MOUNT OWEN CONTINUED OPERATIONS PROJECT

REPORT B
Response to Department of the Environment Submission

August 2015

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Prepared by
Umwelt (Australia) Pty Limited

on behalf of
Mount Owen Pty Limited

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Report No.	**3109/R16B/Final**
Date:	**August 2015**

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1.0 Introduction

The Environmental Impact Statement (EIS) for the Mount Owen Continued Operations Project (the Project) was placed on public exhibition from 20 January 2015 to 6 March 2015.

The Project seeks approval for the continuation of open cut mining operations at the Mount Owen Complex, located within the Hunter Coalfields in the Upper Hunter Valley of New South Wales (NSW), approximately 20 kilometres north-west of Singleton, 24 kilometres south-east of Muswellbrook and to the north of Camberwell Village. Mount Owen Pty Limited (Mount Owen), a subsidiary of Glencore Coal Pty Limited (Glencore), currently owns and operates the Mount Owen Complex.

The Response to Submissions (RTS) has been prepared by Umwelt (Australia) Pty Ltd (Umwelt) on behalf of Mount Owen to address the key issues raised in the submissions received during the public exhibition period of the EIS for the Project. The RTS has been prepared as two separate reports. Report A, responded to the issues raised in the submissions of the Project made by the New South Wales (NSW) Government Agencies, Singleton Council and the community. This report (Report B) responds to specific issues raised by the Commonwealth Department of the Environment (DotE), including advice provided to the NSW Department of Planning and Environment (DP&E) by the Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Large Coal Mining Development.

The submission received from the DotE, dated 25 March 2015, recommended that a response be provided to address the following:

- comments, issues, knowledge gaps and additional analysis requested by the IESC in its advice to DotE and DP&E;
- further information regarding the ecological offsets proposed; and
- a detailed description of the mitigation measures proposed as part of the EIS.

A copy of the DotE Submission is attached as **Appendix A** to this Report. A copy of the IESC Advice is attached as **Appendix B** to this Report.

This Report (Report B) includes:

- An overview of the consultation undertaken with the DotE (Ecology) in relation to the ecological issues raised in their submission and with DotE (Office of Water Science (OWS)) to discuss the issues raised in the IESC advice (**Section 1.1**);
- Response to the issues raised by the IESC in relation to surface water and groundwater impacts (**Section 2.0**); and
- A detailed response to the ecological, biodiversity offset and mitigation/management issues raised by DotE (**Section 3.0**).

1.1 Consultation

1.1.1 Meeting with DotE and OWS Regarding Water Resources Impacts

On 8 July 2015, Umwelt and Mount Owen met with the DotE and the OWS in Canberra to discuss the issues raised in the IESC advice on the Project. Further information on potential impacts on GDEs was requested and a briefing note was provided to the DotE on 23 July 2015. A copy of this briefing note is attached as **Appendix C**. The discussions at the 8 July meeting and DotE's comments on the additional information provided on GDEs following the meeting have informed the response to the issues raised in the IESC advice. These responses are contained in **Section 2.0** of this Report.

1.1.2 Meeting with DotE regarding offsetting issues

On 3 July 2015, Umwelt and Mount Owen met with the DotE in Canberra to discuss the different approaches taken by Umwelt and DotE to calculating offset requirements and the adequacy of the proposed biodiversity offsets. To assist discussion of issues at the meeting, the DotE provided Mount Owen and Umwelt with a copy of the assumptions used in its offset calculations, and Umwelt provided DotE with a briefing note discussing the similarities and differences between the two approaches to the offset calculator assumptions. A copy of the Umwelt briefing note is attached as **Appendix D**. This discussion and the related information have informed the response to the issues raised by DotE in relation to offsetting requirements. These responses are contained in **Section 3.0** of this Report.

2.0 Additional Information in Response to IESC Advice

The DotE and DP&E requested the IESC to review the EIS and supporting documentation to provide advice on the Project in relation to specific questions which were provided by DotE and DP&E. This section provides a response to the issues raised in the letter of advice received from the IESC, as requested by the DotE in their submission.

The IESC advice uses numbered paragraphs to summarise the answer to each question and provides further explanation of the issues identified in the answer to the question. The points raised in the IESC response have been consolidated and addressed in this report by issue.

A summary table of the IESC advice is provided in **Appendix E** which includes the individual comments raised by the IESC by questions and paragraph number, cross referenced against the relevant section numbers in this report for reference.

2.1 Water Management at the Mount Owen Complex

The Mount Owen Complex (Mount Owen, Ravensworth East and Glendell Mines) has an extensive existing water management system (WMS). The key components of the existing WMS are shown on **Figure 2.1**. The WMS is an integrated system, that is, the water from the Mount Owen, Ravensworth East and Glendell Mines are managed together within the integrated WMS. In addition, the Mount Owen Complex is an integral part of the Greater Ravensworth Water Sharing System (GRWSS) with Glencore's Cumnock, Ravensworth Surface Operations, Ravensworth Underground and Liddell mining operations.

The key mining operations and infrastructure linkages between the Mount Owen Complex and other operations within the GRWSS are shown on **Figure 2.2**. All operations are majority owned and managed by Glencore and all operate pursuant to relevant environmental approvals regulating the extraction, use and discharge of water. The GRWSS has been designed to optimise and improve the efficiency of water extraction, use and discharge across the operations within the constraints set by these approvals and other NSW and Commonwealth regulatory requirements. The GRWSS provides for water sharing between the Mount Owen Complex and the other Glencore operations, thereby minimising water extraction from off-site sources (such as Glennies Creek), and maximising recycling of water amongst these operations, all within current regulatory requirements.

The Mount Owen Complex WMS has the following key objectives and functions:

- diversion of clean water around mining operations to minimise capture of upslope runoff and separate clean water runoff from mining activities;
- segregating mine impacted water and runoff from undisturbed and revegetated areas with better water quality to minimise the volume of mine impacted water that requires reuse;
- reuse of mine impacted water within the WMS and within the GRWSS to reduce reliance on raw/clean water (e.g. extraction from Glennies Creek);
- minimising adverse effects on downstream waterways (i.e. hydraulic and water quality impacts); and
- reducing the discharge of pollutants from the mine to the environment.

Water management at the Mount Owen Complex considers three categories of water, each with different potential to cause environmental harm. The target design criteria for each of the three categories of water are summarised in **Table 2.1**.

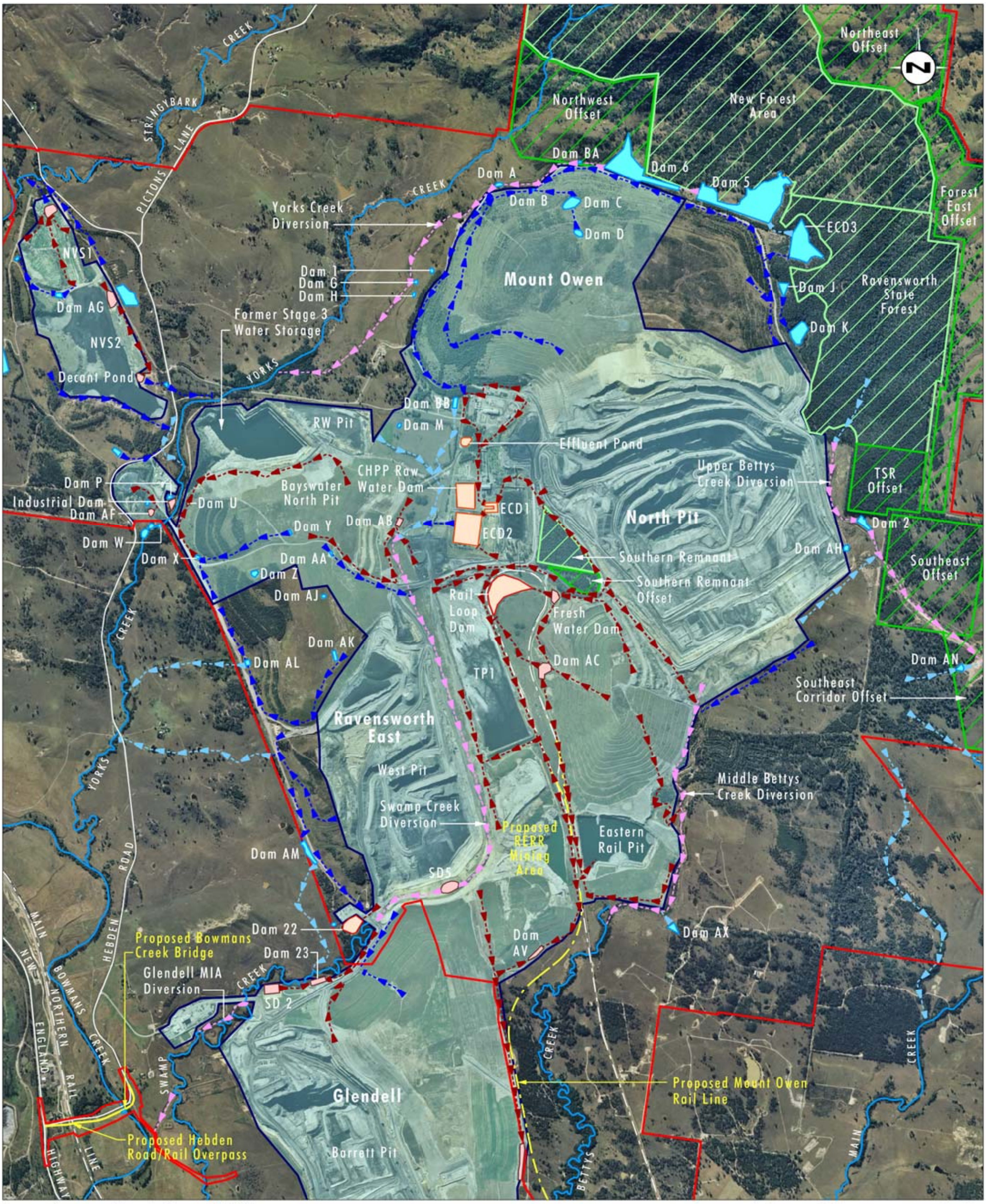


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.5 1.0 2.0km
1:40 000

Legend

- Project Area
- Existing Biodiversity Offset Areas
- Ravensworth State Forest
- Proposed Rail Upgrade Works
- Proposed Hebden Road Upgrade Works
- Clean Water Dam
- Sediment Dam
- Mine Water Dam
- Existing Flow Path
- Clean Water Drain
- Dirty Water Drain
- Existing Diversion Channel
- Drainage Line
- Existing Railway
- Mount Owen Complex Water Management System Catchment

FIGURE 2.1

Existing Surface Water Management

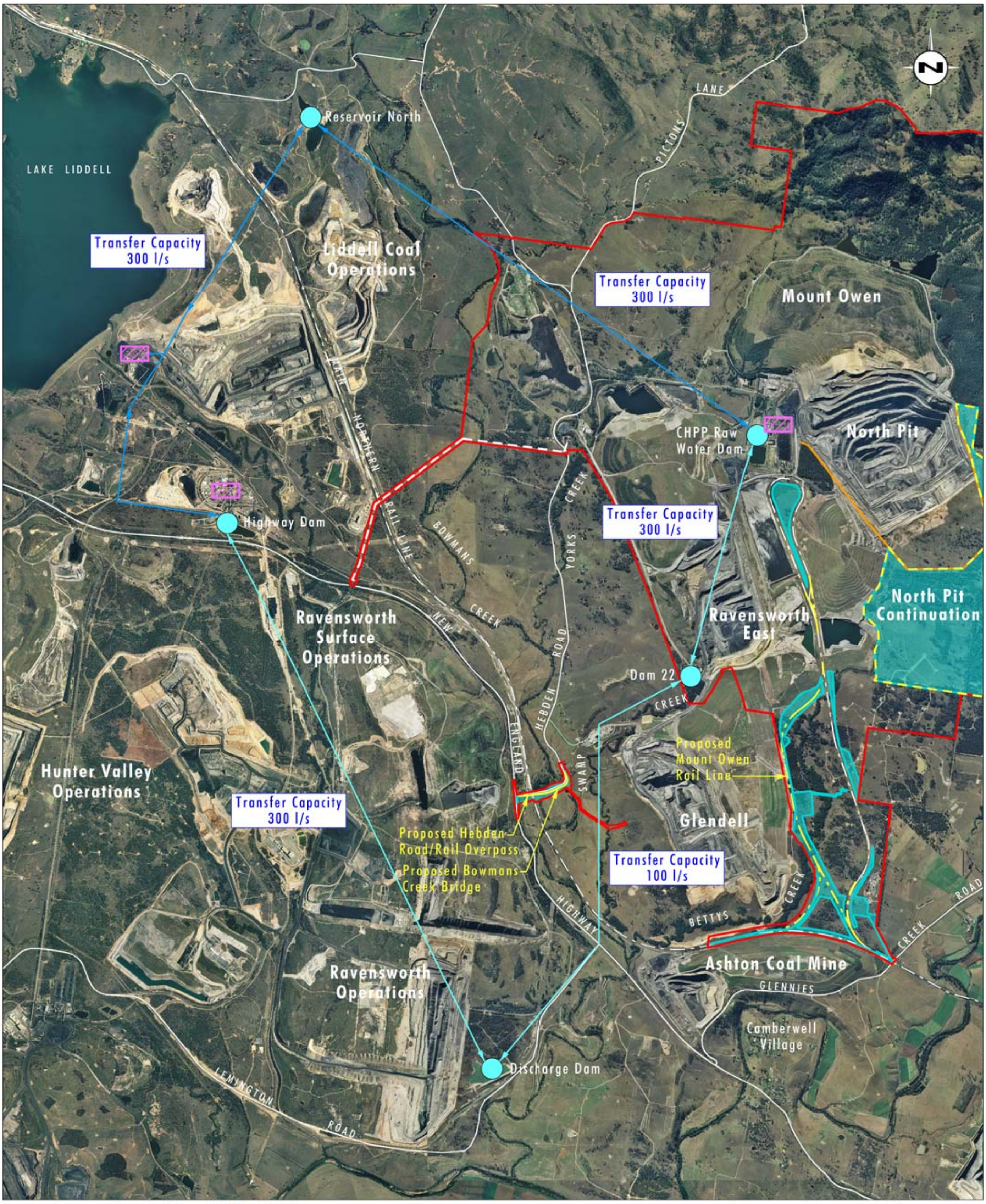


Image Source: Mount Owen (2012-2013)
Data Source: Mount Owen (2015)

0 1.0 2.0 3.0km
1:70 000

Legend

- Project Area
- Approved North Pit Mining Extent
- Proposed North Pit Continuation
- Proposed Rail Upgrade Works
- Proposed Hebden Road Upgrade Works
- Proposed Disturbance Area
- Dam Area
- In Place Flow
- Infrastructure Flow
- CHPP Area

FIGURE 2.2

Key Components of the Greater Ravensworth Water Sharing System (GRWSS)

Table 2.1- Design Criteria for Components of the WMS

Water Category	Water Description	Target Design Criteria
Clean	Runoff from undisturbed or rehabilitated areas	Release, where practicable, to downstream environment.
Dirty	Runoff from disturbed areas (does not include water captured in mining pit areas or runoff from mine infrastructure areas).	Managed in line with the Blue Book (*Managing Urban Stormwater: Soils and Construction Volumes 1* and *2E*). Designed to manage runoff from the 5 day, 95th percentile rainfall event.
Mine	Runoff from areas exposed to coal or water used in coal processing or from coal stockpile areas	Contained for events up to and including the 1% annual exceedance probability (AEP) 24 hour storm event.

As described above, the intent of the WMS is to convey clean water around the mining operations or, when runoff water from rehabilitated areas becomes clean (in accordance with the site specific trigger values listed in the Surface Water Monitoring Program, refer to **Table 2.2**), enable the runoff from these rehabilitated areas to flow directly to the downstream environment instead of being managed as part of the water management system.

Table 2.2 - Water Quality Parameters and Trigger Levels

Parameter Monitored	ANZECC default trigger	Site Specific Trigger Values[1]		
		Bowmans Creek	Ephemeral Creek Systems	
			Flow Conditions	No Flow Conditions
pH	6.5 to 8.0	6.5 to 8.0	6.5 to 8.0	6.5 to 8.6
EC (µs/cm)	2,200	2,200	2,200	5,400
TSS (mg/L)	50	50	50	50
TDS (mg/L)	4,000 to 5,000[2]	1,480	1,480	4,700

1. Source: Mount Owen Complex Surface Water Monitoring Program (2012)
2. Source: ANZECC guidelines (2000) - recommended concentration of TDS in drinking water for beef cattle as no default trigger value is provided by the ANZECC guidelines (2000) for ecosystem protection.

Dirty water (i.e. runoff from disturbed areas outside the mining pit and infrastructure areas, such as overburden emplacement areas (both active and under rehabilitation) captured in the sediment dams) is pumped to the mine water management system. Mine water (i.e. runoff from areas exposed to coal or water used in coal processing or from coal stockpile areas, refer to **Table 2.1**) is also managed as part of the mine water management system. Pollution in New South Wales is regulated by the *Protection of the Environment Operations Act* 1997 (POEO Act) with discharges from the mine water management system required to be licensed by an Environment Protection Licence (EPL) if the discharge would otherwise constitute a pollution of waters (section 120 of the POEO Act). The Mount Owen EPL does not authorise any discharges to the environment from the Mount Owen Complex. Water within the mine water management system is either reused on site or shared within the GRWSS.

Any surplus water is transferred from the Mount Owen Complex to storages within the GRWSS. There are no licensed discharge points from the Mount Owen Complex to any creek systems. In addition, no discharges have occurred from the Mount Owen Complex WMS over the last 10 years. All surplus water in the mine water management system has either been reused on site or transferred to other sites within the GRWSS in accordance with existing approvals.

It is proposed to continue to utilise the existing WMS for the Project. That is, water in the mine water management system will continue to be shared between Glencore's mining operations as part of the GRWSS. Water sharing within the GRWSS assists in minimising the demand for raw/clean water across the GRWSS. In addition, excess water that cannot be reused at the mining operations within the GRWSS will be discharged at either the Liddell and/or Ravensworth Operations in accordance with regulatory arrangements which apply to those sites.

The Project will not require any alteration to the existing regulatory arrangements at other sites and will not result in any increase in discharges over what is already permitted to occur from Glencore's operations which collectively operate within the GRWSS. It should be noted that prior to the implementation of the GRWSS, Mount Owen had an additional approved licensed discharge point. Connectivity to the GRWSS has enabled the removal of this licensed discharge point, There has been no corresponding increase to the approved discharge capacity at either Liddell or Ravensworth Operations and no increase is planned as a result of the Project. The linking of Mount Owen to the GRWSS has therefore resulted in an overall net reduction in approved licensed discharge capacity at these Glencore operations as a result of the water sharing and utilisation flexibility provided by the GRWSS.

2.2 Surface Water Issues

The IESC requested further detail regarding the approach to the assessment of the Project's potential impact on surface water resources. Key issues raised in the advice are listed below.

- Surface Water Quantity - quantitative flow regimes and seasonality, and potential impacts (refer to **Section 2.2.1**(context) and **2.2.2** (assessment))

- Surface Water Quality - additional water quality analysis and potential impacts (refer to **Section 2.2.3** (context) and **2.2.4** (assessment))

- Surface Water Diversions – clarification regarding the works involved in the release of clean water from rehabilitated areas (refer to **Section 2.2.5)**

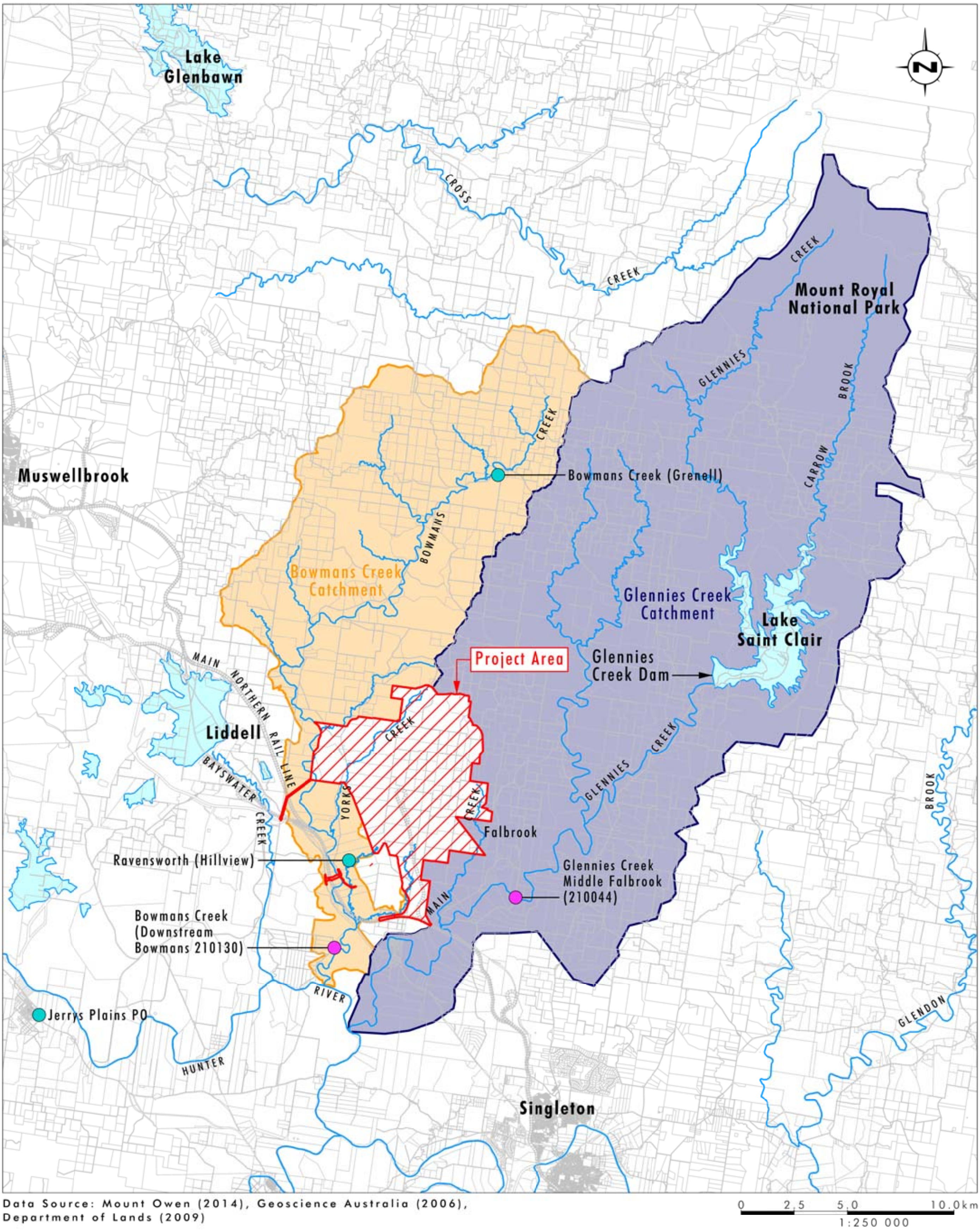
- Water Balance – further information regarding rainfall data inputs and an analysis of the water balance for the GRWSS (refer to **Section 2.2.6**)

2.2.1 Surface Water Quantity - Context

The Project Area is within the catchment areas of Bowmans Creek and Glennies Creek which both flow into the Hunter River (refer to **Figure 2.3**). The tributaries of Bowmans Creek and Glennies Creek are ephemeral. Flow gauging on these systems was discontinued by the NSW Government many years ago, therefore there is limited flow data for these tributaries. An analysis of available flow data for Bowmans Creek and Glennies Creek was presented in the Groundwater Impact Assessment (Appendix 10 of the EIS).

2.2.1.1 Bowmans Creek

The data presented in the Groundwater Impact Assessment shows the stronger ephemeral nature of both Yorks Creek and Swamp Creek in comparison to Bowmans Creek. A further analysis of annual and seasonal flows at Bowmans Creek using data from the "d/s Bowmans 210130" gauging station (data from 1993 to date), is presented in **Figure 2.4**. The location of the Bowmans Creek flow gauge is shown on **Figure 2.3**.



Data Source: Mount Owen (2014), Geoscience Australia (2006), Department of Lands (2009)

Legend

- Project Area
- Glennies Creek Catchment Area
- Bowmans Creek Catchment Area
- Cadastre
- Railway
- Drainage Line
- Rainfall Station
- Flow Gauge

FIGURE 2.3

Catchment Context

File Name (A4): R16/3109_1013.dgn
20150309 9.47

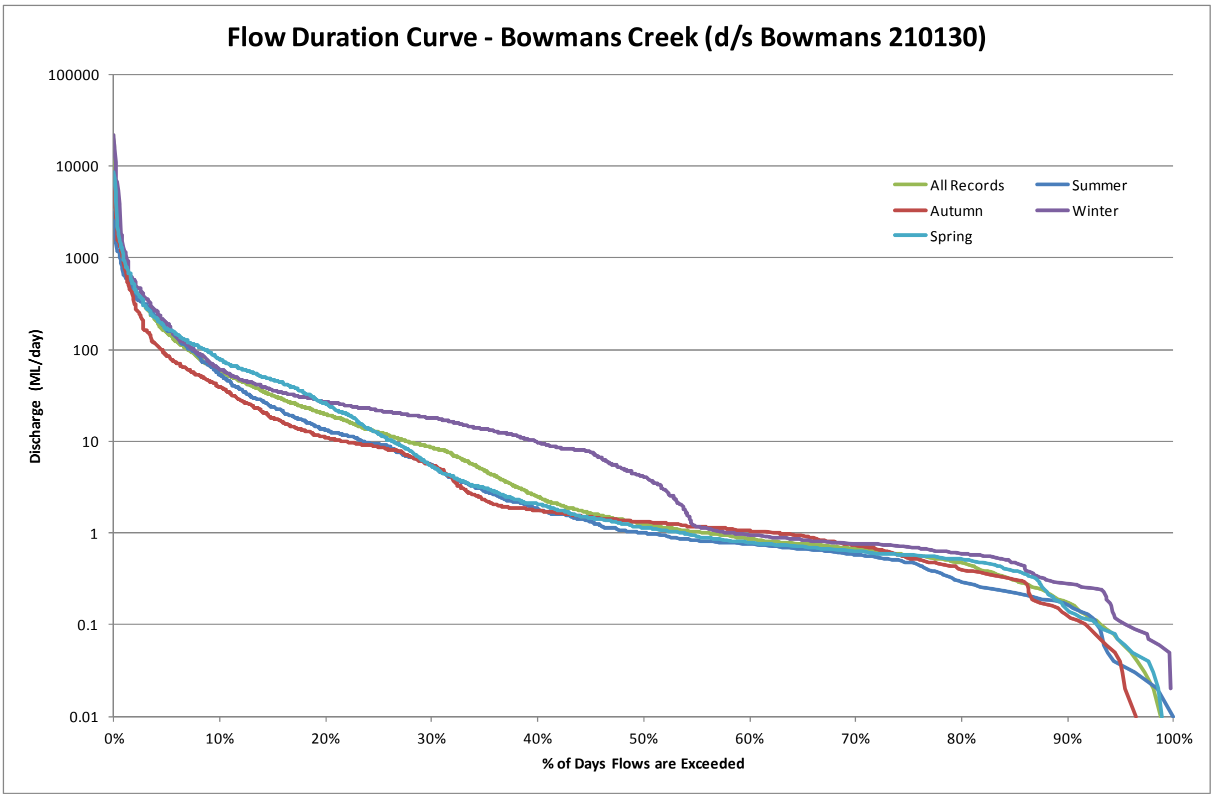


Figure 2.4 - Flow Duration Curve – Bowmans Creek (d/s Bowmans 210130)

The analysis shows relatively consistent flows in Bowmans Creek with some seasonality. The analysis indicates that the majority of larger flow events occur in the winter months with higher peak flows, typically higher mid-range flows and also higher baseflows, occurring during winter. The analysis also indicates that there is little other seasonality in the data records.

2.2.1.2 Glennies Creek

As described in Section 2.1.6 of the Surface Water Assessment, only one tributary of Glennies Creek, Main Creek, is located within the Project Area. Main Creek currently receives water from the upper catchment of Bettys Creek as part of an approved clean water diversion around the approved mining areas. No changes are proposed to this diversion with the Project. A portion of the North Pit final void is located within the catchment area of Main Creek and this will reduce the area of the catchment as a result of water in disturbed areas being managed as part of the mine water management system.

The catchment context of the Project relative to Glennies Creek is shown in the Surface Water Assessment and on **Figure 2.3**. Glennies Creek has a catchment area of approximately 523 square kilometres of which the upper half (approximately 233 square kilometres, or 45 per cent of the total catchment area) is captured in the Glennies Creek Dam. Glennies Creek Dam is located approximately 17 kilometres upstream of the confluence of Main Creek with Glennies Creek.

The construction of Glennies Creek Dam was completed in 1983 and forms part of the Hunter Regulated River System. The Hunter Regulated River System is managed by the NSW Government as part of a Water Sharing Plan regulated under the NSW *Water Management Act 2000*. Water from Glennies Creek Dam is managed to meet downstream requirements for environmental, irrigation, stock and domestic, town water and water conservation usages. As such the flow regimes in Glennies Creek downstream of Glennies Creek Dam are highly modified and are regulated by the NSW State Government.

An analysis of annual and seasonal flows in Glennies Creek using data from the "Middle Falbrook 210044" gauging station (data from 1956 to 2014), is presented in **Figure 2.5**. The location of the Glennies Creek flow gauge is shown on **Figure 2.3**.

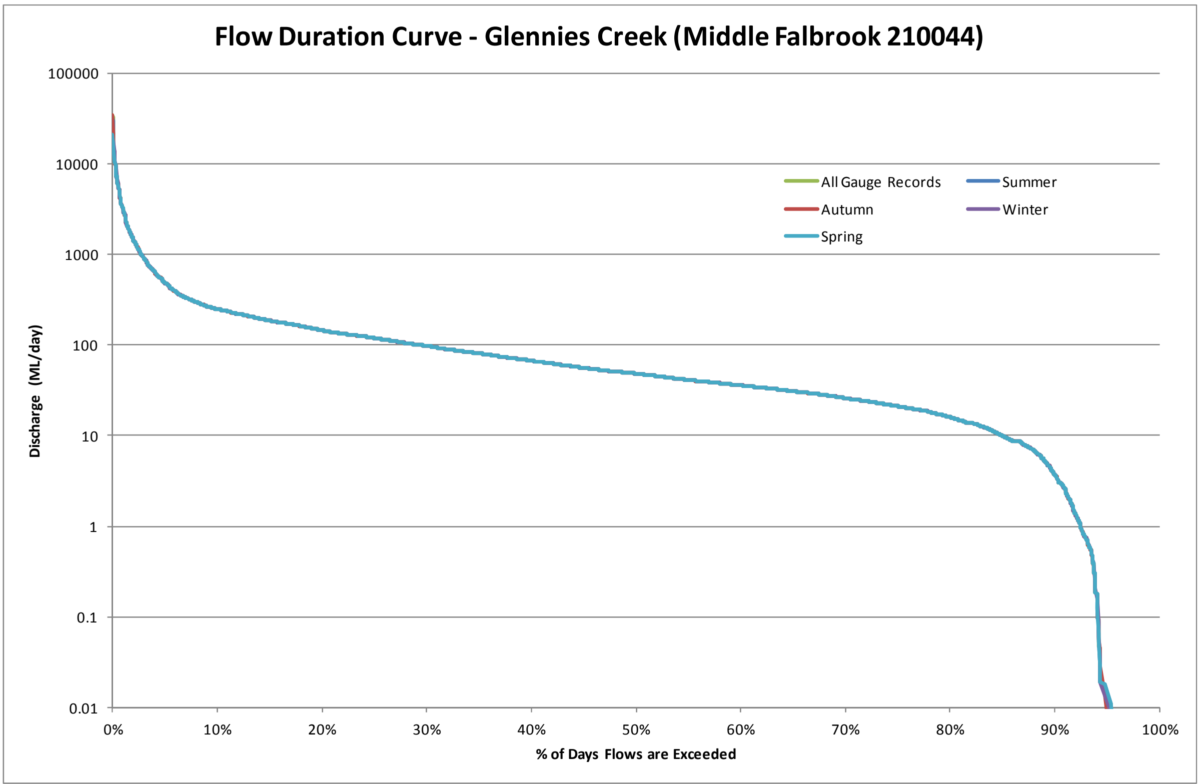


Figure 2.5 – Flow Duration Curve – Glennies Creek (Middle Falbrook 210044)

As can be seen from **Figure 2.5**, the flow duration curve shows no seasonality which is a result of the highly regulated nature of Glennies Creek.

2.2.2 Surface Water Quantity Assessment

The IESC in their advice raised some concerns in regard to the method and rainfall data used in the flow impact assessment. **Section 2.2.2.1** provides a detailed explanation of the method used in the Surface Water Assessment which is independent of the rainfall data queried by the IESC. **Section 2.2.2.2** provides an alternative method for assessing the impacts on flows in Bowmans Creek and Glennies Creek that will result from the Project if approved. **Section 2.2.2.3** of this report provides additional data regarding rainfall data used in the assessment, including clarification regarding the use of the rainfall data in the assessment.

2.2.2.1 Assessment on Surface Flows –Catchment Area Approach

Table 6.1 in the Surface Water Assessment (reproduced in **Table 2.3** below) shows the catchment areas for each creek system impacted by the Project.

Table 2.3 – Predicted Impacts on Catchment Areas

Catchment	Pre-Mining (ha)	Current Area (2012) (ha)[1]	Current Approved Final Landform (ha)	Project		
				Year 5[1] (ha)	Proposed Final Landform[2]	
					Area (ha)	%[4]
Bowmans Creek[3]	**25,055**	**22,010**	**20,390**	**21,590**	**20,520**	**100.6%**
- Stringybark Creek	1,290	1,220	1,300	1,300	1,300	100%
- Yorks Creek	1,230	1,580	1,660	1,800	1,920	116%
- Swamp Creek	2,380	410	1,440	390	1,230	85%
- Bettys Creek	1,810	660	960	700	780	81%
Glennies Creek[3]	**52,335**	**50,265**	**50,405**	**50,215**	**50,255**	**99.7%**
- Main Creek	2,000	2,480	2,620[5]	2,430	2,470	94%

Notes: 1) Excluding WMS
2) Final Landform is when both the decommissioning of infrastructure and the rehabilitation of the post mining landform are completed.
3) Catchment areas modified to reflect changes due to the Project and approved and proposed Liddell Operations. This does not include impacts from other modifications (such as other mining operations) downstream of the Project Area.
4) Project final landform catchment area as a percentage of the current approved final landform.
5) Catchment area updated and larger than identified in Mount Owen Operations EIS, 2003 (previously 1,750 ha), as more accurate terrain data is now available (LiDAR) over entire catchment

The method used in the Surface Water Assessment to determine potential impacts on annual flow volumes included a comparison of the catchment areas for Year 5 and the final landform of the Project with the currently approved catchment areas for each of the downstream catchment and sub catchment areas, that is, Bowmans Creek, Stringybark Creek, Yorks Creek, Swamp Creek, Bettys Creek, Glennies Creek and Main Creek. This approach relies on the assumption that the change in catchment area will be an indicator of the change in annual flow volumes for each catchment. This is considered to be a reasonable assumption given the tributaries directly impacted by the Project are ephemeral and directly reliant on rainfall in the catchment for flows.

This approach is considered the best available due to the limited flow volume data available for the sub catchments and is consistent with the approach used by the NSW Government who apply an average annual runoff rate to consider water use by landholders.

2.2.2.2 Assessment on Surface Flows – Flow Duration Impacts

To assist in the assessment of potential impacts on flows in Bowmans Creek and Glennies Creek, an analysis has been undertaken by adjusting the flow duration curve for each Creek (refer to **Section 2.2.1.2**) to consider predicted changes in catchment contribution and baseflow associated with the Project.

<u>Bowmans Creek</u>

An analysis of potential impacts on flows in Bowmans Creek has been undertaken by adjusting the flow duration curve (for all periods) (refer to **Figure 2.4**) to consider predicted changes in catchment contribution and baseflow associated with the Project. The results are shown in **Figure 2.6**.

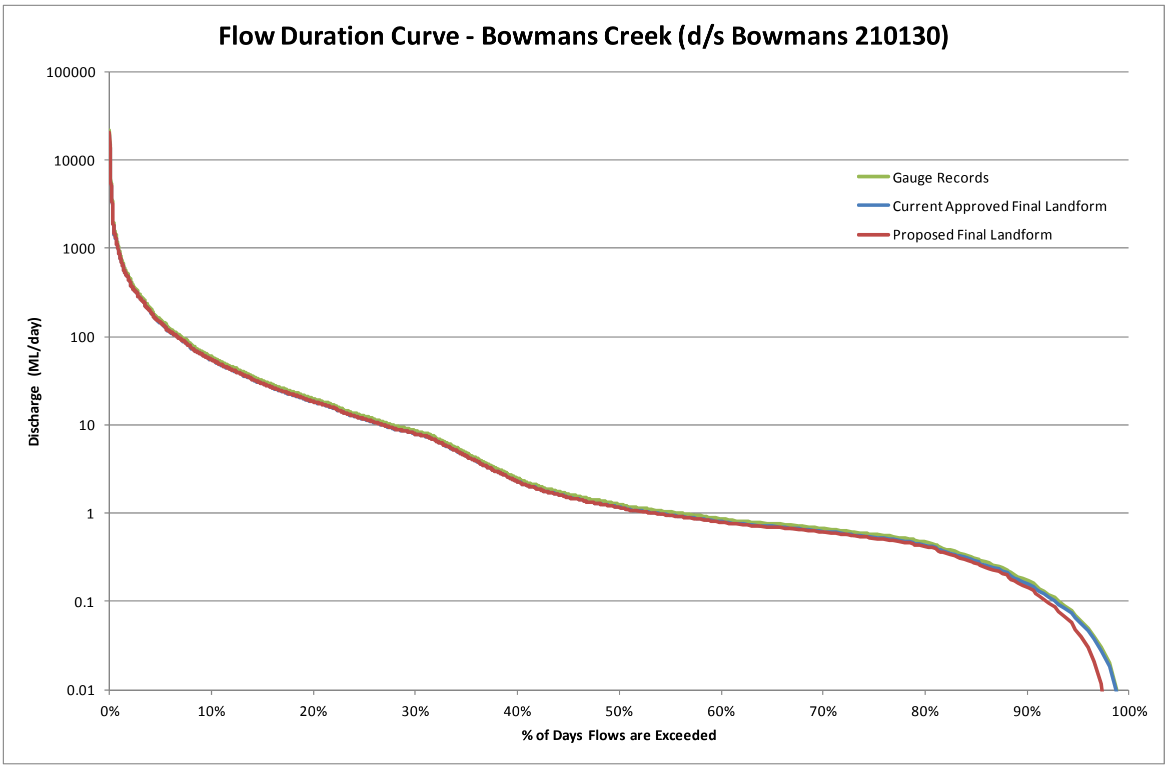


Figure 2.6 – Bowmans Creek – Predicted Flow Impacts

The flow duration curve for the proposed final landform indicates that the predicted flow impacts with the Project show little variation to both the gauge record and the current approved final landform. As shown on **Figure 2.6** the Project will impact on baseflows for less than 2% of the time.

<u>Glennies Creek</u>

An analysis of potential impacts on flows in Glennies Creek as a result of the Project has been undertaken by adjusting the flow duration curve for all periods (refer to **Figure 2.5**) to consider predicted changes in catchment contribution and baseflow. The results are shown in **Figure 2.7**.

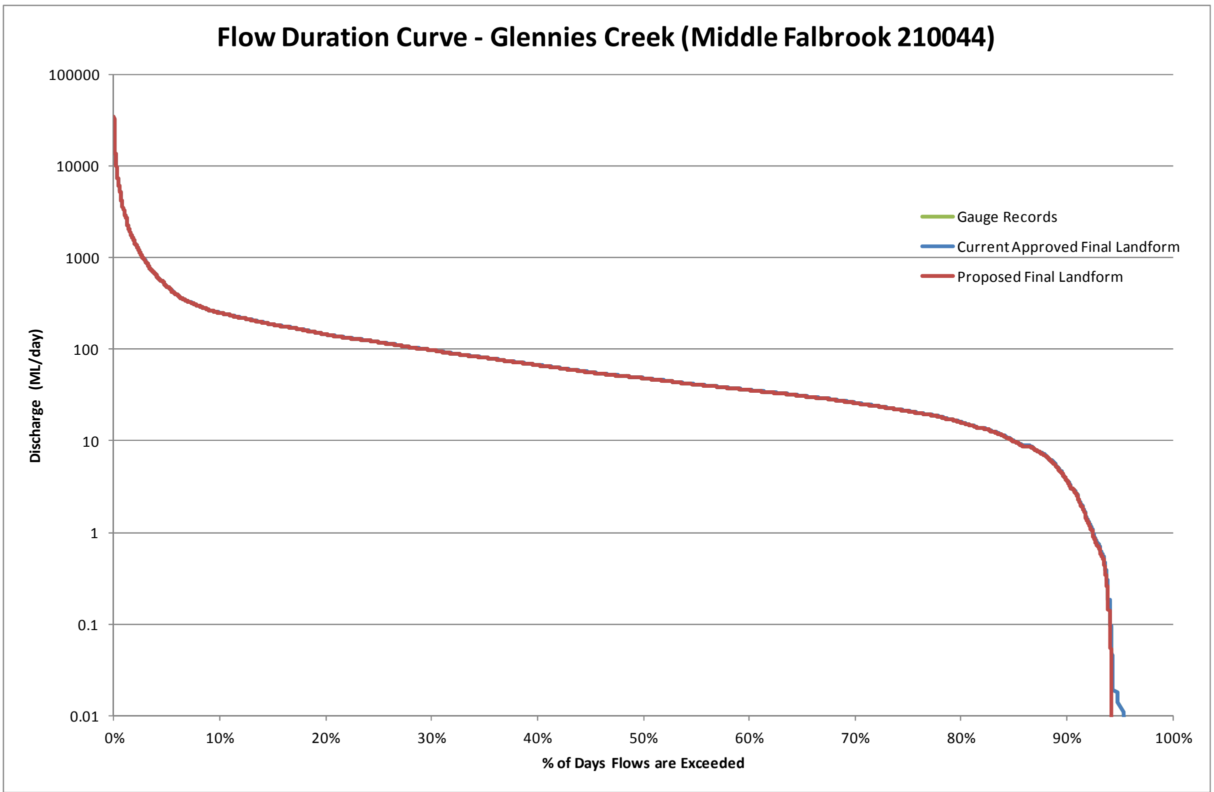


Figure 2.7 – Glennies Creek – Predicted Flow Impacts

The flow duration curve for the proposed final landform indicates that the predicted flow impacts with the Project show little variation to both the gauge record and the current approved final landform. As shown on **Figure 2.7** the Project will not impact on baseflows in Glennies Creek due to the highly regulated processes within Glennies Creek.

