Western Australia Iron Ore

Orebody 31 Hydrogeological Impact Assessment

Summary Document

Department: Resource Planning - Hydrology

Contents

Introduction

Overview

Location

Orebody 31 (OB31) is located approximately 40 kilometres (km) east of Newman Township in the Pilbara region of Western Australia (Figure 1). OB31 is situated to the east of the existing Orebody 17/18 (OB17/18) Mine within Mineral Lease ML244SA, which is subject to the Iron Ore (Mount Newman) Agreement Act 1964 (Newman Agreement Act). OB31 has not previously been developed and as such is considered a greenfield development.

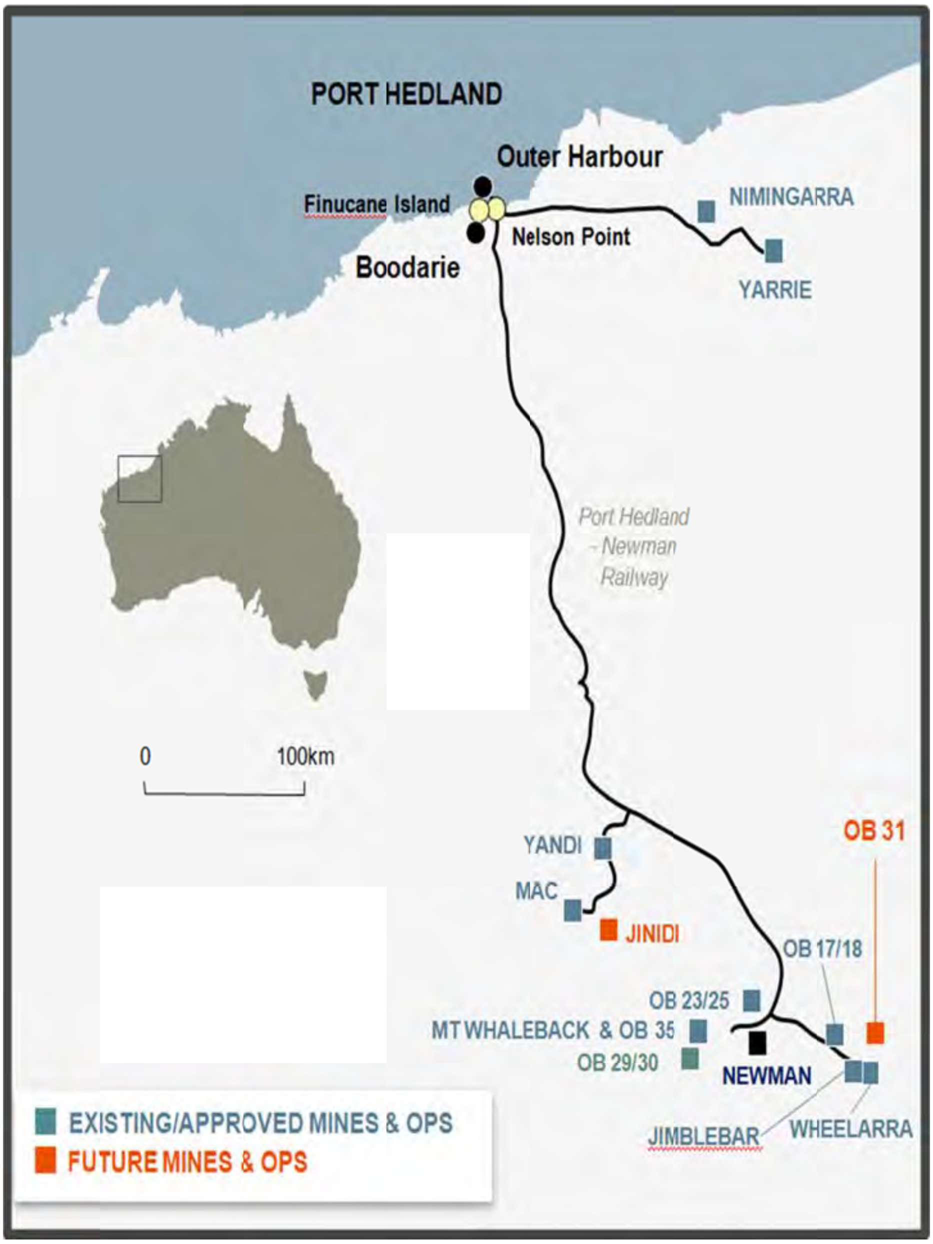
Other operations and approvals in the area

BHP Billiton Iron Ore Pty Ltd (BHP Billiton Iron Ore) currently operates a number of iron ore mines and associated rail and port infrastructure within the Pilbara region of Western Australia. Current mining operations in proximity to OB31 include:

- Newman Joint Venture hub, located approximately two km west of Newman Township, which consists of Mount Whaleback and Orebodies 29, 30 and 35;
- OB17/18 Mine, located approximately 30 km east of Newman Township;
- Wheelarra Hill (Jimblebar) Mine, located approximately 40 km east of Newman Township and five to 10 km south of OB31; and
- Eastern Ridge (Orebodies 23, 24 and 25), located approximately eight km northeast of Newman Township.

The closest operations to OB31 are the OB17/18 Mine and Wheelarra Hill (Jimblebar) Mine (Figure 1).

Figure 1: Location Plan



Project components

The OB31 project consists of the following:

- one single open pit, based on initial studies (future update subject to final drilling results);
- three new OSAs, based on initial studies (future update subject to final drilling results);
- a primary crushing facility;
- haulage (heavy vehicles (HV)) and light vehicles (LV) access roads linking OB31 to existing OB17/18 mine infrastructure;
- power, water, fibre optic cable and other associated services which may be required along road and/or conveyor alignments;
- topsoil and vegetation stockpiles;
- offices, ablutions, LV and HV parking areas, laydown areas, hydrocarbon storage facilities, Ammonium Nitrate storage facilities and magazine areas and other ancillary facilities; and
- water infrastructure including dewatering/potable/monitoring water bores, diesel generator sets, pipelines, turkeys nests and/or other storage facilities as required.

Hydrological processes

Mining projects can affect groundwater and surface water resources and their dependant values (DoW, 2013a). Seventy percent of OB31 lies below the water table. As such, the Proposal will require in-pit and ex-pit mine dewatering (i.e. groundwater abstraction) in advance to facilitate dry mine operating conditions.

An overview of BHP Billiton Iron Ore's hydrogeological studies and investigations (completed and proposed) are provided below.

BHP Billiton Iron Ore commissioned RPS (2014a) to undertake a groundwater field programme to increase the hydrological understanding within the Proposal area and determine the potential impacts of dewatering.

EPA Objective

The EPA applies the following objective, according to the Environmental Assessment Guideline 8 for Environmental Factors and Objectives (EPA, 2013), in its assessment of proposals that may affect hydrological processes:

To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected.

Relevent guidelines and approvals

The groundwater and surface impact assessment has been developed in consideration of the following guidance documents, where practicable:

- Western Australia Water in Mining Guideline (DoW, 2013a);
- Pilbara Regional Water Plan 2010-2030 (DoW, 2012a);
- Pilbara Groundwater Allocation Plan (DoW, 2013b);
- Pilbara Regional Water Supply Strategy: a long-term outlook of water demand and supply (DoW, 2013);
- Strategic Policy 2.09: Use of mine dewatering surplus (DoW, 2013c);
- Operational Policy No. 1.02: Policy on Water Conservation/Efficiency Plans, Achieving Water Use Efficiency Gains through Water Licensing (DoW, 2009b); and
- Operational Policy No. 5.08: Use of Operating Strategies in the Water Licensing Process (DoW, 2010c).

Outline of scope of this document

This impact assessment addresses potential hydrogeological impacts from dewatering and surplus water management for OB31. A number of technical studies have been completed, these are detailed in the appendices and summarised below. Although the primary impact area is in the immediate area of the OB31 project, potential regional impacts are also addressed, particularly Ethel Gorge Threatened Ecological Community (TEC). Ethel Gorge, geographically, is located outside the OB31 catchment area however is included in the impact assessment due to the potential impact from surplus water discharge to Ophthalmia Dam located immediately up gradient from the Ethel Gorge TEC. As such, this impact assessment provides a summary of potential local (immediate vicinity of OB31) impacts along with potential impacts to Ethel Gorge TEC.

Geology

Stratigraphy

OB31 is located 40 km east of Newman at the southern margin of the Pilbara Craton, which is comprised of large granitoid domes and batholiths separated by down-folded sequences of the Pilbara Supergroup sedimentary volcanic and intrusive rocks.

The Pilbara region comprises a portion of the ancient continental Western Shield that dominates the geology of Western Australia. The Western Shield is comprised of pre-Cambrian, Proterozoic and Archaean rocks. The Pilbara Craton dates back to the Archaean, and includes some of the oldest rocks in the world. It is overlain by Proterozoic rocks deposited in the Hamersley and Bangemall Basins. The Hamersley Basin which occupies most of the southern part of the Pilbara Craton can be divided into three stratigraphic groups; the Fortescue, Hamersley and Turee Creek Groups (Beard, 1975). Of the three groups, the Hamersley Group is the most relevant to the Project.

Stratigraphy in the OB31 area is mainly of the Hamersley Group (~2,630 to 2,450 Ma) which is a 2.5 km thick sequence of predominantly deep water sediments with lesser turbidites and intrusives. Lithologies include banded iron formation (BIF), hemipelagic shales, dolomite, chert, tuff and turbiditic volcanics. Since deposition, the Hamersley Group has undergone significant structural and geochemical alteration.

Orebody 31 deposit

The OB31 deposit is an east-west elongated deposit that extends ~4.8 km along strike and is ~1 km wide. The easternmost extent of OB31 is truncated by sub-parallel splays of the north-east trending Wheelarra Fault.

The proposed pit will intersect the following main rock units; the Mt Sylvia and Mt McRae Formations, Dales Gorge, Whaleback Shale and Joffre Members of the Brockman Iron Formation, Yandicoogina Member and Weeli Wolli Formation. The majority of the mineralisation occurs in the Dales Gorge and Joffre Members.

Mineralisation appears to be continuous along strike, with the majority being described as a martite-goethite mineralisation, with occasional intersections of microplaty hematite. The Joffre Member is also mineralised, with similar grades to that of the Dales Gorge Member.

Where outcrop is present, the geology is dominated by hardcapped Dales Gorge or Joffre Member units. Drilling from 1985, suggests that the hardcap thickness varies from 10 to 30 m. The Mt Sylvia and Mt McRae Formations outcrop towards the south-western and south-eastern ends of OB31, whilst the Weeli Wolli Formation outcrops to the north.

The large-scale structure at OB31 comprises an open, east-west striking anticline-syncline pair with southerly dipping axial-planes. The anticline is situated south of the syncline, with the common limb dipping ~40° north, whilst the dips of the southerly limbs are shallower. Smallerscale, parasitic (F2) folding is also reported to be present.

Orebody depth

Based on recent drilling in the area, it is estimated that the orebody depth is approximately 190 metres below ground level (mbgl), while the pit shell is estimated to be approximately up to 205 mbgl. Further drilling is planned in the area which may result in the pit being deeper than is currently estimated.

Hydrogeology

The main local aquifer is the mineralised and submineralised Brockman orebody. This aquifer extends for some distance along strike but is bounded by unmineralised Brockman Iron Formation. To the north and south, the orebody aquifer is inferred to be bounded by low permeability BIF and shales of the Weeli Wolli Formation (hanging wall) and Mt McRae Formation (footwall). In a regional sense, the orebody appears to be largely hydraulically constrained within low permeability aquitards. However, zones of higher permeability indicated by relatively higher airlift yields (1ML/d and higher) have been recorded in bores targeting the footwall (Mt McRae). These high airlift yields appear to be related to a series of faults and structures which have the potential to provide a hydraulic connection with adjoining aquifers.

Regional Hydrogeology – OB31

The Brockman Iron Formation (Brockman; BIF) comprises generally low permeability BIF and shales. However, where mineralised (typically in the Dales Gorge and Joffre Members), the Brockman has enhanced permeability and storage and can be considered an aquifer. Aquifer potential is limited to zones of mineralised and submineralised BIF forming semi-confined to unconfined aquifers. These aquifers are limited at depth and along strike by low permeability unmineralised Brockman and to the north and south by combination of the Yandicoogina Shale Member, Whaleback Shale Member and Mt McRae Shale Formation. In certain settings, the Brockman aquifer may be more hydraulically connected with surrounding units where the geometry of the valley and orebody are such that the footwall sequence of the orebody is juxtaposed to Tertiary valley-fill sediments (RPS, 2014a).

Tertiary valley-fill sediments are developed along an east–west trending valley to the south of OB31 and are thought to be approximately 100–150 m thick in this area consisting of an alternating sequence of alluvial, colluvial, Aeolian and diagenic sediments. Where saturated, the valley fill aquifer is expected to have a higher specific yield than surrounding bedrock aquifers. However, mineral exploration drilling in close proximity to OB31 did not encounter any saturated detritals in the footwall to the immediate south of the proposed OB31 pit; the Tertary aquifer is most likely further to the south of OB31 within the deeper areas of the palaeovalley. The Tertiary detrital aquifer is underlain by the Paraburdoo Member dolomite (Wittenoom Formation) that generally forms a regional semi-confined aquifer system (where weathered) located to the south of the orebody.

The Wittenoom Formation comprises mudstone, shale and dolomite with subordinate BIF in three Members – the West Angela Shale, Paraburdoo Member and Bee Gorge Member. The Paraburdoo Member comprises dolomite and has undergone weathering over much of the Pilbara, resulting in enhanced permeability, and forms the main regional aquifer in many locations.

The Bee Gorge Member is a generally low-permeability unit of argillite-mudstone with lesser dolomite, BIF and shale and overlies the Paraburdoo Member. It is generally considered to have low permeability along with the overlying My Sylvia and Mt McRae Formations, but may have increased permeability where weathered or altered (i.e. partial mineralisation).

Summary of OB31 Field Program

RPS Aquaterra (2014a) was commissioned to carry out a field programme at OB31. The field program at OB31 comprised the following:

- the drilling of 26 exploration bores to assess the hydrogeological properties of the aquifer(s) (airlift yields, groundwater levels and quality) and the geology;
- the installation of 26 standpipe piezometers to be used for short term (during test pumping) and long term water level monitoring;
- the drilling and construction of nine production bores;
- the construction of nine piezometers in suitable, existing RC holes;
- test pumping of the nine production bores to estimate aquifer properties, as well as to assess the hydraulic relationship between the various aquifer units and structural features (faults, dykes, etc.). The test pumping comprised step-rate tests of each of the nine production bores. Longer term (five to 11 days in duration) constant rate tests were undertaken on six of the nine bores; and
- collection of water samples from each production bore at the end of test pumping for laboratory analyses of major ions, as well as Total Dissolved Solids (TDS), pH and a range of metals.

OB31 Conceptual Model

Local Aquifer

The conceptual model of OB31 (Figure 2) shows the major flow processes and associated uncertainities in the current understanding. Results of the internal BHPBIO desktop hydrogeological assessments, exploration drilling, bore construction and test pumping programs at OB31 indicate that the mineralised Dales Gorge and Joffre units make up two broadly (generally east–west striking) potentially discontinuous, high-permeability aquifers that run in parallel. They are separated by the typically lower permeability Whaleback Shale aquitard.

The current hydrogeological understanding suggests that the following lithostratigraphic units can be grouped together as either aquifer or aquitard units:

- **High Permeability Aquifers (K > 5 m/d):** Mineralised Brockman Iron Formation at OB31 (largely unconfined Sy ~0.05), the weathered Paraburdoo Member dolomite and Tertiary Detritals containing thick layers of calcrete.
- **Medium Permeability Aquifers (K ~ 2–5 m/d):** Mineralised Marra Mamba (Mt Newman and McLeod), sub-mineralised Brockman Formation (Dales Gorge and Joffre) and saturated valley fill detritals.
- **Low Permeability Aquifers (K ~ 0.1–2 m/d):** Yandicoogina Member at OB31, un-mineralised Joffre and Dales Gorge Members, deeper sections of the Paraburdoo Member (unweathered) dolomite and, un-mineralised Mt Newman and McLeod Members.
- **Aquitards (K ≤0.1 m/d):** Woongarra Volcanics, Weeli Wolli Formation, Yandicoogina Member, Whaleback Shale, Mt McRae and Mt Sylvia Formations, Bee Gorge (excluding OB31), West Angela and Nammuldi Members.
- **Aquicludes (K <0.001 m/d):** Upper Mafic Volcanic Unit, Jeerinah Formation and all units below approximately 350mRL (200 m below ground surface).

