Preliminary Acid and Metalliferous Drainage Risk Assessment for the OB31 Deposit

prepared for

BHP Billiton Iron Ore Ltd.

by

EARTH SYSTEMS
Environment | Water | Sustainability

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EXECUTIVE SUMMARY

BHP Billiton Iron Ore Ltd (BHPBIO) engaged Earth Systems to conduct a desktop preliminary acid and metalliferous drainage (AMD) risk assessment to quantify the potential for AMD generation and identify risks to the receiving environment associated with the proposed mining operations at the Orebody 31 (OB31) deposit located in the Pilbara Region of Western Australia. Assessing the potential AMD risk associated with the mining OB31 is a key step to developing appropriate AMD management and closure strategies.

To identify potential sources of AMD form these deposits, Earth Systems utilised data within the BHPBIO mine model to calculate a NAPP value for OB31 overburden and wallrock, and then assigned an AMD classification to these materials. A NAPP cut-off value of 3 kg H_2SO_4/t was used to differentiate between potentially acid forming (PAF) materials and non-acid forming (NAF) materials. This is considered a conservative cut-off for this preliminary assessment, based on the limited availability of static geochemical testwork data. The mine model data were then used to quantify the distribution (statistical and spatial) of any PAF overburden and wall rock materials that have the potential to generate AMD. Indicative annual AMD generation rates were calculated based on pyrite oxidation rates for similar geologic materials elsewhere in the Pilbara.

AMD pathways and environmental and social receptors were listed based on a brief review of available literature and a workshop meeting with BHPBIO.

The AMD sources, transport pathways and environmental and social receptors were used to develop a preliminary risk assessment matrix for OB31. The findings of this risk assessment were:

- In general the AMD risk associated with OB31 can be considered very low.
- Only approximately 30,000 tonnes of PAF waste rock is expected from OB31 (approximately 0.01% of total overburden). This rock predominantly lies on the south eastern pit wall and may eventuate as wallrock than overburden given the spatial accuracy related to this preliminary assessment.
- De-saturated Mt. McRae Shale wallrock along the south-eastern zone of the OB31 pit is likely to present the largest source of AMD at the deposit. Based on this preliminary assessment, the annual AMD generation rate from this source may be in the order of 100-150 tonnes H_2SO_4-eq per year. The flux of this AMD into the pit will depend on the pit wall air-entry properties (eg. fracturing) and climatic conditions during mining operations.
- AMD generation from OB31 wallrock can be updated once hydrogeological modelling is undertaken and the likely zone of desaturated wallrock is better understood.
- The risk associated with AMD fluxes into the pit during operations is likely to be low due to the pit acting as a groundwater sink during operations. Hence AMD transport to the environment is likely to be limited. Furthermore, the AMD risk associated with wallrock AMD fluxes during operations can be easily managed by pre-emptively treating exposed sulfidic wallrock faces, or treating acidic water in-situ as it occurs.
- Upon closure, rewetting of this zone may result in mobilisation of the AMD generated within this rock, particularly if conditions were dry during operations. Hence, this scenario is likely to represent the highest AMD risk for the OB31 deposit. AMD fluxes from wallrock upon re-wetting at closure may be managed by treatment (or pre-treatment) of any build-up of acidity using locally available carbonate material.

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1.0 Introduction

BHP Billiton Iron Ore Pty Ltd (BHPBIO) engaged Earth Systems to conduct a desktop preliminary acid and metalliferous drainage (AMD) risk assessment to quantify the potential for AMD generation and identify risks to the receiving environment associated with the proposed mining operation at the Orebody 31 (OB31) deposit located in the Pilbara Region of Western Australia (see Figure 1.1).

Assessing the potential AMD risk associated with the mining of OB31 is a key step to developing appropriate AMD management and closure strategies.

1.1 Project Background

The proposed OB31 deposit are located within the Hamersley Iron Province, and are considered as potential replacements for the OB17/18 resources which are to be mined out in the next 5 years. Mining for OB31 will be by conventional open cut methods with approximately 75% of the mineralisation occurring below the water table. Various waste rock placement options are being considered including external overburden dumps, in-pit storage at OB31 and backfilling of the adjacent OB17/18 pits.

OB31 is likely to be moderately to highly structurally complex resulting from regional scale faulting and folding. The iron ore mineralisation is hosted within both the Dales Gorge and Joffre Members of the Brockman Iron Formation. The Joffre Member contains higher concentrations of elements potentially deleterious to the environment than the Dales Gorge Member. Elevated sulfur values have been identified in the Mt McRae Shale, Whaleback Shale, Weeli Wolli Formation and Turee Creek Formation.

As identified in the OB31 work proposal for FY13, additional works to be conducted at OB13 include a detailed drilling program to advance hydrogeological, geotechnical and geologic knowledge of deposit, including a structural assessment of the Wheelara Fault. Furthermore, a stygofauna / troglofauna study will be conducted utilising past drill holes for monitoring (BHPBIO, 2013a).

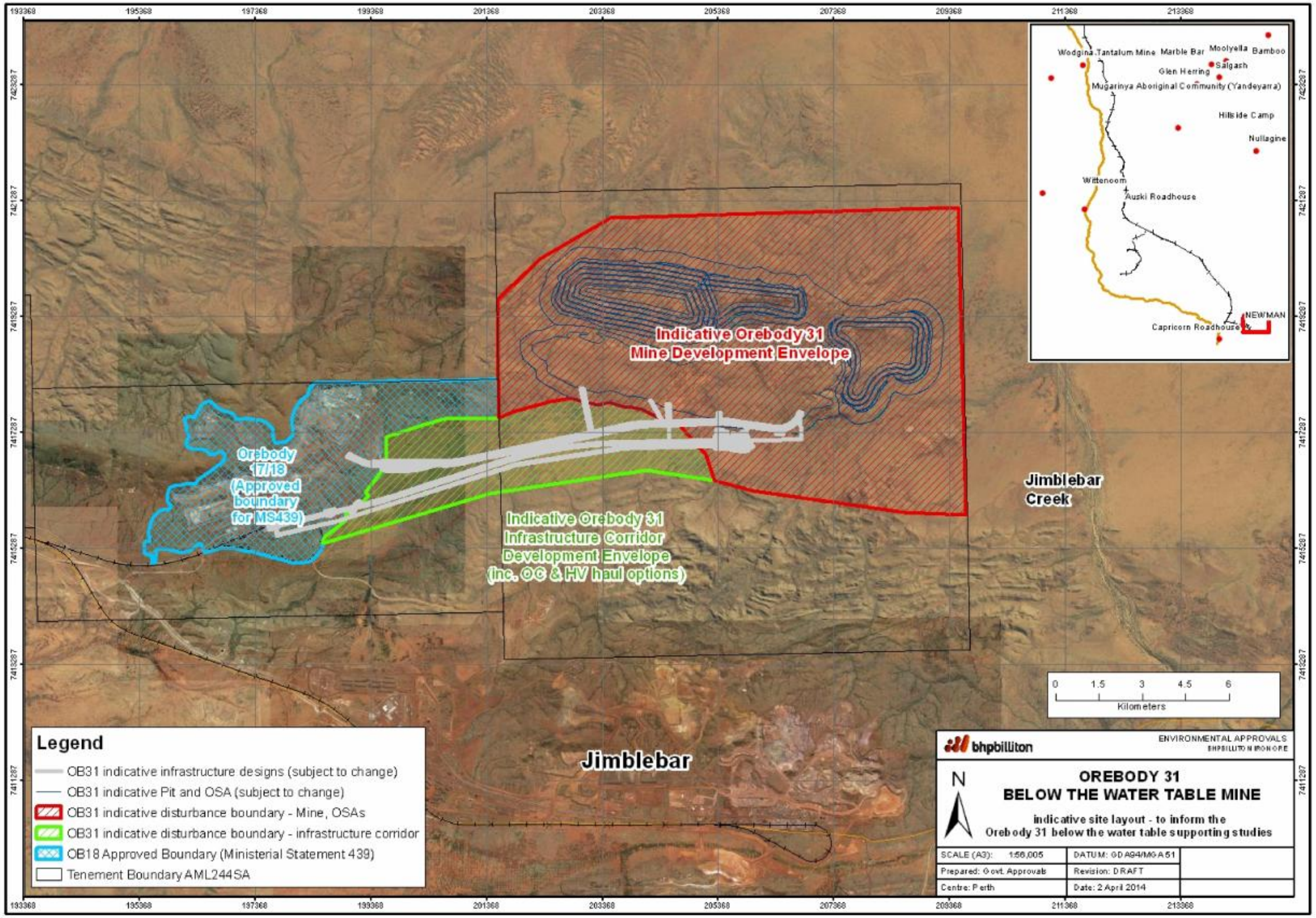

Figure 1.1. Orebody 31 indicative project layout (figure sourced from BHP Billiton Iron Ore).

1.2 AMD Background

1.2.1 AMD Sources

Mining activities can expose sulfide-bearing rocks to atmospheric oxygen through excavation and dewatering. The process of sulfide oxidation can result in the generation of drainage with low pH, elevated dissolved metals and salinity. Drainage with these characteristics is referred to as acid and metalliferous drainage (AMD). When excess neutralising capacity is present, near-neutral pH values may be observed. Near-neutral metalliferous drainage associated with sulfide oxidation is referred to as NMD, a subset of AMD.

In addition to sulfide oxidation, AMD may also be derived from sparingly soluble secondary sulfate minerals such as alunite ($KAl_3(SO_4)_2(OH)_6$) and jarosite ($KFe_3(SO_4)_2(OH)_6$), which release stored acidity upon dissolution. Both minerals are by-products of previous AMD generation and neutralisation reactions. AMD can therefore be derived from secondary sulfate minerals, even in highly weathered materials where sulfides are no longer present.

AMD has the potential to impact receiving surface water and groundwater systems. Attachment A provides background information relating to key AMD generation and neutralisation reactions.

Key sources of AMD on mine sites can include oxidation of sulfide minerals or dissolution of acid-storing secondary sulfate minerals contained within the following waste domains:

- Waste rock / overburden material;
- Unsaturated pit wallrock (cone of depression);
- Tailings; and
- Ore stock piles / ROM pads.

Potential AMD sources and risks associated with iron ore deposits in the Hamersley Iron Province include:

- Proterozoic Formations (eg. Mt. McRae Shale Formation) containing sulfides;
- Pyritic lignite and ligneous clays in Tertiary alluvial deposits; and
- Acidity storing secondary minerals (eg. alunite and jarosite) within oxidised portions of the Proterozoic sediments.

1.2.2 AMD Prediction and Management

A key part of successfully managing AMD at any mine site is the geochemical characterisation of representative mine materials. A combination of static and kinetic geochemical characterisation permits assessment of the nature, magnitude and duration of potential water quality issues arising from AMD generation, and is essential for developing effective AMD management strategies.

Static geochemical characterisation involves identifying and understanding the distribution of acid generating minerals (eg. pyrite, jarosite and alunite) and acid neutralising minerals (eg. calcite) within rocks and tailings material. A key parameter is the Net Acid Producing Potential (NAPP), which represents the difference between the acid generating capacity and acid neutralising capacity of a sample. NAPP data can be used to classify a sample into AMD risk categories that indicate whether a sample is Potentially Acid Forming (PAF) or Non-Acid Forming (NAF).

Once the distribution of PAF and NAF is known, this information can be used to develop production schedules of PAF and NAF wastes to form the basis for AMD management planning, including the design of appropriate waste rock storage facilities.

Kinetic geochemical characterisation identifies the rate at which pollution (ie. AMD / NMD and salinity) will be generated from a sample. The rate of pollution generation is inferred from the pyrite oxidation rate (POR). Hence, kinetic geochemical data provide a basis for estimating the annual pollution potential of a sample, the indicative longevity of any AMD issue and the potential lag time for acidic discharges.

1.3 Environmental Setting

1.3.1 Climate

The climate at OB31 is semi-arid to arid with average annual rainfalls in the Pilbara region ranging between 200 and 350 mm (BHPBIO, 2010). The closest weather station to the OB31 project areas is the Jimblebar Weather Station (~10 km south-east of the nearby OB18 mine site). The average annual rainfall calculated from precipitation data collected at this station from FY96 – FY11 was 383.1 mm (AAR, 2011).

The majority of rainfall occurs during the summer months between December and March with lesser amounts of rainfall in April. Large tropical depressions and cyclones developing off the northwest coast of Western Australia from January to April can produce significant inland rainfall events in the region. A pronounced dry season occurs between the months of May and November. The average annual Class A pan evaporation rate is approximately 2,500 mm $year^{-1}$, greatly exceeding average annual rainfall.

Mean maximum temperatures during the warmest months of the year (November to February) are often above 40°C, while the mean maximum temperature during the winter months (June to August) is approximately 25°C.

1.3.2 Geology

The mineralised ore bodies and formations identified from drilling operations at OB31 and mapping are contained within the Hamersley Group located in the Pilbara Basin. The main geologic formations in the Hamersley Group include (listed in sequential geologic age):

- Marra Mamba Iron Formation;
- Wittenoom Formation;
- Mt. Sylvia Formation;
- Mt. McRae Shale Formation;
- Brockman Iron Formation; and
- Tertiary detrital sediments.

The majority of mineralisation at the OB31 deposit occurs within the Dales Gorge and Joffre members of the Brockman Iron Formation with additional mineralisation within the Tertiary Alluvials. A brief description of each of the main geologic formations in the area is provided below.