As described in Section 6.1 of the Surface Water Assessment, the Project will influence less than approximately 0.3 per cent of the current approved catchment area of Glennies Creek. As described above, Glennies Creek is a highly modified system and as such the hydrological, geomorphological and ecological conditions are driven by the regulation of the river system. The affects of regulation of Glennies Creek are apparent on the flow duration curves presented for gauging station 210044 - Glennies Creek at Middle Falbrook located downstream of the Glennies Creek Dam (refer to **Figure 2.3**). As such, the Project includes measures to monitor Main Creek, a tributary of Glennies Creek, but does not include details of or monitoring of Glennies Creek as this system is highly modified and the potential impacts (i.e. catchment impacts of 0.3 per cent) are considered to be negligible as shown by the analysis above. Any monitoring of hydrological, geomorphological or ecological conditions on Glennies Creek are considered to add no value to the Project assessment due to the extent of modifications and variability in this highly regulated river system.

2.2.2.3 Assessment of impacts of Catchment Changes on Bettys Creek and Swamp Creek

As shown in **Table 2.3**, with the exception of Main Creek, all creek systems will have larger final catchment areas than they have at present. The catchment of Main Creek in the conceptual final landform for the Project will be approximately 10 hectares (>0.5 percent) smaller than it is at present.

The conceptual final landform for the Project will result in a different final landform to that currently approved with resulting changes to catchment areas (refer to **Table 2.3**). The catchments of Swamp Creek and Bettys Creek in the conceptual final landform for the

Project will be approximately 15 per cent and 19 per cent smaller than the currently approved final catchments for each creek respectively. That is, the conceptual final landform for the Project (refer to Figure 2.12 in the EIS) will result in smaller catchments (and correspondingly lower average annual flow volumes) for each of these creeks relative to what is currently proposed with the existing approved operations. The currently approved final landform catchment areas would not be realised until all currently disturbed areas are rehabilitated to a level where runoff from these areas meets appropriate water quality criteria; this is likely to take over 10 years to eventuate given the on-going approved operations at the Mount Owen Complex.

Overall, the Project will result in less than 1 per cent change to the catchment areas of Glennies Creek and Bowmans Creek relative to currently approved final landform.

The implications of these catchment changes on water users and water dependant ecological assets are discussed further in **Section 2.4**.

2.2.3 Surface Water Diversions

As discussed in Section 3.2.1 of the Surface Water Assessment, a series of clean water management measures, including clean water diversions, already exist at the Mount Owen Complex. The existing approved and constructed clean water diversions are of 1st, 2nd and 3rd order tributaries of the Swamp Creek and Bettys Creek ephemeral creek systems. These are identified on **Figure 2.1** as the Yorks Creek Diversion; Upper Bettys Creek Diversion; Middle Bettys Creek Diversion; and the Swamp Creek Diversion.

No creek diversions are proposed as part of the Project.

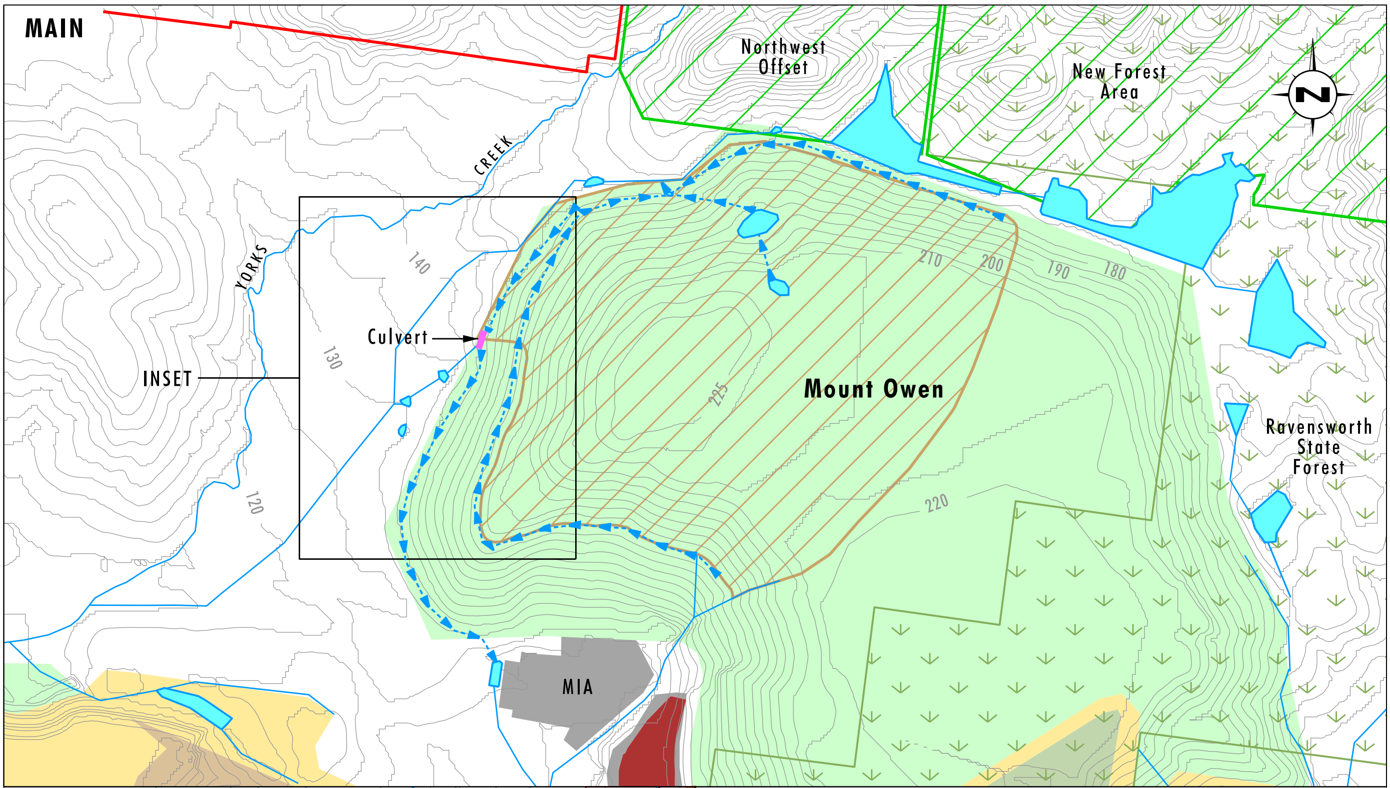
As outlined in Section 4 of the Surface Water Assessment as mining progresses, runoff from disturbed areas will be managed within the water management system and reused, or when water quality from rehabilitated areas meets required guidelines, will be released to downstream waterways.

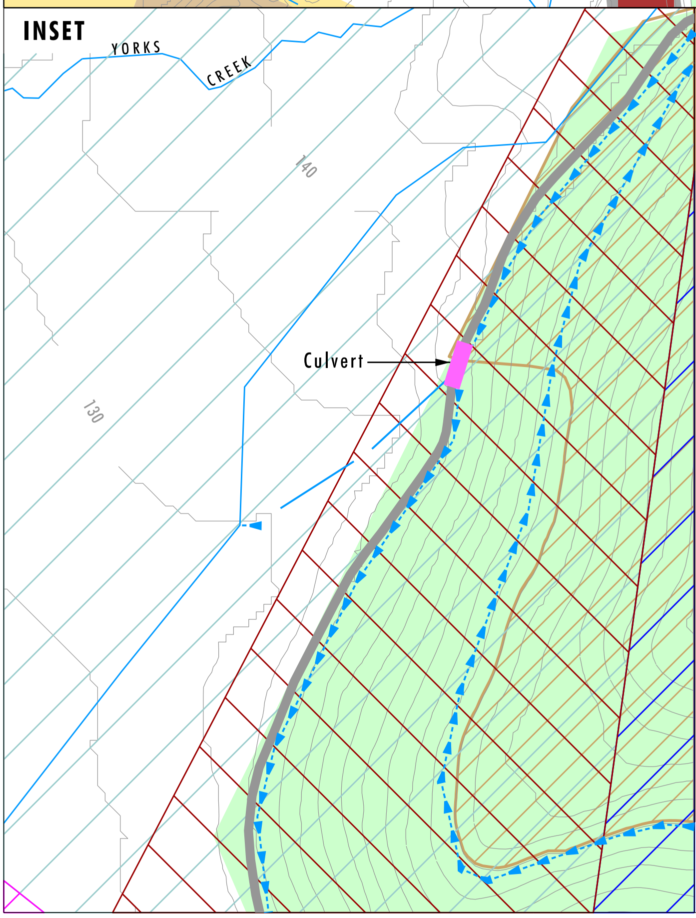
Early in the Project (Year 5) a significant proportion of the North Pit emplacement area will be rehabilitated and runoff will be redirected from the water management system to the Yorks Creek catchment. Runoff water from the rehabilitated area will be released to the Yorks Creek catchment through the construction of drainage culverts under an existing haul road to connect existing flow paths from the rehabilitated area to existing flow paths downstream of the haul road. The location of these works and drainage flows are shown in **Figure 2.8**.

To manage potential impacts of the additional catchment area flowing to Yorks Creek on watercourse stability and flood access, additional flow conveyance and detention capacity will be constructed. These proposed measures are outlined in Section 6.7 of the Surface Water Assessment.

2.2.4 Water Balance

The IESC requested additional information on the reliability of water supply having regard to other demands on the GRWSS. Questions were also asked about the use of Jerry Plains Post Office rainfall data in the impact assessment, whilst the latter concerns were raised in the context of impacts on stream flows, the Jerrys Plains Post Office station (Station 61086) (Jerrys Plains station) rainfall data was not used in the stream flow impact assessment but has been used in the Site Water Balance Assessment (refer to Appendix B of the Surface Water Assessment). Both issues are discussed further below.





- Mininmum equivalent to 4 x Ø750mm diameter culverts to be constructed under access road
- Culverts to be able to convey 1%AEP flood flows
- Scour protection to be placed in base of existing channels upstream and downstream of culvert
- Culvert to grade between existing drainage channels upstream and existing surface downstream
- Downstream culvert outlet to spread flows over wide area to reduce risk of scour/erosion

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2015)
Note: Contour Interval 5m(AHD).
Subject to refinement as part of WMP process

0 100 200 400m
Inset Scale 1:10 000

0 0.25 0.5 1.0km
Main Scale 1:25 000

Legend

- Project Area
- Existing Biodiversity Offset Areas
- Ravensworth State Forest
- Clean Water Dam
- Active Mining Area
- Active Overburden Emplacement
- Coal Stockpile ROM
- Access Road
- Rehabilitation Complete
- Shaped Not Seeded
- Area to be Released Downstream
- Drainage Line
- A423
- CL383
- EL6254
- ML1419
- Culvert
- Water Drains

FIGURE 2.8

Conceptual Drainage Plan North Pit Emplacement Area (Northern Portion) Year 5 - Final

File Name (A4): R16/ReprotB/3109_994.dgn
20150724 12.22

2.2.4.1 Site Rainfall Variability

The IESC has suggested that Grenell rainfall data should have been used instead of Jerrys Plains station rainfall data. To clarify, rainfall data recorded at Jerrys Plains station was only used in the water balance assessment component of the Surface Water Assessment and was not used in the annual flow volume assessment. As discussed in Section 6.1 of the Surface Water Assessment, the Project's potential impacts on annual flow volumes in ephemeral creeks can be predicted by comparing the changes in catchment areas.

Additional information regarding the appropriateness of Jerrys Plains station rainfall data to represent long term on site rainfall records is included below.

Three rainfall stations were considered in the analysis:

- Jerrys Plains (Station 61086) station is located approximately 16 kilometres west south-west of the Mount Owen Complex at an elevation of approximately 87 mAHD.
- Grenell (Station 61270) station is located approximately 10 kilometres north of the Mount Owen Complex at an elevation of approximately 255 mAHD.
- Ravensworth (Hillview) (Station 61028) station is a local discontinued station which has approximately 59 years of rainfall data and was located where the Glendell Mine Infrastructure Area is currently located (approximately 4.5 kilometres to the south west of the Mount Owen mine infrastructure area) at an elevation of approximately 91 mAHD.

The location of these rainfall stations are shown on **Figure 2.3**.

While the Ravensworth (Hillview) rainfall station is the closest station to the Project Area, records at this rainfall station cease in 1979 meaning it is not appropriate for use in the surface water assessment. The Ravensworth (Hillview) rainfall station is however useful in ascertaining which of the Grenell or Jerrys Plains stations are most representative of the Project Area by comparing rainfall data over periods of concurrent recording.

The rainfall data used in the Surface Water Assessment was for a 128 year period at Jerrys Plains station from 1886 to 2014. **Table 2.4** shows the statistical breakdown of the annual rainfall data from Jerrys Plains station over the entire record period used in the Surface Water Assessment.

Table 2.4 –Rainfall Data Used in Assessment

Statistic	Annual Rainfall
Minimum	219 mm
10th %ile	423 mm
Average	642 mm
90th %ile	827 mm
Maximum	1191 mm

A comparison of the overlapping periods of rainfall data at Ravensworth (Hillview) and Jerrys Plains stations is presented in **Tables 2.5.** A comparison of the overlapping periods of rainfall data at Ravensworth (Hillview) and Grenell stations is presented in **Tables 2.5** and **2.6**.

Table 2.5 – Comparison of Rainfall Data – Ravensworth (Hillview) versus Jerrys Plains

Statistic	Annual rainfall in overlap periods (59 years): 1912–1939, 1943-1946, 1953-1979	
	Ravensworth (61028)	Jerrys Plains (61086)
Minimum	293 mm	316 mm
10th %ile	431 mm	399 mm
Average	655 mm	639 mm
90th %ile	844 mm	818 mm
Maximum	1132 mm	950 mm

Table 2.6 – Comparison of Rainfall Data – Ravensworth (Hillview) versus Grenell

Statistic	Annual rainfall in overlap periods (9 years): 1970-1975, 1976-1979	
	Ravensworth (61028)	Grenell (61270)
Minimum	493 mm	723 mm
10th %ile	503 mm	748 mm
Average	650 mm	878 mm
90th %ile	815 mm	1012 mm
Maximum	854 mm	1059 mm

An analysis of the variability in rainfall data at Grenell (station number 61270) (1970 to 2013) is presented in **Figure 2.9** and shows the similarities with rainfall variability at Jerrys Plains.

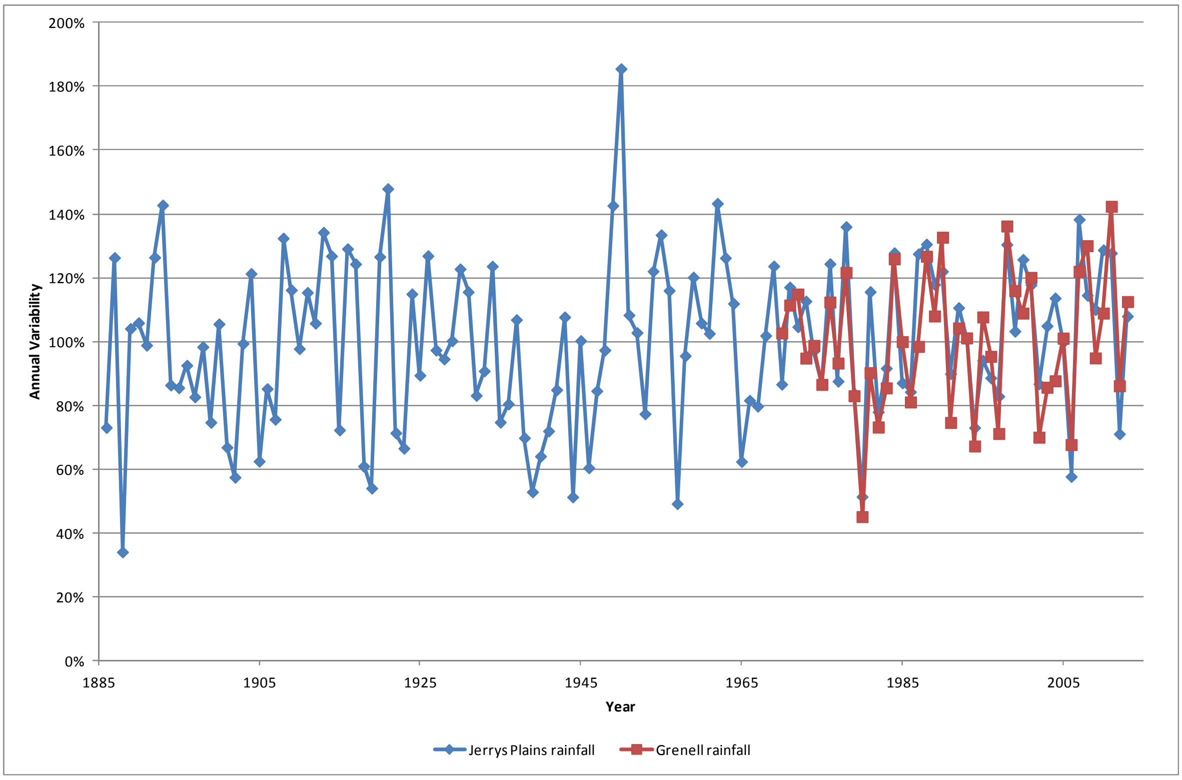


Figure 2.9 - Analysis of the variability in rainfall data at Grenell (station number 61270) (1970 to 2013)

As can be seen from **Tables 2.4** to **2.6**, the rainfall data at the former Ravensworth (Hillview) station shows more similarity to the Jerrys Plains station than the Grenell rainfall stations. Despite being located closer to the Project Area, the Grenell rainfall station observes significantly higher annual rainfall than was observed at Ravensworth (Hillview) rainfall station over the same observation period. The primary reason for this appears to be due to the Grenell rainfall station being located at a much higher altitude (255m AHD) and, by review of the data, is subject to more prominent orographic effects. The rainfall recorded at Grenell is therefore not considered to be representative of the rainfall in the upper catchment areas of Stringybark Creek, Yorks Creek, Swamp Creek or Bettys Creek. While it is located further away, the Jerrys Plains station is located at a similar altitude to the Mount Owen Complex and is located in a similar position relative to the topography of the valley. Given the similarity in rainfall data to the former Ravensworth (Hillview) station, the Jerrys Plains station rainfall data is a long term data record that is considered to be representative of rainfall at the Mount Owen Complex. This conclusion is further supported by the similarity in the variability of rainfall at both the Jerrys Plains station and the Grenell rainfall station indicating a similar pattern of rainfall across the valley.

2.2.4.2 GRWSS Water Balance

An operational water balance model has been developed for the GRWSS (Greater Ravensworth Area Water Balance Model (GRAWBM)). The GRAWBM was run with settings considered to be representative of the Project with limited on site storage and no direct HRSTS discharges from the Mount Owen Complex. The model set up allows for discharge from Liddell and Ravensworth Operations via the HRSTS and subject to existing licence limits, this would include the discharge of water transferred to these operations from the Mount Owen Complex. A summary of the outputs from the Site Water Balance included in the EIS (Appendix B in the Surface Water Assessment) are shown in **Table 2.7.**

Table 2.7 – Mount Owen Complex* Water Balance Model Outputs

Gross Water Balance			
Scenario	**10th Percentile**	**50th Percentile**	**90th Percentile**
Year 1 (2016)	-2,325	-810	1,660
Year 5 (2020)	-2,200	-665	1,810
Year 10 (2025)	-800	340	2,310
Imports from GRWSS			
Scenario	10th Percentile	50th Percentile	90th Percentile
Year 1 (2016)	2,325	1,450	1,840
Year 5 (2020)	2,210	1,320	1,745
Year 10 (2025)	670	280	505
Exports to GRWSS			
Scenario	10th Percentile	50th Percentile	90th Percentile
Year 1 (2016)	190	640	3,790
Year 5 (2020)	195	650	3,840
Year 10 (2025)	105	530	2,950

*Includes Glendell.

The peak deficit of 810 ML shown in **Table 2.7** is the gross (i.e. total) water deficit required to be met in Year 1 in a 50th percentile year. The modelling indicates that during Year 1 in a 50th percentile year, 1,450 ML of water will be pumped to the Mount Owen Complex from the GRWSS and conversely 640 ML pumped from the Mount Owen Complex to the GRWSS.

A comparison of the EIS Site Water Balance results (which considered the *Mount Owen Complex* in isolation) and the model outputs from the operational GRAWBM indicate that:

- The level in Reservoir North (located at Liddell) for the 50th percentile realisation only reaches the lower operating limit of 482 ML once for the modelled period for 3 to 5 months in Year 4. This indicates that for the remaining modelled period (10.5 years modelled) Reservoir North has water available for export to other facilities within the GRWSS, including the Mount Owen Complex.
- The total stored water volume at the Mount Owen Complex for the 5th percentile realisation never reaches zero suggesting that even in a dry year the Mount Owen Complex has an adequate supply of water from the GRWSS, runoff inflow, groundwater inflow and water access licences.
- The total amount of water imported to the Mount Owen Complex from the GRWSS for the 95th percentile realisation over the modelling period was 22,197 ML (21,398 ML from Liddell and 799 ML from Ravensworth), which equates to 2,114 ML/year. This import volume is comparable with the estimated dry year import volumes in the Project water balance for Years 1 and 5 (refer to Appendix B of the Surface Water Assessment).
- The GRAWBM results suggest that the Project water management strategy will meet the operational water demands (dust suppression and CHPP operation) of the mine.
- All surplus water within the water management system can be managed within the GRWSS, therefore no discharges from the water management system are predicted except in events when rainfall exceeds the design criteria for storages and sediment dams (refer to **Table 2.1**).

2.2.5 Surface Water Quality Context

2.2.5.1 Monitoring Program and Purpose

The Surface Water Assessment presented analysis of water quality data collected by Mount Owen since 2008 (i.e. 7 years of data) for pH, electrical conductivity (EC), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS). The assessment presented information on the high variability in water quality parameters, which is to be expected within ephemeral creek systems. The analysis also indicated, as included in annual environmental reporting to the NSW Government, that mining activities to date have had negligible impact on the water quality in downstream creek systems, including Bowmans Creek and its tributaries and Main Creek and Glennies Creek. Further information on the surface water monitoring program at the Mount Owen Complex is included below.

Mount Owen monitor surface water quality in accordance with the NSW State Government approved Mount Owen Complex Surface Water Monitoring Program (approved November 2014). This program includes monitoring of the following elements of the water management system and surrounding creeks:

- surface water flows and quality in upstream and downstream watercourses;
- channel stability in upstream and downstream watercourses;

- condition of Swamp Creek diversion channel;
- stream health conditions in upstream and downstream watercourses; and
- on-site water management.

The surface water monitoring program covers all three water category areas within the Mount Owen Complex: clean; dirty; and mine water systems. The clean water system consists of runoff from undisturbed or rehabilitated areas. The dirty water system consists of runoff from disturbed areas (excluding mine water). The mine water system consists of runoff from areas exposed to coal or water used in coal processing or from coal stockpile areas (refer to **Section 2.1**).

The Surface Water Monitoring Program requires monthly monitoring at all monitoring locations within the clean water system for the following parameters:

- flow (by way of visual observation as streams are ephemeral);
- pH;
- electrical conductivity (EC);
- total suspended solids (TSS); and
- total dissolved solids (TDS).

Mount Owen also monitors a number of organic parameters within all three water systems (i.e. clean, dirty and mine water).

A copy of the current Mount Owen Surface Water Monitoring Program can be downloaded from:
http://mtowencomplex.com.au/EN/EnvironmentalManagement/Pages/PlansandPrograms.aspx

Using historical data sets and methods outlined in ANZECC (2000) site specific water quality triggers have been developed for the above listed parameters. The site specific water quality triggers are presented in **Table 2.8**.

Table 2.8 - Water Quality Parameters and Trigger Levels

Parameter Monitored	ANZECC default trigger	Site Specific Trigger Values[1]		
		Bowmans Creek	Ephemeral Creek Systems	
			Flow Conditions	No Flow Conditions
pH	6.5 to 8.0	7.3 to 8.0	6.5 to 8.0	6.5 to 8.6
EC (µs/cm)	2,200	2,200	2,200	5,400
TSS (mg/L)	50	35	50	50
TDS (mg/L)	4,000 to 5,000[2]	1,480	1,480	4,700

1. Source: Mount Owen Complex Surface Water Monitoring Program (November 2014)
2. Source: ANZECC guidelines (2000) - recommended concentration of TDS in drinking water for beef cattle as no default trigger value is provided by the ANZECC guidelines (2000) for ecosystem protection.

2.2.5.2 Additional Background Surface Water Quality Monitoring Data

Comparison of Mine Water to Downstream Watercourse Water Quality

Recent water quality monitoring in main storage dam (ECD2) (part of the mine water management system), in 12 sediment dams (Sed Dams) and downstream receiving waters of Bowmans Creek (BCM4) shows the range of concentrations and relationship between mine water, dirty water and clean water (i.e. downstream creek systems). This data is presented in **Charts 2.1** to **2.6**. Note: metals data presented is for total metals.

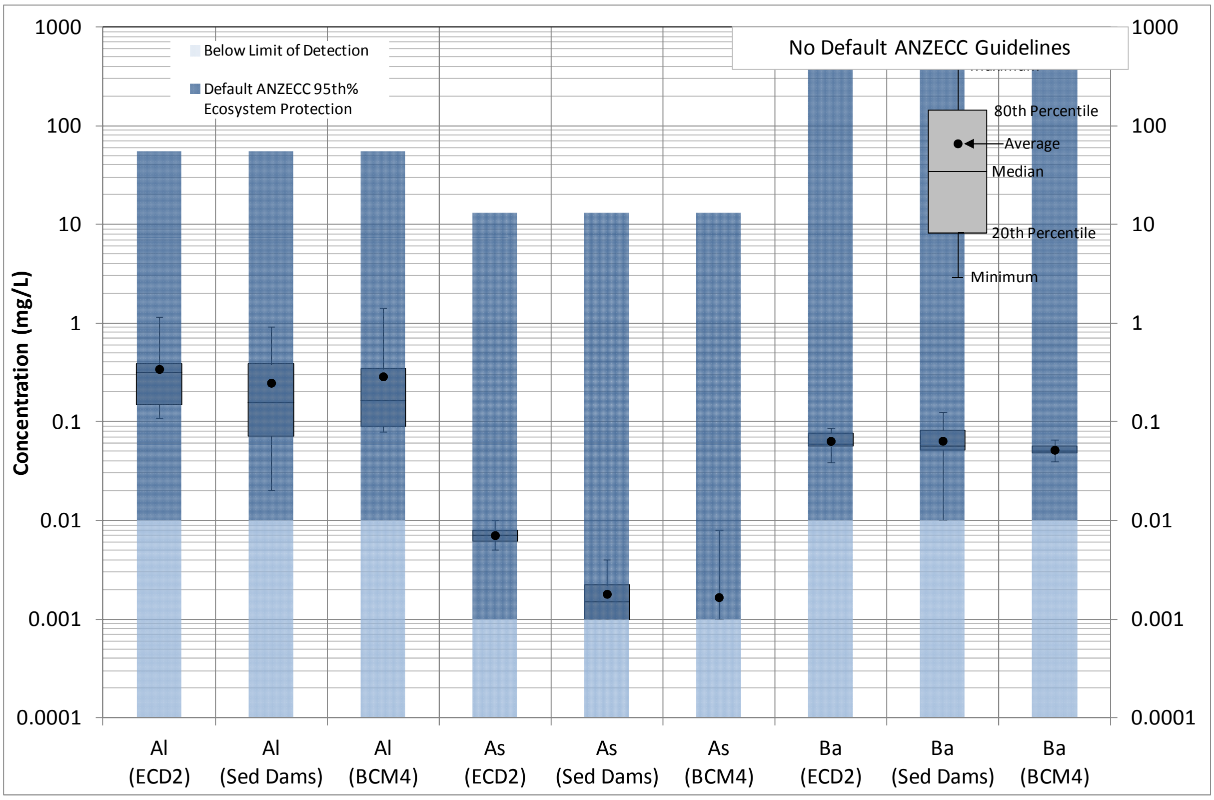


Chart 2.1 - Additional Water Quality Data (Al, As, Ba)

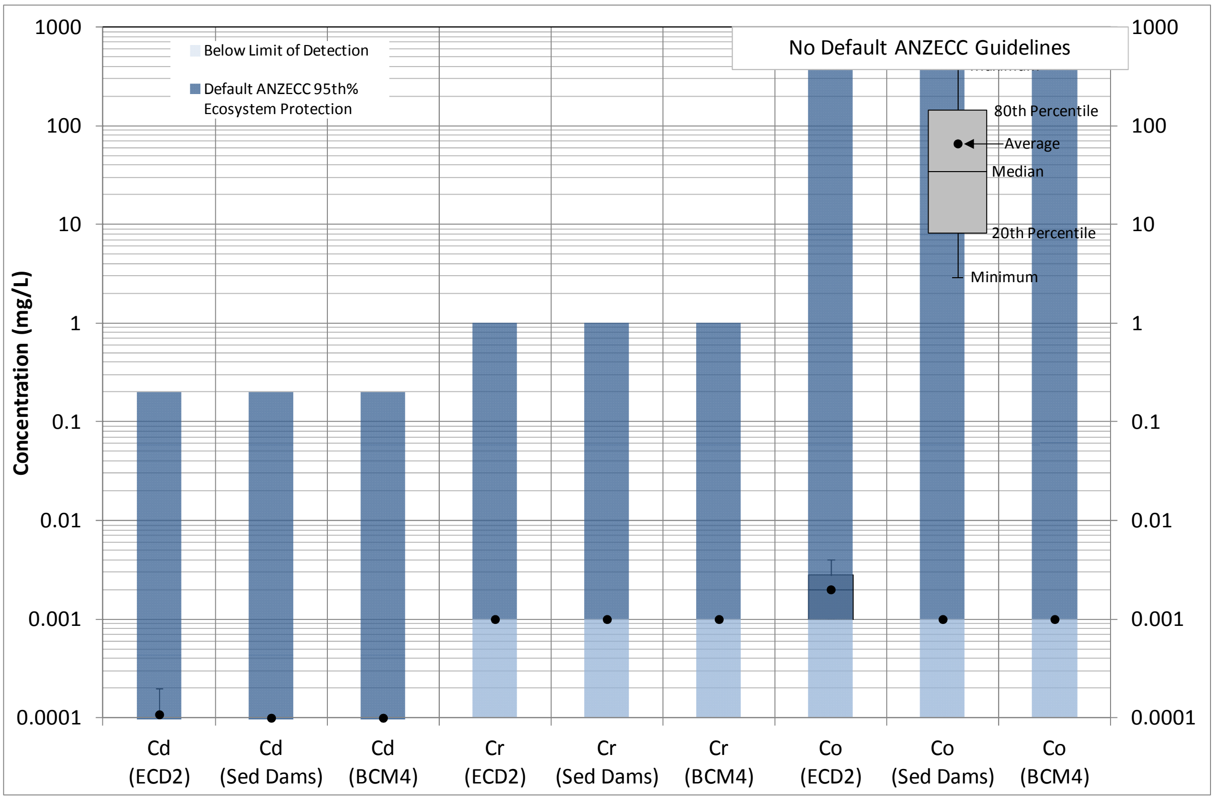


Chart 2.2 - Additional Water Quality Data (Cd, Cr, Co)

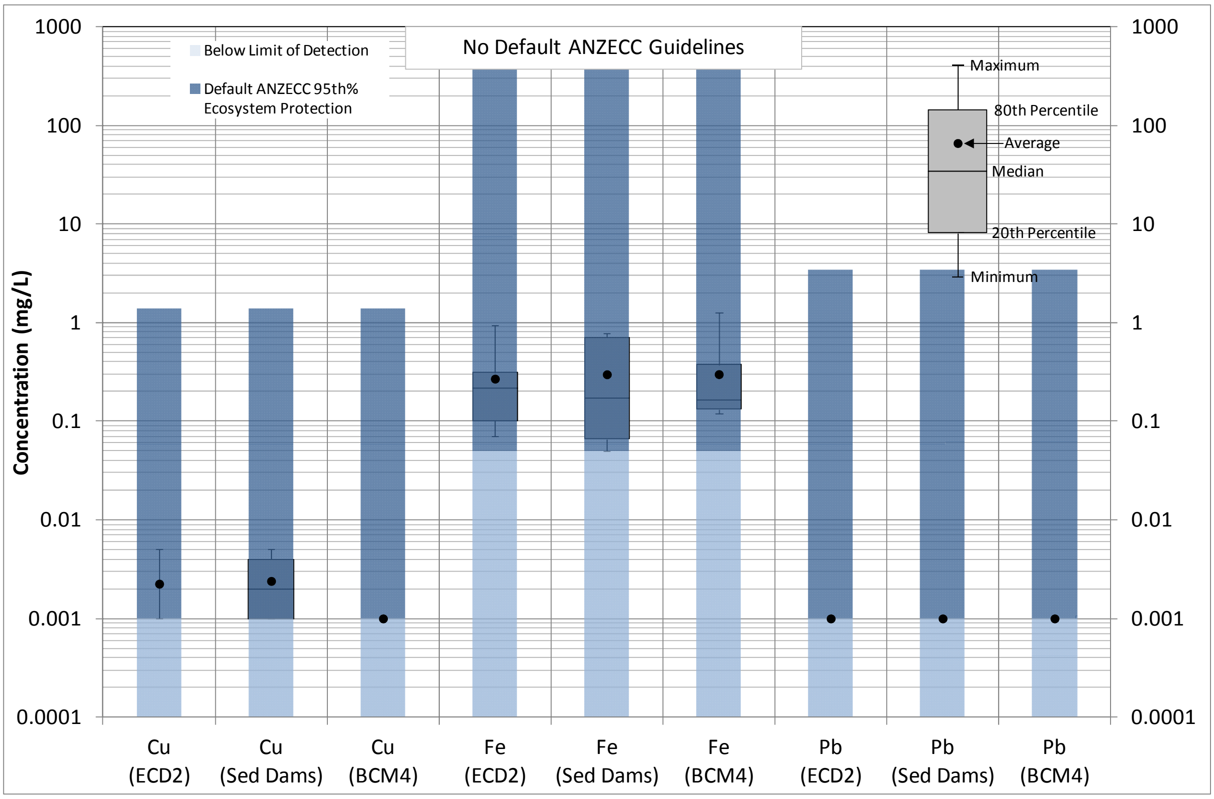


Chart 2.3 - Additional Water Quality Data (Cu, Fe, Pb)

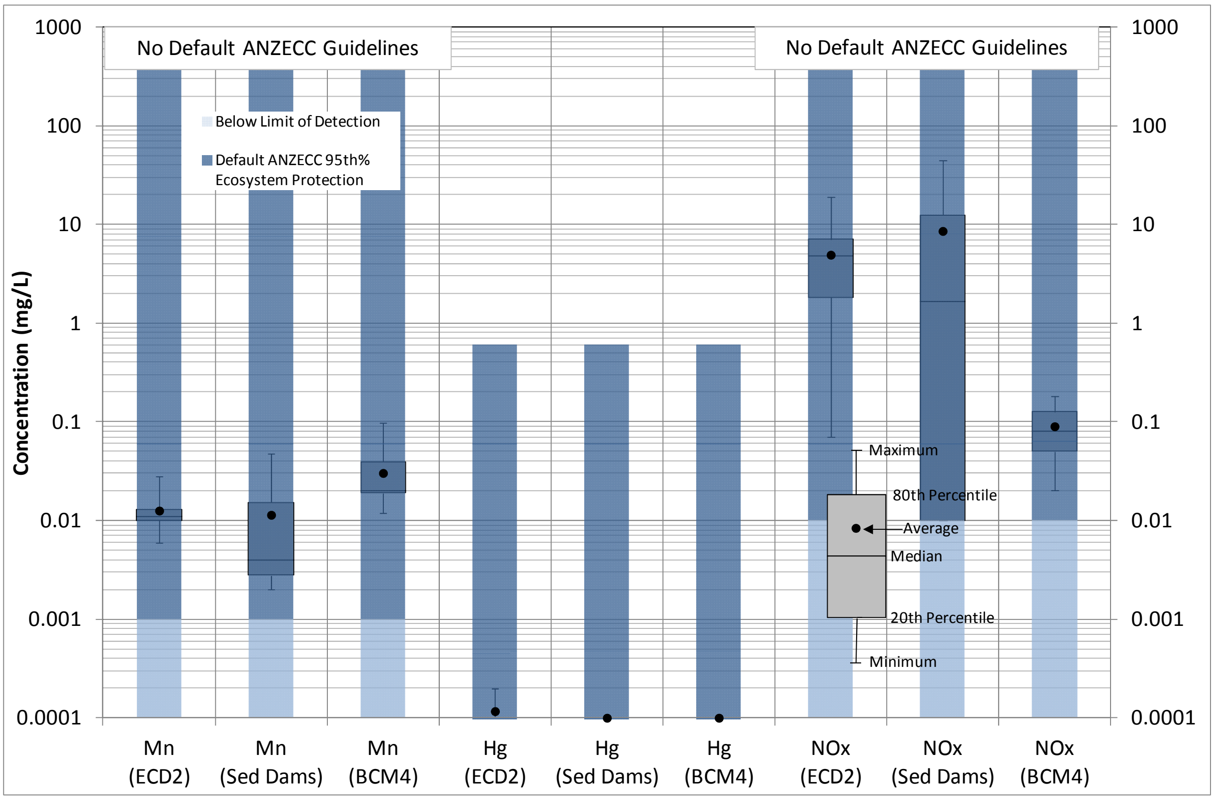


Chart 2.4 - Additional Water Quality Data (Mn, Hg, NOx)

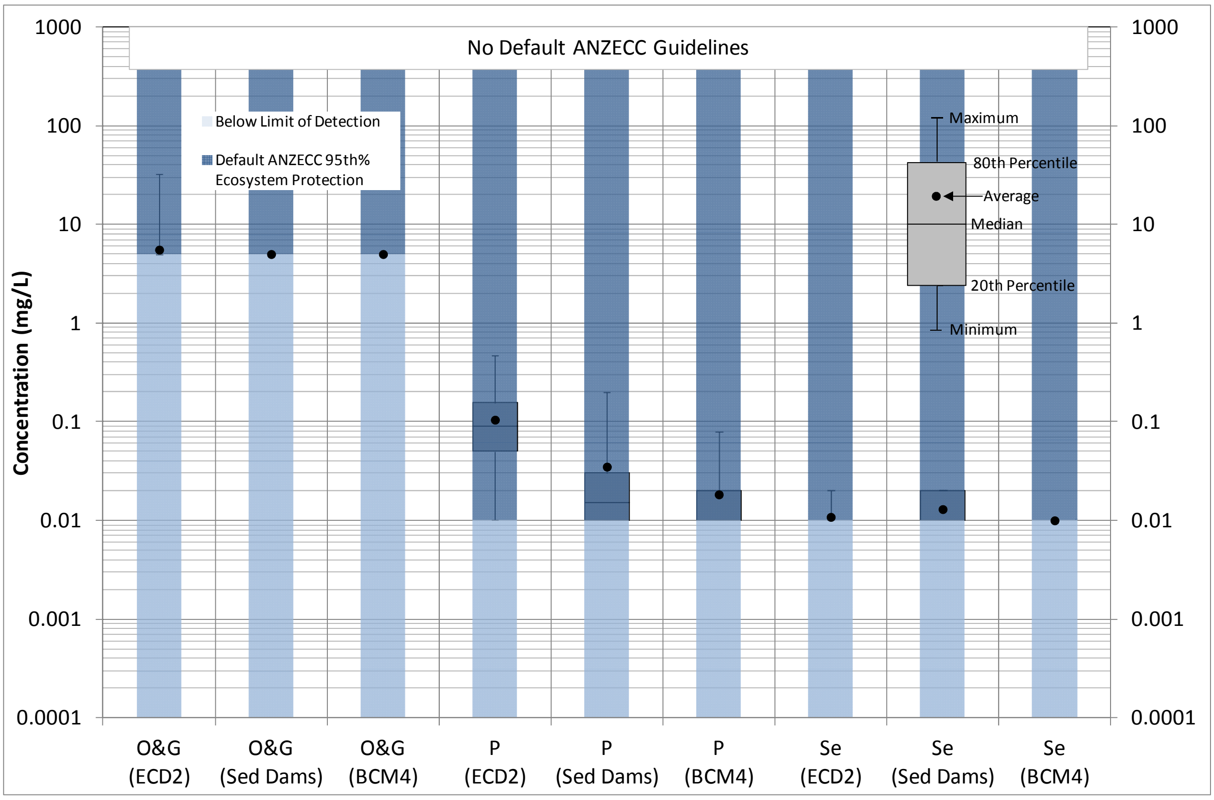


Chart 2.5 - Additional Water Quality Data (O&G, P, Se)

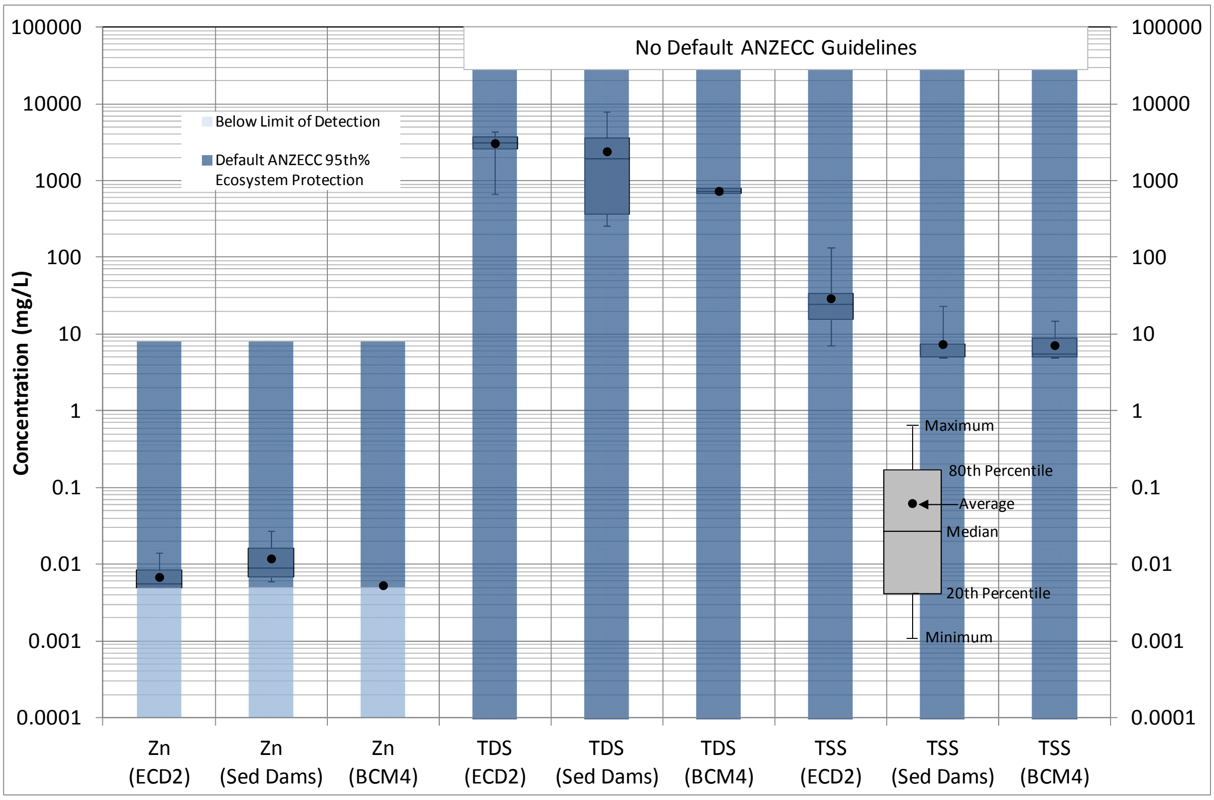


Chart 2.6 - Additional Water Quality Data (Zn, TDS, TSS)

Additional water quality analysis undertaken for the sediment dams (i.e. the dirty water management system) indicates that, as shown in **Charts 2.1** to **2.6**, several metals are at the limit of detection in the water samples with most metals samples being either at or close to the limit of detection and all metals recorded below ANZECC default guidelines (where available). pH data indicates that the water in the sediment dams has a pH typically in the order of 7.9 to 8.3. The results are consistent with the predictions in the EGI Report and support the contention that metals and metalloids are not a significant environmental risk.