The mineralised Dales Gorge aquifer is a high-permeability aquifer with estimated transmissiviies in the range of 1,000 to 1,300 m2/d (K ~ 8–9 m/d). The eastern end of the Dales Gorge aquifer may have an even higher permeability with an estimated transmissivity of around 1,800 m2/d (K~ 13 m/d). Faults have the potential to enhance vertical hydraulic connection through to the lower units including the weathered Paraburdoo Member dolomite aquifer. Along the southern margin of OB31, significant airlift yields were recorded in bores targeting the footwall (Mt Sylvia and upper Bee Gorge Members) which may be related to enhanced permeability associated with some of these structural features. The Dales Gorge aquifer is bounded to the south by the generally low permeability McRae Shale which likely retards groundwater flow in most places, except where faulting may increase permeability locally.

The mineralised Joffre aquifer along the northern side of the deposit shows zonation in permeability with eastern and western sides of the aquifer being high permeability zones with transmissivities in the range of 550 to 700 m2/d (K~ 6–7 m/d). These two high permeability zones are separated by lower permeability in the central part of the the aquifer due to a narrowing and reduced mineralisation. The mineralised Joffre aquifer is bounded to the north by the low permeability Weeli Wolli Formation and to the south by the Whaleback Shale. The mineralised Dales Gorge and Joffre aquifers transition into low permeability unmineralised stratigraphy along strike as well as at depth, laterally constraining the extents of the aquifers.

Groundwater flow and connectivity

Generally, there is a low north-easterly hydraulic gradient along the detrital valley, extending through OB31 to the Wheelarra Fault with groundwater level ranges between 501 mRL (OB18) to 496 mRL (Wheelarra Fault). Across the OB31 deposit, the hydraulic gradient (ΔH = 0.0004) is to the east, towards the Wheelarra Fault with groundwater elevations ranging from around 498 mRL in the west to 496 mRL at the Wheelarra fault, east of OB31. Regional groundwater measurements indicate up to 50m change in hydraulic head between the orebody aquifer and the Weeli Wolli Formation/Woongarra Volcanics (aquitards) to the north of OB31. This indicates low flow hydraulic boundary to the north of the orebody.

Aquifer recharge and throughflow

Studies by RPS (RPS 2014a) suggest rainfall recharge to outcropping/subcropping orebody aquifers is relatively rapid and anticipated to to vary between 1 and 2% of mean annual rainfall. Recharge to the deeper regional aquifer system of the Wittenoom Formation may be a very slow process, which only occurs after significant or prolonged rainfall events.

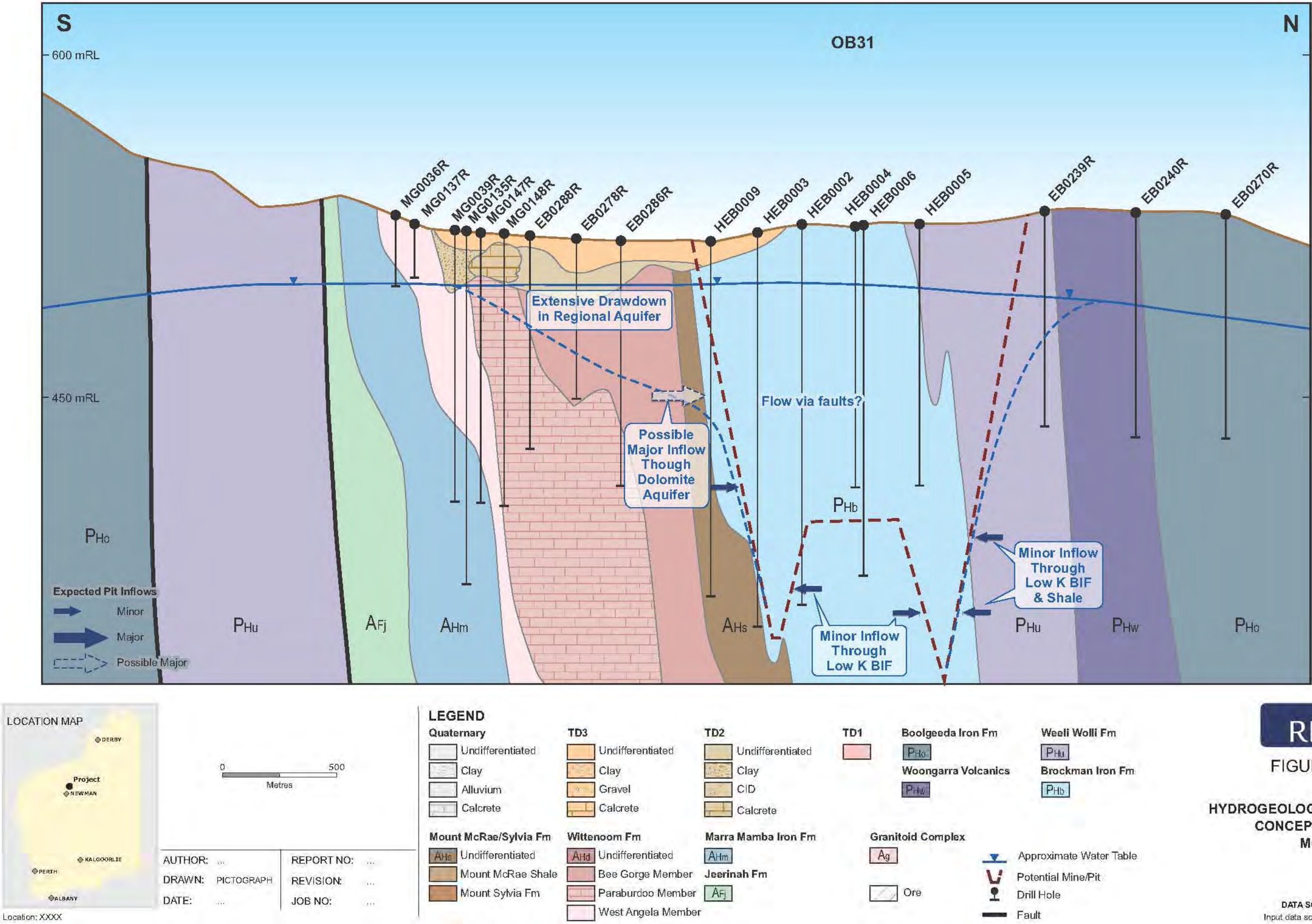


FIGURE 2

Ob31 HYDROGEOLOGICAL CONCEPTUAL MODEL

Ethel Gorge Description

Ethel Gorge (the Gorge) is located on the Fortescue River 15 km north east of Newman. The Gorge is located downstream (north) of the confluence of Homestead, Shovelanna and Warrawanda Creeks within the Fortescue River. The Gorge occurs where the Fortescue River flows through the Ophthalmia Range in a northerly direction. Downstream of the Gorge, the ephemeral river flows in a braided channel system (up to 30 m wide) to the north and then onto a broad flood plain and ultimately into the Fortescue Marsh (RPS, 2014b).

Sub-surface calcrete is extensive in the vicinity of Ethel Gorge. Where it is saturated, the calcrete hosts the regionally significant Ethel Gorge Aquifer Stygobiont Community TEC. This stygofauna calcrete habitat may extend in the surrounding alluvium (Bennelongia, 2013).

Ethel Gorge aquifers have been used for town and mine water supplies for Newman since the Ophthalmia Borefield (formerly the Ethel Gorge Borefield) was developed in 1969. Abstraction from the borefield steadily increased during the 1970s, leading to concerns regarding the long term sustainability of the resource. A managed aquifer recharge scheme – namely Ophthalmia Dam - was constructed on the Fortescue River and started operation in 1982. The dam is 5 km upstream of Ethel Gorge and was constructed to enhance recharge and augment groundwater resources in the Ethel Gorge area. The dam impounds water much of the time and forms a largely permanent surface water body in close proximity to the Gorge. Although historically the dam was built to sustain a drinking water aquifer, it now also has an important management control function to support the eco hydrology of Ethel Gorge (RPS, 2014b).

Ethel Gorge Hydrogeology

The Ethel Gorge groundwater system occurs in valley sediments bounded by predominantly low permeability basement rocks (except where the Tertiary aquifer is in contact with the weathered dolomite) (Figure 3). It consists of a highly permeable alluvial aquifer comprising an upper unit of sandy alluvium and calcrete (upper alluvial aquifer) and a lower unit of gravelly alluvium (deep aquifer). The two units are discontinuously separated by a laterally deposited lower permeability leaky aquitard sequence comprising silts and clays. Orebody aquifers, hosted in the Brockman, may have varying levels of hydraulic connection with the upper alluvial and deep aquifers respectively (evident by piezometric responses from OB25 monitoring bores) where the mineralised zone occurs on the flanks of the valley and is in direct contact with the valley fill.

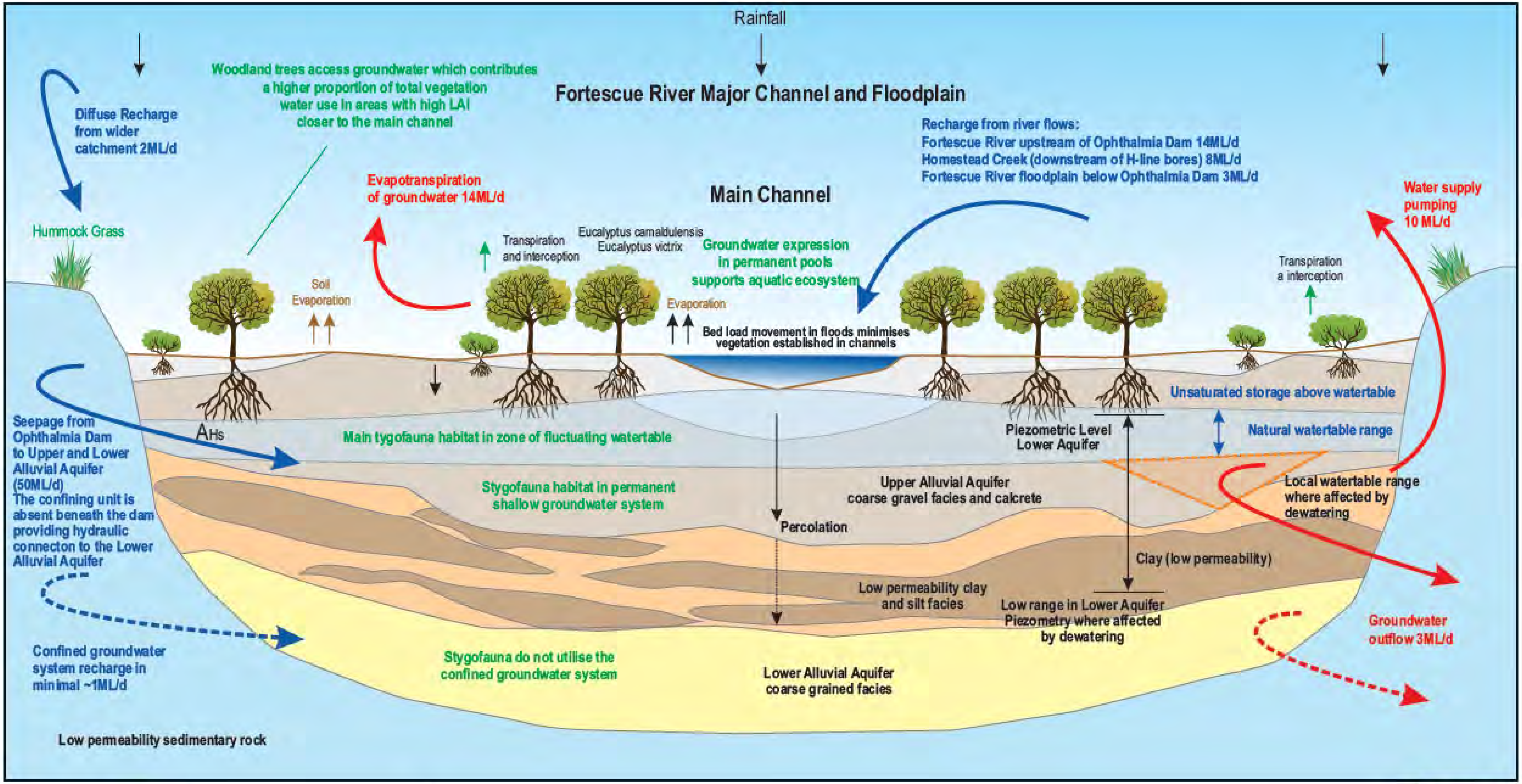
The hydraulic behaviour of the Ethel Gorge groundwater system is dominated by both the Ophthalmia Dam and the Homestead Creek drainage system during periods of high streamflow. The dam serves to detain surface water flow to increase groundwater recharge to the downgradient upper and lower alluvial aquifers.

The upper alluvial aquifer is unconfined and receives recharge from direct infiltration associated with river flow events along the Fortescue and Homestead Creeks. In addition to seasonal recharge along the river channels, the upper aquifer also receives water seeping from Ophthalmia Dam and this supports long-term trends in the volume of water stored in the aquifer and associated water levels.

Groundwater levels in the upper alluvial aquifer are within 10 mbgl across the entire valley floor area. This provides a substantial saturated thickness in the upper alluvium and calcrete, which constitutes the main extent of prospective stygofauna habitat.

The lower alluvial aquifer is largely confined by the overlying aquitard and is predominantly subject to sustained recharge from Ophthalmia Dam. Bore data indicates that the lower aquifer has piezometric heads which commonly equal or exceed water levels in the upper alluvial aquifer, particularly close to the Dam.

Aquifer parameters are within the range of regional values and the system is driven by recharge to the shallow aquifer from floods and notably from the dam, the high permeability in the calcrete and alluvium and low permeability in the basement (Table 1).



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RPS

FIGURE 3

ETHEL GORGE
GROUNDWATER DEPENDANT ECOSYSTEM
CONCEPTUAL ECOHYDROLOGICAL MODEL

DATA SOURCES:
Input data source here

Table 1: Ethel Gorge hydraulic parameters

Model Layers	Hydrgeological Unit	Horizontal Hydraulic Conductivity Kh (m/d)	Vertical Hydraulic Conductivity Kv (m/d)	Specific Storage Ss (1/m)
1 to 2	Calcrete	4.0×10^{1}	4.0×10^{0}	2.0×10^{-6}
3	Clay	1.0×10^{-1}	5.0×10^{-4}	2.0×10^{-6}
4	Gravel	5.0×10^{0}	5.0×10^{-1}	2.0×10^{-6}
1 to 6	Basement (Hamersley Group and unmineralised Brockman Iron Formation)	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-6}
	Brockman Orebody	5.0×10^{0} to 1.0×10^{1}	5.0×10^{-1} to 1.0×10^{0}	4.7×10^{-7} to 2.0×10^{-6}
	Mt McRae Shale and Mt Sylvia Formations	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-6}
	Wittenoom Formation (undifferentiated)	1.0×10^{0} to 1.0×10^{1}	1.0×10^{-1} to 1.0×10^{0}	4.7×10^{-7} to 2.0×10^{-6}
	Marra Mamba Orebody	5.0×10^{0}	5.0×10^{-1}	2.0×10^{-6}
	Basement (unmineralised Marra Mamba Iron Formation, Fortescue Basement and Metagranite/Granitoid)	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-6}
	Faults	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-6}

Recharge to the groundwater systems in the Ethel Gorge area occurs predominantly as seepage from Ophthalmia Dam at an average rate of approximately 50 ML/d (Figure 3). Other sources of recharge include direct infiltration upstream of Ethel Gorge from channel flow events (along the Fortescue River channel when the dam overflows and above the area of impoundment) and also along Homestead Creek and Shovelanna Creek which are unregulated. Total recharge from infiltration along creek channels upgradient from Ethel Gorge is approximately 24 ML/d (average) on an almost annual basis. There is also a small component of throughflow into the Ethel Gorge area from the upstream catchments; estimated to be approximately 2 ML/d in total.