Marra Mamba Iron Formation

The Marra Mamba Iron Formation is approximately 205 m thick and is the oldest formation (2.6 Ma) identified in the project area. It comprises a sequence of Banded Iron Formation (BIF), shales, siltstones and minor cherts. The Formation is divided into the following members:

- **Nammuldi Member** – This is the base unit of the Marra Mamba Iron Formation, comprising yellow weathering chert, cherty BIF and some shale bands (Tyler, 1994). It has a maximum thickness of 100 m.
- **Macleod Member** – This member is the middle unit of the Marra Mamba Iron Formation, consisting of shale with thin BIF interbeds and chert with a maximum thickness of 45 m.
- **Mt. Newman Member** – This uppermost, youngest unit of the Marra Mamba Iron Formation is a sequence of BIF, shales, siltstones and minor cherts containing significant hematite mineralisation with a maximum thickness of 60 m.

The Marra Mamba Iron Formation is known to contain pyritic material and thus has the potential to develop AMD if exposed to atmospheric oxygen.

Wittenoom Formation

The Wittenoom Formation is younger than (2.6-2.5 Ma) and located stratigraphically above the Marra Mamba Formation. The Wittenoom Formation has been deeply eroded in the project area and does not outcrop. It is covered by tertiary sediments located in a valley to the south of OB31 and is estimated to have a thickness of 150 m (Tyler, 1994). The Formation predominantly comprises calcareous and manganiferous shales, cherts and dolomite (Aquaterra, 2009), and includes the following members:

- **West Angeles Member** – This Member is a shale unit located at the base of the Wittenoom Formation and contains dolomite, dolomitic argillite, chert and minor BIF.
- **Paraburdoo Member** – The Paraburdoo Member is the middle unit of the Wittenoom Formation and consists of thin to thick-bedded dolomite with minor amounts of chert and argillite partings. Weathering of this member has developed karst-like formations (Aquaterra, 2009).
- **Bee Gorge Member** – This is the uppermost member of the Wittenoom Formation and consists of alternating beds of shale and dolomite with minor cherts, volcaniclastics and BIF.

Carbonate minerals within the Wittenoom Formation represent a local source for acid neutralisation and are likely to contribute to elevated groundwater alkalinity.

Mount Sylvia Formation

The Mount Sylvia Formation (approximately 2.5 Ma) has a thickness of approximately 45 m and is in the vicinity of the town of Newman. The Formation consists of three BIF separated by interlayered shale and dolomite as well as small amounts of chert. The upper BIF is referred to as Bruno's Band and provides a marker horizon in the Hamersley Basin (Tyler, 1994).

Mount McRae Shale

The Mt. McRae Shale (approximately 30 m thick) consists of alternating bands of black carbonaceous shale and chert and is commonly capped with pyritic chert bands. The Mt. McRae Shale forms the footwall to the ore horizons in the Brockman Iron Formation and contains a limited enriched ore zone.

Several zones within the unit contain abundant pyrite nodules up to 5 cm across (Tyler, 1994), thus the formation is commonly regarded as a significant AMD risk throughout the Pilbara region.

Brockman Iron Formation

The ore mineralisation associated with OB31 is contained within the Brockman Iron Formation and is composed of a sequence of interbedded BIF, shales, siltstones and cherts. The Formation has a total thickness of ~520 m and includes the following members:

- **Dales Gorge Member** – The OB31 hematite mineralisation is primarily contained within the Dales Gorge Member, which is the basal member of the Brockman Iron Formation and comprises an interlayered sequence of 17 BIF and 16 shale macrobands (Tyler, 1994).
- **Whaleback Shale Member** – This member consists of 30 m of shale interbedded with chert and BIF. A lower shale zone is dominated by pyritic black shale; a central zone is composed of chert; and the upper zone is dominated by carbonate-rich material (Tyler, 1994).
- **Joffre Member** – This member is dominated by BIF with minor shale bands (Tyler, 1994).
- **Yandicoogina Shale Member** – This is the uppermost member of the Brockman Iron Formation and comprises a sequence of interbedded chert and shale with dolerite sill intrusions.

Significant concentrations of sulfide-bearing minerals can be found within the Brockman Iron Formation, and thus potential exists for AMD generation.

Tertiary Alluvial Sediments

Tertiary alluvial sediments have been deposited in the east-west valley south of Shovelanna Hill, and overlie the eroded bedrock of the Wittenoom Formation, with a thickness of up to 80 m. The sediments are composed of semi-consolidated and cemented alluvium, colluvium/detritals comprising sands, silts, clays, lignite and ligneous clays and calcrete deposits.

Tertiary sediments have the potential to generate AMD, due to the presence of pyrite, particularly within the lignite and ligneous clays. The pyrite is formed as a result of bacterially mediated sulfate reduction in the presence of iron and organic carbon. Pyrite from these sediments is ultra-fine grained framboidal material that is expected to be far more reactive (ie. faster oxidation rate) than pyrite from the Proterozoic formations. In addition, acidity storing secondary minerals (eg. alunite and jarosite) may be present within the oxidised portion of the sediments. These minerals have the potential to release acidity upon dissolution.

2.0 Scope of Works

Earth Systems was engaged to undertake the following scope of works:

- Review of available data relevant to AMD risk assessment for the OB31 mine.
- Briefly characterise the geology of key rock types within the OB31 deposit.
- Assess the geochemical characteristics and AMD potential of overburden and pit wallrock material for OB31 based on available data.
- Estimate the tonnages of any PAF materials to be disturbed or dewatered as a result of mining operations at OB31.
- Indicate the potential rate of acidity generation from PAF materials.
- List the potential pathways for AMD migration off site.
- List any environmental and social receptors that could potentially be impacted by AMD migration off site.
- Conduct a preliminary AMD risk assessment, using a conventional Source-Pathway-Receptor model, to identify the key AMD risks for the site (if any).
- Canvas appropriate AMD risk management strategies required based on the risk assessment.

3.0 Method

This AMD risk assessment consists of:

- AMD source assessment.
- Identification of potential AMD pathways and environmental and social receptors.
- AMD risk assessment matrix.

The methods used for each component are detailed in the following sections. The methods have been developed in accordance with Australian and international leading practice standards for AMD management, including:

- Australian Federal Government leading practice handbooks on Managing Acid and Metalliferous Drainage (DITR, 2007);
- Risk Assessment and Management (DRET, 2008);
- Global Acid and Metalliferous Drainage (GARD) Guide (INAP, 2009);
- Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC/ARMCANZ, 2000).

In addition, this study conforms to principles of continuous improvement in leading practice AMD management.

3.1 Data Review

The data and information provided by BHPBIO for this study are listed in Table 3.1. Data were reviewed and relevant information extracted for the purposes of this project.

Table 3.1: Data and reports provided by BHPBIO for this assessment. These include relevant reports provided previously for nearby orebodies.

Area	Title	Author	Year
Environment	Prelim Risk Assessment_OB31_draft	BHP Billiton Iron Ore	2013
	ENV- OB18 Biological Assessment Survey Ecologia 01111995.pdf (R)	Ecologia	1995
	ENV- OB18 Flora and Fauna Review Ecologia 01072004.pdf (R)	Ecologia	2004
	ENV- OB18 Fauna Assessment Phase II ENV Australia 13062007.pdf (R)	ENV	2007
	ENV- OB18 Flora and Vegetation Assessment Phase II ENV Australia 13062007.pdf (R)	ENV	2007
	MIN_OB18_Environmental Management Plan (EMP)_EP Act V_BHPBIO_Rev 3 Aug 2008.pdf (R)	BPH Billiton Iron Ore	2008
	MIN_OB18_Significant Species Management Plan_EP Act IV_BHPBIO_Rev 2 May 2008.pdf (R)	BPH Billiton Iron Ore	2008
	MIN-ENV-Mines Ore Body 18 Mine Modification Assessment of Potential Hydrogeological Impacts Biological Survey Aquaterra 110707.pdf (R)	RPS Aquaterra	2007
	TECH_BHPBIO Ore Body 17 Vegetation Survey,pdf (R)	Pilbara Flora	2008
	AE Report July 2011 - June 2012 OB18.pdf (R)	BHP Billiton Iron Ore	2011

Area	Title	Author	Year
Hydro	EXP EPH 201305190 PROP Ninga updated Work Proposal YEJ13.doc	BHP Billiton Iron Ore	2013
	EXP EPH 20130119 PROP OB31 Work Proposal YEJ13.doc	BHP Billiton Iron Ore	2013
	129 Shovelanna (rev a).pdf	RPS Aquaterra	---
	RPD OB18 20121115 RPT OB17 and OB18 Hydrogeology Assessment 025c AQTA.pdf (R)	RPS Aquaterra	2012
	RPD OB18 20110124 RPT TAR YEJ10 Golder.pdf (R)	Golder	2010
	RPD OB18 20111125 RPT AAR-YEJ11 Golder.pdf (R)	Golder	2011
	RPD PER 20121130 PROP DRAFT OB17-18 Hydro Drilling Prop.pdf (R)	BPH Billiton Iron Ore	2012
Maps and Reports	OB24 AMD risk report BHPBIO Oct 2011.pdf	BHP Billiton Iron Ore	2011
	RDP_EPH_20120806_OB31_V1_Report_FINAL Edited.doc	BHP Billiton Iron Ore	2012
	EXP EP 20130903 Ninga Model Stakeholder Meeting.pdf	BHP Billiton Iron Ore	2013
	Fig1_GA of Original Proposal-Apdf.pdf (M)	BPH Billiton Iron Ore	2012
	Fig2_GA of Modification.pdf (M)		
	MIN_OB18_Conceptual Closure Plan_EP Act IV_Golders_092000 (R)	Golder	2000
	RPD EPH 20070808 RPT OB18_Report_2007808 V2.pdf (R)	BPH Billiton Iron Ore	2007
	RPD EPH 20110331 RPT OB17 LOM Study Report V2.pdf (M)	BPH Billiton Iron Ore	2011
	RPD EPH 20110718 RPT 110718_Final_400_OB18_Waste Dump Design Review_G_Fe_Memo.pdf	Snowden	2011
	Copy of BPL WAIO 20120829 RPT BHPBIO_STANDARD_MODELLING_CODES.XLS (D)	-	-
	120815_Final_3599_BHPBIO_OB18WireFrameCheck_G_Fe_Rev2.pdf	Snowden	2012
	OB 17 Drilling Report CATNO_9793.pdf	BHP Billiton Iron Ore	2012

3.2 AMD Source Assessment

The approach adopted by Earth Systems to characterise the AMD potential from OB31 was to utilise the modelled geochemical parameters contained in the BHPBIO mine models, to calculate a NAPP value to use to generate an AMD classification layer for the mine model. The AMD classification layer was then used to identify the statistical and spatial distribution of materials with respect to their potential to generate AMD.

3.2.1 NAPP Characterisation

The purpose of static geochemical characterisation is to develop a classification system that can identify potentially acid forming (PAF) or non-acid forming (NAF) materials that will be disturbed by mining. NAPP is the simplest form of static geochemical characterisation and evaluates the balance between acid generating and acid neutralising potential of a sample. NAPP values are determined by calculating the difference between a sample's maximum potential to generate acidity (MPA) and its acid neutralisation capacity (ANC) as shown in Equation 1.

$$\text{NAPP (kg } H_2SO_4 \text{ / t)} = \text{MPA (kg } H_2SO_4 \text{ / t)} - \text{ANC (kg } H_2SO_4 \text{ / t)} \qquad \text{(Eq. 1)}$$

where,

$$\text{MPA (kg } H_2SO_4 \text{ / t)} = \text{Total S (wt.\% S)} \times 30.6 \qquad \text{(Eq. 2)}$$

The MPA is the stoichiometric maximum amount of acidity that a sample may generate based on the assumption that all sulfur (S) is in the form of pyrite (Eq. 2), and can be readily calculated using total sulfur data.

The ANC measures the inherent capacity of a sample to neutralise acid, with calcium bearing carbonates being the key minerals capable of buffering acidity generated by sulfide oxidation reactions. ANC is usually estimated via laboratory testwork through titration of the solution generated by the reaction of hydrochloric acid (HCl) and the sample (AMIRA, 2002). However, when laboratory data are unavailable, appropriate variables such as Inorganic Carbon, Total Carbon, Loss on Ignition, Ca ± Mg data can be used as a substitute for estimating ANC. Although the latter approach is not as accurate as direct ANC measurement, it provides some information on acid buffering.

The mine model data provided by BHPBIO included total sulfur for each modelled block, allowing calculation of MPA values. However, no laboratory measured ANC data were available. Review of the geological logs showed that dolomite was the key acid neutralising carbonate mineral within the OB31 deposit. Availability of Ca, Mg and Loss on Ignition (LOI) were used to indicatively estimate the ANC in each modelled block by calculating the proportion of dolomite[1].

For this assessment, ANC for each interval was calculated as follows:

- Convert the Ca and Mg wt.% values to mol.%.
- Assign the lowest mol.% value between Ca and Mg to dolomite. This steps allows calculation of the potential proportion of dolomite in each interval based on the stoichiometric formula $Ca,Mg(CO_3)_2$.
- Calculate the theoretical LOI in the form of CO_2 based on a total mass of dolomite as calculated from the step above.
- If this theoretical LOI ≤ measured LOI, then assign all of the calculated LOI for that interval to dolomite.
- Use the mass of dolomite to estimate the ANC in kg H_2SO_4 / t.