Water Quality in Spills from Sediment Dams

In addition to the water quality data presented above, water quality data for pH, EC, TSS and TDS is available from five sediment dams taken during a spill event which occurred the period from 20 April 2015 to 22 April 2015. The samples were taken from close to the point of overflow. These overflows were as a result of 186.2 millimetres of rainfall being recorded at the Mount Owen Complex during this three day period. This rainfall event exceeded the design criteria for sediment dams (refer to **Table 2.1**). All spill water from these dams would have flowed into Bowmans Creek and concurrent sampling was also undertaken in Bowmans Creek upstream and downstream of the point where the spill water entered the Creek. The range of water quality data recorded for the five sediment dams is presented in **Table 2.9**.

Table 2.9 – Sediment Dam Water Quality Data

	pH	EC (µS/cm)	TSS (mg/L)	TDS (mg/L)
Minimum	7.1	97	53	145
Median	7.5	403	165	471
Maximum	7.8	897	340	860

The data recorded for the downstream creek system (i.e. the Bowmans Creek samples) indicated ranges in pH from 7.5 to 7.6, EC from 440 µS/cm to 489 µS/cm, TSS from 10 mg/L to 24 mg/L, and TDS from 227 mg/L to 295 mg/L. While TSS in the sediment dam data is above ANZECC default criteria for ephemeral streams, this is not unusual in high flow events such as occurred at the time of sampling, and are in line with readings recorded by monthly monitoring of Main Creek and Swamp Creek (refer to discussion in Mount Owen Complex Surface Water Monitoring Plan 2014). It should be noted however that the spills have not resulted in levels of TSS exceeding the site specific trigger values for TSS in Bowmans Creek (refer to **Table 2.8**). Importantly, the TDS readings for the sediment dam water samples are at the lower end of the range of results recorded for sediments dams in the recent sampling (refer to **Chart 2.5**) and well within the ANZECC site specific trigger values for both Bowmans Creek and ephemeral creeks (refer to **Table 2.8**). pH and EC results from the sediment dam water samples are also within the ANZECC site specific trigger values. This indicates that the design criteria for the dirty water management system is effective at managing the risk presented by TDS and EC. The pH values of the samples also indicate that any risk presented by mobilisation of metals and metalloids is limited.

2.2.6 Surface Water Quality Assessment

The following discussion examines the potential risks to water quality presented by mining activities and the risks presented by the Project having regard to management measures that are proposed. **Section 2.2.6.1** outlines the geochemical properties of the overburden and coal material being mined and the associated risks to water quality. **Section 2.2.6.2** discusses the risks to water quality associated with the Project. **Section 2.2.6.3** discusses the response protocols that will be implemented in relation to spills from sediment dams which, in accordance with NSW guidance material for managing runoff from disturbed areas, are designed to spill in large rainfall events.

2.2.6.1 Geochemical Assessment and Water Quality

The *Geochemical Assessment of the Mount Owen Optimisation Project* prepared by Environmental Geochemistry International Pty Ltd (EGI) is attached as **Appendix F** to this Report. The study indicated that the bulk of overburden/ interburden materials represented by the samples tested are likely to be non-acid forming (NAF), with a significant excess of acid neutralising capacity and low leachable salinity. Whilst there was the occasional thin zone (0.2 metres) of elevated Sulfur (S) identified close to coal seams, the study concluded that dilution and mixing during mining should be sufficient to mitigate any acid rock drainage (ARD) generation.

In addition to the above, EGI outlined that water extracts from NAF overburden/interburden indicated that neutral mine drainage was unlikely to contain significant metal/metalloid concentrations and that results indicated that there was no potential for alkaline drainage. In consideration of the above, the vast majority of overburden/interburden material are expected to be NAF and therefore will not require special handling.

In regards to exchangeable cation and dispersion percent testing results, EGI outlined that weathered Permian materials represented by the samples tested are likely to be sodic and dispersive. Further, it was also found that finer grained fresh Permian materials may also be partly sodic. As such, this material may be subject to surface crusting and high erosion rates if they are incorporated into the surface of the final rehabilitated landform.

In light of the findings from the EGI geochemical assessment, runoff water from overburden areas is unlikely to contain elevated levels of metal/metalloid concentrations.

There is a potential erosion risk represented by the presence of partly sodic and dispersive weathered Permian materials in overburden and this is the primary reason why suspended solids (and turbidity) are the primary environmental risk associated with run-off from disturbed areas managed as part of the dirty water system. These risks can be managed through the use of gypsum or lime in exposed areas where this material may be present.

There is a very low risk of any polycyclic aromatic hydrocarbons (PAH) or other organics in runoff water as maintenance activities are limited to areas managed as part of the mine water system which is designed to not spill to the environment.

In summary *the Geochemical Assessment of the Mount Owen Optimisation Project* indicates:

- The bulk of overburden/ interburden materials represented by the samples tested are likely to be non-acid forming (NAF), with a significant excess of acid neutralising capacity and low leachable salinity.

- An occasional thin zone (0.2 metres) of elevated (S identified close to coal seams, but the study concluded that dilution and mixing during mining should be sufficient to mitigate any ARD generation.

- Runoff water from overburden areas is unlikely to contain elevated levels of metal/metalloid concentrations.

- Potential erosion risk with partly sodic soils and dispersive Permian materials in overburden indicate elevated TSS is the primary risk associated with runoff water within the dirty water management system.

- Very low risk of PAH or other organics in runoff water as maintenance activities are located in mine water management system areas which are designed to higher containment levels (this is confirmed by recent water quality monitoring data, refer to **Section 2.2.5.2**).

2.2.6.2 Likely Risks to Downstream Water Quality

The surface water monitoring program has been in place at the Mount Owen Complex for a number of years and was developed based on the specific risks to downstream water quality posed by the existing operations. It is considered that the proposed continuation will not change the specific risks to water quality compared to the existing operations.

The highest risks to downstream surface water quality as result of mining operations are summarised in **Table 2.10**. **Table 2.10** identifies the water management control category which is currently applied to manage the risk. These management controls will also be applied to the Project, hence the assessment of risks presented by the existing operations also applies to the Project.

Table 2.10 - Preliminary Risk Surface Water Quality Assessment of Project

Aspect	Water Management Control Category	Risk to Environment	Comment
Discharge of mine water	Mine	Low	Mine water management system is designed to contain events up to and including 1% AEP 24 hour storm event. Surplus water used in GRWSS. No discharge location on site.
Overflow/failure of sediment pond (dirty water)	Dirty	Medium	Numerous sediment dams are required due to complexity of mine site. Sediment dams are managed in line with the Blue Book and designed to manage runoff from the 5 day, 95th percentile rainfall event. Some sediment dams have secondary containment measures downstream. Elevated TSS is primary risk.
Spillage of tailings	Mine	Low	Tailings are disposed of on site within in pit tailings storages. Risk only arises as a result of tailings storages filling in extreme events and overtopping. Management procedures are in place which limit water volume (e.g. freeboard allowances on pits) to minimise the risk of such occurrence.

The higher risks (medium level) outlined in **Table 2.10** are associated with the dirty water management system where the risk is associated with overflow from sediment dams during rainfall events above the design criteria specified in the Blue Book. These design criteria have been established by the NSW Government specifically for sediment control at mining and quarry operations.

As such the primary monitoring parameter for mining impacts in regard to downstream water quality is TSS. Mount Owen also monitor pH, EC and TDS to ensure that overall changes to water quality in downstream creek systems associated with the mining operations, including release of runoff from rehabilitated landforms are monitored for potential impacts.

The low risk of metal/metalloid contamination does not warrant specific monitoring of these substances as part of the routine monitoring program for sediment dam water however any significant change in pH would trigger further analysis of metal/metalloid concentrations in runoff water and this requirement will be included in the Surface Water Monitoring Program. This is discussed further in **Section 2.4.11**. The use of the primary monitoring parameters (pH, EC, TSS and TDS), with additional testing of analytes only required in the event of anomalous pH results, is supported by the results from the recent monitoring programs, geochemical studies and potential risk of spill.

Water quality risks associated with spills from sediment dams during high rainfall events is discussed further in **Section 2.2.7**. Management measures are discussed further in **Section 2.5**.

2.2.7 Spills and Discharges

The purpose of the sediment dams within the dirty water management system is to manage runoff from disturbed areas. The dirty water management system is, and will continue to be, designed in accordance with *Managing Urban Stormwater: Soils and Construction* (the Blue Book), *Volumes 1* and *2E - Mines and Quarries* (Landcom 2004 and DECC 2008) to manage runoff from the 5 day, 95th percentile rainfall event. The selected design criteria is in excess of the minimum recommended design criteria for sediment dams as outlined in Volume 2E of the Blue Book (DECC, 2008). Volume 2E of the Blue Book (DECC, 2008) indicates that for the 95th percentile design storm event the indicative average annual sediment basin overflow frequency will be 1 to 2 spills per year. The predicted 1 to 2 spillages per year from sediment dams identified in the Site Water Balance (refer to Appendix B of the Surface Water Assessment) is associated with this design criteria. These spills will only occur from sediment dams within the dirty water system and not from the mine water system.

Mine water (i.e. runoff from areas exposed to coal or water used in coal processing or from coal stockpile areas) is contained within systems designed to a higher design criteria. The design criteria for mine water is containment for events up to and including the 1 per cent Annual Exceedance Probability (AEP) 24 hour storm event.

The location of receiving waters in the event of spillages are listed in **Table 2.11**. The dams identified in **Table 2.11** are shown in Figures 5.17 to 5.19 in the EIS.

Table 2.11 – Potential receiving points for spills from sediment dams

Dam Name	Spills To
Dam AE	Mine WMS (ECD1)
Dam AB	Dirty WMS (TP1)
SD5	Swamp Creek
Dam AV	Bettys Creek
Dam X	Dirty WMS (Dam U)
Dam U	Yorks Creek
Dam AF	Yorks Creek
Dam 1	Mine WMS (North Pit)
Dam 4	Bettys Creek
Dam AD	Mine WMS (ECD1)
Dam DD	Mine WMS (ECD1)
Dam AW	Bettys Creek
Dam AH	Mine WMS (North Pit)
Dam WP	Dirty WMS (SD5)
Dam TP1	Dirty WMS (SD5)
BNP1	Yorks Creek
BNP2	Yorks Creek
Ravensworth East MIA Dam	Yorks Creek

The schematic for the water management system for the indicative mine plan (Years 5-10) is shown in **Figure 2.10.**

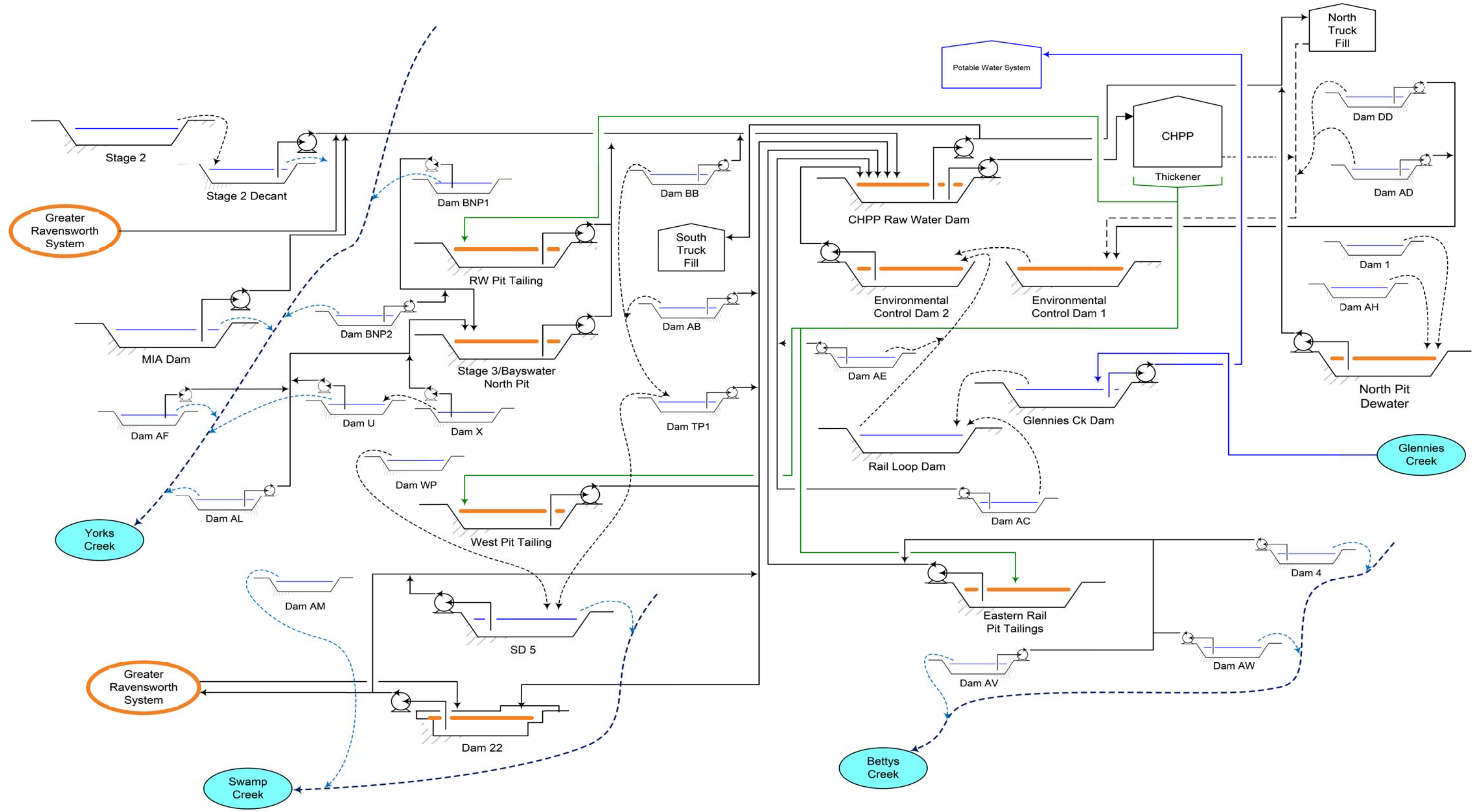


FIGURE 2.10

Water Management System Schematic

Legend
Pumped Flow
Overland Flow
Water Course
Tailings Flow
Fresh Water Flow
Potential Spill to Water Course
Mine Water Dam
Dirty Water Dam

2.2.7.1 Discharges from Mine Water Management System and EPL

As stated in the EIS, Mount Owen will continue to manage water resources within the Project Area in accordance with the Mount Owen Complex Water Management Plan, the Environment Protection Licences (EPLs) and the requirements of the Hunter River Salinity Trading Scheme (HRSTS). Following the recent variation to EPL 4460 (Mount Owen), neither EPL 4460 (Mount Owen) nor EPL 10860 (Ravensworth East) authorise discharge of saline water under the HRSTS from the Mount Owen Complex. A copy of the Mount Owen Complex Water Management Plan can be downloaded from: http://mtowencomplex.com.au/EN/EnvironmentalManagement/Pages/PlansandPrograms.aspx. Copies of the most recent versions of Environment Protection Licences are available at: http://www.epa.nsw.gov.au/prpoeoapp/

As stated in the EIS and Appendix 9 Surface Water Assessment, Mount Owen will share water with other local Glencore operations under the GRWSS. Where the total storage within the GRWSS is in surplus to requirements for all operations, discharges from the GRWSS may be required. These discharges will occur via the licensed discharge points at either Ravensworth Operations or Liddell Coal Operations which are also part of the GRWSS. There is no current intention to discharge from the Mount Owen Complex based on the operation of the GRWSS.

In the absence of any identified need for discharging water from the Mount Owen Complex, an immediate variation of the licence to permit such discharges is not required.

2.3 Groundwater Impacts

The IESC advice noted:

> *The proponent's groundwater model is robust, well constructed and has been peer reviewed. The inclusion of 43 mines within an approximately 451 km^2 domain would allow sub-regional groundwater impacts to be estimated cumulatively.*

Notwithstanding the above, the IESC noted that the scale of the groundwater model used in the assessment did not enable an accurate assessment of the potential impacts on water dependent ecological assets which may rely on the groundwater in the Bettys Creek and Main Creek alluviums. The IESC also queried the extent of potential impacts on the groundwater aquifers in Glennies Creek and the impacts of drawdowns in the Main Creek alluvium on base flows in Glennies Creek.

The following sections discuss the additional modelling undertaken in response to the questions raised by the IESC and detail the assessment findings in relation to the Project's potential impacts on water dependent ecosystems.

2.3.1 Groundwater Impacts Context

While noting the model used in the Groundwater Impact Assessment was appropriate for the assessment of sub-regional groundwater impacts, the IESC advice also noted:

> *The numerical groundwater model has a cell size of 100 m by 100 m which is adequate for estimating regional groundwater behaviour, though is too large to predict fine scale groundwater and surface water interactions. Nevertheless, the groundwater model predicts baseflow reductions to surface watercourses as follows (with results from the 'plus one standard deviation' model run in brackets): 6 ML/year (9 ML/year) decrease to Bettys Creek, 15 ML/year (22 ML/year) decrease to Main Creek and "negligible" losses from Bowmans and*

> *Glennies Creeks. Seasonal quantification or estimation of baseflow within each of the surface watercourses has not been provided. Baseflow analysis was only described as an annual percentage and therefore the importance of baseflow contribution to Bowmans and Glennies Creeks during seasonal or climatic low flow periods is unknown.* [paragraph 6]
>
> *The groundwater model predicts drawdown within the Main Creek alluvium of between 2 m and greater than 6 m (for the plus one standard deviation model run). Within the predicted zone of impact this would lower the Main Creek alluvial water table to between 4 m and 8 m below the surface. The effect on the Central Hunter Swamp Oak Forest GDE of lowering the Main Creek alluvial water table has not been addressed within the EIS.* [paragraph 7]

The key area of consideration is the predicted impacts on the alluvial aquifers associated with Bettys Creek and Main Creek and the associated impacts on ecological systems reliant on these aquifers. It is worth noting that there is no direct connection between the alluvial aquifers and the proposed mining operations, nor is there any predicted cracking of strata directly below the alluvium. Potential impacts to the alluvial aquifers, and any supported GDEs, however, may result from dewatering activities that depressurise hard rock (coal measures) aquifers and indirectly induce leakage from the alluvial aquifers.

The relationship between the alluvium and hard rock aquifers is schematically illustrated in **Figure 2.11**. The area of alluvium used for recharge calculations is the entire alluvium area to the junction with Bowmans Creek alluvium (in the case of the Bettys Creek alluvium) and the junction of the Glennies Creek alluvium (in the case of the Main Creek alluvium)

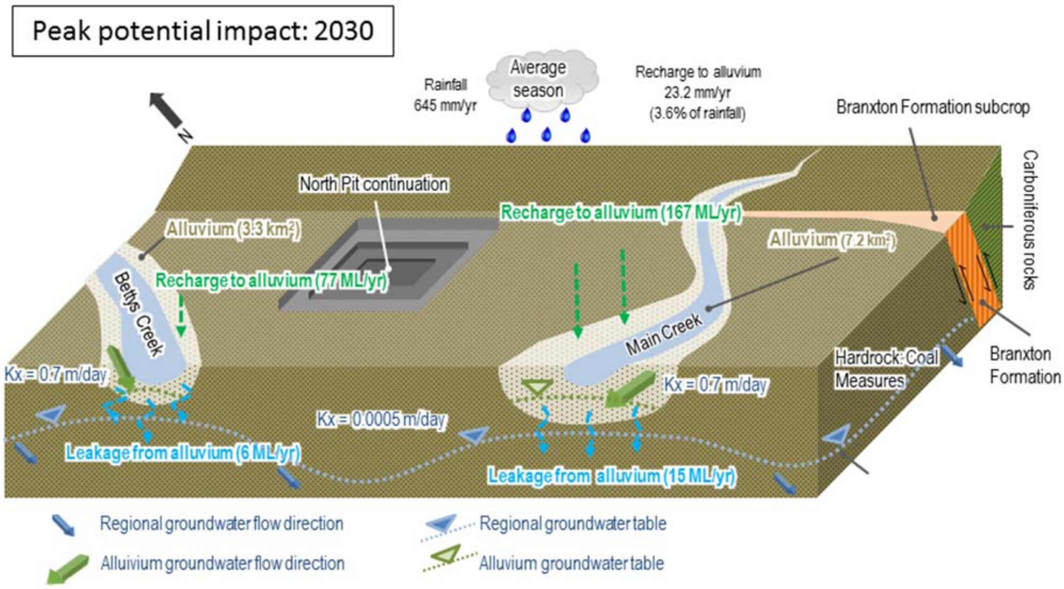


Figure 2.11 Schematic representation of fluxes to and from the alluvial systems of Main Creek and Bettys Creek

The hydraulic characteristics of the alluvial and hard rock aquifers are significantly different. Hydraulic conductivity in the alluvium has been determined to be three orders of magnitude faster than the underlying hard rock, while specific yield is two orders of magnitude higher (Jacobs 2014). Thus, it is expected that seasonal infiltration and flow through the alluvium will occur at a significantly faster rate than any variation in leakage driven by changes in water pressures in deeper formations. Further, while annual leakage from the alluvium predicted under the maximum impact scenario is estimated to be 15 ML/year from Main Creek and 6 ML/year from Bettys Creek, annual predicted recharge of the alluvium from rainfall is predicted to be more than an order of magnitude greater, with the bulk of water being transmitted downstream through the alluvium to the main systems of Glennies and Bowmans Creeks (refer to **Figure 2.11**).

Annually, peak potential leakage impacts caused by drawdown induced from mining operations are less than 10 per cent of mean annual expected recharge for both Main Creek and Bettys Creek.

It is therefore unlikely that depressurisation will cause any observable effects in water table levels in the alluvium under normal (average climate) conditions. Based on historical long term rainfall records, the predicted recharge of the alluvium ranges from 37 ML/year to 309 ML/year in Main Creek and 26 ML/year to 141 ML/year in Bettys Creek (based on the lowest and highest annual rainfalls observed in the 128 years of rainfall data). The calculated minimum level of recharge exceeds the predicted leakage from each alluvial system of 9 ML/year and 22 ML/year respectively (2030 median + 1 SD).

2.3.2 Groundwater Impacts Assessment

The model used in the Groundwater Impact Assessment in Appendix 10 of the EIS (v8.1) utilises a grid size of 100 metres x 100 metres. This scale is considered appropriate for the regional nature of the model and provides adequate resolution to understand and appreciate the potential impacts to groundwater of the proposed continued operations. This grid resolution is considered appropriate to model dewatering effects on the hard rock aquifers. However, as noted in the IESC advice, this model scale could be further refined to understand localised impacts in alluvial aquifers where the extent of the alluvium may be significantly narrower in places than the cell size used. The following sections contain further information on the revised modelling used to better understand the nature of the impacts on the aquifers in the alluvium associated with Bettys Creek and Main Creek.

2.3.2.1 Additional Groundwater Modelling

To better understand the potential impacts of the Project on the alluvium in Main Creek and Bettys Creek a higher resolution model of the Project's impacts on the groundwater aquifers in these alluvial systems was developed. The development of this model and its results are set out in detail in the Letter Report prepared by Jacobs contained in **Appendix G** to this Report. In summary the model was based on the regional model and was set up as follows:

- The model domain was reduced to approximately 50 km^2
- Grid spacing was reduced to 20 metre by 20 metre uniformly across the new model domain, with 345 rows and 360 columns.
- The surface elevation within the alluvium was refined using the latest LiDAR data.
- The base of the alluvium was refined based upon a refined isopach map and the refined surface elevations.
- Constant head boundary conditions were input to all active cells in Layer 2. The head values at each cell were transient and corresponded to the predicted heads in Layer 2 for each stress period from the regional model. These boundary conditions were created for each stochastic realisation. Because Layer 2 is entirely constant heads, there was no need for all subsequently deeper layers. Therefore all layers greater than 2 in the regional model were deleted.
- Model simulations were run using the same configuration and operation as the regional model and predictive scenarios were created from statistical analysis of the calibrated parameter sets generated from the regional model.

Due to the Layer 2 input parameters to the model being based on the Regional Groundwater Model used in the Groundwater Impact Assessment, there is no change to the predicted volumes of water moving from the alluvial aquifers to the sub-cropping strata identified in the Groundwater Impact Assessment.

2.3.2.2 Depressurisation Impacts

The predicted drawdown results are presented in **Figures 2.12** to **2.17** for years 2020, 2025 and 2030, with 2030 representing the maximum expected drawdown for the life of the Project. The mining progression used in the modelling, is shown in Figure 3.13 of the Groundwater Impact Assessment.

The modelling results indicate that the predicted area of impact using the finer resolution grid in the refined model is directly comparable to that determined using the coarser grid in the regional model (refer to Figure 8 in **Appendix G**). However, the refined resolution modelling indicates that the potential impact is restricted to the central region of the alluvial extents only. The drawdown predicted from the revised modelling is slightly less than that determined by the regional model, which is likely due to the improved resolution of the aquifer boundary and base, defined using the recently installed standpipes along Bettys, Main and Glennies Creek. This refined modelling also predicts that there will be no impact to these alluvial aquifers for at least the first 5 years of the Project (consistent with the regional model predictions).

Table 2.12 shows the area of predicted drawdown impacts in each of Main Creek and Bettys Creek alluvium.

Table 2.12 Area of Predicted Drawdown in Alluvium (2030 Median + 1 SD)

Alluvial System	Area (Ha)					
	Predicted Drawdown					Total
	0 – 0.5 m	0.5 – 1 m	1 – 2 m	2 – 3 m	3-4 m	
Main Creek	21.93	15.46	10.28	4.16	0.34	52.17
Bettys Creek	54.25	18.92	5.33	0.00	0.00	78.50
Total	76.18	34.37	15.61	4.16	0.34	130.66
Percentage of total drawdown area	58%	26%	12%	3%	<0.3%	100%

Figures 2.12 to 2.17 show the predicted alluvial drawdown in Years 2020, 2025 and 2030 in Main and Bettys Creeks. As shown in **Figures 2.12** to **2.17** and **Table 2.10**, the vast majority (84%) of the predicted drawdown impact associated with the Project will be less than 1 metre even under the Median + 1 SD model predictions. Under the Median + 1 SD model prediction,, all of the drawdown in the Bettys Creek alluvium will be less than 2 metres. Only approximately 0.34 ha of the Main Creek alluvium is predicted to experience drawdown of up to 4 metres under the Median + 1SD model predictions. The areas of higher predicted drawdown on Main Creek occur where there is a narrowing of the alluvium channel which amplifies the drawdown impact. The maximum predicted depressurisation (2030 Median prediction + 1 SD) is shown graphically in a long section of the alluvium closely aligning to the channel of Main Creek in **Figure 2.18**. The alignment for the long section is shown in Figure 7 in **Appendix G.**

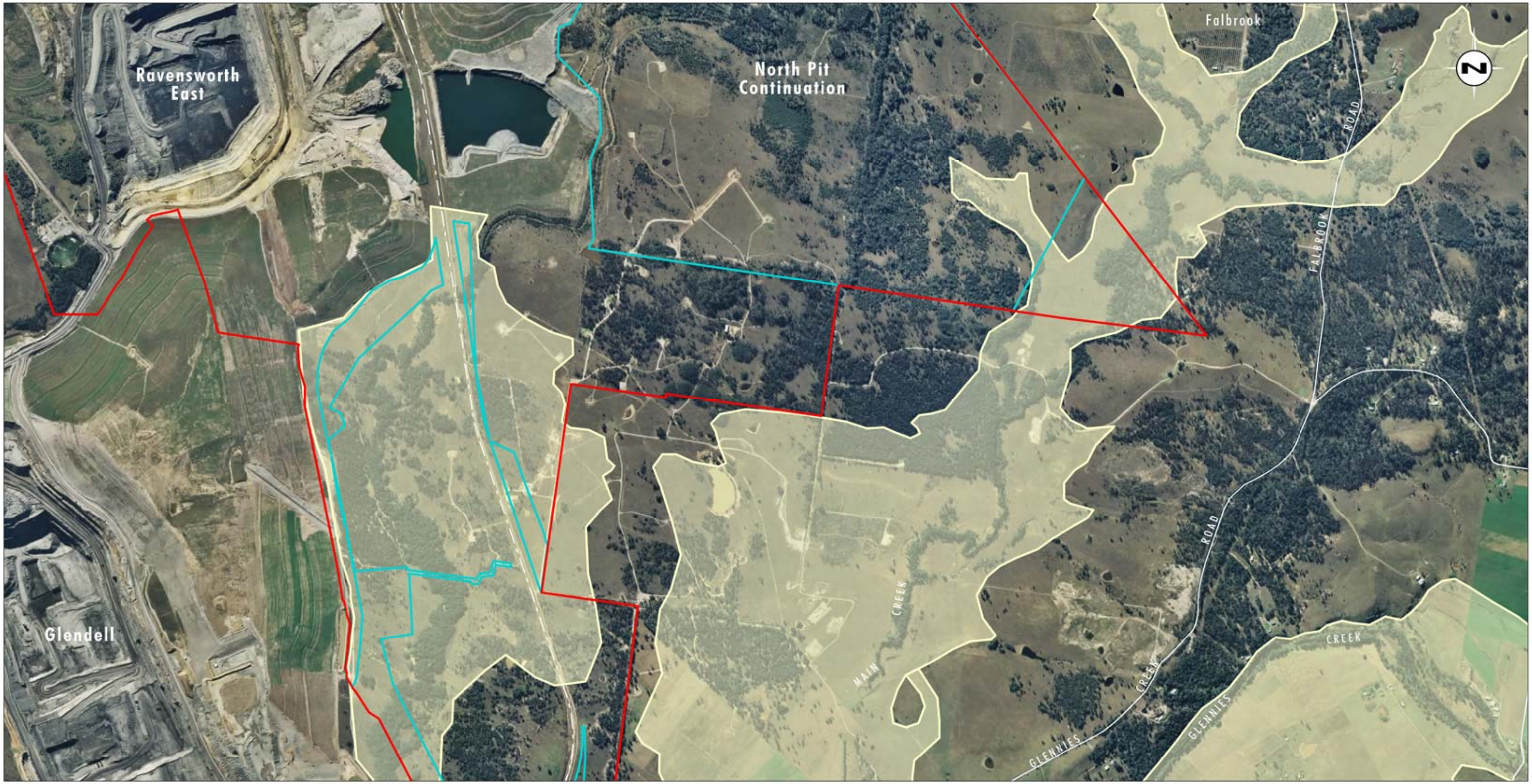


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent

FIGURE 2.12

Predicted Median Incremental Drawdown in Alluvial Aquifers in Year 2020

File Name (A4): R16/ReprotB/3109_998.dgn
20150709 9.02

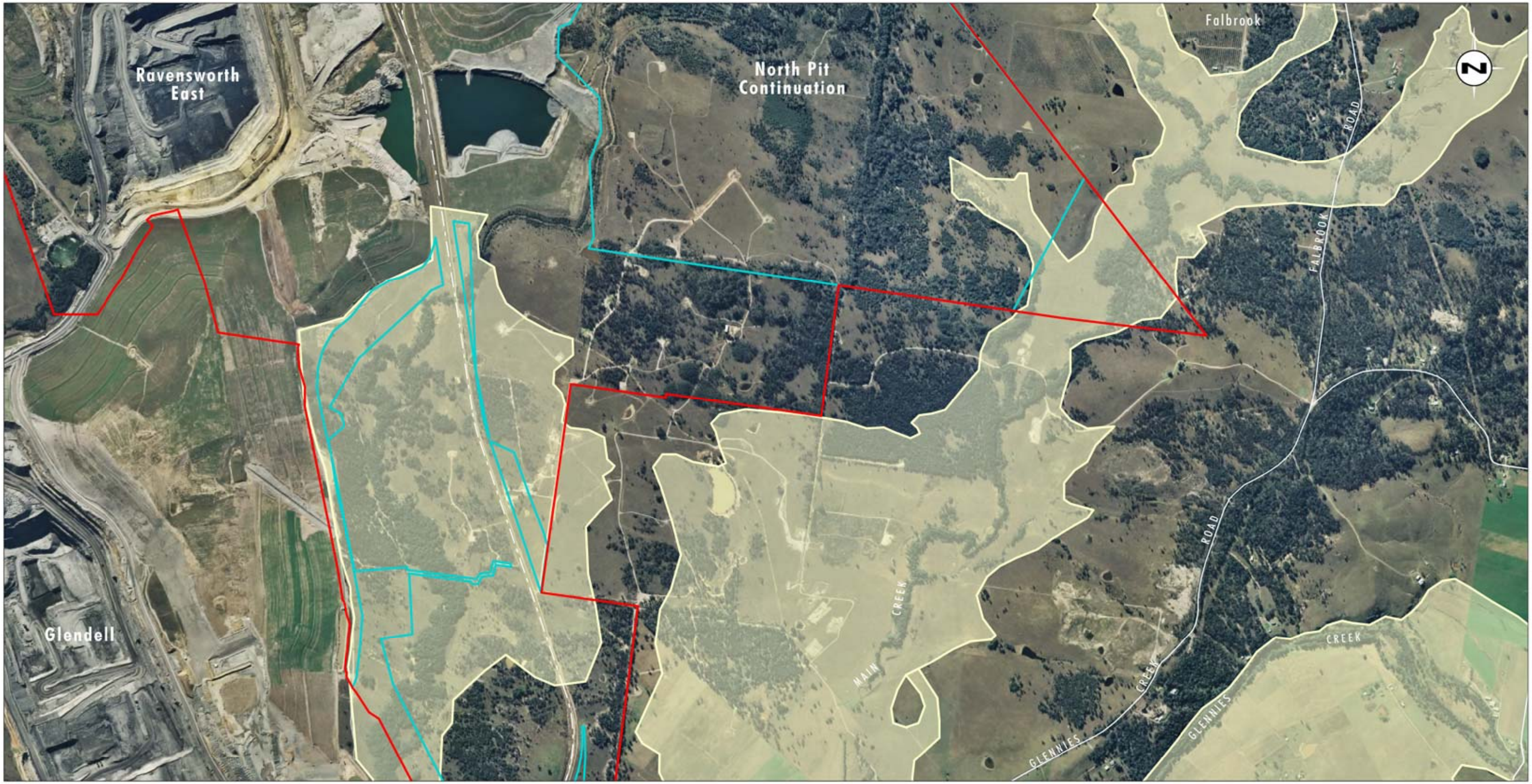


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend
Project Area
Proposed Disturbance Area
Alluvium Extent

FIGURE 2.13

Predicted Median Plus 1 Standard Deviation Incremental Drawdown in Alluvial Aquifers in Year 2020

