DISTRICT WATER MANAGEMENT STRATEGY

Anketell Strategic Industrial Area

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ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	**Definition**
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASS	Acid Sulfate Soils
BoM	Bureau of Meteorology
DAA	Department of Aboriginal Affairs
DER	Department of Environment Regulation
DPaW	Department of Parks and Wildlife
DoW	Department of Water
DWMS	District Water Management Strategy
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GIA	General Industry Area
HFl	Horseflat Land System Roebourne Plain Grassland
HIA	Heavy Industry Area
m AHD	Metres Australian Height Datum
PEC	Priority Ecological Community
RWQMP	Recycled Water Quality Management Plan
RPS	RPS Environment and Planning Pty Ltd
SIA	Strategic Industrial Area
TEC	Threatened Ecological Communities
TPS	Town Planning Scheme
TRF	Threatened Rare Flora
TWL	Top Water Level
WAPC	Western Australian Planning Commission
WC Act	*Wildlife Conservation Act 1950*

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SUMMARY

The Anketell region has long been identified by the state and federal governments as being a potential location for future industrial development, a key reason being the access to deep water close to the coastline (which is the location of a proposed future port) and the proximity to surrounding towns (Wickham, Roebourne and Karratha) and key regional road and rail infrastructure. In 2010, the state government announced that the next major deep water port for the Pilbara would be located at Anketell, north of the Anketell Strategic Industrial Area (SIA).

An Improvement Scheme has been prepared for the Anketell SIA project area and acts as the principal statutory tool for implementing the strategic planning objectives for the project. The Improvement Scheme Framework differs from the typical planning process, and consequently a fit-for-purpose water management framework is required. The Improvement Scheme water management framework must meet the overall objectives of Better Urban Water Management (BUWM); however, it must also be suitable to the unique planning context of the Improvement Scheme process.

Development of the Anketell SIA is intended to occur over a long-term time frame, depending upon the demand for sites within the heavy industrial areas. Due to the uncertain nature of the strategic industry demand for land areas and servicing requirements, development of sites is intended only when required by a future proponent.

As proponents' development requirements can vary considerably based on the type of industry, associated operational requirements and footprint, and site-specific characteristics, the imposition of conventional information requirements (and subsequent subdivision/development conditions) is not always appropriate as it does not reflect the long term, proponent-driven development nature of the SIA. Information requirements (and subsequent subdivision/development conditions) should be considered on a case-by-case basis. In the heavy industrial areas, proponents will be required to investigate, fund and implement the specific infrastructure and services they require to support their developments on their sites (i.e. power, water, telecoms, and wastewater solutions).

This District Water Management Strategy (DWMS) has been developed in the context of the Improvement Scheme process to not only addresses the objectives of BUWM and demonstrate that the area is capable of supporting future development with respect to water related constraints, but also to inform the water management detail required by each proponent at subdivision stage. The report identifies the planning and environment context of the subject site, and outlines the key water servicing, drainage and environmental management considerations to be progressed in support of subsequent design development and planning approval phases. Further consideration of relevant government policies and advice may be warranted as subdivision occurs incrementally over a long-term time frame.

Table 1 below provides a summary of the key water management factors included in the DWMS.

Table 1: Key DWMS Reporting Elements

DWMS Elements	Design Objectives / Comments
Water Management Framework (Section 1.2)	▪ The Improvement Scheme is the principal statutory tool for implementing the strategic planning objectives for the project. ▪ Figure A illustrates the water management and planning framework for the Improvement Scheme process. ▪ This DWMS not only addresses the objectives of BUWM, but also informs the water management detail required by each proponent at subdivision stage, as part of the lot-scale water management plan (WMP). ▪ Table 2 outlines potential requirements for DWMS and WMP detail as part of the Improvement Scheme Process.
Existing Land Use (Section 2.1)	▪ The proposed development comprises three industrial areas with a total combined area of 1,262 ha. These areas are referred to as Heavy Industry Area 1 (HIA1), Heavy Industry Area 2 (HIA2) and General Industrial Area (GIA). ▪ The subject site is comprised of vacant Crown land used in areas as a pastoral station (Mount Welcome Station) ▪ HIA1 and GIA will be transferred from Crown land to freehold with LandCorp as the owner and estate manager. HIA 2 will remain as Crown land subject to future land dealings.
Topography (Section 2.4)	▪ Surface elevations within the proposed development areas range between approximately 3 m AHD in the northern, coastal fringing portion of HIA1 to as high as approximately 40 m AHD in some portions of the site that are flanked by ranges.
Geology and Soils (Section 2.5)	▪ Low-lying areas of alluvial sand and gravel are associated with the river and creek channels with adjacent flood plain areas comprising colluvium and sheetwash deposits of silt, sand and gravel. Elevated areas are comprised of basalt and siltstone.
Surface Water (Section 2.7)	▪ A number of ephemeral watercourses traverse the subject site with the largest, being Rocky Creek. Rocky Creek dissects the western areas of HIA1 and HIA2 and is a relatively large watercourse with a 26 km^2 catchment area. ▪ GIA and the eastern part of HIA1 fall within smaller surface water catchments; the eastern part of HIA1 receives run-off from a significant upstream catchment area into a small creek that runs through the site and may be subject to flooding. GIA does not receive run-off from any external catchment areas or contain any significant watercourses. ▪ The north-western portion of HIA1 is situated on low-lying coastal flats that may be subject to inundation from storm surge during extreme events. The 0.2% AEP (500 year ARI) storm surge level has been estimated at 7.1 m AHD. ▪ A pre-development flood study was completed for the site by RPS. This included hydrologic and hydraulic modelling of each of the surface water catchments. This modelling was updated to consider post-development impacts on flood levels to inform the DWMS; post-development flood levels are presented to inform flood protection levels. ▪ RPS has completed a baseline surface water monitoring program including the installation of four loggers to record water level data between October 2014 and March 2016. The maximum water depth encountered in Rocky Creek was 1.4 m.

DWMS Elements	Design Objectives / Comments
Groundwater (Sections 2.8–2.10)	▪ RPS has completed installed four monitoring bores with loggers to record water level data between October 2014 and March 2016. ▪ Groundwater elevations during that period ranged between a minimum of 2.65 m AHD and a maximum of 7.0 m AHD, with a range at the bores of approximately 3.2 to 15.2 metres below ground level. The groundwater flow direction is north-west towards the coast. ▪ Four groundwater quality sampling events were completed. Groundwater electrical conductivity ranged from 2,600 to 66,000 µS/cm indicating brackish to hypersaline water. ▪ Total nitrogen concentrations were elevated in all bores with concentrations exceeding the ANZECC Fresh Water Guideline. Total phosphorus concentrations also exceeded the ANZECC FWG in the majority of samples. ▪ The site falls within the proclaimed “Pilbara Groundwater Area”, however no allocation limit from groundwater licensing has been identified by the DoW due to the lack of groundwater information for the area. Groundwater allocations are to be managed on a case-by-case basis.
Water Source Planning (Section 3.0)	▪ There is currently no potable water supply infrastructure in the vicinity of the Anketell SIA. The Water Corporation provides bulk potable water to surrounding towns such as Wickham and Roebourne; however, this supply is highly constrained by abstraction limits for the source aquifers. ▪ The Water Corporation has advised that there is no water supply planning for the Anketell site and that industry proponents will need to pursue private water sources. ▪ Options for water supply include sea water desalination, recycling of industrial effluent and abstraction from aquifers in the West Canning Basin. ▪ No wastewater servicing infrastructure exists in the vicinity of Anketell SIA and the Water Corporation has advised that there is currently no planning or capital to provide wastewater servicing to the area. ▪ Wastewater servicing for the development may involve a reticulated system comprising gravity fed catchments feeding into pump stations to convey wastewater to a centralised treatment facility.
Stormwater Management (Section 4.0)	▪ Lots shall aim to retain the first 15 mm of rainfall to improve the quality of stormwater discharging from lots. ▪ The requirement to retain the first 15 mm will be a secondary consideration to lots implementing stormwater management systems to provide a suitable level of stormwater quality control depending on the specific industrial land use, processes and materials present on the site. These requirements will need to be confirmed at the WMP stage. ▪ Open drains will be located alongside road reserves that will be flush kerbed as opposed to the use of piped drainage systems. ▪ Road reserve drains will be used in conjunction with arterial drainage corridors throughout the development to convey stormwater flows from lots to downstream drainage reserves or discharge points. Open drains will be designed to contain 1% AEP (100 year ARI) flows. ▪ Arterial drainage corridors will utilise the existing surface topography and natural drainage features as much as possible to retain the pre-development hydrological regime and minimise earthworks requirements. ▪ Erosion and sediment transport will be minimised by reducing flow velocities using detention basins, drop structures, pitching and vegetation of drainage channels.
Flood Management (Section 5.0)	▪ Post-development flood modelling has been undertaken and indicative post-development 1% AEP flood levels are provided to inform flood protection levels. ▪ Storm surge modelling is not available for the site. The 0.2% AEP storm surge level has been estimated from storm surge modelling that was undertaken as part of the Karratha Coastal Vulnerability Study. The estimated 0.2% AEP storm surge level is 7.1 m AHD. ▪ Post-development flood modelling included an assessment of flood plain encroachment effects to provide an indicative floodway boundary.

DWMS Elements	**Design Objectives / Comments**
Monitoring (Section 6.0)	▪ A baseline groundwater and surface water monitoring program has been undertaken, which includes groundwater level logging, groundwater quality sampling and surface water level logging. ▪ A post-development monitoring program is not currently being proposed for the site, however further liaison with the Department of Water on this issue will be progressed and detailed in subsequent water reports.
Water Related Constraints Assessment (Section 7.0)	▪ A broad assessment of water related constraints for the Anketell SIA has been provided. ▪ This assessment is intended to provide future proponents with broad information to inform future detailed lot scale WMPs.

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APPENDICES

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1.0 INTRODUCTION

1.1 DWMS Objectives

This DWMS supports the use of the Anketell SIA for general and heavy industrial uses by demonstrating that the area is capable of supporting future development in terms of water supply planning, flood mitigation, drainage management and water quality protection.

The report has been developed in accordance with and in consideration of the following guidance documents:

- Guidelines for District Water Management Strategies (DoW 2013)
- State Planning Policy 2.9: Water Resources (WAPC 2006)
- Western Australian State Water Plan (Government of WA 2007)
- Better Urban Water Management (WAPC 2008)
- Stormwater Design Guidelines for Residential Developments (City of Karratha 2011a)
- Stormwater Management at Industrial Sites, Department of Water. Water Quality Protection Note 52 (DoW 2010).

This DWMS incorporates the integrated water cycle management principles discussed in the BUWM guidelines by:

- considering all water resources
- integrating water and land use planning
- using a whole of catchment integration of natural resource use and management
- promoting the sustainable and equitable use of all water sources
- having consideration of the needs of all water users including the environment.

In reviewing the relevant requirements for a DWMS, the following scope of works has been addressed in this report:

1. Investigation of the impact of climate characteristics on hydrological conditions.
2. Investigation of the surrounding topography and catchment characteristics to compare the pre- and post-development hydrological conditions.

3. Identification of soil types present at the site and the implications to the drainage design and stormwater management controls (as applicable).

4. A discussion of regional groundwater levels and quality in the vicinity of the subject site.

5. A review of the site characteristics and required drainage design and functions.

6. An assessment of RPS' Flood Study report and preliminary advice on impacts of the development on the hydrology of the surrounding environment.

7. A discussion of the local stormwater management strategies to be applied and identification of appropriate design principles for the site.

8. Propose overarching engineering principles that will be employed to mitigate any impact from run-off and water issues to ensure that the environment and the development will not be adversely impacted.

9. Detail of allocation and services for potable, non-potable and wastewater, and principles of water efficiency.

In addition to the above, this DWMS contains water management related constraints for Improvement Scheme development, including:

1. Identify environmental and Indigenous heritage constraints to development and water management.

2. Availability of raw material to ensure appropriate flood and/or groundwater clearance.

3. Impact of relief on developability.

4. Area mapping with respect to individual and cumulative development and water management constraints.

1.2 Water Management Planning

This section describes the Improvement Scheme process under which the Anketell SIA development is being progressed and how water management planning will fit into the unique planning framework for the site.

1.2.1 Development of Strategic Industrial Areas

The Department of State Development (DSD) is the lead agency for the Anketell SIA and LandCorp is the SIA estate manager, landowner and lessor. When considering Business Case submissions from future heavy industry proponents seeking to establish within the Anketell SIA, DSD and LandCorp will consider the proposal in the context of the wider Anketell Port Project, the Improvement Scheme, and the supporting technical reports and operational requirements of the Anketell SIA. This is to ensure the SIA is developed to its full potential, namely to establish resource processing industries and associated support activity in order to fulfil its designated role as one of several SIAs in the Pilbara region. This process occurs well before the lodgement of a Development Application with the Western Australian Planning Commission.

1.2.2 Improvement Scheme

In order to facilitate future industrial development, the state government has determined that an Improvement Scheme is the most appropriate planning instrument to govern the development of the Anketell SIA (RPS 2014). Furthermore, an Improvement Scheme is administered by the state where as Local Planning Schemes are administered by local government.

The arrangements for Improvement Schemes are different to Local Planning Schemes administered by local government. A key difference is the requirement for an Improvement Plan to first be prepared, and for that Improvement Plan to provide for the preparation of an Improvement Scheme (RPS 2014).

A simple comparison between the general arrangements of ordinary Local Planning Schemes and the proposed Improvement Scheme is illustrated below (Figure A).

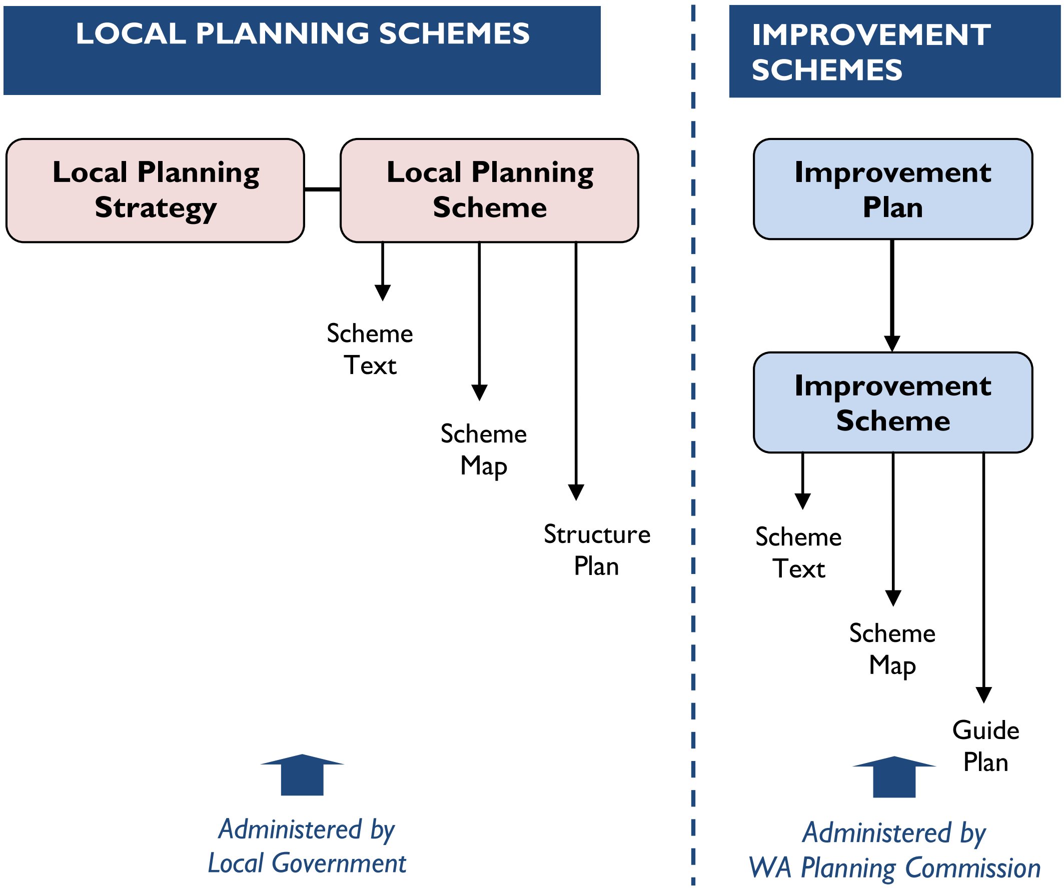

Figure A: Improvement and Local Planning Schemes (RPS 2014)

The Improvement Plan and Improvement Scheme arrangement differs from ordinary planning practices associated with a Local Planning Schemes in that they are regulated by the WAPC and are tailored to suit the circumstances of the project area. The role of the plan/scheme relationship is summarised as follows (RPS 2014).

1.2.2.1 Improvement Plan

Improvement Plans are "strategic instruments" used by the WAPC to facilitate the development of land in areas identified as requiring special planning. An Improvement Plan authorises the making of an Improvement Scheme, and sets out the area and objectives of that Improvement Scheme.

1.2.2.2 Improvement Scheme

Improvement Schemes are "statutory instruments" used by the WAPC to control development within an Improvement Plan area. An Improvement Scheme removes land from the Local Planning Scheme. As such, the City of Karratha's Local Planning Scheme would not have effect once the Improvement Scheme comes into effect.

1.2.3 Improvement Scheme Structure

The Improvement Scheme is the principal planning instrument, providing the statutory control of land use and development. An Improvement Scheme may provide for all matters ordinarily addressed by a local government Local Planning Scheme. Significantly, an Improvement Scheme is not obligated to conform to model scheme provisions set out within Town Planning Regulations 1967. An Improvement Scheme should be fit-for-purpose. That is, it should respond to the specific planning requirements as they apply to the area subject to the Improvement Plan (RPS 2014)

While the *Planning and Development Act 2005* allows broad discretion over the form and content of an Improvement Scheme, arrangements are proposed that will as far as relevant, correspond with model scheme provisions. In this regard, the proposed Scheme structure recognises the familiar report, text and map, with the addition of Guide Plan provisions as follows (RPS 2014):

Scheme Report:	Comparable to a Local Planning Strategy, the report will set out the strategic purposes and basis of Scheme provisions.
Scheme Text:	The range of statutory provisions necessary to achieve the project objectives effectively.
Scheme Map:	Spatial definition of land zones and reserves as required.
Guide Plan:	In view of the circumstances associated with Anketell, the Improvement Scheme proposes a Guide Plan in lieu of a Local Structure Plan (or Development Plan), with the provisions of a Guide Plan specified by the Scheme itself. In this way, the further investigations, detailed designs and management plans can be undertaken in association with applications for subdivision.

The relationship between the components of the Improvement Scheme is illustrated in Figure B.

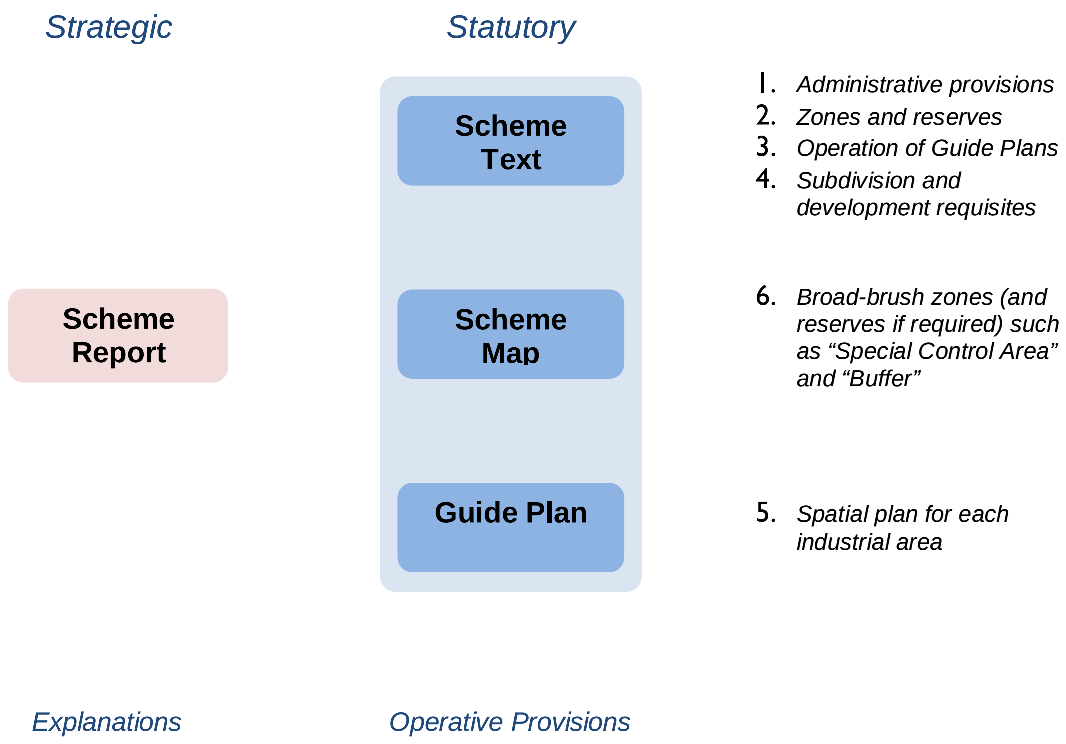

Figure B: Improvement Scheme Arrangements – Anketell SIA (RPS 2014)

1.2.4 BUWM Framework

The Better Urban Water Management (BUWM) framework (WAPC 2008) establishes a requirement for a District Water Management Strategy (DWMS) to be prepared in support of a region scheme amendment or district structure plan. The objective of the DWMS is to demonstrate that the area is capable of supporting future development in terms of water supply planning, flood mitigation, drainage manage and water quality protection. A Local Water Management Strategy (LWMS) is typically undertaken at Local Structure Plan (LSP) stage; its purpose is to support and facilitate approval of the LSP. The LWMS details the integrated water management strategies that will be implemented, and demonstrates that the land is capable of facilitating urban development whilst achieving sustainable, water and environmental outcomes. An Urban Water Management Plan (UWMP) is typically required at subdivision stage, its purpose being to support subdivision approval. The UWMP provides the detail to the design proposed in the LSP.

1.2.5 Improvement Scheme Water Management Framework

The Improvement Scheme water management framework must meet the overall objectives of BUWM; however, it must also meet the unique planning and environmental assessment context of the Improvement Scheme process.

Development of the Anketell SIA is intended to occur over a long-term time frame, depending upon the demand for individual sites within the heavy industrial areas. Due to the uncertain nature and timing of the demand for sites, the specific needs of each proponent and subsequent servicing requirements, development of sites is intended only when required by a future proponent.

As proponents' development requirements can vary considerably based on the type of industry, associated operational requirements and footprint, and site-specific characteristics, the imposition of conventional information requirements (and subsequent subdivision/development conditions) is not always appropriate as it does not reflect the long term, proponent-driven development nature of the SIA. Information requirements (and subsequent subdivision/development conditions) should be considered on a case-by-case basis. In the heavy industrial areas, proponents will be required to investigate, fund and implement the specific infrastructure and services they require to support their developments on their sites (i.e. power, water, telecoms, and wastewater solutions)

Figure C illustrates the water management and planning framework for the Improvement Scheme process.

The objective of the DWMS is to demonstrate that the area is capable of supporting future development in terms of water supply planning, flood mitigation, drainage management and water quality protection. However, the DWMS proposed for the Improvement Scheme process not only addresses the objectives of BUWM, but also informs the water management detail required by each proponent at subdivision/ development stage, as part of a future Water Management Plan (WMP).

The benefit of this approach is that the DWMS identifies broad water management issues while deferring certain investigation and design costs until a foundation proponent is present, and a better understanding of actual land requirements in terms of size, configuration, location, co-location, flood immunity and servicing requirements is known.

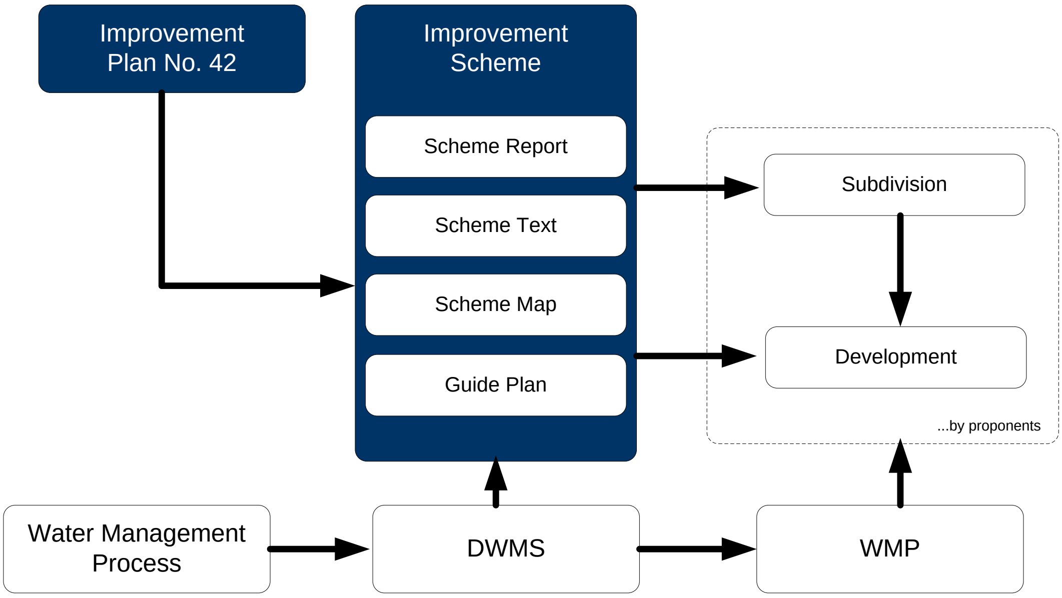

Figure C: Improvement Scheme – Planning and Water Management Framework

Table 2 provides a summary of the water management factors that will be addressed at DWMS and WMP stages.

The second column of Table 2 provides the DWMS scope while the third column provides the detailed design required for the lot scale WMP, which will be undertaken by the proponent. Table 2 is intended to provide a water management framework for Anketell SIA that can be readily utilised by other Improvement Schemes.

Of note in Table 2 is the inclusion of development constraints that have the potential to impact water management at the site. For example, the inclusion of raw material availability has implications in terms of cost to raise lot levels should flood clearance be required in some areas.

Table 2: Improvement Scheme Water Management Investigation Process

Subject	Requirements of DWMS– Scheme Scale	Potential Requirements of Proponent WMP– Lot Scale
Climate	▪ Review climate factors such as heat and cyclones	▪ Building detail for climate protection (heat and cyclone proofing)
Topography	▪ Land relief and slope mapping ▪ Identify relief and slope as limiter of development	▪ Finished earthwork levels
Geotechnical and Soils	▪ Soil and geology mapping (▪ Identify soil types and geotechnical constraints on development (e.g. hard rock, estuarine mud) ▪ Acid sulfate soils mapping ▪ Geotechnical and soils information is suitable to inform catchment-scale hydrological modelling.	▪ Geotechnical assessment ▪ Infiltration testing (if required) ▪ Provide geotechnical classification, including - footing requirements - fill details - groundwater clearance requirements ▪ Acid sulfate soils management plans (if required).
Groundwater	▪ Groundwater monitoring for levels and quality ▪ Groundwater elevation, flow direction and ground clearance ▪ Pre-development groundwater quality	▪ Establish groundwater clearance requirement ▪ Lot scale groundwater monitoring in areas identified in the WMS as shallow water table (e.g. < 3 m) ▪ Detailed design of groundwater controls if required (e.g. subsoil drainage, fill importation) ▪ Design of groundwater quality improvement initiatives (e.g. vegetated swales)
Flooding and Drainage	▪ Describe pre-development drainage system and identify potential post-development drainage corridors ▪ Scheme scale flood modelling ▪ Identify 1% AEP flood levels and flow rates (including storm surge and climate change) ▪ Estimate post-development 1% AEP flood levels and flow rates to inform the establishment of suitable flood protection levels ▪ Flood plain encroachment modelling to identify major flood plain areas to be maintained to prevent impact to hydrological regime and flood levels	▪ Local Drainage Catchment delineation ▪ Lot scale flood and drainage modelling ▪ Detailed design of drainage areas - flow paths for events up to 1% AEP (100 Yr ARI) - confirm inverts, depths and TWLs of drainage infrastructure - confirm capacity for 1% AEP flows - confirm 5 Yr ARI TWL is minimum 300 mm below road levels, - describe erosion protection measures ▪ Drainage design for lots to retain first 15 mm of rain from impervious surfaces ▪ Appropriate stormwater management measures to be identified on an individual lot basis to suit land use type. (e.g. heavy industrial areas may require specific stormwater management measures to ensure treated water is acceptable for discharge to the receiving environment) ▪ Confirm clearance from flood levels (e.g. minimum 0.5 m above 1% AEP flood level for habitable structures) ▪ Lot development not to impact flood levels of neighbouring lots/properties

Subject	Requirements of DWMS– Scheme Scale	Potential Requirements of Proponent WMP– Lot Scale
Water Efficiency/ Supply	▪ Identify landscaping requirement ▪ Identify water supply for landscaping ▪ Provide water efficiency principles ▪ Groundwater abstraction licence (if required)	▪ Detailed water use plan ▪ Detailed landscaping plan ▪ Groundwater abstraction licence and associated hydrogeological investigations (if required).
Servicing	▪ Estimate potable and waste water volume requirements ▪ Broad feasibility of water servicing options - Water Corporation infrastructure - wastewater treatment and reuse - groundwater supply/ abstraction licence - water recycling - desalination	▪ Detailed servicing plan in line with WMS outcomes. Examples include - Water Corporation servicing - on-site wastewater recycling (with RWQMP) - water storage and reuse (e.g. tanks, infiltration areas) - desalination
Environmental Constraints	▪ Identify environmentally sensitive areas ▪ Identify potential impacts of development to environmentally sensitive areas	▪ Detailed environmental impact assessment and EPA referral (if required)
Raw Materials	▪ Identify distance, availability and cost of raw materials (fill)	▪ Identify fill volume requirements
Indigenous Heritage	▪ Identify Indigenous heritage areas ▪ Consultation with Indigenous representative if required	▪ Compliance with the Anketell Indigenous Land Use Agreement where applicable and / or compliance with s18 of the Aboriginal Heritage Act.
Transport	▪ Ensure appropriate transport access	▪ Detailed road layout plan
Report Submission	▪ Western Australian Planning Commission ▪ Department of Water	▪ Western Australian Planning Commission ▪ Department of Water

1.3 Development Planning Background

1.3.1 Anketell Strategic Industrial Area (SIA)

A 1974 study of the Pilbara undertaken jointly by the Commonwealth and state governments identified the Anketell region and Dixon Island for future industrial development. A key reason for the Anketell SIA site being selected was due to it being one of very few sites along the Pilbara coast with access to deep water close to the coastline (which is the location of a proposed future port). In addition, the Pilbara Study preferred the Anketell area because of its proximity to surrounding towns (Wickham, Roebourne and Karratha) and key regional road and rail infrastructure (Department of Northern Development and Department of Industrial Development 1974).

In 2010, the state government announced that the next major deep water port for the Pilbara would be located at Anketell, north of the Anketell SIA. The proposed port will be multi-user facility catering for a range of commodities.

The Anketell Port and Strategic Industrial Area Design Plan identified the requirements for the industrial land components of the Anketell SIA, which are core and support industrial areas, along with infrastructure corridors. The core requirements included (Preston Consulting 2011):

- Heavy industrial land to accommodate industries such as downstream resource processing plus other uses identified under the City of Karratha's Town Planning Scheme. The state's preference is for 1,000 ha of usable heavy industrial land available for third parties within the existing area zoned "Strategic Industry". The heavy industrial area (HIA) is to have reasonable access via an infrastructure corridor to the port and transport corridor links. Some of the potential heavy industrial uses include ammonium nitrate import/export, chemical blending, fuel storage, electrical power generation, wastewater treatment plant. The area is to be protected by suitable buffers to accepted environmental guidelines.

- General industry land comprising approximately 250 ha to be located adjacent to major transport routes to assist the facilitation of trade through the port and the operations of the HIA. Some of the potential general industrial uses include concrete batching, boat maintenance and building and extractive industries.

- Multi-user infrastructure corridor(s) land to accommodate utilities, major roads, and rail lines.

The intended uses within the Strategic Industrial Zone (i.e. HIAs which will accommodate resource processing industries, including downstream processing industries) are set out in the Anketell SIA Improvement Scheme.

1.3.2 Existing Land Use Zoning

Under the Shire of Roebourne's (now the City of Karratha) Town Planning Scheme No.8 (TPS No. 8), the Anketell SIA is zoned as follows:

- HIA1 and HIA2 – zoned "Strategic Industry"
- GIA – zoned "Rural".

TPS No. 8 will no longer apply to the Anketell SIA once the Improvement Scheme takes effect.

1.4 Previous Studies

A number of technical, scientific and cultural investigations have already been undertaken for the site to support the early planning and feasibility assessments for the Anketell SIA. The following supporting studies have been reviewed and they have informed the preparation of this report:

- Aboriginal Heritage Location and Assessment Surveys (field trip two and four) of the Proposed Infrastructure Corridor and the Proposed Western Industrial Estate (Anthropos Australia 2014)
- Anketell Strategic Industrial Area Engineering Services and Infrastructure Plan Report (Wood and Grieve Engineers 2016)
- Anketell Point and Dixon Island Proposed Port Development Area. Level 2 Flora and Vegetation Assessment (AECOM Pty Ltd 2010)
- Anketell Port Proposal. Level 2 Flora and Vegetation Assessment. (AECOM Pty Ltd 2011)
- Level 2 Flora and Vegetation Survey of the Anketell Strategic Industrial Area. (Mattiske Consulting Pty Ltd 2013)
- Rezoning of Land for Industrial Purposes – Anketell Point Environmental Gap Analysis (GHD 2013a)
- Anketell Strategic Industrial Area Industrial Ecology Strategy (GHD 2013b)
- Anketell Strategic Industrial Area Improvement Scheme Report (WAPC 2016)
- Anketell Strategic Industrial Area Transport – Transport and Traffic Planning Report (Final) (Jacobs Group (Australia) Pty Ltd 2016)

- Environmental Assessment Report, Anketell Strategic Industrial Area, Final (RPS 2016a)

- Baseline Groundwater and Surface Water Monitoring Report, Mount Anketell Strategic Industrial Area (RPS 2016b)

- Flood Study Report, Anketell Strategic Industrial Area (RPS 2015a)

- Addendum to Flood Study Report, Anketell Strategic Industrial Area (RPS 2015b)

- Delivery Plan: Anketell Strategic Industrial Area, Improvement Scheme. Report prepared for LandCorp (RPS 2014).

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2.0 EXISTING ENVIRONMENT

2.1 Location and Improvement Scheme Zoning

The Anketell Strategic Industrial Area (SIA) is located within the City of Karratha, approximately 5 kilometres (km) west of Wickham and 9 km north-west of Roebourne (Figure 1). The Anketell SIA, together with the Port Precinct and Infrastructure Corridor, forms the key land use areas of the Anketell Port Project (Figure 2).

The Anketell SIA consists of two core industry areas (HIA1 and HIA2) and one support industry area (GIA), totalling approximately 1,262 hectares (ha). The core and support industry areas are summarised below and their locations within the Anketell SIA are provided in Figure 1:

- Strategic Industry Zone
  - Heavy Industry Area 1 (HIA1) – 667 ha
  - Heavy Industry Area 2 (HIA2) – 422 ha

- Industry Zone
  - General Industry Area (GIA) – 173 ha.

The Anketell SIA also includes an Industry Protection Zone (4,400 ha) located three km from the boundaries of the Strategic Industry Zoned areas. The Industry Protection Zone serves to avoid conflict between heavy industry operations and sensitive land uses.

The Anketell SIA key site characteristics are summarised in Table 3.

Table 3: Key Site and Proposal Characteristics of the Anketell SIA

Aspect	Description
Project location	Anketell SIA is approximately 5 km from Wickham
Anketell SIA context	Total Scheme Area – 7,878.48 ha The Anketell SIA consists of the following industrial areas: ▪ HIA1 – 667 ha ▪ HIA2 – 422 ha ▪ GIA – 173 ha
Current responsible authority	City of Karratha
Proposed responsible authority	Western Australian Planning Commission
Current zoning (under local planning scheme)	HIA1 and HIA2 are zoned as “Strategic Industry” GIA is zoned as “Rural”
Proposed zoning (Improvement Scheme)	GIA to be zoned as Industry HIA1 and HIA2 to be zoned as Strategic Industry Remainder of Scheme Area zoned as Industry Protection

Aspect	**Description**
Current land use	Vacant Crown land used in areas as a pastoral station (Mount Welcome Station). HIA1 and GIA will be transferred from Crown land to freehold with LandCorp as the owner and estate manager. HIA2 will remain as Crown land subject to future land dealings.
Surrounding land uses	▪ To the east of Anketell is Cape Lambert – the iron ore export operations of Rio Tinto. ▪ To the south of Cape Lambert are the small coastal villages of Point Samson and Cossack. ▪ To the west is the recreational beach at Cleaverville, which is used for camping, boating and fishing. ▪ Further west (approximately 25 km) is the Karratha town site. ▪ Dixon Island lies close offshore to Anketell's mainland area.

2.2 Climate

The Anketell area experiences a hot, semi-arid climate. October to April is very hot with average daily maximum temperatures reaching 39 °C. Winters are typically mild with temperatures ranging from 13.6 °C to an average monthly maximum of 26.2 °C in July. The annual mean maximum temperature is 32.4 °C.

The average annual rainfall for Roebourne (approximately 12 km south-east) is 312 mm and for Karratha (airport) is 293 mm (Table 4). The majority of rainfall received in the region occurs during the summer period between January and March. Figure D presents the mean monthly rainfall for Karratha Aero recorded by the Bureau of Meteorology (BoM). A second rainfall peak occurs in June and this rainfall is attributed to the occurrence of tropical cloud bands.

Table 4: Summary of Rainfall Statistics for Karratha Aero and Roebourne

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Karratha Aero (1972–2015)													
Mean	48.1	75.9	49.2	17.2	27.8	34.9	13.8	4.5	1.4	0.5	1.4	14.6	293
Low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53
High	263.4	348.8	291.2	120.7	143.7	271.6	76.2	34.4	20.8	6	38	112.8	855
Roebourne (4035)													
Mean	62.0	67.1	64.0	28.4	27.6	31.1	13.6	4.9	1.4	0.7	1.5	11.0	312
Low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
High	367.8	324.7	408.4	551.9	225.2	308.9	134.6	97.8	40.2	30.5	30.5	172.3	1060

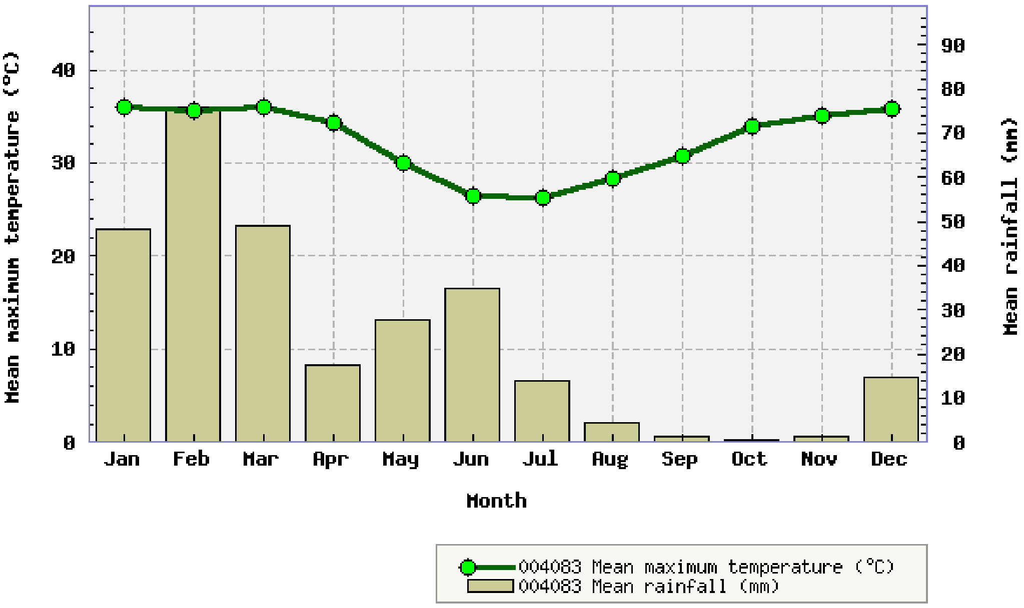
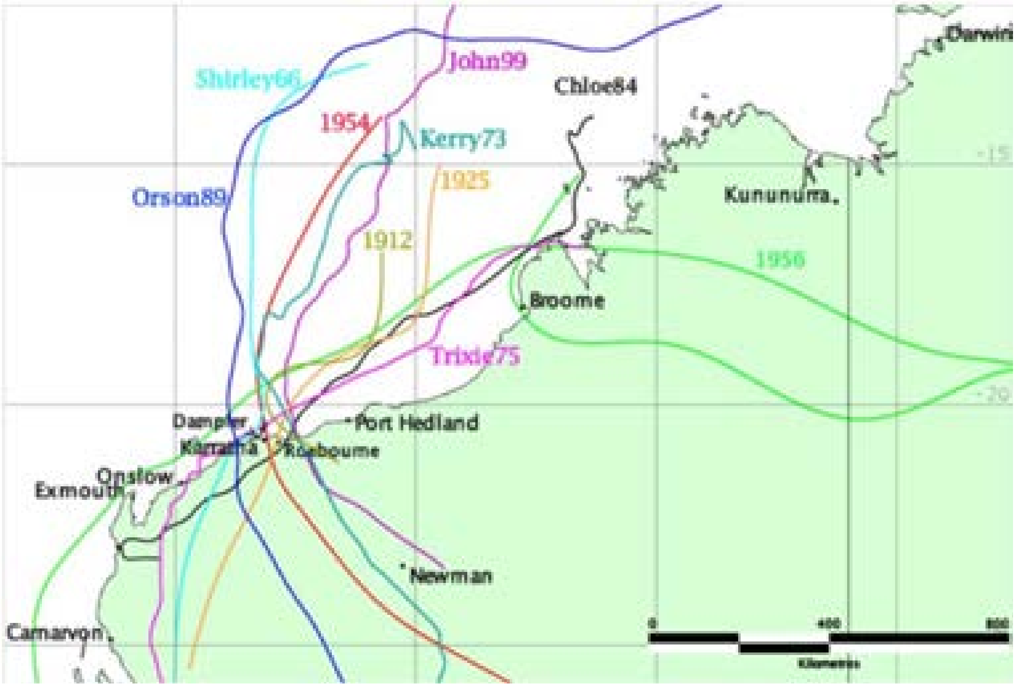


Figure D: **Mean Rainfall and Mean Maximum Temperature (Karratha Airport)**

2.3 Cyclones

The coastline from Port Hedland to the Exmouth Gulf is the most cyclone prone area in Australia. Since 1910, the area, which includes Karratha, Dampier and Roebourne, has been impacted by 48 cyclones that have caused damaging wind gusts in excess of 90 km/h (BoM 2013). Figure E shows the tracks of notable cyclones that have impacted the area. Cyclones are most common in the Pilbara region between mid-December and April, peaking in February and March, which can result in extreme rainfall events.



(Source: BoM 2013)

Figure E: **Tracks of Notable Cyclones that Have Impacted the Area**

2.4 Landform and Topography

2.4.1 Landform

The study area is comprised of dissected flat top hills of granitic, volcanic and metamorphic rocks; interspersed by stony plains on granite. Mount Anketell is the most dominant landform in the region; however, there are many rocky outcrops that are flanked by steep valleys. There are many natural drainage channels throughout the region with Rocky Creek being the largest drainage channel in the study area.

The prevalence of silty or clayey surface deposits across much of the site means that permeability, and therefore infiltration of rainfall to the groundwater system, is expected to be low. During periods of intense rainfall, when the rainfall rate exceeds the infiltration rate, surface water flows are generated.

2.4.2 Topography

The topography of the Anketell SIA areas is shown in Figure 3 (a–c) and is summarised below:

- GIA – the topography is elevated with moderate relief in the southern and western areas (up to ~35 m AHD) and relatively flat over most of the eastern and northern areas (~10 m AHD), (Figure 3a).

- HIA1 – Rocky Creek runs along the western side of HIA1, ranging from approximately 3 to 10 m AHD. In general, the topography ranges between 10 and 25 m AHD, however the site reaches higher elevation along the northern boundary adjacent to the ranges directly north. The eastern area of HIA1 slopes down to the north-east and is flanked by ranges to the east and west (Figure 3b).

- HIA2 – The topography slopes from approximately 40 m AHD at the eastern and western boundaries, down to approximately 15 m AHD along Rocky Creek that dissects the site in a south to north direction (Figure 3c).

2.5 Geology and Soils

2.5.1 Regional Mapping

The regional geology comprises a northern exposure of the Hamersley Basin within the Pilbara Craton that is dominated by the Mount Roe Basalt. Shallow Quaternary superficial deposits, generally < 20 m thick, overlie the Late Archaean bedrock in low-lying areas (GHD 2013a).

Mapped surface geology underlying each of the proposed strategic industrial areas is shown in Figure 4. Low-lying areas of alluvial sand and gravel are associated with the river and creek channels with adjacent flood plain areas comprising colluvium and sheetwash deposits of silt, sand and gravel. The elevated areas are comprised of basalt and siltstone.

2.5.2 Site Investigations

Four monitoring bores were installed as part of the Anketell SIA baseline monitoring program (RPS 2016b) in October 2014. The lithological conditions encountered were variable across the site; the following points summarise the lithology encountered at each of the monitoring locations. Additional detail of the lithology encountered has been adopted from *Australia 1:250 000 Geological Series – Roebourne* (Hickman and Smithies 2000). Figure 5 shows the monitoring bore locations. Monitoring bore logs are provided within the baseline report (RPS 2016b), provided in Appendix 1.

- **NB-1** – Located in GIA, the surficial geology of colluvium consisted of reddish brown, medium–fine grained sand silt and gravels including quartz gravel with a thickness of approximately 2.5 m. Underneath this depth (2.5 m below ground level (mbgl)), a pale yellow metamorphosed sandstone with minor conglomerate was encountered and continued to a depth of 8.5 mbgl; while the moisture within the borehole increased with depth. From a depth of approximately 8.5 mbgl (and below the groundwater table) basaltic rock was encountered, the grey to dark green colour indicated that metamorphosis of the basaltic rock to green schist may have occurred.

- **HIA-N and HIA-S** – Located in HIA1, due to the proximity to Rocky Creek, the lithological profile of these two sites was similar. Surficial sediments consisted of low-gradient sheet wash deposits of sand, silt and clays with minor inclusions of quartz gravels to a depth of approximately 0.5 to 1 mbgl. The underlying sandstone layer extended from approximately 2 mbgl at HIA-S to 4 mbgl at HIA-N. Underlying the sandstone layer, basalt from the Regal Formation extended to the base of the drilling (8 and 10 mbgl for HIA-N and HIA-S respectively). Groundwater was encountered within the basalt at both locations, with groundwater likely to be stored within the fractures.

- **GIA-1** – Located in HIA1, the surficial geology of colluvium encountered at this location consisted of reddish brown, medium/fine grained sand, silt and gravels including quartz gravel with a thickness of approximately 2.5 m. The surficial geology was succeeded by a relatively minor layer of pale yellow metamorphosed sandstone with minor conglomerate and an approximate thickness of 1.5 m. Below a depth of approximately 4 mbgl, Mount Roe Basalt was encountered. Drilling was terminated at a depth of 22 mbgl, at which time groundwater was not measured within the drilling annulus. However, groundwater was encountered the following day indicating slow groundwater recharge into the bore.

2.6 Acid Sulfate Soils

Department of Environment Regulation (DER) acid sulfate soil (ASS) risk-mapping for the Pilbara region indicates the drainage and creek lines which traverse HIA1 and HIA2 are mapped as having “moderate to low” risk of ASS within 3 m of natural soil surface but “high to moderate” beyond 3 m of natural soil surface, particularly in proximity to Rocky Creek. Approximately 25% of GIA is mapped as “moderate to low” risk of ASS (Figure 6).

2.7 Surface Water Hydrology

2.7.1 Surface Drainage

A number of drainage lines traverse the Anketell SIA (Figure 7). Rocky Creek is the dominant drainage line in the area and captures run-off from inland plateau areas. Streamflow in the region is typically ephemeral and highly seasonal as it occurs in direct response to rainfall events such as cyclones. Most run-off from cyclones occurs during the period from January to March (GHD 2013a).

2.7.2 Surface Water Catchments

Topographic surveys indicate the study area is comprised of three distinct surface water catchments, Rocky Creek catchment (within which development areas HIA2 and the western area of HIA1 are situated) and the two relatively small catchments for development areas GIA and the eastern area of HIA1. Figure 8 illustrates the three surface water catchments.

Rocky Creek is a significant natural drainage feature with a mainstream length of approximately 7 km and a catchment area of approximately 25.7 km^2. Rocky Creek is situated between two much larger drainage systems, the Nickol and Harding rivers, and flows northwards to discharge near Dixon Island, approximately 10 km west of Wickham.

The majority of HIA1 is situated within the Rocky Creek catchment. HIA2 falls mostly within the Rocky Creek catchment; however, a minor, southern portion of HIA2 is situated within an upstream area of an adjacent drainage catchment. This elevated area will not be subject to flooding.

The eastern area of HIA1 is situated within a relatively small catchment immediately east of Rocky Creek catchment. This area of HIA1 is located in the upstream portion of the catchment and receives run-off from a steep but very small upstream catchment area. Consequently, there is only a very minor, shallow drainage channel within this area of HIA1 which flows north-east to discharge to an expansive low-lying area of intertidal mud flats and mangroves.

The southern portion of GIA is located within the catchment area of an eastern unnamed tributary of the Nickol River, which flows in a westerly direction to discharge to coastal mudflats adjacent to GIA. The northern portion of GIA comprises minor localised drainage channels, which discharge to the coastal mudflats north, and west of GIA. There are no significant watercourses within GIA, rather just a series of semi defined stormwater flow paths.

2.7.3 Surface Water Monitoring

Four surface water loggers were installed in the major creek lines and measured between October 2014 and March 2016 using pressure transducer loggers to provide high resolution data. Figure 5 shows the surface water monitoring locations (SW-1 to SW-4). The logger installed within SW-2 malfunctioned and hence did not receive data after March 2015. Table 5 summarises the surface water levels and depths recorded during the monitoring period. The surface water elevations presented in Table 5 have been estimated from topographical elevation data at the site of the monitoring location. In May 2015, the surface water depth reached 1.4m at SW-1 while depths at SW-2 and SW-3 peaked at between 0.7 to 0.8 m in March 2015. Locations SW-1 to SW-3 are all located within Rocky Creek. No surface water was encountered at SW-4 located on a creek line at the north-eastern part of the site.

Table 5: Surface Water Levels

Site ID	Water Level Minimum		Water Level Maximum		
	Depth (m)	m AHD	Depth (m)	m AHD	Date
SW-1	0	4.3	1.4	5.7	27/5/15
SW-2	0	9.3	0.71	10.0	12/3/15
SW-3	0	8.8	0.76	9.56	12/3/15
SW-4	0	17.9	0	17.9	NA

2.7.4 Storm Surge and Coastal Inundation

Storm surge and associated coastal inundation are factors that have potential to impact flood levels. Storm surge can be associated with a combination of unusually high tides, strong winds and extreme low pressures. Traditionally, storm surge is considered as one of the possible accompaniments to cyclones. With the study area being one of the most prone to cyclone activity in Australia, the hydraulic modelling has considered likely maximum tide elevations resulting from storm surge in determining downstream boundary conditions.

Storm surge elevations are dependent on a number of factors (including coastal bathymetry, site orientation and coastal exposure with respect to prevailing weather conditions, wind, currents, etc.) and are therefore, variable between sites. Consequently, limited storm surge prediction data is available except where site-specific studies and modelling have been undertaken. The pre-development flood study (RPS 2015a) investigated historical storm surge data for the region and reviewed literature from previous studies relevant to the Anketell site.

There is limited historical storm surge data available for the project area. The Bureau of Meteorology (BoM 2014) states a storm surge coinciding with a high tide in 1939 resulted in a water level of 5.7 m AHD at Port Hedland. This appears to be the highest recorded tide level in the region.

An assessment of storm surge and coastal inundation for the greater Karratha area (GEMS 2011) was undertaken as part of the Karratha Coastal Vulnerability Study (KCVS, JDA et al. 2012). The modelled 100-year ARI storm surge in the KCVS is 6.2 m AHD that is slightly higher than the maximum-recorded storm surge for the region (5.7 m AHD at Port Hedland in 1939). The potential inundation caused by a 0.2% AEP storm surge event including 0.9 m sea level rise is 7.1 m AHD that was adopted from the KCVS (JDA et al. 2012). Figure 9 shows the estimated area of inundation for 0.2% AEP storm surge.

2.7.5 Flood Study

2.7.5.1 Pre-development

Major flooding events in the Pilbara region are typically associated with seasonal cyclonic activity that can cause extreme rainfall events and coastal storm surge. RPS was commissioned by LandCorp to complete a flood study to investigate the hydrological processes and risk of flooding at the SIA in order to inform future planning and design decisions. The study included an assessment of the pre-development hydrological characteristics, hydraulic modelling of the 1% Annual Exceedance Probability (AEP) event (1 in 100-year ARI) and provided general flood management advice for each of the four development areas of the SIA. The study utilised soils data described in Section 2.5, which is considered suitable for this scale of modelling. The Flood Study Report (RPS 2015a) is provided in Appendix 2. Note that the flood study report provided in Appendix 2 utilises obsolete nomenclature for the industrial areas, however its outcomes are unchanged.

