NORTHPARKES

ENVIRONMENTAL ASSESSMENT

Northparkes Mines Step Change Project

JULY 2013

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Appendix 10

Groundwater Impact Assessment

July 2013

NORTHPARKES MINE STEP CHANGE PROJECT

Groundwater Impact Assessment Report

Submitted to:
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REPORT

Report Number. 117626007-007-Rev1

Golder Associates

Executive Summary

Under the Environmental Planning and Assessment Act 1979, Rio Tinto is required to prepare an Environmental Assessment (EA) for the approval of the proposed continuation of mining of its Northparkes Mine (NPM), located in the Project Area, near Parkes, New South Wales (NSW). The EA will address the potential impacts and issues of the proposed Northparkes Step Change Project (the Project).

The Project involves the extension of the existing mine in terms of mined areas, depth of mining and duration of mining; however, the required groundwater usage will not increase for the Project. The water requirements to service the expanded operations are estimated to remain at the current processing rates of up to approximately 7,000 megalitres (ML) per year. The Project Area is located within the Lachlan Fold Belt, which comprises generally hydraulically tight rocks that produce low to very low yields. Therefore the primary sources of the required water come from imported groundwater, surface water, recycled site water or a combination of the sources, depending on external controls such climate (flood or drought). It is noted, however, that the required groundwater component will not increase for the Project.

The purpose of this Groundwater Water Impact Assessment (GWIA) is to establish a reasonable understanding of the groundwater system upon which to evaluate potential impacts from NPM operations on groundwater resources within and around the Project Area. Its purpose is also to identify the regional environmental values and the existing or proposed groundwater necessary to manage impacts based on a groundwater monitoring strategy. Amongst the environmental values of potential concern are: the long term impact to the groundwater resources from Project Area operations; and impacts to other groundwater users. Impacts to the identified groundwater dependant ecosystems are specifically required to be addressed.

Environmental Values

A review of environmental values was performed including a review of groundwater dependant ecosystems (GDEs), groundwater users and social and cultural environmental values.

There are no GDEs (springs, karsts, wetlands) or national parks located within the Study Area. The Wombin State Forest, lies 5 km northwest of the Project Area operational boundary and the Limestone State Forest is located within the Project Area.

There are no formally identified GDEs within the GWMA (011). There are GDEs identified, however, in the Water Sharing Plan for NSW Murray Darling Basin Fractured Rock Groundwater Source and draft WSP for Lachlan Unregulated and Alluvial Water Sources, but these are well beyond the modelled influence of dewatering in the Project Area.

Geology/Hydrogeological Summary

The Project Area is located within the Regional Lachlan Fold Belt. The characteristics of the LFB result in poor aquifer storage and transmissivity.

The geology of the Project Area can be divided into two general rock types: volcanics, volcaniclastics and sediments comprising the deeper fresh *Bedrock*; and the overlying transported and weathered sediments comprising the *Regolith.* The Northparkes deposits occur within the Late Ordovician Goonumbla Volcanic Group, which are hosted within the Bedrock.

The Project Area consists of a weathered shallow regolith overlying fresh bedrock strata. The bedrock strata, which host the Northparkes deposits, are characteristically tight rocks with a low fracture density. The permeability of the bedrock is fracture-controlled, resulting in a low permeability. The occurrence of open fractures decreases with depth into the fresh bedrock, where fractures are either closed due to the structural setting of the region, or are infilled from chemical and weathering processes. The upper stratum of the Bedrock, referred to as Saprock, is low yielding and of low water quality, but is accessed by regional groundwater users.

The ore body intrusions are near vertical and are surrounded by contact alteration zones ("mineralised zones"). The ore bodies and mineralised zones each display separate fracturing and permeability characteristics from the bedrock. The ore bodies display low permeability, whereas the surrounding mineralised zones have more open fractures and form local aquifers, but do not show regional continuity.

The Regolith overlies the Bedrock and comprises highly weathered sediments of the upper Bedrock Strata (Saprolite), as well as the overlying transported surface sediments (alluvium-colluvium). The Regolith comprises low permeable clays and soils. Permeability is predominantly intergranular-controlled; however, large volumes of flow are inhibited by the presence of clays. The regolith is predominantly undersaturated, except for pockets of groundwater that form perched groundwater zones within the Bogan River Palaeochannel sediments. Overall, the regolith is regarded as a low yielding, slightly brackish to saline unit and not considered as a groundwater resource in the Study Area.

Recharge occurs predominantly in the mountain ranges that surround the Study Area, where the bedrock outcrops. The recharge to bed rock is estimated at less than 0.1 mm/year (less than 1% of annual rainfall). The bedrock in the Study Area therefore has low porosity and storage capacity.

Groundwater Impact Estimation

The Project Area consists of a weathered shallow regolith overlying bedrock strata. The Lachlan Fold Belt is generally hydraulically tight rocks with low fracture density and therefore low porosity and storage capacity.

Prediction simulations were prepared based on an assumed mine plan to assess potential changes to groundwater heads due to the proposed Project. Modelling indicates the predicted impact due to extension of the mine is contained to within close proximity to expected subsidence craters. The extent of modelled drawdown of groundwater in the bedrock at cessation of the proposed mining is approximately 4.5 km from the pits. There is a steady increase expected in groundwater seepage into the mine as the mine progresses. Predictive modelling for 2010 suggests a maximum modelled inflow is 0.8 ML/day, at the end of 2010 and a slightly lower peak inflow of 0.7 ML/day at the end of 2021. E26 and E48 are the most significant contributors to modelled groundwater seepage.

Qualitative assessment of the impact of groundwater decline on groundwater quality indicates minimal potential for adverse impact.

Risk Assessment

The groundwater impact assessment indicates that the proposed Project does not pose a high risk to the groundwater regime. Risk assessment of the Study Area indicates there is no high priority GDE in the immediate vicinity of the modelled area of influence due to dewatering. The extent of modelled drawdown of groundwater in the bedrock at cessation of the proposed mining is approximately 4.5 km from the pits.

The nearest high priority GDEs spring (Lambert Springs), identified in the WSP for the NSW MDB Fractured Rock Groundwater Sources, is located outside of the Study Area and at a distance greater than 50 km southeast of the Project Area and is located well beyond the modelled zone of influence of the mine dewatering. The Project is expected to have no impact on river baseflow as the river system is of the "influent" type.

As the aquifers around the Project Area are very low yielding and of low quality, there is currently little development of groundwater sources in the vicinity of the Project Area and the potential for future development of these groundwater sources is minimal. The majority of groundwater varies from brackish to saline and has been classified as unsuitable for potable or agricultural use (either domestic, irrigation or for livestock watering) due to the elevated concentrations of sodium and chloride. The alluvial-regolith aquifer system within and in the vicinity of the Study Area is low yielding and not generally used for productive land use such as the borefields in the Lachlan Valley. Based on the extent of the predicted drawdown associated with the Project, no private groundwater users have been identified as being affected or potentially by the Project.

Management and mitigations for key potential groundwater impacts have been identified. The extent of dewatering, impacts on current users and future resources will be assessed through the life of the project.

The volume of water taken as a result of mining activities was modelled in this study prior to project approval. The dewatering volumes will be monitored to verify that volumes are within licenced allocations. A monitoring program will be implemented and groundwater level and water quality monitoring data will be analysed to identify measureable interference of aquifers. The waste containment dams will be sized to prevent overflow and adhere to regulations, which require the consideration of flood events, and constructed to limit or prevent underground leakage. There will be careful site design and planning to ensure that the subsidence zone does not encroach on the current and proposed tailings and water storage facilities. Fuel and chemical storages will be constructed and adequately bunded to the relevant Australian Standards. Spill containment procedures are to be implemented to prevent migration and exposure of chemicals. Immediate clean-up of spills, which is standard practice and/or a legislated requirement at mine sites, should prevent contamination of shallow strata and subsequent leakage to the groundwater system. Trigger levels, regarding declines in groundwater levels and the degradation of groundwater quality, will be established to manage the potential impacts. Where monitoring results indicate levels in excess of the trigger values, an investigation appropriate for the situation will be conducted to assess the need to implement management/mitigation/remedial measures. An adaptive management approach will be applied to mitigate the risk in relation to the block caves at closure. The proposed rehabilitation management and monitoring plans will be reviewed and altered as necessary. Trigger values for surface and groundwater quality will be updated as part of the monitoring approach.

The findings of the risk assessment indicate that the risks associated with groundwater in the Study Area can be mitigated. No residual risks are considered as ‘high’ in the risk analysis after efficient implementation of management and mitigation measures.

The assessment of ecological communities, the risk assessment and controls of acid rock drainage are covered under separate scope of work and are not included in this report.

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1.0 INTRODUCTION

1.1 The Project

Northparkes Mines (NPM) located in the Project Area (coincident with the Mine Lease Area) is a copper-gold mine operation located approximately 27 kilometres (km) north of Parkes in central New South Wales (NSW) (refer to Figure 1). NPM currently operates under PA06_0026, as modified in February 2007 by the NSW Department of Planning pursuant to Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

NPM have reviewed potential future operational scenarios and are proposing to undertake a Step Change Project at NPM (the Project). The Project (reference MP11_0060) will encompasses the continuation of underground block cave mining in two existing ore bodies (referred to as E48 and E26), the development of underground block cave mining (in the E22 resource), additional campaign open cut mining located in existing mining leases and an extended mine life of 7 years until 2032.

Figure 1 presents the location of the Project, Figure 2 shows the Groundwater Impact Assessment (GWIA) Study Area and Figure 3 shows the major components of the Project, including the locations of the resources given above. The major Project components are discussed further in Section 1.3.

1.2 Water Use and Impacts

Copper-Gold mining operations at NPM have the potential to impact on local and regional groundwater resources and the environmental values supported by these groundwater resources. The largest use of water by the mine is for the processing of ore extracts from the mine.

This GWIA documents potential impacts to groundwater systems and associated environmental values arising from the Project. The GWIA scope of work is specifically designed to address the Projects' regulatory requirements, inclusive of the Director-General's requirements (DGR), discussed in detail in Section 1.3.1.

The existing Project Area is located within the wider "Study Area" (the extent is shown on Figure 2). The Study Area comprises the larger area around the Project Area for which data were sought. The boundary for the Study Area is approximately 15 km from the Project Area.

The Study Area was defined based on previous studies (for which the Study Area was within a 5 to 10 km radius of the (mine) site by Parsons Brinckerhoff [PB], 2003; and PB, 2011). Previous studies showed the groundwater drawdown impact zone for current operations to be contained within the centre of the Study Area (up to 2 km from the Project Area; Mackie Environmental Research (MER) 2006). Figure 2 shows the extent of the Study Area in which data was considered by this assessment for the purpose of describing the existing environment, environmental values and potential impacts.

NPM currently has approval to process up to 8.5 million tonnes per annum (MTpa) of ore, which requires up to 7,000 megalitres (ML) per year of water (GHD, 2009). The geological strata underlying the Study Area, which are part of a geological structure known as the Lachlan Fold Belt (LFB), yield relatively low volumes of groundwater compared to the mine's requirements. Sources of water in addition to water obtained from mine dewatering are required to carry out mine operations.

NPM currently sources water from the Parkes Shire Council (PSC) borefield within the Upper Lachlan Alluvium (Figure 2), via a shared pipeline, as well as NPM's own bores on the Avondale property (located immediately north of the PSC borefield). The volume of water obtained from PSC decreased from 3,500 ML in 2009 to 2,650 ML/year in 2012. The reduction of water from the PSC borefield was a consequence of additional water being sourced from harvesting surface water runoff from disturbed areas as part of the onsite water management system (NPM, 2010a). NPM hold a number of water licences, as shown in Table 1.

Table 1: NPM Water Licences

Licence Type	Licence Number	Entitlement (ML/Year)
Bore licence – high security (Avondale, Bore 6)	70BL226550	1600
Bore licence – high security (Avondale, Bore 7)	70BL230929	1600
Bore licence – high security (Avondale)	70BL229975	14
Bore licence – high security (Dawes, Bore 8)	70BL226584	1050
Bore licence – dewatering (E26 and E48)	80BL245448	232
Bore licence – dewatering (E22)	80BL245449	
Bore licence – dewatering (E27)	80BL245450	
River water licence - general	70AL600028	2976

Under the Project, the water quantities required for mining operations will not change because the mine will continue to process ore at the current rates. The extension is intended to extend the life of mine by expanding the existing mined areas to additional open cut areas as well as block cave mining, as discussed in Section 1.3 and shown in Figure 3.

1.3 Project Background

Economic quantities of copper (Cu) and gold (Au) are present in porphyry copper ore deposits in the LFB. The Cu-Au occurs predominantly in sulphide minerals within quartz stockwork veins, and to a lesser extent within oxide minerals which blanket the deposits.

Mining these porphyry deposits at NPM involved open cut pit and underground block cave methods. Underground block cave mining employed at NPM is a mass mining method that allows for the bulk mining of large, relatively lower grade, ore bodies.

Dewatering programmes were developed by Coffey (1993; 1994) to extensively dewater the site aquifers prior to mining, which began in 1995. Dewatering occurred by means of bores to lower the water table and to allow extraction of the ore. Due to the very low permeability of the bedrock, groundwater is encountered only as seepage into the mine via fracture zones (MER, 2006). Historically, mine dewatering has been maintained by pumping groundwater seepage from sumps located at the base levels of the mine. The volume of water from seepages is insufficient for ore processing, hence the need to source water elsewhere including the PSC borefield.

The Project proposes to maintain the approved ore processing rate of up to 8.5MTpa and includes the continuation of underground block cave mining in two established ore bodies (E26 and E48) in accordance with existing approvals. The proposed Project is shown on Figure 1 and includes the following proposed developments relative to the GWIA:

- Continuation of approved underground block cave mining in the E48 and E26 ore bodies, and associated underground infrastructure;
- Development of underground block caving in the E22 resource beneath the E22 open cut void;
- Campaign open cut mining through development of five open cut resources including;
  - Development of four small open cut pits E31, E31N, E28, E28N; and
  - Proposed E26 open cut which is located in an area of previous underground block cave subsidence (existing vertical extent of subsidence void is approximately 200 metres);
- Amendments to the configuration of tailings storage facilities (TSFs) including:

  - Continuation of tailings disposal to the existing and approved TSFs (TSF 1 and 2, infill between TSF 1 and 2, and Estcourt) to an approved height of 28 metres;
  - Provision for additional raises on Estcourt TSF to provide for an increased height from the approved 25 metres to up to approximately 28 metres above ground surface; and
  - Development of a new TSF 3, which will extend to the south and from the southern embankment of TSF 2 to a height of approximately 28 metres above ground surface, which incorporates the approved Rosedale TSF;
- Development of new waste dumps for the management of E28/E28N and E26 open cut waste rock. Waste rock from open cut mining areas will be utilised in the development of TSF 3;
- Continuation of approved ore processing infrastructure up to 8.5 Mtpa capacity, and road haulage of copper concentrate to the existing Goonumbla rail siding;
- Continued use of existing site infrastructure including administration buildings, workshop, internal access roads and service infrastructure;
- Continued use of surface mining infrastructure including ventilation shafts, hoisting shaft and ore conveyors;
- Continuation of existing approved water supply and management processes;
- Development of an amended access road to service all mine related traffic entering the site;
- Establishment of new visitor car parking facilities and access control to support the amended mine access;
- Continuation of approved mining operations for an extended life of an additional 7 years until end of 2032; and
- Rehabilitation and closure of the Project Area will be carried out after the end of the operational life of the Project in accordance with relevant approvals.

Table 2 provides a summary of approved and proposed operations for various mine components.

Table 2: Selected Components of the NPM Step Change Project of Relevance to the Groundwater Impact Assessment

Component	Existing and Approved Operations	Proposed Step Change Project Operations
Mining Areas	■ Block cave mining of E26 and E48 ore bodies; and ■ Open cut mining of E22 (ceased in 2010).	■ Continued block caving of the E26 and E48 ore bodies (as per current approval); ■ Development of block cave mining in the E22 resource (previously subject to open cut mining); ■ Development of open cut mining area in existing mine subsidence zone for E26; ■ Development of four small open cuts (E28, E28N, E31 and E31N); ■ All proposed open cut mining areas are located within the existing PA 06_0026 Project Area and existing Mining leases.
Mine Life	■ Until 2025.	■ Extension of mining by 7 years until 2032.
Infrastructure	**Operation of:** ■ Tailings storage facilities.	**Construction and operation of:** ■ TSF to be augmented to connect existing and approved TSF through the development of Rosedale TSF to the south of TSF 2; ■ Establishment of new waste stockpiles to store waste material generated during open cut mining campaigns, including a vehicle washdown area; and ■ Continued operation of existing processing plant, site offices, underground access, water supply infrastructure and logistics connections.
Ore Processing	■ Up to 8.5 Mtpa.	■ Continuation of processing up to 8.5 Mtpa of ore through the existing processing plant sourced from underground and open cut mining areas.

All components of the Project are located within land which is subject to both the existing Project Approval (PA06_0026) Area and established mining leases (ML 1247, ML1367 and ML1641).

1.3.1 Objectives of the GWIA

This GWIA forms a component of the Environmental Assessment (EA) for the Project. The purpose of this GWIA is to establish a reasonable understanding of the groundwater system upon which to evaluate potential impacts from NPM operations on groundwater resources within the Study Area. Its purpose is also to identify the regional environmental values and the existing or proposed measures necessary to manage impacts based on a groundwater monitoring strategy. Potential issues and environmental values of potential concern include:

- Groundwater-related DGR;
- NSW Office of Water (NOW, under the NSW Department of Primary Industries, or DPI) comments;

- The long term impact to the groundwater resources from Project Area operations; and
- Impacts to other groundwater users.

Impacts to the identified groundwater dependant ecosystems are specifically required to be addressed.

A qualitative assessment of the project specific groundwater impacts for the proposed mining operations has been undertaken, the objectives are summarised in Table 3.

Table 3: Objectives of the GWIA (Groundwater-related DGRs)

Objective	Report Section
Director Generals Requirements (DGRs)	
A detailed assessment of potential impacts on the quantity of existing groundwater resources in accordance with the NSW *Aquifer Interference Policy (AIP).*	Section 5.0
Detailed modelling of potential groundwater impacts including identification of any highly productive groundwater (as defined by the *AIP*) or groundwater dependent ecosystems.	Section 5.0
Impacts on affected licensed water users and basic landholder rights.	Sections 4.9 and 5.0
Impacts on riparian, ecological, geomorphological and hydrological values of watercourses, including watercourse diversions and environmental flows.	Sections 4.8 and 5.0
Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP).	Section 4.6.1 and Section 5.0
During the preparation of the EA, you should undertake an appropriate level of consultation with the relevant local, State or Commonwealth government authorities, service providers, community groups or affected landowners. In particular you must consult with the: ■ Department of Primary Industries (including the NSW Office of Water);	See NOW requirements below
NSW Office of Water (NOW) Requirements	
An impact assessment on adjacent licensed water users (surface and groundwater), the riparian environment and groundwater-dependent ecosystems. This is to meet the requirements of the NSW State Groundwater Policy Framework document in addition to the objects and principles of the Water Management Act 2000	Section 4.9
An assessment of the potential to intercept groundwater and predicted dewatering volumes, water quality and disposal/retention methods. This is to also include the modelled zone of influence for a number of stages both during mine operations and post mine life until equilibrium is achieved	Section 5.0
Preparation of a surface water management plan and groundwater management plan to integrate the proposed water balance and management for the site and to identify adequate mitigating and monitoring requirements	Section 7.0
Existing and proposed water licensing requirements in accordance with the Water Act 1912 and Water Management Act 2000 (whichever is relevant) and the NSW Inland Groundwater Water Shortage Zones Order	Section 2.0.

Objective	Report Section
No. 2, 2008 (22 December 2008). This is to demonstrate that existing licences (include licence numbers) and licensed uses are appropriate, and to identify where additional licences are proposed.	
An impact assessment of the construction, operation and final landform of any proposed on-site waste rock emplacements, tailings storage facilities and other potentially contaminating facilities to meet the requirements of the NSW State Groundwater Policy framework document and the objects and principles of the Water Management Act 2000.	Section 6.0.

1.3.2 Report Structure

This report considers the groundwater component of the Project only. The GWIA is presented in the following format:

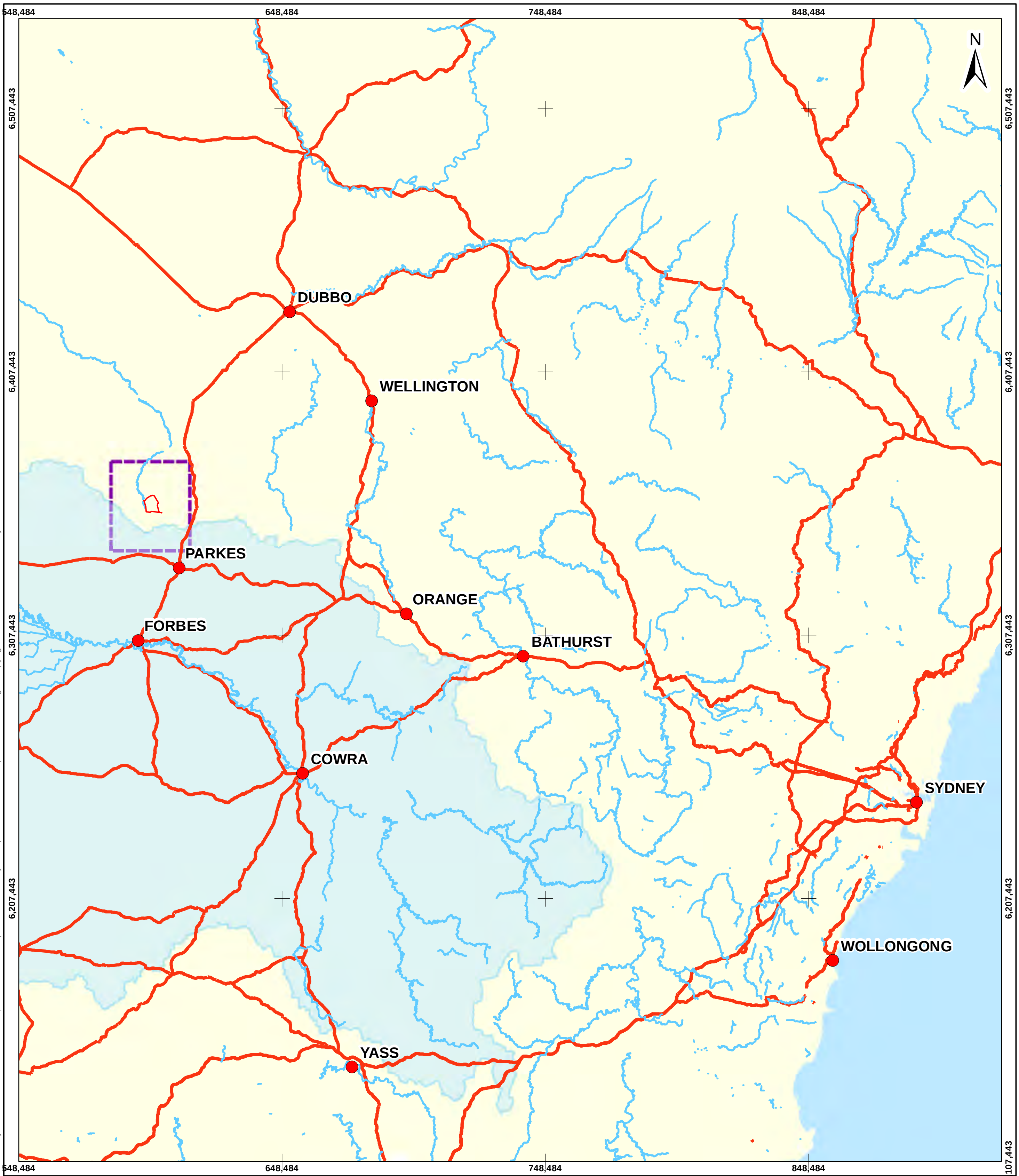
- Section 1.0 – Introduction
- Section 2.0 – Legislative Framework
- Section 3.0 – Data review
- Section 4.0 – Site Characterisation
- Section 5.0 – Hydrogeological Modelling
- Section 6.0 – Groundwater Impact Assessment
- Section 7.0 – Groundwater Monitoring
- Section 8.0 – Conclusion
- Section 9.0 – Recommendations on Management Measures
- Section 10.0 – References
- Section 11.0 – Acronyms and glossary of terms used in the report

Supporting documents are included in the following appendices:

- Appendix A – Metadata (on a CD)
- Appendix B – Legislative framework
- Appendix C – Project Area Model
- Appendix D – Groundwater Impact Assessment and Risk Register
- Appendix E – Water Quality Data (on a CD)
- Appendix F – Limitations

1.4 Limitations

Your attention is drawn to the document - “Limitations”, which is included in of this report (Appendix F). The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.



