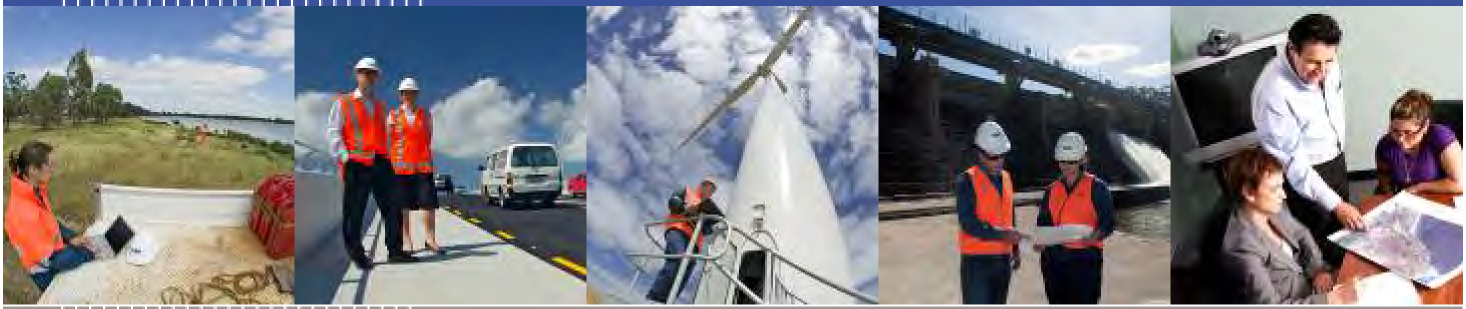

Report

North Perth Basin Mineral Sands Project

Atlas Deposit Hydrogeological and Hydrological Scoping Studies

22 FEBRUARY 2013

Prepared for

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Table of Contents

Table of Contents

Table of Contents

Tables

Charts

Figures

Table of Contents

Appendices

Abbreviations

Abbreviation	Description
AHD	Australian Height Datum
AR&R	Australian Rainfall and Runoff
ARI	Average Recurrence Interval
ASS	Acid Sulphate Soil
BoM	Bureau of Meteorology
DoW	Department of Water
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
ESA	Environmental Sensitive Areas
IFD	Intensity Frequency Duration
GDE	Groundwater Dependant Ecosystem
ha	Hectares
MB	Monitoring Bore
m bRP	meters below Reference Point
RIWI	Rights in Water and Irrigation
TDS	Total Dissolved Solids
TPB	Test Production Bore
GWSA	Geological Survey of Western Australia

Executive Summary

Image Resources NL (Image) is planning to develop ten mineral sand deposits located within the Northern Perth Basin. URS has been commissioned by Image to undertake hydrogeological and hydrological scoping studies for the deposit referred as 'Atlas'. The Atlas Deposit is located 22 km southeast of Cervantes Township in a setting bounded to the west by the Nambung National Park, location of the Pinnacles formations.

The Atlas Tenement (Project Area) covers 947 hectares (ha) just north of Wongonderrah Road. The land is predominantly utilised for grazing and agricultural purposes. The Project Area is situated on the Swan Coastal Plain. Major watercourses intersect the Atlas Deposit.

Hydrogeological Scoping Assessment

The following summarises the findings of the hydrogeological scoping assessment:

- **Local Hydrogeology**: The formations below the Project Area comprise the Superficial Aquifer and the Yarragadee Aquifer; both aquifers are unconfined. The Guildford Formation in the Superficial Aquifer is relatively transmissive. Groundwater in this deposit is relatively shallow with water depths ranging from 5 to 2 m during the dry season. The water quality is fresh to brackish, fluctuating seasonally as the rainfall recharges the aquifer. The Yarragadee Formation, around 10 to 15 m below ground level, is a multilayered, relatively transmissive aquifer with inter-beds of sand, clay and mudstone. The water is slightly saline in this aquifer. Downgradient of the Project Area, beneath the National Park, is the Tamalla Limestone, which is highly vulnerable to variations in the surface water flows and quality entering the aquifer via karstic features.
- **Groundwater Dependent Areas**: Groundwater and surface water interactions are considered important to the local flow regime. The water table during the wet season can eventually reach the ground level. The Mount Jetty Creek area in the central part of the deposit has been identified as a groundwater discharge area; there are numerous wetlands including some potential GDEs. The level of groundwater dependency of the different vegetation stands requires investigation in context to the magnitude of the depth to the water table.
- **Pit Dewatering**: The pit developments require dewatering prior to mining to lower the local water table below the pit floor. The expected drawdown to the water table has been simulated in a preliminary groundwater model, based on the sump dewatering over the current mining plan of extraction over four years. Dewatering rates are predicted to be 3.5 GL/annum in the first year, decreasing to 0.70 GL/annum.
- **Water Supply**: The Project Area sits within the Jurien Bay proclaimed groundwater area. The predicted mine site demand is 2.2 GL/annum of process water; the process water should preferably be fresh. Dewatering can meet demand at the start of mining. Towards the end of mining, up to 1.5 GL/annum of process water would have to be supplied from deeper aquifers, preferably within the Atlas Tenement. The Yarragadee Formation aquifer below the tenement is the preferred option for supplying the processing plant but may not be suitable for potable supply owing to its salinity.
- **Environmental Risks**: The cumulative drawdown footprint at the end of the mining is predicted to extend beneath GDEs in the south, to the Mount Jetty Creek wetlands and to the eastern boundary of the Nambung National Park. The predicted drawdowns are relatively shallow, being an average of 2 m of drawdown 500 m away from the pit. The predicted cumulative drawdown beneath GDEs, and the potential ecological consequences, is considered to be a key issue for the regulatory approvals process.. There is a potential risk that the cumulative drawdowns may reach the borefields of the Coolarjallo east of the proposed mine site. Further refinements and calibration to the groundwater model, supported by a monitoring and test pumping programme, are necessary to

refine the drawdown predictions and to support the impact assessment process. Targeted reinjection of any surplus water may help mitigate drawdown impacts near sensitive receptors.

- **Groundwater Monitoring Programme**: A groundwater level and quality monitoring programme is required. The five existing monitoring bores will be utilised. It is recommended that the existing monitoring network is expanded to include multilevel piezometers at 21 locations in key areas of interest, both within the mining area as well as along the boundary of Nambung National Park, in the groundwater discharge areas of Mount Jetty Creek and Frederick Smith Creek. Four test production bores targeting the superficial formations and the Yarragadee Formation are recommended to permit assessment of site-specific hydraulic properties.

Hydrological Scoping Assessment

The following summarises the findings on the hydrological scoping assessment:

- **Project Watershed**: The average annual rainfall is relatively small (536 mm/year) with the majority of rain occurring during the winter. The upper catchment is composed by the Arrowsmith Region. The watershed upstream of the Project Area covers an approximate area of 160 km^2, 21 per cent of the Nambung River Catchment. Many drainage lines intersect the Atlas Tenement. The main watercourse is the Mount Jetty Creek flowing through the middle of the footprint and the Bibby Creek in the northern boundary. Other shorter watercourses flow also through the mining footprint. Water from the upper catchment discharges into the wetlands area. When the wetlands are at full capacity, water flows into the Nambung River. The surface water then enters the karstic formations of the Tamala Limestone. Groundwater is consequently vulnerable to changes in the Nambung River flows or water quality.
- **Predicted Discharge Rates**: The peak flows have been computed with a hydrological model using the Australian Rainfall & Runoff 1987 guidelines to determine catchment losses and using rainfall intensities obtained from the Bureau of Meteorology. The hydrological model has not been calibrated as the watercourses are not currently monitored. The interpretations of the outputs model are as follows:
  - Runoff from upper catchments is very limited for events below the 1 in 5 year return period rainfall event. There is a high probability that the drainage lines would be activated during the wet season. During the wet season, the catchment losses would be significantly lower and significant flows may be recorded. Any minor rainfall events would be converted to runoff on the saturated soils.
  - The losses are exceeded for events above the 1 in 5 year return period rainfall event. The sub-catchments produce significant flow volumes. Peak flows in the vicinity of the mine range from 7 to 41 m^3/s in the watercourses intersecting the Atlas Tenement. Low velocities are expected due to the flat topography. The 100 year return period flood event of the Nambung River is estimated to be up to 244 m^3/s. This high value is not consistent with observed flow data from an adjacent catchment. Monitoring to permit more detailed model calibration is recommended to increase confidence in flood event predictions.
- **Flood Risk**: The predicted flood risk to the mine infrastructure is relatively high. This is due to the high volumes of runoff conveyed by the upper local watercourses during a standard design flood event (1 in 100 year return period). However, the flow velocities are expected to be low, significantly reducing the risk. Mitigations of the flood risk will require engineering Including catchment diversion drains.

Executive Summary

- **Environmental Risk**: The environmental risk is considered as low provided the catchment diversion drains can maintain flood water flows and quality similar to the baseline conditions. Changes to the surface water regime may also riparian vegetation and the wetland systems. Any future potential contamination of the surface water would propagate quickly to groundwater via the karstic systems, potentially impacting regional water resources. Also, any reduction in volume flowing into the Nambung River would decrease the recharge to the regional aquifers.
- **Surface Water Management:** The sediment load in the man-made channels will require control. There may be a need to cover the channel beds with liners to avoid infiltration to the adjacent pits and avoid erosion issues. The channels are recommended to be reinstated and rehabilitated once the pits are fully backfilled to help restore baseline conditions. It is recommended to reinstate using the initial top soils and to vegetate the banks and floodplain. Hydraulic continuity of the surface water system should be sought during and after operations. Diversion drains would be designed in such way that the erosion and sediment load would be minimised.
- **Surface Water Monitoring Programme**: A surface water monitoring programme will be required to characterise baseline conditions, calibrate hydrological models and to permit identification of impacts during construction and operation of the mine. A network of four stream gauges is recommended to be installed within the catchment. Additionally, a rain gauge is recommended.

Introduction

1.1 Project Description

Image Resources NL (Image) is a diversified mineral exploration company with a mineral sands resource based in the Northern Perth Basin of Western Australia.

Image is planning to develop ten deposits located within the Northern Perth Basin. URS has been commissioned by Image to undertake hydrogeological and hydrological scoping studies for the deposit referred as ‘Atlas’. The Atlas Deposit is located 22 km southeast of Cervantes Township in a setting bounded to the west by the Nambung National Park.

The Atlas tenement (Project Area) covers 947 hectares (ha) just north of Wongonderrah Road (Figure 1.1). The land is predominantly utilised for grazing and agricultural purposes. Major watercourses intersect the Atlas Deposit.

1.2 Objectives of this Study

The purpose of this study is to provide a preliminary outline the potential impacts on the environment and existing water users from of mining the Atlas Deposit. The study will:

- Broadly characterise the baseline for the surface and groundwater based on available public domain data.
- Develop a conceptual hydrogeological model.
- Estimate the abstraction of groundwater associated with the pit dewatering and the process water supply.
- Develop a preliminary numerical model to predict the potential cone of drawdown resulting from process water supply and pit dewatering activities.
- Assess the potential impacts associated with the mining activities on environmentally sensitive areas and existing water users. This scoping study outlines the area of predicted drawdown impact in context to mapping of potential Groundwater Dependent Ecosystems (GDEs) prepared by Department of Environment and Conservation (DEC). It is known that the water table has a strong relationship with the GDEs in the vicinity of the Project area.
- Characterise the potential surface water issues associated with the proposed mining activities.
- Provide guidance for mine management by establishing a water balance and a water supply strategy.
- Propose preliminary strategies with which to mitigate potential environmental impacts.
- Develop a surface and groundwater monitoring programme likely to support the regulatory approval.

1.3 Data Available

The Northern Perth Basin forms an extension of the sedimentary stratigraphy mapped beneath the Perth environs. Groundwater is abundant in the region, hosted by the Superficial Aquifer and the deeper unconfined Yarragadee Aquifer, and forms a significant and high-value resource. As such, there have been numerous reconnaissance studies completed by the State Government. These studies provide an overview of the Project Area.

There have also been several operating mineral sands mines within the Northern Perth Basin:

- Cooljarloo.
- Gingin.
- Eneabba and Eneabba West.

The occurrence of these mines and associated approvals and operating references in the public domain provides precedence for and knowledge of the local baseline environments and potential environmental impacts on sensitive ecosystems.

Outside of these projects, there is also experience available from proposed mining at Cataby (mineral sands), Hill River (coal) and Eneabba West (coal).

1.4 Gap Analysis

The desktop study identified gaps in the baseline dataset that are necessary to address to develop future robust impact assessment studies on surface and groundwater resources. The following have been identified as data gaps:

- The hydraulic parameters for the aquifers in the vicinity of the Project Area are not known. Test pumping would provide site-specific hydraulic properties for the superficial formations and the Yarragadee within the Atlas Tenement. The other regional aquifers included in the numerical model domain have not been well characterised. Investigation, such as a drilling and test pumping programme, would provide more information on hydraulic parameters for the regional aquifers.
- There is limited information on the cumulative impacts associated with pit dewatering and water supply pumping activities within the Project Area. The relationship between the superficial formations and the Yarragadee Formation would be informed by an appropriate monitoring programme. Based on reliable hydraulic parameters, the groundwater flow model would simulate the cumulative impact of both abstractions. This would better define the understanding of the expected drawdown.
- Groundwater Dependent Ecosystems (GDEs) cover a large part of the Project Area. The drawdown of the groundwater associated with the pit dewatering potentially impact an extensive area outside of the Atlas Tenement. A vegetation survey has been undertaken by 360 Consulting within the Tenement. There is a lack of survey data in the area of influence of the drawdown. The level of dependency of the vegetation should be assessed based on the nature of the species and the depth to water table. The level of dependency would inform the potential impact to the flora from mining activities based on predicted drawdowns.
- The presence of Potential Acid Sulphate Soils has to be assessed by soil sampling during the exploration programme. This is crucial information to obtain as the risk of pollution is considered high because of the local geological context. The superficial formations in the Project Area are sandy facies. Groundwater within the superficial formations discharges into the Tamala Limestone. The pollution risk on the Nambung River would be a major impediment to the regulators.
- The hydrology study showed a flood risk from the watercourses intersecting the Atlas tenement. There is a lack of calibration data in the Project Area. A thoroughly calibration process based on the surface water monitoring programme would support an adjustment of the hydrological losses of the water shed upstream of the Site. This is crucial information to obtain as current hydrological outputs may lead to overdesign for the hydraulic structures.

1 Introduction

- The wetlands in the Project Area are currently not well characterised in term of potential groundwater dependency of the ecological habitats. The expected drawdown for the pit dewatering combined with water supply pumping are likely to dry out many of the depressions present in the wetlands. This may constitute a significant impediment to the regulatory approvals process.

Proposed Mining Activities

2.1 Mining Tenements

The Atlas Deposit tenements covers 947 ha composed of mining lease, exploration licence and prospecting licence (Figure 1-1). The tenements largely traverse cleared agricultural land. The majority of the Atlas Deposit is located on Lot No. 582912 and is classified as Vacant Crown Land. To the north, Lot No. 582913 belongs to a private owner.

2.2 Mining Plans

The following mining plan has been supplied by Image for the purpose of the study:

- The Atlas Deposit would be developed using dry mining techniques.
- The ore is located below the existing water table within the Superficial Aquifer.
- The proposed pit location and associated elevations are shown on Figure 2.1. The deposit is oriented south to north. The major pit is planned to be excavated extending from Wongonderrah Road 5.4 km north. The width of the pit would vary from 140 m to 370 m. The depth of the main pit is between 10 to 15 m bgl. The pit footprint is 132.8 ha.
- A smaller pit is located 900 m north of the major pit. This pit has an average depth of 15 m. The smaller pit footprint is 132.87 ha.
- The mining plan would occur by phase or block units; the deposit would be divided into four block units which would be progressively mined. Backfill of the mined voids with tailings would occur as the mining advances.
- The pit developments would need to be supported by dewatering prior to mining to lower the local water table below the pit floor. In-pit drains and sumps would be operated to keep the pit dry.
- The Project will require a wet plant to beneficiate run of mine sands and produce a heavy mineral concentrate. The wet plant would be mobile; shifting sites as mining is progressed.
- The heavy mineral concentrate would subsequently be separated in discrete product streams in a dry mill. The dry mill is likely to remain on one location for the Project.
- A secure water supply is required for mineral processing, including the dry mill, with preference for fresh water. Water demands for the wet plant are estimated to be 2.1 GL/annum, including ancillary demands required to support infrastructure. Water demands for the dry mill are estimated to be 0.095 GL/annum. The total water demand is approximately 2.2 GL/annum to be supplied from local sources. Abstracted groundwater would preferentially be used for mineral processing and to maintain ecological system in the surroundings.
- The Atlas Deposit is expected to be mined in four years as shown on Figure 2.2. .
- Landform rehabilitation would occur as the pit is progressed. Sub and top soils would be re-established.

2.3 Legislation Associated with Mining Activities

Surface water and groundwater management in Western Australia is guided by legislation, regulations, policies and strategies at the national and state level. A summary overview of the legislative and policy framework is described in Appendix A.

The Project would most likely require an assessment under Part IV of the Environmental Protection Act (1896). An impact assessment of the mining activities on the surface and groundwater components would be required.

2 Proposed Mining Activities

The main policies required for the proposed mine site are:

- Operational Policy No. 5.12 – Hydrogeological reporting associated with a groundwater well licence.
- Section 26 D RIWI 1914 – Licence to construct or alter wells.
- Section 17 Permit – Permit to authorise interference or obstruction of the bed and banks of a watercourse or wetland.

Settings

3.1 Physiography

The Project Area is situated on the Swan Coastal Plain, separated from the Arrowsmith Region to the east by the Gingin Scarp. The coastal plain is between 12 and 35 km wide and lies mostly below 50 m AHD; there is a gradual rise inland where it merges into the foot-slopes of the uplands that form the Arrowsmith Region.

Ground elevation over the Project area ranges from 40 to 48 m AHD. The terrain slopes gently from east to west based on the Digital Elevation Model (DEM) generated from the contours lines supplied by Image (Figure 3.1). Mount Jetty Creek intersects the deposit in the centre of the Project area. This area is the lowest topography along the deposit with a minimum surface elevation of 40 m AHD.

3.2 Climate/Rainfall

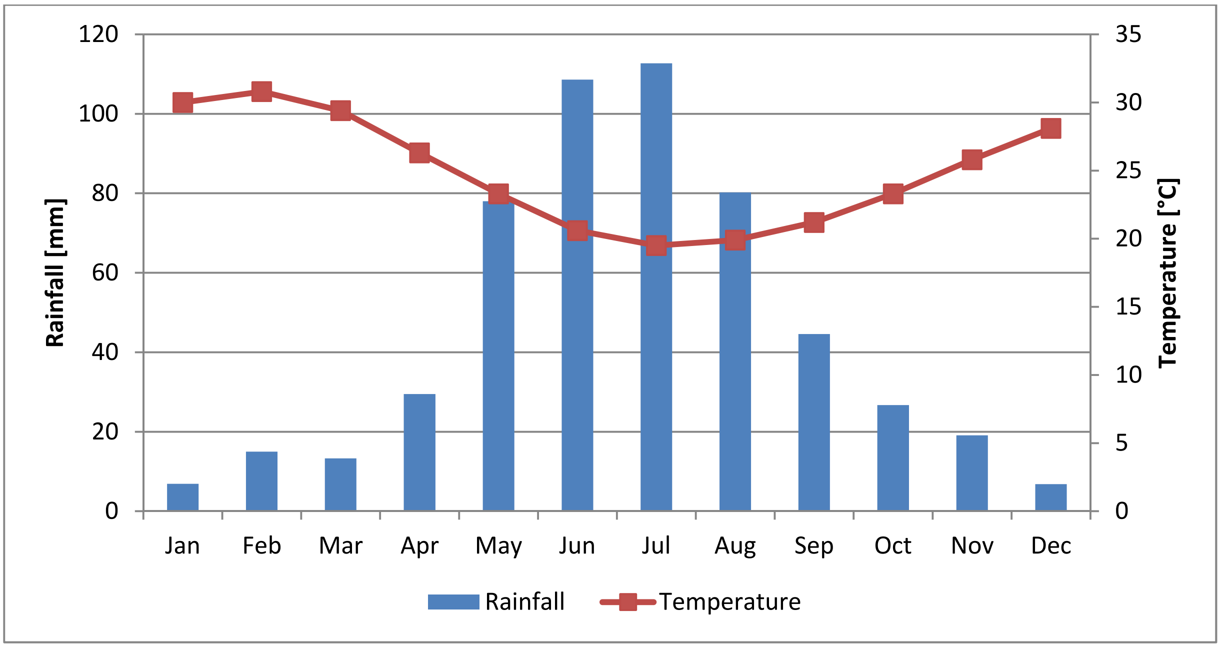
The climate is Mediterranean, characterised by hot dry summers and cool wet winters.

Three rainfall gauges in the vicinity of the Project area are managed by the Bureau of Meteorology (BoM, 2012a). They are referenced as Nambung (BoM, 009276), Cervantes (BoM, 009169) and Jurien Bay (BoM, 009131). The Jurien Bay gauge, 33 km north of the Project area, has been used for this study; it records from 1968 to present.

The average annual rainfall is 536.3 mm, with the highest wet months occurring during the winter in June and July. Table 3-1 Mean Rainfall and Temperature for Jurien Bay (1968 to Present) presents the mean monthly rainfall and temperature from 1968.

The mean annual evaporation is estimated to 1,700 mm (Department of Agriculture, 2006). Rainfall exceeds potential evaporation only during the period May to August.

Table 3-1 Mean Rainfall and Temperature for Jurien Bay (1968 to Present)



3.3 Environmental Sensitive Areas

Figure 3-2 shows the locations of the environmental sensitive areas in the vicinity of the Project.

3.3.1 Nambung National Park

The Nambung National Park is administrated by the Department of Environment and Conservation (DEC). The surface water (wetlands) and groundwater resources of the park have important conservation values for the diversity of flora and fauna they support. In the underlying aquifer, there are a number of karst features. The surface and groundwater systems are strongly interconnected, which makes the groundwater system susceptible to pollution.

The key considerations with regard to Nambung National Park are:

- Limit changes to the surface water environment and hence downstream water balance and surface water availability.
- Ensure that abstraction of groundwater does not impose detrimental drawdown risks and impacts to dependent ecosystems due to reductions in groundwater presence and availability.
- Protect the groundwater sources used for drinking water supply.

3.3.2 Wetlands

The DEC geomorphic mapping shows the wetlands associated with the Nambung National Park extend to cover a portion of the northern and central extent of the Project area. These wetlands have not been yet been assigned a management category by the DEC (360 Environmental, 2012).

3.3.3 Groundwater Dependant Ecosystems

Preliminary identification of potential Groundwater Dependent Ecosystems (GDEs) in the Northern Perth Basin were undertaken by Rutherford, Roy and Johnson (2005) for the Department of Water (DoW). The potential GDEs were determined from estimates of depths to the water table and the nature of remanent stands of native vegetation. GDEs are extensive in the vicinity of the Project area as shown on Figure 3-2.

In Operational Policy No. 5.12, it is noted that the significance of the GDEs and the likelihood of their being impacted by the drawdown should be taken into account when determining the requirements for hydrogeological assessment.

Determining the degree of dependence of an ecosystem on groundwater sources is an important step in describing the potential impacts of altered water regimes on dependent ecosystems (Froend, Bowen & Associates 2007). The underlying assumption in this process is that the closer the proximity of a plant’s rooting zone to groundwater, the greater the potential dependency (Hatton and Evans, 2001). In the Project Area, the water table is shallow and may support the vegetation. The assessment of the dependency of the vegetation within the drawdown footprint is outside of this scope of work. It is recommended that a specialist ecology consultant surveys the vegetation in the area of potential impact. Depending on the species encountered, the ecologist would assess the resistivity of type of vegetation under temporary water stress. If the stress would be judged unacceptable, mitigation would be sought to reduce the risk of damage. Groundwater flow modelling in conjunction with ecological assessment would aid assessment of groundwater dependency and consequently potential impacts.

3.4 Geology and Stratigraphy

The surface geology between Lancelin and Jurien is a mantle of mainly sandy Quaternary sediments that cover the whole coastal plain. The most significant units (Bassendean Sands, Tamala Limestone and Safety Bay Sands) represent progressively younger units. The Bassendean Sands are the upper layer of the Project area.