The study also investigated the potential for inundation of the site caused by a 0.2% AEP (1 in 500-year ARI), storm surge event, including a 0.9 m sea level rise in accordance with State Planning Policy 2.6. No other coastal processes such as erosion and deposition were considered in the study. An estimated storm surge level of 7.1 m AHD was adopted from the KCVS (JDA et al. 2012).

The study indicated the source of potential flooding at the SIA is primarily from Rocky Creek. Hydraulic modelling of Rocky Creek was undertaken using a combined 1D–2D model. Rocky Creek was modelled in 1D though the use of field surveyed cross-sections to establish the channel geometry accurately and the remaining catchment area was modelled in 2D with the use of high-resolution topographic data. The flood modelling results were mapped to represent flood extents, depths, water levels and velocities for the 1% AEP event, and water levels for the 5% AEP (1 in 20-year ARI) event. Modelled peak flow rates at particular locations within the SIA were also provided.

The model indicates that Rocky Creek is likely to overtop its banks during a 1% AEP event and cause inundation of low-lying areas within HIA1. Significant depths of flooding and relatively high velocities would be expected to occur along the main, downstream portion of Rocky Creek during a 1% AEP flood event. In addition, the northern portion of HIA1, adjacent to the coast, is situated below the estimated 0.2% AEP storm surge level and so may be subject to inundation from coastal processes during extreme events. Development area H1A1 receives run-off from a steep up-gradient catchment and will require appropriate stormwater management measures to manage flows through or around down-gradient development areas. The drainage design for H1A1 may need to consider the use of diversion drains or levees to divert flows in these areas. The model can be used for future assessment of stormwater management designs.

The potential for flooding impacts within the eastern part of HIA1 is generally limited to the small creek that runs through the middle of the site. The eastern part of HIA1 is relatively elevated and not subject to inundation from coastal processes. Some upstream locations along the boundary of this part of HIA1 experience significant flows entering the site; consideration of flow control measures will be required in these locations.

GIA is not flood prone and is not impacted by backwater affects or inundation from storm surge. As such, development within G1A is not affected by flooding; however appropriate stormwater management measures will need to be considered for the management of overland stormwater flow paths. This will include providing adequate grade and sizing of drainage infrastructure to convey flows through the site safely.

The model was used to simulate flood levels for a 100 year planning timeframe including a potential sea level rise of 0.9 m to account for the effects of climate change. Flood levels within the SIA sites are not affected by the modelled sea level rise except for the very downstream portion of HIA1 where Rocky Creek discharges to the coast.

A model sensitivity analysis was undertaken for a range of input parameters. The modelled flood levels are not sensitive to changes in Manning's roughness coefficient and loss rate within the range of values tested. As expected, the model is moderately sensitive to rainfall intensity with changes to flood levels of between approximately 0.2 m and 0.5 m occurring. However, the sensitivity analysis for rainfall intensity was undertaken primarily to provide an indication of the potential for future climate variability to impact flood levels; the modelled rainfall intensity values are in accordance with standard methods.

Figure 10 (a–c) presents the pre-development 1% AEP flood affected areas and peak water levels as determined by the Flood Study Report (RPS 2015a). Figure 11 (a-c) provides peak flow rates for a number of locations within the main watercourses of the subject site.

2.7.5.2 Post-development

Development of the SIA sites will need to consider flood levels and the provision of adequate clearance from these for the protection of infrastructure and human safety. DoW flood protection policy includes providing 0.5 m clearance from flood levels to habitable floor levels. Flood protection levels should also be based on the post-development flood levels rather than the pre-development flood levels.

The post-development flood model was used to simulate the potential impacts of development on flood levels and to provide indicative post-development flood levels for the purpose of informing flood protection levels and potential fill requirements for the site.

It should be noted that the post-development flood levels are based on simplified assumptions due to the limited design detail at this stage of the development process. However, the modelling is considered to be fit for purpose for the DWMS stage, and suitable for describing the catchment-scale flood behaviour of the subject site and for informing any future, lot-scale flood modelling required at the WMP stage.

The details and results of the post-development flood modelling are described in an addendum to the previous Flood Study Report. The addendum report (RPS 2015b) is provided as Appendix 3. The post-development modelling is also summarised in Section 5 of this report.

2.7.6 Surface Water Management

The site is located within the Pilbara Surface Water Area proclaimed under the *Rights in Water and Irrigation Act 1914*.

2.8 Groundwater Levels and Flows

2.8.1 Regional

2.8.1.1 PB Hydrogeology Report

PB (2011) has completed a hydrogeological assessment for an area of approximately 200 km^2 that includes the Anketell site. PB (2011) indicate the area is underlain by a very low permeability fractured rock aquifer with alluvial and colluvial sediments being unsaturated, or if saturated, are isolated and therefore not connected to the main groundwater system.

According to PB (2011), groundwater within the Pilbara region originates from direct infiltration of rainfall and indirectly from surface water flows, and rainfall recharge into the groundwater system is low while evapotranspiration is high. The occurrence of groundwater within the project area is limited to low flow fractured rock aquifer systems. Groundwater may occur in shallow Quaternary sediments (e.g. along creek lines) where present, however there is unlikely to be significant aquifer yield due to limited saturation. Consequently, there are no significant supplies of freshwater in the area; the adjacent townships of Wickham and Port Samson are supplied by the Water Corporation's West Pilbara Scheme Supply, which sources it water primarily from Harding Dam and the Millstream Aquifer.

Groundwater flow is generally perpendicular towards the coast line (north). PB (2011) has provided a groundwater elevation contour map, which shows that across the PB project area groundwater ranges between < 2 metres below ground level (mbgl) to the north in tidal flat zones adjacent to the coast through to >100 m along ridge lines.

2.8.1.2 Department of Water Monitoring Bores

A search was made of DoW monitoring bores in the region. There is limited water monitoring data in the vicinity of the site and data reliability is questionable. Depth to water has been measured in several locations (although bore casings have not been surveyed), however the date of measurement is generally unknown. Table 6 shows the depth to groundwater information provided by DoW. According to the DoW database, one monitoring bore is (or was) located within the Anketell SIA site, and the measured depth to water (date unknown) was 2.29 mbgl.

Table 6: Regional Groundwater Elevation Data (DoW 2015a)

Label	Easting (m)	Northing (m)	Date	Depth to Water (m)
70910033	499975	7703773	30/06/1929	14.33
70910033	499975	7703773	15/06/1971	15.52
70910190	514394	7704194	Unknown	8.84
70910202	505133	7704968	Unknown	10.97
70910203	508271	7704595	Unknown	17.83
70910204	511638	7704744	Unknown	11.35
70910205	511687	7703866	Unknown	27.98
70910233	514553	7715671	Unknown	4.27
70910234	514473	7713535	15/09/1960	4.88
70910235	513194	7712120	Unknown	13.56
70910236	513345	7707156	Unknown	10.72
70910237	520380	7718308	30/06/2001	5.5
70910238	520380	7718308	30/06/2001	5.5
70910239	520279	7719026	30/06/1901	9.2
70910240	519574	7719027	Unknown	4.9
70910244	510889	7712866	Unknown	11.66
70910244	510889	7712866	11/05/1973	9.75
70910245	506670	7712439	Unknown	2.29

Label	Easting (m)	Northing (m)	Date	Depth to Water (m)
70910248	512519	7707570	Unknown	8.43
70910249	510665	7715136	Unknown	2.43
70910784	498249	7704468	Unknown	4.27
70910828	519542	7719065	Unknown	3.4

2.8.2 Local

Groundwater levels where measured as part of the Anketell SIA baseline monitoring program (RPS 2016b), which consisted of the installation of four groundwater monitoring bores in October 2014. Pressure transducer loggers were installed in each monitoring bore to provide high resolution data of the groundwater levels between October 2014 and March 2016. Figure 5 shows the bore locations

Table 7 below summarises the groundwater levels and elevations recorded during the monitoring period. The groundwater elevations presented in Table 7 have been estimated from topographical elevation data at the site of the monitoring well (i.e. top of bore casings have not been surveyed at this stage).

Groundwater elevations ranged from 2.6 m AHD at Bore HIA-N recorded in January 2016 to 7 m AHD at Bore HIA-S recorded in May 2015. The depth to groundwater ranged between 3.9 and 15.9 mbtoc (metres below top of casing). This equates to a groundwater depth of approximately 3.2 to 15.2 mbgl (metres below ground level) over the monitoring period (assuming bore casing is ~ 0.7 m above ground level).

Table 7: Groundwater Elevations

Bore ID	Water Level Minimum			Water Level Maximum		
	mbtoc	m AHD	Date	mbtoc	m AHD	Date
NB-1	7.55	3.74	7/1/15[1]	7.27	4.02	4/10/14
HIA-N	4.9	2.65	29/1/16	3.86	3.69	1/6/15
HIA-S	5.17	6.18	8/3/15	4.38	6.97	30/5/15
GIA-1	15.87	4.73	20/3/16	15.21	5.39[2]	7/10/14

Note: mbtoc (metres below top of collar).
m AHD (metres Australian Height Datum)
a. Logger operated to 6/10/2015.
b. A single higher value was encountered in Bore GIA-1 logger data, this is considered an outlier and has been disregarded.

The maximum groundwater level (MGL) measured at the four on-site bores over the monitoring period are shown in Figure 12. Figure 12 shows that groundwater flows in a north-west direction towards to the coast. It is inferred that localised groundwater mounding occurs underneath Rocky Creek during periods of high rainfall. The rainfall initiates surface water flows within the creek, which is expected to be a source of aquifer recharge in the vicinity.

Depth to groundwater contours, which have been calculated by subtracting the MGL from the topography, are shown on Figure 13. Figure 14 shows areas with depth to groundwater less than 3 m.

Of note is the significant difference in groundwater depth estimated from on-site measurements compared to DoW regional data; regional DoW data indicates the depth to groundwater is 2.29 m at DoW Bore 70910245, while contouring estimated from on-site monitoring bores indicates the depth to water at DoW Bore 70910245 should be approximately 20 m. This difference is expected to be due to the unreliability of the regional DoW data.

2.9 Groundwater Quality

2.9.1 Monitoring Program

Groundwater quality sampling was conducted from the four monitoring bores in October 2014, March 2015, October 2015 and March 2016. The monitoring events were timed for pre-wet season (October) and post-wet season (late March) conditions.

The groundwater analysis suite was developed with reference to the Department of Environment and Conservation guidelines for *Potentially Contaminating Activities, Industries and Landuses* (2004). As the study area has no evidence of any historical contaminating activities, the following analysis suite was adopted:

- total dissolved solids (TDS)
- major anions and cations
- total alkalinity
- dissolved metals – arsenic, cadmium, chromium, copper, nickel, lead, mercury and zinc
- nutrients – total nitrogen, total kjeldahl nitrogen, NOx-N, total phosphorus, filtered reactive phosphorus.

2.9.2 Water Quality Results

This section summarises the water quality results. Full details are provided in the baseline monitoring report (RPS 2016b) provided in Appendix 1.

2.9.2.1 Physico-chemical Parameters

Physico-chemical parameters were monitored in the field at each location.

The field-testing indicates the pH of the groundwater ranges from 6.1 to 7.4, which classifies the groundwater as neutral.

The electrical conductivity (EC) showed significant spatial variability across the site ranging from 66,100 µS/cm (~43,000 mg/L calculated Total Dissolved Solids (TDS)) at NB-1 to 2,590 µS/cm (1,683 mg/L TDS) at GIA-1.

The high salinity measured at Bore NB-1 is likely due to its proximity to the inter-tidal inlet located approximately 700 m to the south and up-hydraulic gradient. Evaporation of surface water within the inlet prior to infiltration into the superficial aquifer below may also contribute to the increased salinity encountered at this location. The salinity recorded at Bore NB-1 is similar to marine water and the Australian Water Resources Council (AWRC 1998) classifies this water as hyper-saline.

Bores HIA-N and HIA-S recorded EC concentrations of 6,850 and 5,100 µS/cm (4,450 and 3,315 mg/L TDS), during the March 2016 and October 2014 monitoring events respectively. The EC values recorded at these bores classify the groundwater as saline for the majority of the monitoring period, with the groundwater at Bore HIA-S being classified as brackish during the March 2015 event. The salinity of the groundwater at these locations may be influenced by evaporation occurring within Rocky Creek prior to surface water infiltrating into the superficial aquifer.

The maximum EC recorded at Bore GIA-1 was 3,640 µS/cm (2,366 mg/L TDS), which classifies the groundwater at this location as brackish. The somewhat fresher groundwater at this location may be due to the presence of groundwater at significant depth within basalt, consequently resulting in lower groundwater dissolution and/or evapoconcentration compared to other bores.

Table 8 shows the AWRC salinity classification and potential use, and Table 9 summarises the results of physico-chemical testing.

Table 8: Salinity Classifications (AWRC 1998)

TDS (mg/L)	AWRC Classification	Potential Use
< 500	Fresh	All purposes, domestic and irrigation
500–1500	Fresh*	Most purposes, 1000–1500 mg/L is upper limit for drinking
1500–3000	Brackish	Limited irrigation, livestock
3000–7000	Saline	Most livestock
7000–14000	Saline	Some livestock
> 14000	Saline to Hypersaline	Limited industrial use

Table 9: Groundwater Physico-chemical Parameters

Bore ID	Date	Temperature (°C)	pH	EC (µS/cm)	TDS (mg/L)
NB-1	21/10/2014	29.5	6.2	58,700	38,155
	26/03/2015	34.5	6.4	42,200	27,430
	6/10/2016	33	6.5	55,600	36,140
	24/03/2016	31.4	6.1	66,100	42,965
HIA-N	21/10/2014	28.7	7.3	6,580	4,277
	26/03/2015	33.6	7.2	5,380	3,497
	6/10/2016	31.6	6.9	6,780	4,407
	24/03/2016	30.7	6.8	6,850	4,453
HIA-S	21/10/2014	30.5	7.4	5,100	3,315
	26/03/2015	32.7	7.1	4,070	2,646
	6/10/2016	32	7.0	4,990	3,244
	24/03/2016	30.9	6.8	5,040	3,276
GIA-1	21/10/2014	-	-	-	-
	26/03/2015	32.9	7.1	2,590	1,684
	6/10/2016	32	7.0	3,630	2,360
	24/03/2016	30.6	6.8	3,640	2,366

Note: TDS (mg/L) calculated as 0.65 EC (µS/cm)

2.9.3 Analytical Testing

2.9.3.1 Guidelines

The laboratory analysis results for the entire 2014–2016 monitoring period are provided in Appendix 1. The results are compared to the ANZECC/ARMCANZ (2000) *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water Quality,* with specific reference to marine ecosystem protection guidelines (MEPG) and freshwater guidelines (FWG) for tropical Australia. The results are also compared to Department of Health (2006) *Contaminated Sites Reporting Guidelines for Chemicals in Groundwater* domestic non-potable groundwater (DNPG) use guidelines that are considered appropriate in relation to non-potable uses. The following sections provide a brief discussion of the results.

2.9.3.2 Nutrients

Total nitrogen (TN) concentrations are elevated across the site and exceed the FWG. The maximum TN concentration was recorded in Bore NB-1 at 7.8 mg/L; this is considered to be largely influenced by marine water associated with the intertidal estuaries nearby. Total phosphorus (TP) concentrations exceeded the FWG during the majority of the monitoring period. A maximum TP concentration of 0.2 mg/L was recorded in Bore NB-1.

2.9.3.3 Dissolved Metals

The majority of the dissolved metals analysed for were recorded at or below the limit of reporting (LOR). Dissolved arsenic, cadmium, copper, nickel and zinc were recorded at concentrations that exceeded ecological water guidelines (MEPG, FWG) with one sample for dissolved nickel exceeding the non-potable guideline (DNPG) values.

2.10 Groundwater Management Area

The groundwater area is proclaimed as the "Pilbara Groundwater Area" and the Groundwater Sub-area is "Ashburton". The Hydrogeological Atlas (DoW 2015b) indicates the site is underlain by the unconfined "Pilbara-Fractured Rock" aquifer, which consists of "rocks of low permeability, fractured and weathered rocks – local aquifers". This indicates bore abstraction yields are expected to be low.

Information on groundwater resources at the site is limited; hence, a DoW allocation limit for the sub-area has not been identified. An allocation limit for this sub-area has not been identified as this aquifer is classed as a "non-target" aquifer under the *Pilbara Groundwater Allocation Plan* (DoW 2012). As such, groundwater allocations are to be managed on a case-by-case basis.

A review of the Water Register (DoW 2015c) indicates there are two bore licences in the vicinity of the site, each with an allocation of 45,000 kL/yr. The Water Register indicates the allocated volumes are abstracted from a number of bores (seven bores for Licence 172100 and 11 bores for Licence 177790); hence, it can be assumed the individual bores are low yielding. Table 10 and Figure F below show licence details. Figure F indicates an abstraction bore is located at the eastern area of HIA1, however further investigation would be required to confirm the accuracy of this location in the Water Register.

Table 10: Nearby Bore Users

Licence Number	Issue Date	Expiry Date	Allocation (kL/yr)	Aquifer	Licence Holder	Drawpoints
172100	09.09.2010	08.09.2015	45,000	Pilbara – Fractured Rock	MCC Australia Holding	11
177790	17.07.2013	16.07.2023	45,000	Pilbara – Fractured Rock	Vaughan William Corps	7

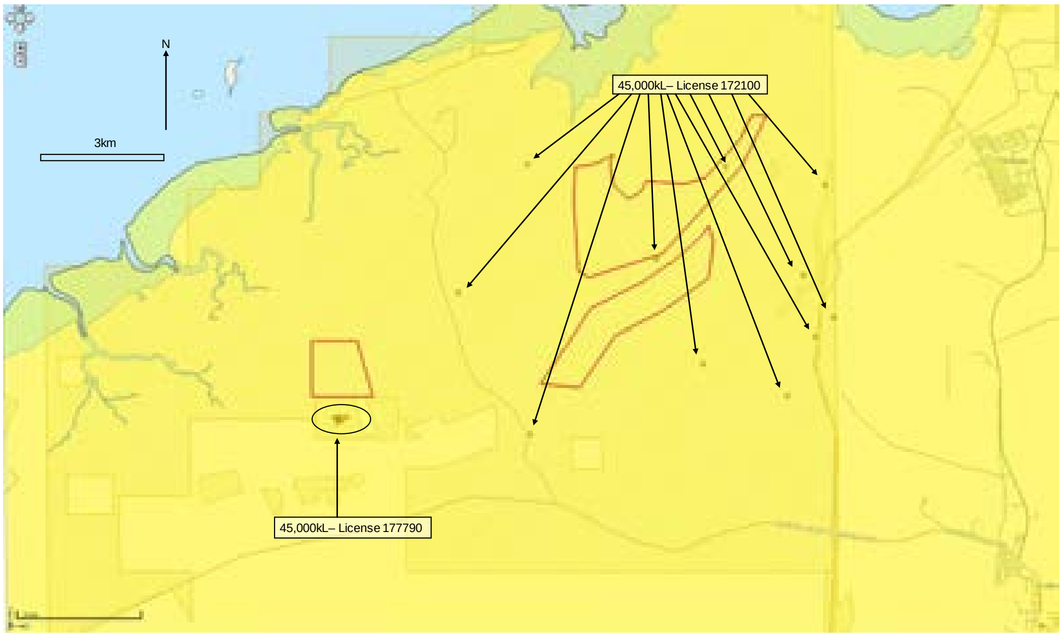


Figure F: **Nearby Groundwater Drawpoints**

2.11 Flora

2.11.1 Flora and Vegetation Survey

Mattiske undertook a Level 2 Flora and Vegetation survey of the Anketell SIA from 2 April to 5 April 2013 (Mattiske 2013). Other flora and vegetation surveys have been undertaken in the Anketell region, the data from which has been compiled by Mattiske in the Level 2 Flora and Vegetation Survey and Report.

Twenty-four vegetation communities were mapped across the site by Mattiske (2013), with vegetation community descriptions and areas provided in Figure 15[1].

2.11.2 Threatened and Priority Ecological Communities

Ecological communities are defined as "naturally occurring biological assemblages that occur in a particular type of habitat" (English and Blythe 1997). Threatened Ecological Communities (TECs) are ecological communities that have been assessed and assigned to one of four categories related to the status of the threat to the community, i.e. Presumed Totally Destroyed, Critically Endangered, Endangered, and Vulnerable.

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[1] It should be noted that since Mattiske undertook its vegetation assessment there have been slight adjustments to the boundaries for the industrial areas within the Anketell SIA (Figure 15). Therefore, it is proposed that Mattiske undertake a desktop assessment that will review the outcome of the Level 2 survey from 2013 and infer the likely vegetation communities for the areas located outside of the original vegetation assessment boundary.

Possible TECs that do not meet survey criteria are added to the Department of Parks and Wildlife's (DPaW's) Priority Ecological Community (PEC) Lists under Priorities 1, 2 and 3 (P1, P2, and P3). These ecological communities are adequately known; are rare but not threatened, or meet criteria for Near Threatened. PECs that have been recently removed from the threatened list are placed in Priority 4 (P4). These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5 (P5).

No TECs were inferred to occur within the Anketell SIA survey area.

Four PECs were identified as occurring within the region; during the survey undertaken by Mattiske only one of these ecological communities was identified within the Anketell SIA, the Horseflat Land System of the Roebourne Plains (P3). Floristic aspects of the Horseflat Land System Roebourne Plain Grassland (P3) are inferred to occur within the HF1 community as mapped in Figure 16. The HF1 community was generally observed as being in "very good to excellent" condition, with the primary factor negatively influencing condition being densities of the highly invasive weed **Cenchrus ciliaris*.

The surveyed HFI Roebourne Plain Grassland PEC totaled 107.83 ha across the two HIAs (17.06 ha and 67.49 ha) and GIA (23.28 ha). This PEC represented 8.37% of the total vegetation community surveyed and mapped within the Anketell SIA.

2.11.3 Significant Flora

Threatened Rare Flora (TRF) species in Western Australia are protected by the *Wildlife Conservation Act 1950* (WC Act), which is administered by DPaW. DPaW also maintains a list of Priority Flora species. Vegetation and flora investigations undertaken by Mattiske in 2007 and 2013 indicate that two Priority Flora species were recorded within the survey area. A brief description of these taxa is outlined in Table 11 and their location shown in Figure 15.

Table 11: Priority Flora Identified during Site Survey (Mattiske 2013)

Species	Location	Preferred Habitat
Goodenia nuda (P4)	GIA2-10	Alluvial and clay soils of flood plains. There are 66 records of this taxon in the database of the Western Australian Herbarium (DPAW 2013). Recorded at one location in the current survey within the HF1 community, a grassland association occurring on clay flood plains. The occurrence of this species within the survey area also represents a minor range extension.
Rhynchosia bungarensis (P4)	HIA1-6 HIA1-13	Pebbly, shingly coarse sands amongst boulders and banks of flow lines. There are 70 records of this taxon in the database of the Western Australian Herbarium (DPAW 2013). Recorded at two locations within the CDA3 and CDA1 communities, both communities are associated with drainage lines.

Note: Industrial Area GIA was formerly referred to as GIA2. Hence, Location GIA2-10 shown in Table 11 is located within GIA

2.12 Terrestrial Fauna

Terrestrial Ecosystems in June 2013 undertook an assessment of conservation significant fauna across the Anketell SIA sites HIA1, HIA2 and GIA. The fauna assessment was specifically designed to determine whether northern quoll, mulgara and bilbies are present in the project area, and which species of EPBC Act listed migratory birds are present or likely to be present in the Anketell SIA.

Conservation significant aerial species include migratory birds protected under the EPBC Act and Wildlife Conservation (WC) Act. Conservation significant terrestrial species known or likely to be in the Anketell SIA include (Terrestrial Ecosystems 2013):

- northern quoll (*Dasyurus hallucatus*)
- northern short-tailed mouse (*Leggadina lakedownensis*)
- pebble-mound mouse (*Pseudomys chapmani*)
- lined soil-crevice skink (*Notoscincus butleri*).

Species possibly in the Anketell SIA include:

- Pilbara olive python (*Liasis olivaceus barroni*)
- spectacled hare-wallaby (*Lagorchestes conspicillatus leichardti*).

Of these species, the northern quoll has the highest threatened species status, listed as an endangered species under the EPBC Act. During the targeted survey, one male northern quoll was captured in GIA and 12 ha of critical northern quoll habitat was mapped within GIA and HIA1 (Figure 17).

Terrestrial Ecosystems (2013) concluded bird and bat species known or potentially occurring in the project area include:

- common sandpiper (*Actitis hypoleucos*)
- fork-tailed swallow (*Apus pacificus*),
- Caspian tern (*Hydroprogne caspia*)
- great egret (*Ardea alba*),
- lesser crested tern (*Sterna benghalensis*)
- little curlew (*Numenius minutus*)
- Oriental plover (*Charadrius veredus*)
- Oriental pratincole (*Glareola maldivarum*)
- rainbow bee-eater (*Merops ornatus*)
- white-bellied sea-eagle (*Haliaeetus leucogaster*)
- peregrine falcon (*Falco peregrinus*)
- Australian bustard (*Ardeotis australis*)
- star finch (*Neochmia ruficauda*)
- bush stone-curlew (*Burhinus grallarius*)
- little northern free-tail bat (*Mormopterus loriae cobourgiana*).

All of these species are able and likely to move away from a disturbance; therefore, potential impacts are likely to be low and not significant. Migratory bird species' habitat areas identified by Terrestrial Ecosystems (2013) are shown on Figure 17.

2.13 Contamination

A search of the DER contaminated sites database indicates there are no identified contaminated sites within the Anketell SIA. As the area is currently used as pastoral land and it has largely remained in a natural condition, it is anticipated that there have not been potentially contaminating land uses / activities within the site.

2.14 Cultural Heritage

2.14.1 DAA Search

The *Aboriginal Heritage Act 1972* defines Aboriginal heritage sites and provides for the preservation of places and objects customarily used by or traditionally important to Aboriginals, and prohibits the concealment, destruction or alteration of any Aboriginal heritage sites.

A search of the Department of Aboriginal Affairs (DAA) Aboriginal Heritage Enquiry System was undertaken in 2015 and it indicates that a number of Aboriginal sites are located within HIA1 and HIA2 or in close proximity to the industrial areas (Figure 18).

Below are listed the Registered Aboriginal Heritage Sites and Other Heritage Places located within the industrial areas:

- Registered Aboriginal Heritage Sites
  - Site 347 (Artefacts / Scatter)
  - Site 8007 (Artefacts / Scatter, Midden / Scatter)
  - Site 616 (Artefacts / Scatter)
  - Site 378 (Artefacts / Scatter)
  - Site 946 (Artefacts / Scatter, Midden / Scatter, Grinding Patches / Grooves)
  - Site 369 (Artefacts / Scatter, Midden / Scatter, Grinding Patches / Grooves)
  - Site 381 (Artefacts / Scatter)
  - Site 380 (Artefacts / Scatter)
  - Site 379 (Artefacts / Scatter)

- Other Heritage Places
  - Site 31348 (Artefacts / Scatter) (Lodged)
  - Site 31353 (Artefacts / Scatter) (Lodged).

2.14.2 Indigenous Land Use Agreement and Native Title

2.14.2.1 Agreement and Title Details

The Ngarluma Aboriginal Corporation (NAC) is the registered native title body corporate for the Ngarluma people, who hold determined, non-exclusive native title rights and interests within the land areas proposed for the Anketell Project, and some of the areas that are subject to the proposed Anketell Improvement Scheme.

An Indigenous Land Use Agreement between the state, the NAC, and Western Australian Land Authority (LandCorp) in relation to the Anketell Project Area, the Anketell Port, Infrastructure Corridor and Industrial Estates Agreement (the Anketell ILUA), ensures that any activity in relation to the Anketell Project, subject to complying with the Anketell ILUA, is consistent with the *Native Title Act 1993* and validly affects the native title rights and interests that were determined to exist at common law in Daniel v State of Western Australia WAD 6017/1996.

2.14.2.2 Aboriginal Heritage Surveys

A number of Aboriginal heritage location and assessment surveys have been conducted across the proposed infrastructure corridor and western industrial area sites by Anthropos Australis (WA) Pty Ltd during 2014. These surveys indicate that there are number of Aboriginal heritage locations and potential Aboriginal heritage locations throughout the region. Please refer to the Anthropos Australis reporting series for greater detail on the results of the surveys.

2.15 Raw Materials

GSWA (2014) has undertaken mapping of potential raw materials in the area around Karratha, including the Anketell site. Figure 19 shows the basic raw materials and mining tenements within a 20 km radius of the Anketell SIA and highlights mining tenements that could potentially supply fill material for the site.

2.16 Transport Access

The *Transport and Traffic Report* (Jacobs Group Pty Ltd 2016) has been developed for the Anketell SIA, which outlines the proposed access routes. Access to HIA1 and G1A will be provided by a western corridor port access road, while a proposed central corridor located between H1A1 and HIA2 is expected to provide direct access to these sites.

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3.0 WATER SOURCE PLANNING

The following water supply and wastewater servicing have been adopted from the *Anketell Strategic Industrial Area Engineering Services and Infrastructure Plan Report* (Wood and Grieve Engineers 2016). This report has been provided as Appendix 4.

This section is also informed by the following technical reports:

- Anketell Port and Strategic Industrial Area Design Plan Report (Preston Consulting 2011)
- Anketell Strategic Industrial Area – Industrial Ecology Strategy (GHD 2013).

3.1 Existing Water Servicing

3.1.1 Potable Water

Bulk potable water in the vicinity of the Anketell SIA is supplied by Water Corporation, which operates the West Pilbara Water Supply Scheme. This scheme relies on surface water supply from the Harding River Dam and groundwater abstraction from the Millstream Aquifer, both sources of which are highly constrained due to rainfall recharge and abstraction limits.

Water is piped from these locations to service towns surrounding the proposed SIA, namely Karratha, Wickham and Roebourne. While service is provided to the surrounding towns, there is no existing water supply infrastructure in the vicinity of the SIA (Wood and Grieve 2016).

3.1.2 Non-potable Water

The site is underlain by the unconfined "Pilbara – Fractured Rock" aquifer, which is expected to be limited by low bore abstraction yields. Information on groundwater resources at the site is limited; hence, a DoW allocation limit for the sub-area has not been identified. An allocation limit for this sub-area has not been identified as this aquifer is classed as a "non-target" aquifer under the *Pilbara Groundwater Allocation Plan* (DoW 2012). As such, groundwater allocations are to be managed on a case-by-case basis.

3.1.3 Wastewater

The treatment and disposal of wastewater in the Pilbara region is typically undertaken by the Water Corporation on a catchment basis within each town site.

The prevailing weather conditions allow for relatively inexpensive treatment by means of evaporation and oxidation ponds, which are currently being used in the region. This treatment method produces effluent of a low quality that is currently being reused for municipal purposes only, under strict operating conditions.

The Water Corporation have advised Wood and Grieve that the wastewater facilities in Karratha are currently being upgraded to produce recycled water that is fit for use as low quality industrial feed water.

The Water Corporation has also advised that there are no existing wastewater treatment plants or reticulation in the vicinity of the Anketell SIA, nor are there currently any plans or capital to construct a wastewater treatment plant or reticulation network in the vicinity of the Anketell SIA. The nearest small town site treatment plants are located at Wickham and Roebourne.

3.2 Water Servicing Requirements to Support Development

3.2.1 Development Demand

3.2.1.1 Water Supply Demand

GHD prepared *The Industrial Ecology Strategy* (2013b) that has provided indicative industrial water requirements. The document divides water usage of the Anketell SIA into three categories, described below:

- Potable Water – Standard quality water typically used for human consumption
- High Quality Industrial Feed Water – High quality water for use in boilers and processing, among other industrial applications.
- Low Quality Industrial Feed (Process) Water – Low quality water for purposes such as dust suppression and industrial cooling.

Table 12 below presents the estimated water requirements for the Anketell SIA. The data is taken from GHD (2013b), but has been amended on a pro-rata area basis by Wood and Grieve (2016) to incorporate the revised HIA1 area.

Table 12: Estimated Water Requirements for the Anketell SIA

Area	Potable Water Usage (ML/yr)	High Quality Industrial Feed Water Usage (ML/yr)	Low Quality Industrial Feed Water Usage (ML/yr)
HIA1 and HIA2	90	8,257	16,817
GIA	16	460	486
TOTAL	106	8,717	17,303

The estimated total sum of water requirements for the Anketell SIA of 26,126 ML/yr is in excess of the total current production of the Water Corporation's West Pilbara Supply Scheme.

3.2.1.2 Wastewater Disposal Demand

Excluding output from a potential industrial feed water facility located within the SIA, the SIA is expected to discharge an estimated 21,840 ML of wastewater per year (GHD 2013b, amended on a pro-rata area basis by Wood and Grieve (2016) to incorporate the revised HIA1 area). The amount of water requiring treatment prior to reuse is dependent upon industry requirements, however some portion of this water may potentially be suitable for reuse without treatment.

3.2.2 Water Supply Servicing

3.2.2.1 Potential Options

The Water Corporation have advised that there is no supply planning covering the Anketell SIA. They have also advised that previous discussions held with the Department of State Development (DSD) several years ago concluded that industry proponents would pursue private water sources.

The DoW have advised that the availability of groundwater in the area is limited, and it is unlikely that the existing aquifers will yield a reliable supply for a large scale and long term project of this nature.

An alternative water supply is groundwater abstraction from aquifers in the West Canning Basin, located approximately 100 km to the east of Port Hedland. There is potential that groundwater from the Broome Sandstone and Wallal aquifers may be utilised to supply the Anketell SIA. However, the distance of these aquifers from the SIA may be prohibitive and further investigations into the feasibility of this option would be required.

Given that neither scheme water nor sufficient groundwater is available for use within the Anketell SIA, privately owned facilities will be required to meet the forecast water demands. The water supply for the Anketell SIA will be from a centralised facility that will source water from a combination of sea water and industrial effluents. The Water Corporation advised that a portion of both low and high quality feed water may be sourced via wastewater recycling.

3.2.2.2 Preferred Water Supply Options

Desalination has been identified as the likely water source for the Anketell Port and Strategic Industrial Area development. The *Anketell Port and Strategic Industrial Area Design Plan Report* (Preston Consulting 2011) states "water supply is likely to require one or more desalination plants" and makes several references to desalination having a land requirement for the port precinct. The *Anketell Strategic Industrial Area – Industrial Ecology Strategy* (GHD 2013) also refers to the fact that the Design Plan includes desalination in the port precinct. The GHD report also goes into significant detail regarding the importance of wastewater recycling to provide industrial feedwater and describes the achievability of a "water factory supplying high and low quality industrial feedwater" as "high".

The GHD report discusses co-location and centralisation of a water treatment facility, and proposes to allocate 40 ha of land for a centralised water facility within the HIA area adjacent to the central infrastructure corridor (the report also notes that future studies or initiatives may suggest a preferable location for a feedwater facility or arrangement outside of the SIA). The report also recommends a modular approach to the water facility to allow expansion as future requirements come online.

3.2.3 Wastewater Servicing

Providing that the Water Corporation's stance with regard to the exclusions of current plans or capital to construct wastewater treatment plants or reticulation networks in the vicinity of the Anketell SIA continues, wastewater treatment must be arranged independently of the Water Corporation.

It has been recommended that a series of gravity-fed reticulation catchments will be required throughout the Anketell SIA, feeding into pump stations to convey wastewater to a treatment facility centralised near HIA1 and HIA2 for the treatment and potential reuse of wastewater.

3.3 Water Servicing Future Approvals

Development of the Anketell SIA will occur over a long-term time frame, depending upon the demand for individual sites within the heavy industrial areas. Due to the uncertain nature and timing of the demand for sites, the specific needs of each proponent and subsequent servicing requirements are not known at this stage.

As proponents' development requirements can vary considerably based on the type of industry, associated operational requirements and footprint, and site-specific characteristics, proponents will be required to investigate, fund and implement the specific infrastructure and services they require to support their developments on their sites, including potable and wastewater servicing. Centralised/shared facilities are likely to be funded and implemented by a combination of major foundation proponents (or "anchor tenants") and private service providers.

Depending on the water servicing options adopted for the Anketell SIA, one or more of the following documents would require approval by the relevant regulatory authority:

- Recycled Water Quality Management Plan – (for recycled wastewater)
  - Nutrient and Irrigation Management Plan
  - Operation and Maintenance Management Plan

- Hydrogeological Assessment Report – (for groundwater abstraction)
  - Groundwater Licence Applications

  - Operating Strategy

  - approval documents associated with the construction of the reticulation network

- Environmental Protection Authority Approvals – (for desalination plant)
  - Marine Water Quality Management Plans
  - Acid Sulfate Soil (ASS) Management Plans
  - Dewatering Management Plans.

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4.0 STORMWATER MANAGEMENT STRATEGY

4.1 Drainage Principles

The following guiding drainage principles will inform the development of the detailed drainage design for the Anketell SIA:

- Protect properties and infrastructure from potential risks of flooding and water-logging.
- Establish effective drainage flow paths and open drains for safe conveyance of flood waters.
- Maintain post-development stormwater quality relative to pre-development conditions (and improve where possible) to protect downstream receiving environments.
- Reduce stormwater velocities to prevent mobilisation and export of sediments and to manage erosion risks effectively.

4.2 Drainage Design Guidance

There are no specific guidelines for stormwater management in industrial sites of the north-west. Consequently, the stormwater management design is based on design parameters that have been adopted from a number of relevant guidance documents including:

- City of Karratha's (CoK's) Stormwater Guidelines for Residential Developments (large developments) (CoK 2011a)
- Gap Ridge Industrial Estate, General Industrial Precinct Design Guidelines for Landscaping and Stormwater Management (CoK 2011b). The Gap Ridge estate is located approximately 20 km west of the site in the CoK
- Stormwater Management at Industrial Sites, Department of Water, Water Quality Protection Note 52 (DoW 2010).
- various Department of Water guidance publications on stormwater management.

Design parameters from the above guidance documents that are relevant to the Anketell SIA are summarised below in Sections 4.2.1 to 4.2.3. These design parameters are intended to inform water management planning at the lot scale WMP stage. The overarching drainage strategy for the site that describes how the following design parameters shall be incorporated into the future design of the Anketell site is included in Section 4.3.

4.2.1 Stormwater Guidelines for Residential Developments – Large Developments

4.2.1.1 General

The CoK (2011a) stormwater guidelines class large developments as five lots or greater where stormwater disposal requirements will primarily be catchment focused. CoK indicate their ideal drainage network for large developments is represented by utilising kerbed roads as the initial conveyor of stormwater, with kerb breaks located at topographic low points discharging to large open channels that direct the stormwater away from the urban zone.

Kerbed roads are not proposed at the Anketell SIA; rather drainage from roads will be directed into adjacent open drains or swales, which will serve as the primary conveyer of stormwater. Discussion with CoK engineering staff (9 June 2015) indicates a preference for flush kerbing (such as at the Gap Ridge Industrial Area), which facilitates parking for heavy vehicles.

Some of the relevant key design parameters described in the CoK stormwater guidelines for drainage systems and associated structures are as follows:

- The top water level (TWL) of open channels shall be minimum 300 mm below the level of the road shoulder for the 5-year ARI event.
- Maximum flow velocities in open channels shall not exceed 2 m/s in open channels, which can be arrested by the inclusion of drop structures.
- Detention storage areas may be provided at suitable locations to reduce peak flow rates to the capacity of downstream facilities.
- The minimum habitable floor level shall be 500 mm above the 100 year ARI flood level.
- Drainage channels should be constructed with minimum 1:4 side slopes and vegetated where possible to limit erosion of drain sides.

4.2.1.2 Minor Flood Events

- The roof of any building shall not contain downpipes but discharge directly to the lot.
- Lots should be landscaped to prevent direct run-off from impervious surfaces to the drainage network (roads or arterial drains) and to prevent erosion.
- The main channel in the open drains will be designed to contain the 5-year ARI event, and where appropriate, Water Sensitive Urban Design (WSUD) principles in the form of sedimentation basins, gabions, V notch weir structures will be incorporated to maintain low flow velocities and allow settling of suspended solids.

4.2.1.3 Major Events

- Flow generated in excess of the 5 yr ARI event to be conveyed by overland flow paths directing stormwater to drainage reserves.

- Drainage reserves will be designed to contain all 100 yr ARI flows.

- Developments will need to demonstrate that the 100-year flood level in downstream drainage reserves does not increase by more than 0.15 m as a result of the development.

- Weir structures or other drop structures shall be provided in arterial drains to limit downstream sedimentation and ensure velocities do not exceed 2 m/s.

4.2.2 Gap Ridge Industrial Estate Landscaping and Stormwater Guidelines

A number of relevant landscaping and stormwater management guidelines for the Gap Ridge Industrial Estate (CoK 2011b) are summarised in the following sections.

- All lots require a 3.0 m wide landscape strip along all street frontages of the lot. Drainage management measures are to be integrated into this strip through the installation of vegetated allotment swales.

- Allotments with drainage easements shall include a swale area constructed with a "one in six slope" and are to be planted to obtain 100% vegetation coverage with a combination of trees, shrubs, groundcovers and grasses (tussock plants).

- All on-site drainage systems must be regularly maintained and in good working order as a condition of any development consent granted to a site.

- No work or structures will be permitted within roadside drainage reserves during construction or thereafter, unless prior approval from the CoK is obtained.

- Site layout, building location, car parking, landscaping and setbacks should be established having consideration for on-site stormwater management.

4.2.3 Stormwater Management at Industrial Sites (DoW 2010)

Water Quality Protection Note 52 (DoW 2010) applies to light, general and heavy industrial sites throughout Western Australia and provides a list of recommendations related to stormwater management practices. A number of recommendations that may be relevant to the type of development at the Anketell site are summarised below. It is recognised that the implementation of some of the following measures may not be practical depending on the type of industrial development and/or local site conditions (i.e. infiltration as a means of stormwater disposal may be limited by the hydraulic capacity of on-site soils).

4.2.3.1 Stormwater Management

- Uncontaminated stormwater run-off from roofs, paths and the landscape should not be allowed to mix with process effluent, stored chemicals or stormwater run-off from areas susceptible to chemical spills. Where practical, processing areas involving the use of chemicals should be weatherproof or covered.

- Areas where stormwater may become contaminated should drain to treatment facilities for removal of solids and chemical residues and testing prior to disposal. Diversion banks, kerbing, surface grade changes, containment bunds and contained drains should be used to control stormwater run-off from large sites.

- Turbidity should be controlled by ensuring stormwater run-off is not directed towards or over areas cleared of vegetation, raw material stockpiles or earthworks vulnerable to erosion. Where practical, stormwater should be effectively treated then used preferentially as a process water source, irrigated onto well-vegetated areas or infiltrated to ground via soak pits.

4.2.3.2 Stormwater Treatment

- Treatment options to limit suspended soil particles and turbidity include
  - sedimentation basins
  - bio-retention systems and constructed wetlands
  - chemical coagulation, using metal salts or polymers, followed by settling
  - sand or membrane filters, with periodic backwash into holding basins.

- Fuel, oil and grease removal options include
  - petrol and oil traps
  - inclined-plate separators
  - chemical coagulation and launder systems
  - dissolved air flotation units.

- Litter reduction options include
  - employee waste awareness programs
  - clearly marked recycle bins
  - floor bucket traps (routinely maintained)
  - trash racks/bar screens on process water drains
  - centrifugal litter separators.

4.2.3.3 Stormwater Disposal

- Stormwater should be considered as a potential resource, in particular in areas where water sources are limited and storage reservoirs can be constructed economically.

- Options for stormwater use include

  - capture for process use, flushing, cooling water or dust suppression
  - seasonal storage to supplement irrigation supplies.

- The following options for discharge of excess stormwater, after it has been effectively treated should be considered
  - on-site infiltration/soakage to recharge an underlying groundwater aquifer.

  - discharge to a local government or Water Corporation main drainage system, where approved after consideration of flow capacity and water quality characteristics.

  - release to a local wetland or waterway. For discharge to surface water bodies, stormwater should be uncontaminated and compatible with the seasonal quality of the receiving water resources.

- Erosion controls are likely to be needed for surface drainage systems excavated in steep land (slope greater than one in 15) or through disturbed land.

- Stormwater system entry points should have signs indicating where they discharge and advising that the environment may be harmed by the release of contaminants. This helps to minimise the illicit disposal of contaminating liquids such as parts cleansers and floor wash-down.

4.2.4 DoW Stormwater Guidance

In addition to *Stormwater Management at Industrial Sites* (DoW 2010), various other DoW guidance documents have been considered in the preparation of this DWMS. These documents provide the overarching objectives and principles of stormwater management for developments in Western Australia as well as technical guidance on the correct design and implementation of stormwater management systems. The relevant publications include:

- Stormwater Management Manual for Western Australia (DoW 2004–2007)
- Decision Process for Stormwater Management in WA (DoW 2009)
- Stormwater Design Considerations (DoW 2011).

4.3 Proposed Drainage Strategy

4.3.1 Overview

Water sensitive urban design (WSUD) techniques applied on the Swan Coastal Plain typically rely on the use of soakwells, swales and vegetated bio-retention areas for managing the quality and quantity of stormwater run-off. Due to varying climatic and environmental constraints in the north-west region, a modified approach to urban stormwater management that focuses on the use of traditional drainage "conveyance" solutions is generally applied.

Drainage networks in the region are commonly designed around a series of open drains, which are considered the most effective method of managing and conveying large stormwater flows. Drainage infrastructure in industrial and rural areas is typically characterised by the use of flush kerbed roads that discharge flows to large open channels to convey stormwater away from developed areas safely.

Traditional pipe and pit drainage networks are generally not supported in the region as the low storm frequency results in significant accumulation of sediment within the catchment that can block pipes and inlet structures. As such, the drainage strategy proposes to use open drains/swales as the principle stormwater conveyance mechanism with piped systems only being considered for use in localised or landlocked low points (as required). CoK will be engaged early in the detailed drainage design process to ensure that the strategies proposed below are consistent with the council's desired stormwater objectives for the site.

4.3.2 Lot Drainage

Due to the intensity of rainfall events in the region, roofs will not have gutters or downpipes and the soil types of the region are typically not conducive to the use of soakwells. It is proposed that lot owners retain the first 15 mm of rainfall from the developed portion of their lot on site through appropriate landscaping aimed at preventing direct run-off from impervious surfaces to the drainage network. Retention of the first 15 mm from impervious areas will aid in improving the quality of stormwater discharging from lots and reducing the impact of the development on post-development flow rates.

Due to the expected size of lots and the heavy industrial land use, individual lots will require significant stormwater management infrastructure for managing flows through their site (e.g. bunding to separate stormwater from process water and materials) and for controlling stormwater quality (e.g. hydrocarbon traps and sedimentation ponds). These requirements will be specific to the type of processes and materials occurring on each lot and will need to be identified at the WMP stage. The general requirement to retain the first 15 mm from impervious surfaces should be considered a minimum requirement and it does not preclude the implementation of more specific stormwater management practices relevant to the land use for individual lots.

For run-off generated in events greater than 15 mm, and which has been appropriately treated according to the requirement of the individual lot, lots will be graded to provide drainage towards open drains. These will be located either alongside road reserves or within arterial drainage corridors that will be established (at the location of natural drainage channels wherever possible) to convey stormwater to a downstream drainage reserve or point of discharge from the site.

4.3.3 Road Drainage

The road network will be designed with flush kerbed roads that discharge flows to open drains designed to convey stormwater through the development safely via an arterial drainage system. Road centreline levels will be designed to be significantly lower than the surrounding lots such that the road can overtop without risk of flooding damage to properties.

Open drainage channels shall be sized so that the 5 year ARI top water level (TWL) is at least 300 mm below the level of the road shoulder. The open drains will be designed to maintain low flow velocities (<2 m/s) which in turn will minimise erosion and sediment transportation. This will include drains having minimum 1:4 side slopes and being vegetated where practical. WSUD principles (e.g. weir structures, gabions, detention storage) will also be incorporated where suitable to further reduce flow velocities and scour potential. The final form and function of the road drainage reserves will be the subject of further discussion with CoK, with more detailed designs to be presented in the WMPs.

4.3.4 Arterial Drainage Corridors

The proposed drainage strategy involves the use of arterial drainage corridors through the site that will be designed to contain and convey all flows up to the 1% AEP (100 year ARI) event. The alignment of the drainage corridors will utilise the existing topography and natural flow regime of the site wherever possible to minimise the requirement for earthworks and engineered drainage infrastructure. Whilst existing drainage flow paths will be maintained and used for arterial drainage corridors wherever possible, these are likely to be formalised in places to reduce the width of area required for drainage.

It is anticipated that weirs, drop structures, rock pitching and vegetation will be utilised within the arterial drainage network to control stormwater flow rates and discharge velocities. These structures will also provide opportunities for improving stormwater quality prior to discharge to downstream receiving environments.

Maintaining a level of vegetation cover in the drainage reserves is important for increasing soil stabilisation and reducing erosion, however it is recognised that vegetation can inhibit stormwater flows and as such the landscaping design will need to represent a sensible balance between effective conveyance, flood protection and erosion prevention.

Figure 20 provides potential locations for arterial drainage corridors, which represent the main existing flow channels at the site. Figure 20 also shows the approximate surface water sub-catchment boundaries and flow directions to describe the pre-development hydrological regime. The final alignment, form and function of the arterial drainage corridors will need to be reviewed at WMP stage, once final fill levels, internal road layout and potential requirements for subsoil drainage have been established.

4.4 Water Quality Control Measures

4.4.1 Controlling Flow Rates

The intensity of major rainfall events and the use of overland flow as the principle method of stormwater conveyance present a number of constraints in terms of the stormwater treatment options in the North West region. For this reason, typical strategies for water quality improvement focus on reducing flow velocities and minimising sediment mobilisation in stormwater prior to discharge to downstream receiving environments.

4.4.2 Structural Controls

To maintain low flow velocities and minimise erosion and sedimentation transport, the drainage design will consider applying various structural controls including detention/ sedimentation basins, gabions, V-notch weirs, drop structures and vegetation of open channels. For scour protection, mortared stone pitching will also be provided at all outlet structures, as well as bends and junctions greater than 22.5°. The final design parameters for the outfall locations will be investigated in future WMPs.

4.4.3 Industrial Water Quality

Section 4.2.3 provides a list of recommendations related to stormwater management at industrial sites (DoW 2010) to ensure downstream stormwater receptors are protected. The applicability of these recommendations will depend on the industry type; an assessment of their relevance will be undertaken at the lot scale WMP stage.

5.0 FLOOD MANAGEMENT

5.1 Post-development Flood Modelling

A Flood Study Report (RPS 2015a) was prepared which described the pre-development hydrology of the site and involved the development of a detailed 1D–2D model to estimate 1% AEP flood levels. This model was subsequently used to undertake the post-development flood modelling described below.

The key objective of the modelling was to determine the potential impacts of the development to flow rates and, consequently, to flood levels within the site. The model was also used to simulate potential impacts on flood levels from encroaching (through filling of the site for example) on the flood plain area. This information would in turn influence flood protection levels and potential fill requirements.

The post-development model simulated the increased flow rates arising from development of the site by modifying the hydrologic input parameters (impervious surface, infiltration and roughness values) used in the model to represent an industrial development. The modelling was undertaken at a catchment scale, which is suitable to the current phase of the project and level of detail available. Further hydraulic modelling may be required at later stages when detailed design information is available, in order to assess the impact of specific design features (e.g. fill areas or bridges).

The full details and results of the post-development flood modelling are provided in an addendum report to the Flood Study Report. The Flood Study Report and addendum report are provided as Appendices 2 and 3, respectively. Note that the flood study report and addendum provided in Appendices 2 and 3 utilise obsolete nomenclature for the industrial areas, however the outcomes are unchanged.

5.2 Post-development Flow Rates and Levels

Table 13 below provides the pre- and post-development flow rates measured at a number of locations within the model; the locations that the flow rates correspond to, are provided in Figure G below. The post-development flow rates at these locations are up to 40% (and average 12%) higher than the pre-development flow rates.