File Name (A4): R16/ReprotB/3109_999.dgn
20150709 9.02

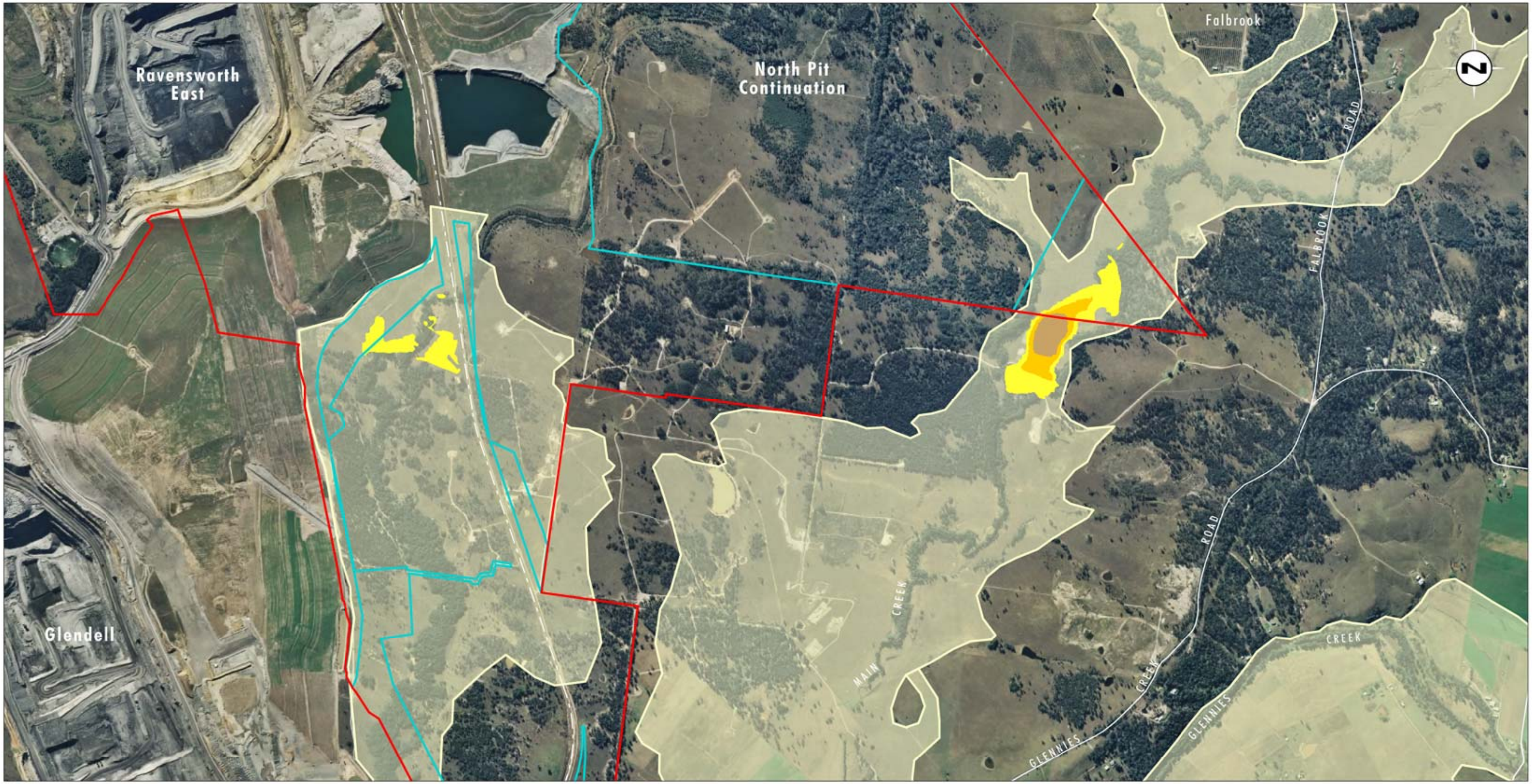


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

Project Area
Proposed Disturbance Area
Alluvium Extent

Predicted Drawdown (m)
0.1 - 0.5
0.5 - 1.0
1.0 - 2.0

FIGURE 2.14

Predicted Median Incremental Drawdown in Alluvial Aquifers in Year 2025

File Name (A4): R16/ReprotB/3109_1000.dgn
20150709 9.03

umwelt

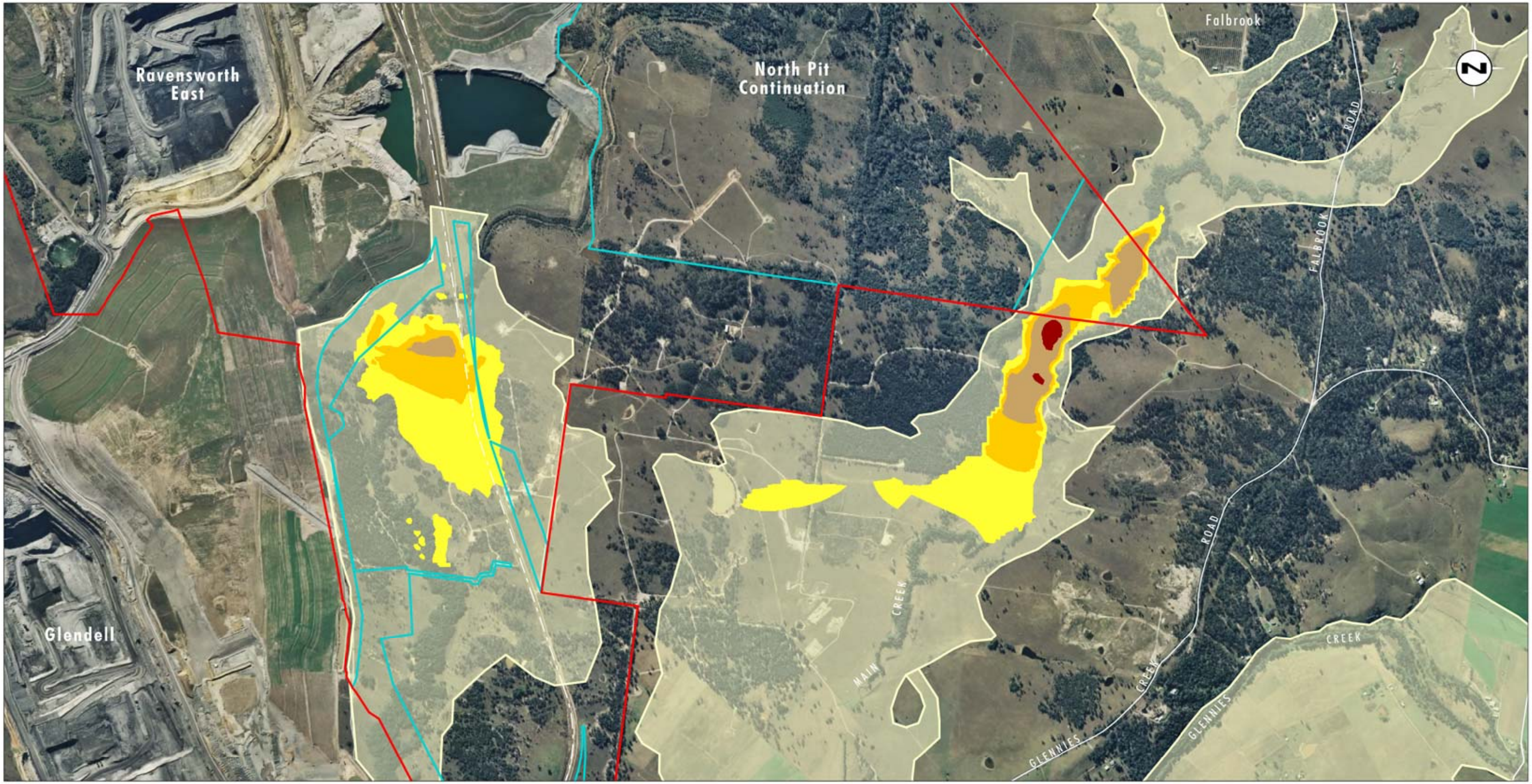


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent

Predicted Drawdown (m)

- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0

FIGURE 2.15

Predicted Median Plus 1 Standard Deviation Incremental Drawdown in Alluvial Aquifers in Year 2025

File Name (A4): R16/ReprotB/3109_1001.dgn
20150709 9.04

umwelt

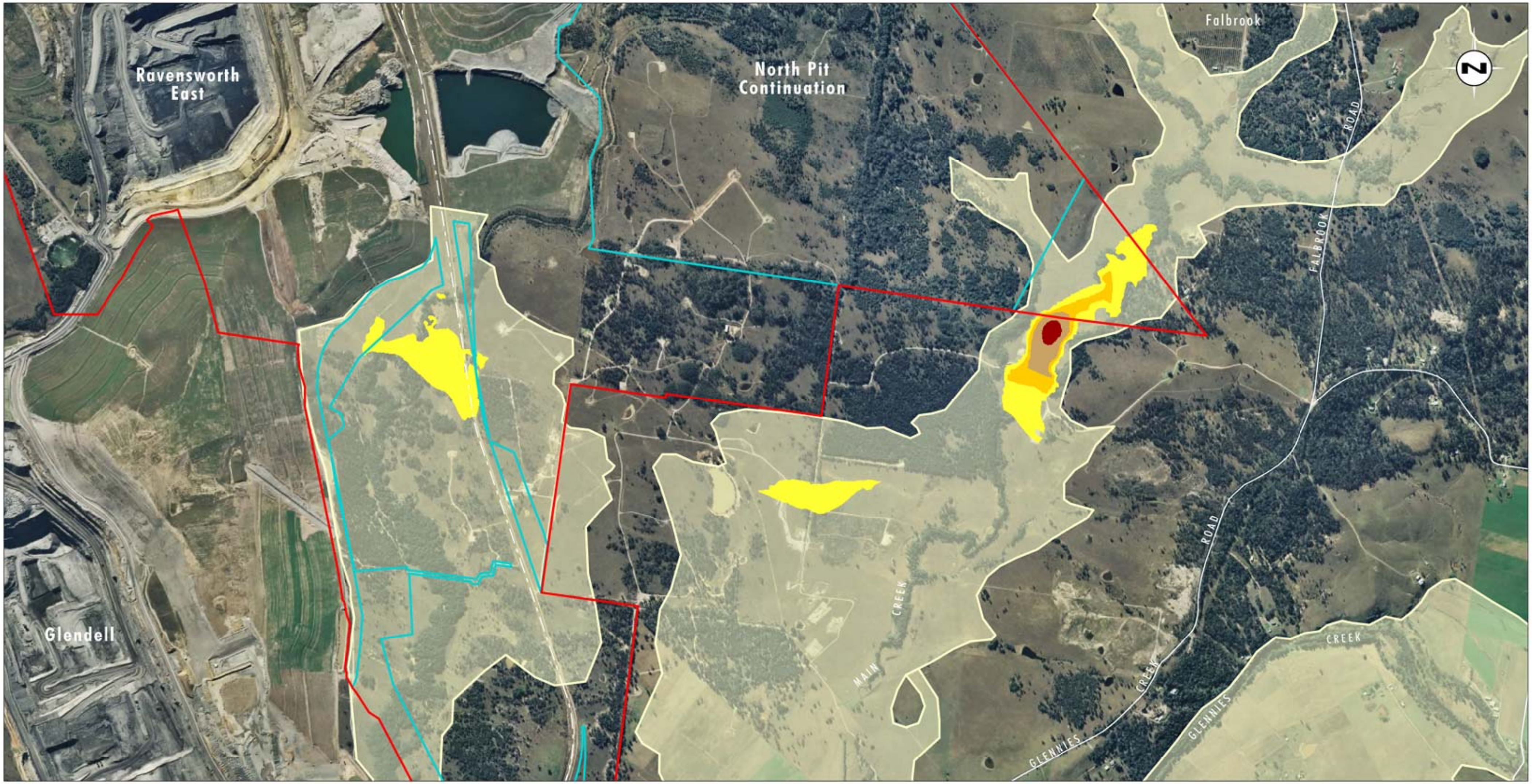


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent

Predicted Drawdown (m)

- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0

FIGURE 2.16

Predicted Median Incremental Drawdown in Alluvial Aquifers in Year 2030

File Name (A4): R16/ReprotB/3109_1002.dgn
20150709 9.04

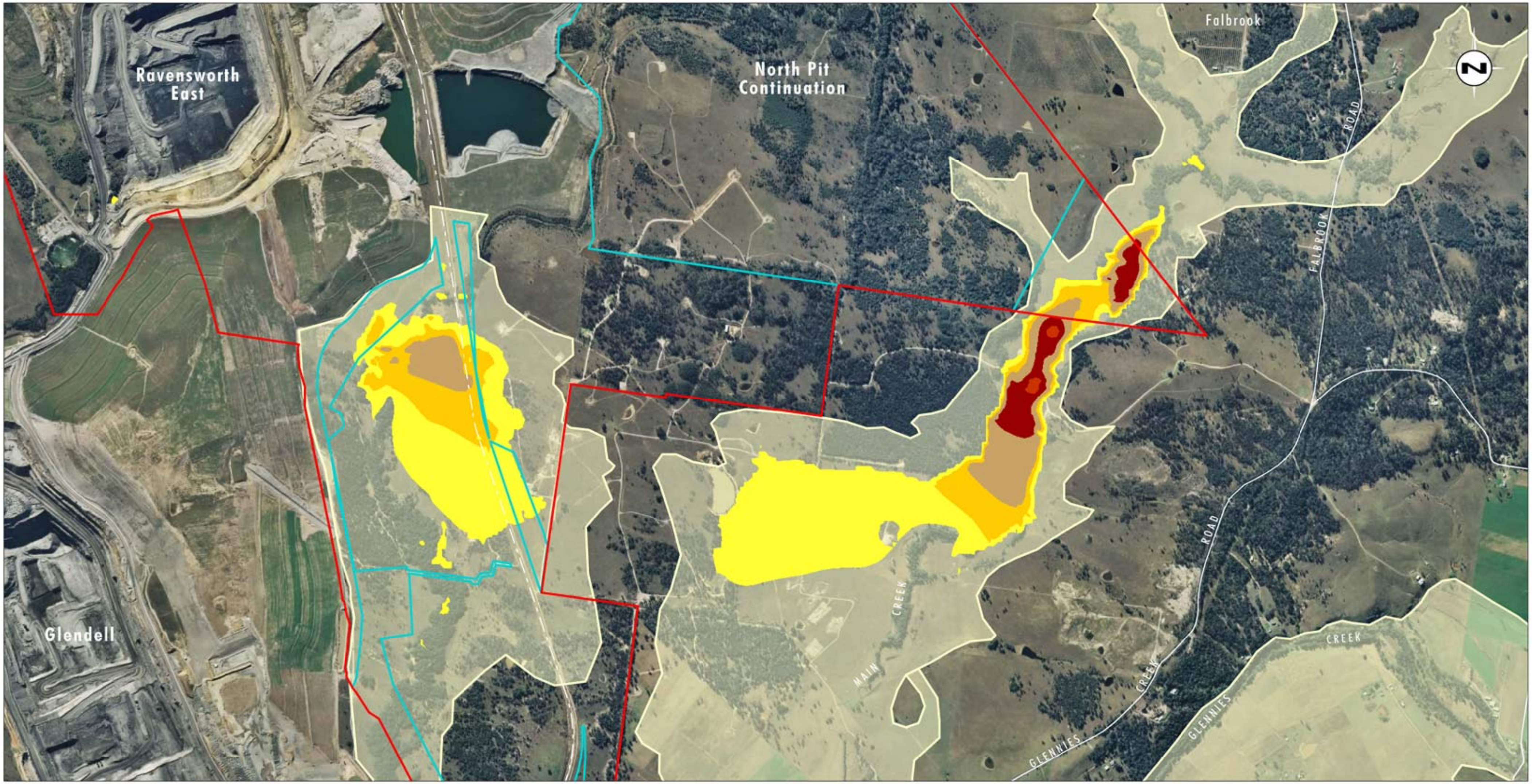


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent

Predicted Drawdown (m)

- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0

FIGURE 2.17

Predicted Median Plus 1 Standard Deviation Incremental Drawdown in Alluvial Aquifers in Year 2030

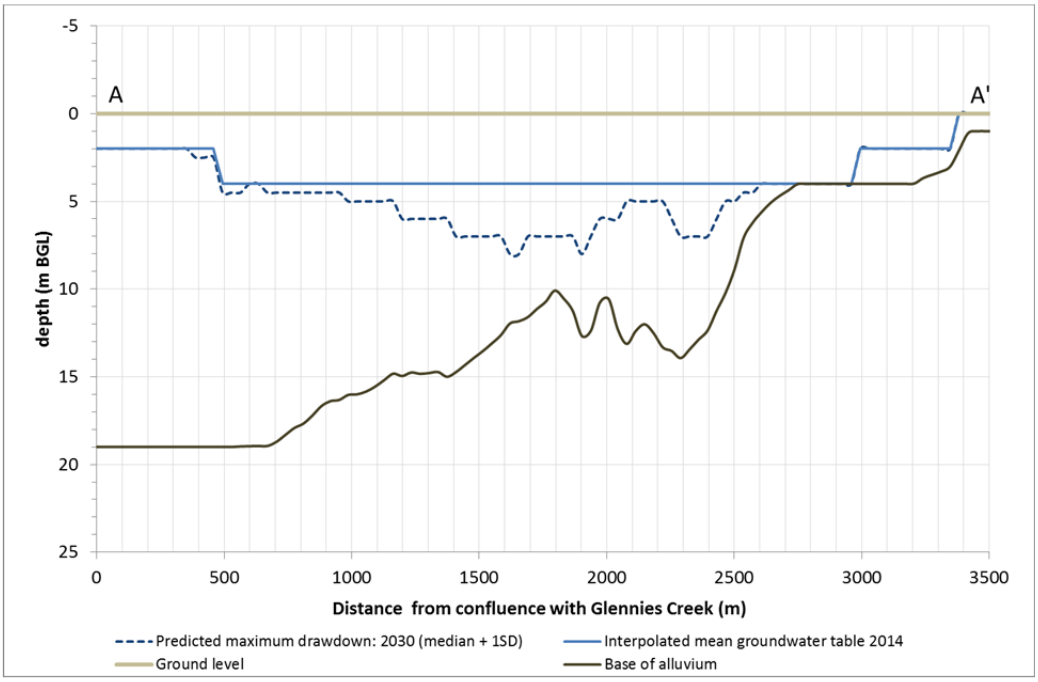


Figure 2.18 Cross-section depicting current and predicted maximum impact watertable depth and alluvium thickness along Main Creek

As can be seen from **Figure 2.18**, even under maximum predicted drawdown (a situation only likely to be observable during extended dry periods), groundwater will remain present in the alluvium below Main Creek in all locations where groundwater is currently present. Accordingly, connectivity between the alluvial aquifer in Main Creek and Glennies Creek will be maintained. A similar situation is expected in relation to the predicted impacts in Bettys Creek where there the predicted drawdown of that aquifer is less than for Main Creek.

2.3.2.3 Impacts on Surface Flows

As shown in **Figure 2.19,** intra-annual variability in alluvium aquifer water levels may range up to 1 metre each year, with greater ranges for shallow water tables in the headwaters (NPZ102, NPZ103). Bore NPZ101, is sighted within the zone of potential drawdown in the Main Creek alluvium and water tables at this site have been relatively constant at just over 4 metres below ground level over the past year. Peak predicted potential additional drawdown may result in an additional 1 metre watertable drop at this location. The alluvium at this location is approximately 13 metres thick. The location of bores shown in Figure 2.19 is shown in Figure 2.9 of the Groundwater Assessment.

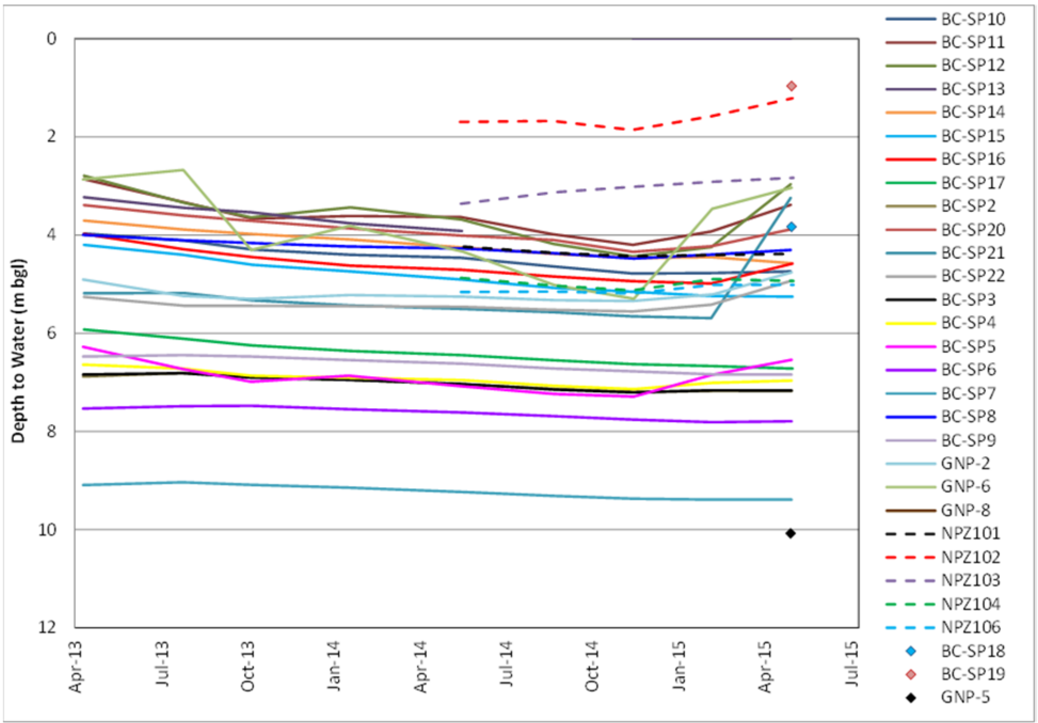


Figure 2.19 Alluvial groundwater levels across the regional model domain over the past two years. New standpipes within the refined model domain are indicated as dashed lines (NPZ101 – NPZ106)

The predicted drawdown in the Bettys Creek and Main Creek alluvial aquifers is limited to the upper reaches of these alluvial systems where the volume of alluvium is relatively small compared to downstream reaches of the creeks. The Main Creek channel is less than 2 metres in depth. All bores in the main channel of the alluvium record groundwater table depths in excess of 4 metres, indicating that the creeks are largely disconnected from the groundwater systems for these tributaries and will not contribute to baseflows in Main Creek or Bettys Creek. Accordingly, the predicted drawdown will have no impact on surface flows in Main Creek and Bettys Creek. This will particularly be the case during drier periods when the water table in the alluvium will be even lower due to lower recharge rates.

As can be seen from **Figures 2.12** to **2.17**, there is no predicted drawdown in the Glennies Creek alluvium with the only predicted impact resulting from the drawdown in the alluvium associated with Main Creek. The predicted median reduction in groundwater flux in Main Creek (2030) is 15ML/year (approximately 0.04ML.day). The reduction in Main Creek alluvial groundwater volumes will have a corresponding reduction in groundwater flowing from the Main Creek Alluvium to the Glennies Creek alluvium with a consequent impact on baseflows. As detailed in Section 3.5.1.1 of the Groundwater Impact Assessment, this estimated leakage rate is equivalent to less than 0.3 per cent of the estimated baseflow contribution to Glennies Creek.

Due to it being a regulated system, Glennies Creek shows no seasonality in its flows (refer to **Section 2.2.1.2**). It follows that the level of predicted impact on base flows in Glennies Creek as a result of the predicted drawdown in Main Creek is considered to be negligible.

2.3.3 Groundwater Impact Summary

The alluvial aquifers associated with the tributaries Main Creek and Bettys Creek are considered less productive alluvial water sources (under the NSW Aquifer Interference Policy (AIP) guidelines) due to their low natural flow volumes, ephemeral conditions and limited extent, depth and condition of the alluvium. The following points summarise the findings of the Groundwater Impact Assessment and the additional assessment documented in this Report.

Water Table Impacts

- No high priority GDEs (refer to **Section 2.4**) or culturally significant sites have been identified within 40 metres of the predicted water table variation areas. Riparian vegetation present in areas of predicted drawdown is not considered likely to be impacted by the predicted drawdowns;
- Model simulations predict drawdown is limited to upper reaches of the Main Creek and Bettys Creek alluviums and there is no predicted drawdown within the Glennies Creek and Bowmans Creek alluvial aquifers;
- Model simulations predict drawdown of greater than 2 metres within 4.5 hectares of the Main Creek alluvial systems. Predicted drawdown of more than 2 metres exceeds the minimal impact criteria specified in the AIP. However, as discussed in **Section 2.4** of this Report and Section 4.3 of the Groundwater Impact Assessment, drawdown impacts in the Main Creek alluvium would not adversely impact, or prevent, the long-term viability of any water-dependent asset;
- Model simulations predict drawdown of up to 2 metres within the Bettys Creek alluvial systems. This is within the minimal impact criteria specified in the AIP. As discussed in **Section 2.4** of this Report and **Section 4.3** of the Groundwater Impact Assessment, drawdown impacts in the Bettys Creek alluvium would not adversely impact, or prevent, the long-term viability of any water-dependent asset; and
- The areal extent of predicted drawdown is localised to small reaches of Main Creek and Bettys Creek. No registered bores are located within the extent of predicted drawdown for either creek. No groundwater users or water supply works are currently identified within the predicted extent of drawdown.

Water Pressure Impacts

- Steady-state post-mining simulations indicate groundwater heads within the Main Creek and Bettys Creek alluvial aquifers recover to levels equal to or above observed levels at the introduction of the WSPs. For Main Creek, the Hunter Regulated River WSP commenced in February 2009, and for Bettys Creek the Hunter Unregulated and Alluvial WSP commenced in August 2009.

Water Quality Impacts

- Model simulations provide no indication that the Project will alter the hydrogeological regime in a manner that would adversely affect groundwater quality within the alluvial aquifers.

2.4 Impacts on Water Dependant Ecological Assets

The Project has potential to impact on water dependant ecological assets through changes in surface flows and impacts to alluvial groundwater systems.
Ecological communities with potential to be impacted by changes in surface water flows or levels of groundwater in the alluvium are:

- Aquatic fauna dependant on base flows linked to alluvial groundwater;
- Stygofauna and hyporheic fauna present in the alluvium and alluvial aquifers; and

- Riparian vegetation or swamps reliant on alluvial groundwater.

The IESC advice included the following comments in relation to predicted impacts on water dependant ecological assets:

> *The effect on the Central Hunter Swamp Oak Forest GDE of lowering the Main Creek alluvial water table has not been addressed within the EIS.* [Paragraph 7]
>
> *The EIS states (App 10, p 92) that no GDEs are associated with Yorks Creek and Swamp Creek. However, the riparian zones of these watercourses are mapped as containing the Central Hunter Swamp Oak Forest which is considered to be a GDE (EIS, App 11, Figure 4.1). The proponent has not mapped or estimated the area inhabited by groundwater dependent riparian vegetation outside of the project area, including within the zone of predicted alluvial impact and downstream of the proposed project area.* [Paragraph 8]
>
> *The proponent states that ephemeral streams represent limited habitat opportunities for aquatic fauna. However, the EIS states in a number of places (for example App 10, p 26 and App 11, p 2.3-2.4) that pools of standing/stagnant water remain in ephemeral streams. These pools may be semi permanent and represent important refugia for aquatic fauna. The ecological assessment does not assess the habitat value, duration of persistence or map the extent or location of these pools.* [Paragraph 9]
>
> *Given the Main Creek alluvium supports known groundwater dependent riparian vegetation that is also habitat known to be utilised by the nationally listed endangered Spotted-tail quoll, information identified in paragraphs 8 and 9 is needed to determine the existing habitat conditions along this watercourse.* [Paragraph 10]
>
> *The proponent has undertaken sufficiently robust ecological stream habitat and aquatic fauna assessments for Bowmans Creek and Bettys Creek. However, equivalent assessments of Main Creek and Glennies Creek have not been provided within the EIS. To understand the existing ecological conditions within, and provide a robust assessment for Glennies and Main Creek, a description of the riparian, in-stream, and alluvial habitat for fauna and flora needs to be provided. This would include:*
>
> *a. mapping of vegetation including in riparian zones and areas of shallow groundwater*
> *b. sampling of GDEs including stygofauna and hyporheic fauna*
> *c. an in-stream aquatic fauna survey (e.g. fish, macroinvertebrates, amphibians)*
> *d. an existing conditions aquatic habitat assessment in line with a national standard (for example using the AUSRIVAS (2007) sampling protocols utilised for Bowmans Creek)*
> *e. the development of ecological conceptualisations using the method described in Commonwealth of Australia (2015) to identify the ecological and water relationships of the Project Area.* [Paragraph 14]

The Project's predicted impacts on aquatic fauna is discussed further in **Sections 2.4.1**.

The Project's predicted impacts on Stygofauna and hyporheic fauna are discussed in **Sections 2.4.2.** The Project's predicted impacts on riparian vegetation and any associated ecological impacts are discussed in **Sections 2.4.3**

2.4.1 Aquatic Fauna

Reductions in surface flows due to reduced catchment areas can impact on the volume of water and duration of flows or persistence of pools in ephemeral systems. This remains relevant to the issues identified in extract from the IESC advice above.

2.4.1.1 Changes in surface flows (impacts of Project relative to existing conditions)

As can be seen from **Table 2.3**, the catchment areas for the creeks impacted by the Project will remain similar to or be larger than the current catchment areas for these creeks during the life of the Project. Only Swamp Creek and Main Creek will experience a reduction in catchment area relative to existing conditions (approximately 5 % reduction in Year 5 in the case of Swamp Creek and approximately 2% reduction in the case of Main Creek) during the life of the Project.

As ephemeral systems, water flow in these systems is dependent on localised runoff. The predicted reduction in flows as a result of decreased catchment in Swamp Creek or Main Creek (relative to existing conditions) is unlikely to be observable given the significant natural variability already present in these ephemeral systems due to the large annual variability in rainfall (refer to **Figure 2.9**). These changes are unlikely to have any measurable impact on aquatic fauna in these creeks given the predicted changes are well within the natural variability already occurring in these systems. In both cases, the final catchment areas of these creeks, following completion of rehabilitation, will increase from what exists at present.

Additionally, the previous diversion of the upper reaches of Bettys Creek into Main Creek means Main Creek currently has (and will continue to have) a larger catchment than existed prior to mining. Accordingly, the Project will have a negligible impact on the volume of water flowing in Main Creek in addition to the persistence of pools. Potential impacts on aquatic fauna present in pools downstream as a result of the Project are also likely to be negligible.

The Project is unlikely to have any negative impacts on the habitat value, duration or persistence of pools of standing/stagnant water present downstream of the Project in the other creeks where there is an increase in catchment area.

As can be seen from **Table 2.3** and **Section 2.2.2**, there are negligible changes to the catchment areas and flow rates for Bowmans Creek and Glennies Creek as a result of the Project and, accordingly, any impacts on aquatic fauna in these creek systems as a result of changes to catchment areas during the life of the Project would similarly be negligible.

2.4.1.2 Changes in surface flows (impact of Project relative to approved landform catchment)

As discussed in **Section 2.2.2.3**, the Project will result in 15% and 19% change in the Bettys Creek and Swamp Creek catchments respectively, relative to the existing approved final landform. However, as discussed above the Project's conceptual final landform will not result in a reduction in the size of the catchments of these creek systems from that which exists presently.

The existing aquatic fauna in both systems will have adapted to the existing flow conditions in these creeks. As the Project will not further reduce the catchment areas for these creeks, there will be no additional impact on the aquatic fauna due to changed flow conditions relative to what has already occurred as a result of the existing approved mining development. The change in catchment areas resulting from the Project is therefore predicted to have no adverse impacts on aquatic fauna in either Bettys Creek or Swamp Creek or any other downstream catchment.

As can be seen from **Table 2.3** and **Section 2.2.2**, there are negligible changes to the catchment areas and flow rates for Bowmans Creek and Glennies Creek as a result of the Project and, accordingly, any impacts on aquatic fauna in these creek systems as a result of changes to final landform catchment areas would similarly be negligible.

2.4.1.3 Groundwater/ surface flow interactions (impacts on persistent pools)

As discussed in **Sections 2.2** and **2.3**, the aquifers in the alluvium associated with Bettys Creek and Main Creek are considered unlikely to contribute to baseflows in the creeks themselves (i.e. the observed water tables are below the bed of creeks). Both creeks have isolated deeper pools which may hold water for extended periods following flows in the creeks ceasing. These pools offer refuge for fauna during periods when there is no running water in the creek.

These water holes in Bettys Creek and Main Creek currently dry out during dry periods and the persistence of the pools is more likely associated with these deeper pools being areas where finer clay materials at the bottom of the pools effectively form a less permeable barrier which prevents water from draining into the alluvium. The persistence is therefore associated with the depth of the pool rather than any connectivity with the underlying aquifer. Observations that the water table is generally disconnected from the creek bed, and drops during extended dry periods, supports the argument that there is unlikely to be any connectivity between these pools and the aquifers during dry periods when the refuge value of persistent pools is more important. The depressurisation impacts associated with the Project will therefore have no impact on these potential refuges and associated aquatic fauna in Main Creek or Bettys Creek.

2.4.1.4 Summary of impacts on aquatic fauna

The creek systems directly impacted by the Project are all ephemeral and persistent pools present in the creek systems dry out completely during dry periods. Aquatic fauna in these systems are already adapted to these conditions.

The predicted impacts on alluvial aquifer systems is not predicted to have any impact on baseflows or persistent pools present in Main Creek or Bettys Creek due to there being no connectivity between the creek bed and the alluvial aquifers in the area of predicted drawdown.

The Project will have a negligible impact on the volume of water in, or the persistence of pools in, Main Creek, Bettys Creek and Swamp Creek. Any potential impact on aquatic fauna present in pools downstream as a result of the Project is likely to be negligible. Further mapping of the extent or location of pools or an assessment of their habitat values, area and duration of persistence in these creek systems is therefore not considered to be warranted.

As discussed in **Section 2.2.2.2** and shown on **Figure 2.7,** the Project will not impact on baseflows in Glennies Creek due to the highly regulated processes within Glennies Creek. The mapping of the extent or location of pools or assessment of habitat value, in and adjacent to Glennies Creek is therefore not considered to be warranted.

2.4.2 Stygofauna and Hyporheic Fauna

The refined groundwater modelling indicates the predicted potential drawdown area within the alluvium is more constrained than was predicted in the model used for the Groundwater Impact Assessment in the EIS. This higher resolution modelling of predicted impacts enables a better understanding of potential impacts on existing ecological communities.

As shown in **Figure 2.18**, the predicted drawdown in the Main Creek alluvial aquifer will not result in a permanent draining of the alluvial aquifer at any point. Even if depressurisation did result in a loss of connectivity between parts of the alluvial aquifers in the upper reaches of the Main Creek alluvium (for example during extreme drought periods), the natural flux in the alluvial system and the higher permeability of the alluvium relative to the permeabilities of the sub-cropping strata means this connectivity (and thus connectivity with the Glennies Creek alluvial aquifer) would be re-established during wetter periods when the alluvium 'fills and spills' (refer to **Figure 2.18**).

The connectivity between the Glennies Creek alluvium and the Main Creek alluvium means there is a strong likelihood that stygofauna and hyporheic fauna species in these areas are similar or identical. There is unlikely to be any stygofauna and hyporheic fauna species present in the Main Creek alluvium that are not also present in the Glennies Creek alluvium and the same applies for the interconnected Bettys Creek and Bowmans Creek alluvium. Any impacts on stygofauna and hyporheic fauna as a result of depressurisation will be localised and in the unlikely event that there is a complete drainage of the alluvial aquifer in isolated areas of the alluvium where there is a predicted drawdown, stygofauna and hyporheic fauna populations will re-establish when connectivity is re-established during wetter periods. Accordingly, no significant impact on stygofauna or hyporheic fauna would be expected and no specific sampling of hyporheic or stygofauna is considered to be warranted either as part of the assessment of the Project or as part of the Surface Water and Groundwater Response Plan.

2.4.3 Riparian Vegetation

2.4.3.1 Potentially Affected Communities

Mapped vegetation types and the location of standpipes recently installed in the alluvium in the areas of Main Creek and Bettys Creek where there are predicted drawdown impacts are shown on **Figure 2.20** with the extent of the predicted potential maximum drawdown (2030 Median + 1SD).

The Central Hunter Swamp Oak Forest community (the main community present in the areas of predicted drawdown in Main Creek and Bettys Creek) and a small area of Hunter Lowland Red Gum Forest mapped as occurring on Main Creek to the east of the North Pit Continuation may possibly be groundwater dependent due to reliance in some circumstances on groundwater in periods of drought. However, these vegetation communities exist further upstream and in other creek systems where there is unlikely to be any significant alluvial groundwater present. This is particularly the case with the Hunter Lowland Red Gum Forest which is mapped as extending well into areas where there is little or no alluvium (refer to **Figure 2.20**) and vegetation in this area would be reliant on soil moisture and rainfall.

The dependence of the Central Hunter Swamp Oak Forest (and in particular, Swamp Oak (*Casuarina glauca)* which is the only species in the Central Hunter Swamp Oak Forest community present in the area of impact which is likely to have a root system deep enough to be in contact with the alluvial groundwater at present), on groundwater in this location will depend on the depth of the root systems of the vegetation and their ability to maximise use of rainfall and surface moisture. The root system of *C. glauca* consists of a dense network of fibres making up the main root ball with numerous lateral and sinker roots extending from it. The deepest sinker roots are present directly below the stem and there is a very even reduction in root depth with distance away from the stem-line (Docker, 2003). A review of literature indicates that *C. glauca* can have a strong reliance (Cramer, 1999) or little reliance (Wei et al, 2013) on groundwater. Most studies of the species have focussed on *C. glauca* growing in swamp like conditions or areas with elevated water tables (0 to 3 metres below ground level) where there is a clear connectivity between the root system and alluvial groundwater. These studies have identified *C. glauca* as having a typically shallow root system to less than 3 metres in depth (see also Docker, 2003). However, in the Hunter Valley, the species is considered to be an opportunistic coloniser that readily colonises areas with little or no groundwater present; for example, the species has been widely observed growing on roadsides where it would be reliant on runoff water and on hill slopes where it would be reliant on runoff and soil moisture.

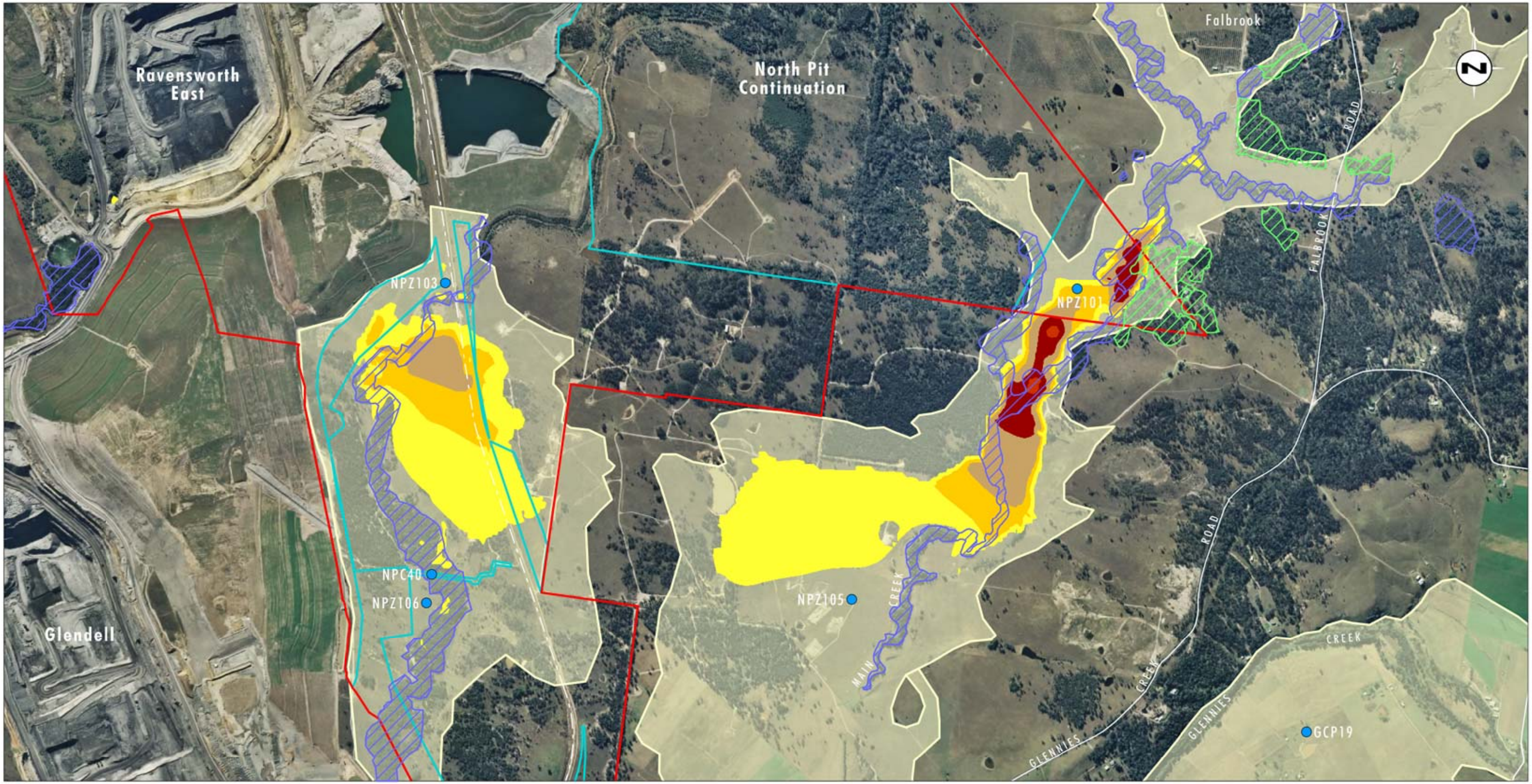


Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent
- Central Hunter Swamp Oak Forest
- Hunter Lowland Red Gum Forest
- Alluvial Groundwater Monitoring Bore Locations

Predicted Drawdown (m)

- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0

FIGURE 2.20

Ecological Communities in Area of Predicted Drawdown (2030 + 1SD)

File Name (A4): R16/ReprotB/3109_1004.dgn
20150714 13.40

Without excavation of trees to determine rooting depth or detailed isotype studies, it will not be possible to determine the likely extent of groundwater use of *C. glauca* present along Main Creek and Bettys Creek. However, this degree of study is not considered to be warranted as, based on the current depth of the water table along Main Creek and Bettys Creek (refer to **Figures 2.18** and **2.19**), it is expected that the species, which is typically shallow rooted, will have little direct connectivity with the groundwater alluvium and is more likely to be reliant on soil moisture. This view accords with the findings in Wei *et al* (2013) however it cannot be ruled out that some sinker roots in larger trees may extend to the alluvial groundwater particularly during wetter periods when the water table in the alluvium is higher. As discussed above, it is during extended dry periods when the drawdown effects in Main Creek and Bettys Creek are likely to be more evident, however it is also noted that the water table during dry periods is also expected to decrease naturally in these periods due to reduced recharge rates resulting in a lower water table.