NORTHPARKES MINE GWA

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PROJECT LOCATION

LEGEND

- Northparkes Project Area
- City/Town
- Major River
- Major Road
- Lachlan River Basin
- Study Area

0 5 10 20 30 40 50 Kilometers

SCALE (at A4) 1:2,000,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
CHECKED:	RS

FIGURE 1

Golder Associates

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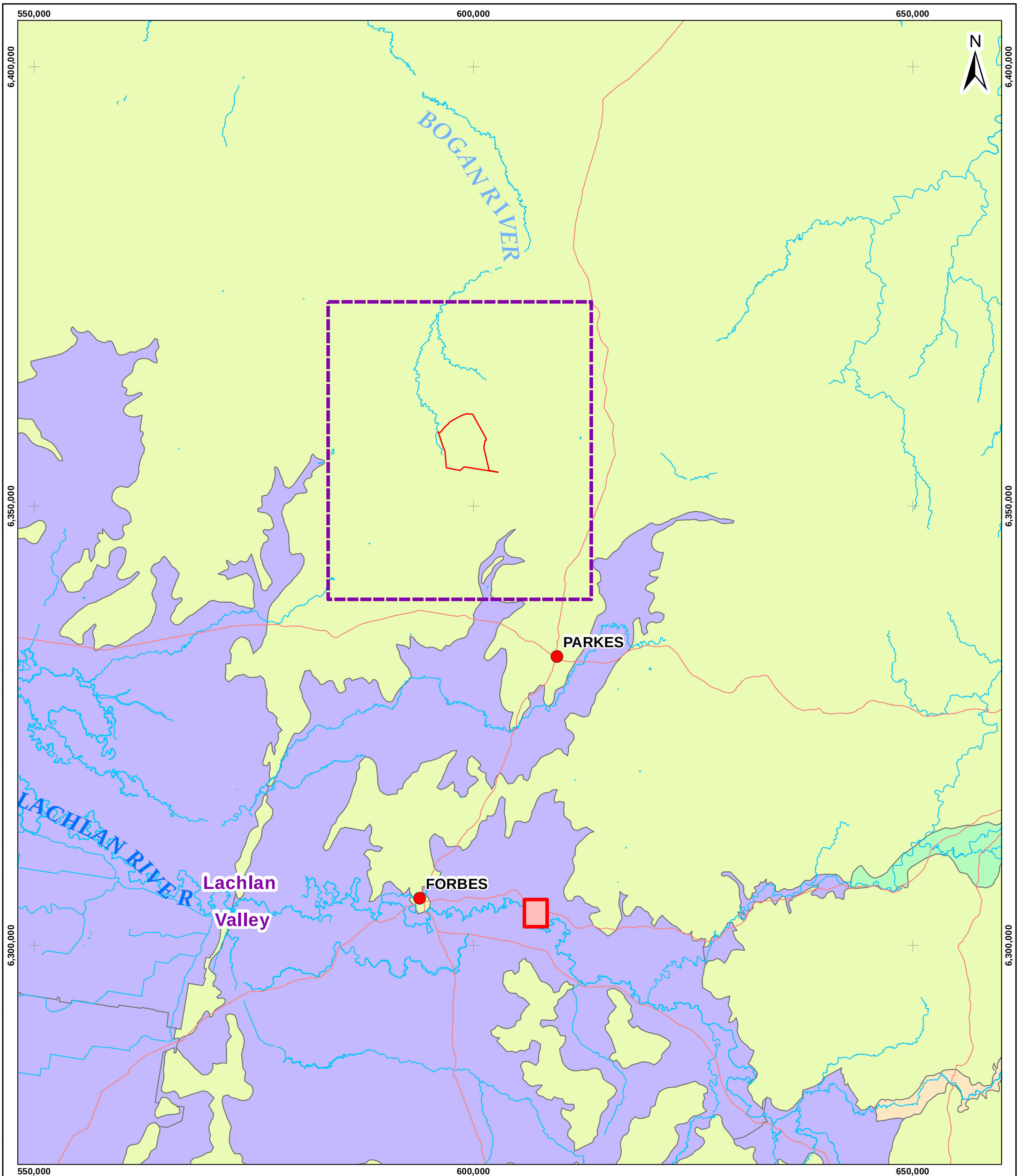

NORTHPARKES MINE GWA

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STUDY AREA

LEGEND

- Project Area
- City/Town
- River
- Major Road
- Study Area
- PSC Borefield

Groundwater Management Area

- Belubula Alluvium (GMA 021)
- Lachlan Fold Belt (GMA 811)
- Orange Basalt (GMA 801)
- Upper Lachlan Alluvium (GMA 011)

0 2.5 5 10 15 20 Kilometers

SCALE (at A4) 1:600,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
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FIGURE 2

Golder Associates

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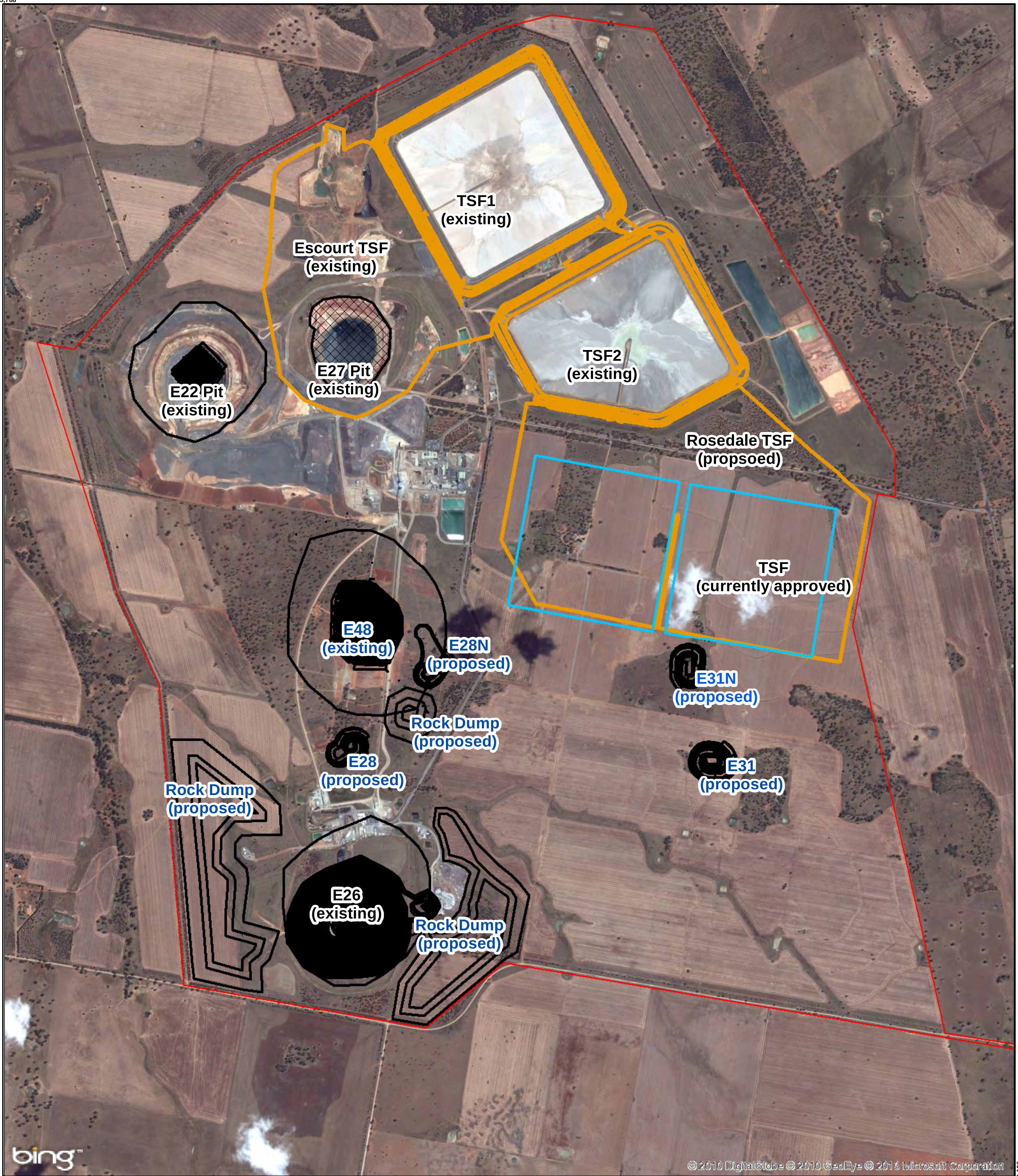

NORTHPARKES MINE
Groundwater Modelling

UMWELT (AUSTRALIA) PTY. LTD.

Existing and Proposed Mine Operations at Northparkes Mine

LEGEND

- Pit Layout
- Project Area
- Tailings Storage Facilities (Existing and Proposed)
- Mine Operations (Existing and Proposed)
- TSF Currently Approved Permits

0 0.5 1 2 Kilometers

SCALE (at A4) 1:24,000
Coordinate System: GDA 1994 MGA Zone 55

PROJECT: 117626007
DATE: 30/04/2013
DRAWN: HW
CHECKED: LJ

NOTES

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FIGURE 3

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2.0 LEGISLATIVE FRAMEWORK

NPM is seeking Project Approval from the Minister for Planning under Part 3A of the EP&A Act for the development of further mining operations including open cut mining, and depth extensions to existing ore bodies and development of a new ore body. Because the Project's water demand will not require an increased groundwater demand, this does not form a significant consideration of this GWIA. The key legislations applicable to groundwater issues related to the Project are listed below and discussed in details in APPENDIX B.

- Commonwealth Water Legislation:
  - *Water Act 2007* and the *Murray Darling Basin Plan; and*
  - *Environment Protection and Biodiversity Conservation Act 1999;*
- Water Legislation in NSW:
  - *Environmental Planning and Assessment Act 1979;*
  - *Water Management Act 200*0;
  - *Water Act 1912; and*
  - *Environmental Planning and Assessment Act 1979* (EP&A Act);
- NSW State Groundwater Related Policies:
  - 'NSW Groundwater Policy Framework Document – General';
  - 'NSW Groundwater Quality Protection Policy', 1998;
  - 'NSW Groundwater Dependant Ecosystem Policy', 2002; and
  - 'Aquifer Interference Policy', 2012;
- Water Licensing Requirements; and
- Guidelines for Fresh and Marine Water Quality (ANZECC).

The Study Area is located within the Murray Darling Basin (MDB) and the groundwater management area (GMA) Lachlan Fold Belt (GMA 811) (see Figure 4). A summary of the GMA and water resource plan areas (WRPA) relevant to the Study Area is described in APPENDIX B.

Table 4: Summary of GMA and WRPA relevant to the Project

GMA	WRPA in the MDB Plan and related groundwater SDL resource units	WSP	BDL[1] for the SDL[2] resource unit	Long-term average SDL for a SDL-resource	Water Allocation Status
Lachlan Fold Belt (GMA 811)	Lachlan and South Western Fractured Rock WRPA (GW11) SDL - Lachlan Fold Belt (GS20)	*Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources* Potentially impacted water management zones - 'Other'	142.4 GL/year	259.0 GL/year	-

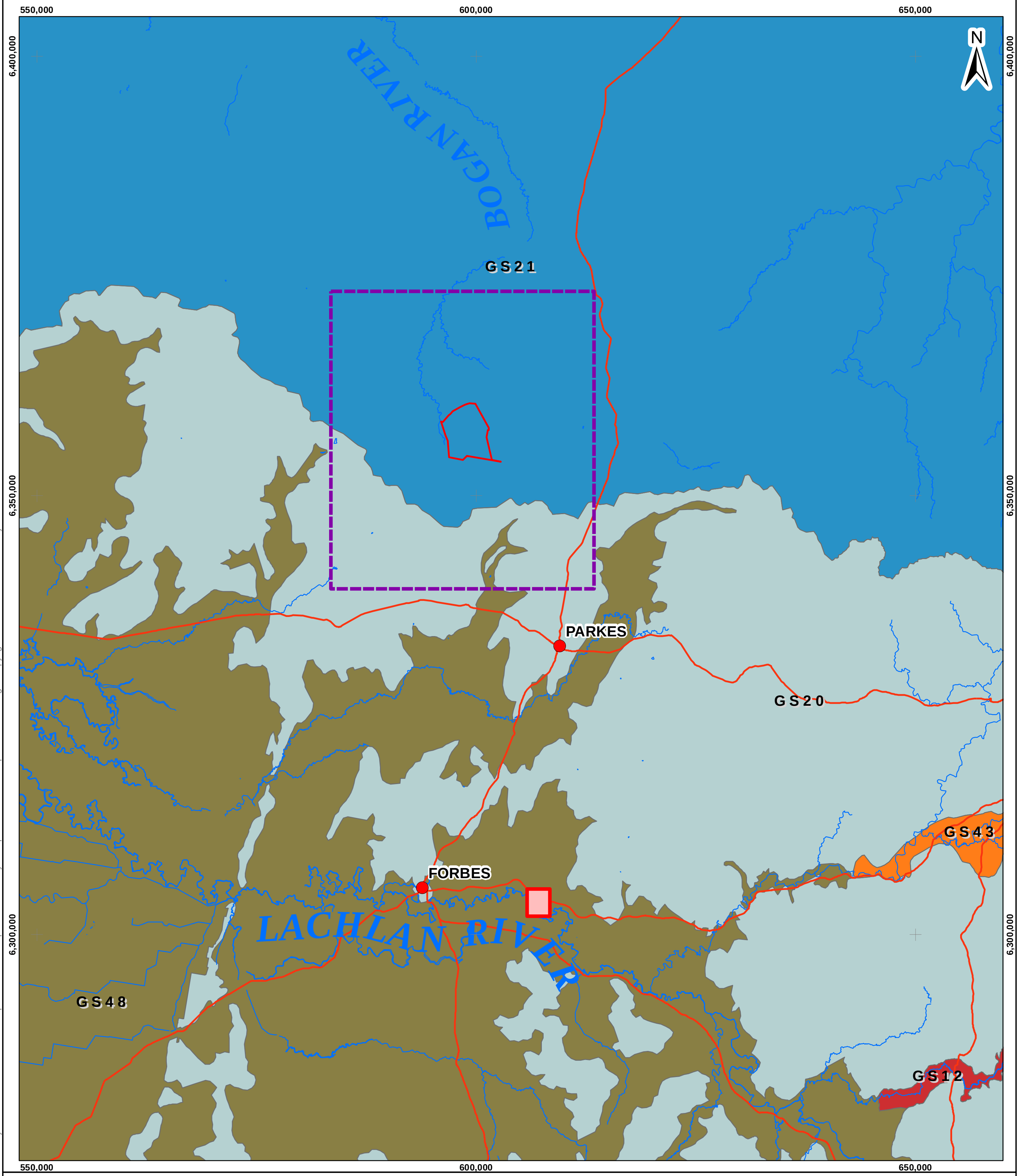
[1] Baseline Diversion Limit (BDL) = the baseline limit of take from an SDL resource unit
[2] Sustainable Diversion Limit (SDL) = maximum long-term annual average quantities of water that can on a sustainable basis from Basin water resources as a whole
WSP: Water Sharing Plan
GMA: Groundwater management area
WRPA: Water resource plan area
MDB: Murray Darling Basin

Table 5: Legislation and policies applicable to the extraction and management of groundwater in the Project Area

Legislation and Policy	Area of Application
Commonwealth Legislation *Water Act 2007* and the *Murray Darling Basin Plan*	The Commonwealth *Water Act 2007* (Water Act 2007) regulates the management of water resources in the Murray Darling Basin (MDB). It was enacted to enable the Commonwealth to coordinate the management of water resources in the MDB (through the Murray-Darling Basin Authority (MDBA) as the national regulatory authority, through the implement the Murray-Darling Basin Plan (Basin Plan). The Basin Plan includes enforceable limits on the quantities of surface water and groundwater that can be taken from the Murray-Darling Basin water resources. Under the Basin Plan (2012), there are two water resource plan areas (WRPA) within the Study Area (Lachlan and South Western Fractured Rock WRPA (GW11) and Lachlan Alluvium WRPA (GW10)). There is only a small area of the Lachlan Alluvium WRPA (GW10) within the Study Area, 15 km south of the Project Area. To date, the zone of influence from NPM activities is restricted within the vicinity of the Project Area itself, due to the hydraulic properties of the host rock. It is not the intention of the Project to source water from the Lachlan Alluvium and this WRPA (GW10) is not considered to be relevant to the Project. The groundwater SDL resource unit Lachlan Fold Belt (GS20) of the Lachlan and South Western Fractured Rock WRPA (GW11) covers most of the Study Area. GS20 is considered relevant to the Project (refer to Figure 4); therefore, the Water Act 2007 covers the fractured rocks of the Lachlan Fold Belt.
Commonwealth Legislation *Environmental Protection and Biodiversity Conservation*	Provides the regulatory framework for Matters of National Environmental Significance (MNES). Projects that have an impact on MNES require concurrent approval under the Commonwealth Environment Protection Biodiversity Conservation Act 1999 (EPBC Act). The ecological assessment for the Project includes an assessment of potential impacts on matters of national significance. This assessment concluded that the Project is not

Legislation and Policy	Area of Application
(EPBC) Act 1999	likely to have a significant impact on a MNES.
NSW *Environmental Planning and Assessment Act 1979*	The *Environmental Planning and Assessment Act 1979* (EP&A Act) regulates all development in NSW including the Project, which is to be assessed as a transitional Part 3A Project in accordance with the EP&A Act. DP&I issued revised DGRs for the Project on 11 March 2013.
NSW *Water Management Act 2000* – Project-related Water Sharing Plans (WSP)	*Water Management Act 2000* provisions for developing water sharing plans and licensing water extractions operate independently of the Basin Plan. The WSP that is relevant to the Project is the *Water Sharing Plan for the NSW Murray Darling Basin (MDB) Fractured Rock Groundwater Sources, January 2012* Water supply for NPM is covered under the applicable WSPs. If a water resource is fully allocated, water for mining use is not subject to exemptions for the allocation caps. In this situation, further water allocation is only available through the water market. Entitlements cannot be traded or sold between separate and different GMAs. New water access licences may be considered in this area if it is a local water utility, major water utility, domestic and stock and town water supply, and salinity and water table management. Granting of water access licences may also be considered as part of a controlled allocation order made in relation to any unassigned water in this water source. NPM already hold a number of WALs under the WMA 2000 (up to 7,472 ML per annum in addition to water sourced from the PSC). It is not the intention of the Project to increase the water requirements. The regolith and oxidized zone of the host rock are very tight low yielding ‘aquifers’ and very low quantity of inflow is expected around the Project Area. The estimated dewatering volume based on the numerical groundwater modelling is in the range of 0.7 ML/day) (refer to Section 5.0) and there is no increase in existing groundwater requirements as a result of the Project.
NSW *Water Management Act 2000* - Water Access Licences (WALs)	The WMA 2000 establishes categories of water access licences (WALs). The category most relevant to the Project’s activities is an aquifer WAL. Each year, "available water determinations" are made specifying the percentage of the "share component" that may be consumed for each licence category. These determinations will vary depending on environmental conditions such as recharge rates and changes in demands on water resources regulated by the WSP. The licensing regime under the WMA 2000 differs from the Water Act as licences are not tied to the land and water entitlements are therefore tradeable within a defined groundwater source. NPM already hold a number of WALs under the WMA 2000 (up to 7,472 ML per annum in addition to water sourced from the PSC).It is projected that the Project’s water requirements will not require an increased water take and the Project will not alter NPMs existing WALs nor impact upon further WSPs than what is existing.
NSW *Water Act 1912*	The Water Act 1912 (Water Act) has a limited role in regulation of surface water and groundwater in NSW as it is currently being phased out and replaced by the WMA 2000. The Water Act applies only to water sources (rivers, lakes and groundwater aquifers) in NSW where a WSP (implemented in accordance with the WMA 2000) has not commenced. Water supply for the Study Area is covered under the relevant WSP (*Water Sharing Plan for the NSW Murray Darling Basin (MDB) Fractured Rock Groundwater Sources, January*

Legislation and Policy	Area of Application
	2012); therefore, the Water Act 1912 does not apply to the Project.
NSW Groundwater Policy Framework Document – General	The NSW State Groundwater Policy provides a direction on the ecologically sustainable management of NSW groundwater resources, including consideration of the beneficial use of aquifers for both now and in the future. In accordance with the NOW comments, an impact assessment of the Project activities upon adjacent licensed groundwater users, the riparian environment and groundwater-dependent ecosystems has been undertaken to meet the requirements of the NSW State Groundwater Policy in addition to the objects and principles of the Water Management Act 2000 (refer Section 5.2.9).
'NSW Groundwater Quality Protection Policy', 1998	The NSW Groundwater Quality Protection Policy (1998) is designed to protect groundwater resources against pollution. The majority of groundwater vary from brackish to saline and have been classified as unsuitable for potable use (either domestic, irrigation or for livestock watering) due to the elevated concentrations of sodium and chloride. There were no findings of significant risk based on the acid rock drainage risk review at the Study Area (RioTinto, 2011). The potential impact on groundwater quality in the Study Area in relation to the tailings storage facilities, waste rock dumps, ore stockpiles, chemical storages, sulphur minerals in the rubble-filled block caves at closure will be addressed using effective management measures and monitoring approach (refer Section 6.0).
'NSW Groundwater Dependent Ecosystems Policy' (2002)	The NSW Groundwater Dependent Ecosystems Policy (2002) provides guidance and how to protect and manage GDEs. The Groundwater Dependant Ecosystem Policy (2002) lists the following types of ecosystem in NSW: Terrestrial vegetation, Baseflow in streams (e.g. spring flow), Aquifer and cave ecosystems; and Wetlands. There are no springs or wetlands located within the Study Area. As will be noted in Section 4.0 of this report, the GDE Lamberts spring identified in the WSP Murray Darling Basin Fractured Rock Aquifers are outside the Study Area and more than 50 km away from the Project.
'NSW Aquifer Interference (AI) Policy' (2012)	The AI Policy applies to all aquifer interference activities including mining, extractive, coal seam gas, dewatering, water injection into aquifers and activities with the potential to impact groundwater quality or result in structural damage to an aquifer. The AI Policy provides definition of the groundwater impact assessments and management of groundwater associated with mining developments, and sets out a framework for assessing the impacts of aquifer interference activities on water resources. The AI Policy requires new mining and petroleum exploration activities that take more than 3 ML/year from groundwater sources to hold a water access licence. For the NPM Project, mine dewatering occurs within the WSP MDB Fractured Rock Aquifers and there is no highly productive aquifer overlying the target formation; therefore, there is limited potential to impact adjacent groundwater sources. Predicted dewatering volume at the Study Area is approximately 0.7 ML/day based on the numerical groundwater model results (please refer to Section 5.2 of this report). NPM already hold a number of WALs under the WMA 2000 as well as water sourced from the PSC and it is envisaged that no further WALs or additional water from the PSC borefield is required for the Project.