The Project area is predominantly comprised of pale, deep Bassendean Sands with minor components of yellow deep sand, gravelly sands, sandy duplexes and wet soils (Department of Agriculture and Food, 2012a). The Bassendean Sands form dunes which consist of deflated low ridges of siliceous sand, with intervening swampy depressions. The dunes occur on the eastern Nambung National Park and in the Project area. The dunes are characterised by a grey surface layer with yellow subsoil. The intra-dune depressions contain grey siliceous sands and sometimes an organic or calcareous layer within 2 m of the surface. Seasonal swamps with a grey, sandy surface often cover a mottled grey-brown and yellow-brown clay substrate that occurs less than 1 m beneath the surface.

In the northern area of the Project, the dominant succession is the Guildford Formation, characterised by sandy facies including alluvium.

The Tamala Limestone contains hard limestone interbedded with minor sandy limestone (Kern A.M., 1997).

Beneath the superficial formations is a thick sedimentary pile of the Northern Perth Basin that incorporates the Yarragadee Formation, Cadda Formation, Cattamarra Coal Measures and Eneabba Formation.

The Yarragadee Formation is an extensive unit, consisting of discontinuous interbedded sandstones, siltstones and shales. The formation thickness is estimated to be above 2,500 m in the Gingin Region.

The Cadda Formation intersects the northern part of the Project area and forms a minor multi-layered aquifer with a relatively high content of shale and siltstone (Kern A.M. 1997).

The Cattamarra Coal Measures is an extensive formation present to the east of the Project area. This succession contains a multilayered confined aquifer consisting of interbedded siltstone, fine to coarse sandstone (Kern A.M. 1997).

The Eneabba Formation is a major multilayered confined aquifer west of the Project area (Kern A.M. 1997).

Figure 3-3 presents the major geological units summarised in this section.

3.5 Water Resources

The water supply for the Cervantes Township is provided by a borefield located about 4 km to the east of Cervantes. The current water source protection plan defines a water reserve which is located approximately 5 km west of the Project area. This area is classified as a Priority 2 source protection area.

3 Settings

Water users are not abundant in the vicinity of the Project. The census conducted by MWES Consulting in May, July and November 2012 surveyed two bores owned by private users (Figure 3-4). Three extra bores are listed on the right bank of Frederick Smith Creek about 1.5 km from the Project Area. These bores were found during the census in November 2012 but were considered unusable. For this reason, they are excluded from this study.

An extensive borefield has been developed within the Yarragadee Aquifer source 6 km east of the Project Area. This borefield mainly supports the Cooljarloo Project.

Hydrogeological Aspects

4.1 References on Baseline Hydrogeology

The hydrogeology of the Northern Perth Basin has been broadly mapped by the Department of Water (DoW). There are a number of references that provide mapping in the vicinity of the Project Area, including:

- Kern, A.M. (1993a) – The Geology and Hydrogeology of the Superficial Formations between Cervantes and Lancelin, Perth Basin, Western Australia Geological Survey, Professional Papers, Report 34, p.11-36.
- Kern, A.M. (1997b) - *Hydrogeology of the Coastal Plain between Cervantes and Leeman, Perth Basin,* Water and Rivers Commission, Hydrogeology Record, Series No HG 3.
- MWES Consulting (2012) – *Image Resources, Water Sampling and In-situ Parameters Survey*, Field Report from July 3rd to 11th 2012, Prepared for Image Resources in August 2012, unpublished report.
- The census groundwater investigations in May July and November 2012 by MWES Consulting provide up-to-date groundwater levels and bore characteristics.

4.2 Local Aquifer Systems

Two aquifer systems are known beneath the Project area:

- An unconfined aquifer system (Superficial Aquifer) typically extending from 0 to 17 m below ground level (m bgl).
- The Yarragadee Formation, from 17 to about 1,500 m bgl (Rockwater, 2009). This aquifer system is hydraulically connected to the Superficial Aquifer.

Others aquifer systems beneath the Project area that may influence the local and sub-regional hydrogeology include:

- Kockatea Shale, along the shoreline.
- Lesueur Sandstone.
- Tamala Limestone, overlying the Kockatea Shale and the Lesueur Sandstone.
- Cattamarra Coal Measures.
- Eneabba Formation.

4.3 Hydrogeology of the Superficial Formations

The superficial aquifers in the Project area are formed by the Guildford Formation and the Bassendean Sands (Figure 4-1). These successions incorporate sand beds which form the predominate aquifer. The geological logs of the Atlas deposit show a predominance of sandy facies, typically contributing about 75 per cent of the superficial formations thickness. Subordinate fractions include about nine and 10 per cent sandy clay and clayey sand, respectively.

The average saturated thickness in the Project area is 10 m. Groundwater recharge is mainly by direct infiltration of rainfall. Groundwater flows westerly towards the Indian Ocean. Downward leakage from the superficial formations to the Yarragadee Formation occurs about 8 km on the east of the Project Area. On the eastern side of the Atlas Deposit, upward flow occurs from the Yarragadee Formation to the superficial formations (Kern A.M., 1997).

The water table is linked to the topography. Water table elevations vary from 50 m AHD around 4 km to the east of the Project area to 25 m AHD around 6 km west of the Project area. The hydraulic gradient of the water table is typically about 2.5 per cent; locally in the vicinity of the Project area the hydraulic gradient steepens. Depths to the water table are shallow. At selected local settings, the depth to the water table is only about 1 m bgl. In these settings, there may be groundwater discharge by evaporation and transpiration and, as baseflow contributions to seasonal stream flow during times when recharge by rainfall and runoff raises the water table to the ground surface.

The water table elevations and depth to water table maps of the Project area are showed on Figure 4-2, Figure 4-3 and Figure 4-4. They reflect interpretations by GWSA in 1987. The census study in July and November 2012 shows similar results in the southern Project area, whereas in the north there is an offset of 2 m.

Aquifer transmissivity is known to vary significantly beneath the coastal plain. The variation was linked to clay contents and occurrence of Tamala Limestone (Kern A.M. 1997).

The groundwater in the local superficial formations is generally fresh, with a salinity of less than 1,000 mg/L Total Dissolved Solids (TDS) (WRC, 2002).

4.4 Hydrogeology of the Yarragadee Formation

The Yarragadee Formation is a major aquifer beneath the coastal plain and is known to contain large volumes of fresh groundwater. It is a multilayered aquifer, with inter-beds of sand, clay and mudstone providing a layer-cake succession.

Groundwater flow in the Yarragadee Formation is predominantly to the west. Recharge on the coastal plain occurs from rainfall and infiltration through the superficial formations. Groundwater recharge has increased due to clearing for agriculture. The water table was interpreted to be rising at annual rates of up to 0.25 m (Commander, 1981).

The aquifer is unconfined in the Arrowsmith Region, but tends to be confined beneath the western coastal plain (Kern A.M. 1997). The Yarragadee Formation is likely to be unconfined in the Project Area. Existing local monitoring bores (MWES, 2012) indicate seasonal low depths to water table in the range from 5.4 to 5.7 m.

Regionally, the groundwater in the Yarragadee Formation is typically fresh to saline with a salinity ranging from about 500 to 4,000 mg/L TDS (Nidagal, 1995 and MWES, 2012 & 2013).

4.5 Long-Term Water Table Variation

The DoW records groundwater levels in a network of monitoring bores in the Region. Existing monitoring bores CS35S and CS35D (Ref. 61730554 and Ref. 61730555; DoW, 2012a) are located within the Project area and provide a “snap-shot” of groundwater levels in the superficial formations and Yarragadee Formation. There are water table records from 1986 to present for both monitoring bores as shown on Figure 4-5. These records reflect periodical monitoring only, with the data frequency disabling an understanding of the amplitude of seasonal fluctuations. As such, the monitoring bore data informs broad trends only. The available data shows four trends:

- A decline in groundwater levels from 1986 to 1994 for both the superficial formations ad Yarragadee Formation. The decline was about 3 m for the superficial formations and 0.5 m for the Yarragadee Formation. The initial data for the superficial formations appear to be questionable.

- From 1986 to 2004, the superficial formation water table elevations stabilised. The trend for the Yarragadee Formation recovered from its former decline.
- From 2004 to 2007, a decline occurs for both aquifer systems.
- Since 2007, the data reflect changes of less than 0.8 m amplitude.

4.6 Groundwater Quality Review

MWES Consulting conducted a census and baseline water sampling survey in the vicinity of the Project during July and November 2012. Figure 4-6 displays the locations of the sampled monitoring bores.

The surveys (MWES, 2012) measured:

- Turbidity, pH, dissolved oxygen, temperature and Electrical Conductivity (EC) in selected monitoring bores in July 2012.
- Temperature, pH and Electrical Conductivity (EC) in selected monitoring bores in July 2012.

Salinity is considered to broadly define the water quality in terms of water supply. Typically, a relationship of 1 unit of Total Dissolved Solids (TDS) = 0.64 EC units is used to calculate salinity (as TDS, eWater, 2000); this relationship has been shown to vary. The TDS for AGW1 was measured by an accredited laboratory as 3,380 mg/L TDS. Therefore the Project area relationship may broadly be characterised as TDS = 0.62 EC. The measured EC was recognised to vary with depth within the monitoring bore water column. Therefore the EC values in Table 4-1 reflect the deepest measurement in each monitoring bore.

Table 4-1 Measured Groundwater Quality in July and November 2012

Monitoring Bore	Bore Depth (m bRP)	Survey Period	pH	DO (%sat)	Turbidity (NTU)	Temp (°C)	EC (µS/cm)	TDS (mg/L)
AGW1	15.70	Jul-12	6.85	61.1	7.0	22.4	5,440	3,380[1]
		Nov-12	6.59	-	-	23.4	4,920	3,050[2]
AGW2	46.65	Jul-12	6.77	66.9	7.1	20.6	3,000	1,860[2]
		Nov-12	6.64	-	-	17.6	2,158	1,340[2]
AGW3	10.77	Jul-12	6.09	63.1	66.0	21.0	1,368	848[2]
		Nov-12	4.49	-	-	21.4	2,670	1,655[2]
AGW4	103.00	Jul-12	9.00	26.0	11.0	20.9	7,330	4,544[2]
		Nov-12	8.84	-	-	23.8	8,660	5,369[2]
AGW5	49.16	Jul-12	7.30	82.5	3.4	20.4	1,226	760[2]
		Nov-12	7.27	-	-	21.8	1,201	744[2]

Notes:

1 Value determined by an accredited laboratory

2 Value estimated with the relationship TDS = 0.62 EC

The measured groundwater qualities indicate the following:

- The groundwater salinity in the Superficial Aquifer ranged from 760 to 3,380 mg/L TDS, which represents fresh to brackish water. The elevated TDS may be due to the Mount Jetty Creek forming a groundwater discharge area and associated concentration of salt due to evapotranspiration. There may also be a reflection of increased contributions of flow from the Yarragadee Formation.

- Groundwater in the Yarragadee Formation is more saline, comprising brackish to low salinity water.

4.7 Conceptual Hydrogeology Model

Groundwater flow from the Gingin Scarp to the shoreline is conceptualised as following:

- The physical and hydrogeological characteristics of the superficial formation vary both vertically and laterally. The hydraulic conductivity typically increases from Gingin Scarp in the east to the Tamala Limestone and Safety Bay Sands further west. In the Project area, the sandy facies of the Guildford Formation and the Bassendean Sands form a transmissive aquifer. Kern (1997) interpreted an average hydraulic conductivity of 20 m/day for the Guildford Formation. Based on 6,755 samples (each of 1.0 m) and associated geological logs of the Atlas Deposit, the composite hydraulic conductivity of the Guildford Formation and Bassendean Sand was estimated to be about 8.0 m/day. The saturated Superficial Aquifer ranges in thickness from 15 m to the north to 5 m in the south near Wongonderrah Road.
- The Warradarge Fault is located marginally up-gradient of the Project area.
- The Lesueur Fault is interpreted to be down-gradient of the Project area.
- The influence of the Warradarge and Lesueur faults on the local and regional groundwater flow is not known.
- There is likely to be a general reduction in rainfall infiltration and hence a reduction of the recharge toward the east where the sediments typically host increased clay contents.
- The Yarragadee Formation is considered unconfined beneath the Project area. The Superficial Aquifer and the Yarragadee Aquifer show similar water table elevations and similar historical trends. The poorly sorted sandstone of the Yarragadee Aquifer has comparatively low transmissivity. Literature indicates hydraulic conductivity ranging from 0.7 to 4.0 m/day.
- The Safety Bay Sands are expected to have a hydraulic conductivity of 15 m/day (DoW 2008).
- The Tamala Limestone is expected to have a hydraulic conductivity ranging from 100 to 1,000 m/day.
- The Lesueur Sandstone is expected to have a hydraulic conductivity of 15 m/day (WRC 1997).

4.8 Preliminary Groundwater Flow Model

The development of a preliminary groundwater flow model was undertaken to enable prediction of potential drawdown impacts from the Project and associated risks linked to pit dewatering and process water supply abstractions.

MODFLOW-Surfact (Hydrogeologic Inc. 1996) was used as the modelling platform using Visual MODFLOW 2009.1 as the pre- and post-processor. MODFLOW is a 3D block-centred finite difference code developed by the United States Geological Survey to simulate groundwater flow.

The model layout includes the predominant geological formations surveyed within the model domain, including the Superficial Aquifer, Yarragadee aquifer, Kockatea Shale, Lesueur Sandstone, Cattamarra Coal Measures and the Eneabba Formation.

4.8.1 Model Domain

The model domain (Figure 4-7) incorporating the Atlas Deposit extends to:

- 22 km north to Hill River.
- 17 km east to the Gingin Scarp.
- 24 km south the Leederville Formation, which constitutes a geological boundary.
- 16 km west to the Indian Ocean, which forms a natural boundary.

The model boundary conditions include:

- No-flow conditions to the north, east, south and west.
- The no-flow conditions are far enough form the deposit to not influence the stress-field associated with simulated Project-related abstractions.

The total domain is 1,743 km^2. The Image deposits referred as Hyperion and Helene are included in the domain. The Nambung National Park is located in the southwest area of the model.

4.8.2 Model Layers

The model has been constructed using three layers that represent the Superficial Aquifer and the underlying Mesozoic successions, including the Yarragadee Aquifer. The bottom of the model is set to -170 m AHD in order to adequately represent the deep formations.

The layers are constructed from top to bottom as follows:

- Layer 1: Topography derived from the DEM based on the contours lines supplied by Image (Figure 4-8).
- Layer 2: Superficial Aquifer with constant thickness of 15 m across the model domain. The superficial formations are undifferentiated in the model.
- Layer 3: from east to west, Yarragadee Formation, Cattamarra Coal Measures, Eneabba Formation, Lesueur Sandstone and Kockatea Shale. The distribution of the formations is based on the geological interpretation provided on Figure 3-3.

4.8.3 Hydraulic Parameters

Figure 4-9 represents the hydraulic conductivities zones applied to each layer of the model.

The Guildford Formation is transmissive with a calibrated value up to 11 m/day for the horizontal hydraulic conductivity. In the Project Area, the facies is sandy clayey with a high hydraulic conductivity of 11 m/day. However this value is still below the estimated hydraulic conductivity of 20 m/day (Kern A.1997). The other simulated hydraulic conductivities are set up to 1 m/day; the exception was for the Lesueur Sandstone where a hydraulic conductivity of 15 m/day was applied.

Table 4-2 Hydraulic Parameters of the Numerical Flow Model

Formations	Hydraulic Conductivity (m/day)	
	Horizontal	Vertical
Guilford Formation	11	1.1
Yarragadee Formation	1	1
Cattamarra Coal Measures	1	1
Eneabba Formation	1	1
Lesueur Sandstone	15	1.5
Kockatea Shale	1	1

4.8.4 Recharge

For modelling purposes, the net rainfall which recharges the aquifers excludes the watershed runoff, evapotranspiration or infiltration to the water table. The recharge was calibrated at 7 to 8 per cent of the annual average rainfall An area which is up gradient of the Project area was excluded from the recharge domain to satisfy the calibration (Figure 4-10).

The actual recharge rate would vary across the model domain (Kern A. 1997). This aspect should be refined for further simulations.

Calibration

The model has been broadly calibrated based on the available data. The monitoring bore dataset was sourced from the DoW, including the Leeman shallow and Cataby shallow networks. The present calibration included 13 monitoring bores within the model domain and recording water table data for the Superficial Aquifer and groundwater levels in the Yarragadee Aquifer. The observation data selected were from February to March 2012. ..Table 4-3 present the details of the 13 monitoring bores used for the calibration. Further calibration should be undertaken to capture the seasonal variations of the water table within the Superficial Aquifer.

4 Hydrogeological Aspects

Table 4-3 Bores Used for the Numerical Model Calibration

DoW Bore Reference	MGA50 Coordinates		Aquifer	Water Table (m AHD)	Observation Date
	Easting	Northing			
61730201	321024	6625337	Superficial formations	0.30	Mar-12
61730204	325745	6626255		17.05	Mar-11
61730206	331211	6625801		46.50	Feb-12
61730207	337165	6625858		73.70	Feb-12
61730210	316647	6635149		1.20	Feb-12
61730212	322879	6634861		14.70	Feb-12
61730214	330262	6635964		80.40	Feb-12
61730557	343595	6618399		83.50	Feb-11
61730556	337794	6618277		53.00	Feb-12
61730554	332144	6616789		40.10	Feb-12
61718078	329198	6617305		36.40	Feb-12
61718042	342229	6645373	Yarragadee Formation	128.00	Jan-12
61730516	330014	6589171	Superficial formations	0.55	Feb-12
61730536	322464	6603768		0.05	Dec-04

4.8.5 Steady-State Simulation

The steady-state model simulated the groundwater initial heads based on the baseline, pre-mining conditions. Figure 4-11 shows the simulated steady-state water table. The Normalised RMS error, which defines the fineness of the calibration is 8.9 per cent and is considered as fair. The numerical model reasonably replicates observed upward heads (aquifer flowing upwards) in the Yarragadee Aquifer up-gradient of the Project area (Kern A. 1997). Also reasonably replicated was the downward gradient down-gradient of the Project area.

These initial heads are used to start the transient predictive simulations.

4.8.6 Predictive Pit Dewatering Simulations

Transient simulations of the pit dewatering have been run to predict groundwater abstraction volumes and potential drawdown footprints during the mine life. The pit dewatering was based on a four year mining sequence from north to south

In the numerical model, the pits were dewatered using virtual in-pit sumps. During transient simulations, the irrelevant in-pit sumps would be inactive.

The simulated drawdown footprints for the Superficial Aquifer are presented on Figure 4-12, Figure 4-13, Figure 4-14 and Figure 4-15.

The outcomes of the pit dewatering simulations are summarised as follows:

- The drawdown footprint extends significantly as the mining advances south.
- The maximum drawdown footprint is after the fourth years. At the end of operations, the footprint extends about 3 km west and impacts the Nambung National Park. However the drawdown is limited to 1 m for the footprint outside of the Atlas Tenement.

4.8.7 Assumptions and Limitations

Assumptions

The developed model is a conceptualisation of the geology encountered within the domain. The model is comparatively straightforward in form, though with sufficient complexity to represent the geological formations. The model domain covers a large area to take account of the potential no-flow boundaries, such as the Hill River. The numerical model conforms within practical limits to the Murray-Darling Basin Commission (2000), which is the methodology used for H3 Hydrogeological Reports (DoW 2009).

The Grid resolution is a 200 by 200 m cell size which a reasonable size for the model domain.

The hydraulic parameterisation of the model was based on literature which provided reliable values for hydraulic conductivity. Sensitivity and uncertainty analyses would be required during model refinement activities that incorporate the findings of local site investigations.

.In the model, the area up-gradient of the Gingin Scarp is judged to be unreliable. In this setting, the Superficial Aquifer was simulated, but is actually understood to be absent. This area is not interacting with the Project area and consequently this aspect of the preliminary model was not considered to be a significant drawback.

Limitations

Refinements to the developed model are required to adequately support a H3 Hydrogeological Report, including:

- Using a more developed conceptual hydrogeological model based on the findings of local site investigations.
- Refining the grid resolution, particularly within the Project area and the stress-field for water supply source areas.
- Refining the model layer elevations, particularly for the Superficial Aquifer up-gradient and down-gradient of the Project area.
- Use of the hydraulic parameters interpreted from aquifer tests to be conducted within the Project area.
- Calibrate the model with the outputs of the planned groundwater exploration programme.
- The backfilled tailing contains residual water and associated water balances that are not included in the present model. A significant portion of water would recharge the Superficial Aquifer during mining progress. This water source would modify the transient water balance of the Project area, influencing predictions of groundwater availability and residual drawdown.

4.9 Preliminary Risk Assessment Associated with Mining Activities

A preliminary risk assessment was used to identify potential regulatory impediments to the Project. This assessment was based on the findings of the desk-top assessment and predictive modelling

4.9.1 Pit Dewatering

Groundwater Dependant Ecosystems

The potential change to the GDEs constitutes a potential challenge for the Project as the predicted drawdown footprint from four years of pit dewatering abstraction was indicated to cover 44 km^2. The majority of the GDEs and vegetation patches surveyed by 360 Consulting are located in the southern Atlas tenements.

It is not possible to draw firm conclusions on the likely impacts to the vegetation due to the predicted drawdown footprint. The level of dependency of the different vegetation stands to the groundwater should be investigated in context to the magnitude of the predicted drawdown and changes to the depth to the water table. The implications of the predicted drawdowns in terms of potential changes to the GDEs should be assessed, taking into account depth to the water table, drawdown rate, and vegetation classes.

In the case of identification of potential adverse impacts on the GDEs such as vulnerable vegetation, mitigation measures would be implemented. The viability of a targeted groundwater injection scheme should be considered.

Water Users

The pit dewatering and associated drawdown was expected to affect two private bores surveyed by MWES Consulting. The northern bore (Cockram01) may be destroyed during mining operations. The western bore (Barleyman01) would be influenced by 0.5 m drawdown during the mining operation. The yield of this bore should not be significantly affected.

The rights of other users of the local water resources should be protected and preserved such that any diminished in supply would be mitigated. Affected streams and bores may need to be artificially recharged.

4.9.2 Potential Acid Sulphate Soils

The exposure of potential acid sulphate soils is a potential risk for environmental impacts and groundwater quality degradation. Acid sulphate soils contain significant amount of sulphite, which upon oxidation can generate sulphuric acid. Oxidation may occur because of the lowering of the water table.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australian Soil Resource Information System (ASRIS) database indicates an extremely low probability of Acid Sulphate Soils (ASS) occurring within the Project area (CSIRO 2012).

Due to the high number of wetlands and creeks in the vicinity of the Project area, it would be prudent to complete an assessment of the likelihood of the presence of potential acid sulphate soils and any adverse impacts that may be linked to the Project.

4.10 Preliminary Water Balance

A high-level water balance has been generated based on the predictive modelling findings. This water balance gives an indication of the potential of discrete sources to satisfy the mineral processing water supply demands (2.2 GL/annum).

The water balance (Table 4-4) is presented on a yearly basis with the following assumptions:

- The volume of dewater from the pit is estimated from the model.
- The average pit dewatering abstraction was 2.0 GL/annum. The volume excludes the potential decant water from the tailings.
- Stream flow harvesting was not included in the water balance. This source was not recommended as a decrease of flood waters on the Nambung River may represent a significant regulatory impediment.
- The deep aquifer source is proposed to be the in the Yarragadee Aquifer beneath the Project area.

Table 4-4 Preliminary Water Balance Estimates

Deposit	Year	Water Supply Demand (GL/annum)	Pit Dewatering Volume (GL/annum)	Deep Aquifer Supply (GL/annum)
Atlas	1	2.2	3.52	0.00
	2	2.2	2.53	0.00
	3	2.2	1.23	0.97
	4	2.2	0.71	1.49

The following conclusions can be drawn from the estimates above:

- The predicted volumes of groundwater abstraction for pit dewatering during Year 1 and Year 2 are comparatively high. The in-pit sumps would have to pump at high flow rates. For instance, dewatering in Year 1 would require a pump capacity of about 9,600 kL/day. There may be a number of practical limitations in achieving abstractions of this magnitude and maintaining open drains capable of achieving the required dewatering ahead of mining.
- The pit dewatering abstractions progressively decrease over the four years due to the propagation of drawdown and associated lowering of the water table throughout the Project area.
- For Year 1 and Year 2, the predicted pit dewatering abstractions are sufficient to satisfy the supply demand. Surplus groundwater disposal would have to be assessed and managed to avoid environmental impacts.
- There is a need for abstracting fresh water from the Yarragadee Aquifer. The demand varies respectively from 1.0 to 1.5 GL/annum for Year 3 and Year 4.