For the purpose of this assessment, it is assumed that there is potential for some level of groundwater use by the *C. glauca* present in the Main Creek and Bettys Creek alluvial extent however it is highly likely that any use of alluvial groundwater by the species is likely to be opportunistic with the species known to be able to rely on soil and surface moisture alone.

Trees in the Hunter Lowland Red Gum Forest in the area of predicted impact are similarly likely to be opportunistic users of alluvial groundwater but, like the *C. glauca*, this community can be found in areas where groundwater is not present. This community is not considered to be a GDE for the purposes of this assessment.

2.4.3.2 Area of Predicted Impact

As can be seen in **Figure 2.20**, approximately 1 kilometre of the Central Hunter Swamp Oak Forest along Main Creek is located over the area of proposed drawdown of more than 1 metre (i.e. greater drawdown than has been observed in natural fluctuations over the 12 month period to April 2015).

The area of Central Hunter Swamp Oak Forest located over areas of predicted groundwater drawdown is shown in **Table 2.11**.

Table 2.11 Area of Central Hunter Swamp Oak Forest Located in Areas of Predicted Drawdown in Alluvium (2030 Median + 1 SD)

Alluvial System	Area (Ha)					
	Predicted Drawdown					Total
	0 – 0.5 m	0.5 – 1 m	1 – 2 m	2 – 3 m	3-4 m	
Main Creek Alluvium - Central Hunter Swamp Oak Forest	13.68	10.49	8.36	3.86	0.34	36.73
Bettys Creek Alluvium - Central Hunter Swamp Oak Forest	4.85	2.17	0.60	0	0	7.62
Total area of Central Hunter Swamp Oak Forest exceeding predicted drawdown	18.53	12.66	8.96	3.86	0.34	44.35
Percentage of community in area of predicted drawdown	42%	29%	20%	9%	<1%	

The level of groundwater observed at piezometer NPC40 (located on Bettys Creek in Central Hunter Swamp Oak Forest) when installed in 2008 was approximately 8 to 9 metres below ground level, a similar level to the lowest predicted water table (medium +1 SD) along Main Creek. It would be expected that the level of the water table on Bettys Creek at this location would have been even lower during the drought ending in mid 2007, as indicated by the fluctuations observed at piezometer North (refer to Figure 2.11 in the Groundwater Impact Assessment). Piezometer NPC40 is no longer functional, however NPZ106 is located in a similar location and indicates the current water table at that location is approximately 5 metres below ground level. The *C. glauca* (and Central Hunter Swamp Oak Forest community generally) along Bettys Creek in this area remain healthy indicating an ability to survive in areas where groundwater is more than 5 metres below the surface and a tolerance to fluctuations of a further 3-4 metres below this during period of drought. This magnitude of fluctuation and depth to groundwater occurring naturally is similar to or greater than that predicted to occur in Main Creek under the Project scenario (refer to **Figure 2.19** and **Table 2.11**), however, as noted above, the drawdown caused by the depressurisation of the underlying aquifers will be slow, with the effect only likely to be noticeable during extended dry periods due to much faster fluctuations associated with the natural variability in the system.

To the extent that there is groundwater dependence by *C. glauca*, the plants in the immediate area of predicted impact on groundwater levels already have a demonstrated tolerance to lower water tables than are predicted to result from the Project and can handle large fluctuations in groundwater levels. Additionally, it is noted that the maximum drawdown predicted from the Project will occur over an extended period (approximately 15 years) at a steady rate that would enable root growth in the *C. glauca* to adapt to the change and send down seeker roots to 'follow' the water to greater depths. The long timeframe for drawdown impacts to occur (>10 years) is considered to be sufficient to allow the *C. glauca* to adapt to lower groundwater levels to the extent that it is reliant on them. Accordingly, it is not expected that the predicted drawdowns in the Main Creek and Bettys Creek alluvium will have a significant impact on either individual trees, the species more broadly or the communities present.

Based on the 2030 Median + 1 SD predictions, approximately 70% of area of Central Hunter Swamp Oak Forest in the area of impact is predicted to experience drawdowns less than the fluctuations observed in these systems over the past 12 months (i.e. up to 1 metre). As such, the impact on the community in this area will be negligible. Approximately 13 hectares of Central Hunter Swamp Oak Forest community is located in areas of predicted groundwater drawdown of between 1 and 4 metres, however, less than 0.5 hectares is predicted to experience drawdowns of more than 3 metres.

2.4.3.3 Nature of Potential Impacts

It should be stressed that the Central Hunter Swamp Oak Forest community is not listed as a threatened ecological community, nor is *C. glauca* listed as a threatened species. The area of Central Hunter Swamp Oak Forest on the Main Creek alluvium potentially impacted is very small in the regional and even local context. Even if all of the community in the area of predicted drawdown of more than 2 metres was lost or diminished in size (approximately 4 hectares), this loss would not be significant given the broader occurrence of the community and species both locally and regionally. These areas of potential impact are to be contrasted to the estimated 1,217 hectares of Central Hunter Swamp Oak Forest present in the Upper Hunter (Peake, 2006). Significantly smaller areas of impact are predicted under the 2030 Median impact predictions.

As noted in the IESC advice, the significance of any impact on this community is through the potential impacts to terrestrial fauna movement that may result if vegetation in the area of predicted drawdown is impacted. The spotted-tailed quoll is the key species of concern in this regard.

In the event that die back of *C. glauca* does occur on either Bettys Creek or Main Creek in the area of observed impact, the process would be slow with other tree species, less reliant on groundwater, opportunistically growing and replacing the *C. glauca.* Increased abundance of the Hunter Lowland Red Gum Forest could be expected with potentially greater ecological benefits than that provided by *C. glauca* and the Central Hunter Swamp Oak Forest community due to this communities increased species diversity. The Hunter Lowland Red Gum Forest is already present in the less disturbed areas of the Main Creek alluvium and the upper reaches of Swamp Creek and Main Creek and it is likely that this community was more abundant in alluvial areas of both creeks prior to clearing activities in the 19th and 20th centuries. There is a reasonable likelihood that the dominance of the Central Hunter Swamp Oak Forest along the lower reaches of Bettys Creek and Main Creek is the result of opportunistic colonisation by *C. glauca* into riparian areas where Hunter Lowland Red Gum Forest was removed by clearing activities rather than it being endemic. Accordingly, any management process which transitions the Central Hunter Swamp Oak Forest to the Hunter Lowland Red Gum Forest community therefore should not be viewed as a negative ecological outcome. In the event of dieback being observed in the *C. glauca*, the planting of tree species found in the Hunter Lowland Red Gum Forest community is a viable management measure which would assist in maintaining the existing connectivity provided by the Central Hunter Swamp Oak Forest.

In the worst case scenario, the localised dieback of *C. glauca* would not result in the loss of all vegetation along the creek and understorey species are likely to increase in abundance in the absence of *C. glauca* and continue to provide habitat for ground species such as the spotted-tailed quoll. Further, any transition to the Hunter Lowland Red Gum Forest community would see connectivity maintained.

Management measures focussed on retaining the habitat connectivity are considered to be more important than maintaining the Central Hunter Swamp Oak Forest community whose presence in the area may be an artefact of opportunistic colonisation following clearing rather than historical presence in the area. Additionally, management actions that increase the resilience of understorey species, particularly in dry weather (for example fencing of riparian corridors), would further mitigate any impacts that die-back in overstorey species may have on fauna movement. Potential mitigation measures and the triggers for their implementation will be developed as part of the revision of the Surface Water and Groundwater Response Plan (refer to **Section 2.5**) The loss of individual *C. glauca* trees would not result in a loss of habitat connectivity and, to the extent that the impacted vegetation is used by species such as the spotted-tail quoll, any impacts on movement are likely to be minimal.

Given the impacts on water levels in the alluvium will not occur for 5 years from commencement of the Project and the potential impacts on vegetation (if any) are well understood and will be restricted to a defined area (refer to **Table 2.11** and **Figure 2.20**). Mitigation measures are available to mitigate (and even reverse) these potential impacts. Accordingly, the vegetation assessment identified in the IESC advice is not considered warranted at this stage of the development assessment process. However, due to the uncertainties regarding the extent of *C. glauca* reliance on alluvial groundwater, some level of monitoring will be required as the Project progresses to identify any unexpected consequences and appropriate mitigation measures. This is discussed further in **Section 2.5.1.4.**

2.4.4 Use of Ecological Conceptualisations in Assessment Approach

It is noted that the document *Modelling water-related ecological responses to coal seam gas extraction and coal mining* (Commonwealth of Australia 2015) was released during finalising of preparation of the EIS for the Project and accordingly was not considered as part of the assessment process.

Notwithstanding, as discussed above**,** the predicted impacts on GDEs (including stygofauna and hyporheic fauna) are expected to be minimal in both scale and magnitude based on an understanding of both hydrogeological systems and ecological functioning in the area of impact.

While it is recognised that an ecological conceptualisations approach is appropriate for Projects with larger predicted impacts, or potential impacts on particularly sensitive or vulnerable communities, this additional level of assessment suggested in the IESC advice in relation to surface water ecological communities and stygofauna and hyporheic fauna is not considered to be warranted in the present circumstances for the reasons identified in **Section 2.4** above.

2.5 Impact Mitigation and Management Strategies

The IESC has sought additional information on the management strategies currently employed at the Mount Owen Complex to avoid, mitigate and manage potential impacts and any proposed changes to these strategies to manage any new or changed risks associated with the Project.

2.5.1 Management Plans

The existing *Mount Owen Complex Water Management Plan (approved November 2014)* includes the sub plans:

- Erosion and Sediment Control Plan (approved July 2014)
- Surface Water Monitoring Plan (approved November 2014)
- Groundwater Monitoring Plan (approved August 2014)
- *Surface Water and Groundwater Response Plan* (approved July 2014).

Copies of these plans are available on the Mount Owen Complex website http://www.mtowencomplex.com.au/EN/EnvironmentalManagement/Pages/PlansandPrograms.aspx.

Table 2.13 outlines the current requirements for plans related to water management at Mount Owen, and revisions proposed to the existing plans should the Mount Owen Continued Operations Project be approved, in addition to relevant triggers for such revisions.

Table 2.13 Summary of Existing Water Management Plans and Proposed Revisions

Current Planning Consent Requirements		Current Objectives / Requirements	Proposed Management Plan Revisions	Review Triggers
Mount Owen (DA 14-1-2004)	**Ravensworth East (DA 52-03-099)**			
Water Management Plan	Water Management Plan	Outlines relevant development consent, EPL, water licence and other statutory requirements Outlines design criteria for clean, dirty and mine water Outlines water management system components, including schematic, water storages Outlines predicted water inflows, including proposed catchment area changes over mine life, groundwater inflows Outlines predicted water outflows Overview of tailings management strategy Outline of reporting requirements	Update consent and EPL details and water licence (as required) Update target design criteria for dirty water Update water schematic, storages (as required), including provision of off-line storage capacity adjacent to Ravensworth East MIA, sedimentation dams as required Update catchment area changes, predicted groundwater inflows Update predicted water outflows Update tailings management strategy Consultation with relevant agencies regarding changes	Water Management Plan to be updated within 12 months of Project approval.
Site water balance	Site water balance	Measure: • Water use on site • Water transfer across site • Water transfer between site and surrounding mines • Review site water balance annually • Report results in annual review	Update description of site water balance and future prediction Update description of integration with GRWSS water balance model Description of review requirements for site and GRWSS water balance models	Water balance models to be reviewed within 3 years of Project approval
Erosion and Sediment Control Plan	Erosion and Sediment Control Plan	Primarily concerned with management of dirty water Overview of soil landscapes within the Complex Description of erosion and sediment control measures (in general accordance with Department of Housing's *Managing Urban Stormwater: Soils and Construction* manual)	Update description of soil landscapes with findings of Agricultural Impact Statement Update target design criteria for dirty water Consultation with relevant agencies regarding proposed changes to Plan	
Surface Water Monitoring Plan	Surface Water Monitoring Plan	Regular monitoring includes: surface water flows and quality upstream and downstream of the development in Yorks Creek, Swamp Creek, Bettys Creek and Main Creek; channel stability in Yorks Creek, Swamp Creek, Bettys Creek and Main Creek; • waterlogging adjacent to the lower reaches of Main Creek; • long term monitoring of the condition of the Swamp Creek diversion channel and potentially affected downstream watercourses; and • reporting the results of this monitoring in the annual review	Inclusion of an additional monitoring point on Main Creek (MC3) Inclusion of a trigger (low pH based) to undertake expanded suite of water quality analysis in sedimentation dams Inclusion of site specific trigger values for relevant parameters Annual monitoring of seepage and runoff from pit walls and floors and coal stockpiles for any evidence of ARD and metalliferous drainage. Parameters include pH, EC, acidity/alkalinity, SO_4, Ca, Mg, K, Na, Cl, Al, As, Co, Cu, Fe, Mn, Ni and Zn. Annual field monitoring of pH and EC in water in tailings storages should also be undertaken with monitoring of the following additional parameters in the event of low pH	Monitoring at MC3 to commence upon Project approval. Progressive update of monitoring program as new sedimentation dams are constructed.

Current Planning Consent Requirements		Current Objectives / Requirements	Proposed Management Plan Revisions	Review Triggers
Mount Owen (DA 14-1-2004)	**Ravensworth East (DA 52-03-099)**			
			readings which may indicate ARD or metalliferous drainage: acidity/alkalinity, SO_4, Ca, Mg, K, Na, Cl, Al, As, Co, Cu, Fe, Mn, Ni and Zn	
Ground Water Monitoring Plan	Ground Water Monitoring Plan	Regular monitoring includes: volume of ground water seeping into the open cut mine workings; regional groundwater levels and quality in the surrounding aquifers; groundwater pressure response in the surrounding coal measures; and reporting the results of this monitoring in the annual review	Inclusion of groundwater monitoring points installed as part over last 2 years, as part of data gathering for development of groundwater model. Installation and inclusion of additional piezometer in area of maximum predicted drawdown in Main Creek alluvium. Installation and inclusion of additional piezometer in area of maximum predicted drawdown in Bettys Creek alluvium. Review of groundwater monitoring program in relation to analyte sampling, in consultation with NOW	Installation of new piezometers to commence as soon as practicable after Project approval.
Surface and Groundwater Response Plan	Surface and Ground Water Response Plan,	Outlines protocol for the investigation, notification and mitigation of any exceedances of impact assessment criteria Procedures to be followed if any unforeseen impacts are detected	Update to include review schedule of groundwater model Revised to include a TARP associated with larger than predicted impacts to the hard rock aquifer system. Include trigger for future revision to include a TARP associated with larger than predicted impacts on alluvial systems Revision to be in consultation with OEH	First review of groundwater model to be within 5 years of Project commencement.

The effectiveness of the existing management measures implemented at Mount Owen are assessed annually as part of the Annual Environmental Management Report required under the Mining Act and Annual Review required under the conditions of the Mount Owen development consent. The Plans themselves also include periodic review requirements. In addition to the reviews undertaken by Mount Owen, the effectiveness of these management plans is assessed as part of the Independent Environmental Audit process undertaken every three years pursuant to the terms of the Mount Owen development consents. The most recent Independent Environmental Compliance Audit was undertaken in 2014 and there were no issues identified in relation to the water management systems. A copy of the report on this audit can be found at:
http://mtowencomplex.com.au/EN/ReportsandPublications/Pages/Audits.aspx

As discussed in Section 6.0 of the EIS, Mount Owen will continue to manage operations at the Mount Owen Complex in accordance with the Mount Owen Complex Water Management Plan (associated subplans), the EPL and the HRSTS. Mount Owen have committed to revising the exiting Mount Owen Complex Water Management Plan to reflect the Project in relation to surface water and groundwater monitoring and management measures as described in Section 6.0 of the EIS. As discussed in the EIS, these plans will also be revised throughout the life of the Project as the Project progresses and additional monitoring data becomes available.

These Plans will be prepared in consultation with relevant government agencies and must be approved by the DP&E prior to implementation.

The following sets out additional detail regarding some of the key changes to monitoring requirements identified in the EIS and this Report.

2.5.1.1 Response Protocols for Overflows from Dirty Water System

The response protocols for overflows from the dirty water system are covered by the *Mount Owen Complex Surface Water and Groundwater Response Plan* and *Mount Owen Complex Surface Water Monitoring Program*.

These plans outline the following steps for initial overflows and the subsequent monitoring requirements.

Water Management Response Actions

Investigate discharge, considering any mitigating factors where applicable:

- report discharge as per legislative requirements for incident reporting; and
- review adequacy of existing water management infrastructure and controls.

Criteria Exceedance Protocol

Mount Owen will monitor surface water and groundwater in accordance with the *Surface Water and Groundwater Monitoring Program.* If the surface water or groundwater monitoring reports/result(s) are outside the surface water and stream health impact assessment criteria or maximum reported groundwater quality results outlined in these programs, further investigations are required. As part of such investigation, Mount Owen will:

- confirm the timing and general location of the exceedance(s);
- confirm the meteorological conditions at the time of the exceedance(s) (where relevant);

- identify any potential contributing factors;
- assess the monitoring results against background trends to identify any anomalies or causes;
- if the exceedance is not attributable to activities associated with the Mount Owen Complex, the routine monitoring program will be assessed for its effectiveness;
- where the exceedance is potentially attributable to activities associated with the Mount Owen Complex, appropriate mitigation and management strategies will be developed and implemented;
- where mitigation and management strategies have been implemented additional monitoring and regular reviews will be undertaken to measure the effectiveness of the strategies undertaken; and
- the exceedance will be reported in accordance with the reporting mechanisms outlined in the Surface Water and Groundwater Monitoring Programs.

Revised Monitoring Requirements

As discussed in **Section 2.1.3**, the key risk to water quality as a result of spills from the dirty water system are related to elevated TSS levels. During spill events, water quality of the spill water is already monitored for TSS, TDS, EC and pH. This monitoring regime will be continued.

In the event that the field test for pH indicates low pH, the water samples collected will also be analysed for acidity/alkalinity, SO_4, Ca, Mg, K, Na, Cl, Al, As, Co, Cu, Fe, Mn, Ni and Zn to identify whether any metals and metalloids that may be present in the overburden material have been mobilised.

In the event of low field pH readings in the spill water, monitoring of water quality upstream and downstream from the point of inflow of spill water to creek will also test the same suite of parameters.

2.5.1.2 Additional Water Quality Monitoring

Main Creek

As noted in Section 8.1.4 and Figure 2.3 of the Surface Water Assessment water quality will continue to be monitored at two points upstream of the Proposed North Pit Continuation (MC1 and MC2) and at a new monitoring point (MC3) downstream of the Project Area.

There are no proposed discharges from the Mine Water Management System into Main Creek and the only potential water quality impacts on Main Creek are associated with spills from the dirty water management system during rainfall events which are higher than the design criteria for sediment dams under the Blue Book.

Consistent with existing requirements, monitoring at MC1, MC2 and MC 3 will be limited to TSS, TDS, EC and pH. Regular monitoring for metals, metalloids, PAHs and ionic compositions at these locations is not considered warranted given the nature of the risk presented by the Project. In the event that there is a low pH recorded in water spilling from a dirty water system, the water sample from the sediment dam discharge point and water samples from upstream and downstream monitoring locations will be tested to identify any potential changes in metals and metalloid concentrations (refer to **Section 2.2.7**).

Pit seepage and runoff from waste rock areas

Consistent with the recommendations in the EGI report (refer to **Section 2.2.7**) the annual water quality monitoring programme will include monitoring of seepage and runoff from pit walls and floors, waste rock dumps, coal stockpiles and washery waste disposal areas to check for any evidence of ARD and metalliferous drainage, and identify any need for additional controls. Parameters will include pH, EC, acidity/alkalinity, SO_4, Ca, Mg, K, Na, Cl, Al, As, Co, Cu, Fe, Mn, Ni and Zn.

2.5.1.3 Additional Groundwater Monitoring

There are piezometers currently installed in the alluvium in each of Bettys Creek and Main Creek. Six of these (including all three in Main Creek) have only been installed and monitored since 2012. These monitoring points are considered to be sufficient for monitoring changes in alluvial groundwater systems. Longer periods of monitoring of piezometers NPZ101-NPZ106 will provide a better understanding of natural variability within the Bettys Creek and Main Creek alluvial systems. Piezometer NPZ101 is located close to the area of maximum predicted drawdown however the predicted drawdown in this area is less than 1 metre. An additional standpipe piezometer in the Main Creek alluvium in the area of maximum predicted drawdown is proposed. Similarly, an additional standpipe piezometer located in the area of maximum predicted drawdown in Bettys Creek is also recommended. Other existing piezometers in hardrock aquifer systems are appropriately located to monitor changes in aquifers that are associated with the predicted drawdown in the alluvial aquifers.

The existing Surface Water and Groundwater Response Plan included in the Mount Owen Water Management Plan will be updated to include requirements for monitoring changes in alluvial groundwater levels.

Based on the groundwater modelling predictions (refer to **Section 2.3**), there is unlikely to be any impact on these alluvial systems for at least 5 years after the Project commences and any such impacts are unlikely to be significant (refer to Section 4.0 of the Groundwater Impact Assessment). Notwithstanding the predicted low level of impact, Trigger Action Response Plans (TARPs) will be developed and included in the Surface Water and Groundwater Response Plan to ensure any unexpected impacts are identified and appropriate mitigation and management measures implemented. Initially, this TARP will not be developed around observations of groundwater levels in the alluvium. The existing monitoring data in the area of maximum predicted drawdown is not presently considered to be adequate to set statistically robust triggers in the TARP. However, based on the modelling there is sufficient time to obtain additional monitoring to better inform the setting of appropriate and statistically robust trigger levels for TARPs based on monitored changes in alluvial groundwater levels that have regard to natural variability.

The Surface Water and Groundwater Response Plan will be updated within 12 months of approval to reflect the Project. Until sufficient baseline data is collated in relation to alluvial groundwater levels, the Surface Water and Groundwater Response Plan will utilise monitoring information in hard rock aquifer bores for setting triggers in the TARP with management measures implemented if larger than predicted impacts on hardrock aquifer systems are observed. The Plan will be reviewed and updated to include a TARP based on observations in the alluvial aquifers prior to the predicted impacts occurring. This will be undertaken in line with the periodic review of the groundwater model as additional data and monitoring results become available. This approach is considered appropriate to ensure predicted impacts on the alluvial groundwater systems are monitored and the need for any mitigation measures assessed through the life of the Project are based on the best available data. The selection of triggers and mitigation measures will be considered by appropriate regulatory agencies prior to implementation of any variations to the Surface Water and

Groundwater Response Plan. The TARPs will be reviewed throughout the life of the Project as discussed in **Section 2.5.1.**

2.5.1.4 Riparian Vegetation Monitoring

The existing Surface Water and Groundwater Response Plan will be updated to include requirements for monitoring of the ecological condition of vegetation communities potentially impacted by changes in alluvial groundwater levels. This plan will also include analogue sites in areas of the alluvium that are not predicted to be impacted by the Project as well as upstream locations where the community is present in areas where there is minimal alluvium.

In the event of an observable impact, reasonable and feasible management options would be implemented. As noted in **Section 2.3.3.3**, these management options would be focused on improving the resilience of existing riparian vegetation and the maintenance of habitat connectivity generally and may include:

- Planting of tree species less reliant on groundwater;
- Additional vegetation planting adjacent to creek lines to reduce reliance on riparian vegetation for connectivity; and/or
- Fencing of riparian vegetation to remove grazing pressures on ground and understorey species during dry periods.

The selection of management measures associated with any observed impact to riparian vegetation should have regard to the nature of the identified impact and its cause and any potential lag time between impact and effectiveness of the proposed management measure(s).

The monitoring and management measures that may be required in response to any potential groundwater impacts on the Main Creek and Bettys Creek alluvial systems (including TARPS) will be developed in consultation with relevant government agencies and finalised and implemented prior to any predicted impacts on alluvial ground water levels (Year 5 of the Project).

2.5.1.5 Final Landform Planning and Monitoring

As part of the mine closure planning process, Mount Owen has committed to undertake further groundwater modelling associated with mine closure to assist in refining the final landform, with this modelling to commence at least 5 years from cessation of mining. This modelling will update groundwater modelling predictions and evaluate the long term pit lake hydrochemistry and water level that will prevail post closure.

As a means to confirm the ongoing management and land use strategy associated with the void, a Final Void Management Plan incorporating the outcomes of the above groundwater assessments will be developed and included in the Final Closure Plan. The Final Closure Plan will be submitted to the appropriate regulatory agencies for approval two years prior to cessation of mining.

Further details regarding the development of the Final Closure Management Plan are discussed in the Mine Closure and Rehabilitation Strategy (Appendix 18 of the EIS).

3.0 Department of the Environment (DotE)

As discussed in **Section 1.0**, the submission received from the DotE during the exhibition period for the EIS recommended that a response to the matters raised in their submission be provided in relation to the following:

- Further information regarding the proposed offsets (pending this information, further offsets are likely to be required and details of these should be provided); and
- A detailed description of the mitigation proposed as part of their EIS.

This section includes the comments from the DotE submission (bold, italics) and a detailed response to each comment.

3.1 Impacts - Threatened species and ecological communities

The Department considers that significant impacts are likely to occur for:

- ***the Spotted-tail Quoll;***
- ***the Regent Honeyeater;***
- ***the Swift Parrot; and***
- ***the Koala - the proponent has identified that, using the Referral Guidelines, 163.7 hectares of habitat critical to its survival (a score higher than 5) will be cleared as part of the Project. According to the guidelines, such an impact at this scale is significant to the Koala.***

In light of the information presented in the EIS, the Department does not consider that significant impacts are likely to occur regarding the Green and Golden Bell Frog and the New Holland mouse**.**

The Assessments of Significance in Appendix F of the Ecological Assessment concluded that the Project was unlikely to result in a significant impact on the spotted-tailed quoll (*Dasyurus maculatus maculatus*), swift parrot (*Lathamus discolor*), regent honeyeater (*Anthochaera phrygia*) and koala (*Phascolarctos cinereus*).

For the endangered spotted-tailed quoll, swift parrot and regent honeyeater, no significant impact was concluded as the Project was unlikely to lead to a long-term decrease in a population of these species, fragment existing populations, adversely impact habitat critical to the survival of these species, disrupt the breeding cycle of these species, impact the habitat to the extent that these species are likely to decline, introduce a disease or interfere with the recovery of these species as per the criteria in the Significant Impact Guidelines 1.1 (DotE 2013). It is understood that the DotE consider these species to be significantly impacted due to the Project reducing the area of habitat available for these species.

The Matters of National Environmental Significance (MNES) Report in Appendix 4 of the EIS assessed the koala against the (then) draft Koala Referral Guidelines (DotE 2013) which concluded that the potential habitat for the species in the Proposed Disturbance Area scored higher than ‘5’, indicating habitat critical for the species. Despite this, the Project was found unlikely to substantially interfere with the recovery of the species as per Table 3 of the draft Koala Referral Guidelines (DotE 2013). In addition, no significant impact was concluded due to the low occurrence of records in the Project Area and low occurrence of known koala feed trees in the Proposed Disturbance Area. It was not considered that an important population of the koala occurred within the Proposed Disturbance Area and therefore the species was unlikely to be significantly impacted as per the criteria in the Significant Impact Guidelines 1.1 (DotE 2013).

It is, however, acknowledged that the Project would result in the loss of potential habitat for these species in the Upper Hunter and therefore the Biodiversity Offsetting Strategy has been developed to provide offsets of suitable habitat for these species in the Upper Hunter. As such, Umwelt assessed the adequacy of these offsets against the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Environmental Offsets Policy and the application of the EPBC Act Offset Calculator Guide.

Representatives from Umwelt, Mount Owen and DotE met on 3 July 2015 to discuss the outcomes of the EPBC Act Offset Calculator. As identified in the DotE submission, proposed Biodiversity Offset Sites adequately offset the koala. This species is not further discussed in this response. Offset adequacy for the spotted-tailed quoll, swift parrot and regent honeyeater were further discussed and in response to this, further information is provided in this Report on the offsets in relation to these species.

This is examined further in the context of the response to issues raised by DotE on offsets in **Section 3.1.2** below.

It is noted that the EPBC Act listing for the regent honeyeater has been upgraded from ‘endangered’ to ‘critically endangered’, effective from 8 July 2015. The re-issued Conservation Advice for the species (TSSC 2015) contains updated information on the regent honeyeater population size reduction that makes the species eligible for the ‘critically endangered’ listing. Under s158A of the EPBC Act, this change is not applicable to the Project impact assessment and offsetting requirements as the listing change was made after the Project was declared a ‘controlled action’. The Conservation Advice for regent honeyeater (TSSC 2015) has been reviewed. Although the species has not been recorded on the site despite almost 20 years of annual monitoring, the biodiversity offsetting strategy aims to provide a gain in box-gum woodland in the Hunter Valley with substantial regeneration works in the current grassland habitats of the proposed offset sites. The proposed offset is consistent with the Conservation Advice.

3.2 Offsets

The Department has recently released a policy that endorses the FBA and the BioBanking methodology for EPBC Act Offset purposes. Where a project demonstrates compliance with these endorsed methodologies, the EPBC Act Offsets Policy would not need to be applied. The Department understands that this proposed project falls within the 'transitional period' of the new offsetting policy and that therefore the endorsed policies have not been applied in full. On this basis, the EPBC Act Offsets Policy still applies for this project.

Regarding the EPBC Act Offsets Policy, insufficient information is currently provided in the EIS to apply the Offsets Policy in full. This information was requested as part of the supplementary DGRs and the Department's adequacy review. In the absence of this information, the Department has run an indicative assessment based on the available information.

The information requested in the Supplementary DGRs (as provided on 8 November 2013) and the adequacy review (dated 19 February 2014) was provided in the MNES Report which was included as Appendix 4 of the EIS. Table 1.1 of the MNES Report provides a cross reference to all information requirements from DotE and the section in which they are addressed.

Currently, the offsets proposed (Cross Creek Offset Site, Esparanga Offset Site and the Stringybark Creek Habitat Corridor Regeneration Strategy) meet approximately 75%, 34%, 28% and 110% of the EPBC Act Offset Policy requirements for the Spotted-tail Quoll, Regent Honeyeater, Swift Parrot and Koala, respectively. Further offsets are therefore likely to be required for a number of the species, and should be investigated as part of the Response to Submissions and Preferred Project Report.

The original Umwelt assessment resulted in the following offset calculator outcomes presented in **Table 3.1** for the spotted-tailed quoll, swift parrot and regent honeyeater.

Table 3.1 – Umwelt EPBC Offset Calculator Outcomes as presented in Section 7.9 of the Ecological Assessment

Species Assessed by Offset Calculator	Calculated Proportion of Impact Addressed by Offsets			
	Cross Creek Offset Site	Stringybark Creek Habitat Corridor	Esparanga Offset Site	Total Value of Offset Sites
spotted-tailed quoll *(woodland impacts)*	73 %	12 %	22 %	107 %
spotted-tailed quoll *(grassland impacts)*	42 %	33 %	31 %	106 %
swift parrot	130 %	31 %	69 %	230 %
regent honeyeater	129 %	30 %	59 %	218 %

The DotE assessment included a range of key differing approaches to that of the Umwelt assessment such as:

- separating the woodland impacts by age-class;
- not including the restoration of Esparanga or Stringybark Creek;
- substantially lower confidence percentages for the 'risk of loss' scores; and
- excluding a range of eucalypt habitats for the swift parrot and regent honeyeater.

Table 3.2 below outlines the outcomes of the DotE assessment.

Table 3.2 – DotE EPBC Offset Calculator Outcomes

Species Assessed by Offset Calculator	Calculated Proportion of Impact Addressed by Offsets							
	Cross Creek Offset Site		Stringybark Creek Habitat Corridor		Esparanga Offset Site		Total Value of Offset Sites	
	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)
spotted-tailed quoll	118%	16%	-	7%	-	52%	118%	75%
swift parrot	287%	9%	-	5%	-	14%	287%	28%
regent honeyeater	358%	11%	-	5%	-	17%	358%	33%

A briefing note response to the DotE EPBC Offset Calculator Assessment was sent to DotE on 18 June 2015 (refer to **Appendix D**). A range of differences between the approaches undertaken by Umwelt and DotE were examined in this briefing note and during the meeting of 3 July 2015. These differences are further addressed below and expand on the information provided in the briefing note.

Woodland Impact Age Classes

One of the key differences in the Umwelt and DotE assessments is the approach taken in assessing woodland impacts within the Proposed Disturbance Area. DotE separated impacts to younger (30 year old) and more mature (57 year old) vegetation in the Proposed Disturbance Area. The application of these impacts were then separated at the offset sites i.e. restored grasslands at the offset sites were used to address 30 year old woodland and the existing woodland at the offset sites were used to address the 57 year old woodland. This is a thoroughly different approach to Umwelt's approach which included all woodland (regardless of broad age classes) as one assessment.

The approach taken by Umwelt is consistent to that taken for other similar Projects submitted to DotE for approval. Using all woodland age-classes together has been a consistent approach for other similar assessments including the North Parkes Extension Project, and more local projects such as the Terminal Four (T4) Project, Bulga Optimisation Project and the adjacent Liddell Coal Operations Project. In DotE's response to these assessments, woodland impacts were not separated into age classes. Of particular note, the Bulga Optimisation Project EPBC Calculator Assessment was undertaken for the swift parrot and regent honeyeater using the same approach and was accepted, unchanged, in the Preliminary Documentation provided to the (then) DSEWPC in October 2013. DotE feedback from the Liddell Project Calculator Assessment allowed the restoration of grasslands to woodland for the spotted-tailed quoll, but did not separate the age classes of the woodland habitats in the Project Area, even though the Project Area included both older and younger vegetation stands.

It appears that DotE have, for the purposes of undertaking its offset calculations, broadly treated all of the Central Hunter Ironbark – Spotted Gum – Grey Box Forest in the Proposed Disturbance Area as being mature woodland (57 years old) with all other woodland/forest communities as being regenerated woodland (30 years old). An examination of the 1983 set of photographs (shown in Figure 2.2b of the Ecological Assessment) shows that the majority of the woodland within the Proposed Disturbance Area present at that time (and therefore currently older than 30 years) occurs along Bettys Creek, and in regenerated patches in the North Pit Continuation impact area. This comprises approximately 56 hectares of woodland vegetation however the DotE calculator assessment uses a number of 131.9 hectares of apparently mature (older than 30 years and up to 57 years old) Central Hunter Ironbark – Spotted Gum – Grey Box Forest for the impact calculations. It also appears that riparian vegetation, such as Central Hunter Swamp Oak Forest has been included in the regenerated (30 year old) impact calculations when, according to the aerial photography, this vegetation has been present along Bettys Creek since the 1950s and is therefore at least 60 years old.

Additionally, the age-classes for woodland in the DotE assessment of offsets were not separated in a similar fashion to that of the Proposed Disturbance Area. For example, the woodland at the Cross Creek Offset Site ranges from large mature eucalypt-dominated areas along drainage lines (**Plate 3.1**) to the younger isolated patches of regrowth likely to be regenerating after many years of grazing pressure (**Plate 3.2**). Vegetation communities at Esparanga are similarly variable with mature woodland occurring on the ridges of the site (**Plate 3.3**) and regenerating woodlands on the edges of grassland (**Plate 3.4**).

PLATE 3.1
Mature vegetation at Cross Creek Offset Site

PLATE 3.2
Regrowth at Cross Creek Offset Site

PLATE 3.3
Mature vegetation at Esparanga Offset Site

PLATE 3.4
Regenerating Woodland at Esparanga Offset Site

For comparative purposes, Umwelt applied the woodland age-class separation in DotE's approach and then amended these assessments by including the restoration of habitats (to 57 years) at the Stringybark Creek and Esparanga offset sites (further discussed below) and the inclusion of all eucalypt habitat as habitat for the swift parrot and regent honeyeater (further discussed below) in the offset calculations; no adjustment was made to the areas of different age classes in the Proposed Disturbance Area used by DotE despite there being concerns that DotE areas overstate the amount of woodland greater than 30 years old. This comparative assessment identified that the proposed offsets exceeded the 90% minimum direct offset threshold for koala, spotted-tailed quoll, swift parrot and regent honeyeater.

The separation of these woodland age-classes appears to be overly complicated and unnecessary given the outcomes of the Umwelt assessment and the comparative assessment provided similar results and offsets over the 90% threshold required by the Policy.

While it is acknowledged that the separation of habitat age classes may be appropriate for some species that have specific age-related requirements in habitats (such as the New Holland mouse, a successional species known to occur in habitats disturbed in the last 5 years, with the age of vegetation correlating to increases and decreases in habitat use), the approach is considered to be inappropriate for the species which are the subject of this assessment.

The approach taken by Umwelt to collectively assess the woodland habitat as a whole is considered appropriate for the species assessed. For example, both regenerating and more mature woodlands are capable of providing flowering and lerp resources for swift parrot and regent honeyeater. Swift parrots were recorded in young planted eucalypts adjacent to the Bulga site car park in 2012 (in the Lower Hunter approximately 24 kilometres south of Mount Owen) and also in more mature flowering eucalypts in Ravensworth State Forest in 2005, 2007 and 2014. In addition, the spotted-tailed quoll is known to forage and den in a range of vegetation ages as seen in monitoring surveys across the Mount Owen Complex, including within Ravensworth State Forest, mine rehabilitation and planted regeneration of varying age classes.

<u>Inclusion/Exclusion of Restoration at Esparanga and Stringybark Creek</u>

DotE excluded the regeneration and restoration works at the Stringybark Creek and Esparanga Offset Sites in their calculation assessment for spotted-tailed quoll, swift parrot and regent honeyeater. This is presumably because the younger woodland offset (30 year) (using the DotE approach) is covered for all species through the regeneration of grassland into woodland firstly at the Cross Creek Offset Site. However regeneration at the Esparanga and Stringybark Creek sites is still relevant for habitat gains for other impacts on mature woodland. These areas should not be ignored in providing suitable habitat for species over a greater 'time until ecological benefit' timeframe. Indeed, the EPBC Offsets Calculator specifically provides functionality to increase the 'time until ecological benefit', which subsequently discounts the overall offset outcome (favouring prompt ecological benefits over delayed ones). The *'How to Use the Offsets Assessment Guide'* guidance note for use of the calculator explains that, in the context of the 'time until ecological benefit' parameter, *"revegetation actions may take decades to provide the required improvement".*

It has been suggested by DotE that, in principle, its approach of separating out age classes of vegetation was undertaken to assess "like-for-like" offset value (i.e. regenerated woodland for regenerated woodland). However, it is noted that there is no specific "like-for-like" requirement in the eight principles of the EPBC Act Offsets Policy (DSEWPC 2012, pg 16-24) and therefore there is no reason to exclude these restored areas for offsets for mature woodland impacts provided the appropriate values for the 'time until ecological benefit' are used in the calculator.

For comparative purposes, Umwelt applied the woodland age-class separation in DotE's approach and then amended these assessments by including the restoration of habitats (to 57 years) at the Stringybark Creek and Esparanga offset sites to the offset calculations, by entering the 'time until ecological benefit' as 57 years. Along with other amendments (discussed above and below) the comparative assessment provided overall similar results and offsets over the 90% threshold required by the Policy for all species assessed.

Eucalypt-dominated Woodlands for Swift Parrot and Regent Honeyeater

Umwelt concluded that all eucalypt-dominated woodland would be suitable habitat for swift parrot and regent honeyeater within the Proposed Disturbance Area and the offset sites. However, the DotE EPBC Act Offset Calculator Assessment restricted this to just spotted gum-ironbark woodlands. This is further discussed in **Table 3.5** and in the sections below.

Umwelt Comparative Assessment

Umwelt have taken the assessments by DotE (refer to **Table 3.2**) and applied the restoration of Stringybark and Esparanga grasslands to the offsets for mature (57 year old) woodland for the species with offset deficits and included all eucalypt-dominated woodland habitat to the offset calculations for swift parrot and regent honeyeater. These amendments are shown in **Table 3.3** below which indicates that the ecological benefits provided by the three offset sites, including the restoration of woodland and forest habitat, would provide sufficient offsetting for the spotted-tailed quoll, swift parrot and regent honeyeater using the EPBC Act Offset Calculator. Note: the 'Risk of Loss' scores in this comparative assessment used the values adopted in the DotE approach.

Table 3.3 – Umwelt Comparative Assessment

Species Assessed by Offset Calculator	Calculated Proportion of Impact Addressed by Offsets							
	Cross Creek		Stringybark Corridor		Esparanga		Total Value of Offset Sites	
	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)
spotted-tailed quoll	118%	16%	-	7% + 12% from restoration	-	52% + 22% from restoration	118%	109%
swift parrot	100%#	12% + 41%† from residual restoration	-	5% + 11% from restoration	-	51% + 18%+ from restoration	100%	138%
regent honeyeater	102%^	15% + 43%* from residual restoration	-	5% + 11% from restoration	-	62% + 22%+ from restoration	102%	158%

Notes:
^ 90 hectares of restoration
*225.3 hectares of restoration
#110 hectares of restoration
†205.3 hectares of restoration
+91 hectares of restoration

Of note, the Department recommends that the proponent revise the vegetation types being proposed to offset impacts to the Central hunter lronbark- Spotted Gum- Grey Box Forest. As these woodlands are up to 57 years old, the use of regenerating grassland habitats in the EPBC calculator to offset impacts to is not consistent with the "like for like" principal of the Policy. It is unlikely that the regeneration of this habitat will achieve a similar ecological benefit as that provided by the 57 year-old woodland in a period of 20 or 30 years, as is required by the EPBC Act Offsets Policy.