NORTHPARKES MINE GWA

UMWELT (AUSTRALIA) PTY. LTD.

GROUNDWATER SDL RESOURCE UNITS WITHIN THE STUDY AREA

LEGEND

- Project Area
- Parkes Borefield Location
- City/Town
- Study Area
- Major Road
- River

Lachlan and South Western Fractured Rock WRPA (GW11)

- Lachlan Fold Belt: Lachlan (GS20)
- Lachlan Fold Belt: Macquarie–Castlereagh (GS21)
- Orange Basalt (GS43)

Lachlan Alluvium WRPA (GW10)

- GS48 Upper Lachlan Alluvium
- GS12 Belubula Alluvium

0 2.5 5 10 15 20 Kilometers

SCALE (at A4) 1:600,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT: 117626007
DATE: 30/04/2013
DRAWN: SRS
CHECKED: RS

FIGURE 4

NOTES

SDL: Sustainable Diversion Limit
LFB: Lachlan Fold Belt
Groundwater SDL Resource unit data supplied by the Murray Darling Basin Authority.
See Figure 2 for Groundwater Management Area (GMA) boundaries of GMA 811 and GMA011

Golder Associates

File Location: J:\hyd\2011\117626007_Umwelt_NorthParkesMine\Technical Doc\GIS\Project\Rev0\117626007_007_R_F004_WRPA-Rev0.mxd

3.0 DATA REVIEW

Hydrogeological modelling of the Study Area and Project Area are key to the understanding the potential impacts of the Project. Building an understanding of the controlling factors for the behaviour of groundwater from a review of the Site Characteristics has been undertaken from extensive data review. This data review and understanding of the site was used to develop a Conceptual Groundwater Model (CGM) of the Study Area.

Data was obtained from Umwelt and NOW was supplemented by readily obtainable public data, literature review and previous studies, as discussed in the following sections.

3.1 Sources of Data

Data for the GWIA was primarily provided by NPM and additional data was collated from publicly available literature, governmental databases and websites. The data reviewed as part of this GWIA is summarised in Table 6.

Table 6: Data Summary

Data	Source	Details & Comment
Bores names & locations, bore hydrogeological information	NOW	Extraction from PINNEENA Groundwater (GW) Database Version 3.2
Bore use, licensing	NOW	Extraction from PINNEENA GW
Surface water levels	NOW	Extraction from PINNEENA Continuous Monitoring (CM) Database Version 9.3
Geology	NPM	Project Area geology
	NOW	Geological logs
	Literature	Selected papers and reports (Refer to Table 7)
Maps and images	DMR / AGSO / GSNSW*	Geological maps
	Bing Maps / NPM	Satellite images/aerial photos
	NPM	Topography – Digital elevation model
Planning development	NPM	Proposed operations (DWG and PDF files)
Regulatory / Licences	NPM	Environmental Protection License
Groundwater extraction	NPM	Produced water volumes.
	NOW / NPM	Groundwater licence data
Estimates for future production	NPM	Tonnage estimates provided (excel file)
Well construction information	NOW	Previous reports (Table 7)
	NOW	Information available in PINNEENA GW database
Tailing Ponds data	NPM	Existing approved operations (DWG and PDF files)
Environmental values	NOW	WSP springs location
Water quality data	NPM	Chemistry data for selected environmental monitoring
	NOW	Field information within the NOW Groundwater database
	NOW / PSC	Water quality data by pers. comm. (K Kolstad,

Data	Source	Details & Comment
		NOW; and A Francis, PSC)
Weather data	BOM*	Climate data obtained BOM website - http:// www.bom.gov.au/

*Notes:
DMR = Department of Mineral Resources
AGSO = Australian Geological Survey Organisation
GSNSW = Geological Survey of NSW
BOM = Bureau of Meteorology

Registered groundwater bore data (such as water levels, water quality, bore construction) was obtained from NOW sources:

- NSW Pinneena Surface Water Database (NOW, 2010a);
- NSW Pinneena Groundwater Database (NOW, 2010b); and
- Water quality monitoring data (pers. comm. with K Kolstad, NOW, 2011).

Up to date NPM site data was provided by NPM. Complementary documentation was sought from literature review and other published reports.

Previous and related studies relevant to this study are summarised in Table 7. Key regional studies of the geology and hydrogeology of the LFB include SRK (2000), MER (1999), PB (2003), NPM (2010) and PB (2011). Numerical models have also been developed for the Study Area, with the focus on groundwater dynamics in the bedrock (LFB) at the NPM Project Area (MER, 2006).

Golder has previously worked with NPM on a variety of projects relating to groundwater. A list of the relevant groundwater studies and previous work are included in Table 7.

Table 7: List of Previous and Relevant Studies

Reference	Source	Content
Golder, 2011a. 'Pietsch' Bore Hydrogeological Impact Appraisal. Prepared for Northparkes Mines, 29 October 2011.	NPM/Golder	Advice in respect of the “Pietsch Bore Claim” matter (related to PSC borefield and perceived impacts), dated 26 September 2011.
Golder, 2011b. Northparkes Mines Pre-Feasibility Assessment – Physical Hydrogeological Assessment for Additional Groundwater Supply. Prepared for Northparkes Mines and PSC, 6 September 2011.	NPM/PSC/Golder	Provision of hydrogeological advice regarding the status of the groundwater resource, its availability and sustainability in the immediate area of the PSC borefield.
Golder, 2011c. Physical Hydrogeological Assessment for Additional Groundwater Supply. Reference No. 117626004-003-Rev0, dated 6 September 2011.	NPM/Golder	Due diligence on the hydrogeological potential for the Upper Lachlan Aquifer to supply process water at an acceptable rate of 10 to 15 GL/year (320-475 L/sec) and without unacceptable impact on neighbouring users
Golder, 2010a. Order of magnitude study, groundwater resource assessment – management study. Prepared for NPM, April 2010	NPM/Golder	OoM-level groundwater resource assessment to investigate and identify potential groundwater resources for the proposed extension within a 100 km radius of NPM.
Mackie Environmental Research (MER), 2006. Northparkes Mines E48 Project: Groundwater Studies. *In* Northparkes Mines E48 Project Environmental Assessment, R.W. Corkery, 2006. April 2006.	NPM	Development of a numerical groundwater flow model of the fractured rock basement at the NPM site to undertake a pre-feasibility assessment of likely impacts.
NPM, 2010b. Chapter 9: Orebody Knowledge. *In* Order of Magnitude Study.	NPM	Description of the regional and local orebody geology
Parsons Brinckerhoff (PB), 2011. Groundwater Monitoring Program – Bore Specifications Report. Prepared for NPM January 2011.	NPM	Recommended location, drilling methods and construction design for bores to monitor the potential impact to groundwater from the TSFs.
Raymond, M.S., 2002. Practical Assessment of Fractured Rock Hydrogeology in the Open Cut Area at Northparkes Mine, NSW, December 2002	University of Canterbury	Master’s Thesis.
SRK Consulting, 2000. Structural Evolution and controls on Cu-Au mineralisation, Goonumbla Region: Interpretation of high resolution airborne magnetic data. Prepared for NPM, October 2000.	SRK	Supplementary data to the previous work illustrating the geology and principal structural elements of the Goonumbla region.

3.2 Data Compilation (Metadata Management)

A key component of the data review was an assessment of the bores and wells located within the Study Area. The data from PINNEENA, NOW and NPM were compiled into a common “metadata table”.

Metadata refers to “data about data”. That is, information on the:

- Data available;
- Amount of data;
- Coverage of data;
- Quality of data; and
- Source of the data.

A summary of the fields reported in the metadata is presented in “Metadata Field Summary” (APPENDIX A).

As part of the data quality checking process, data from each bore record, from both the NOW database and pers. comms. sources were compared. The data were assigned a “data quality” score of 1 (adequate data available) to 3 (no data available) for each of the following criteria:

- Bore stratigraphy;
- Bore construction;
- Bore depth;
- Water levels;
- Bore chemistry (EC and pH);
- Water quality (major ions).

A detailed list of the above criteria and scoring system are presented in the "Metadata Assessment Card” in APPENDIX A).

The full data set for the Study Area is presented in Table A1 (APPENDIX A). Summary maps showing spatial variation of the metadata are shown on Figures A1 to A6 (APPENDIX A).

Data was received in various formats; in some instances, the accuracy of the data provided was questionable. Data quality was screened according to standard metadata criteria and data were excluded from further analysis if found to be of poor quality (discussed further in Data Quality, Section 3.3).

Overall, the full data set and information reviewed from sources listed in Table 6 were adequate for the purposes of this GWIA for the EA.

3.3 Data Quality of the Existing Environment

3.3.1 Climate

The Bureau of Meteorology (BOM) provides monthly average data for temperature and rainfall for weather stations throughout Australia. For a more detailed description, refer to < http://www.bom.gov.au/ >. For this study, rainfall and temperature data was available from 1889 to 2012.

The closest BOM station to the Study Area is Parkes (Macarthur Street) weather station (station number: 065026), located approximately 27 km south-east from the Project Area, at an elevation of 324 m AHD. Mean monthly rainfall and temperature data monitoring at this site commenced in 1889 until December 2012 when the station was closed. Mean daily evaporation data was available only from years 1970 to 1982.

The nearest station with recent evaporation data is Condobolin (AG Research Station) weather station (station number: 050052) located 95 km west of Parkes, at 195 m AHD elevation. Due to the distance, the difference in elevation and significantly different average annual rainfall (130 mm difference), the average evaporation data from the Parkes (Macarthur Street) weather station (station number: 065026) for 1970 to 1982 was used in the assessment.

Overall, these data were considered adequate for the purposes of this GWIA.

3.3.2 Local Bores/Well Construction Details

NOW requires drilling contractors undertaking the drilling of water bores to be licensed. The main intention of this requirement is to prevent adverse impacts potentially arising from poor well construction and consequential inter-aquifer leakage. Private bore construction practices were assessed on the basis of the information provided in the NOW database. The information was often incomplete or in doubt for the available data set.

A total of 185 NOW database bores were identified, and an additional 87 bores were identified from NPM records. The metadata table identifies the data available for each bore and when available, provides general information for each bore.

Typically, poor quality information was attributed to contradictory information, lack of coordinates or units for measurements, or the absence of key hydraulic parameters for some formations. All coordinates were converted to Geocentric Datum of Australia (GDA94), Map Grid of Australia Zone 55 (MGA55). Corrections and/or conversions were made when required. All elevations in the report are provided in metres (m), in relation to the Australian Height Datum (m AHD).

The target formation information was not readily available from the PINNEENA database, which gathers information on water licensing. Due to poor data entry format and poor data consistency in the database most bores could not be related to a formation target directly. In addition the data provided by NOW, and NPM, were used to complete some of the empty metadata fields. Conflicts between data sources were solved on a case-by-case basis.

Overall, these data were considered adequate for the purposes of this GWIA.

3.3.3 Geology and Stratigraphy

A description of the regional geology is presented in the NSW State 1:1million Stratotectonic Geology and the associated explanatory notes (DMR, 1996). The local geology was presented using geological surface maps of Forbes and Narromine Geological Sheets and explanatory notes (AGSO, 2000; and GSNSW, 1997). Geological information for the Project Area was also made available by NPM and focused on the structure of the LFB (refer to Table 7).

The boundaries of the Forbes and Narromine surface geology maps occur within the Study Area. The Forbes map comprises the area south of the Bogan River alluvium, and the Narromine map lies to the north, comprising the majority of the local geological map within the Study Area. The 2000 Forbes map has slightly different interpretations of the regolith-alluvium-colluvium surface layers in comparison to the 1997 Narromine map. The units between the maps were interpreted to be matched as closely as possible.

The occurrence, lithology and palaeo-environment of the strata are presented in Section 4.4 and discussed individually in the following sections, beginning with the oldest bedrocks.

Overall, these data were considered adequate for the purposes of this GWIA.

3.3.4 Groundwater Levels

Groundwater level and quality data outside of the Project Area were obtained from the NOW PINNEENA groundwater database. The data were extracted from the Works Database within PINNEENA. Groundwater levels within, or adjacent to, the Project Area were provided by NPM from groundwater monitoring wells. Overall, the data provided for the Project Area is of generally good quality, with water levels available since

1995 with associated dates and datum. The datum (i.e. ground elevation) for some monitoring wells was determined by Golder using the digital elevation model provided.

Note that the metadata map for groundwater level data (APPENDIX A) shows all surveyed bores with dated water levels (standing and continuous) as given a Score of "1" (or "good") according to APPENDIX A. Outside the Study Area, recent and continuous water levels were rare, with most of the bore water levels recorded at the time of drilling (since 1925).

The PINNEENA database did not provide target aquifer information (the strata or depth from which a bore was thought to extract from). It was not possible to assign target formations of any bores within the fractured basement rocks of the LFB due to absent or incomplete bore construction, aquifer and/or stratigraphy information.

Overall, these data were considered adequate for the purposes of this GWIA.

3.3.5 Groundwater Quality

Water quality data was primarily provided by NPM for mine monitoring bores pre-mining in 1984 and during mining in 2010. This data was of predominantly good quality, however, it was noted that the 1984 water quality data did not have complete coordinate references and the locations could not be plotted. The 1984 sample locations were described as being within the Project Area, near deposits E22, E26 and E27 and were included in the groundwater quality assessment. The water quality data is presented in Appendix E.

Some field data (pH, Electrical conductivity or EC) was available from the PINNEENA database for the Study Area. Additional water quality data was provided for 1979 by NOW (pers. comm. K Kolstad; NOW, 2011). The analytes selected for the groundwater water quality assessment were pH, EC and major ions. Available water quality information for each bore was identified and assessed. No water chemistry data could be linked to a target aquifer.

The quality of available data cannot be verified; however, data reliability and accuracy for major ions can be estimated from the electro-neutrality of the ion balance, since positive and negative charges in the water should be equal. Ion balance error (IBE) is calculated as follows:

$$IBE(\%) = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} \times 100$$

Where cations and anions are expressed in milliequivalents per litre (meq/L). A milliequivalent is a measurement of the molar concentration of the ion multiplied (normalised) by the ionic charge of the ion. Approximately 85% (64 out of 75 samples) of the analytical data had IBE values within the ±20% range, indicating that the major ion analyses were of acceptable quality for consideration in this study. Eleven samples with IBE over the ±20 % range have been excluded from the assessment. It is acknowledged that a smaller IBE tolerance range is typically considered to be acceptable for data validation purposes (e.g. ±5%); however this range would have excluded too many samples to perform a meaningful assessment of groundwater quality at the Project Area. Hence, a raised IBE tolerance has been adopted with the acknowledgement of an incremental decrease in data quality.

Overall, these data were considered adequate for the purposes of this GWIA.

4.0 SITE CHARACTERISATION

The development of the CGM and risk assessment requires an understanding of the Project Area and wider Study Area. This section of the GWIA identifies topography, land use, climate and geology within the Study Area and their importance to the dynamics of the groundwater system.

The site characterisation includes the assessment and summary of:

- Topography, surface water, climate and land use, and the relevance to this groundwater assessment;
- The regional and local geology;
- Regional hydrogeology;
- Available results of local groundwater analysis (hydraulic testing, water quality);
- Environmental values.

Local hydrogeology is discussed in detail under the Hydrogeology and CGM (Section 5.1) and will draw interpretation from the data presented in the Site Characterisation.

4.1 Topography and Land Use

Topography and land use influences the groundwater flow and occurrence by affecting climatic behavior, runoff, recharge and the geometry of the water table.

The Study Area is located within the central part of the South Western Slopes bioregion, west of the western slopes and plains of the Great Dividing Range. The area is predominately classed as flat, with slopes less than 3 degrees. Areas of high relief lie east of the Study Area, in the area of Goobang National Park, located approximately 28 km away (NSW National Parks and Wildlife Service, 2003).

The Project Area is located within a valley of the upper Bogan River Catchment, at approximately 280 mAHD. The valley is bound to the south, west and east by high ground formed by sedimentary and volcanic rock ranging in elevation from 270 mAHD to approximately 320 mAHD in the south.

The area surrounding the existing Project Area is dominated by cleared agricultural land, mostly for wheat, canola, barley and field peas, with patches of native remnant vegetation.

4.2 Surface Water Conceptualisation

The interaction of surface water and groundwater is a key component of the water cycle. The behaviour of surface water in the Study Area can represent either a loss from groundwater (as baseflow to the river) or as a gain to groundwater (as leakage from the stream bed), or some combination of the two. Therefore it is essential to gain an understanding of the surface water and groundwater interaction as part of this GWIA.

From its origin near Parkes, the Bogan River is approximately 617 km in length until its confluence with the Darling River, near Bourke. The Bogan River channel runs north-south on the western side of the Project Area, coming to within 1 km of Pit E22 at its closest point. Project Area surface drainage is northwards.

A tributary of the Bogan River, the Goonumbla Creek, runs east to west across the Project Area (Figure 1). Surface drainage is northwards towards the Macquarie River and through the Wombin State Forest, located 7 km northwest of the mine. The Bogan River is ephemeral and only exhibits flow only during sustained wet periods (MER, 2006). The Project Area is located on a high ground between the tributaries.

Within the upper valley, the Bogan River has a number of tributaries (PB, 2003);

- Towards the east:
  - Tenandra Creek;
  - Goonumbla Creek; and

- Cookopie Creek.

- Towards the west lies the Timaldrie Creek.

The tributaries listed above, like the Bogan River, are all ephemeral drainage channels, exhibiting flow only during periods of high rainfall (PB, 2003). NPM is located on an area of high ground between the Bogan River to the west, Goonumbla Creek through the Project Area, and Cookopie Creek to the east.

Raymond (2002) classifies the Bogan River and its tributaries as intermittently flowing streams with poorly-defined channels. Flow only occurs after sustained periods of intense rainfall, in response to overland runoff. Losses due to evaporation are significant and there is no permanent baseflow because the groundwater table lies well below the base of the channel. Isolated lenses of shallow perched groundwater have been found beneath some channel sections where alluvial deposition has accumulated sufficient sediment. Owing to the high evaporation rate, recharge to these perched aquifers is likely to be very low and they do not have substantial resource potential.

In the vicinity of the Project Area, Raymond (2002) notes that the Bogan River channel constitutes a subtle depression about 10 to 20 m wide, partially lined by river red gum (Eucalyptus camaldulentis). For some months after a flow event a line of shallow, reed-filled pools lie in the channel. River bed sediments comprise grey or brown clays.

Flow in the Bogan River only becomes more continuous about 160 km from its source near Nyngan. Occasional floods occur after prolonged rainfall due to the undefined nature of the watercourses and extensive clay cover on the plains, which has low infiltration capacity.

Available information suggests the water table lies well below the base of the surface water features and does not intersect the surface drainage lines (Raymond, 2002). This suggests the groundwater does not provide baseflow to the surface water. Furthermore, low permeability clay soils and regolith units in the valley impede rainfall infiltration and can cause localised perched water table conditions, indicated by areas of surface ponding after rainstorms (Raymond, 2002).

4.3 Climate

Climate affects groundwater occurrence and flow by influencing the intensity and distribution of rainfall and evaporation, both temporally and spatially. This influences the amount of water lost or gained to different parts of the water cycle by varying the amount going to surface runoff to rivers, infiltration to the ground as recharge to the water table or the portion lost to evaporation. An understanding of climatic effects is important to groundwater flow and occurrence.

Furthermore, future changes to the climate can affect the water cycle and relative portions of gains or losses to the water cycle. This GWIA considers climate change as published by CSIRO: The impact of climate change on groundwater resources: The climatic sensitivity of groundwater recharge in Australia. (Baron et. al. 2010). Climate change may have the effect of reducing future recharge, so affecting groundwater levels in the Study Area.

The local climate is described as semi-arid with warm to hot summers and mild to cool winters (BoM, 2012). Monthly environmental monitoring at NPM showed that rainfall is distributed relatively uniformly through the year with an annual average of approximately 530 mm.

The seasonal distribution of climate for the Study Area is shown in Figure 5. At Parkes BoM station, average rainfall is 587.5 mm per annum (period of 1889 to 2012). Rainfall is slightly higher in summer months but can vary markedly; the average monthly rainfall ranges from 41.4 mm in April up to 57.6 mm in January. Losses to evaporation are significant. Evaporation is approximately 1,570 mm per annum (period of 1970 to 1982) at this station.

Occasional flooding has occurred after prolonged rainfall due to the undefined nature of the watercourses and extensive clay cover on the plains, which has low infiltration capacity. Notably, floods occurred from 2010 to 2012 across the Study Area after significant rainfall following sustained drought periods. Flood warnings for the Bogan River were issued in February 2010 and March 2012 by NSW State Emergency

Services. The most recent major Bogan River flood event occurred in April 1990 when the town of Nyngan (170 km north of the Project Area) was inundated following 300 mm rainfall in one month (Raymond, 2002; BoM, 2012).

The highest average maximum monthly temperature is 32.3°C, recorded in January and the lowest minimum monthly temperature was 4.0º recorded in July (Table 8). The evaporation pattern typically corresponds to the temperature range, as would be anticipated.