Table 13: Post-development Flow Rates

Flow Location	Peak Flow Rate for 6 Hr Event (m^3/s)		
	Pre-development	Post-development	Percentage Increase
1	287	312	9%
2	311	360	16%
3	27	28	4%
4	129	161	25%

Flow Location	**Peak Flow Rate for 6 Hr Event (m^3/s)**		
	Pre-development	**Post-development**	**Percentage Increase**
5	95	115	21%
6	152	159	5%
7	90	97	8%
8	69	78	13%
9	43	48	12%
10	15	21	40%
11	25	26	4%
12	24	24	0%
13	24	25	4%

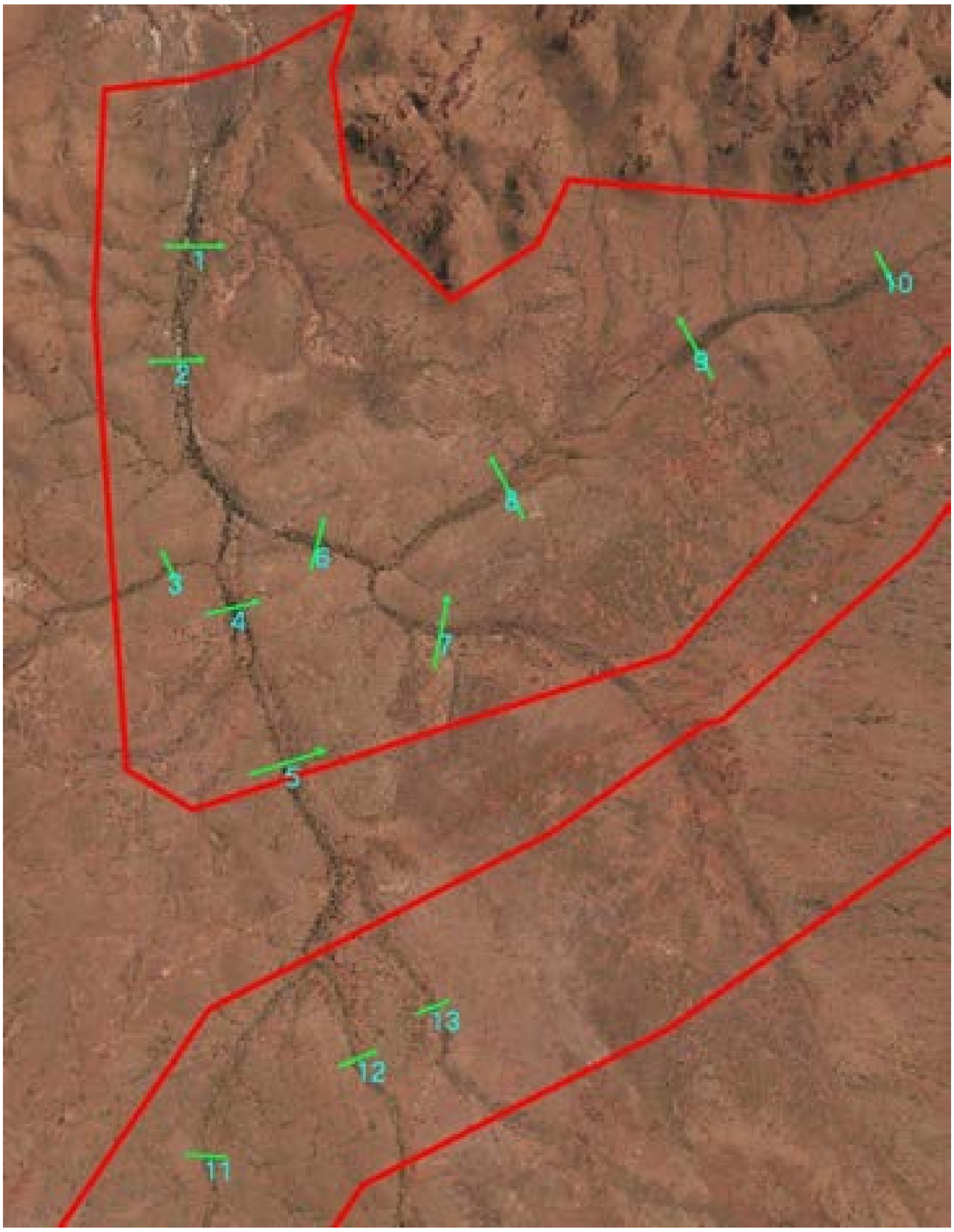

Figure G: **Rocky Creek Peak Flow Measurement Locations**

The impact of these increased flow rates on flood levels was then modelled assuming no changes to the topographic surface (i.e. no filling or modification of the major flow channels). The impact to flood levels caused by the higher (post-development) flow rates is relatively minor with peak flood levels generally increasing by less than 0.1 m from the modelled pre-development flood levels.

The Department of Water's flood protection policy includes providing 0.5 m clearance from the post-development 1% AEP flood level to the floor level of habitable structures. The post-development 1% AEP flood levels are presented in Figures 21 (a–c) and can be used by future proponents of lot-scale development to determine suitable flood protection levels. However, it should be noted that further, localised modelling would likely be required at detailed design stage to determine the effect of drainage infrastructure and other structures within the flood plain on the post-development flood levels at the lot-scale.

5.3 Flood Plain Encroachment Modelling

5.3.1 Encroachment Results

The model was used to simulate the effect on flood levels caused by obstructing (through filling for example) certain areas of the flood plain. This was undertaken to provide an indicative floodway extent, which represents the area of the flood plain, that is most important for flood conveyance and which should not be obstructed in order to avoid significant impacts to flood levels.

Floodway does not have a single and consistent quantitative definition. For determining the floodway extent for the main flood plain areas within the Anketell site, this study has defined the floodway as the area, which should not be even partially obstructed in order to prevent flood levels increasing by more than 0.15 m. This conforms to CoK (2011) general stormwater design guidelines, which require that total development within the flood fringe does not raise the 1% AEP flood level by more than 0.15 m.

The results of the pre-development model were used to assess the flood plain hydrology and identify the more important flood conveyance and storage areas. Floodway modelling then involved a iterative process of adjusting the boundary of encroachment around these important flow areas until the resulting flood levels were within 0.15 m of the pre-development flood levels at all locations along the flood plain. Figures H and I below illustrate the resulting floodway extent for the HIA1 Rocky Creek Catchment and for the creek within the HIA1 Eastern Catchment, along with the simulated increase in post-development flood levels. These floodway extents are also provided in Figures 22 and 23 at the rear of this report.

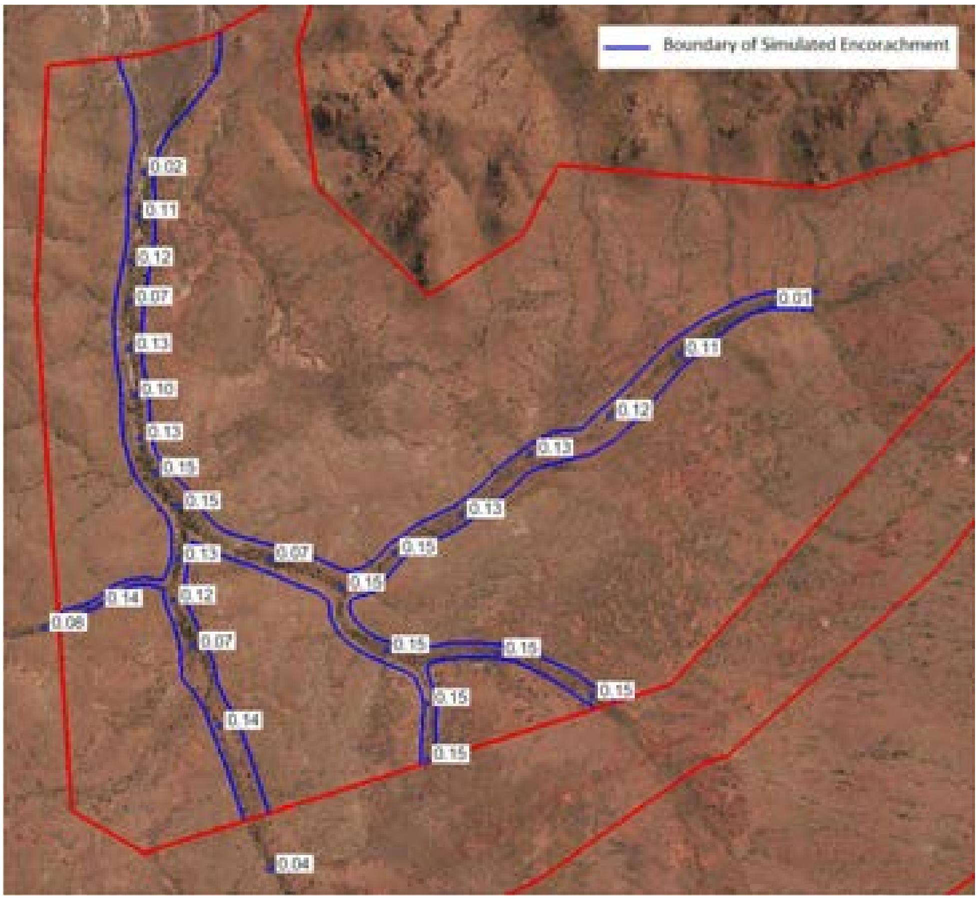

Figure H: Modelled HIA1 Rocky Creek Catchment Floodway Extent with Change to Flood Levels

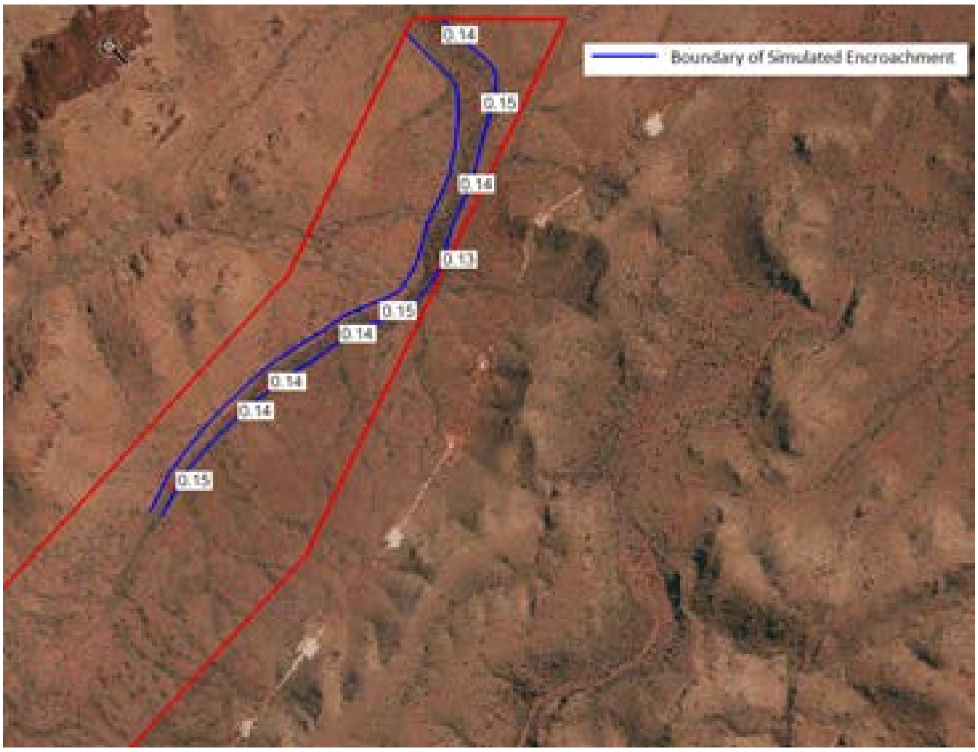

Figure I: Modelled HIA1 Eastern Catchment Floodway Extent with Change to Flood Levels

It should be noted that the floodway extents presented herein indicate the boundary of acceptable (according to the above floodway definition) encroachment into the main flood plain areas; the illustrated floodway extents should not be inferred as meaning that all areas outside of these boundaries are suitable for development. There are other significant flow channels within the site that will also need consideration in order to maintain pre-development flow capacity and prevent localised flooding. The encroachment modelling has not included all of these flow channels for reasons of practicality.

It is expected that proponents will complete their own hydrologic assessments and modelling to inform the drainage design for their own sites, including ensuring that the natural flood conveyance of the site is not adversely impacted.

5.3.2 Encroachment Sensitivity Analysis

A number of scenarios were modelled representing various degrees of encroachment on the Rocky Creek flood plain within HIA1, in order to determine the sensitivity of the flood levels and flow velocities to obstruction of the flood plain. Flow velocity is relevant as excessive velocities can cause damage to natural or constructed drainage channels and to other infrastructure. For example, velocities in excess of 2.0 m/s can cause scouring and destabilisation of foundations and poles (NSW Government 2005) and CoK (2011a) specify that maximum flow velocities shall not exceed 2 m/s in open channels without suitable erosion protection.

Table 14 below provides a summary of an encroachment modelling sensitivity analysis for the main section of Rocky Creek (results that are more complete are provided in Appendix 3). For each scenario, the table presents the width of flow conveyance, the resulting increase in flood levels compared to pre-development flood levels, as well as the average peak velocity (averaged along the creek) and the maximum peak velocity (at any point within the creek).

Table 14: Encroachment Sensitivity Analysis

Scenario Number	Encroachment Boundary Scenario	Approx. Width of Drainage Area	Max Impact to Flood Levels	Average Peak Velocity (m/s)	Maximum Peak Velocity (m/s)
1	No encroachment	150–200 m	0 m	1.2	1.9
2	Modelled Floodway Extent	80–110 m	0.15 m	1.2	1.9
3	Pre-development V × D = 2.0	80–90 m	0.4 m	1.3	2.0
4	10 m either side of creek channel	50 m	1.0 m	1.4	2.0
5	Creek channel (no flood plain)	25–30 m	1.6 m	1.6	2.6
6	30 m Constructed Channel	30 m	0.6 m	2.8	3.8
7	40 m Constructed Channel	40 m	0.1 m	2.5	3.4

The results indicate that a wide excavated drain (Scenario 7) could be used to convey the major flood events with acceptable impacts to flood levels (i.e. <0.15 m) in the downstream channel, whilst occupying a smaller footprint than retaining the natural creek channel and flood plain. However, this scenario resulted in peak flow velocities increasing by approximately 100%, indicating that this option, whilst retaining a more developable area, would likely incur greater costs associated with significant engineering to manage flow velocities and potential scour and erosion issues.

This approach would also give rise to other considerations including the environmental impacts of vegetation clearing and habitat removal as well as potential Indigenous heritage site issues. This approach would require further modelling and design work including engineering input to confirm adequate sizing and scour control for a constructed drain.

6.0 IMPLEMENTATION AND MONITORING

6.1 Monitoring

The proposed stormwater management strategy outlined in this DWMS focuses on implementation of current best management practice for the region, and is consistent with previous advice from DoW relating to development projects in the region.

A post-development monitoring program is not currently being considered for the development, however it is recognised that establishing suitable water quality objectives may be required to maintain an acceptable quality of stormwater entering Rocky Creek.

The DoW will be engaged further as the planning process progresses to determine the requirement for post-development monitoring at the lot scale WMP stage (as required).

6.2 Implementation

This DWMS has been completed to demonstrate that the Anketell SIA is capable of supporting future development in terms of water supply planning, flood mitigation, drainage management and water quality protection. The DWMS has been tailored to suit the requirements of the Improvement Scheme process and not only addresses the objectives of BUWM, but also informs the water management detail required by each proponent at subdivision/development stage, as part of a future WMP.

The benefit of this approach is that the DWMS identifies broad water management issues while deferring certain investigation and design costs until such time as a foundation proponent is present, and a better understanding of actual land requirements in terms of size, configuration, location, co-location, flood immunity and servicing requirements is known.

Table 2 provides a summary of the water management factors that are addressed at both DWMS and WMP stages. The second column of Table 2 provides the DWMS scope while the third column provides the detailed design required for the lot scale WMP, which will be undertaken by the proponent. Table 2 is intended to provide a water management framework for Anketell SIA that can be readily utilised by other Improvement Schemes.

Of note in Table 2 is the inclusion of development constraints that have the potential to impact water management at the site. The next section (Section 7) provides a broad assessment of the water related constraints for the Anketell SIA. The constraints assessment has been undertaken to provide future proponents with information on which to base more localised investigation at the detailed design stage of development.

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7.0 WATER RELATED CONSTRAINTS ASSESSMENT

7.1 Objective

This section provides a broad assessment of water related constraints for the Anketell SIA. The following constraints assessment is broad in scale only and is intended to provide future proponents with information based on the investigations undertaken to date. It is expected that further, more detailed investigation is undertaken in specific areas at the detailed design stage of development and that these will inform detailed WMPs to be prepared by proponents.

7.2 Climate

The area is cyclone prone, most commonly between mid-December and April, peaking in February and March, which can result in extreme rainfall events. This will need to be considered in relation to building suitability and seasonal time frame for construction.

7.3 Topography

The land slope has a major influence on development potential. Steeper land slope increases erosion potential and the difficulty and cost of development. DECCW (2010) note almost all land use operations become increasingly difficult as land slope increases, particularly above moderately inclined levels (>20%) and the City of Gold Coast Planning Scheme (2011) specifies building work is not undertaken on land with a maximum slope exceeding 20% in urban areas and 25% in non-urban areas. DoW (2010) indicates erosion controls may be needed ay industrial sites for surface drainage systems excavated in steep land, defined as a slope greater than one in 15 (7%).

Figure 24 shows there is minimal land slope constraint (nominally selected as land slope exceeding 10%) at the site.

7.4 Geotechnical and Soils

7.4.1 Geotechnical

Geological mapping indicates the following soil types are encountered:

- **Rock outcrop** (basalt, dolerite, gabbro, komatiite, chert, sandstone, BIF) (Ab, Aba, AFr, AFra, Aog, Aod, Auk, Acc, Ast, Aci, Acf)

- **Sheetwash deposits**
  - silt, sand and pebbles (Qw)
  - silt, sand and clay with gilgai (small lakes formed by depressions in areas of expansive clay) (Qwb)
- **Alluvial** sand and gravel in rivers and creeks; clay, silt and sand in channels and flood plains (Qaa)
- **Colluvium** sand, silt and gravel (Qc)
- **Tidal flats** silt and mud (Qhmu).

Geotechnical constraints are expected to relate to rock outcrop and tidal flat areas. Rock outcrops can impede construction activities and occur over a significant portion of the site, while tidal flats are expected to offer poor stability and are limited to a small area at the northern boundary of HIA1.

Figure 25 shows areas that have these potential geotechnical constraints.

7.4.2 Acid Sulfate Soils

The majority of the site has no known risk of ASS mapped across it, however the drainage lines within GIA, HIA1 and HIA2 have been mapped as having a moderate to low risk of ASS within 3m of natural soil surface but high to moderate beyond 3 m of natural soil surface. If these areas are proposed to be disturbed by construction works, an ASS investigation should be undertaken to determine soil characteristics and where required a detailed Acid Sulfate Soil and Dewatering Management Plan prepared to the satisfaction of the WAPC on advice from the DER.

Figure 6 shows areas that have potential ASS constraints.

7.5 Groundwater

Shallow groundwater may impact on development foundations and result in standing water for extended periods. Groundwater monitoring undertaken at four locations was used to estimate the maximum groundwater level (MGL) over the October 2014 to March 2016 monitoring period. This was used to provide the minimum groundwater clearance over the monitoring period.

Figure 14 shows areas constrained with respect to groundwater, which are those with monitored groundwater clearance less than 3 m.

7.6 Flooding and Drainage

7.6.1 Surface Water Flooding

Surface water flooding is a major constraint in the cyclone prone area and can result in serious impact to lives and infrastructure. Figures 22 and 23 show areas within the indicative post-development floodway. DoW recommends minimum habitable floor levels are 0.5 m above this 1% AEP flood level.

7.6.2 Storm Surge

Storm surge and associated inundation are factors that can constrain development. Figure 9 illustrates the potential inundation caused by a 0.2% AEP storm surge event including 0.9 m sea level rise. This mapping corresponds to a storm surge level of 7.1 m AHD that was adopted from the KCVS (JDA et al. 2012).

7.7 Water Supply

The site is highly constrained in relation to water supply, including:

- expected low groundwater bore yields
- Water Corporation has advised there are no plans for wastewater and potable servicing.

Potential water supply options are:

- groundwater abstraction from regional aquifers, desalination and wastewater recycling.

Potential wastewater servicing options include on-site wastewater treatment plant(s).

7.8 Environmental Constraints

7.8.1 Flora

Figure 16 shows the area of Horseplain Flats Vegetation, a P3 Priority Ecological Community and the two locations of threatened rare flora.

7.8.2 Fauna

Significant fauna habitat including those of migratory birds and the northern quoll are shown on Figure 17.

7.9 Raw Materials

Figure 19 shows the basic raw materials and mining tenements within a 20 km radius of the Anketell SIA, and highlights areas in close proximity that could potentially supply fill material for the site.

7.10 Transport

The *Transport and Traffic Report* (Jacobs Group Pty Ltd 2016) has been developed for the Anketell SIA that outlines the proposed access routes. Access to HIA1 and G1A will be provided by a western corridor port access road, while a proposed central corridor located between H1A1 and HIA2 is expected to provide direct access to these sites. No internal roads have been designated at this stage.

7.11 Indigenous Heritage

Figure 18 shows Indigenous Heritage Sites within HIA1 and HIA2.

7.12 Final Constraints Map

Figure 26 provides an indication of areas that may be more heavily constrained for development. The mapping has been overlaid to identify areas that may be subject to multiple constraints; the mapping in Figure 26 identifies these areas as follows:

- green – no constraints
- orange – 1 to 2 constraints
- red – 3 or more constraints.

It should be noted that the constraints mapping is intended to provide a high level overview of potential water related constraints across the site and that development is not necessarily precluded in the areas indicated.

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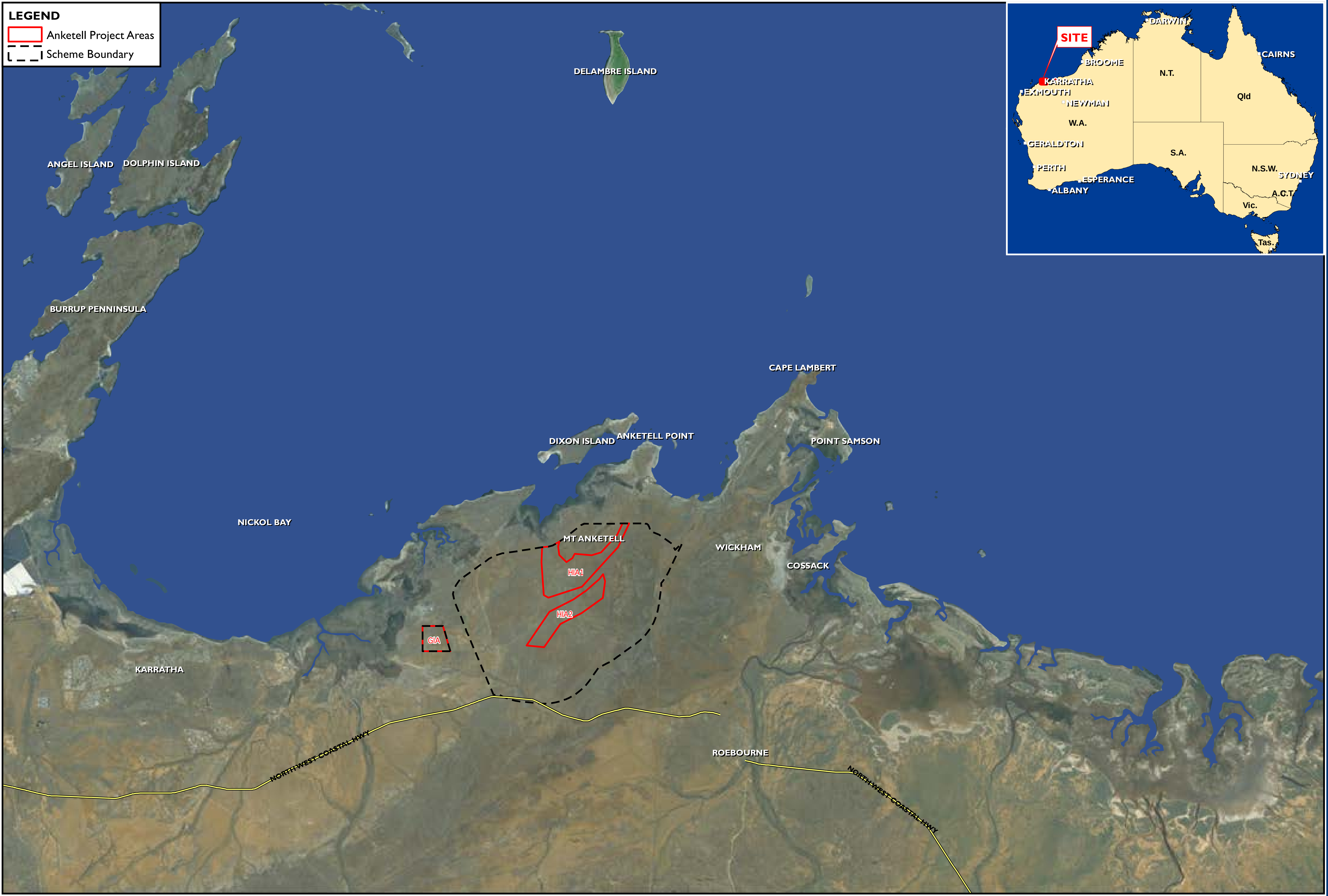
FIGURES



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0 1.25 2.5 5 7.5 10 km

Figure 1

Site Location

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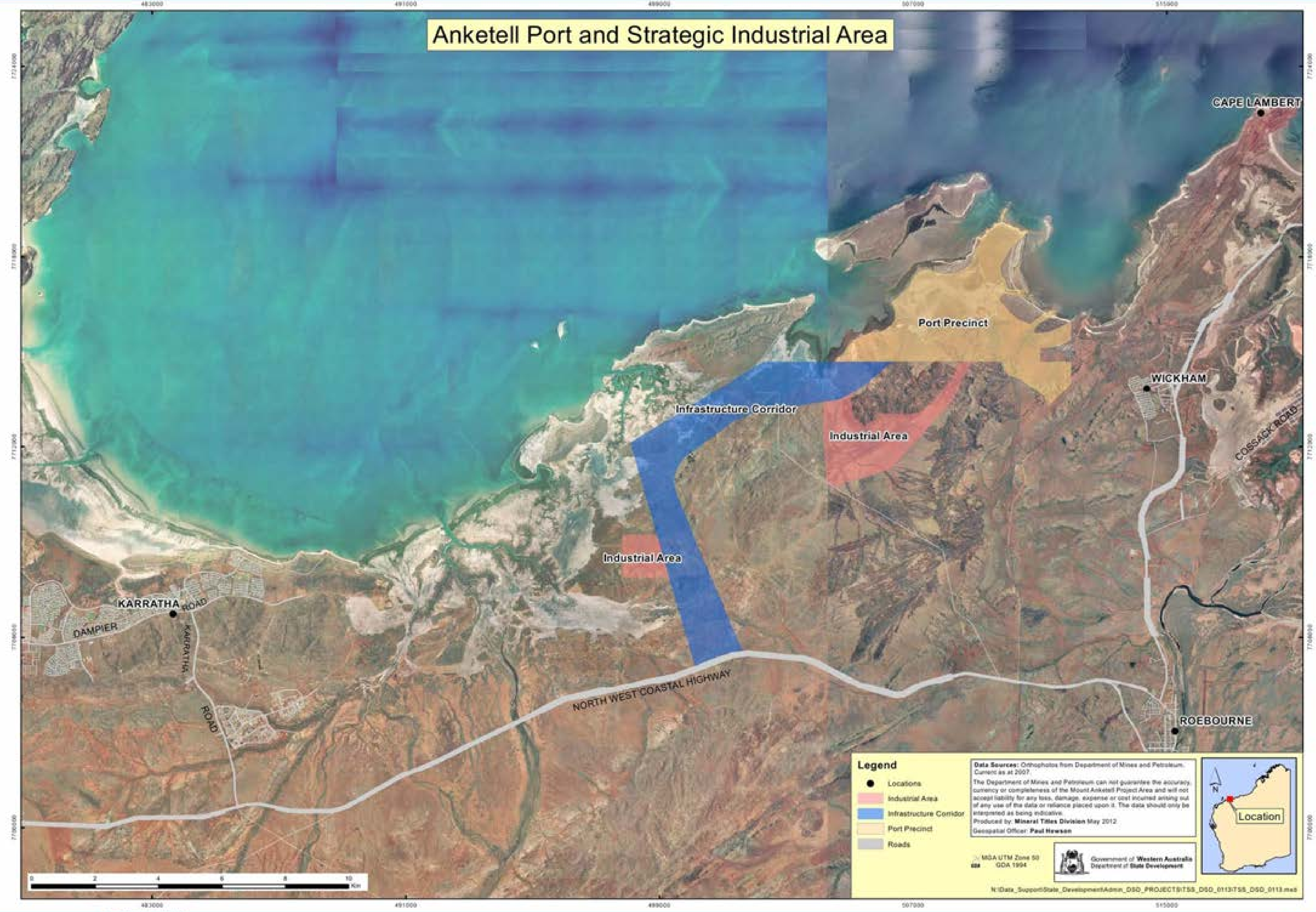

Data Sources: Orthophotos from Department of Mines and Petroleum. Current as at 2007.

The Department of Mines and Petroleum can not guarantee the accuracy, currency or completeness of the Mount Anketell Project Area and will not accept liability for any loss, damage, expense or cost incurred arising out of any use of the data or reliance placed upon it. The data should only be interpreted as being indicative.

Produced by: **Mineral Titles Division** May 2012

Geospatial Officer: **Paul Hewson**

RPS

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Source: Anketell Port Master Plan - June 2014 (Figure 1)

Figure 2

Anketell Port and Strategic Industrial Area

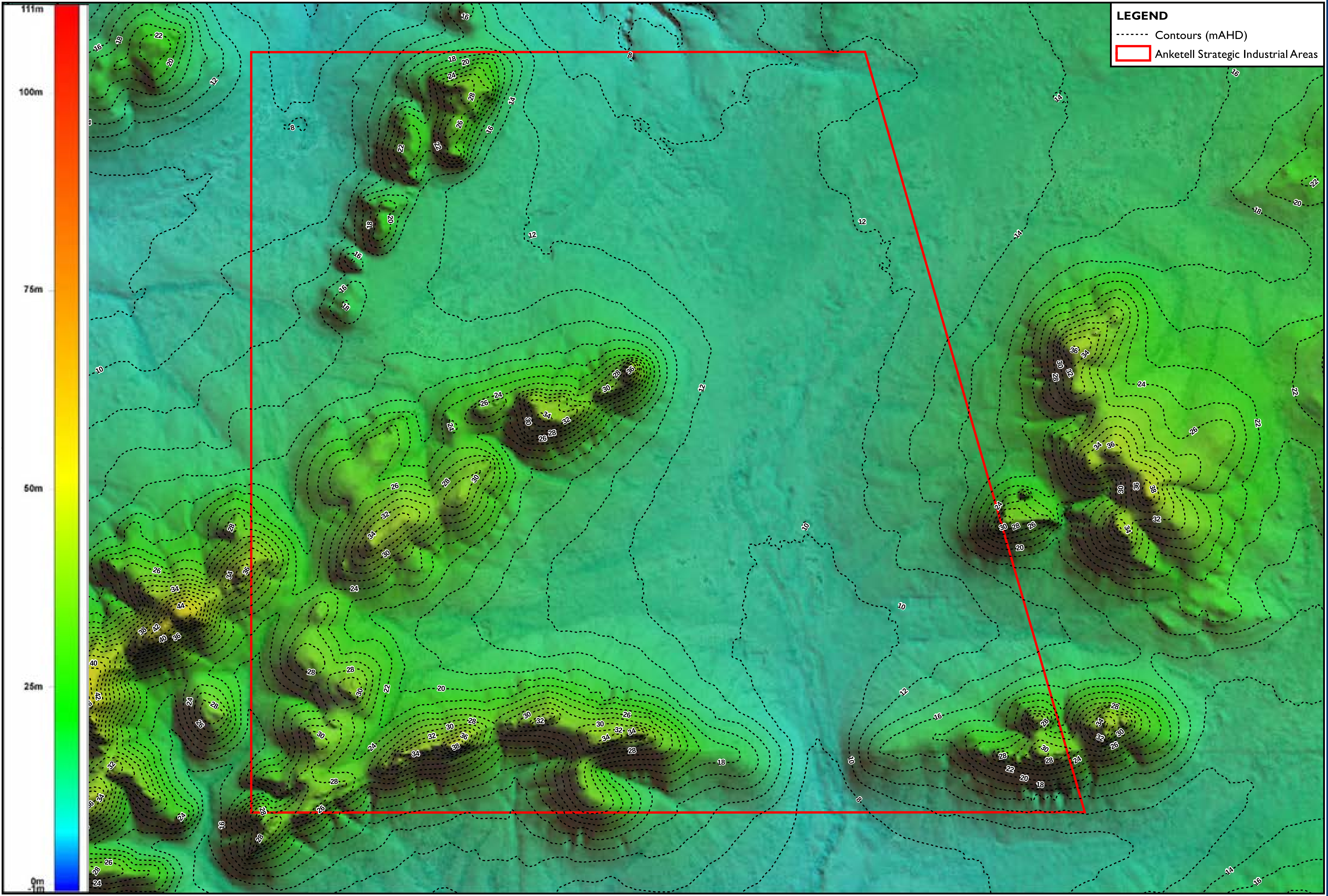

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Figure 3a

Topography - GIA

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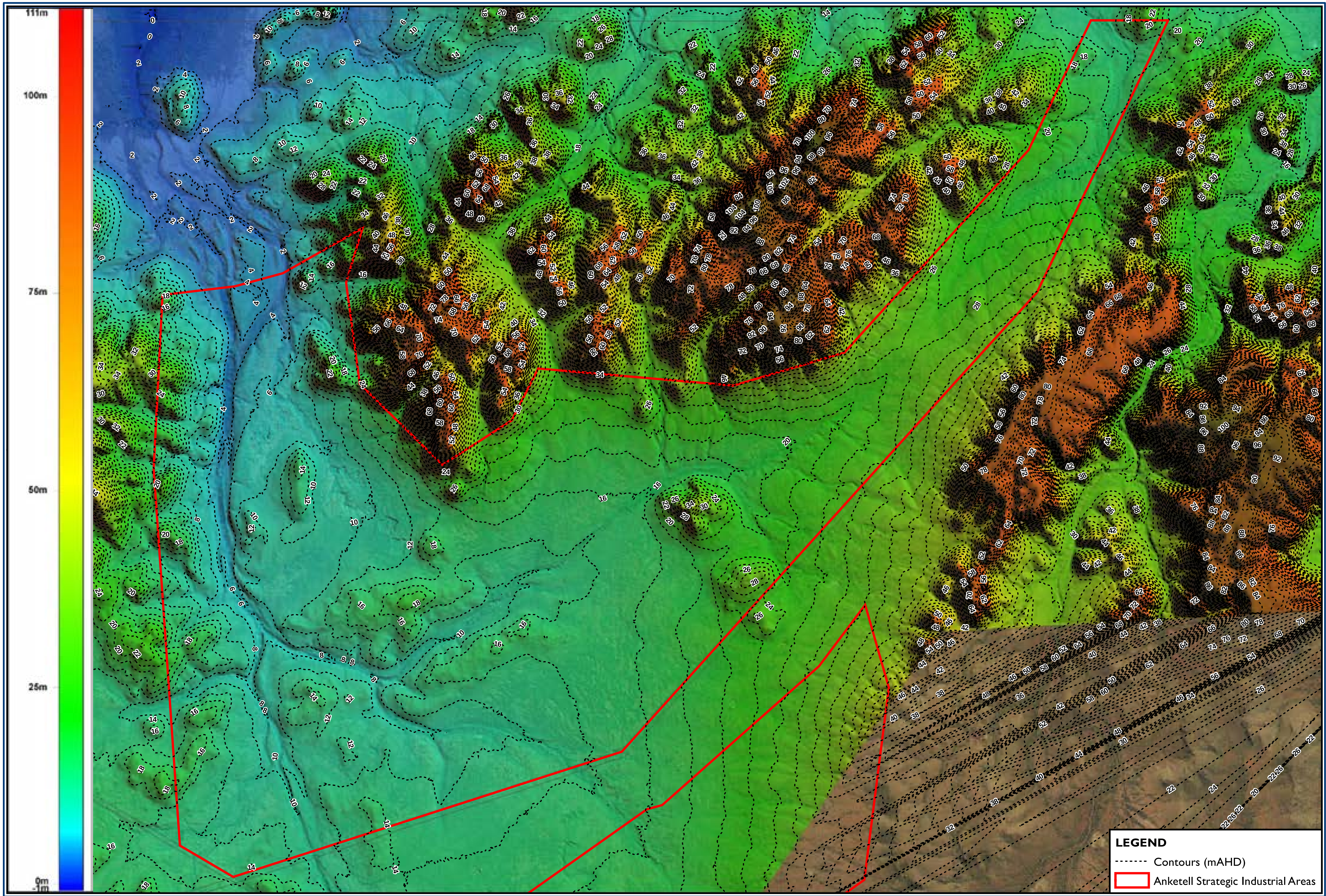

Figure 3b

Topography - HIA1

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Source: RPS 2016

GDA 1994 MGA Zone 50

0 65 130 260 390 520 m

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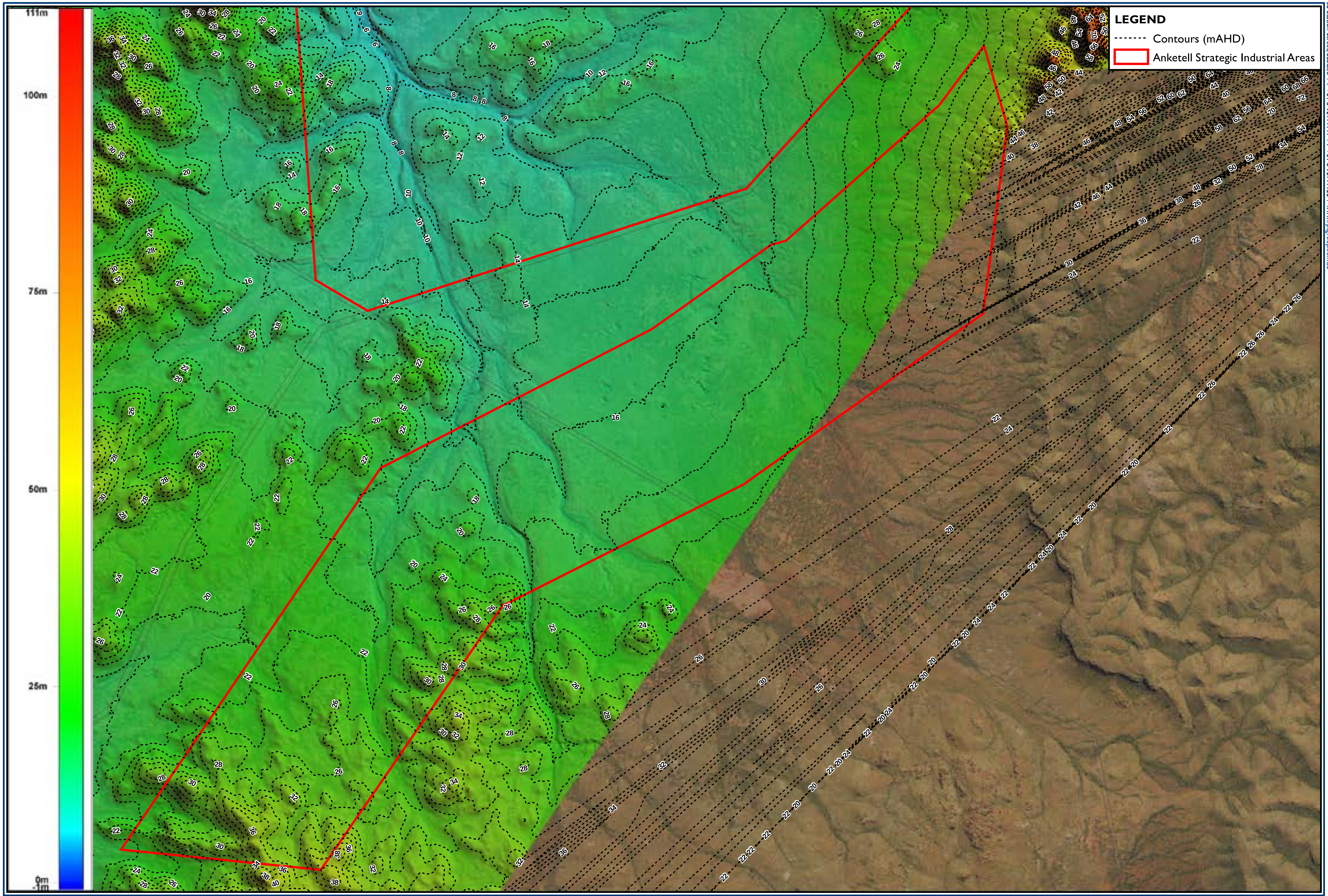

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Job Number: L1305907
Doc Number: 03c
Date: 16.04.16
Scale: 1:15,867 @ A3
Created by: MA
Source: RPS, 2016

GDA 1994 MGA Zone 50

0 62.5 125 250 375 500 m

Figure 3c

Topography - HIA2

LEGEND

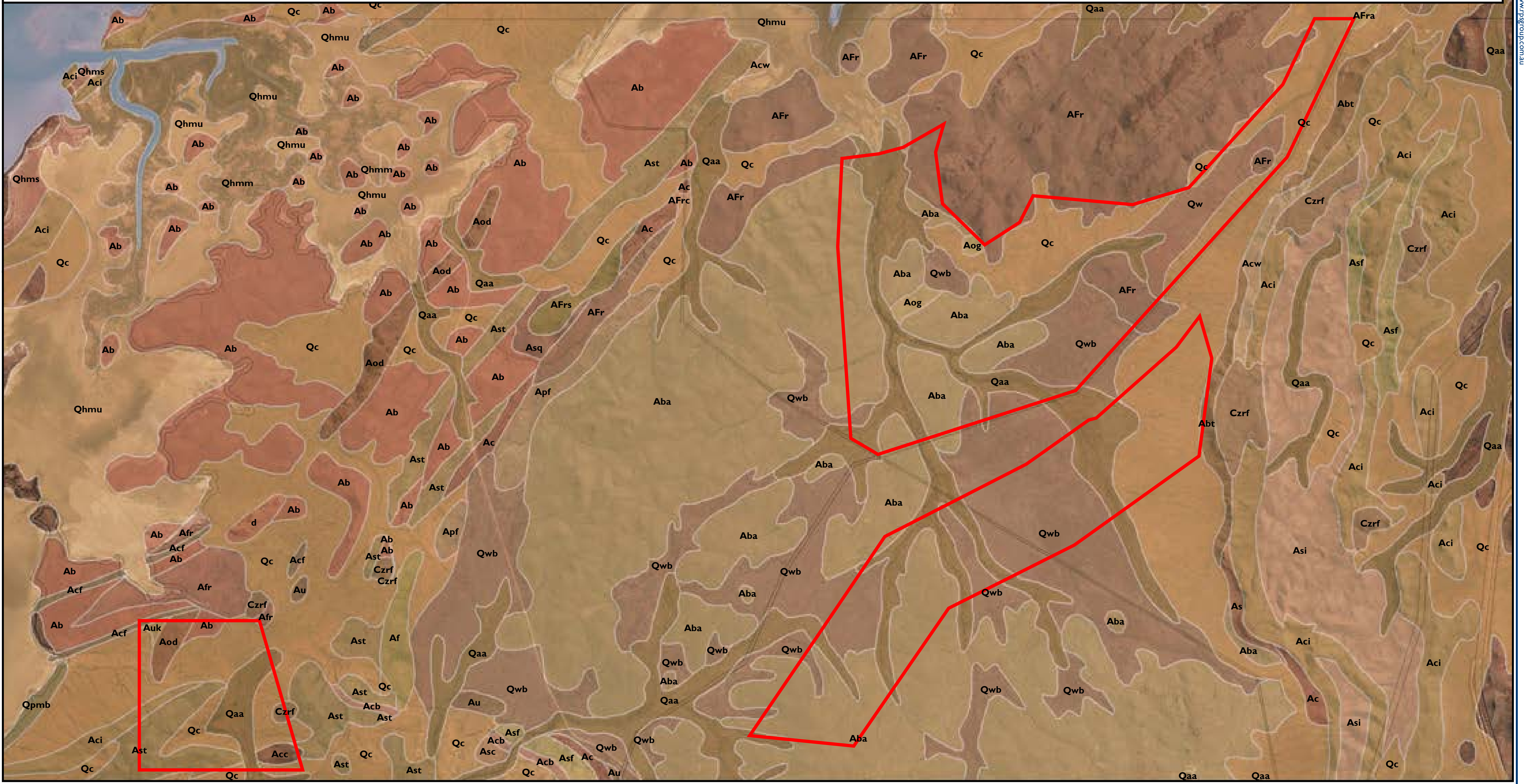
▭ Anketell Project Areas

▭ Cadastre

Surficial Geology (Geoscience, 2013)

CODE, NARRATIVE

- ▨ AFr - MOUNT ROE BASALT: massive, vesicular, and glomeroporphyritic basalt
- ▨ AFra - MOUNT ROE BASALT: Basaltic agglomerate
- ▨ AFrc - MOUNT ROE BASALT: Polymictic conglomerate and sandstone
- ▨ AFrs - MOUNT ROE BASALT: Sandstone and conglomerate; minor shale
- ▨ Ab - Basaltic rock, undivided; generally metamorphosed to greenschist facies
- ▨ Aba - Strongly foliated basalt; metamorphosed to amphibolite facies
- ▨ Abt - Basaltic tuff, well bedded; metamorphosed
- ▨ Ac - Chert, undivided
- ▨ Acb - Black chert
- ▨ Acf - Ferruginous chert, banded iron-formation, and metamorphosed intercalated fine-grained clastic sedimentary rocks
- ▨ Aci - Banded iron-formation; minor ferruginous chert
- ▨ Acw - Grey-white banded chert, locally associated with quartzite
- ▨ Af - Felsic volcanic rock, undivided; chiefly dacite; metamorphosed
- ▨ Afr - Rhyolite; metamorphosed
- ▨ Aod - Dolerite; metamorphosed
- ▨ Aog - Gabbro; metamorphosed
- ▨ Apf - Quartz-feldspar porphyry, rhyolite, and dacite; chiefly intrusive; metamorphosed
- ▨ As - Sedimentary rocks, undivided; metamorphosed
- ▨ Asc - Metaconglomerate
- ▨ Asf - Felsic volcaniclastic rock; metamorphosed
- ▨ Asi - Ferruginous clastic sedimentary rocks, dominantly pelitic; includes minor chert beds; metamorphosed
- ▨ Asq - Quartzite
- ▨ Ast - Sandstone; minor conglomerate and siltstone; metamorphosed
- ▨ Au - Ultramafic rock, undivided; includes schist; local silicification
- ▨ Auk - Komatiite; characterized by olivine spinifex textures; metamorphosed
- ▨ Czrf - Ferricrete; includes ferruginous duricrust and pisolitic ironstone; residual origin; dissected by present-day drainage
- ▨ Qaa - Alluvial sand and gravel in rivers and creeks; clay, silt, and sand in channels on floodplains
- ▨ Qc - Colluvium - sand, silt, and gravel in outwash fans; scree, talus; proximal mass-wasting deposits
- ▨ Qhmm - Marine mud and silt; intertidal with mangroves
- ▨ Qhms - Shelly sand in coastal dunes and old beach deposits; contains Anadara granosa
- ▨ Qhmu - Silt and mud in supratidal to intertidal flats and lagoons
- ▨ Qpmb - Coastal limestone - lime-cemented shelly sand, dune sand, and beach conglomerate
- ▨ Qs - Eolian sand - red-yellow, wind-blown sand; local sand ridges
- ▨ Qw - Low-gradient sheetwash deposits - silt, sand, and pebbles in distal outwash fans; no defined drainage
- ▨ Qwb - Low-gradient sheetwash deposits - sand, silt, and clay in distal outwash fans, with gilgai surface in areas of expansive clay
- ▨ d - Dolerite dyke, interpreted beneath regolith from aeromagnetic data where dashed
- ▨ Ocean



Job Number: L1305907
Doc Number: 004
Date: 16.04.16
Scale: 1:35,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

GDA 1994 MGA Zone 50

0 0.25 0.5 1 1.5 2 km

Figure 4

Geology

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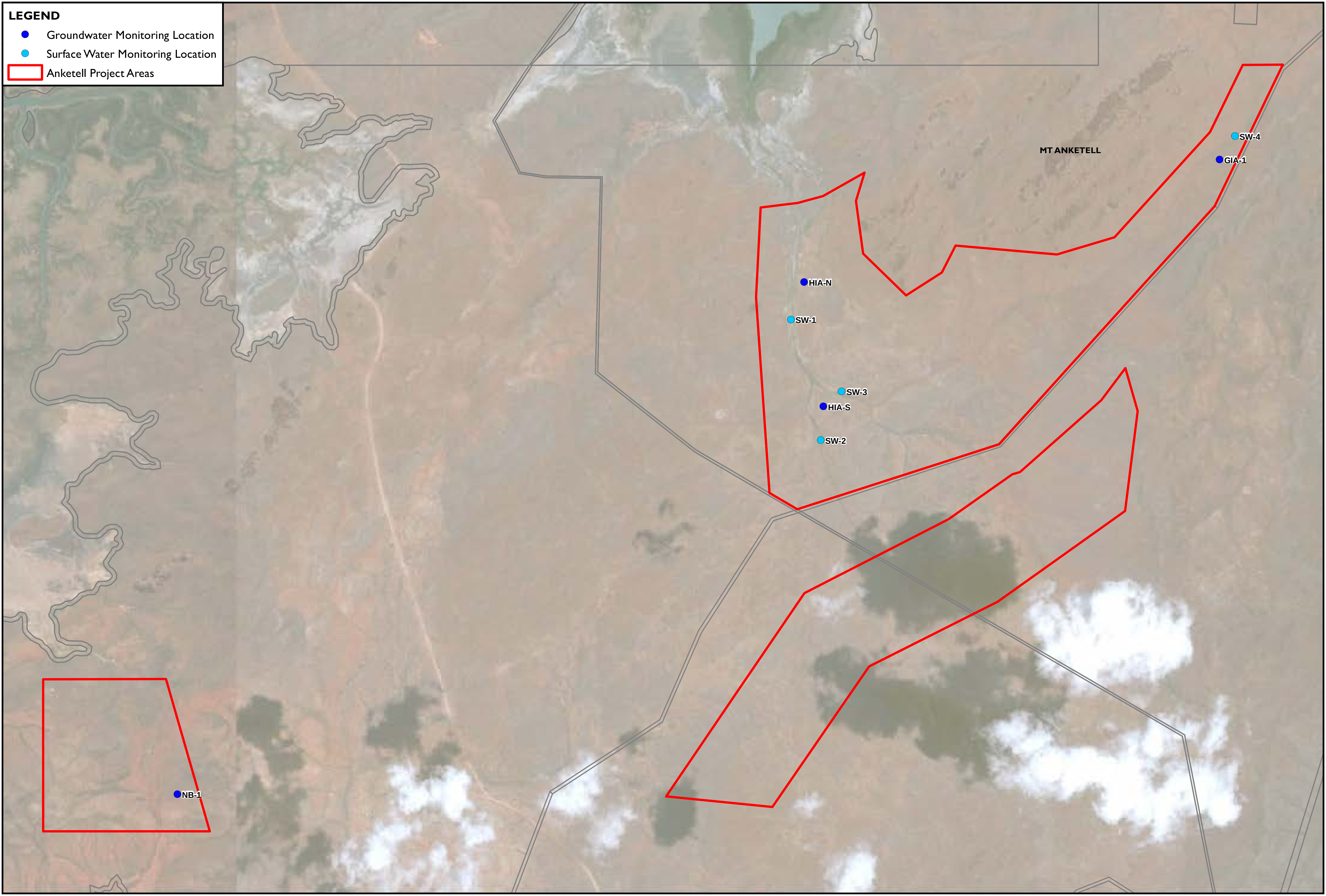

Figure 5

Groundwater and Surface Water Monitoring Locations

RPS

Job Number: L1305907
Doc Number: 005
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MA
Source: Orthophoto - ESRI Online World Imagery

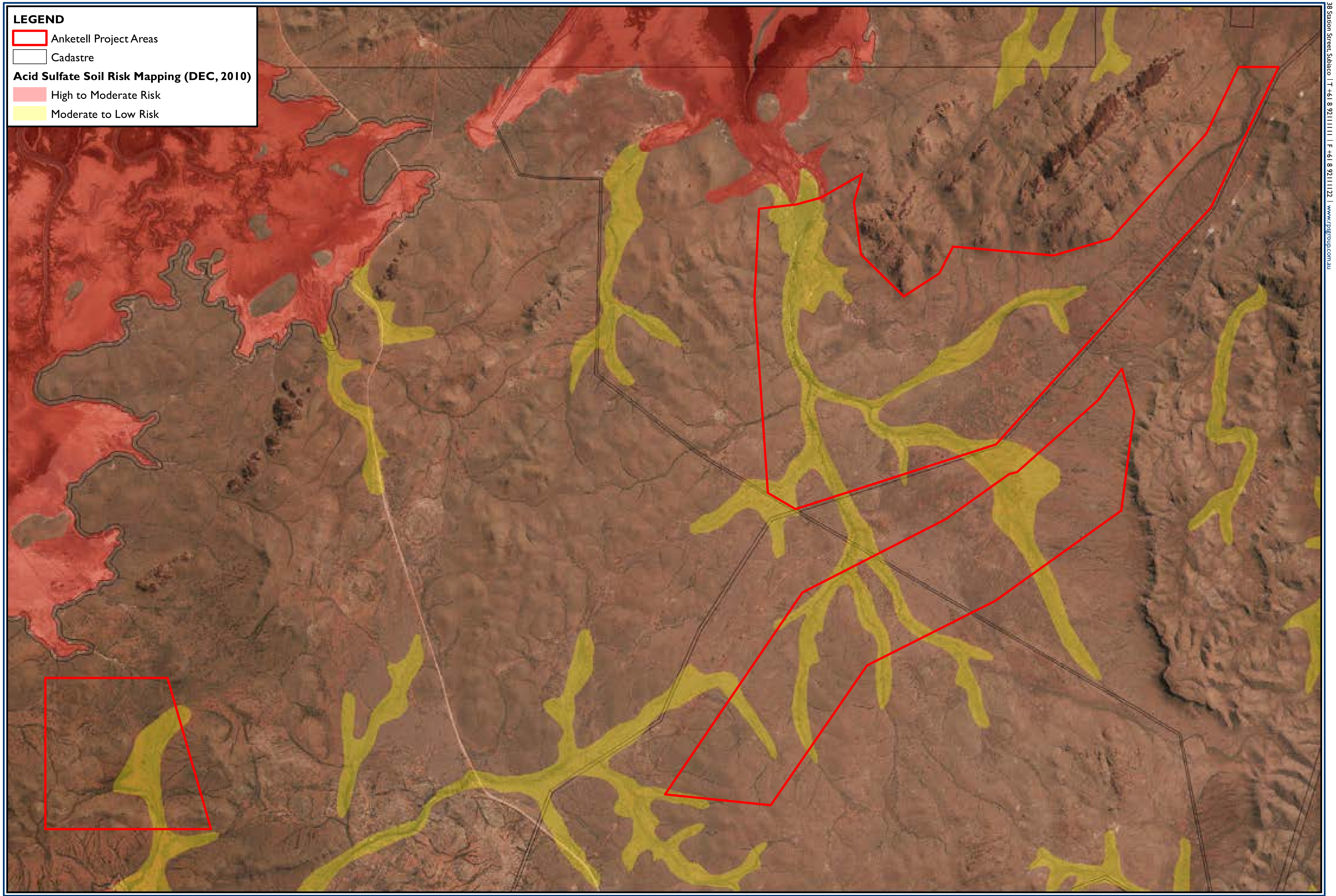

Figure 6

Acid Sulfate Soil Risk Mapping

RPS

Job Number: L1305907
Doc Number: 006
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