4.11 Water Supply Strategy

The preferred source for meeting water supply demands would be the pit dewatering abstractions. Shortfalls from the pit dewatering occur in the latter Project years; during these times a portion of the water supply demand of 2.2 GL/annum should be supplied from the local Yarragadee Aquifer.

The Project area is located in the Proclaimed Groundwater Area referred as Jurien Bay. The groundwater sub-area is Nambung and the aquifer is Yarragadee North. The Yarragadee North

Aquifer allocation limit within the Project area is presented in Table 4-5. Figure 4-16 locates the local resource available in the context of the Project area.

Table 4-5 Groundwater Allocation Limit Yarragadee North Aquifer (June 2012)

Sub-area	Aquifer	Allocation Limit (kL/annum)	Available Resource
Nambung	Perth – Yarragadee North	8,800,000	6,300,000 GL/annum available

The volume available from the local Yarragadee Aquifer is sufficient to satisfy the water supply demand of the Project.

South of the Atlas Deposit and along Wongonderrah Road, DoW manages two monitoring bores in the Superficial and Yarragadee aquifer. These monitoring bores (CS35D and CS35S) are showed on Figure 3-4; they are located within the DoW allocation area for the Yarragadee North Aquifer and the Image operational area. Image would have to locate potential water supply production bores within their Mining Lease tenements to facilitate the regulatory approvals process. On the southeast of the Image Tenement, the top of Yarragadee Formation is only at 8 m bgl. CS35D extends to approximately 50 m bgl within the Yarragadee Aquifer. The TDS increases with depth from 530 to 1,450 mg/L. According the geological cross-section by Kern A. 1987, the Yarragadee Aquifer extends to at least 100 m below the surface in this setting.

This location is considered the most preferable for the installation of a production bore. The production bore should be at least 100 m depth to increase the potential yield. The drawdown associated in likely to influence the superficial aquifer as the Yarragadee Formation is likely to be unconfined in the Project area. Cumulative impact from the water supply scheme and the pit dewatering may impact GDEs and water users in the surroundings. The cumulative impact on the water table should be simulated in the numerical model.

The hydraulic conductivity of the Yarragadee Formation is estimated to be 1 m/day. Based on this assumption, the transmissivity of the aquifer is estimated to be about 90 m^2/day.

Pumping approximately 4,000 kL/day would require a pump of diameter 229/232 mm. Preference would be to construct a pump-well diameter to 300 mm.

The estimate cost for such bore characteristics is $194,000 (excl. GST) based on two recent projects in the Northern Perth Basin in September 2011 and May 2012.

4.12 Groundwater Level Recovery and Mine Closure

The groundwater recovery has been simulated over a period of six years after the cessation of groundwater abstraction associated with mining. The recovery simulation only applies to the Superficial Aquifer.

The result shows that after six years after cessation:

- The residual drawdown footprint remains extensive well outside of the Atlas Tenement
- The residual drawdowns are 1-2 m within the Project Area.

Key hydrogeological aspects would include:

- Continued operation of measures applied to mitigate adverse drawdown impacts on GDEs and environmentally sensitive areas. These operations would continue until the potential impacts of the residual drawdown were negligible.
- Continue operations to supplement the supplies to existing users that were influenced by the Project abstractions.
- Assessment of water recovery. This assessment would include periods of water table recovery to steady-state conditions and the implications of any residual drawdown from the baseline environment. Ensure groundwater recovers from drawdown as a result of mining activities.

4.13 Water Licensing and Groundwater Monitoring Programme

4.13.1 Water Licencing

In regards to the potential impact on local and regional water resources of the mining activities, groundwater licence should be sought for:

- Groundwater abstraction for the pit dewatering activity.
- Groundwater abstraction for the process water supply activities.

The abstraction of groundwater generally requires statutory authorisation in the form of a licence granted under Section 5C of the RIWI Act 1914. The level of assessment is likely to be a H3 Hydrogeological Report. This is a detailed hydrogeological assessment including the development of a numerical model using the Murray-Darling Basin modelling guidelines (Murray-Darling Basin Commission, 2000), based on a drilling programme of well production and monitoring. The requirements are detailed in Operational Policy No. 5.12 (DoW, 2009b).

4.13.2 Groundwater Monitoring Programme

The objective for the programme would be to provide adequate data in order to develop a H3 report that would inform the risk assessment to the environmental sensitive areas and water users.

The existing monitoring bores would be utilised in the groundwater monitoring programme. Additional monitoring bores and test production bores are recommended.

Figure 4-17 shows the location for the proposed monitoring bores (MB) and test production bores. The locations are proposed on the basis of the following strategy:

- Install monitoring bores in all deep formations: Lesueur Sandstone, Eneabba Formation, Cadda Formation, Yarragadee Formation and Cattamarra Coal Measures.
- Install a network of monitoring bores around Nambung National Park boundary.
- Install a network of monitoring bores in the groundwater discharge areas such as Mount Jetty Creek and Frederick Smith Creek.
- Install a network of monitoring bores along the deposit to define the local stratigraphy.
- Preferentially locate monitoring bores within the Image exploration licence tenement and along fence lines or distribution lines to facilitate access.

Based on those assumptions, this groundwater investigation programme comprises:

- Three multi-level monitoring bores, comprising grouped or nested 50 mm nominal diameter piezometers, located in twenty-one stations and targeting:

4 Hydrogeological Aspects

- — The superficial formations with a shallow and deep piezometer to monitor the vertical anisotropy of the formations as the hydraulic parameters are expected to differ vertically. Shallow bores should be screened at least 3 m below the water table. Deep bores should be screened at the bottom of the superficial formations where is the mineral sand layer.
- — The Lesueur Sandstone, Eneabba Formation, Cadda Formation, Yarragadee Formation and Cattamarra Coal Measures with bore depths varying from 8 to 50 m.

- Test production bores (TPBs) including:
  - — Three TPBs (TPBA01, TPBA02, and TPBA03) drilled into the Superficial Aquifer to assess the hydraulic parameters within the Atlas Deposit.
  - — One TPB (TPBA04) in the preferred location for a water supply bore, within the Image Mining Lease tenements, near Wongonderrah Road, 2.5 km distant from Mount Jetty Creek and on the eastern side of the proposed pits to limit impact on Nambung National Park. The TPB into the Yarragadee Aquifer would inform on the potentiality for water supply, environmental risks and impacts on existing users

The multi-level monitoring bores would be intended to provide:

- Groundwater levels and quality under existing pre-mining conditions.
- The observed hydraulic gradient for the unconfined aquifer and underlying formations.
- The lithology of the formations impacting on the Project area.
- Aquifer responses during test pumping.
- Potential long-term monitoring of the potential mining impacts on water users and environmental sensitive areas.

The TPBs would be intended to provide an estimate of the hydraulic parameters for the superficial and deep formations along the deposit based on test pumping. The test pumping of each TPB would include step-drawdown, constant-discharge and recovery tests. Test pumping is required for the development of a H3 Hydrogeological Report. The tests should be undertaken in accordance with Australian Standards (AS 2368-1990 Test pumping of water wells). The minimum requirements for test pumping are outlined in the Guidelines and Minimum Construction Requirements for Water Bores in Australia (September 2003).

The DoW manages two monitoring bores referred as CS35S (Reference 31730554) and CS35D (Reference 31730555) (DoW 2012a) in their database. These bores would be incorporated into the monitoring programme, especially during the pumping tests.

Three private water users are present in the Project Area and already monitored by MWES Consulting. If possible, these private bores should undergo additional monitoring during the pumping tests. Data collected from private bores would consolidate the above monitoring programme.

Combination of multi-level monitoring bores and existing bores should allow characterisation of the hydrostratigraphy. The interpretation from the monitoring programme would be used to:

- Develop a detailed hydrogeological conceptual model.
- Refine and update the numerical model, which can subsequently be used to:
  - — Predict the impacts of mining including the annual plan on unit blocks.
  - — Develop an advanced water balance for process water supply.
  - — Design the on-going monitoring bores programme that would inform the observed dewatering impact around the pits.

4 Hydrogeological Aspects

- Simulate potential remediation scenario that may be required to minimise the environmental impacts.

- Inform management strategies to reduce the risk of adverse impacts to the superficial groundwater resources and the deep aquifers.

Hydrological Aspects

5.1 Baseline Surface Water Hydrology

5.1.1 Topography and Catchments

The runoff from the Arrowsmith Region and shedding off the Gingin Scarp terminates in a series of wetlands on the coastal plain. The wetlands have been identified in discrete geomorphic units such as creek, dampland, floodplain, lake, palusplain, and sumpland (Figure 5-1). When the wetlands are full, water overflows into karstic systems downstream within the Tamala Limestone (Kern A., 1997). In the vicinity of the Project area, a small proportion of the wetlands are protected to conserve their ecological values. Several wetlands in the vicinity are isolated from the surface water drainage; they are fed by direct rainfall and groundwater baseflow contributions.

The Nambung River is the confluence of several tributaries, including Mount Jetty Creek and Frederick Smith Creek, which flow through the Project Area. The confluence occurs 6 km downstream of the project area. The Nambung River flows into an underground karst system in the Nambung National Park, with subsequent seepage along the coastline. The Nambung River system is recognised by DEC (DEC, 1995) as important for the diversity of habitats. Due to the low and infrequent nature of rainfall in the North Perth Basin, creek lines are typically ephemeral.

5.1.2 Predicted Peak Discharge Rates

Historical observed flow data does not exist within the catchment of the Nambung River. Therefore, the Australian Rainfall and Runoff methodology (Pilgrim D.H. 2001) has been adopted to predict peak discharge rates.

Rainfall runoff modelling was conducted to determine the watershed characteristics of the upstream sub-catchments and predict stream flows within the baseline environment (pre-mining conditions).The software XP-Rafts was used to generate design runoff hydrographs for design rainfall events for 2-, 5-, 10-, 20- and 100-year Average Recurrence Intervals (ARIs). These ARIs cover the standard design rainfall events for flood risk and environmental risk assessments. The design rainfall events were derived from Intensity-Frequency-Duration (IFD) that established rainfall temporal patterns in the project area. The XP-Rafts hydrological model computes excess rainfall that will be routed into stream flows based on the channel shape, slope and length and the sub-catchments characteristics. The catchment losses defined as initial and continuous losses are derived from Australian Rainfall and Runoff (Pilgrim D.H., 2001). The catchment losses have been validated against the findings of the report on the Boonanarring and Gingin North deposits (URS, 2012).

5.1.2.1 Sub-Catchments Modelling

The watershed was divided into sub-catchment areas for runoff computation along the Project area. The criteria used to delineate the sub-catchments included the vegetation, soil and land-use types. Height sub-catchments have been defined with a nomenclature from CA_01 to CA_08 (Figure 5-2). Table 5-1 presents the parameters of the sub-catchments. The major creeks flowing toward the Project area are defined into single sub-catchments such as Bibby Creek and Mount Jetty Creek (CA_03, CA_04, CA_05 and CA_06). The downstream sub-catchment is the Nambung River downstream stretch where the river enters into karstic features. Therefore the entire Nambung River was modelled.

5 Hydrological Aspects

Table 5-1 Sub-catchments Parameters for Hydrological Modelling

XP-Rafts Sub-catchments	Creek	Catchment Slope (%)	Total Area (km2)	Manning's 'n' (n value)
CA_01	Tributary	2.14	175.69	0.05
CA_02	Bibby Creek	4.11	172.39	0.04
CA_03	Tributary	2.38	33.30	0.03
CA_04	Tributary	1.21	11.21	0.03
CA_05	Mount Jetty Creek	2.14	97.13	0.04
CA_06	Tributary	0.61	25.01	0.05
CA_07	Tributary	1.39	132.37	0.06
CA_08	Frederick Smith Creek	2.06	108.32	0.05
Nambung River	**Nambung River**	**NA**	**755.44**	**NA**

The watershed upstream of the Project Area covers an area of 160.64 km^2. This represents 21 per cent of the Nambung River catchment.

Manning's *n* values describe the surface resistance of the floodplain and the sub-catchment surface (US Army Corps of Engineers, 2008). The surface resistance influences the hydrograph geometries; rougher terrain flattens hydrographs whilst smoother terrain tends to lead to sharper hydrographs. The values are derived from the standard Chow method (1959) based on land cover and soil composition. The three main categories identified in the watershed are:

- 0.06 for light bush and tree.
- 0.04 for cultivated areas with mature field crop.
- 0.03 for cultivated areas with no crop.

The sub-catchments are a combination of pasture, bush and cultivated areas.. The composite manning's *n* values for each sub-catchments have been calculated based on the ratio of each category.

5.1.2.2 Rainfall Patterns

The Intensity-Duration-Frequency (IFD) is a major input into the hydrological model as design flood events are based on design rainfall events. The IFD specifies the duration and the intensity of the rainfall events in the Project area. BoM developed a program online providing the coefficients (BoM, 2012b). The Atlas Deposit IFD has been extracted for the centre of the Project Area (Latitude -30.564N, longitude 115.232S). Table 5-2 presents the design rainfall intensities for the Project area.

Table 5-2 BoM Intensity-Frequency-Duration for the Project Area (MGA 50, E334001, N6617376).

Storm Duration	Average Recurrence Interval (years)						
	1	2	5	10	20	50	100
5 Minutes	56.0	74.0	98.1	115.0	138.0	172.0	201.0
6 Minutes	52.2	69.0	91.3	107.0	128.0	160.0	186.0
10 Minutes	41.7	55.0	72.3	84.4	101.0	125.0	146.0
20 Minutes	29.1	38.3	49.9	57.9	69.0	85.0	98.5
30 Minutes	23.1	30.3	39.2	45.4	53.9	66.1	76.4
1 Hour	15.1	19.7	25.3	29.1	34.3	41.9	48.2
2 Hours	9.5	12.5	15.9	18.3	21.5	26.2	30.1
3 Hours	7.2	9.4	12.1	13.9	16.3	19.9	22.8
6 Hours	4.5	5.9	7.5	8.7	10.2	12.4	14.2
12 Hours	2.9	3.7	4.7	5.5	6.3	7.7	8.8
24 Hours	1.8	2.42	3.0	3.4	3.9	4.7	5.3
48 Hours	1.2	1.5	1.8	2.0	2.3	2.8	3.1
72 Hours	0.9	1.2	1.4	1.5	1.7	1.9	2.2

Note: The intensity values are in mm/hour.

5.1.2.3 Catchment Losses

Catchment losses applied in the XP-Rafts model are estimated in accordance with the Australian Rainfall & Runoff (Pilgrim D.H, 2001). Table 5-3 details the losses extracted for the guideline. The initial losses describe the amount of rainfall infiltrated into the ground before run-off commences. The initial losses are considered relatively high. The 100 year initial loss value, absent from the AR&R guideline, have been extrapolated using the linear method. The losses showed in Table 5-3 have been verified against similar catchment conditions near Gingin Township where stream flow gauge data are available.

5 Hydrological Aspects

Table 5-3 AR&R (1987) Losses Values in the Project Area

Estimated Losses	ARI Rainfall Event (years)					
	2	5	10	20	50	100
Initial Loss (mm)	42	70	84	66	66	66
Continuing Loss (mm)	5	5	5	5	5	5

5.1.2.4 Baseline Hydrological Modelling Results

The XP-Rafts modelling outputs estimate the peak flows at the downstream point of each sub-catchments for the 2-, 5-, 10-, 20- and 100-year ARI flood events. The peak flows for the discrete ARIs are presented in Table 5-4. The full hydrographs are displayed in Chart 5-1. The critical storm duration for all events is 12 hours except for CA_03 and CA_04 sub-catchments, which is 6 hours.

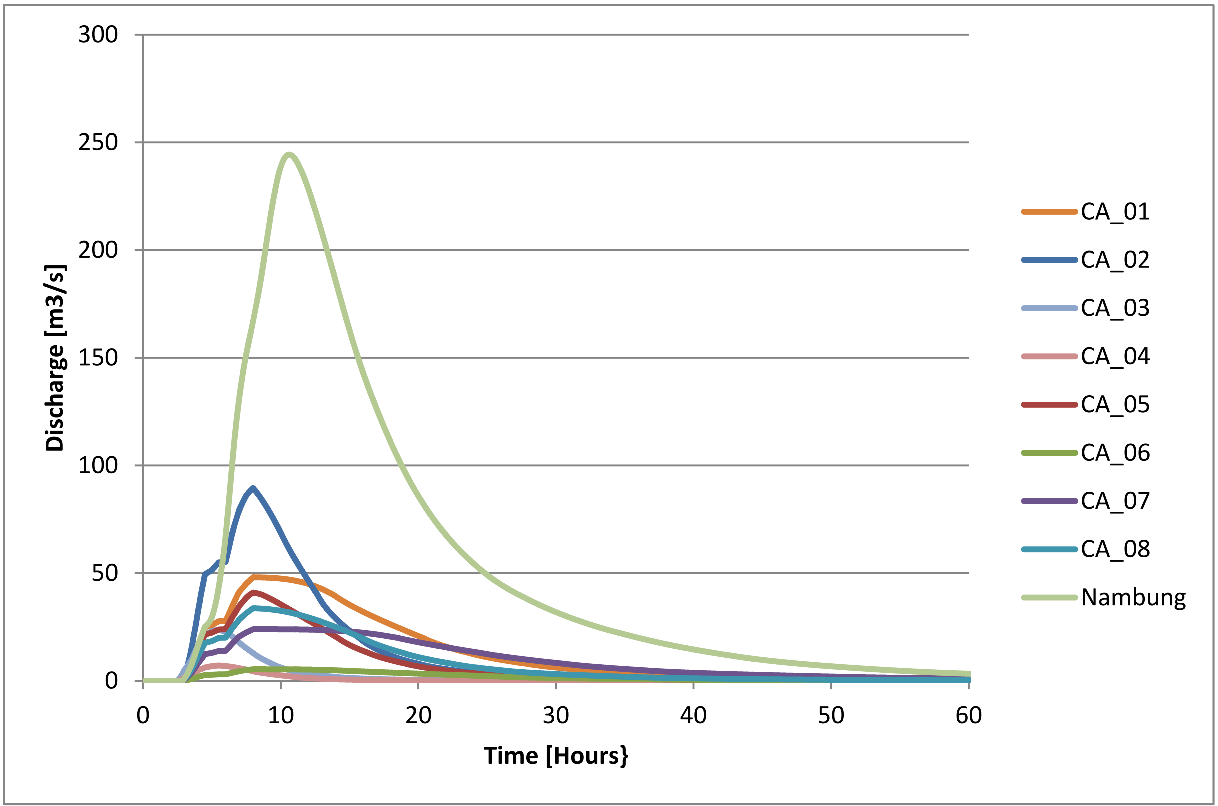
Table 5-4 Sub-catchments Peak Flows for ARIs

ARIs (years)	Peak Flows (m^3/s)								
	Sub-Catchments								
	CA_01	CA_02	CA_03	CA_04	CA_05	CA_06	CA_07	CA_08	NAMBUNG RIVER
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.12	0.22	0.06	0.01	0.10	0.01	0.04	0.07	0.60
10	3.00	6.10	1.90	0.50	2.60	0.30	1.50	3.70	17.10
20	21.20	41.90	12.50	3.60	18.00	2.30	10.30	14.70	114.90
100	48.10	89.50	23.7 (6hrs)*	7.1 (6hrs)*	40.90	5.30	23.90	33.70	244.30

Note: Critical duration = 12hrs, except when noted in the table*

5 Hydrological Aspects

Chart 5-1 1:100 year ARI Hydrographs at the Downstream Point of each Sub-catchment



5.1.2.5 Model Output Interpretations

The interpretations based on the outputs of the hydrological model are:

- The runoff is nil for below 1 in 2 years return period rain events. The initial losses that represent soil infiltration capability and vegetation interception are higher than the rainfall intensities. No runoff is generated.. Any clearing upstream of the Project area would increase the runoff.
- Runoff is generated from rain events above the 1 in 5 year return period. The sub-catchments upstream of the Project area all produce small flows from 0.01 to 0.1 m^3/s. The peak flow computed for the downstream Nambung River is very small, i.e. 0.60 m^3/s or 60 L/s.
- Between the 10 and the 100 year return period flood events, the increase in peak flow rates in the Nambung River is very significant, rising from 17 to 244 m^3/s and following an exponential curve. The sub-catchments flowing toward the Project area produce high peak flow rates.
- The 1 in 100 year flood event is generally used as a standard design event for stormwater drainage design. The peak flows expected along the Project area would vary from 7 to 41 m^3/s. The design for hydraulic structures for such high flows would require a calibrated model. A 2D hydraulic modelling approach is recommended during future Project stages in order to simulate the flood extents for discrete ARI events, compute the associated flow velocities and assess the changes in flow regime that may impact the downstream ecosystems.
- The volume of water generated during severe flood events is expected to be very high with 12.11 GL of water generated for a 1 in 100 year flood event at the downstream point of the Nambung River.

- The increase of peak flows from the 5 to 100 year ARI flood events is considered to be potentially overestimated. Observed stream flow data (DoW, 617002) are available for the Hill River, which is 22 km upstream of the Project Area with a similar soil context. Over the past 40 years, the largest flow event experienced in the Hill River catchment comprised a total runoff volume of 3.5 GL over 72 hours in 1974. The Hill River watershed has generated very little runoff over the last five years with a maximum peak flow recorded of 1.5 m^3/s (DoW 2012b). Surface water flow monitoring will permit better calibration of the hydrological model in future; this will allow assessment of the reasons for the discrepancy, whether real or a modelling artefact, between the predicted flow rates for the Project area and the observed flow rates in the adjacent, larger catchment.

5.1.2.6 Limitations for the Modelling

No sensitivity modelling has been undertaken at this stage with respect to the simulated roughness values and catchment losses. Further stages of study including preliminary impact assessment and feasibility studies should include sensitivity analysis to determine the sensitivity of the model in regards to these variables. This would increase the level of confidence on the model outputs to support the environmental impact assessment. As discussed above, the preliminary modelling appears to overestimate the flows for a 100 year flood event. Overestimation could lead to overdesign of the drainage infrastructure to mitigate the flood risk for the proposed mine.

The model has not been calibrated to date because of the lack of the historical observed data in the Nambung River watershed. However, further modelling should use the observed data from the Hill River Catchment, which is equipped with two stream flow gauges.

5.1.3 Surface Water Quality

The ephemeral nature of the creek flows influences surface water monitoring options. MWES Consulting sampled five surface water pools around the Project Area in July 2012 during the wet season, plus one of the same pools in November 2012 during the dry season. Surface water was present in the bed creeks in the form of ponding or flowing water. Parameters such as flow rate, pH, Electrical Conductivity or Total Dissolved Solids (TDS) have been measured in-situ or in a laboratory.

Three rain gauge datasets are available near the Nambung National Park (BoM 2012a): Nambung (BoM, 009276), Cervantes (BoM, 009169) and Jurien Bay (BoM, 009131). The rain gauges recorded a significant amount of rain in June 2012, with three events respectively 66 mm, 93 mm and 123 mm. The large amount of rain in the Nambung River catchment explains the presence of surface water in all five sample locations. Table 5-5 presents a selection of the results of the survey. Location of the samples is showed in Figure 4-6.