Table 8: Study Area Climate Data Summary – Mean Monthly Statistics

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max. Temperature (˚C)	32.3	31.6	28.5	23.6	18.6	14.9	14.0	15.9	19.5	23.6	27.7	30.6	23.4
Min. Temperature (˚C)	17.9	17.8	15.0	10.9	7.5	5.1	4.0	4.9	7.3	10.4	13.5	16.2	10.9
Rainfall (mm)	57.6	49.1	47.4	41.4	47.2	49.5	49.1	49.2	41.8	52.4	49.5	53.0	587.5
Evaporation (mm)	229.4	184.8	161.2	102	62	42	46.5	65.1	96	142.6	177	244.9	1570.6

Source: BOM, PARKES weather station (065026)

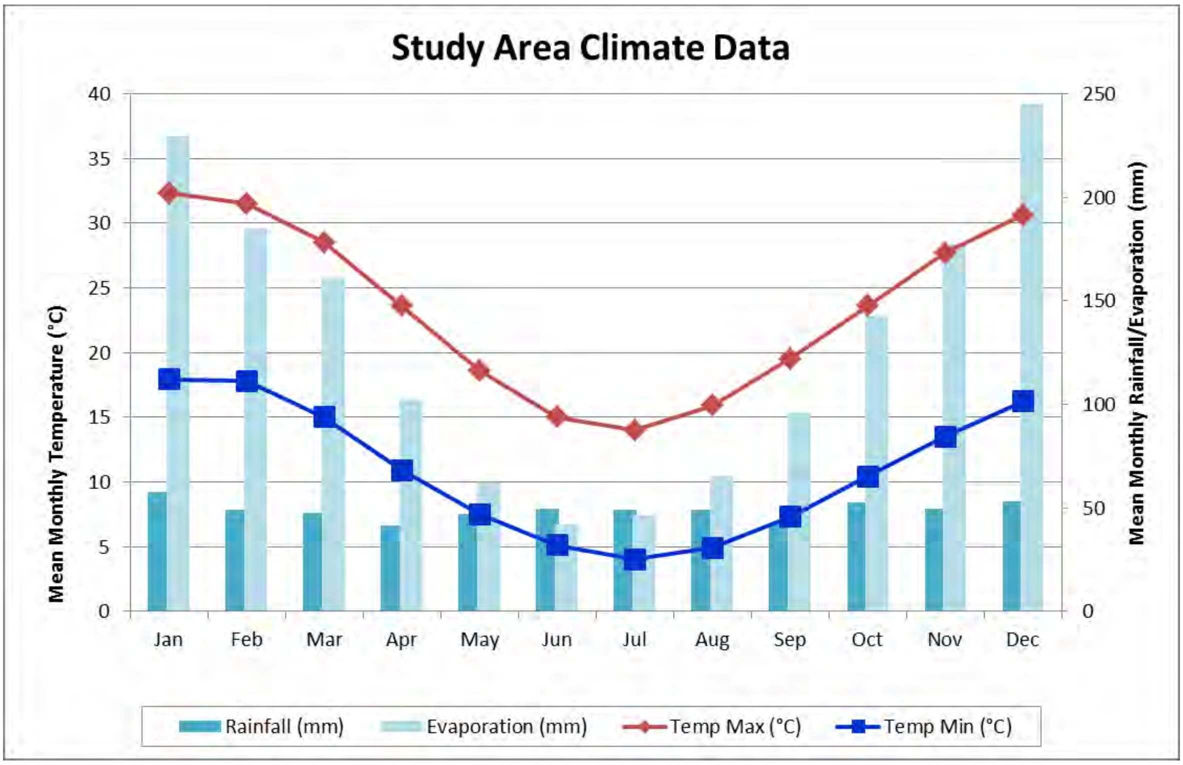


Figure 5: Rainfall and Temperature Diagram - Monthly Averages for Parkes Weather Station (BOM, 2012)

4.4 Regional Geology

Regional geology and geological structure influences groundwater according to their occurrence, distribution and relative positions in respect of their ability to either permit or retard groundwater flow as well as their ability to store and release groundwater.

The regional geology of the Study Area is presented in Figure 6. The Study Area is predominantly underlain by the ancient Ordovician-Devonian age rocks comprising the LFB, which has been structurally subdivided into several discrete north-south trending zones (Gilligan & Scheibner, 1978).

Consolidated rock, (the bedrock or basement rock), occurs mainly in distinct ridges which form the eastern and western boundaries of the LFB, and have a north–south trend (see Figure 6). The Study Area lies east of the Marsden Thrust Fault and within the Bogan Gate Synclinorial Zone.

4.4.1 Lachlan Fold Belt

The LFB covers a very large area (about 300,000 km^2) equivalent to almost one quarter the size of NSW. The LFB is not limited to NSW but extends through Victoria, Tasmania and Queensland. LFB rocks host numerous varieties of gold and base metal deposits, including the NPM deposits, which are hosted within the Goonumbla Volcanic Group.

The Late Ordovician to Early Silurian age LFB comprises metamorphosed sedimentary and volcanic rocks, forming the regional bedrock (Figure 6). It incorporates complex sequences of faulted, folded and metamorphosed rocks of similar age (middle Palaeozoic). Structural faulting and folding has occurred during periods of major tectonic movement, where uplifting of crustal blocks in the region has occurred in stages over the Cretaceous and Tertiary periods (Stephenson and Lambeck, 1985; Raymond, 2002). The LFB forms the basement of large alluvial basins such as the Murray Darling Basin (MDB).

Structurally, the basement geology comprises LFB sediments and volcanics within the north trending Bogan Gate Synclinoral Zone. The western part of this belt is known as the Western Girilambone Anticlinoral Zone and is comprised largely of sediments of the Goonumbla Volcanic Zone (GVZ) together with volcanics and intrusives (MER, 2006).

The Late Ordovician Goonumbla Volcanic Group is part of a volcanic belt within the LFB, which extends through central western NSW with an approximately north-south trend. This group is comprises andesitic lavas and volcanogenic sandstone, conglomerate and some limestone that were deposited in a submarine environment (located within the Ordovician Sediments and Mafic Volcanics within and east of the Study Area, Figure 6). The sequence is overlain to the north by Late Silurian sedimentary rocks and to the west by Devonian sedimentary rocks (Figure 6).

4.4.2 Volcanic Strata

The Orange Basalt of Tertiary age underlies Mt Canobolas (near the township of Orange, Figure 6) and surrounding areas to the east of the Study Area (Tertiary units are not represented on the Regional Geology map, Figure 6; refer to WRPA GS44 on Figure 4 for location). These fractured Tertiary basalts are the youngest consolidated rocks in the catchment. The Tertiary rocks are more or less flat-lying and occur as cappings on the Palaeozoic rocks.

Also prominent are large areas of granite and granodiorite (felsic) intrusions of Devonian age located in a north-south trending zone east of the Study Area (Figure 6).

4.4.3 Regional Structural Features

Fault structures in the region have been described and mapped in detail by SRK (2000). The Study Area lies within the north-south trending Early Ordovician to Early Devonian Girilambone Anticlinorial zone (refer to Figure 7 for regional structures). The Project Area lies within an Ordovician intrusive volcanic complex immediately west of the Parkes Fault.

SRK (2000) reports that the Parkes Fault structure has been the locus of several phases of deformation between the middle Ordovician and Carboniferous, resulting in the development of complex folding and fault arrays. Movements on the zone were initially oblique sinistral reverse during the Late Ordovician and subsequently oblique dextral reverse. The Late Ordovician copper-gold porphyries found at NPM occur within a relatively undeformed and low-grade block of intermediate volcanics and sediments (SRK, 2000).

Shallow-marine to continental sediments and felsic volcanic rocks of the Silurian to Devonian unconformably overlie older strata and intrusions in the west and are faulted against them within the Parkes Fault Zone to the east (Figure 7). These formations are relatively undeformed and dip gently to the west.E26 comprises two ore bodies separated by a fault complex that trends WSW-ENE. This hydraulic separation is apparent in pre-mining groundwater levels as well as those observed in the post mining drawdown, with steep hydraulic gradients to the south of E26 (MER, 2006).

4.5 Local Geology

The mapped geology of the Study Area is presented in Figure 8. This figure indicates that the majority of the Study Area is covered by a veneer of unconsolidated colluvium and alluvium of Tertiary-Quaternary age. The mapped area is predominantly underlain by the Ordovician-Devonian age rocks of the LFB.

The Northparkes deposits occur within the Late Ordovician Goonumbla Volcanic Group, located to the north and west of the town of Parkes (Figure 6 and Figure 8).

The geology of the Project Area can be divided into two rock types:

- The fresh bedrock; and
- Regolith.

Key references used for the Project Area geological information were MER (2006), NPM (2010), PB (2011), Butcher, *et al*., (*in press*), SRK (2010) and GHD (2009).

4.5.1 Bedrock

The LFB comprises metamorphosed sedimentary and volcaniclastic rocks, forming the regional bedrock. The bedrock mass is very low permeability, fractured rock, and is host to volcanic intrusions that form the ore bodies at NPM.

The NPM deposits are typical porphyry copper systems, where mineralisation and alteration are zoned around quartz monzonite intrusions. In places, the mafic monzonite intrusions are transitional to monzodiorite, diorite, and gabbro. The intrusions trend north-south and are vertically oriented. The porphyries form narrow (typically less than 50 m in diameter) but vertically extensive (greater than 900 m) pipes.

Mineralisation extends from the porphyries into their host rock, forming mineralised zones (or “haloes”) around each ore body. Sulphide mineralisation occurs in quartz stockwork veins, as disseminations and fracture coatings. The highest ore grades are generally associated with the most intense stockwork veining. All of the NPM deposits are cross cut by late faults/veins filled with quartz-carbonate and base sulphide minerals. The associated sericite alteration extends up to 10 m from the fault zone (Butcher et al., *in press*).

The Goonumbla Volcanics at NPM have undergone little deformation, with gentle to moderate bedding dips as a result of regional folding. The dominant structure observed to date in the Northparkes area is the Altona Fault, an east dipping, low angle-thrust fault, which truncates at the top of E48 deposit, about 50 m below the surface (NPM, 2010b).

An upper oxidised zone of bedrock, referred to as saprock, overlies the mineralised bedrock. An “Oxide Transition Zone” (OTZ) occurs between the more oxidised saprock and the underlying fresh bedrock. Saprock is distinguished from the overlying regolith by its greater rock strength, determined when drilling refusal is reached (Raymond, 2002). Saprock was intersected at the site between approximately 20 m and 50 metres below ground level (mbgl) at the Project Area, with thicknesses ranging from 7 to 45 m across the Project Area (GHD, 2009). The saprock unit shows stronger chemical weathering over the intrusive units.

The frequency of fracturing across the site is variable. Fracturing in the bedrock at NPM appears to be near vertical and striking east to west (for example, near E27); whereas fracturing is less frequent near E22, where northerly trending open structures are evident (MER, 2006). The fractures at E22 tend to have a greater occurrence of carbonate or zeolite infill when compared to E27 where they tend to be cleaner and more open (Raymond, 2002).

4.5.2 Regolith

A regolith developed over the bedrock of the Study Area. The regolith, or "saprolite", is a highly chemically altered unit of the upper bedrock, comprising clays and sediments. Saprolite is weaker than the underlying saprock unit (which is distinguished from saprolite by drilling refusal).

Overlying the saprolite are transported sediments (alluvium and colluvium), which blanket the Project Area to depths of 30 m or more (reported as 10 to 40m on a regional scale; GHD, 2009). Alluvium and colluvium are generally not classified as Regolith; however, for consistency, Golder has adopted the naming convention of the recent studies (MER, 2006; GHD, 2009; PB, 2011). In this study, the term 'Regolith' applies to all weathered and transported materials overlying the fresh bedrock. Saprolite forms the base of the Regolith profile. This profile is collectively called a Regolith by NPM because of its heterogeneous nature and gradational weathering profile (PB, 2011). The Regolith is mapped on Figure 8 as Regolith and Tertiary-Quaternary deposits.

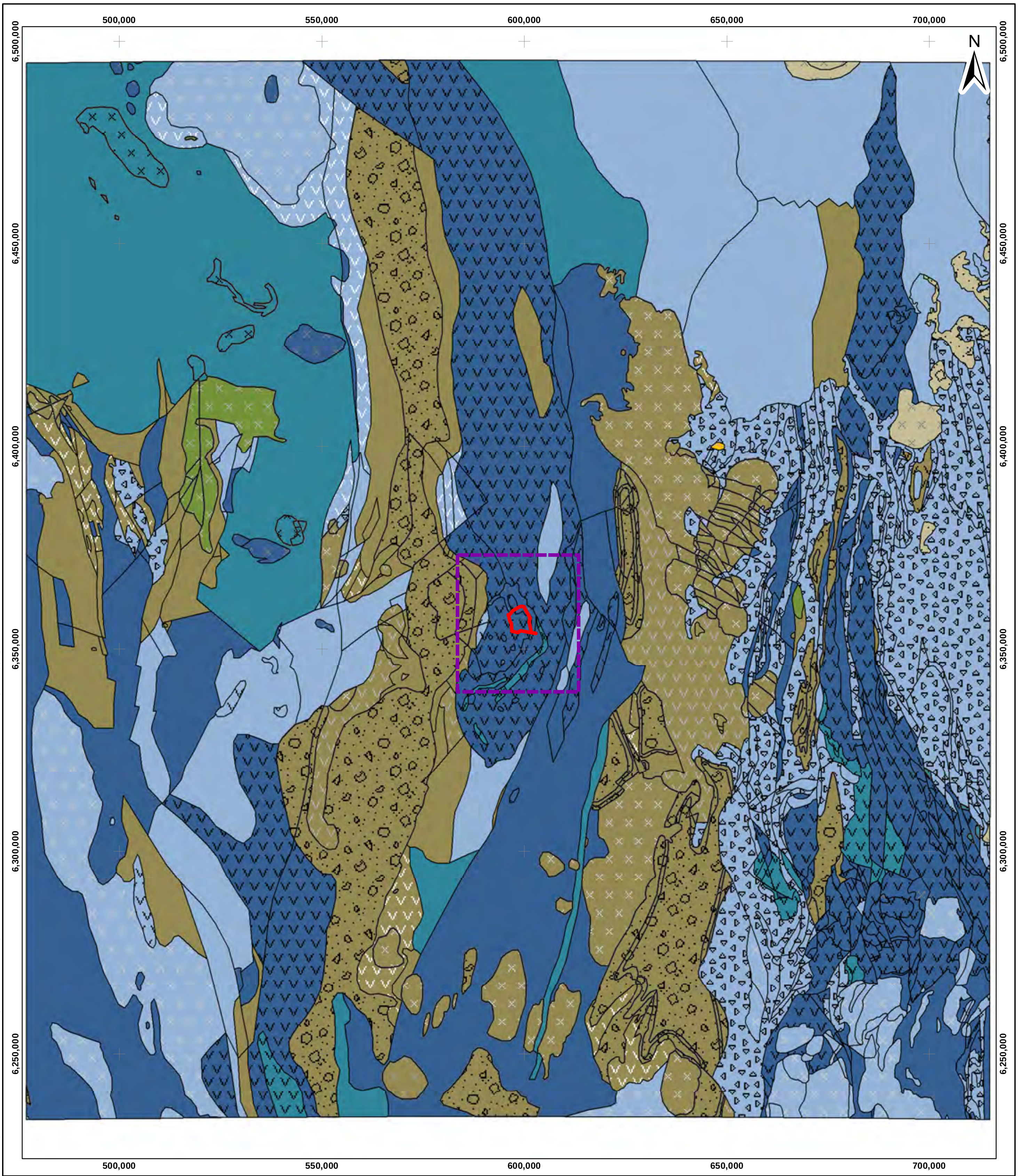
The Regolith is generally absent in the high ground to the south where Ordovician bedrock outcrops form the high relief (Figure 8) and reaches maximum thickness in the valley in the area of Wombin State Forest to the north of the mine (refer to Figure 4). These materials comprise surficial soils, clays, silts and occasional sands of Tertiary and Quaternary age. The Regolith is composed of the weathering products of the underlying rocks, and transported weathering products of similar rocks from higher slopes.

The Regolith originally capped the Northparkes ore deposits. At the Project Area the Regolith is composed of a thin surface layer of soil underlain by clays, which thickens considerably over mineralised zones and shows increased mottling at depth (PB, 2011). Across the Project Area, the Regolith-saprolite unit varies in thickness from 5 m to more than 40 m (MER, 2006). The Regolith is thinnest in the south-eastern corner of E22 pit (Raymond, 2002).

Above the mineralised zones, the lower Regolith is enriched in copper oxide minerals by chemical weathering, whereas the upper Regolith was gold rich and copper poor. In the thicker sequences of Regolith, the base is usually characterised by the presence of small iron and manganese nodules that are characteristic of the water table in semi-arid climates (PB, 2011). During the course of pit development, these zones were removed and are now evident as palaeochannel features or zonal weathering in the pit walls (MER, 2006).

4.5.3 Local Structural Features

Hydraulic testing undertaken by Coffey (1993) suggested the presence of a fault structure running approximately east-west to the south of E26 (the most southerly exploited ore body). This fault was inferred to be a barrier to groundwater flow due to the elongation of groundwater drawdown contours in this orientation.



NORTHPARKES MINE GWA

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REGIONAL GEOLOGY

NOTES

Regional Geology has been sourced from Department of Mineral Resources (DMR, 1999)

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LEGEND

Stratotectonic Geology

Tertiary
- Intrusive -Unspecified

Jurassic-Cretaceous
- Intrusive -Unspecified
- Sedimentary -Quartzose or Unspecified

Permian
- Sedimentary -Molassic
- Intrusive -Unspecified

Devonian
- Intrusive - Felsic
- Intrusive - Unspecified
- Sedimentary -Quartzose or Unspecified
- Sedimentary -Molassic
- Volcanic -Felsic
- Volcanic -Mafic
- Volcanic -Mixed / Bimodal

Silurian-Devonian
- Intrusive -Mafic
- Volcanic -Mafic
- Volcanic -Felsic
- Sedimentary -Volcaniclastics
- Intrusive -Felsic
- Sedimentary -Quartzose or Unspecified

Ordovician
- Volcanic-Mafic
- Intrusive -Unspecified
- Sedimentary -Quartzose or Unspecified

Cambrian-Silurian
- Intrusive - Mafic
- Sedimentary - Quartzose or Unspecified
- Volcanic-Mafic
- Study Area
- Project Area

0 4.5 9 18 27 36 45 Kilometers

SCALE (at A4) 1:1,300,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
CHECKED:	RS

FIGURE 6

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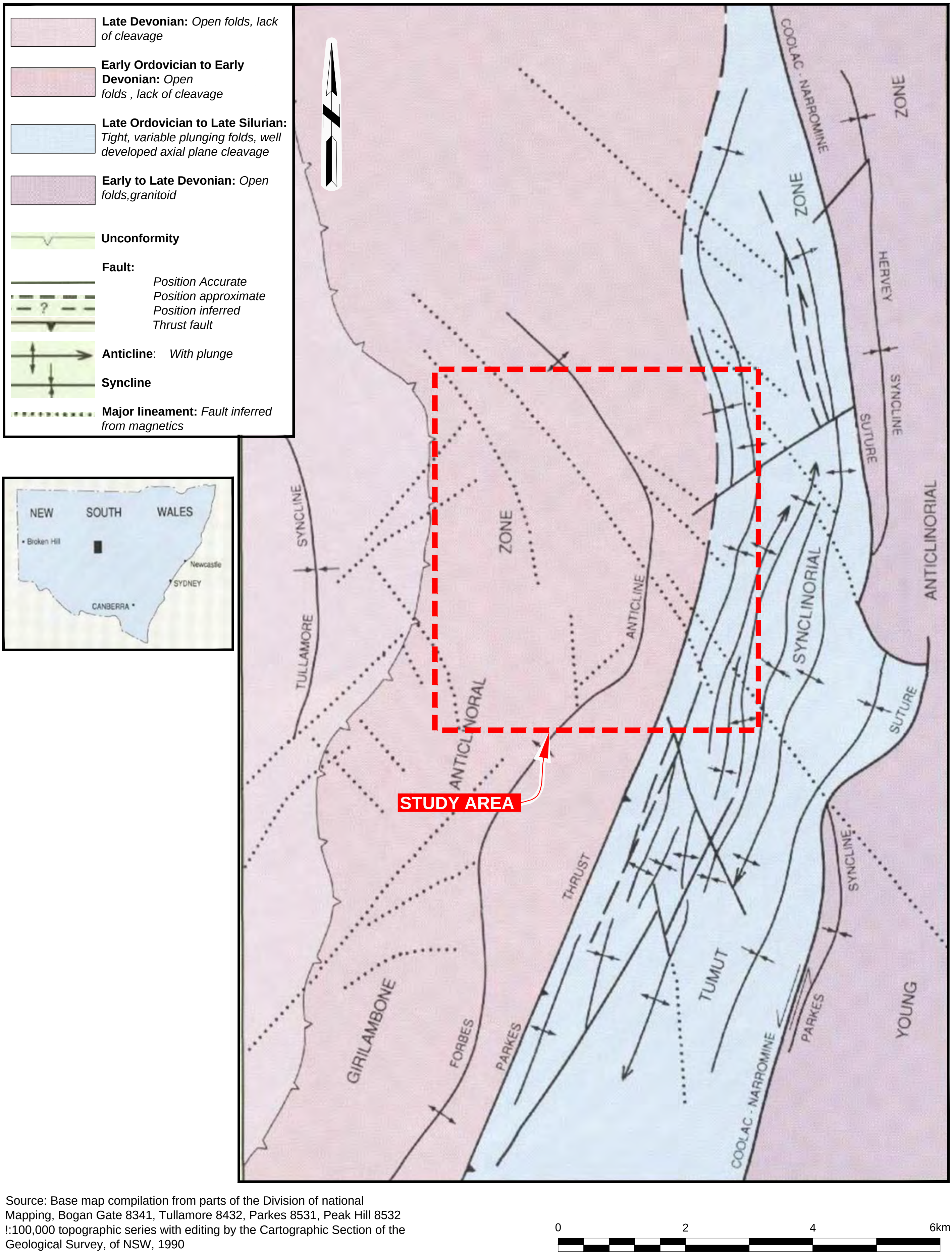
File Location: \\SYD1-S-FILE02\Jobs\hyd\2011\117626007_Umwelt_NorthParkesMine\Technical Doc\GIS\Project\Rev0\117626007_007_R_F010_RegGeol-Rev0.mxd