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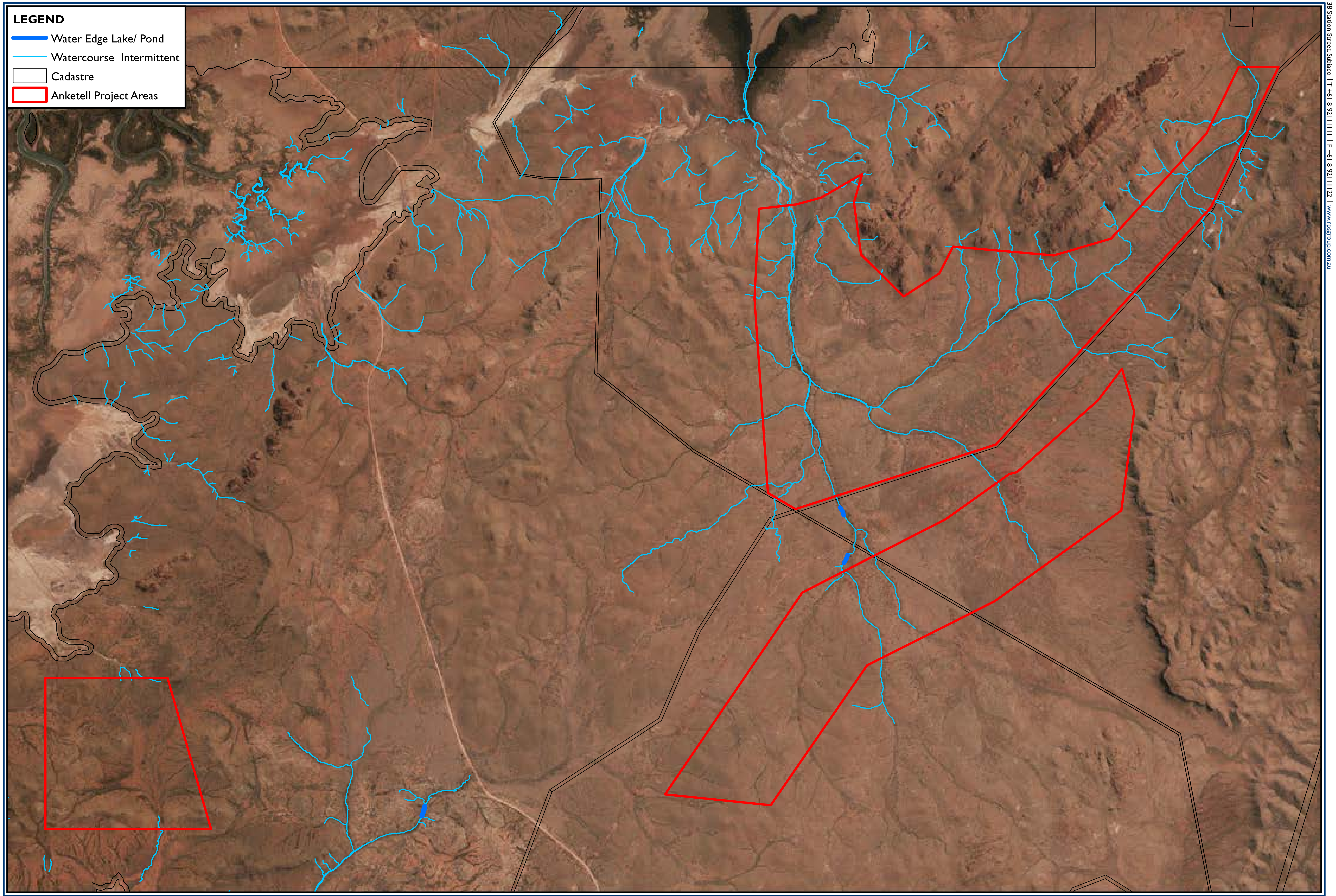
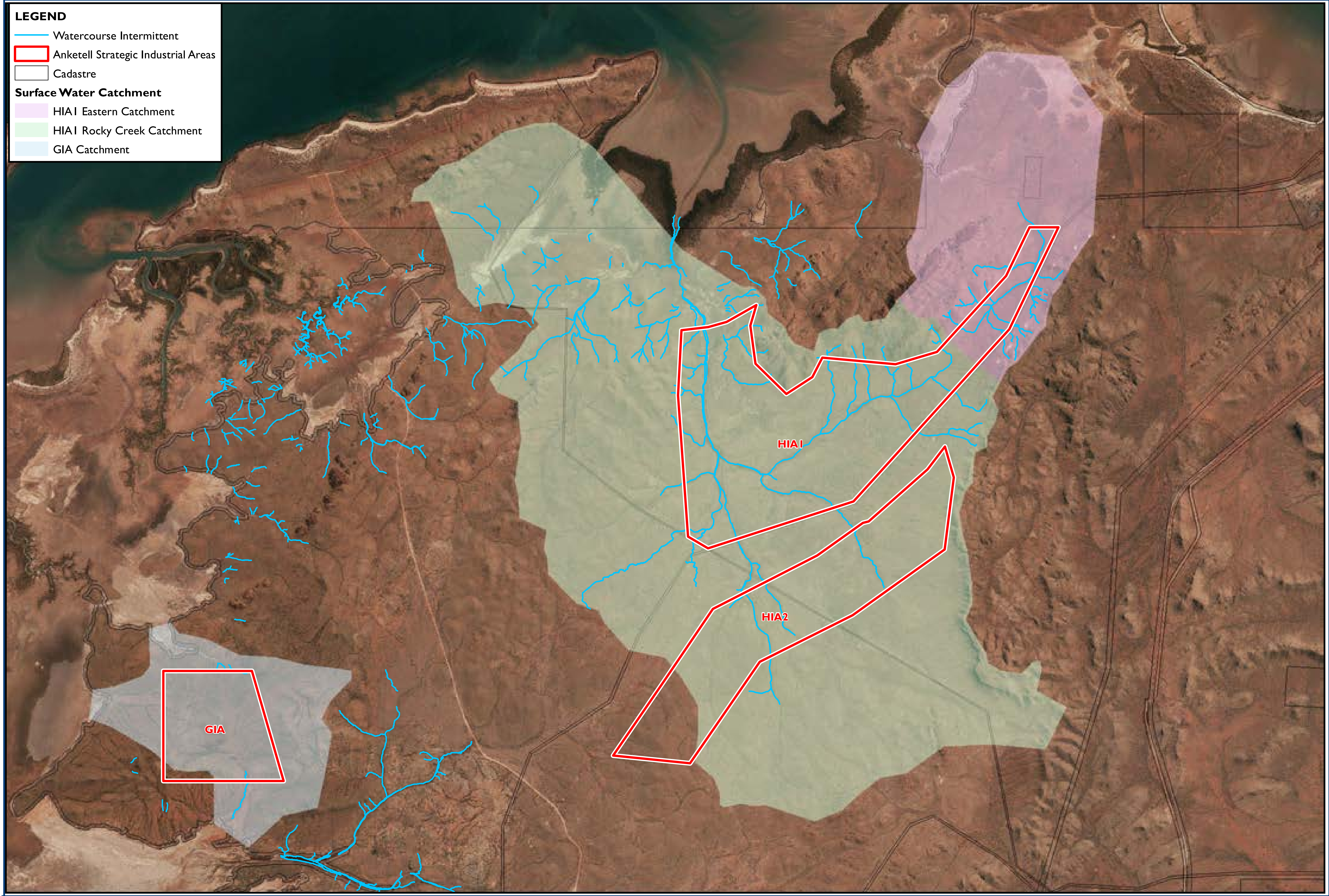


Figure 7

Surface Water Drainage

RPS

Job Number: L1305907
Doc Number: 007
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013



RPS

Job Number: L1305907
Doc Number: 008
Date: 16.04.16
Scale: 1:41,445 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

Figure 8

Surface Water Catchments

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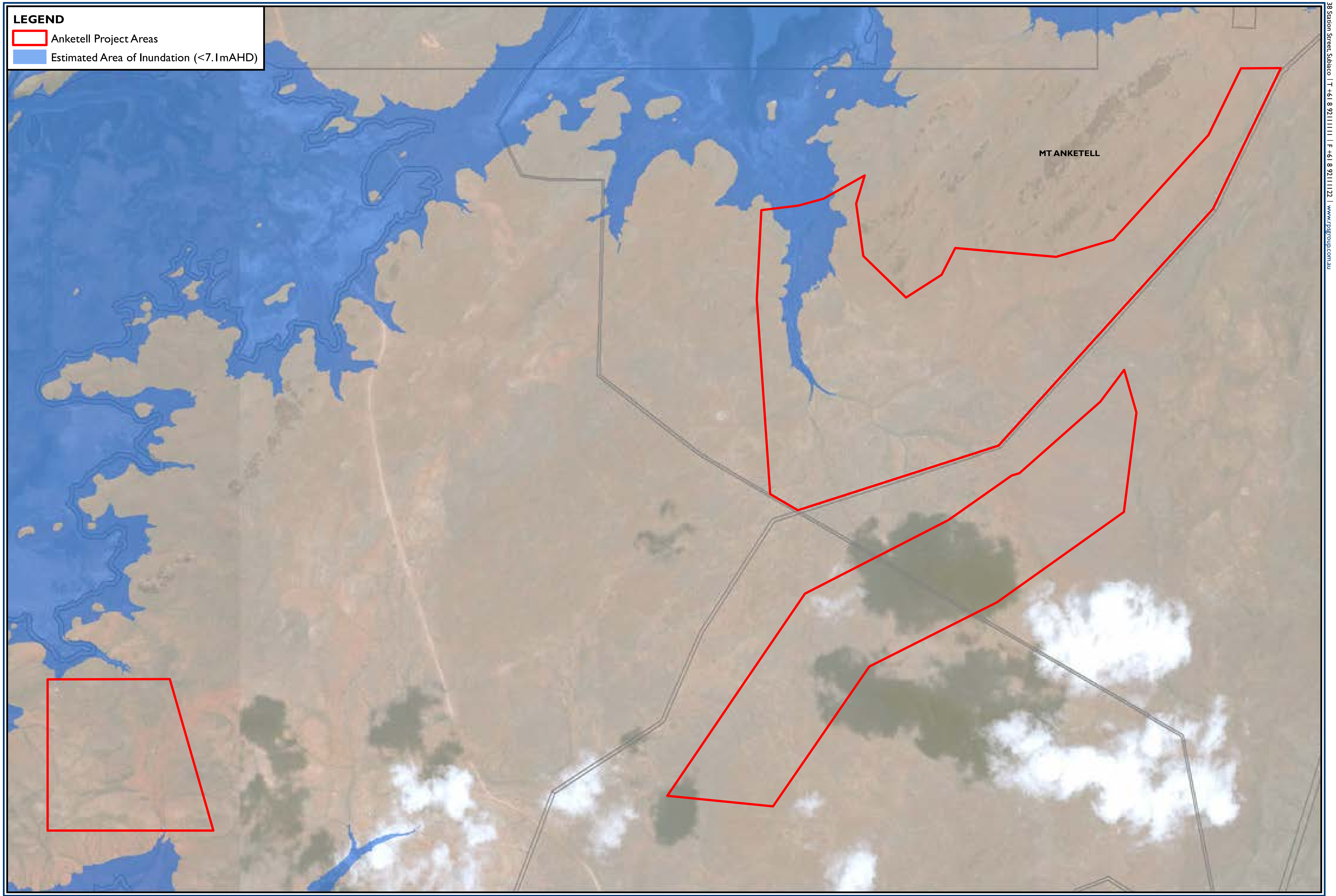

RPS

Job Number: L1305907
Doc Number: 009
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MR
Source: Orthophoto - ESRI Online World Imagery

GDA 1994 MGA Zone 50

0 0.25 0.5 1 1.5 2 km

Figure 9

Estimated Area of Inundation for 0.2% AEP Storm Surge

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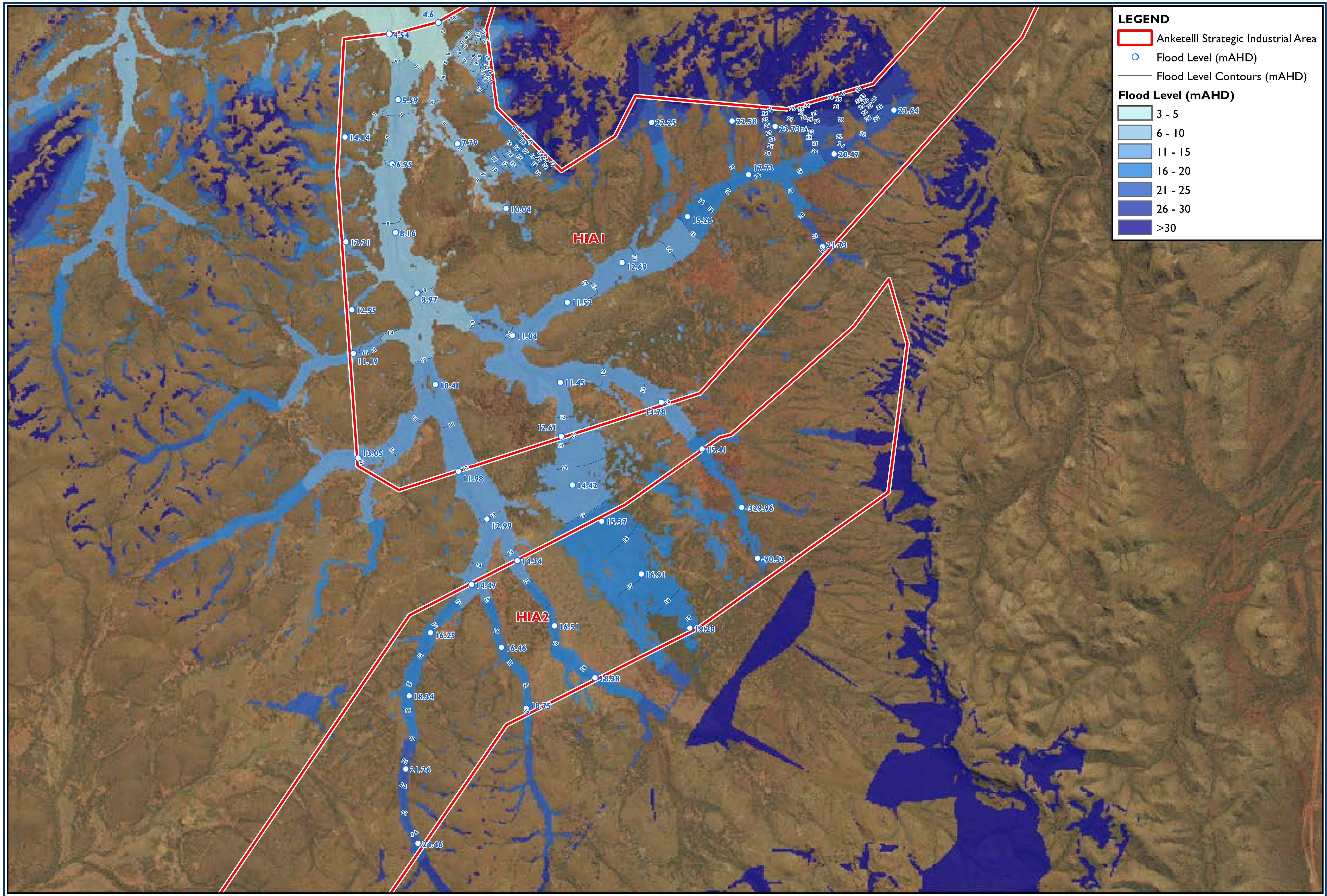

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RPS

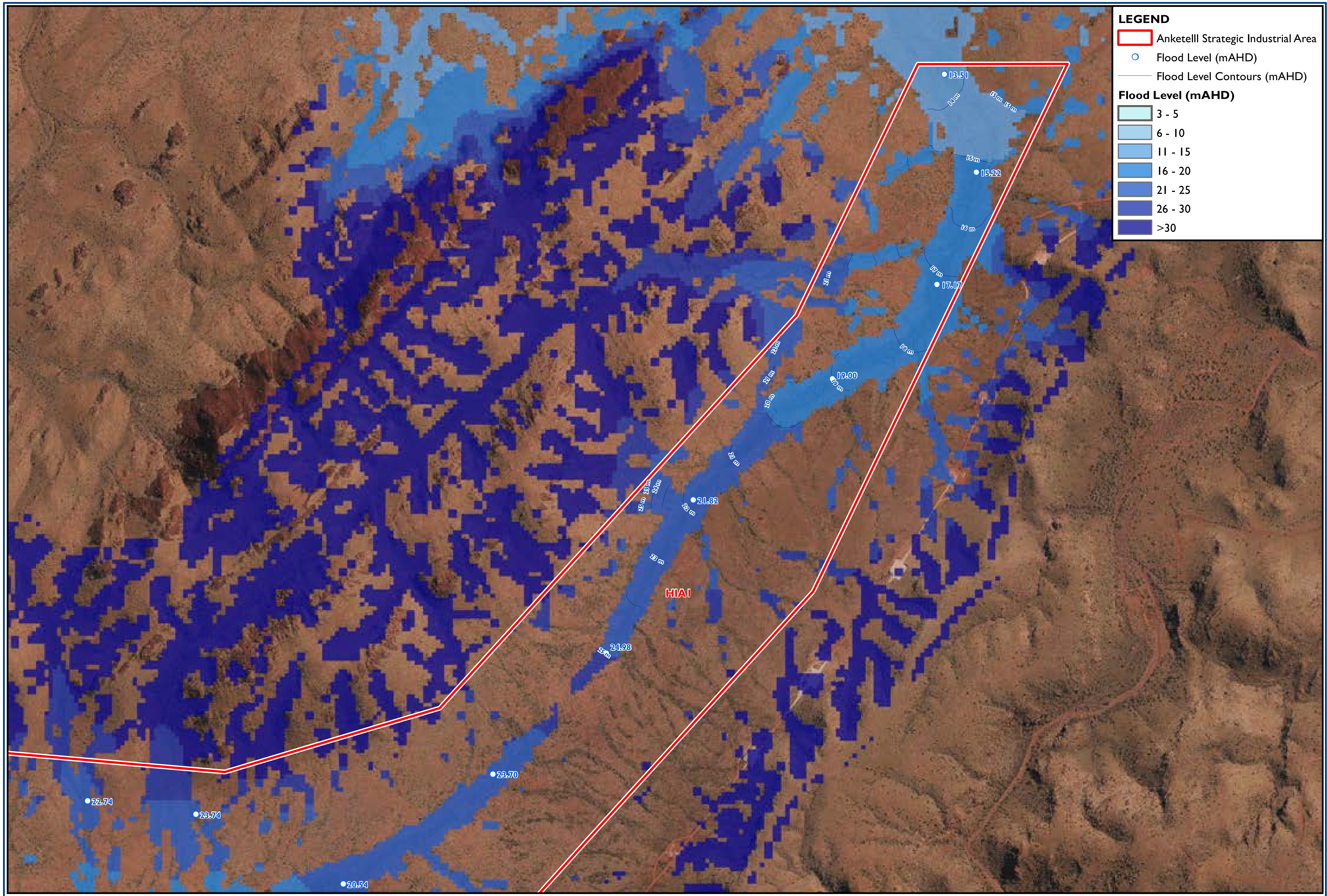
Job Number: L1305907
Doc Number: 010a
Date: 16.04.16
Scale: 1:20,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50

0 0.125 0.25 0.5 0.75 1 km

Figure 10a

Rocky Creek Catchment Pre-development – 1% AEP Flood Level

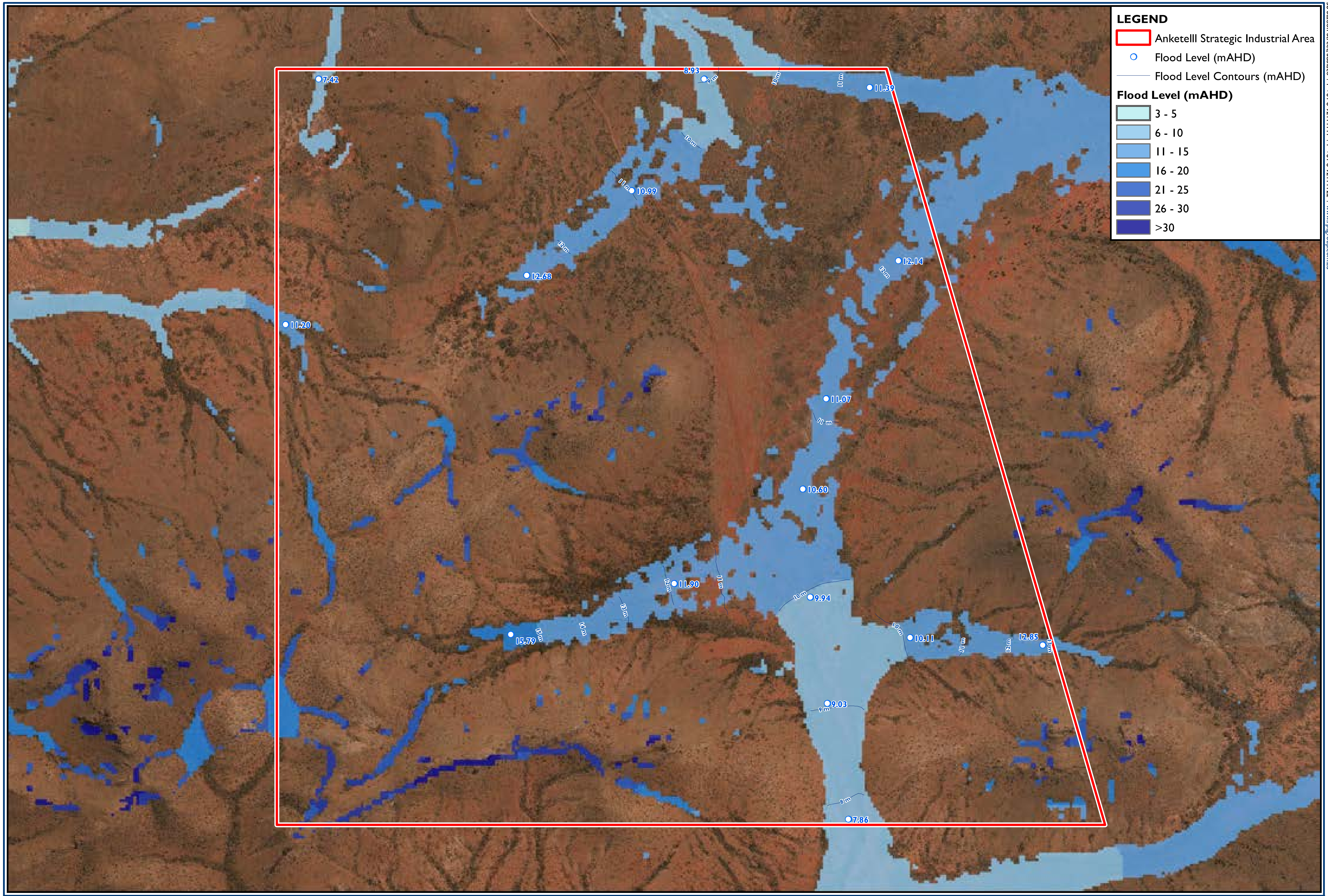


RPS

Job Number: L1305907
Doc Number: 010b
Date: 16.04.16
Scale: 1:8,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

Figure 10b

HIA1 Eastern Catchment Pre-development – 1% AEP Flood Level



RPS

Job Number: L1305907
Doc Number: 010c
Date: 16.04.16
Scale: 1:6,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50

0 0.05 0.1 0.2 km

Figure 10c

GIA Pre-development – 1% AEP Flood Level

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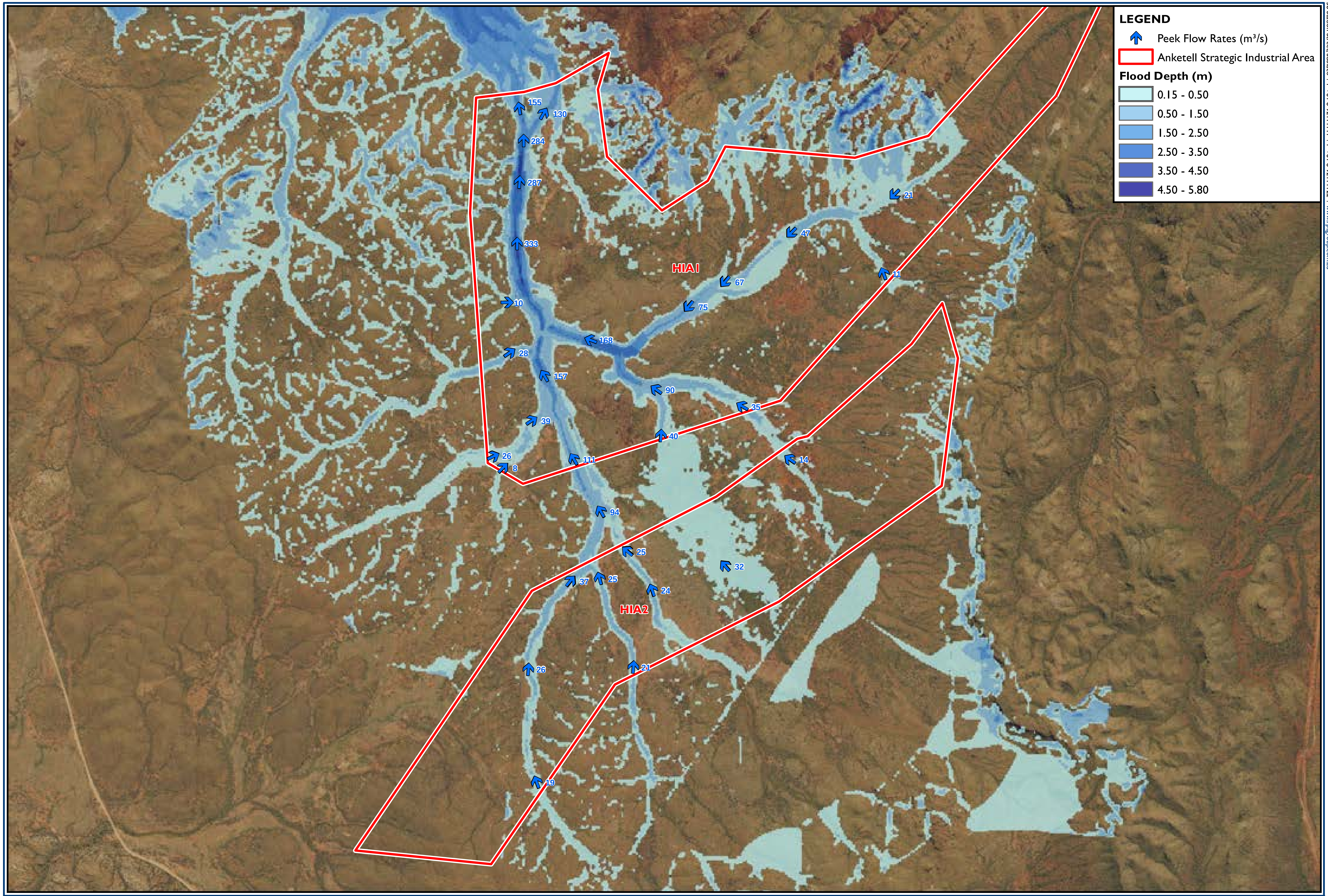

Figure 11a

Rocky Creek Catchment Pre-development – 1% AEP Peak Flow Rate

RPS

Job Number: L1305907
Doc Number: 011a
Date: 16.04.16
Scale: 1:23,344 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50

0 0.125 0.25 0.5 0.75 1 km

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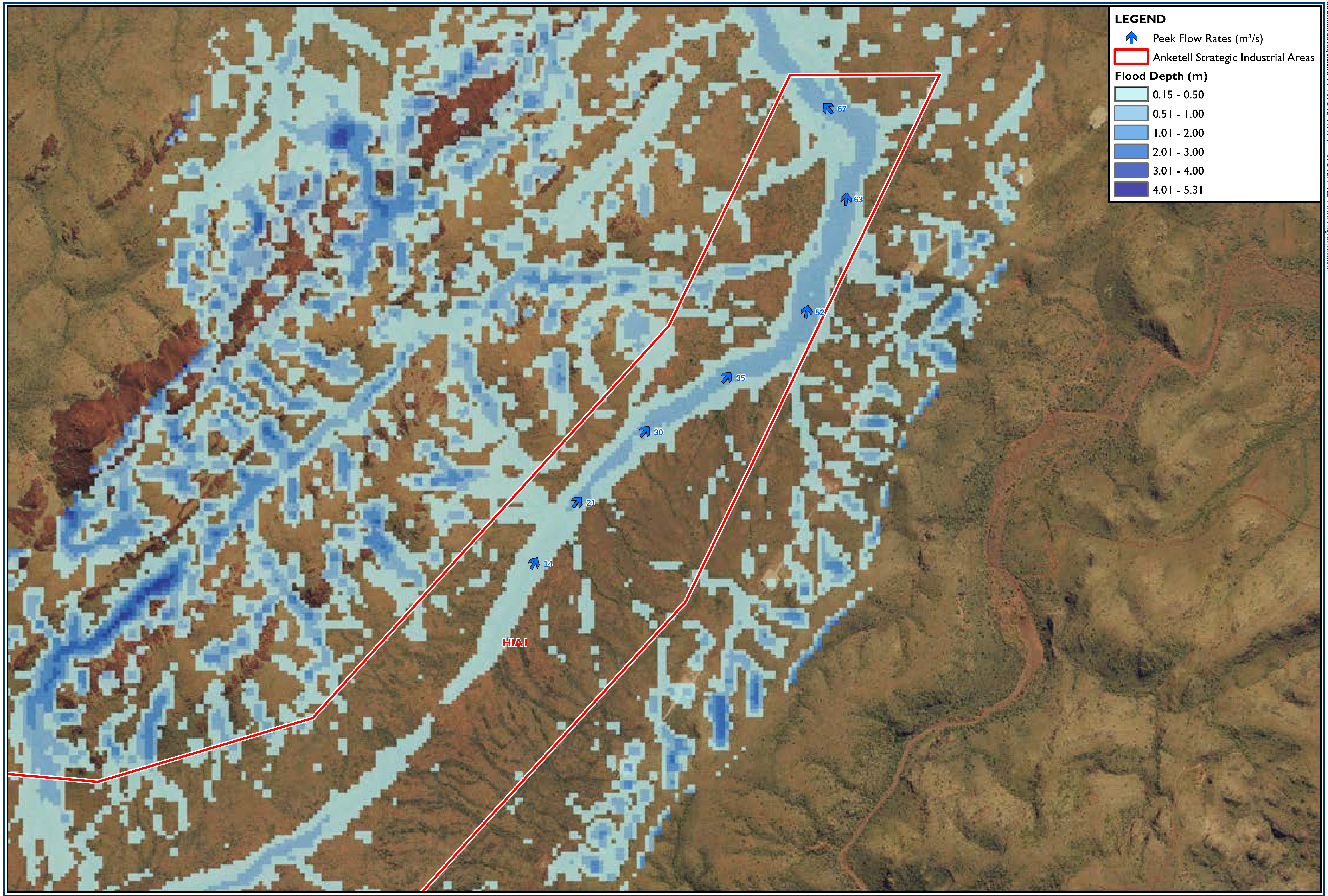

RPS

Job Number: L1305907
Doc Number: 011b
Date: 16.04.16
Scale: 1:8,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

Figure 11b

HIA1 Eastern Catchment Pre-development – 1% AEP Peak Flow Rate

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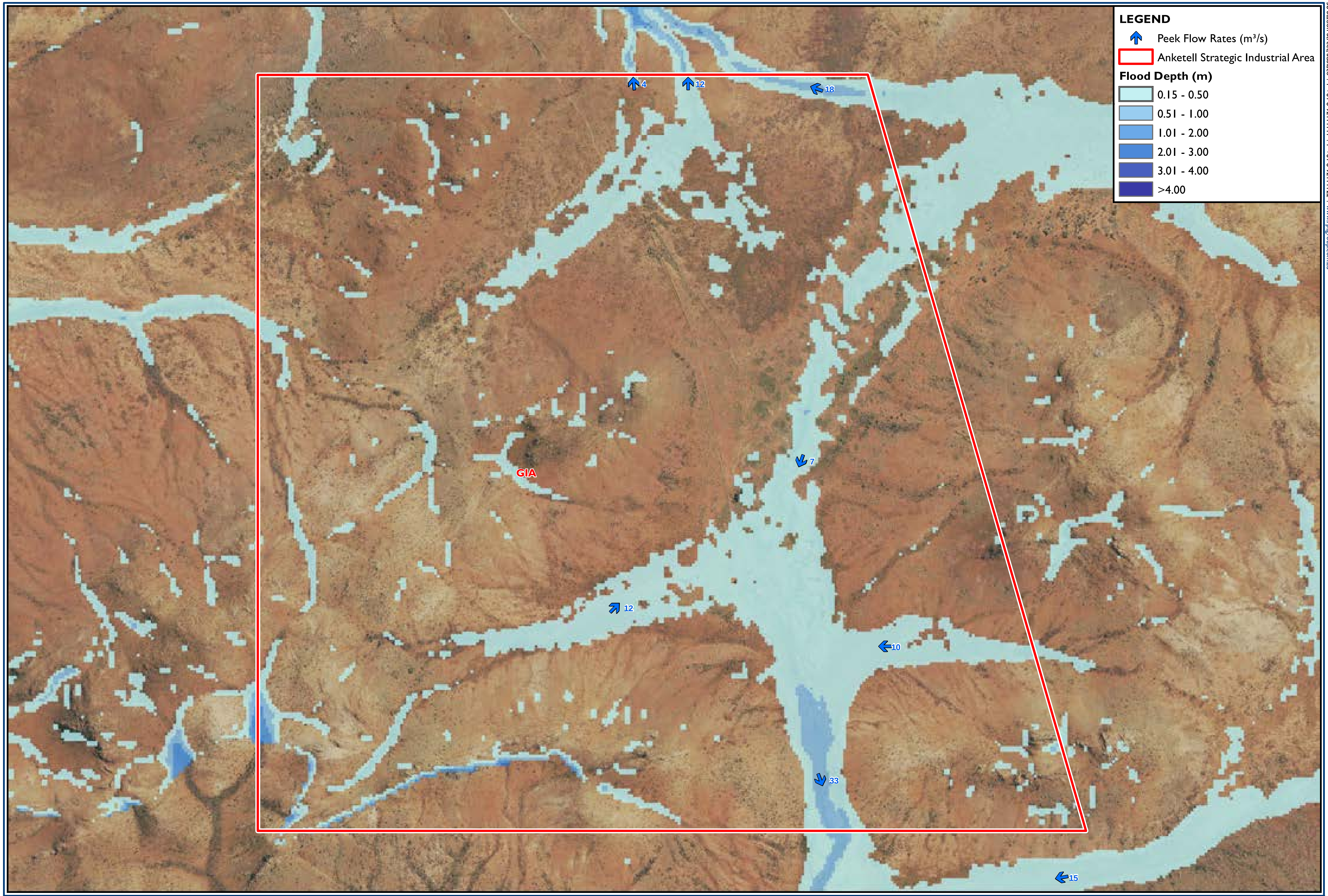

RPS

Job Number: L1305907
Doc Number: 011c
Date: 16.04.16
Scale: 1:6,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2013

Figure 11c

GIA Pre-development – 1% AEP Peak Flow Rate

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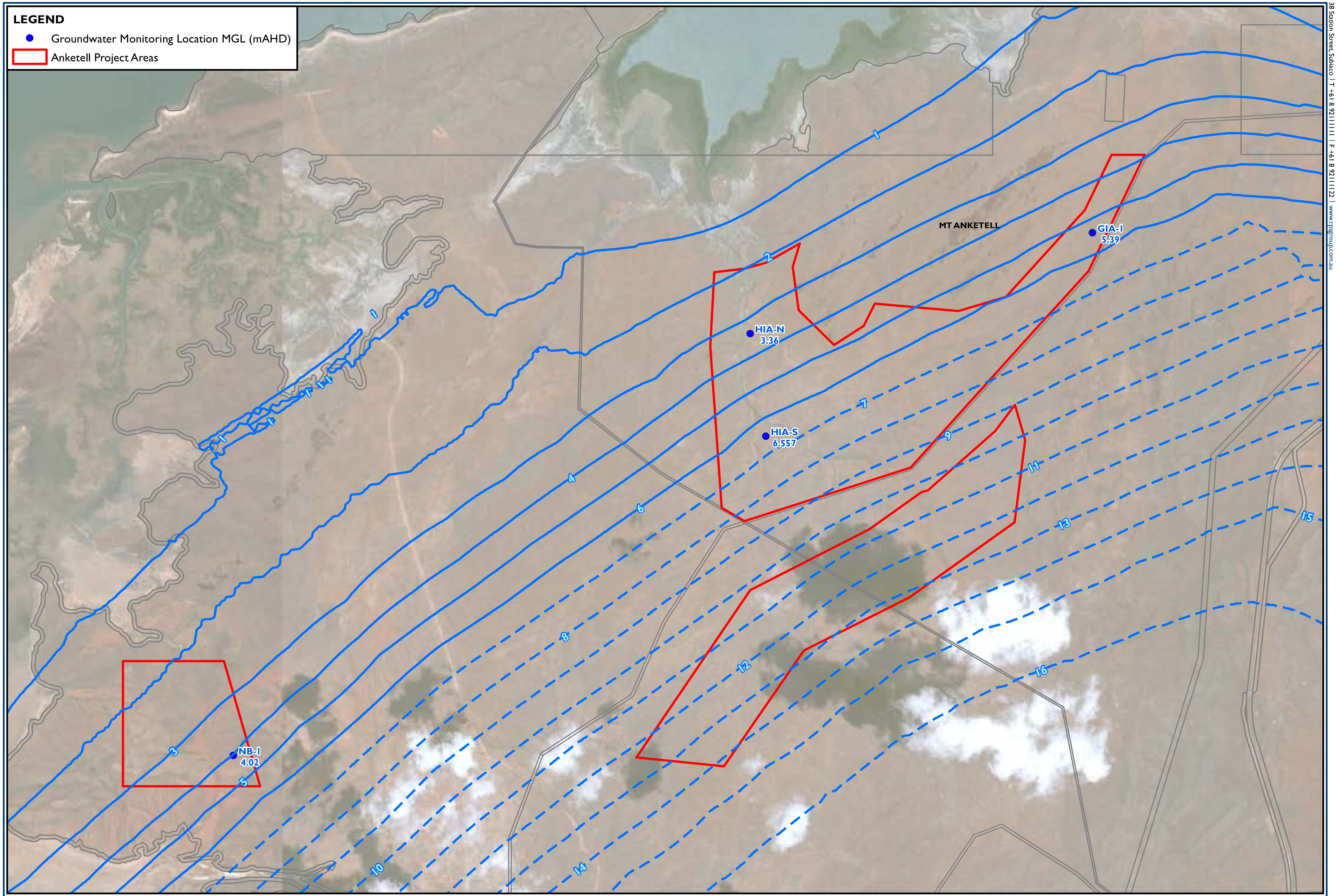

Job Number: L1305907
Doc Number: 012
Date: 16.04.16
Scale: 1:36,263 @ A3
Created by: MR
Source: Orthophoto - ESRI Online World Imagery

GDA 1994 MGA Zone 50

0 0.25 0.5 1 1.5 2 km

Figure 12

Maximum Groundwater Level (2014–2016 Wet Seasons)

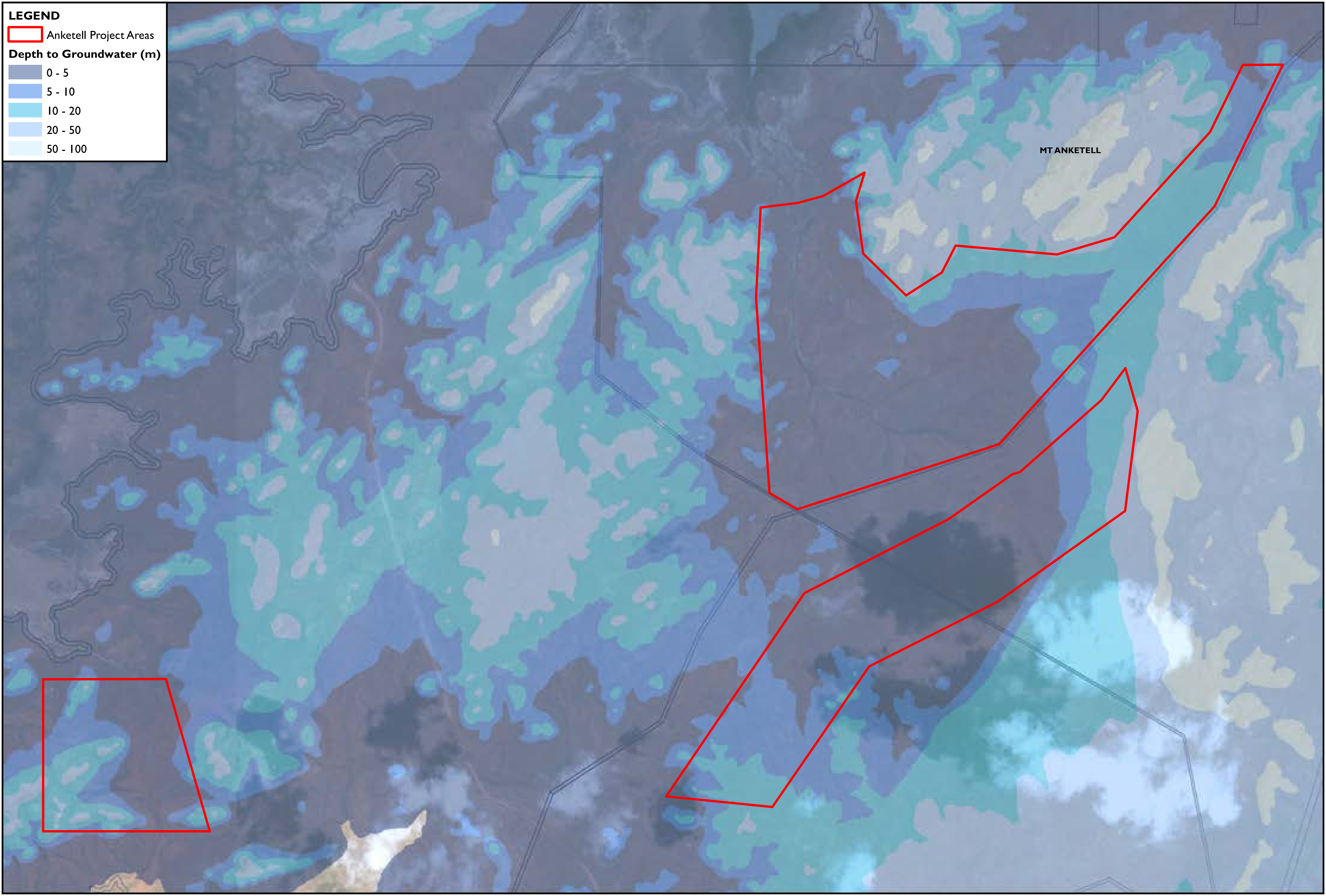

Figure 13

Depth to Maximum Groundwater Level (2014–2016 Wet Seasons)

Job Number: L1305907
Doc Number: 013
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MR
Source: Orthophoto - ESRI Online World Imagery

RPS
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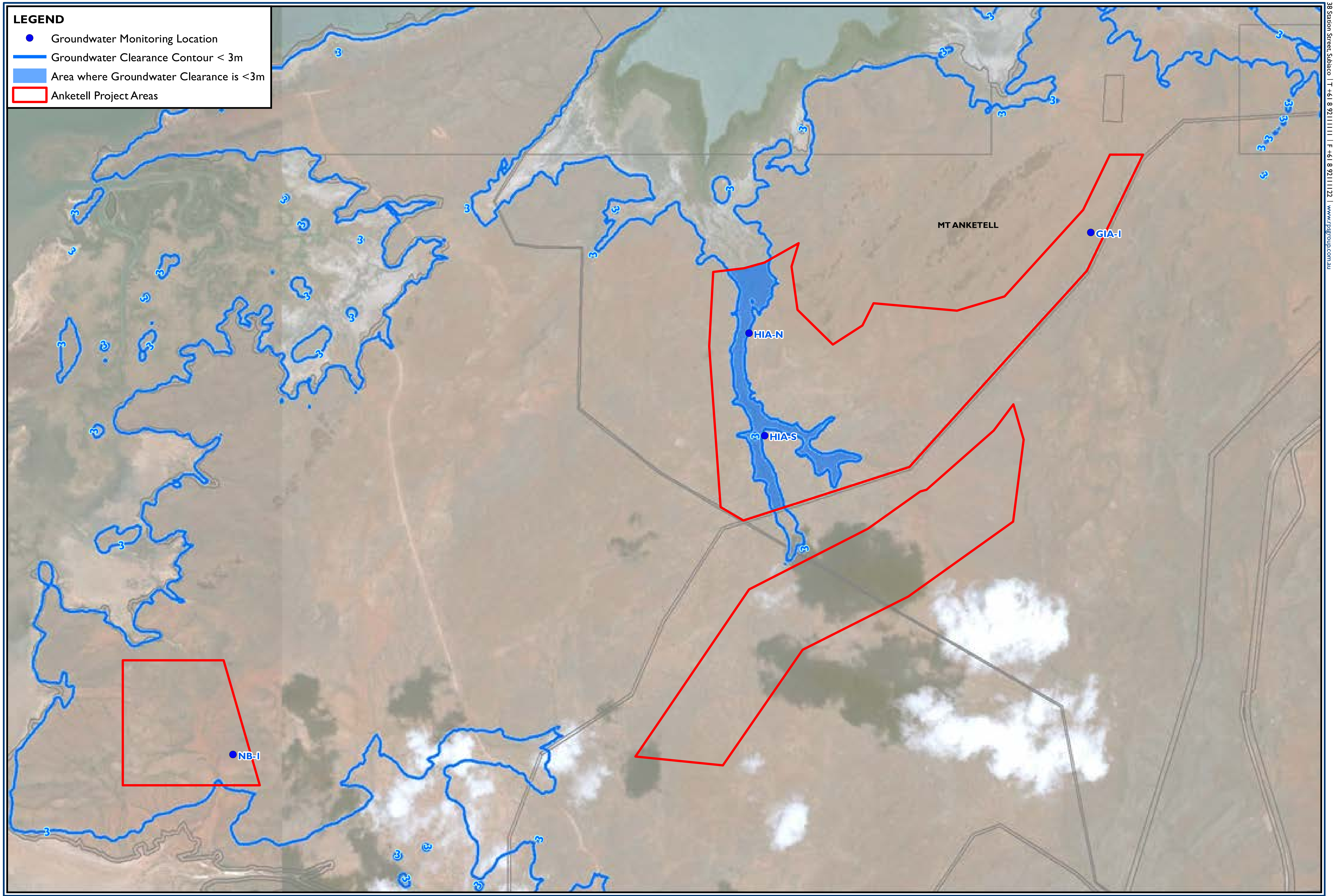


RPS

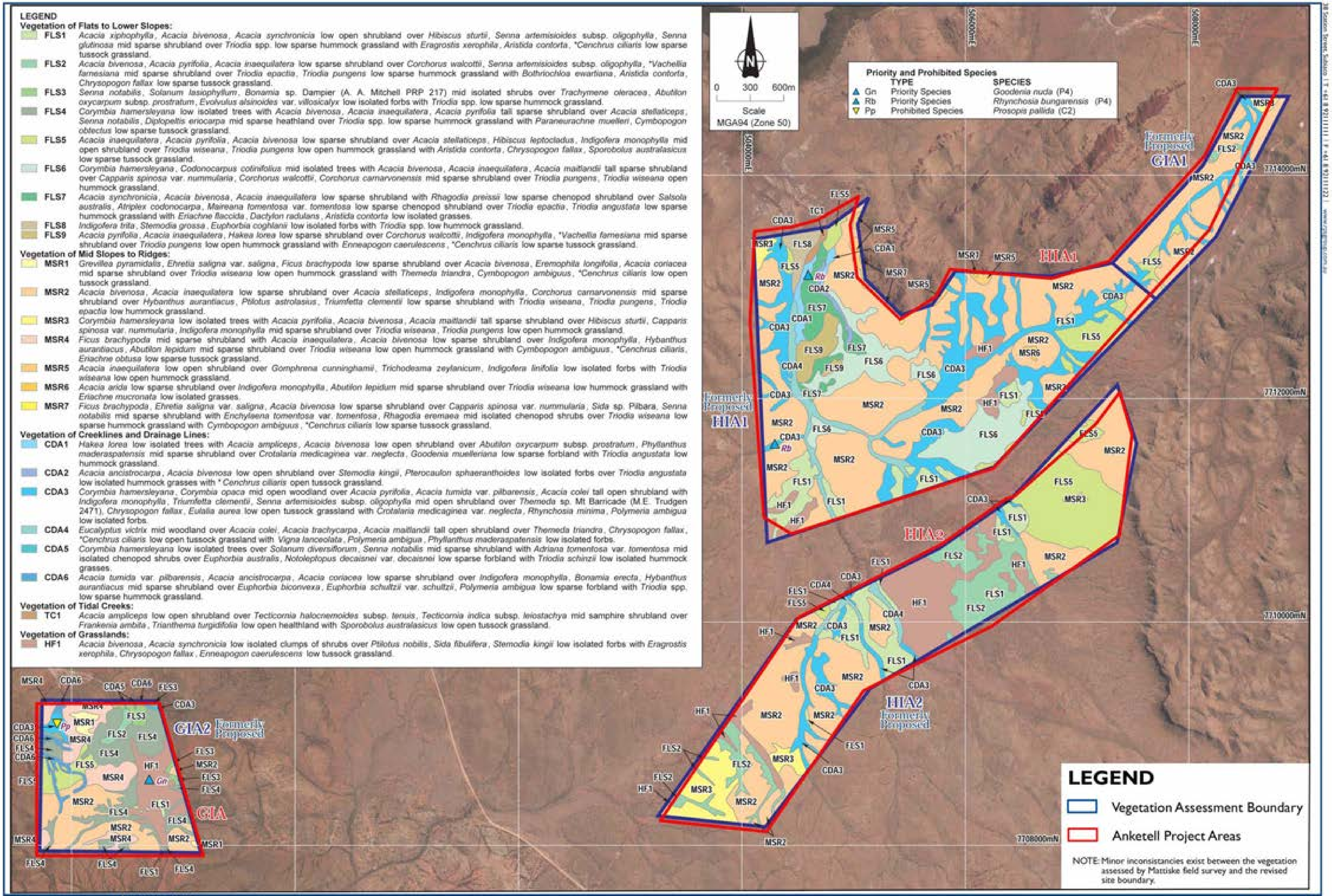
Job Number: L1305905
Doc Number: 014
Date: 16.04.16
Scale: 1:36,263 @ A3
Created by: MR
Source: Orthophoto - ESRI Online World Imagery

GDA 1994 MGA Zone 50

0 0.25 0.5 1 1.5 2 km

Figure 14

Groundwater Clearance < 3 m (2014–2016 Wet Seasons)



LEGEND

Vegetation of Flats to Lower Slopes:

🟩	**FLS1**	*Acacia xiphophylla*, *Acacia bivenosa*, *Acacia synchronicia* low open shrubland over *Hibiscus sturtii*, *Senna artemisioides* subsp. *oligophylla*, *Senna glutinosa* mid sparse shrubland over *Triodia* spp. low sparse hummock grassland with *Eragrostis xerophila*, *Aristida contorta*, *Cenchrus ciliaris* low sparse tussock grassland.
🟩	**FLS2**	*Acacia bivenosa*, *Acacia pyrifolia*, *Acacia inaequilatera* low sparse shrubland over *Corchorus walcottii*, *Senna artemisioides* subsp. *oligophylla*, *Vachellia farnesiana* mid sparse shrubland over *Triodia epactia*, *Triodia pungens* low sparse hummock grassland with *Bothriochloa ewartiana*, *Aristida contorta*, *Chrysopogon fallax* low sparse tussock grassland.
🟩	**FLS3**	*Senna notabilis*, *Solanum lasiophyllum*, *Bonamia* sp. Dampier (A. A. Mitchell PRP 217) mid isolated shrubs over *Trachymene oleracea*, *Abutilon oxycarpum* subsp. *prostratum*, *Evolvulus alsinoides* var. *villosicalyx* low isolated forbs with *Triodia* spp. low sparse hummock grassland.
🟩	**FLS4**	*Corymbia hamersleyana* low isolated trees with *Acacia bivenosa*, *Acacia inaequilatera*, *Acacia pyrifolia* tall sparse shrubland over *Acacia stellaticeps*, *Senna notabilis*, *Diplopeltis eriocarpa* mid sparse heathland over *Triodia* spp. low sparse hummock grassland with *Paraneurachne muelleri*, *Cymbopogon obtectus* low sparse tussock grassland.
🟩	**FLS5**	*Acacia inaequilatera*, *Acacia pyrifolia*, *Acacia bivenosa* low sparse shrubland over *Acacia stellaticeps*, *Hibiscus leptocladus*, *Indigofera monophylla* mid open shrubland over *Triodia wiseana*, *Triodia pungens* low open hummock grassland with *Aristida contorta*, *Chrysopogon fallax*, *Sporobolus australasicus* low sparse tussock grassland.
🟩	**FLS6**	*Corymbia hamersleyana*, *Codonocarpus cotinifolius* mid isolated trees with *Acacia bivenosa*, *Acacia inaequilatera*, *Acacia maitlandii* tall sparse shrubland over *Capparis spinosa* var. *nummularia*, *Corchorus walcottii*, *Corchorus carnarvonensis* mid sparse shrubland over *Triodia pungens*, *Triodia wiseana* open hummock grassland.
🟩	**FLS7**	*Acacia synchronicia*, *Acacia bivenosa*, *Acacia inaequilatera* low sparse shrubland with *Rhagodia preissii* low sparse chenopod shrubland over *Salsola australis*, *Atriplex codonocarpa*, *Maireana tomentosa* var. *tomentosa* low sparse chenopod shrubland over *Triodia epactia*, *Triodia angustata* low sparse hummock grassland with *Eriachne flaccida*, *Dactylon radulans*, *Aristida contorta* low isolated grasses.
🟫	**FLS8**	*Indigofera trita*, *Stemodia grossa*, *Euphorbia coghlanii* low isolated forbs with *Triodia* spp. low hummock grassland.
🟫	**FLS9**	*Acacia pyrifolia*, *Acacia inaequilatera*, *Hakea lorea* low sparse shrubland over *Corchorus walcottii*, *Indigofera monophylla*, *Vachellia farnesiana* mid sparse shrubland over *Triodia pungens* low open hummock grassland with *Enneapogon caerulescens*, *Cenchrus ciliaris* low sparse tussock grassland.