Table 5-5 Key Surface Water Monitoring Results (July and November 2012 Surveys)

Sample Site ID	Coordinates MGA 50		Bed Conditions	Flow Rate [ML/day]	pH*	EC* [us/cm]	Turbidity *[NTU]	TDS** [mg/L]	Type
July 2012									
ASW1	332646	6621936	Running Water	1.23	9.38	5,380	7.43	3,380	Brackish
ASW2	332680	6620217	Running Water	1.1	7.46	2,810	11.75	1,630	Brackish
ASW3	329743	6619880	Pool	No Flow	8.05	5,970	5.02	3,350	Brackish

5 Hydrological Aspects

Sample Site ID	Coordinates MGA 50		Bed Conditions	Flow Rate [ML/day]	pH*	EC* [us/cm]	Turbidity *[NTU]	TDS** [mg/L]	Type
ASW4	329470	6615319	Running Water	0.52	8.55	13,030	6.23	10,200	Saline
ASW5	327420	6616728	Pool	No Flow	8.03	7,740	7.05	NA	NA
November 2012									
ASW1	332646	6621936	Dry	-	-	-	-	-	-
ASW2	332680	6620217	Dry	-	-	-	-	-	-
ASW3	329743	6619880	Running Water	1.1	7.17	2,455	16.91	1,522	Brackish
ASW4	329470	6615319	Dry	-	-	-	-	-	-
ASW5	327420	6616728	Dry	-	-	-	-	-	-

*In-situ measurements

**Laboratory results

Preliminary interpretations based on Table 5-5 are:

- Surface water ainMount Jetty Creek (ASW1 and ASW2) is brackish. The nearby bore AGW1 (Figure 5-3) is 15.70 m deep. Concentrations of TDS, sulphate and sodium are similar in the groundwater and the surface water. There is a strong correlation between the groundwater and the surface water quality, reflecting the shallow depth of groundwater and the inferred interactions between the groundwater and surface water regimes.
- Surface water in Frederick Smith Creek (ASW4 and ASW5) is saline with TDS values up to 10,200 mg/L. However, the superficial aquifer in this area is less saline with a TDS of only 4,650 mg/L (bore AGW4). This creek is also known as a groundwater discharge area (Kern A.M. 1993). Evaporation of the surface water is most likely to occur in the low lying areas of the creek with a subsequent increase of salinity in the sediment. Flood events may dissolve or remobilise the salts.
- Metal concentrations are all very low for all five samples. The results have been compared to the trigger values for freshwater provided by the ANZEC 2000 guidelines applicable to Western Australia. All metals analysed in the survey are within the 95% level of protection for species.
- The turbidity expressed in NTU is relatively low for all five samples, being between 5 to 12 NTU.

5.2 Flood Risk, Potential Impact and Mitigation of Proposed Infrastructure

The following aspects are covered within this section:

- Preliminary flood risk assessment on the proposed mine site infrastructure and mitigation proposals.
- Characterisation of the potential change on flow regime leading to environmental adverse impacts and remediation.
- Management in term of flow diversion and sediment loading.

5.2.1 Preliminary Flood Risk Assessment

The Atlas operational area intersects several drainage lines (Figure 5-2). The 100 year ARI peak flow events for these drainage lines vary from 7 to 41 m^3/s in the vicinity of the proposed pits. The simulated peak flows from the hydrological model are considered to be high. The flood risk for the proposed infrastructure is considered to be high. The risk is exacerbated by the orientation of the drainage lines perpendicular to the pits. Mitigation should be sought to remediate the flood risk in the form of:

- Flood bunds on the upstream part of the operational area.
- Flow diversion channels.

The suggested minimum design event criteria (based on the Minerals Council of Australia 1997) are:

- Access road, culverts and drainage ditches: 10 year ARI to 50 year ARI flood peak.
- Drainage courses: 100 year ARI flood peak.

It is recommended that 2D hydraulic modelling is undertaken in order to design the flow diversion channel and for environmental impact assessment. The method will provide good confidence in the drainage design.

5.2.2 Catchment Area Losses

Loss of surface area producing runoff or infiltration will occur within the pit footprint. The incident rainfall will not significantly recharge the underlying superficial formations. The area that is expected to be impacted is 132.8 ha. This represents 0.7% of the watershed upstream of the proposed mine.

The rest of the proposed infrastructure (haul roads, accommodation village, administration pads, etc.) should still generate runoff. Stormwater collected from these areas should be carefully managed as contaminants could pollute the vulnerable Nambung River downstream of the site. The surface water management plan should include specific drainage systems to mitigate the risk of downstream pollution.

5.2.3 Mobilisation of Sediment from Disturbed Areas

There is potential for increased erosion and associated increased sediment loading due to runoff during and after construction. This potential impact is attributed to increased areas of disturbed and exposed soils. Appropriate stormwater drainage systems are required to drain the operational area and the upstream sub-catchments. The challenge would be to maintain a similar degree of sedimentation load within the watercourse during and post-operations to mitigate the potential environmental impacts. Potential solutions include stilling basins to collect runoff from disturbed areas and the design of flow diversions to limit potential scouring. The channels are recommended to be reinstated and rehabilitated once the pits are fully backfilled to help restore baseline conditions. It is recommended to reinstate using the initial top soils and to vegetate the banks and floodplain.

5.2.4 Flow Diversion

Flow diversion activities are mainly regulated under Section 17 Permit – Permit to authorise interference or obstruction of the bed and banks of a watercourse or wetland. Conceptual plans for the diversion of the creeks, management of downstream effects and rehabilitation of the streams are required for the Environmental Impact Assessment (EIA).

The channel diversion approval study would need to include:

- Development of catchment runoff characteristics;
- Selection of drainage diversion routes;
- Simulation in a 2D platform to evaluate the impact of the diversion on downstream surface water flow volume and rates;
- Consideration of flood protection bunding requirements;
- Evaluation of closure strategy and residual long-term issues; and
- Development of a monitoring and management plan and evaluate closure issues.

5.3 Surface Water Monitoring Programme

Ongoing surface water monitoring is recommended. It is unlikely that creeks will contain water during the summer season and thus the monitoring should place emphasis on data collection during winter. Additional surface water locations should be monitored to characterise better the baseline conditions. The Nambung River downstream of the confluence of Mount Jetty Creek and Frederick Smith Creek should be sampled.

Additionally, a network of stream flow monitoring stations should be established to enable quantitative and qualitative assessments of the flow regime in support of the regulatory process.

This network would be intended to provide the support for the Environmental Impact Assessment and guide the preliminary design for the drainage structures. The monitoring will aid characterisation of the contribution of Mount Jetty Creek to flows and quality in the Nambung River and the National Park. This will aid calibration of the hydrological modelling. The link between Mount Jetty Creek and the Nambung River and the National Park is considered likely to be of significant interest during the regulatory approvals process..

The following monitoring devices should be installed in the Project Area (Figure 4-17):

- A rainfall gauge station should be installed within the Mount Jetty Creek Catchment. Rainfall data is recommended to be recorded at an interval of 15 minutes to characterise the rainfall intensities.
- Four crest gauges stations should be installed at key locations in the catchment. A crest gauge records the height of water in a waterway and can be used to estimate peak flows. The strategy for this monitoring is to refine the ratio of flow contribution from the upper catchment to the Nambung River
- Turbidity is a key parameter to monitor under flood conditions. At least one logger continuously monitoring water quality during flood events should be implemented. The proposed location is just downstream of the proposed mine site but upstream of Munbinea Road.

Conclusions and Recommendations

6.1 Groundwater Aspects

- The superficial aquifer is shallow below the Atlas Tenement.
- The Mount Jetty Creek wetland is a seasonal groundwater discharge area. Wetlands and GDEs are numerous in the Project Area.
- The Yarragadee Aquifer is estimated to be only about 20 m bgl. The aquifer is unconfined and constitutes a potential groundwater resource for the process water supply.
- The mine site water demand is assumed to 2.2 GL/annum. The pit dewatering system, comprising in-pit sumps, could supply a high portion for the process water supply, especially during the two first years. There is need to also abstract from the Yarragadee to meet the remainder of the process water demand. The aquifer resource allocation available covers the demand in the sub-area. However, the capacity of the aquifer should be determined by aquifer tests. The most suitable location for the implementation of the deep bore into the Yarragadee would be south of the Deposit, away from the northern wetlands.
- The groundwater flow model has simulated a large drawdown footprint associated with the pit dewatering. Cumulative drawdown impacts are expected with the water supply abstraction from the Yarragadee Formation.
- The predicted drawdown footprint extends into the Nambung National Park. The drawdown footprint extends beneath an extensive area of Groundwater Dependant Systems (GDEs). However, the level of dependency of these GDEs should be assessed in order to quantify the level of impact.
- A groundwater monitoring and test pumping programme is recommended to better characterise aquifer properties and baseline hydrogeological conditions. The monitoring bores should be screened into the superficial formations and the Yarragadee Formation. Three test production bore are recommended to support the design of the pit dewatering and the water supply bore.

6.2 Surface Water Aspects

- The catchment area upstream of the mine site covers an area of 160.64 km^2. The watercourses originate from the Arrowsmith Region and terminate in the wetlands of the Bassendean Sand. Ultimately they flow into the Nambung River before entering into karstic features in the Nambung National Park. The watershed has high conservation values (DEC, 1995) and altered hydrology might affect these ecosystems.
- A hydrological model simulated hydrographs for discrete flood events. The runoff is very minor for rain events below the 1 in 5 year return period. However once the initial losses are exceeded the peak flows increase rapidly. The 1 in 100 year return period flood for the downstream Nambung River is estimated to be 244 m^3/s, however this is considered to be a potential overestimate based on data from a similar catchment nearby. This requires further assessment following surface water monitoring to permit calibration of the model in more detail.
- The watercourses intersecting the Atlas tenements generate high peak flow for the 1:100 year ARI. The flood risk for the proposed infrastructure is high. Mitigation measures to reduce the flood risk will be required, including diverting the flows through diversion channels and construction of flood bunds.
- Flow continuity between upstream and downstream of the site has to be maintained to avoid significant impacts on the hydrology of the Nambung National Park. Such impacts would represent an impediment to the regulator process.

6 Conclusions and Recommendations

- The hydrological model has been partially calibrated. A full calibration will be necessary to confirm the high peak flows. In term of environmental impact assessment and flood design, it is recommended to develop a 2D hydraulic model.
- Ongoing surface water monitoring is recommended to better characterise baseline conditions and aid the impact assessment process.

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Figures

Atlas Tenement

N
W E
S

0 1 2 3 4 Kilometers

Scale: 1:200,000

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

LOCATION PLAN

URS

INTRODUCTION

Figure: **1-1**

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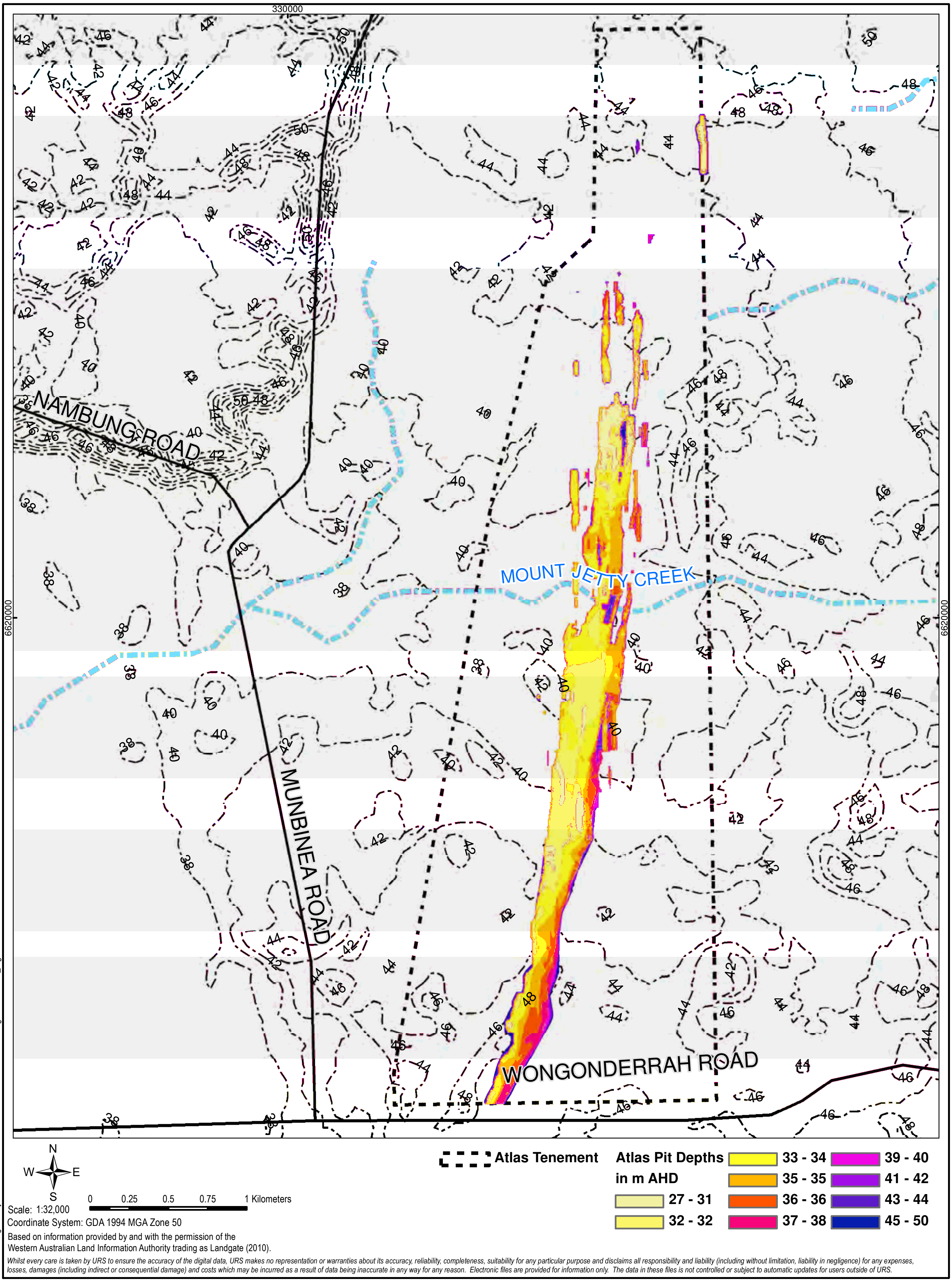

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

BOTTOM ELEVATION OF PROPOSED PITS

URS

PROPOSED MINING ACTIVITIES

Figure: **2-1**

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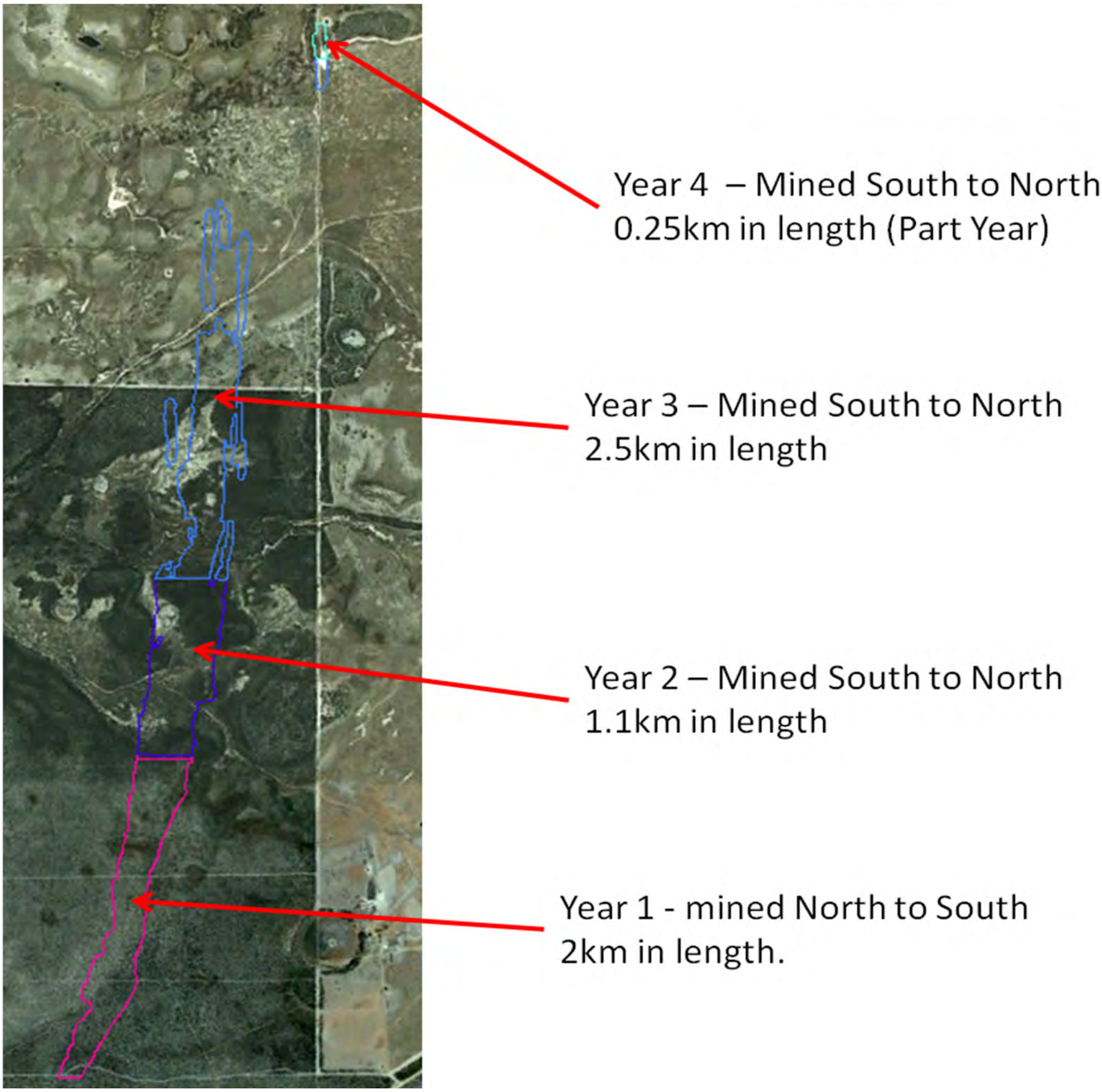

Source: Image Resources NL, 2012

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECTS
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGY SCOPING STUDIES

ATLAS MINE PATH AND SEQUENCE

URS

PROPOSED MINING ACTIVITIES

Figure: **2-2**

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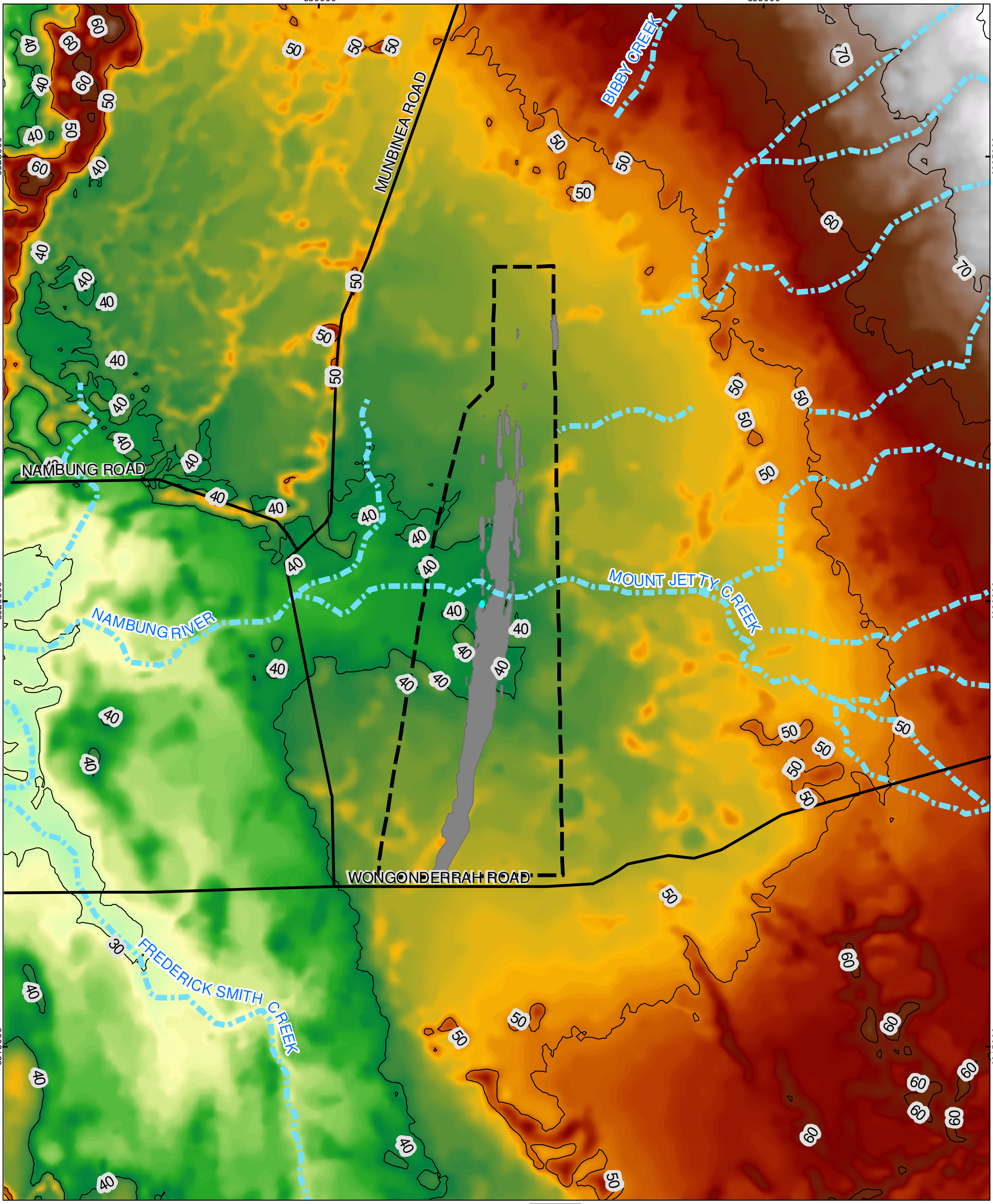


N
W E
S

Scale: 1:60,000

0 0.4 0.8 1.2 1.6 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Atlas Pits Footprint

Atlas Tenement

Atlas Coutour Lines 10 m Interval

Digital Elevation Model [m AHD]

High : 163.0

Low : 23.0

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

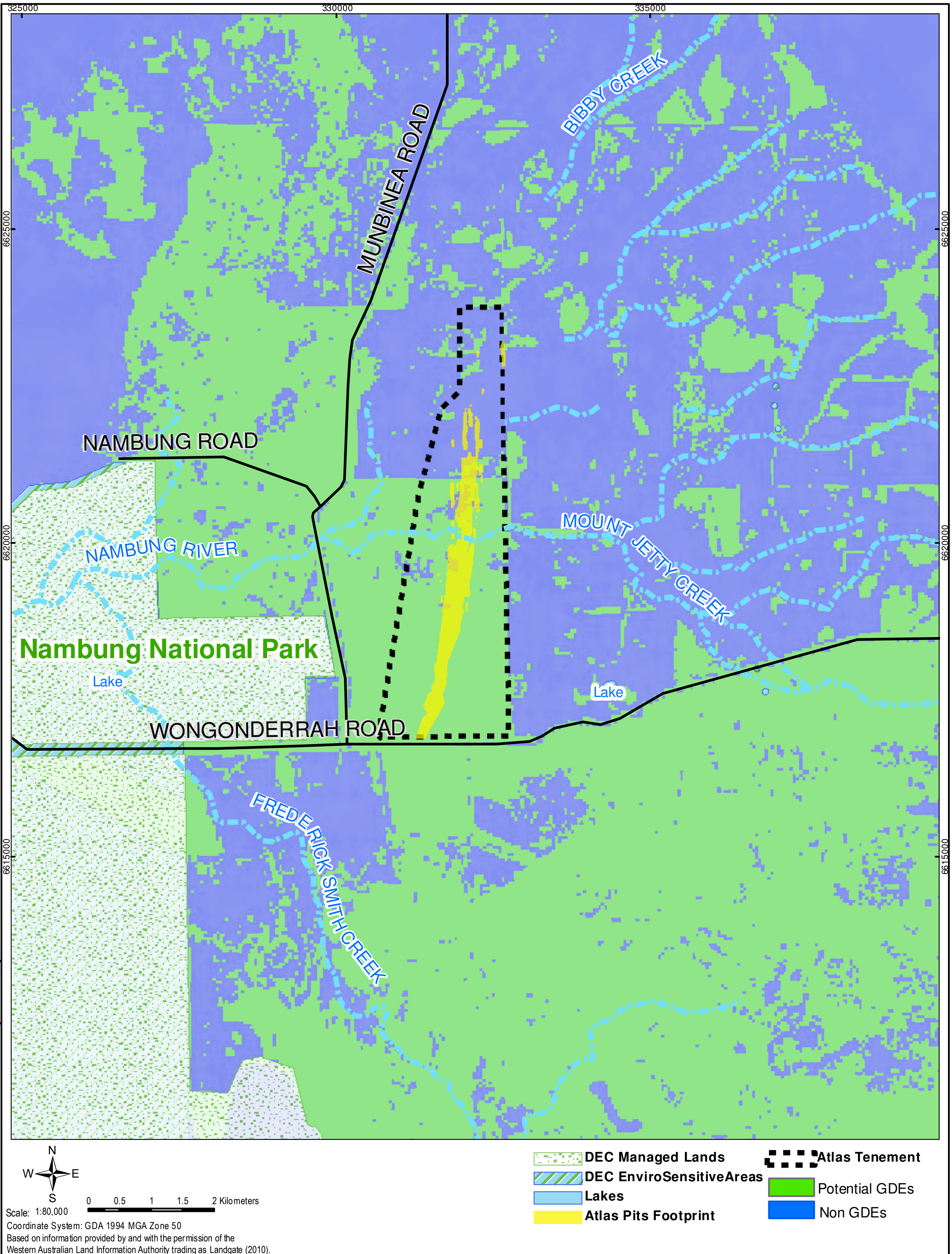
TOPOGRAPHY

URS

SETTINGS

File No: **42908116-WG-077.mxd** Drawn: **LS** Approved: **IB** Date: **20/2/2013**