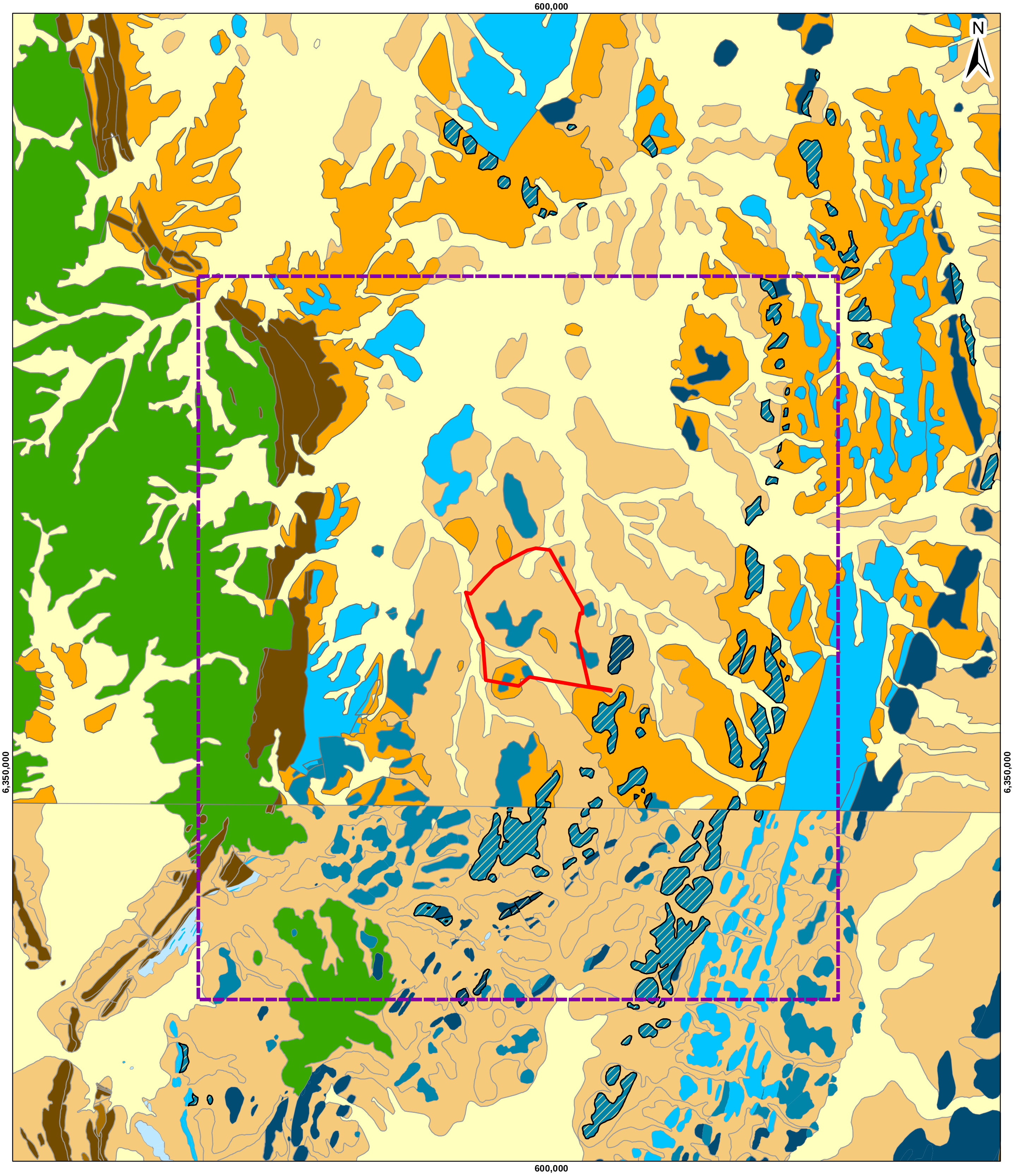


Source: Base map compilation from parts of the Division of national Mapping, Bogan Gate 8341, Tullamore 8432, Parkes 8531, Peak Hill 8532 !:100,000 topographic series with editing by the Cartographic Section of the Geological Survey, of NSW, 1990

Golder Associates www.golder.com GOLDER ASSOCIATES PTY. LTD.	CLIENT: UMWELT (AUSTRALIA) PTY LTD		PROJECT: NORTHPARKES MINE				
	DRAWN BY: HC	DATE: 19.04.2013	DRAWING TITLE: STRUCTURAL GEOLOGY				
	CHECKED BY: HW	DATE: 19.04.2013					
	SCALE: AS SHOWN	SHEET SIZE: A4	PROJECT No: 117626007	DOC No: 007	DOC TYPE: R	FIGURE No: F007	REVISION: 0

FIGURE 7

Xref: GAP_LOGO-A3.dwg; structure scale.jpg;
Plot Date: 19 April 2013 Time:1:22:16 PM By: Campbell, Helen Path: J:\hyd\2011\117626007_Umwelt_NorthParkesMine\Technical Doc\CADD\FIGURES - File Name:117626007-007-R-F007-REV0.dwg



NORTHPARKES MINE GWA

UMWELT (AUSTRALIA) PTY. LTD.

LOCAL GEOLOGY

NOTES

Geology has been sourced from two separate maps:
- Forbes 1:250,000 Geological Sheet (AGSO, 2000); and
- Narromine 1:250,000 Geological Sheet (GSNSW, 1972)

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LEGEND

- Project Area
- Study Area
- Goonumbla Volcanics
- Quarternary/Tertiary Alluvium
- Quarternary/Tertiary Colluvium
- Quarternary/Tertiary Regolith
- Jurassic Clastic Sediments
- Devonian Volcanics
- Devonian Clastic Sediments
- Silurian Volcanics
- Silurian Chemical/Clastic Sediments
- Ordovician Volcanics
- Ordovician Chemical/Clastic Sediments

0 0.75 1.5 3 4.5 6 7.5 Kilometers

SCALE (at A4) 1:250,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
CHECKED:	RS

FIGURE 8

Golder Associates

File Location: \\SYD1-S-FILE02\Jobs\hyd\2011\117626007_Umwelt_NorthParkesMine\Technical Doc\GIS\Project\Rev0\117626007_007_R_F010_LocGeol-Rev0.mxd

4.6 Hydrogeological Setting

4.6.1 Groundwater Availability and Use

A search of the NOW registered water bores showed a total of 185 bores in the Study Area that have been installed since 1920. These bores indicated an exploitation of this oxidised zone and underlying metavolcanics.

From the existing bore data, 52% of the registered bores are registered as stock and irrigation supply bores, and 23% as domestic. The available data indicates that none of the water bores were completed within the regolith. Individual bore yields provides an indication of the production capacity of the aquifers. The average reported bore yield for GMA 811 is < 1 L/s (Golder, 2010a).

The LFB is considered a poor groundwater resource. The fold belt rocks, which are the enclosing bedrocks to the Upper Lachlan Alluvium, generally have low yielding bores due to their low permeability and low fracture density and therefore low in porosity and storage capacity (fractures predominantly clay filled). Bores are typically low yielding (domestic water supplies) and do not tap into consistent and extensive aquifer systems.

The Project will operate utilising water obtained from the PSC borefield and water licences (Table 1). There is no proposed increase in groundwater abstraction for the Project.

4.6.2 Local Groundwater Management Units

The complex folding, faulting and metamorphism of the LFB has formed the basement of the large alluvial basin, such as the MDB. Groundwater is an important source of water across the MBD with particular importance in specific areas. There are 20 major groundwater management units that represent 75% of the groundwater extraction in the MDB. The MDB is also subdivided into 19 surface water resource regions, including the Macquarie-Castlereagh Rivers Basin, which forms the setting for the regional hydrogeology of the Study Area (Refer to CGM Sections for detailed local hydrogeology in the Study Area; Section 5.1).

There are two GMAs in the Study Area. As shown on Figure 2 and Figure 4, the GMA 811 (LFB) surrounds the Upper Lachlan Alluvium and mostly located to the North and South of the Project Area. There is a small zone of GMA011 (Upper Lachlan Alluvium) to the south of the Study Area. This GMA (811) covers the bedrock and regolith encountered in the Project Area. It is considered that GMA811 (LFB) is the most relevant to the Project:

Table 9: GMAs within the Study Area

GMA number	GMA Name	GMA Area (km^2)*	GMA Type	Aquifers
GMA811	Lachlan Fold Belt	210,585	Fractured Rock	Fractured rock

*Value for the full area of the GMA, not limited to the Study Area

There was no current Water Sharing Plan (WSP) in operation in the Study Area.

Characteristics of the hydrogeology relevant to the GWIA are discussed in the following sections, starting with a discussion of the regional hydrogeology along with a discussion of the sources of data.

4.6.3 Regional Hydrogeology

NPM is located in the Upper Bogan Valley, within the LFB sequence, a consolidated, bedrock sequence overlain by unconsolidated alluvium. The LFB is generally considered to be a poor aquifer (Golder ,2010a). The alluvium in the Upper Bogan River catchment is also considered to be a poor aquifer (Raymond, 2002).

NPM is located outside the recognized groundwater intake area of the Great Artesian Basin to the north, and there is no evidence for connection with the Lachlan alluvial groundwater system to the south. Therefore, groundwater at NPM is thought to only contribute to local aquifers in the Upper Bogan valley, but the evidence is that this contribution is minor (Raymond, 2002).

The regional groundwater resource is contained within the fractured rock aquifers of the LFB complex. Groundwater resources in the region are generally limited due to the low potential for rainfall infiltration through surficial silts and clays, and the poor storage and transmission characteristics of the deeper strata. A groundwater bore installed in well-fractured, highly permeable zones may appear to have a good water supply; however the aquifer sustainable yields are unpredictable and often low to very low.

The regional water table prevails at a depth of about 40 mbgl and groundwater quality is variable but mostly brackish to saline (MER, 2006). The regional groundwater is assumed to flow in a north-westerly to northerly direction, based on trends interpolated by MER (2006) and PB (2003). This trend is consistent with surface drainage away from the regional catchment divide, which is located south of the Study Area.

Overlying the LFB are inactive quaternary alluvial-colluvial plains and residually weathered bedrock, some of which host minor unconsolidated aquifers (Figure 6). Due to the general poor water quality of the LFB and regolith, the groundwater use is predominantly for stock feeding, if it is utilised for any purpose.

4.6.4 Hydraulic Parameters

Permeability in the regolith is predominantly intergranular controlled (i.e. via primary porosity) and is inhibited by the clayey nature of the sediments (MER, 2006). Testing showed that the Regolith has a significantly lower hydraulic conductivity range than the underlying weathered bedrock. Below the Regolith, host rocks have negligible intergranular (primary) porosity; the permeability of the bedrock rock units is predominantly fracture-controlled (i.e. via secondary porosity).

The strata encountered in the Project Area were described in the Local Geology (Section 4.5). The results from a series of hydraulic tests in the Project Area was most recently discussed by PB (2011) and previously summarised in MER (2006) for analyses undertaken by:

- Australian Groundwater Consultants (1984);
- Golder (1987);
- Mackie Martin and Associates (1988);
- Coffey (1993);
- KH Morgan and Associates (1997);
- K&H Construction (1999; unreferenced);
- Australia Tailings Consultants (2000);
- Raymond (2002);
- PB (2003); and
- Knight Piésold (2008; reported by GHD, 2009).

The types of hydraulic testing undertaken in the above studies included both field and laboratory tests. Field tests included: infiltrometer, falling head, slug, pumping and recovery, packer, and airlift tests. Laboratory tests included triaxial permeability and falling head analysis. Reported test results for hydraulic conductivity (K) from the previous studies are summarised in Table 10 for each identified strata with hydraulic conductivity values reported in metres per second, or m/s.

Determining hydraulic parameters for fractured media is difficult due to the anisotropic nature of the secondary porosity characteristics. Pumping tests conducted in an open cut area returned hydraulic estimates that reflect the tight, low permeability characteristics of the bedrock: storativity is approximately 10^{-3}, hydraulic conductivity (K) varies 10^{-5} to 10^{-8} m/s, and transmissivity (T) varies 0.01 to 6.2 m^2/day (Raymond, 2012). Storativity and specific yield data were not available for individual strata. However, numerical models developed for the Project Area by PB (2003) and MER (2006) provided calibrated values. These are discussed and summarised in Section 5.2 (Numerical Groundwater Model).

Regolith

An additional stratum ("transported regolith") was previously reported where distinct changes in permeability were observed in the regolith up to 6 m depth, and has been included in Table 10. Transported regolith refers to red-coloured surficial soils and clays that exhibit a higher hydraulic conductivity (approximately $3x10^{-10}$ m/s to $6x10^{-6}$ m/s) than the underlying Regolith unit, which dominantly comprises practically impermeable clays ($3x10^{-12}$ m/s to $8x10^{-10}$ m/s). The large range in hydraulic conductivities for the upper part of the regolith is due to the heterogeneity expected in the upper part of the regolith where weathered and transported material dominates (PB, 2011).

Tests carried out by PB (2003) indicated that infiltration of the surface soils varied between 7.1 and 41.1 mm/day. These rates have not been corrected for evaporation (4 mm mean daily evaporation; BOM, 2012) and so were slightly overestimated.

Bedrock

Beneath the Regolith, the fractured saprock has a higher range of hydraulic conductivity values (approximately $8x10^{-10}$ m/s to $7x10^{-6}$ m/s). Fracturing, and therefore permeability of the bedrock decreases with depth, to as low as $1x10^{-13}$ m/s in deep unweathered hard rock strata (MER, 2006). Raymond reports that deep saprolite is usually in hydraulic continuity with the fractured rock system, which draws on storage in the overlying regolith; however, the extent and rates of connectivity have not been discussed in detail in the previous studies.

Individual mineralised haloes, which occur in the bed rock as altered contact zones around vertical intrusions, are considered to exhibit characteristics separate from the bedrock. The fractured haloes exhibit with high fracture connectivity from structures oriented parallel to the pit wall. These structures locally represent a pathway for enhanced groundwater flow, but have low fracture connectivity and poor hydraulic connection with regional groundwater flow (Raymond, 2002). Although each halo zone is separated, each displays similar characteristics to one another, where permeability is principally in the vertical direction (PB, 2003). Increased fracturing in the mineralised zones has resulted in increased hydraulic conductivity (approximately 2x10-6 m/s to 5x10-8 m/s) in comparison to the bedrock. The hydraulic conductivity for the mineralised zones decreases notably from about 125 m depth (Table 10; PB, 2003)

Low rates of seepage have been observed in the mine workings (averaging approximately 1 ML/day [MER 2006]), as discussed further in Section 5.2.8 and shown in Figure 28):

- E22 exhibited no fracture seepage from pit walls until 210 m AHD and with very little seepage below this (MER, 2006). The E22 and E27 pits had an isotropic hydraulic conductivity value of $4.0x10^{-3}$ m/day;
- E26 was started as an open cut pit before underground operations commenced. Groundwater seepage into the pit was very low, although it was enhanced after periods of rainfall by shallow percolation through the regolith (MER, 2006). Subsequent underground operations have reflected a low permeability regime with low aquifer storage.

The MER (2006) model predicted E48 inflows for the NPM E48 Project. The available site records show the total dewatering rates for the combined underground operations since 2002. The individual dewatering rates for each pit were not available. Groundwater conditions at E48 have therefore been inferred from bore investigations. MER (2006) concludes from these investigations that, of the 98 bores drilled into this area, only a handful encountered water bearing zones below 30 to 40 metres below ground level (mbgl), resulting in a low potential storage in this area.

Table 10: Summary of Hydraulic Conductivity (K) Values from the Previous Studies

Strata	Sub-Strata	Depth (mbgl)	K (m/s)		Pump Tests in Open Cut (Raymond, 2012)		
			Range	Mean	S (-)	K (m/s)	T (m^2/day)
Regolith	Transported Regolith	0 – 6	2.7×10^{-10} – 5.6×10^{-6}	7.3×10^{-7}	-	-	-
	Regolith and Saprolite	2 – 36	3.1×10^{-12} – 7.7×10^{-10}	2.0×10^{-10}	-	-	-
Bedrock	Saprock (including OTZ) [(1)]	23 – 150	7.7×10^{-10} – 7.4×10^{-6}	5.0×10^{-7}	~10^{-6}	10^{-8} – 10^{-5}	0.01 - 6.2
	Unweathered	0 – 592	1.2×10^{-13} – 7.4×10^{-6}	7.4×10^{-7}			
	Mineralised Haloes	50 – 125	-	2.3×10^{-7}			
		>125	4.6×10^{-8} – 1.1×10^{-7} [(2)]	-			

Notes:

(1) OTZ = oxide transition zone, the zone referred to in the previous studies as the transition zone between the fresh bedrock and the saprock (MER, 2006; PB, 2003, Raymond, 2002). Note that in the previous studies, the OTZ has been categorised under saprock, whereas in this study the OTZ is considered part of the deep bedrock.

(2) Denotes test results were not available and values were derived from model calibration (MER, 2006).

Table 11: Summary of Available Ore Body Hydraulic Parameters (Raymond, 2002; MER, 2006)

Ore Body	Mine Type	Depth Ranges	Hydraulic Conductivity *	Transmissivity	Specific Storage (S_s)	Specific Yield (S_y)	Observed Seepage from Bedrock into Mine Workings	
			(m/s)	m^2/day			Rate (ML/day)	Elevation (m AHD)
E20	-	23.1 – 150	$2.1x10^{-7}$	-	-	-	–	–
E22	Open Cut	40 – 99	–	0.1 – 0.3	$7.8x10^{-8}$ – $2.3x10^{-7}$	-	0.07 – 0.25	210
E26	Underground	20.7 – 592	$1.2x10^{-8}$ – $2.3x10^{-6}$	0.07 – 122	$1x10^{-5}$ – $6x10^{-3}$	$5x10^{-4}$ – $5x10^{-2}$	0.22	224
E27	Open Cut	18.3 – 301	$6.3x10^{-10}$ – $4.8x10^{-6}$	0.02 – 6.2	$4.3x 10^{-3}$	-	0.1 – 0.5	205

4.7 Groundwater Levels and Flow Direction

A number of groundwater level monitoring locations were available in the vicinity of the Project Area. These are summarised in Table 12 and the locations plotted in Figure 9. Water levels of the monitoring bores are shown in Figure 10, Figure 11, Figure 12 and Figure 13.

Groundwater level monitoring is mainly targeted in the bedrock strata, with a number of observation bores completed in both the regolith and bedrock, providing a composite groundwater level from both units. The target monitoring strata in Table 12 were interpreted by MER (2006), which differ slightly from the hydrostratigraphy interpretation in the current study (refer to Section 5.1.1) due to both: the interpretation required for the MER (2006) numerical model; and lack of construction bores for verification of screened strata for the current study. The MER (2006) water level graphs were updated by Golder for this report (Figure 12and Figure 13). The water level graphs provide an indication of the duration of monitoring.

The water levels of groundwater in the regolith range from approximately 233 to 273 m AHD, in boreholes MB2 and MB6 (respectively). Depending on location and ground elevation, this ranged from 7 to 53 mbgl in boreholes Long Paddock and MB6 (respectively). Monitoring bore MB7, interpreted to be in the regolith, and was dry at 24 mbgl.

The water levels of the bedrock (including the transition from regolith to bedrock) range from approximately 220 to 261 m AHD, in boreholes MB11 and MB17 (respectively). Depending on location and ground elevation, the groundwater level is equivalent to 9 to 58 mbgl in boreholes W1 and P149 (respectively).

Pre-mining water levels in 1983 were used to create a groundwater level contour map representing the saprock zone (PB, 2011). The contours show the regional groundwater flow is in a northerly, down-valley direction towards Wombin State Forest (Figure 14; PB, 2011).

Cessation of monitoring is often an indication that the observation bore has been destroyed in the course of mining, however, some bores are semi-continuously monitored (W13, W14, W15; MER,2006). A summary of relevant points from groundwater level monitoring include:

- The monitoring bores listed in Table 12 have been sampled at roughly 6 monthly intervals. At this frequency of sampling, it is improbable that rainfall recharge events would be detected;
- MER (2006) reported that from the approximate start of mining groundwater levels were seen to respond to the dewatering, particularly in the Regolith / Bedrock composite observation bores and some delayed response in the Bedrock observation bores (Figure 13). Long term pre-mining groundwater levels were not available and it is not possible to determine the effects of sustained drought conditions over the last decade. Overall, the water levels since 2004 are generally stable. The extreme rainfall events observed in February 2010 and March 2012 (Section 4.3) do not show identifiable impacts on the water levels in Figure 12 and Figure 13. MER (2006) suggest there may be a lag in response to rainfall recharge by as much as 2 years;
- Observation bores located in close proximity to the tailing storage facilities (TSF), TSF1 and TSF2, (regolith bores: MB1 to MB6 inclusive and regolith / bedrock bores: W14 and MB8) all show a pronounced groundwater level increase that is likely to be a response to the TSF;
- Despite their close proximity to pit E27, the above mentioned bores that are also in close proximity to TSF1 and TSF2 do not show the effects of dewatering. This may be a result of the steepness of the drawdown cone and zone of influence around each pit, or discharge to the pit could be offset by recharge from the TSF;
- Groundwater levels in the alluvium / regolith in observation bores towards the southeast (up-gradient) of the Project Area (Long Paddock, Wright, Hillers; Figure 10) do not show significant impacts from dewatering. Water level changes in these bores cannot be attributed to similar changes observed in the mine bore water levels (Figure 12 and Figure 13). However, interpretation of the up-gradient bores is constrained by the limited sampling frequency, and pre-mining groundwater levels are not available; and

- Groundwater levels are generally stable after 2004 with limited additional drawdown due to continued mining. This is likely to be due to a state of equilibrium being achieved in the existing mine dewatering.