Vegetation of Mid Slopes to Ridges:

🟨	**MSR1**	*Grevillea pyramidalis*, *Ehretia saligna* var. *saligna*, *Ficus brachypoda* low sparse shrubland over *Acacia bivenosa*, *Eremophila longifolia*, *Acacia coriacea* mid sparse shrubland over *Triodia wiseana* low open hummock grassland with *Themeda triandra*, *Cymbopogon ambiguus*, *Cenchrus ciliaris* low open tussock grassland.
🟧	**MSR2**	*Acacia bivenosa*, *Acacia inaequilatera* low sparse shrubland over *Acacia stellaticeps*, *Indigofera monophylla*, *Corchorus carnarvonensis* mid sparse shrubland over *Hybanthus aurantiacus*, *Ptilotus astrolasius*, *Triumfetta clementii* low sparse shrubland with *Triodia wiseana*, *Triodia pungens*, *Triodia epactia* low hummock grassland.
🟨	**MSR3**	*Corymbia hamersleyana* low isolated trees with *Acacia pyrifolia*, *Acacia bivenosa*, *Acacia maitlandii* tall sparse shrubland over *Hibiscus sturtii*, *Capparis spinosa* var. *nummularia*, *Indigofera monophylla* mid sparse shrubland over *Triodia wiseana*, *Triodia pungens* low open hummock grassland.
🟧	**MSR4**	*Ficus brachypoda* mid sparse shrubland with *Acacia inaequilatera*, *Acacia bivenosa* low sparse shrubland over *Indigofera monophylla*, *Hybanthus aurantiacus*, *Abutilon lepidum* mid sparse shrubland over *Triodia wiseana* low open hummock grassland with *Cymbopogon ambiguus*, *Cenchrus ciliaris*, *Eriachne obtusa* low sparse tussock grassland.
🟧	**MSR5**	*Acacia inaequilatera* low open shrubland over *Gomphrena cunninghamii*, *Trichodesma zeylanicum*, *Indigofera linifolia* low isolated forbs with *Triodia wiseana* low open hummock grassland.
🟧	**MSR6**	*Acacia arida* low sparse shrubland over *Indigofera monophylla*, *Abutilon lepidum* mid sparse shrubland over *Triodia wiseana* low hummock grassland with *Eriachne mucronata* low isolated grasses.
🟨	**MSR7**	*Ficus brachypoda*, *Ehretia saligna* var. *saligna*, *Acacia bivenosa* low sparse shrubland over *Capparis spinosa* var. *nummularia*, *Sida* sp. Pilbara, *Senna notabilis* mid sparse shrubland with *Enchylaena tomentosa* var. *tomentosa*, *Rhagodia eremaea* mid isolated chenopod shrubs over *Triodia wiseana* low sparse hummock grassland with *Cymbopogon ambiguus*, *Cenchrus ciliaris* low sparse tussock grassland.

Vegetation of Creeklines and Drainage Lines:

🟦	**CDA1**	*Hakea lorea* low isolated trees with *Acacia ampliceps*, *Acacia bivenosa* low open shrubland over *Abutilon oxycarpum* subsp. *prostratum*, *Phyllanthus maderaspatensis* mid sparse shrubland over *Crotalaria medicaginea* var. *neglecta*, *Goodenia muelleriana* low sparse forbland with *Triodia angustata* low hummock grassland.
🟦	**CDA2**	*Acacia ancistrocarpa*, *Acacia bivenosa* low open shrubland over *Stemodia kingii*, *Pterocaulon sphaeranthoides* low isolated forbs over *Triodia angustata* low isolated hummock grasses with * *Cenchrus ciliaris* open tussock grassland.
🟦	**CDA3**	*Corymbia hamersleyana*, *Corymbia opaca* mid open woodland over *Acacia pyrifolia*, *Acacia tumida* var. *pilbarensis*, *Acacia colei* tall open shrubland with *Indigofera monophylla*, *Triumfetta clementii*, *Senna artemisioides* subsp. *oligophylla* mid open shrubland over *Themeda* sp. Mt Barricade (M.E. Trudgen 2471), *Chrysopogon fallax*, *Eulalia aurea* low open tussock grassland with *Crotalaria medicaginea* var. *neglecta*, *Rhynchosia minima*, *Polymeria ambigua* low isolated forbs.
🟦	**CDA4**	*Eucalyptus victrix* mid woodland over *Acacia colei*, *Acacia trachycarpa*, *Acacia maitlandii* tall open shrubland over *Themeda triandra*, *Chrysopogon fallax*, *Cenchrus ciliaris* low open tussock grassland with *Vigna lanceolata*, *Polymeria ambigua*, *Phyllanthus maderaspatensis* low isolated forbs.
🟦	**CDA5**	*Corymbia hamersleyana* low isolated trees over *Solanum diversiflorum*, *Senna notabilis* mid sparse shrubland with *Adriana tomentosa* var. *tomentosa* mid isolated chenopod shrubs over *Euphorbia australis*, *Notoleptopus decaisnei* var. *decaisnei* low sparse forbland with *Triodia schinzii* low isolated hummock grasses.
🟦	**CDA6**	*Acacia tumida* var. *pilbarensis*, *Acacia ancistrocarpa*, *Acacia coriacea* low sparse shrubland over *Indigofera monophylla*, *Bonamia erecta*, *Hybanthus aurantiacus* mid sparse shrubland over *Euphorbia biconvexa*, *Euphorbia schultzii* var. *schultzii*, *Polymeria ambigua* low sparse forbland with *Triodia* spp. low sparse hummock grassland.

Vegetation of Tidal Creeks:

🟫	**TC1**	*Acacia ampliceps* low open shrubland over *Tecticornia halocnemoides* subsp. *tenuis*, *Tecticornia indica* subsp. *leiostachya* mid samphire shrubland over *Frankenia ambita*, *Trianthema turgidifolia* low open healthland with *Sporobolus australasicus* low open tussock grassland.

Vegetation of Grasslands:

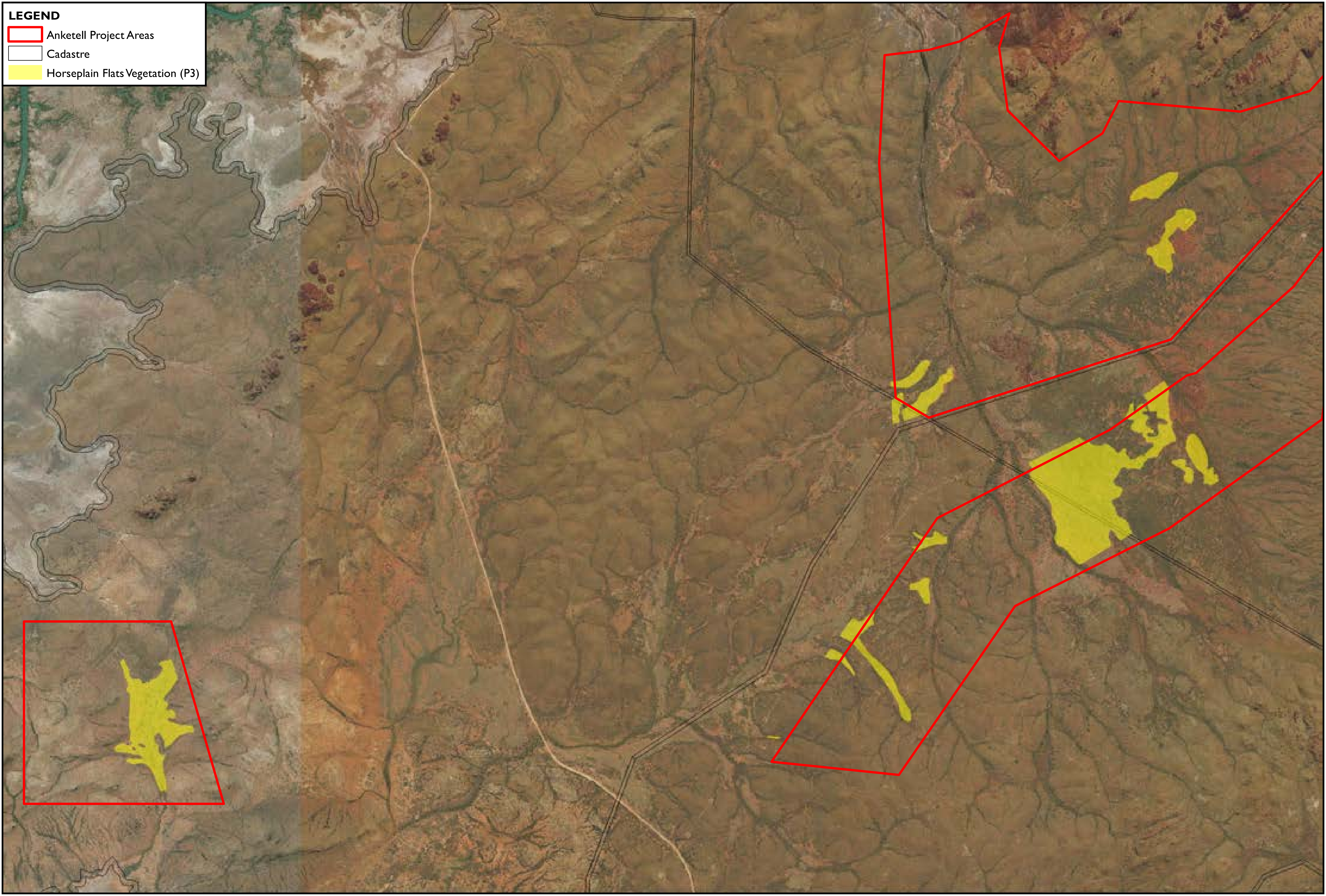
🟫	**HF1**	*Acacia bivenosa*, *Acacia synchronicia* low isolated clumps of shrubs over *Ptilotus nobilis*, *Sida fibulifera*, *Stemodia kingii* low isolated forbs with *Eragrostis xerophila*, *Chrysopogon fallax*, *Enneapogon caerulescens* low tussock grassland.

RPS

Job Number: L1305907
Doc Number: 015
Date: 16.04.16
Scale: Not to Scale @ A3
Created by: HA
Source: Vegetation - Mattiske Consulting, Aug 2013

Figure 15

Vegetation



RPS

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Doc Number: 016
Date: 16.04.16
Scale: 1:25,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

Figure 16

Horseplain Flats Vegetation (P3)

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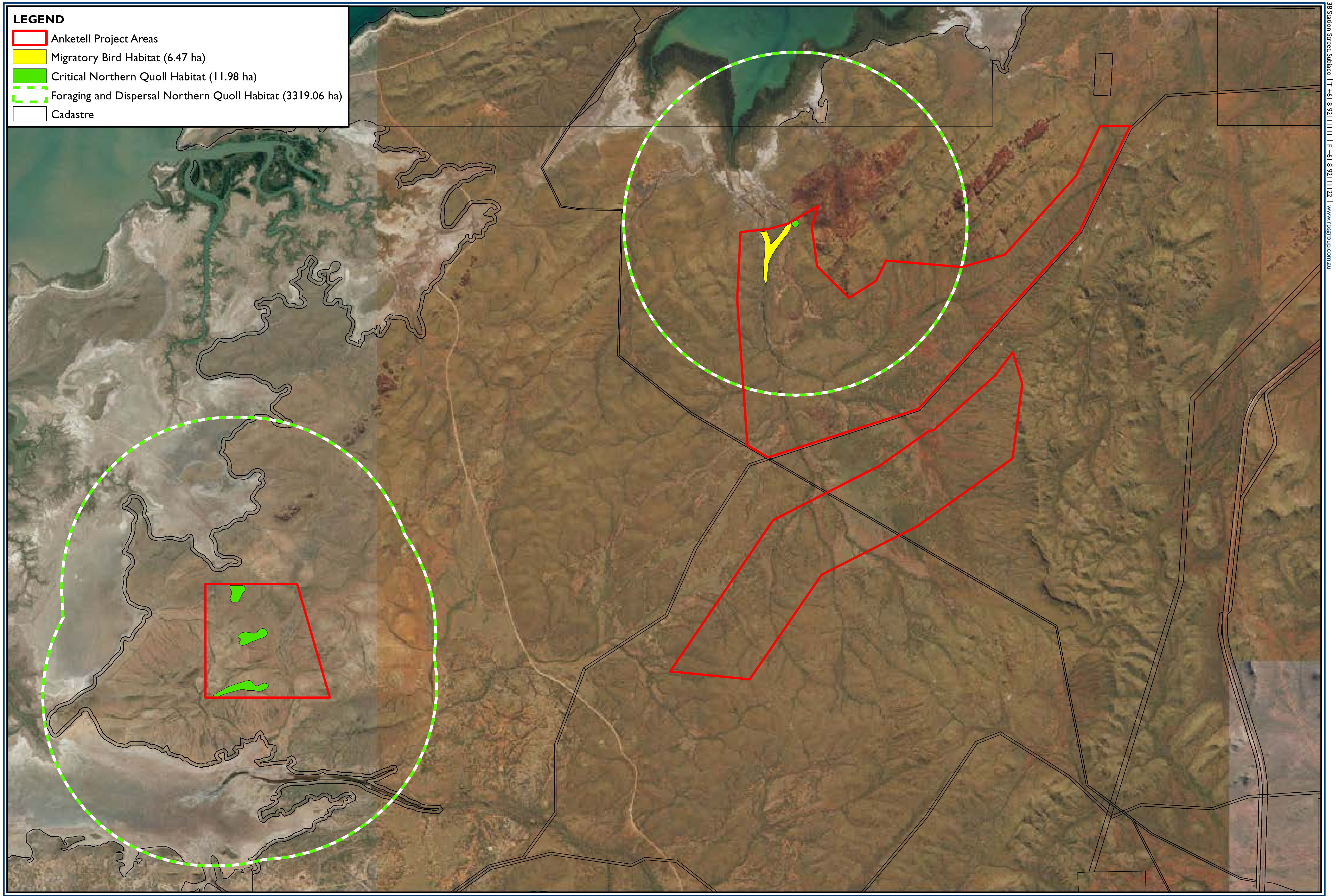


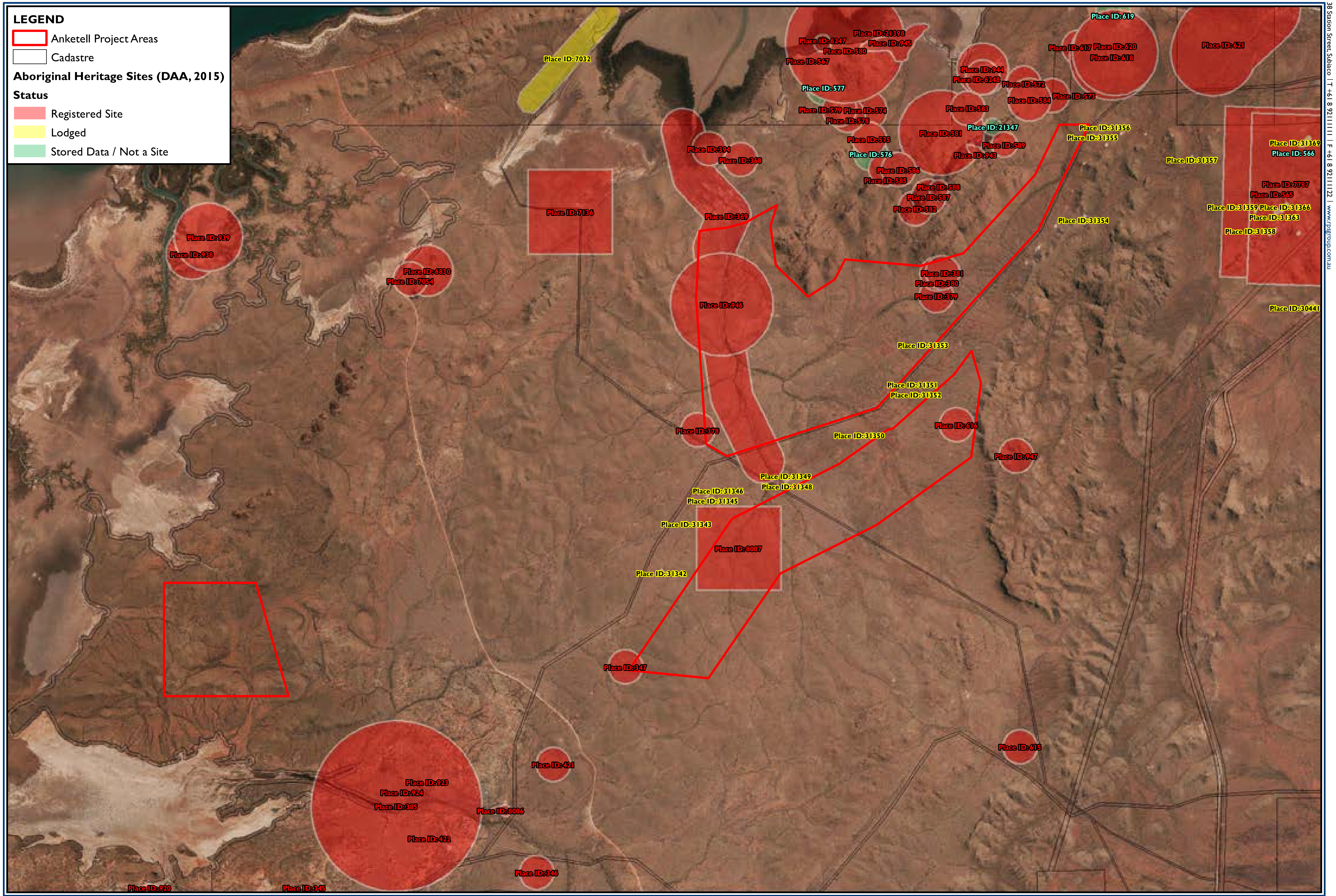
RPS

Job Number: L1305907
Doc Number: 017
Date: 16.04.16
Scale: 1:40,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre and Contours - Landgate, 2013 Fauna - Terrestrial Ecosystems, 2013

GDA 1994 MGA Zone 50

Figure 17

Significant Fauna Habitat



RPS

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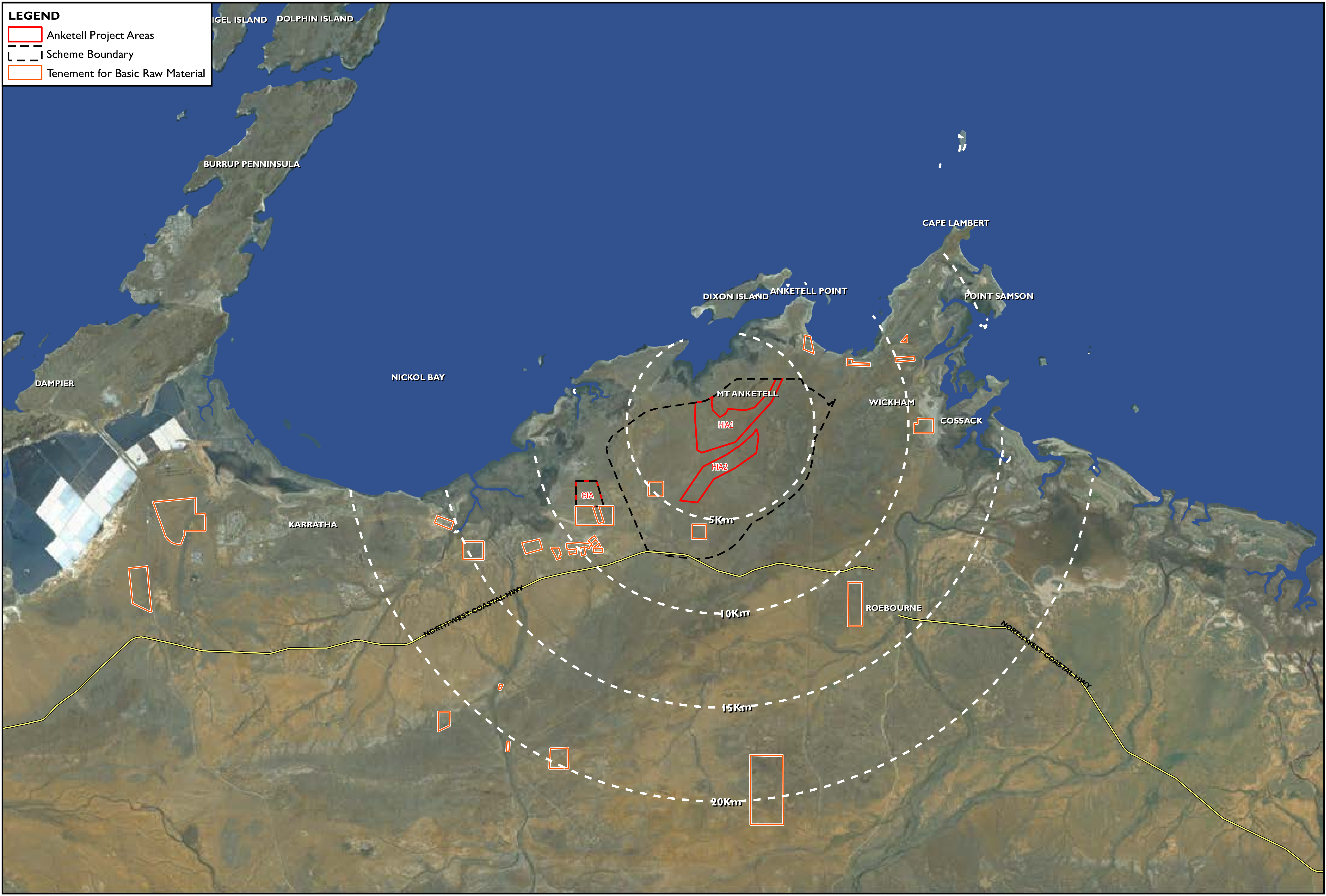
Doc Number: 018
Date: 16.04.16
Scale: 1:40,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre and Contours - Landgate, 2013

GDA 1994 MGA Zone 50
0 0.25 0.5 1 1.5 2 km

Figure 18

Aboriginal Heritage



RPS

Job Number: L1305907
Doc Number: 019
Date: 16.04.16
Scale: 1:180,000 @ A3
Created by: MR
Source: Orthophoto - ESRI Online

GDA 1994 MGA Zone 50
0 1.25 2.5 5 7.5 10 km

Figure 19

Proximity to Raw Fill Material

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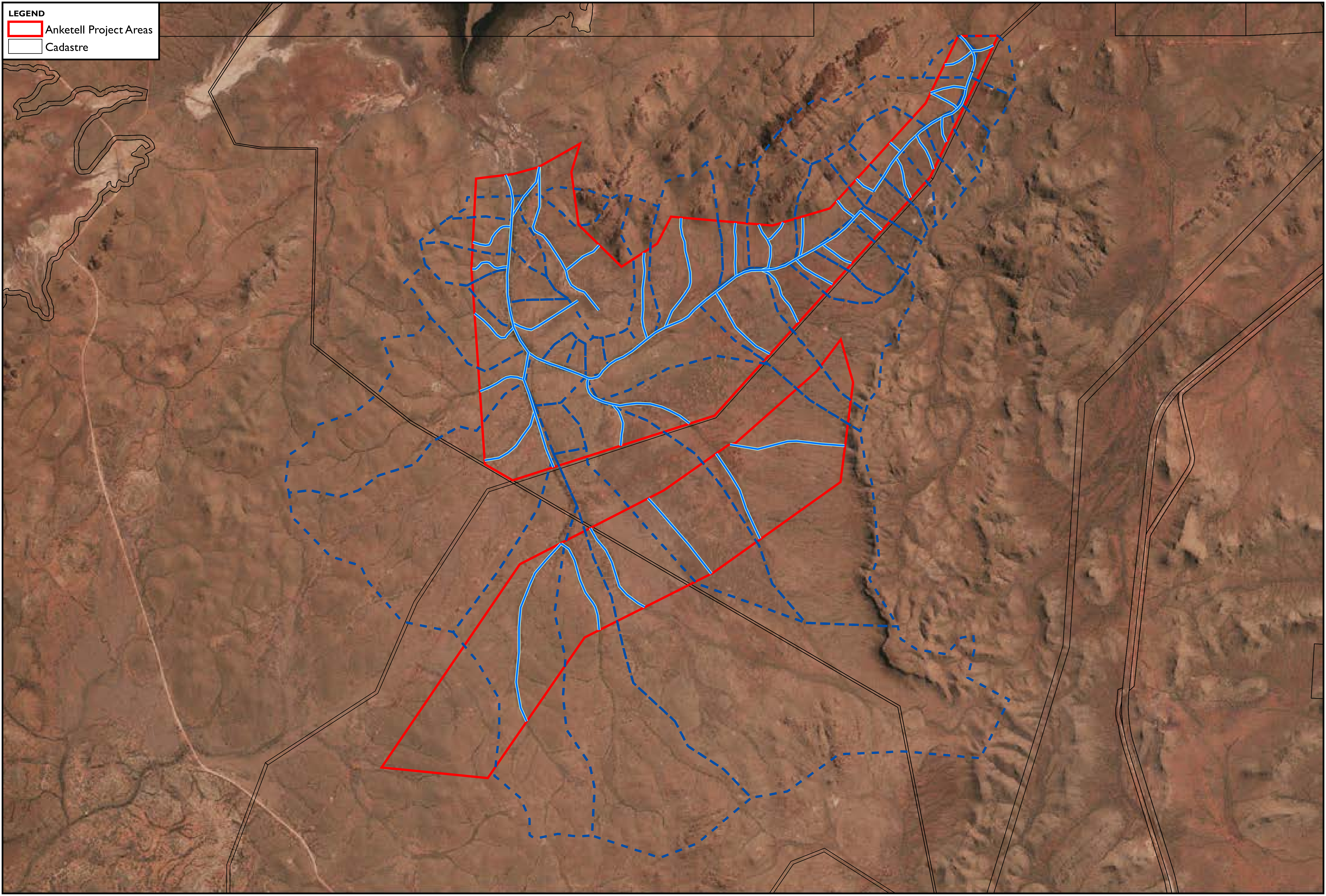

Figure 20

Potential Arterial Drainage Corridor Locations

RPS

Job Number: L1305907
Doc Number: 020
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MR
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

GDA 1994 MGA Zone 50

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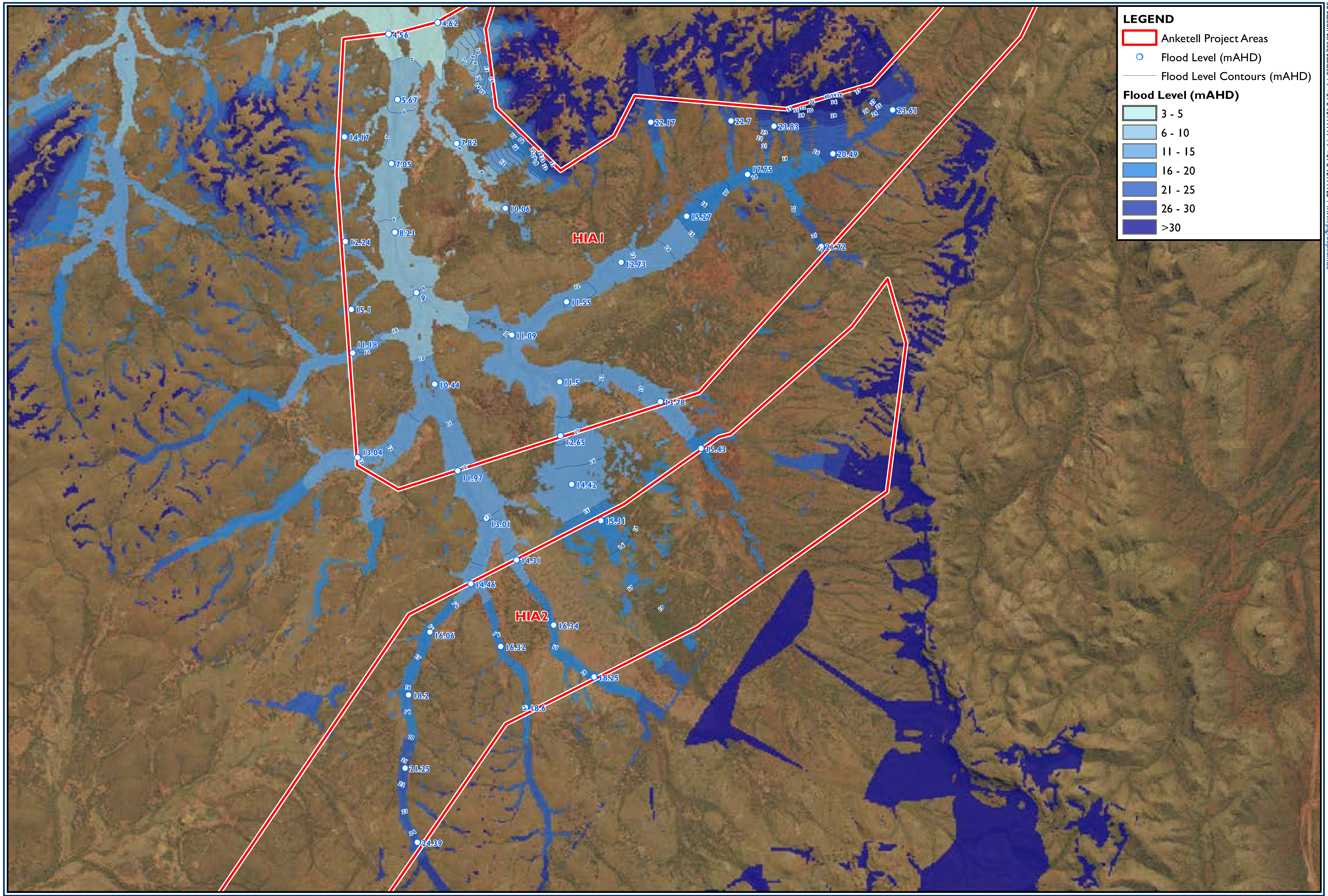


RPS

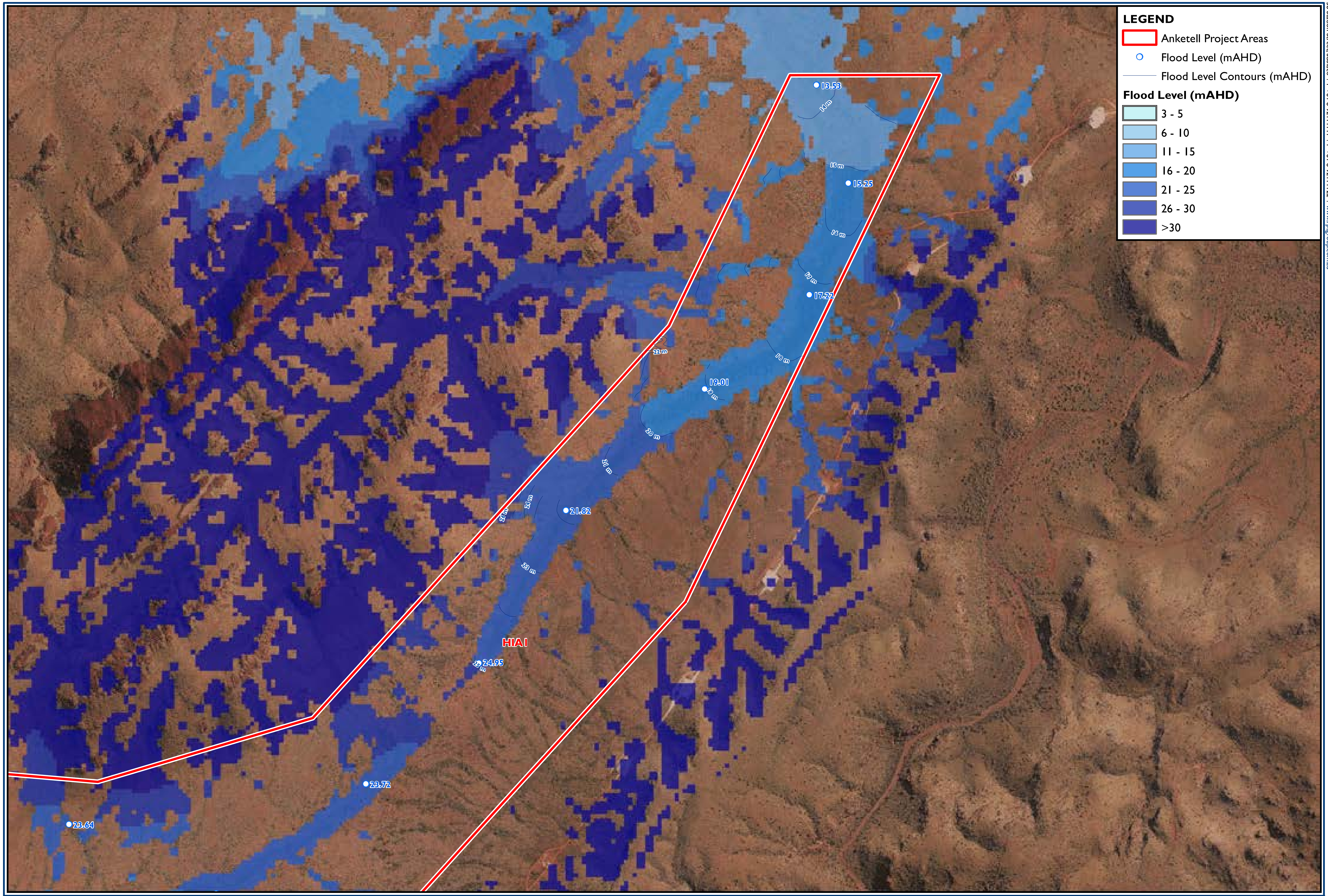
Job Number: L1305907
Doc Number: 021a
Date: 16.04.16
Scale: 1:20,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50

0 0.125 0.25 0.5 0.75 1 km

Figure 21a

Rocky Creek Catchment Indicative Post-development 1% AEP Flood Level



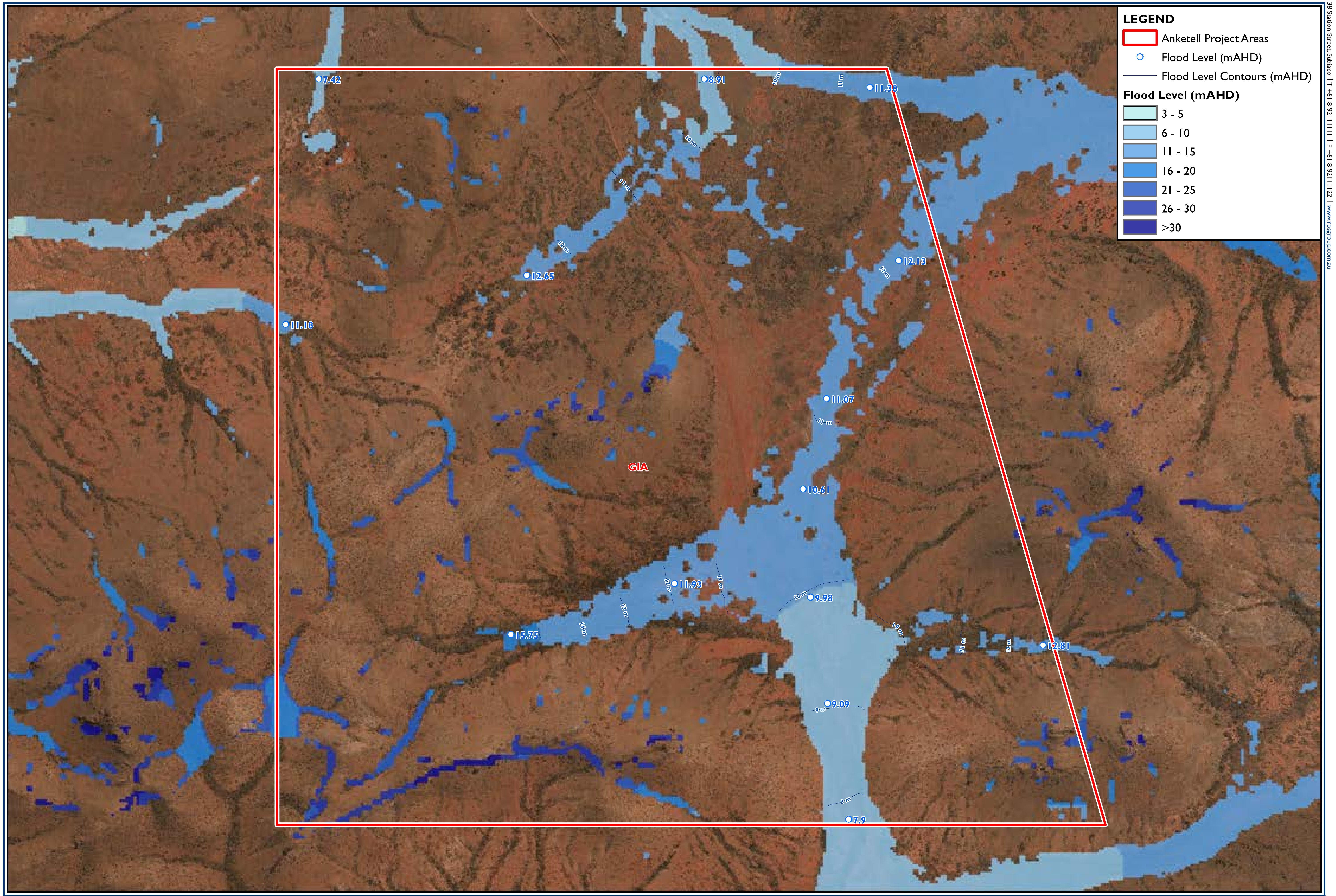
RPS

Job Number: L1305907
Doc Number: 021b
Date: 16.04.16
Scale: 1:8,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50

Figure 21b

HIA1 Eastern Catchment Indicative Post-development 1% AEP Flood Level



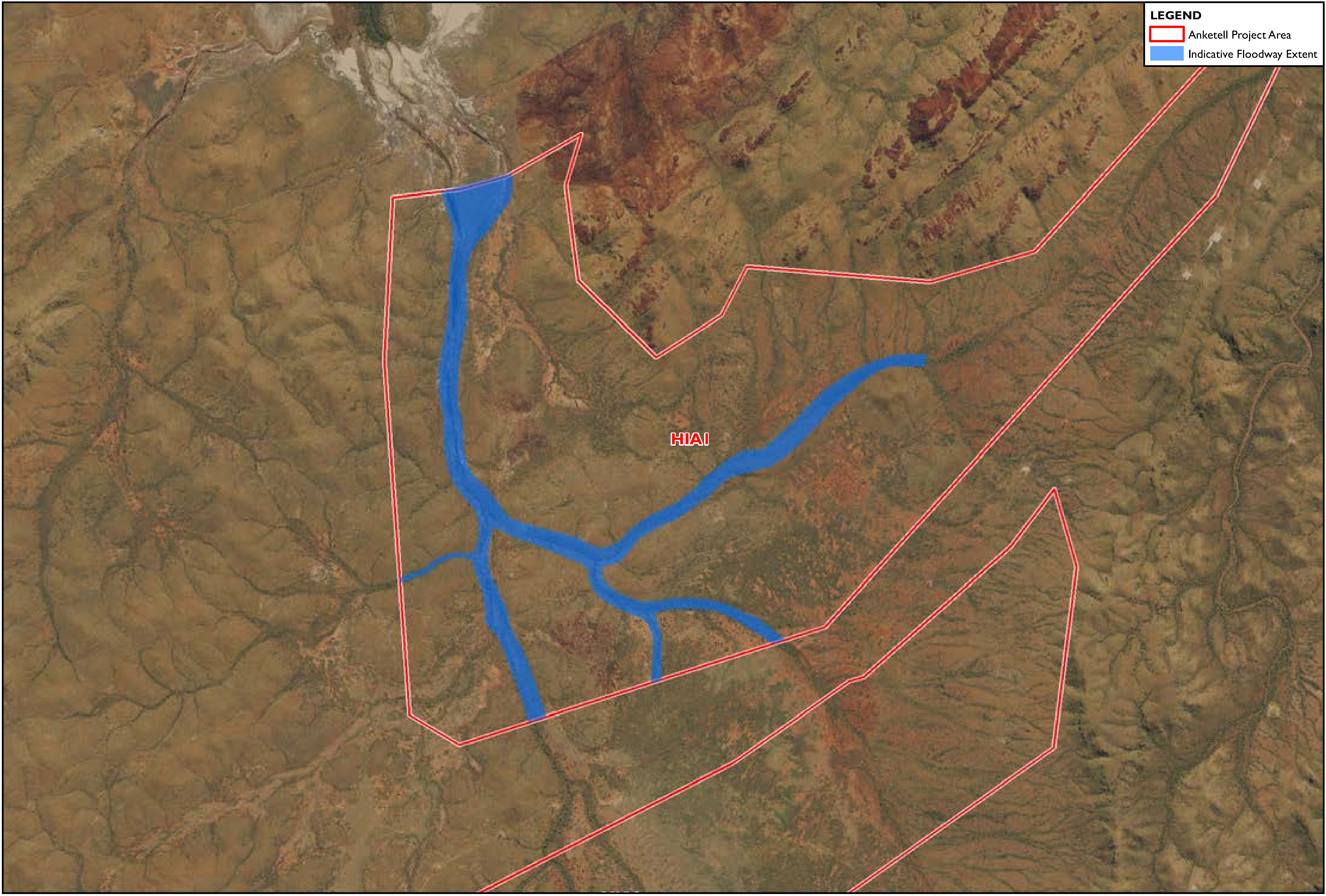
RPS

Job Number: L1305907
Doc Number: 021c
Date: 16.04.16
Scale: 1:6,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50
0 0.05 0.1 0.2 km

Figure 21c

GIA Indicative Post-development 1% AEP Flood Level



RPS

Job Number: L1305907
Doc Number: 022
Date: 16.04.16
Scale: 1:16,550 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50

0 0.125 0.25 0.5 0.75 1 km

Figure 22

Rocky Creek Catchment Indicative Floodway Extent

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RPS

Job Number: L1305907
Doc Number: 023
Date: 16.04.16
Scale: 1:15,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

Figure 23

HIA1 Eastern Catchment Indicative Floodway Extent

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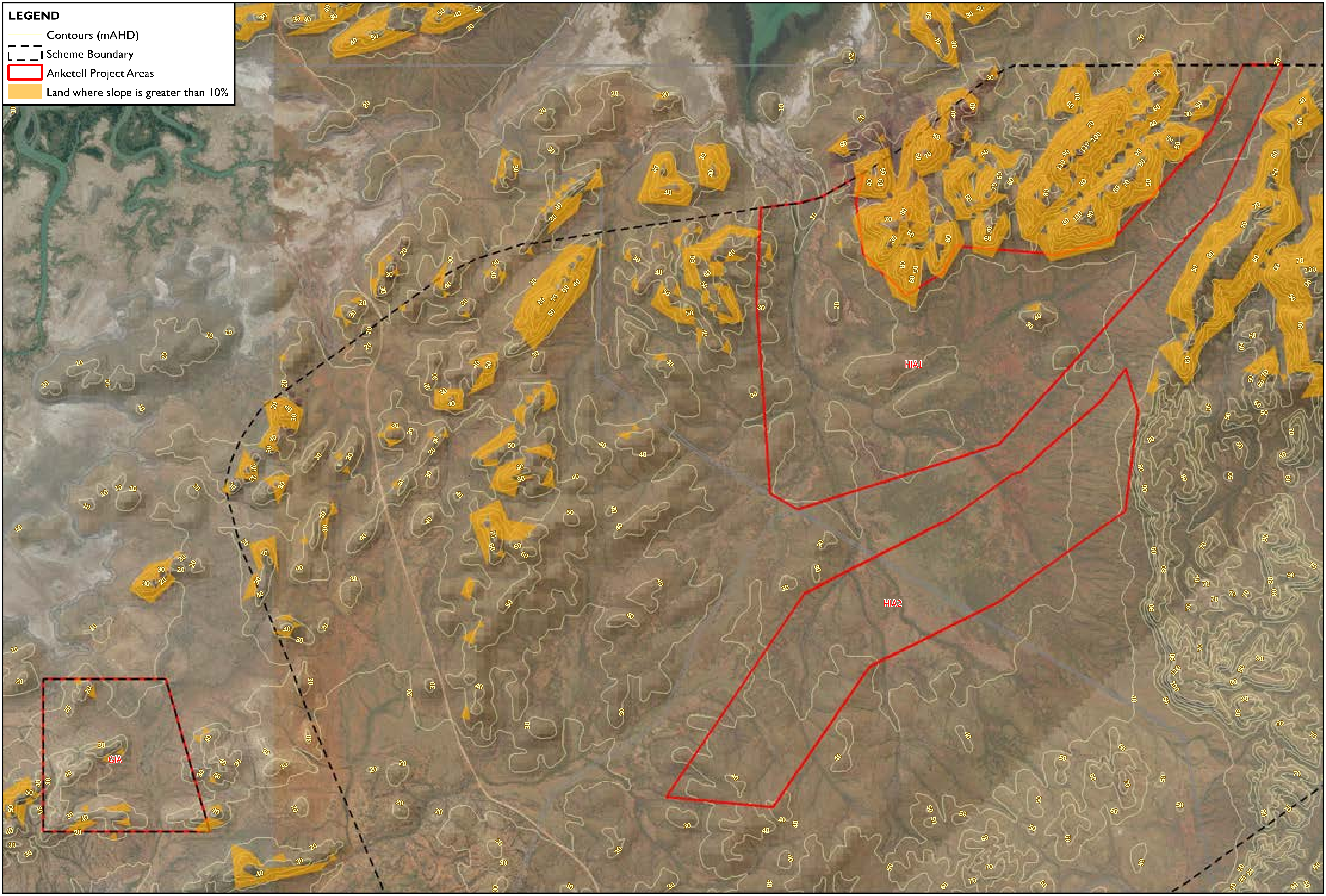

RPS

Job Number: L1305907
Doc Number: 024
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MR
Source: Orthophoto - Landgate, Cadastre - Landgate, 2013

GDA 1994 MGA Zone 50

0 0.25 0.5 1 1.5 2 km

Figure 24

Topography - Areas of Land Slope > 10%

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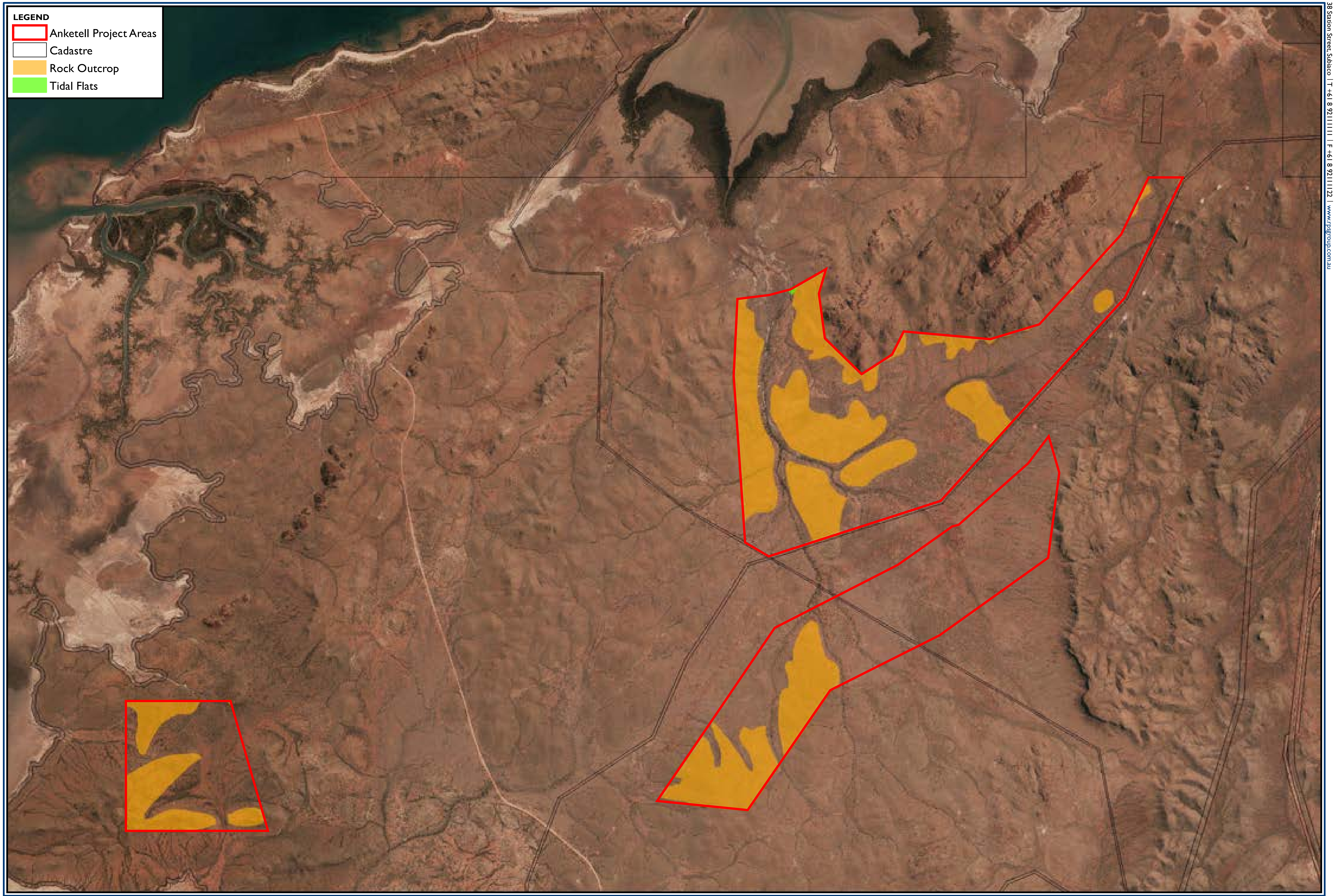

Figure 25

Potential Geotechnical Constraints

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Job Number: L1305907
Doc Number: 025
Date: 16.04.16
Scale: 1:35,000 @ A3
Created by: MR
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

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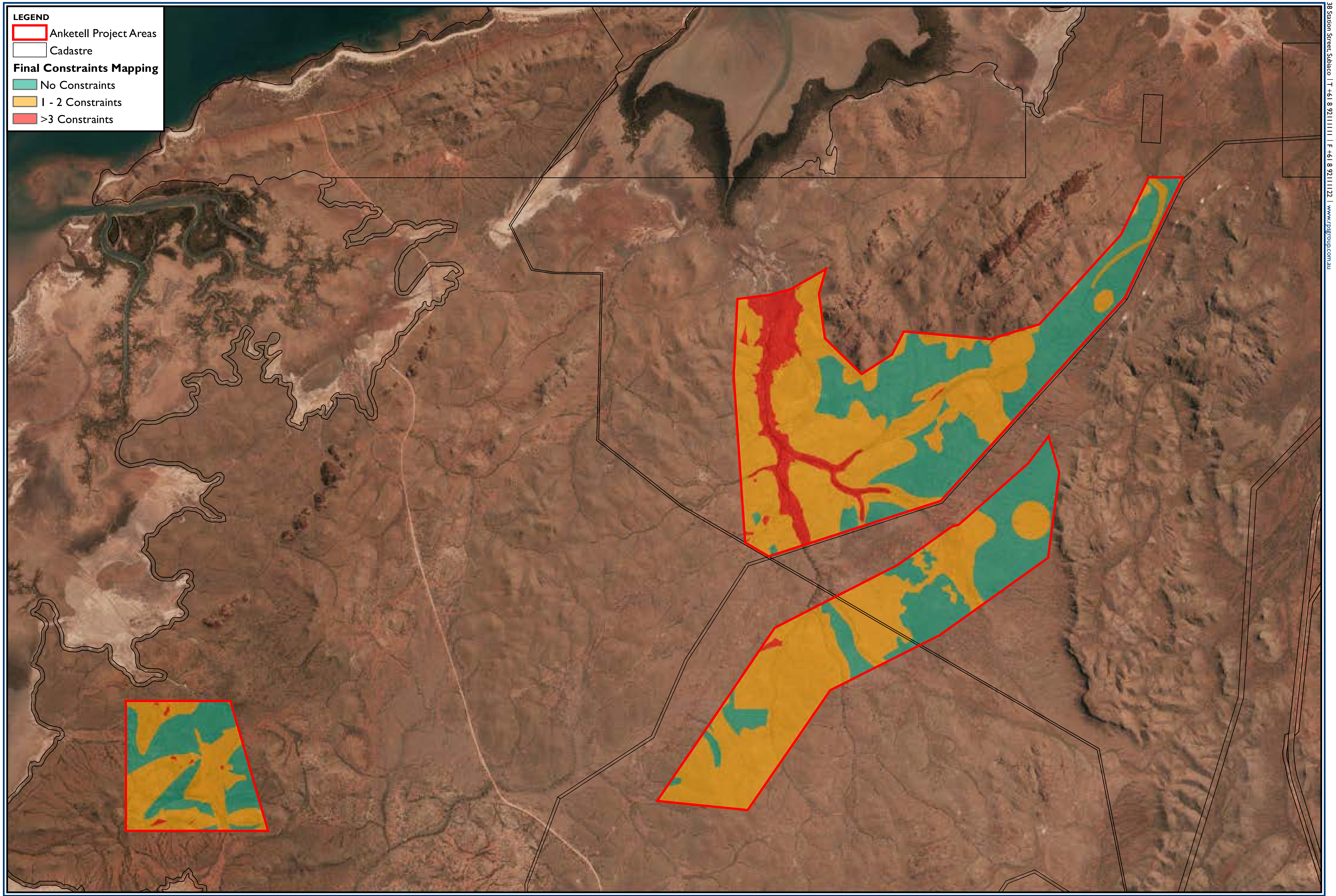

Figure 26

Final Constraints Mapping

Job Number: L1305907
Doc Number: 026
Date: 16.04.16
Scale: 1:35,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2014

GDA 1994 MGA Zone 50

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RPS

APPENDIX 1

Baseline Groundwater and Surface Water Monitoring Report

RPS

BASELINE GROUNDWATER AND SURFACE WATER MONITORING REPORT

Mount Anketell Strategic Industrial Area

BASELINE GROUNDWATER AND SURFACE WATER MONITORING REPORT

Mount Anketell Strategic Industrial Area

Prepared by:

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Report No: L1305905
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Rev 1	*Final for Issue*		*CarDav*	*15.04.16*	*SN 15.04.16*	*C. Davies*	*15.04.16*

Disclaimer

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APPENDICES

1.0 INTRODUCTION

The Anketell region has been considered a potential industrial area since the 1970s when the Commonwealth and state governments conducted an assessment to determine potential future Pilbara port facilities and supporting industrial land use requirements. In 2010, the state government announced that the next major deep water port for the Pilbara would be located at Anketell. The proposed port will be a multi-use facility catering for a range of commodities.