Once a conservative estimate of ANC was obtained it was combined with the calculated MPA (Eq. 2) to generate an estimated NAPP for each block in the OB31 mine model. This approach provides a more accurate basis for AMD classification than MPA alone (based on total sulfur alone) as NAPP values account for any neutralising capacity in the rocks.

3.2.2 AMD Classification and PAF Mass Balance

NAPP values were used to classify each block within the mine model as potentially acid forming (PAF) and non-acid forming (NAF). Based on Earth Systems experience with the lithologies encountered at OB31, a suitable cut-off value to differentiate between NAF and PAF, using total sulfur alone, may be between 0.1-0.3 wt.%S. For the purposes of this preliminary assessment, a NAPP cutoff value of 3 kg H_2SO_4/t has been adopted, corresponding to a rock containing 0.1 wt.%S and no appreciable ANC. Once

[1] Dolomite is a mineral carbonate with the formula $Ca,Mg(CO_3)_2$. A mol of dolomite contains a 1:1 ratio of Ca and Mg. One mole of dolomite contains 0.5 moles of Ca and 0.5 moles of Mg.

additional geochemical testwork is carried out on the various lithologies, a more reliable NAPP cut-off value, specific to these deposits, can be determined. Hence, all blocks containing NAPP ≥ 3 kg H_2SO_4/t we classified as PAF and blocks containing NAPP < 3 kg H_2SO_4/t we classified as NAF.

For comparison with other BHPBIO data for the deposits, two alternative assessments of the AMD classification were made using:

- A NAPP cutoff of 6 kg H_2SO_4/t, corresponding to a rock containing 0.2 wt.%S and no appreciable ANC. This scenario uses BHPBIOs standard sulfur cutoff and also considers the calculated ANC of the material.
- A Total S cutoff of 0.2 wt%S, based on BHPBIOs standard sulfur cutoff for PAF material.

3.2.3 PAF Distribution and Mass Balance

An export of the mine model for OB31, surface topography and pitshell surfaces were imported into a GIS package. These were used to delineate the blocks within the mine model with respect to their location within the pit (as overburden) or within the wall rock zone. Two material groups were extracted:

- Overburden. Overburden within the mine pit, determined based on the "ore-classification code" assigned to each block in the mine model within the pit shell. Blocks attributed as "0" within the "ore" attribute were considered to be overburden.
- Wallrock. The wallrock zone of most interest is that dewatered for mining operations. As the specific zones of dewatered rock could not be determined from the data available, an indicative zone of 30 m (vertically) below the extent of the pit shells was adopted for this study to provide an indication of potential wallrock AMD characteristics.

A GIS package was used to plot the spatial distribution of any PAF materials within the pits and wall rock zones.

Summary statistics were generated for Total Sulfur, calculated ANC and NAPP for key rock-types within the overburden and wallrock zones.

The tonnages of any PAF overburden were quantified based on the mine model block volumes and in-situ rock densities provided. The distribution of PAF classified blocks above and below the groundwater table was also assessed. Each block was assigned to be above or below the groundwater level based on its "wtable" attribute within the mine model.

3.2.4 AMD Generation Rates

AMD generation rates allow quantification of the annual tonnage of AMD generated from a mine material (expressed as a mass of sulfuric acid equivalent or t/H_2SO_4-eq/year). The AMD generation rate is related to the pyrite oxidation rate of a material, which is routinely measured via kinetic geochemical testwork in the laboratory or in the field.

As kinetic geochemical data were not available for this assessment, sulfide oxidation rates were assumed based on kinetic geochemical testwork conducted by Earth Systems on other sulfidic mine materials in the Pilbara region. A pyrite oxidation rate of 3 wt.% FeS_2 per year[2] for overburden and 0.3 wt.% FeS_2 per year for wallrock has been assumed.

[2] Pyrite oxidation rate units, expressed as a weight percent of the mass of pyrite exposed to atmospheric oxygen that will oxidise per year.

Acidity generation rates were indicatively calculated where appropriate, based on the tonnage of PAF identified, the average pyrite content (conservatively based on total sulfur) and assumed pyrite oxidation rate for the material. For example, for a 1 Mt overburden dump containing 0.2 wt.% pyrite, and oxidising at 3 wt.% FeS_2 per year, the indicative acidity generation rate for the overburden dump would be 50 t of H_2SO_4 equivalent acidity per year.

3.3 Potential AMD Pathways and Environmental and Social Receptors

Potential pathways for AMD migration off site and relevant environmental and social receptors were provided during a workshop meeting held by BHPBIO. Earth Systems also reviewed the reports provided and identified any additional potential pathways and receptors not discussed during the workshop.

3.4 Preliminary AMD Risk Assessment

A preliminary AMD risk assessment for OB31 was completed using a risk assessment framework consistent with the standard approaches outlined in *Risk Assessment and Management* (DRET, 2008) and the *Planning for Integrated Mine Closure: Toolkit* (ICMM, 2008). The risk assessment incorporates a Source-Pathway-Receptor model and incudes both operations phase and closure AMD risks associated with the following:

- External overburden storage areas (OSAs).
- Backfilled (ie. in-pit OSAs) overburden, above and below the final groundwater rebound level / pit lake water level.
- Pit wallrock, above and below the final groundwater level / pit lake water level.

Potential hazards were initially given a risk rating (low, medium, high or very high) based on the likelihood of occurrence and consequence of each hazard, with consideration of the estimated AMD generation rates, potential pathways and the sensitivity of the receiving environment. The risk assessment matrix and consequence and likelihood scales are provided in Attachment C.

AMD management and mitigation requirements were then considered in light of the initial risk ratings. Residual risk ratings were then developed for each hazard, assuming effective implementation of the recommended AMD management and mitigation strategies.

4.0 Results

4.1 Overburden

Table 4.1 to Table 4.3 provide summary statistics for Total Sulfur, calculated ANC and NAPP for the mine model blocks for key overburden rock types for OB31. Key statistical results were:

- Sulfur can be considered very low throughout the deposit. 99th percentile values for all lithologies were below 0.1 wt.%S, except for Weeli Wolli Formation (0.21 wt.%S) and the Alluvials (0.32 wt.%S).
- The highest total sulfur values were contained within Mt. McRae Shale, however the highest mean and median values were present in the Alluvials. Sulfur in these near-surface sediments is probably secondary, however NAG and/or sulfur speciation testing would be required to confirm this.
- In general, calculated ANCs were lower in the BIF Whaleback Shale, BIF Dales Gorge Member, Mt Sylvia Formation and Mt. McRae Shale Formation blocks, with average calculated ANC values ranging from 1.0 to 1.2 kg H_2SO_4/t. The Alluvials, Weeli Wolli Formation and BIF Yandicoogina Shale Member had higher average calculated ANC values ranging from 9.4 to 10.3 kg H_2SO_4/t.
- Based on these total S and ANC values, NAPP values were largely negative and of low order, with median NAPP ranging from -0.5 to -9.6 kg H_2SO_4/t and average NAPP ranging from -0.7 to -9.6 kg H_2SO_4/t. The maximum NAPP value for a mine model block was 25 kg H_2SO_4/t for a Mt. McRae Shale block.

Table 4.1: OB31 mine model Total Sulfur summary statistics for key lithologies within the in-pit overburden.

Lithology	Total S (wt% S)					
	Mean	Median	Min	Max	95th %ile	99th %ile
Tertiary Alluvials	0.04	0.03	<0.01	0.49	0.15	0.32
Weeli Wolli Formation	0.02	0.01	<0.01	0.37	0.08	0.21
BIF, Yandicoogina Shale Member	0.02	0.02	<0.01	0.29	0.06	0.08
BIF, Joffre Member	0.01	0.01	<0.01	0.16	0.04	0.05
BIF, Whaleback Shale	0.01	0.01	<0.01	0.12	0.04	0.08
BIF, Dales Gorge Member	0.01	0.01	<0.01	0.47	0.02	0.04
Mt McRae Shale	0.02	0.01	<0.01	1.02	0.02	0.06
Mt Sylvia Formation	0.01	0.01	<0.01	0.06	0.01	0.02
Wittenoom Formation	0.01	0.01	<0.01	0.01	0.01	0.01

Table 4.2: OB31 mine model calculated ANC summary statistics for key lithologies within the in-pit overburden.

Lithology	ANC (kg H_2SO_4 / t)					
	Mean	Median	Min	Max	95th %ile	99th %ile
Tertiary Alluvials	9.4	4.3	0.1	133	36	58
Weeli Wolli Formation	9.4	2.5	1.0	97	37	77
BIF, Yandicoogina Shale Member	10.3	6.0	0.8	66	33	49
BIF, Joffre Member	4.5	1.3	0.5	235	23	58
BIF, Whaleback Shale	1.3	1.2	0.4	8	2	3
BIF, Dales Gorge Member	1.0	0.8	0.3	21	2	5
Mt McRae Shale	2.3	1.3	0.4	50	8	14
Mt Sylvia Formation	1.2	0.8	0.7	8	3	8
Wittenoom Formation	8.6	10.0	5.5	10	10	10

Table 4.3: OB31 mine model NAPP summary statistics for key lithologies within the in-pit overburden.

Lithology	NAPP (kg H_2SO_4 / tonne)					
	Mean	Median	Min	Max	95th %ile	99th %ile
Tertiary Alluvials	-8.0	-3.4	-133	0.8	-0.4	0.1
Weeli Wolli Formation	-8.7	-2.1	-94	-0.8	-1.3	-1.0
BIF, Yandicoogina Shale Member	-9.6	-5.4	-66	-0.4	-1.2	-0.9
BIF, Joffre Member	-4.1	-0.9	-235	1.5	-0.4	0.0
BIF, Whaleback Shale	-0.8	-0.8	-6.7	2.4	-0.1	1.1
BIF, Dales Gorge Member	-0.7	-0.5	-21	11	-0.1	0.5
Mt McRae Shale	-1.8	-0.9	-50	25	-0.4	0.01
Mt Sylvia Formation	-1.0	-0.6	-7.7	-0.4	-0.4	-0.4
Wittenoom Formation	-8.2	-9.6	-9.6	-5.2	-5.2	-5.2

Overburden rock types, their tonnages, relative proportions (by mass as a proportion of the total overburden mass) and PAF classified proportions are provided in Table 4.4. The key results were:

- The bulk of the overburden is dominated by BIF (69%) and Alluvials (22%). Mt McRae Shale accounted for approximately 3% of the overburden (approximately 10 Mt).
- Only 32,000 tonnes of overburden was classified as PAF based on the NAPP value of greater than or equal to 3 kg H_2SO_4/t. This represents approximately 0.01% of the total overburden mass.
- The PAF was dominated by Mt McRae Shale (82% of the PAF material). The rest of the PAF was associated with BIF - Dales Gorge Member.
- All PAF classified material is below the groundwater level.
- The average Total Sulfur concentration for PAF classified overburden blocks was 0.55 wt%S.

The spatial distribution of PAF overburden blocks are plotted in Figure 4.1 and Figure 4.2. From these figures it can be seen that the PAF material is located in the south-eastern part of the OB31 pit and all located approximately on the pit shell boundary.

Based on 30,000 tonnes of PAF waste rock with an average total sulfur content of 0.55 wt%S and a pyrite oxidation rate (POR) of 3 wt%FeS_2 per year (refer to Section 3.2.4 for details), the AMD potential of this material is estimated at 10-20 tonnes H_2SO_4 per year, if allowed to oxidise under atmospheric conditions.

Table 4.4: OB31 overburden tonnages, relative proportions (by mass), and PAF mass balance based on a NAPP cutoff value of 3 kg H_2SO_4/t to differentiate between PAF and NAF materials.

Lithology	Estimated tonnage*	Proportion relative to total overburden	PAF classified overburden**			
			Tonnage	Proportion relative to mass of lithology	Proportion relative to mass of total overburden	Proportion above ground water level ^
Tertiary Alluvials	65,567,763	22%	-	-	-	-
Weeli Wolli Formation	13,421,219	5%	-	-	-	-
BIF, Yandicoogina Shale Member	39,345,440	13%	-	-	-	-
BIF, Joffre Member	71,726,302	24%	-	-	-	-
BIF, Whaleback Shale	57,292,045	20%	-	-	-	-
BIF, Dales Gorge Member	34,900,145	12%	5,714	0.02%	0.00%	0%
Mt McRae Shale	9,935,572	3%	26,054	0.26%	0.01%	0%
Mt Sylvia Formation	1,094,552	0.40%	-	-	-	-
Wittenoom Formation	55,190	0.02%	-	-	-	-
Total	***293,338,230***	***-***	***31,769***	***-***	***0.01%***	***0%***

* Estimated by summation of block mass based on density, block dimensions and ore-classification attributes in provided from the OB31 mine model.

** Blocks with a calculated NAPP ≥ 3 kg H_2SO_4/t.

^ Groundwater level status (above/below) derived directly from each block attribute in the mine model.

For comparison with other BHPBIO projects, the PAF mass balance was repeated using a NAPP value of 6 kg H_2SO_4/t (Table 4.5), and also using a Total S cutoff of 0.2 wt%S (Table 4.6). Form these tables:

- Using a NAPP cutoff value of 6 results in approximately 50% less material classified as PAF.
- Using a Total Sulfur cutoff of 0.2 wt%S, significantly more material is classified as PAF (1.6 Mt) as no consideration is given to the acid neutralising capacity of the material. Alao, most (1.3 Mt) of the PAF classified material relates to material above the groundwater level, where the sulfur is likely to be present in the form of non-acid generating sulfate minerals.