Figure: **3-1** Rev. **A** A4



Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

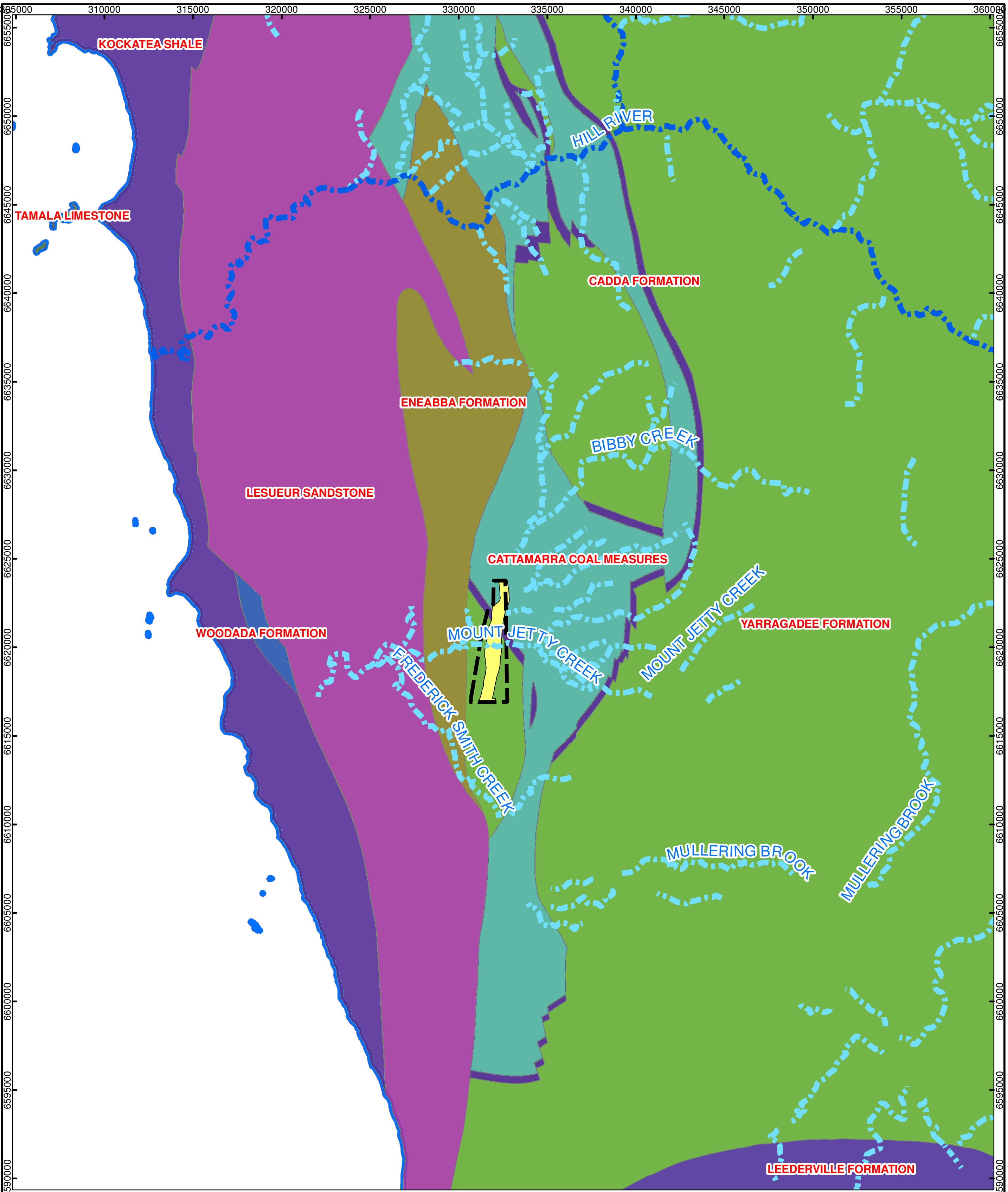
NATURES RESERVES AND DEC ENVIRONEMENTAL SENSITIVE AREAS

URS

SETTINGS

Figure: **3-2**

File No: **42908116-WG-065.mxd** | Drawn: **LS** | Approved: **IB** | Date: **19/2/2013** | Rev. **A** | A4



Atlas Operational Area
Atlas Tenement

N W E S

Scale: 1:300,000

0 2.5 5 7.5 10 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

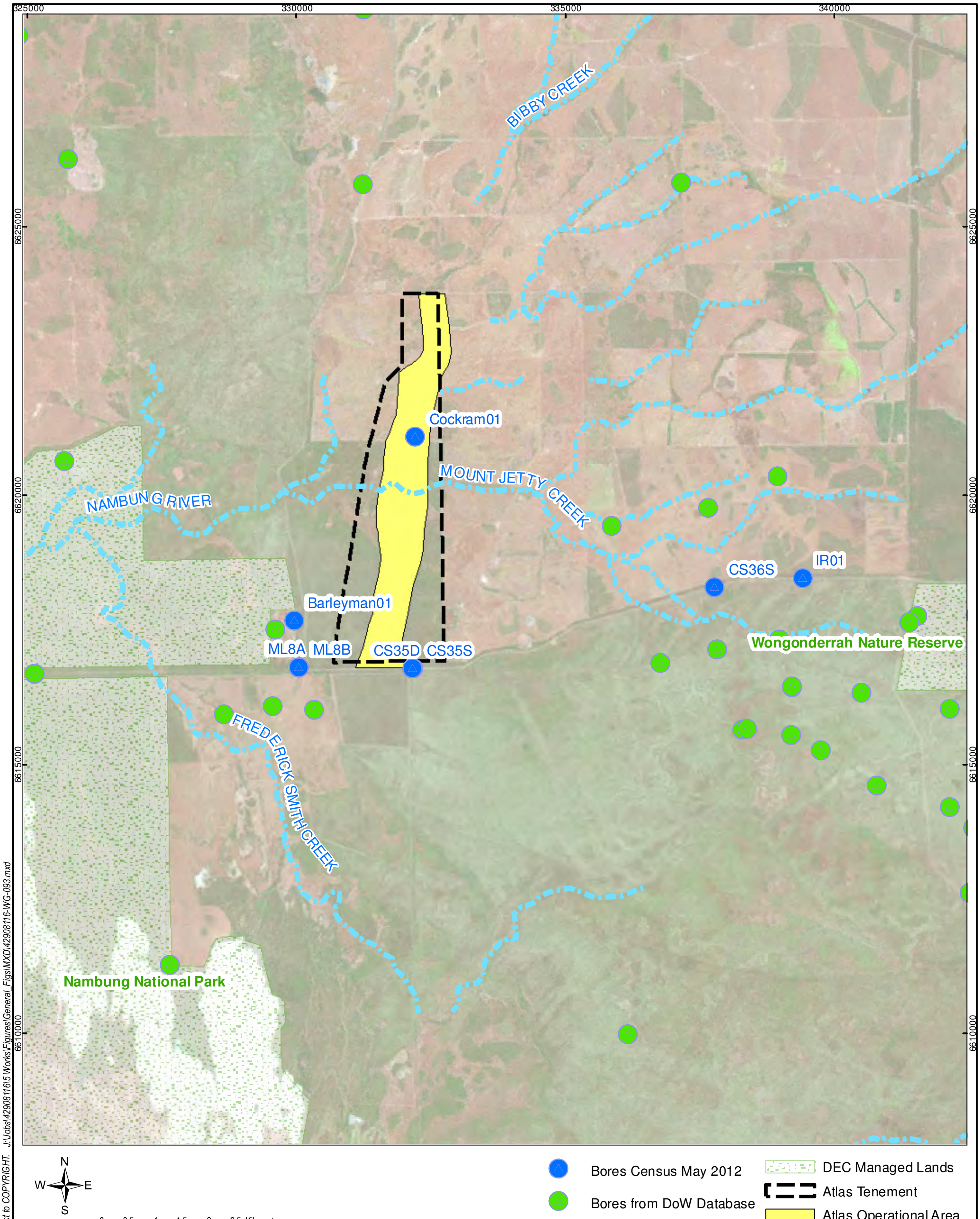
REGIONAL GEOLOGICAL UNITS

URS

SETTINGS

Figure: **3-3**

File No: **42908116-WG-078.mxd** Drawn: **LS** Approved: **IB** Date: **20/2/2013** Rev. **A** A4



Scale: 1:95,000
Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

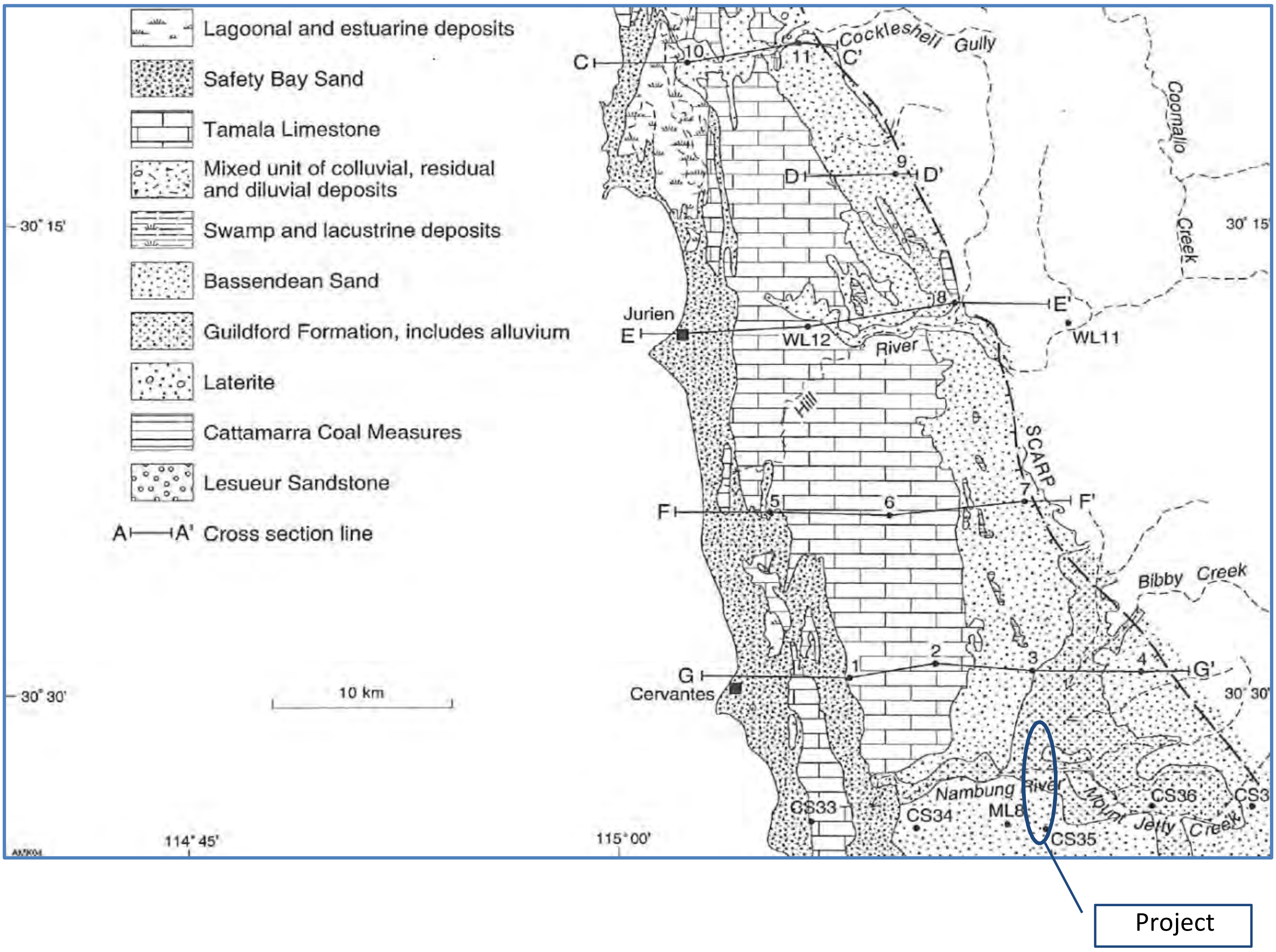
WATER USERS

URS

SETTINGS

Figure: **3-4**

File No: **42908116-WG-093.mxd** Drawn: **LS** Approved: **IB** Date: **20/2/2013** Rev. **A** A4



Source: URS, Kern, A.M. (1997b) - *Hydrogeology of the Coastal Plain between Cervantes and Leeman, Perth Basin,* Water and Rivers Commission, Hydrogeology Record, Series No HG 3.

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECTS
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGY SCOPING STUDIES

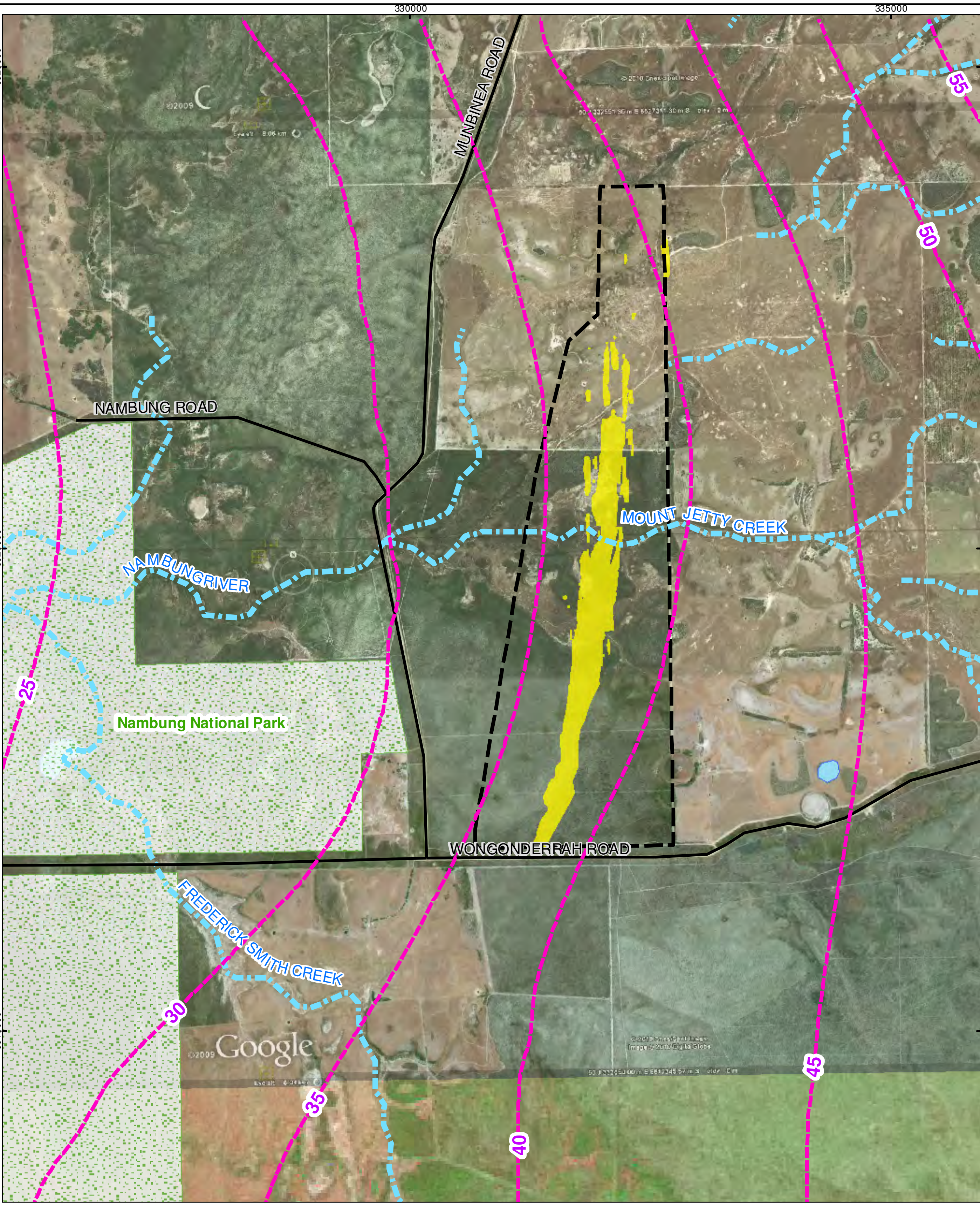
SURFACE GEOLOGY

URS

HYDROGEOLOGICAL ASPECTS

Figure: 4-1

File No: 42908116-WG-089.xlsx | Drawn: LS | Approved: IB | Date: 29-11-2012 | Rev: A | A4



NOTE: background map supplied by the client

Scale: 1:55,000

0 0.4 0.8 1.2 1.6 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Water Table Elevation in mAHD

Atlas Tenement

DEC Managed Lands

Atlas_Pits_Footprint

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

WATER TABLE ELEVATIONS IN THE SUPERFICIAL AQUIFER

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-2**

File No: **42908116-WG-086.mxd** Drawn: **LS** Approved: **IB** Date: **20/2/2013** Rev. **A** A4

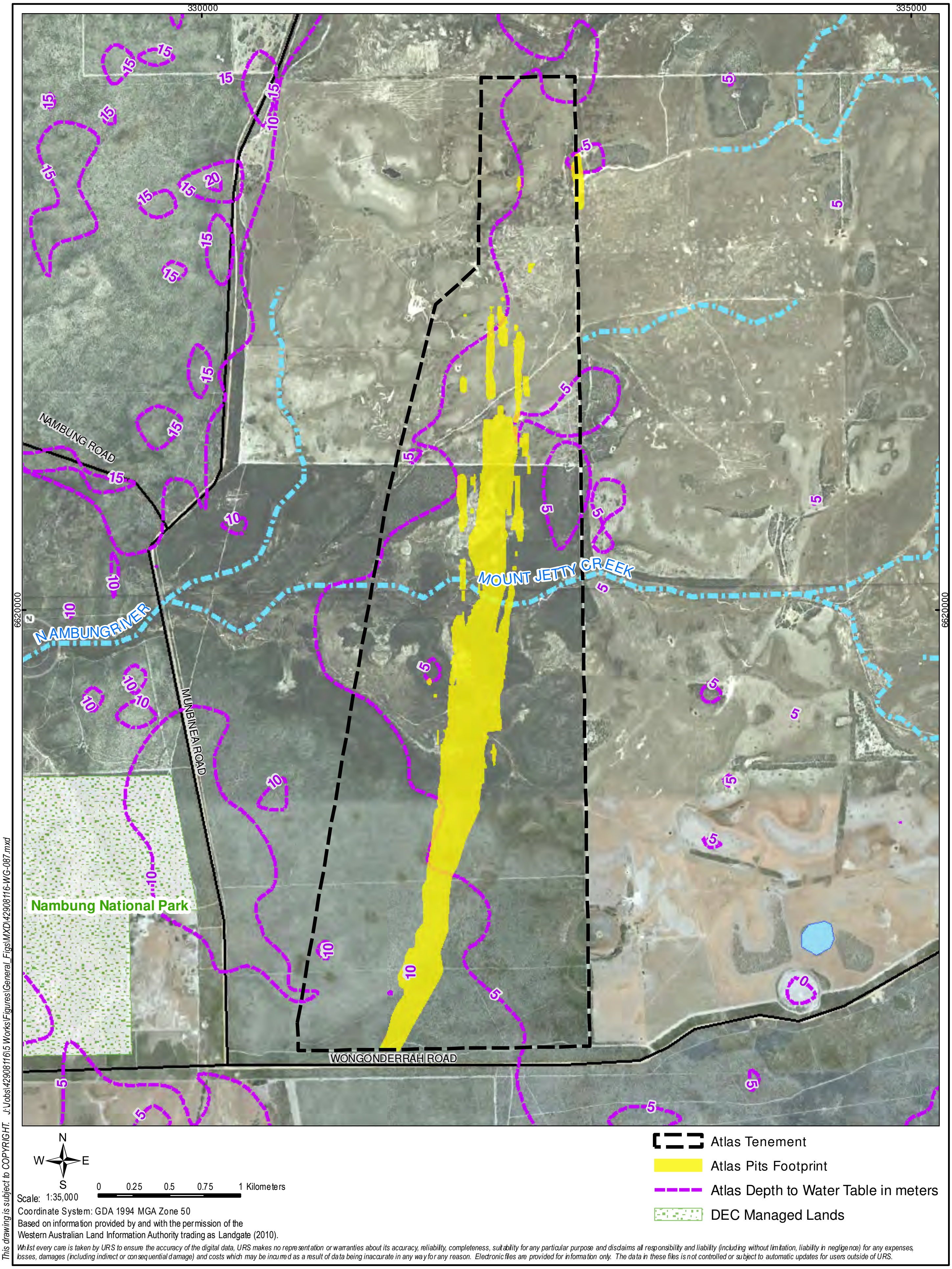


IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

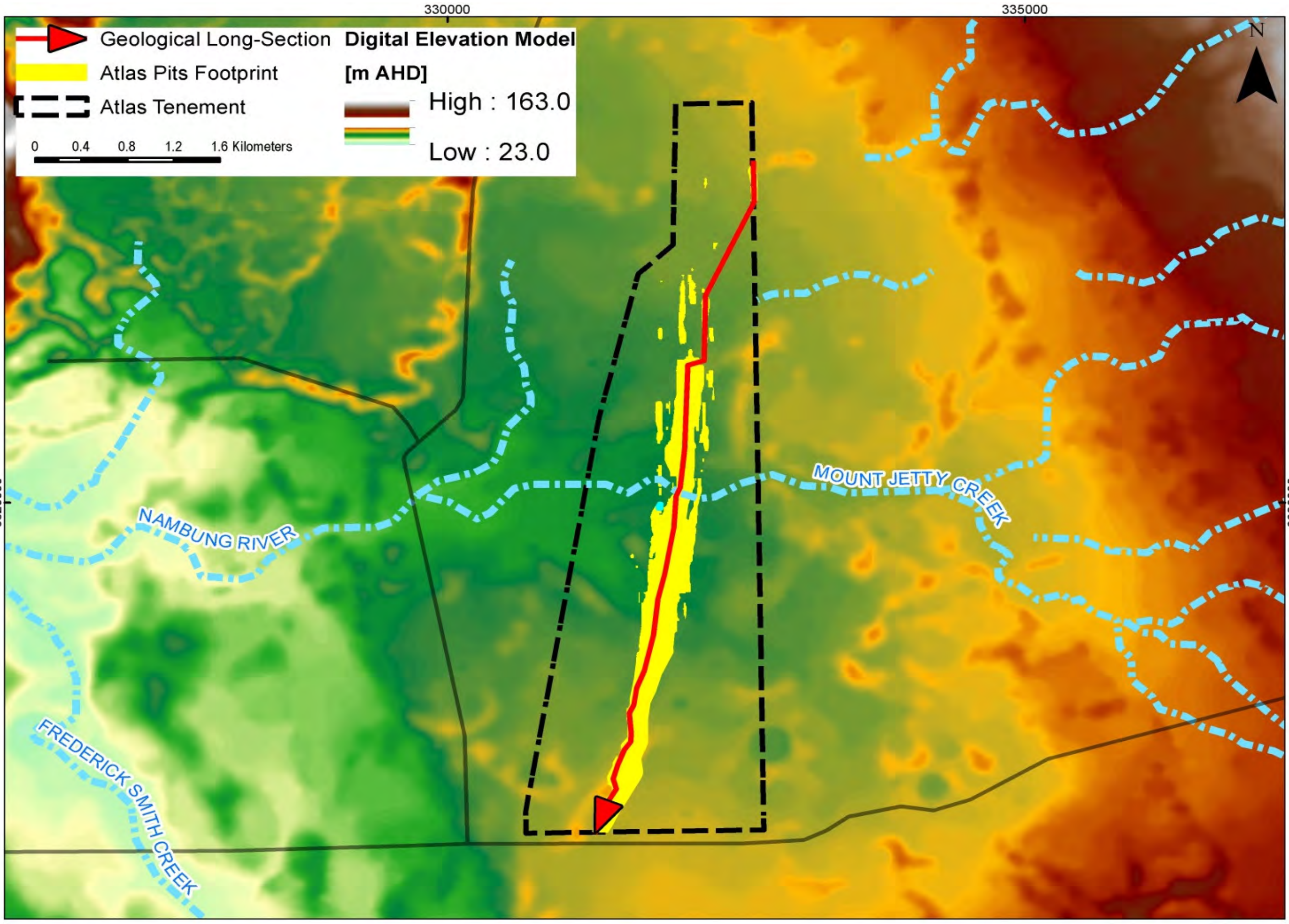
DEPTHS TO WATER TABLE IN THE SUPERFICIAL AQUIFER