The Anketell Strategic Industrial Area (SIA) is proposed to support the future Anketell Port. The SIA is located within the Shire of Roebourne, approximately 5 kilometres (km) west of Wickham (Figure 1) and 30 km east of Karratha. The SIA comprises four development areas totalling 1,262 hectares (ha).

1.1 Objectives

The objective of this baseline groundwater and surface water monitoring study is to investigate the regional groundwater quality and quantity to inform planning and design considerations for the SIA development. More specifically, the baseline study aims to:

- Describe the hydrogeological characteristics of the site.
- Obtain groundwater quality during pre- and post-wet season conditions.
- Measure the regional groundwater levels throughout the duration of the wet season to establish seasonal variations in groundwater levels and flows.
- Collect real time surface water and groundwater data to compare creek flood events and groundwater response.
- Provide data to be incorporated into water management strategy and approval documents.

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2.0 SITE DESCRIPTION

2.1 Site Location

The Anketell Strategic Industrial Area (SIA) is located within the Shire of Roebourne, approximately 5 kilometres (km) west of Wickham and 30 km east of Karratha (Figure 1).

The SIA consists of two heavy industry areas and two general industry areas, totalling approximately 1,262 ha. The heavy and general industry area locations are provided in Figure 2. The key site characteristics are summarised in Table A.

Table A: Key Characteristics of the Anketell SIA

Aspect	Description
Project location	Anketell SIA is approximately 5 km from Wickham
Anketell SIA context	Total Scheme Area – 7,878.48 ha The Anketell SIA consists of the following industrial areas: ▪ HIA1 – 667 ha ▪ HIA2 – 422 ha ▪ GIA – 173 ha
Current responsible authority	City of Karratha
Proposed responsible authority	Western Australian Planning Commission
Current zoning (under local planning scheme)	HIA1 and HIA2 are zoned as “Strategic Industry” GIA is zoned as “Rural”
Proposed zoning (Improvement Scheme)	GIA to be zoned as Industry HIA1 and HIA2 to be zoned as Strategic Industry Remainder of Scheme Area zoned as Industry Protection
Current land use	Vacant Crown land used in areas as a pastoral station (Mount Welcome Station). HIA1 and GIA will be transferred from Crown land to freehold with LandCorp as the owner and estate manager. HIA2 will remain as Crown land subject to future land dealings.
Surrounding land uses	▪ To the east of Anketell is Cape Lambert – the iron ore export operations of Rio Tinto. ▪ To the south of Cape Lambert are the small coastal villages of Point Samson and Cossack. ▪ To the west is the recreational beach at Cleaverville, which is used for camping, boating and fishing. ▪ Further west (approximately 25 km) is the Karratha town site. ▪ Dixon Island lies close offshore to Anketell’s mainland area.

2.2 Regional Geology

The regional geology comprises a northern exposure of the Hamersley Basin within the Pilbara Craton, which is dominated by the Mount Roe Basalt. Shallow Quaternary superficial deposits, generally < 20 m thick, overlie the Late Archaean bedrock in low-lying areas (GHD 2013). Detailed site geology is provided in the lithology logs obtained during the bore installation process; the lithological logs are described in more detail in Section 4.1 and are presented in Appendix 1.

Mapped surface geology underlying each of the proposed strategic industrial areas is shown in Figure 3. Low-lying areas of alluvial sand and gravel are associated with the river and creek channels with adjacent flood plain areas comprising colluvium and sheetwash deposits of silt, sand and gravel. The elevated areas are comprised of basalt and siltstone.

The prevalence of silty or clayey surface deposits across much of the site means that permeability, and therefore infiltration of rainfall to the groundwater system, is expected to be low.

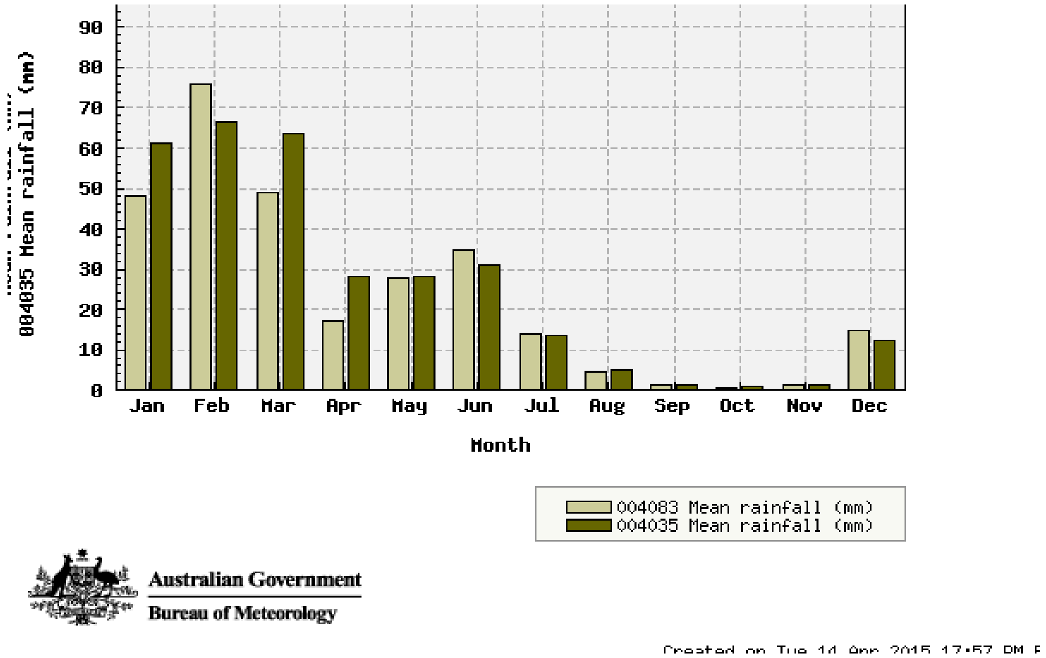
2.3 Climate

The Mount Anketell area experiences a hot, semi-arid climate. October to April is very hot with average daily maximum temperatures reaching 39 °C. Winters are typically mild with temperatures ranging from 13.6 °C to an average monthly maximum of 26.2 °C in July. The annual mean maximum temperature is 32.4 °C (BoM 2015).

The average annual rainfall for Roebourne (approximately 12 km south-east) is 312.3 mm and for Karratha (airport) is 292.8 mm (Table B). The majority of the rainfall received in the region occurs during the summer period between December and March. Graph A presents the mean monthly rainfall for Roebourne and Karratha recorded by the Bureau of Meteorology (BoM). A second peak in the rainfall occurs in June and this rainfall is attributed to the occurrence of tropical cloud bands.

Table B: Summary of Rainfall Statistics for Karratha Aero and Roebourne

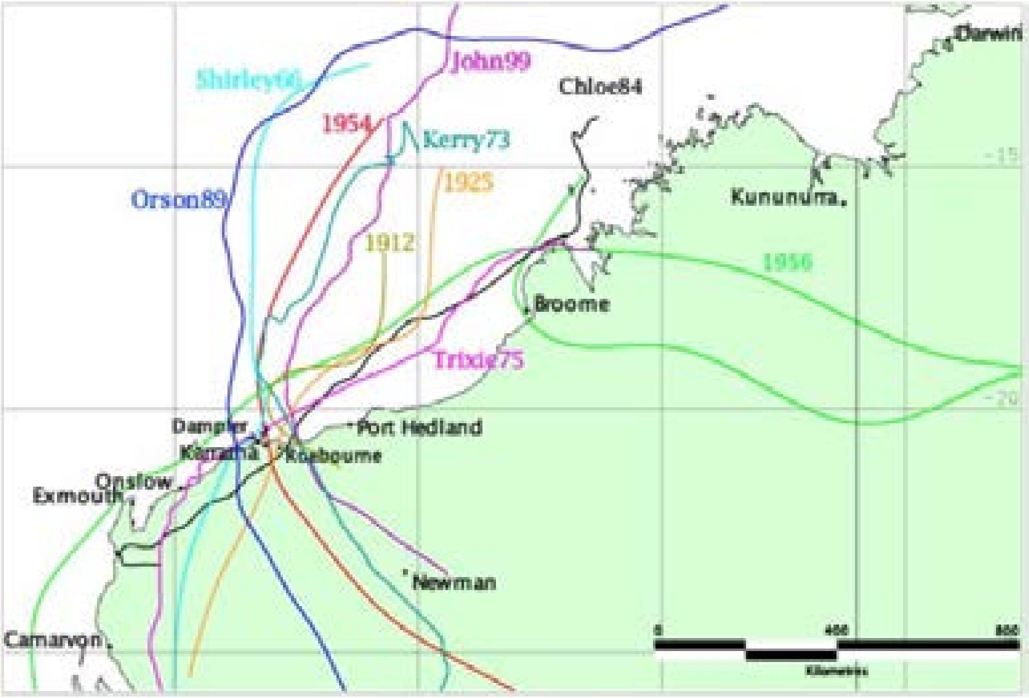
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Karratha Aero (1972–2015)													
Mean	48.1	75.9	49.2	17.2	27.8	34.9	13.8	4.5	1.4	0.5	1.4	14.6	292.8
Low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53
High	263.4	348.8	291.2	120.7	143.7	271.6	76.2	34.4	20.8	6	38	112.8	855.4
Roebourne (4035)													
Mean	62.0	67.1	64.0	28.4	27.6	31.1	13.6	4.9	1.4	0.7	1.5	11.0	312.3
Low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
High	367.8	324.7	408.4	551.9	225.2	308.9	134.6	97.8	40.2	30.5	30.5	172.3	1059.9



Graph A: Mean Monthly Rainfall for Karratha Aero and Roebourne

2.4 Cyclones

The coastline from Port Hedland to the Exmouth Gulf is the most cyclone prone area in Australia. Since 1910, the area that includes Karratha, Dampier and Roebourne has been impacted by 48 cyclones that have caused damaging wind gusts in excess of 90 km/h (BoM 2013). Figure A shows the tracks of notable cyclones that have impacted the area.



(Source: BoM 2013)

Figure A: Tracks of Notable Cyclones that have impacted the Area

Cyclones are most common in the Pilbara region between mid-December and April, peaking in February and March, which can result in extreme rainfall events.

3.0 SCOPE OF WORKS

3.1 Overview

The following scope of works was undertaken to meet the objectives of this baseline monitoring project:

1. **Hydrogeological Assessment Review** – RPS sourced and reviewed the Parsons Brinckerhoff (PB) Hydrogeological Assessment of Cape Lambert to provide hydrogeological information for the site and to assist in the development of the monitoring network

2. **Monitoring Network** – Establishment of a monitoring network consisting of four groundwater bores and four surface water monitoring locations

3. **Water Quality Sampling** – Collection and analysis of groundwater samples on a six-monthly basis for two years (four events).

4. **Water Quality Analysis** – The analysis of the groundwater aligns with the Department of Environment and Conservation guidelines for Potentially Contaminating Activities, Industries and Landuses (2004).

5. **Baseline Water Quality Report** – Preparation of a baseline groundwater quality report.

3.2 Hydrogeological Assessment Review

LandCorp provided the Parsons Brinckerhoff *Hydrogeological Assessment of Cape Lambert* (referred to herein as the "PB report") for review by RPS. The review of this report provided hydrogeological information for the region. Based on the hydrogeological information provided within the report, RPS was able to design a monitoring network (Figure 4) on the basis of indicative groundwater levels, regional geology and significant hydrogeological features within the study area.

3.3 Monitoring Network

Based on the hydrogeological information presented in the PB report and provided by LandCorp regarding Aboriginal heritage locations (Anthropos Australis 2014) within the study area, a monitoring network was designed that provided a suitable spatial distribution of locations.

3.3.1 Groundwater Monitoring Bores

Four groundwater monitoring bores were installed during October 2014. Table C presents a summary of the monitoring bore details. The construction and lithological logs for the monitoring bores are presented in Appendix 1. Pressure transducer loggers were installed in each monitoring bore to provide high resolution data of the groundwater levels. The logger data and groundwater level trends are discussed in Section 4.3.1.

Table C: Groundwater Monitoring Bore Summary

Bore ID	Easting	Northing	Total Depth (mbgl)
HIA-N	504563	7712764	8
HIA-S	504733	7711661	10
GIA-1	508248	7713851	22
NB-1	499004	7708222	16

Note: Bore co-ordinates are in GDA 94 format.

All monitoring bores were installed using a rotary air-blast drilling rig mounted on the back of a Land Cruiser® utility vehicle. Lithology samples were collected at 0.5 m intervals to allow for accurate logging of the lithological profiles. The lithology encountered during the monitoring bore installation is discussed in Section 4.1. The bore construction was in line with the *Minimum Construction Requirements for Water Bores in Australia, Third Edition* (National Water Commission 2012).

3.3.2 Surface Water Monitoring Locations

Four surface water loggers were installed in the major creek lines that were identified during the *Flood Study Report, Anketell Strategic Industrial Area* (RPS 2014). The locations also aligned with nodes used in the flood study model to allow future comparison of model data against on-site surface water measurements. Plate A below provides the location and photographs of each of the surface water monitoring locations. Pressure transducer loggers were also installed at these locations to provide high resolution data and to capture surface water flow response to rainfall events. The logger data, and surface water levels and trends are discussed in Section 5.3.

SW-1: **E: 504445, N: 7712432**
Location: **Rocky Creek (HIA 1)**

SW-2: **E: 504709, N: 7711362**
Location: **Rocky Creek (HIA 1)**

SW-3: **E: 504896, N: 7711795**
Location: **Rocky Creek (HIA 1)**

SW-4: **E: 508384, N: 7714059**
Location: **Minor Channel (HIA 1)**

Plate A: Surface Water Monitoring Locations

3.4 Groundwater Quality Sampling

The groundwater quality sampling was conducted on a six-monthly basis over the period October 2014 to March 2016. The sampling events were timed for pre-wet season (October) and post-wet season (late March) conditions. The groundwater samples were collected using a 12 v electric submersible pump with a controller to regulate the discharge rate. Due to the significant depth to water and the limitations of the pump, a bailer was used to sample Monitoring Bore GIA-1[1]. The bores were purged prior to sampling and water samples were stored in accordance with the following guidance documents:

---

[1] Due to insufficient groundwater volume a sample was not collected during October 2014 from this bore.

- Department of Environment and Conservation. 2001a. Development of Sampling and Analysis Programs. Contaminated Sites Management Series

- Standards Australia. 1998. *AS/NZS 5667.11:1998, Water Quality—Sampling. Part 11: Guidance on Sampling of Groundwater*. www.standards.com.au

- Standards Australia. 1998. *AS/NZS 5667.1:1998, Water Quality—Sampling. Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples*. www.standards.com.au.

During the purging process, the following physico-chemical parameters were recorded to validate stabilisation prior to sampling:

- pH
- Temperature (°C)
- Electrical Conductivity (µS/cm).

The groundwater sampling logs collected during sampling events are presented in Appendix 2.

3.5 Groundwater Quality Analysis

The groundwater analysis suite was developed in consultation with the Department of Environment and Conservation guidelines for *Potentially Contaminating Activities, Industries and Landuses* (2004). As the study area has no evidence of any historical contaminating activities, the following analysis suite was adopted:

- Total Dissolved Solids (TDS)

- Major anions and cations

- Total Alkalinity

- Dissolved Metals – Arsenic, Cadmium, Chromium, Copper, Nickel, Lead, Mercury and Zinc

- Nutrients – Total Nitrogen, Total Kjeldahl Nitrogen, NOx-N, Total Phosphorus, Filtered Reactive Phosphorus.

The water quality samples were stored on ice and transported to a NATA accredited laboratory within prescribed holdings times. Discussion of the water quality analysis results is presented in Section 4.4.

4.0 RESULTS

4.1 Lithology

The lithological conditions encountered varied across the site; the following points summarise the lithology encountered at each of the monitoring locations. Additional detail of the lithology encountered has been adopted from *Australia 1:250 000 Geological Series – Roebourne* (Hickman and Smithies 2000):

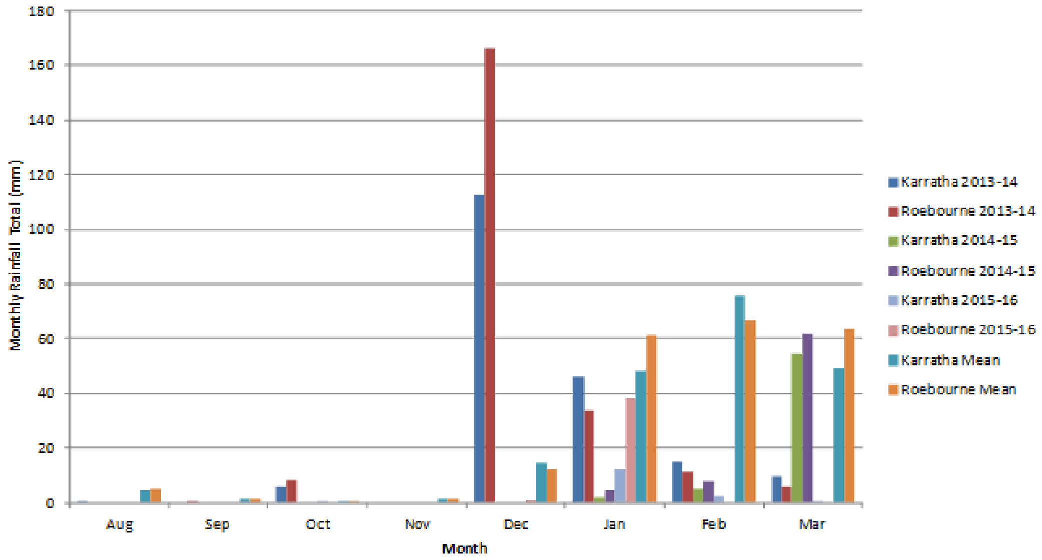
- **Bore NB-1** – The surficial geology of colluvium consisted of reddish brown, medium/fine grained sand silt and gravels including quartz gravel with a thickness of approximately 2.5 m. Underneath this depth (2.5 m below ground level (mbgl)), a pale yellow metamorphosed sandstone with minor conglomerate was encountered and continued to a depth of 8.5 mbgl, while the moisture within the borehole increased with depth. From a depth of approximately 8.5 mbgl (and below the groundwater table) basaltic rock was encountered, the grey to dark green colour indicated that metamorphosis of the basaltic rock to greenschist may have occurred.

- **Bores HIA-N and HIA-S** – Due to the proximity to Rocky Creek, the lithological profile of these two sites was similar. Surficial sediments consisted of low-gradient sheet wash deposits of sand, silt and clays with minor inclusions of quartz gravels to a depth of approximately 0.5 to 1 mbgl. The underlying sandstone layer extended from approximately 2 mbgl at HIA-S to 4 mbgl at HIA-N. Underlying the sandstone layer, basalt from the Regal Formation extended to the base of the drilling (8 and 10 mbgl for HIA-N and HIA-S respectively). Groundwater was encountered within the basalt at both locations, with groundwater likely to be stored within the fractures.

- **Bore GIA-1** – The surficial geology of colluvium encountered at this location consisted of reddish brown, medium/fine grained sand, silt and gravels including quartz gravel with a thickness of approximately 2.5 m. The surficial geology was succeeded by a relatively minor layer of pale yellow metamorphosed sandstone with minor conglomerate with an approximate thickness of 1.5 m. Below a depth of approximately 4 mbgl Mount Roe Basalt was encountered. Drilling was terminated at a depth of 22 mbgl, at which time groundwater was not measured within the drilling annulus. However, groundwater was encountered the following day indicating slow groundwater recharge into the bore.

4.2 Rainfall during the Monitoring Period

Section 2.3 presents the long-term mean monthly rainfall values for the BoM meteorological stations at Karratha Aero (Station 4083) and Roebourne (Station 4035). Graph B below compares the monthly rainfall totals for the monitoring period (2014–2016) with rainfall for the previous wet season (2013–2014) and long-term historical data.



Graph B: Wet Season Rainfall Comparisons

As evidenced in Graph B, the rainfall received during the 2014–2016 monitoring period is very low in comparison to the previous wet season and historical rainfall. The rainfall received throughout the duration of the monitoring period (2014–2016) for the Karratha monitoring station was 39 mm for two wet seasons (19.5 mm average) which is an order of magnitude lower than the long term wet season average of 195.6 mm (Table D).

Table D: Rainfall Analysis

Month	Karratha Wet Season (Aug–March)				Roebourne Wet Season (Aug–March)			
	Mean	2013–2014	2014–2015	2015–2016	Mean	2013–2014	2014–2015	2015–2016
August	4.5	0.2	0	0	4.9	0	0	0
September	1.4	0	0	0	1.3	0.4	0	0
October	0.5	6	0	0.4	0.8	8.4	0	0
November	1.4	0	0	0	1.5	0	0	0
December	14.6	112.8	0	0	12.2	166	0	1
January	48.1	46	2	12.2	61.3	34.1	4.8	38.2
February	75.9	15	5	2.2	66.6	11.6	7.6	0
March	49.2	9.4	54.4	0.2	63.6	6.2	61.8	0
Total	195.6	189.4	61.4	15.0	212.2	226.7	74.2	39.2
Per cent of Mean	100.0	96.8	31.4	7.7	100.0	106.8	35.0	18.5

4.3 Groundwater Elevations and Flow

4.3.1 Groundwater Elevations

Groundwater levels where measured throughout the monitoring period using pressure transducer loggers to provide high resolution data. Table E summarises the groundwater levels and elevations recorded during the monitoring period. The groundwater elevations presented in Table E have been estimated from topographical elevation data at the site of the monitoring well (i.e. top of bore casings have not been surveyed at this stage).

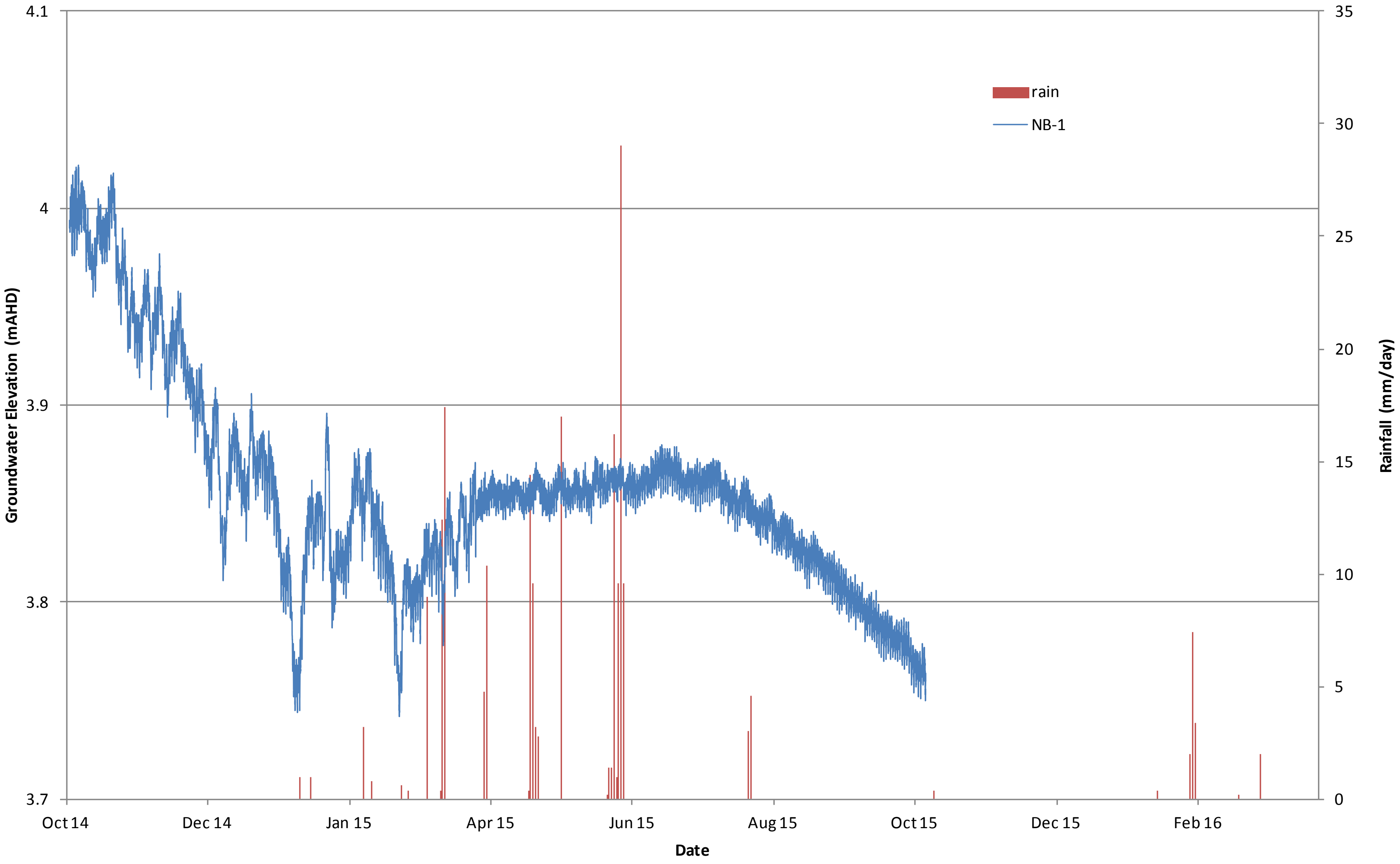
Groundwater elevations ranged from 2.6 m AHD at Bore HIA-N recorded in January 2016 to 7 m AHD at Bore HIA-S recorded in May 2015. The depth to groundwater ranged between 3.9 and 15.9 mbtoc (metres below top of casing). This equates to a groundwater depth of approximately 3.2 to 15.2 mbgl (metres below ground level) over the monitoring period (assuming bore casing is ~ 0.7 m above ground level).

Table E: Groundwater Elevations

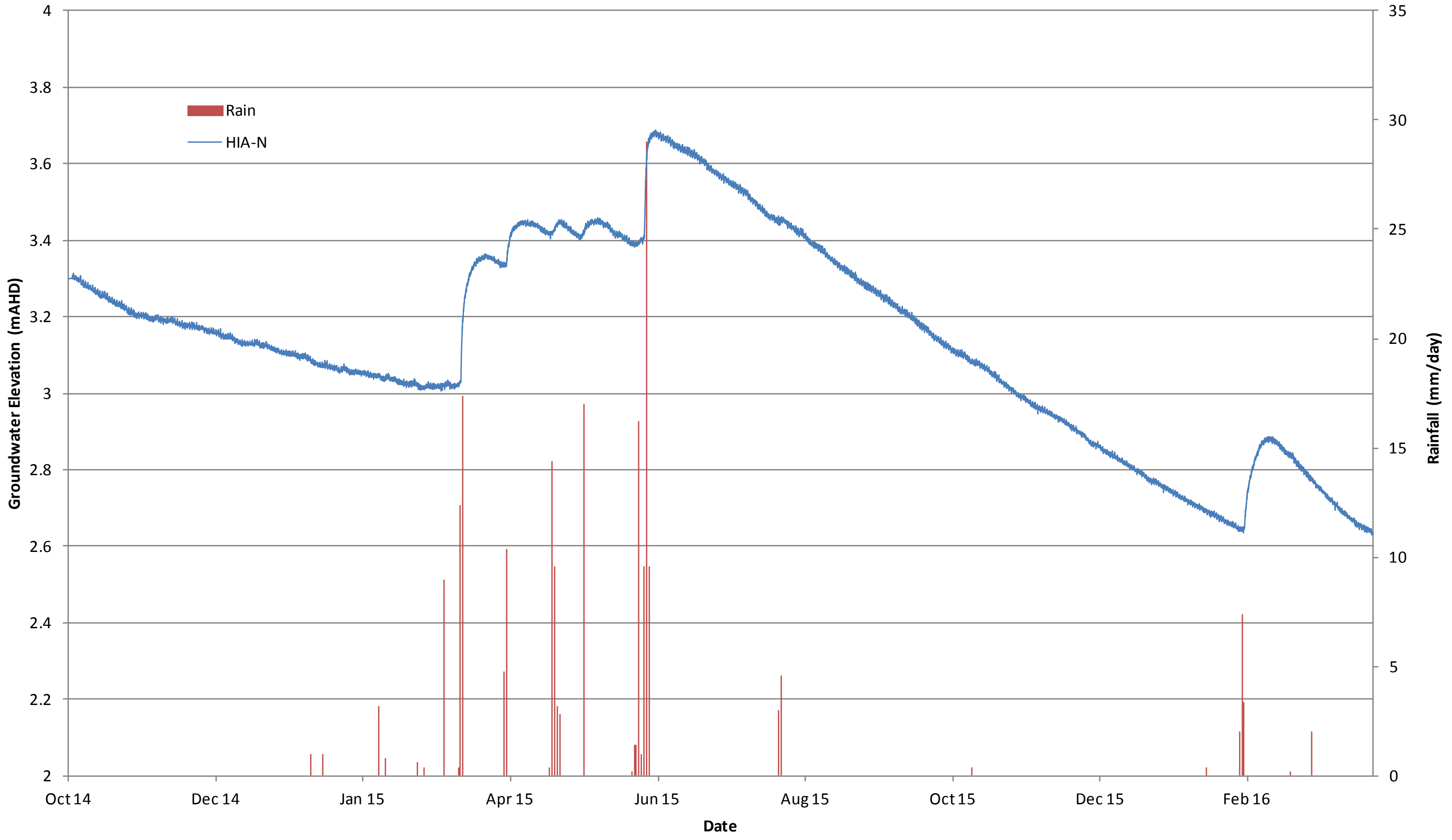
Bore ID	Water Level Minimum			Water Level Maximum		
	mbtoc	m AHD	Date	mbtoc	m AHD	Date
NB-1	7.55	3.74	7/1/15[1]	7.27	4.02	4/10/14
HIA-N	4.9	2.65	29/1/16	3.86	3.69	1/6/15
HIA-S	5.17	6.18	8/3/15	4.38	6.97	30/5/15
GIA-1	15.87	4.73	20/3/16	15.21	5.39[2]	7/10/14

Note: mbtoc (metres below top of collar).
m AHD (metres Australian Height Datum)
1. Logger operated to 6 October 2015.
2. A single higher value was encountered in Bore GIA-1 logger data, this is considered an outlier and has been disregarded

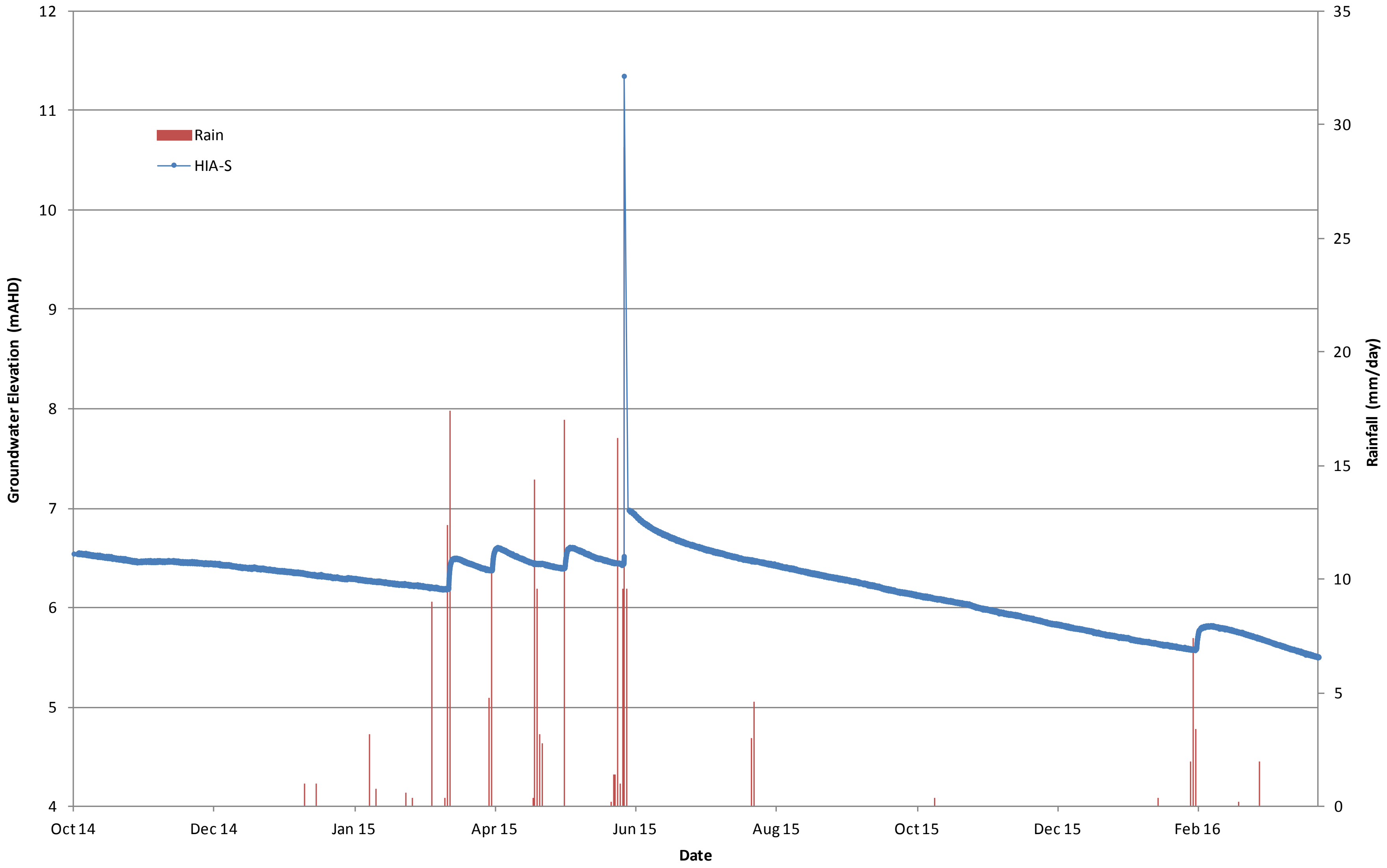
Graphs C to F present the monitoring bore hydrographs with rainfall from the Karratha Aero meteorological station (4083). The bore hydrographs show that overall, groundwater elevations declined at a rate of about 4 cm per month. Groundwater levels in HIA-N and HIA-S located along Rocky Creek showed a significant response (~0.3 m) to rainfall, while there was minimal groundwater level response in the deeper bores (NB-1 and GIA-1). It is likely the responses shown at HIA-N and HIA-S were due to their close proximity to Rocky Creek, which recorded surface water flows in response to the same rainfall events.



Graph C: Hydrograph and Rainfall for Groundwater Bore NB-1

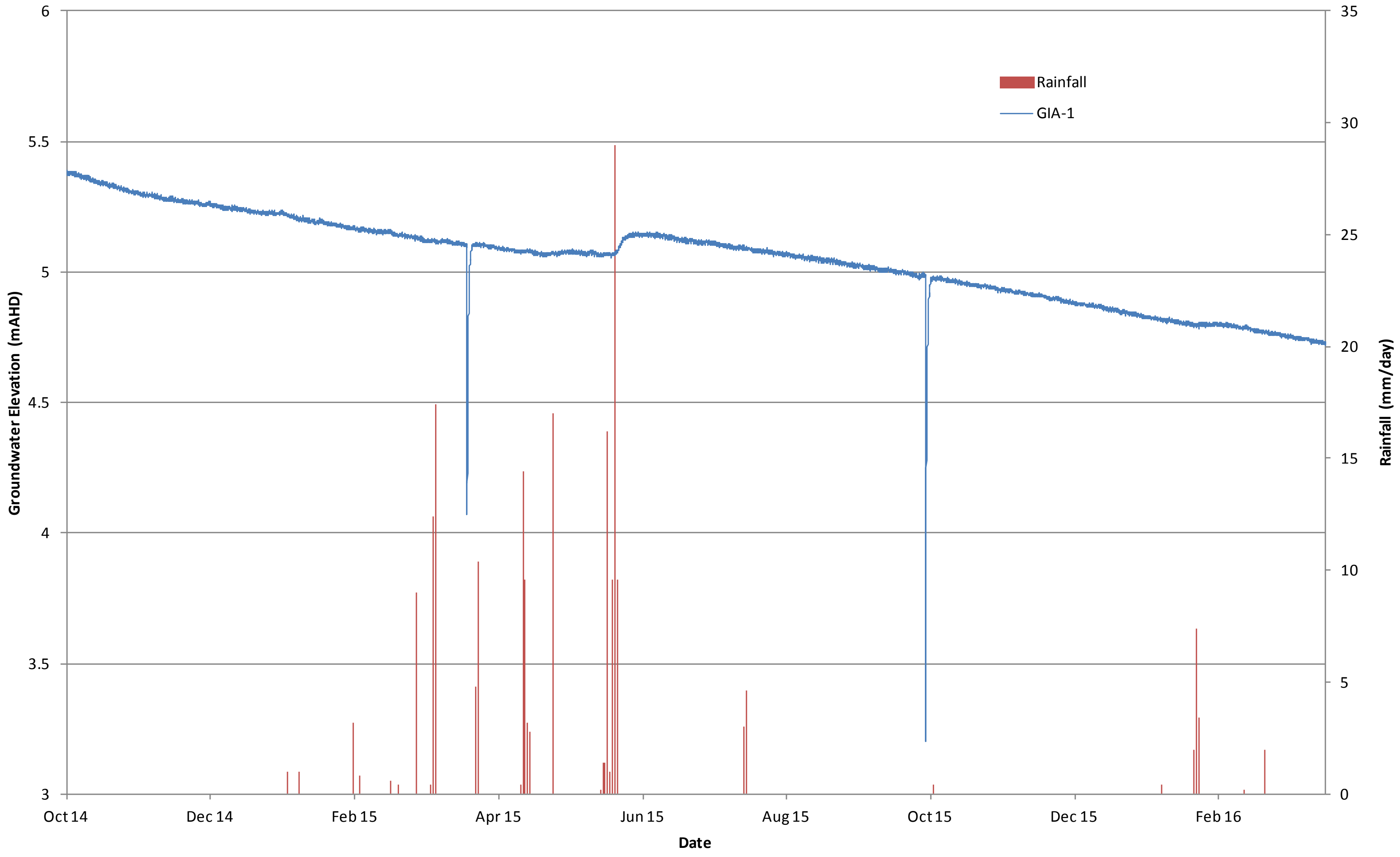


Graph D: Hydrograph and Rainfall for Groundwater Monitoring Bore HIA-N



Note: a single higher value was encountered in Bore GIA-1 logger data, this is considered an outlier and has been disregarded

Graph E: Hydrograph and Rainfall for Groundwater Monitoring Bore HIA-S



Note: The sharp water level drops relate to sampling events.

Graph F: **Hydrograph and Rainfall for Groundwater Monitoring Bore GIA-1**

4.3.2 Groundwater Flow

Monitored groundwater elevations across the site have been used to map indicative groundwater elevation contours for October 2014 (Figure 5). The contours show that groundwater flows in a north-west direction towards the coast. The indicative groundwater flow direction is similar to that presented in the PB report.

It is inferred that localised groundwater mounding occurs underneath Rocky Creek during periods of high rainfall. The rainfall initiates surface water flows within the creek, which becomes a significant source of aquifer recharge in the vicinity. This is shown by the rapid groundwater elevation increase at HIA-N and HIA-S during rainfall events.

4.3.3 Tidal Attenuation

The groundwater hydrographs indicate there is minor tidal influence occurring within the superficial aquifer within the study area, due to its proximity to the coast and tidal inlets.

The tides in the Karratha region vary and can be over 4 m during a spring tide (City of Karratha 2015). The tidal impact on the groundwater elevations at the site occur in two main cycles:

- the semi-diurnal cycle of the tides between high and low. The site generally experiences two high tides and two low tides every 24 hours
- the neap and spring tide cycle occurs twice every lunar month. During a neap tide, the tidal range is moderated (smaller tidal range); during the spring tide, the tidal range is increased.

The hydrographs indicate that the semi-diurnal influence due to tidal fluctuation across the site is approximately 1.5 cm at HIA-N, HIA-S and GIA-1 and 2 cm at NB-1. NB-1 also exhibits tidal attenuation caused by the lunar cycle of spring and neap tides. The lunar cycle tidal influence is approximately 5 cm at NB-1. The tidal signal recorded during the monitoring period indicates that groundwater flows and levels are not significantly impacted by tides.

4.4 Groundwater Quality

4.4.1 Physico-chemical Parameters

During each monitoring event, the physico-chemical parameters as outlined in Section 3.4 were measured prior to sampling using a calibrated water quality meter. Table F below presents the physico-chemical parameters recorded during the 2014–2016 monitoring period.

Table F: Groundwater Physico-chemical Parameters

Bore ID	Date	Temperature (°C)	pH	EC (µS/cm)	TDS (mg/L)
NB-1	21/10/2014	29.5	6.2	58,700	38,155
	26/03/2015	34.5	6.4	42,200	27,430
	6/10/2016	33	6.5	55,600	36,140
	24/03/2016	31.4	6.1	66,100	42,965
HIA-N	21/10/2014	28.7	7.3	6,580	4,277
	26/03/2015	33.6	7.2	5,380	3,497
	6/10/2016	31.6	6.9	6,780	4,407
	24/03/2016	30.7	6.8	6,850	4,453
HIA-S	21/10/2014	30.5	7.4	5,100	3,315
	26/03/2015	32.7	7.1	4,070	2,646
	6/10/2016	32	7.0	4,990	3,244
	24/03/2016	30.9	6.8	5,040	3,276
GIA-1	21/10/2014	-	-	-	-
	26/03/2015	32.9	7.1	2,590	1,684
	6/10/2016	32	7.0	3,630	2,360
	24/03/2016	30.6	6.8	3,640	2,366

Note: TDS (mg/L) calculated as 0.65 EC (µS/cm)

4.4.1.1 pH

The field-testing indicates the pH of the groundwater ranges from 6.1 to 7.4, which classifies the groundwater as neutral.

4.4.1.2 Temperature

The temperature of the groundwater ranged from 28.7 °C in October to 34.5 °C in March, at Bore HIA-N and Bore NB-1 respectively. The temperature of the groundwater is similar to the mean annual maximum temperature of the Karratha Aero meteorological station (4083) of 32.4 °C.

4.4.1.3 Electrical Conductivity

The electrical conductivity (EC) showed significant spatial variability across the site ranging from 66,100 µS/cm (~43,000 mg/L calculated Total Dissolved Solids (TDS)) at Bore NB-1 to 2,590 µS/cm (1,683 mg/L TDS) at Bore GIA-1.

The high salinity measured at Bore NB-1 is likely due to its proximity to the inter-tidal inlet located approximately 700 m to the south and up-hydraulic gradient. Evaporation of surface water within the inlet prior to infiltration into the superficial aquifer below may also contribute to the increased salinity encountered at this location. The salinity recorded at Bore NB-1 is similar to marine water and the Australian Water Resources Council (AWRC 1998) classifies this water as hyper-saline.

Bores HIA-N and HIA-S recorded EC concentrations of 6,850 and 5,100 µS/cm (4,450 and 3,315 mg/L TDS), during the March 2016 and October 2014 monitoring events respectively. The EC values recorded at these bores classify the groundwater as saline for the majority of the monitoring period, with the groundwater at Bore HIA-S being classified as brackish during the March 2015 event. The salinity of the groundwater at these locations may be influenced by evaporation occurring within Rocky Creek prior to surface water infiltrating into the superficial aquifer.

The maximum EC recorded at Bore GIA-1 was 3,640 µS/cm (2,366 mg/L TDS), which classifies the groundwater at this location as brackish. The somewhat fresher groundwater at this location may be due to the presence of groundwater at significant depth within basalt, consequently resulting in lower groundwater dissolution and/or evapoconcentration compared to other bores.

Table G shows the AWRC salinity classification and potential use.

Table G: Salinity Classifications (AWRC 1998)

TDS (mg/L)	AWRC Classification	Potential Use
<500	Fresh	All purposes, domestic and irrigation
500–1500	Fresh*	Most purposes, 1000–1500 mg/L is upper limit for drinking
1500–3000	Brackish	Limited irrigation, livestock
3000–7000	Saline	Most livestock
7000–14000	Saline	Some livestock
>14000	Saline to Hypersaline	Limited industrial use

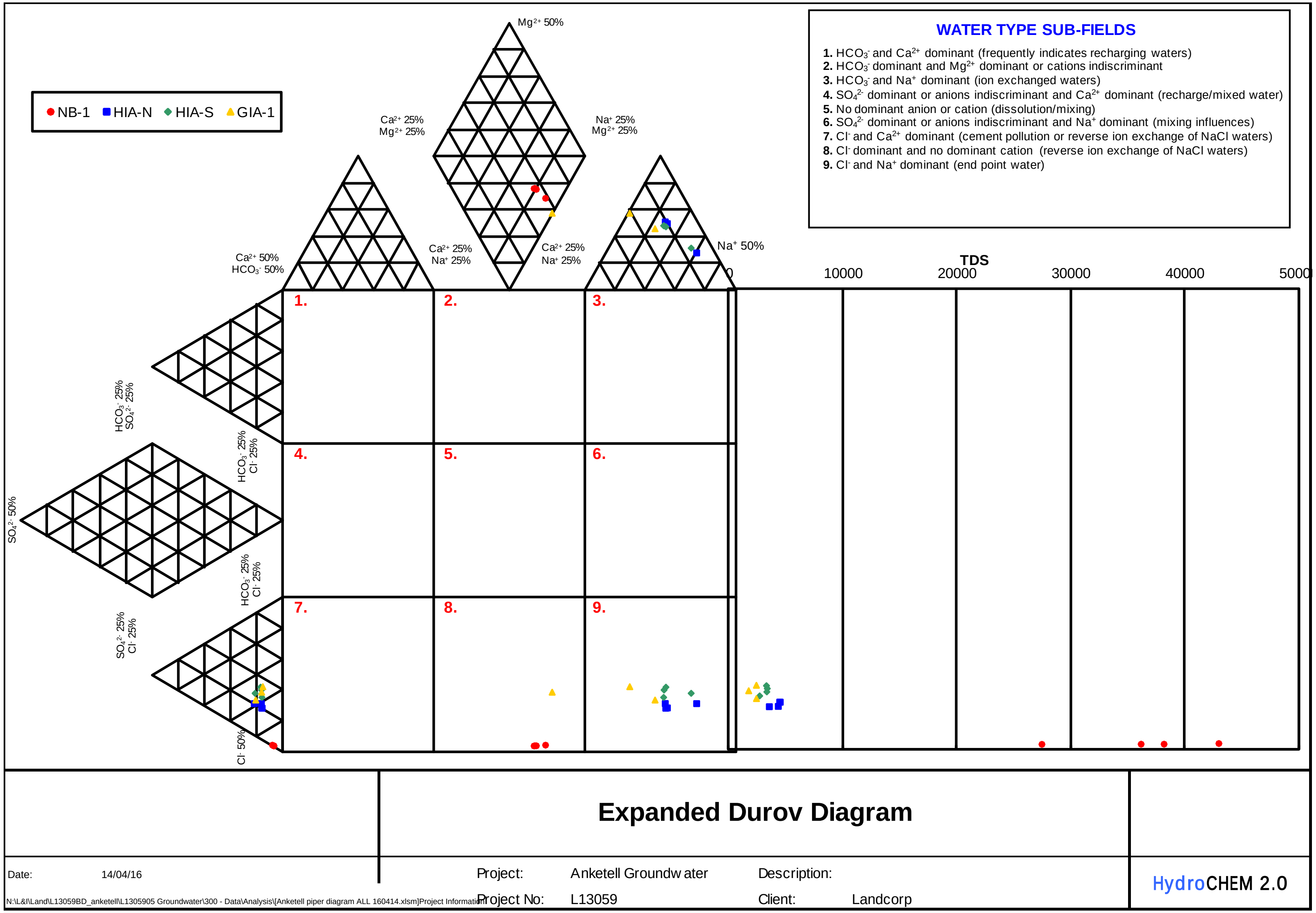
4.4.2 Analytical Results

4.4.2.1 Guidelines

The laboratory analysis results for the entire 2014–2016 monitoring period are provided in Tables 1 and 2 at the rear of the report. The laboratory provided reports are presented in Appendix 3. The results are compared to the ANZECC/ARMCANZ (2000) *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water Quality,* with specific reference to marine ecosystem protection guidelines (MEPG) and freshwater guidelines (FWG) for tropical Australia. The results are also compared to Department of Health (2006) *Contaminated Sites Reporting Guidelines for Chemicals in Groundwater* domestic non-potable groundwater (DNPG) use guidelines that are considered appropriate in relation to non-potable uses. The following sections provide a brief discussion of the results.

4.4.2.2 Groundwater Type

As illustrated in the Expanded Durov Diagram (Graph G) the groundwater at the site can be characterised as two main types. The groundwater at Bore HIA-H and Bore HIA-S is characterised as being chloride and sodium dominant and is representative of end point water. The groundwater at Bore NB-1 is characterised as chloride dominant with no dominant cation, which indicates that groundwater chemistry may be related to reverse ion exchange of sodium chloride water. Groundwater from Bore GIA-1 covers both types.



WATER TYPE SUB-FIELDS

1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

Expanded Durov Diagram

Date: 14/04/16
N:\L&I\Land\L13059BD_anketell\L1305905 Groundwater\300 - Data\Analysis\[Anketell piper diagram ALL 160414.xlsm]Project Information
Project: Anketell Groundw ater
Project No: L13059
Description:
Client: Landcorp
HydroCHEM 2.0

Graph G: Expanded Durov Diagram

4.4.2.3 Groundwater Nutrients

Total Nitrogen

The total nitrogen (TN) concentrations were consistently above the ANZECC (2000) MEPG of 0.1 mg/L and/or FWG for Tropical Australia of 1 mg/L. All samples exceeded the MPEG and three of the four bores exceeded the FWG. The highest TN concentration of 7.8 mg/L was encountered in NB-1; this concentration is expected to be sourced from seawater (or evapoconcentrated rainwater), with natural seawater nitrogen concentrations in the order of 11 mg/L.