Table 4.5: OB31 overburden tonnages, relative proportions (by mass), and PAF mass balance based on a NAPP cutoff value of 6 kg H_2SO_4/t to differentiate between PAF and NAF materials.

Lithology	Estimated Tonnage*	Proportion relative to total overburden	PAF Classified Overburden**			
			Tonnage	Proportion relative to mass of lithology	Proportion relative to mass of total overburden	Proportion above groundwater level^
Tertiary Alluvials	65,567,763	22%	-	-	-	-
Weeli Wolli	13,421,219	5%	-	-	-	-
BIF, Shale Member	39,345,440	13%	-	-	-	-
BIF, Joffre Member	71,726,302	24%	-	-	-	-
BIF, Whaleback Shale	57,292,045	20%	-	-	-	-
BIF, Dales Gorge Member	34,900,145	12%	948	0.003%	0.000%	6%
Mt McRae	9,935,572	3%	15,472	0.16%	0.005%	94%
Mt Sylvia	1,094,552	0.4%	-	-	-	-
Wittenoom	55,190	0.02%	-	-	-	-
Total	***293,338,230***	***100%***	***16,420***		***0%***	***100%***

* Estimated by summation of block mass based on density, block dimensions and ore-classification attributes in provided from the OB31 mine model.

** Blocks with a calculated NAPP ≥ 6 kg H_2SO_4/t.

^ Groundwater level status (above/below) derived directly from each block attribute in the mine model.

Table 4.6: OB31 overburden tonnages, relative proportions (by mass), and PAF mass balance based on a Total Sulfur cutoff of 0.2 wt%S (ie. no consideration of acid neutralising capacity) to differentiate between PAF and NAF materials.

Lithology	Estimated Tonnage*	Proportion relative to total overburden	PAF Classified Overburden**			
			Tonnage	Proportion relative to mass of lithology	Proportion relative to mass of total overburden	Proportion above groundwater level^
Tertiary Alluvials	65,567,763	22%	1,338,246	2%	0%	81%
Weeli Wolli	13,421,219	5%	141,780	1%	0%	9%
BIF, Shale Member	39,345,440	13%	54,828	0%	0%	3%
BIF, Joffre Member	71,726,302	24%	-	-	-	-
BIF, Whaleback Shale	57,292,045	20%	-	-	-	-
BIF, Dales Gorge Member	34,900,145	12%	18,961	0.054%	0.006%	1%
Mt McRae	9,935,572	3%	92,440	0.93%	0.032%	6%
Mt Sylvia	1,094,552	0.4%	-	-	-	-
Wittenoom	55,190	0.02%	-	-	-	-
Total	***293,338,230***	***100%***	***1,646,256***		***1%***	***100%***

* Estimated by summation of block mass based on density, block dimensions and ore-classification attributes in provided from the OB31 mine model.

** Blocks with a Total S ≥ 0.2 wt%S.

^ Groundwater level status (above/below) derived directly from each block attribute in the mine model.

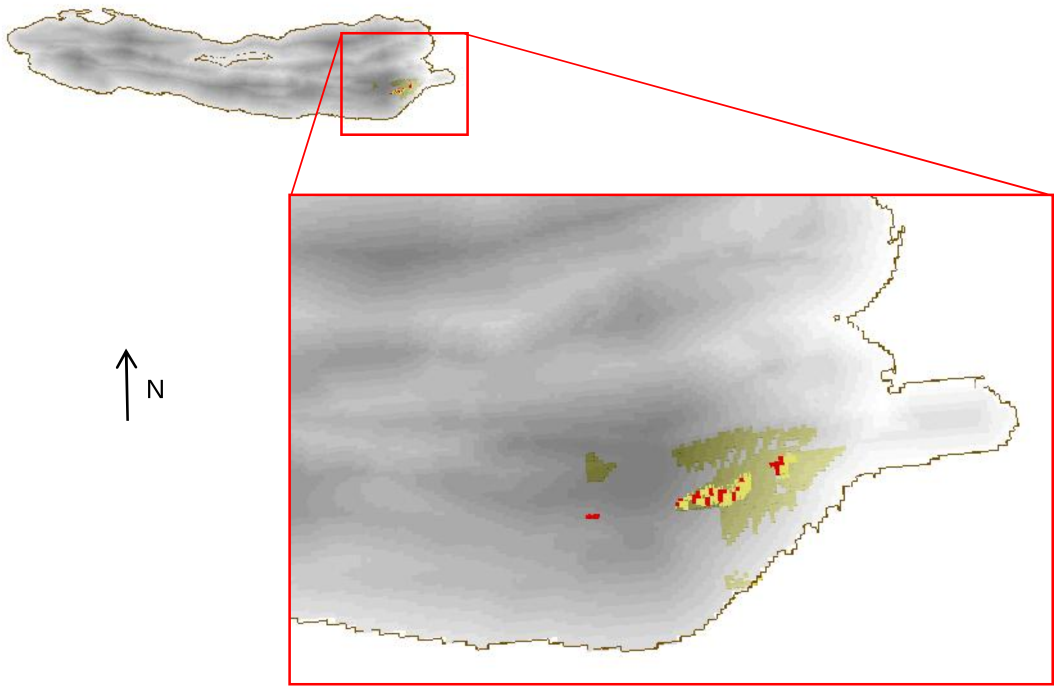

Figure 4.1: Plan view of the OB31 pit shell (depth delineated by grey colour-scale) and PAF classified blocks. In-pit PAF overburden blocks are shaded in red. Wallrock PAF blocks (nominally 30m below the pit shell) are shaded in yellow. PAF rocks defined as those with NAPP ≥ 3 kg H_2SO_4/t.

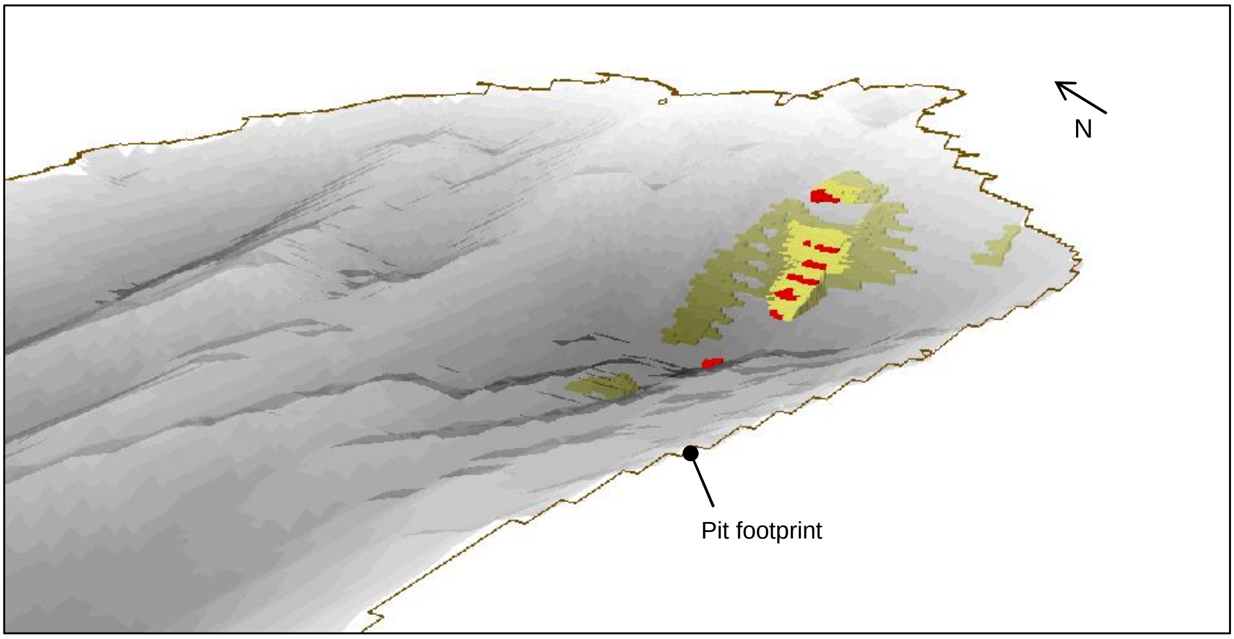

Figure 4.2: 3D view of the south-eastern part of the OB31 pit depicting PAF classified overburden blocks (red shading) and PAF classified wall rock blocks (yellow shading). PAF rocks defined as those with NAPP ≥ 3 kg H_2SO_4/t.

4.2 Wallrock

Table 4.7 provides summary statistics for NAPP within the assumed wall rock zone (30m vertically below the pit shell) at OB31. The spatial distribution of PAF wall rock blocks is plotted in Figure 4.1 and Figure 4.2. The key results were:

- Mt McRae Shale makes up almost 20% of the wall rock zone.
- NAPP for the Mt. McRae Shale ranged from -67 to 48 kg H_2SO_4/t, with approximately 3-4% of the Mt. McRae shale wallrock blocks having NAPP of greater than 3 kg H_2SO_4/t, and hence classified as PAF. Several blocks within the BIF Dales Gorge Member and Mt Sylvia Formation were also classified as PAF.
- PAF wall rock blocks are predominantly located in one zone along the south eastern pit wall.
- The average total sulfur content of PAF classified wallrock blocks was 0.95wt%S.

PAF blocks within the wall rock zone assumed for this assessment amounts to approximately 1,500,000 tonnes, with an average Total Sulfur content of 0.95 wt%, a POR of 0.3 wt%FeS_2/year (see Section 3.2.4 for further details), the AMD potential form the wall rock, if allowed to oxidise under atmospheric conditions is estimated at 100-150 tonnes H_2SO_4-eq per year.

Table 4.7: NAPP summary statistics for OB31 mine model blocks within the wallrock zone, assumed for this assessment to be the zone 30m vertically below the pit shell).

Lithology	Block Count	Relative proportion of blocks	NAPP (kg H_2SO_4/t)					
			Mean	Median	Min	Max	95th %ile	99th %ile
Tertiary Alluvials	806	0.3%	-9.6	-4.7	-61	0.1	-0.9	-0.5
Weeli Wolli Formation	6,662	2.5%	-6.6	-2.0	-91	-0.9	-1.2	-1.0
BIF, Yandicoogina Shale Member	12,860	4.9%	-5.1	-2.1	-66	-0.7	-1.1	-0.9
BIF, Joffre Member	99,062	37.9%	-1.4	-0.6	-79	1.3	-0.4	-0.3
BIF, Whaleback Shale	26,606	10.2%	-0.9	-0.9	-3.6	-0.1	-0.6	-0.5
BIF, Dales Gorge Member	53,009	20.3%	-0.6	-0.6	-28	16	-0.3	0.3
Mt McRae Shale	50,997	19.5%	-0.9	-0.6	-67	48	0.3	32
Mt Sylvia Formation	9,653	3.7%	-1.0	-0.8	-16	17	-0.4	-0.4
Wittenoom Formation	1,624	0.6%	-7.0	-5.4	-18	-0.5	-1.3	-0.8

4.2.1 Comparison with BHPBIO results

Some additional static geochemical testwork results were provided during this assessment, collected from drill holes during a recent drilling program. The samples largely represent the BIF and Tertiary Alluvials, with only one Mt. McRae Shale sample (Tabulated results are provided in Attachment D). The static geochemical testwork confirmed the general characteristics of the deposit determined from the calculated NAPP from the mine model:

- Sulfur was only detected in 4 samples, and a significant proportion of this is likely to be present as sulfate. Given the near-neutral 1:5 pH values, the sulfate salts are unlikely to be present as acid storing salts (eg. jarosite, alunite or melanterite).
- ANC was very low amongst the samples with the exception of the Tertiary Alluvials where ANC varied and ranged from 0.7 - 63.9 kg H_2SO_4/t.

- Based on the total S and ANC values, NAPP values were negative.
- NAG pH values were generally near-neutral, subsequently no $NAG_{4.5}$ results were measured. Interestingly, $NAG_{7.0}$ values were recorded in over half the samples, and ranging from <0.1 to 9.4 kg H_2SO_4/t. This is likely due to small amounts of Fe^{2+} in the water, possibly released via the dissolution of iron-bearing carbonates.

Of these samples, 16 had corresponding assay data contained within the assay database previously provided to Earth Systems (Export_Samples_Head.csv). MPA, ANC and NAPP were calculated by Earth Systems for each sample based on assay parameters LOI, CaO, MgO and S (all reported in wt%). Measured ANC from the data provided and ANC calculated by Earth Systems were compared to show whether the calculation method had potential for wide-spread application to all assay intervals or mine model blocks. The results showed that in general, calculated ANC can be used to provide a first-pass approximation of the measured value (see Figure 4.3 and Figure 4.4). However, due to the small number of data, these results are considered inconclusive.

