2		**12**
Total			2	2	6					2		**12**

a – sites located in the impact area and species categorised as potential, likely or Confirmed SREs are shaded in grey.

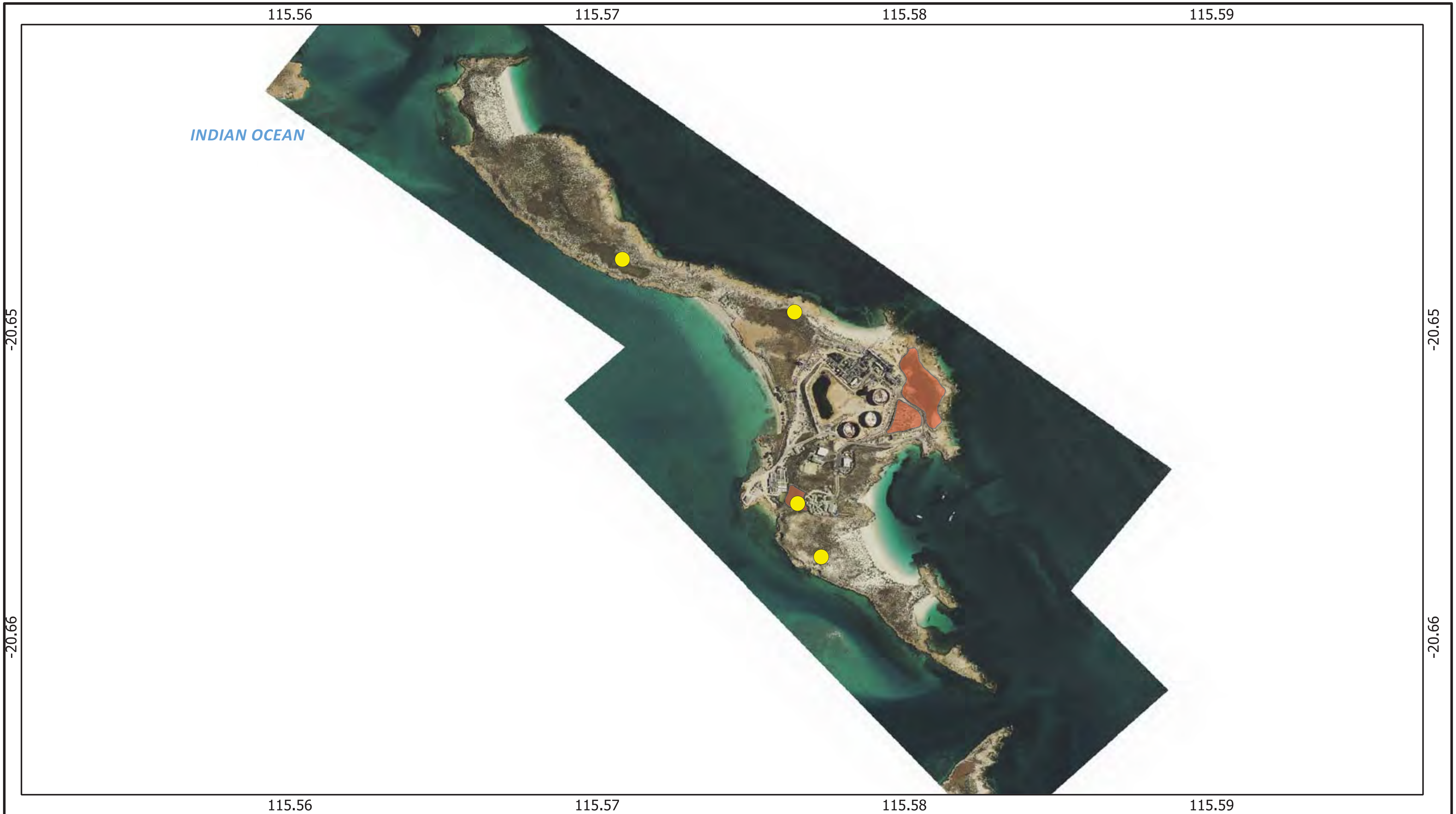

Figure 4-17
Records of Aname 'MYG079' (Mygalomorphae) from the short-range endemic survey of the Varanus Island Fill Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:14000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	PROJECT: Varanus Island Fill Project

4.6.1 Family Nemesiidae (Wishbone Spiders)

Members of the mygalomorph spider family Nemesiidae are represented in Western Australia by several genera, including *Aname*, *Chenistonia*, *Yilgarnia*, *Stanwellia*, *Teyl*, *Swolnpes* and *Kwonkan* (Main & Framenau 2009). They usually dig burrows in the soil, and do not cover their burrow entrances with lids. Insert family description from SRE database.

4.6.1.1 Genus *Aname*

The genus *Aname* currently includes 37 named species in Australia and is well represented by four named and numerous unnamed species from many different regions in Western Australia. *Aname* currently represent a highly diverse array of species of very small to large spiders. Males generally have a spur and spine on the first tibia of males opposing an often incrassate metatarsus. Members of the genus *Aname* are believed to be most common in sclerophyll forest, but are also known from rainforests and deserts (Raven 1981). *Aname* regularly belongs to the most diverse mygalomorph genera in biological spider surveys and with 12 species the Pilbara survey (Durrant *et al.* 2010) resulted in a similar number as found during the Carnarvon Basin survey (13 species) (Main *et al.* 2000). Many *Aname* species appear to have restricted distributions as shown by two studies from northern Australia, including the Pilbara (Harvey *et al.* 2012; Raven 1985).

***Aname* 'MYG079'**

Three females and nine juvenile specimens of *Aname* 'MYG079' (Figure 4-8) were collected from one impact site and three reference sites on Varanus Island (Table 4-9; Figure 4-17). These spiders were collected from sand dune and mid-island basin habitats. *Aname* 'MYG079' has been previously recorded from Barrow Island and Varanus Island only and is a likely SRE. Some species of the *Aname mainae*-group (similar to *Aname* 'MYG079') have been recorded on the Pilbara mainland, for example the Burrup Peninsula. These may also be conspecific with *Aname* 'MYG079.

4.7 PSEUDOSCORPIONES (FALSE SCORPIONS OR PSEUDOSCORPIONS)

Pseudoscorpiones resemble scorpions in that they possess a pair of long pedipalps with pincers which are directed forward; however, they do not possess the tail or a sting of scorpions. Most species are small to very small in size (most species are less than 1 cm long) (Harvey & Yen 1989). Pseudoscorpions can be found inhabiting a wide variety of habitats including leaf litter, soil, under the bark of trees, under stones, and in rock crevices (Harvey & Yen 1989; Main 1985). In Western Australia, 17 families of pseudoscorpions have been recorded to date (Harvey 2011a). The group contains several SRE species, for example species in the genus *Synsphyronus* (family Garypidae) are often habitat specific SREs on rocky outcrops (Harvey 2011b).

The desktop review identified eight SRE taxa of pseudoscorpion, five of these from Barrow Island exclusively, and three more from the mainland (Table 4-1; Figure 4-3). However, no pseudoscorpion species has previously been recorded from Varanus Island.

A total of 136 specimens of pseudoscorpions representing five taxa in five genera and two families, Olpiidae and Cheiridiidae, were collected in the survey on Varanus Island (Table 4-10; Figure 4-18). Olpiidae were collected at all of the survey sites, with the most dominant species *Euryolpium* sp. indet. accounting for more than 80% of specimens collected. *Austrohorus*, *Beierolpium* and *Indolpium* (Olpiidae) belong to the most frequently collected pseudoscorpion genera in the Pilbara and their terrestrial representatives are generally not believed to contain many, if any, SREs (M.S. Harvey personal communication). The systematic status of the many populations of Cheiridiidae is currently unknown but it is very unlikely that any represent short-range endemic species, including those of the genus *Apocheiridium* (M.S. Harvey personal communication).

Species diversity estimators predicted that between six and eight species were present on Varanus Island, indicating that not all species of pseudoscorpion were collected (Table 4-7; Figure 4-13). In comparison, the desktop review revealed that at least sixteen species of pseudoscorpion occur on Barrow Island.

Table 4-10 Pseudoscorpions (Pseudoscorpiones) collected during the short-range endemic survey of the Varanus Island Fill Project, by site

	Site[a]											
Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
Olpiidae												
Austrohorus sp. indet.	7											**7**
Beierolpium '8/2'	1											**1**
Euryolpium sp. indet.		4	6	19	2	16	17	14	10	11	12	**111**
Olpiidae sp. indet.			1		15							**16**
Cheiridiidae												
Apocheiridium sp. indet.	1											**1**
Total	**9**	**4**	**7**	**19**	**17**	**16**	**17**	**14**	**10**	**11**	**12**	**136**

a – sites located in the impact area are shaded in grey.

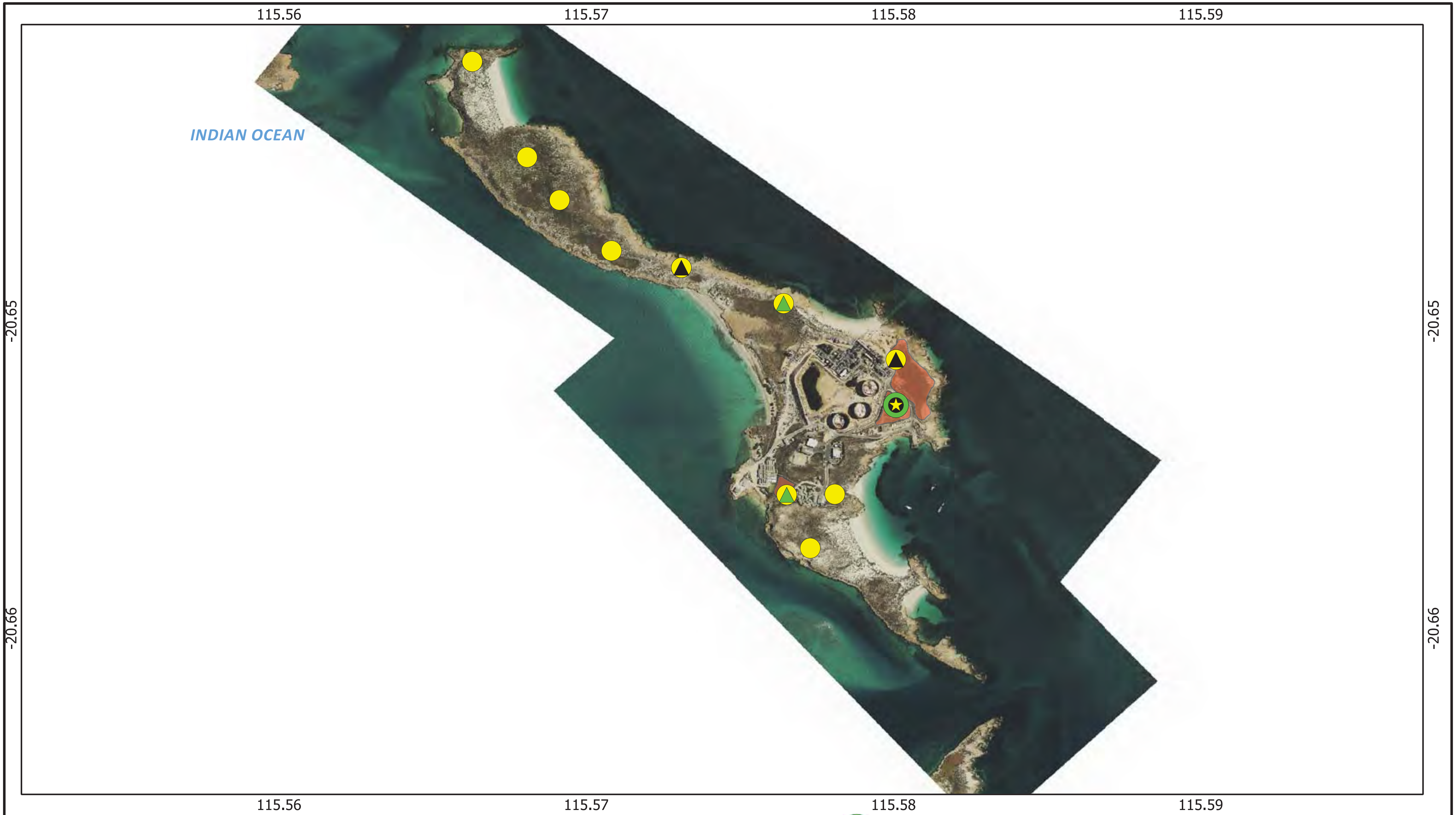

Figure 4-18
Records of pseudoscorpions from the short-range endemic survey of the Varanus Island Fill Project

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AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:14000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	PROJECT: Varanus Island Fill Project

- Apocheiridium sp. indet.
- Austrohorus sp. indet.
- Beierolpium '8/2'
- Euryolpium sp. indet.
- Indolpium sp. indet.
- Olpiidae sp. indet.
- impact area

0 0.25 0.5 km

N

4.8 Scorpiones (Scorpions)

Scorpions are characterised by the presence of chelate pedipalps, pectines and an elongate metasoma furnished with a sting. Scorpions are important components of arid ecosystems because their levels of diversity and abundance contribute significantly to the biomass of animal assemblages and they are important predators and prey for other species (Volschenk *et al.* 2010).

The DEC Pilbara Biological Survey recovered two families of scorpions, Buthidae and Urodacidae. The buthids were represented by two genera, *Lychas* (10 species) and *Isometroides* (2 species). The family Urodacidae was represented by 10 species in the single genus *Urodacus* (Volschenk *et al.* 2010). However, the regional scorpion fauna is clearly more diverse both at the species and the genus level, than was recorded in this comprehensive survey. For example, the urodacid genus *Aops* was recently described from Barrow Island (Volschenk & Prendini 2008) and has since also be found on the mainland in the Pilbara.

Four SRE scorpions were identified from the desktop study (Table 4-1; Figure 4-3). All four species are endemic to Barrow Island.

A total of three scorpion specimens belonging to single species were collected in the survey (Table 4-11; Figure 4-19). *Lychas* 'hairy tail group' is a widespread species and is therefore not considered an SRE.

Species richness estimators were not calculated for scorpions due to the low number of records that do not allow for a reliable statistical estimate.

Table 4-11 Scorpions (Scorpiones) collected during the short-range endemic survey of the Varanus Island Fill Project, by site

	Site[a]											
Taxon[a]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Totals**
Buthidae												
Lychas 'hairy tail group'								3				**3**
Totals								**3**				**3**

a – sites located in the impact area and species categorised as potential, likely or Confirmed SREs are shaded in grey.

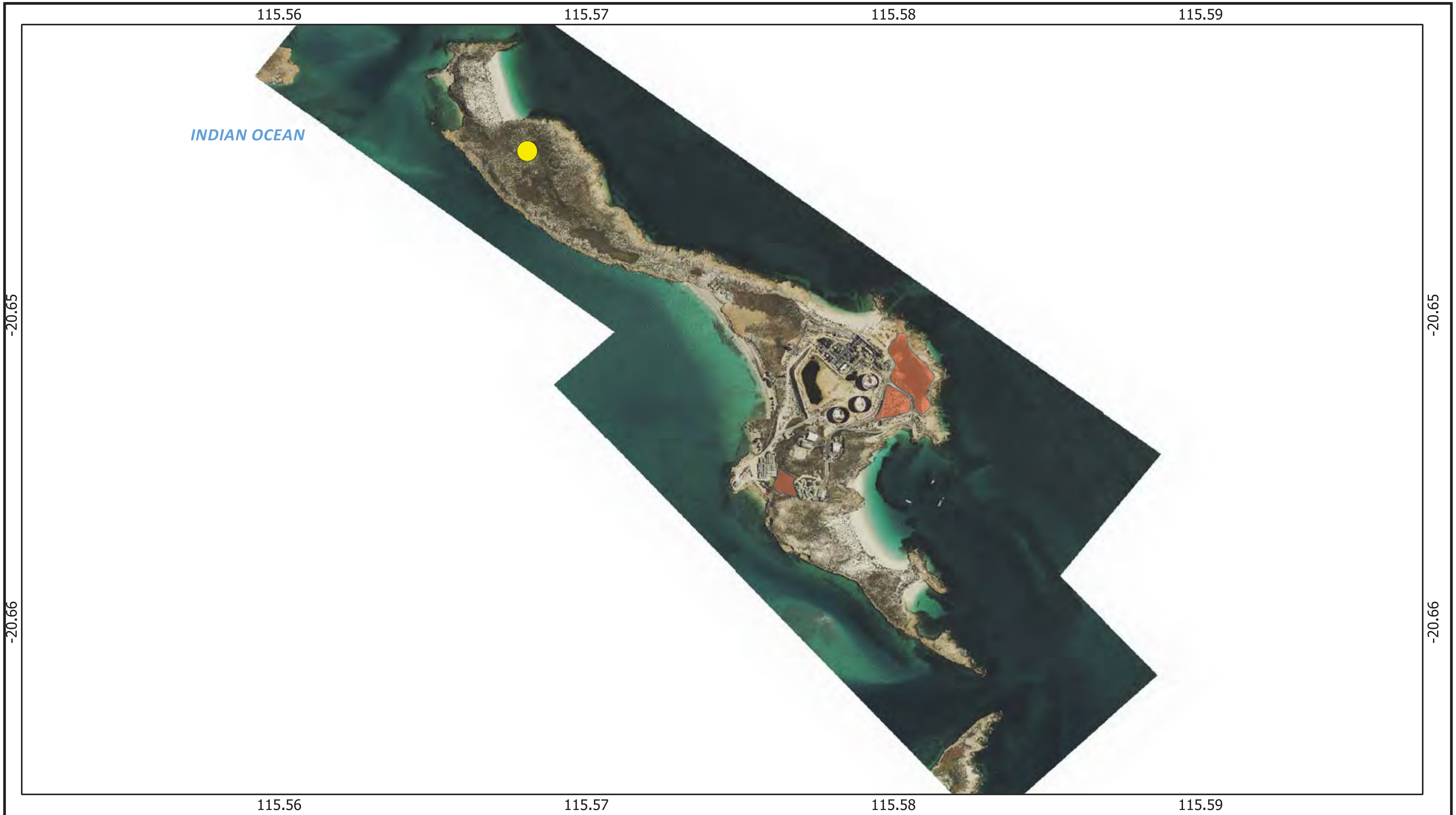

Figure 4-19
Records of scorpions from the short-range endemic survey of the Varanus Island Fill Project

AUTHOR: A.E. Leung	CLIENT: Apache Energy Ltd
DATE: August 2012	Scale: 1:14000
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

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PROJECT: Varanus Island Fill Project

4.9 CHILOPODA (CENTIPEDES)

The centipedes represent a diverse group of predatory arthropods. Each pair of legs is attached to a separate body segment which distinguishes this class from the millipedes (Diplopoda; two pairs of legs per segment) (Colloff *et al.* 2005). Adult body length ranges from 4 to 300 mm, with most species measuring 10 to 100 mm long. In most cases, they feed on small live arthropods and other invertebrates, although large scolopendrids can take vertebrate prey (Edgecombe & Giribet 2007).

All five orders of centipedes can be found in Australia, of which one, the Craterostigmorpha, only occurs in Tasmania and New Zealand (Colloff *et al.* 2005). Scolopendromorpha and Scutigeromorpha (house centipedes) are the most commonly encountered centipedes in WA. Most species are very fast runners and are highly mobile and therefore, widespread (e. g. Edgecombe & Barrow 2007; Edgecombe & Giribet 2009; Koch 1982, 1983a, b, c). Therefore, they are not considered target groups for SRE surveys.

In contrast, Geophilomorpha, Lithobiomorpha and the Cryptopidae (within the Scolopendromorpha) may include Gondwanan refugial SREs based on the habitat preference for moist and deep leaf litter. Geophilomorpha and Cryptopidae have been found in subterranean environments in the Pilbara where they are limited to very small ranges (e. g. Edgecombe 2005).

Five taxa of centipede were identified from the desktop study (Table 4-1; Figure 4-4). Of these, four represented unknown genera collected on Barrow Island. The remaining record, *Cryptops* sp. indet., has been found on Barrow Island and on the mainland; however, this genus may represent several species.

A total of 16 specimens of centipedes of *Cryptops* were collected in the survey (Table 4-12; Figure 4-20). Six specimens from along the study area were submitted for molecular analyses, but only three of these provided good sequences (see section 4.2.1). All specimens sequenced belong to the same species suggesting that only one species is present on Varanus Island.

Species richness estimators were not calculated for centipedes due to the low number of records that do not allow for a reliable statistical estimate.

Table 4-12 Centipedes (Chilopoda) collected during the SRE survey of the Varanus Island Fill Project, by site

	Site[a]											
Taxon[a]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Totals**
Cryptopidae												
Cryptops sp. indet.	2			1		3		4	3		3	**16**
Totals	**2**			**1**		**3**		**4**	**3**		**3**	**16**

a – sites located in the impact area and species categorised as potential, likely or Confirmed SREs are shaded in grey.