Ammonia-N

The ammonia-N (NH_4-N) concentrations exceeded the MEPG and FWG value of 0.01 mg/L in all of the samples collected during the monitoring period. The concentration ranged from <0.02 mg/L in all bores to 0.8 mg/L at NB-1. It should be noted that the limit of reporting (LOR) is higher than the guideline value for the March 2016 event; due to sample holding times and laboratory availability, the samples could not be analysed at the lower limit.

Oxides of Nitrogen

The NOx-N concentrations exceeded the MPEG and FWG values of 0.008 and 0.01 mg/L respectively in all samples collected during the monitoring period. The NOx-N concentrations were up to 1.6 mg/L at NB-1.

Phosphorus

The total phosphorus (TP) concentrations exceeded the FWG (0.1 mg/L) and/or MEPG (0.015 mg/L) in all of the bores with a maximum of 0.2 mg/L recorded at NB-1. Filtered reactive phosphorus (FRP) exceeded the FWG and MEPG value of 0.005 mg/L in all bores. It should be noted that the LOR is higher than the guideline value; due to sample holding times and laboratory availability, the samples could not be analysed at the lower limit.

4.4.2.4 Dissolved Metals

The dissolved metals concentrations analysed during the 2014–2016 monitoring period were generally recorded below the laboratory detection limit (LOR) and/or guidelines values for arsenic, chromium, lead and mercury indicating low background concentrations of these dissolved metals in the groundwater.

There were numerous detections of dissolved cadmium, copper, nickel, and zinc with the following guideline exceedances:

Cadmium

The concentrations recorded at NB-1 exceeded the MEPG of 0.0007 mg/L with concentrations up to of 0.0112 mg/L (17 times guideline).

Copper

Copper concentrations exceeded the MEPG value of 0.0013 mg/L in all bores, with concentrations up to of 0.021 mg/L (16 times guideline) in NB-1.

Nickel

Nickel concentrations exceeded the FWG and MEPG guideline (0.011 and 0.007 mg/L respectively) at three locations (HIA-N, HIA-S and NB-1). Of note is the significantly higher concentration of 0.286 mg/L encountered in NB-1 which exceeds the DNPG value of 0.2 mg/L. Its source is unknown, however decreased in subsequent monitoring events.

Zinc

Zinc concentrations exceeded the FWG value of 0.008 mg/L at two locations (NB-1 and GIA-1), with a maximum of 0.031 mg/L in NB-1 (4 times guideline). It should be noted that due to the high TDS of the water samples for NB-1 during both events, the LOR had to be increased to 0.05 mg/L, which exceeded the FWG value of 0.008 mg/L.

4.4.2.5 Major Ions

The chloride concentration exceeded the DNPG value of 2,500 mg/L in NB-1 throughout the entire monitoring period. The chloride concentration ranged from 30,800 to 34,200 mg/L at NB-1, which is approximately 20 times greater than the rest of the site and is likely due to its proximity to the inter-tidal inlet located to the south.

4.4.3 Quality Control

4.4.3.1 QA/QC Calculation

RPS requires that laboratories have a QA/QC program that is endorsed by NATA and meets the following criteria:

- Contaminant concentrations in rinsate and blank samples is to be at or below the nominated limits of detection.

- Relative percentage differences (RPDs) between original and duplicate samples is to range between +/- 50%. If the RPD is greater than +/- 50%, the higher value is used for evaluation purposes.

Calculation of the RPD value is provided in the following equation:

$$RPD = \frac{(Co - Cs)}{\left(\frac{Co + Cs}{2}\right)} x100$$

where: Co = concentration of the original sample
Cs = concentration of the duplicate sample

The RPD calculation was used to normalise each pair of results to allow for better QA/QC data interpretation. For those RPD values that exceed a generally acceptable 30–50% (Standards Australia 2005), data correlation is considered poor, however consideration needs to be given to sample homogeneity and the concentrations detected.

Analytical data validation is the process of assessing whether data comply with method requirements and project specifications. The objective of this process is to ensure that data of known and predetermined quality are reported, and identify if the data can be used to fulfil the overall project objectives.

In summary, the process involves the checking of analytical procedures and an assessment of the accuracy of analytical data from a range of standard QA/QC measures undertaken by both the sampler and the analytical laboratory.

The QA/QC measures that were checked/assessed include the following:

- preservation and storage of samples upon collection and during transport to the laboratory
- holding times
- use of appropriate analytical procedures
- required limits of reporting, to ensure all lower quantifiable levels (LQL) are below the adopted guidelines
- frequency of conducting quality control measurements
- field duplicates (relative percentage difference (RPD)).

4.4.3.2 QA/QC Results

Table 2 at the rear of this document presents the QA/QC results including the calculated RPD. The results are summarised below:

- Duplicate concentrations exceeded the 50% RPD criterion for analysis on two occasions. This occurred for the October 2014 analysis for Nickel (-153% RPD).

The high RPD is expected to be due to the relatively low concentrations of nickel encountered in the primary (0.002 mg/L) and secondary (0.015 mg/L) samples.

- An RPD value of 67% was calculated for arsenic for the October 2015 event. The high RPD is also expected to be due to the low concentrations of arsenic encountered in the primary (0.002 mg/L) and secondary (0.001 mg/L) samples.

4.5 Surface Water

4.5.1 Data Logger Results

Four surface water loggers were installed in the major creek lines and measured between October 2014 and March 2016 using pressure transducer loggers to provide high resolution data. Figure 4 shows the surface water monitoring locations (SW-1 to SW-4). The logger installed within SW-2 malfunctioned and hence did not receive data after March 2015.

The surface water elevations presented in Table H have been estimated from topographical elevation data at the site of the monitoring location. In May 2015, the surface water depth reached 1.4m at SW-1 while depths at SW-2 and SW-3 peaked at between 0.7 to 0.8 m in March 2015. Locations SW-1 to SW-3 are all located within Rocky Creek. No surface water was encountered at SW-4 located on a creek line at the north-eastern part of the site.

Table H: Surface Water Levels

Site ID	Water Level Minimum		Water Level Maximum			Range (m)
	Depth (m)	m AHD	Depth (m)	m AHD	Date	
SW-1	0	4.3	1.4	5.7	27.05.15	1.4
SW-2	0	9.3	0.71	10.0	12.03.15	0.71
SW-3	0	8.8	0.76	9.56	12.03.15	0.76
SW-4	0	17.9	0	17.9	NA	NA

Graphs H to J present the surface water monitoring location hydrographs with rainfall from the Karratha Aero meteorological station (4083). The surface water hydrographs show that there were no surface water flows until March 2015 due to the limited rainfall received in the study area.

The surface water hydrographs are typical of short term flow events with a sharp initial peak in water levels followed by a sharp fall in the water level within the creek. As shown on the graphs, typically after the initial peak water level, water declines quickly over several hours for sites SW-1 and SW-2. After this period, the rate of decline decreases due to ponding of water in the location of the loggers. SW-3 shows a different response, with surface water levels increasing and decreasing rapidly with no residual ponding in the creek line.

4.5.2 SW-1 Water Level

The water depth peak recorded at SW-1 was 1.4 m, after which water declined over several hours at a rapid rate due to creek outflow to a depth of 0.6 m; at this level creek flow ceased. After this rapid decline in water levels, Graph H shows a slower linear decline within the creek at a rate of approximately 25 mm/day. This water level decline is a combination of evaporation and infiltration. Adopting a pan evaporation coefficient of 80% and a daily pan evaporation rate for Dampier of 10.1 mm/day resulted in an estimated water evaporation rate of 8 mm/day, hence the water infiltration rate directly under the creek at this location is estimated at 17 mm/day. The creek bed at this location was comprised of laterite gravels and cobbles (approximately 100 to 200 mm diameter) underlying a layer of fine alluvial sediments.

4.5.3 SW-2 Water Level

The water depth peak recorded at SW-2 was 0.71 m, after which water declined over several hours at a rapid rate due to creek outflow to a depth of 0.3 m; at this level creek flow ceased. After this rapid decline in water levels, Graph I shows a slower linear decline within the creek at a rate of approximately 53 mm/day. Based on an estimated water evaporation rate of 8 mm/day, the water infiltration rate directly under the creek at this location is estimated at 45 mm/day. The creek bed geology at this location was noticeably sandier than SW-1, with the creek bed consisting mostly of gravel with occasional cobbles (approximately 100–200 mm diameter).

4.5.4 SW-3 Water Level

The water depth peak recorded at SW-3 was 0.76 m, after which water declined over several hours at a rapid rate due to creek outflow (Graph J). Due to its location (not within a topographic depression), no standing water remained in this location.

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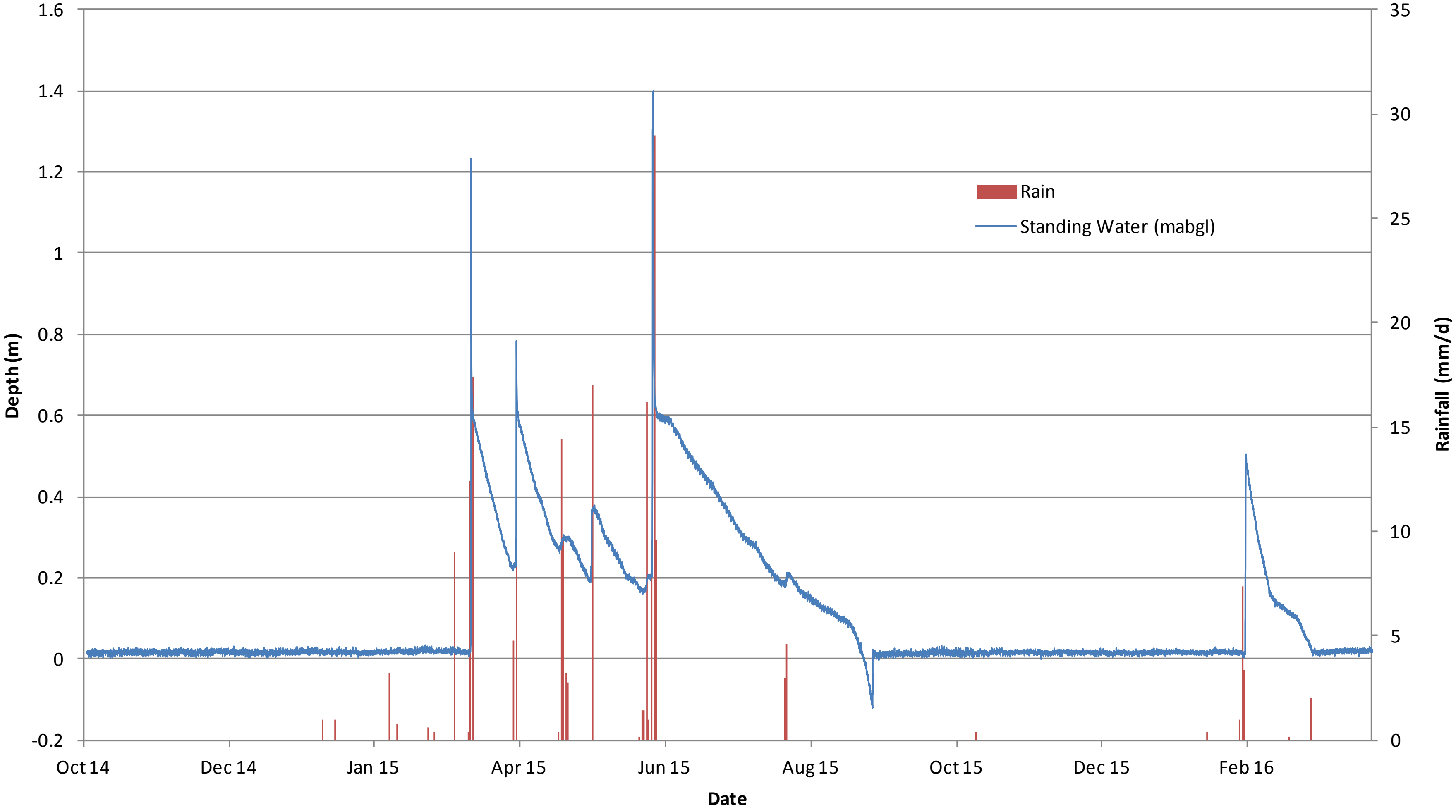
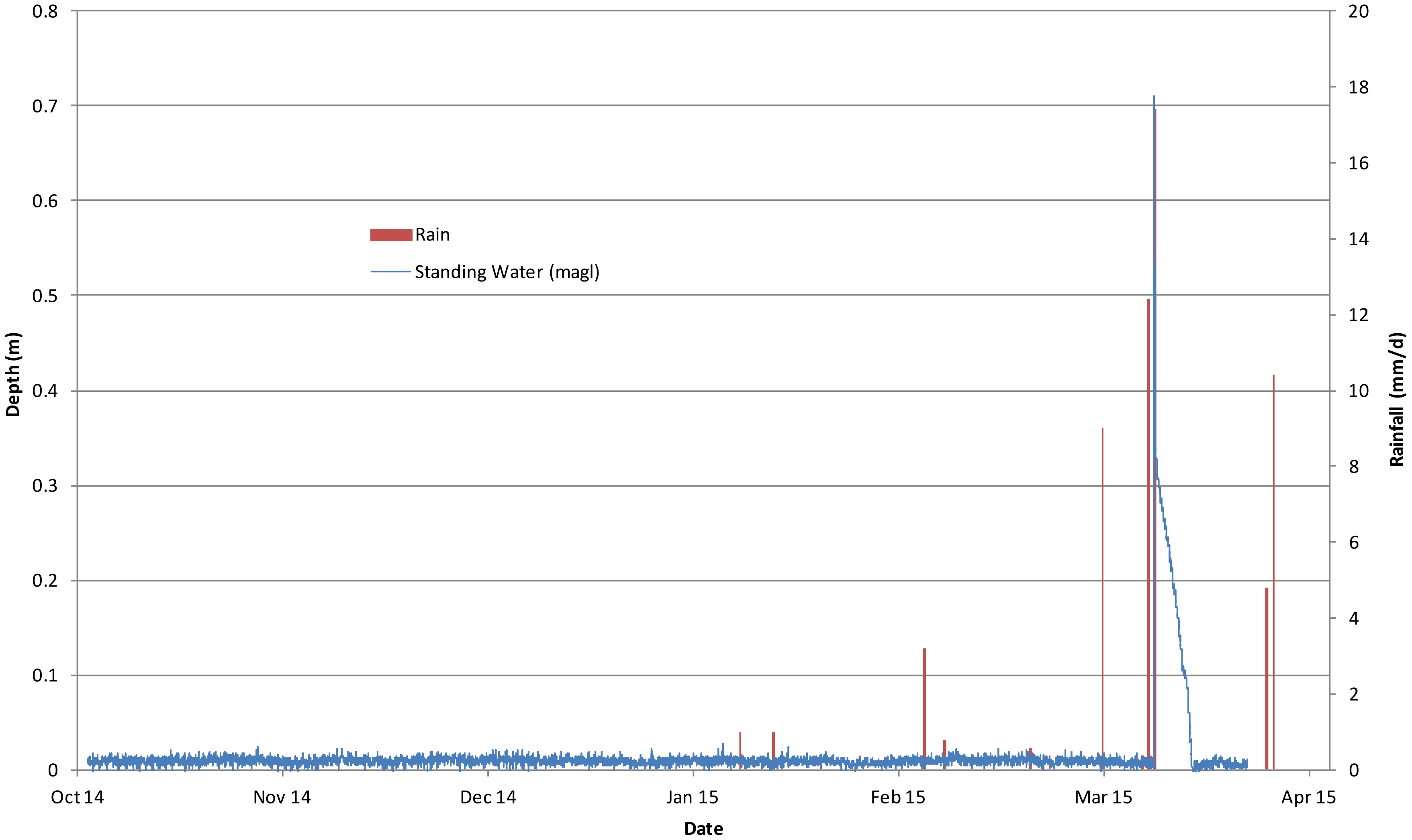
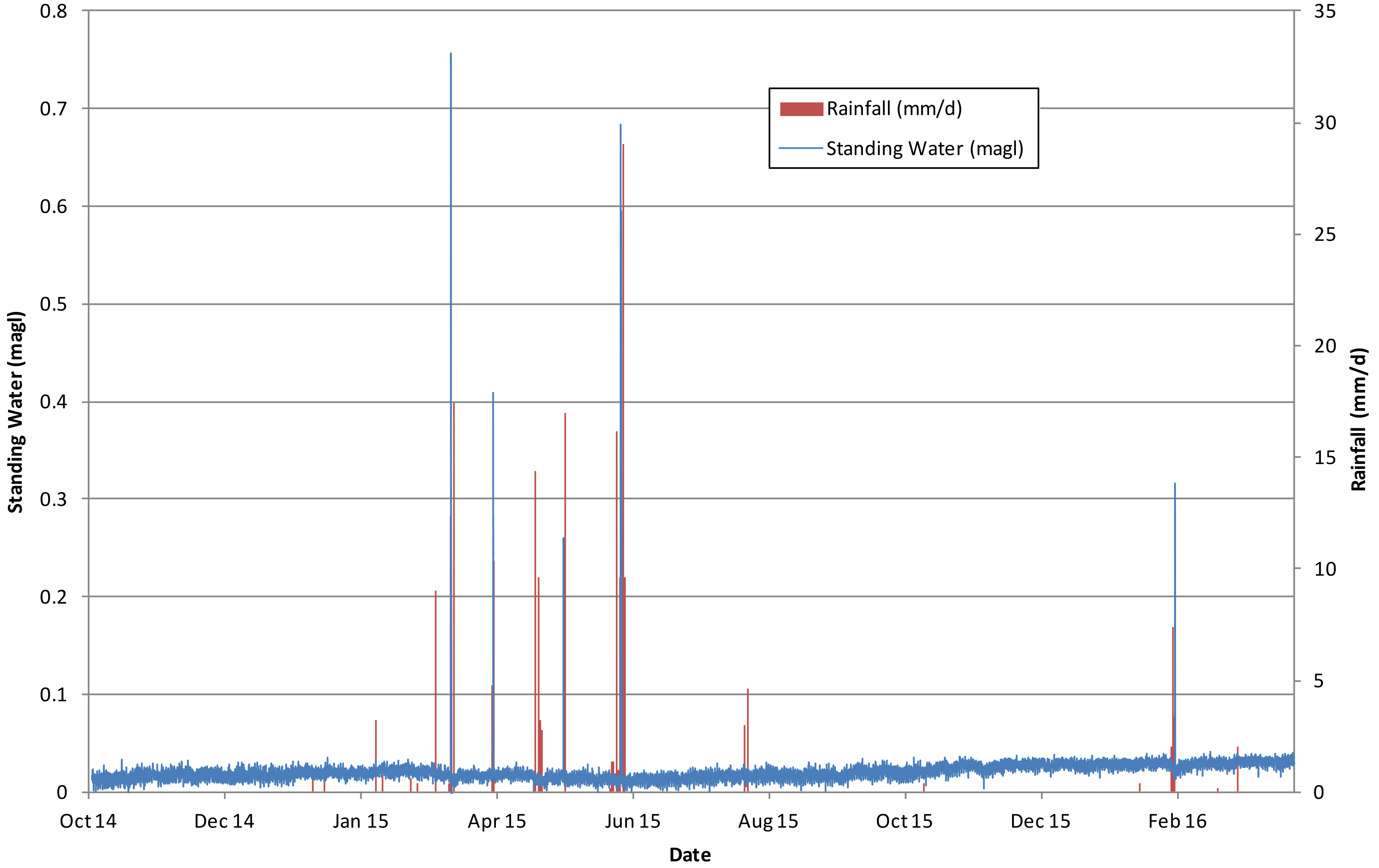


Graph H: **Hydrograph and Rainfall for Surface Water Monitoring Location SW-1**



Graph I: Hydrograph and Rainfall for Surface Water Monitoring Location SW-2



Graph J: **Hydrograph and Rainfall for Surface Water Monitoring Location SW-3**

5.0 SUMMARY AND RECOMMENDATIONS

The 2014–2016 baseline groundwater and surface water monitoring program for the Anketell Strategic Industrial Area has been completed. The points below summarise the major outcomes of the monitoring program:

- Groundwater elevations ranged from 2.6 to 7 mAHD across the site. The depth to groundwater ranged from 3.2 to 15.2 mbgl over the monitoring period. Groundwater flow is generally in a north-west direction towards the coast.

- Both the semi-diurnal and lunar month tidal cycles are shown to influence groundwater elevations. However, the impact is considered minor at up to approximately ± 5 cm. No major storms occurred over the monitoring period hence the impact of storm surge has not been monitored or assessed.

- Groundwater salinity had significant spatial variation across the site and ranged from approximately 1,700 mg/L to 43,000 mg/L. Groundwater salinity was influenced by recharge from creek lines and impact from marine waters.

- The majority of the dissolved metals analysed for were recorded at or below the limit of reporting. Dissolved arsenic, cadmium, copper, nickel and zinc were recorded at concentrations that exceeded ecological water guidelines (MEPG, FWG) with one sample for dissolved nickel exceeding the non-potable guideline (DNPG) values.

- Groundwater nutrients exceeded the MEPG and FWG throughout the monitoring period. The concentrations are higher at NB-1 compared to the rest of the site; the higher concentration is considered due to marine water and/or evapoconcentration of rainwater.

- Creek flow occurred once during the monitoring period and the maximum depth of water encountered was 1.4 m. Infiltration rates of ponded water within the creeks (once flow had ceased) were estimated at 17 mm/day at SW-1 and 45 mm/day at SW-2. The variation in infiltrations rates is likely due to the variations in creek bed geology.

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TABLES

Table 1: Laboratory Analysis Results

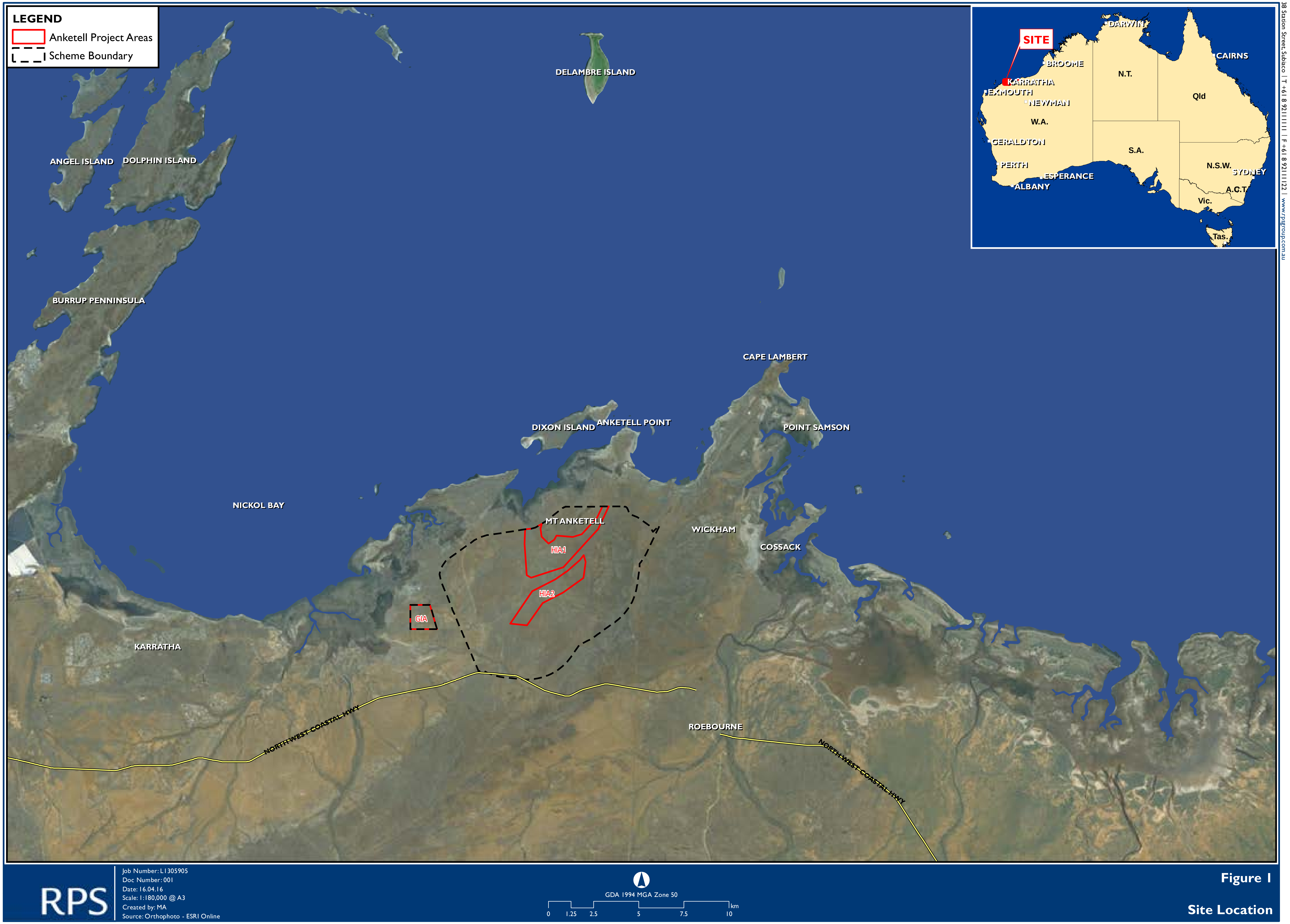
Sample ID	Sample Date	Dissolved Metals										Alkalinity				Major Ions						Nutrients						
		Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury	Aluminium	Iron	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Sulfate as SO4	Chloride (Cl)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Ammonia as N	Nitrite + Nitrate as N	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus as P	Reactive Phosphorus as P	Total Dissolved Solids
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Fresh Water Guideline		0.013	0.0002	-	0.0014	0.011	0.0034	0.008	-	0.055	0.3	-	-	-	-	-	-	-	-	-	-	0.01	0.01	-	1	0.1	0.005	
Marine Water Guideline		-	0.0007	-	0.0013	0.007	0.0044	0.015	-	-	1	-	-	-	-	-	-	-	-	-	-	0.01	0.008	-	0.1	0.015	0.005	
Domestic Non-Potable		0.07	0.02	0.5	20	0.2	0.1	30	0.01	2	3	-	-	-	-	5,000	2,500	-	-	-	-	4.1	120	-	-	-	-	
NB-1	2/10/2014	<0.01	0.0112	<0.010	0.021	<0.010	<0.01	<0.05	0.0012	-	-	<1	<1	160	160	1,790	34,200	5,270	5,410	10,500	73	0.8	1.62	6.2	7.8	0.2	<0.01	75,800
	26/03/2015	<0.01	0.009	<0.01	0.016	0.286	<0.01	<0.05	<0.0001	-	-	<1	<1	157	157	1,600	32,000	4,870	4,920	9,480	88	0.38	1.07	<1	1.1	<0.1	0.01	63,000
	6/10/2015	<0.01	0.0116	<0.01	0.019	0.119	<0.01	<0.05	0.0004	-	-	<1	<1	161	161	1,570	30,800	4,770	4,910	9,770	75	0.83	1.56	1	2.6	<0.1	<0.01	-
	29/03/2016	0.018	0.0095	0.001	0.002	0.054	0.004	0.031	0.0013	<0.01	<0.01	-	<5	150	150	2,000	34,000	4,500	4,500	11,000	62	<0.02	1.4	0.2	1.4	0.03	0.03	-
HIA-N	2/10/2014	0.002	<0.0001	<0.001	0.002	0.002	<0.001	0.005	<0.0001	-	-	<1	<1	472	472	300	2,180	154	226	1,110	1	0.03	0.46	<0.2	0.5	0.05	<0.01	4,690
	26/03/2015	0.003	<0.0001	<0.001	0.001	0.001	<0.001	0.007	<0.0001	-	-	<1	<1	486	486	302	2,250	159	220	1,080	<1	0.09	0.34	0.1	0.4	0.02	0.02	4,540
	6/10/2015	0.002	<0.0001	<0.001	0.003	0.017	<0.001	0.007	<0.0001	-	-	<1	<1	489	489	279	1,960	171	248	1,170	<1	0.04	0.29	<0.1	0.3	<0.01	<0.01	-
	29/03/2016	0.003	<0.0001	<0.001	<0.001	0.002	<0.001	<0.005	<0.0001	<0.01	<0.01	-	<5	470	470	400	2,100	86	120	1,300	0.8	<0.02	0.29	<0.2	0.4	0.06	0.06	-
HIA-S	2/10/2014	0.001	<0.0001	<0.001	0.001	0.012	<0.001	<0.005	<0.0001	-	-	<1	<1	522	522	213	1,430	138	171	860	<1	0.03	0.65	0.1	0.8	<0.01	<0.01	3,460
	26/03/2015	0.002	<0.0001	<0.001	0.001	<0.001	<0.001	<0.005	<0.0001	-	-	<1	<1	502	502	235	1,660	135	166	831	<1	0.06	0.93	0.2	1.1	<0.01	0.01	3,300
	6/10/2015	0.001	<0.0001	<0.001	0.002	0.002	<0.001	<0.005	<0.0001	-	-	<1	<1	508	508	206	1,310	134	170	879	<1	0.02	0.98	0.2	1.2	<0.01	<0.01	-
	29/03/2016	0.002	<0.0001	<0.001	<0.001	0.001	<0.001	<0.005	<0.0001	<0.01	<0.01		<5	470	470	290	1,500	60	82	760	0.5	<0.02	1.2	0.2	1.4	0.05	0.05	-
GIA-1	26/03/2015	<0.001	<0.0001	<0.001	0.002	0.002	<0.001	0.012	<0.0001	-	-	<1	<1	377	377	160	1,090	155	126	409	3	0.07	0.68	0.4	1.1	0.12	0.01	2,560
	6/10/2015	<0.001	<0.0001	<0.001	0.002	0.002	<0.001	0.008	<0.0001	-	-	<1	<1	379	379	134	949	168	141	465	3	0.02	0.02	0.2	0.2	0.11	<0.01	-
	29/03/2016	<0.001	<0.0001	<0.001	<0.001	0.001	<0.001	<0.005	<0.0001	<0.01	<0.01	-	<5	310	310	220	1,200	100	91	460	2.4	<0.02	0.09	<0.2	0.4	0.17	0.03	-

FWG	ANZECC/ARMCANZ (2000) Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water - Fresh water guidelines for Tropical Australia
MEPG	ANZECC/ARMCANZ (2000) Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water - Marine Ecosystems Protection Guidelines
DNPG	Department of Health (2006) Contaminated Sites Reporting Guidelines for Chemicals in Groundwater - Domestic Non-potable groundwater

Table 2: Groundwater QA/QC Results

Sample ID	Sample Date	Dissolved Metals										Alkalinity				Major Ions						Nutrients						
		Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury	Aluminium	Iron	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Sulfate as SO4	Chloride (Cl)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Ammonia as N	Nitrite + Nitrate as N	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus as P	Reactive Phosphorus as P	Total Dissolved Solids
HIA-N	2/10/2014	0.002	<0.0001	<0.001	0.002	0.002	<0.001	<0.005	<0.0001	-	-	<1	<1	472	472	300	2180	154	226	1110	1	0.03	0.46	<0.2	0.5	0.05	<0.01	4,690
HIA-Z (HIA-N)		0.003	<0.0001	<0.001	0.002	0.015	<0.001	<0.005	<0.0001	-	-	<1	<1	472	472	302	2160	154	223	1110	1	0.03	0.44	<0.2	0.4	0.05	<0.01	4,630
RPD(%)		**-40**	**NA**	**NA**	**0**	**-153**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0**	**0**	**-1**	**1**	**0**	**1**	**0**	**0**	**0**	**4**	**NA**	**22**	**0**	**NA**	**1**
NB-1	26/03/2015	<0.01	0.009	<0.01	0.016	0.286	<0.01	<0.05	<0.0001	-	-	<1	<1	157	157	1600	32000	4870	4920	9480	88	0.38	1.07	<1	1.1	<0.1	0.01	63,000
MB-Z (NB-1)		<0.010	0.0094	<0.010	0.015	0.303	<0.010	<0.050	<0.0001	-	-	<1	<1	160	160	1580	31900	4690	4730	9180	84	0.39	1.08	<1.0	1.1	<0.1	<0.01	61,400
RPD(%)		**NA**	**-4**	**NA**	**6**	**-6**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**-2**	**-2**	**1**	**0**	**4**	**4**	**3**	**5**	**-3**	**-1**	**NA**	**0**	**NA**	**NA**	**3**
HIA-N	6/10/2015	0.002	<0.0001	<0.001	0.003	0.017	<0.001	0.007	<0.0001	-	-	<1	<1	489	489	279	1960	171	248	1170	<1	0.04	0.29	<0.1	0.3	<0.01	<0.01	-
MB-Z (HIA-N)		0.001	<0.0001	<0.001	0.002	0.015	<0.001	0.006	<0.0001	-	-	<1	<1	486	486	294	1950	167	244	1140	<1	0.06	0.3	<0.1	0.3	<0.01	<0.01	-
RPD(%)		**67**	**NA**	**NA**	**40**	**13**	**NA**	**15**	**NA**	**NA**	**NA**	**NA**	**NA**	**1**	**1**	**-5**	**1**	**2**	**2**	**3**	**NA**	**-40**	**-3**	**NA**	**0**	**NA**	**NA**	**NA**
HIA-N	29/03/2016	0.003	<0.0001	<0.001	<0.001	0.002	<0.001	<0.005	<0.0001	<0.01	<0.01	-	<5	470	470	400	2100	86	120	1300	0.8	<0.02	0.29	<0.2	0.4	0.06	0.06	-
MB-Z (HIA-N)		0.004	<0.0001	<0.001	<0.001	0.002	<0.001	<0.005	<0.0001	<0.01	<0.01	-	<5	470	470	430	2200	94	120	1200	0.8	<0.02	0.31	<0.2	0.4	0.05	0.05	-
RPD(%)		**-29**	**NA**	**NA**	**NA**	**0**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0**	**0**	**-7**	**-5**	**-9**	**0**	**8**	**0**	**NA**	**-7**	**NA**	**0**	**18**	**18**	**NA**

FIGURES



RPS

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Doc Number: 001
Date: 16.04.16
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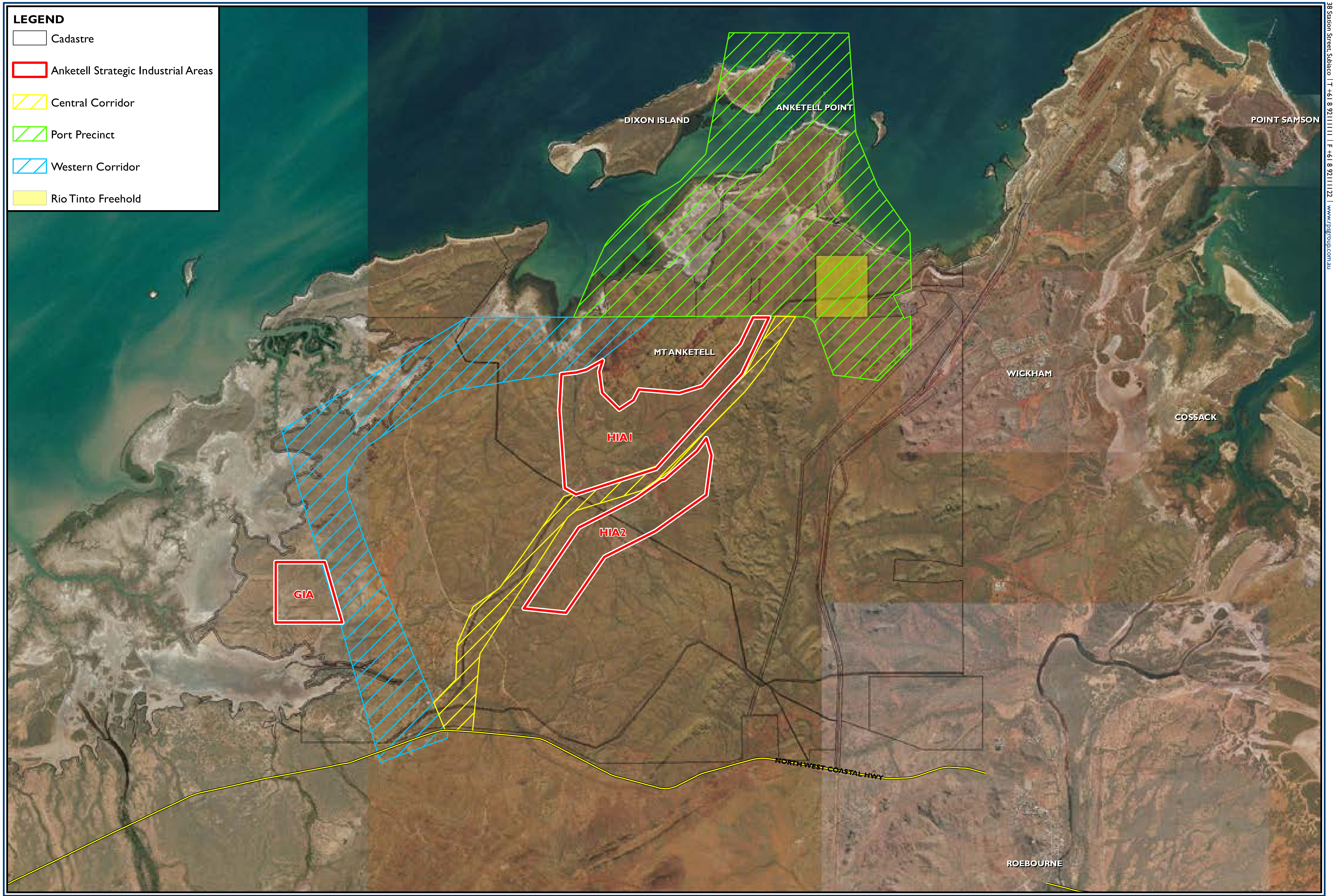
Created by: MA
Source: Orthophoto - ESRI Online

Figure 1

Site Location



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Created by: MA
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

Figure 2

Anketell Project Design Plan

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LEGEND

🟥 Anketell Project Areas

☐ Cadastre

Surficial Geology (Geoscience, 2013)

CODE, NARRATIVE

▨ AFr - MOUNT ROE BASALT: massive, vesicular, and glomeroporphyritic basalt

▨ AFra - MOUNT ROE BASALT: Basaltic agglomerate

▨ AFrc - MOUNT ROE BASALT: Polymictic conglomerate and sandstone

▨ AFrs - MOUNT ROE BASALT: Sandstone and conglomerate; minor shale

▨ Ab - Basaltic rock, undivided; generally metamorphosed to greenschist facies

▨ Aba - Strongly foliated basalt; metamorphosed to amphibolite facies

▨ Abt - Basaltic tuff, well bedded; metamorphosed

▨ Ac - Chert, undivided

▨ Acb - Black chert

▨ Acf - Ferruginous chert, banded iron-formation, and metamorphosed intercalated fine-grained clastic sedimentary rocks

▨ Aci - Banded iron-formation; minor ferruginous chert

▨ Acw - Grey-white banded chert, locally associated with quartzite

▨ Af - Felsic volcanic rock, undivided; chiefly dacite; metamorphosed

▨ Afr - Rhyolite; metamorphosed

▨ Aod - Dolerite; metamorphosed

▨ Aog - Gabbro; metamorphosed

▨ Apf - Quartz-feldspar porphyry, rhyolite, and dacite; chiefly intrusive; metamorphosed

▨ As - Sedimentary rocks, undivided; metamorphosed

▨ Asc - Metaconglomerate

▨ Asf - Felsic volcaniclastic rock; metamorphosed

▨ Asi - Ferruginous clastic sedimentary rocks, dominantly pelitic; includes minor chert beds; metamorphosed

▨ Asq - Quartzite

▨ Ast - Sandstone; minor conglomerate and siltstone; metamorphosed

▨ Au - Ultramafic rock, undivided; includes schist; local silicification

▨ Auk - Komatiite; characterized by olivine spinifex textures; metamorphosed

▨ Czrf - Ferricrete; includes ferruginous duricrust and pisolitic ironstone; residual origin; dissected by present-day drainage

▨ Qaa - Alluvial sand and gravel in rivers and creeks; clay, silt, and sand in channels on floodplains

▨ Qc - Colluvium - sand, silt, and gravel in outwash fans; scree, talus; proximal mass-wasting deposits

▨ Qhmm - Marine mud and silt; intertidal with mangroves

▨ Qhms - Shelly sand in coastal dunes and old beach deposits; contains Anadara granosa

▨ Qhmu - Silt and mud in supratidal to intertidal flats and lagoons

▨ Qpmb - Coastal limestone - lime-cemented shelly sand, dune sand, and beach conglomerate

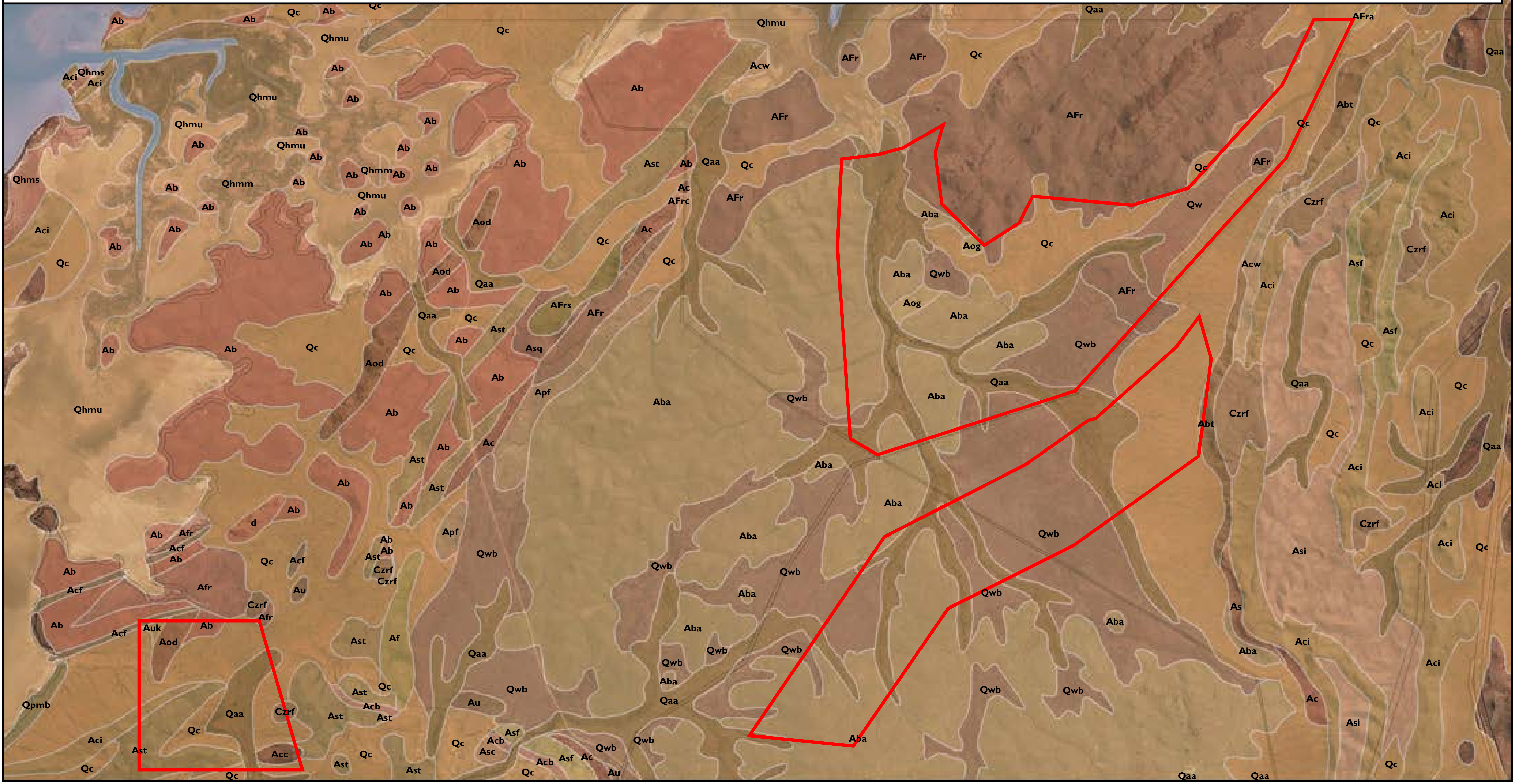
▨ Qs - Eolian sand - red-yellow, wind-blown sand; local sand ridges

▨ Qw - Low-gradient sheetwash deposits - silt, sand, and pebbles in distal outwash fans; no defined drainage

▨ Qwb - Low-gradient sheetwash deposits - sand, silt, and clay in distal outwash fans, with gilgai surface in areas of expansive clay

▨ d - Dolerite dyke, interpreted beneath regolith from aeromagnetic data where dashed

▨ Ocean



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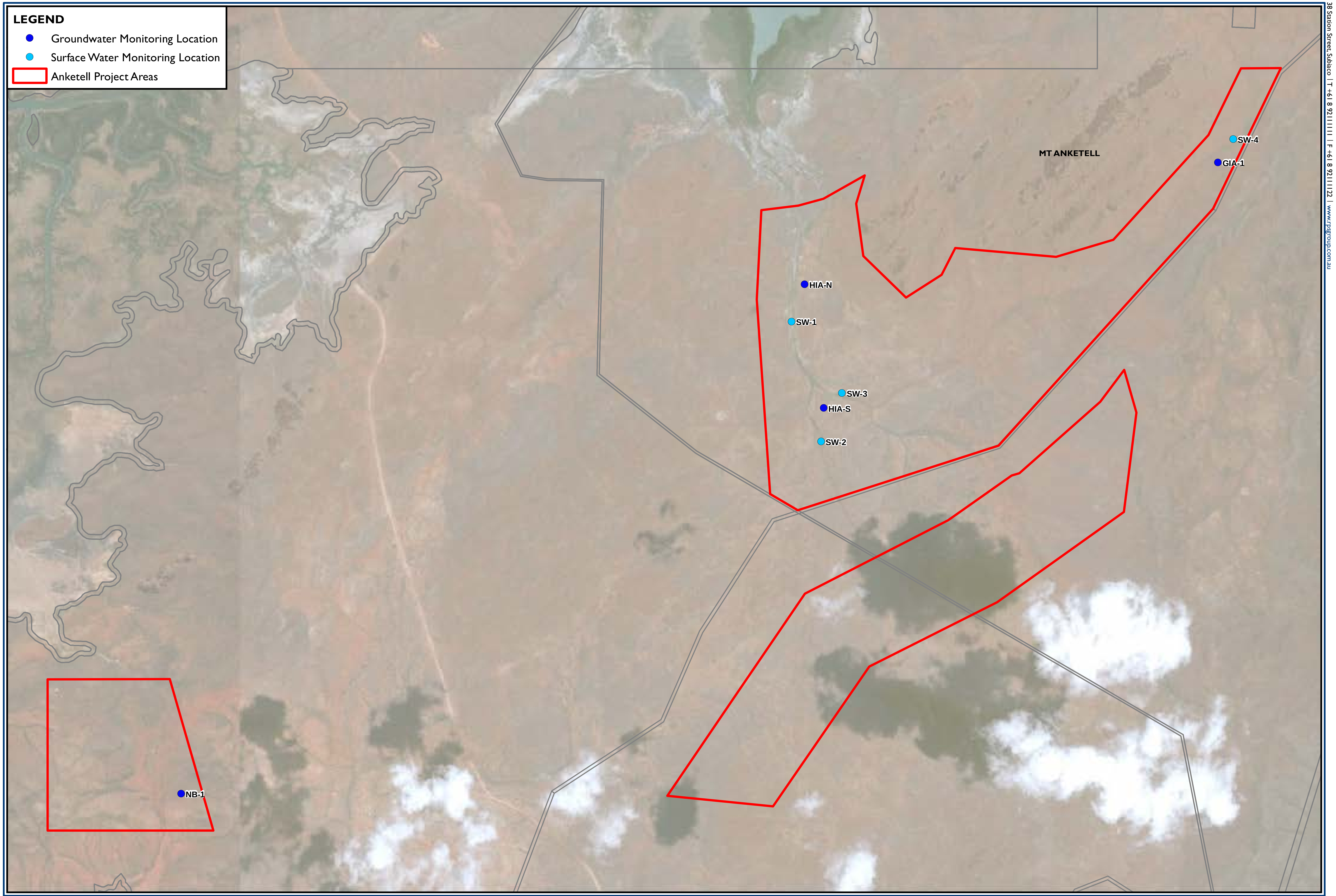
Source: Orthophoto - Landgate, 2012 Cadastre - Landgate, 2013

GDA 1994 MGA Zone 50

0 0.25 0.5 1 1.5 2 km

Figure 3

Surface Geology



RPS

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Doc Number: 004
Date: 16.04.16
Scale: 1:30,000 @ A3
Created by: MA
Source: Orthophoto - ESRI Online World Imagery

Figure 4

Groundwater and Surface Water Monitoring Locations

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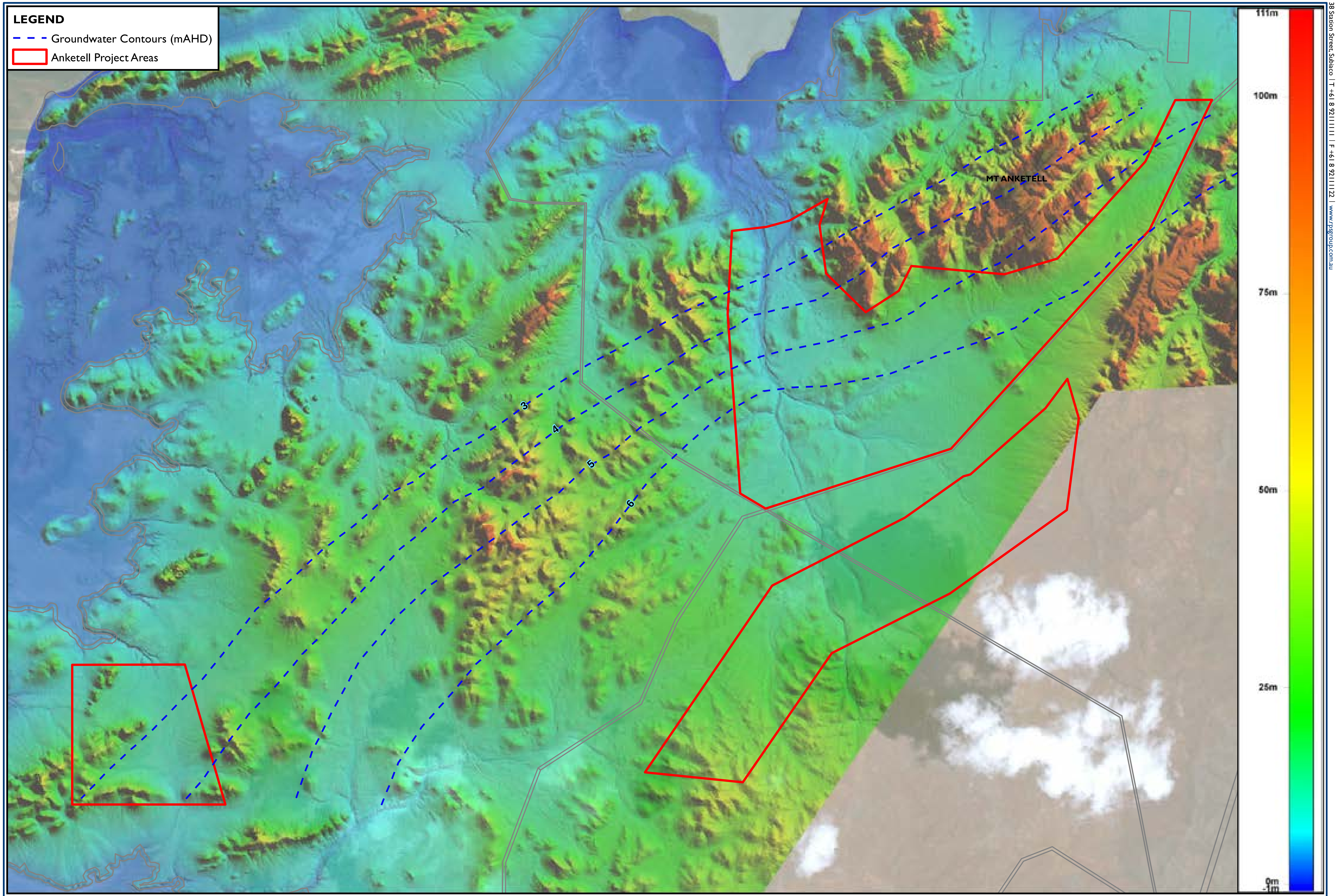

RPS

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Doc Number: 005
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Created by: MA
Source: Orthophoto - ESRI Online World Imagery

GDA 1994 MGA Zone 50

Figure 5

Groundwater Elevation Contours – October 2014

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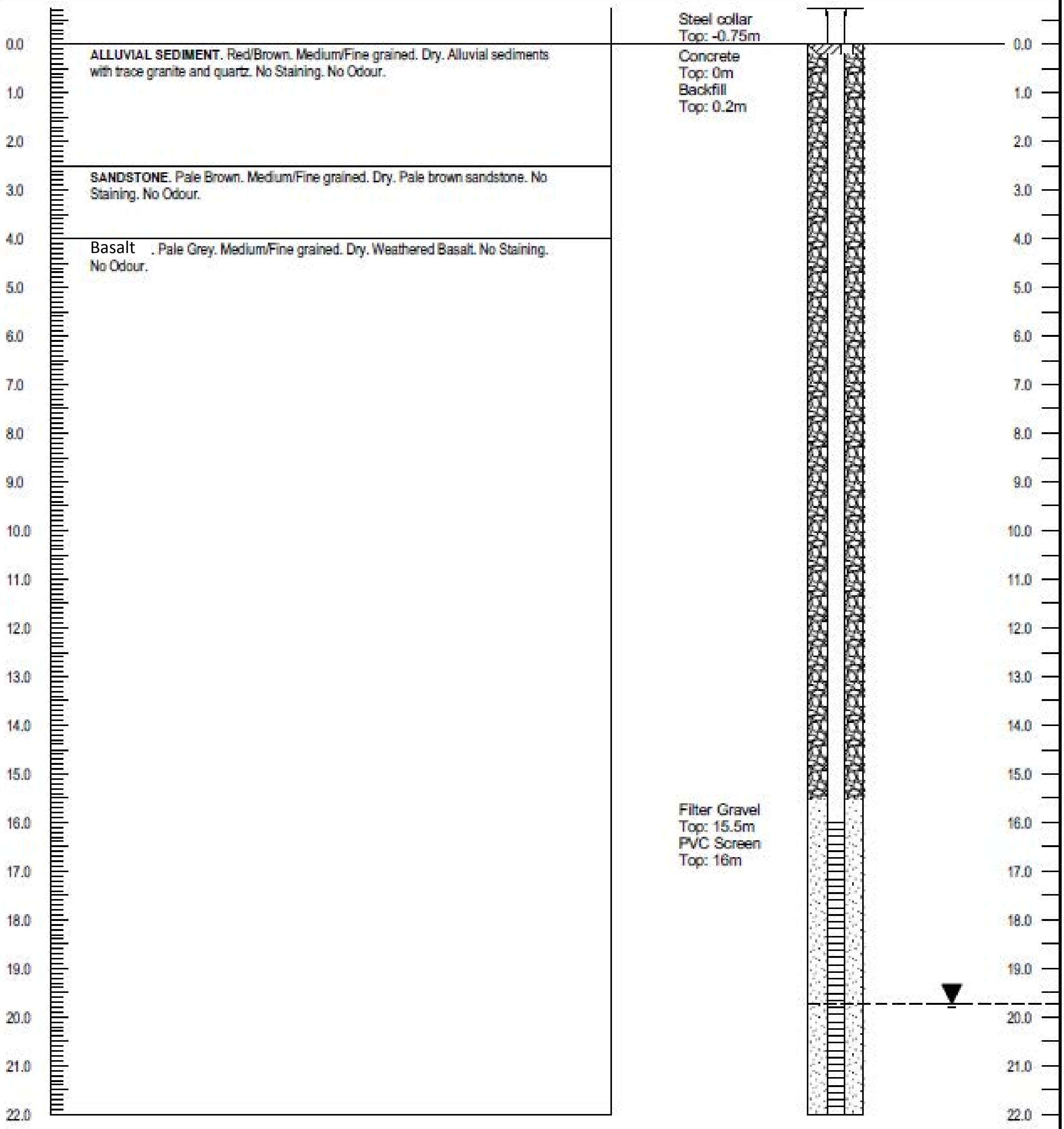
APPENDIX 1

Bore Construction and Lithological Logs

BOREHOLE CONSTRUCTION LOG

PROJECT NUMBER: L1305905
WEATHER:
BOREHOLE ID: GIA-1
DRILLING METHOD: Rotary Air Blast
SITE: Anketell
LOCATION:
TOTAL DEPTH: 22 m
EAST: 508248
NORTH: 7713851
TOP of COLLAR RL: mAHD
DATE BEGUN: 2/10/2014
DATE COMPLETED: 2/10/2014
STATIC WATER LEVEL: 19.72 mbgl
SCIENTIST:
CASE DIAMETER: 50 mm
PVC CLASS: 9
DRILLING COMPANY: Roeborne Drilling
LOCKABLE BORE: Yes
DRILLER: Craig
SHEET: 1 of 1

LITHOLOGY DESCRIPTION **BORE INSTALLATION**



ALLUVIAL SEDIMENT. Red/Brown. Medium/Fine grained. Dry. Alluvial sediments with trace granite and quartz. No Staining. No Odour.