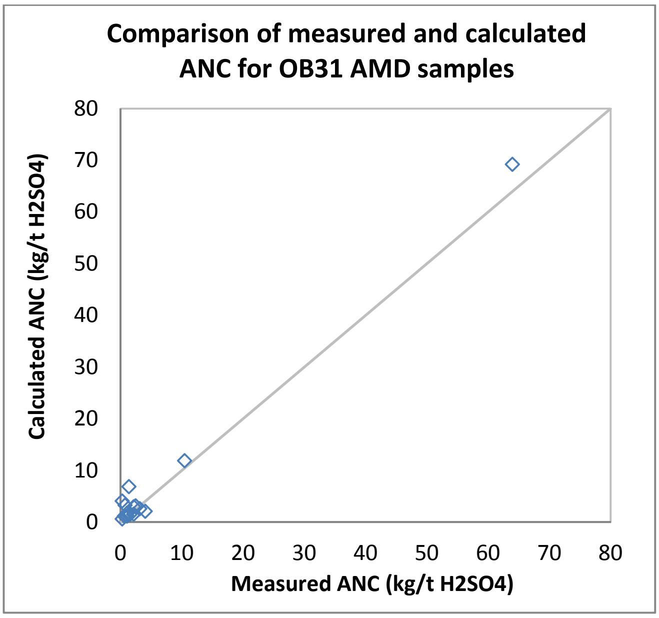

Figure 4.3: Calculated ANC vs. Measured ANC (both in kg H_2SO_4/t).

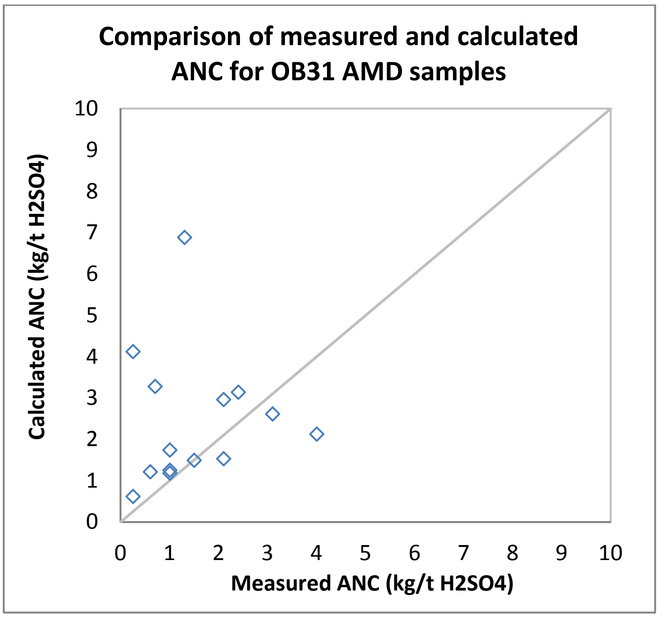

Figure 4.4: Calculated ANC vs. Measured ANC (both in kg H_2SO_4/t), for values ranging from 0-10 kg H_2SO_4/t.

Table 4.8 provides a list of the 35 OB31 mine model blocks that were classified as PAF as part of this assessment and their corresponding attributes within the OB31 mine model (the legends for the mine model attributes are provided in the table footer). Whilst all the blocks are classified as 'waste', the waste type classification ("design" column) and PAF classification ("PAF" column) do not appear to consistently capture the AMD potential of these blocks.

Table 4.8: Comparison of OB31 PAF overburden materials (as classified by Earth Systems) and their corresponding attributes within the OB31 mine model. Note that some material classified as fibrous in the BHPBIO model may also be PAF.

Centroid x	Centroid y	Centroid z	Dept h	Stratnum *	S (wt %)	PAF classification code in the BHPBIO model**	Design** *	Ore ^	Wtable^ ^
206405	7417705	398	124.6	5400	0.46	1.00	2	0	1
206415	7417705	398	124.2	5400	0.40	0.86	3	0	1
206425	7417705	398	123.7	5400	0.25	0.53	3	0	1
206405	7417705	402	120.5	5400	0.28	0.60	3	0	1
206605	7417715	398	121.5	5400	0.37	0.79	3	0	1
206645	7417715	410	110.4	5400	0.34	0.73	3	0	1
206645	7417725	410	110.7	5400	0.25	0.53	3	0	1
206655	7417725	410	110.8	5400	0.46	1.00	2	0	1
206675	7417705	422	98.8	5400	0.39	0.79	3	0	1
206675	7417715	422	98.8	5400	0.27	0.53	3	0	1

Centroid x	Centroid y	Centroid z	Depth	Stratnum *	S (wt %)	PAF classification code in the BHPBIO model**	Design***	Ore ^	Wtable^^
206685	7417725	422	99.6	5400	0.46	0.93	3	0	1
206705	7417705	434	88.3	5400	1.02	0.73	3	0	1
206705	7417715	434	88.2	5400	0.84	0.60	3	0	1
206715	7417725	434	88.9	5400	0.93	0.66	3	0	1
206735	7417705	446	77.4	5400	0.64	0.00	3	0	1
206735	7417715	446	77.7	5400	0.64	0.00	3	0	1
206745	7417725	446	79.4	5400	0.90	0.00	3	0	1
206835	7417745	482	55.0	5400	0.73	0.00	3	0	1
206835	7417755	482	57.4	5400	0.79	0.00	1	0	1
206835	7417755	486	53.6	5400	0.79	0.00	1	0	1
206825	7417765	482	56.0	5400	0.79	0.00	1	0	1
206835	7417765	482	57.5	5400	0.79	0.00	1	0	1
206845	7417765	482	59.2	5400	0.79	0.00	1	0	1
206845	7417775	482	59.4	5400	0.79	0.00	1	0	1
206835	7417765	486	53.7	5400	0.79	0.00	1	0	1
206845	7417765	486	55.2	5400	0.79	0.00	1	0	1
206845	7417775	486	55.7	5400	0.68	0.00	3	0	1
206835	7417765	490	50.1	5400	0.73	0.00	3	0	1
206845	7417765	490	51.5	5400	0.79	0.00	1	0	1
206615	7417725	398	122.0	5610	0.17	0.35	3	0	1
206655	7417725	414	107.1	5610	0.14	0.29	3	0	1
206655	7417735	410	111.1	5610	0.17	0.35	3	0	1
206685	7417735	422	99.6	5610	0.21	0.41	3	0	1
206705	7417725	434	88.3	5610	0.16	0.11	3	0	1
206755	7417745	446	80.9	5610	0.47	0.12	3	0	1

* “stratnum” refers to BHPBIO’s standard geological coding system. 5400 refers to Mt. McRae Shale Undifferentiated. 5610 refers to BIF - Colonial Chert Member / Dales Gorge Member.

** “paf” refers to BHPBIO’s mine model PAF classification where 1= PAF and 0 = NAF. It is unclear what values between 0 and 1 represent.

*** “Desig” refers to the ore designation category within the mine model. 1 = Waste, 2 = PAF waste, 3 = Fibrous Waste, 4 = Blend and 5 = High Grade Ore.

^ “Ore” Refers to the ore classification for the mine model block. 1 = Ore and 2 = Waste

^^ “Wtable” refers to whether the mine model block is above or below the pre-development groundwater level. 0 = above the groundwater level and 1 = below the groundwater level.

5.0 AMD Pathways and Environmental and Social Receptors

This section identifies and describes the pathways for AMD migration and receptors that could potentially be impacted by AMD from OB31.

The following potential pathways for AMD migration off site have been identified:

- Surface runoff from overburden storage areas (OSAs) and/or pit wallrock.
- Surface seepage from OSAs and/or pit wallrock.
- Dewatering discharge via pipeline into surrounding catchment.
- Percolation into groundwater from OSAs and/or pit wallrock.
- Off-site discharge of water into local creek(s). For example controlled (or uncontrolled) release of pit water following a high rainfall event.

Potential environmental and social receptors are:

- Surface water (streams and water bodies) ecosystems.
- Groundwater ecosystems.
- Terrestrial flora and fauna.
- Subterranean flora and fauna.
- Social receptors (local communities and site personnel).

A description of the potential pathways and receptors is provided in the sections that follow.

5.1 Surface Water

5.1.1 Streams

Watercourses potentially affected by AMD from OB31 include:

- Shovelanna Creek (ephemeral), which is located west of OB31, and flows north-west into the Fortescue River immediately downstream of Ophthalmia Dam, near the town of Newman. While OB31 is outside of the Shovelanna Creek catchment, XX>
- Jimblebar Creek flows in a northerly direction to the Fortescue River and is approximately 5 km east of the eastern extent of the OB31 deposit.

Surface water drainage lines for OB31 and other regional deposits are depicted in Figure 5.1

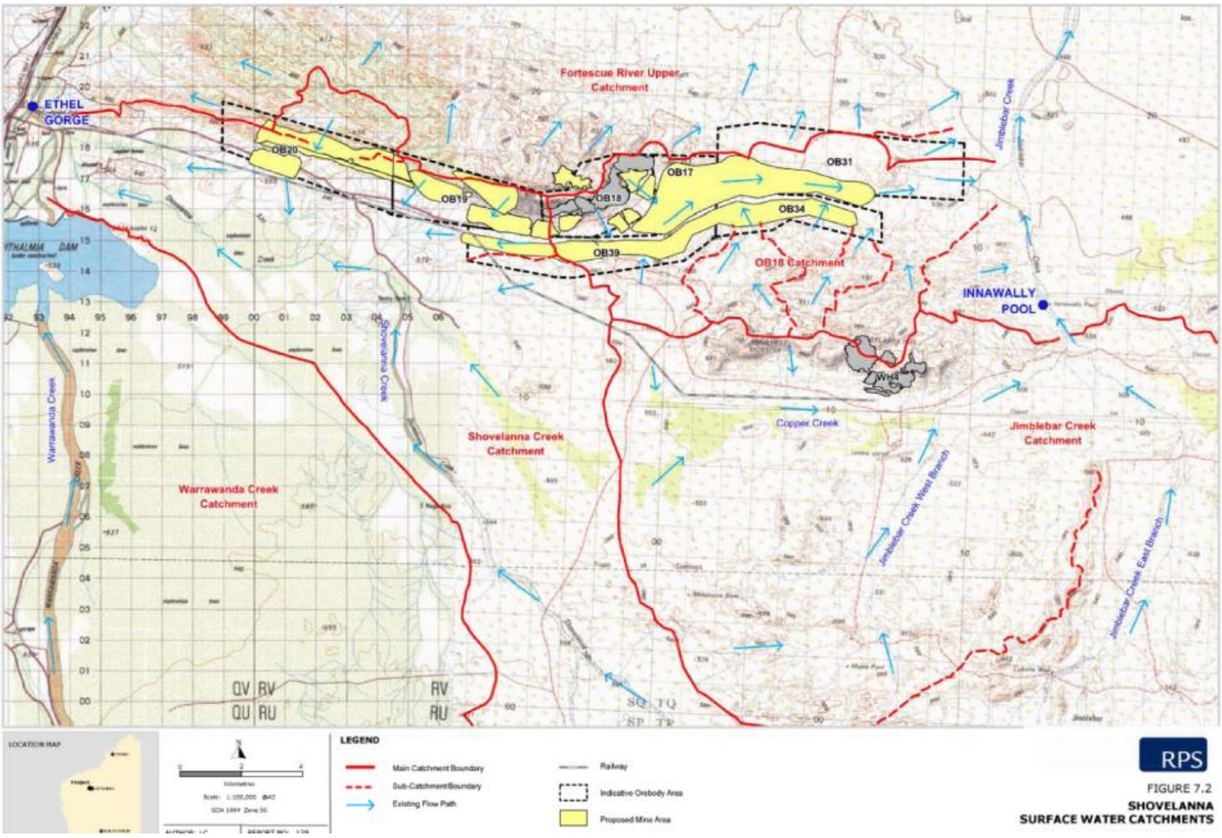

Figure 5.1. Surface water drainage lines for OB31 and regional iron ore deposits (image provided by BHP Billiton Iron Ore).

5.1.2 Water Bodies

Water bodies potentially affected by mining activities and AMD from OB31 include:

- Ophthalmia Dam, located along the Fortescue River downstream of the town of Newman. The Ophthalmia Dam is contained within the Newman Water Reserve, which consists of surface and groundwater reserves (Ophthalmia Borefiled supplies drinking water to the town of Newman). Ophthalmia Dam may also receive dewater discharge via pipeline into the Ophthalmia Dam catchment.
- The Fortescue Marshes are of significant ecological importance and are located ~110 km downstream of the OB31 deposit.

5.2 Hydrogeology

5.2.1 Groundwater Occurrence

The main regional aquifers identified in the project area are located within the Marra Mamba Iron Formation, the Paraburdoo Member of the Wittenoom Formation, the Dales Gorge Member of the Brockman Iron Formation and the Tertiary alluvial sediments (TAR, 2010).

Orebody 31

- The local aquifer is confined within the mineralised Brockman Formation orebody with an estimated 80% of the orebody located below the groundwater table. Groundwater levels in relation to the orebody are depicted in Figure 5.3.
- The orebody aquifer is bounded to the north and the south by the banded iron formations and shales of the Weeli Wolli Formation and Mt. McRae Shale which exhibit low permeability. Eastern portions of the orebody and associated aquifer are terminated by the Wheelara Fault and western portions are confined by the unmineralised Brockman Formation.
- Connection between the OB31 orebody aquifer and regional aquifers is likely to exist along the Wheelara Fault, as indicated by hydraulic testing at OB31 (Aquaterra, 2014). Hydrogeologic investigations are currently ongoing to further investigate the structural connections between aquifers at OB31.