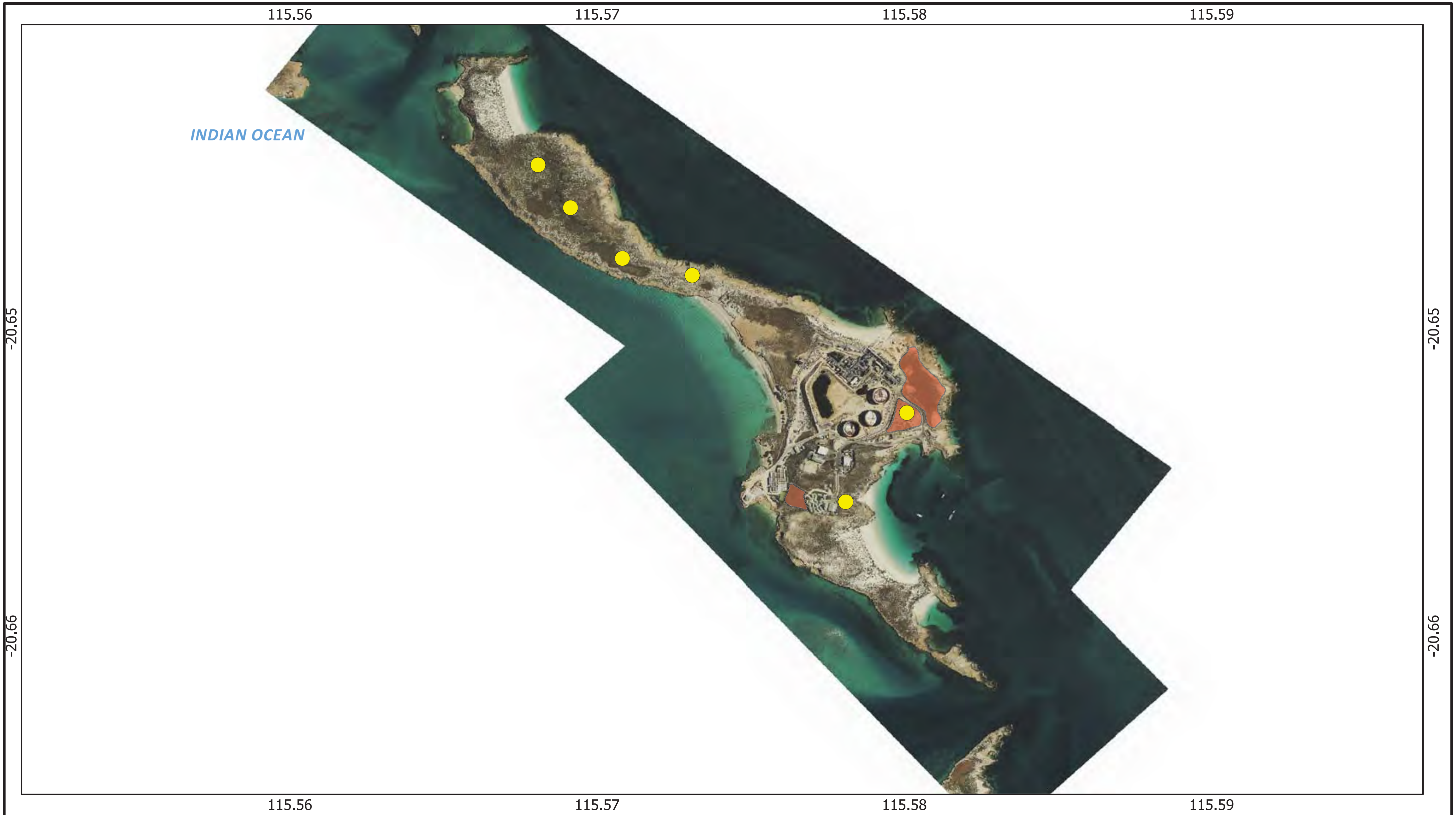

Figure 4-20
Records of Cryptops sp. indet. (Cryptopidae) from the SRE survey of the Varanus Island Fill Project

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PROJECT: Varanus Island Fill Project

4.9.1 Cryptopidae

The Cryptopidae are characterised by the lack of eyes (ocelli) and four articulating segments of legs. They are smaller than most other scolopendromorphans and uniformly yellowish-brown. Two genera are named, *Cryptops* (with five subgenera) and *Paracryptops*, but only *Cryptops* is currently known from Australia (Edgecombe 2005; Edgecombe & Bonato 2011).

4.9.1.1 Genus *Cryptops*

Six species in the genus *Cryptops* are currently known from Australia, of which *C. roeplainensis* was only recently described from caves on the Nullarbor Plain (Edgecombe 2005). The taxonomy of the group is poorly resolved, but recent molecular analyses of COI sequence data revealed high genetic divergence suggesting considerable species diversity in the Pilbara region of WA (Phoenix unpublished data).

***Cryptops* sp. indet.**

Sixteen specimens were collected from six survey sites, including one impact site. They were collected from all three habitat types; however, the majority of specimens were collected from limestone plain sites, with only one individual found at a mid-island basin and two found in sand dune habitats (Figure 4-20). Due to the cryptic lifestyle in leaf litter and upper layers of soil which is reflected in the troglobitic adaptations even in epigean species, members of the genus *Cryptops* are considered potential SREs. However, it is possible that the species from Varanus Island that was identified based on molecular data also occurs elsewhere, in particular Barrow Island.

4.10 ISOPODA (SLATERS)

Almost 200 described species of Oniscidea, a suborder of the Isopoda containing the supralittoral, terrestrial and secondarily aquatic slaters (or woodlice), have been recorded from Australia. The WA fauna is comparatively poorly known with many undescribed species (Judd & Horwitz 2003). Slaters are an ideal biological model for faunistic and biogeographical studies, due to their reduced dispersal ability and narrow habitat preferences (e.g. Taiti & Argano 2009). Consequently, they belong to one of the target groups of SRE surveys (EPA 2009; Harvey 2002).

A single species of terrestrial slaters was identified in the desktop review, *Barrowdillo pseudopyrgoniscus* (Table 4-1). Prior to this survey, this species was only known from Barrow Island.

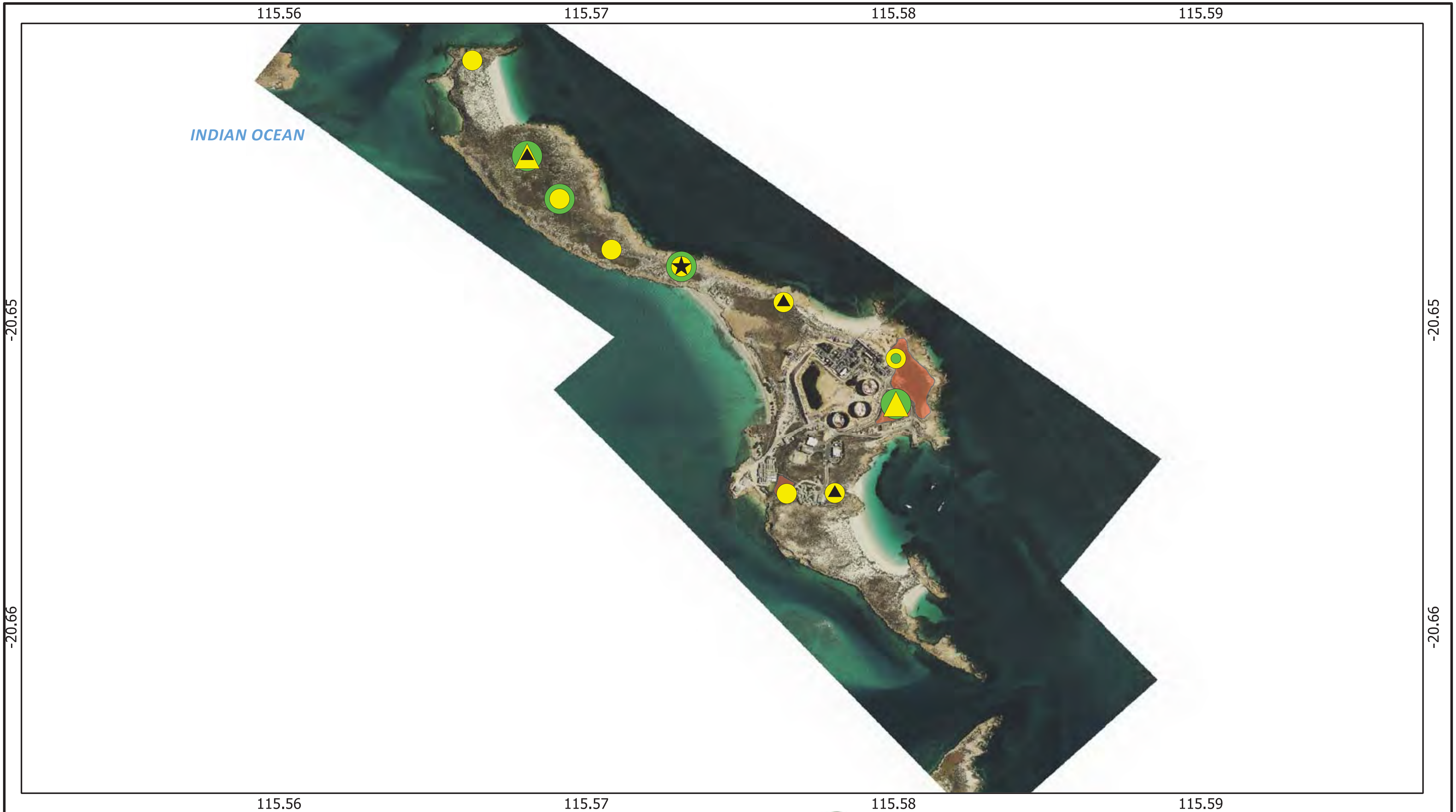
A total of 104 specimens of isopod specimens representing at least five species in five genera and two families were collected in the survey (Table 4-13; Figure 4-21). Two of these species are widespread. For example, *Buddelundia* 'sp. 60' occurs throughout the north-west Pilbara and also on Barrow Island (S. Judd 2012, email to Volker Framenau) and *Laevophiloscia yalgooensis* is common throughout Western Australia including Barrow Island (Dalens 1993). In contrast, *Barrowdillo pseudopyrgoniscus*, *Spherillo* 'varanus island' and cf. (= close form to) *Spherillo* 'varanus island' are considered SREs.

Species accumulation estimators suggest that only up to one species may have been missed during the survey (Table 4-7; Figure 4-14).

Table 4-13 Slaters (Isopoda) collected during the short-range endemic survey of the Varanus Island Fill Project, by site

	Site[a]											
Taxon[a]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Totals**
Armadillidae												
Armadillidae ‘varanus island’		1										**1**
Armadillidae sp. indet.							1					**1**
Barrowdillo pseudopyrgoniscus	3					6		3	3			**15**
Buddelundia ‘sp. 60’		5	14	4	14	1			3		3	**44**
Spherillo ‘varanus island’			11					1			21	**33**
Philosciidae												
Philosciidae sp. indet.									1			**1**
Laevophiloscia yalgooensis									1			**1**
Laevophiloscia sp. indet.	2							6				**8**
Totals	**5**	**6**	**25**	**4**	**14**	**7**	**1**	**10**	**8**	**-**	**24**	**104**

a – sites located in the impact area and species categorised as potential, likely or Confirmed SRE SREs are shaded in grey.



Barrowdillo pseudopyrgoniscus
Buddelundia '60'
Armadillidae 'varanus island'
Laevophiloscia sp. indet.
Laevophiloscia yalgoonensis
Spherillo 'varanus island'
impact area

0 0.25 0.5 km

N

Figure 4-21
Records of slaters from the short-range endemic survey of the Varanus Island Fill Project

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AUTHOR: A.E. Leung	**CLIENT: Apache Energy Ltd**
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PROJECT: Varanus Island Fill Project

4.10.1 Armadillidae

Armadillidae typically have a convex dorsal surface and the animal can roll up into a ball. The family is diverse in Australia, currently 24 genera are described; many species live in litter or under wood and stones in forest or woodland or near the coast (Green *et al.* 2010).

4.10.1.1 Genus *Barrowdillo*

Barrowdillo currently includes only a single described species endemic to from Barrow Island. However, at least four more undescribed species are known from collections (S. Judd 2012, email to Volker Framenau). *Barrowdillo* differs from *Buddelundia*, amongst others, in its ornamentation (Figure 4-9c) (Dalens 1993).

Barrowdillo pseudopyrgoniscus

Barrowdillo pseudopyrgoniscus (Figure 4-9c) was described based on specimens collected in two caves on Barrow Island (Dalens 1993). However, based on morphological features, e.g. fully developed eyes and pigmentation, it is not a troglobite and does also occur outside caves (Dalens 1993). *Barrowdillo pseudopyrgoniscus* is a potential SRE, having only been collected from Barrow Island previously, however it is expected to also occur on the neighbouring mainland (S. Judd 2012, email to Volker Framenau).

A total of 15 specimens were collected from four sites on Varanus Island, including one site in the impact area (Table 4-13).

4.10.1.2 Genus *Spherillo*

Slaters in the genus *Spherillo* possess a characteristic ventral groove (sulcus marginali) on the epimera of the first pereonite. They are characteristically very small (<3 mm in length) and have troglobitic tendencies (reduced eyes and pigment) (S. Judd 2012, email to Volker Framenau). Six species are currently described from Australia, but none of these occurs in WA (Green *et al.* 2010). The genus is taxonomically poorly understood and a placement of species in the genus must be considered tentative. Most species within *Spherillo* are considered likely SREs based on their cryptic lifestyle and perceived poor dispersal capabilities (S. Judd 2012, email to Volker Framenau).

***Spherillo* 'varanus island'**

Spherillo 'varanus island' has previously not been recorded; however it is very similar to a species found on Barrow Island and may be conspecific (Figure 4-9e) (S. Judd 2012, email to Volker Framenau). *Spherillo* 'varanus island' is considered a potential SRE based on the ecology and morphology of species in the genus (see above). The species was only collected in non-impact sites and in all habitat types surveyed (Table 4-13).

4.10.1.3 Genus indet. Armadillidae

This undescribed genus is morphologically similar to *Spherillo* but differs in the lack of the ventral groove on the epimera of the first pereonite which places it in a different, as yet undescribed genus (S. Judd 2012, email to Volker Framenau). Before this survey, four species were known from throughout WA, but all only from single localities only. This suggests most species of the genus to be SREs.

Armadillidae 'varanus island'

A single, male specimen of Armadillidae 'varanus island' (Figure 4-9d) was collected from this survey. This specimen was collected only at site 02, an impact site (Table 4-13). However, juvenile specimens of *Spherillo* 'varanus island', found in non-impact areas of Varanus Island, may represent juvenile specimens of Armadillidae 'varanus island' and this species may therefore be more widespread (S. Judd 2012, email to Volker Framenau). Considering the rarity of this genus in collections, this species should be regarded as a likely SRE.

4.11 MOLLUSCA (SNAILS)

Molluscs are one of the most diverse groups of invertebrates and the Australian fauna is characterised by a high degree of endemism (Beesley *et al.* 1998). Lands snails belong to the target groups for SRE surveys due to their limited dispersal capabilities, in combination with often strict dependencies on particular soils (EPA 2009; Harvey 2002). These characteristics have also resulted in a significant global decline of non-marine molluscs (Lydeard *et al.* 2004).

Eighteen species from five genera and three families of molluscs were identified from the desktop study as short-range endemics (Table 4-1; Figure 4-5; Figure 4-6). Two of these have previously been recorded from Varanus Island, *Quistrachia barrowensis* and *Rhagada plicata*.

The 673 specimens collected during the survey samples belong to eight species in six genera in the pulmonate families Camaenidae, Ellobiidae, Pupillidae, and Subulinidae and one species in the semi-aquatic family Truncatellidae (Table 4-14; Figure 4-22). With the exception of the Camaenidae, all of the species are thought to be widespread. *Melampus faciatus* occurs throughout tropical northern Australia but was initially described from Papua New Guinea and The Philippines (Smith 1992). *Pupoides contrarius* and *Pupoides lepidulus* are widespread along the northwestern Western Australian coastline (Smith 1992). *Gastrocopta mussoni* is found throughout the northern half of Australia into Queensland (Pokryszko 1996) and *Eremopeas interioris* commonly collected from the Pilbara into central Australia including the Northern Territory, Queensland and South Australia (Solem 1988). Members of the genus *Truncatella* are small to minute land snails that live very close to seawater in tropical and subtropical regions (Smith 1992). Being dispersed by marine drifts of plant material, they are not thought to include SREs.

Two species of camaenid snails were collected during the surveys on Varanus Island and tissue was submitted to the WA Museum for COI sequencing. The analyses identified *Rhagada plicata* and *Quistrachia montebelloensis*, the latter apparently a senior synonym of *Quistrachia barrowensis* (M. Johnson 2012, email to Volker Framenau) (see section 4.2.1). Both are considered confirmed SREs.

Species estimators suggest that all species present during the survey were recovered, with the exception of possibly one (Table 4-7; Figure 4-15).

Table 4-14 Snails (Mollusca) collected during the SRE survey of the Varanus Island Fill Project, by site

	Site[a]											
Taxon[a]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Totals**
Camaenidae												
Quistrachia montebelloensis	38	6	7	20	5	21	30	38	21		28	**214**
Rhagada plicata					5					17	27	**49**
Ellobiidae												
Melampus cf. *faciatus*									1		16	**17**
Pupillidae												
Pupoides contrarius	14			7	22	29	32	30	49	1	16	**200**
Pupoides lepidulus	3					29	4	33	4		9	**82**
Gastrocopta mussoni	1				1	29	1				67	**99**
Subulinidae												
Eremopeas interioris	3						5	3				**11**
Truncatellidae												
Truncatella sp. indet.											1	**1**
Totals	**59**	**6**	**7**	**27**	**33**	**108**	**72**	**104**	**75**	**18**	**164**	**673**

a – sites located in the impact area and species categorised as potential, likely or Confirmed SREs are shaded in grey.

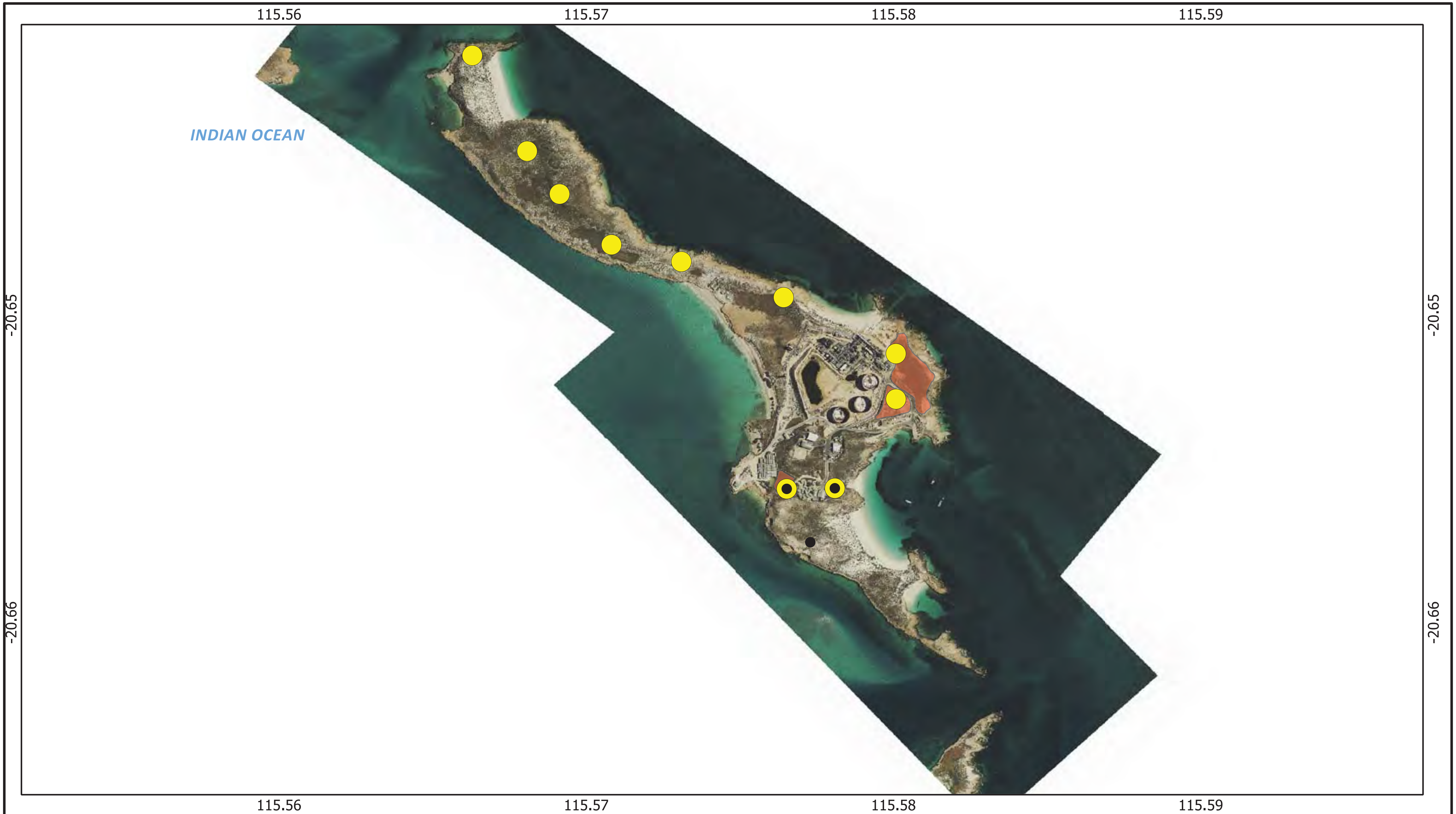

Figure 4-22
Records of short-range endemic snails from the short-range endemic survey of the Varanus Island Fill Project

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AUTHOR: A.E. Leung	**CLIENT:** Apache Energy Ltd
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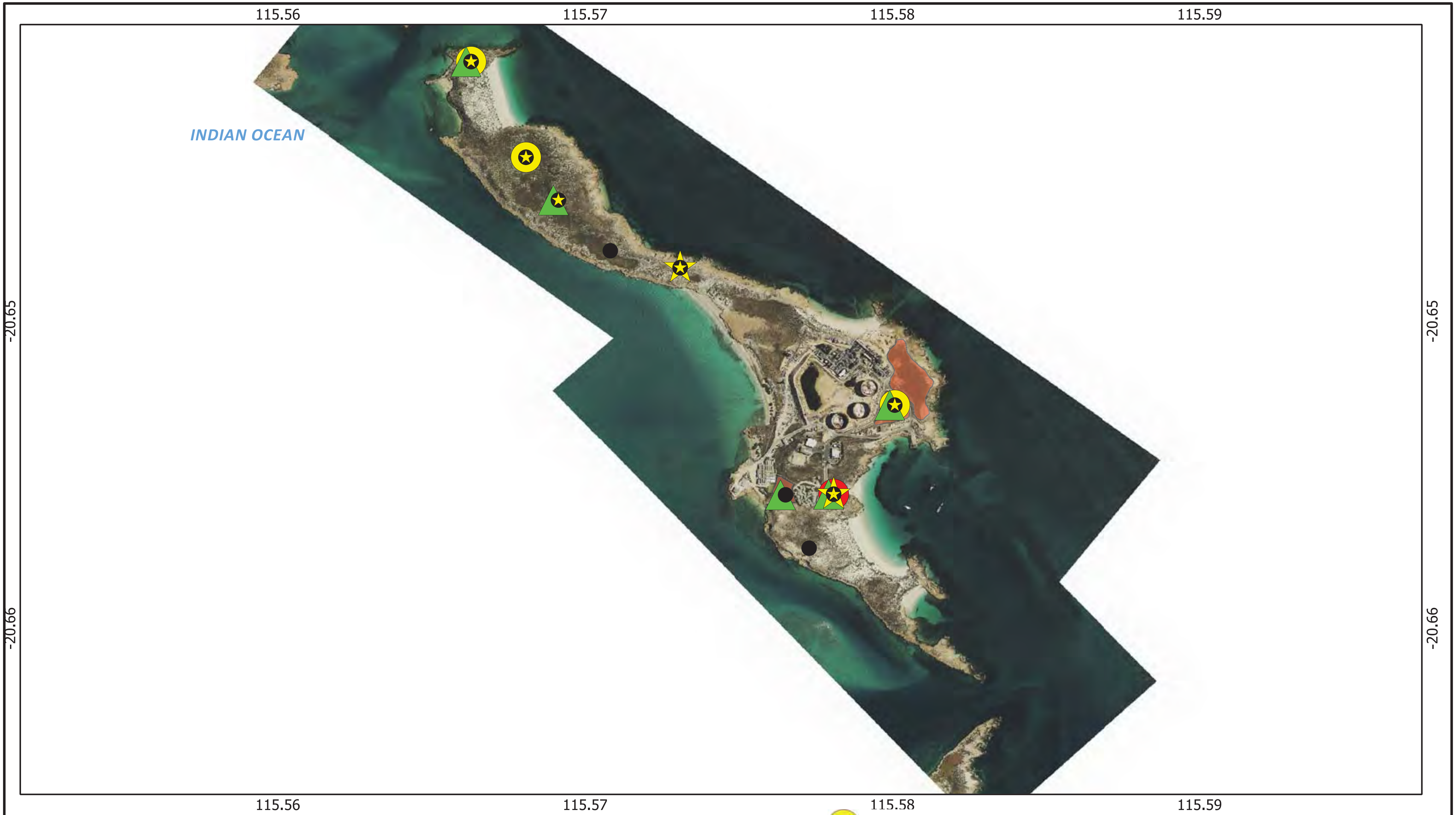
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

PROJECT: Varanus Island Fill Project

Quistrachia montebelloensis
Rhagada plicata
impact area

0 0.25 0.5 km

N



Eremopeas interioris
Gastrocopta mussoni
Melampus cf. fasciatus
Pupoides contrarius
Pupoides lepidulus
Truncatella sp. indet.