Recharge volumes mainly replenish the shallow alluvial aquifer. Percolation into the lower aquifer is restricted by the lower permeability aquitard and the hydraulic loading (pressurisation) of the deep aquifer.

Groundwater discharge occurs as throughflow along Ethel Gorge (approximately 3 ML/d), evapotranspiration from riparian vegetation communities (approximately 14 ML/d) downstream of the dam and pumping (approximately 10 ML/d) for pre-dewatering steady state conditions.

Ecohydrology

Local Ecological Assets within the OB31 Project Area

Onshore Environmental have undertaken a flora survey within the OB31 project area (Onshore Environmental, 2014) and did not identify any TEC or PEC within the project area.

Onshore Environmental did not identify any groundwater dependent vegetation (GDV) over the majority of the project area. This was determined from local fine scale vegetation mapping that did not identify any phreatophytic species. There were no obligate GDV identified thoughout the project area. In the south east corner of the project, where depth to groundwater is between 5 to 25 mbgl, facultative vegetation community types were identified in the form of Eucalyptus victrix associated within the drainage line that discharges to Jimblebar Creek. There are no emphemral, permanent surface water pools or wetlands within the project area of influence that are supported by the regional water table.

Bennelongia have undertaken a Stygofuana and troglofauna sampling and desk top review study (Bennelongia, 2014). Drawdown was determined as only potentially affecting Stygofauna, species identified are known to have large habitat ranges throughout the Eastern Pilbara (Bennelongia, 2014).

Regional Ecological Assets

The OB31 project is within the Fortescue Marsh catchment area and is located 100 km up stream from the Marsh and 30 km upstream from the Fortescue River. The nearest recognised tributary to the Fortescue River catchment is Jimblebar Creek located 5 km east of the eastern-most pit extent. A small unnamed drainage line receives run off from OB31 catchment and drains to the east where it joins Jimblebar Creek.

The nearest ephemeral water body is Innawally Pool (on Jimblebar Creek), which is located 5.5 km upstream from the confluence of the unnamed creek and Jimblebar Creek (Figure 4). The nearest protected ecological asset to OB31 is the Threatened Ecological Community (TEC) community of the Ethel Gorge Stygobiont Community, located 22 km to the west; OB31 catchment does not directly drain to Ethel Gorge catchment (Figure 5).

Figure 4: Location of Innawally Pool in relation to OB31

Ethel Gorge TEC

The Ethel Gorge TEC and Ethel Gorge are identified in the EPWRMP (BHPBilliton, 2015a) as key Eastern Pilbara regional biodiversity assets and thus are considered in more detail as part of the impact assessment of OB31. The TEC is listed by the Department of Parks and Wildlife (DPaW) with some stygofauna species endemic to Ethel Gorge. The stygofauna habitat comprises saturated calcrete and alluvium aquifers, which underlies the broad Ophthalmia valley and Ethel Gorge, the latter containing the most abundant and diverse community.

Information on habitat requirements for stygofauna, including their distributions within heterogeneous groundwater environments and tolerances of differing water qualities, is very limited in the Pilbara and elsewhere (DoW 2013a). As a general rule stygofauna are often most abundant and diverse near the watertable, with species richness and abundance decreasing with distance below the watertable in association with decreasing oxygen and nutrients (Stumpp & Hose, 2013). Shallow watertable areas typically have greater stygofauna diversity, where attenuation of organic matter and oxygen by the overlying unsaturated profile is minimised. Areas with a depth to the watertable of less than 15 m from the surface have been found to favour high stygofauna diversity in alluvial aquifers in eastern Australia (Hancock & Boulton, 2008). However the depth at which stygofauna communities can persist is also influenced by different geology. Where transfer of water from the surface to aquifer is rapid, the suitable depth to watertable is likely to be greater (RPS, 2014b).

The current spatial extent of the TEC is illustrated on Figure 5, as defined by DPaW, this boundary is understood to be based on the surface expression of calcrete in the area. Over 40 years of monitoring data demonstrates that groundwater levels in this area fluctuate by up to 6 m in response to seasonal rainfall and runoff variations; however, habitat for stygofauna is considered to be maintained by zones of permanent saturation in the shallow alluvial groundwater system.

The quality of stygofauna habitat is influenced by the level of connectivity between pores, cavities, and fractures which facilitate fauna movement and dispersal. The spatial heterogeneity of the calcrete habitat at Ethel Gorge is not well understood. The zone of watertable fluctuations (i.e. the boundary between unsaturated and saturated zone) may constitute an ecotone with different species assemblages in comparison with constantly saturated and unsaturated zones respectively; however, this has not been confirmed at Ethel Gorge (RPS, 2014b).

The Ethel Gorge area also supports riparian vegetation communities along the major channels including (DEC 2013):

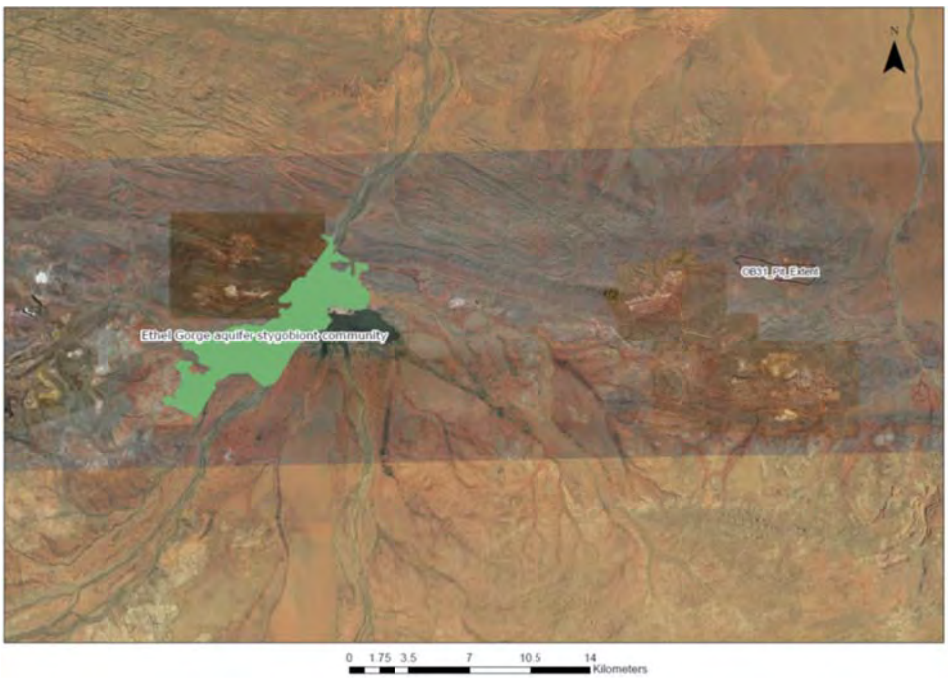
- Open Forest of *Eucalyptus victrix* (Coolibah) and *Eucalyptus camaldulensis* (River Red Gum) over sedges of *Cyperus vainatus* and *Typha domingensis* along major drainage lines.
- Open Woodland of *Eucalyptus victrix* over Low Open Woodland of *Acacia citrinoviridis* over Scattered Tussock Grasses of *Cenchrus ciliaris.*
- Open Mallee of *Eucalyptus socialis* subsp. *eucentrica* over Very Open Hummock Grassland of *Triodia pungens* on floodplains.

The entire upstream catchment area of Ethel Gorge hosts approximately 3,650 ha of Eucalypt woodland communities including the facultative phreatophytes *E. camaldulensis and E. victrix*. These species along with other vegetation species access shallow groundwater to varying degrees and contribute to groundwater discharge via evapotranspiration. Woodland transpiration is likely to occur from areas where the watertable is less than 10 to 20 mbgl which is a vast area over the broader region (3,640 ha). The proportion of groundwater used by the woodland vegetation (as a component of total water use) would be expected to be greatest where the depth to watertable is shallow (i.e. where soil moisture storage in the unsaturated profile is limited by depth). The water balance indicates the dominant groundwater discharge mechanism from the Gorge downstream from the dam is by evapotranspiration (14 ML/d) from vegetation followed by groundwater outflow (~3 ML/d) (Fiugre 3). Due to the shallow depth to water through the Gorge, there is a strong coupling between hydrology and ecology of the terrestrial environment.

The relative proportion of vegetation water use from groundwater in comparison with soil moisture remains uncertain (i.e. rainfall and runoff). It is possible that in some areas, groundwater is only accessed transiently, during prolonged dry periods where the unsaturated profile deepens. In general terms, a greater reliance on groundwater would be expected as the moisture content in the unsaturated profile decreases below plant wilting point. Vegetation communities overlying stygofauna habitat may be an important source of carbon and nutrients for stygobiont communities. Phreatophytic roots are known to be a source of organic matter to aquifer invertebrates (Jasinska *et al.*, 1996).

Historically, water levels in Ethel Gorge were much lower than those observed today when groundwater abstraction during the 1970s (before the construction of the Ophthalmia Dam) resulted in falling water levels throughout the Ophthalmia aquifers (upper and lower alluvial aquifers) over a period of about 10 years. In some areas, saturated thickness was reduced to less than 50%. Since it's commissioning in 1982, the Ophthalmia Dam has also changed the groundwater regime of the area, generally contributing to elevated groundwater levels by prolonging the period of recharge. Despite these highly dynamic hydrologic events, stygofauna surveys carried out since the 1990s indicate a rich and abundant stygofauna community, suggesting that stygofauna were able to recover from the groundwater drawdown events.This suggests that stygofauna is less sensitive to the rate of groundwater change compared to for example phreatophytic vegetation species, which has to develop root systems to access groundwater.

Figure 5: Location of Ethel Goreg TEC to the OB31 project



Existing and potential stressors (RPS, 2014b)

Pumping related to dewatering of BHPBIO mining areas (Orebody 23 and Orebody 25) has resulted in reductions in water levels in the vicinity of these operations (Figure 3). The largest reductions are noted from the deep alluvial aquifer and represent a depressurisation response. Water levels in the shallow alluvial aquifer have generally declined by less than 10 m (within 500 m of the BWT mining areas). Thus to date the calcrete of the TEC has remained largely saturated, with limited aerial extent influenced by dewatering drawdown influences.

Long-term depressurisation of the deep alluvial aquifer, as a result of ongoing dewatering activities, has the potential to accentuate leakage into the underlying deep aquifer where the piezometric head falls below the water levels in the upper alluvial aquifer. This has the potential to reduce groundwater levels in the upper alluvial aquifer. The ability of stygofauna to recolonise areas that become re-saturated after a dewatering event is unknown; although rich stygofauna habitat within Ethel Gorge has experienced significant drawdown prior to the construction of the dam which have since resaturated. However in the Ethel Gorge area, the high watertable and seasonally variable influx of water and nutrients from storm events are likely to aid in stygofauna dispersal.

Ophthalmia borefield provides water supply to the Newman townsite, Ophthalmia borefield is part of an integrated water supply system providing water to the Newman townsite along with Homestead Borefield. Drawdown from the the operation of the Ophthalmia Borfield reduces the saturated thickenss in immediate vicinity of the production bores. The drawdown from abstraction is mitigated by Ophthalmia dam which is designed to detain surface flow within the Fortescue River in order to enhance recharge.

Impact Assessment

There are two potential impacts associated from the OB31 project with respect to altered hydrology; these are:

1. Regional water table drawdown in response to mine dewatering at OB31; and
2. Changes to surface and groundwater regimes in response to surplus water management (options local to OB31, and at discharge to Ophthalmia Dam).

These potential impacts are considered during operations and following mine closure.

Drawdown from Mine Dewatering

A groundwater model has been developed (Appendix 1) for OB31 and has been used to estimate the required dewatering volumes to enable the mine plan, the radial extent of drawdown and to assess the long term recovery during closure.

Details of the modelling program are described in Appendix A. Drawdown propagates preferentially to the west following transmissivity along the Wittenoom Formation with drawdown constrained by the Wheelarra Fault (to the south and east) and to the north by lower permeability Weeli Wolli and Yandicoogina Formations (Figure 4-2 – Appendix 1).

The OB31 numerical model also considers cumulative drawdown from existing approved BWT operations (namely Jimblebar mine). Drawdown at the proposed and existing operations is attenuated by the Wheelarra Fault, which is expected to form a regional hydraulic boundary to drawdown propagation (refer to OB31 conceptual model section).

The two metre drawdown contour extends to the Warrawandu potable borefield north of the Warrawandu accommodation village. The 2 m drawdown contour does not extend into the Ethel Gorge TEC boundary for any of the parameter sets tested in uncertainty analysis (Figure 4-2 – Appendix 1).

The key uncertainty to be recognised for estimation of dewatering volume and drawdown is the degree of hydraulic connectivity with the regional aquifer system. This is tested through uncertainty analysis, and in the long-term will be progressively addressed as a long term monitoring data set is developed from the installed network.

Impacts to GDEs

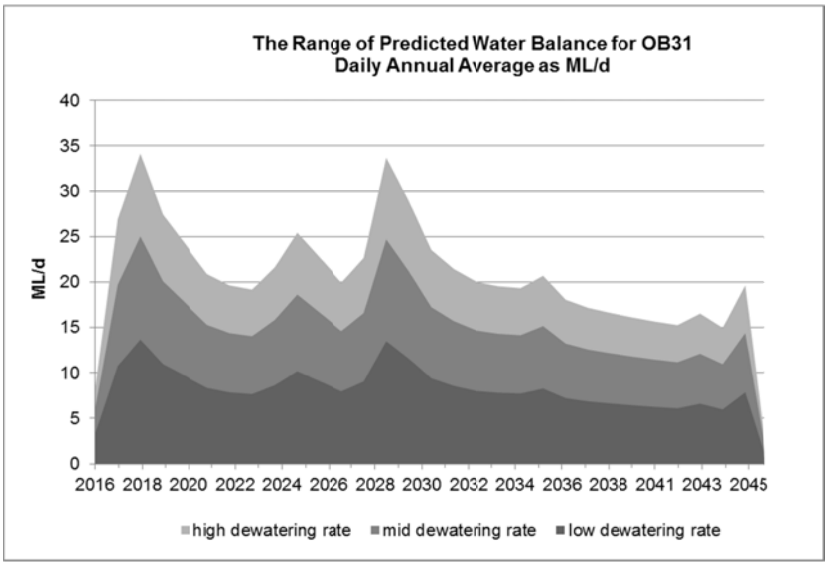
As discussed (Onshore, 2014) the only known extent of potential groundwater dependent vegetation (GDV) is to the south east of the orebody where *E. victrix* is mapped in an area with the water table surface between 5 and 20 mbgl. It is predicted this area will experience up to 30 m of drawdown. There are no other known GDV within the study area that would be affected by drawdown.

Bennelongia have undertaken stygofauna sampling within the predicted maximum extent of drawdown and the nearest known stygofuana community is the Ethel Gorge TEC (Bennelongia, 2014). As discussed above, this is not predicted to be affected by dewatering drawdown from OB31. The depth to water is deep across the majority of the study area (>30 mbgl) as such the area is unlikely to host significant stygofauna habitat areas (Bennelongia, 2014). The regional water table is predominantly in the Wittenoom Formation; the detrital calcrete systems which are often associated with stygofauna communities are largely unsaturated. As such the risk of impact to stygofauna communities is considered low in the vicinity of the mine.

Changes to surface and groundwater regimes in response to surplus water management

The numerical modelling provided estimates of the range of anticipated dewatering rates required to access below water table ore at a mining rate of 15 Mtpa (Figure 6). The predicted dewatering range relects the current hydrogeological uncertainty and potential mine development scenarios. The higher and lower dewatering estimates have been provided below. With a predicted water demand of up to 4 ML/d, a surplus water volume of up to 30 ML/d is possible.

Figure 6: The upper and lower dewatering estimate for OB31



In accordance with the Pilbara Water in Mining guidelines (DoW, 2013), multiple surplus water management options are being considered in order of preference (Table 2). The Eastern Pilbara surplus water management plan (BHPBilliton 2015b) covers three mining hubs (Jimblebar, Eastern Ridge and Whaleback) within the Newman area to address a net water surplus volume and summarise the regional cumulative water management strategic approach. The surplus plan is in recognition of the need for a regional approach which addresses the collective and cumulative management of surface and groundwater as outlined in the Pilbara Water Resource Management Strategy (BHP Billiton, 2014). The introduction of the mines which are enabled by the plan will be staged as new mines commence and as existing mines are included over the mid term.