5.2.2 Groundwater Flow Regime

Groundwater fluctuations following large rainfall events indicate that primary groundwater recharge is associated with the direct infiltration of rainfall and secondary infiltration of surface runoff (Aquaterra, 2012).

Limited data suggests that groundwater flow directions mimic surface water flows, with a groundwater divide potentially occurring near the incised gap in the Marra Mamba Ridge north-east of the Warrawandu mining village (Aquaterra, 2014). Groundwater west of the divide generally flows west towards Ethel Gorge while groundwater east of the divide generally flows east towards Jimblebar Creek through the Tertiary Alluvials.

The impact on local and regional groundwater flows resulting from dewatering activities is currently uncertain and currently being investigated by BHPBIO to identify any hydraulic connection between the Brockman orebody aquifer and the permeable Tertiary detrital aquifer via faulting (Wheelara Fault). Sustained pumping to maintain pit dewatering may lower groundwater levels over a broad area due to connectivity with the highly permeable Tertiary Alluvials.

Groundwater level recovery at OB31 will likely be slow as a result of slow groundwater throughflow and low groundwater recharge rates.

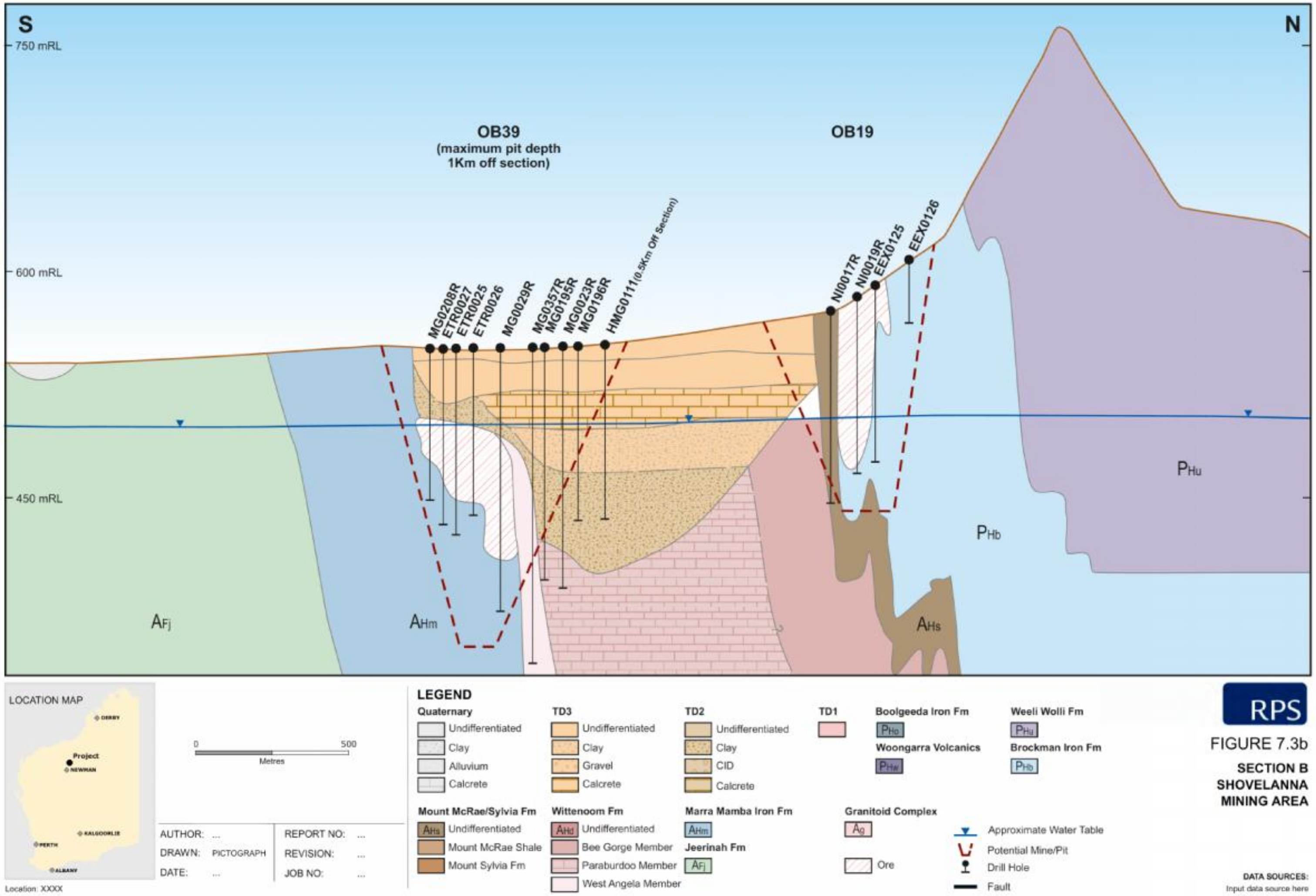

Figure 5.2. Hydrogeological cross-section for Orebody 19 (Aquaterra, 2014).

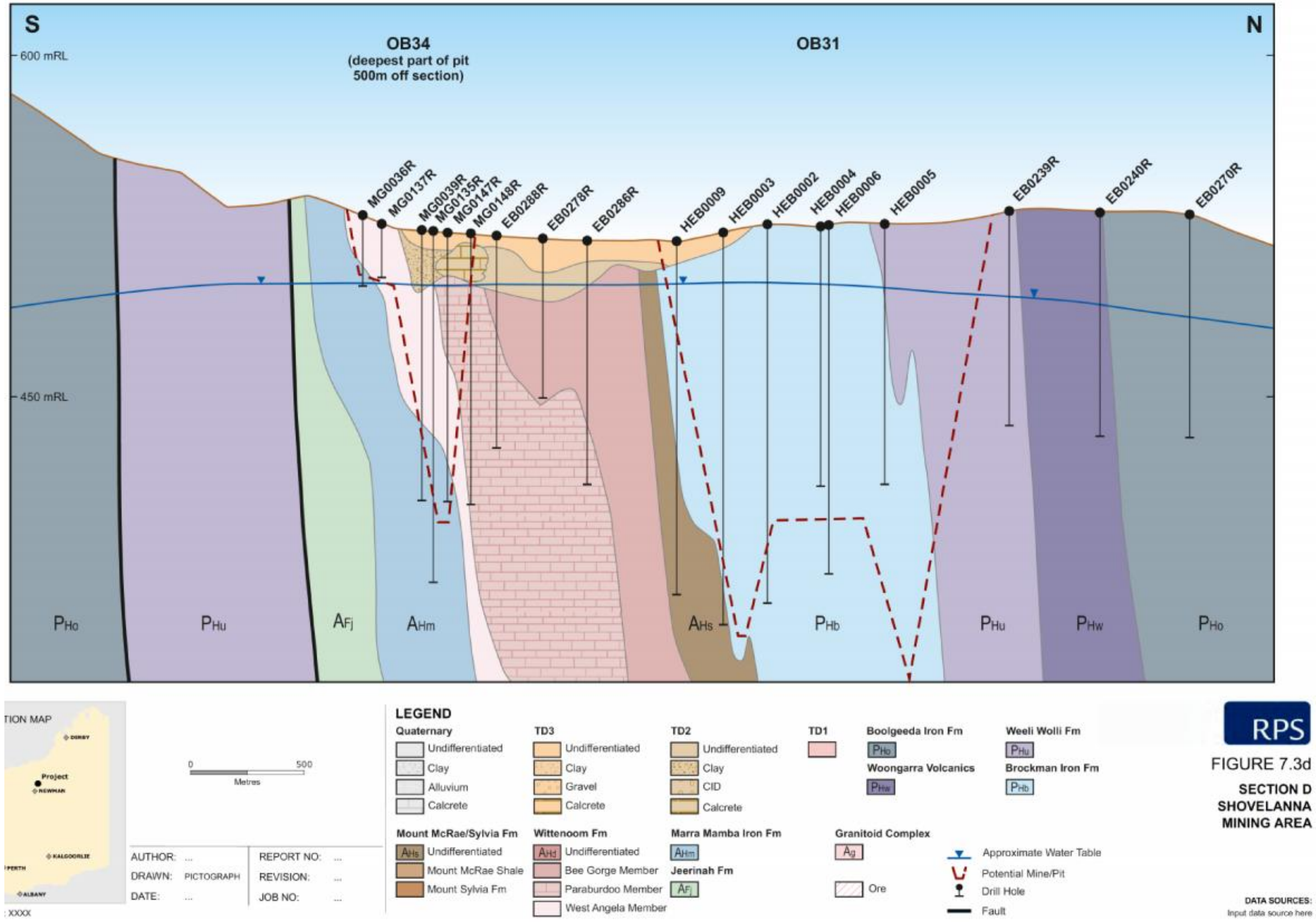

Figure 5.3. Hydrogeological cross-section for Orebody 31 (Aquaterra, 2014).

5.2.3 Groundwater Use

Groundwater is extracted from the Warrawandu Borefield and the OB18 Borefield. The Warrawandu Borefield supplies water to the Warrawandu mining village, while the OB18 borefield is predominantly used for process water, construction, dust suppression and potable drinking purposes (BHP Billiton, 2008). The majority of the OB18 production bores were installed in the Tertiary sediments and the underlying Wittenoom Formation, with one production bore installed in Tertiary sediments and the underlying Marra Mamba Iron Formation (BHPBIO, 2011).

Down hydraulic gradient to the west of the orebodies, the town of Newman sources groundwater for the town's drinking water supply. The groundwater bores are located in the Ophthalmia Dam Borefield which abstracts water from the Wittenoom Formation and overlying Tertiary sediments, where there is generally some separation between aquifers by confining clay sequences (Department of Water, 2009). Additional water supplies for the town of Newman are sourced from the Homestead Borefield located just west of Ophthalmia dam.

5.3 Flora and Vegetation

The following summary was provided by BHPBIO: "Flora and vegetation baseline surveys carried out in the area have not recorded any Threatened Flora, Threatened Ecological Communities (TEC) or Priority Ecological Communities (TEC). Three priority flora species were recorded (two P3 species and one P4 species) and the majority of taxa have been recorded in adjacent tenements. Generally, the vegetation condition was rated as 'Good to Excellent'. Four introduced species have been recorded. Additional flora and vegetation environmental impact assessments are currently underway."

5.4 Terrestrial Fauna

The following summary was provided by BHPBIO: "No PECs or TECs relating to terrestrial fauna were recorded within the project area. Five conservation significant species were recorded from the area (three P4 species and two Migratory species). The project area is not considered to be the whole of or part of, or be necessary for the maintenance of, a significant habitat for fauna indigenous to Western Australia. Minor drainage lines were recorded, however, no major watercourses or wetland habitats were identified. The five main habitats identified in the study area are considered widespread throughout the Pilbara. Terrestrial vertebrate fauna environmental impact assessments are currently underway."

5.5 Subterranean Fauna

The following summary was provided by BHPBIO: "Recent surveys of the area and surrounds have recorded 12 species of stygofauna and 29 species of troglofauna. These numbers are considered low in comparison to other project surveys near Newman. There is potential aquifer connectivity extending beyond the project area, indicating that stygofauna species and communities may be interconnected and not limited to the project area. Stygofauna and troglofauna environmental impact assessments are currently underway to review potential impacts and determine aquifer connectivity."

5.6 Short Range Endemic Invertebrate Fauna:

The following summary was provided by BHPBIO: "Short-range endemic (SRE) invertebrate fauna surveys carried out in the area and surrounds did not recorded any confirmed SRE species. Ten species collected were considered to be potential SRE species. The mountainous zones within the project area were considered to be most prospective habitats for SRE species. SRE invertebrate fauna environmental impact assessments are currently underway."

5.7 Social

Any communities that utilise water resources within, surrounding or downstream of the project area can be considered as potential social 'receptors'.

The town of Newman, with a population of approximately 7,000 residents is located approximately 40 km to the west-southwest of OB31. Although the town is positioned upstream of the Ophthalmia Dam, the town's potable water is sourced from the Newman Water Reserve which includes local aquifers, the Ophthalmia Dam Borefield.

Potable water for the Warrawandu Village community, which accommodates local mining personnel, is sourced from the Warrawandu Borefield.

BHPBIO personnel involved in site water management have the potential to come into contact with surface water runoff or seepage from stockpiled materials, or ponded water in the pits, and are therefore also considered 'receptors'.

Based on the information reviewed, it is understood there are no other significant social receptors within, surrounding or downstream of the project area.

6.0 Preliminary AMD Risk Assessment

6.1 Risk Assessment Matrix

The potential AMD sources, AMD transport pathways and environmental and social receptors identified in this assessment are listed in Table 6.1. The preliminary AMD risk assessment matrix for OB31 during operations and post closure is provided in Table 6.2.

Table 6.1: Summary of AMD sources, transport pathways and environmental and social receptors used to develop the preliminary risk assessment matrix for OB31.