The Biodiversity Offset Strategy has been prepared in accordance with the EPBC Act Offsets Policy (DSEWPC 2012) and the eight Offset Principles (as described in Section 7.8.2 of the Ecological Assessment and Section 7.1 of the MNES report). The eight Offset Principles are as follows:

1. Suitable offsets must deliver an overall conservation outcome that improves or maintains the viability of the protected matter.

2. Suitable offsets must be built around direct offsets but may include other compensatory measures.

3. Suitable offsets must be in proportion to the level of statutory protection that applies to the protected matter.

4. Suitable offsets must be of a size and scale proportionate to the residual impacts on the protected matter.

5. Suitable offsets must effectively account for and manage the risks of the offset not succeeding.

6. Suitable offsets must be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs.

7. Suitable offsets must be efficient, effective, timely, transparent, scientifically robust and reasonable.

8. Suitable offsets must have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced.

As noted above, there is no “like-for-like” requirement in the eight principles of the EPBC Act Offsets Policy (DSEWPC 2012, pg 16-24). The Umwelt EPBC Act Offsets Calculator Assessment used restored grasslands at the offset sites as offset for all the woodland vegetation occurring across the Proposed Disturbance Area. The restoration of these areas, along with the maintenance and management of existing woodland habitats, would provide a net gain in woodland habitats in the Hunter Valley. This is further discussed in the section above on the exclusion of restoration works at the Esparanga and Stringybark Creek sites.

On-site mine site rehabilitation was also not considered as an offset measure in the Department's EPBC offset calculations due the time delay involved in rehabilitating a currently active mine site.

The Umwelt Offsets Calculator Assessment also did not consider mine site rehabilitation in the Biodiversity Offset Strategy, however it is noted that the spotted-tailed quoll is known to occur in existing mine rehabilitation within the Mount Owen Complex (refer to section below regarding the ‘risk of loss’ for spotted-tailed quoll).

Mount Owen has committed to undertaking a final landform rehabilitation strategy (as discussed in Section 6.2 of the Ecological Assessment and Section 5.16 of the EIS) across the Project Area to mitigate the impacts that would occur as a result of the Project. The rehabilitation of post-mining areas is predicted to provide a long-term benefit to the ecological values of the Project Area and wider locality. Mount Owen has had considerable success in re-establishing vegetation communities on mine spoil by working closely with researchers from the University of Newcastle to develop vegetation communities trending towards the Central Hunter Ironbark – Spotted Gum – Grey Box Forest EEC and providing known habitat for 11 threatened species.

Conceptual mine plans (Years 1, 5, 10 and final landform) for the Project (as outlined in Figures 2.9 to 2.12 of the EIS) show the progression of the North Pit Continuation and rehabilitation works across the Proposed Disturbance Area. Year 1 is expected to result in the loss of approximately 15 hectares of native woodland vegetation and 6 hectares of derived native grassland. By Year 5, mining in the North Pit Continuation will have progressed in a southerly direction with a total loss of approximately 95 hectares of native woodland vegetation and 18 hectares of derived native grassland. No progression of rehabilitation is expected in the Proposed Disturbance Area in Year 1 or 5 however rehabilitation will have continued to progress in other areas of the Mount Owen Complex. Year 10 represents the southernmost extent of the North Pit Continuation mining limit with approximately 171 hectares of native woodland vegetation and approximately 79 hectares of derived native grassland to be cleared by this stage. By Year 10, approximately 21 hectares of mine rehabilitation will have been completed in the northeast of the North Pit Continuation impact area (i.e. within the Proposed Disturbance Area) targeting the restoration of Central Hunter Ironbark – Spotted Gum – Grey Box Forest consistent with current rehabilitation practices undertaken at Mount Owen. This rehabilitation is in addition to the progressive rehabilitation of other areas within the Mount Owen Complex (as is shown in Figures 2.9 to 2.12 of the EIS). There will be minimal additional vegetation impacts associated with the Project beyond Year 10 of the Project.

The proposed Biodiversity Offsets Sites will be actively managed as offsets by Year 1 of the Project, that is, the regeneration of vegetation communities in the existing grasslands is expected to be at least 10 years old by Year 10 of the Project. This includes approximately 465 hectares of currently derived native grassland at the Cross Creek, Esparanga and Stringybark Creek Offset Sites that will contain 10 year old regenerated woodland at the Year 10 stage of the Project. By the end of the life of the Project, these regenerated areas will be approximately 20 years old. Based on the age class of the areas of regrowth vegetation characteristic of the Project Area, regenerated communities of an approximately 20 year age class are considered likely to provide significant ecological values in a regional context.

Existing woodland communities in the Biodiversity Offset Sites will be at least 20 years older at the end of the life of the Project. The existing woodland communities at the Biodiversity Offset Sites range from regenerating (less than 10 years old) to mature (potentially up to 80 years old) and collectively include approximately 291 hectares of existing woodland/forest vegetation. The biodiversity values of these areas will be further enhanced through ongoing management and monitoring including weed and pest control, perimeter fencing and revegetation as required.

The final percentages output from the EPBC Act Offsets Policy are likely to increase marginally with greater confidence in results dependent on the proponent providing more information relating to the following matters:

- ***Risks of loss associated with the offset sites:***

- ***The Department requested in the adequacy review that the proponent provide more information regarding: the risk of damage, degradation or destruction to any proposed offset site(s) in the absence of any formal protection;***

- ***Information is required on the current and proposed tenure for the offset sites (e.g. conservation covenant or state conservation area). The specific mechanisms that will be used to secure these offsets need to be clearly outlined, as does any difference in mechanisms proposed between the two "offset" sites and the Stringybark regeneration strategy.***

Cross Creek Offset Site

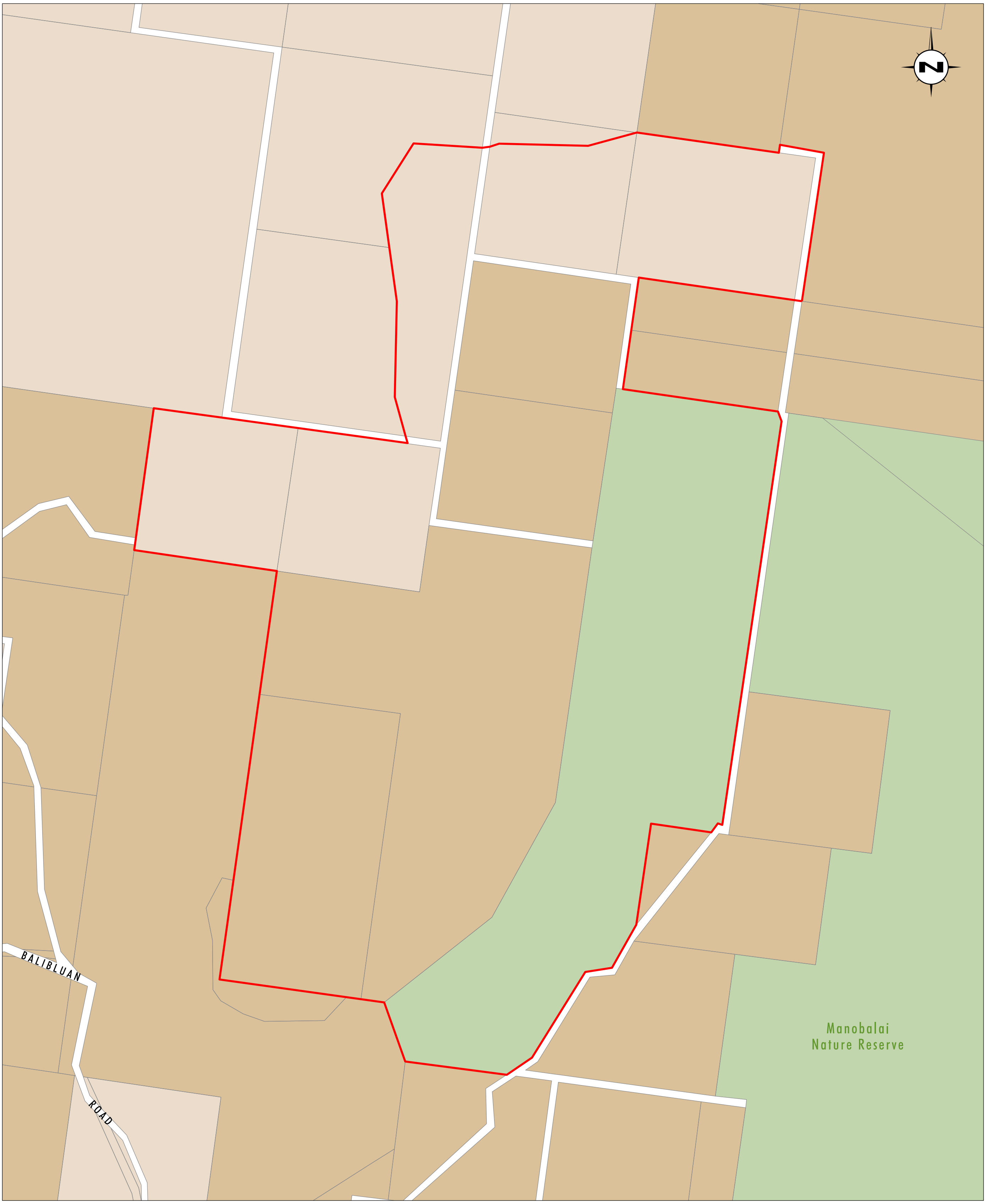
The Cross Creek property is not adjacent to the Mount Owen (or any Glencore) mining lease. The likelihood of the area containing coal is very low as it is located in a barren area east of the Hunter Thrust Fault. The tenure of this site is freehold and privately owned by Glencore. The site is entirely zoned RU1 – Primary Production under the Singleton LEP 2013. Extensive agriculture, forestry, and intensive plant agriculture are all permissible without consent and a wide range of other development is permissible with consent in the RU1 zone. Certain native vegetation disturbance activities associated with routine agricultural activities can also be undertaken without any further approval requirements.

If the Cross Creek Offset Site is not used as an offset site, it is likely the area would be sold by Glencore with the land likely to be used for agricultural purposes. Potential clearing and increased grazing intensity in woodland areas would be required to make this property commercially viable as a farming enterprise. This would likely result in the loss of some of the woodland habitats on the site.

DotE scored the risk of habitat loss without the establishment of the offset site at only 10% for all of the species assessments, with a confidence score of only 40%. Given that the likelihood of future economic extraction of coal is minimal, but the potential for woodland habitat clearance is moderate, the Umwelt calculator assessment scored the risk of loss without the establishment of the offset site at 20% for all the species assessments, with a confidence in this score of 90%. This risk of loss score is considered to be conservative and appropriate given the potential for agricultural improvements without the establishment of the offset and therefore there is a high level of confidence for this score.

Esparanga Offset Site

The Esparanga property is not within or adjacent to a Glencore mining lease. The site lies approximately 10km northwest of Mangoola within AUTH 286. Although there is some potential for coal in this area, the seams are at depths exceeding 500m (based on inferred depths from a borehole >5km distant) which is currently not viable for extraction. The eastern boundary abuts Manobalai Nature Reserve. The tenure of this site is freehold and is privately owned by Glencore. The site is zoned RU1 – Primary Production (approximately 82 hectares), E3 – Environmental Management (approximately 130 hectares) and E1 – National Parks and Nature Reserves (approximately 85 hectares) under the Muswellbrook LEP 2009 (refer to **Figure 3.1**). Extensive agriculture (grazing) is permissible without consent in both the RU1 and E3 zones. Intensive Plant agriculture is also permissible in the RU1 zone. Certain native vegetation disturbance activities associated with routine agricultural activities can also be undertaken in all zones without any further approval requirements. The land zoned E1 – National Parks appears to be in error as this is privately owned and is not regulated under the *National Parks and Wildlife Act 1974*. While this zoning would prohibit agricultural activities, existing use rights would apply to this land meaning agriculture can continue to be carried out. Further, these existing use rights would enable consent to be sought for other impermissible uses that may be inconsistent with the E1 zoning. If the land is not used as an offset, it is likely that a rezoning of this E1 land would be sought to reflect



Data Source: Mount Owen (2013), Muswellbrook LEP 2009

Legend

- Esparanga Offset Site
- E1 National Parks and Nature Reserves
- E3 Environmental Management
- RU1 Primary Production

FIGURE 3.1

LEP Zoning for the Esparanga Offset Site the private ownership of the land. Even if rezoned to E3, grazing would remain permissible without consent in this area.

If the Esparanga Offset Site is not used as an offset site, it is likely the area would be sold by Glencore with the land likely to be used for agricultural purposes. Potential clearing and increased grazing intensity in woodland areas would be required to make this property commercially viable as a farming enterprise in the applicable LEP zones. This could occur in any wooded areas of the property.

DotE scored the risk of habitat loss without the establishment of the offset site at 10% for all of the species assessments, but with a confidence score of only 40%. Given that the likelihood of future economic extraction of coal is minimal and the site is located adjacent to a conservation area and zoned mainly for environmental purposes, the Umwelt calculator assessment also scored the risk of loss without the establishment of the offset site at 10% for all the species assessments, but with a confidence in this score of 90%. As with the Cross Creek offset site, this land would be used for grazing and/or other agricultural purposes that may require woodland clearance if not set aside for offsetting. Given the likely improvements to the land necessary to make the property commercially viable as a grazing enterprise, the assumed risk of loss of 10% is considered to be conservative and the high confidence score is considered to be appropriate.

Stringybark Creek Habitat Corridor

The Stringybark Creek Habitat Corridor site is adjacent to a Glencore mining lease and a portion of it (13%) falls within AUTH 423. There is a moderate likelihood of the area containing coal as there is potential for the eastern portion of the area to be intersecting the Greta Coal Measures, the Maitland Group and/or the Wittingham Coal Measures. It is also contiguous with areas that are already considered to preclude mining such as the Yorks Creek Voluntary Conservation Area (VCA) to the south, the New Forest Area to the north and east and the North West Offset Area to the east. The tenure of this site is freehold and privately owned by Mount Owen. The site is entirely zoned RU1 – Primary Production under the Singleton LEP 2013. Extensive agriculture, forestry and intensive plant agriculture are all permissible without consent and a wide range of other development is permissible with consent in the RU1 zone. Certain native vegetation disturbance activities associated with routine agricultural activities can also be undertaken without any further approval requirements.

Without the establishment of the offset site, the Stringybark Creek Habitat Corridor would be used for agricultural purposes which are applicable in the LEP zoning of the site. The site also has a moderate likelihood of coal resources and may be further investigated for open-cut coal mining. Additionally, the increased spread of African olive (*Olea europaea* subsp. *cuspidata*) has the potential to suppress native species growth and regeneration which may degrade the remaining woodland communities on the site.

DotE scored the risk of habitat loss without the establishment of the offset site at only 10% for all of the species assessments, with a confidence score of only 40%. Conversely, the Umwelt calculator assessment scored the risk of habitat loss without the establishment of the offset site at 40% for all the species assessments, with a confidence in this score of 90%. The assumed risk of loss of 40% and the confidence score is considered to be appropriate given the potential for future extraction of coal and degradation of the existing ecological values due to potential clearance of woodland habitats to enable economically viable grazing and the invasion of African olive into woodland communities.

Conservation Mechanisms

The Biodiversity Offset sites will be secured for long-term conservation. The offset lands will be secured through the available and appropriate mechanisms listed in Section 126L of the *Threatened Species Conservation Act 1995* (TSC Act) and be determined in consultation with the relevant government agencies. The management of the sites will consider the criteria listed in Principle 5 of the *'Biodiversity Offsets Policy for Major Projects'* and the eight principles outlined in the *'EPBC Act Environmental Offsets Policy'*. The same conservation mechanisms would be used at all three proposed offset sites, including the Stringybark Creek Habitat Corridor.

- ***Changes in quality in the offset sites:***

The changes in quality scores for the species assessed by Umwelt in the EPBC Offset Calculator Assessment were described in detail in Appendix H of the Ecological Assessment and are reiterated below for those species highlighted by DotE.

It should be noted that generally, the Umwelt and DotE assessments differed only slightly in the habitat quality scores and were generally consistent with losses and gains depending on the establishment (or otherwise) of the offset sites.

Spotted-tailed Quoll

At each of the three offset sites the establishment of the offset site and implementation of proposed management measures will result in the habitat quality for spotted-tail quoll being of equal or higher value than the habitat quality of the Proposed Disturbance Area, which was assigned as being 5.

Esparanga Offset Site

Spotted-tailed quoll woodland habitat quality was assessed as currently 6 out of 10 at the Esparanga Offset Site with known presence of the species established during targeted surveys and the identification of well connected habitat. Habitat quality at Esparanga Offset Site will remain at 6 without the offset due to the environmental zoning attributes and currently highly connected habitat in the site. The Esparanga Offset Site will increase from 6 to 7 as an offset site with an increase in quality associated with the removal of grazing and improved connectivity between habitat areas.

Cross Creek Offset Site

Woodland habitat quality at the Cross Creek Offset Site is currently low at 3 due to the isolated and disturbed nature of the woodland habitat. Without the offset, the quality of habitat will decrease to 2 due to likely increased grazing pressure. The Cross Creek Offset Site is expected to increase from a quality score of 3 to 6 with the establishment of the offset site due to the removal of grazing pressures and the increase of connected habitats through the restoration of surrounding grassland habitats.

Stringybark Creek Habitat Corridor

Woodland habitat quality at the Stringybark Creek Habitat Corridor is currently low at 3 due to the isolated and disturbed nature of the woodland habitat. Without the offset, the quality of habitat will decrease to 2 at the Stringybark Creek Habitat Corridor due to the threat of African olive (*Olea europaea* subsp. *cuspidata*) invasion and establishment which can result in the suppression of native species growth and regeneration, limiting biodiversity and the availability of prey resources for the species. The Stringybark Creek Habitat Corridor site is expected to increase from a quality score of 3 to 6 with the establishment of the offset sites that will include specific management measures to control African olive.

Restoration of Grasslands

Umwelt also considered grassland as habitat for quoll whereas DotE do not consider this habitat for the impact calculations. Spotted-tailed quolls are likely to utilise open grassland habitats to traverse between areas of higher quality woodland habitat (as per radio-tracking data from Mount Owen). Consequently, Umwelt acknowledged that this habitat is not of high quality for the species by rating it low (quality score of 3 out of 10). This was also the original method used to assess the offset requirements for the species for the adjacent Liddell Coal Operations Extension Project. Glencore and DotE have since negotiated the Liddell assessment approach and agreed that impacts on grassland were not to be considered in the EPBC Offsets Calculator for the spotted-tailed quoll. \For the purposes of the assessment comparison below, Umwelt have adopted the DotE approach of not including grassland in the impact calculation.

However, the calculations that were undertaken found that the grassland habitat quality from the active management and regeneration to woodland habitat would provide equal habitat qualities to the surrounding woodlands over a 20 year timeframe. At each of the three offset sites, the grassland returned to woodland will achieve an equivalent habitat quality score to woodland areas of the Proposed Disturbance Area which was assigned as being 5.

<u>Swift Parrot</u>

At each of the three offset sites the establishment of the offset site and implementation of proposed management measures will result in the habitat quality for swift parrot being of equal value to the habitat quality of the Proposed Disturbance Area, which was assigned as being 6.

Esparanga Offset Site

Swift parrot woodland habitat quality was assessed as currently 4 out of 10 at the Esparanga Offset Site as although potential habitat for the species occurs at the site, it has not been recorded. Few specific threats to eucalypt woodland are known at the Esparanga Offset Site and therefore habitat quality will remain at 4 without the offset. Although some grazing pressure may occur without the establishment of the offset, it is unlikely this will substantially reduce the quality of the woodland habitats at the site. Establishment of this site as an offset will improve the habitat value for swift parrot from a quality score of 4 to 6 due to an increase in quality, improved connectivity of habitat areas and reduction in threats (agricultural pressures, weeds and pests).

Cross Creek Offset Site

Woodland habitat quality at the Cross Creek Offset Site is currently low at 4 due to the isolated and disturbed nature of the woodland habitat. However, the score does take into account nearby records in Ravensworth State Forest. Without the offset and associated management measures, the value of the habitat will continue to deteriorate as a result of ongoing (and potentially increased) grazing pressure and associated agricultural management activities which can result in the suppression of native species growth and regeneration reducing biodiversity and the availability of resources for target fauna species. The value of the swift parrot habitat at the Cross Creek Offset Site, if not used as an offset site, will decrease to 3 due to these factors. Establishment of this site as an offset will improve the habitat value for swift parrot from a quality score of 4 to 6 due to an increase in quality, improved connectivity of habitat areas and reduction in threats (agricultural pressures, weeds and pests).

Stringybark Creek Habitat Corridor

Woodland habitat quality at the Stringybark Creek Habitat Corridor is currently low at 4 due to the isolated and disturbed nature of the woodland habitat. However, the score does take into account nearby records in Ravensworth State Forest. Without the offset and associated management measures, the value of the habitat will continue to deteriorate as a result of ongoing (and potentially increased) grazing pressure and associated agricultural management activities and/or the threat of African olive invasion and establishment which can result in the suppression of native species growth and regeneration reducing biodiversity and the availability of resources for target fauna species. The value of the swift parrot habitat at the Stringybark Creek Habitat Corridor, if not used as an offset site, will decrease to 3 due to these factors. Establishment of this site as an offset will improve the habitat value for the swift parrot from a quality score of 4 to 6 due to an increase in quality, improved connectivity of habitat areas and reduction in threats (agricultural pressures, weeds and pests).

Restoration of Grasslands

As grassland does not provide any habitat features for the swift parrot, the start quality and quality without offset of the grassland present at the three offset sites is zero. The habitat quality with the offset for each of the proposed offset sites is 6 after 20 years of regeneration as it is expected that regenerated eucalypts would be providing flowering foraging resources by this time. Records of flowering regeneration eucalypts have been recorded in regenerated sites younger than 20 years of age across the Central and Upper Hunter, providing very high confidence in this statement. Regenerated areas will include known foraging species at the offset sites including *Corymbia maculata*, *Eucalyptus crebra* and *Eucalyptus moluccana* (Birdlife 2013). The increase of habitat quality in these grassland habitats includes the active management and regeneration to woodland habitat, providing high quality foraging habitat and reduction of disturbances and threats in these areas. At each of the three offset sites the grassland returned to woodland will achieve an equivalent habitat quality score to woodland areas of the Proposed Disturbance Area, which was assigned as being 6.

<u>Regent Honeyeater</u>

At each of the three offset sites the establishment of the offset site and implementation of proposed management measures will result in the habitat quality for regent honeyeater being of equal or higher value than the habitat quality of the Proposed Disturbance Area, which was assigned as being 5.

The recent change in listing status for this species is addressed in **Section 3.1** above and, as discussed, this does not change the offsetting outcomes described for the EPBC Offset Calculator Assessment below.

Esparanga Offset Site

Regent honeyeater woodland habitat quality is currently considered to have a value of 5 out of 10 at the Esparanga Offset Site due to highly connected habitats and proximate records of the species. Few specific threats to eucalypt woodland are known at the Esparanga Offset Site and therefore habitat quality will remain at 5 without the offset. Although some grazing pressure may occur without the establishment of the offset, it is unlikely this will substantially reduce the quality of the woodland habitats at the site. The Esparanga Offset Site will increase from 5 to 6 if managed as an offset site due to reduced pressure from grazing and associated activities and improved connectivity to other habitat areas as a result of regenerating grassland areas.

Cross Creek Offset Site

Regent honeyeater woodland habitat quality is currently considered to have a value of 4 out of 10 at the Cross Creek Offset Site due to a lack of known records of the species, despite potential foraging habitat available. Without the offset and associated management measures, the value of the habitat in all areas will continue to deteriorate as a result of ongoing (and potentially increased) grazing pressure and associated agricultural management activities. The value of the regent honeyeater habitat at the Cross Creek Offset Site, if not used as an offset site, will decrease to 3 due to these factors. The Cross Creek Offset Site will increase from a quality score of 4 to 5 if managed as offset sites as a result of reduced pressure on woodlands from grazing and associated management activities, weeds and other feral animals and improved connectivity to surrounding habitats.

Stringybark Creek Habitat Corridor

Regent honeyeater woodland habitat quality is currently considered to have a value of 4 out of 10 at the Stringybark Creek Habitat Corridor due to a lack of known records of the species, despite potential foraging habitat available. Without the offset and associated management measures, the value of the habitat in all areas will continue to deteriorate as a result of ongoing (and potentially increased) grazing pressure and associated agricultural management activities. The threat of African olive invasion and establishment (which can result in the suppression of native species growth and regeneration reducing biodiversity and the availability of resources for target fauna species) will further reduce the habitat value of the woodland at the Stringybark Creek Habitat Corridor if it is not managed as an offset. The value of the regent honeyeater habitat at the Stringybark Creek Habitat Corridor will decrease to 3 due to these factors. The Stringybark Creek Habitat Corridor will increase from a quality score of 4 to 5 if managed as offset sites as a result of reduced pressure on woodlands from grazing and associated management activities, weeds and other feral animals and improved connectivity to surrounding habitats.

Restoration of Grasslands

As grassland does not provide any habitat features for the regent honeyeater, the start quality and quality without offset of the grassland present at the three offset sites is zero. The habitat quality with the offset for each of the proposed offset sites is 6 after 20 years of regeneration as it is a very high level of confidence that regenerated eucalypts would be providing flowering foraging resources by this time. Regenerated areas will include known foraging species at the offset sites including *Corymbia maculata*, *Eucalyptus crebra* and *Eucalyptus moluccana* (Birdlife 2013). The increase of habitat quality in these grassland habitats includes the active management and regeneration to woodland habitat, providing high quality foraging habitat and reduction of disturbances and threats in these areas. The grassland at the offset sites will increase from zero to 5 with the active regeneration to quality woodland and improved connectivity. At each of the three offset sites the existing grassland areas will improve to habitat quality of equal value than the habitat quality of the Proposed Disturbance Area, which was also assigned as being 5 for woodland.

The Department requested in the adequacy review that the proponent provide more information regarding the management proposed in the offset sites over a foreseeable time period and evidence for the likely degree of success of revegetation programs proposed in the offset areas;

- ***information on the current management of the proposed offset sites***

The Cross Creek and Esparanga Offset Sites are currently licensed to other parties for grazing purposes. In accordance with the licence agreements, the licensees are responsible for the control of noxious weeds and pests and maintenance of boundary fencing. However, current management does not extend to the control of environmental weeds that can pose a serious threat to biodiversity or the strategic management of grazing to enhance biodiversity outcomes.

The Stringybark Creek Habitat Corridor is Mount Owen-owned land. No land management activities are currently undertaken at this site other than periodic weed and pest control activities.

There are no Biodiversity Management Plans in place for the Cross Creek, Esparanga Offset Sites or the Stringybark Creek Habitat Corridor.

- ***Information demonstrating that the purchase and ongoing maintenance costs of offset areas will be adequately provided for.***

All proposed offset sites are currently owned by Glencore or Mount Owen and therefore there is no risk associated with obtaining tenure over the sites.

The overall costs of the proposed offsets package are primarily related to the implementation of related management actions (as the lands themselves have already been purchased). The estimated costs of the three proposed offset sites over a 20 year period (excluding contingency costs) is approximately $3M (approximately $1.7M for Cross Creek, $0.8M for Esparanga and a further $0.5M for the Stringybark Creek Habitat Corridor). This cost includes scope for:

- Low-intensity regeneration works (assisted planting) of the Cross Creek Offset Site;
- Low-intensity regeneration works (assisted planting) of the Esparanga Offset Site;
- Moderate/high intensity planting regeneration works and African olive management at the Stringybark Creek Habitat Corridor;
- Fencing of all three offset areas; and
- Long-term management costs (including annual feral animal and weed control, conservation signage, fencing maintenance) of all three offset sites.

Table 3.4 presents all proposed mitigation actions and a conceptual cost estimate of each action. The conceptual cost estimate provides an indicative assessment of the capital requirements for the implementation of works at the Cross Creek and Esparanga Offset Sites and the Stringybark Creek Habitat Corridor. These costs are preliminary and based on broad assumptions of the management requirements for each offset area and typical management costs based on a per-hectare rate. Following approval of the Proposed Action, these management controls will be further refined through the development of an updated *Biodiversity Offset Management Plan* which will be refined over the life of the Project through site survey and ongoing monitoring. A contingency factor has been applied to the conceptual cost estimate for management actions. Glencore commits to the provisioning of adequate resources and budget for the implementation of management actions including rehabilitation at each of the proposed offset sites.

Table 3.4 – Summary of Management Action Costs Over 20 Years

Offset Site	Management Action	Area for Management Action (ha)	Perimeter of Site (m)	Offset Fencing ($)	Revegetation		Long-Term Management Costs ($)[#]	TOTAL ($)
					Low Intensity ($)*	Moderate to High Intensity ($)[^]		
Cross Creek Offset Site	Fencing Perimeter of Site	-	8,409	109,317	-	-	-	109,317
	Assisted Natural Regeneration in Grassland	315	-	-	1,096,830	-	397,530	1,494,360
	Management of existing woodlands	52	-	-	-	-	65,624	65,624
							Total	**1,669,301**
							30% contingency for Cross Creek Offset Site	**500,790**
Esparanga Offset Site	Fencing Perimeter of Site	-	9,535	123,955	-	-	-	123,955
	Assisted Natural Regeneration in Grassland	91	-	-	316,862	-	114,842	431,704
	Management of existing woodlands	211	-	-	-	-	266,282	266,282
							Total	**821,941**
							30% contingency for Esparanga Offset Site	**246,582**

Stringybark Creek Habitat Corridor	Fencing Perimeter of Site	-	5,493	71,409	-	-	-	71,409
	Intensive Regeneration and Planting of Grassland	59	-	-	-	269,335	74,458	343,793
	African olive management	8	-	-	-	36,520	10,096	46,616
	Management of existing woodlands	28	-	-	-	-	35,336	35,336
							Total	**497,154**
							30% contingency for Stringybark Creek Habitat Corridor	**149,146**
							TOTAL (without 30% contingency)	**$2,988,396.00**
							TOTAL (with 30% contingency)	**$3,884,914..00**

+ Total calculated at $13/m

* Total calculated at $3,4282/ha

^ Total calculated at $4,565/ha

Total calculated at $1,262/ha

Other minor differences between the EPBC calculations performed by the proponent and the Department's initial assessment include:

- ***the quality of the impact site for the Spotted-tail Quoll and Koala;***

The quality scores allocated by Umwelt and the DotE for the spotted-tailed quoll and koala do have minor differences due to DotE scoring the habitat value of the mature (57 year old) and younger regenerated woodland (30 year old) separately.

Umwelt scored the woodland vegetation in the Proposed Disturbance Area as being a 5 out of 10 for the spotted-tailed tail quoll; DotE score the habitat as 6 out of10 for mature woodland and 5 out of 10 for younger regenerated woodland. The lower scores for the spotted-tail quoll account for that species not regularly being recorded in the habitats of the Proposed Disturbance Area, with most occurrences known in the northern areas of the Mount Owen Complex and within Ravensworth State Forest (refer to **Figure 3.2**). For the koala, Umwelt scored the woodland vegetation in the Proposed Disturbance Area as being a 4 out of 10, whereas the DotE scored this habitat as 5 out of10 for mature woodland and 4 out of 10 for younger regenerated woodland.

In both cases, there appears to be a generally good correlation between the habitat quality scores in that the Umwelt assessment scored the entire woodland habitats within the Proposed Disturbance Area the same as DotE scored the younger (30 year old) woodland. The differences shown here are more relevant to the different approaches taken by Umwelt and DotE in the separation of woodland age-classes in the assessments. This is discussed in detail in the sections above.

- ***the area of habitat utilised in the Cross Creek and Esparanga offsets by the Regent Honeyeater and Swift Parrot; and***

Umwelt are of the view that all eucalypt-dominated woodland within the Proposed Disturbance Area and the offset sites would be suitable habitat for swift parrot and regent honeyeater and this was assumed for the purposes of offset calculations. DotE's EPBC Act Offset Calculator Assessment however has restricted offset calculations to just spotted gum-ironbark woodlands.

Along with Spotted Gum Ironbark Woodlands, Birdlife Australia (2013) notes in *Swift Parrots and Regent Honeyeaters in the Lower Hunter Region of NSW* that a range of other important foraging species and suitable woodland communities occur for the species. No equivalent report exists for the Upper Hunter, however the vegetation communities and important foraging species identified in Birdlife Australia for the Lower Hunter are consistent or very similar across the two adjacent localities. The DotE SPRAT species profiles (DotE 2015b and b) also contain further information regarding suitable feeding resources for these species. A summary of the habitat types of both species is provided below.

<u>Swift Parrot Habitat</u>

The swift parrot feeds mostly on nectar, mainly from eucalypts, but also eats psyllid insects and lerps, seeds and fruit. It is a mostly arboreal forager, foraging mainly in eucalypts, but occasionally coming to the ground to feed on seeds, fallen flowers, fruit and lerp, and to drink (DotE 2015b). Birdlife (2013) note that the National Recovery Plan for the Swift Parrot details that the species is known to utilise woodland communities relevant to the Upper Hunter including Hunter Lowland Red Gum Forest and River-flat Eucalypt Forest with key winter foraging species being forest red gum (*Eucalyptus tereticornis*), spotted gum (*Corymbia maculata*), white box (*E. albens*) and yellow box (*E. melliodora*). Birdlife (2013) also cite evidence of swift parrots feeding on flowering grey box (*E. moluccana*) and narrow-leaved ironbark (*E. crebra*) for lerps around North Rothbury in 2005. Swift parrots have also been

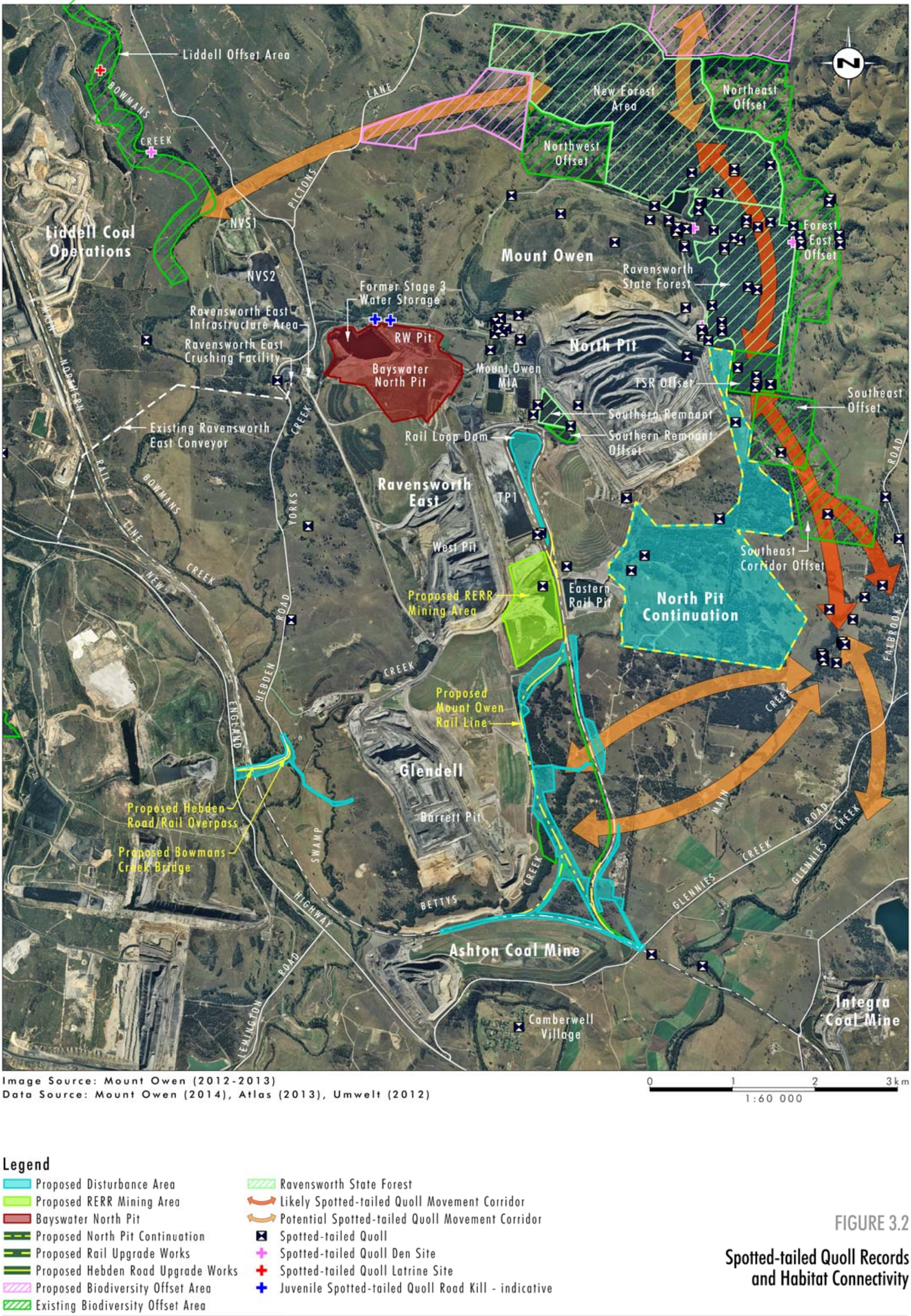


FIGURE 3.2

Spotted-tailed Quoll Records and Habitat Connectivity

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observed foraging on lerp from rough-barked apple (*Angophora floribunda*) during drought conditions (DotE 2015b). Annual monitoring of the Mount Owen Complex has recorded swift parrots feeding in flowering spotted gums, narrow-leaved ironbarks, and forest red gums in 2005, 2007 and 2014 respectively. Flowering times for foraging species in the Hunter Valley for the swift parrot correlate with the migration times when the swift parrot occupies mainland Australia (generally between March and October). Usage of sites depends on the availability of these foraging resources which appears to be cyclic between peak flowering events in particular locations (DotE 2015b).

<u>Regent Honeyeater Habitat</u>

The diet of the regent honeyeater consists mainly of nectar, supplemented with some insects and their exudates (e.g. lerp, honeydew), and occasionally fruit, or, very rarely, other plant items such as seeds or sap (DotE 2015c). Nectar is taken mainly from a variety of eucalypt species and often from mistletoes (DotE 2015c). For regent honeyeaters grey gum (*E. punctata*), spotted-gum (*C. maculata*), broad-leaved ironbark (*E. fibrosa*), thin-leaved stringybark (*E. eugenioides*) and box mistletoe *Amyema miquelii* are considered important foraging species according to the advanced draft of the updated National Regent Honeyeater Recovery Plan as quoted in Birdlife (2013). Birdlife (2013) also identify narrow-leaved ironbark (*E. crebra*) as a known foraging resource for the regent honeyeater. The DotE SPRAT profile of the species (DotE 2015c) also identifies Blakely's red gum (*E. blakelyi*) and rough-barked apple (*Angophora floribunda*) as known nectar foraging resources. Flowering times for foraging species in the Hunter Valley for the regent honeyeater correlate with the migration times when the species disperses from breeding habitats to forage in the winter months. Usage of sites depends on the availability of these foraging resources and sites may be used intermittently by the species over the years (DotE 2015c).

Table 3.5 below provides a description of the woodland communities within the offset sites and the suitable eucalypt foraging species for the swift parrot and regent honeyeater.