0 0.25 0.5 km

N

impact area

Figure 4-23 **Records of non-short-range endemic snails from the short-range endemic survey of the Varanus Island Fill Proiect**	PHOENIX ENVIRONMENTAL SCIENCES
AUTHOR: A.E. Leung	**CLIENT: Apache Energy Ltd**
DATE: August 2012	**Scale: 1:14000**
PROJECT: Varanus Island Fill Project	
Coordinate System: Projection: Transverse Mercator; Datum: GDA94	

4.11.1 Camaenidae

The Camaenidae is one of the most diverse land snail families in Australia both in species richness and morphology. Shell diameter ranges between 5 to 70 mm and shell shapes vary from discoidal and lenticular to globose, trochoidal, conical and elongate (Stanisic *et al.* 2010) The family is found Australia-wide with the exception of Tasmania and south-west WA (Stanisic *et al.* 2010).

In northern WA, the Camaenidae are the dominant group of land snails, with greatest diversity in the Kimberley region, where 19 of the 25 camaenid genera include SREs (Harvey *et al.* 2011; Solem 1997). In the Ningbing Ranges east of Kununurra, for example, the median geographical range of the 26 species occupying the area is less than one square-kilometre (Cameron 1992). Many of these ranges are shrinking, due to grazing and fire (Solem 1997) which resulted in the listing of 31 camaenid species under the Wildlife Conservation Act 1950 (Western Australian Government 2012).

Based on the latest taxonomic revision, the Pilbara camaenid fauna comprised 27 species from six genera, distributed in latitude between Port Hedland and Cape Range, with no evidence of sympatry between congeneric species (Solem 1997). However, recent targeted sampling of camaenid land snails in the region has shown that many forms are parapatric, allowing direct genetic tests of reproductive isolation. This has revealed that some species have broader distributions than formerly thought, while other described species are actually complexes of multiple species, some with very narrow distributions. The molecular analyses have also shown the unreliability of shell characteristics on their own for assessing species taxonomy in many of these snails (Stankowski 2011). However, molecular 'barcoding' of COI sequence data may also not provide satisfactory results to distinguish species in some camaenid genera (Köhler & Johnson 2012).

4.11.1.1 Genus *Quistrachia*

Shells of the genus *Quistrachia* differ from those of *Rhagada* by the presence of a pustulose apex and a continuation of the pustules on the spire, absence of any strong post-apical shell sculpture and an open umbilicus or a narrow lateral crack (Solem 1997). The genus currently includes nine described species and is limited to north-western WA (Solem 1997). All currently known species are SREs.

Quistrachia montebelloensis

With 214 specimens, *Quistrachia montebelloensis* was the most commonly collected snail on Varanus Island and was found at 10 of 11 sites (Table 4-14; Figure 4-22). This species was up until know known from the Montebello Islands only but the molecular analysis suggests it to be conspecific with *Quistrachia barrowensis*. *Quistrachia montebelloensis* is the older available name and used here pending a formal synonymisation of both species (M. Johnson and C. Whisson 2012, email to Volker Framenau). The species is now known from throughout the Barrow/Montebello/Lowendal archipelagos and based on its recent taxonomic treatment is considered a confirmed SRE.

4.11.1.2 Genus *Rhagada*

The genus *Rhagada* is characterised by a smooth or nearly smooth shell apex, lack of micropustules on the shell surface and simple radial ribs (Solem 1997). The genus is endemic to WA and, with 29 species, the second most diverse genus of the Camaenidae in the state (Johnson *et al.* 2004; Solem 1997). Solem (1997) has reported 18 species from the northern tip of Dampier Land through Bernier Island, Shark Bay. Live specimens of *Rhagada* have been found on lawns, in the shade of termite mounds and under isolated trees. The aestivate by burrowing into sandy soil, in litter, under spinifex and, less frequently, in rock rubble (Solem 1997).

As in other camaenid land snails in northern WA, recent molecular studies have revealed that there are taxonomic uncertainties when species are assessed based on morphology alone (Stankowski 2011). For example, detailed molecular and morphological analyses have shown continuity among morphologically diverse forms of *Rhagada* on Rosemary Island (Dampier Archipelago), suggesting that they represent a single species (Stankowski 2011). In contrast, other populations of *Rhagada* from the central Pilbara (*Rhagada convicta*, *Rhagada radleyi*) with fewer morphological differences are highly divergent lineages (Johnson *et al.* 2012). A molecular study of north-west coastal *Rhagada* has recently clarified the relationships of some species, including a sister-relationship of R. 'barrow small' from Barrow Island and Rhagada plicata (Johnson *et al.* 2012), both of which are here considered conspecific.

Rhagada plicata

Rhagada plicata is the smallest of all currently named *Rhagada* and was originally described from the Montebello Islands (Solem 1997). Forty-nine specimens of *Rhagada plicata* were collected on Varanus Island (Table 4-14; Figure 4-22). Similar to *Quistrachia montebelloensis*, *Rhagada plicata* is known from throughout the Barrow/Montebello/Lowendal archipelagos and is based on considerable recent molecular work considered a confirmed SRE.

4.12 SURVEY LIMITATIONS

Of the possible limitations as identified by *Guidance Statement 56* (EPA 2004), few had an effect on the outcome of this survey. The survey was conducted by experienced staff and the entire island was accessible, in particular throughout the proposed impact area. All main SRE taxa were collected although the desktop review identified some taxa of potential SREs from neighbouring Barrow Island that are generally not targeted, for example mites (Acari) and araneomorph spiders, except Selenopidae. Some logistic constraints did not allow larger numbers of specimens to be transported away from the island. There is a large amount of contextual information available from the region due to the intensive collections of invertebrates on Barrow Island; however, no contextual data on invertebrates was available from Varanus Island prior to the survey. Species accumulation curves suggest that most species in the SRE target taxa were collected, possibly with the exception of pseudoscorpions. Overall, the survey results appear to appropriately reflect the SRE invertebrate fauna of Varanus Island.

5 DISCUSSION

5.1.1 Terrestrial Invertebrates

This section presents an assessment of impacts to terrestrial SRE fauna by the Project. The EPA's objectives in relation to SRE fauna are to:

- ensure the protection of key habitats for SRE species
- maintain the distribution, abundance and productivity of populations of SRE taxa
- ensure that the conservation status of SRE taxa is not adversely changed as a result of development proposals (EPA 2009).

In assessing development proposals, the EPA aims to ensure that proposals do not potentially threaten the viability of, or lead to the extinction of any SRE species (EPA 2009).

Accordingly, the main aim of this assessment was to:

- determine whether any SRE taxa may be restricted solely to the proposed impact areas for the Project and therefore be at risk of extinction from the Project
- determine whether adequate habitat exists outside the proposed impact areas for SRE species recorded within the proposed impact areas (risk-based assessment).

Eight SRE invertebrate taxa were collected on Varanus Island. Five of these are currently known from outside Varanus Island, i.e. the flatrock spider *Karaops burbidgei* (Selenopidae), the trapdoor spider *Aname* 'MYG079' (Nemesiidae), the slater *Barrowdillo pseudopyrgoniscus* (Armadillidae), and the land snails *Rhagada plicata* and *Quistrachia montebelloensis* (Camaenidae). All are known from Barrow Island confirming the value of the surveys of this neighbouring island for an assessment of SREs from Varanus Island. The two land snails are also known from the Montebello Islands. Due to their wider distribution the effect of the Project on these species is considered very low.

It is currently impossible to assess the distribution of the centipede *Cryptops* sp. indet. (Cryptopidae) as the family is taxonomically poorly resolved. Cryptopidae are found on Barrow Island and the mainland within the area defined by the desktop review and based on the distribution pattern of most other SREs of the survey it is likely that the species from Varanus Island also occurs at least on Barrow Island. The molecular analyses conducted here showed that all *Cryptops* sp. indet. which were successfully sequenced, belong to the same species suggesting it to be widespread on Varanus Island. Consequently, impacts of the Project on the species are considered very low.

It is possible that the slater *Spherillo* 'varanus island' (Armadillidae) is conspecific with a *Spherillo* species from Barrow Island (S. Judd 2012, email to Volker Framenau). In addition, *Spherillo* 'varanus island' was only collected at sites in the non-impact area. Therefore, the impact of the Project on this species is considered very low.

The only SRE species currently exclusively known from an impact site is Armadillidae 'varanus island', here rated likely SRE. The single male specimen of this species was collected at site 02, a mid-island basin habitat of which part of is earmarked for the Project. However, the consulting taxonomist conceded that juvenile specimens of *Spherillo* 'varanus island', found in non-impact areas of Varanus Island, may represent juvenile specimens of Armadillidae 'varanus island' and this species may therefore be more widespread (S. Judd 2012, email to Volker Framenau). Mid-island basin habitat is not only found in the impact area but outside (e.g. sites 03 and 04) providing potential refugial areas if Armadillidae 'varanus island' was restricted to Varanus Island. Despite intense collecting, specimens similar to Armadillidae 'varanus island' have so far not been recorded from Barrow Island (S. Judd 2012, email to Volker Framenau). Based on the availability of mid-island basin habitat outside the impact area (risk-based assessment; see EPA 2009), but taking into consideration that this species has for far not been found on Barrow Island, the impact on Armadillidae 'varanus island' is considered moderate.

5.1.2 Subterranean invertebrates

This section presents an assessment of the likelihood that subterranean fauna are present on Varanus Island and how they may be affected by the Project. In assessing development proposals, the EPA's broad objective for subterranean fauna is to ensure there is adequate protection for important habitats for subterranean fauna and that no subterranean fauna species is threatened with extinction (EPA 2007). Accordingly, the main aim of the subterranean fauna desktop review was to determine wether:

- any subterranean fauna species occur in the proposed impact area of the Project and therefore be affected by Project
- adequate habitat exists outside the proposed impact area as refugia for those potentially occurring in the impact areas.

The impact area for the Project, in regard to subterranean fauna is defined as the area where excavation of fill material for the Project may result in direct removal of habitat for troglofauna and stygofauna. A final footprint for the removal of substrate, in particular the depth to which this will be removed, was not available at the time of the study.

Our desktop review did not reveal any records of troglofauna on Varanus Island, but it suggests that stygofauna is present; subterranean amphipods have apparently been collected on the island (Bradbury & Williams 1997). This suggests that freshwater and an anchialine layer may persist under Varanus Island despite is comparatively small size.

In the absence of systematic subterranean fauna surveys the likelihood of the presence of subterranean fauna, both troglofauna and stygofauna, is based on an assessment of the geology of Varanus Island and corresponding geologies on Barrow Island, which support a rich diversity of subterranean fauna. Varanus Island is comprised of a single geological type i.e. Pleistocene coastal limestone covered by lime-cemented shelly sand, dune sand, and beach conglomerate (Geological Survey of Western Australia 2003). This geology is well represented on the eastern side of Barrow Island where subterranean fauna has been recorded (e.g. Biota 2005; Biota & RPS 2005b). It is therefore very likely that troglofauna, in addition to stygofauna, are present on Varanus Island and may be present within the project area. The potential extent of troglofauna habitat is believed to correspond with the extent of the island.

This project is likely to impact on a relatively small proportion of the available troglofauna habitat as the proposed area of impact covers a small proportion of the island surface (Figure 1-2).

Two types of impact may result from the proposed development:

- primary (direct) impact from removal of troglofauna habitat
- secondary (indirect) impact from removal of surface vegetation.

The extent of the primary impact would be proportional to the depth to which rock is extracted, with the maximum impact to troglofauna occurring if all of the rock is removed to the water table. Phoenix has recorded troglofauna from less than one metre depth (unpublished data) and therefore there is potential for some level of direct impact to occur on troglofauna. However, If troglofauna are present in the area proposed for disturbance, then it is also likely that they are present elsewhere on the island due to the island's geological uniformity. It is therefore unlikely that the proposed project would threaten species to the point of extinction.

A direct impact on stygofauna is unlikely as fill material will only be removed from the surface.

Another mitigating factor in assessing the impact on subterranean fauna of Varanus Island is the very recent geological history that connects the Barrow, Montebello and Lowendal archipelagos with the mainland. These offshore islands were connected to the mainland as recent as about 8,000 years ago. Many subterranean species from Barrow Island are also found at Cape Range more than 140 km away. Stygofauna originally collected at Cape Range and on Barrow Island were subsequently also found in alluvial river-aquifer systems on the Pilbara coastal plain, i.e. the Robe and Fortescue Rivers (Eberhard *et al.* 2005). This suggests that the Cape Range and Barrow Island karsts were colonised migrated either from the Pilbara Craton or the fringing Mesozoic deposits (Humphreys 1993b; Humphreys 1993a). Varanus Island may therefore share a considerable percentage of its subterranean fauna with Barrow Island, Cape Range or the Pilbara coastal plain.

5.2 RECOMMENDATIONS

5.2.1 Terrestrial invertebrates

The aim of this study was to report on the terrestrial invertebrate SRE biodiversity on Varanus Island, particularly for areas proposed for land clearing. In light of the results, key recommendations are:

- to avoid and minimise disturbance at and near site 02, where a potentially unique SRE invertebrate, Armadillidae 'varanus island' was found
- to conduct surveys adequate to fill distinct gaps in knowledge of some SREs found on Varanus Island, in particular *Cryptops* centipedes and slaters, including Armadillidae 'varanus island'. Whilst it is likely that these species are found on nearby Barrow Island, this should be demonstrated to more accurately assess any impact on their populations on Varanus Island.

Possible threats to Varanus Island SREs go beyond further infrastructure developments. For example, introduced species may alter the invertebrate assemblage with can have a severe effect on the rarer species. In that regard, a further recommendation is:

- to conduct terrestrial invertebrate baseline surveys beyond SREs to assess any future changes in invertebrate assemblages, and to evaluate if there are other SREs on the island in addition to the groups targeted here, i.e. mites and araneomorph spiders.

5.2.2 Subterranean invertebrates

Gaps in the knowledge of the subterranean fauna of Varanus Island are more obvious than in relation to the terrestrial invertebrate fauna. Despite the likelihood of troglofauna occurring, none has so far been collected.

- baseline subterranean fauna surveys are recommended (both troglofauna and stygofauna) to assess the impact of the project on subterranean invertebrates.

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Appendix 1 Site descriptions

Site number: 01

Coordinates (GDA94): -20.652728 S 115.579566 E; 7715638 N, 352026 E, Zone 50K

Impact Area: yes

Habitat

Type: limestone plain

Geography: hill top and slopes

Vegetation: veg cover: 60%; herbs only; herb count within 100m: 70

Soil: none

Rockiness: limestone (continuous >90% cover)

Litter: small amounts only under large herbs

Disturbance and fire: developed area to east of site (plant operations)

Site number: 02

Coordinates (GDA94): -20.651221 S 115.580154 E; 7715805 N, 352086 E, Zone 50K

Impact Area: yes

Habitat

Type: mid-island basin

Geography: basin, flat

Vegetation: veg cover: 35%; herbs only; herb count within 100m: 100

Soil: whitish sand

Rockiness: limestone (5–30% cover)

Litter: small amounts only under large herbs

Disturbance and fire: developed area to east and south of site (plant operations)

Site number: 03

Coordinates (GDA94): -20.649391 S 115.576497 E; 7716005 N, 351703 E, Zone 50K

Impact Area: no

Habitat

Type: mid-island basin

Geography: gentle slope towards depression

Vegetation: veg cover: 95%; herbs only; herb count within 100m: 200

Soil: whitish sand

Rockiness: limestone (30-50% cover)

Litter: small amounts only under large herbs

Disturbance and fire: none

Site number: 04

Coordinates (GDA94): -20.647677 S 115.570895 E; 7716189 N, 351117 E, Zone 50K

Impact Area: no

Habitat

Type: mid-island basin

Geography: basin

Vegetation: 95% veg cover; herbs only; herb count within 100m: 150

Soil: whitish sand

Rockiness: limestone (5–30% cover)

Litter: small amounts only under large herbs

Disturbance and fire: none

Site number: 05

Coordinates (GDA94): -20.65562 S 115.576599 E; 7715315 N, 351719 E, Zone 50K

Impact Area: yes

Habitat

Type: sand dune

Geography: slope west and south

Vegetation: 90% veg cover; herbs only; herb count within 100m: 110

Soil: white sand

Rockiness: limestone (5-30% cover)

Litter: small amounts only under large herbs

Disturbance and fire: developed are above site (accommodation)

Site number: 06

Coordinates (GDA94): -20.646027 S 115.569206 E; 7716370 N, 350940 E, Zone 50K

Impact Area: no

Habitat

Type: limestone plain

Geography: hilltop slope

Vegetation: cover: 50–90% herbs only; herb count within 100m: 150

Soil: none

Rockiness: limestone (continuous >90% cover)

Litter: small amounts only under large herbs

Disturbance and fire: none

Site number: 07

Coordinates (GDA94): -20.64152 S 115.566364 E; 7716867 N, 350639 E, Zone 50K

Impact Area: no

Habitat

Type: limestone plain

Geography: hill top, slope

Vegetation: cover: 50–90%; herbs only; herb count within 100m: 120

Soil: none

Rockiness: limestone (30-50% cover)

Litter: small amounts only under large herbs

Disturbance and fire: none

Site number: 08

Coordinates (GDA94): -20.644633 S 115.56815 E; 7716524 N, 350828 E, Zone 50K

Impact Area: no

Habitat

Type: limestone plain

Geography: hill top, flat

Vegetation: veg cover: 80%; herbs only; herb count within 100m: 60

Soil: none

Rockiness: limestone (continuous: >90 % cover)

Litter: small amounts only under large herbs

Disturbance and fire: none

Site number: 09

Coordinates (GDA94): -20.648228 S 115.573169 E; 7716130 N, 351355 E, Zone 50K

Impact Area: no

Habitat

Type: limestone plain

Geography: hill top, flat

Vegetation: veg cover: 50%, herbs only; herb count within 100m: 60

Soil: none

Rockiness: limestone (continuous: >90% cover)

Litter: small amounts only under large herbs

Disturbance and fire: none

Site number: 10

Coordinates (GDA94): -20.657357 S 115.577366 E; 7715124 N, 351801 E, Zone 50K

Impact Area: no

Habitat

Type: sand dune

Geography: slopes into and including depression

Vegetation: 75% veg cover; herbs only; herb count within 100m: 80

Soil: white sand

Rockiness: none

Litter: small amounts only under large herbs

Disturbance and fire: none

Site number: 11

Coordinates (GDA94): -20.6556 S 115.578165 E; 7715319 N, 351883 E, Zone 50K

Impact Area: no

Habitat

Type: sand dune

Geography: east-facing slopes down to beach

Vegetation: 80% veg cover; herbs only; herb count within 100m: 100

Soil: whitish sand

Rockiness: limestone (50-90% cover)

Litter: small amounts only under large herbs

Disturbance and fire: developed areas above site (dining and accommodation)