Potential AMD Sources	AMD Transport Pathways	Environmental and Social Receptors
During operations		
- 10-20 tonnes H_2SO_4/year from PAF overburden stored in ex-pit OSA's. - 10-20 tonnes H_2SO_4/year from PAF overburden stored in-pit. - 100-150 tonnes H_2SO_4/year from PAF wallrock.	- Surface runoff / surface - Expressions of seepage - Percolation into groundwater - Controlled or uncontrolled discharge of pit lake water	- Surface water ecosystems (Jimblebar Creek) - Groundwater quality (for reuse) - Terrestrial flora and fauna utilising impacted surface waters. - Subterranean flora and fauna - Social receptors
Post-closure		
- 10-20 tonnes H_2SO_4/year from PAF overburden stored in ex-pit OSA's. - Accumulated AMD from PAF overburden stored in-pit. - Accumulated AMD from PAF wallrock.	- Surface runoff / surface - Expressions of seepage - Percolation into groundwater - Controlled or uncontrolled discharge of pit lake water	- Surface water ecosystems (Jimblebar Creek) - Groundwater quality (for reuse) - Terrestrial flora and fauna utilising impacted surface waters. - Subterranean flora and fauna - Social receptors

6.2 Risk Mitigation

Management for AMD materials across BHP Billiton Iron Ore's Pilbara sites is outlined at a high-level in the WAIO AMD Management Standard (BHPBIO, 2014). The overall strategy for AMD management is illustrated in Figure 6.1 with considerations across the full mine life cycle.

To inform the selection of AMD mitigation measures, options have been documented for each of the potential risks identified in Table 6.2. General mitigation measures are described below.

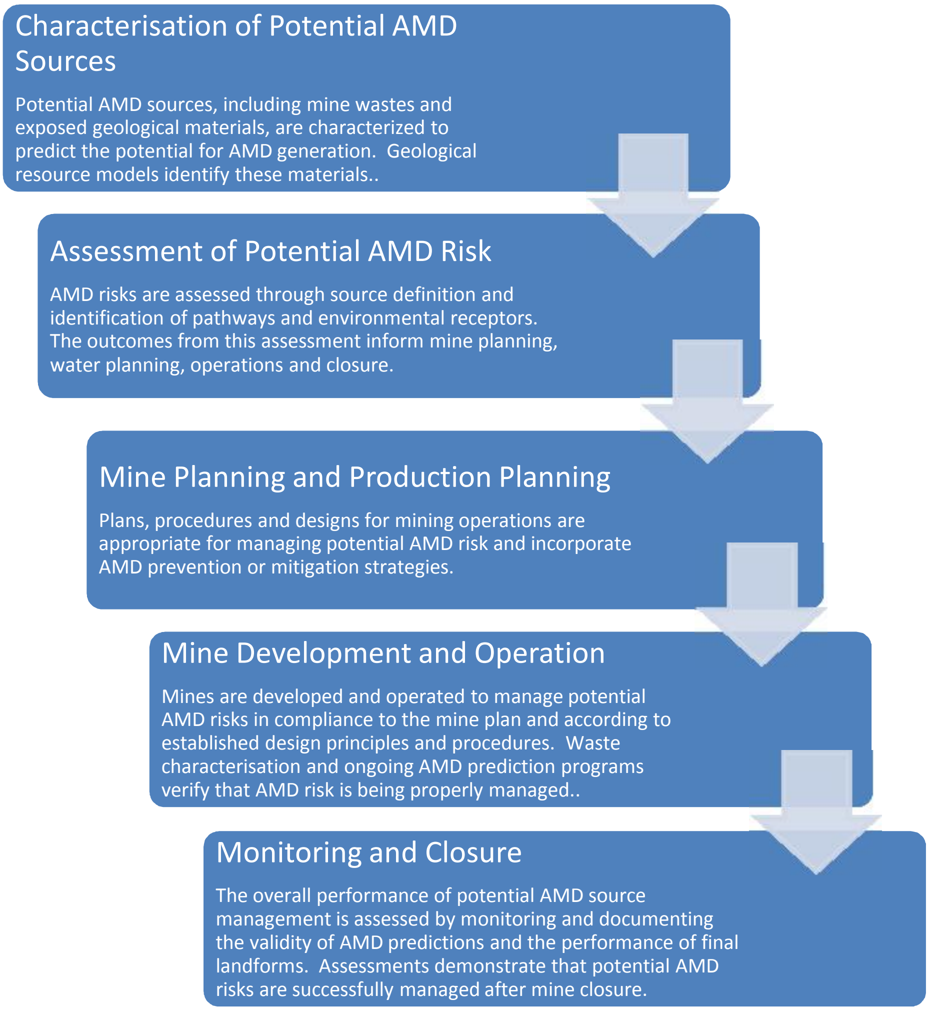

Figure 6.1. The AMD management process (BHPBIO 2014)

6.2.1 AMD Risk Planning

Specific Investigations that may be undertaken:

- Waste material (overburden and wallrock) characterisation including sulfur speciation and AMD classification based on Acid Base Accounting.
- Refinement of AMD Risk Assessment including modelling hydro-geochemical reactions and transport (if appropriate).

Specific planning and operational measures:

- PAF waste modelling and scheduling (including PAF waste segregation).
- Selective handling of procedures for PAF overburden (if required).
- Design, construction and operational procedures for PAF OSA's (if required).
- Design, construction and operational procedures for appropriate water treatment plant or infrastructure (if required).
- Development of site specific closure strategies.
- AMD related environmental monitoring (e.g. runoff / seepage / groundwater quality, groundwater levels).

6.2.2 Management of Specific AMD Risks

Overburden

Management strategies for overburden that could be employed include:

- Modification of the pit shell to limit or prevent the excavation of PAF overburden. This will dramatically lower the reactivity of the material as it will remain.
- Sub-aqueous disposal in OB31 or OB18 pit below the expected rebounded groundwater/pit lake water level.
- Disposal in specifically designed (to prevent and or minimise AMD generation) PAF overburden storage area (or cell within an OSA).
- Passive AMD treatment approaches.

Wallrock

PAF wallrock may require appropriate management. Management strategies that could be employed include:

- Application of alkaline amendment to the exposed face of PAF wallrock. This could be achieved using mobile plant to prepare limestone or hydrated lime slurry and spray it onto high risk wallrock zones using a monitor cannon.
- Active treatment of wallrock runoff during operations.
- Flooding of exposed wallrock upon closure (via pit lake or pit backfilling pit and groundwater recovery)
- Blending pit back-fill material with locally available carbonate material to neutralise any AMD generated and released upon rewetting.

6.3 Residual AMD Risk

The residual AMD risk for the OB31 deposits, should AMD issues be managed according to the approaches described above, is expected to be low.

Table 6.2: Risk Assessment matrix for OB31

Risk				Risk allocation			Risk Mitigation	Residual Risk		
No.	**Hazard Scenario**	**Pathway**	**Receptor**	**Cons.**	**Likelihood**	**Risk**	**Management Options**	**Cons.**	**Likelihood**	**Risk**
Operations Phase										
Overburden										
1	10-20 t H_2SO_4/year AMD from PAF overburden stored ex-pit	Seepage (percolation)	Groundwater	Minor	Possible	Medium	• Segregate PAF overburden. • Construct PAF OSAs in accordance with leading practise to minimise AMD generation and discharge. • If groundwater rebound level is to be above the base of pit shell, consider relocating PAF overburden into the pit void below the final groundwater rebound level as soon as possible. • If required, collect and treat AMD runoff or seepage from overburden stockpiles containing PAF material.	Minor	Unlikely	Low
2		Runoff or seepage	Surface water	Minor	Possible	Medium	• As above (Item 1).	Minor	Unlikely	Low
3	10-20 t H_2SO_4/year AMD from PAF overburden stored in-pit	Seepage (percolation) into groundwater. Assumes AMD infiltrates into base of pit and that pit acts as groundwater sink during operations.	Groundwater	Minor	Possible	Medium	• Stockpile material within the pit according to leading practise to minimise AMD generation (eg. paddock dump and compact) • Consider blending / amending locally available carbonate material with the overburden. • Reuse pit water on site. • Treat pit water during operations, if required.	Insignificant	Unlikely	Low
Pit Wallrock										
4	Release of AMD from unsaturated pit wallrock	Seepage (percolation) into groundwater	Groundwater	Minor	Possible	Medium	• Reuse pit water on site if possible. • Treat pit water during operations, if required. • Spray alkaline slurry over pit walls to neutralise AMD.	Insignificant	Unlikely	Low
Post Closure										
Overburden										
5	10-20 t H_2SO_4/year AMD from PAF overburden stored ex-pit	Seepage (percolation)	Groundwater	Minor	Possible	Medium	• As above (Item 1).	Minor	Unlikely	Low
6		Surface runoff / surface expressions of seepage	Surface water	Minor	Possible	Medium	• As above (Item 1).	Minor	Unlikely	Low
7	Pulse of AMD from PAF overburden stored in pit ***below*** the groundwater rebound level, upon groundwater rebound	Seepage (percolation) into groundwater as a result of groundwater rebound and/or rainfall infiltration	Groundwater	Moderate	Possible	High	• Develop strategy for managing AMD from backfilled PAF overburden. • This may include characterisation of the AMD generated during operations and blending with a suitable amount of neutralising material prior to disposal, in order to neutralise the stored acidity upon rewetting.	Minor	Unlikely	Low
8	Ongoing release of AMD, from PAF overburden stored in pit ***above*** the groundwater rebound level	Seepage (percolation) into groundwater as a result of rainfall infiltration	Groundwater	Minor	Possible	Medium	• As above (Item 3). • Also consider passive treatment / bioremediation options if annual acidity load is sufficiently low.	Insignificant	Unlikely	Low

Risk				Risk allocation			Risk Mitigation	Residual Risk		
No.	**Hazard Scenario**	**Pathway**	**Receptor**	**Cons.**	**Likelihood**	**Risk**	**Management Options**	**Cons.**	**Likelihood**	**Risk**
8		Controlled or uncontrolled discharge into water body from pit lake	Surface Water	Minor	Possible	Medium	• As above (Item 3). • Also consider passive treatment / bioremediation options if annual acidity load is sufficiently low.	Insignificant	Unlikely	Low
Pit Wallrock										
9	Pulse of AMD from pit wallrock ***below*** final groundwater rebound level upon groundwater rebound / re-wetting	Seepage (percolation) into groundwater as a result of groundwater rebound and/or rainfall infiltration	Groundwater	Moderate	Possible	High	• Pre-emptively spray exposed sulfidic walls with alkaline amendment prior to re-wetting. • Treat pit lake water once fully rebounded. • Blend alkaline material with any pit back-filled material to neutralise AMD upon re-wetting.	Minor	Unlikely	Low
10		Discharge / overflow of pit lake water	Surface water	Minor	Possible	Medium	• As above (Item 9). • Also consider passive treatment / bioremediation options if annual acidity load is sufficiently low.	Minor	Unlikely	Low
11	Ongoing release of AMD from unsaturated pit wallrock ***above*** final groundwater rebound level.	Seepage (percolation) into groundwater as a result of rainfall infiltration	Groundwater	Minor	Possible	Medium	• Consider passive treatment or bioremediation approaches should AMD load be appropriate. • ongoing active water treatment.	Minor	Unlikely	Low
12		Discharge / overflow of pit lake water	Surface water	Minor	Possible	Medium	• As above (Item 11).	Minor	Unlikely	Low

7.0 Conclusions

General conclusions

- AMD risk classifications based on NAPP are considered more accurate than classification based on Total Sulfur alone. Based on the behaviour of similar rocks in the Pilbara region, a NAPP cut-off value of 3 kg H_2SO_4/tonne is considered appropriate at this stage to distinguish between PAF and NAF rock. Once sufficient static geochemical testwork data are available, this cut-off value may be revised if necessary.
- The current AMD classification within the BHPBIO mine model for OB31 appears to contain some inconsistencies. NAPP estimates from this assessment could be imported into the mine model to assist with mine planning and waste scheduling.
- Based on limited validation data, calculation of ANC appears to present a possible method for wide-spread application for all BHPBIO sites.

OB31 AMD Risk

- In general the AMD risk associated with OB31 can be considered very low.
- Only approximately 30,000 tonnes of PAF waste rock is expected from OB31 (approximately 0.01% of total overburden). This rock predominantly lies on the south eastern pit wall and may eventuate as wallrock than overburden given the spatial accuracy related to this preliminary assessment.
- De-saturated Mt. McRae Shale wallrock along the south-eastern zone of the OB31 pit is likely to present the largest source of AMD at the deposit. Based on this preliminary assessment, the annual AMD generation rate from this source may be in the order of 100-150 tonnes H_2SO_4-eq per year. The flux of this AMD into the pit will depend on the pit wall air-entry properties (eg. fracturing) and climatic conditions during mining operations.
- AMD generation from OB31 wallrock can be updated once hydrogeological modelling is undertaken and the likely zone of desaturated wallrock is better understood.
- The risk associated with AMD fluxes into the pit during operations is likely to be low due to the pit acting as a groundwater sink during operations. Hence AMD transport to the environment is likely to be limited. Furthermore, the AMD risk associated with wallrock AMD fluxes during operations can be easily managed by pre-emptively treating exposed sulfidic wallrock faces, or treating acidic water in-situ as it occurs.
- Upon closure, rewetting of this zone may result in mobilisation of the AMD generated within this rock, particularly if conditions were dry during operations. Hence, this scenario is likely to represent the highest AMD risk for the OB31 deposit. AMD fluxes from wallrock upon re-wetting at closure may be managed by treatment (or pre-treatment) of any build-up of acidity using locally available carbonate material.

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Attachment A:

Acid and Metalliferous Drainage (AMD), Acidity and Acidity Load

ATTACHMENT A: ACID AND METALLIFEROUS DRAINAGE (AMD), ACIDITY AND ACIDITY LOAD

When sulfidic material is exposed to oxidising conditions, sulfides begin to oxidise and water subsequently transports reaction products including acidity, sulfate, iron and other metals into surface water and groundwater. This water is referred to as acid and metalliferous drainage (AMD). Acid and metal production associated with pyrite oxidation is shown in Reactions 1 to 4.