Orebody 31 (OB31) will be the first mine to be included in the surplus plan. The plan includes only industrial water management with potable and wastewater managed through Drinking Water Source Protection Plans and the Environmental Management Plan for each hub.

The DoW policy stipulates that mine dewatering volumes must first be used for:

- Mitigation of environmental impacts; and
- Fit-for-purpose onsite activities (e.g. processing, dust suppression and mine camp use).

Any dewatering volumes that remain after these requirements have been met constitute mine dewatering surplus with options for management as follows:

1. Transfer water to meet other demands.
2. Reinjection back into an aquifer.
3. Controlled release to the environment.

For the purposes of aligning surplus water management options with DoW policy; options have been categorised based on the primary management objective as either:

1. **Transfer surplus water to a demand area**, for mine production, dust suppression, potable supply or community or 3rd party activities.
2. **Aquifer return**, includes reinjection or infiltration.
3. **Release,** includes evaporation and surface water discharge.

The approach is in line with the BHP Billiton sustainability charter and considers prioritisation of transferring surplus water to delivery points and infiltrating water to the aquifer to minimise any potential impacts to receiving receptors and offset the area of pumping influence.The surplus options considered for OB31 are outlined in Table 2.

Table 2: Surplus water management options considered

Surplus Management Options	Rationale	Limitation
Primary Option – Discharge to Ophthalmia Dam and surrounding infiltration ponds MAR system. **Application** - up to 30 ML/d.	The transfer of water and discharge to an approved MAR facility enables flexibility and regional water management sustainability and mitigates impacts to Ethel Gorge GDEs as a preventative control. A pipeline ultimately provides a regional water management solution which integrates and transfer water between multiple mining areas and surplus water area. The approach would prepare the region for future water challenges and maximise the opportunity for beneficial water use.	The long term sustainability of transferring surplus water to Ophthalmia Dam MAR system may ultimately be limited by the Dam and underlying aquifer capacity. The capacity would be reach when 1) discharged water is "rejected" into Fortescue River once the aquifer fills and spills, and 2) aquifer water quality degrades due to salt loads generated through evapotranspiration developing above unacceptable thresholds.
Backup Option – Controlled discharge to Jimblebar Creek **Application -** Up to 30 ML/d for periods of up to 3 months during wet season or when needed through failure or maintenance of Option 1.	Controlled discharge to Jimblebar Creek is being considered as an emergency backup option and seasonal discharge alternative. Ultimately, creek discharge may become more of a permanent alternative however it is recognised further assessment work is required. The creek capacity and ecological response to discharge will be assessed through a hydrodynamic trial to determine what role creek discharge may play as part of an integrated surplus water management approach.	The potential for impacts to the riparian vegetation and fauna within the Jimblebar Creek require assessment to determine the extent and period of wetting front and changes to water permanency and quality. The ultimate capacity of Creek discharge would be the impact to Fortescue Marsh should the wetting front migrate an unacceptable distance to the north.
Alternative under evaluation - Return to the Ophthalmia Range dolomite aquifer via MAR **Application** - capacity to be defined during later studies (10 ML/d potential)	Returns surplus to the groundwater to minimise drawdown and area of influence within areas of potential impact around OB31 and neighbouring mines (OB18). Drawing on Jimblebar MAR trial results, the orebody and dolomite aquifers appear to have some capacity to accommodate injected water. Up to 12 MAR bores would be required to inject the anticipated volumes along a strike length of over 20 km.	A suitable reinjection location has not been located with sufficient. MAR may have application on a smaller scale and volume and used in conjunction with Ophthalmia or Creek discharge to locally minimise drawdown effects. A MAR trial is planned for 2015 in the vicinity of OB18.

Impact assessment – Ethel Gorge

A number of surplus water management options have been evaluated as part of OB31 environmental approvals and the overall Eastern Pilbara Water Resource Management Plan (EPWRMP) (BHPBilliton, 2015a). The discharge of surplus mine dewater to Ophthalmia Dam has been selected as the preferred option. The dam and the surrounding recharge ponds do mitigate and prevent environmental impact to Ethel Gorge and can enable flexible integrated catchment scale water management. The purpose built Ophthalmia Dam MAR scheme has been in operation for over 30 years and has effectively enhanced recharge to the downstream aquifers in the Ethel Gorge TEC area and the Ophthalmia drinking water borefield to mitigate impacts from groundwater abstraction. The Ethel Gorge aquifer will have a maximum volumetric capacity and salt load tolerance. If the MAR system is used excessively as a surplus management option, an unacceptable change to hydrological conditions may ultimately occur (such as rising water levels or a degradation of water quality). An alternative or supporting surplus option may need to be considered to manage this risk.

To establish the upper surplus water discharge capacity, specific assessments have been conducted using a regional numerical model (RPS, 2014d) (Appendix 2) to predict changes to water level and, an analytical water quality model (RPS, 2014e, f) (Appendix 3) to address the development of an unacceptable salt load. These studies predicted changes in hydrological conditions by simulating a range of stresses and threatening process including:

1. the addition of OB31 surplus discharge,
2. the continued discharge of approved mines,
3. abstraction from the Ophthalmia borefield, and
4. the use of Ophthalmia Dam and the infiltration basins / ponds.

The outputs included the predicted range of changes in:

1. down gradient groundwater response, and
2. salt balance of the dam and Ethel Gorge (Appendices 2 and 3).

Importantly, the models considered various volumetric and operational configurations to establish the likely range of outcomes, sensitivities and volumetric thresholds.

Changes to Hydrological Conditions

Predicted Changes to Water Level

The primary area of assessment focused on the Ethel Gorge unconfined aquifer that supports the stygobiont community and riparian vegetation to the north of the Dam. As discussed above, historically the unconfined alluvial aquifer experiences natural variances in water level and quality, typical of the Pilbara dominated by extreme climatic conditions. The groundwater dependent communities have adapted to these natural variance conditions, such as relatively rapid rises in groundwater levels after significant runoff events, followed by decay in water levels during period of low recharge.

The Ethel Gorge aquifer has also undergone additional hydrologic change with the introduction of threatening processes since the 1970s including the operation of the Ophthalmia Borefield for water supply to Newman, the construction of the Ophthalmia Dam and adjoining recharge facilities, adjoining dewatering activities and mine surplus water infiltration. Despite these highly dynamic stresses, monitoring programs have demonstrated that the shallow unconfined aquifer in Ethel Gorge continues to support high biodiversity stygofauna community and riparian vegetation.

The volumetric capacity (the water level threshold at which impact occurs) and the water balance of the Ethel Gorge aquifer is primarily controlled by Evapotranspiration (EVT), infiltration of rainfall runoff and Dam leakage. These parameters have a degree of uncertainty.

In order to determine the sustainable discharge capacity various discharge volumes (15 ML/d up to 120 ML/d) and two EVT rates were incorporated into the Ethel Gorge numerical model and Ophthalmia Dam water balance model. The EVT rates applied in the model are considered to cover the range of outflow uncertainty (Appendix 2) and the surplus volumetric scenarios reflect the full range of potential mine development scenarios and schedules, over and above OB31, enabling cumulative effects to be considered.

Initially, the model was run for 30 years on yearly time steps for a “no discharge” scenario to establish baseline hydrological conditions. The model was also run for incremental increases in dewatering discharge (15, 30, 60 and 120 ML/d). Water was directed into the Dam and once the dam was full any additional surplus was directed into the recharge basins and ponds to reflect operational reality. The various scenarios were compared with the predicted baseline conditions to evaluate the change in water levels in the unconfined aquifer. The EVT flux for the Gorge was assessed at equivalent rates of around 1.4 and 2.0 mm/day plant water use. The modelled aquifer water levels responded by rising until the aquifer filled and rejected the recharge as seepage into Fortescue River. The timeframes and volume of discharge was established for each surplus and EVT sensitivity run (Appendix 2).

Change Assessment and Impact Predictions

As outlined in the EPWRMP, the key water management objective is to maintain water levels within the long term natural range and allow for seasonal variation to prevent the prolonged inundation of the fringing riparian vegetation.

The predictive modelling indicates the Ethel Gorge aquifer can accommodate 40 ML/d of additional long term surplus water infiltration whilst maintaining water levels within management threshold ranges. Above 50 ML/d the seasonal trends decrease and by 120 ML/d results in up to 30 ML/d of groundwater discharging into the Fortescue River drainage lines within 3 years.

Based on these preliminary results, the Ethel Gorge aquifer system can sustainably accommodate a dewatering discharge rate of at least 30ML/d, and potentially up to 50 ML/d before management thresholds are reached. As part of the adaptive management approach outlined in the EPWRMP, ongoing monitoring and conceptual refinement will be undertaken to address the uncertainty and provide operational improvements.

Changes to Water Quality

The key water quality parameter considered in the impact change assessment and the EPWRMP is total dissolved solids (TDS), although it is recognised that a number of other water quality and physical parameters may be important for the sustainability of the stygofauna community, including nutrients and dissolved oxygen.

Although considerable uncertainty exists as to the sensitivity of stygofauna community health to TDS the investigation thresholds represent statistically representative historical ranges of up to 4,000 mg/L. The approach is assumed to be precautionary as monitoring has shown that stygofauna abundance is not impacted for TDS >4,000 mg/L.

Details of this assessment are provided in Appendix 3. Any change in the water quality conditions are most likely to result from an increase in the salt load of the aquifer over time as surplus water with higher TDS is infiltrated into the aquifer through the dam or the recharge ponds. Modelling demonstrates that the TDS increase with distance from the dam, owing primarily to evaporative concentration effects over the mid to long term. It is predicted that the TDS could potentially exceed the thresholds within 20 years after discharge commences. However, the timeframes are dependent upon the volume of surplus water, natural recharge of fresh runoff water and the operation of the MAR system.

High level hydrogeochemcial assessment was undertaken to determine potential impact of discharge the Brockman Orebody Aquifer water type to the Ophthalmia and subsequent potential changes in chemistry. A preliminary review of the data for the OB31 aquifer suggests a Ca+Mg/Na+K type without a dominant signature. Ethel Gorge water tends toward a relatively high proportion of Na, Cl; and Ophthalmia Dam water has an HCO_3 type signature. Potential hydrogeochemical impact as a result of discharge includes:

1. Carbonate saturation (elevated alkalinity / bicarbonate ion concentration);
2. Sulfide oxidation leading to potential decrease in pH and mobilisation of metals; and
3. Chloride salinity.

Water quality monitoring will be undertaken in accordance with the adaptive management approach outlined within the Eastern Pilbara Water Resource Management Plan.

Managed Aquifer Recharge via local borefield

MAR via a local injection borefield has been evaluated. Based on the current assessment, this option is considered less favourable due to; the potential for recirculation back to the dewatering operation; and the expected capacity of the dolomite and valley fill aquifer system being inadequate to receive all surplus to be managed. As such this option is not expected to represent a sole solution for surplus but may form an option for periodic peak surplus management. The depth to water table is greater than 60 m below the ground surface within the injection area, reducing the potential adverse impact from mounding, particularly as there is no groundwater dependent vegetation identified over the majority of the study area. The viability of a long-term MAR scheme will be assessed with additional numerical modelling once a transient model calibration is undertaken.

Creek discharge to Jimblebar Creek (and potential expansion to Carramulla Creek)

There are two potential creek discharge options including Jimblebar Creek and Caramulla Creek which are being explored as short-term contingency or seasonal options at this stage. Creek discharge is the least preferable surplus management option in acknowledgement of the DoW's guidance (2013).

There is very limited data regarding the sub-surface storage capacity of both creek systems. A proposed hydrodynamic trial will enable the assessment of creek response to discharge, particularly the propagation of the wetting front, to indicate the degree of sub-surface storage available. The hydrodynamic trial has been designed to provide a long term monitoring data set. Several production bores within the orebody will be run for a fixed rate for a fixed period, with the principal aim to assess the degree of along strike connectivity, regional connectivity and pore pressure responses in low permeability units. The water produced will be discharged to Jimlbebar Creek where wetting front monitoring will enable assessment of hydraulic leakage of the alluvium.

Permanent or temporal discharge will be evalauted as part of ongoing assessments. Preliminary biodiversity studies have identified limited high value biodiversity assets along or within the creek down gradient of the proposed discharge point (Fortescue Marsh 100 km downstream). If the trial indicates the lower dewatering estimate, it is possible that a combination of various sustainable discharge options will be explored. Riparian vegetation baseline surveys are being undertaken as part of the project to identify species that may be sensitive to altered hydrology, as this will enable a more thorough assessment of the influence of creek discharge on the local biodiversity values.

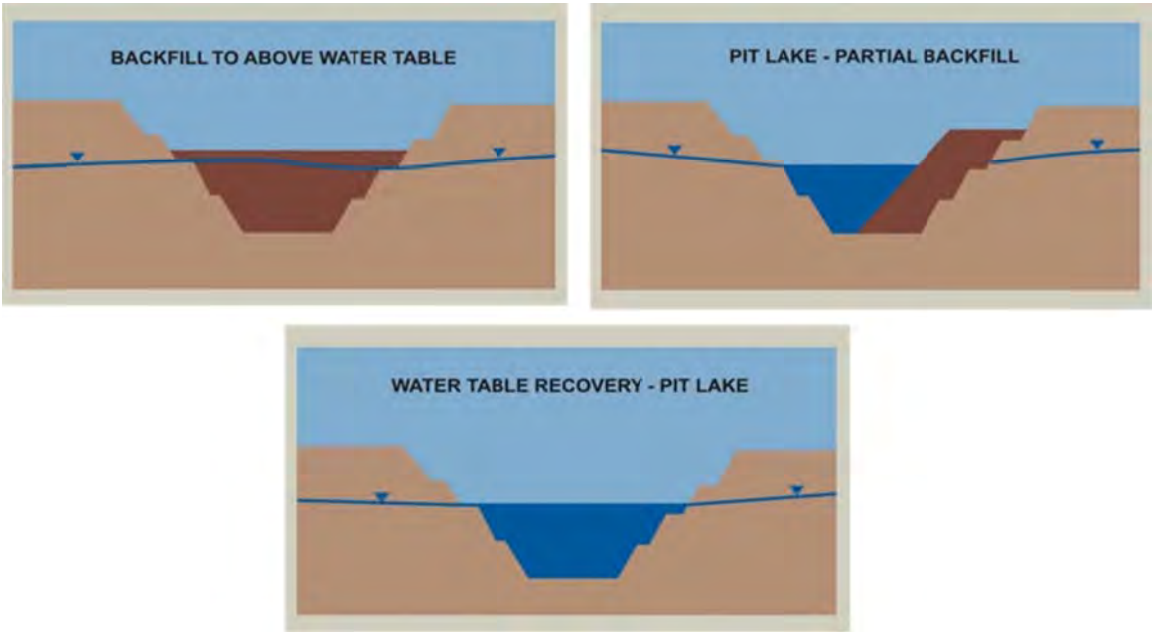
Hydrological Legacy after Mine Closure

The purpose of the closure assessment is to determine the long term hydrological impact of different closure management options for OB31. The focus of this work is the hydrological impact particularly relating to pit void management. As discussed previously, OB31 is approximately 70% BWT and once the orebody is mined out the pit void will extend well below the premining water table.

The OB31 numerical model (Appendix 1) was used to determine the long term hydrological change using three different closure management options including:

- completely infilled pit void to 5 m above the premining water level,
- partial back fill void and
- an empty void with the development of a pit lake (Figure 7).