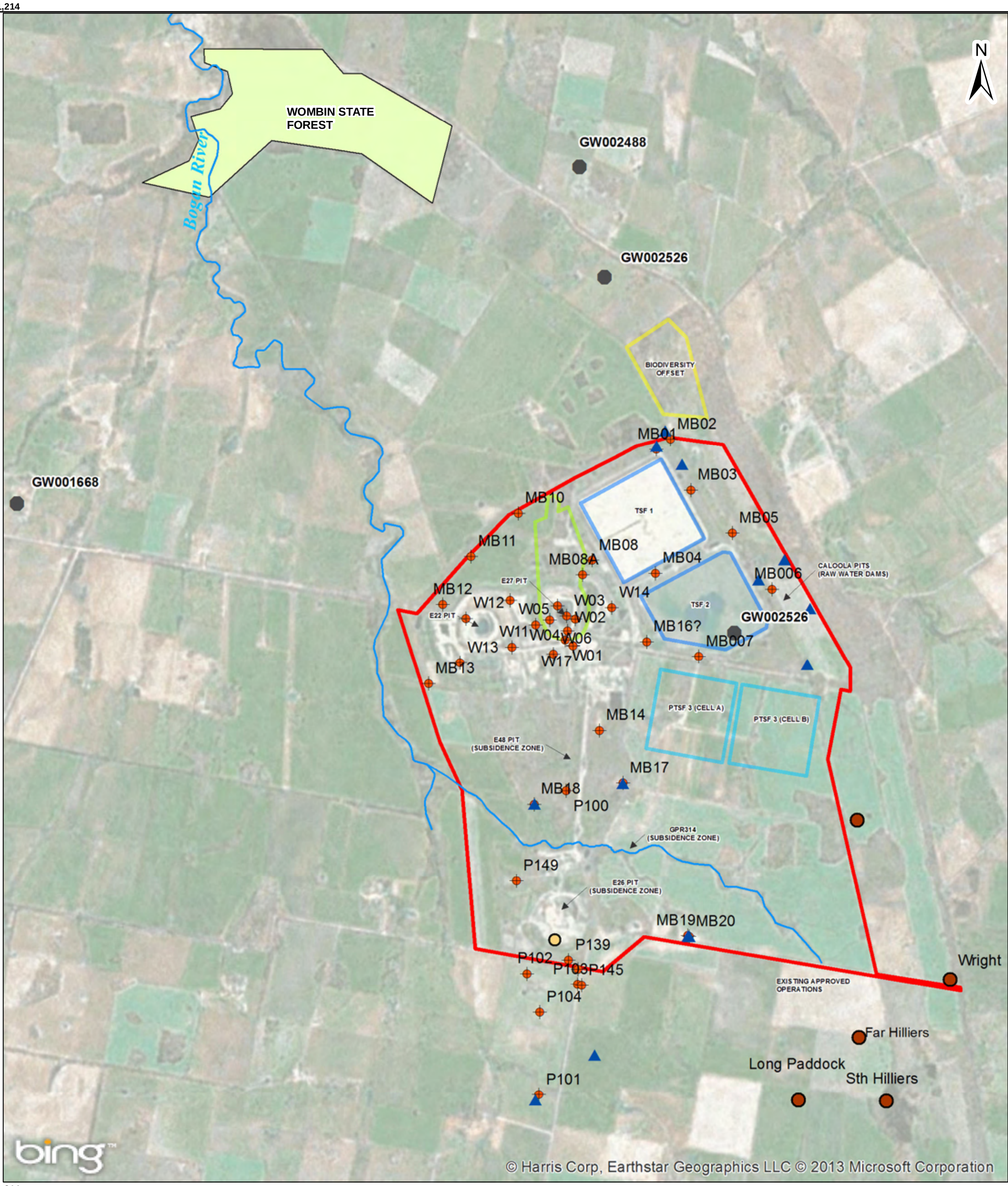
Table 12: Groundwater Monitoring Network in the vicinity of the Project Area

Bore Reference	Drilled Depth (m)	Target Monitoring Strata	Bore Reference	Drilled Depth (m)	Target Monitoring Strata
P71	130	Bedrock	MB 17	66	Regolith / Bedrock?
P100	30	Bedrock	MB 18	90	Regolith / Bedrock?
P101	24	Bedrock	MB 19	102	Regolith / Bedrock?
P102	18	Bedrock	MB 20	54	Regolith / Bedrock?
P103	24	Bedrock	W1	100	Regolith / Bedrock
P104	18	Bedrock	W2	100	Regolith / Bedrock
P139	108	Bedrock	W3	100	Regolith / Bedrock
P145	120	Bedrock	W4	120	Regolith / Bedrock
P149	90	Bedrock	W5	102	Regolith / Bedrock
MB1	-	Regolith	W6	108	Regolith / Bedrock
MB2	-	Regolith	W11	150	Bedrock
MB3	-	Regolith	W12	150	Bedrock
MB4	-	Regolith	W13	150	Regolith / Bedrock
MB5	-	Regolith	W14	150	Regolith / Bedrock
MB6	-	Regolith	W15	150	Regolith / Bedrock
MB7	-	Regolith	W16	100	Bedrock
MB008	59.55	Regolith / Bedrock	W17	60	Bedrock
MB008A	62.6	Regolith / Bedrock	W18	100	Regolith / Bedrock
MB10	-	Regolith / Bedrock	Far Hilliers	-	Alluvial / Regolith?
MB11	44.6	Regolith / Bedrock	Long Paddock	-	Alluvial / Regolith?
MB12	57	Regolith / Bedrock	South Hilliers	-	Alluvial / Regolith?
MB13	45.2	Regolith / Bedrock	Wright	-	Alluvial / Regolith?
MB14	60.15	Regolith / Bedrock	Moss	-	Alluvial / Regolith?
MB16	50.55	Regolith / Bedrock?	PDH-29	>200	Bedrock

Notes:

"-" Denotes a value that is not known.

"?" Denotes a likely, but questionable, interpretation due to incomplete data



NORTHPARKES MINE GWIA

UMWELT (AUSTRALIA) PTY. LTD.

MINE SITE MONITORING BORE LOCATIONS

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LEGEND

- Railroad
- Major Roads
- Rivers
- Wombin Forest Region
- Project Area
- Existing Approved Permits
- Tailings Storage Facilities
- Potential Tailings Storage Facilities
- Biodiversity Offset Area

Mine Site Monitoring Bores

- MB01

Now Registered Bores

- General Use
- Monitoring Bore
- NOT KNOWN
- Stock
- Test Bore

0 0.2 0.4 0.8 1.2 1.6 2 Kilometers

SCALE (at A4) 1:65,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
CHECKED:	RS

FIGURE 9

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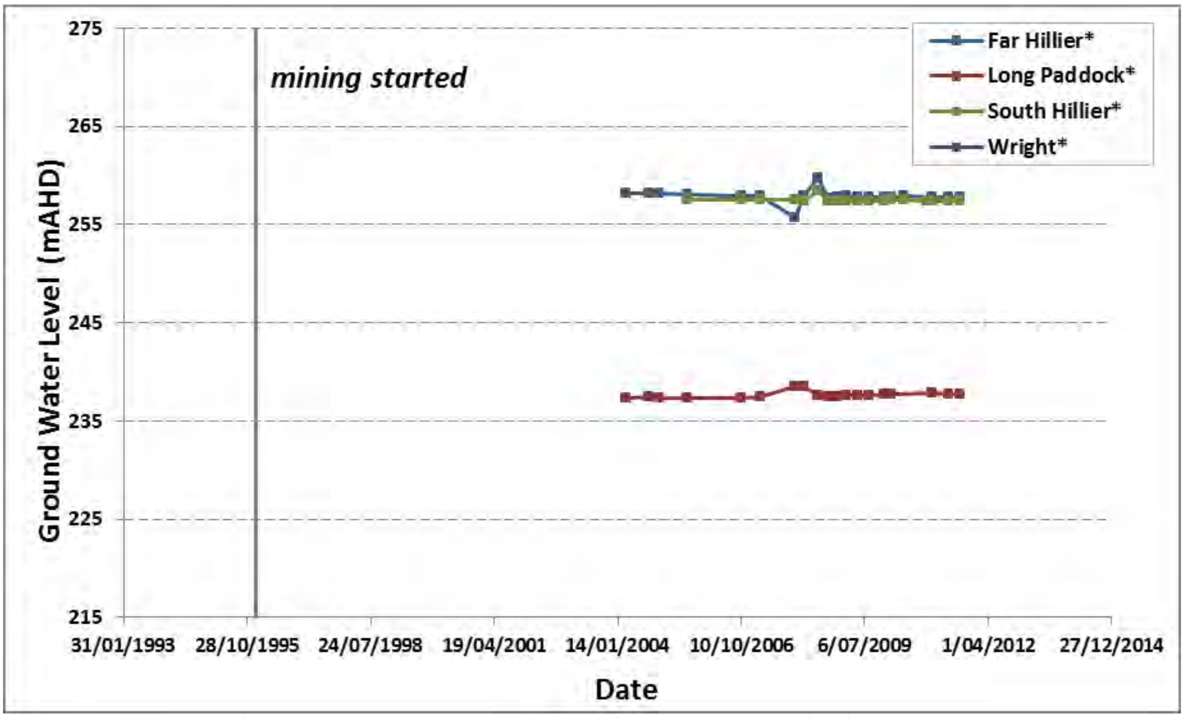


Figure 10: Monitored Groundwater Levels in the vicinity of the Project Area for Observed Alluvial and Regolith

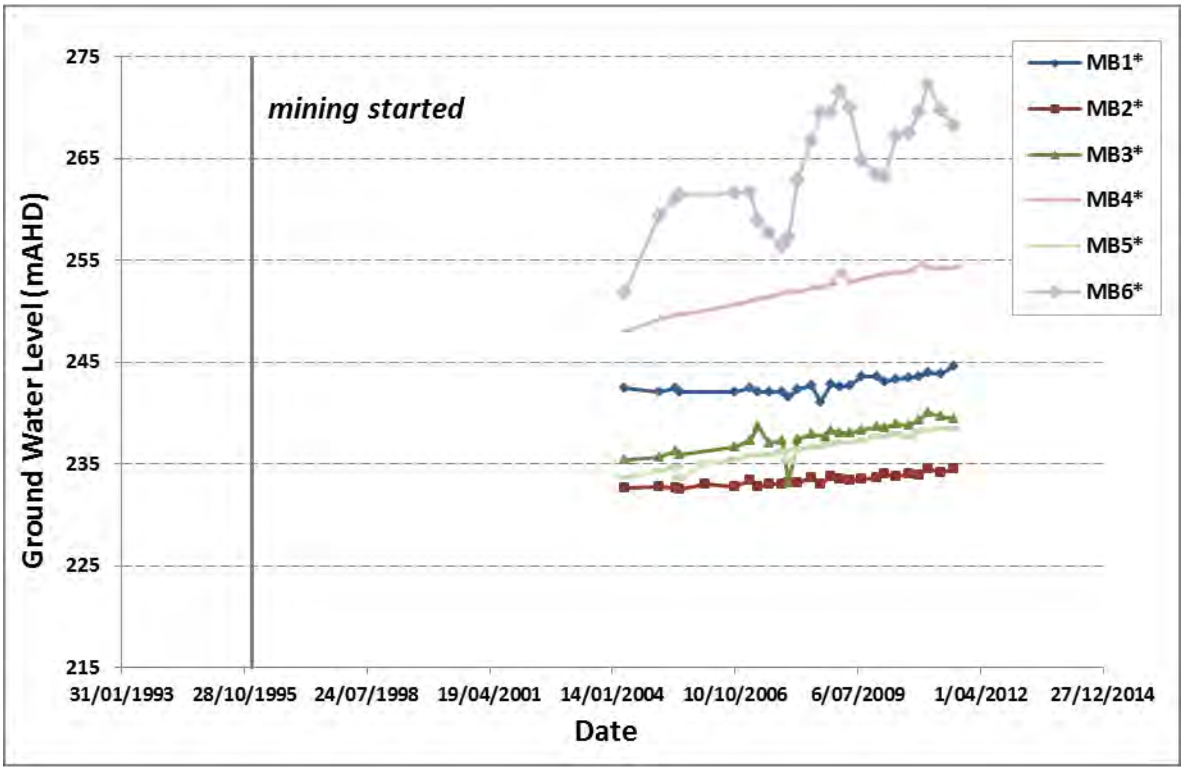


Figure 11: Monitored Groundwater Levels in the vicinity of the Project Area for Observed Regolith

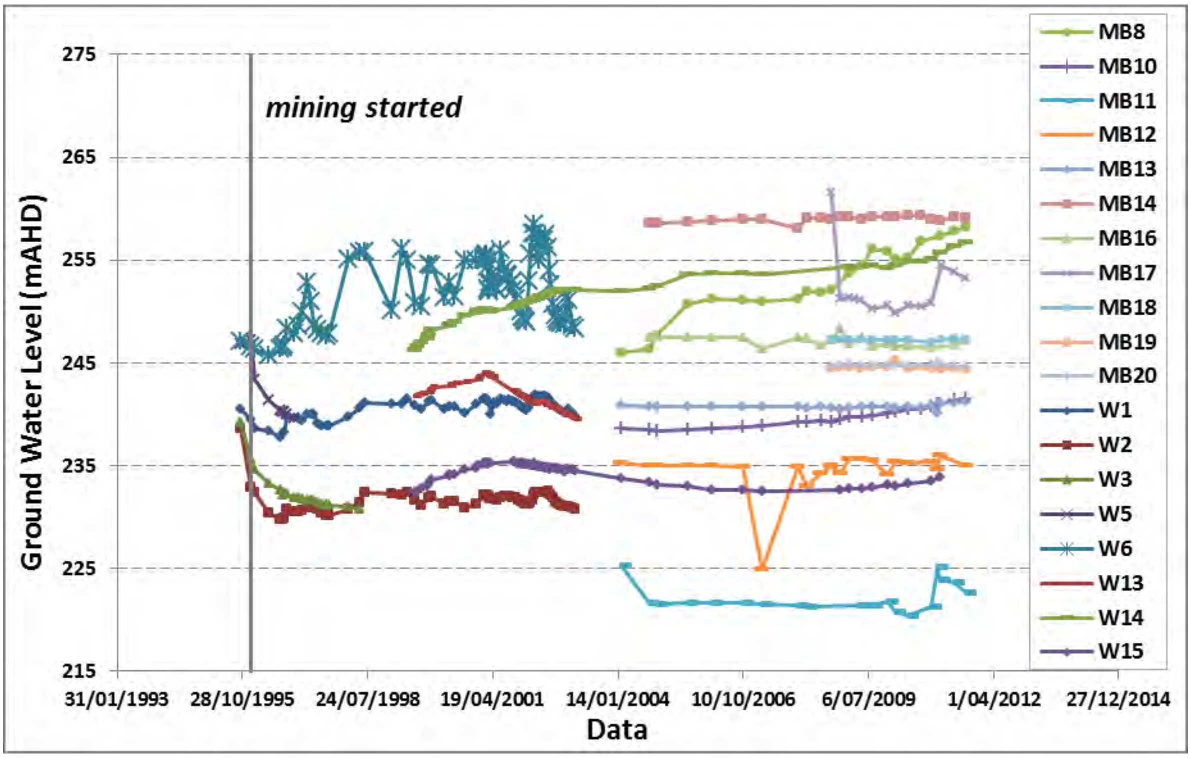


Figure 12: Monitored Groundwater Levels in the vicinity of the Project Area for Observed Regolith and Bedrock

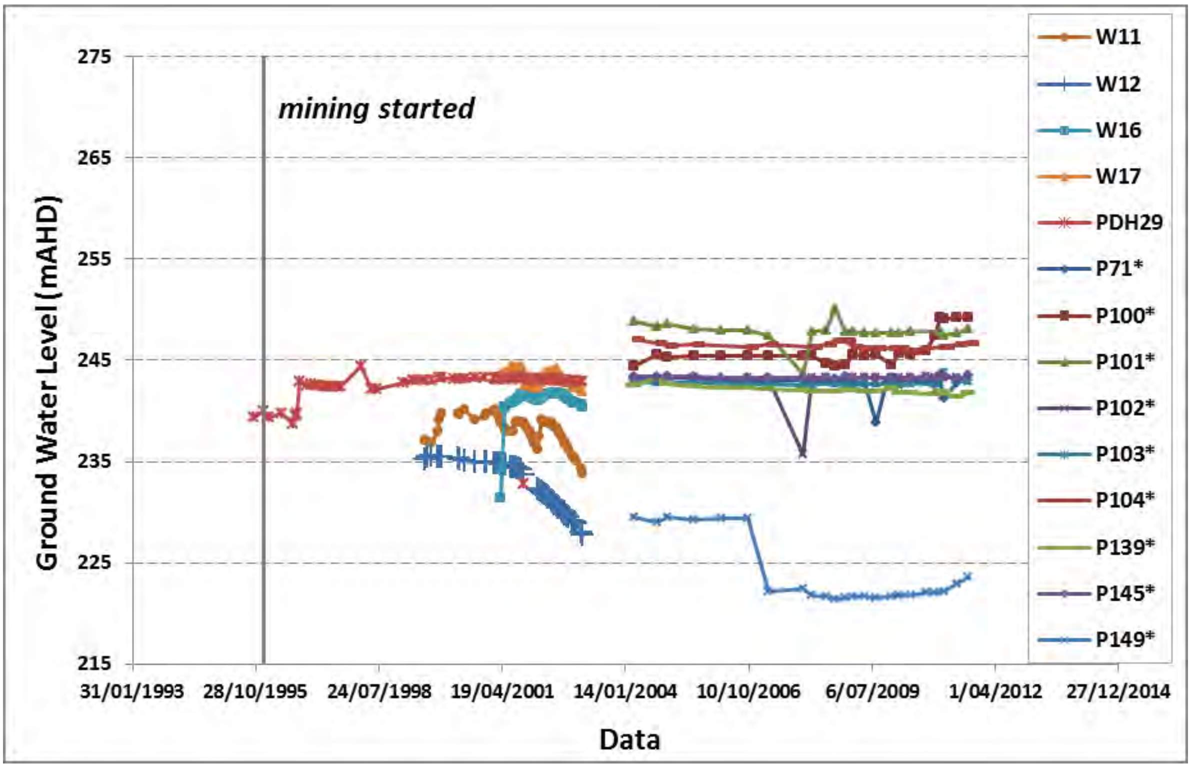
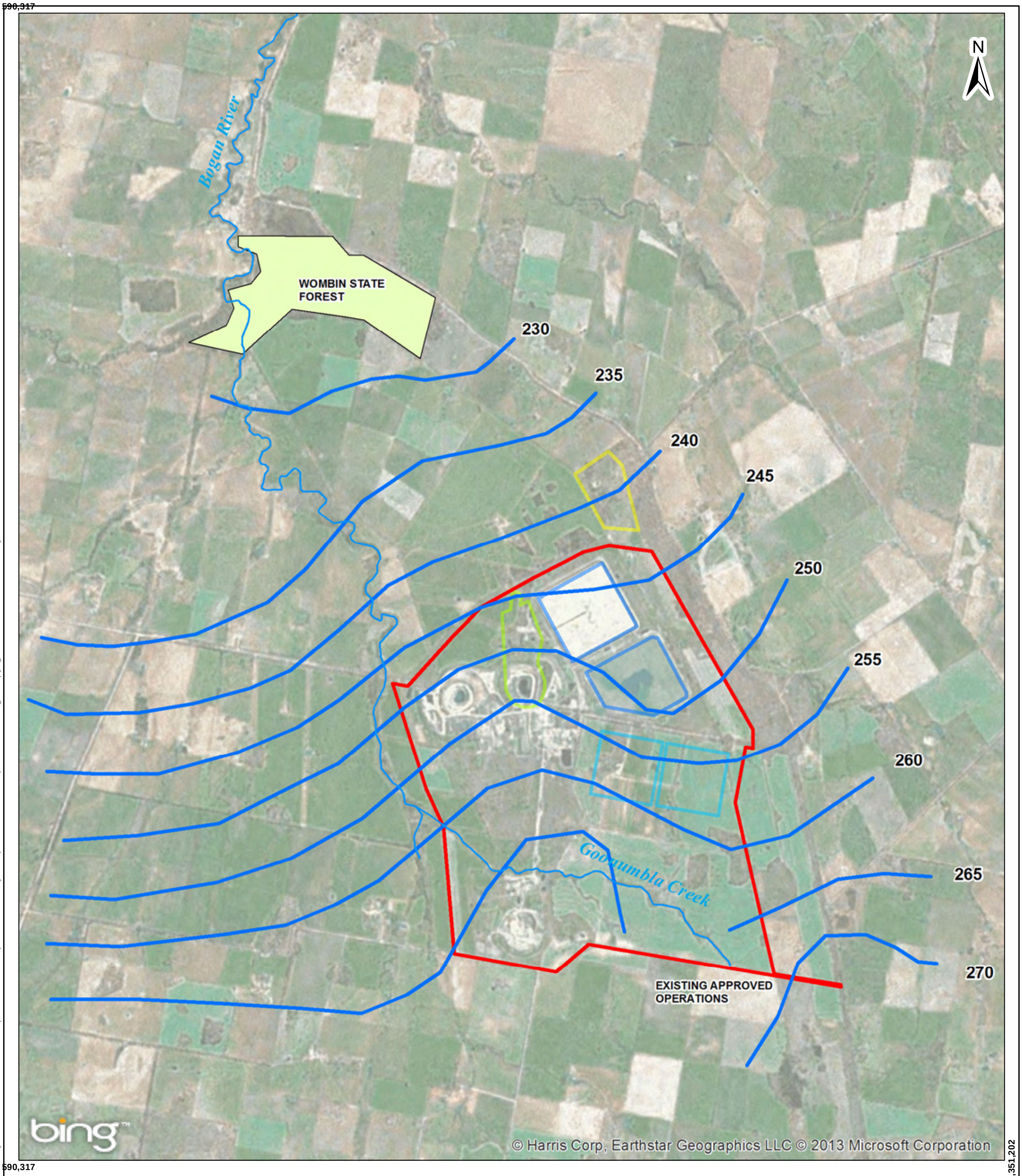


Figure 13: Monitored Groundwater Levels in the vicinity of the Project Area for Observed Bedrock



NORTHPARKES MINE GWIA

UMWELT (AUSTRALIA) PTY. LTD.

HYDROGEOLOGICAL CONTOUR MAP OF THE MINE SITE (PRE-MINING, 1983)

LEGEND

- Rivers
- Groundwater Level Contour
- Wombin Forest Region
- Project Area

Mine Layout

- Existing Approved Permits
- Tailings Storage Facilities
- Existing Approved Permits
- Biodiversity Offset Area

NOTES Source: Regional composite groundwater level contours for 1983 (Pre-Mining) interpreted by PB, 2003

0 0.25 0.5 1 1.5 2 2.5 Kilometers

SCALE (at A4) 1:80,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
CHECKED:	RS

FIGURE 14

Golder Associates

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4.8 Groundwater Quality

The mineralised rocks at NPM represent source areas for saline groundwater (Raymond, 2002). The dynamics of the hydrogeological system are still not fully-understood, and because groundwater in the Upper Bogan is moving very slowly, the system is operating at a large spatial and temporal scale. It is not known if or where this saline groundwater discharges within the Darling System.

Groundwater quality in the Study Area has been characterised through an ongoing monitoring program incorporating a monitoring well network, and opportunistic sampling from exploration boreholes (i.e. not completed as monitoring wells). The Project Area monitoring well network is presented in Figure 9 for reference. Routine groundwater monitoring includes water level measurements in local and regional piezometers, water quality sampling and monitoring of underground pumping rates for water management purposes. Further details of the groundwater monitoring program are included in Section 7.0 of this report.

The data assessment criteria were outlined in Data quality, Section 3.3.5

4.8.1 Water Quality Description

The groundwater quality assessment included analysis of pH, total dissolved solids (TDS) and major ion chemistry. Groundwater classification in terms of pH is presented in Table 13.

Table 13: Groundwater pH (Bates, 1973)

Range	Description
pH < 5	Acid
pH 5 – 7	Slightly Acid
pH 7	Neutral
pH 7 – 9	Slightly Alkaline
pH >9	Alkaline

TDS and EC are measures of the dissolved salt content. TDS is reported as a concentration (in mg/L) and is either measured by evaporating a known volume of water and weighing the residual solids, or calculated by adding the major ion concentrations.

A range of salinity classifications (based on TDS concentration) have been published in literature. Classifications are generally based on beneficial use applications (irrigation or livestock watering) and do not define the full range of TDS found in natural waters (e.g. seawater or brines). The water salinity classification adopted for this study is presented in Table 14, as adopted from Fetter (1994), with a further division of brackish water into slightly brackish and brackish (USDA, 2007).

Table 14: Groundwater classification based on TDS concentrations

Salinity Classes (modified from Fetter, 1994)	
Water type	**TDS (mg/L)**
Fresh	less than 1,000
Slightly brackish	1,000 to 3,000
Brackish	3,000 to 10,000
Saline	10,000 to 100,000
Brine	more than 100,000

EC is a measure of the conductance of a liquid and is reported in microSiemens per centimetre (µS/cm) at 25°C. There is a linear relationship between TDS and EC values for water samples (Refer to Section 4.8.3).