Appendix 2 Short-range endemic invertebrates identified in the desktop review

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
Acari (mites)							
T11267	Acari	Laelapidae	*Haemolaelaps*	*marsupialis*	Barrow Island	20°48`S	115°24`E
T11264	Acari	Laelapidae	*Mesolaelaps*	*antipodianus*	Barrow Island	20°48`S	115°24`E
T11265	Acari	Laelapidae	*Mesolaelaps*	*antipodianus*	Barrow Island	20°48`S	115°24`E
T11266	Acari	Laelapidae	*Mesolaelaps*	*antipodianus*	Barrow Island	20°48`S	115°24`E
Araneae (spiders)							
T46537	Araneae	Ammoxenidae	*Barrowammo*	*waldockae*	Barrow Island, Bandicoot Bay	20°52`S	115°20`E
T46538	Araneae	Ammoxenidae	*Barrowammo*	*waldockae*	Barrow Island, Bandicoot Bay	20°52`S	115°20`E
T46539	Araneae	Ammoxenidae	*Barrowammo*	*waldockae*	Barrow Island, Bandicoot Bay	20°52`S	115°20`E
T57771	Araneae	Miturgidae	Miturga	`serrata`	Barrow Island, Bandicoot Bay	20°52`04"S	115°20`01"E
T88788	Araneae	Oonopidae	?*Orchestina*	`Barrow sp. 2`	Barrow Island, Gorgon Project footprint plot GP6	20°47`05"S	115°26`28"E
T73224	Araneae	Oonopidae	*Grymeus*	`nasutus`	Barrow Island, E. of Old Airport, site TLN13	20°48`04"S	115°26`33"E
T57532	Araneae	Oonopidae	*Grymeus*	`nasutus`	Barrow Island, 1 km W. of Warehouse	20°43`43"S	115°25`56"E
T88856	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, Gorgon Project footprint plot GP3	20°47`09"S	115°27`26"E
T100895	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, plot N15, `Tiger Cage`	20°48`20"S	115°25`52"E
T100896	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, plot N15, `Tiger Cage`	20°48`20"S	115°25`52"E
T88897	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, plot N06a, storage area (old airport)	20°47`34"S	115°25`27"E
T89177	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, plot N04b, barge landing	20°43`44"S	115°28`23"E
T88957	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, plot N28, near barge landing (CO2 data well site)	20°47`05"S	115°23`38"E
T89216	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, plot N23, old administration building	20°49`09"S	115°23`40"E
T89070	Araneae	Oonopidae	*Orchestina*	`barrow`	Barrow Island, plot N06b, storage area (old airport)	20°47`52"S	115°25`56"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T89081	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, plot N7b, base/warehouse	20°49\`06"S	115°23\`09"E
T57507	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, WAPET Camp	20°49\`43"S	115°26\`40"E
T57508	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, Bandicoot Bay	20°52\`04"S	115°20\`01"E
T87310	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, site 22	20°47\`12"S	115°27\`17"E
T87311	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, site 22	20°47\`12"S	115°27\`17"E
T87312	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, site 22	20°47\`12"S	115°27\`17"E
T87313	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, plot 22, old drill workshops	20°49\`55"S	115°25\`13"E
T87314	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island old rubbish dump	20°47\`51"S	115°20\`55"E
T87315	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, Chevron Texaco Camp	20°49\`43"S	115°26\`36"E
T87316	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, site 17	20°47\`38"S	115°27\`24"E
T87317	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, site 45	20°47\`18"S	115°26\`31"E
T87318	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, plot 26, current gravel pit	20°49\`01"S	115°26\`06"E
T87319	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, plot 26, current gravel pit	20°49\`01"S	115°26\`06"E
T87320	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, plot 26, current gravel pit	20°49\`01"S	115°26\`06"E
T87321	Araneae	Oonopidae	*Orchestina*	\`barrow\`	Barrow Island, plot 26, current gravel pit	20°49\`01"S	115°26\`06"E
T73219	Araneae	Oonopidae	*Pelicinus*	*saaristoi*	Barrow Island, New Airport, site QUNA1	20°51\`57"S	115°24\`23"E
T83647	Araneae	Oonopidae	*Pelicinus*	*saaristoi*	Barrow Island, site 17	20°47\`38"S	115°27\`24"E
T83648	Araneae	Oonopidae	*Pelicinus*	*saaristoi*	Barrow Island, future construction village	20°49\`00"S	115°26\`16"E
T83649	Araneae	Oonopidae	*Pelicinus*	*saaristoi*	Barrow Island, current airport	20°52\`01"S	115°24\`19"E
T89054	Araneae	Oonopidae	*Pelicinus*	*saaristoi*	Barrow Island, plot N04a, barge landing	20°43\`29"S	115°28\`20"E
T89068	Araneae	Oonopidae	*Pelicinus*	*saaristoi*	Barrow Island, plot N06b, storage area (old airport)	20°47\`52"S	115°25\`56"E
T97861	Araneae	Selenopidae	*Karaops*	\`sp. (juv.)\`	Barrow Island, plot N09, central processing facility	20°47\`05"S	115°23\`38"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T97862	Araneae	Selenopidae	*Karaops*	\`sp. (juv.)\`	Barrow Island, plot N10, evaporation pit	20°49\`23"S	115°22\`21"E
T97863	Araneae	Selenopidae	*Karaops*	\`sp. (juv.)\`	Barrow Island, Gorgon Project Footprint, plot GP 6	20°47\`05"S	115°26\`28"E
T28021	Araneae	Selenopidae	*Karaops*	\`sp. (juv.)\`	Dampier, Old Medical Centre	20°40\`S	116°42\`E
T54972	Araneae	Selenopidae	*Karaops*	\`sp. (juv.)\`	Barrow Island, Base	20°49\`14"S	115°23\`08"E
T54977	Araneae	Selenopidae	*Karaops*	\`sp. (juv.)\`	near Hearson Cove, Burrup Peninsula	20°37\`06"S	116°48\`05"E
T114678	Araneae	Selenopidae	*Karaops*	\`sp. juv.\`	Karratha to Millstream-Chichester National Park	21°12\`28.81"S	117°02\`42.49"E
T114805	Araneae	Selenopidae	*Karaops*	\`sp. juv.\`	Dixon Island, 24 km NE. of Karratha	20°38\`13.16"S	117°03\`06.01"E
T76698	Araneae	Selenopidae	*Karaops*	burbidgei	Barrow Island, site 45	20°47\`18"S	115°28\`31"E
T55000	Araneae	Selenopidae	*Karaops*	*burbidgei*	Barrow Island, John Wayne Country, rocky site	20°45\`08"S	115°22\`05"E
T20272	Araneae	Zodariidae	*Spinasteron*	*casuarium*	Enderby Island	20°36\`S	116°29\`E
Curtin Uni	Araneae	Actinopodidae	*Missulena*	sp. indet.	Barrow Island	20°43\`29.51"S	115°28\`19.89"E
T3718	Araneae	Actinopodidae	*Missulena*	*occatoria*-group	Mardie Station	21°13\`S	115°58\`E
T115386	Araneae	Barychelidae	*Aurecocrypta*	\`po3\`	c. 12 km NE. of Mardie, cracking clays site	21°08\`00.06"S	116°07\`00.02"E
T98356	Araneae	Barychelidae	*Aureocrypta*	\`Barrow sp. 1\`	Barrow Island, temporary construction facility @ well pad X81	20°44\`22.7"S	115°25\`18.2"E
T98357	Araneae	Barychelidae	*Aureocrypta*	\`Barrow sp. 1\`	Barrow Island, temporary construction facility @ well pad X81	20°44\`22.7"S	115°25\`18.2"E
T98358	Araneae	Barychelidae	*Aureocrypta*	\`Barrow sp. 1\`	Barrow Island, temporary construction facility @ well pad X81	20°44\`22.7"S	115°25\`18.2"E
T92143	Araneae	Barychelidae	*Idiommata*	\`sp. (female)\`	Barrow Island, c. 2 km W. of Town Point, site L3 (Gorgon Gas Plant Treatment site)	20°47\`18"S	115°26\`36"E
T115387	Araneae	Barychelidae	*Synothele*	\`preston\`	c. 18 km SE. of Mardie, site 74	21°17\`37.72"S	116°09\`30.02"E
T19867	Araneae	Barychelidae	*Synothele*	*butleri*	Barrow Island	20°48\`S	115°24\`E
T88977	Araneae	Ctenizidae	*Conothele*	\`Barrow sp. 1\`	Barrow Island, plot N08, terminal tanks	20°46\`45"S	115°27\`43"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T92159	Araneae	Ctenizidae	*Conothele*	\`Barrow sp. 1\`	Barrow Island, Gorgon Project camp (site N01)	20°49\`02"S	115°26\`24"E
T107722	Araneae	Ctenizidae	*Conothele*	\`Barrow sp. 1\`?	Barrow Island, LNG Plant, area 2, 1.2 km S. of Terminal Tanks	20°47\`20.0"S	115°27\`39.1"E
T26764	Araneae	Ctenizidae	*Conothele*	\`Barrow sp. 2\`	Barrow Island	20°48\`S	115°24\`E
T107721	Araneae	Ctenizidae	*Conothele*	\`Barrow sp. 3\`	Barrow Island, A station	20°50\`37.3"S	115°20\`59.1"E
T110207	Araneae	Ctenizidae	*Conothele*	\`sp. (juv.)\`	Barrow Island, 105.3 km NNE of Onslow	20°44\`48"S	115°28\`14"E
T110211	Araneae	Ctenizidae	*Conothele*	\`sp. (juv.)\`	Barrow Island, 110.7 km NNE of Onslow	20°41\`05"S	115°26\`20"E
T110214	Araneae	Ctenizidae	*Conothele*	\`sp. (juv.)\`	Barrow Island, 102.0 km NNE of Onslow	20°46\`18"S	115°27\`07"E
T60559	Araneae	Ctenizidae	*Conothele*	\`sp.\`	4 km SW. of Zebra Hill, on Munni Munni Creek	21°13\`05"S	116°49\`34"E
T98255	Araneae	Idiopidae	*Eucyrtops*	\`sp. (juv.)\`	Karratha, ca. 20 km ENE, site SRE23, 05	20°39\`23.14"S	117°04\`38.05"E
T96997	Araneae	Idiopidae	*Euoplos*	\`MYG081\`	9 km NW. of Lake Poongkaliyarra, Pilbara Biological Survey site DRC05	20°56\`23.8"S	117°02\`05.3"E
T110196	Araneae	Idiopidae	*Euoplos*	\`MYG218\`	Barrow Island, 102.0 km NNE of Onslow	20°46\`18"S	115°27\`07"E
T110183	Araneae	Idiopidae	*Euoplos*	\`sp. (?MYG218; female)\`	Barrow Island, 102.0 km NNE of Onslow	20°46\`17"S	115°27\`05"E
T110204	Araneae	Idiopidae	*Euoplos*	\`sp. (?MYG218; juv.)\`	Barrow Island, 102.0 km NNE of Onslow	20°46\`18"S	115°27\`07"E
T110212	Araneae	Idiopidae	*Euoplos*	\`sp. (?MYG218; juv.)\`	Barrow Island, 102.0 km NNE of Onslow	20°46\`18"S	115°27\`07"E
T31765	Araneae	Nemesiidae	*Aname*	\`Barrow Island\`	Barrow Island, WAPET Camp	20°49\`43"S	115°26\`40"E
T31766	Araneae	Nemesiidae	*Aname*	\`Barrow Island\`	Barrow Island, WAPET Camp	20°49\`43"S	115°26\`40"E
T31803	Araneae	Nemesiidae	*Aname*	\`Barrow Island\`	Barrow Island, WAPET Camp	20°49\`43"S	115°26\`40"E
T31804	Araneae	Nemesiidae	*Aname*	\`Barrow Island\`	Barrow Island, John Wayne Country, rocky site	20°45\`08"S	115°22\`05"E
T31380	Araneae	Nemesiidae	*Aname*	\`Barrow Island\`	Barrow Island, WAPET Camp	20°49\`43"S	115°26\`40"E
T46405	Araneae	Nemesiidae	*Aname*	*mainae* sp. gp	Lowendal Islands, Abutilon Island	20°40\`S	115°34\`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T27314	Araneae	Nemesiidae	*Aname*	`*mainae* sp. gp`	Barrow Island	20°48`S	115°24`E
T102039	Araneae	Nemesiidae	*Aname*	`MYG079 juvenile`	Barrow Island, 100 km NNE. of Onslow	20°51`58"S	115°24`28"E
T102051	Araneae	Nemesiidae	*Aname*	`MYG079 juvenile`	Barrow Island, 100 km NNE. of Onslow	20°43`34"S	115°28`24"E
T117257	Araneae	Nemesiidae	*Aname*	`MYG079`	Quarantine Interception, Q640 from Barrow Island, 100 Person Camp carpark, 100 km NNE. of Onslow	20°49`41"S	115°26`42"E
T113806	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`37"S	115°26`48"E
T113807	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`37"S	115°26`48"E
T113808	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`37"S	115°26`48"E
T113809	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°43`32"S	115°28`22"E
T113810	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°43`31"S	115°28`18"E
T113811	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°43`41"S	115°28`21"E
T113812	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°43`34"S	115°28`24"E
T102037	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`26"S	115°26`36"E
T113813	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°51`59"S	115°24`27"E
T102038	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`34"S	115°28`24"E
T113814	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°51`59"S	115°24`27"E
T113815	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`26"S	115°26`36"E
T113816	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`33"S	115°26`40"E
T102041	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`39"S	115°28`30"E
T113817	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`33"S	115°26`40"E
T113818	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°51`58"S	115°24`28"E
T102043	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`35"S	115°26`38"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T113819	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`35"S	115°26`37"E
T113820	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`35"S	115°26`37"E
T102045	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`33"S	115°28`23"E
T113821	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`34"S	115°26`48"E
T102046	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`34"S	115°28`24"E
T113822	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°49`37"S	115°26`48"E
T113823	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`21"S	115°27`37"E
T102048	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`33"S	115°26`48"E
T113824	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`21"S	115°27`37"E
T102049	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`33"S	115°26`40"E
T113825	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`21"S	115°27`37"E
T102050	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`34"S	115°28`24"E
T113826	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°41`32"S	115°25`4"E
T113827	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`21"S	115°27`41"E
T102052	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`34"S	115°28`24"E
T113828	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`25"S	115°27`32"E
T102053	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°51`56"S	115°24`26"E
T113829	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`25"S	115°27`32"E
T102054	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°51`60"S	115°24`21"E
T113830	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`25"S	115°27`32"E
T102055	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`33"S	115°28`23"E
T113831	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island	20°47`22"S	115°27`35"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T102056	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°51`56"S	115°24`26"E
T102057	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`36"S	115°26`48"E
T102058	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`34"S	115°28`24"E
T102059	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`32"S	115°26`43"E
T102060	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`39"S	115°28`30"E
T102061	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`32"S	115°26`43"E
T102062	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`33"S	115°26`40"E
T102063	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°49`35"S	115°26`38"E
T102064	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island, 100 km NNE. of Onslow	20°43`43"S	115°28`26"E
T119217	Araneae	Nemesiidae	*Aname*	`MYG079`	Varanus Island	20°39`15.7"S	115°34`41.5"E
T96992	Araneae	Nemesiidae	*Aname*	`MYG079`	Barrow Island camp mess, kitchen	20°49`43"S	115°26`40"E
T102047	Araneae	Nemesiidae	*Aname*	`MYG178`	Barrow Island, 100 km NNE. of Onslow	20°51`56"S	115°24`29"E
T110185	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; female)`	Barrow Island, 111.5 km NNE of Onslow	20°40`55"S	115°27`18"E
T110188	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; female)`	Barrow Island, 110.7 km NNE of Onslow	20°41`04"S	115°26`21"E
T110189	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; female)`	Barrow Island, 111.5 km NNE of Onslow	20°40`56"S	115°27`18"E
T110193	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; female)`	Barrow Island, 105.2 km NNE of Onslow	20°44`51"S	115°28`12"E
T110190	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; juv.)`	Barrow Island, 100.3 km NNE of Onslow	20°47`25"S	115°27`31"E
T110191	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; juv.)`	Barrow Island, 100.3 km NNE of Onslow	20°47`25"S	115°27`31"E
T110194	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; juv.)`	Barrow Island, 106.4 km NNE of Onslow	20°43`47"S	115°27`23"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T110213	Araneae	Nemesiidae	*Aname*	`sp. (?MYG079; juv.)`	Barrow Island, 106.4 km NNE of Onslow	20°43`47"S	115°27`23"E
T110195	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 102.0 km NNE of Onslow	20°46`18"S	115°27`07"E
T20603	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island	20°48`S	115°24`E
T74216	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 250 m SW. of Terminal Tanks, site BIHT11	20°47`23"S	115°27`21"E
T88841	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, Gorgon Project footprint plot GP9	20°47`59"S	115°27`00"E
T88884	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, plot N02, old dump	20°47`47"S	115°21`01"E
T89092	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, plot N12, Osprey camp	20°49`55"S	115°25`52"E
T96520	Araneae	Nemesiidae	*Aname*	sp. indet.	Cape Lambert, 24.3 km NE. of Karratha	20°41`05"S	117°04`21"E
T98865	Araneae	Nemesiidae	*Aname*	sp. indet.	Cape Preston, 64.7 km WSW. of Karratha	20°57`56"S	116°16`25"E
T98869	Araneae	Nemesiidae	*Aname*	sp. indet.	Cape Preston, 67.1 km WSW. of Karratha	21°02`50"S	116°17`31"E
T98870	Araneae	Nemesiidae	*Aname*	sp. indet.	Cape Preston, 64.7 km WSW. of Karratha	20°57`56"S	116°16`25"E
T88912	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, plot N11, former ODE camp	20°48`52"S	115°22`32"E
T96605	Araneae	Nemesiidae	*Aname*	sp. indet.	Aquila, 30.2 km S. of Karratha	20°56`52"S	116°14`43"E
T110182	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 102.0 km NNE of Onslow	20°46`18"S	115°27`07"E
T110197	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 111.5 km NNE of Onslow	20°40`55"S	115°27`18"E
T110198	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 102.0 km NNE of Onslow	20°46`17"S	115°27`06"E
T110200	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 100.3 km NNE of Onslow	20°47`25"S	115°27`31"E
T110201	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 101.4 km NNE of Onslow	20°46`30"S	115°26`42"E
T110202	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 102.9 km NNE of Onslow	20°45`55"S	115°27`06"E
T110203	Araneae	Nemesiidae	*Aname*	sp. indet.	Barrow Island, 101.5 km NNE of Onslow	20°46`29"S	115°26`54"E
T110206	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, 101.5 km NNE of Onslow	20°46`29"S	115°26`54"E
T27531	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island	20°48`S	115°24`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T88978	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, plot N12, Osprey camp	20°49`55"S	115°25`52"E
T110788	Araneae	Nemesiidae	Aname	sp. indet.	quarantine seizure, Barrow Island, HDD Construction Camp, site BWI	20°50`S	115°26`E
T102854	Araneae	Nemesiidae	Aname	sp. indet.	Aquila, 65 km SW. of Karratha	21°02`40"S	116°19`06"E
T102856	Araneae	Nemesiidae	Aname	sp. indet.	Aquila, 54 km SW. of Karratha	20°57`48"S	116°23`27"E
T102857	Araneae	Nemesiidae	Aname	sp. indet.	Aquila, 54 km SW. of Karratha	20°57`48"S	116°23`27"E
T102858	Araneae	Nemesiidae	Aname	sp. indet.	Aquila, 54 km SW. of Karratha	20°57`48"S	116°23`27"E
T102859	Araneae	Nemesiidae	Aname	sp. indet.	Aquila, 54 km SW. of Karratha	20°57`48"S	116°23`27"E
T98765	Araneae	Nemesiidae	Aname	sp. indet.	Cape Preston, 66.3 km WSW. of Karratha	20°59`48"S	116°16`24"E
T98766	Araneae	Nemesiidae	Aname	sp. indet.	Cape Preston, 66.3 km WSW. of Karratha	20°59`49"S	116°16`24"E
T98768	Araneae	Nemesiidae	Aname	sp. indet.	Cape Preston, 64.7 km WSW. of Karratha	20°57`56"S	116°16`25"E
T98258	Araneae	Nemesiidae	Aname	sp. indet.	Cleaverville, ca. 3.5 km S, site SRE17	20°40`23.30"S	117°02`45.73"E
T98770	Araneae	Nemesiidae	Aname	sp. indet.	Cape Preston, 64.7 km WSW. of Karratha	20°57`56"S	116°16`25"E
T98771	Araneae	Nemesiidae	Aname	sp. indet.	Cape Preston, 64.7 km WSW. of Karratha	20°57`56"S	116°16`24"E
T98260	Araneae	Nemesiidae	Aname	sp. indet.	Cleaverville, ca. 6.5 km WNW, site SRE23	20°39`23.14"S	117°04`38.05"E
T98261	Araneae	Nemesiidae	Aname	sp. indet.	Cleaverville, ca. 3.5 km S, site SRE16	20°40`37.34"S	117°02`14.43"E
T98774	Araneae	Nemesiidae	Aname	sp. indet.	Cape Preston, 67.1 km WSW. of Karratha	21°02`48"S	115°17`29"E
T88798	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, Gorgon Project footprint plot GPX	20°47`45"S	115°27`08"E
T74214	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, 250 m SW. of Terminal Tanks, site BIHT11	20°47`23"S	115°27`21"E
T88806	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, Gorgon Project footprint plot GP3	20°47`09"S	115°27`26"E
T74215	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, 250 m SW. of Terminal Tanks, site BIHT11	20°47`23"S	115°27`21"E
T74217	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, S. side of Terminal Creek, E. of road, site BIHT12	20°48`28"S	115°27`02"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T74218	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, S. side of Terminal Creek, E. of road, site BIHT13	20°48`24"S	115°27`01"E
T74219	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, c. 250 m SW. of Terminal Tanks, site BIHT14	20°47`20"S	115°27`19"E
T74220	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, c. 250 m SW. of Terminal Tanks, site BIHT15	20°47`20"S	115°27`17"E
T88812	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, Gorgon Project footprint plot GP9	20°47`59"S	115°27`00"E
T88815	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, Gorgon Project footprint plot GP4	20°47`03"S	115°27`33"E
T88827	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, Gorgon Project footprint plot GP3	20°47`09"S	115°27`26"E
T115237	Araneae	Nemesiidae	Aname	sp. indet.	Fortescue River mouth, site 52	20°59`57.63"S	116°08`36.60"E
T31156	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, Bandicoot Bay	20°52`07"S	115°20`01"E
T115382	Araneae	Nemesiidae	Aname	sp. indet.	c. 1 km. E. of Mardie, site F2	21°11`08.84"S	116°08`37.64"E
T27450	Araneae	Nemesiidae	Aname	sp. indet.	N. of Hearson Cove, Burrup Peninsula	20°38`S	116°48`E
T27451	Araneae	Nemesiidae	Aname	sp. indet.	N. of Hearson Cove, Burrup Peninsula	20°38`S	116°48`E
T28006	Araneae	Nemesiidae	Aname	sp. indet.	Varanus Island	20°39`S	115°34`E
T44187	Araneae	Nemesiidae	Aname	sp. indet.	Barrow Island, WAPET Camp	20°49`12"S	115°26`24"E
T115383	Araneae	Nemesiidae	Kwonkan	`po2`	c. 29 km NE. of Mardie, site 63	21°05`07.60"S	116°16`31.62"E
T115384	Araneae	Nemesiidae	Kwonkan	`po2`	c. 12 km NE. of Mardie, cracking clays site	21°08`00.06"S	116°07`00.02"E
T110184	Araneae	Nemesiidae	Kwonkan	`sp. (female)`	Barrow Island, 106.4 km NNE of Onslow	20°43`47"S	115°27`24"E
T110187	Araneae	Nemesiidae	Kwonkan	`sp. (female)`	Barrow Island, 106.4 km NNE of Onslow	20°43`47"S	115°27`24"E
T110199	Araneae	Nemesiidae	Kwonkan	`sp. (female)`	Barrow Island, 106.4 km NNE of Onslow	20°43`50"S	115°27`23"E
T88942	Araneae	Nemesiidae	Kwonkan	`sp. (juv.)`	Barrow Island, plot N22, old drill workshops	20°49`55"S	115°25`13"E
T99463	Araneae	Nemesiidae	*Yilgarnia*	`Barrow sp. 1`	Barrow Island, site 45	20°47`18"S	115°26`31"E
T110186	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Barrow Island, 102.0 km NNE of Onslow	20°46`17"S	115°27`06"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T110192	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Barrow Island, 101.6 km NNE of Onslow	20°46`30"S	115°26`57"E
T110205	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Barrow Island, 101.6 km NNE of Onslow	20°46`30"S	115°26`57"E
T110208	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Barrow Island, 101.6 km NNE of Onslow	20°46`30"S	115°26`57"E
T110209	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Barrow Island, 101.6 km NNE of Onslow	20°46`30"S	115°26`57"E
T110210	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Barrow Island, 101.6 km NNE of Onslow	20°46`30"S	115°26`57"E
T113798	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Barrow Island	20°52`17"S	115°23`10"E
T98743	Araneae	Nemesiidae	*Yilgarnia*	`sp. (juv.)`	Burrup Peninsula	20°37`29"S	116°46`20"E
T92147	Araneae	Nemesiidae	*Yilgarnia*	`sp.`	Barrow Island, c. 3 km W. of Town Point, site L4 (Gorgon Gas Plant Treatment site)	20°47`27"S	115°26`27"E
Schizomida (schiomids)							
T119506	Schizomida	Hubbardiidae	`Gen. indet.`	`SCH006`	Central Block, ca. 65 km NNW. Pannawonica	21°03`36.8"S	116°08`55.7"E
T119507	Schizomida	Hubbardiidae	`Gen. indet.`	`SCH006`	Central Block, ca. 65 km NNW. Pannawonica	21°05`18.6"S	116°08`25.4"E
T93374	Schizomida	Hubbardiidae	`Gen. nov.`	`Cape Preston`	Balmoral, N. of, Cape Preston	21°04`28.3"S	116°08`29.9"E
T93375	Schizomida	Hubbardiidae	`Gen. nov.`	`Cape Preston`	Balmoral, N. of, Cape Preston	21°04`33.4"S	116°08`42.6"E
T93376	Schizomida	Hubbardiidae	`Gen. nov.`	`Cape Preston`	Balmoral, N. of, Cape Preston	21°04`55.3"S	116°08`24.3"E
T93377	Schizomida	Hubbardiidae	`Gen. nov.`	`Cape Preston`	Balmoral, N. of, Cape Preston	21°04`16.7"S	116°08`28.3"E
T93378	Schizomida	Hubbardiidae	`Gen. nov.`	`Cape Preston`	Balmoral, N. of, Cape Preston	21°03`57.5"S	116°08`46.6"E
T122887	Schizomida	Hubbardiidae	*Draculoides*	`sp. juv.`	Barrow Island	20°49`12"S	115°26`04"E
T110377	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island	20°49`12"S	115°26`04"E
T110378	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island	20°47`53"S	115°26`05"E
T104448	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore S7P1T2-3	20°48`29"S	115°24`58"E
T104449	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore GW03BP1T2-3	20°47`27.21"S	115°27`27.14"E
T104451	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore S5P1T2-7	20°47`53"S	115°26`05"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T104452	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore GW04DT3-3	20°47`33"S	115°27`19"E
T104467	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore GW03BP2T3-4, troglofauna trap, 8m deep	20°47`27"S	115°27`27"E
T60180	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, site WL4	20°46`S	115°24`E
T60181	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, site WB.2	20°46`S	115°24`E
T104471	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore GW05-D-251, stygofauna haul	20°47`32.57"S	115°27`19.51"E
T104474	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore S6-252, stygofauna haul	20°48`04"S	115°26`44"E
T71967	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (borehole BMW4)	20°47`02"S	115°23`39"E
T28778	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Ledge Cave (Cave B-1)	20°48`S	115°20`E
T28779	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Ledge Cave (Cave B-1)	20°48`S	115°20`E
T28780	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
T28781	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
T28782	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
T28783	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
T28784	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
T104048	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore GWo1BP2T1-3, troglofauna trap, 4m deep	20°47`13"S	115°27`36"E
T28785	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
T104049	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore GWo1BP2T2-3, troglofauna trap, 7m deep	20°47`13"S	115°27`36"E
T28786	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
104050	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore S5P2T1-3, troglofauna trap, 5m deep	20°47`53"S	115°26`05"E
28787	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
104051	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore S5P2T2-2, troglofauna trap, 10m deep	20°47`53"S	115°26`05"E
28788	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
104052	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, bore GW03BP2T2-3, troglofauna trap, 6m deep	20°47`27"S	115°27`27"E
28789	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
28790	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
28791	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
28792	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°48`S	115°20`E
28793	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Bore WB2	20°52`S	115°21`E
28794	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Bore WB2	20°52`S	115°21`E
28795	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-6	20°51`S	115°23`E
76924	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 1.3 km NW. of Chevron Texaco Camp (borehole S9; Trap1-81)	20°49`12"S	115°26`04"E
28796	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-10	20°49`S	115°23`E
76925	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.0 km N. of Chevron Texaco Camp (borehole B16; Trap1-82)	20°47`32"S	115°27`03"E
28797	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-10	20°49`S	115°23`E
76926	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.4 km N. of Chevron Texaco Camp (borehole B20; Trap2-85)	20°47`19"S	115°26`48"E
28798	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-10	20°49`S	115°23`E
76927	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km N. of Chevron Texaco Camp (borehole S2; Trap 2-83)	20°46`33"S	115°26`53"E
T28799	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-10	20°49`S	115°23`E
T76928	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.9 km N. of Chevron Texaco Camp (borehole B9; Trap 2-82)	20°47`27"S	115°27`14"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T76929	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (borehole BMW4; Trap 2-86)	20°47`02"S	115°23`39"E
T76930	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 3.9 km NW. of Chevron Texaco Camp (borehole B23; Trap 1-81)	20°47`34"S	115°26`50"E
T76931	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.4 km NW. of Chevron Texaco Camp (borehole B11; Trap 1-82)	20°47`19"S	115°27`04"E
T76932	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km N. of Chevron Texaco Camp (borehole S3; Trap 1-82)	20°46`37"S	115°27`26"E
T76933	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.2 km N. of Chevron Texaco Camp (borehole B18; Trap 1-83)	20°47`26"S	115°26`57"E
T76934	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.6 km N. of Chevron Texaco Camp (borehole B21; Trap 1-81)	20°47`12"S	115°26`41"E
T76935	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.3 km N. of Chevron Texaco Camp (borehole B10; Trap 1-81)	20°47`25"S	115°27`10"E
T76936	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 3.4 km NNW. of Chevron Texaco Camp (borehole S5; Trap 1-82)	20°47`54"S	115°26`05"E
T76937	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km N. of Chevron Texaco Camp (borehole S3; Trap 1-58)	20°46`37"S	115°27`26"E