Figure 7: Schematic representation of the different pit closure options assessed

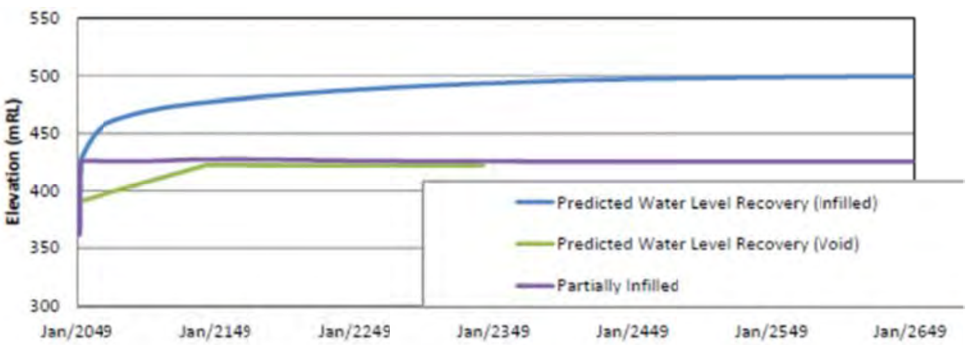


Each of the closure management options were implemented in modelling from 2048 following the cessation of dewatering at OB31. Full details of the closure prediction model set up and scenario is provided in Appendix A. For the backfilled void (assuming backfilled material of equivalent hydraulic parameters as the ore body aquifer) the water levels will rebound to premining level after an extended period of time as flow from the regional aquifer and recharge replenishes the storage of the backfilled void. For the empty void, a pit lake develops at a rate governed by the rate of groundwater and surface inflows and loss via direct evaporation. Under the open void scenario rebound to the premining water level is unlikely due to the ongoing evaporative loss from the pit lake.

The modeling predicted these dynamics, with the infilled void rebounding 100 m within 50 years of the cessation of dewatering. There was full recovery of water levels to premining levels after 600 years (90% recovery after 300 years). The partially backfilled void rebounded 55 m within 20 years of closure and achieved steady state water level after 70 years. For the pit lake scenario, water levels recover rapidly in the first 20 years following dewatering; however, the rate of rebound decreases significantly to a steady level of 420 mAHD (70 m below the premining level) (Figure 8). Each of the closure management options present different long term hydrological states. The completely backfilled void recreates the premining hydraulic gradient with through flow occurring to the north and north east. The pit lake and partial backfill options create a regional groundwater sink. The final water level is lower than the regional water table and so groundwater discharges to the pit lake where evaporation occurs.

Each closure options present different potential hydrological legacy conditions. The backfilled void recreates a premining hydrological condition; however, increases the risk of downstream impact through the potential transport of any potential acid metaliferious drainage associated with mine waste. Conversely, the pit lake sustains a drawdown footprint however reduces downstream impacts by containing poor quality water within the pit.

Figure 8: Predicted water level recovery following mining at OB31 in each of the pushback phases (Appendix 1)



Water Management Plan

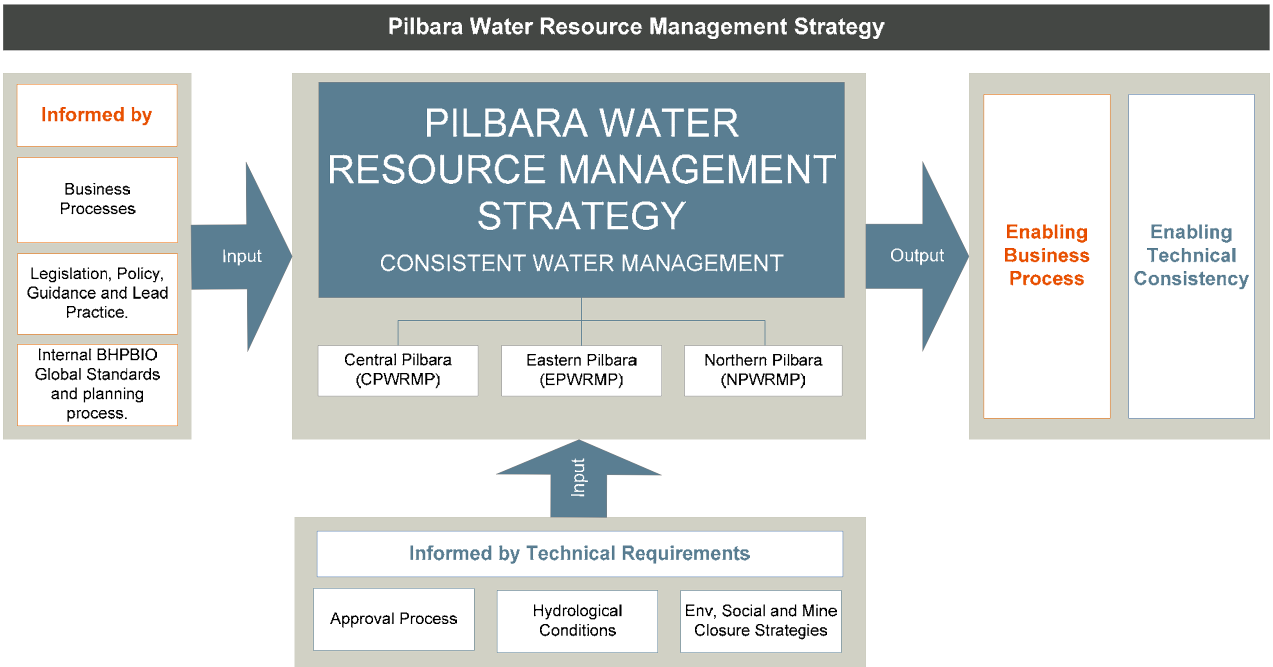
Eastern Pilbara Water Resource Management Plan

WAIO has formulated and operates under a regional water management strategy that delivers sustainable, feasible and cost effective measures to address our existing and future challenges. Importantly, the approach prepares the business for various and changing water balance scenarios and directs proactive management measures to mitigate potential impacts relating to hydrological change on a regional scale.

The objective is to enable sustainable water resource management for below water table mining operations and operations which intercept surface water flow by setting outcome-based conditions and adaptive management techniques to mitigate and offset our operational effects on water levels and quality through 1) preferentially returning surplus dewater to the aquifer and 2) maintaining baseline hydrological conditions at the key environmental receptors.

The PWRMS was designed and planned to provide a consistent approach to water management across the business, as well as providing operational and approval flexibility, as shown below:

Figure 9: Overview of the Pilbara Water Resource Management Strategy -



The EPWRMP (BHPBilliton, 2015a) aims to provide a consistent method to identify:

1. the hydrological changes (groundwater and surface water quantity, levels and quality) resulting from BHPBIO mining and closure activities,
2. the receiving receptors (water resources, environment, social and third party operations),
3. the potential impacts, and
4. the required risk-based adaptive management to mitigate potential impacts to acceptable levels.

The EPWRMP is guided by a water outcome-based objective:

To manage the range of potential hydrological changes (groundwater, surface water and/or soil moisture) resulting from BHPBIO Eastern Pilbara Hub operations impacting on receiving receptors to an acceptable level.

This objective is supported by thresholds to monitor whether a hydrological change can result in an impact to a receiving receptor as a result of BHP Billiton Iron Ore operations. Two receptors have been identified as having the potential to be impacted by changes in hydrological processes associated with the implementation of the Orebody 31 proposal, these being the Ethel Gorge TEC and Jimblebar Creek.

Early warning triggers are also defined to provide the point at which water management options must be considered and implemented to avoid potential impact to a receiving receptor; the trigger is intended to operate sufficiently early to allow water management options to be activated well oin advance of the breach of a threshold value for the receiving receptor.

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Appendix 1 OB31 groundwater numerical model

Planning

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OB31 – DEWATERING PREDICTIONS

Document information

Function	Resource Planning - Hydrology
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Table of Contents

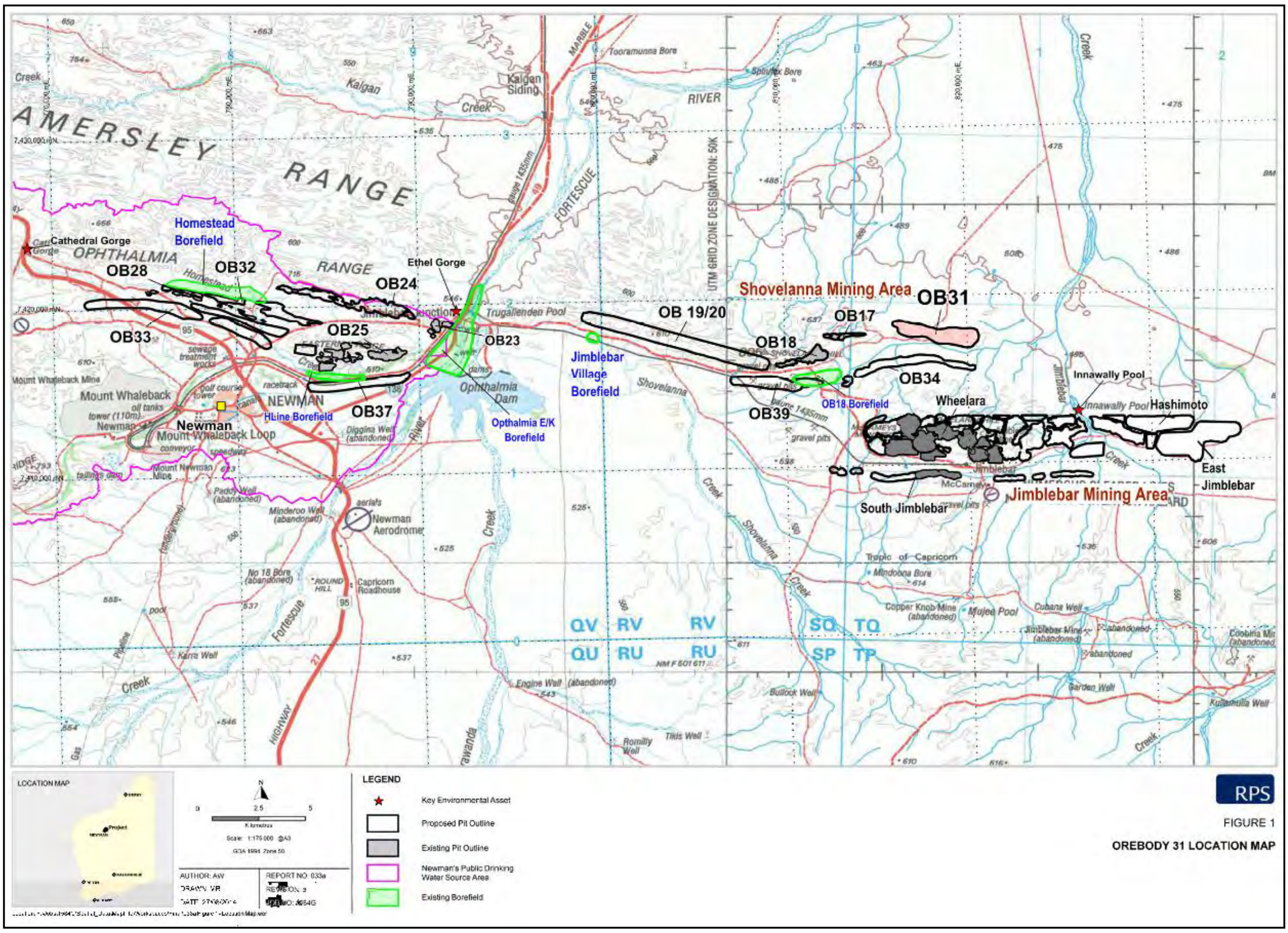
1 INTRODUCTION

1.1 BACKGROUND

The Orebody 31 (OB31) deposit is located approximately 40 km east of Newman and lies within BHPBIO's Shovelanna – Ninga – Mesa Gap mining area (hereafter referred to as the Shovelanna mining area). BHPBIO's current mining operations at OB17 and OB18, as well as the future proposed mining areas at OB19/20, OB34 and OB39 are also located within this area. The locations of these orebodies within the Shovelanna mining area are shown in Figure 1.1.

BHP Billiton Iron Ore (BHPBIO) are currently seeking approval to develop OB31 to sustain iron ore production as the OB18 mine is depleted. The purpose of this modeling study is to support engineering design and environmental impact from dewatering operations at OB31.

Figure 1.1 – Location map



1.2 OBJECTIVES AND SCOPE OF WORK

The objectives of the study were to:

- develop and calibrate a groundwater numerical model of the OB31 area suitable for simulating long term dewatering activities;
- to use the model to predict the dewatering required to support mining at OB31; and
- to test the uncertainty in these predictions.

1.3 PREVIOUS WORK

A regional scale groundwater model was developed as part of the hydrogeological assessment for the Jimblebar Iron Ore Project (Aquaterra, 2009). The model included the Shovelanna, South Jimblebar, Wheelarra Hill and Hashimoto mining areas. In 2012, the model was modified in the South Jimblebar area and calibrated to long term monitoring data from operation of the Jimblebar water supply borefield and the South Jimblebar Hydrodynamic Trial (RPS Aquaterra, 2012). Although the Shovelanna area was included in all versions of this model, no calibration was undertaken and no predictive stresses have been applied in this area in the previous studies. The preferred method for this modelling was therefore to utilise and update this existing regional model with the most recent understanding of the Shovelanna hydrogeological system.

2 CONCEPTUAL MODEL

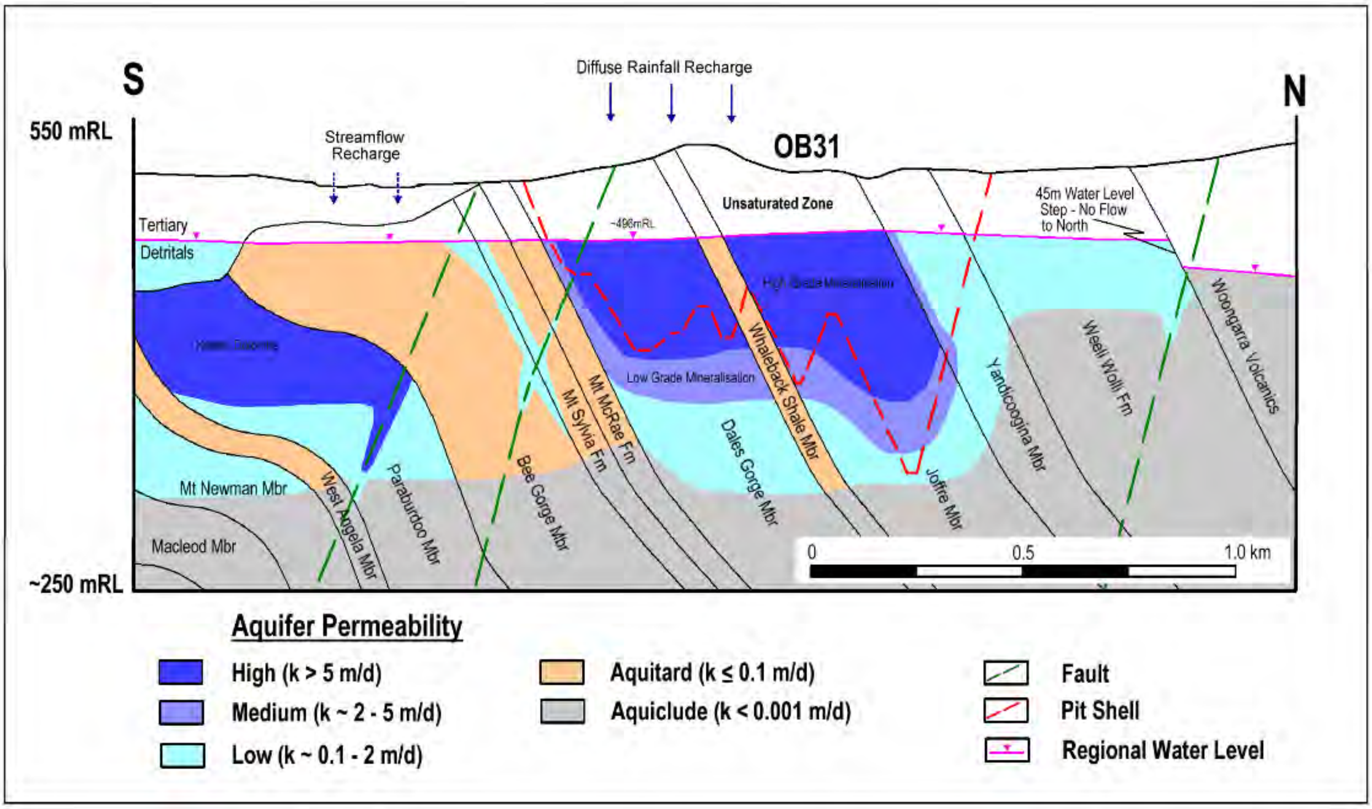
OB31 high grade ore is found within mineralised members of the Brockman Iron Formation. These mineralised units form an aquifer with elevated hydraulic conductivity and storage. The mineralisation is concentrated mainly within the Dales Gorge and Joffre Members. It is these hydrostratigraphic units (orebody aquifers) therefore that will need to be dewatered during mining of OB31.