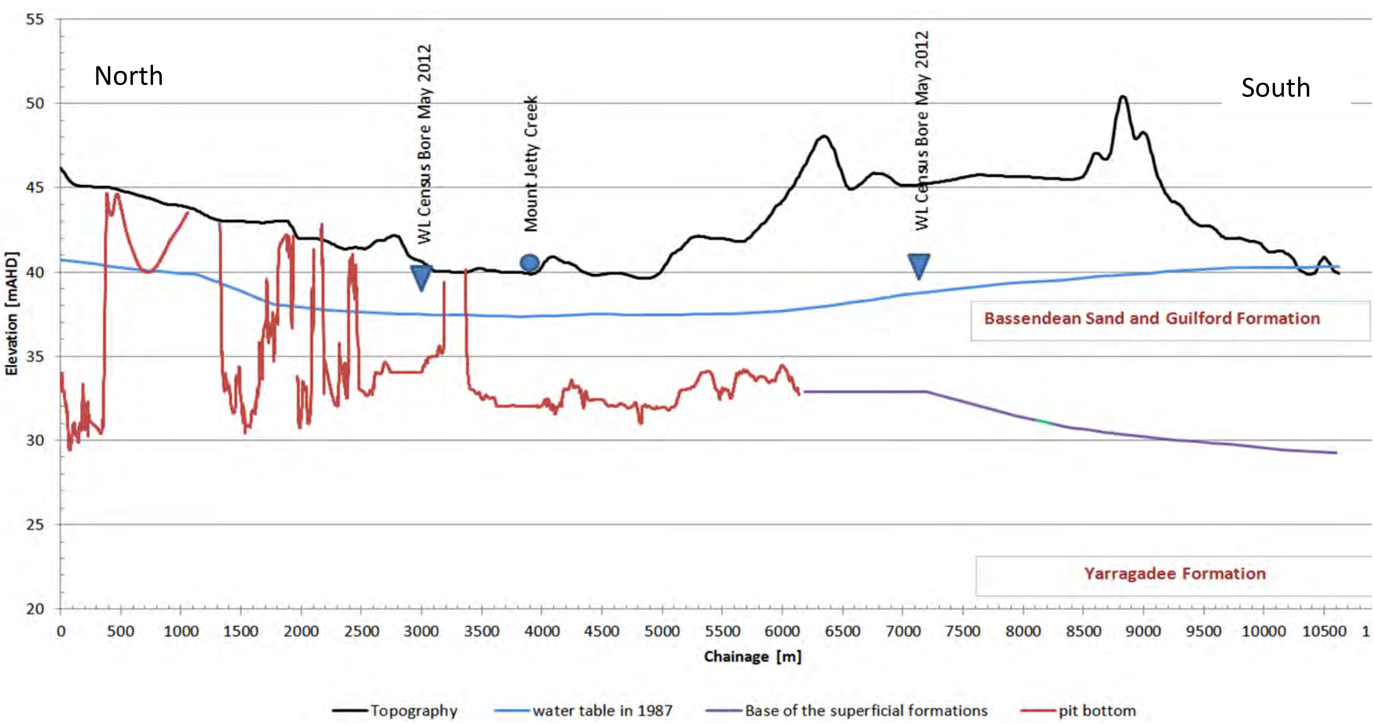
URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-3**

File No: **42908116-WG-087.mxd** Drawn: **LS** Approved: **IB** Date: **20/2/2013** Rev. **A** A4





Source: URS, Kern, A.M. (1997b) - *Hydrogeology of the Coastal Plain between Cervantes and Leeman, Perth Basin,* Water and Rivers Commission, Hydrogeology Record, Series No HG 3.

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECTS
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGY SCOPING STUDIES

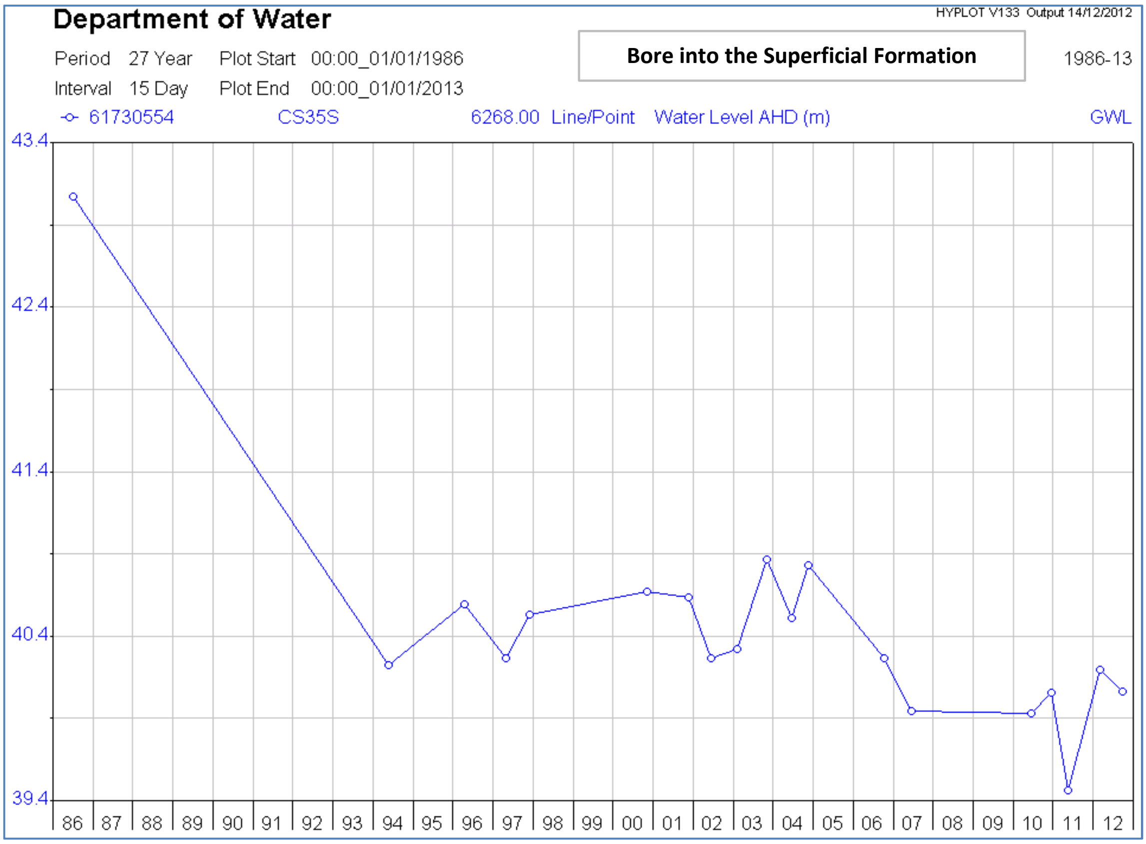
Geological Long-Section

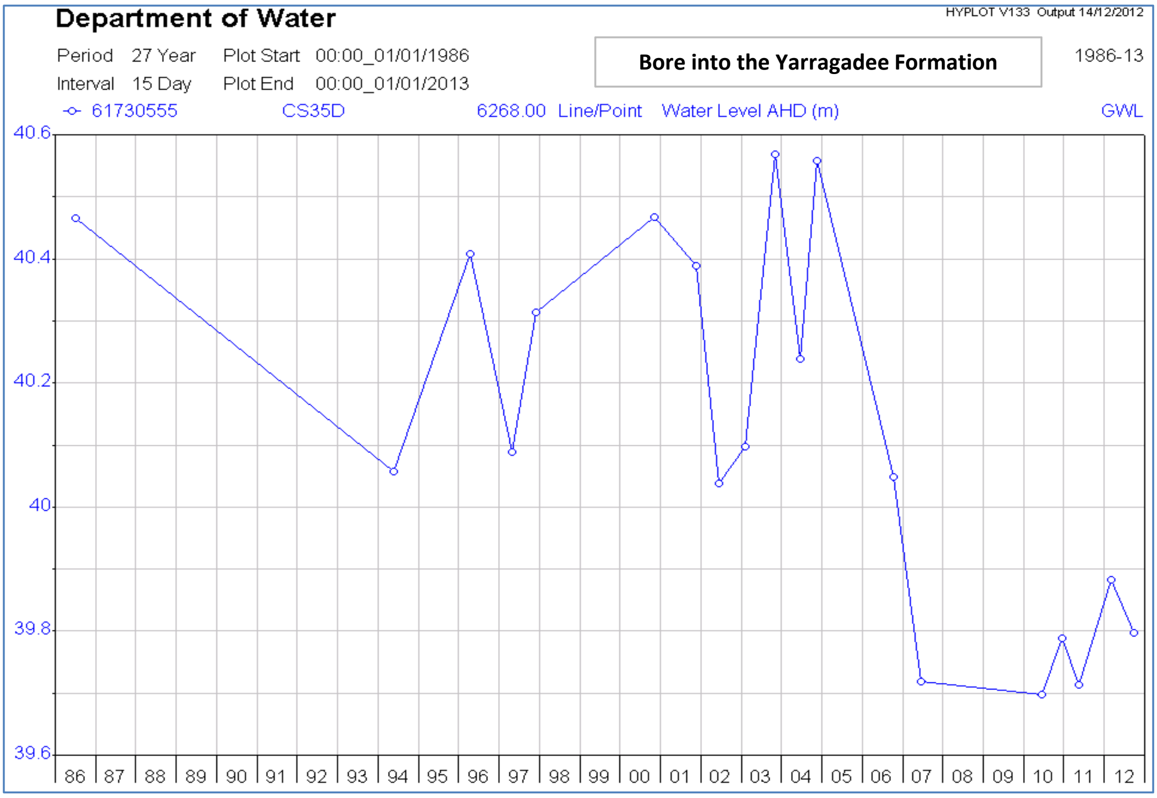
URS

HYDROGEOLOGICAL ASPECTS

Figure: 4-4

File No: 42908116-WG-090.xlsx | Drawn: LS | Approved: IB | Date: 29-11-2012 | Rev: A | A4





Source: DoW (2012a) – *Water Resources Data WRDATA, Groundwater Sites* http://kumina.water.wa.gov.au/waterinformation/wrdata/GWL/index.htm, Accessed 16 December 2012.

"J:\Jobs\42908116\5 Works\Figures\General_Figs\TABLE\"

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECTS
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGY SCOPING STUDIES

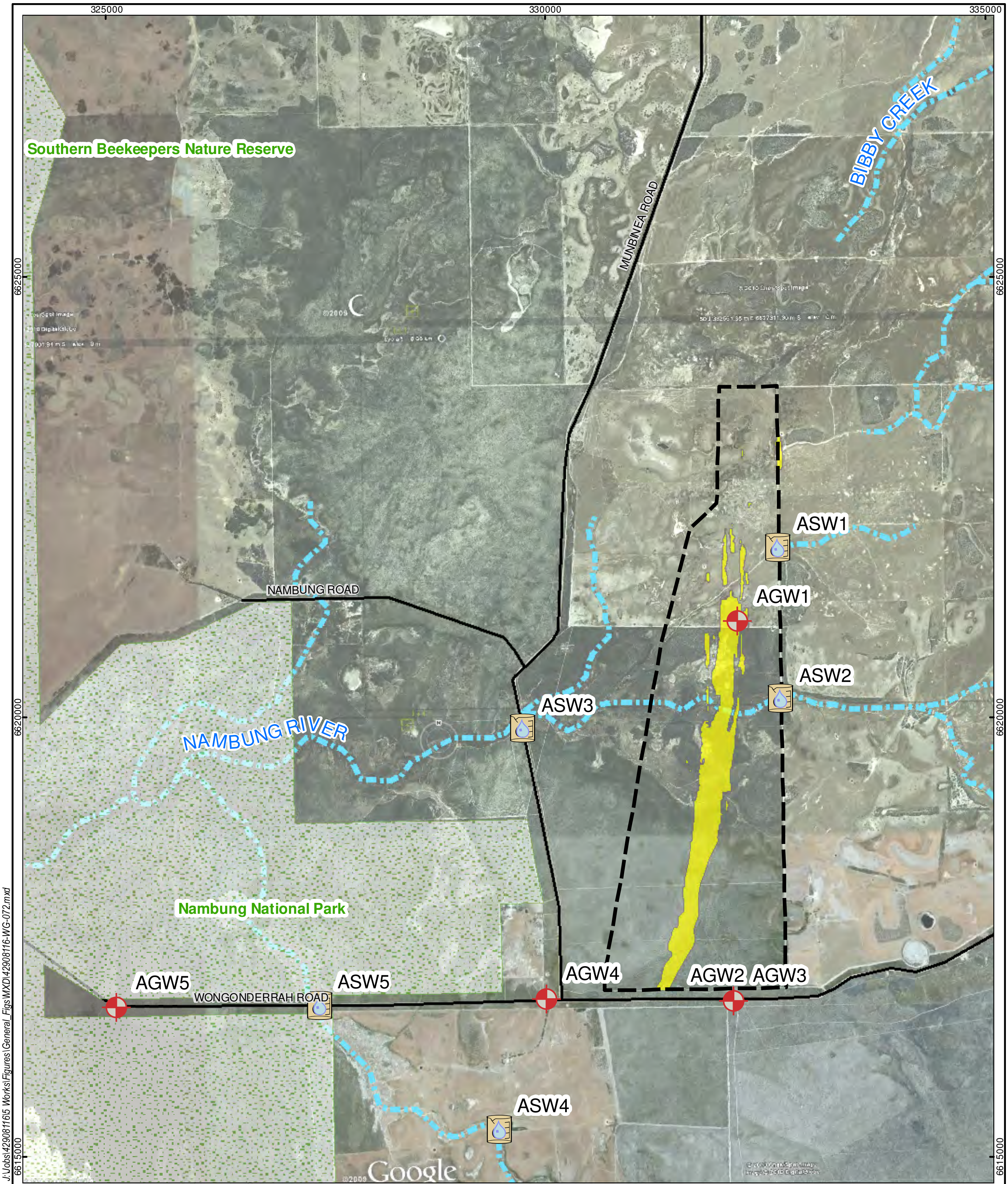
WATER TABLE ELEVATIONS BORES CS3S and CS35D

URS

HYDROGEOLOGICAL ASPECTS

Figure: 4-5

File No: 42908116-WG-070.xlsx Drawn: LS Approved: IB Date: 29-11-2012 Rev: **A** A4



N
W E
S

NOTE: background map supplied by the client

Scale: 1:60,000

0 0.5 1 1.5 2 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Atlas SW and GW Samples in July 2012

F11

Surface Water Sampling

Groundwater Sampling

Atlas Tenement

Atlas_Pits_Footprint

DEC Managed Lands

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

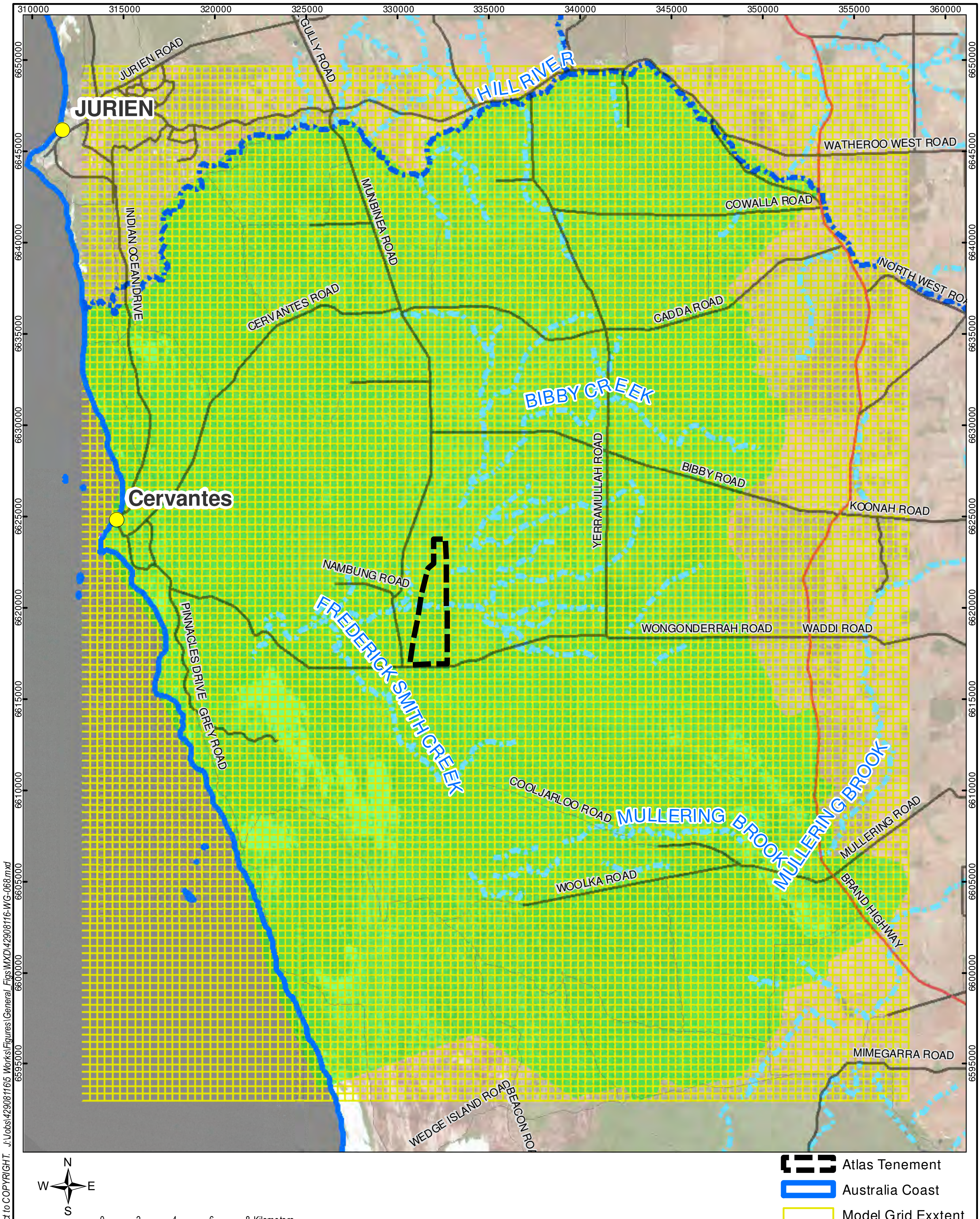
LOCATION OF THE GROUNDWATER AND SURFACE WATER SAMPLES

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-6**

File No: **42908116-WG-072.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

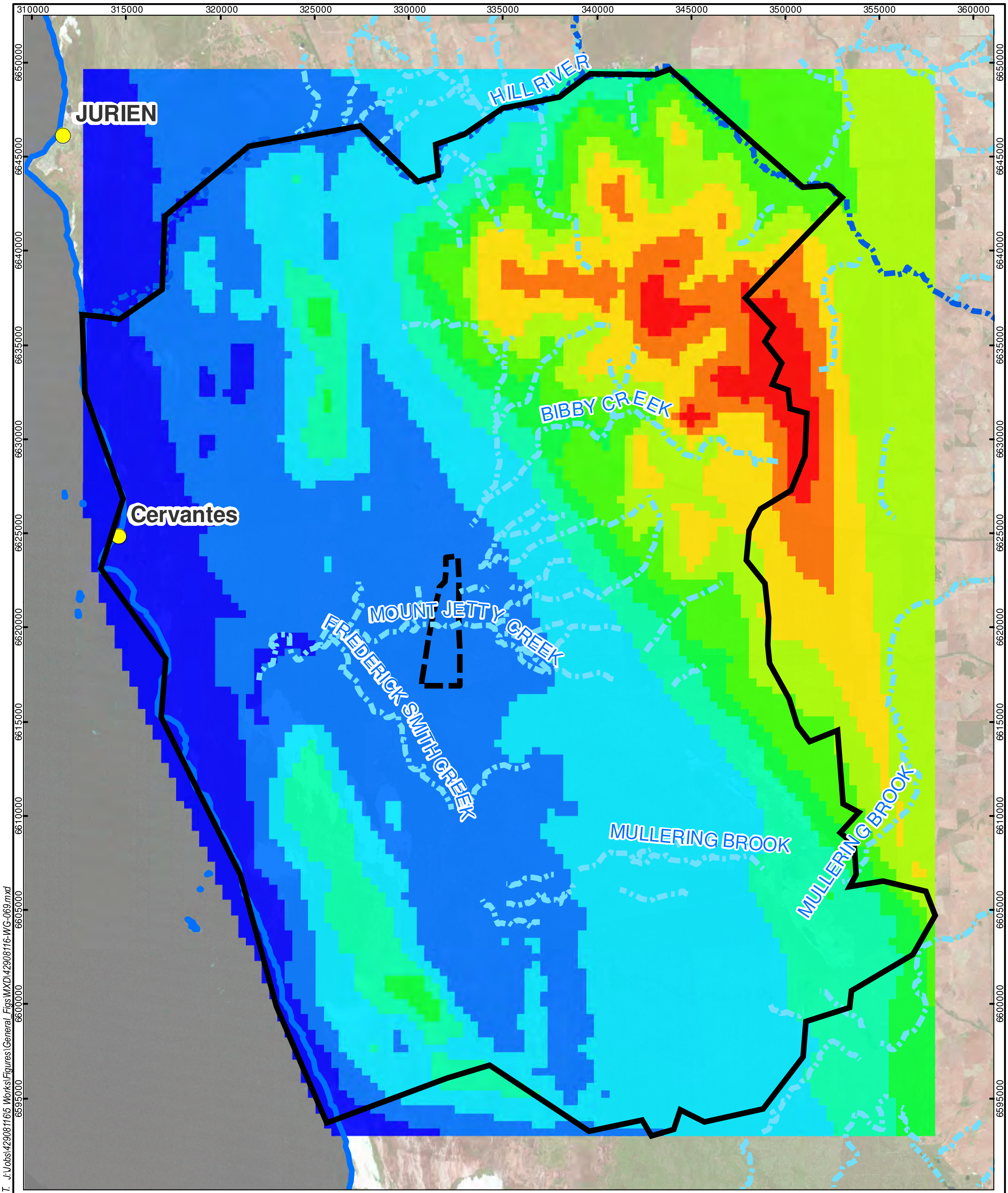
MODEL DOMAIN AND GRID RESOLUTION

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-7**

File No: **42908116-WG-068.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



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Model Active Cells
Atlas Tenement

Surface Elevation [mAHD]

0 - 27	137 - 163
28 - 54	164 - 190
55 - 81	191 - 217
82 - 109	218 - 244
110 - 136	245 - 271

N W E S

Scale: 1:280,000 0 2 4 6 8 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

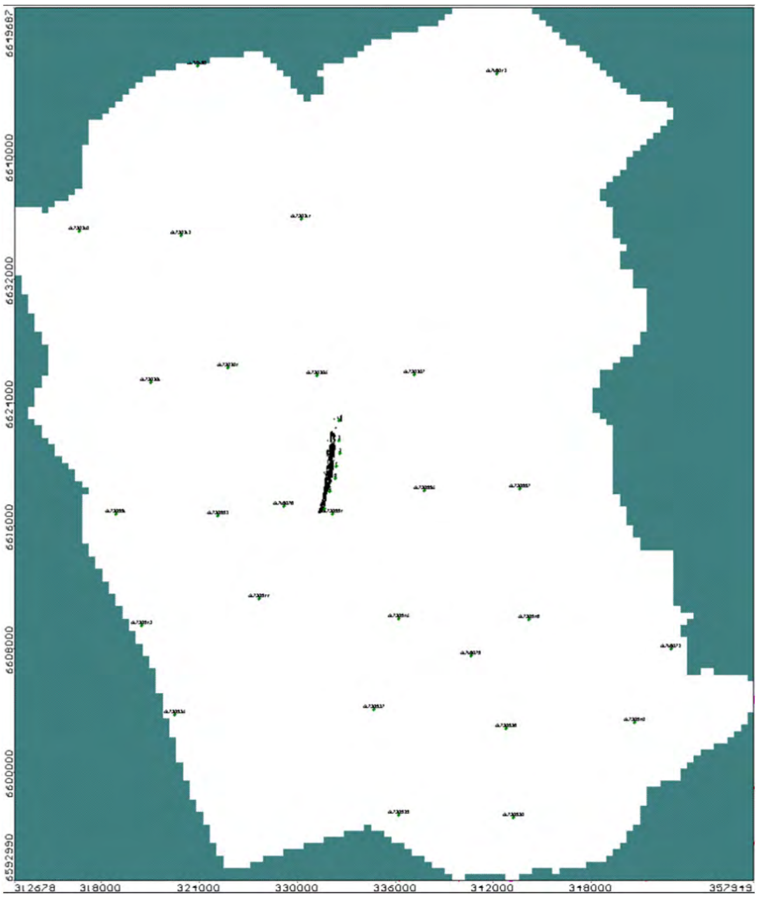
MODEL TOPOGRAPHY

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-8**

File No: **42908116-WG-069.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



Layer 2: Superficial Aquifers

Zone	Kx [m/d]	Ky [m/d]
1	11	11
2	1	1
3	1	1
4	15	15
5	1	1
6	1	1

Layer 3: Mesozoic Formations

K is the hydraulic conductivity in m/day

Zone	Kx [m/d]	Ky [m/d]
1	11	11
2	1	1
3	1	1
4	15	15
5	1	1
6	1	1

Source: URS, 2012.