T75204	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km N. of Chevron Texaco Camp, borehole S3 (trap 1)	20°46`37"S	115°27`26"E
T75205	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp, borehole BMW4 (trap 4)	20°47`02"S	115°23`39"E
T75206	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7 km NW. of Chevron Texaco Camp,borehole CHW2 (trap 2)	20°47`04"S	115°23`41"E
T75207	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 6.3 km W. of Chevron Texaco Camp, borehole BMW7 (trap 2)	20°49`07"S	115°23`04"E
T75208	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.9 km N. of Chevron Texaco Camp, borehole B9 (trap 1)	20°47`27"S	115°27`14"E
T75209	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.6 km N. of Chevron Texaco Camp,	20°47`13"S	115°26`57"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
					borehole B12 (trap 2)		
T75210	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp, borehole BMW4 (trap 2)	20°47`02"S	115°23`39"E
T75214	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km NW. of Chevron Texaco Camp, borehole S2 (Trap2-85)	20°46`33"S	115°26`53"E
T66001	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.0 km N. of Chevron Texaco Camp (B16; T1-3) vial17	20°47`32"S	115°27`03"E
T66002	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.2 km N. of Chevron Texaco Camp (B18; T1-1) vial4	20°47`26"S	115°26`57"E
T66003	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.2 km N. of Chevron Texaco Camp (B18; T2-1) vial1	20°47`26"S	115°26`57"E
T31443	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°47`S	115°22`E
T42195	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, old WB2 anode well	20°51`36"S	115°21`17"E
T66004	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.0 km N. of Chevron Texaco Camp (B24; T3-1) vial157	20°47`30"S	115°26`47"E
T42196	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, old WF7 anode well	20°51`01"S	115°22`43"E
T112596	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island	20°49`12"S	115°26`4"E
T66005	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (BMW4; T3-2) vial 131	20°47`02"S	115°23`39"E
T42197	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Cave B-1	20°47`53"S	115°19`53"E
T66006	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (BMW5; T2-1) vial 145	20°47`04"S	115°23`38"E
T42198	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, Bore WB2	20°51`36"S	115°21`17"E
T66007	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (BMW5; T4-2) vial 151	20°47`04"S	115°23`38"E
T42199	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, old L4 anode well	20°48`22"S	115°23`21"E
T112599	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island	20°49`12"S	115°26`4"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T66008	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 6.3 km W. of Chevron Texaco Camp (BMW7; T3-1) vial 184	20°49`07"S	115°23`04"E
T66009	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.0 km NW. of Chevron Texaco Camp (CHW2; T3-2) vial 114	20°47`04"S	115°23`41"E
T66010	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 7.0 km NW. of Chevron Texaco Camp (CHW2; T4-2) vial 121	20°47`04"S	115°23`41"E
T66011	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 4.5 km N. of Chevron Texaco Camp (non ref; T2-1) vial 171	20°47`14"S	115°26`41"E
T66012	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km N. of Chevron Texaco Camp (S2; T1-6) vial 46	20°46`33"S	115°26`53"E
T66013	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km N. of Chevron Texaco Camp (S3; T2-1) vial 37	20°46`37"S	115°27`26"E
T66014	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 5.8 km N. of Chevron Texaco Camp (S3; T1-4) vial 36	20°46`37"S	115°27`26"E
T66015	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 3.4 km NNW. of Chevron Texaco Camp (S5; T1-2) vial 67	20°47`54"S	115°26`05"E
T66016	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 3.0 km N. of Chevron Texaco Camp (S6; T1-2) vial 202	20°48`04"S	115°26`44"E
T66017	Schizomida	Hubbardiidae	*Draculoides*	*bramstokeri*	Barrow Island, 3.0 km N. of Chevron Texaco Camp (S7; T1-3) vial 51	20°48`47"S	115°25`18"E
Scorpiones (scorpions)							
T85120	Scorpiones	Buthidae	*Isometroides*	`barrow`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50`11"S	115°22`30"E
T85123	Scorpiones	Buthidae	*Isometroides*	`barrow`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50`11"S	115°22`30"E
T92156	Scorpiones	Buthidae	*Lychas*	`glauerti ?`	Barrow Island, c. 3 km SW. of Town Point, site V1 (Gorgon Gas Plant Treatment site)	20°47`37"S	115°26`27"E
T96537	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, old drill workshops, plot N22	20°49`55"S	115°25`13"E
T96538	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, old drill workshops, plot N22	20°49`55"S	115°25`13"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T96539	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, storage area (old airport), plot N06	20°47`51"S	115°25`58"E
T96540	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, evaporation pit, plot N10	20°49`23"S	115°22`21"E
T96541	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, Gorgon Project footprint plot GP9	20°47`59"S	115°27`00"E
T96542	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, Gorgon Project footprint plot GP3	20°47`09"S	115°27`26"E
T96549	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, future construction village	20°49`00"S	115°26`16"E
T85106	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, southern escarpment, NE. of Bandicoot Bay, near SS08.8	20°50`11.6"S	115°22`19.9"E
T85107	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, southern escarpment, NE. of Bandicoot Bay, near SS08.8	20°50`11.6"S	115°22`19.9"E
T85110	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50`11"S	115°22`30"E
T85116	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50`06"S	115°22`37"E
T85158	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, northern end, towards tea trees	20°40`22"S	115°26`24"E
T85159	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 2 km SW. of base (L1, B Station West side,SS7.08)	20°50`14"S	115°22`27"E
T85172	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, Biggada Creek Road (L4)	20°46`46"S	115°21`26"E
T79078	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 0.5 km NW. of Town Point (SS2, #05)	20°47`00"S	115°27`31"E
T79079	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 0.5 km NW. of Town Point (SS2, #04)	20°47`00"S	115°27`31"E
T79080	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 0.5 km W. of Town Point (SS1, #19)	20°47`12"S	115°27`26"E
T79081	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 0.5 km W. of Town Point (SS1, #16)	20°47`12"S	115°27`26"E
T79082	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 0.5 km W. of Town Point (SS1, #20)	20°47`12"S	115°27`26"E
T79083	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 0.5 km W. of Town Point (SS1, #17)	20°47`12"S	115°27`26"E
T92139	Scorpiones	Buthidae	*Lychas*	`glauerti`	Barrow Island, c. 2 km WSW. of Town Point, site L3 (Gorgon Gas Plant Treatment site)	20°47`18"S	115°26`36"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T79084	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 0.5 km W. of Town Point (SS1, #18)	20°47\`12"S	115°27\`26"E
T79085	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 2 km SW. of Town Point (SS4, #26)	20°47\`10"S	115°26\`54"E
T79086	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 2 km SW. of Town Point (SS4, #22)	20°47\`10"S	115°26\`54"E
T79087	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 1 km SW. of Town Point (SS4, #24)	20°47\`10"S	115°26\`54"E
T79088	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 0.5 km NW. of Town Point (SS2, #03)	20°47\`00"S	115°27\`31"E
T92149	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 2 km W. of Town Point, site L7 (Gorgon Gas Plant Treatment site)	20°47\`21"S	115°26\`37"E
T92151	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 3 km SW. of Town Point, site V1 (Gorgon Gas Plant Treatment site)	20°47\`37"S	115°26\`27"E
T92152	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 3 km SW. of Town Point, site V1 (Gorgon Gas Plant Treatment site)	20°47\`37"S	115°26\`27"E
T92153	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 3 km SW. of Town Point, site V1 (Gorgon Gas Plant Treatment site)	20°47\`37"S	115°26\`27"E
T92154	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 3 km SW. of Town Point, site V1 (Gorgon Gas Plant Treatment site)	20°47\`37"S	115°26\`27"E
T92155	Scorpiones	Buthidae	*Lychas*	\`glauerti\`	Barrow Island, c. 3 km SW. of Town Point, site V1 (Gorgon Gas Plant Treatment site)	20°47\`37"S	115°26\`27"E
T85113	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50\`06"S	115°22\`37"E
T85114	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50\`06"S	115°22\`37"E
T85117	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50\`06"S	115°22\`37"E
T85119	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50\`06"S	115°22\`37"E
T85121	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50\`06"S	115°22\`37"E
T85122	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km SW. of Base (B Station West side,	20°50\`11"S	115°22\`30"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
					SS7.08)		
T85156	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, SS7.08 (B Station West side)	20°50\`11"S	115°22\`30"E
T85157	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km SW. of Base (B Station West side, SS7.08)	20°50\`11"S	115°22\`27"E
T85161	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, Biggada Creek Road @	20°46\`46"S	115°21\`26"E
T85162	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, Biggada Creek Road @	20°46\`46"S	115°21\`26"E
T85163	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, N. of Biggada Creek (R Block site SS08.4) @	20°46\`22"S	115°21\`19"E
T85164	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, N. of Biggada Creek (R Block site SS08.4) @	20°46\`21"S	115°22\`21"E
T85165	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, N. of Biggada Creek (R Block site SS08.4) @	20°46\`21"S	115°22\`21"E
T85166	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, N. of Biggada Creek (R Block site SS08.4) @	20°46\`21"S	115°22\`21"E
T85167	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, N. of Biggada Creek (R Block site SS08.4) @	20°46\`21"S	115°22\`20"E
T85178	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, Airport Road @	20°51\`26"S	115°24\`39"E
T92142	Scorpiones	Urodacidae	*Aops*	\`ops\`	Barrow Island, c. 2 km W. of Town Point, site L3 (Gorgon Gas Plant Treatment site)	20°47\`18"S	115°26\`36"E
T39583	Scorpiones	Urodacidae	*Aops*	*oncodactylus*	Barrow Island, Ledge Cave (cave B-1)	20°48\`S	115°19\`E
Pseudoscorpiones (pseudoscorpions)							
T114676	Pseudosc.	Hyidae	*Indohya*	\`sp. nov. PSE002\`	Karratha to Millstream-Chichester National Park	21°02\`29.16"S	116°55\`47.76"E
T71969	Pseudosc.	Syarinidae	*Ideoblothrus*	*nesotymbus*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (borehole BMW4)	20°47\`02"S	115°23\`39"E
T75203	Pseudosc.	Syarinidae	*Ideoblothrus*	*nesotymbus*	Barrow Island, 5.8 km N. of Chevron Texaco Camp, borehole S2 (trap 1)	20°46\`33"S	115°26\`53"E
T75213	Pseudosc.	Syarinidae	*Ideoblothrus*	*nesotymbus*	Barrow Island, 5.8 km NW. of Chevron Texaco Camp, borehole S2 (Trap2-84)	20°46\`33"S	115°26\`53"E
T66019	Pseudosc.	Syarinidae	*Ideoblothrus*	*nesotymbus*	Barrow Island, 4.3 km N. of Chevron Texaco Camp (B19; T1-1) vial 23	20°47\`23"S	115°26\`54"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T71319	Pseudosc.	Syarinidae	*Ideoblothrus*	*westi*	Fortescue River, borehole B7	21°03`17"S	116°09`35"E
T57472	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Bogg's Beach	20°47`25"S	115°20`17"E
T57473	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T57474	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Bogg's Beach	20°47`25"S	115°20`17"E
T57475	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Bogg's Beach	20°48`S	115°21`E
T57476	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Bogg's Beach	20°47`25"S	115°20`17"E
T57477	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T57478	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T29575	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T57479	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T29576	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T57480	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T29577	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T57481	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Cape Malouet	20°43`03"S	115°23`42"E
T65212	Pseudosc.	Garypidae	*Anagarypus*	*heatwolei*	Barrow Island, Flacourt Bay	20°44`35"S	115°22`57"E
T98244	Pseudosc.	Garypidae	*Synsphyronus*	`indet. (juv.)`	Dixon Island, ca. 15 km NW. of Roeborne, site SRE03	20°37`00.96"S	117°04`24.36"E
T60177	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, trapline 1.27	20°47`21"S	115°27`18"E
T59964	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, WSW. of Latitude Point	20°46`51"S	115°26`28"E
T101471	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, plot N22, old drill workshops	20°49`55"S	115°25`13"E
T57749	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Terminal Tanks, site BI1.41	20°47`24"S	115°27`22"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T123308	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot CC2	20°49`02"S	115°26`24"E
T123309	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot GP7	20°47`51"S	115°26`27"E
T123310	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot GP5	20°46`59"S	115°27`03"E
T123311	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot GPX	20°47`45"S	115°27`08"E
T123312	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot GP8	20°47`59"S	115°26`25"E
T123313	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot CC2	20°49`02"S	115°26`24"E
T123314	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot CC2	20°49`02"S	115°26`24"E
T123315	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot GP4	20°47`03"S	115°27`33"E
T123316	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot GP9	20°47`59"S	115°27`00"E
T123317	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, Gorgon Project footprint plot GP6	20°47`05"S	115°26`28"E
T123318	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, plot N20, old air strip	20°45`00"S	115°26`51"E
T123319	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, plot N05a, current airport, front office	20°51`58"S	115°24`22"E
T123320	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, plot N05b, current airport, helicopter hanger	20°51`50"S	115°24`23"E
T123321	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow Island`	Barrow Island, plot N05b, current airport	20°51`50"S	115°24`23"E
T123322	Pseudosc.	Garypidae	*Synsphyronus*	`PSE032 Barrow	Barrow Island, site 45	20°47`18"S	115°26`31"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
				Island`			
T89024	Pseudosc.	Garypidae	*Synsphyronus*	`sp. B`	45.4 km S. of Roebourne. OPP	21°10`40"S	117°03`09"E
T17999	Pseudosc.	Garypidae	*Synsphyronus*	`sp.`	Enderby Island	20°36`S	116°29`E
T18003	Pseudosc.	Garypidae	*Synsphyronus*	`sp.`	Nelson Rocks	20°29`S	116°34`E
T18004	Pseudosc.	Garypidae	*Synsphyronus*	`sp.`	Nelson Rocks	20°29`S	116°34`E
T18005	Pseudosc.	Garypidae	*Synsphyronus*	`sp.`	Nelson Rocks	20°29`S	116°34`E
T18006	Pseudosc.	Garypidae	*Synsphyronus*	`sp.`	Nelson Rocks	20°29`S	116°34`E
T101480	Pseudosc.	Garypinidae	*Protogarypinus*	`sp.`	Barrow Island, plot N10, evaporation pit	20°49`23"S	115°22`21"E
T101469	Pseudosc.	Chthoniidae	*Tyrannochth.*	`sp.`	Barrow Island, old rubbish dump	20°47`51"S	115°20`55"E
T101470	Pseudosc.	Chthoniidae	*Tyrannochth.*	`sp.`	Barrow Island, site 45	20°47`18"S	115°26`31"E
T110375	Pseudosc.	Chthoniidae	*Tyrannochth.*	*garthhumphr.*	Barrow Island	20°49`12"S	115°26`04"E
T110376	Pseudosc.	Chthoniidae	*Tyrannochth.*	*garthhumphr.*	Barrow Island	20°48`04"S	115°26`44"E
T104469	Pseudosc.	Chthoniidae	*Tyrannochth.*	*garthhumphr.*	Barrow Island, bore S2-250, stygofauna haul	20°46`33.22"S	115°26`53.39"E
T71968	Pseudosc.	Chthoniidae	*Tyrannochth.*	*garthhumphr.*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (borehole BMW5)	20°47`04"S	115°23`38"E
T73384	Pseudosc.	Chthoniidae	*Tyrannochth.*	*garthhumphr.*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (borehole BMW5)	20°47`04"S	115°23`38"E
T73385	Pseudosc.	Chthoniidae	*Tyrannochth.*	*garthhumphr.*	Barrow Island, 7.1 km NW. of Chevron Texaco Camp (borehole BMW5)	20°47`04"S	115°23`38"E
Diplopoda (millipedes)							
T76147	Polydesmida	Paradoxosom.	`DIPAAA`	`DIP020`	Pilbara Survey site DRC 2, crown land reserve, NW. of Mt Prinsep	20°46`18"S	116°50`59"E
T76142	Polydesmida	Paradoxosom.	*Antichiropus*	`DIP025`	Pilbara Survey site DRC 5, Mt Welcome Station, W. of Mt Roe	20°56`24"S	117°02`05"E
T76051	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check	13.5 km W. of Wickham, Pilbara Biological Survey site	20°41`18.3"S	117°00`24.9"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
				(male)`	DRC11		
T76056	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check (male)`	3.5 km N. of Karratha Station, Pilbara Biological Survey site DRW05	20°51`14.1"S	116°40`07.9"E
T76065	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check (male)`	11 km ESE. of Marda Pool, Pilbara Biological Survey site DRW07	21°03`20.4"S	116°15`06"E
T76072	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check (male)`	11 km ESE. of Marda Pool, Pilbara Biological Survey site DRW07	21°03`20.4"S	116°15`06"E
T76141	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check (male)`	Pilbara Survey site DRW 8, Mardie Station, Eramurra Creek	21°03`48"S	116°14`01"E
T76146	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check (male)`	Pilbara Survey site DRW 8, Mardie Station, Eramurra Creek	21°03`48"S	116°14`01"E
T76152	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check (male)`	Pilbara Survey site DRC 2, crown land reserve, SE. of Dampier	20°46`05"S	116°50`31"E
T112622	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. check (male)`	3.5 km N. of Karratha Station, Pilbara Biological Survey site DRW05	20°51`14.1"S	116°40`07.9"E
T76058	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (female)`	3.5 km S. of Marda Pool, Pilbara Biological Survey site DRW11	21°03`55.9"S	116°09`01.7"E
T76156	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (female)`	Pilbara Survey site DRC 5, Mt Welcome Station, W. of Mt Roe	20°56`24"S	117°02`05"E
T76158	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (female)`	Pilbara Survey site DRC 2, crown land reserve, SE. of Dampier	20°46`05"S	116°50`31"E
T76160	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (female)`	Pilbara Survey site DRW 8, Mardie Station, Eramurra Creek	21°03`48"S	116°14`01"E
T76161	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (female)`	Pilbara Survey site DRC 1, crown land reserve, SE. of Dampier	20°46`05"S	116°50`31"E
T76170	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (female)`	Pilbara Survey site DRC 9, Mt Welcome Station, W. of Mt Roebourne	20°48`29"S	117°04`21"E
T112611	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (female)`	Pilbara Survey site DRC 2, crown land reserve, SE. of Dampier	20°46`05"S	116°50`31"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T73498	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (juv.)`	Cape Lambert, 24.2 km E. of Karratha	20°43`60"S	117°04`42"E
T114680	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (juv.)`	Karratha to Millstream-Chichester National Park	20°59`07.08"S	116°52`51.97"E
T114681	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (juv.)`	Karratha to Millstream-Chichester National Park	20°59`07.08"S	116°52`51.97"E
T114682	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet. (juv.)`	Karratha to Millstream-Chichester National Park	20°51`29.25"S	116°47`43.65"E
T73900	Polydesmida	Paradoxosom.	*Antichiropus*	`sp. indet.`	Barrow Island	20°48`S	115°24`E
T56353	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow Island, current airport, helicopter hangar, site N05b	20°51`50"S	115°24`23"E
T56354	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow Island, old administration building, site N23	20°49`09"S	115°23`40"E
T57637	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow Island, WSW. of Latitude point	20°46`51"S	115°26`28"E
T121015	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot GP5	20°46`59"S	115°27`03"E
T121016	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot GP7	20°47`51"S	115°26`27"E
T121017	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot CC2	20°49`02"S	115°26`24"E
T121018	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot GP9	20°47`59"S	115°27`00"E
T121019	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot GP7	20°47`51"S	115°26`27"E
T121020	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot GP4	20°47`03"S	115°27`33"E
T121021	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot GP5	20°46`59"S	115°27`03"E
T121022	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, site 105	20°48`08"S	115°26`48"E
T121023	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, future construction village	20°49`00"S	115°26`16"E
T121024	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot GP9	20°47`59"S	115°27`00"E
T121025	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot CC1	20°49`01"S	115°26`15"E
T121026	Polydesmida	Paradoxosom.	*Boreohesperus*	`DIP001`	Barrow island, Gorgon project, footprint plot CC2	20°49`02"S	115°26`24"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
T121027	Polydesmida	Paradoxosom.	*Boreohesperus*	\`DIP001\`	Barrow island, old rubbish dump	20°47\`51"S	115°20\`55"E
T121028	Polydesmida	Paradoxosom.	*Boreohesperus*	\`DIP001\`	Barrow island, Gorgon project, footprint plot CC2	20°49\`02"S	115°26\`24"E
T121029	Polydesmida	Paradoxosom.	*Boreohesperus*	\`DIP001\`	Barrow island, site 22	20°47\`12"S	115°27\`17"E
T121030	Polydesmida	Paradoxosom.	*Boreohesperus*	\`DIP001\`	Barrow Island, Chevron Texaco camp	20°49\`43"S	115°26\`36"E
T123094	Polydesmida	Paradoxosom.	*Boreohesperus*	\`DIP001\`	Barrow Island, 500m E. of Base	20°49\`02.0"S	115°23\`24.4"E
T76070	Polydesmida	Paradoxosom.	*Boreohesperus*	\`DIP022\`	6 km SE. of Marda Pool, Pilbara Biological Survey site DRW10	21°04\`11.8"S	116°12\`15.5"E
Chilopoda (centipedes)							
T99484	Geophilom.		\`Barrow gen. 2\`	\`Barrow sp. 1\`	Barrow Island, Gorgon Project Footprint site CBH	20°49\`30"S	115°26\`47"E
T99485	Geophilom.		\`Barrow gen. 3\`	\`Barrow sp. 1\`	Barrow Island, plot N07, base/warehouse	20°49\`04"S	115°23\`06"E
T99486	Geophilom.		\`Barrow gen. 4\`	\`Barrow sp. 1\`	Barrow Island, plot N14, old incinerator	20°48\`37"S	115°25\`37"E
T99487	Lithobiom.		\`Barrow gen. 1\`	\`Barrow sp. 1\`	Barrow Island, plot N07a, base/warehouse	20°48\`59"S	115°23\`09"E
T113054	Geophilom.	Cryptopidae	*Cryptops*	\`sp.\`	Anketell Rail Corridor, NNW. Tom Price	20°45\`02.37"S	117°00\`34.52"E
Curtin	Scolopendr.	Cryptopidae	*Cryptops*	\`sp.\`	Barrow Island	20°47'4.94"S	115°27'33.86"E
Mollusca (land snails)							
	Gastropoda	Bithyniidae	*Gabbia*	aff. *smithii*	KARRATHA	20°44\`S	116°51\`E
	Gastropoda	Bithyniidae	*Gabbia*	aff. *smithii*	KARRATHA	20°56\`21.876"S	116°50\`50.184"E
	Gastropoda	Camaenidae	cf. *Kimboraga*	sp.	ROSEMARY ISLAND	20°29\`S	116°35\`E
	Gastropoda	Camaenidae	cf. *Kimboraga*	sp.	DOLPHIN ISLAND	20°29\`S	116°50\`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°48\`00"S	115°21\`47.9"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46\`S	115°24\`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45.7\`S	115°22.7\`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°44\`41"S	115°22\`37.0"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47\`52"S	115°24\`23"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`52"S	115°24`23"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BANDICOOT BAY	20°53`S	115°20`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	CAPE DUPUY	20°40`S	115°26`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BANDICOOT BAY	20°53`S	115°20`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	FLACOURT BAY	20°45`S	115°22`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	FLACOURT BAY	20°45`S	115°22`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	FLACOURT BAY	20°46`S	115°21`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	SOUTH DOUBLE ISLAND	20°45`S	115°29`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	VARANUS ISLAND	20°39`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	barrowensis	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`31.3"S	115°28`06.3"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`06.3"S	115°28`02.3"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`04.1"S	115°24`01.9"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`29.5"S	115°26`36.6"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BIGGADA CREEK	20°47`S	115°22`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`40.6"S	115°28`12.6"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45`52.2"S	115°28`14.7"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45`54.9"S	115°28`30.7"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45`26.8"S	115°28`11.8"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`32.4"S	115°26`26.0"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`32.3"S	115°26`30.0"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°44`45.3"S	115°22`57.5"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°44`50.5"S	115°23`05.8"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45`02.5"S	115°23`02.1"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45`20.4"S	115°23`24.0"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45`25.3"S	115°23`32.0"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	SOUTH PASCO ISLAND	20°58`S	115°20`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°16`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°45`S	115°27`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	LOWENDAL ISLAND	20°59`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°50`38"S	115°22`54.0"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°48.344`S	115°27.043`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`27"S	115°26`27"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°49`05.626"S	115°23`08.70"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.541`S	115°26.308`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.412`S	115°27.387`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.297`S	115°27.769`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.269`S	115°27.743`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.326`S	115°27.816`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°40.272`S	115°26.239`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.326`S	115°27.816`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.276`S	115°27.749`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.269`S	115°29.743`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°46.466`S	115°26.111`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°40.272`S	115°26.239`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°40.259`S	115°26.220`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47.355`S	115°27.753`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°51`S	115°23`E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`54.2"S	115°26`50.5"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`05"S	115°27`27"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°47`46"S	115°27`13"E
	Gastropoda	Camaenidae	*Quistrachia*	*barrowensis*	BARROW ISLAND	20°48.058`S	115°27.262`E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	DOUBLE ISLAND	20°44`S	115°29`E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	DOUBLE ISLAND	20°44`S	115°29`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	PASCO ISLAND	20°57`39.6"S	115°20`22.4"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`20.19"S	115°34`41.46"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`29.84"S	115°33`58.48"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`57.80"S	115°34`35.40"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`20.22"S	115°34`35.77"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`40.68"S	115°34`5.34"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`4.44"S	115°34`48.56"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`45.58"S	115°34`9.13"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`20.19"S	115°34`41.46"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`51.65"S	115°34`15.09"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`51.65"S	115°34`15.09"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`9.87"S	115°34`46.53"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`51.65"S	115°34`15.09"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`53.64"S	115°34`23.37"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`20.19"S	115°34`41.46"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`51.65"S	115°34`15.09"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`9.87"S	115°34`46.53"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`20.22"S	115°34`35.77"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°39`9.87"S	115°34`46.53"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`40.68"S	115°34`5.34"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`53.64"S	115°34`23.37"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`40.68"S	115°34`5.34"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. barrowensis*	VARANUS ISLAND	20°38`45.58"S	115°34`9.13"E
	Gastropoda	Camaenidae	*Quistrachia*	*herberti*	FORTESCUE R. R/HOUSE	21°17`S	116°08`E