The groundwater level gradient at OB31 is relatively flat with groundwater flow from west to east through the orebody aquifers. The depth to groundwater ranges from around 15 to 45 metres below surface. The water level elevation varies between 495 and 498 mRL. It is likely that recharge to the groundwater system via rainfall and throughflow from outside the groundwater catchment is very low.

The thickness of the orebody aquifers generally vary between 80 and 120 m, but reach a maximum thickness of approximately 150 m in the south-eastern section of the deposit. It is estimated that approximately 70% of the deposit lies below the regional water level.

The orebody aquifers are bounded immediately to the north and south by the lower hydraulic conductivity stratigraphies (Figure 2.1) of banded iron formation and shale of the Weeli Wolli Formation (north) and Mt McRae Shale (south). At a regional scale the aquifers are bounded by the low permeability Wheelarra Fault to the east.

Figure 2.1 – Hydrogeological cross section



The Dales Gorge and Joffre Members are continuous to the west (and also beneath the orebody), however, as the mineralisation envelope is not expected to extend in this direction, the permeability will be much lower in these units away from OB31.

The regional aquifer system is comprised of Tertiary Detritals underlain by weathered Paraburdoo dolomite and is confined to a relatively narrow strip along the northern edge of OB34 and OB39. Due to the presence of the McRae Shale the regional aquifer system is not in direct hydraulic connection with the orebody aquifer. However, testing of the area south-east of the OB31 aquifers has indicated that connection through the shale may be provided by structural features (e.g. southerly dipping thrust faults).

The hydrogeological investigations undertaken at OB31 have provided sufficient information for the main flow mechanisms to be defined. However, as the aquifers have not been tested for a significant amount of time (commensurate to the time needed for dewatering) uncertainties remain. The greatest uncertainties in terms of the factors that will control the scale of dewatering required at OB31 are:

- The extent and degree of hydraulic connection between the orebody aquifer and the regional aquifer system along the southern margin of the OB31 deposit.
- The westward extent of permeable (submineralised) Dales Gorge and Joffre units.
- The continuity of the regional aquifer system and the degree of hydraulic connection with Ethel Gorge to the west and Jimblebar Creek to the east.
- The hydraulic characteristics of the Wheelarra Fault System to the east of OB31.

3 NUMERICAL MODEL

3.1 MODEL SET-UP

The groundwater model was developed using the Modflow Surfact code (Hydrogeologic, Version 3.0) operating under the Groundwater Vistas graphical user interface (Rumbaugh and Rumbaugh, 1996 to 2007).

The model domain and grid and the location of model boundary conditions is shown in Figure 3.1.

The model uses a minimum model grid size of 50 m by 50 m and is divided into 291 rows and 671 columns.

The model and all associated data are specified using the GDA94 Zone 51 coordinate system. The model domain covers an area of 48 km (west to east) by 20 km (south to north).

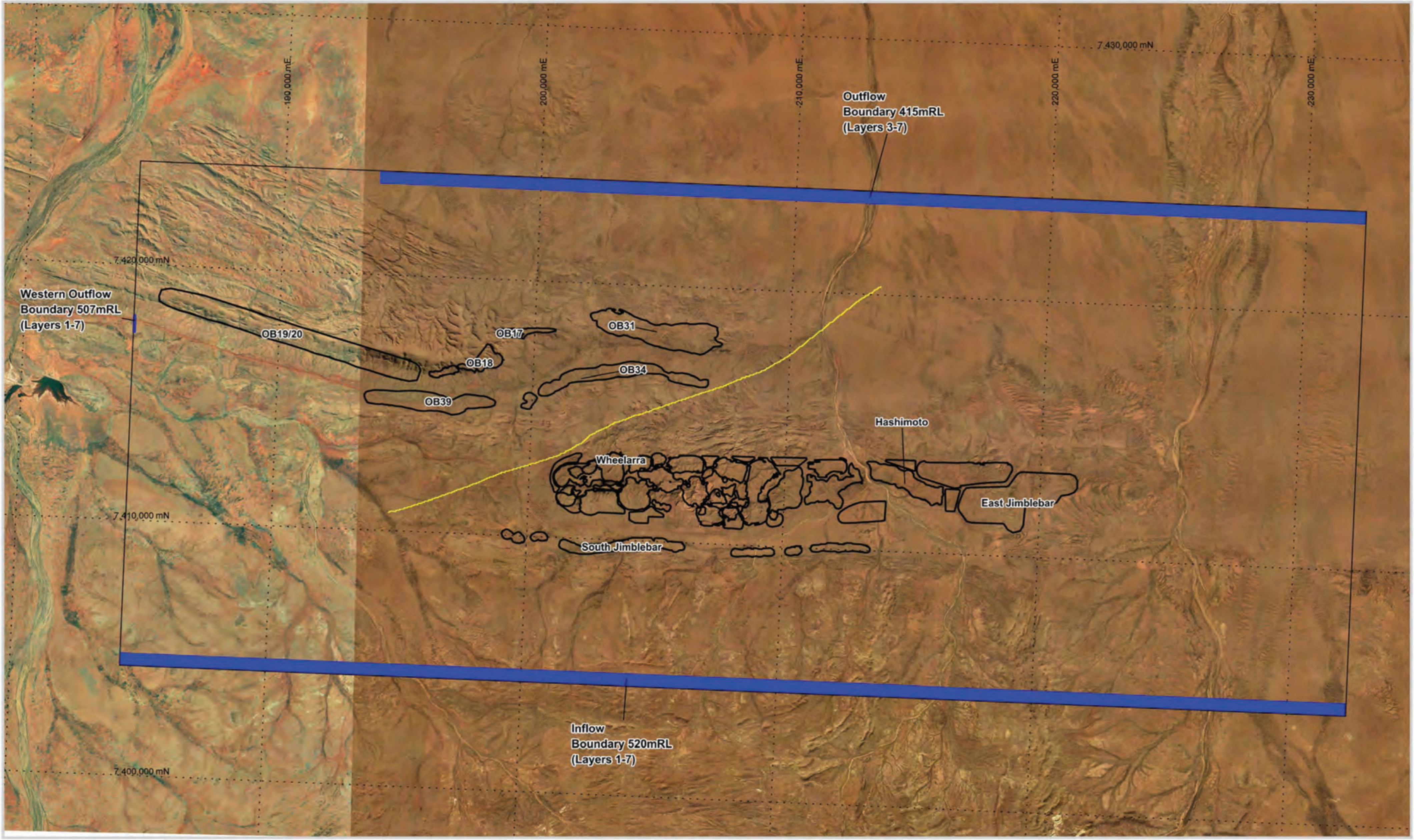
The hydrogeology of the OB31 and surrounding areas is represented by seven layers as summarised in

Table 3.1.

Table 3.1 – Model layer set-up

Layer	Description	Thickness
1 - 3	Tertiary valley fill aquifer (alluvium) Upper sections of OB31 and South Jimblebar orebody aquifers. Aquifers associated with mineralised Marra Mamba and Brockman iron formations west of Wheelarra fault (OB17, 18, 34 and OB39). Weathered dolomite aquifer (Paraburdoo Member) (West of Wheelarra fault). Weathered to fresh basement rocks adjacent to OB17, 18, 19, 20, 31, 34 and OB39 and Tertiary valley-fill / South Jimblebar orebody.	Layer 1: approximately 120 m thick Layer 2: 36 m thick Layer 3: 36 m thick
4 - 5	Lower sections of OB31 and South Jimblebar orebody aquifers. Lower sections/patches of Tertiary valley fill aquifer (alluvium) (West of Wheelarra fault). Weathered dolomite aquifer (Paraburdoo Member). Basement rocks surrounding the weathered dolomite and orebody aquifers	Layer 4: 30 m thick Layer 5: 30 m thick
6	Fresh dolomite aquifer (Paraburdoo Member). South Jimblebar orebody aquifer. Basement rocks surrounding the dolomite and orebody aquifers.	Layer 6: 24 m thick
7	Basement rocks.	Layer 7: 52 m thick

Layer 1 has a variable thickness as defined by the top set at ground level and the base set at 458 mRL. The thicknesses of the remaining layers are uniform. The hydrogeological units represented in Layer 3 are illustrated in Figure 3.2.



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0 5

Kilometres

Scale: 1:125,000 @A3

GDA 1994 Zone 50

AUTHOR:	JP	REPORT NO:	033
DRAWN:	MR	REVISION:	c
DATE:	12/06/2014	JOB NO:	1584G

Location: F:\Jobs\1584GB\Spatial_Data\Mapinfo\Workspaces\033a\Final\033a Figure 5 - Model Extent

LEGEND

- Pit Outline
- Wheelarra Fault represented as Horizontal Flow Boundary (model Layers 1 to 7)
- Modelled Constant Head Boundary

DATA SOURCES:
BHPB Iron Ore

RPS

FIGURE 3-1

MODEL EXTENT AND BOUNDARY CONDITIONS

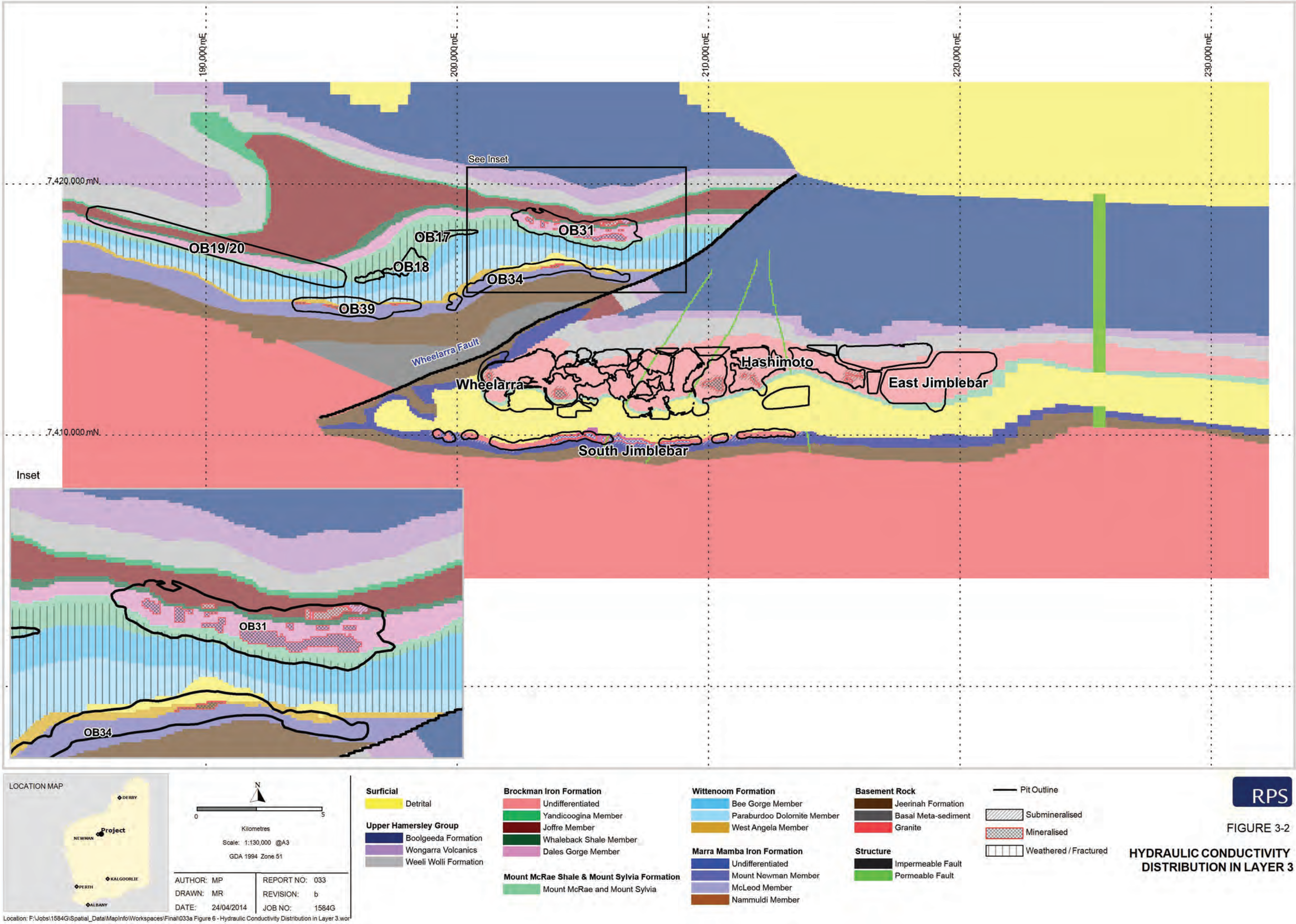


FIGURE 3-2

HYDRAULIC CONDUCTIVITY DISTRIBUTION IN LAYER 3

3.2 REGIONAL THROUGHFLOW

To reproduce the regional groundwater throughflow characteristics, fixed head boundaries are included across the southern, western and northern boundaries of the model domain as shown in Figure 3.1. The heads are set at:

- Southern inflow = 520 mRL
- Western inflow = 507 mRL
- Northern outflow = 415 mRL

All other model boundaries are assigned as the no-flow type and are aligned consistent with catchment boundaries or perpendicular to the inferred direction of groundwater flow.

3.3 RAINFALL RECHARGE

Recharge is assigned as a proportion of recorded average annual rainfall (310 mm per year) to the following areas:

- Valley-fill alluvium (0.5% average annual rainfall)
- Creek channels in valley floors (1.0% average annual rainfall)
- Outcropping orebody aquifers (2.5% average annual rainfall)

3.4 EVAPOTRANSPIRATION

Evapotranspiration (EVT) from phreatophytic vegetation was incorporated in the model and defined based on detailed vegetation mapping. The EVT surface was assigned 5 m below the ground surface with extinction depth of 15 m. The EVT rate was assigned a constant value of 1 m/year or 2.64 $x10^{-4}$ m/d.

3.5 CALIBRATION

3.5.1 Pre-development groundwater levels

The model was calibrated to pre-development groundwater levels measured at a total of 353 hydrogeological investigation bores and mineral resource exploration bores in the Shovelanna mining area (including OB17, OB18, OB19/20, OB31, OB34 and OB39).

3.5.2 Time variant groundwater responses

The model was calibrated against almost ten years of observations associated with groundwater abstraction from the OB18 water supply borefield. The borefield has been operated since 2005 with average abstraction rates in the order of 2,000 kL/d. The OB18 borefield consists of six production bores and 14 monitoring bores. Whilst this data is somewhat distant from OB31, it does provide valuable information on the hydraulic characteristics of the regional aquifer system.