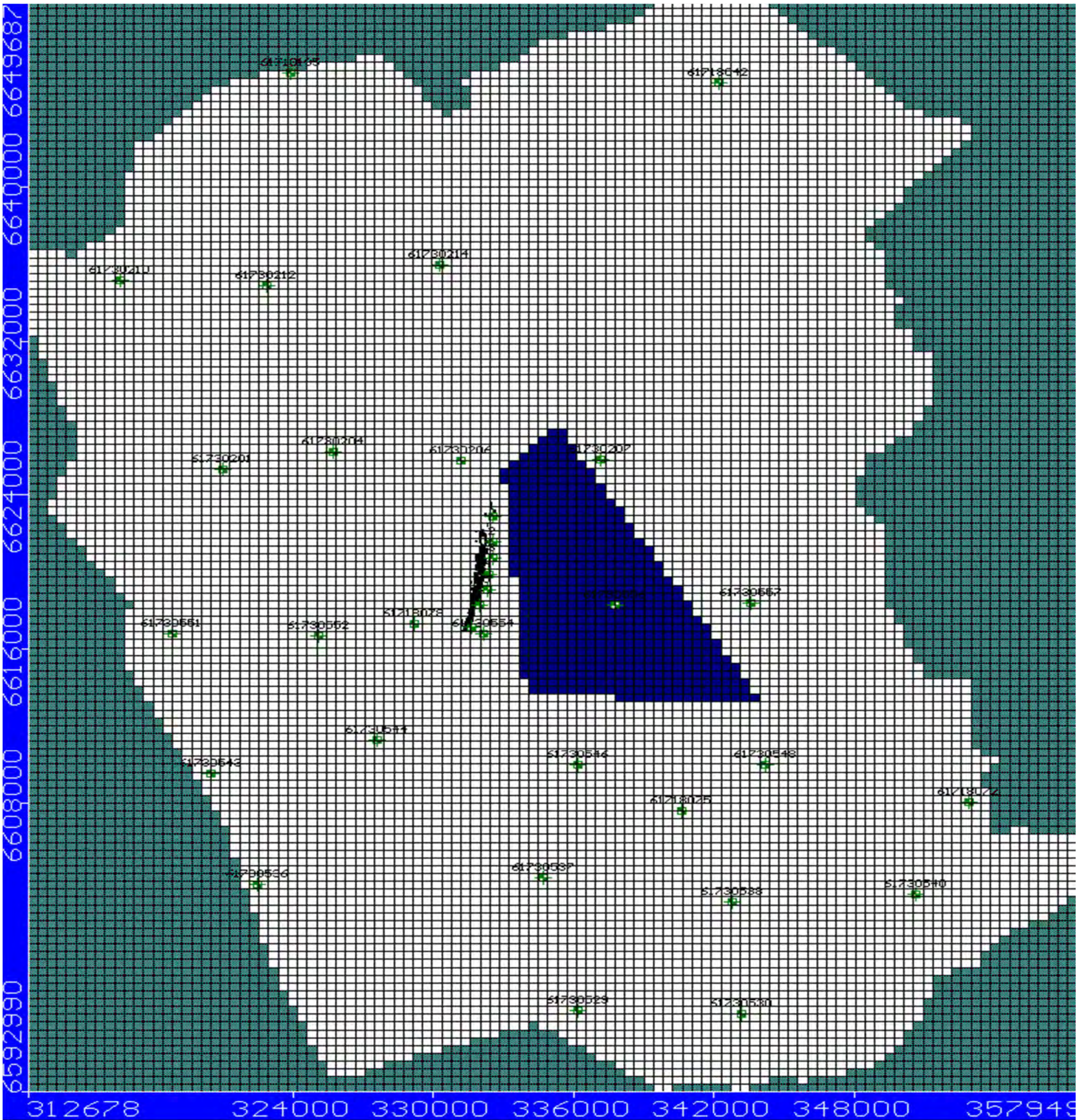
IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECTS
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGY SCOPING STUDIES

Model Material Type Distribution (Plan Views)

URS | **HYDROGEOLOGICAL ASPECTS** | Figure: **4-9**

File No: 42908116-WG-079.xlsx | Drawn: LS | Approved: IB | Date: 29-11-2012 | Rev: **A** | A4



Notes:
- The blue zone is not a recharged area.
- The white zone is a recharge area calibrated to 7-8 % of the rainfall amount

Source: URS, 2012.

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECTS
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGY SCOPING STUDIES

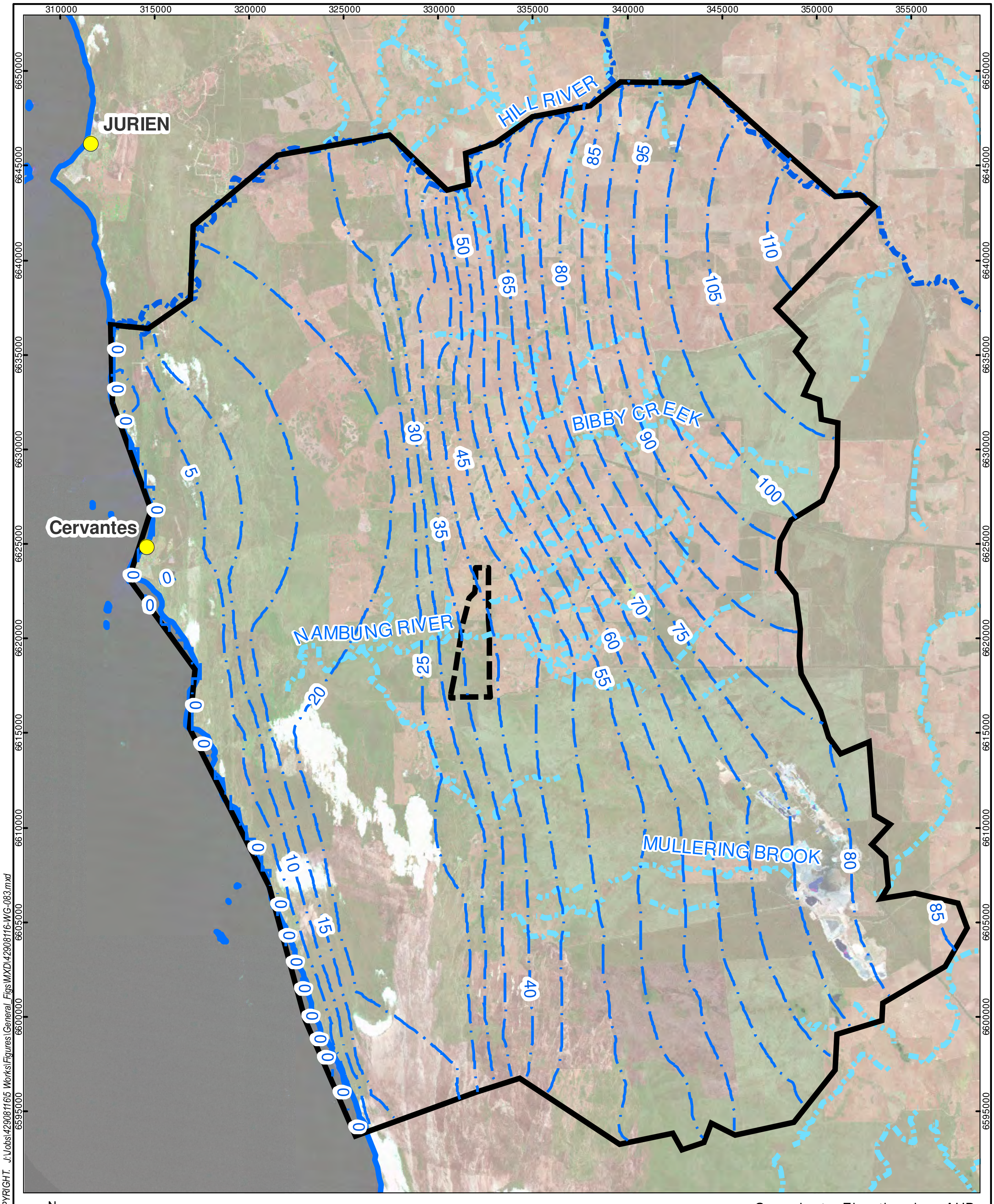
MODEL RECHARGE

URS

HYDROGEOLOGICAL ASPECTS

Figure: 4-10

File No: 42908116-WG-070.xlsx | Drawn: LS | Approved: IB | Date: 29-11-2012 | Rev: A | A4



Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

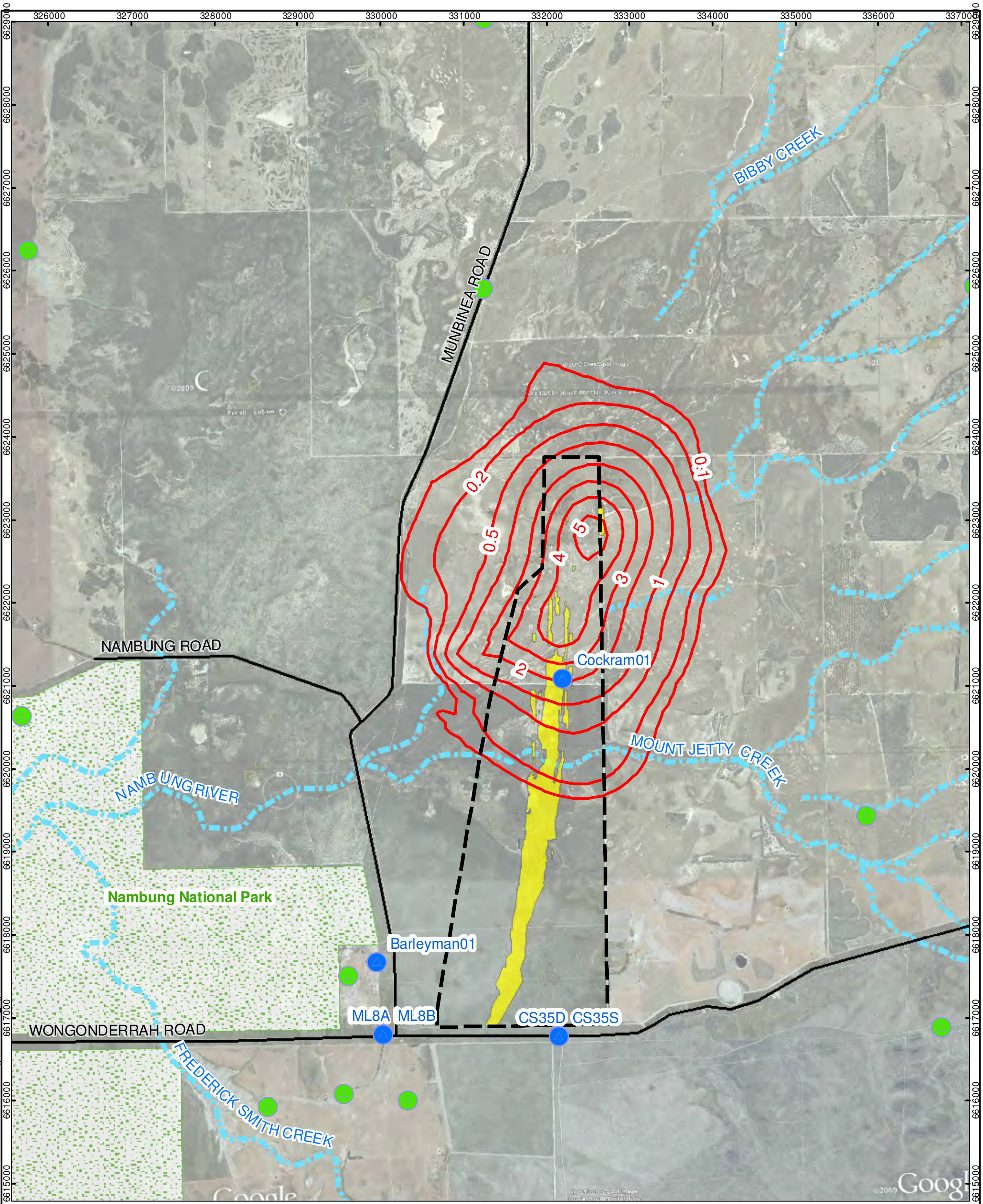
CALIBRATED PRE-MINING GROUNDWATER ELEVATIONS

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-11**

File No: **42908116-WG-083.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev.**A** A4



NOTE: background map supplied by the client

N
W E
S

Scale: 1:62,500
0 0.5 1 1.5 2 Kilometers

Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

- Bores Census May 2012
- Bores from DoW Database
- Atlas Tenement
- Grounwater Drawdown Year 1
- Atlas Pits Footprint
- DEC Managed Lands

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

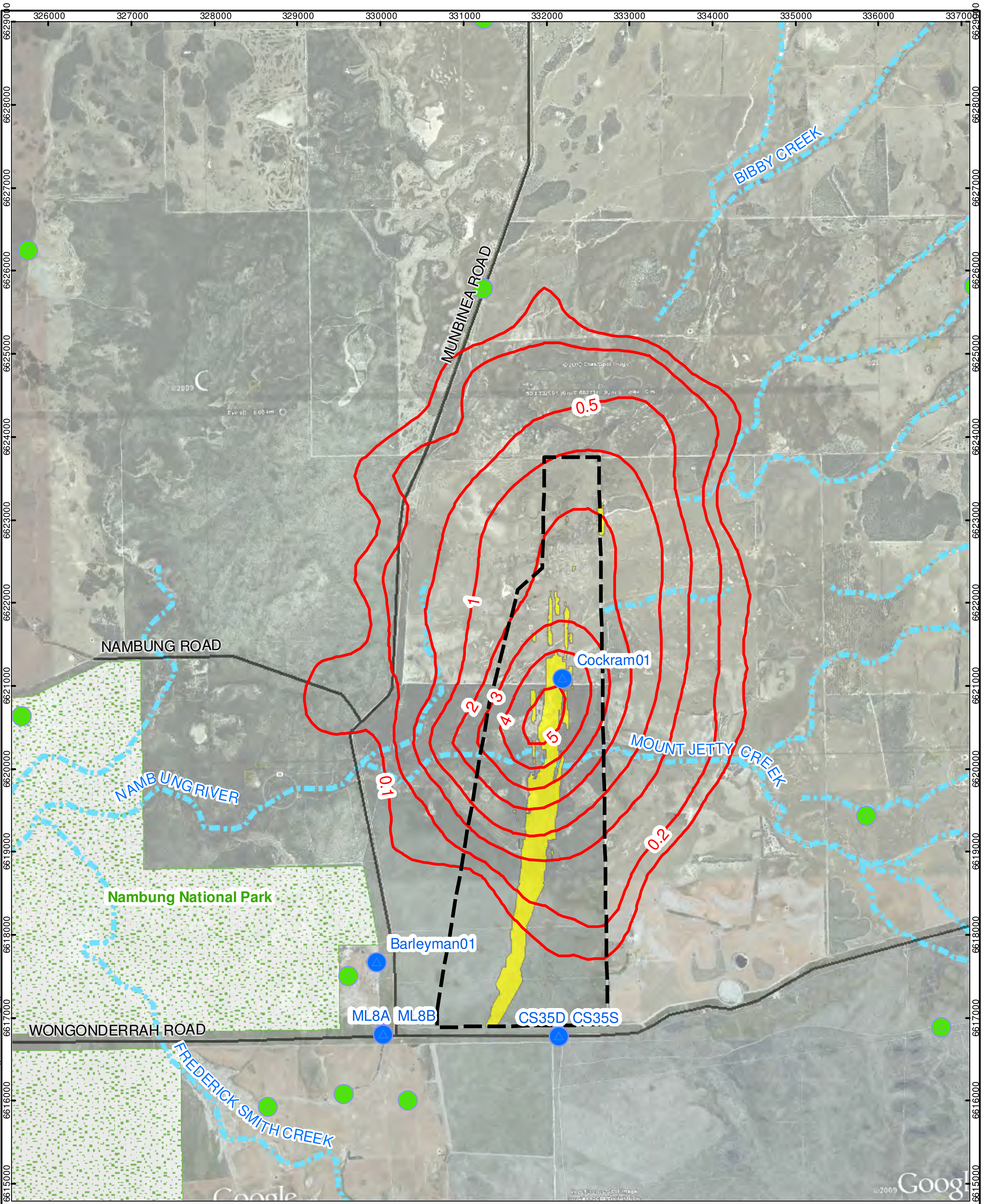
SIMULATED DRAWDWON SUPERFICIAL FORMATIONS YEAR 1

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-12**

File No: **42908116-WG-094.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



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NOTE: background map supplied by the client

N W E S

Scale: 1:62,500

0 0.5 1 1.5 2 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

- Bores Census May 2012
- Bores from DoW Database
- Atlas Tenement
- Grounwater Drawdown Year 2
- Atlas Pits Footprint
- DEC Managed Lands

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

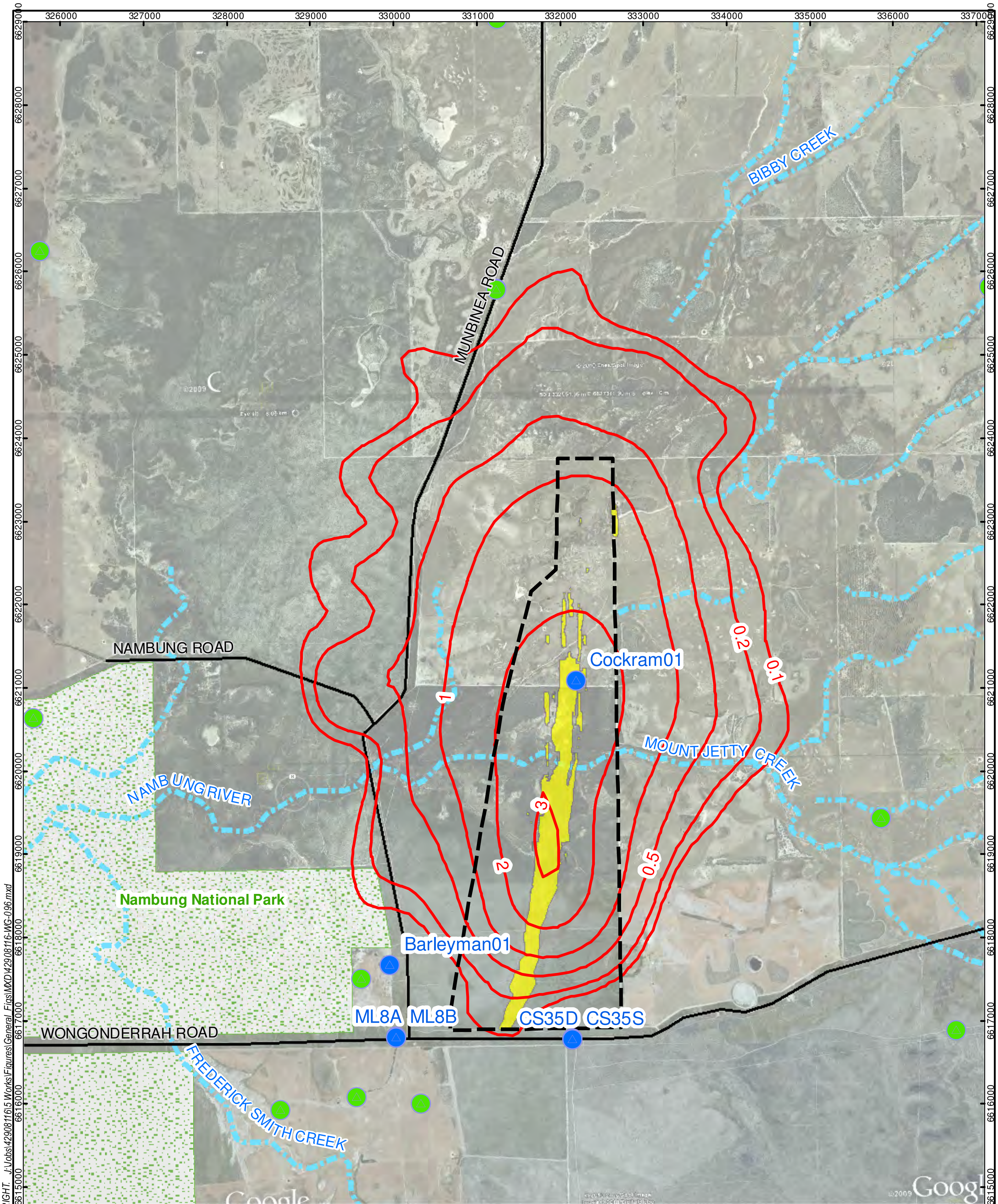
SIMULATED DRAWDOWN SUPERFICIAL FORMATIONS YEAR 2

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-13**

File No: **42908116-WG-095.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



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NOTE: background map supplied by the client

N
W E
S

Scale: 1:62,500

0 0.5 1 1.5 2 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Bores Census May 2012