Table 3.5 – Key Foraging Resources for Swift Parrot and Regent Honeyeater in the Eucalypt-dominated Woodlands within Offset Sites

Offset Site / Woodland Community	Existing Area (ha)	Area to be Restored from Grasslands (ha)	Overstorey Floristic Description	Key Foraging Resources	
				Swift Parrot	Regent Honeyeater
CROSS CREEK OFFSET SITE					
Central Hunter Ironbark – Spotted Gum – Grey Box Forest	37.2	315.3	Dominated by narrow-leaved ironbark (*Eucalyptus crebra*), spotted gum (*Corymbia maculata*) and occasionally grey box (*E. moluccana*).	*Corymbia maculata* *Eucalyptus moluccana* *Eucalyptus crebra*	*Corymbia maculata* *Eucalyptus crebra*
Central Hunter Ironbark – Spotted Gum – Grey Box Forest (Red Gum variant)	14.5	0.0	Dominated by Blakelys red gum (*Eucalyptus blakelyi*) with sub-dominants including rough-barked apple (*Angophora floribunda*), thin-leaved stringybark (*E. eugenioides*), broad-leaved ironbark (*E. fibrosa*) and grey gum (*E. punctata*).	*Angophora floribunda*	*Eucalyptus blakelyi* *Eucalyptus eugenioides* *Eucalyptus fibrosa* *Eucalyptus punctata* *Angophora floribunda*
Total Suitable Habitat	51.7	315.3			
ESPARANGA OFFSET SITE					
Upper Hunter White Box – Ironbark Grassy Woodland	46.0	85.1	Characterised by the predominance of the white/grey box intergrade (*Eucalyptus albens – moluccana*), Other canopy species such as grey box (*E. moluccana*), yellow box (*E. melliodora*), narrow-leaved ironbark (*E. crebra*) and Blakelys red gum (*E. blakelyi*) can occur infrequently.	*Eucalyptus albens – moluccana* *Eucalyptus moluccana* *Eucalyptus melliodora* *Eucalyptus crebra*	*Eucalyptus albens – moluccana* *Eucalyptus moluccana* *Eucalyptus blakelyi* *Eucalyptus crebra*
Spotted Gum Open Forest Complex on Sandstone	3.2	0.0	Dominated by spotted gum (*Corymbia maculata*) and narrow-leaved ironbark (*Eucalyptus crebra*), with grey gum (*E. punctata*) and narrow-leaved stringybark (*E. sparsifolia*) occurring infrequently.	*Corymbia maculata* *Eucalyptus crebra*	*Corymbia maculata* *Eucalyptus punctata* *Eucalyptus crebra*

Offset Site / Woodland Community	Existing Area (ha)	Area to be Restored from Grasslands (ha)	Overstorey Floristic Description	Key Foraging Resources	
				Swift Parrot	Regent Honeyeater
Shrubby White Box Woodland	9.2	0.0	Dominated by white/grey box intergrade (*Eucalyptus albens – moluccana*). Other canopy species may occur in ecotonal areas, such as narrow-leaved ironbark (*E. crebra*), Blakelys red gum (*E. blakelyi*), grey box (*E. moluccana*) and rough-barked apple (*Angophora floribunda*).	*Eucalyptus albens – moluccana* *Eucalyptus moluccana* *Eucalyptus crebra* *Angophora floribunda*	*Eucalyptus albens – moluccana* *Eucalyptus moluccana* *Eucalyptus blakelyi* *Eucalyptus crebra* *Angophora floribunda* *Amyema miquelii*
Red Gum Open Forest on Alluvium/Colluvium	2.7	5.9	Blakely's red gum (*Eucalyptus blakelyi*) is the dominant canopy species present; however, rough-barked apple (*Angophora floribunda*) and narrow-leaved ironbark (*E. crebra*) also occur in reasonable densities.	*Eucalyptus crebra* *Angophora floribunda*	*Eucalyptus blakelyi* *Eucalyptus crebra* *Angophora floribunda*
Narrabeen Sheltered Dry Forest	59.3	0.0	Dominated by grey gum (*Eucalyptus punctata*), narrow-leaved ironbark (*E. crebra*) and red ironbark (*E. fibrosa*) with various associations with rough-barked apple (*Angophora floribunda*), Blakelys red gum (*E. blakelyi*) and narrow-leaved stringybark (*E. sparsifolia*).	*Eucalyptus crebra* *Angophora floribunda*	*Eucalyptus crebra* *Eucalyptus fibrosa* *Eucalyptus punctata* *Angophora floribunda* *Amyema miquelii*
Narrabeen Ironbark Woodland	91.0	0.0	The dominant canopy species is narrow-leaved ironbark (*Eucalyptus crebra*) and red ironbark (*E. fibrosa*), however grey gum (*E. punctata*) and black cypress pine (*Callitris endlicheri*) can occur.	*Eucalyptus crebra*	*Eucalyptus crebra* *Eucalyptus punctata*
Total Suitable Habitat	211.4	91.0			
STRINGYBARK CREEK HABITAT CORRIDOR					
Spotted Gum – Narrow-leaved Ironbark Forest	21.6	43.8	Characterised by a tall, mid-dense canopy of narrow-leaved ironbark (*Eucalyptus crebra*) and broad-leaved ironbark (*E. fibrosa*), with sub-dominant species including spotted gum (*Corymbia maculata*) and grey gum (*E. punctata*).	*Eucalyptus crebra* *Corymbia maculata*	*Eucalyptus crebra* *Eucalyptus fibrosa* *Corymbia maculata* *Eucalyptus punctata*
Drainage Flat Red Gum Woodland	1.0	15.0	Dominated by forest red gum (*Eucalyptus tereticornis*) and rough-barked apple (*Angophora floribunda*). Scattered narrow-leaved ironbark (*E. crebra*) and spotted gum	*Eucalyptus tereticornis* *Angophora floribunda* *Eucalyptus crebra*	*Angophora floribunda* *Eucalyptus crebra* *Corymbia maculata*

Offset Site / Woodland Community	Existing Area (ha)	Area to be Restored from Grasslands (ha)	Overstorey Floristic Description	Key Foraging Resources	
				Swift Parrot	Regent Honeyeater
			(*Corymbia maculata*) trees were recorded upslope of the creekline.	*Corymbia maculata*	
Depauperate Dry Rainforest	4.7	0.0	Dominated by spotted gum (*Corymbia maculata*), grey gum (*Eucalyptus punctata*), forest red gum (*E. tereticornis*) and rusty fig (*Ficus rubiginosa*). Additional tree species that occurred scattered through the community or small groups included narrow-leaved stringybark (*E. sparsifolia*) and rough-barked apple (*Angophora floribunda*).	*Corymbia maculata* *Eucalyptus tereticornis* *Eucalyptus crebra* *Angophora floribunda*	*Corymbia maculata* *Eucalyptus punctata* *Angophora floribunda*
Total Suitable Habitat	27.3	58.8			

The Red Gum Open Forest, Narrabeen Sheltered Dry Forest and Narrabeen Ironbark Woodland all contain foraging resources for both species and should be included as suitable habitat in the calculator assessment. As shown in **Table 3.5** above, Umwelt identified approximately 211 hectares of potential swift parrot and regent honeyeater habitat on the Esparanga Offset Site. It appears that DotE only included a total of 58.4 hectares inclusive of Upper Hunter White Box – Ironbark Grassy Woodland, Spotted Gum Open Forest Complex on Sandstone and Shrubby White Box Woodland.

Umwelt also identified 51.7 hectares of potential swift parrot and regent honeyeater habitat on the Cross Creek Offset Site. As shown in **Table 3.5**, this includes all eucalypt-dominated woodland and forest being Central Hunter Ironbark – Spotted Gum – Grey Box Forest and the Red Gum variant on this community. The variant community still contains foraging resources for these species such as *Angophora floribunda and Eucalyptus blakelyi* and should be included as suitable habitat in the calculator assessment. It appears that DotE excluded the variant community in their calculations.

Umwelt also identified 27.3 hectares of potential swift parrot and regent honeyeater habitat on the Stringybark Creek Habitat Corridor. As shown in **Table 3.5**, this includes all eucalypt-dominated woodland and forest. It appears that DotE also included 0.5 hectares of Swamp Oak Forest in their calculations. The Swamp Oak Forest at the Stringybark Creek Habitat Corridor is described as being dominated by swamp oak (*Casuarina glauca*) with some emergent forest red gum (*Eucalyptus tereticornis*) trees. The suitability of Swamp Oak Forest and the occurrence of forest red gum was not included in the Umwelt assessment due to it not being eucalypt-dominated, however in the context of extent, 0.5 hectares does not result in major differences in the results.

- ***risks of loss with and without offsets and time until ecological benefit for offsets proposed for the Spotted-tail Quoll.***

<u>‘Risk of Loss’ With and Without the Offset</u>

The ‘Risk of Loss’ with and without the offset is discussed broadly across the proposed Biodiversity Offset Sites in the sections above regarding the current management and likelihood of damage, degradation or destruction to habitat in the absence of any formal protection. Generally, it is considered that the ‘Risk of Loss’ at the Cross Creek and Esparanga sites without the offset are low (20% and 10%, respectively). The ‘Risk of Loss’ at the Stringybark Creek site without the offset is considered to be moderate due to the potential for future extraction of coal and degradation of the existing ecological values due to potential clearance of woodland habitats to enable economically viable grazing and the invasion of African olive into woodland communities.

<u>‘Time Until Ecological Benefit’</u>

For the Spotted-tailed quoll, Umwelt rated the ‘time until ecological benefit’ as 10 years based on the spotted-tailed quoll being recorded relatively frequently over the period 1995 to 2013 in rehabilitation sites and in regeneration sites containing vegetation less than 10 years old. Further detail to justify this is provided below.

Rehabilitation works have been undertaken progressively at Mount Owen since 1998, with the oldest rehabilitation being approximately 15 years old and the most recently seeded areas being established in 2013. Six spotted-tailed quoll records have been obtained from approximately 10-15 year old rehabilitation on Mount Owen between 2011 and 2013 (refer to **Plate 3.5**). In addition to this, a denning site has been recorded in a large constructed wood stockpile (not in a natural hollow) near an area of overburden (refer to **Plate 3.6**). The spotted-tailed quoll has also been tracked to a den site that consisted of large overburden

PLATE 3.5
Quoll observed in rehabilitation area at Mount Owen

PLATE 3.6
Quoll Denning Site in wood stockpile at Mount Owen

boulders at the side of an inactive haul road (refer to **Plate 3.7**). The vegetation of the most mature areas of rehabilitation at Mount Owen (10-15 years old) varies between a sparse to mid-dense canopy dominated by spotted gum (*Corymbia maculata*) between 5 and 12 metres in height, interspersed with a tall acacia layer dominated by green wattle (*Acacia decurrens*) and cooba (*Acacia saligna*). The shrub and groundcover layers in this rehabilitation are both dominated by native species; however vary between being sparse to mid-dense with a relatively high abundance of introduced species.

A further six spotted-tailed quoll records have been made in the Mount Owen regenerating woodland areas of the New Forest Area, which was generally devoid of native woodland and forest vegetation in 1994. Regeneration of this area consisted of a combination of active management of grasslands through plantings and passive regeneration of grasslands. Active plantings as well as regeneration works commenced between 1996 and 1998. The revegetated and regenerated vegetation of the New Forest is thus in the order of 16-18 years of age and provides good condition habitat that the spotted-tailed quoll is using. In addition to these, the spotted-tailed quoll has been recorded (via radio-tracking data) moving between the Forest East, Southeast and Southeast Corridor Offsets, all of which have been subject to a mix of active revegetation and passive regeneration which commenced in 2004, demonstrating the utilisation of habitats around 10 years old.

Locations of spotted-tailed quoll recorded in and around the Mount Owen Complex are shown on **Figure 3.2**.

3.3 Mitigation Measures

The Department recommends that the proponent provides further information about proposed mitigation measures, as requested in the Department's adequacy review.

Throughout the EIS, the proponent draws heavily on the implementation of management plans that exist for current operations, including: the Landscape Management Plan, Flora and Fauna Management Plan, Erosion and Sediment Control Plan and the Water Management Plan. The proponent states that these plans will be revised and/or consolidated should the project be approved.

The Department requested, in our adequacy review, that a copy of these plans and justification of how they would be updated to address the impacts of the mine extension be included in the EIS. This has not been addressed. We are therefore unable to determine, from the EIS submitted, the effectiveness of the currently implemented management plans, how they would be updated to address the extension proposed and therefore the success of mitigation measures in reducing impacts to MNES from the proposed action. This concern is also raised by the IESC.

The Department recommends that the proponent provide the abovementioned management plans with clear descriptions of how actions will be updated to effectively avoid and mitigate impacts regarding MNES as part of the Response to Submissions. Mitigation measures must include objectives, performance measures, corrective actions and thresholds for corrective actions in accordance with SMART principles. This information is required prior to a decision being made on the proposal.

As previously discussed, the Landscape Management Plan, Flora and Fauna Management Plan, Erosion and Sediment Control Plan and the Water Management Plan are available on the Mount Owen Complex website for review http://www.mtowencomplex.com.au/EN/EnvironmentalManagement/Pages/PlansandPrograms.aspx.

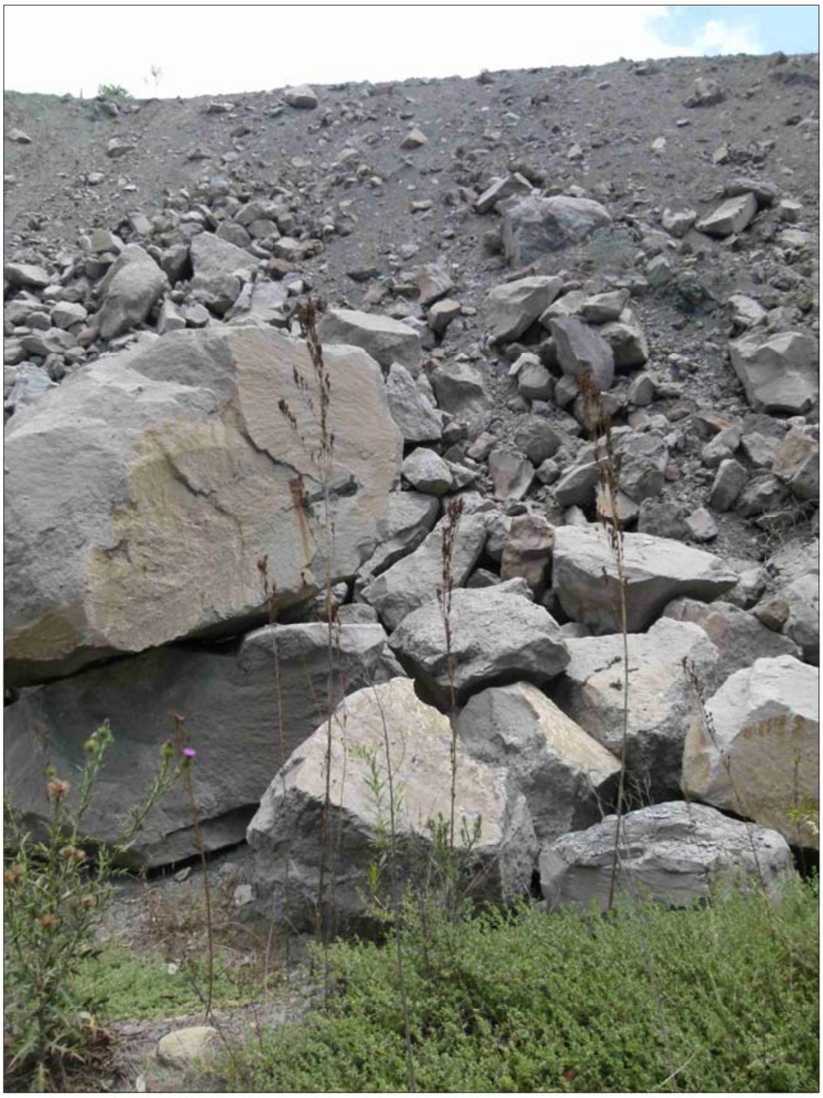

PLATE 3.7
Quoll Denning Site in overburden boulders at Mount Owen

These existing management plans have been developed to include the purpose and scope, implementation of management and mitigation measures, measurement and evaluation requirements and a process for review and improvement. Monitoring indicates the management measures identified in the existing management plans have been successful in managing impacts to levels consistent with those predicted in earlier assessment studies and this provides confidence that the continuation and, where necessary, revision, of these measures will manage impacts to levels of impact predicted in the EIS.

As detailed in the EIS, the relevant management plans will be updated to reflect the Project and to include the updated management and mitigation measures committed to by Mount Owen, as detailed in Section 6.0 of the EIS, should the Project be approved as summarised in **Table 3.6** below.

Table 3.6 – Summary of Proposed Management Plan Amendments in Relation to Ecological MNES[1]

Current Management Plan	Current Objectives / Requirements	Proposed Management Plan Revisions	MNES Addressed
Biodiversity Management Plan (December 2014)	• Describes specific management areas and the baseline environmental information. • Outlines relevant legislation and existing approvals. • Describes the roles and responsibilities under the Plan. • Describes land management strategies including erosion and sedimentation control, fire management, weed control, feral animal control, security and access to sites. • Describes management measures for impacted areas including vegetation clearing, seed collection, and fauna management. • Outlines the targeted threatened fauna species that are significantly impacted by the Mount Owen Mine. • Outlines the existing Biodiversity Offset Strategy. • Outlines the research undertaken by the University of Newcastle. • Outlines the flora and fauna monitoring locations, schedule and methodology. • Outlines auditing and review processes.	• Incorporate the Flora and Fauna Management Plan into revised Landscape Management Plan. • Update with new management areas (Cross Creek, Esparanga and Stringybark Creek Habitat Corridor) and update regional information in the context of Esparanga Offset Site. • Update relevant legislation and existing approvals. • Update personnel roles and responsibilities, if required. • Update land management strategies to include consideration of biodiversity issues in new management areas (Cross Creek, Esparanga and Stringybark Creek Habitat Corridor). • Update impact management areas to include new impact areas. • Update targeted threatened fauna species in light of the results of the Ecological Assessment (Umwelt 2014). • Include strategies for next box installation and hollow salvage programs for habitat augmentation in offset sites. • Update description and figures showing the Biodiversity Offset Areas to include Cross Creek, Esparanga and Stringybark Creek Habitat Corridor. • Update and review monitoring locations and methodology in light of new Biodiversity Offset Areas and revegetation programs. • Update auditing and review processes, if required. • Update plan with clear performance indicators and thresholds for corrective actions.	EPBC Act-listed threatened species that benefit from onsite management measures such as pre-clearance surveys, tree-felling supervision and habitat augmentation and offset site establishment, improvements and revegetation. • spotted-tailed quoll; • koala; • regent honeyeater; • swift parrot; • large-eared pied bat; • grey-headed flying-fox.
Landscape Management Plan (November 2011) (including the Rehabilitation Management Plan)	• Describes completion criteria and rehabilitation monitoring in relation to specific ecological issues of each operational phase. • Outlines rehabilitation strategy for construction phases, including mine rehabilitation, landform design, topsoil management, surface preparation and revegetation • Outlines requirements for initial and long-term rehabilitation monitoring. • Summarises the land management strategies at the Mount Owen Complex. • Outlines the flora and fauna management strategies (including monitoring) for the Mount Owen Complex as	• Incorporate the Flora and Fauna Management Plan into revised Landscape Management Plan. • Update completion criteria and rehabilitation monitoring in relation to specific ecological issues of the Mount Owen Continued Operations Project. • Update the rehabilitation strategies and monitoring requirements in consideration of new areas to be rehabilitated as a result of the Project. • Update land management strategies to include consideration of biodiversity issues in new management areas. • Update and review monitoring locations and methodology in light of new revegetation programs.	EPBC Act-listed threatened species that benefit from onsite management measures such as pre-clearance surveys, tree-felling supervision and mine rehabilitation. • spotted-tailed quoll; • koala; • regent honeyeater; • swift parrot;

[1] Refer to **Section 2.5** for additional proposed management measures relevant to impacts on water resources, including water dependent ecological assets.

Current Management Plan	Current Objectives / Requirements	Proposed Management Plan Revisions	MNES Addressed
	detailed in the Biodiversity Management Plan (2014).	• Update plan with clear performance indicators and thresholds for corrective actions.	• large-eared pied bat; • grey-headed flying-fox.
Water Management Plan (November 2014)	• Outlines relevant development consent, EPL, water licence and other statutory requirements. • Outlines design criteria for clean, dirty and mine water. • Outlines water management system components, including schematic, water storages. • Outlines predicted water inflows, including proposed catchment area changes over mine life, groundwater inflows. • Outlines predicted water outflows. • Overview of tailings management strategy. • Outline of reporting requirements.	• Update consent and EPL details and water licence (as required). • Update target design criteria for dirty water. • Update water schematic, storages (as required), including provision of off-line storage capacity adjacent to Ravensworth East MIA, sedimentation dams. • Update catchment area changes, predicted groundwater inflows • Update predicted water outflows • Update tailings management strategy • Update plan with clear performance indicators and thresholds for corrective actions.	EPBC Act-listed threatened species that benefit from onsite water management measures that protect surrounding environments. • spotted-tailed quoll; • koala; • regent honeyeater; • swift parrot; • large-eared pied bat; • grey-headed flying-fox.
Erosion and Sediment Control Plan (July 2014)	• Outlines the existing environment of the site. • Outlines the potential impacts of mining operations regarding sediment flowing into surrounding catchments. • Overview of soil landscapes within the Mount Owen Complex. • Description of erosion and sediment control measures (in general accordance with Department of Housing's *Managing Urban Stormwater: Soils and Construction* manual). • Outlines monitoring and maintenance requirements.	• Update description of soil landscapes with findings of Agricultural Impact Statement. • Update potential impacts as outlined in the Surface Water Assessment (Umwelt 2014). • Update target design criteria for dirty water. • Update plan with clear performance indicators and thresholds for corrective actions.	EPBC Act-listed threatened species that benefit from onsite erosion and sedimentation management measures that protect surrounding environments. • spotted-tailed quoll; • koala; • regent honeyeater; • swift parrot; • large-eared pied bat; • grey-headed flying-fox.

As detailed in **Section 2.5**, the effectiveness of the existing management measures implemented at Mount Owen is regularly assessed and the plans updated as necessary.

As discussed in the EIS and **Section 2.5**, the plans will be revised to reflect the proposed changes described in **Table 3.6**. The revised plans will be developed in consultation with the relevant authorities and must be approved by the DP&E prior to implementation. All management plans will also be revised throughout the life of the Project as the Project progresses and additional monitoring data becomes available.

Regarding the Spotted-tail Quoll specifically, as stated in Appendix 11 of the EIS, the proposed action has the potential to create a substantial barrier for the species in accessing habitat areas in the southern portion of the project area, within the proposed disturbance area. This is inconsistent with this species' recovery plan objective of reducing the rate of loss and fragmentation of Spotted-tail Quoll habitat. Therefore, the Department recommends that Main Creek is revegetated as a mitigation measure for proposed impacts from this project. Additionally, as the revegetation of Bowmans Creek is already a requirement of mining actions associated with Liddell mine, the Department recommends that the revegetation of Stringybark Creek to link with Bowmans Creek to encourage movement of the Spotted-tail Quoll between refugia, should be further explored by the proponent.

It is noted that the North Pit Continuation impact area will result in the loss of woodland communities to the southeast of the Mount Owen Complex. This will not result in any direct impacts on the connectivity of Main Creek which occurs approximately 300 metres to the east of the Proposed Disturbance Area. The loss of woodland within the Proposed Disturbance Area will reduce the connectivity of habitats in the southeast of the Project Area however the primary path of connectivity along Main Creek and west towards Bettys Creek will be unaffected by the Project (refer to **Figure 3.2**). The existing Biodiversity Offset Areas to the south of Ravensworth State Forest (TSR Offset, Southeast Offset and Southeast Corridor Offset) will not be directly impacted as a result of the Project, and connectivity between the New Forest Area and Ravensworth State Forest in the north to woodland habitats along Main and Glennies Creek in the south will be retained (refer to **Figure 3.2**).

The revegetation of Main Creek has not been proposed for this Project as key parts of this area are not currently owned by Glencore and the majority of revegetation efforts have been focused on the lands to the north and northwest of the Mount Owen Complex in the areas under the control or ownership of Glencore; these areas are also the areas of high spotted-tailed quoll occurrences. The spotted-tailed quoll has been recorded over many years occupying the lands in and around Ravensworth State Forest, the New Forest Area and to the west toward Liddell. Den and latrine sites are known to occur in and around Ravensworth State Forest, north of the existing Mount Owen North Pit and west to Bowmans Creek. The species has been mainly recorded in these northern areas of the Mount Owen Complex with only sporadic records of the species occurring south of Falbrook. The location of records, known dens sites and latrines are shown on **Figure 3.2**.

The land along Main Creek to the south of the Proposed North Pit Continuation is also subject to exploration and mining titles and the potential for future resource extraction in this area effectively precludes it from being used as an offset area.

The intent of the proposed Stringybark Creek Habitat Corridor is to improve the habitat linkages between known spotted-tailed quoll habitat in and adjacent to Mount Owen and known habitat along Bowmans Creek, including that proposed for in-perpetuity conservation as part of the Liddell Biodiversity Strategy. It is acknowledged that the proposed Stringybark Creek Habitat Corridor Offset does not complete the linkage and there are parcels of land between the western-most portion of the proposed Stringybark Creek Corridor Offset and the eastern-most portion of Bowmans Creek that are not proposed for offsetting or revegetation as part of this Project. The land in question is within the Project Area, but sections are not currently owned by Glencore and the area is identified as containing potential coal resources. It is therefore difficult to commit to the rehabilitation of this remaining gap in habitat linkage. However, subject to ownership and potential mining constraints, Mount Owen will continue to investigate the potential to improve the vegetation linkages in this area in the future.

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APPENDIX A

Submission from DotE

Attachment A - DoE's comments on Mount Owen Continued Operations Project (EPBC 2013/6978)

1. Impacts

Threatened species and ecological communities

The Department considers that significant impacts are likely to occur for:

- the Spotted-tail Quoll;
- the Regent Honeyeater;
- the Swift Parrot; and
- the Koala - the proponent has identified that, using the Referral Guidelines, 163.7 hectares of habitat critical to its survival (a score higher than 5) will be cleared as part of the proposed action. According to the guidelines, such an impact at this scale is significant to the Koala.

In light of the information presented in the EIS, the Department does not consider that significant impacts are likely to occur regarding the Green and Golden Bell Frog and the New Holland mouse.

A water resource

The Department notes that the Independent Expert Scientific Committee (IESC) has provided advice to the decision maker regarding this project. The Department recommends that the proponent responds to and addresses comments, issues, knowledge gaps and additional analysis requested by the IESC in its advice, especially regarding Glennies and Main Creek. This information, which should be included as part of the proponent's PPR and RtS, is required to provide a sufficiently robust assessment of the likelihood, extent and significance of potential impacts on water resources resulting from the project. The proponent should also revise impact assessments provided in the EIS documentation to adequately quantify the extent of any impacts.

2. Mitigation Measures

The Department recommends that the proponent provides further information about proposed mitigation measures, as requested in the Department's adequacy review.

Throughout the EIS, the proponent draws heavily on the implementation of management plans that exist for current operations, including: the Landscape Management Plan, Flora and Fauna Management Plan, Erosion and Sediment Control Plan and the Water Management Plan. The proponent states that these plans will be revised and/or consolidated should the project be approved.

The Department requested, in our adequacy review, that a copy of these plans and justification of how they would be updated to address the impacts of the mine extension be included in the EIS. This has not been addressed. We are therefore unable to determine, from the EIS submitted, the effectiveness of the currently implemented management plans, how they would be updated to address the extension proposed and therefore the success of mitigation measures in reducing impacts to MNES from the proposed action. This concern is also raised by the IESC.

The Department recommends that the proponent provide the abovementioned management plans with clear descriptions of how actions will be updated to effectively avoid and mitigate impacts regarding MNES as part of the Response to Submissions. Mitigation measures must include objectives, performance measures, corrective actions and thresholds for corrective actions in accordance with SMART principles. This information is required prior to a decision being made on the proposal.

Regarding the Spotted-tail Quoll specifically, as stated in Appendix 11 of the EIS, the proposed action has the potential to create a substantial barrier for the species in accessing habitat areas in the southern portion of the project area, within the proposed disturbance area. This is inconsistent with this species' recovery plan objective of reducing the rate of loss and fragmentation of Spotted-tail Quoll habitat. Therefore, the Department recommends that Main Creek is revegetated as a mitigation measure for proposed impacts from this project. Additionally, as the revegetation of Bowmans Creek is already a requirement of mining actions associated with Liddell mine, the Department recommends that the revegetation of Stringybark Creek to link with Bowmans Creek to encourage movement of the Spotted-tail Quoll between refugia, should be further explored by the proponent.

Offsets

The Department has recently released a policy that endorses the FBA and the BioBanking methodology for EPBC Act Offset purposes. Where a project demonstrates compliance with these endorsed methodologies, the EPBC Act Offsets Policy would not need to be applied. The Department understands that this proposed project falls within the 'transitional period' of the new offsetting policy and that therefore the endorsed policies have not been applied in full. On this basis, the EPBC Act Offsets Policy still applies for this project.

Regarding the EPBC Act Offsets Policy, insufficient information is currently provided in the EIS to apply the Offsets Policy in full. This information was requested as part of the supplementary DGRs and the Department's adequacy review. In the absence of this information, the Department has run an indicative assessment based on the available information

Currently, the offsets proposed (Cross Creek Offset Site, Esparanga Offset Site and the Stringybark Creek Habitat Corridor Regeneration Strategy) meet approximately 75%, 34%, 28% and 110% of the EPBC Act Offset Policy requirements for the Spotted-tail Quoll, Regent Honeyeater, Swift Parrot and Koala, respectively. Further offsets are therefore likely to be required for a number of the species, and should be investigated as part of the Response to Submissions and Preferred Project Report.

Of note, the Department recommends that the proponent revise the vegetation types being proposed to offset impacts to the Central hunter Ironbark – Spotted Gum – Grey Box Forest. As these woodlands are up to 57 years old, the use of regenerating grassland habitats in the EPBC calculator to offset impacts to is not consistent with the "like for like" principal of the Policy. It is unlikely that the regeneration of this habitat will achieve a similar ecological benefit as that provided by the 57 year-old woodland in a period of 20 or 30 years, as is required by the EPBC Act Offsets Policy.

On-site mine site rehabilitation was also not considered as an offset measure in the Department's EPBC offset calculations due the time delay involved in rehabilitating a currently active mine site.

The final percentages output from the EPBC Act Offsets Policy are likely to increase marginally with greater confidence in results dependent on the proponent providing more information relating to the following matters:

- Risks of loss associated with the offset sites:
  - The Department requested in the adequacy review that the proponent provide more information regarding: the risk of damage, degradation or destruction to any proposed offset site(s) in the absence of any formal protection;
  - Information is required on the current and proposed tenure for the offset sites (e.g. conservation covenant or state conservation area). The specific mechanisms that will be used to secure these offsets need to be clearly outlined, as does any difference in mechanisms proposed between the two "offset" sites and the Stringybark regeneration strategy.
- Changes in quality in the offset sites:
  - The Department requested in the adequacy review that the proponent provide more information regarding the management proposed in the offset sites over a foreseeable time period and evidence for the likely degree of success of revegetation programs proposed in the offset areas;
  - information on the current management of the proposed offset sites
- Information demonstrating that the purchase and ongoing maintenance costs of offset areas will be adequately provided for.

Other minor differences between the EPBC calculations performed by the proponent and the Department's initial assessment include:

- the quality of the impact site for the Spotted-tail Quoll and Koala;
- the area of habitat utilised in the Cross Creek and Esparanga offsets by the Regent Honeyeater and Swift Parrot; and
- risks of loss with and without offsets and time until ecological benefit for offsets proposed for the Spotted-tail Quoll.

The Department would be happy to discuss these in further detail once the additional information requested above is provided, and the inputs into the EPBC Act Offsets Policy are reviewed.

Australian Government
Department of the Environment

EPBC Ref: 2013/6978

Mr Matthew Sprott
Senior Planning Officer
Department of Planning & Environment
23-33 Bridge Street
SYDNEY NSW 2000

Dear Mr Sprott

Comment on final Environmental Impact Statement for the Mt Owen Continued Operations Project

Thank you for your invitation to comment on the Mt Owen Continued Operations Project final Environmental Impact Statement, which was provided to the Department of the Environment (the Department) on 20 January 2015.

Please find attached to this letter the Department's comments in relation to the EIS and matters of National Environmental Significance (NES), as requested. The Department recommends that several matters are required to be addressed by the proponent in the Preferred Project Report and Response to Submission. These include:

- a response to and addressing the comments, issues, knowledge gaps and additional analysis requested by the IESC in its advice;
- a detailed description of the mitigation proposed as part of their EIS; and
- further information regarding the offsets proposed. Pending this information, further offsets are likely to be required and details of these should also be provided.

The Department's detailed comments are at Attachment A.

If you have any questions about these, please contact the project manager, Kyran Staunton, by e-mail: kyran.staunton@environment.gov.au, or by telephone: 02 6274 2526 and quote the EPBC reference number shown at the beginning of this letter.

Yours sincerely

Mark Hall

Mark Hall
A/g Director
NSW & ACT Section
25 March 2015

APPENDIX B

IESC Advice

Advice to decision maker on coal mining project

IESC 2015-062: Mount Owen Continued Operations Project (EPBC 2013/6978; SSD 5850) – Expansion

Requesting agency	The Australian Government Department of the Environment The New South Wales Department of Planning and Environment
Date of request	27 January 2015
Date request accepted	27 January 2015
Advice stage	Assessment

Context

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) was requested by the Australian Government Department of the Environment and the New South Wales Department of Planning and Environment to provide advice on the Mount Owen Continued Operations Project (MOCO project) proposed by Mt Owen Pty Ltd (wholly owned by Glencore) in New South Wales.

This advice draws upon aspects of information in the Environmental Impact Statement (EIS) together with the expert deliberations of the IESC. The project assessment documentation and information accessed by the IESC are listed in the source documentation at the end of this advice.

The proposed MOCO project is located in the Hunter Valley, approximately 20 km northwest of Singleton and 24 km southeast of Muswellbrook. The proposed project area is located within the Hunter River Catchment and within the sub catchments of Bowmans Creek (to the west) and Glennies Creek (to the east).

The proposed MOCO project is an extension of the existing Mount Owen Operations and Ravensworth East open cut coal mines. Under the proposal, these two mining operations will be amalgamated into a single operation to improve extractive capacity and coal handling efficiency. The MOCO project proposes to concurrently extend and mine, at a rate of up to 15 million tonnes per annum, three existing open cut pits: Bayswater North Pit, Ravensworth East Resource Recovery, and the North Pit Extension (NPE). Coal is proposed to be extracted from the Ravensworth to Hebden seams, within the Whittingham Coal Measures. The MOCO project would enable mining to continue until 2030 with an additional 92 million tonnes of coal proposed to be extracted. Associated works include upgraded coal handling facilities, new rail infrastructure, and a bridge over Bowmans Creek.

Key potential impacts

The key impacts potentially resulting from the proposed MOCO project are predominantly of local importance and are likely to be similar in scale and significance to the impacts resulting from the existing Mount Owen and Ravensworth East mining operations. Noting the above, the potential impacts will contribute to regional, mining-related, cumulative impacts to water resources within the Hunter Valley. Key potential impacts include decline in riparian groundwater dependent ecosystems (GDEs) along ephemeral streams that provide habitat for the nationally listed endangered Spotted-tail quoll (*Dasyurus maculatus maculatus*). There is a lack of information regarding the existing conditions of Glennies Creek, which creates uncertainty and difficulty in identifying the surface water quality and quantity impacts to Glennies Creek, and to the Hunter River.

Assessment against information guidelines

The IESC, in line with its Information Guidelines (IESC, 2014), has considered whether the proposed project assessment has used the following:

Relevant data and information: key conclusions

The proponent's assessment of Bowmans Creek is comprehensive. However, water quality monitoring in all watercourses does not include individual chemical species and contaminants. Quantitative flow data for Glennies Creek has not been provided or analysed. The water balance model predicts spillage from sediment dams to occur twice per year. The location and receiving surface watercourses of spills have not been identified. It is unclear whether the proponent has a licence to discharge under the Hunter River Salinity Trading Scheme (HRSTS).

Application of appropriate methodologies: key conclusions

The proponent's groundwater model is robust, well constructed and has been peer reviewed. The inclusion of 43 mines within an approximately 451 km^2 domain would allow sub-regional groundwater impacts to be estimated cumulatively. Aquatic fauna and habitat surveys within Glennies Creek and Main Creek have not been undertaken, or if they have, are not included in the EIS. Information on the presence or absence of GDEs along riparian corridors has not been provided outside of the project boundary even though the potential impacts of the project extend beyond the boundary.

Reasonable values and parameters in calculation: key conclusions

The numerical groundwater model is suitable for groundwater drawdown and flow assessments, however a cell size of 100 m by 100 m is too large to predict fine scale groundwater and surface water relationships. The changes to baseflows in creeks and rivers within the project area have been predicted on an annual scale and do not consider the importance of baseflow during seasonal or climatic low flow periods.

Advice

The IESC's advice, in response to the requesting agencies' specific questions is provided below.

Question 1: Do the groundwater and surface water assessments, including numerical modelling therein, provide reasonable estimations of the risk (including likelihood, extent and significance) to water resources, with particular reference to Bowmans Creek, Glennies Creek and the Hunter River, in the short and long term?

Response

1. The project specific risks to Bowmans Creek provided within the EIS appear to be reasonably estimated, except with regard to quantification of seasonal flow regimes and water quality other

than total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC) and pH. Limited information on the potential hydrological and ecological risks to Glennies Creek and the Hunter River has been provided in the EIS. A reasonable estimation of the risks to Glennies Creek and the Hunter River would need to include quantitative flow regime data (including seasonal, high flow and contribution to the Hunter River), existing water quality data and ecological assessments (in-stream, hyporheic and riparian zones).

<u>Explanation</u>

Surface water

2. Apart from the uncertainties raised in paragraphs 3 and 4, identification and assessments of the existing hydrological conditions along Bowmans Creek (including its tributaries, Stringybark Creek, Yorks Creek, Swamp Creek and Bettys Creek) are reasonable. Based on the assessment, risks within these watercourses are unlikely to significantly change compared to those from the existing mining operations.

3. Information on existing water quality conditions within Bowmans Creek (and tributaries) and the assessment of potential impacts to water quality as a result of the MOCO project in all watercourses includes TDS, TSS, EC and pH, but would need to include metals, metalloids, polycyclic aromatic hydrocarbons (PAHs) and ionic compositions.

4. The current seasonal flow regime has not been described or quantified for all watercourses in the area. The assessment of existing hydrological, geomorphological and ecological conditions along Glennies Creek is minimal throughout the assessment documentation. The limited data and information presented with regards to Glennies Creek makes it difficult to assess the proponent's estimation of risk, including downstream risks to the Hunter River.

5. The proponent states that "due to the limited localised impact, it is anticipated that the Project will have negligible impact on major downstream watercourses including Bowmans Creek, Glennies Creek and the Hunter River" (EIS, App 9, p 6.4). The assessment of potential surface water flow impacts is based on contributing catchment area losses within Yorks Creek, Bettys Creek, Swamp Creek and Main Creek and by inferring potential flow volumes using historical rainfall records from Jerrys Plains (approximately 19 km to the south). Flow within the tributaries was monitored visually though this data was not provided. The assessment of existing flows within Bowmans Creek and Glennies Creek was not supported by quantitative seasonal flow data from existing flow gauges on these two watercourses (for example, Bowmans Creek gauge 210130 and Glennies Creek gauge 210044 where presumably there is existing data). A discussion on the uncertainties and assumptions associated with this method of assessment, including the potential impact of using the Bowmans Creek (Grenell) (station number 61270) meteorological station for the rainfall source, is needed.

Groundwater

6. The numerical groundwater model has a cell size of 100 m by 100 m which is adequate for estimating regional groundwater behaviour, though is too large to predict fine scale groundwater and surface water interactions. Nevertheless, the groundwater model predicts baseflow reductions to surface watercourses as follows (with results from the 'plus one standard deviation' model run in brackets): 6 ML/year (9 ML/year) decrease to Bettys Creek, 15 ML/year (22 ML/year) decrease to Main Creek and "negligible" losses from Bowmans and Glennies Creeks. Seasonal quantification or estimation of baseflow within each of the surface watercourses has not been provided. Baseflow analysis was only described as an annual percentage and therefore the importance of baseflow contribution to Bowmans and Glennies Creeks during seasonal or climatic low flow periods is unknown.

7. The groundwater model predicts drawdown within the Main Creek alluvium of between 2 m and greater than 6 m (for the plus one standard deviation model run). Within the predicted zone of impact this would lower the Main Creek alluvial water table to between 4 m and 8 m below the surface. The effect on the Central Hunter Swamp Oak Forest GDE of lowering the Main Creek alluvial water table has not been addressed within the EIS.

Water dependent ecological assets

8. The EIS states (App 10, p 92) that no GDEs are associated with Yorks Creek and Swamp Creek. However, the riparian zones of these watercourses are mapped as containing the Central Hunter Swamp Oak Forest which is considered to be a GDE (EIS, App 11, Figure 4.1). The proponent has not mapped or estimated the area inhabited by groundwater dependent riparian vegetation outside of the project area, including within the zone of predicted alluvial impact and downstream of the proposed project area.

9. The proponent states that ephemeral streams represent limited habitat opportunities for aquatic fauna. However, the EIS states in a number of places (for example App 10, p 26 and App 11, p 2.3-2.4) that pools of standing/stagnant water remain in ephemeral streams. These pools may be semi permanent and represent important refugia for aquatic fauna. The ecological assessment does not assess the habitat value, duration of persistence or map the extent or location of these pools.

10. Given the Main Creek alluvium supports known groundwater dependent riparian vegetation that is also habitat known to be utilised by the nationally listed endangered Spotted-tail quoll, information identified in paragraphs 8 and 9 is needed to determine the existing habitat conditions along this watercourse.

Question 2: If not, what additional information would be required to provide a sufficiently robust assessment of the likelihood, extent and significance of potential impacts on water resources resulting from the project?

<u>Response</u>

11. The assessment of risk to Glennies Creek needs to include data and information that describes the existing hydrological (water quality, flow quantity, seasonal regime) and ecological (presence of fauna, habitat quality/quantity) conditions within the Glennies Creek system, including its tributary Main Creek.

12. Water quality monitoring within receiving surface water systems needs to include contaminants such as metals, PAHs and ionic composition to determine the potential downstream project specific and cumulative water quality impacts to the Hunter River.

<u>Explanation</u>

13. While the assessments of the majority of surface watercourses within the vicinity of the proposed project area are sufficiently robust, the assessment of existing conditions within Glennies Creek is limited. An assessment of the following is needed to understand the existing conditions within Glennies Creek and provide a robust assessment:

    a. Flow data, including seasonal and annual quantities, and details of Main Creek's alluvial groundwater and surface water contribution to flows in Glennies Creek.

    b. Water quality data above and downstream of Main Creek. Data needs to include the full range of contaminants such as those already considered within existing monitoring (paragraph 3) as well as metals, metalloids, PAHs and ionic compositions.

c. An assessment of surface water contaminant contribution to cumulative impacts on downstream environments within Glennies Creek and the Hunter River.