The model was also calibrated against data collected from constant rate test pumping tests at three separate locations within the OB31 orebody aquifer. The tests were conducted over the period October 2013 to March 2014. Details of the selected tests are summarised in

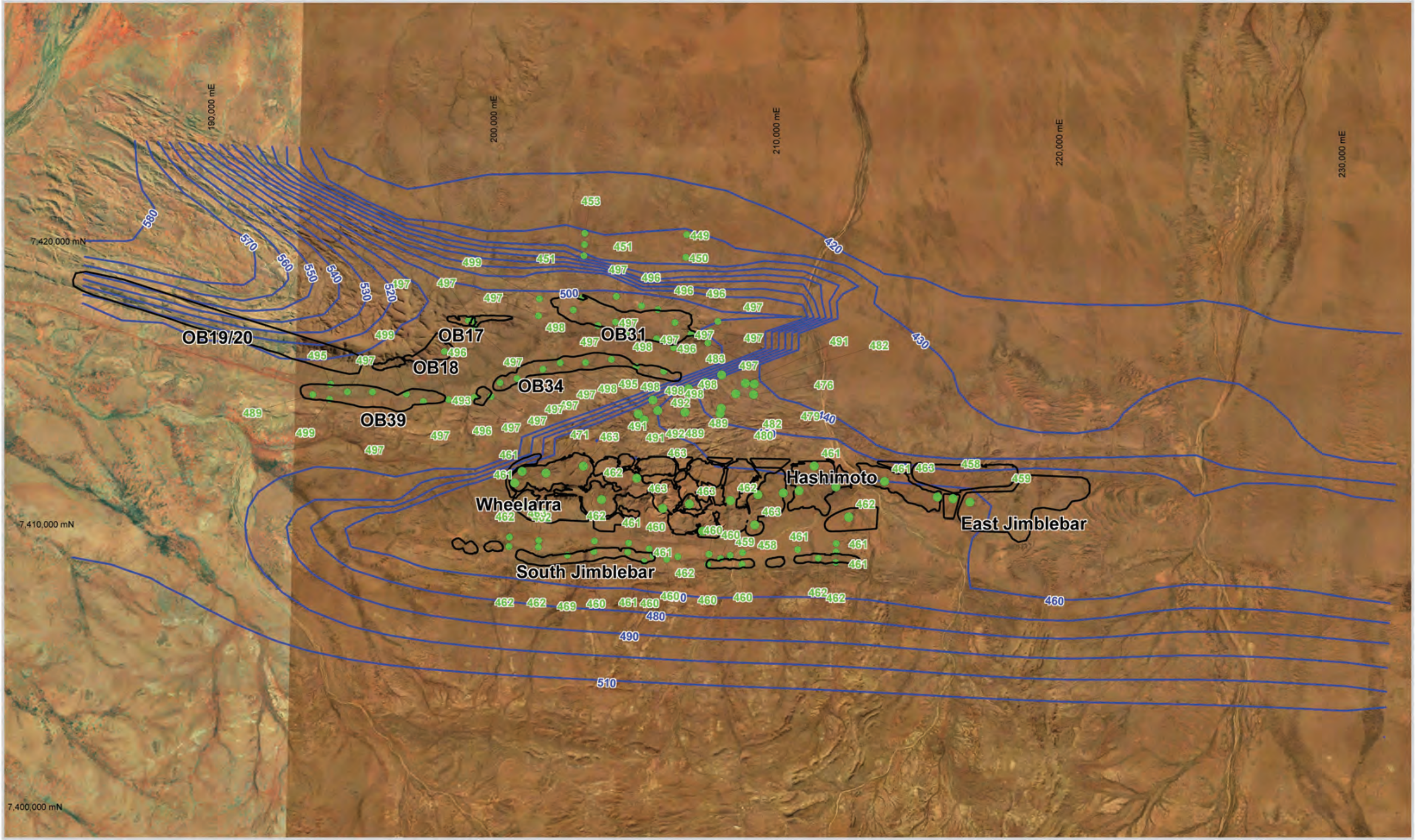
Table 3.12.

Table 3.2 OB31 Constant Rate Test Pumping Details

Production Bore ID	Test Duration (days)	Constant Pumping Rate (kL/d)
HEB0021	5	8,640
HEB0022	11	4,320
HEB0033	10	4,752

3.5.3 Results

The model was able to reproduce these data with an appropriate level of accuracy. The observed and simulated predevelopment groundwater levels are shown in Figure 3.3. This shows that west of the Wheelarra Fault the simulated values match the observed well. Just to the east of the fault there is a small area where the simulated values are significantly lower than the observed, although this is unlikely to influence the model dewatering predictions.



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Kilometres

Scale: 1:125,000 @A3

GDA 1994 Zone 51

AUTHOR: MP	REPORT NO: 033
DRAWN: MR	REVISION: c
DATE: 24/04/2014	JOB NO: 1584G

LEGEND

- 485 Observed Water Level (mRL)
- Predicted Water level (mRL)
- Orebody outline

RPS

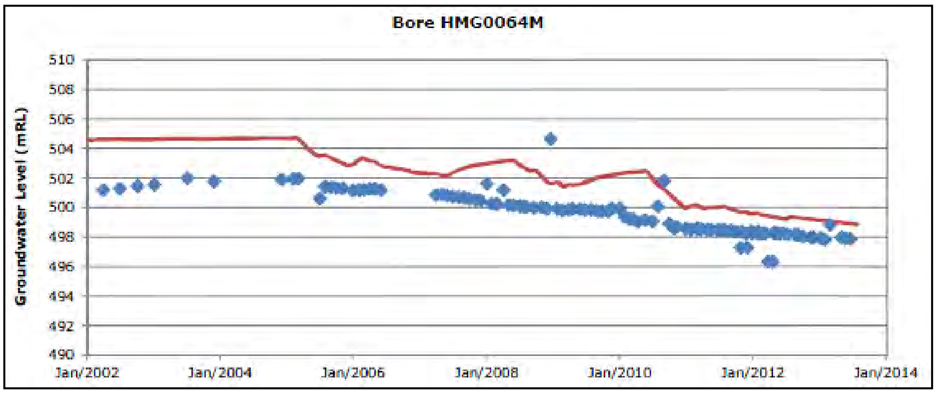
FIGURE 3-3

MEASURED WATER LEVELS AND PREDICTED STEADY STATE WATER LEVEL CONTOURS

Location: F:\Jobs\1584G\Spatial_Data\MapInfo\Workspaces\Final\033a Figure 19 - MEASURED WATER LEVELS AND PREDICTED STEADY STATE WATER LEVEL CONTOURS.wor

Figure 3.4 provides some examples of observed and simulated groundwater levels close to the OB18 water supply borefield. These show that the model replicates the rate of groundwater drawdown well in this area and, that in this area at least, the hydraulic parameters applied to the regional aquifer and the surrounding units are appropriate.

Figure 3.4 – Calibration to OB18 water supply borefield data



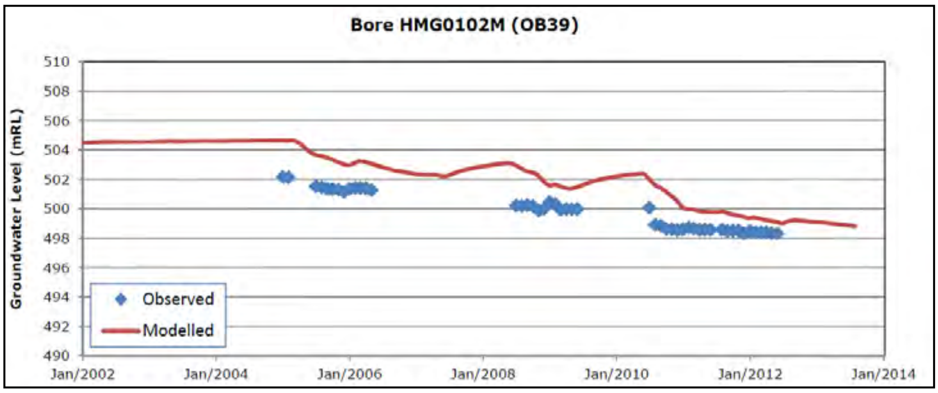
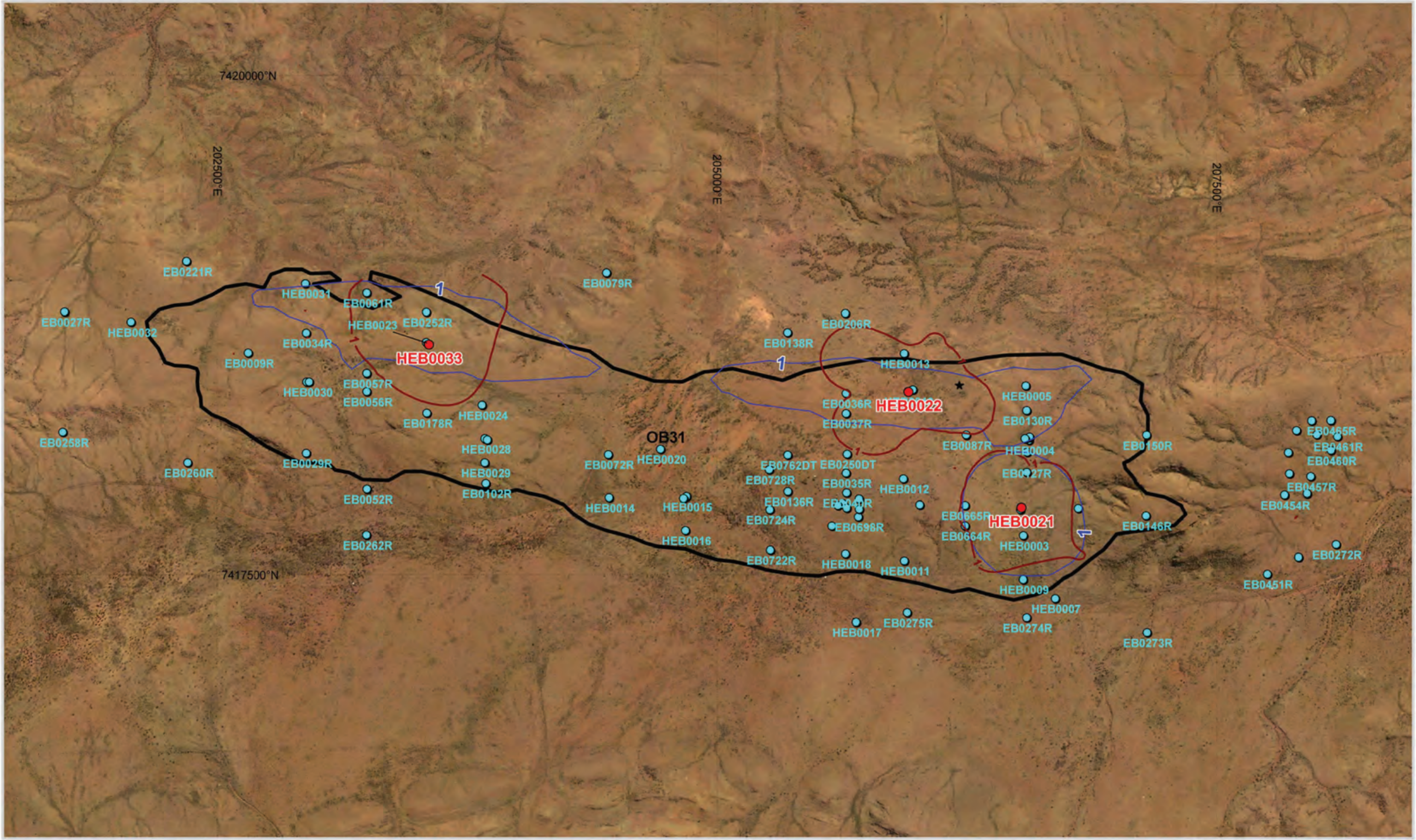


Figure 3.5 shows the observed and simulated 1 m drawdown contours produced by the three constant rate tests. The observed response at HEB0021 is replicated very well by the model. The response at the other two tests is not replicated as well however as the simulated response is more elongated along the east / west direction than the observed, which is more radial.



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metres

Scale: 1:17 000 @A3

GDA 1994 Zone 51

AUTHOR: MP	REPORT NO: 033
DRAWN: MP	REVISION: b
DATE: 23/06/2014	JOB NO: 1584G

Location:F:\Jobs\1584G\Spatial_Data\MapInfo\Workspaces\Final\033a Figure 26 - Pumping test at OB31.wor

LEGEND

- Observed Drawdown (m)
- Predicted Drawdown (m)
- OB31 Pit Outline
- Pumping bore
- Monitoring bore

RPS

FIGURE 3-5

OREBODY 31 OBSERVED AND PREDICTED DRAWDOWN IN THE WATER TABLE

Whilst every effort has been made to calibrate the model to these three datasets, it is clear that the information is not sufficient to provide a robust transient calibration in the Shovelanna area for the purposes of the dewatering predictions over a 30 year mine life. Therefore a significant amount of uncertainty remains in the model parameterisation, in particular with respect to the regional hydraulic connection and orebody aquifer storage and extent.

3.5.4 Hydraulic parameters

A summary of the hydraulic parameters of the key hydrostratigraphic units included in the model is provided in

Table 3.13. These values were determined through the process of model calibration and the use of estimates based on experience and knowledge of similar systems in the Pilbara.

Table 3.3: Base Case hydraulic parameters

Hydrogeological Unit	Description	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Specific Storage (m^{-1})	Specific Yield (%)
Yandicoogina Member	Fractured	0.1	0.1	1.0 × 10-5	1
	Fresh	1.0 × 10-3	1.0 × 10-3	1.0 × 10-5	0.1
Joffre Member	Fresh	1.0 × 10-3	1.0 × 10-3	4.7 × 10-7	0.1
	Fresh / Fractured	5.0 × 10-2	5.0 × 10-2	4.7 × 10-7	1
	Mineralised	8.0	8.0	4.7 × 10-7	2
Whaleback Shale	-	1.0 × 10-3	1.0 × 10-3	2.0 × 10-4	1
Dales Gorge Member	Fresh	1.0 × 10-3	1.0 × 10-3	4.7 × 10-7	0.1
	Submineralised	8	8	4.7 × 10-7	5
	Mineralised	10	10	4.7 × 10-7	5
Mt McRae Shale	-	1.0 × 10-3	1.0 × 10-3	2.0 × 10-4	0.1
Mt Sylvia Formation and Bee Gorge Member	Upper	0.1	0.1	4.7 × 10-7	0.1
	Lower	1.0 × 10-3	1.0 × 10-3	4.7 × 10-7	0.1
Paraburdoo Member	Weathered	10	10	4.7 × 10-7	0.5
	Fresh	1.0 × 10-3	1.0 × 10-3	4.7 × 10-7	0.1

4 DEWATERING PREDICTIONS

4.1 APPROACH

The historical time variant model was adapted for the purposes of simulating future dewatering of OB31. To investigate the significance of the uncertainties with hydraulic parameters the model was run twice, once with the Base Case hydraulic parameters and once with a modified set of parameters (known as the “Upper Bound”). The Upper Bound run was designed to test the upper limit of dewatering estimates. To do this key aquifer parameters controlling regional connection and aquifer storage were increased to their highest possible values.

4.2 MODEL SET-UP AND ASSUMPTIONS

The predictive model was run for a period of 31 years (YEJ2018 to YEJ2048). Inflow and outflow boundary condition settings were unchanged from the historical model.

Dewatering was simulated using drain boundary conditions. The drain elevations were set consistent with the projected base of the pit varying with time as summarised in Table 4.1. No proactive dewatering was simulated. The drains were left in place until the end of the model and dewatering was therefore assumed to continue to the end of YEJ2048.

Pumping from South Jimblebar was assumed to continue at 2014 rates until the end of the model. Abstraction from the OB18 borefield was assumed to cease at the start of the predictive model, with that water being made up from the OB31 abstraction.

The Base Case model used the parameter values shown in Table 3.3. The following changes were made to the Upper Bound model:

- The hydraulic conductivity of unmineralised Dales Gorge Member was increased to 0.1 m/d (Base Case 0.001 m/d).
- The hydraulic conductivity of Mt McRae Shale Formation was increased to 0.1 m/d (Base Case 0.001 m/d).
- The confined storage of all units west of the Wheelarra Fault was increased to 5×10^{-6} (Base Case 5×10^{-7}).
- The specific yield of all units west of Wheelarra Fault was increased to 1% (Base Case 0.1% and 0.5%).

- The specific yield of mineralised Dales Gorge Member was increased to 10% (Base Case 5%).