	Gastropoda	Camaenidae	*Quistrachia*	*herberti*	FORTESCUE RIVER	21°28`S	116°37`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*herberti*	FORTESCUE RIVER	21°28`19.5"S	116°49`09.2"E
	Gastropoda	Camaenidae	*Quistrachia*	*herberti*	KARRATHA	21°10`36.444"S	117°02`10.58"E
	Gastropoda	Camaenidae	*Quistrachia*	*herberti*	KARRATHA	21°10`41.148"S	117°2`45.834"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. herberti*	HARDING RIVER	21°22.797`S	117°03.590`E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. herberti*	FORTESCUE RIVER	21°03`37.9"S	116°08`39.5"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°40`S	116°43`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DOLPHIN ISLAND	20°29`S	116°50`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	ROSEMARY ISLAND	20°30`S	116°35`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	ROCKY HILL	20°31`27"S	116°50`54"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	WITHNELL BAY	20°34`16"S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	COOLIBAH CREEK	20°38`49"S	116°45`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°38`52"S	116°47`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°34`19"S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°40`17"S	116°43`18"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	MURDERERS POOL	20°38`39"S	116°44`58"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	WITHNELL BAY	20°35`S	116°47`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	KING BAY	20°38`23"S	116°45`22"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°31`40"S	116°50`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	KANGAROO HILL	20°39`15"S	116°43`18"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°31`33"S	116°50`16"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	MOUNT WONGAMA	20°34`26"S	116°48`26"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	HEARSON COVE	20°37`41"S	116°47`51"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	OLD HEARSON VILLAGE	20°36`03"S	116°47`51"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	SEARIPPLE PASSAGE	20°31`46"S	116°49`49"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	V34 CREEK	20°32`01"S	116°50`54"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	KING BAY	20°38`26"S	116°44`37"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	CONZINC BAY	20°33`S	116°48`53"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°34`S	116°49`24"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	CONZINC CREEK	20°33`11"S	116°48`55"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	SLOPING POINT	20°31`40"S	116°51`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	KING BAY	20°38`23"S	116°45`22"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°39`S	116°45`22"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DOLPHIN ISLAND	20°31`1"S	116°51`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	HEARSON COVE	20°38`16"S	116°47`47"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	HEARSON COVE	20°38`13"S	116°47`51"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	ROSEMARY ISLAND	20°30`S	116°34`58"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°32`48"S	116°48`57"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	KARRATHA	20°43`55"S	116°50`26"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	WITHNELL BAY	20°34`16"S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	ANGEL ISLAND	20°31`1"S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DOLPHIN ISLAND	20°31`1"S	116°51`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	KING BAY	20°38`19"S	116°45`08"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°31`53"S	116°48`29"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	HEARSON COVE	20°38`S	116°47`33"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	ROCKY HILL	20°40`04"S	116°45`31"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	HEARSON COVE	20°37`58"S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	WITHNELL BAY	20°34`39"S	116°47`47"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DOLPHIN ISLAND	20°31`S	116°51`00"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	ROSEMARY ISLAND	20°30`S	116°34`58"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	CONZINC BAY	20°33`07"S	116°48`50"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	KING BAY	20°37`50"S	116°45`50"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	CONZINC BAY	20°32`12"S	116°49`07"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°41`12.059"S	116°40`03.28"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°41`46.514"S	116°40`07.01"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°42`01.340"S	116°40`19.98"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°42`01.340"S	116°40`19.98"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°42`17.707"S	116°40`57.45"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°42`14.978"S	116°40`07.3"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°42`30.202"S	116°38`30.32"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	PISTOL RANGES	20°38`21.073"S	116°46`40.53"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	PISTOL RANGES	20°38`43.625"S	116°46`47.17"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	PISTOL RANGES	20°39`36.252"S	116°46`43.43"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	PISTOL RANGES	20°39`06.615"S	116°46`16.48"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	GIDLEY ISLAND	20°26`"S	116°49`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	HEARSON COVE	20°37`22.8"S	116°47`58.9"E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°35`S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	DAMPIER	20°38`S	116°45`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Quistrachia*	*legendrei*	BURRUP PENINSULA	20°37`29"S	116°46`20"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. monteb.*	HERMITE ISLAND	20°26`31.5"S	115°31`55.1"E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. monteb.*	ALPHA ISLAND	20°24`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. monteb.*	MONTEBELLO ISLANDS	20°26.513`S	115°32.319`E
	Gastropoda	Camaenidae	*Quistrachia*	*cf. monteb.*	HERMITE ISLAND	20°26`31.7"S	115°31`58.1"E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	MONTEBELLO ISLANDS	20°26`S	115°37`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	*cf. monteb.*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	TRIMOUILLE ISLAND	20°24`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	ALPHA ISLAND	20°24`S	115°32`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	MONTEBELLO ISLANDS	20°26`55"S	115°31`36"E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	MONTEBELLO ISLANDS	20°26`S	115°37`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	MONTEBELLO ISLANDS	20°26`15"S	115°31`29"E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	MONTEBELLO ISLANDS	20°26`S	115°37`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	ALPHA ISLAND	20°24`S	115°32`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	TRIMOUILLE ISLAND	20°24`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	AH CHUNG ISLAND	20°31.3`S	115°31.8`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	VARANUS ISLAND	20°39`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	BLUEBELL ISLAND	20°24`S	115°31`1"E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	ALPHA ISLAND	20°24`S	115°31`58"E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	CROCUS ISLAND	20°25`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	*montebelloens.*	VARANUS ISLAND	20°39`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. "W"	QUARTZ HILL	20°45`S	116°57`E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. "W"	PILBARA	20°45`47.5"S	116°57`37.8"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`20.87"S	117°01`35.91"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°44`33.93"S	117°00`58.22"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°40`39.41"S	117°02`46.26"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`20.87"S	117°01`35.91"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°43`55.56"S	117°05`12.05"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`10.81"S	117°01`31.97"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`30.97"S	116°59`30.19"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°40`49.39"S	117°04`46.13"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°40`56.46"S	117°05`00.08"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`10.81"S	117°01`31.97"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°44`00.69"S	117°04`41.95"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`22.19"S	117°01`09.63"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`29.06"S	117°00`45.22"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°41`20.05"S	117°06`56.72"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°42`22.02"S	117°04`59.02"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°40`39.16"S	117°05`28.23"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	ANKETELL POINT	20°39`29.06"S	117°00`45.22"E
	Gastropoda	Camaenidae	*Quistrachia*	sp. nov. X	KARRATHA	20°39`57.15"S	117°03`13.82"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	VARANUS ISLAND	20°39`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BARROW ISLAND	20°49`43"S	115°26`40"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	EAST LEWIS ISLAND	20°37.50`S	116°39.18`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	EAST LEWIS ISLAND	20°36`S	116°39`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	DOLPHIN ISLAND	20°28`02.8"S	116°57`08.8"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	ROSEMARY ISLAND	20°28`54.6"S	116°36`17.7"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BURRUP PENINSULA	20°36`54.1"S	116°45`25.1"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	WEST INTERCOURSE ISLAND	20°42`S	116°36`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BURRUP PENINSULA	20°35`S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BURRUP PENINSULA	20°35`S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BURRUP PENINSULA	20°35`S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	ANGEL ISLAND	20°29`S	116°48`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BURRUP PENINSULA	20°35`S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	PILBARA	20°45`53"S	117°04`01"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	PINDERI HILLS	21°03`S	116°51`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	KARRATHA	20°43`S	116°51`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	KARRATHA	20°39`27.11"S	117°06`12.49"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	KARRATHA	20°43`58"S	116°52`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	HEARSON COVE	20°37`58"S	116°48`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	NW COASTAL HWY	21°17`35.94"S	116°09`03.81"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CLEAVERVILLE	20°39`S	117°1`1"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	NORTH WEST ISLAND	20°22`S	115°31`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	VARANUS ISLAND	20°39`S	115°34`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BARROW ISLAND	20°46`1"S	115°24`E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	BRINDLE ISLAND	20°39`S	115°34`1"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CAPE PRESTON	21°3`21.636"S	116°13`23.9"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CAPE PRESTON	21°3`0.796"S	116°13`32.42"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CAPE PRESTON	21°3`0.796"S	116°13`32.42"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CAPE PRESTON	21°19`04.51"S	116°08`50.08"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CAPE PRESTON	20°50`28.144"S	116°12`23.28"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CAPE PRESTON	20°51`21.132"S	116°12`26.81"E
	Gastropoda	Camaenidae	*Quistrachia*	sp.	CAPE PRESTON	20°51`21.132"S	116°12`26.81"E
	Gastropoda	Camaenidae	*cf. Quistrachia*	sp.	BOODIE ISLAND	20°57`S	115°19`E
	Gastropoda	Camaenidae	*cf. Quistrachia*	sp.	BOODIE ISLAND	20°57`S	115°19`E
	Gastropoda	Camaenidae	*cf. Quistrachia*	sp.	KARRATHA	20°43`S	116°51`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	ANGEL ISLAND	20°29`S	116°48`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	DOLPHIN ISLAND	20°29`S	116°50`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	DOLPHIN ISLAND	20°29`S	116°50`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	DOLPHIN ISLAND	20°29`S	116°50`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	DOLPHIN ISLAND	20°29`S	116°50`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	ANGEL ISLAND	20°29`S	116°48`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	ENDERBY ISLAND	20°36`S	116°30`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	KING BAY	20°37`50"S	116°45`50"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	V34 POOL CREEK	20°32`01"S	116°50`52"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	BURRUP PENINSULA	20°32`06"S	116°50`40"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	V34 CREEK	20°32`01"S	116°50`54"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	WITHNELL BAY	20°34`26"S	116°48`26"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	SEARIPPLE PASSAGE	20°31`43"S	116°49`49"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	BURRUP PENINSULA	20°33`60"S	116°49`17"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	WITHNELL BAY	20°33`60"S	116°49`17"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	SEARIPPLE PASSAGE	20°31`46"S	116°49`49"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	WATERING COVE	20°36`S	116°49`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	WITHNELL BAY	20°34`22"S	116°48`25"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	BURRUP PENINSULA	20°31`53"S	116°48`29"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	DOLPHIN ISLAND	20°31`1"S	116°51`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	BURRUP PENINSULA	20°32`06"S	116°48`33"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	CONZINC BAY	20°33`07"S	116°48`50"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	CONZINC BAY	20°33`07"S	116°48`53"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	CONZINC CREEK	20°33`11"S	116°48`55"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	SLOPING POINT	20°31`40"S	116°51`05"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	CONZINC BAY	20°32`06"S	116°48`36"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	BURRUP PENINSULA	20°35`S	116°48`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	BURRUP PENINSULA	20°34`19"S	116°48`05"E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	DOLPHIN ISLAND	20°31`1"S	116°51`E
	Gastropoda	Camaenidae	*Rhagada*	*angulata*	DOLPHIN ISLAND	20°31`S	116°51`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°30`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°30`S	116°34`58"E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°30`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	ROSEMARY ISLAND	20°30`S	116°34`58"E
	Gastropoda	Camaenidae	*Rhagada*	*dampierana*	EAST LEWIS ISLAND	20°36`S	116°39`E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	ROSEMARY ISLAND	20°28`30"S	116°32`E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	KENDREW ISLAND	20°29`S	116°32`E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	GOODWYN ISLAND	20°31`58"S	116°31`58"E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	GOODWYN ISLAND	20°31`58"S	116°31`58"E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	KENDREW ISLAND	20°28`30"S	116°32`00"E
	Gastropoda	Camaenidae	*Rhagada*	*elachystoma*	ROSEMARY ISLAND	20°30`S	116°34`58"E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	ROSEMARY ISLAND	20°29`S	116°35`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	DELAMBRE ISLAND	20°26`S	117°04`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	DELAMBRE ISLAND	20°26`S	117°04`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	ENDERBY ISLAND	20°36`S	116°30`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	ELPHICK NOB ISLAND	20°28`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	ELPHICK NOB ISLAND	20°28`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	LEGENDRE ISLAND	20°22`58"S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	LEGENDRE ISLAND	20°22`58"S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	DELAMBRE ISLAND	20°26`S	117°04`E
	Gastropoda	Camaenidae	*Rhagada*	*intermedia*	DELAMBRE ISLAND	20°26`S	117°04`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	CONZINC ISLAND	20°32`S	116°46`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ENDERBY ISLAND	20°36`S	116°30`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	CONZINC ISLAND	20°31`58"S	116°46`E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°30`S	116°34`58"E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°30`S	116°34`58"E
	Gastropoda	Camaenidae	*Rhagada*	*minima*	ROSEMARY ISLAND	20°30`S	116°34`58"E
	Gastropoda	Camaenidae	*Rhagada*	*perprima*	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	*perprima*	ENDERBY ISLAND	20°36`S	116°30`E
	Gastropoda	Camaenidae	*Rhagada*	*perprima*	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	*perprima*	WEST LEWIS ISLAND	20°34`58"S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	*perprima*	WEST LEWIS ISLAND	20°35`S	116°37`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	*perprima*	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	VARANUS ISLAND	20°39`20.19"S	115°34`41.46"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	VARANUS ISLAND	20°39`20.22"S	115°34`35.77"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	VARANUS ISLAND	20°39`26.88"S	115°34`38.60"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	VARANUS ISLAND	20°39`20.22"S	115°34`35.77"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	VARANUS ISLAND	20°39`20.19"S	115°34`41.46"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	VARANUS ISLAND	20°39`26.88"S	115°34`38.60"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	PRIMROSE ISLAND	20°22`18.9"S	115°31`09.7"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. plicata*	NORTH WEST ISLAND	20°22`04.8"S	115°31`59.6"E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	TRIMOUILLE ISLAND	20°24`S	115°34`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	TRIMOUILLE ISLAND	20°24`S	115°34`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	TRIMOUILLE ISLAND	20°24`S	115°34`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	MONTEBELLO ISLANDS	20°26`S	115°37`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	ALPHA ISLAND	20°24`S	115°32`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	ALPHA ISLAND	20°24`S	115°32`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	NORTH WEST ISLAND	20°22`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	TRIMOUILLE ISLAND	20°24`S	115°34`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	BLUEBELL ISLAND	20°24`S	115°31`1"E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	CROCUS ISLAND	20°25`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	ALPHA ISLAND	20°24`S	115°31`58"E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	NORTH WEST ISLAND	20°22`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*plicata*	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	*cf. pilbarana*	KARRATHA	21°2`29.16"S	116°55`47.76"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. pilbarana*	KARRATHA	21°10`4.962"S	117°0`38.844"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. pilbarana*	KARRATHA	21°4`47.226"S	116°58`47.18"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. pilbarana*	KARRATHA	21°6`39.714"S	116°59`36.17"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. pilbarana*	KARRATHA	21°4`11.382"S	116°58`12.65"E
	Gastropoda	Camaenidae	*Rhagada*	*cf. pilbarana*	KARRATHA	21°1`48.186"S	116°54`51.96"E
	Gastropoda	Camaenidae	*Rhagada*	*pilbarana*	HARDING RIVER	20°55`58"S	117°7`E
	Gastropoda	Camaenidae	*Rhagada*	*pilbarana*	KARRATHA	21°12`14.034"S	117°2`38.532"E
	Gastropoda	Camaenidae	*Rhagada*	sp. nov. `Hearson Cove`	HEARSON COVE	20°38`S	116°48`E
	Gastropoda	Camaenidae	*Rhagada*	sp. nov. `Hearson Cove`	HEARSON COVE	20°38`S	116°48`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	LEGENDRE ISLAND	20°23`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`52"S	115°24`23"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`S	116°48`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°40`30"S	115°27`40"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	ROEBOURNE	20°47`S	117°00`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	sp.	MILLSTREAM	21°30`S	117°00`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DAMPIER	20°40`S	116°43`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KENDREW ISLAND	20°28`30"S	116°32`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WHALERS BAY	20°31`S	116°40`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DAMPIER	20°40`S	116°43`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	MAITLAND RIVER	20°40`S	116°43`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KARRATHA HOMESTEAD	20°53`S	116°40`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KARRATHA	20°44`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DAMPIER	20°40`S	116°43`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DAMPIER	20°40`S	116°43`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	ROSEMARY ISLAND	20°29`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DOLPHIN ISLAND	20°29`S	116°50`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KING BAY	20°38`S	116°45`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KING BAY	20°38`S	116°45`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BROOKE ISLAND	20°26`S	115°30`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WEST LEWIS ISLAND	20°35`S	116°37`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DAMPIER	20°40`S	116°43`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KARRATHA HOMESTEAD	20°53`S	116°40`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	sp.	KARRATHA	20°44`S	116°52`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	ROSEMARY ISLAND	20°30`S	116°35`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KING BAY	20°38`19"S	116°45`15"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°31`40"S	116°48`33"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	SLOPING POINT	20°31`40"S	116°51`04"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WITHNELL BAY	20°34`22"S	116°48`26"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°38`13"S	116°46`00"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	SEARIPPLE PASSAGE	20°31`46"S	116°49`49"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°36`44"S	116°47`38"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WITHNELL BAY	20°34`22"S	116°48`25"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WITHNELL BAY	20°33`53"S	116°47`51"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	COWRIE COVE	20°35`59"S	116°48`05"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°40`23"S	116°45`18"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WITHNELL BAY	20°35`25"S	116°48`25"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KING BAY	20°38`26"S	116°44`37"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°32`06"S	116°50`40"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	V34 CREEK	20°32`01"S	116°50`54"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KING BAY	20°38`19"S	116°44`34"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°38`13"S	116°46`00"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°39`02"S	116°45`22"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`03"S	116°47`16"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	RIFLE RANGE	20°40`52"S	116°44`37"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`06"S	116°46`21"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	MOUNT WONGAMA	20°34`25"S	116°48`25"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°38`52"S	116°46`31"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	MURDERERS POOL	20°38`39"S	116°44`58"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	sp.	KING BAY	20°38`23"S	116°45`22"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°34`19"S	116°48`05"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`10"S	116°47`16"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°31`53"S	116°48`29"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°40`08"S	116°45`24"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`16"S	116°47`37"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	V34 POOL CREEK	20°32`01"S	116°50`52"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`07"S	116°47`33"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°33`59"S	116°49`17"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KING BAY	20°37`50"S	116°45`50"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	OLD HEARSON VILLAGE	20°36`03"S	116°47`51"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°37`41"S	116°47`51"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	CONZINC CREEK	20°33`11"S	116°48`55"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	CONZINC BAY	20°33`07"S	116°48`50"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	CONZINC BAY	20°32`12"S	116°49`07"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WITHNELL BAY	20°34`58"S	116°46`58"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WATERING COVE	20°36`S	116°49`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	CONZINC CREEK	20°33`04"S	116°48`50"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°37`58"S	116°48`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`13"S	116°47`51"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSONS COVE	20°38`16"S	116°47`47"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HERMITE ISLAND	20°28`S	115°31`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HAUY ISLAND	20°25`58"S	116°58`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	VARANUS ISLAND	20°39`S	115°34`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	WHALERS BAY	20°31`S	116°40`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	METHANEX SITE	20°36`55.301"S	116°47`39.78"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	sp.	METHANEX SITE	20°36`54.489"S	116°47`40.36"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	METHANEX SITE	20°37`23.618"S	116°47`26.12"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	METHANEX SITE	20°37`23.101"S	116°47`28.85"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	METHANEX SITE	20°36`51.414"S	116°47`26.03"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BIGGADA CREEK	20°47`S	115°22`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°48`00"S	115°21`47.9"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°50`38"S	115°22`54.0"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DU BOULAY CREEK	21°01`S	116°08`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	MARDIE HOMESTEAD	21°11`S	115°58`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DU BOULAY CREEK	21°01`S	116°08`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	CAPE PRESTON	20°49`S	116°12`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	QUARTZ HILL	20°45`47.5"S	116°57`37.8"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47.326`S	115°27.816`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47.276`S	115°23.749`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°40`24.18"S	115°26`56.83"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`53"S	115°19`53"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47.289`S	115°27.763`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47.297`S	115°27.769`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`52"S	115°24`23"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`52"S	115°24`23"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°48.058`S	115°27.262`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°40.259`S	115°26.220`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46.466`S	115°26.111`E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°40.272`S	115°26.239`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`12"S	115°27`17"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`13"S	115°26`57"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`30"S	115°26`47"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`52"S	115°24`23"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`40.1"S	115°27`20.6"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°41`01.27"S	115°27`52.25"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°40`54"S	115°28`08"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°49`14"S	115°23`08"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	DAMPIER	20°39`45"S	116°42`48"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`52"S	115°24`23"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`52"S	115°24`23"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	PICNIC CREEK	20°35`21.06"S	116°47`22.06"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	MIAREE POOL	20°51`14.08"S	116°36`46.01"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20.62°S	116.78°E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`21.2"S	115°27`43.7"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°35`09"S	116°48`16"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	KARRATHA	21°1`48.186"S	116°54`51.96"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	SURF POINT	20°41`S	115°28`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`31.4"S	115°27`27.1"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`S	115°24`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°45`27.6"S	115°23`37.1"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`24.9"S	115°26`33.3"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°46`31.3"S	115°28`06.3"E