Bores from DoW Database

Atlas Tenement

Grounwater Drawdown Year 3

Atlas Pits Footprint

DEC Managed Lands

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

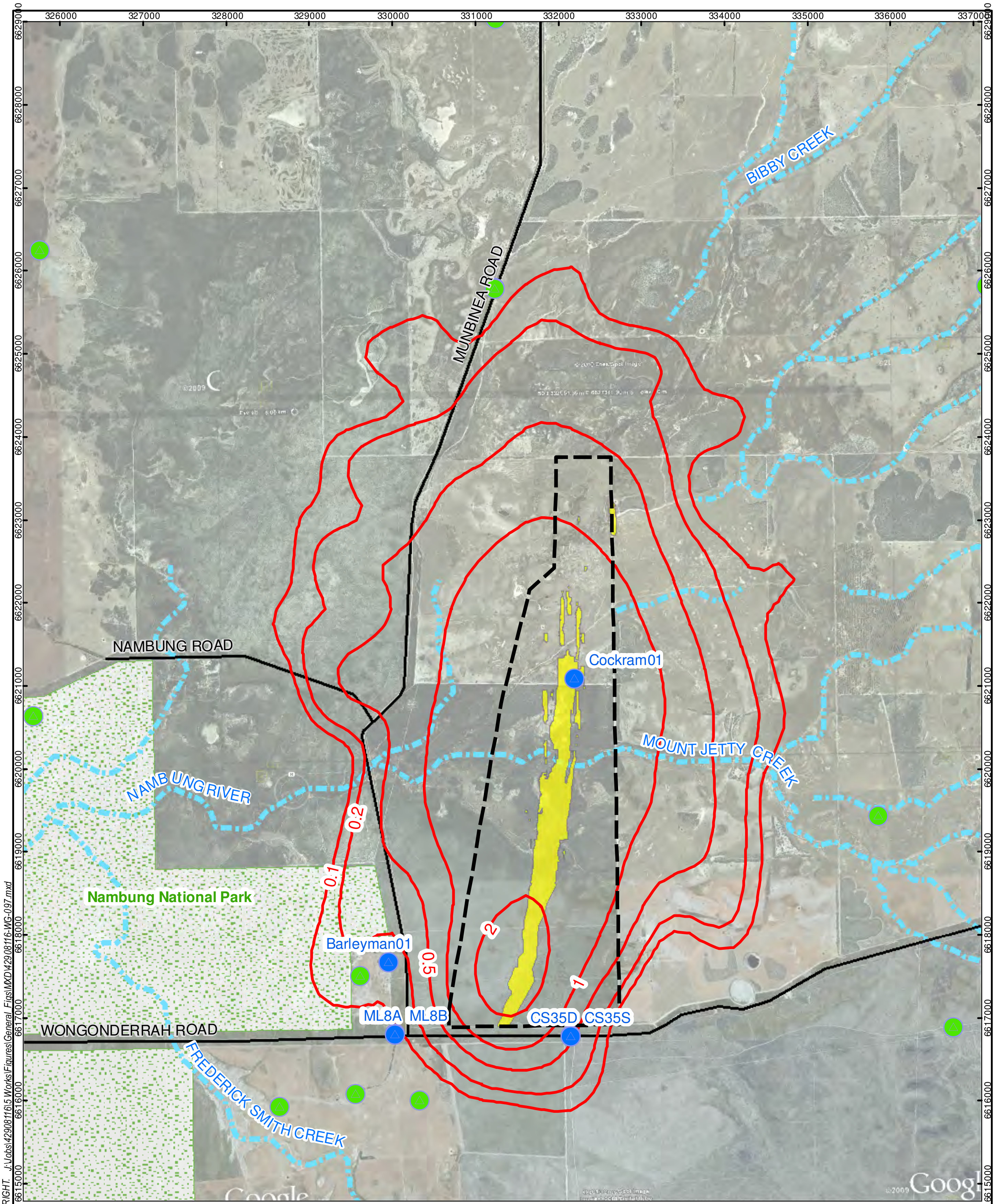
SIMULATED DRAWDOWN SUPERFICIAL FORMATIONS YEAR 3

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-14**

File No: **42908116-WG-096.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



NOTE: background map supplied by the client

N W E S

Scale: 1:62,500 — 0 0.5 1 1.5 2 Kilometers

Coordinate System: GDA 1994 MGA Zone 50

Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

- Bores Census May 2012
- Bores from DoW Database
- Atlas Tenement
- Grounwater Drawdown Year 4
- Atlas Pits Footprint
- DEC Managed Lands

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

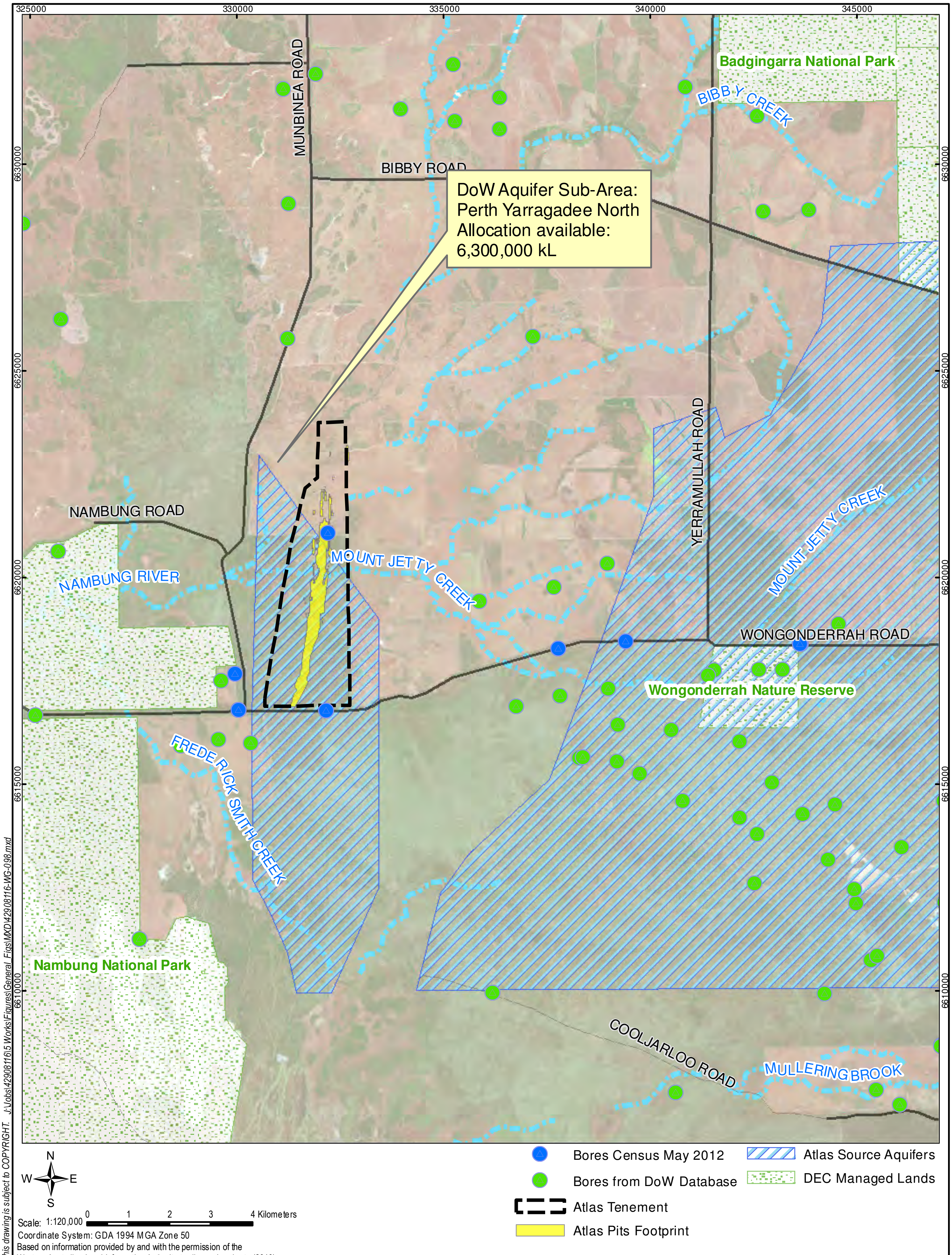
SIMULATED DRAWDOWN SUPERFICIAL FORMATIONS YEAR 4

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-15**

File No: **42908116-WG-097.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

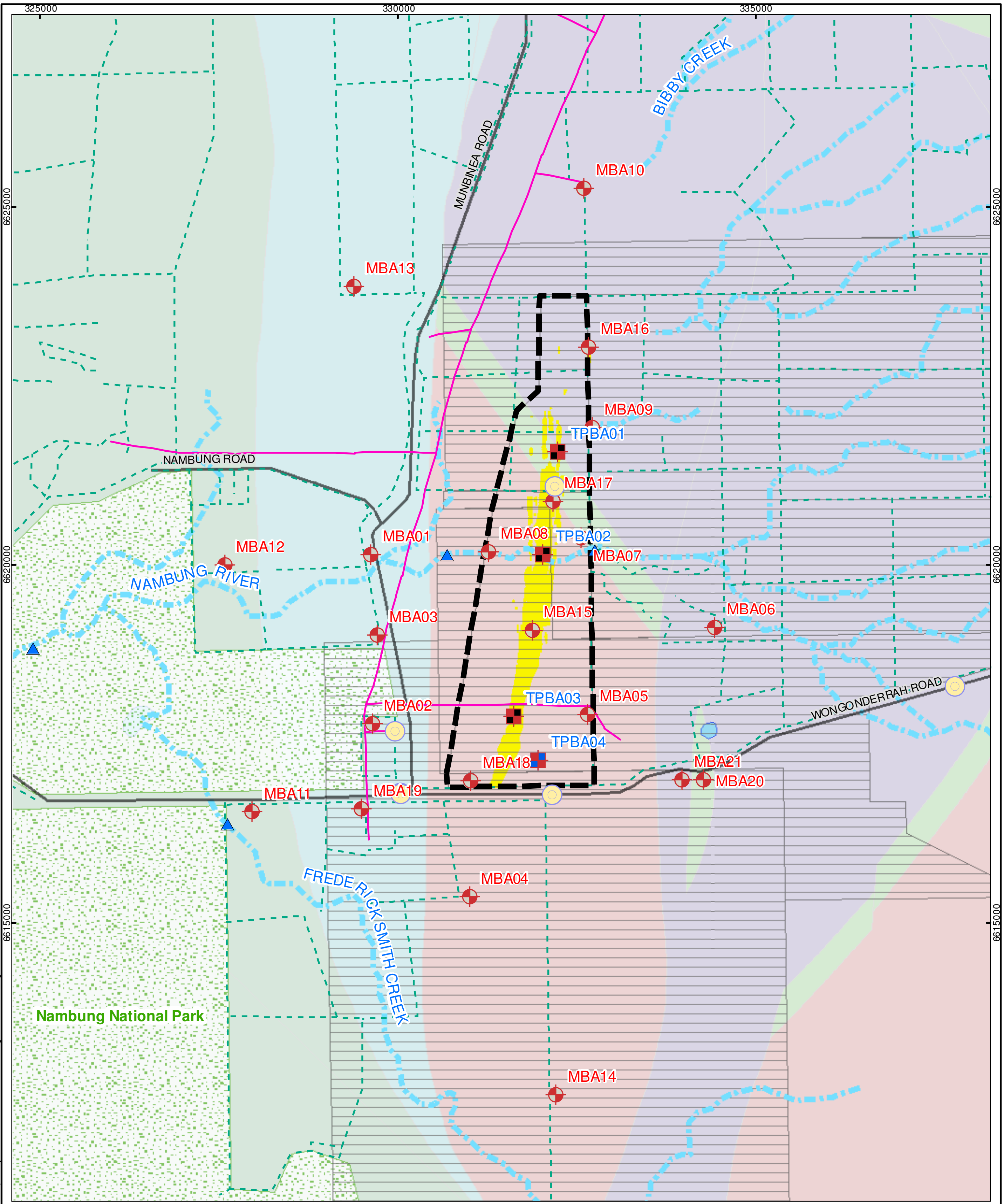
GROUNDWATER RESOURCES

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-16**

File No: **42908116-WG-098.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4



Fence Lines
Atlas Pits Footprint
High Voltage Lines
DEC Managed Lands
Census Bores May 2012
Atlas Tenement
Atlas SW Monitoring Programme
Atlas Exploration Licence Tenement
Atlas Test Production Bores for Yarragadee
Atlas Proposed Monitoring Bores Programme
Atlas Test Production Bores for Superficial Aquifer

N W E S

0 0.5 1 1.5 2 Kilometers

Scale: 1:74,000

Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

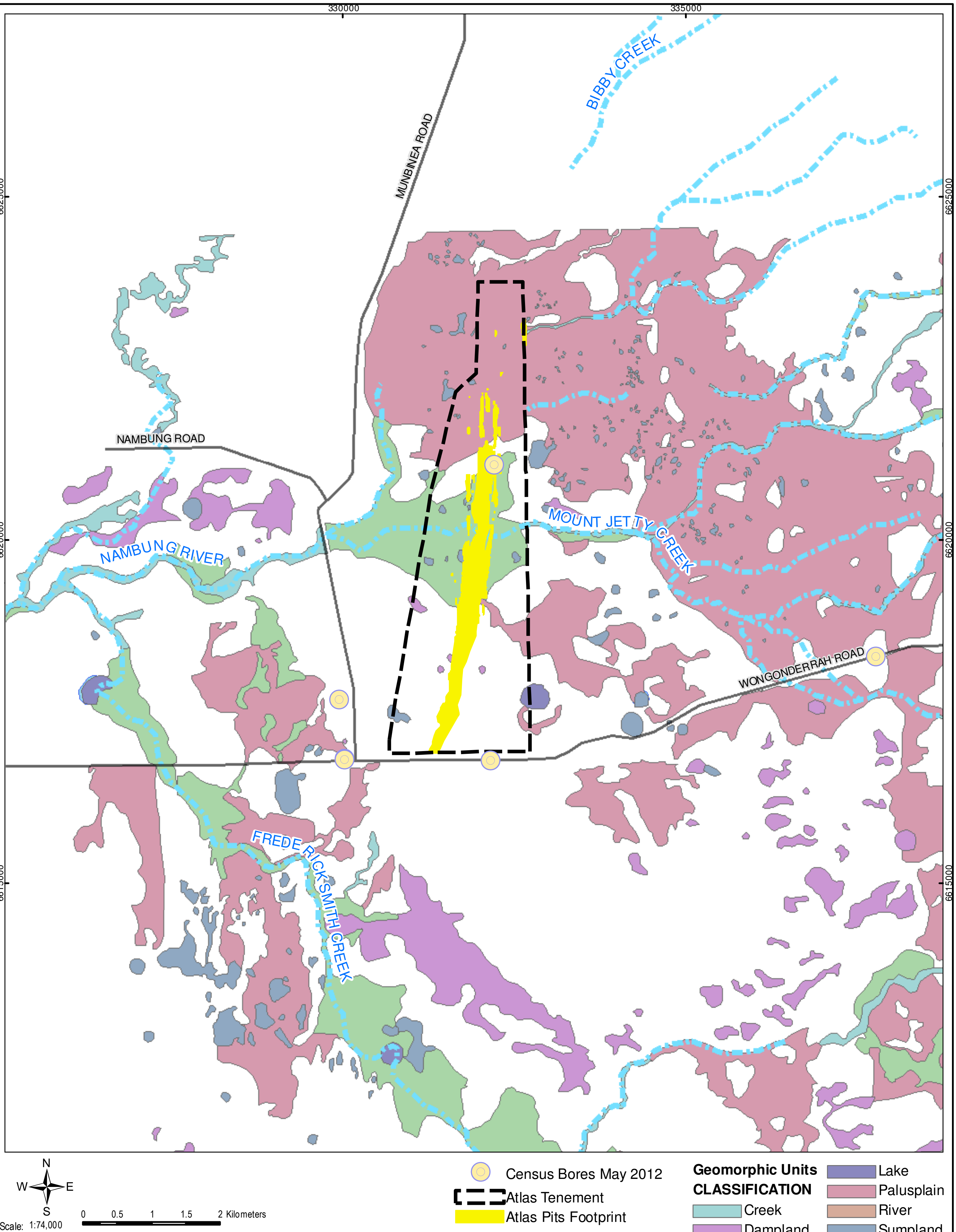
PROPOSED MONITORING AND TEST PRODUCTION BORES

URS

HYDROGEOLOGICAL ASPECTS

Figure: **4-17**

File No: **42908116-WG-085.mxd** Drawn: **LS** Approved: **IB** Date: **20/2/2013** Rev. **A** A4



Coordinate System: GDA 1994 MGA Zone 50
Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

GEOMORPHIC UNITS

URS

HYDROGEOLOGICAL ASPECTS

Figure: **5-1**

File No: **42908116-WG-088.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4

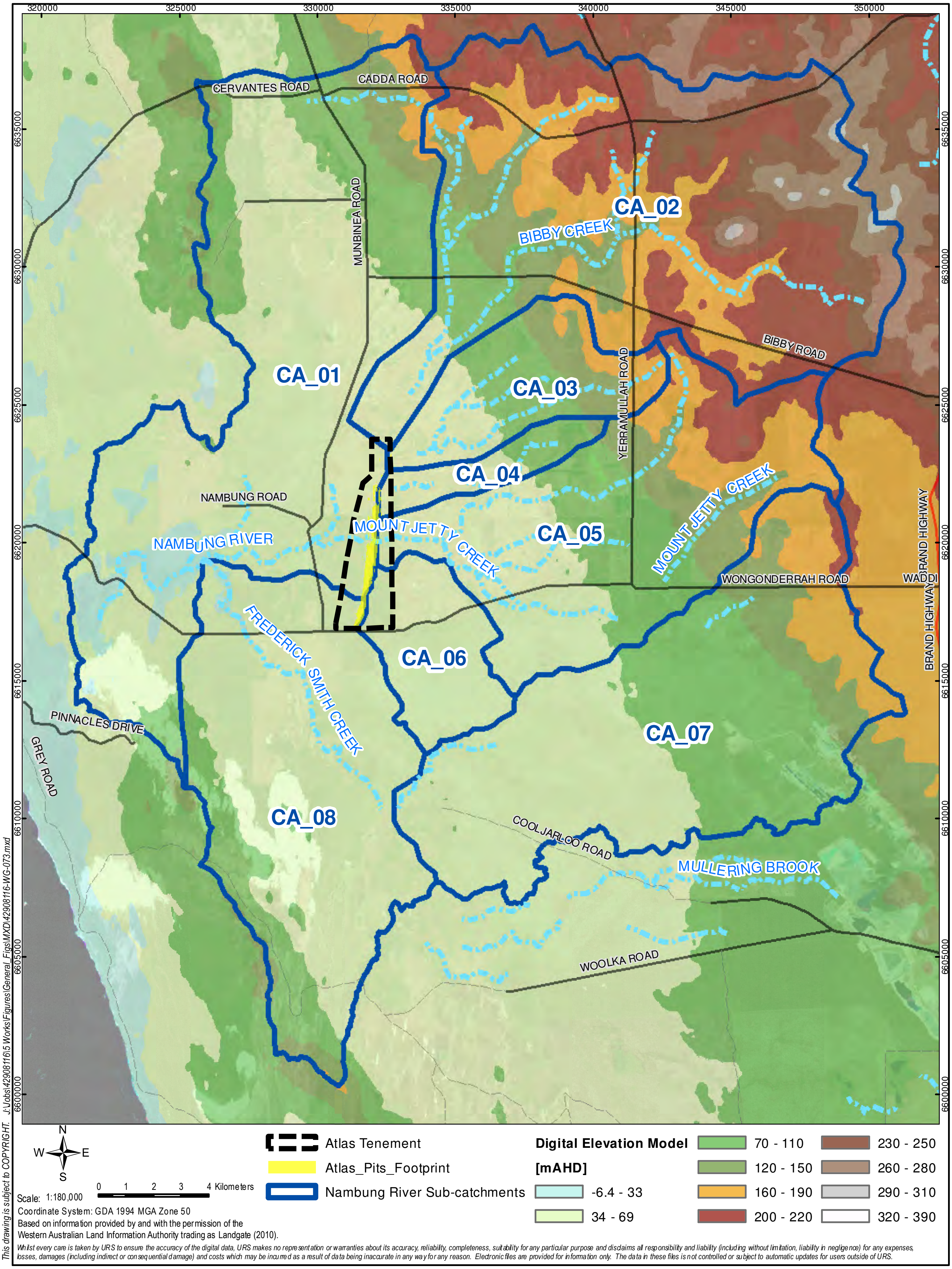


IMAGE RESOURCES NL

NORTH PERTH BASIN MINERAL SANDS PROJECT
ATLAS DEPOSIT
HYDROGEOLOGICAL AND HYDROLOGICAL SCOPING STUDIES

NAMBUNG RIVER SUB-CATCHMENTS

URS

HYDROLOGY ASPECTS

Figure: **5-2**

File No: **42908116-WG-073.mxd** Drawn: **LS** Approved: **IB** Date: **19/2/2013** Rev. **A** A4

A

Appendix A Legislative and Policy Framework for Groundwater and Surface Water

Legislative and Policy Framework for Groundwater and Surface Water

Document	Description and Intent
Legislation	
Rights in Water and Irrigation Act 1914	This Act governs the regulation of water resources in Western Australia, defining water management and monitoring for individual projects.
Environmental Protection Act 1986	This Act governs the regulation of the environmental approvals process in Western Australia and aims to regulate environmental harm as a result of project proposals.
Mining Act 1978	This Act is the principal statute governing mining in Western Australia. The Mining Act allows people to apply for rights to explore for and extract minerals.
Policy	
Operational Policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence.	This policy describes three hydrogeological levels of assessments for groundwater abstractions based on environmental and user impacts.
National Strategy for Ecologically Sustainable Development (1992)	This policy establishes the need to develop and manage, in an integrated way, the quality of water resources and to develop mechanisms that aim to maintain ecological Systems whilst meeting economic and social needs.
State wide Policy No. 3: Policy Statement on Water Sharing (State Government, 2000)	Overarching policy statement on allocating water administered under the *Rights in Water and Irrigation Act 1914.*
Operational Policy No. 5.08: Use of Operating Strategies in the Water Licensing Process (Department of Water, 2010)	This policy aims to link licensee operations with water resources management and address risks associated with water shortages.
State wide Policy No. 5: Environmental Water Provisions Policy for Western Australia (State Government, 2000)	This policy informs how water would be provided and managed to protect ecological values and sustainable development consistent with the requirements of the *Rights in Water and Irrigation Act 1914* and the *Environmental Protection Act 1986.*
Guidelines	
ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000)	This guideline specifies water quality limits for protection of ecosystem health.
Water Quality Protection Guidelines No 1: Water Quality Management in Mining and Mineral Processing: An Overview (Department of Water, 2000)	This guideline provides an overview of the application of the various specific Water Quality Protection Guidelines.
Water Quality Protection Guidelines No 6: Mining and Mineral Processing – Mine site Stormwater (Department of Water, 2000)	The guidelines provide a high level outline of the requirements for the management of stormwater on a mine site.

Document	Description and Intent
Water Quality Protection Note No. 52: Stormwater Management at Industrial Sites (Department of Water, 2010)	This protection note applies to management of stormwater on industrial sites, setting out requirements for stormwater system design, management, treatment, disposal and contingency planning.
Operational Policy 1.02 : Policy on Water Conservation/Efficiency Plans : Achieving Water use Efficiency Gains Through Water Licensing (Department of Water, 2009)	This policy seeks to ensure that water licensees use water entitlements efficiently and requires preparation of a Water Conservation/Efficiency Plan (WCEP) as part of an Operating Strategy.
Water Quality Protection Note No 30: Groundwater Monitoring Wells (Department of Water, 2006)	This protection note defines requirements for the location, construction and sampling of groundwater monitoring wells.
Water Quality Protection Guidelines No. 4: Mining and Mineral Processing - Installation of Mine site Groundwater Monitoring Wells (Department of Water, 2000)	This guideline sets out the requirements for design, construction, sampling and decommissioning of groundwater monitoring wells for projects that have the potential to change groundwater levels and water quality.
Water Quality Protection Guidelines No. 5: Mining and Mineral Processing – Mine site Water Quality Monitoring (Department of Water, 2000)	This guideline sets out the requirements for design, construction, sampling techniques, monitoring frequency, water quality criteria and reporting for establishing and operating mine site water monitoring programmes in order to protect the quality of the water resources.
Water Quality Protection Guidelines No. 9: Mining and Mineral Processing - Acid Mine Drainage (Department of Water, 2000)	This guideline is applicable to mining and mineral processing operations that have the potential to generate acidic mine water and sets out the requirements for the prevention, monitoring and disposal of acid mine drainage. The discharge of acid mine drainage is regulated through the *Mining Act 1978.*
Water Quality Protection Guidelines No. 11: Mining and Mineral Processing - Mine Dewatering (Department of Water, 2000)	This guideline is used to manage the change of mine site dewatering on the quality of water resources, applies to the discharge of abstracted water as part of mining or mineral processing operations and proposes water quality criteria for receiving waters. The guideline also frames requirements for the assessment of changes, dewatering treatment and disposal, receiving water quality criteria and monitoring.

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