4.8.2 Major Ion Chemistry

AQUACHEM software (Waterloo Hydrogeological Inc, 2003) was used for graphical interpretations of the groundwater quality data as follows:

4.8.2.1 Piper Diagram

Cation and anion concentrations for each groundwater sample were converted to meq/L and plotted as percentages of their respective totals in two triangles of the Piper diagram (Figure 15). The cation and anion relative percentages in each triangle are then projected into a quadrilateral polygon that describes the water type. The Piper diagram therefore is a convenient tool to differentiate groundwater types based on the relative major ion composition.

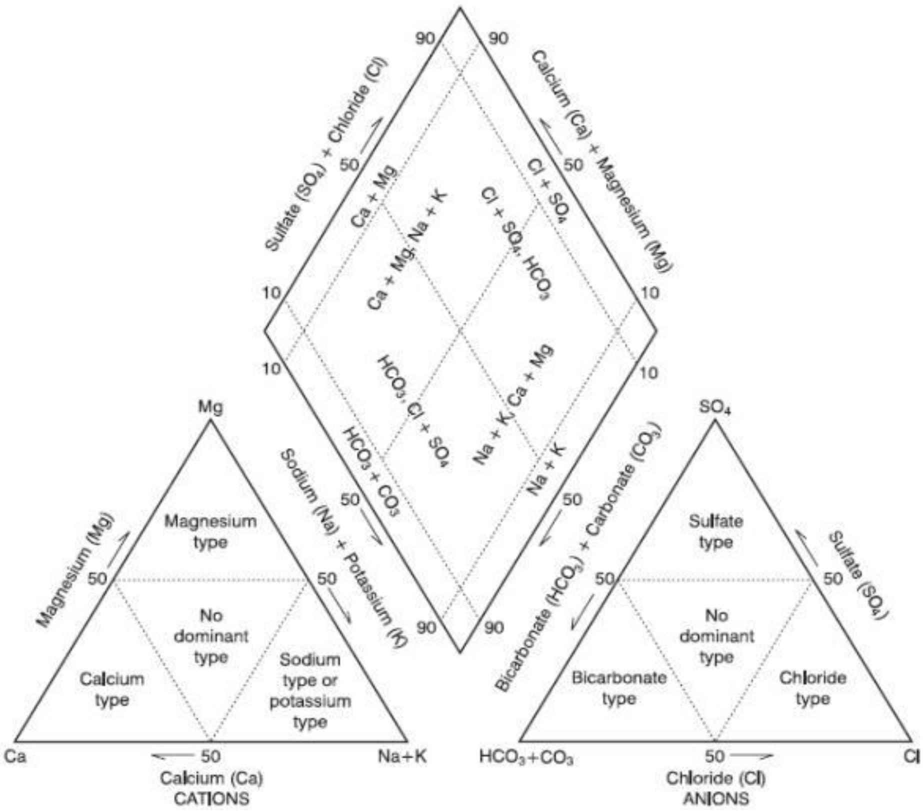


Figure 15: Classification of Hydrochemical Facies Using Piper Diagrams

4.8.2.2 Wilcox Diagram

The Wilcox plot is also known as the U.S. Department of Agriculture diagram (Waterloo Hydrogeological Inc, 2003). A Wilcox plot is used to determine the suitability of water for irrigation purposes. The Wilcox plot is a simple semi-log scatter plot of sodium hazard (sodium absorption ratio (SAR)) on the Y-axis versus salinity hazard (EC) on the X-axis. The salinity and sodium hazard classes are presented in Table 15 and Table 16 and described in detail in Section 4.8.4).

Table 15: Salinity Hazard Classes (Waterloo Hydrogeological Inc, 2003)

Salinity Hazard Class	Electrical Conductivity (µS/cm)	Characteristics
C1 – Low	0-250	Can be used for irrigation on most soil with minimal likelihood that soil salinity will develop
C2 – Medium	251-750	Can be used for irrigation if a moderate amount of drainage occurs
C3 – High	751-2250	Not suitable for use on soil with restricted drainage; some soils with adequate drainage may require special management control for salinity
C4 – Very High	> 2250	Not suitable for irrigation under normal conditions

Table 16: Sodium Hazard Classes (Waterloo Hydrogeological Inc, 2003)

Sodium Hazard Class	Sodium Adsorption Ratio (SAR)	Characteristics
S1 – Low	0-10	Suitable for irrigation on most soil with minimal danger of harmful levels of exchangeable sodium
S2 – Medium	10-18	Appreciable sodium hazard in fine textured soil having high cation exchange capacity
S3 – High	18-26	Produces harmful levels of exchangeable sodium in most soils
S4 – Very High	>26	Unsatisfactory for irrigation purposes

4.8.3 Groundwater Quality Assessment

Water quality data provided by NPM included 81 samples collected from groundwater bores located within the Study area and water quality data were available for nine samples from the NOW database (pers. comm. K Kolstad, November 2011). Only 80 samples were considered suitable for interpretive use in this study based on the IBE screening criteria discussed in Section 3.3.5 however not all samples could not be assigned to a particular aquifer formation.

Groundwater pH values in the Study Area ranged from pH 6.5 to 9.6. The most alkaline sample (pH 9.6) was collected from P103. In the majority of samples the pH ranged between 6.8 and 7.5.

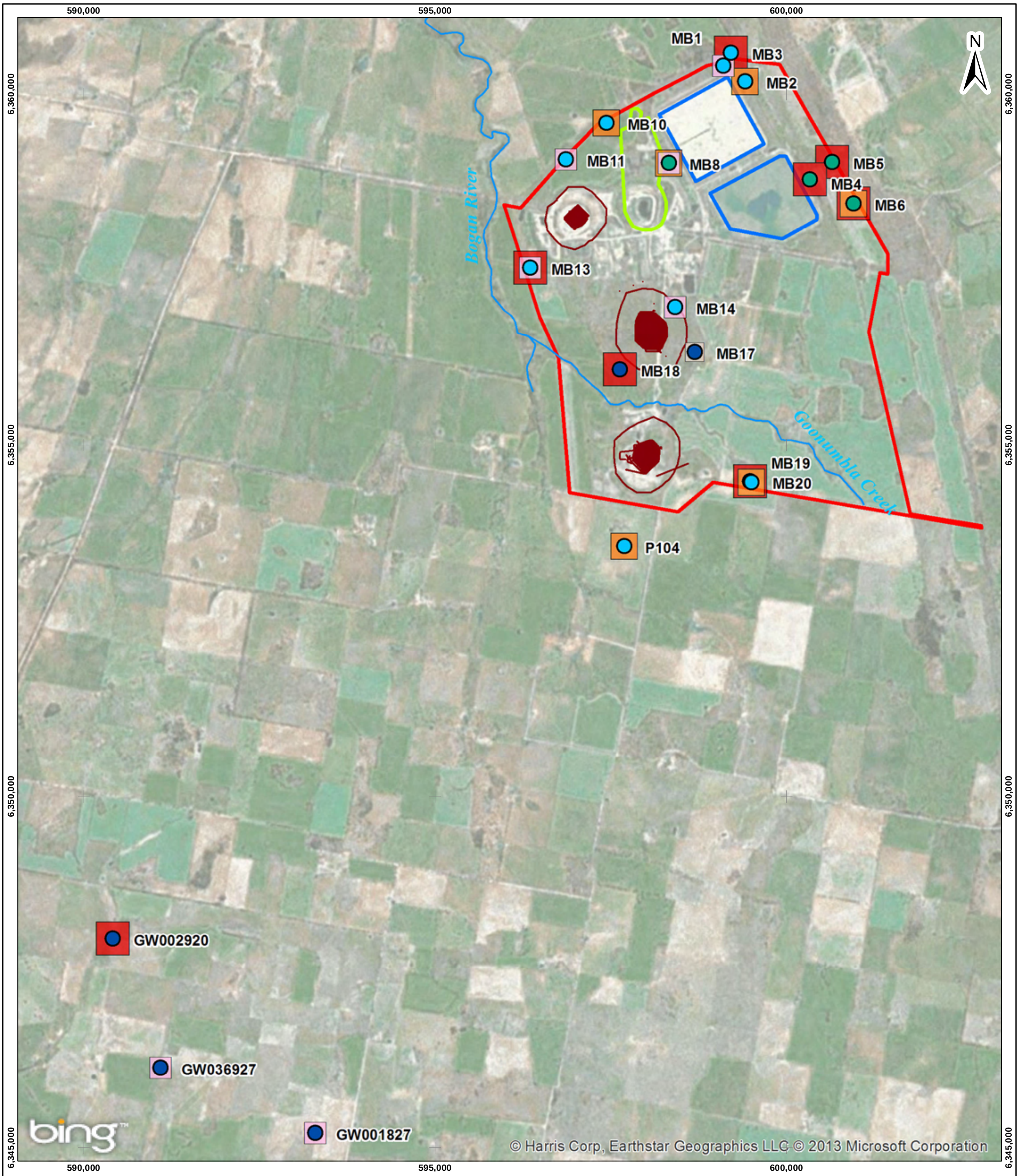
Based on 70 recorded TDS in the Study Area, concentrations (Figure 17) the groundwater varies from fresh water to saline water (TDS from 169 to 28,440 mg/L). Eleven samples (11) are classified as fresh water with TDS concentrations in the range 169-762 mg/L representing 16% of the samples. Twenty-nine (29) samples are classified as slightly brackish or brackish with TDS concentrations in the range 1,000-10,000 mg/L (41%). Thirty (30) saline samples were collected with TDS concentrations in the range 10,000-28,440 mg/L (43%).

No direct TDS measurement was made for ten samples. For these samples, TDS may be estimated from recorded E.C. (based on the relationship presented in Figure 17), giving: four additional slightly brackish samples (1,400 to 1,700 mg/L); four additional brackish samples (3,300 to 7,500 mg/L); and two additional saline samples (13,000 to 18,600 mg/L).

The distribution of TDS versus completed bore depth is presented in Figure 18. The spatial distribution of samples with interpreted target formations is shown in Figure 16. The groundwater level monitoring is mainly targeted in the bedrock strata, with a number of bores completed in both the regolith and bedrock, providing a composite groundwater quality measurement from both units. Therefore, Figure 18 includes the relationship between EC and the completed depth of bores with interpreted target formations.

A wide range of salinities are presented for the groundwater for each interpreted strata: the saprock ranges from slightly brackish to saline (TDS 1,450 to 16,082 mg/L); the OTZ ranges from brackish to saline (TDS 1,720 to 18,338 mg/L); and the bedrock ranges from fresh to saline (TDS 484 to 18,537 mg/L). It is noted that in the water has become less saline (dropping by one salinity class) between the 2009 and 2010 results for MB8 and MB13, which are both within the mine workings areas, whereas the salinity for MB6, located next to the tailings, has increased in salinity (TDS from 8,610 mg/L to 15,000 mgL) from 2009 to 2010.

As presented on Figure 19 the dominant ions are sodium, magnesium and chloride, and water types include sodium-chloride or sodium-magnesium-chloride. Concentrations of SO_4, HCO_3 and Ca are variable. The major ion chemistry is consistent with that reported by Raymond (2002) following a detailed analysis of existing borehole data and further samples collected by that author in 2001. Raymond found significant spatial and temporal variation in water quality across the NPM site and noted that most boreholes were constructed in the known ore bodies. This may bias data towards the character of groundwater associated with the ore-bearing lithologies. For further information on the Raymond study, which includes trace-elements analysis, a discussion of data variability across the site and data reliability from previous studies, the reader is directed to the original text.



NORTHPARKES MINE GWIA

UMWELT (AUSTRALIA) PTY. LTD.

SPATIAL DISTRIBUTION OF WATER QUALITY - TOTAL DISSOLVED SOLIDS

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LEGEND

- Study Area
- Pit Layout
- Existing Approved Permits
- Tailings Storage Facilities
- Rivers
- Project Area

Interpreted Strata

- Saprock
- OTZ
- Fresh Bedrock

TDS

- 0 - 1000 mg/L
- 1000 - 3000 mg/L
- 3000 - 10,000 mg/L
- 10,000 - 100,000 mg/L

0 0.4 0.8 1.6 2.4 Kilometers

SCALE (at A4) 1:75,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
CHECKED:	RS

FIGURE 16

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The piper plots indicate that:

- Pre-mining water quality results, within or near orebodies, were more saline than the current available data set range;
- Fresh bedrock shows the widest range in groundwater salinity, with the lowest and highest TDS concentrations and are plotted predominantly as Na-Cl (3 samples) and Na-Mg-Cl-SO_4 (2 samples) to Na-SO_4-Cl-HCO_3 (2 samples) water types.
- Nine (9) groundwater samples from five boreholes up-gradient of the Project Area are predominantly fresh (TDS 169 to 762 mg/L) except for P101, which is significantly more saline (TDS 10,100 to 10,300 mg/L). The water for these ranged from Mg-Na-Ca-HCO3 to Ca-Na-Mg-Cl types (Note: these locations do not have assigned target formations and were not spatially plotted).

Overall, based on the plots presented in this section:

- The data agrees with Raymond (2002), spatial and temporal variation in water quality across the NPM site near the ore bodies;
- Up-gradient of the site and bedrock mineralisation, groundwater is generally fresh in a cluster of bores 1 km southeast of the Project Area boundary;
- There are no apparent spatial or depth-related trends for TDS, or not enough data points assigned to target formations, to assume any trends for TDS concentrations based on the plotted data in Figure 18 and Figure 19 and

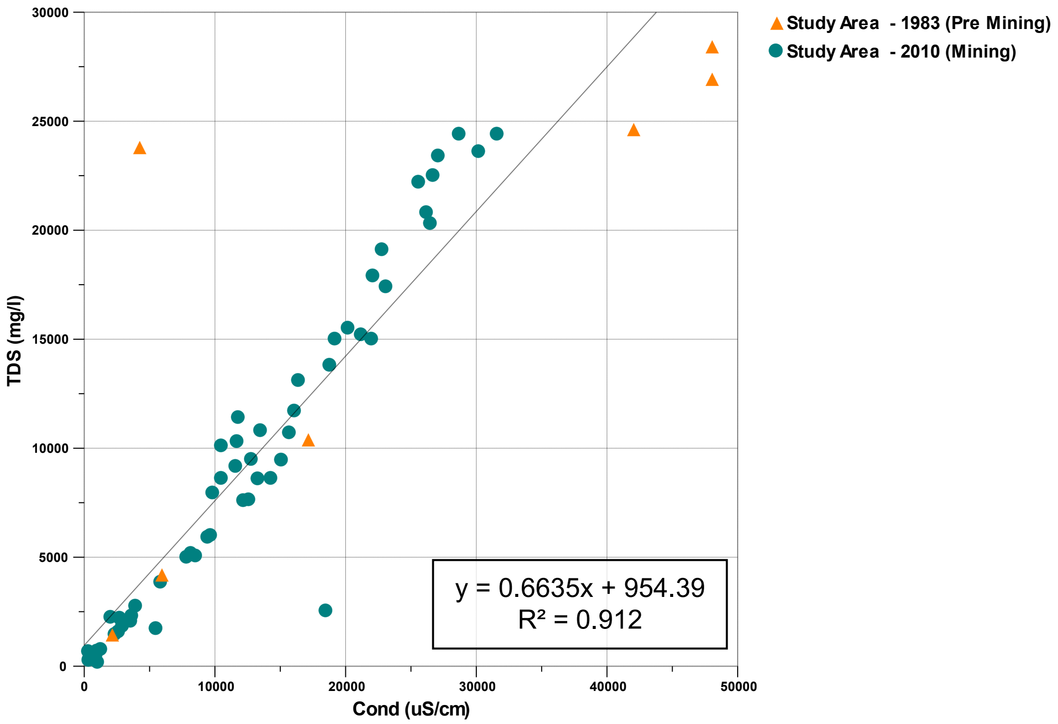


Figure 17: Relationship between Groundwater Electrical Conductivity and TDS

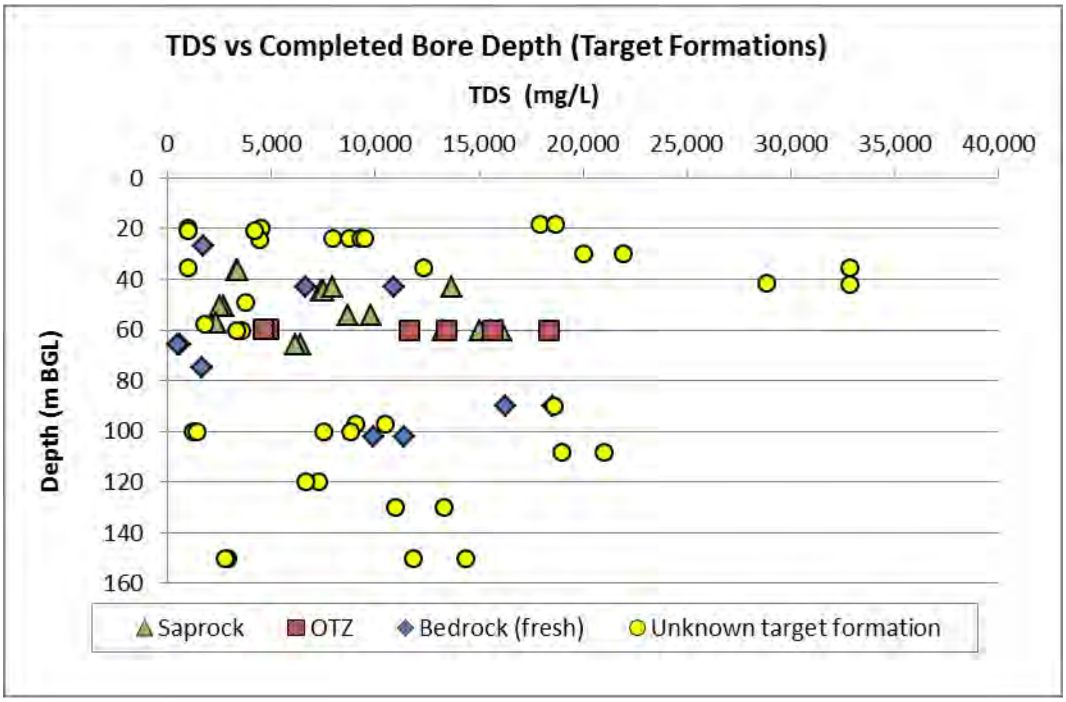


Figure 18: Relationship between Groundwater TDS and Depth

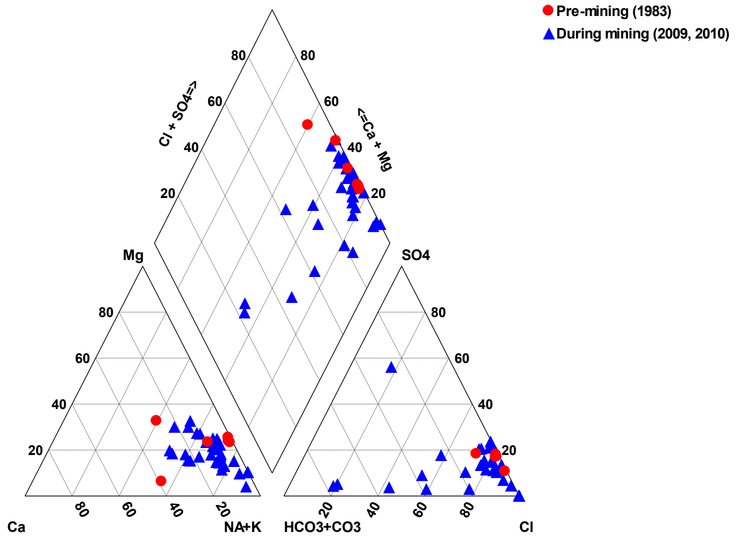
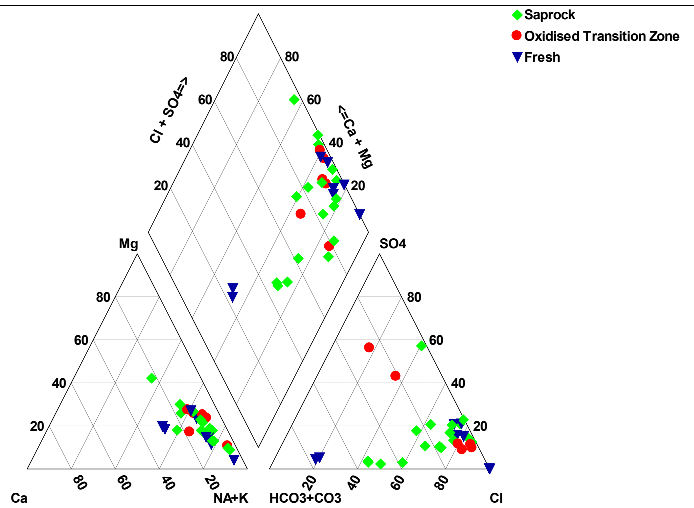
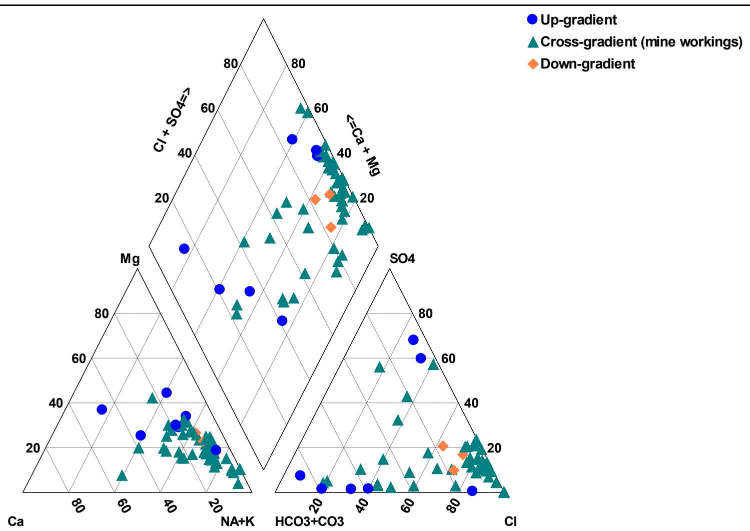
PRE-MINING AND DURING MINING GROUNDWATER QUALITY DATA (NPM PIT AREA) ■ Pre-mining/baseline data (1983) ■ During Mining data (2009, 2010)	
DURING MINING - GROUNDWATER QUALITY DATA WITH KNOWN TARGET FORMATIONS (INTERPRETED BEDROCK SUB-STRATA) ■ Saprock: Saprock, weathered rocks (monzonite, andesite, volcanics) ■ Oxidised transition zone: (weathered and fresh vocanics, saprock and bedrock) ■ Fresh bedrocks: Trachyte, sandstone, latite, volcanics, hardrock)	
DURING MINING – AVAILABLE GROUNDWATER QUALITY DATA (2009, 2010)* ■ Upgradient: Far Hillier, Long Pad, P101, South Hillier, Wright ■ Cross-gradient: DDH3, DDH30, DDH7, MB1, MB13, MB14, MB17, MB18, MB19, MB2, MB20, MB3, MB4, MB5, MB6, MB8, P100, P102, P103, P104, P139, P145, P149, P71, PDH18, PDH26, PDH70, PDH72, W14, W15, W16, W17, W18 ■ Downgradient: MB10,MB11 **see Figure 9 for bore locations with coordinates avialable*	

Figure 19: Piper Diagrams

4.8.4 Comparison of Groundwater Quality to Regulatory Guidelines

4.8.4.1 Public Supplies and Domestic Use

The Australian drinking water guidelines (ADWG, 2011) established drinking water criteria for public supplies of drinking water. The ADWG (2011) guidelines include the following:

- A health-related guideline value is the concentration that does not result in any significant risk to the health of the consumer over a lifetime of consumption; and
- An aesthetic guideline is the concentration associated with acceptability of water, based on appearance, taste and odour.