An initial oxidation reaction involves the oxidation of pyrite to produce ferrous ions (Fe^{2+}), sulfate and acid, as shown in Reaction 1.

FeS_2 +	7/2 O_2	+ H_2O →	Fe^{2+} +	2 SO_4^{2-}	+ 2 H^+	***[Reaction 1]***
Pyrite	oxygen	water	ferrous ion	sulfate	acid	

The ferrous ions (Fe^{2+}) released by pyrite oxidation may be further oxidised to ferric ions (Fe^{3+}) consuming some acid (Reaction 2). Notice that this reaction does not involve pyrite.

Fe^{2+}	+ 1/4 O_2 +	H^+ →	Fe^{3+}	+ ½ H_2O	***[Reaction 2]***
Ferrous ion	oxygen	acid	ferric ion	water	

The ferric ions then react with water to form ferric hydroxide ($Fe(OH)_3$), which precipitates out of solution, producing additional acid (Reaction 3).

Fe^{3+} +	3 H_2O →	$Fe(OH)_3$ +	3 H^+	***[Reaction 3]***
Ferric ion	water	ferric hydroxide (orange precipitate)	acid	

As shown in Reaction 3, the precipitation of ferric hydroxide is a key acid producing stage. Once sulfide minerals have oxidised and released Fe^{2+} ions, it is extremely difficult to prevent ferrous ions oxidising to ferric ions with concomitant iron hydroxide precipitation and further acid generation.

A summary reaction of the complete oxidation of pyrite (by oxygen) in mine waste materials may be expressed as follows (Reactions 1-3 combined):

FeS_2	+ 15/4 O_2	+ 7/2 H_2O →	2 SO_4^{2-}	+ 4 H^+	+ $Fe(OH)_3$	***[Reaction 4]***
Pyrite	oxygen	water	sulfate	acid	ferric hydroxide	

Furthermore, the presence of ferric ions (Fe^{3+}) can accelerate the oxidation of pyrite, generating additional sulfate and acid, as shown in Reaction 5.

$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$$

[Reaction 5]

Pyrite	ferric iron	water	ferrous iron	sulfate	acid

Note that in Reaction 5, 16 moles of acid are produced per mole of pyrite oxidised, as compared with 4 moles of acid generated when pyrite is oxidised by molecular oxygen (Reaction 4). Whether pyrite oxidation proceeds through Reaction 4 or 5 depends on the chemical conditions in solution at the pyrite surface. Reaction 5 suggests that soluble ferric ions can play a significant role in promoting sulfide oxidising reactions that result in AMD.

Two distinct processes, both promoted by oxidation of sulfide minerals, are responsible for decreasing the pH of an aqueous solution:

- Acid (H^+) is directly generated by the oxidation of sulfur (Reaction 1).
- Acid (H^+) is generated by the precipitation of metal hydroxides (e.g. $Fe(OH)_3$, $Mn(OH)_4$: Reaction 3) during oxidation / neutralisation / dilution reactions.

While process 1 is controlled only by the availability of oxygen and water, process 2 depends on the solubility of the metal aqueous species, which in turn is controlled by the factors such as pH of the solution and oxidation state of the metal. In other words, the generation of acid through process 1 is limited by the sulfide oxidation rate, while the generation of acid through process 2 is delayed until metals can precipitate from solution (thus the term "latent acidity" or "mineral acidity").

The term "acid" quantifies only the actual amount of H^+ present in solution and is generally expressed as pH. The term "acidity", on the other hand, accounts for both the actual H^+ concentration of the aqueous solution and the potential for acid generation due to mineral or latent acidity (i.e. H^+ produced by process 2).

In general acidity increases as pH decreases, but there is not always a direct relationship between acidity and pH. Based on earlier descriptions of metalliferous drainage, it is possible to have AMD with an elevated acidity but near neutral pH values. It is therefore important to quantify the contributions of both hydrogen ion concentrations (acid) and mineral contributions (latent acidity) in order to determine the total acidity of a water. Acidity is generally expressed as a mass of calcium carbonate ($CaCO_3$) equivalent per unit volume (e.g. mg/L $CaCO_3$).

Acidity is either measured in the field or laboratory by titration or estimates of acidity can be made from water chemistry data (pH and dissolved metal concentrations) using shareware such as ABATES.

Acidity load refers to the product of the total acidity (acid plus latent acidity) and flow rate (or volume) and is expressed as a mass of $CaCO_3$ equivalent per unit time (or mass of $CaCO_3$ for a given volume of water).

Acidity load (tonnes $CaCO_3$ eq. per year) [Reaction 6]

	= 10^{-3} *(conversion factor)*
	x flow volume per year *(ML/yr)*
	x acidity *(mg/L)*

Attachment B

Risk Assessment Matrix and Consequence and Likelihood Scales (ICMM, 2008)

ATTACHMENT B

RISK ASSESSMENT FRAMEWORK

Table B1: Risk assessment matrix used in this report (after DRET, 2008).

Likelihood Level	Consequence level				
	Insignificant	Minor	Moderate	Major	Catastrophic
Improbable	Low	Low	Medium	Medium	High
Unlikely	Low	Low	Medium	Medium	High
Possible	Low	Medium	High	High	High
Likely	Medium	Medium	High	High	Peak/Very High
Almost certain	Medium	High	High	Peak/Very High	Peak/Very High

Table B2: Consequence scales used for risk assessment (ICMM, 2008)..

Scale	Negative Consequences
Insignificant	Not inconsequential, but no more severe than that.
Minor	Some consequence, generally reversible in a short term and/or with modest application of resources (similar to daily operating budget for a mine, if financial comparisons are appropriate).
Moderate	Consequences may be reversible, usually requiring some time and/or significant application of resources (similar to monthly operating budget, if financial comparisons are appropriate).
Major	Generally irreversible consequences, with impacts apparent for a prolonged period of time (similar time-scale to mine life, where time-scale comparisons are appropriate).
Catastrophic	Irreversible consequences, impacts exceeding period similar to life o mine (where time-scale comparisons are appropriate.

Table B3: Likelihood scales used for risk assessment (ICMM, 2008)..

Scale	Descriptor	Negative Consequences
1	Improbable	It would require a substantial change in circumstances to create an environment for this to occur, and even then, this is a rare occurrence in the mining and metals industry anywhere.
2	Unlikely	There are no specific circumstances to suggest this could happen, but it has happened before at least once in the mining and metals industry.
3	Possible	There is at least a 5% chance it could happen, or it has happened occasionally in other areas before, or it has happened (albeit infrequently) in the mining and metals industry in the past or risk mitigation treatment cannot reduce the inherent likelihood further.
4	Likely	There is at least a 50% chance it could happen, or it has happened several times in similar areas before, or this consequence is not uncommon in the mining and metals industry or risk mitigation treatment cannot reduce the inherent likelihood further.
5	Almost Certain	Has happened/will probably happen during mine life and there is no reason to suspect it will not happen again or it has occurred in this area before.

Attachment C

OB31 Static Geochemical testwork results provided to support this assessment

Drill Hole ID	Depth From (mbgl)	Depth To (mbgl)	Strat.	BHP Sample ID	pH (1:2)	APP	NAPP	EC (1:2)	NAG pH	NAG (pH 4.5)	NAG (pH 7.0)	ANC	ANC	Fizz Rating	Moisture	Sulfate (as SO4)	Total S (as S)
					pH Unit	kg H2SO4/t	kg H2SO4/t	µS/cm	pH Unit	kg H2SO4/t	kg H2SO4/t	kg H2SO4 equiv./t	% CaCO3	Fizz Unit	% (dried@103°C)	mg/kg	%
EB0641R	72.00	75.00	Y	N416182	7.0	<0.5	-0.6	114.0	5.9	<0.1	6.9	0.6	<0.1	0	<1.0	<100	<0.01
EB0642R	12.00	15.00	HJ	N416220	6.7	<0.5	-2.1	303.0	6.9	<0.1	<0.1	2.1	0.2	0	<1.0	<100	<0.01
EB0643R	33.00	36.00	HJ	N416289	7.2	<0.5	-1.0	67.0	6.4	<0.1	0.6	1.0	<0.1	0	<1.0	<100	<0.01
EB0643R	39.00	42.00	Y	N416293	7.3	<0.5	-3.1	103.0	6.5	<0.1	0.6	3.1	0.3	0	<1.0	<100	<0.01
EB0644R	12.00	15.00	TD3	N416358	7.6	<0.5	-63.9	544.0	7.2	<0.1	<0.1	63.9	6.5	2	<1.0	<100	<0.01
EB0645R	24.00	27.00	J6	N416412	6.7	<0.5	-1.5	262.0	6.5	<0.1	1.2	1.5	0.2	0	<1.0	<100	<0.01
EB0647R	105.00	108.00	R	N505546	7.5	<0.5	<0.5	229.0	8.2	<0.1	<0.1	<0.5	<0.1	0	<1.0	<100	<0.01
EB0648R	33.00	36.00	W	N505565	6.8	<0.5	-1.0	126.0	7.6	<0.1	<0.1	1.0	<0.1	0	<1.0	<100	<0.01
EB0649R	102.00	105.00	J1	N505639	7.1	<0.5	-1.0	94.0	7.6	<0.1	<0.1	1.0	<0.1	0	<1.0	<100	<0.01
EB0649R	108.00	111.00	WC	N505643	7.0	<0.5	-2.1	84.0	6.7	<0.1	0.3	2.1	0.2	0	<1.0	<100	<0.01
EB0649R	138.00	141.00	D4	N505655	6.9	<0.5	<0.5	74.0	6.2	<0.1	1.2	<0.5	<0.1	0	<1.0	<100	<0.01
EB0650R	3.00	6.00	TD3	N505663	6.5	0.9	<0.5	233.0	7.5	<0.1	<0.1	0.7	<0.1	0	<1.0	120	0.03
EB0901R	33.00	36.00	?	N505729	7.2	<0.5	-4.0	136.0	6.1	<0.1	4.6	4.0	0.4	0	<1.0	<100	<0.01
EB0902R	3.00	6.00	TD3	N505758	7.0	<0.5	-2.4	103.0	6.6	<0.1	0.5	2.4	0.2	0	<1.0	<100	<0.01
EB0903R	3.00	6.00	TD3	N505789	7.7	<0.5	-1.3	317.0	6.3	<0.1	8.0	1.3	0.1	0	<1.0	120	<0.01
EB0904R	51.00	54.00	Y	N505856	7.8	<0.5	-0.8	148.0	6.6	<0.1	2.5	0.8	<0.1	0	<1.0	<100	<0.01
EB0907R	3.00	6.00	J1	N502014	7.7	<0.5	<0.5	241.0	7.8	<0.1	<0.1	<0.5	<0.1	0	<1.0	180	0.01
EB0907R	48.00	51.00	D4	N502031	7.4	<0.5	<0.5	95.0	8.2	<0.1	<0.1	<0.5	<0.1	0	<1.0	<100	<0.01
EB0907R	111.00	114.00	D2	N502058	7.3	<0.5	<0.5	93.0	8.2	<0.1	<0.1	<0.5	<0.1	0	<1.0	<100	<0.01
EB0907R	126.00	129.00	D1	N502065	7.2	<0.5	<0.5	53.0	7.7	<0.1	<0.1	<0.5	<0.1	0	<1.0	<100	<0.01
EB0908R	0.0	3.0	TD3	N502086	8.0	<0.5	-10.4	176.0	9.9	<0.1	<0.1	10.4	1.1	1	<1.0	<100	<0.01
EB0909R	54.0	57.0	W	N502147	7.8	<0.5	<0.5	42.0	5.7	<0.1	9.4	<0.5	<0.1	0	<1.0	<100	<0.01
EB0911R	33.00	36.00	W	N502244	7.1	<0.5	-1.3	90.0	8.0	<0.1	<0.1	1.3	0.1	0	<1.0	<100	<0.01
EB0912R	66.00	69.00	W	N502313	7.1	<0.5	<0.5	80.0	6.4	<0.1	3.2	<0.5	<0.1	0	<1.0	<100	<0.01
EB0913R	27.00	30.00	J2	N502364	7.2	<0.5	<0.5	67.0	7.8	<0.1	<0.1	<0.5	<0.1	0	<1.0	<100	<0.01
EB0914R	6.00	9.00	J3J5	N502399	7.0	<0.5	-0.7	105.0	6.3	<0.1	3.8	1.0	<0.1	0	<1.0	<100	0.01
EB0915R	30.00	33.00	J2	N502459	7.2	<0.5	<0.5	55.0	6.4	<0.1	2.5	<0.5	<0.1	0	<1.0	<100	<0.01
EB0915R	60.00	63.00	J1	N502473	7.1	<0.5	<0.5	52.0	6.3	<0.1	3.8	<0.5	<0.1	0	<1.0	<100	<0.01
EB0916R	3.00	6.00	D3	N502486	7.8	1.2	-0.9	192.0	6.7	<0.1	4.6	2.1	0.2	0	<1.0	280	0.04
EB0928R	51.00	54.00	J2	N516457	7.6	<0.5	-1.2	54.0	8.2	<0.1	<0.1	1.2	0.1	0	<1.0	<100	<0.01