4.3 MINE PLAN

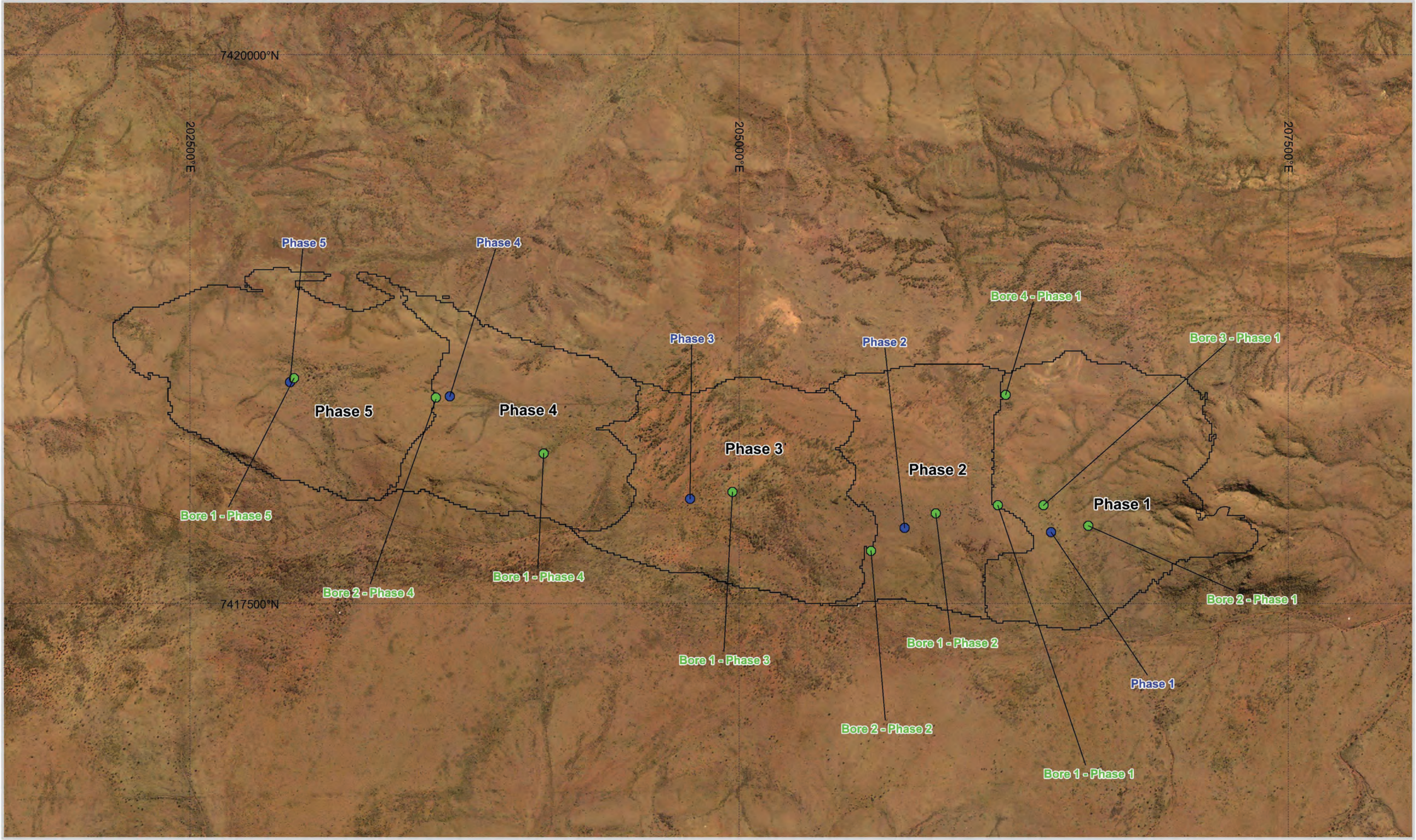
The mine plan includes five Phases (Phases 1 to 5) within the proposed mine area as shown in Figure 4.1.

Mining is planned to commence at the western end of OB31 and progress to the east. The mine schedule adopted for dewatering predictions is summarised in

Table 3.1. Elevations shown in bold type indicate mining below the water table.

Table 4.1: OB31 Mine Schedule Phases 1 to 5

	Phase 1 (mRL)	Phase 2 (mRL)	Phase 3 (mRL)	Phase 4 (mRL)	Phase 5 (mRL)
YEJ2018				540	516
YEJ2019				540	504
YEJ2020				540	**480**
YEJ2021				528	**456**
YEJ2022				528	**444**
YEJ2023				516	**372**
YEJ2024				504	
YEJ2025				**492**	
YEJ2026				**468**	
YEJ2027			516	**456**	
YEJ2028			516	**432**	
YEJ2029			**492**	**372**	
YEJ2030			**468**		
YEJ2031		516	**456**		
YEJ2032	552	516	**420**		
YEJ2033	552	**492**	**372**		
YEJ2034	552	**480**			
YEJ2035	552	**468**			
YEJ2036	528	**456**			
YEJ2037	528	**432**			
YEJ2038	516	**420**			
YEJ2039	504	**372**			
YEJ2040	**492**				
YEJ2041	**480**				
YEJ2042	**468**				
YEJ2043	**456**				
YEJ2044	**444**				
YEJ2045	**432**				
YEJ2046	**408**				
YEJ2047	**408**				
YEJ2048	**360**				



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Meters

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GDA 1994 Zone 51

AUTHOR: MP	REPORT NO: 033
DRAWN: MP	REVISION: b
DATE: 12/06/2014	JOB NO: 1584G

Location: F:\Jobs\1584G\Spatial Data\MapInfo\Workspaces\Final\033a Figure 27 - OB31 mining phases.wor

LEGEND

- Pit Outline
- Modelled observation bore location
- Pumping bore used to simulate dewatering

RPS

FIGURE 4-1

OREBODY 31
MINING PHASES

4.4 RESULTS

The predicted regional drawdown in YEJ2048 is shown for both cases in Figure 4.2. The figures show that drawdown:

- local to the OB31 aquifer is in excess of 100 m.
- does not extend across the Wheelarra Fault either from OB31 to the Jimblebar area or vice versa
- to the westernmost part of OB39 is just under 10 m in the Base Case and almost 30 m in the Upper Bound.
- is focused through the higher permeability material that runs west to east through the catchment.

The predicted dewatering rates from the Base Case model are shown in Figure 4.3. With these best estimate parameters the model predicts that:

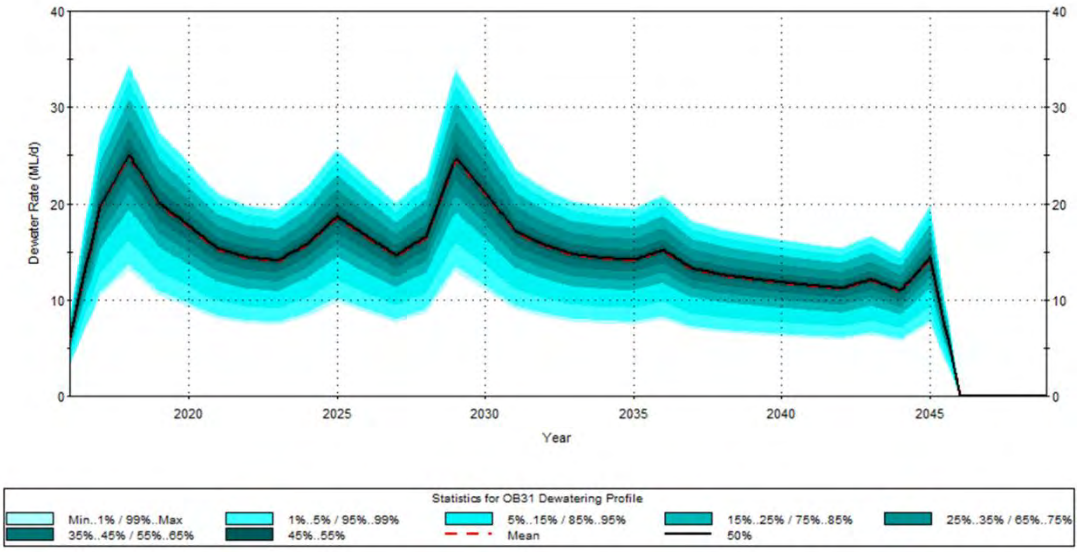
- Maximum dewatering of about 11,500 kL/d will occur in YEJ2021.
- Average dewatering over the mine life will be around 4,900 kL/d.
- Excluding the peaks, the background dewatering is relatively constant at about 4,000 kL/d.

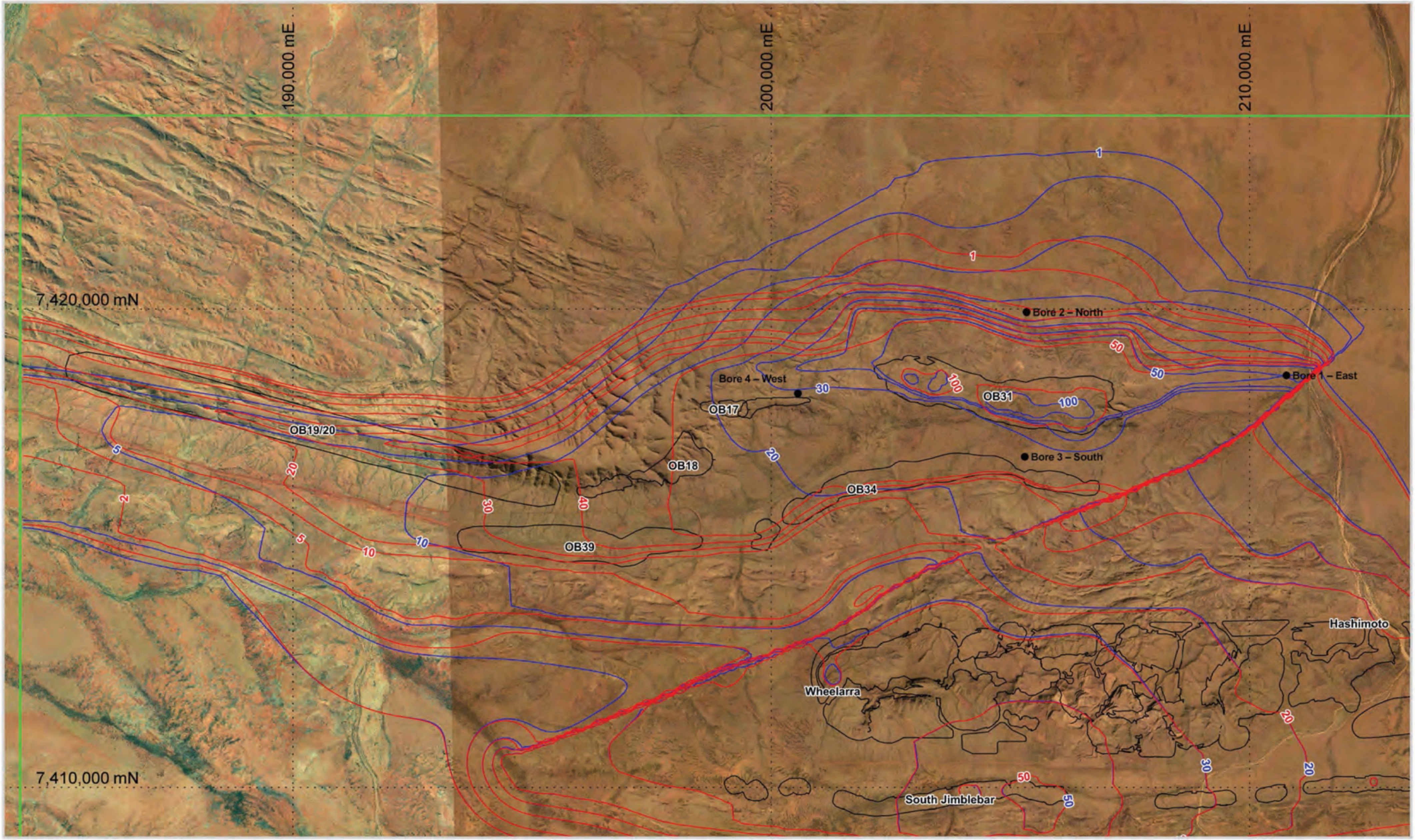
The Upper Bound run produces roughly double the dewatering of the Base Case. With greater aquifer storage and connection with the regional aquifer system the model predicts that:

- Maximum dewatering of about 21,000 kL/d will occur in YEJ2021 and YEJ2032.
- Average dewatering over the mine life will be around 11,600 kL/d.

In both models several peaks in dewatering are predicted after the initial maximum in YEJ2021. These are related to the commencement of mining at lower elevations and/or new Phases.

Figure 4.3 – Predicted OB31 life of mine dewatering





Kilometres

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GDA 1994 Zone 51

AUTHOR: MP	REPORT NO: 033
DRAWN: MP	REVISION: c
DATE: 12/06/2014	JOB NO: 1584G

Location: F:\Jobs\1584G\Spatial Data\MapInfo\Workspaces\Final\033b Figure 32 - Predicted high case drawdown.wor

LEGEND

- Pit Outline
- Predicted drawdown (m) - Base case
- Predicted drawdown (m) - Upper Bound
- Model Domain

RPS

FIGURE 4-2

PREDICTED DRAWDOWN (BASE CASE AND UPPER BOUND) YEJ2048

5 CLOSURE

5.1 INTRODUCTION

The Base Case model was used to simulate post closure (from YEJ2048) groundwater conditions at OB31. The models were run with three closure scenarios (fully backfilled, partially backfilled and no backfill). The models were time variant models and run until the groundwater levels returned to equilibrium in the local OB31 area. The various assumptions and model settings required are outlined below:

- There is no further pumping in the catchment from YEJ2048
- Both partial and complete backfilling of the void is finished at the same time that mine dewatering ceases (i.e. in YEJ2048)
- Backfill hydraulic parameters are identical to the OB31 orebody aquifer
- Recharge to backfilled material is unchanged from the pre-mine condition
- Voids are simulated by:
    - Increasing specific yield and hydraulic conductivity to 99% and 100 m/d respectively.
    - Assigning evaporation to the void footprint at 50% of measured pan evaporation (which equals 1.85 m/yr)
    - Assigning recharge of 100% average rainfall to the void area
    - Assigning 20% of incident run-off from the pit catchment to the void
- In the partial backfill scenario it is assumed that the southern half of the voids are backfilled to 5 m above pre-development water level and the northern half is left as a void. The void and backfill settings are the same as above.

5.2 RESULTS

Complete backfilling of the OB31 pit voids is predicted to result in recovery of the local groundwater table to the pre-development level (roughly 500 mRL). Full recovery occurs slowly (over many hundreds of years) however 75% of the recovery occurs within the first 50 years.

If the OB31 pits are not backfilled the model predicts that a lake will form and reach its final level within 20 years. The lake is predicted to stabilise at 420 mRL in Phases 1, 3, 4 and 5. However, due to the lack of hydraulic connection at depth between the Phase 2 pit void and the other voids, the lake in Phase 2 stabilises at a lower level (385 mRL). In this situation therefore, the local groundwater system will not return to its pre-development level.

In the partial backfill case a continuous pit lake forms in the remaining pit void. The water level of the lake is predicted to be about 425 mRL. The backfill therefore has the effect of connecting the Phase 2 void with the others. Equilibrium is predicted within 70 years of closure.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Numerical groundwater flow modelling has provided predictions of the time variant dewatering requirements to develop the OB31 deposit. Based on the best estimates for hydraulic parameters and the local and regional geological setting the dewatering is expected to average 4,900 kL/d over the mine life. As calibration data is limited in the area a realistic upper limit to the dewatering estimates has also been provided. This shows that if regional aquifer connectivity and orebody aquifer storage are higher than assumed in the best estimate case, the dewatering may average 11,600 kL/d.

6.2 UNCERTAINTY AND LIMITATIONS

The main uncertainties associated with the model are:

- Lack of any long term transient calibration data in the OB31 area commensurate with long term mine dewatering.
- Uncertainty over hydraulic connection between the orebody aquifers and the regional aquifers through the Mt McRae Shale.
- Uncertainty in the hydraulic characteristics of the orebody stratigraphic along strike (to the west).
- Assumptions inherent in the mine plan (i.e. rate, sequence, timing and depth of pushbacks).
- Assumptions in closure settings (particularly backfill properties and evaporation rates)

6.3 RECOMMENDATIONS

It is recommended that long-term pumping and monitoring (in the form of a hydrodynamic trial conducted over several months) be implemented in the OB31 deposit. This will assess the hydraulic connection between the OB31 aquifers and the regional aquifer system, as well as the connection across the Wheelarra Fault. The monitoring and abstraction data should then be used to advance the model calibration. This will then provide more confidence in the best estimate dewatering predictions and reduce the range of possibilities.

7 REFERENCES

Aquaterra, (2009): *Hydrogeological Assessment for South Jimblebar Iron Ore Project*. Ref. 1008/057b. Perth, Aug 2009.

RPS Aquaterra, (2012): *South Jimblebar Hydrogeological Assessment in support of 5c Groundwater Licence*, Ref 1008Q/090a.