The assessment criteria for public supplies and domestic use are presented in Table 17. Sodium and chloride appear to account for the highest percentage of exceedences within the Project Area ("cross gradient" of the mine workings). Most of the analysed samples exceed the sodium drinking water standard. Fluoride concentrations exceed the drinking water criteria in 9% of samples where fluoride was included in the analytical suite. The pH standard was exceeded in 8% of samples, with samples being slightly alkaline to alkaline rather than acidic.

Table 17: Comparison of groundwater quality to Australian drinking water criteria for Project Area (ADWG, 2011)

Analyte	Drinking water standard (mg/L; except pH)	No of Pre-mining (Cross-Gradient) samples exceeding standard***	No of During mining (Cross - Gradient) samples exceeding standard***
pH	6.5 - 8.5	0% (0 out of 7 samples)	8% (4 out of 48 samples)
Chloride	250**	100% (7 out of 7 samples)	91% (42 out of 46 samples)
Sodium	180**	100% (7 out of 7 samples)	93% (43 out of 46 samples)
Sulphate	250**	86% (6 out of 7 samples)	72% (33 out of 46 samples)
	500*	86% (6 out of 7 samples)	63% (29 out of 46 samples)
TDS	< 600 – good quality	0% (0 out of 7 samples)	4% (2 out of 46 samples)
	600-900 – acceptable based on taste	0% (0 out of 7 samples)	2% (1 out of 46 samples)
	900-1,200 – poor quality	0% (0 out of 7 samples)	0% (0 out of 46 samples)
	>1,200 – excessive scaling, corrosion, unsatisfactory taste	100% (7 out of 7 samples)	93% (43 out of 46 samples)
Fluoride	1.5*	60% (7 out of 47 samples)	9% (3 out of 33 samples)
Copper	1**	0% (0 out of 5 samples)	0% (0 out of 41 samples)
	2*	0% (0 out of 5 samples)	0% (0 out of 41 samples)
Iron	0.3	NA	90% (9 out of 10 samples)
Manganese	0.1**	NA	63% (29 out of 46 samples)
	0.5*	NA	35% (16 out of 46 samples)
Zinc	3	NA	0% (0 out of 41 samples)
Nitrate	50*	NA	NA

* - health value; ** aesthetic value;; ***TDS concentrations complying with standard
NA – data not available

Some natural exceedences of the ANZECC guidelines for stock water for aluminium, calcium, cobalt, fluoride and lead have been recorded (NPM, 2006).

The mobility of metals in the groundwater system in the Project Area is limited, due in part to neutral to alkaline pH conditions, the low values of hydraulic conductivity and the presence of clay, which has a high capacity for adsorption and/or exchange of metals in groundwater. Hydrogeochemical modelling indicates that metal species are distributed mostly as insoluble metal carbonates, sulphates, sulphides, oxides and hydroxides (Crosbie, 2006). The Eh and pH of the groundwater environment are the major controls over the mobility of metals.

RTTI (2011) reviewed the operational management plans for acid rock drainage (ARD) in 2011, as required every four years. There were no findings of significant risk and only three moderate risk findings. Management plans have been established in the RTTI (2011).

Total hardness is a commonly used measure to characterise the suitability of water for public-supply and domestic use. Total hardness can be characterised into four classes (Table 18; ADWG, 2011). Total hardness for samples within the Project Area (cross gradient of the mine workings) was calculated from the chemical composition and refers to the sum of calcium and magnesium (expressed in mg/L of $CaCO_3$). For pre-mining samples, 100% represented very hard groundwater and would have the potential to cause scaling. For the during-mining data, no samples represent soft groundwater, 2% are moderately hard, 17% are hard and approximately 80% are very hard.

Table 18: Groundwater Hardness

Total Hardness as $CaCO_3$ (mg/L)	Hardness Classes	Percent of Pre-mining (Cross-Gradient) Samples	Percent of During mining Samples
<60	Soft, but possibly corrosive	0% (0 out of 7 samples)	0% (0 out of 46 samples)
60-200	Good quality (moderately hard)	0% (0 out of 7 samples)	2% (1 out of 46 samples)
200-500	Increasing scaling problem (hard)	0% (0 out of 7 samples)	17% (8 out of 46 samples)
>500	Severe scaling (very hard)	100% (7 out of 7 samples)	80% (37 out of 46 samples)

Groundwater suitability for livestock watering is assessed on the basis of TDS concentrations and the concentration of specific ions, particularly calcium and sulphate. This assessment is based on pre-mining and during mining available data. The trigger values for both calcium and sulphate are 1,000 mg/L. Calcium and sulphate concentrations exceeded 1000 mg/L in 5 and out of 66 (8%) and 30 out of 63 (48%) samples, respectively.

Recommended TDS concentrations in drinking water for livestock watering are summarised in Table 19. Approximately 84% of all sampled groundwater from the Study Area (pre-mining and mining samples) were slightly brackish to saline, with TDS concentrations greater than 3,000 mg/L. The average and median TDS values are 8969 and 7553 mg/L respectively. Twenty-one (21) of the 80 groundwater samples for which TDS data were available (or able to be calculated) were within a suitable range for livestock watering (TDS 169 - 1,830 mg/L), while the remaining samples generally exceed one or more of the “no adverse effect on animals” criteria listed in Table 19.

Table 19: Tolerances of Livestock to TDS in Drinking Water (ANZECC & ARMCANZ, 2000)

Livestock	TDS (mg/L)		
	No adverse effect on animals	Stock should adapt without loss of production	Stock may tolerate these levels for short periods if introduced gradually
Beef cattle	< 4,000	4,000 – 5,000	5,000 – 10,000
Dairy cattle	< 2,500	2,500 – 4,000	4,000 – 7,000
Sheep	< 5,000	5,000 – 10,000	10,000 – 13,000
Horses	< 4,000	4,000 – 6,000	6,000 – 7,000
Pigs	< 4,000	4,000 – 6,000	6,000 – 8,000
Poultry	< 2,000	2,000 – 3,000	3,000 – 4,000

4.8.4.2 Agricultural Use (Existing Users)

Agricultural use of groundwater includes irrigation and livestock watering. Irrigating with water that has a high content of dissolved salts and excess sodium can adversely impact the soil structure or adversely affect plant growth. This can depend on the amount of salt present in the water, the soil type being irrigated, the climate and the specific plant species and the growth stage.

The irrigation water quality classification system is based on two characteristics:

- salinity hazard; and
- sodium (alkali) hazard of the water.

The salinity and sodium hazards are each divided into four classes based on EC values and sodium absorption ratio (SAR). The SAR indicates the tendency of sodium (Na) to replace calcium (Ca) and magnesium (Mg) in soil and is calculated as follows:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca + Mg)}{2}}}$$

where*: Na- Sodium, Ca –Calcium, Mg- Magnesium are in milliequivalents/litre.*

The salinity and sodium hazards are combined into a single plot to evaluate the suitability of water for irrigation (Figure 20). The salinity and sodium hazard classes are presented in Table 15 and Table 16.

Figure 20 indicates that groundwater from in the Project Area plots within a wide range of both sodium and salinity hazard classes. Most of the groundwater from in the Project Area fall into high sodium hazard class (S4) and very high salinity hazard class (C4). Based on this classification groundwater in the Study Area would not be suitable for irrigation without prior treatment. It is noted that there are no irrigation bores in the Project Area.

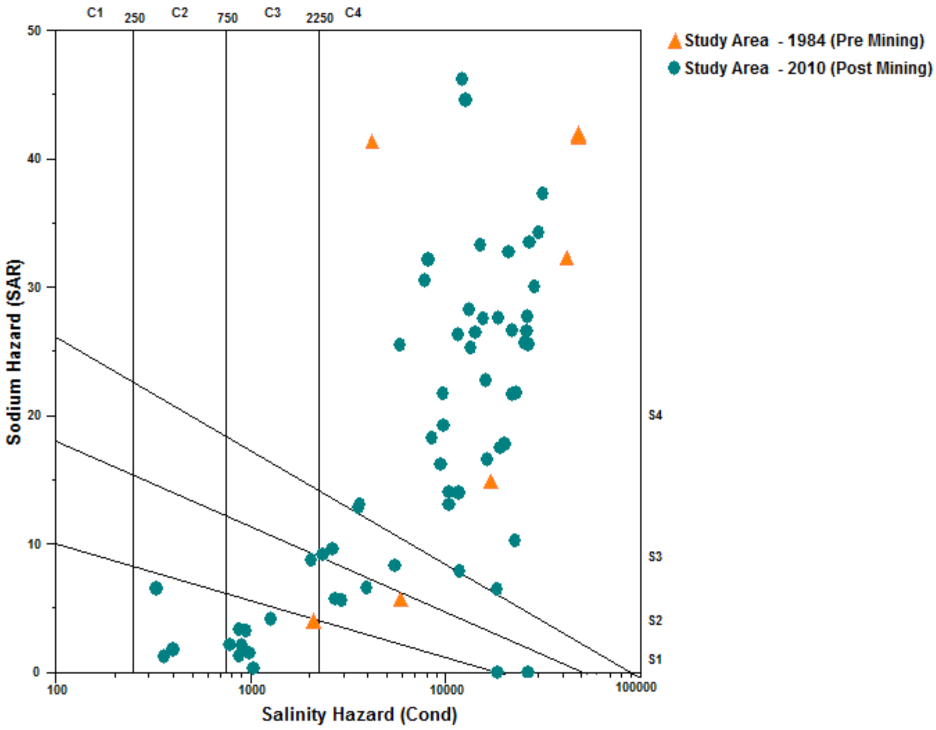


Figure 20: Wilcox Plot Showing Salinity and Sodicity Hazard Classes

4.8.5 Water Quality Conclusions

The geochemical assessment of groundwater quality was based on an analysis of available data from the Project Area, which was biased towards data from mine aquifers but included a limited number of samples from the other major formations. Conclusions related to groundwater quality include:

- The most common groundwater types are sodium-chloride or sodium-magnesium-chloride, however some variation in dominant ions and water types was observed in some samples;
- Groundwater salinity varies from fresh (TDS 169 mg/L) to saline (TDS 28,440 mg/L) with the majority of groundwater samples (84%) being from slightly brackish to saline (TDS 1,400 to 28,440 mg/L);
- Comparison of existing water quality analysis results with regulatory guidelines indicates that:
  - Groundwater from the mine monitoring wells would not be suitable for use as potable water mostly due to elevated concentrations of sodium and chloride;
  - The majority (74%) of groundwater sampled in the Project Area is not suitable for livestock watering without prior treatment; and
  - Groundwater in the Study Area was characterised as posing a high salinity and sodicity hazard and would not be suitable for irrigation without chemical adjustment. It is noted that no irrigation is undertaken in the Project Area.

4.9 Environmental Values

The Environmental Values (EVs) of a surface water or groundwater resource are defined as:

> *"particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health which require protection from the effects of pollution, waste discharges and deposits" (ANZECC, 2000).*

The term "environmental values" is also considered to be interchangeable with the term "beneficial uses" commonly referenced with respect to groundwater resources.

The EVs defined in the 'NSW State Groundwater Quality Protection Policy' (NSW Government 1998) include:

- Ecosystem protection;
- Recreation and aesthetics;
- Raw water for drinking water supply;
- Agricultural water, and
- Industrial water.

There are a number of EVs values associated to surface water bodies; however, these may/may not be related to groundwater systems. These include the full range of values considered in relevant guidelines for the Study Area, and a summary of the GDEs that are considered to be relevant in the Study Area. Environmental values relevant to groundwater resources in the Study Area could potentially be:

- National parks, state parks and nature reserves;
- Historic sites and aboriginal areas;
- State conservation areas;
- GDEs;
- Stock and Domestic water supply;
- Irrigation water supply;
- Town water supply; and
- Other Groundwater Users.

The ecological values and comprehensive ecological assessment are discussed in separate technical reports prepared for NPM (Umwelt 2013, Northparkes Mines Step Change Project Flora and Fauna Assessment).

4.9.1 Groundwater Dependant Ecosystems

GDEs can be defined as those ecosystems whose ecological processes and biodiversity are wholly or partially reliant on groundwater. The extent of GDE dependency on groundwater can range from being marginally or episodically dependent to being entirely dependent on groundwater (SKM, 2001).

Examples of GDEs include:

- Wetlands and red gum forests;
- Other terrestrial vegetation;

- Ecosystems in streams fed by groundwater;
- Limestone cave systems;
- Springs; and
- Hanging valleys and swamps.

GDE's could include aquatic ecosystems in rivers and streams that receive groundwater baseflow. Baseflow typically accounts for a significant fraction of total flow volume in major rivers and streams. Baseflow can sustain stream flow volumes long after rainfall events, or throughout dry seasons, and is therefore critical to the maintenance of aquatic ecosystems in rivers and streams in many Australian environments. Baseflow can occur as springs discharging into a river or stream, or as diffuse influx of groundwater through banks and bed sediments.

The WSP for the *NSW MDB Fractured Rock Groundwater Sources* identifies environmental values for consideration. There are no GDEs identified in the WSP within the Study Area, including wetlands listed under the Commonwealth of Australia's EPBC Act Protected Matters database (Ramsar sites). A number of high priority karst environment GDEs are also identified in the WSP for the *NSW MDB Fractured Rock Groundwater Sources*; however, these karsts are located outside of the Study Area, west of Cowra (refer to Figure 1).

High priority GDEs are currently under investigation by NOW and some of these may be identified during the term of this Plan. The full list of potential GDEs will be identified on the NSW Office of Water GDE Register and as a precautionary approach, will be considered in the assessment of any works approval within the Plan area. If verified as high priority GDEs, the Schedule will be amended to include further GDEs (NOW, 2011c). There are no known GDEs in the Study Area.

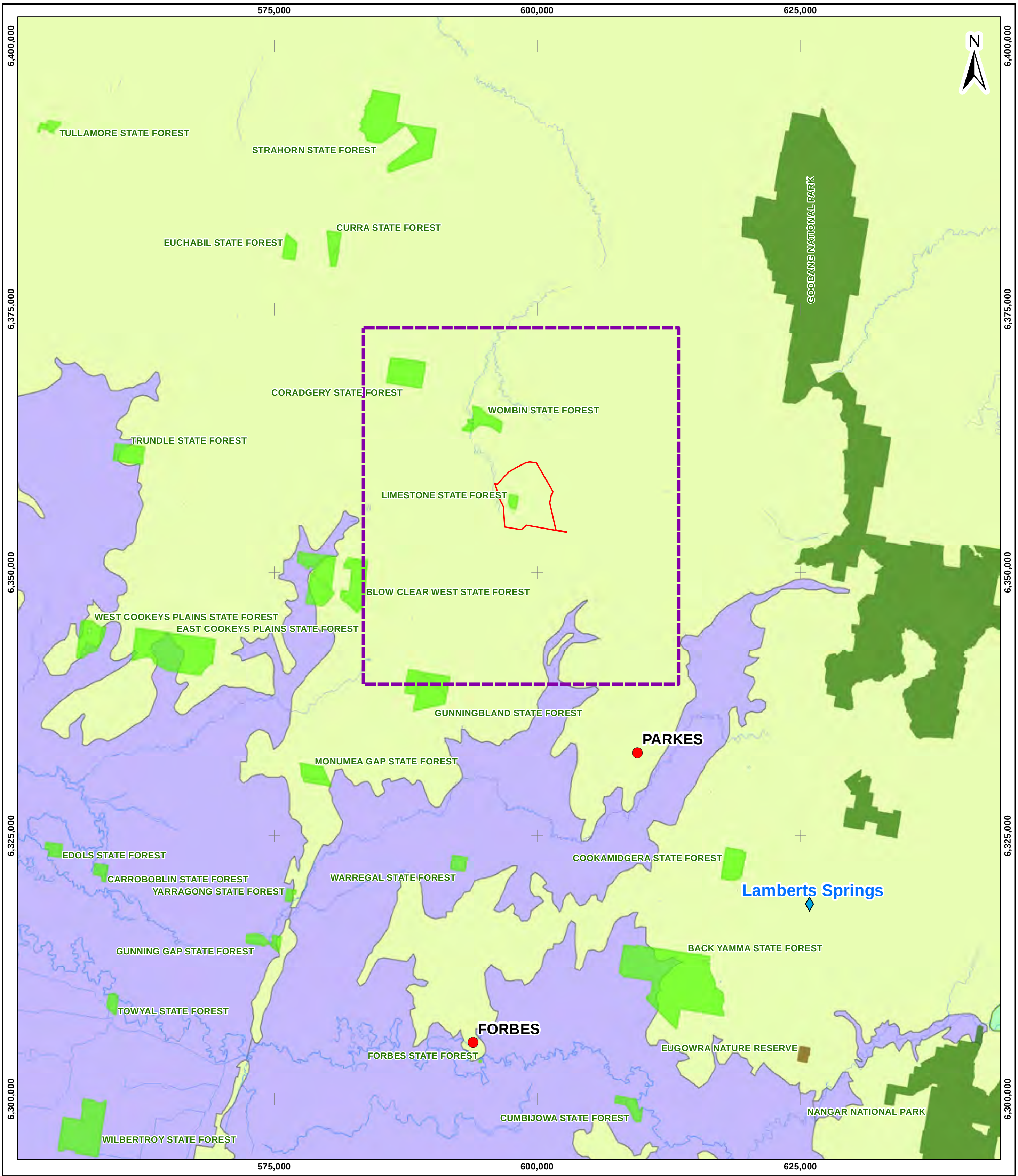
Springs

The nearest GDE is Lamberts Springs (Figure 21), located 50 km south east of the Project Area. The Lambert Springs are in another catchment, separated by outcropping basement rocks which form highlands between the Project Area and the springs. Lamberts Springs is located well beyond the zone of influence (identified by groundwater modelling in Section 5.3 below) and is not likely to be impacted by dewatering activities proposed by NPM.

Groundwater Ecosystems – Stygofauna

Groundwater fauna, or *stygofauna*, comprise the microscopic, aquatic animals that live in underground water. It is made up predominantly of many kinds of crustacean invertebrates but also includes worms, snails, insects and occasionally blind fish. Groundwater fauna contribute substantially to the biodiversity of Australia (Humpfreys, 2006). *Stygofauna* are known to exist in limestone, calcrete, and fractured rock aquifers, but appear most abundant in alluvial aquifers (Maria et al., 2012; Hancock and Boulton, 2008). Many *stygofauna* species are restricted to very small geographical areas; therefore, the new development that extends below the water table need to be considered carefully to avoid species extinction. The survey of *stygofauna* is currently not a compulsory feature of environmental impact assessment report in NSW.

It is unknown whether *stygofauna* (groundwater fauna) are present in the groundwater systems in the Study Area. The majority of groundwater has a high electrical conductivity and the occurrence of alluvial aquifers is limited in the Study Area; therefore, the likelihood of encountering *stygofauna* on the Project Site is considered to be low.



NORTHPARKES MINE GWA

UMWELT (AUSTRALIA) PTY. LTD.

ENVIRONMENTAL VALUES IN THE STUDY AREA

LEGEND

- Project Area
- Study Area
- City/Town
- Spring Location
- Nature Reserve
- National Park
- State Forest

Groundwater Management Area

- Lachlan Fold Belt (GMA 811)
- Upper Lachlan Alluvium (GMA 011)

0 4.25 8.5 17 Kilometers

SCALE (at A4) 1:500,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT:	117626007
DATE:	30/04/2013
DRAWN:	FA
CHECKED:	RS

FIGURE 21

Golder Associates

File Location: \\SYD1-S-FILE02\Jobs\hyd\2011\117626007_Umwelt_NorthParkesMine\Technical Doc\GIS\Project\Rev0\117626007_007_R_F011_EVs-Rev0.mxd

4.9.2 Drinking Water and Groundwater Users

Groundwater as both a drinking water supply and water resource for the entire community is considered to be an important environmental value in the Study Area.

Groundwater is a common drinking water source for many inland areas of Australia, especially where aquifers of good quality and yield are present at reasonably shallow depths. The LFB groundwater quality is variable but mostly brackish to saline, and bore yields are often low to very low. The groundwater use data for the Study Area is limited. The NOW database indicates 185 bores have been installed within the Study Area. From this data, 94 bores are registered for stock and irrigation supply, and 41 are registered for domestic use. Groundwater use data is not available.

PB (2011) stated that the majority of private bores are constructed in drainage channels in high ground on the southern perimeter of the valley. Groundwater is sourced from the oxidised zone below the regolith. It is generally considered to be a low to moderately valuable resource and new beneficial uses of the resource are unlikely. Due to the scarce water supply in the Study Area, NPM imports water from the Lachlan Valley. Irrigation, commercial and mining entitlements account for the majority share of the total entitlements in the Upper Lachlan Alluvium, consisting of over 90% of the total number of entitlements in the Upper Lachlan Alluvium GMA (164,686 ML). The external source of water from Lachlan Valley Alluvium will not increase as part of the Project and is not further discussed as a groundwater resource in this report.

Groundwater use within the Study Area is further discussed in Section 4.6.1.

4.9.3 Local Community Recreational, Aesthetic, Cultural and Spiritual Values

The environmentally sensitive receptors within the Study Area are shown on Figure 21. The location of national parks and State Forests (which can include Aboriginal Conservation Areas) were supplied by National Parks and Wildlife Services (NPWS); the location of National Parks and State Forests are from MapInfo Street Pro.

There are a number of state forests, scattered across the Study Area. Based on the information provided, the following environmentally sensitive locations have been identified around the Project Area:

- Coradgery State Forest, approximately 15 km north-west of the Project Area;
- Wombin State Forest, approximately 7 km north-west of the Project Area; and
- Limestone State Forest, within the Project Area.

The Limestone State Forest is currently managed by NPM in consultation of Forests NSW, in accordance with land swap and management agreements developed as part of the E48 Project.

There are no identified Aboriginal Conservation Areas in the vicinity of the Project Area.

As discussed in Section 4.1 the mine is in the Bogan River catchment. Surface runoff from the Study Area is expected to flow primarily northwards towards the Macquarie River and through the Wombin State Forest, located 7 km northwest of the Project Area. The Wombin State Forest and the Bogan River tributary are identified as potential receptors to groundwater impacts within the Study Area.

No Aboriginal Conservation Areas were identified in the vicinity of the Study Area.