SANDSTONE. Pale Brown. Medium/Fine grained. Dry. Pale brown sandstone. No Staining. No Odour.

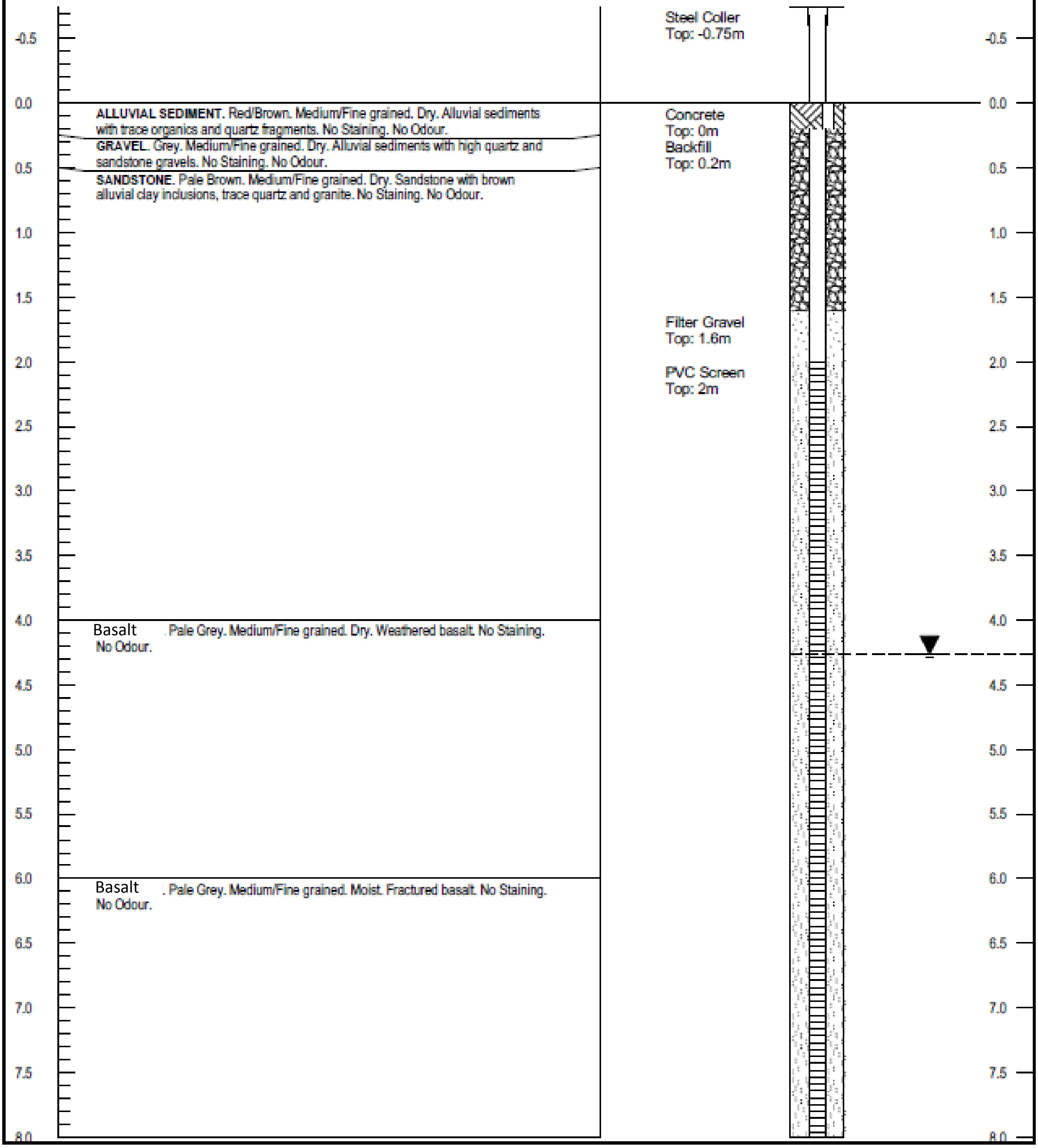
Basalt . Pale Grey. Medium/Fine grained. Dry. Weathered Basalt. No Staining. No Odour.

RPS

BOREHOLE CONSTRUCTION LOG

PROJECT NUMBER: L1305905
WEATHER:
BOREHOLE ID: HIA-N
DRILLING METHOD: Rotary Air Blast
SITE: Anketell LOCATION:
TOTAL DEPTH: 8 m
EAST: 504563 NORTH: 7712764
TOP of COLLAR RL: mAHD
DATE BEGUN: 2/10/2014 DATE COMPLETED: 2/10/2014
STATIC WATER LEVEL: 4.261 mbgl
SCIENTIST:
CASE DIAMETER: 50 mm PVC CLASS: 9
DRILLING COMPANY: Roeborne Drilling
LOCKABLE BORE: Yes
DRILLER: Craig
SHEET: 1 of 1

LITHOLOGY DESCRIPTION **BORE INSTALLATION**



ALLUVIAL SEDIMENT. Red/Brown. Medium/Fine grained. Dry. Alluvial sediments with trace organics and quartz fragments. No Staining. No Odour.

GRAVEL. Grey. Medium/Fine grained. Dry. Alluvial sediments with high quartz and sandstone gravels. No Staining. No Odour.

SANDSTONE. Pale Brown. Medium/Fine grained. Dry. Sandstone with brown alluvial clay inclusions, trace quartz and granite. No Staining. No Odour.

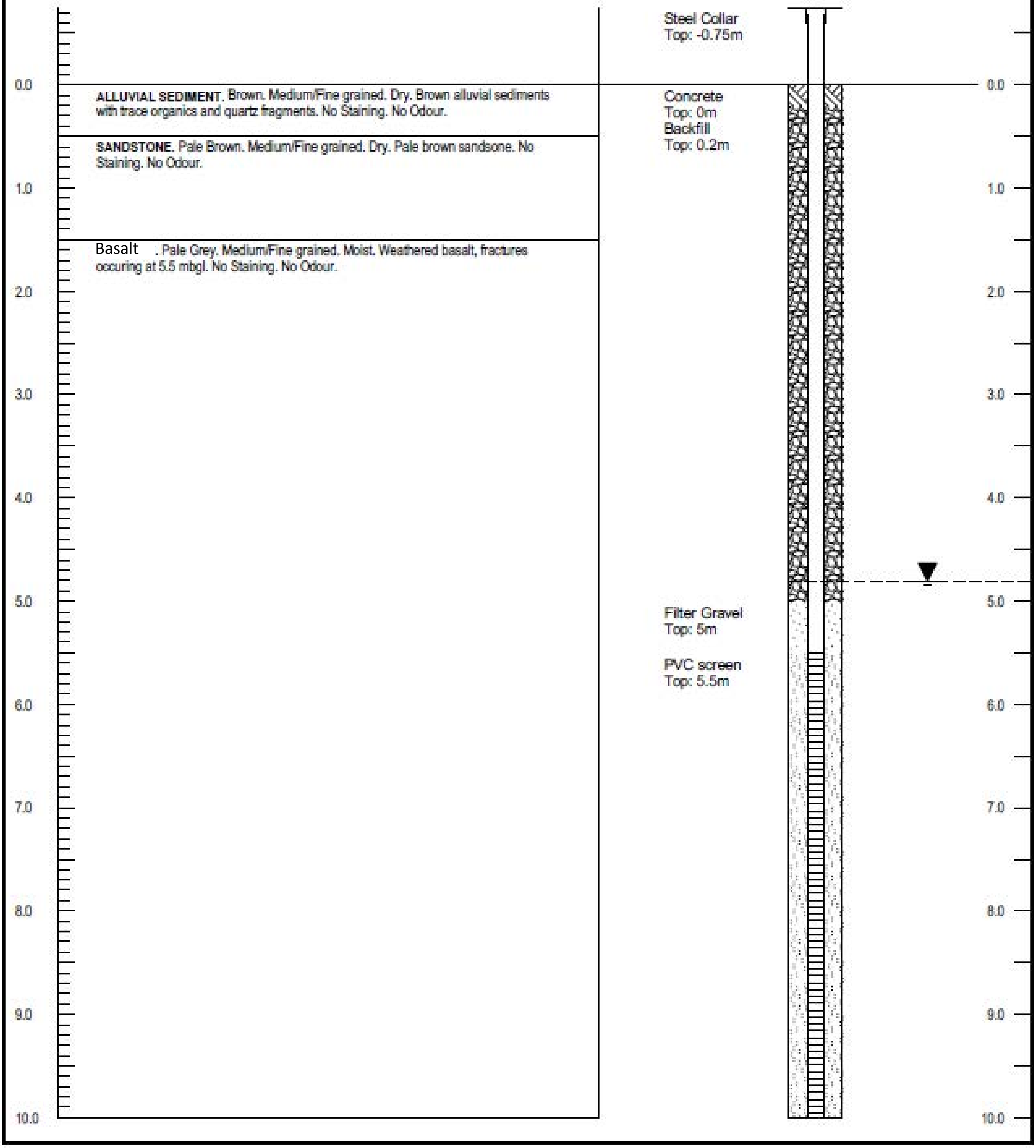
Basalt . Pale Grey. Medium/Fine grained. Dry. Weathered basalt. No Staining. No Odour.

Basalt . Pale Grey. Medium/Fine grained. Moist. Fractured basalt. No Staining. No Odour.

BOREHOLE CONSTRUCTION LOG

PROJECT NUMBER: L1305905				WEATHER:
BOREHOLE ID: HIA-S				DRILLING METHOD: Rotary Air Blast
SITE: Anketell		LOCATION:		TOTAL DEPTH: 10 m
EAST:	504733	NORTH:	7711661	TOP of COLLAR RL: mAHD
DATE BEGUN:	2/10/2014	DATE COMPLETED:	2/10/2014	STATIC WATER LEVEL: 4.805 mbgl
SCIENTIST:				CASE DIAMETER: 50 mm PVC CLASS: 9
DRILLING COMPANY: Roeborne Drilling				LOCKABLE BORE: Yes
DRILLER: Craig				SHEET: 1 of 1

LITHOLOGY DESCRIPTION	BORE INSTALLATION



ALLUVIAL SEDIMENT. Brown. Medium/Fine grained. Dry. Brown alluvial sediments with trace organics and quartz fragments. No Staining. No Odour.

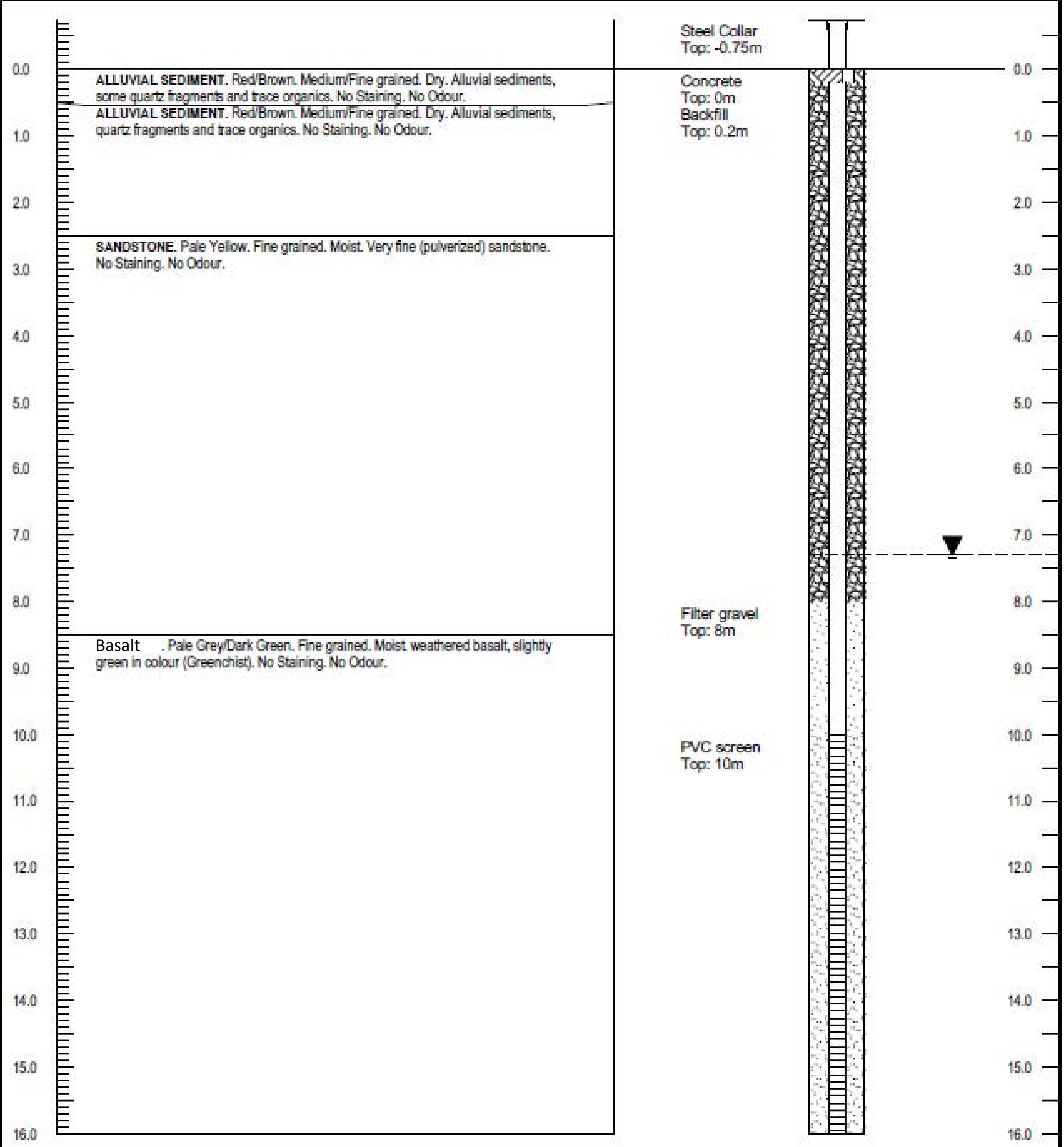
SANDSTONE. Pale Brown. Medium/Fine grained. Dry. Pale brown sandsone. No Staining. No Odour.

Basalt . Pale Grey. Medium/Fine grained. Moist. Weathered basalt, fractures occuring at 5.5 mbgl. No Staining. No Odour.

BOREHOLE CONSTRUCTION LOG

PROJECT NUMBER: L1305905				WEATHER:	
BOREHOLE ID: NB-1				DRILLING METHOD: Rotary Air Blast	
SITE: Anketell		LOCATION:		TOTAL DEPTH: 16 m	
EAST:	499004	NORTH:	7708222	TOP of COLLAR RL: mAHD	
DATE BEGUN:	2/10/2014	DATE COMPLETED:	2/10/2014	STATIC WATER LEVEL: 7.3 mbgl	
SCIENTIST:				CASE DIAMETER: 50 mm	PVC CLASS: 9
DRILLING COMPANY: Roeborne Drilling				LOCKABLE BORE: Yes	
DRILLER: Craig				SHEET: 1 of 1	

LITHOLOGY DESCRIPTION | **BORE INSTALLATION**



ALLUVIAL SEDIMENT. Red/Brown. Medium/Fine grained. Dry. Alluvial sediments, some quartz fragments and trace organics. No Staining. No Odour.

ALLUVIAL SEDIMENT. Red/Brown. Medium/Fine grained. Dry. Alluvial sediments, quartz fragments and trace organics. No Staining. No Odour.

SANDSTONE. Pale Yellow. Fine grained. Moist. Very fine (pulverized) sandstone. No Staining. No Odour.

Basalt . Pale Grey/Dark Green. Fine grained. Moist. weathered basalt, slightly green in colour (Greenchist). No Staining. No Odour.

APPENDIX 2

Groundwater Sampling Logs

RPS

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	12v Electric Pump
Sample Location:	HIA-N	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 4.261 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	504563 **Northing:** 7712764	**Recovery Depth:**	
Date:	2/10/2014	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:	HIA-Z (duplicate)		

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
20	Slightly Turbid	Brown	28.7	7.32	6580	255	4.6

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Slightly Turbid	Brown	28.7	7.32	6580	255	4.6

TTA Filtered:

Total Alkalinity Filtered:

multiprobe battery flat, additional water sample for parameters taken before sampling.

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	12v Electric Pump
Sample Location:	HIA-S	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 4.805 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	504733 **Northing:** 7711661	**Recovery Depth:**	
Date:	2/10/2014	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:			

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
20	Slightly Turbid	Pale Brown	30.5	7.41	5100	140	4.47

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Slightly Turbid	Pale Brown	30.5	7.41	5100	140	4.47

TTA Filtered:

Total Alkalinity Filtered:

Multiprobe battery flat, extra sample taken for physico-chemical parameters

GROUNDWATER SAMPLING LOG

Project Number:	L1305905			**Recovery Method:**	12v Electric Pump		
Sample Location:	NB-1			**Storage/Preservation:**	Ice and Eskie		
Site Name:	Anketell			**Depth to Water:**	7.3 mbtoc	**Depth to Base:**	
Sampling Area:				**Collar Elevation:**	mAHD	**Water Elevation:**	mAHD
Easting:	499004	**Northing:**	7708222	**Recovery Depth:**			
Date:	2/10/2014			**Sampling Rate (L/min):**		**Purge Rate (L/min):**	
Scientist(s):	SH			**0.45 micron Filtering Used:**	No		
QA/QC Sample IDs:							

minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
20	Slightly Turbid / clear	Pale Brown / clear	29.5	6.24	58700	266	2.82

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Slightly Turbid / clear	Pale Brown / clear	29.5	6.24	58700	266	2.82

TTA Filtered:

Total Alkalinity Filtered:

multiprobe battery flat, extra sample taken for physico-chemical parameters

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	Bailer
Sample Location:	GIA-1	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 15.39 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	508248 **Northing:** 7713851	**Recovery Depth:**	
Date:	26/03/2015	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:			

Litres	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Slightly Turbid	Pale Brown / Off White	33.5	7.16	2910	52	1.1
2	Slightly Turbid	Pale Brown / Off White	33.1	7.1	2800	63	0.66
3	Slightly Turbid	Pale Brown / Off White	33	7.08	2690	68	0.8
4	Turbid	Brown	33	7.08	2610	73	0.76
5	Turbid	Brown	32.9	7.07	2590	74	0.86

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Turbid	Brown	32.9	7.07	2590	74	0.86

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	12v Electric Pump
Sample Location:	HIA-N	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:**	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	504563 **Northing:** 7712764	**Recovery Depth:**	
Date:	26/03/2015	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:			

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Turbid	Red / Brown	36.2	7.18	5360	70	2.01
2	Turbid	Red / Brown	34.8	7.18	5280	67	1.21
3	Turbid	Red / Brown	34.3	7.2	5290	66	0.96
4	Slightly Turbid	Red / Brown	33.9	7.21	5320	68	0.83
5	Slightly Turbid	Red / Brown	33.6	7.22	5340	68	0.77
6	Slightly Turbid	Red / Brown	33.5	7.22	5350	69	0.71
7	Slightly Turbid	Red / Brown	33.6	7.21	5330	69	0.68
8	Slightly Turbid	Red / Brown	33.6	7.21	5380	68	0.66

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Slightly Turbid	Red / Brown	33.6	7.21	5380	68	0.66

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	12v Electric Pump
Sample Location:	HIA-S	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 4.965 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	504733 **Northing:** 7711661	**Recovery Depth:**	
Date:	26/03/2015	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:			

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Turbid	Brown	33.4	7.11	4310	45	1.34
2	Turbid	Brown	32.9	7.09	4220	55	0.9
3	Slightly Turbid	Brown	32.8	7.09	4150	62	0.85
4	Slightly Turbid	Brown	32.7	7.08	4070	66	0.81
5	Clear	Clear	32.7	7.08	4060	69	0.79
6	Clear	Clear	32.7	7.08	4070	71	0.77

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Clear	Clear	32.7	7.08	4070	71	0.77

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	12v Electric Pump
Sample Location:	NB-1	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 7.47 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	499004 **Northing:** 7708222	**Recovery Depth:**	
Date:	26/03/2015	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:	MB-Z		

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Clear	Clear	34.5	6.13	50600	192	0.88
2	Clear	Clear	33.4	6.31	48200	178	0.66
3	Clear	Clear	33.4	6.37	46600	173	0.61
4	Clear	Clear	33.6	6.35	45400	167	0.43
5	Clear / Slightly Turbid	Clear / Pale Brown	34.2	6.34	44300	161	1.36
6	Clear / Slightly Turbid	Clear / Pale Brown	34.3	6.34	43400	157	1.61
7	Clear / Slightly Turbid	Clear / Pale Brown	34.4	6.34	42800	155	1.67
8	Clear / Slightly Turbid	Clear / Pale Brown	34.5	6.35	42200	153	1.68

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Clear / Slightly Turbid	Clear / Pale Brown	34.5	6.35	42200	153	1.68

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	Bailer
Sample Location:	GIA-1	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 15.532 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	508248 **Northing:** 7713851	**Recovery Depth:**	
Date:	6/10/2015	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:			

Litre	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Slightly Turbid	Pale Brown	33.5	7.01	3470		
2	Slightly Turbid	Pale Brown	33	6.96	3510		
3	Slightly Turbid	Pale Brown	32.8	6.96	3520		
4	Slightly Turbid	Pale Brown	32.7	6.96	3530		
5	Slightly Turbid	Pale Brown	32.6	6.95	3590		
6	Slightly Turbid	Pale Brown	32.6	6.95	3620		
7	Slightly Turbid	Pale Brown	32.5	6.96	3620		
8	Slightly Turbid	Pale Brown	32.3	6.97	3630		
9	Slightly Turbid	Pale Brown	32	6.98	3630		

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Slightly Turbid	Pale Brown	32	6.98	3630		

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	12v Electric Pump
Sample Location:	HIA-N	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 4.445 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	504563 **Northing:** 7712764	**Recovery Depth:**	
Date:	6/10/2015	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:	MB-Z		

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Turbid	Brown	32.5	6.93	6900		
2	Slightly Turbid	Pale Brown	32	6.93	6770		
3	Slightly Turbid	Pale Brown	31.8	6.93	6780		
4	Slightly Turbid / Clear	Pale Brown	31.6	6.93	6790		
5	Slightly Turbid / Clear	Pale Brown	31.6	6.93	6780		
6	Slightly Turbid / Clear	Pale Brown	31.6	6.93	6780		
7	Slightly Turbid / Clear	Pale Brown	31.6	6.93	6780		
8	Slightly Turbid / Clear	Pale Brown	31.6	6.93	6780		

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Slightly Turbid / Clear	Pale Brown	31.6	6.93	6780		

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

Project Number:	L1305905		**Recovery Method:**	12v Electric Pump	
Sample Location:	HIA-S		**Storage/Preservation:**	Ice and Eskie	
Site Name:	Anketell		**Depth to Water:**	5.241 mbtoc	**Depth to Base:**
Sampling Area:			**Collar Elevation:**	mAHD	**Water Elevation:** mAHD
Easting:	504733	**Northing:** 7711661	**Recovery Depth:**		
Date:	6/10/2015		**Sampling Rate (L/min):**		**Purge Rate (L/min):**
Scientist(s):	SH		**0.45 micron Filtering Used:**	No	
QA/QC Sample IDs:					

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Slightly Turbid	Pale Brown	32.8	6.97	5000		
2	Slightly Turbid / Clear	Clear / Pale Brown	32.1	6.96	5000		
3	Slightly Turbid / Clear	Clear / Pale Brown	32.1	6.97	4990		
4	Clear	Clear	32	6.97	4990		
5	Clear	Clear	32	6.97	4990		
6	Clear	Clear	32	6.97	4990		

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Clear	Clear	32	6.97	4990		

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

Project Number:	L1305905	**Recovery Method:**	12v Electric Pump
Sample Location:	NB-1	**Storage/Preservation:**	Ice and Eskie
Site Name:	Anketell	**Depth to Water:** 7.55 mbtoc	**Depth to Base:**
Sampling Area:		**Collar Elevation:** mAHD	**Water Elevation:** mAHD
Easting:	499004 **Northing:** 7708222	**Recovery Depth:**	
Date:	6/10/2015	**Sampling Rate (L/min):**	**Purge Rate (L/min):**
Scientist(s):	SH	**0.45 micron Filtering Used:**	No
QA/QC Sample IDs:			

Minutes	Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
1	Slightly Turbd / Clear	Clear / P. Brown	34	6.79	57100		
2	Slightly Turbd / Clear	Clear / P. Brown	32.5	6.79	57900		
3	Slightly Turbd / Clear	Clear / P. Brown	32.4	6.78	58500		
4	Slightly Turbd / Clear	Clear / P. Brown	32.4	6.64	58100		
5	Slightly Turbd / Clear	Clear / P. Brown	32.8	6.59	56600		
6	Slightly Turbd / Clear	Clear / P. Brown	32.9	6.57	55900		
7	Slightly Turbd / Clear	Clear / P. Brown	33	6.55	55700		
8	Slightly Turbd / Clear	Clear / P. Brown	33	6.49	55600		

Final Stability

Appearance	Colour	Temp (deg C)	pH	E.C. (uS/cm)	Redox (mV)	D.O. (ppm)
Slightly Turbd / Clear	Clear / P. Brown	33	6.49	55600		

TTA Filtered:

Total Alkalinity Filtered:

GROUNDWATER SAMPLING LOG

RPS

PROJECT NUMBER:	L1305905	SAMPLE RECOVERY METHOD:	Bailer
SITE NAME:	Mt Anketell	COLLAR ELEVATION (m AHD):	
SAMPLING AREA:		DEPTH TO GROUNDWATER (mbtoc / mbgl):	15.822
SAMPLING LOCATION ID:	**GIA-1**	STANDING WATER LEVEL (m AHD)	
SCIENTIST(S):	S. Hewitt	RECOVERY DEPTH (mbtoc / mbgl):	17
DATE:	24/03/2016	DEPTH TO BASE: (mbtoc / mbgl):	
TIME:		SAMPLE STORAGE / PRESERVATION:	Ice / Esky
QA/QC SAMPLE IDs:			

GROUNDWATER STABILISATION DATA

Mins / Litres	APPEARANCE	COLOUR	TEMP (°C)	pH	E.C. (µs/cm)	REDOX (mV)	D.O. (ppm)
2	Clear	Clear	33.0	6.87	3440		
4	Clear	Clear	31.7	6.81	3570		
6	Slightly Turbid	Pale Brown	31.2	6.80	3610		
8	Turbid	Pale Brown	31.1	6.80	3640		
10	Turbid	Pale Brown	30.9	6.82	3650		
12	Turbid	Pale Brown	30.6	6.84	3640		
		FINAL STABILITY	0.0	0.0	0	0.0	0.0

PURGE RATE (Litres/Min):	-
SAMPLING RATE (Litres/Min):	-
0.45 MICRON FILTRATION USED	Yes

ADDITIONAL COMMENTS:

EASTING:		NORTHING:	

GROUNDWATER SAMPLING LOG

RPS

PROJECT NUMBER:	L1305905	SAMPLE RECOVERY METHOD:	12v Pump
SITE NAME:	Mt Anketell	COLLAR ELEVATION (m AHD):	
SAMPLING AREA:		DEPTH TO GROUNDWATER (mbtoc / mbgl):	4.861
SAMPLING LOCATION ID:	**HIA-N**	STANDING WATER LEVEL (m AHD)	
SCIENTIST(S):	S. Hewitt	RECOVERY DEPTH (mbtoc / mbgl):	5.8
DATE:	24/03/2016	DEPTH TO BASE: (mbtoc / mbgl):	
TIME:		SAMPLE STORAGE / PRESERVATION:	Ice / Esky
QA/QC SAMPLE IDs:			

GROUNDWATER STABILISATION DATA

Mins / Litres	APPEARANCE	COLOUR	TEMP (°C)	pH	E.C. (µs/cm)	REDOX (mV)	D.O. (ppm)
1	Slightly Turbid	Pale Brown	31.1	6.81	6600		
2	Slightly Turbid	Pale Brown	30.9	6.80	6780		
3	S. Turbid / clear	P.brown / clear	30.8	6.80	6850		
4	clear	clear	30.8	6.80	6850		
5	clear	clear	30.8	6.80	6850		
6	clear	clear	30.8	6.80	6850		
7	clear	clear	30.8	6.80	6850		
8	clear	clear	30.7	6.80	6850		
		FINAL STABILITY	0.0	0.0	0	0.0	0.0

PURGE RATE (Litres/Min):	-
SAMPLING RATE (Litres/Min):	-
0.45 MICRON FILTRATION USED	Yes

ADDITIONAL COMMENTS:

EASTING:		NORTHING:	

GROUNDWATER SAMPLING LOG

PROJECT NUMBER:	L1305905	SAMPLE RECOVERY METHOD:	12v Pump
SITE NAME:	Mt Anketell	COLLAR ELEVATION (m AHD):	
SAMPLING AREA:		DEPTH TO GROUNDWATER (mbtoc / mbgl):	5.681
SAMPLING LOCATION ID:	**HIA-S**	STANDING WATER LEVEL (m AHD)	
SCIENTIST(S):	S. Hewitt	RECOVERY DEPTH (mbtoc / mbgl):	6.7
DATE:	24/03/2016	DEPTH TO BASE: (mbtoc / mbgl):	
TIME:		SAMPLE STORAGE / PRESERVATION:	Ice / Esky
QA/QC SAMPLE IDs:			

GROUNDWATER STABILISATION DATA

Mins / Litres	APPEARANCE	COLOUR	TEMP (°C)	pH	E.C. (µs/cm)	REDOX (mV)	D.O. (ppm)
1	Turbid	off white	33.0	6.86	4900		
2	Turbid	off white	31.8	6.74	4980		
3	Slightly Turbid	off white	31.2	6.75	5010		
4	Slightly Turbid	off white	31.1	6.77	5020		
5	clear	clear	30.9	6.78	5030		
6	clear	clear	30.9	6.78	5040		
7	clear	clear	30.9	6.79	5040		
8	clear	clear	30.9	6.79	5040		
		FINAL STABILITY	0.0	0.0	0	0.0	0.0

PURGE RATE (Litres/Min):	-
SAMPLING RATE (Litres/Min):	-
0.45 MICRON FILTRATION USED	Yes

ADDITIONAL COMMENTS:

EASTING:		NORTHING:	

GROUNDWATER SAMPLING LOG

RPS

PROJECT NUMBER:	L1305905	SAMPLE RECOVERY METHOD:	12v Pump
SITE NAME:	Mt Anketell	COLLAR ELEVATION (m AHD):	
SAMPLING AREA:		DEPTH TO GROUNDWATER (mbtoc / mbgl):	7.815
SAMPLING LOCATION ID:	**NB-1**	STANDING WATER LEVEL (m AHD)	
SCIENTIST(S):	S. Hewitt	RECOVERY DEPTH (mbtoc / mbgl):	8.815
DATE:	24/03/2016	DEPTH TO BASE: (mbtoc / mbgl):	
TIME:		SAMPLE STORAGE / PRESERVATION:	Ice / Esky
QA/QC SAMPLE IDs:			

GROUNDWATER STABILISATION DATA

Mins / Litres	APPEARANCE	COLOUR	TEMP (°C)	pH	E.C. (µs/cm)	REDOX (mV)	D.O. (ppm)
1	Clear	Clear	32.0	6.29	62800		
2	Clear	Clear	31.4	6.27	64600		
3	Clear	Clear	31.2	6.24	64200		
4	Clear	Clear	31.2	6.23	63800		
5	Clear	Clear	31.4	6.24	6300		
6	Clear	Clear	31.4	6.25	62900		
7	Clear	Clear	31.4	6.15	64800		
8	Clear	Clear	31.4	6.11	65500		
9	Clear	Clear	31.4	6.09	65900		
10	Clear	Clear	31.4	6.08	66100		
		FINAL STABILITY	0.0	0.0	0	0.0	0.0

PURGE RATE (Litres/Min):	-
SAMPLING RATE (Litres/Min):	-
0.45 MICRON FILTRATION USED	Yes

ADDITIONAL COMMENTS:

EASTING:		NORTHING:	

APPENDIX 3

Laboratory Analysis Reports

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1408097**	Page	: 1 of 4
Client	: **RPS ENVIRONMENT PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: SIMON HEWITT	Contact	: Scott James
Address	: 38 STATION STREET SUBIACO WA, AUSTRALIA 6008	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: simon.hewitt@rpsgroup.com.au	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 93824744	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 93821177	Facsimile	: +61-8-9209 7600
Project	: L1305905	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 03-OCT-2014
Sampler	: S.H.	Issue Date	: 10-OCT-2014
Site	: Mt Anketell		
		No. of samples received	: 4
Quote number	: EN/064/14	No. of samples analysed	: 4

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA

WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics
Daniel Fisher	Inorganics Analyst	Perth Inorganics
Efua Wilson	Metals Chemist	Perth Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG020: Metals LOR for particular sample(s) raised due to high TDS content.**
- **EK061G/EK067G (TKN/TP): LOR for various samples raised due to possible sample matrix interference.**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**NB-1**	**HIA-N**	**HIA-S**	**HIA-Z**	----
			Client sampling date / time	02-OCT-2014 15:00	02-OCT-2014 15:00	02-OCT-2014 15:00	02-OCT-2014 15:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1408097-001**	**EP1408097-002**	**EP1408097-003**	**EP1408097-004**	**----**
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	----	10	mg/L	**75800**	**4690**	**3460**	**4630**	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**160**	**472**	**522**	**472**	----
Total Alkalinity as CaCO3	----	1	mg/L	**160**	**472**	**522**	**472**	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**1790**	**300**	**213**	**302**	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**34200**	**2180**	**1430**	**2160**	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**5270**	**154**	**138**	**154**	----
Magnesium	7439-95-4	1	mg/L	**5410**	**226**	**171**	**223**	----
Sodium	7440-23-5	1	mg/L	**10500**	**1110**	**860**	**1110**	----
Potassium	7440-09-7	1	mg/L	**73**	**1**	<1	**1**	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	**0.002**	**0.001**	**0.003**	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0112**	<0.0001	<0.0001	<0.0001	----
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.001	<0.001	<0.001	----
Copper	7440-50-8	0.001	mg/L	**0.021**	**0.002**	**0.001**	**0.002**	----
Nickel	7440-02-0	0.001	mg/L	<0.010	**0.002**	**0.012**	**0.015**	----
Lead	7439-92-1	0.001	mg/L	<0.010	<0.001	<0.001	<0.001	----
Zinc	7440-66-6	0.005	mg/L	<0.050	**0.005**	<0.005	<0.005	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	**0.0012**	<0.0001	<0.0001	<0.0001	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.80**	**0.03**	**0.03**	**0.03**	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**1.62**	**0.46**	**0.65**	**0.44**	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**6.2**	<0.2	**0.1**	<0.2	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	**7.8**	**0.5**	**0.8**	**0.4**	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**NB-1**	**HIA-N**	**HIA-S**	**HIA-Z**	----
			Client sampling date / time	02-OCT-2014 15:00	02-OCT-2014 15:00	02-OCT-2014 15:00	02-OCT-2014 15:00	----
Compound	CAS Number	LOR	Unit	**EP1408097-001**	**EP1408097-002**	**EP1408097-003**	**EP1408097-004**	**----**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.20**	**0.05**	<0.01	**0.05**	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**1000**	**77.2**	**55.2**	**76.6**	----
Total Cations	----	0.01	meq/L	**1170**	**74.6**	**58.4**	**74.4**	----
Ionic Balance	----	0.01	%	**7.45**	**1.71**	**2.77**	**1.54**	----

CERTIFICATE OF ANALYSIS

Work Order : **EP1502254**

Client : **RPS ENVIRONMENT PTY LTD**
Contact : SIMON HEWITT
Address : 38 STATION STREET
SUBIACO WA, AUSTRALIA 6008
E-mail : simon.hewitt@rpsgroup.com.au
Telephone : +61 08 93824744
Facsimile : +61 08 93821177
Project : L1305905
Order number : ----
C-O-C number : ----
Sampler : S.H
Site : Mt Anketell

Quote number : EN/064/14

Page : 1 of 4

Laboratory : Environmental Division Perth
Contact : Luke Jones
Address : 10 Hod Way Malaga WA Australia 6090
E-mail : LUKE.JONES@alsglobal.com
Telephone : 08 9209 7631
Facsimile : 08 9209 7600
QC Level : NEPM 2013 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 27-MAR-2015
Issue Date : 08-APR-2015

No. of samples received : 5
No. of samples analysed : 5

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with
ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics
Efua Wilson	Metals Chemist	Perth Inorganics
Jeremy Truong	Senior Inorganic Chemist	Perth Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG020: Metals LOR for particular sample(s) raised due to high TDS content.**
- **EK061G/EK067G (TKN/TP): LOR raised for sample 'NB-1' and 'MB-Z' due to high TDS content.**
- **It is recognised that total phosphorus is less than reactive phosphorus for sample 'HIA-S'. However, the difference is within experimental variation of the methods.**
- **TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	NB-1	HIA-N	HIA-S	GIA-1	MB-Z
			Client sampling date / time	26-MAR-2015 15:00	26-MAR-2015 15:00	26-MAR-2015 15:00	26-MAR-2015 15:00	26-MAR-2015 15:00
Compound	CAS Number	LOR	Unit	EP1502254-001	EP1502254-002	EP1502254-003	EP1502254-004	EP1502254-005
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	----	10	mg/L	63000	4540	3300	2560	61400
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	157	486	502	377	160
Total Alkalinity as CaCO3	----	1	mg/L	157	486	502	377	160
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1600	302	235	160	1580
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	32000	2250	1660	1090	31900
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	4870	159	135	155	4690
Magnesium	7439-95-4	1	mg/L	4920	220	166	126	4730
Sodium	7440-23-5	1	mg/L	9480	1080	831	409	9180
Potassium	7440-09-7	1	mg/L	88	<1	<1	3	84
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	0.003	0.002	<0.001	<0.010
Cadmium	7440-43-9	0.0001	mg/L	0.0090	<0.0001	<0.0001	<0.0001	0.0094
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.001	<0.001	<0.001	<0.010
Copper	7440-50-8	0.001	mg/L	0.016	0.001	0.001	0.002	0.015
Nickel	7440-02-0	0.001	mg/L	0.286	0.001	<0.001	0.002	0.303
Lead	7439-92-1	0.001	mg/L	<0.010	<0.001	<0.001	<0.001	<0.010
Zinc	7440-66-6	0.005	mg/L	<0.050	0.007	<0.005	0.012	<0.050
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	0.38	0.09	0.06	0.07	0.39
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	1.07	0.34	0.93	0.68	1.08
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<1.0	0.1	0.2	0.4	<1.0
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	1.1	0.4	1.1	1.1	1.1

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**NB-1**	**HIA-N**	**HIA-S**	**GIA-1**	**MB-Z**
			Client sampling date / time	26-MAR-2015 15:00	26-MAR-2015 15:00	26-MAR-2015 15:00	26-MAR-2015 15:00	26-MAR-2015 15:00
Compound	CAS Number	LOR	Unit	**EP1502254-001**	**EP1502254-002**	**EP1502254-003**	**EP1502254-004**	**EP1502254-005**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.10	**0.02**	<0.01	**0.12**	<0.10
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	**0.01**	**0.02**	**0.01**	**0.01**	<0.01
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**939**	**79.5**	**61.8**	**41.6**	**936**
Total Cations	----	0.01	meq/L	**1060**	**73.0**	**56.6**	**36.0**	**1020**
Ionic Balance	----	0.01	%	**6.18**	**4.24**	**4.41**	**7.27**	**4.54**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order : **EP1514626**
Client : **RPS ENVIRONMENT PTY LTD**
Contact : SIMON HEWITT
Address : 38 STATION STREET
SUBIACO WA, AUSTRALIA 6008
E-mail : simon.hewitt@rpsgroup.com.au
Telephone : +61 08 93824744
Facsimile : +61 08 93821177
Project : L1305905
Order number : ----
C-O-C number : ----
Sampler : SIMON HEWITT
Site : Mt Anketell

Quote number : ----

Page : 1 of 4
Laboratory : Environmental Division Perth
Contact : Luke Jones
Address : 10 Hod Way Malaga WA Australia 6090
E-mail : LUKE.JONES@alsglobal.com
Telephone : 08 9209 7631
Facsimile : +61-8-9209 7600
QC Level : NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Date Samples Received : 08-Oct-2015 12:10
Date Analysis Commenced : 08-Oct-2015
Issue Date : 15-Oct-2015 16:45

No. of samples received : 5
No. of samples analysed : 5

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics
Efua Wilson	Metals Chemist	Perth Inorganics
Jeremy Truong	Laboratory Supervisor	Perth Inorganics

General Comments

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Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

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Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

- EK061G/EK067G (TKN/TP): LOR for sample 'NB-1' raised due to the high amount of TDS present.
- EG020: Metals LOR raised due to high TDS content.

Analytical Results

Sub-Matrix: **GROUNDWATER** (Matrix: **WATER**)			*Client sample ID*	**NB-1**	**HIA-N**	**HIA-S**	**GIA-1**	**MB-Z**
			Client sampling date / time	[06-Oct-2015]	[06-Oct-2015]	[06-Oct-2015]	[06-Oct-2015]	[06-Oct-2015]
Compound	*CAS Number*	*LOR*	*Unit*	**EP1514626-001**	**EP1514626-002**	**EP1514626-003**	**EP1514626-004**	**EP1514626-005**
				Result	Result	Result	Result	Result
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**161**	**489**	**508**	**379**	**486**
Total Alkalinity as CaCO3	----	1	mg/L	**161**	**489**	**508**	**379**	**486**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**1570**	**279**	**206**	**134**	**294**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**30800**	**1960**	**1310**	**949**	**1950**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**4770**	**171**	**134**	**168**	**167**
Magnesium	7439-95-4	1	mg/L	**4910**	**248**	**170**	**141**	**244**
Sodium	7440-23-5	1	mg/L	**9770**	**1170**	**879**	**465**	**1140**
Potassium	7440-09-7	1	mg/L	**75**	<1	<1	**3**	<1
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.010	**0.002**	**0.001**	<0.001	**0.001**
Cadmium	7440-43-9	0.0001	mg/L	**0.0116**	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.010	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	**0.019**	**0.003**	**0.002**	**0.002**	**0.002**
Nickel	7440-02-0	0.001	mg/L	**0.119**	**0.017**	**0.002**	**0.002**	**0.015**
Lead	7439-92-1	0.001	mg/L	<0.010	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	<0.050	**0.007**	<0.005	**0.008**	**0.006**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	**0.0004**	<0.0001	<0.0001	<0.0001	<0.0001
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.83**	**0.04**	**0.02**	**0.02**	**0.06**
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	**0.02**	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser								
^ **Nitrate as N**	14797-55-8	0.01	mg/L	**1.54**	**0.29**	**0.98**	**0.02**	**0.30**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**1.56**	**0.29**	**0.98**	**0.02**	**0.30**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**1.0**	<0.1	**0.2**	**0.2**	<0.1

Analytical Results

Sub-Matrix: **GROUNDWATER** (Matrix: **WATER**)			Client sample ID	**NB-1**	**HIA-N**	**HIA-S**	**GIA-1**	**MB-Z**
			Client sampling date / time	[06-Oct-2015]	[06-Oct-2015]	[06-Oct-2015]	[06-Oct-2015]	[06-Oct-2015]
Compound	CAS Number	LOR	Unit	**EP1514626-001**	**EP1514626-002**	**EP1514626-003**	**EP1514626-004**	**EP1514626-005**
				Result	Result	Result	Result	Result
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	**2.6**	**0.3**	**1.2**	**0.2**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.10	<0.01	<0.01	**0.11**	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EN055: Ionic Balance								
^ **Total Anions**	----	0.01	meq/L	**905**	**70.9**	**51.4**	**37.1**	**70.8**
^ **Total Cations**	----	0.01	meq/L	**1070**	**79.8**	**58.9**	**40.3**	**78.0**
^ **Ionic Balance**	----	0.01	%	**8.34**	**5.94**	**6.80**	**4.08**	**4.80**

LABORATORY REPORT

Job Number: 16-02247
Revision: 00
Date: 1 April 2016

ADDRESS:
RPS Environment Pty Ltd
PO Box 170
West Perth WA 6872

ATTENTION: Simon Hewitt

DATE RECEIVED: 29/03/2016

YOUR REFERENCE: L1305905 Mt Anketell

PURCHASE ORDER:

APPROVALS:

Douglas Todd
Laboratory Manager

Sam Becker
Inorganics Manager

REPORT COMMENTS:

Samples are analysed on an as received basis unless otherwise noted.

METHOD REFERENCES:

ARL No. 040	Arsenic by Hydride Atomic Absorption
ARL No. 29/402/403	Metals in Water by AAS/ICPOES/ICPMS
ARL No. 406	Mercury by Cold Vapour Atomic Absorption Spectrophotometry
ARL No. 029	Metals in Water by AAS
ARL No. 330	Persulphate Method for Simultaneous Determination of TN & TP
ARL No. 308	Total Phosphorus in Water by Discrete Analyser
ARL No. 305	Chloride in Water by Discrete Analyser
ARL No. 301	Sulphate in Water by Discrete Analyser
ARL No. 309	Filterable Reactive Phosphorus in Water by Discrete Analyser
ARL No. 303	Ammonia in Water by Discrete Analyser
ARL No. 313/319	NOx in Water by Discrete Analyser
ARL No. 037	Alkalinity in Water

LABORATORY REPORT

RPS Environment Pty Ltd

ARL Job No: *16-02247* *Revision:* *00* *Date:* 1 April 2016

8 Heavy Metals in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-02247-1 NB-1**	**16-02247-2 HIA-N**	**16-02247-3 HIA-S**	**16-02247-4 GIA-1**	**16-02247-5 MB-Z**
Arsenic - Dissolved	0.001	mg/L	0.018	0.003	0.002	<0.001	0.004
Cadmium - Dissolved	0.0001	mg/L	0.0095	<0.0001	<0.0001	<0.0001	<0.0001
Chromium - Dissolved	0.001	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Copper - Dissolved	0.001	mg/L	0.002	<0.001	<0.001	<0.001	<0.001
Mercury - Dissolved	0.0001	mg/L	0.0013	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Dissolved	0.001	mg/L	0.054	0.002	0.001	0.001	0.002
Lead - Dissolved	0.001	mg/L	0.004	<0.001	<0.001	<0.001	<0.001
Zinc - Dissolved	0.005	mg/L	0.031	<0.005	<0.005	<0.005	<0.005

Metals in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-02247-1 NB-1**	**16-02247-2 HIA-N**	**16-02247-3 HIA-S**	**16-02247-4 GIA-1**	**16-02247-5 MB-Z**
Aluminium - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium - Dissolved	0.1	mg/L	4,500	86	60	100	94
Iron - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium - Dissolved	0.1	mg/L	62	0.8	0.5	2.4	0.8
Magnesium - Dissolved	0.1	mg/L	4,500	120	82	91	120
Sodium - Dissolved	0.1	mg/L	11,000	1,300	760	460	1,200

Total Nitrogen in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-02247-1 NB-1**	**16-02247-2 HIA-N**	**16-02247-3 HIA-S**	**16-02247-4 GIA-1**	**16-02247-5 MB-Z**
Total Nitrogen	0.2	mg/L	1.4	0.4	1.4	0.4	0.4
TKN	0.2	mg/L	<0.2	<0.2	0.2	<0.2	<0.2

Total Phosphorus in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-02247-1 NB-1**	**16-02247-2 HIA-N**	**16-02247-3 HIA-S**	**16-02247-4 GIA-1**	**16-02247-5 MB-Z**
Total Phosphorus	0.01	mg/L	0.03	0.06	0.05	0.17	0.05

Ions by Discrete Analyser Sample No: Sample Description:	**LOR**	**UNITS**	**16-02247-1 NB-1**	**16-02247-2 HIA-N**	**16-02247-3 HIA-S**	**16-02247-4 GIA-1**	**16-02247-5 MB-Z**
Chloride	5	mg/L	34,000	2,100	1,500	1,200	2,200
Sulphate	1	mg/L	2,000	400	290	220	430
Filterable Reactive Phosphorus	0.01	mg/L	0.03	0.06	0.05	0.03	0.05
Ammonia-N	0.02	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate-N	0.01	mg/L	1.4	0.29	1.2	0.09	0.31
NOx-N	0.01	mg/L	1.4	0.29	1.2	0.09	0.31

LABORATORY REPORT

RPS Environment Pty Ltd

ARL Job No: *16-02247* *Revision:* *00* *Date:* 1 April 2016

Physical Parameters Sample No: Sample Description:	**LOR**	**UNITS**	**16-02247-1 NB-1**	**16-02247-2 HIA-N**	**16-02247-3 HIA-S**	**16-02247-4 GIA-1**	**16-02247-5 MB-Z**
Alkalinity	5	mgCaCO$_3$/L	150	470	470	310	470
Bicarbonate (HCO$_3^-$)	5	mgCaCO$_3$/L	150	470	470	310	470
Carbonate (CO$_3^{2-}$)	5	mgCaCO$_3$/L	<5	<5	<5	<5	<5

Result Definitions

LOR Limit of Reporting
[NT] Not Tested
[ND] Not Detected at indicated Limit of Reporting
[NR] Analysis Not Requested
(SS) Surrogate Standard Compound - Used for QC purposes. Acceptance Criteria is 60-120%.
* Denotes test not covered by NATA Accreditation