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude (GDA94)	Longitude (GDA94)
	Gastropoda	Camaenidae	*Rhagada*	sp.	LATITUDE POINT	20°47`S	115°28`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°47`10"S	115°26`40"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°45.7`S	115°22.7`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	PISTOL RANGES	20°39`36.252"S	116°46`43.43"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°38`54.163"S	116°47`12.52"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	PISTOL RANGES	20°38`43.625"S	116°46`47.17"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	PISTOL RANGES	20°38`21.073"S	116°46`40.53"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°40`20.932"S	116°45`19.38"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`13.690"S	116°47`33.38"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BURRUP PENINSULA	20°39`24.706"S	116°46`44.90"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	HEARSON COVE	20°38`29.687"S	116°47`27.76"E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°40.272`S	115°26.239`E
	Gastropoda	Camaenidae	*Rhagada*	sp.	BARROW ISLAND	20°48.148`S	115°26.898`E
	Gastropoda	Pupillidae	*Gastrocopta*	sp. nov. CW1	BARROW ISLAND	20°42`25"S	115°25`10"E

Appendix 3 Number of specimens of short-range endemic target taxa collected during survey

Sites	01	02	03	04	05	06	07	08	09	10	11	Total
Araneae (spiders)												
Selenopidae												
Karaops burbidgei	1	0	0	0	0	2	2	3	1	0	0	**9**
Nemesiidae												
Aname 'MYG079'	0	0	2	3	6	0	0	0	0	2	0	**13**
Pseudoscorpiones (pseudoscorpions)												
Olpiidae												
Austrohorus sp. indet.	7	0	0	0	0	0	0	0	0	0	0	**7**
Beierolpium '8/2'	1	0	0	0	0	0	0	0	0	0	0	**1**
Euryolpium sp. indet.	0	4	6	19	2	16	17	14	10	11	12	**111**
Indolpium sp. indet.	0	6	0	0	0	0	0	0	1	0	0	**7**
Olpiidae sp. indet.	0	0	1	0	15	0	0	0	0	0	0	**16**
Cheirididae												
Apocheiridium sp. indet.	1	0	0	0	0	0	0	0	0	0	0	**1**
Scorpiones (scorpions)												
Buthidae												
Lychas 'hairy tail grp'	0	0	0	0	0	0	0	3	0	0	0	**3**
Chilopoda (centipedes)												
Cryptopidae												
Cryptops sp. indet.	2	0	0	1	0	3	0	4	3	0	3	**16**
Isopoda (slaters)												
Armadillidae												

Sites	01	02	03	04	05	06	07	08	09	10	11	Total
Armadillidae sp. indet.	0	0	0	0	0	0	1	0	0	0	0	1
Armadillidae 'Varanus Island'	0	1	0	0	0	0	0	0	0	0	0	1
Barrowdillo pseudopyrgoniscus	3	0	0	0	0	6	0	3	3	0	0	15
Buddelundia '60'	0	5	14	4	14	1	0	0	3	0	3	44
Spherillo 'Varanus Island'	0	0	11	0	0	0	0	1	0	0	21	33
Philoscidae												
Laevophiloscia yalgoonensis	2	0	0	0	0	0	0	6	0	0	0	8
Laevophiloscia sp. indet.	0	0	0	0	0	0	0	0	1	0	0	1
Mollusca (land snails)												
Camaeinidae												
Quistrachia montebelloensis	38	6	7	20	5	21	30	38	21	0	28	214
Rhagada plicata	0	0	0	0	5	0	0	0	0	17	27	49
Ellobiidae												
Melampus cf. *fasciatus*	0	0	0	0	0	0	0	0	1	0	16	17
Pupillidae												
Gastrocopta mussoni	1	0	0	0	1	29	1	0	0	0	67	99
Pupoides contrarius	14	0	0	7	22	29	32	30	49	1	16	200
Pupoides lepidulus	3	0	0	0	0	29	4	33	4	0	9	82
Subulinidae												
Eremopeas interioris	3	0	0	0	0	0	5	3	0	0	0	11
Truncatellidae												
Truncatella sp. indet.	0	0	0	0	0	0	0	0	0	0	1	1
Total	**76**	**22**	**41**	**54**	**70**	**136**	**92**	**138**	**97**	**31**	**203**	**960**

APPENDIX 6 – SVT ENGINEERING CONSULTANTS NOISE AND GROUND-BORNE VIBRATION ASSESSMENT REPORT (2012)

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27 November 2012

Document no: 1253905-1-200

Sonja Mavrick
Apache Energy Limited

100 St Georges Terrace

Perth, WA 6000

Dear Sonja,

RE: VARANUS ISLAND NOISE & GROUND-BORNE VIBRATION ASSESSMENT

Apache Energy Limited (AEL) has commissioned SVT to predict noise and vibration levels as a result of proposed earthworks, including rock clearing (D10 dozer, Erkat rotary cutter and hydraulic rock breaker), rock crushing and blasting, associated with for the AEL Varanus Island Compression Project (VICP) on Varanus Island.

AIM

The aim of the briefing note is to present the results of the predicted noise and vibration levels at sensitive fauna sites around Varanus Island.

OVERVIEW

AEL plans to undertake VICP Site preparation work within variable strength (<10 MPa up to 60 MPa) calcarenite rock areas that will require significant earthwork including mechanical rock breaking, rotary cutting, clearing, short term rock crushing and potential precision blasting (if required to the inadequacy of D10 dozer and hydraulic breaker).

As the proposed works are located in proximity to sensitive seabird habitats and turtle rookeries, AEL seeks to investigate the potential noise and vibration impacts of the proposed earthworks on the surrounding fauna sensitive location prior to proceeding with this work.

SCOPE

As requested by AEL, the proposed scope of work will be limited to the prediction of noise and vibration levels on identified fauna species and will not include an assessment of impacts on other fauna or humans.

1. NOISE MODELLING – OVERVIEW

1.1 Noise Model Software

An acoustic model has been developed using the SoundPlan noise modelling program developed by SoundPlan LLC. SoundPlan calculates sound pressure levels at nominated receiver locations and produces noise contours over a defined area of interest. The inputs required are noise source data, ground topographical data, meteorological data and receiver locations.

The SoundPlan noise model has a range of different algorithms which it can use to calculate noise levels for user defined meteorological conditions. The CONCAWE algorithm was used for the fixed plant and mobile equipment noise model.

1.2 Input Data

1.2.1 Source Sound Power Levels

The sound power levels used in the model (see Appendix B) are based on SVT's database of similar equipment used in the industry.

1.2.2 Topography and Ground Types

Topographical information for the noise model was provided to SVT by Apache in .dxf format files. The topography was imported directly into the noise model.

Ground absorption for hard and soft surfaces is as specified by the CONCAWE[1] propagation algorithms. The ground absorption for land was set to soft ground. CONCAWE is a conservative algorithm, which has been shown to over predict by 3 dB (as accepted by the Department of Environment and Conservation).

1.2.3 Receiving Locations

The locations of the sensitive receivers used in the model are shown in Table 1.

[1] CONCAWE (Conservation of Clean Air and Water in Europe) was established in 1963 by a group of oil companies to carry out research on environmental issues relevant to the oil industry. The outcome was an empirical algorithm which predicts noise levels at receiving locations.

Table 1 Receiver Location Co-Ordinates

Location	GPS Co-ordinates (GDA-94)
NE R1	7715812.25 N , 352060.09 E
NE R2	7715785.82 N , 352081.06 E
NE R3	7715735.16 N , 352107.65 E
NE R4	7715686.93 N , 352129.53 E
NE R5	7715668.24 N , 352147.88 E
NE R6	7715640.35 N , 352155.4 E
NW R1	7715937.87 N , 351771.92 E
NW R2	7715911.44 N , 351754.25 E
NW R3	7715837.64 N , 351712.53 E
NW R4	7715802.64 N , 351696.37 E
NW R5	7715774.99 N , 351687.73 E
NW R6	7715682.38 N , 351694.52 E
S R1	7715284.84 N , 351654.81 E
S R2	7715293.92 N , 351687.2 E
S R3	7715288.78 N , 351723.93 E
S R4	7715271.39 N , 351764.61 E
S R5	7715270.2 N , 351806.47 E
S R6	7715268.22 N , 351836.29 E
S R7	7715268.21 N , 351874.8 E
S R8	7715267.81 N , 351919.83 E
S R9	7715268.33 N , 351970.12 E

1.3 Meteorology

Certain meteorological conditions can increase noise levels at a receiving location by a process known as refraction. When refraction occurs, sound waves that would normally propagate directly outwards from a source can be bent downwards causing an increase in noise levels. Such refraction occurs during temperature inversions and where there is a wind gradient.

Meteorological conditions assigned to the model are in accordance with EPA's recommendations for worst-case weather conditions outlined in *Guidance for the Assessment of Environmental Factors, Draft No.8, May 2007*:

- Day (07:00 - 19:00) wind speed – 4m/s; Pasquill Stability Class "E"; temperature inversion – 0 degC/100m; temperature - 20°C; and relative humidity – 50%.

- Night (19:00 – 07:00) wind speed – 3m/s; Pasquill Stability Class "F"; temperature inversion – 2 degC/100m; temperature – 15°C; and relative humidity – 50%.

Worst-case conditions usually occur during night-time, when downward refraction bends the waves towards the ground increasing the noise levels at the receiver. The night time meteorological conditions were used in the model.

1.4 Noise Model Configuration

The following noise sources[2] have been modelled:

1) At KMCR and Accommodation area:
   - dozer
   - rock breaker
2) At VICP and VICP NE area:
   - dozer
   - rock breaker
   - mobile crusher plant

Figure 1 shows the layout of the noise source and receiver locations as used in the model[3].

1.5 Modelling Scenarios

Four scenarios have been modeled as follows:

- Scenario 1 sources located at KMCR (Kitchen/Mess Cyclone Refuge) area,
- Scenario 2 sources located at VICP (Varanus Island Compression Project) area,
- Scenario 3 sources located at VICP NE (Northeastern of VICP) area, and
- Scenario 4 sources located at Accommodation area.

1.6 Frequency weightings

Turtles and seabirds hear different frequencies of noise to that of humans. Typical modelling results show the L_{A10} and $L_{A90,}$ levels which are A-weighted (i.e. weighted for human hearing). These levels are not representative of what noise is audible to turtles and seabirds. Therefore, additional

[2] Apache have indicated that an Erkat ER1200 rotary cutter fitted to a 32t excavator. This machine will significantly reduce vibration source in comparison to a D10 bulldozer ripping

[3] Yellow circles demarcate receivers. Purple circles indicate noise sources.

processing of noise modelling results was undertaken to determine the received noise levels of sensitive fauna on Varanus Island by filtering the noise modelling results to include only the frequencies of noise audible to these species. The following frequencies have been used in the processing of the frequency data (i.e. 1/3 octave band data);

- Turtles 100Hz – 1kHz
- Seabirds 182Hz – 2.75kHz

A detailed explanation of why these auditory bandwidths have been chosen is given in Appendix B.

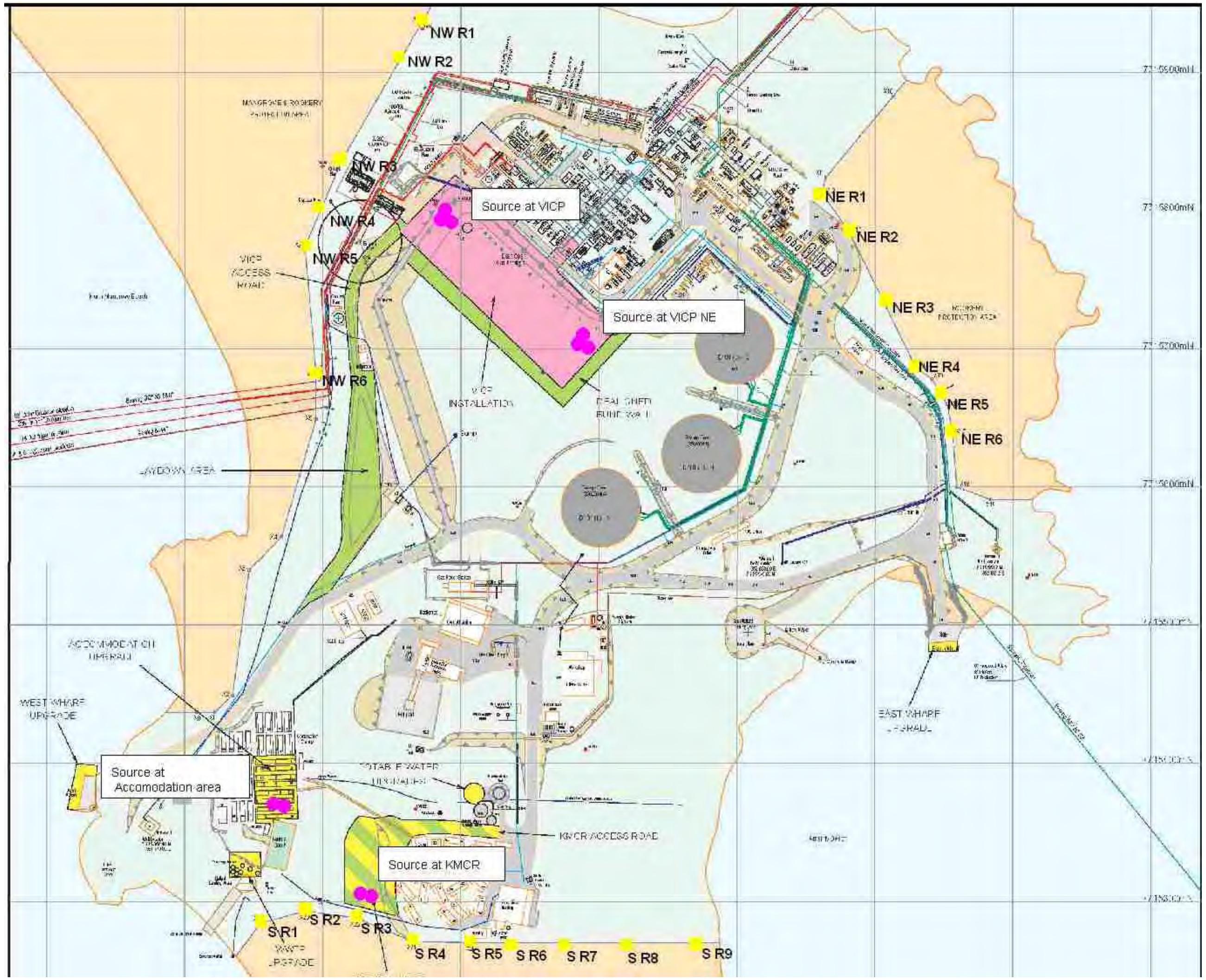

Figure 1 Varanus Island receivers and sources location

2. RECEIVED NOISE LEVELS

The following sections present the results of all noise modeling scenarios, with locations where received noise is greater than 70dB highlighted in red. As there are no regulatory noise levels for fauna, SVT have chosen 70dB because it is representative of the highest 10th percentile of noise results over all the scenarios. The purpose of choosing the 10th percentile is not to compare against any criteria, but rather to highlight the locations and operations of largest noise impact.

2.1 Predicted received noise levels in dB(A) for all four scenarios

Predicted received noise levels for all scenarios are shown in Table 2.

Table 2 Predicted received noise level at All four scenarios

All Scenarios					
Receivers		Sources at:			
		KMCR	VICP	VICP NE	Accommodation area
		predicted received noise level (in dBA)			
1	NE R1	39.6	61.9	60.8	40.8
2	NE R2	39.6	61.0	57.3	32.9
3	NE R3	39.7	55.5	55.2	33.3
4	NE R4	30.6	55.0	56.9	30.1
5	NE R5	30.4	59.9	57.2	30.2
6	NE R6	39.6	59.9	53.0	30.6
7	NW R1	50.7	67.6	64.2	52.3
8	NW R2	51.0	68.8	64.8	52.9
9	NW R3	50.9	71.2	60.6	54.7
10	NW R4	50.7	70.3	56.2	55.6
11	NW R5	51.0	69.2	55.5	56.4
12	NW R6	53.5	67.3	65.2	59.2
13	S R1	71.1	56.7	49.4	70.8
14	S R2	76.2	56.9	47.7	72.0
15	S R3	85.8	49.3	46.3	61.6
16	S R4	77.0	57.1	58.6	60.5
17	S R5	71.3	57.0	58.9	52.8
18	S R6	68.1	57.0	59.0	49.6
19	S R7	57.0	56.8	59.0	46.4
20	S R8	43.2	55.8	58.7	37.1
21	S R9	38.7	43.6	46.8	35.0

2.2 Predicted received noise level including received noise levels with fauna weighting applied

Table 3 shows predicted noise levels for turtles and seabirds with sources located at KMCR area.

Table 3 Predicted received noise level*Error! Bookmark not defined.* ***with sources located at KMCR***

Scenario 1: sources at KMCR				
Receivers	Received Noise level		dB (Turtle)	dB (Seabird)
	dB(A)	*dB(lin)*	*(100 - 1000 Hz unweighted)*	*(182 - 2750 Hz unweighted)*
1 NE R1	39.6	52.6	47.2	42.7
2 NE R2	39.6	52.7	47.3	42.7
3 NE R3	39.7	53.2	47.7	42.9
4 NE R4	30.6	46.8	40.2	33.9
5 NE R5	30.4	46.5	39.8	33.5
6 NE R6	39.6	53.0	47.3	42.5
7 NW R1	50.7	55.2	51.6	51.0
8 NW R2	51.0	55.5	51.8	51.2
9 NW R3	50.9	56.6	52.0	51.0
10 NW R4	50.7	57.1	52.5	50.8
11 NW R5	51.0	57.7	53.1	51.3
12 NW R6	53.5	59.7	55.2	53.5
13 S R1	71.1	76.1	72.4	70.7
14 S R2	76.2	82.3	79.2	76.9
15 S R3	85.8	91.3	88.4	86.7
16 S R4	77.0	81.5	78.3	77.0
17 S R5	71.3	75.1	71.2	70.5
18 S R6	68.1	71.7	67.3	66.9
19 S R7	57.0	67.1	62.9	58.7
20 S R8	43.2	58.1	52.8	46.2
21 S R9	38.7	53.5	47.1	40.4

Table 4 shows predicted noise level with sources located at VICP area.

Table 4 Predicted received noise level*Error! Bookmark not defined.* ***with sources located at VICP***

Scenario 2: sources at VICP					
Receivers		Received Noise level		dB (Turtle)	dB (Seabird)
		dB(A)	*dB(lin)*	*(100 - 1000 Hz unweighted)*	*(182 - 2750 Hz unweighted)*
1	NE R1	61.9	69.9	66.2	63.2
2	NE R2	61.0	68.7	64.8	61.9
3	NE R3	55.5	65.4	61.8	57.7
4	NE R4	55.0	64.6	61.1	57.1
5	NE R5	59.9	65.3	62.5	60.9
6	NE R6	59.9	66.8	63.2	60.9
7	NW R1	67.6	76.9	74.2	69.8
8	NW R2	68.8	78.1	75.6	71.1
9	NW R3	71.2	79.9	77.6	73.3
10	NW R4	70.3	79.0	76.5	72.0
11	NW R5	69.2	78.0	75.5	70.8
12	NW R6	67.3	75.6	72.5	68.5
13	S R1	56.7	62.6	59.6	58.1
14	S R2	56.9	63.4	59.7	57.9
15	S R3	49.3	60.4	56.5	52.2
16	S R4	57.1	64.3	61.4	58.8
17	S R5	57.0	63.6	61.1	58.8
18	S R6	57.0	64.6	61.4	58.7
19	S R7	56.8	64.0	61.1	58.6
20	S R8	55.8	61.7	59.0	57.3
21	S R9	43.6	57.4	52.6	46.8

Table 5 shows predicted noise level with sources located at Northeastern of VICP area.

Table 5 Predicted received noise level*Error! Bookmark not defined.* ***with sources located at Northeastern of VICP***

Scenario 3: sources at VICP NE					
Receivers		Received Noise level		dB (Turtle)	dB (Seabird)
		dB(A)	*dB(lin)*	*(100 - 1000 Hz unweighted)*	*(182 - 2750 Hz unweighted)*
1	NE R1	60.8	70.0	66.4	62.2
2	NE R2	57.3	68.6	65.2	59.9
3	NE R3	55.2	67.6	63.9	58.1
4	NE R4	56.9	67.7	64.1	59.3
5	NE R5	57.2	67.2	63.7	59.4
6	NE R6	53.0	65.6	61.7	56.0
7	NW R1	64.2	70.5	67.1	65.1
8	NW R2	64.8	71.4	68.1	65.7
9	NW R3	60.6	69.6	66.2	62.1
10	NW R4	56.2	68.7	64.9	59.1
11	NW R5	55.5	68.5	64.6	58.5
12	NW R6	65.2	70.8	67.4	65.1
13	S R1	49.4	60.6	56.7	52.2
14	S R2	47.7	60.5	56.2	50.9
15	S R3	46.3	59.7	55.2	49.5
16	S R4	58.6	64.3	61.9	60.2
17	S R5	58.9	66.2	63.0	60.5
18	S R6	59.0	66.7	63.4	60.6
19	S R7	59.0	66.2	63.1	60.7
20	S R8	58.7	63.8	61.0	59.6
21	S R9	46.8	60.1	55.4	49.7

Table 6 shows predicted noise level with sources located at Accommodation area.

Table 6 Predicted received noise level with sources located at Accommodation area

Scenario 4: sources at Accommodation area					
Receivers		Received Noise level		dB (Turtle)	dB (Seabird)
		dB(A)	dB(lin)	(100 - 1000 Hz unweighted)	(182 - 2750 Hz unweighted)
1	NE R1	40.8	53.2	47.9	43.6
2	NE R2	32.9	47.9	42.1	36.6
3	NE R3	33.3	48.2	42.4	37.0
4	NE R4	30.1	46.2	39.5	33.1
5	NE R5	30.2	46.5	39.9	33.4
6	NE R6	30.6	46.9	40.3	33.8
7	NW R1	52.3	59.3	55.2	53.3
8	NW R2	52.9	60.1	55.8	53.8
9	NW R3	54.7	61.7	57.3	55.4
10	NW R4	55.6	62.5	58.1	56.2
11	NW R5	56.4	63.2	58.8	57.0
12	NW R6	59.2	65.9	61.5	59.6
13	S R1	70.8	74.8	71.0	70.2
14	S R2	72.0	77.4	74.2	72.1
15	S R3	61.6	70.7	67.5	63.5
16	S R4	60.5	68.7	65.0	61.7
17	S R5	52.8	65.5	61.0	55.6
18	S R6	49.6	63.5	58.5	52.5
19	S R7	46.4	60.6	55.1	49.1
20	S R8	37.1	51.7	44.8	38.1
21	S R9	35.0	48.1	40.9	35.4

3. VIBRATION LEVELS

In order to assess vibration caused by the VICP site preparation work on Varanus Island, the predicted ground borne vibration levels of 1mm/s and 10mm/s have been used to determine charge size at which those vibration levels will be reached at each receiver. The predictions have been made assuming a limestone ground type, which is expected on Varanus Island. As a guide to vibration levels, 10mm/s will result in structural damage to buildings (and therefore possibly structural damage to burrows).

For example: as shown in Table 7, receiver NE R1 will experience a vibration level of 1mm/s if a 55 kg instantaneous charge is detonated at KMCR or a 11.4 kg charge is detonated at VICP or a 6.45 kg charge at VICP NE or a 53 kg charge is detonated at the accommodation.

All charge sizes less than 25 kg's have been marked in red for both of the 1 mm/s and the 10 mm/s tables. It is expected that a 25 kg charge will be the smallest possible instantaneous charge that could be detonated.

3.1 Ground –borne vibration and blasting for vibration 1mm/s

Table 7[4] shows maximum instantaneous charge with blasting at all scenarios for minimum vibration 1mm/s.

Table 7 Maximum instantaneous charge for minimum vibration 1mm/s

Min vibration for 1mm/s					
		Blasting at:			
	Receivers	KMCR	VICP	VICP NE	Accommodation
		max instantaneous charge (in kg)			
1	NE R1	55.61	11.46	6.45	53.25
2	NE R2	53.84	13.22	6.86	52.39
3	NE R3	49.82	16.20	7.65	49.86
4	NE R4	46.49	19.60	9.07	47.90
5	NE R5	46.67	22.22	10.62	48.79
6	NE R6	44.69	24.22	11.63	47.49
7	NW R1	60.80	3.18	10.28	50.49
8	NW R2	55.67	2.25	9.16	45.53
9	NW R3	42.90	1.10	7.24	33.40
10	NW R4	37.57	1.21	6.88	28.45
11	NW R5	33.62	1.49	6.66	24.88
12	NW R6	21.69	3.10	5.53	14.90
13	S R1	0.87	41.61	34.34	1.10
14	S R2	0.26	39.10	31.12	0.95
15	S R3	0.04	39.00	29.77	1.53

[4] All maximum instantaneous charge values < 25 kg are marked in red

Min vibration for 1mm/s					
		Blasting at:			
Receivers		KMCR	VICP	VICP NE	Accommodation
		max instantaneous charge (in kg)			
16	S R4	0.38	41.20	30.27	3.01
17	S R5	1.14	41.40	29.18	4.59
18	S R6	2.01	42.03	28.86	6.06
19	S R7	3.50	42.84	28.52	8.27
20	S R8	5.81	44.42	28.73	11.44
21	S R9	9.13	46.78	29.57	15.69

3.2 Ground –borne vibration and blasting for vibration 10mm/s

Table 8 shows maximum instantaneous charge with blasting at all scenarios for maximum vibration 10mm/s.

Table 8 Maximum instantaneous charge*Error! Bookmark not defined.* ***for maximum vibration 10mm/s***

Max vibration for 10mm/s					
		Blasting at:			
Receivers		KMCR	VICP	VICP NE	Accomodation
		max instantaneous charge (in kg)			
1	NE R1	988.89	203.77	114.67	946.88
2	NE R2	957.47	235.10	121.91	931.64
3	NE R3	885.97	288.14	136.06	886.65
4	NE R4	826.78	348.63	161.35	851.82
5	NE R5	829.95	395.07	188.86	867.62
6	NE R6	794.71	430.66	206.86	844.58
7	NW R1	1081.18	56.57	182.86	897.79
8	NW R2	989.90	40.05	162.88	809.71
9	NW R3	762.88	19.55	128.72	594.02
10	NW R4	668.08	21.55	122.31	505.88
11	NW R5	597.87	26.55	118.46	442.51
12	NW R6	385.65	55.18	98.39	265.02
13	S R1	15.40	739.90	610.68	19.56
14	S R2	4.65	695.35	553.33	16.88
15	S R3	0.72	693.49	529.36	27.28
16	S R4	6.82	732.61	538.34	53.45
17	S R5	20.22	736.12	518.88	81.56
18	S R6	35.66	747.44	513.27	107.70
19	S R7	62.15	761.87	507.09	147.12
20	S R8	103.38	789.99	510.81	203.46
21	S R9	162.43	831.83	525.89	279.04

4. CONCLUSION

SVT has predicted possible received noise and vibration levels as a result of the proposed VICP construction works at sensitive fauna areas around Varanus Island.

The noise results have been frequency weighted for turtles and seabirds.

The predictions can be used by the turtle and seabird experts to determine possible impacts due to noise and vibration on marine turtles and seabirds.

Yours sincerely,

Maya Maroef & Granger Bennett

APPENDIX A : SOUND POWER LEVELS

Source	Octave Band Sound Power Levels - dB(lin)									Overall dB(A)
	31 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	
Dozer D10	120.0	121.0	117.0	112.0	102.0	102.0	99.9	89.9	85.3	109.3
Rock breaker	103.0	102.0	102.0	106.0	111.0	112.0	112.0	109.0	103.0	118
Mobile Crusher Plant	111.0	121.0	122.0	118.0	116.0	114.0	110.0	104.0	98.7	119.2

APPENDIX B : NOISE EFFECTS ON FAUNA

The AEL Varanus Island project is focused on the following sensitive receivers; Human, Turtles and seabirds. All of these receivers hear different frequencies of noise and therefore the filtered 1/3 octave band noise monitoring data collected needs to be analysed according to the receiver affected. The range of hearing used for each receiver for the AEL Varanus Island project is as follows;

- Humans – 12.5Hz-20kHz
- Turtles – 2kHz – 10kHz
- Seabirds – 182Hz – 2.75kHz. The frequency weighting for seabird are based on paper *"Acoustic convergence between two nocturnal burrowing seabirds: experiments with a penguin Eudyptula minor and a shearwater Puffinus tenuirostris by Pieere Jouventin & Thierry Aubin in Ibis (2000).*

The following sections outline information on the hearing range of turtles and provide reasons for the frequency bands chosen for each receiver.

Appendix B-1 : 1/3 octave band Information on Turtles

A turtle's auditory bandwidth and sensitivities are different to that of humans. This implies that noise data measured must be filtered to remove frequencies that the turtle cannot hear. Due to the lack of literature regarding airborne noise perception by turtles, the auditory bandwidths in this report are determined from peer reviewed and widely accepted literature regarding underwater hearing of Turtles. It is assumed and also expected that the auditory bandwidths will remain the same in air as it is in water (this is due to the size of the bassila membrane in the cochlea of the animal). It is however, expected that the auditory sensitivities will change (this is due to the change in acoustic impedance between air and water). As a result auditory sensitivities of turtles are not considered in this report. The following section discusses turtle auditory bandwidths and sensitivities.

There have been studies undertaken regarding underwater noise impacts on turtles and the frequency bandwidth audible to turtles. These studies have shown that each turtle species has slightly different auditory bandwidths. In order to simplify the complexity of different bandwidths it is proposed that a general bandwidth between 100 Hz and 1 kHz be taken. This bandwidth is wide enough to cover all known turtle bandwidths and is therefore representative of the noise perceived by all turtles.

There is no available literature that discusses turtle sensitivities within the auditory bandwidth in air. As a result it is proposed that the frequency information will be filtered using a flat response over the bandwidth of hearing (100 Hz to 1 kHz). The time averaged pressure taken over this bandwidth will be denoted using Leq (Turtle), i.e. equivalent level turtle.

Appendix B-1.1 Turtles - 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 2kHz and their maximum sensitivity is between 300Hz and 400Hz[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 100Hz to 800Hz bandwidth, with best sensitivity between 600Hz and 700Hz, while adults have a bandwidth of 100Hz to 500Hz, with the greatest sensitivity between 200Hz and 400Hz[7,8]. This indicates that a turtle's frequency and sensitivity bandwidth decreases with age.

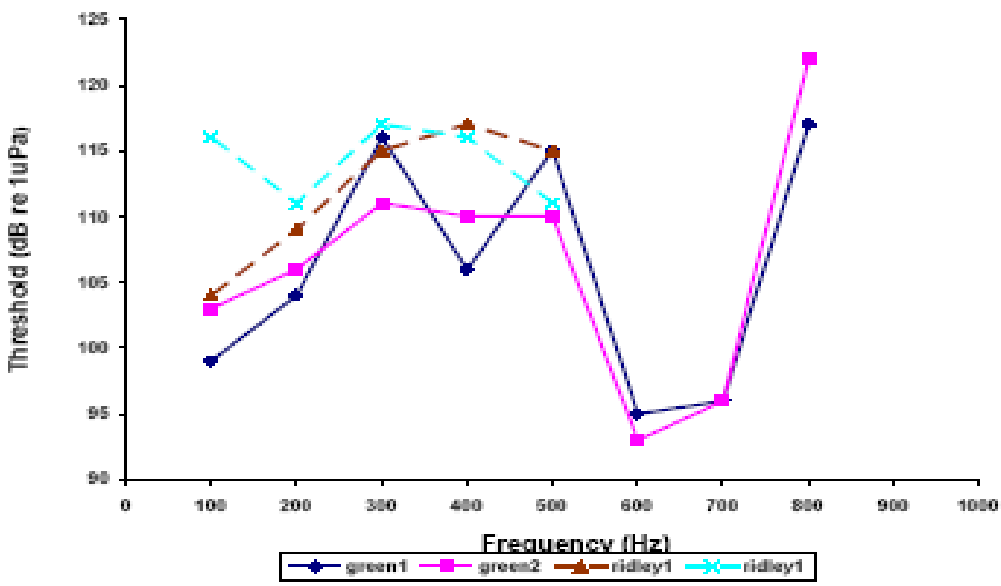

Figure B-1 Audiograms of two juvenile green turtles and two juvenile Ridley's turtles[9]

[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

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

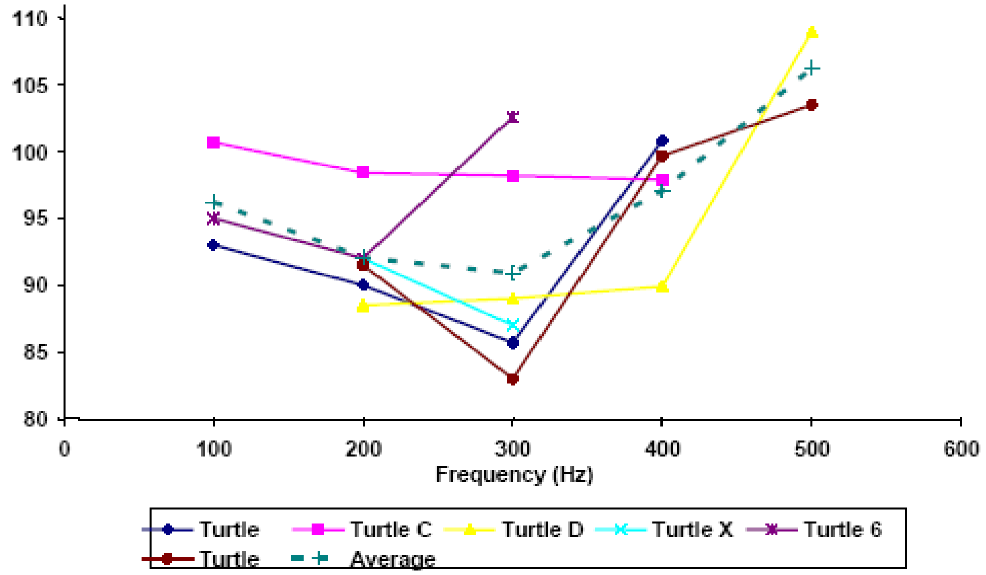

Figure B-2 Audiograms of six sub-adult Green turtles[10]

Appendix B-1.2 Turtles - Avoidance and Physical injury

There is a possibility that nesting turtles may experience masking and/or behavioural change and avoid the nesting area/beach affected by noise.

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 safety range be used for guidance[11]. It should be noted that these also only relate to underwater noise.

Using the safety range formula as noted[12] and converting back to peak SPL using Ross[13] formula, a value of 222dB re 1µPa is obtained. Based on this SPL, a value of 222dB re 1µPa should not be exceeded for adult turtles to avoid physical injury.

Hatchlings will be evaluated using the SEL values for fish. As Flatback hatchling weights can vary between 30g and 51g, the SEL value for hatchlings will be taken as 198dB re 1µPa^{2}s, assuming that hatchlings will suffer the same effects as fish exposed to a similar impulsive pressure wave. This is based on the no injury regression line in Figure B 3[14].

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

[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. Peninsula Publishing. Los Altos. California, USA

[14] Popper *et al* (Interim Criteria for Injury of Fish to Pile Driving Operations: A White Paper) suggest a 187 dB re 1µPa2s criterion for fish. This is based on the 50% mortality line and testing done on 0.01 g fish. Considering the rationale behind the criteria it was decided to use the no mortality regression line and the weight of the turtle hatchlings.

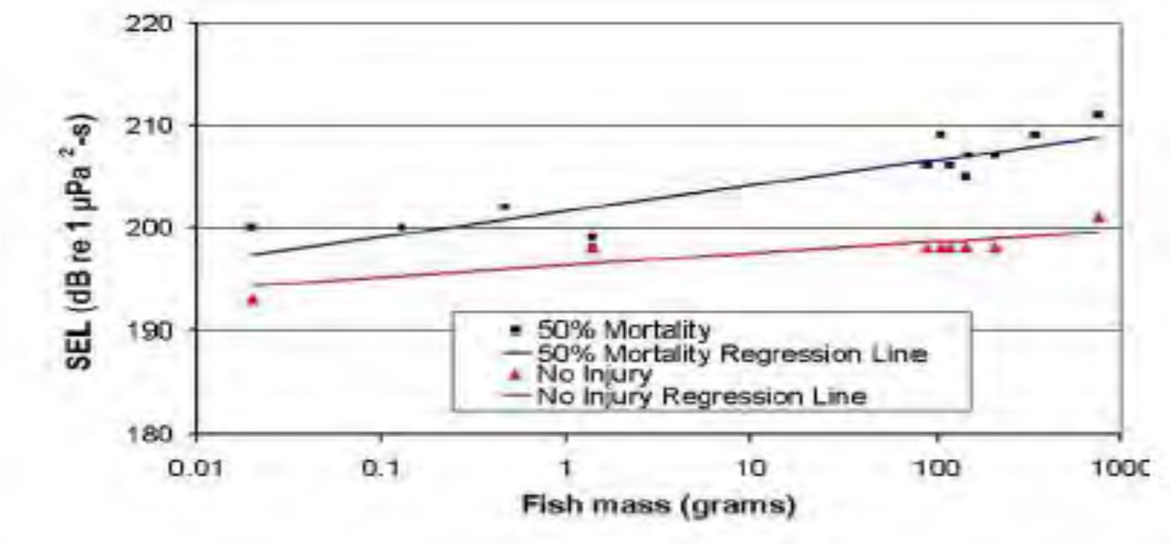

Figure B-3 Fish mortality regression line plotted against SEL and fish mass