14. The proponent has undertaken sufficiently robust ecological stream habitat and aquatic fauna assessments for Bowmans Creek and Bettys Creek. However, equivalent assessments of Main Creek and Glennies Creek have not been provided within the EIS. To understand the existing ecological conditions within, and provide a robust assessment for Glennies and Main Creek, a description of the riparian, in-stream, and alluvial habitat for fauna and flora needs to be provided. This would include:

    a. mapping of vegetation including in riparian zones and areas of shallow groundwater

    b. sampling of GDEs including stygofauna and hyporheic fauna

    c. an in-stream aquatic fauna survey (e.g. fish, macroinvertebrates, amphibians)

    d. an existing conditions aquatic habitat assessment in line with a national standard (for example using the AUSRIVAS (2007) sampling protocols utilised for Bowmans Creek)

    e. the development of ecological conceptualisations using the method described in Commonwealth of Australia (2015) to identify the ecological and water relationships of the MOCO project area.

15. The geochemical characterisation study needs to be included as a component of the EIS. The document is referenced in the Mine Closure and Rehabilitation Strategy (EIS, Appendix 18) as Environmental Geochemistry International Pty Ltd, 2013 *Geochemical Assessment of the Mount Owen Optimisation Project*. This is an important document to allow a thorough assessment of the potential geochemical risks posed by the final landform including the three final voids.

Question 3: Has the proponent provided effective strategies to avoid, mitigate, and / or reduce the likelihood, extent and significance of these impacts?

<u>Response</u>

16. The potential to implement avoidance measures is limited by the large scale of the project, compared to the size of the proponent's mining leases. However, where possible the proponent has attempted to reduce the project's disturbance footprint by proposing development on existing disturbed sites and has increased the setback for the NPE to 450 m from Main Creek's central flow channel.

17. Mitigation measures are proposed to be implemented through existing management plans which have not been included within the assessment documentation. It is not possible to determine how effective the measures have been, or would be, at mitigating or reducing impacts from the existing operations as this information has not been provided within the EIS.

<u>Explanation</u>

18. The proponent commits to continue utilising various approved plans, programs and strategies to mitigate potential impacts to water resources, including the Landscape Management Plan, Erosion and Sediment Control Plan, Water Management Plan and the Flora and Fauna Management Plan. These plans are not included as a component of the EIS, though are available on the proponent's website. The proposed mitigation measures that have been described broadly include ongoing review of groundwater modelling, biodiversity offsetting, rehabilitation, the addition of new monitoring locations, surface water diversions and erosion and sediment control techniques. The ongoing effectiveness or results of these measures within the existing operations have not been clearly stated. Water quality within existing stream diversions

(including metals, PAHs and ionic compositions), as well as their habitat values and geomorphological stability has not been provided.

19. The groundwater impact assessment states (EIS, App 10, p 128) that, if necessary, the proponent would adjust mining and dewatering plans to mitigate unacceptable actual or predicted impacts on the alluvial systems of Glennies Creek and Bowmans Creek. The criteria to be used to determine an unacceptable impact should be provided in relation to the alluvial systems (or impacts to riparian GDEs) associated with the tributaries of Glennies Creek or Bowmans Creek.

20. Given the predicted drawdown in the Main Creek alluvium of between 2 m and up to greater than 6 m (for the plus one standard deviation prediction), there is a risk of impact to the riparian Central Hunter Swamp Oak Forest GDE along this watercourse. Mitigation, rehabilitation or vegetation improvement is not proposed, or has not been described within the EIS, to compensate for the predicted drawdown impacts to riparian vegetation along Main Creek.

Question 4: If not, what additional measures should be recommended to avoid, mitigate, reduce or remediate the likelihood, extent and significance of these impacts?

Response

21. The proponent's mitigation strategy should consider the potential impacts to riparian vegetation affected by but outside of the proposed project area, such as along reaches of Bettys Creek and Main Creek. Stream diversion specifications as well as construction and performance criteria should be provided to determine the diversion's ability to avoid or mitigate potential downstream surface water impacts. The legacy risks associated with the three final voids need to be identified and mitigated or managed, including those associated with potential post mining contamination of aquifers and connectivity with the underlying longwall mine.

Explanation

22. Given the riparian Central Hunter Swamp Oak Forest community is a GDE and a known habitat corridor for the nationally listed endangered Spotted-tail quoll, the application of mitigation or remediation measures along Main Creek (including outside of the proposed project boundary) within the zone of impact is warranted. These measures would need to include improved mapping of riparian vegetation potentially affected by drawdown but outside of the MOCO project boundary as well as ongoing monitoring of condition to determine if mitigation or remediation is required. If required, mitigation measures could include provision of additional water to the Main Creek alluvium, improvement of bank stability and water quality as well as vegetation remediation, rehabilitation and Spotted-tail quoll habitat improvement.

23. Ongoing monitoring and refined mapping of GDEs that occur outside of the project boundary, which may be impacted by the proposed project, is also needed to determine the extent of the potential impacts of the proposed project.

24. Specifications for surface water diversions as well as construction and performance criteria are needed to determine the effectiveness of each diversion in mitigating surface water quality and quantity impacts to downstream watercourses, particularly within Glennies Creek and the Hunter River. These specifications need to include: construction materials and geochemistry, meander length, in-stream flow velocities, shear stresses within flow channels, sediment control measures as well as modelled performance under a variety of flow velocities and vegetation establishment.

25. The final landform, in its current conceptual form, following the completion of the proposed project contains three final voids. The proponent has identified the key rehabilitation and final landform design criteria in their Mine Closure and Rehabilitation Strategy. This report will need to be updated to demonstrate that the legacy issues and risks to water resources as a result of the final

landform have been assessed and will be adequately mitigated and managed. This will need to include:

a. the design of a post-mining groundwater and surface water monitoring network to provide a representative indication of groundwater and surface water quality to identify any leaching of saline or acidic material

b. an assessment of the potential risks to regional hydrogeological units and surface watercourses caused by potential leakage or connectivity from the NPE final void into the underlying goaf of the Integra underground operations.

Question 5: Does the EIS provide a reasonable consideration of the potential for discharges (including salt) to nearby watercourses and the significance of any resulting impacts to water quality and the downstream environment? If not, what additional information would be required to provide a sufficiently robust assessment of these matters?

Response

26. The EIS does not provide reasonable consideration of the potential for discharges. The water balance model predicts spillages to occur twice a year however the locations of receiving surface water systems are not identified. The water quality impacts of spillages to the downstream watercourses for a variety of contaminants have not been considered. The EIS inconsistently states that discharges will occur under the HRSTS, when the proponent's Environmental Protection Licence (EPL) EPL 4460 has been varied to remove conditions relating to discharges under the HRSTS.

Explanation

27. The proponent's water balance modelling results indicate that the frequency of spills from sediment dams following rainfall events is twice a year. Average spill volumes caused by rainfall events are predicted to be between 478 ML/ year and 534 ML/year, with maximum spill volumes between 3,765 ML/year and 4,173 ML/year (EIS, App. 9, App. B, p 14). Spills from water management system (WMS) dams may occur more regularly than predicted given the water balance model utilises the lower average annual rainfall values from the Jerrys Plains meteorological station, rather than the 35 per cent greater average annual rainfalls observed at the Bowmans Creek (Grenell) meteorological station.

28. The Mount Owen EPL 4460 was varied in November 2014, removing conditions regarding the proponent's licence to discharge water under the HRSTS to Swamp Creek (NSW EPA, 2014a). Additionally, the Ravensworth East EPL does not contain conditions that relate to water discharges (NSW EPA, 2014b). The EIS consistently states that, if required, excess mine water will be discharged to the HRSTS under EPL 4460. The proponent will need to clarify whether discharges to the Hunter River will actually occur or provide details of an alternative method of containing their excess saline water.

29. The WMS for the proposed project is based on the existing systems in place at the Mount Owen and Ravensworth East mines. However, detailed information has not been provided for the WMS currently implemented at the existing operations. With regards to the MOCO project's WMS, the following information is needed:

a. A water management schematic, illustrating water transfers between stores, under a range of climatic scenarios and including licensed surface water and groundwater extraction/discharge quantities

b. The location of particular sediment dams or water storages that are considered most at risk of regular spills

c. Identification of receiving watercourses of spills

d. Water quality monitoring of the full range of contaminants (including metals/metalloids, ionic composition and PAHs) prior to, during and following spills, consistent with the recent findings of Krogh et al. (2013), to provide evidence that spills have negligible impacts on the downstream water resources, including the Hunter River

e. Alternative options, including redesign of dams and their storage capacity within the WMS, to avoid bi-annual spills, or mitigate their impacts.

Other considerations

30. The Northern Sydney Basin bioregion which includes the Hunter subregion has been identified as a Bioregional Assessment priority region. It is anticipated that the Bioregional Assessment programme will deliver a regional groundwater model for the Hunter subregion which will include the MOCO project, the adjacent coal mines and coal mine hydrogeological processes. Data and relevant information from the proposed project should be made accessible to this Bioregional Assessment and other research projects.

Date of advice	11 March 2015
Source documentation available to the IESC in the formulation of this advice	Umwelt, 2015. Glencore – Environmental Impact Statement, Mount Owen Continued Operations Project. January 2015. Hydro Algorithmics, 2014. Mount Owen Continued Operations – Groundwater Impact Assessment Peer Review. 27 October 2014. Mt Owen Pty Ltd, 2014. Various management plans. Available at http://www.mtowen complex.com.au/EN/EnvironmentalManagement/Pages/PlansandPrograms.aspx
References cited within the IESC's advice	AUSRIVAS, (2007). AUSRIVAS, Australian River Assessment System. http://ausrivas.ewater.com.au/ Commonwealth of Australia, 2015. Modelling water-related ecological responses to coal seam gas extraction and coal mining, prepared by Auricht Projects and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for the Department of the Environment, Commonwealth of Australia. IESC, 2014. Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals. April 2014. Available at: http://iesc.environment.gov.au/pubs/iesc-information-guidelines.pdf Krogh, M., Dorani, F., Foulsham, E., McSorley, A., and Hoey, D., 2013. Hunter Catchment Salinity Assessment. Final Report. NSW Environment Protection Authority. NSW Environment Protection Authority (NSW EPA), 2014a. Notice of variation of licence no. 4460. 07 November 2014. NSW Environment Protection Authority (NSW EPA), 2014b. Notice of variation of licence no. 10860. 16 October 2014.

APPENDIX C

Umwelt Briefing Note on GDE issues

Briefing Note

To: Department of the Environment

cc: Vicki McBride and Bret Jenkins (Glencore)

From: Umwelt

Author: David Holmes

Date: 22July 2015

Subject: Response to IESC Questions regarding Proposed Mount Owen Continued Operations Project on Groundwater Dependant Ecosystems and Aquatic Fauna

1.0 Introduction

The Department of the Environment's submission on the Mount Owen Continued Operations Project (the Project) enclosed the advice received from the Independent Expert Scientific Committee (IESC) following the Committee's review of the EIS prepared for the Project. This advice identified a number of areas where the IESC considered that further information was required to understand the impact of the Project on water resources (including ecological resources dependant on surface and groundwater flows).

Umwelt and Glencore met with representatives of the Commonwealth Office of Water Science (OWS) and the Department of the Environment (DotE) on 8 July 2015 in Canberra to discuss the issues raised in the IESC advice. Following that meeting, it was agreed that Umwelt would provide further information on issues related to the Project's potential impacts on Groundwater Dependant Ecosystems (GDEs). Additional information on ecological issues raised by DotE and surface water issues raised by the IESC will be provided in a Response to Submission report.

This briefing note contains further information on the identification of GDEs potentially impacted by the Project and outlines the nature of these impacts and proposed management measures. The Response to Submissions report will also include a response to the GDE issues raised by the IESC having regard to any additional comments raised by DotE and the OWS following consideration of this briefing note.

Section 2.0 of the Briefing Note contains further information on the Project's predicted impacts on alluvial groundwater and also discusses the Project's predicted impacts on stream flows in Main Creek, Bettys Creek and Glennies Creek which are relevant to the consideration of impacts on aquatic ecosystems that may be present in these creeks. **Section 3.0** discussed the potential impacts on GDEs and aquatic ecosystems and contains a justification for the level of assessment undertaken and included in the EIS. **Section 4.0** discusses monitoring and management measures that will be implemented to understand and manage any impacts the Project may have on GDEs and aquatic ecosystems.

2.0 Predicted Groundwater Impacts

The IESC advice concluded:

> *The proponent's groundwater model is robust, well constructed and has been peer reviewed. The inclusion of 43 mines within an approximately 451 km^2 domain would allow sub-regional groundwater impacts to be estimated cumulatively.*

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However it also noted:

> *The numerical groundwater model has a cell size of 100 m by 100 m which is adequate for estimating regional groundwater behaviour, though is too large to predict fine scale groundwater and surface water interactions. Nevertheless, the groundwater model predicts baseflow reductions to surface watercourses as follows (with results from the 'plus one standard deviation' model run in brackets): 6 ML/year (9 ML/year) decrease to Bettys Creek, 15 ML/year (22 ML/year) decrease to Main Creek and "negligible" losses from Bowmans and Glennies Creeks. Seasonal quantification or estimation of baseflow within each of the surface watercourses has not been provided. Baseflow analysis was only described as an annual percentage and therefore the importance of baseflow contribution to Bowmans and Glennies Creeks during seasonal or climatic low flow periods is unknown.* [paragraph 6]

> *The groundwater model predicts drawdown within the Main Creek alluvium of between 2 m and greater than 6 m (for the plus one standard deviation model run). Within the predicted zone of impact this would lower the Main Creek alluvial water table to between 4 m and 8 m below the surface. The effect on the Central Hunter Swamp Oak Forest GDE of lowering the Main Creek alluvial water table has not been addressed within the EIS.* [paragraph 7]

The key area of consideration is the predicted impacts on the alluvial aquifers associated with each of Bettys Creek and Main Creek and the associated impacts on ecological systems reliant on these aquifers. It is worth noting that there is no direct connection between the alluvial aquifers and the proposed mining operations, nor is there any predicted cracking of strata directly below the alluvium. Potential impacts to the alluvial aquifers, and any supported GDEs, however, may result from dewatering activities that depressurise hard rock (coal measures) aquifers and indirectly induce leakage from the alluvial aquifers.

The relationship between the alluvium and hard rock aquifers is schematically illustrated in **Figure 1**.

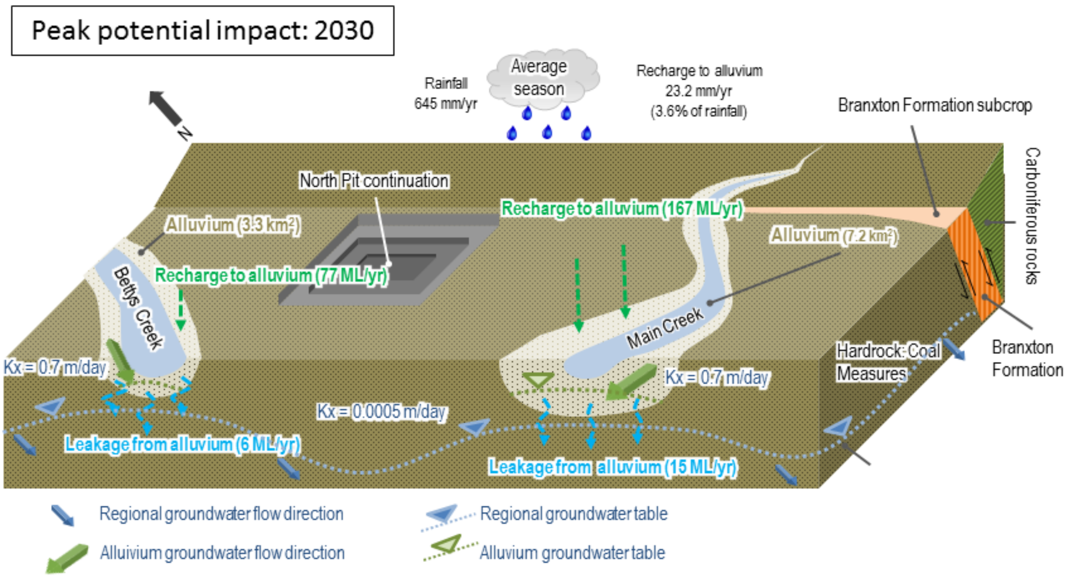

Figure 1 Schematic representation of fluxes to and from the alluvial systems of Main Creek and Bettys Creek

The hydraulic characteristics of the alluvial and hard rock aquifers are significantly different. Hydraulic conductivity in the alluvium has been determined to be three orders of magnitude faster than the underlying hard rock, while specific yield is two orders of magnitude higher (Jacobs 2014). Thus, it is expected that seasonal infiltration and flow through the alluvium will occur at a significantly faster rate than any variation in leakage driven by changes in water pressures in deeper formations. Further, while annual leakage from the alluvium predicted under the maximum impact scenario is estimated to be 15 ML/year from Main Creek and 6 ML/year from Bettys Creek, annual predicted recharge from rainfall is predicted to be more than an order of magnitude greater, with the bulk of water being transmitted downstream through the alluvium to the main systems of Glennies and Bowmans Creeks (refer to **Figure 1**).

Annually, peak potential leakage impacts caused by drawdown induced from mining operations are less than 10 per cent of mean annual expected recharge for both Bettys Creek and Main Creek.

It is therefore unlikely that depressurisation will cause any observable effects under normal (average climate) conditions. Based on historical long term rainfall records, the predicted recharge of the alluvium ranges from 26 ML/year to 141 ML/year in Bettys Creek and 37 ML/year to 309 ML/year in Main Creek (based on the lowest and highest annual rainfalls observed in the 128 years of rainfall data). The calculated minimum level of recharge exceeds the predicted leakage from each alluvial system of 9 ML/year and 22 ML/year respectively (2030 median + 1 SD).

The model used in the Groundwater Impact Assessment in Appendix 10 of the EIS (v8.1) utilises a grid size of 100 metres x 100 metres. This scale is considered appropriate for the regional nature of the model and provides adequate resolution to understand and appreciate the potential impacts to groundwater of the proposed expansion. This grid resolution is considered appropriate to model dewatering effects on the hard rock aquifers. However, as noted in the IESC advice, this model scale could be further refined to understand localised impacts in alluvial aquifers where the extent of the alluvium may be significantly narrower in places than the cell size used.

To better understand the potential impacts of the Project on the alluvium in Main Creek and Bettys Creek a higher resolution model of the Project's impacts on the groundwater aquifer was developed, as described below.

2.1 Detailed Modelling of Impacts on Alluvial Aquifers

Jacobs has undertaken additional modelling to better understand the localised impacts that may arise in the alluvium associated with Bettys Creek and Main Creek. The development of this model and its results are set out in detail in the Letter Report prepared by Jacobs contained in **Appendix A** to this Briefing Note.

In summary the model was based on the regional model and was set up as follows:

- The model domain was reduced to approximately 50 km^2
- Grid spacing was reduced to 20 metre by 20 metre uniformly across the new model domain, with 345 rows and 360 columns.
- The surface elevation within the alluvium was refined using the latest LiDAR data.
- The base of the alluvium was refined based upon a refined isopach map and the refined surface elevations.
- Constant head boundary conditions were input to all active cells in Layer 2. The head values at each cell were transient and corresponded to the predicted heads in Layer 2 for each stress period from the regional model. These boundary conditions were created for each stochastic realisation. Because Layer 2 is entirely constant heads, there was no need for all subsequently deeper layers. Therefore all layers greater than 2 in the regional model were deleted.

Model simulations were run using the same configuration and operation as the regional model and predictive scenarios were created from statistical analysis of the calibrated parameter sets generated from the regional model.

2.2 Depressurisation Impacts

The predicted drawdown results are presented in **Figures 2** to **7** for years 2020, 2025 and 2030, with 2030 representing the maximum expected drawdown for the life of the Project.

The modelling results indicate that the predicted area of impact using the finer resolution grid in the refined model is directly comparable to that determined using the coarser grid in the regional model (refer to Figure 8 in **Appendix A**). However, the refined resolution modelling indicates that the potential impact is restricted to the central region of the alluvial extents only. The drawdown predicted from the revised modelling is comparable and actually slightly less that determined by the regional model, which is likely due to the improved resolution of the aquifer boundary and base, defined using the recently installed standpipes along Bettys, Main and Glennies Creek. This refined modelling also predicts that there will be no impact to these alluvial aquifers for at least the next 5 years (consistent with the regional model predictions).
Table 1 shows the area of predicted drawdown impacts in each of Main Creek and Bettys Creek alluvium.

Table 1 Area of Predicted Drawdown in Alluvium (2030 Median + 1 SD)

Alluvial System	Area (Ha)					
	Predicted Drawdown (m)					Total
	0 – 0.5	0.5 - 1	1 - 2	2 - 3	3-4	
Main Creek	21.93	15.46	10.28	4.16	0.34	52.17
Bettys Creek	54.25	18.92	5.33	0.00	0.00	78.50
Total	76.18	34.37	15.61	4.16	0.34	130.66
Percentage of total drawdown area	58%	26%	12%	3%	<0.3%	100%

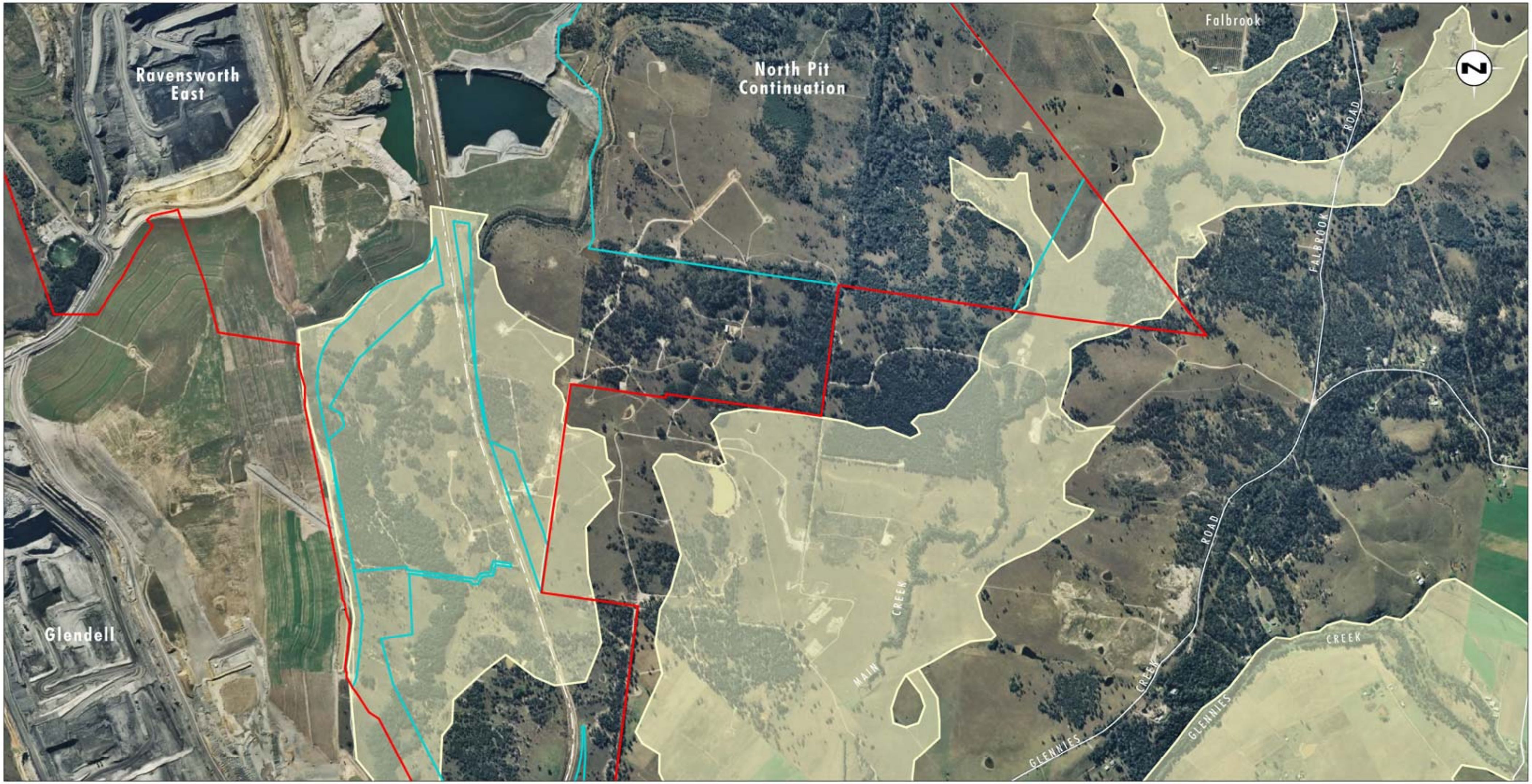

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent

FIGURE 2

Predicted Median Incremental Drawdown in Alluvial Aquifers in Year 2020

File Name (A4): R16/BriefingNote/3109_1015.dgn
20150709 9.02

umwelt

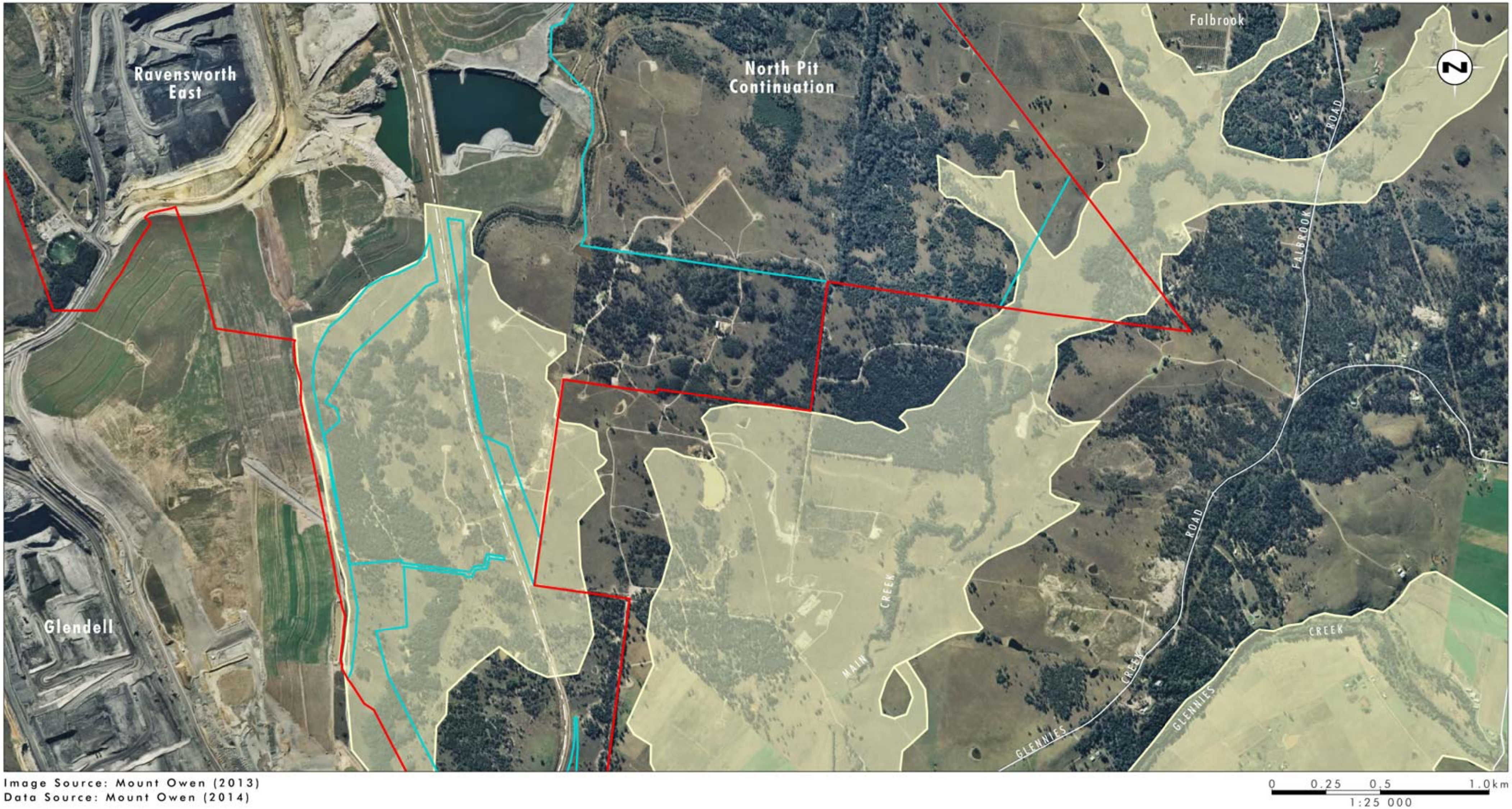

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

Legend
- Project Area
- Proposed Disturbance Area
- Alluvium Extent

FIGURE 3

Predicted Median Plus 1 Standard Deviation Incremental Drawdown in Alluvial Aquifers in Year 2020

File Name (A4): R16/BriefingNote/3109_1016.dgn
20150709 9.02

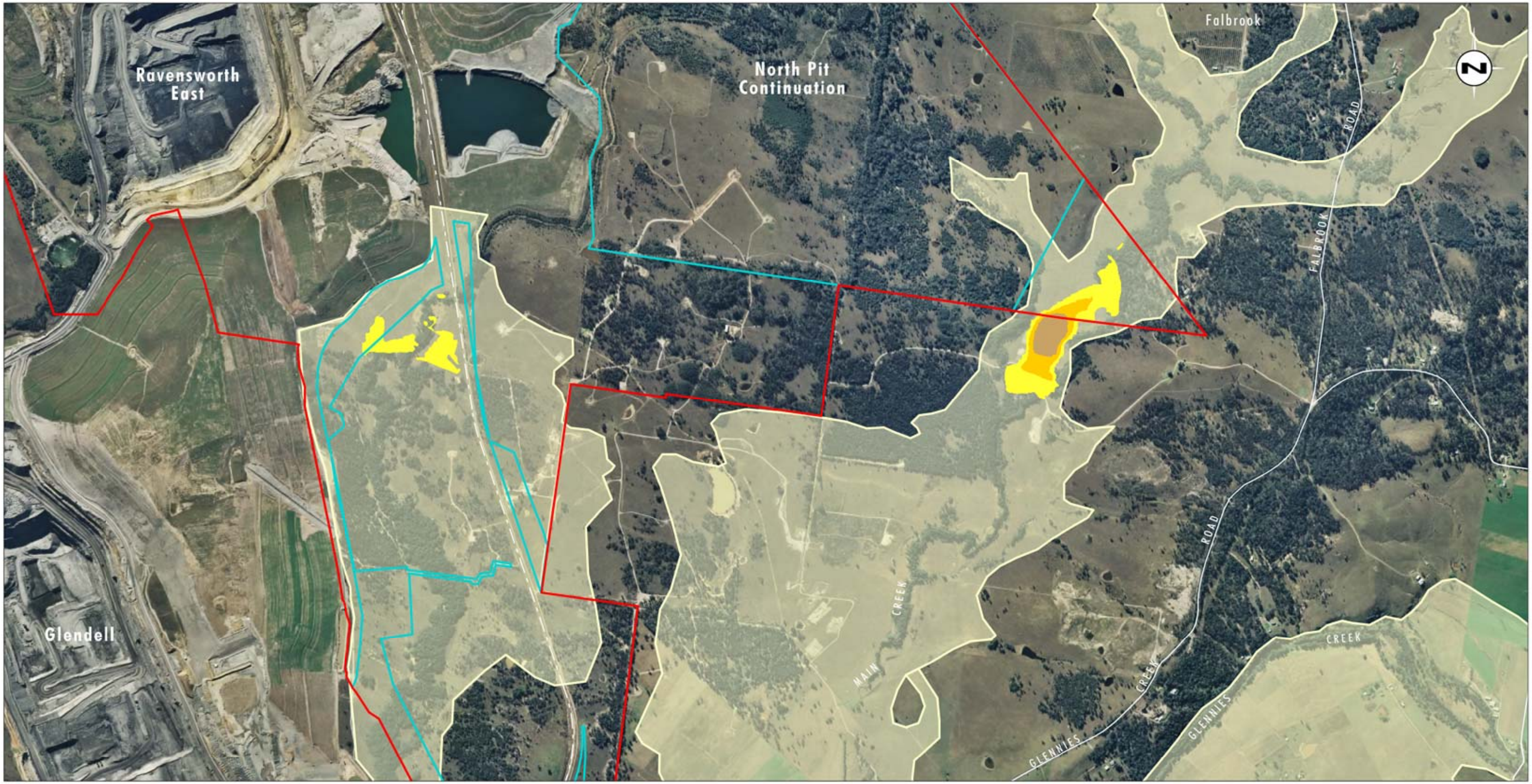

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

Project Area
Proposed Disturbance Area
Alluvium Extent

Predicted Drawdown (m)
0.1 - 0.5
0.5 - 1.0
1.0 - 2.0

FIGURE 4

Predicted Median Incremental Drawdown in Alluvial Aquifers in Year 2025

File Name (A4): R16/BriefingNote/3109_1017.dgn
20150709 9.03

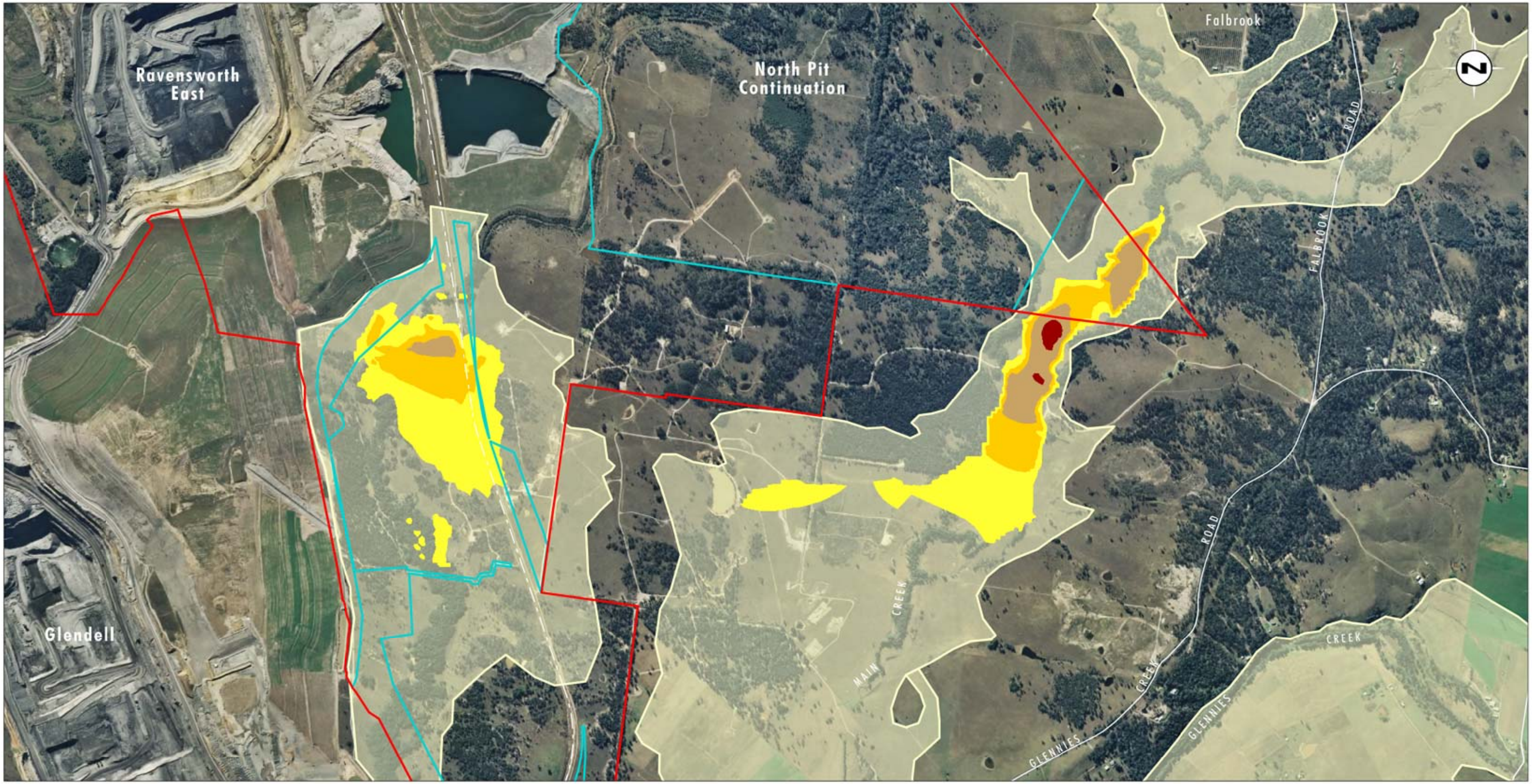

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

Project Area
Proposed Disturbance Area
Alluvium Extent

Predicted Drawdown (m)
0.1 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0

FIGURE 5

Predicted Median Plus 1 Standard Deviation Incremental Drawdown in Alluvial Aquifers in Year 2025

File Name (A4): R16/BriefingNote/3109_1018.dgn
20150709 9.04

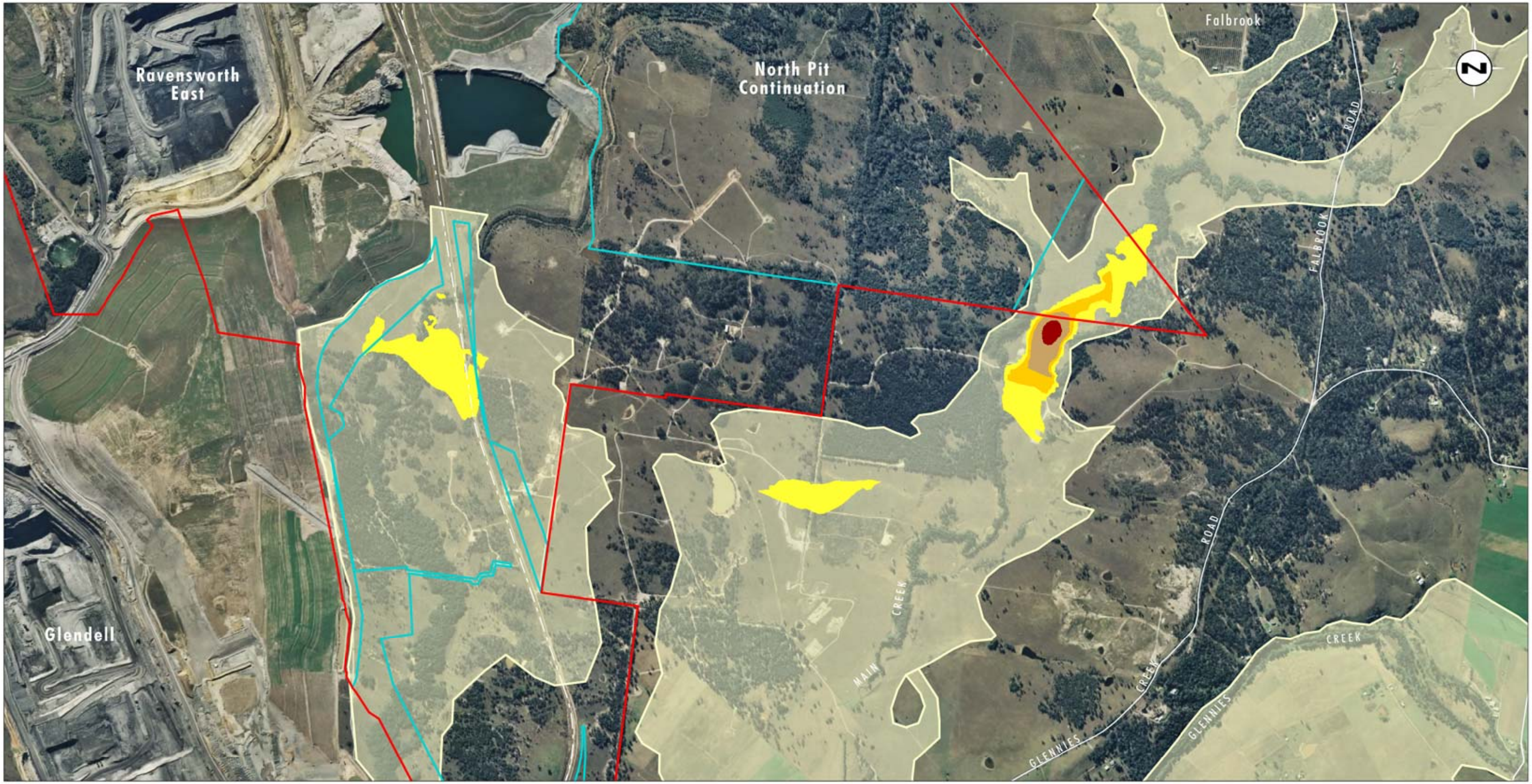

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

Project Area
Proposed Disturbance Area
Alluvium Extent

Predicted Drawdown (m)
0.1 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0

FIGURE 6

Predicted Median Incremental Drawdown in Alluvial Aquifers in Year 2030

File Name (A4): R16/BriefingNote/3109_1019.dgn
20150709 9.04

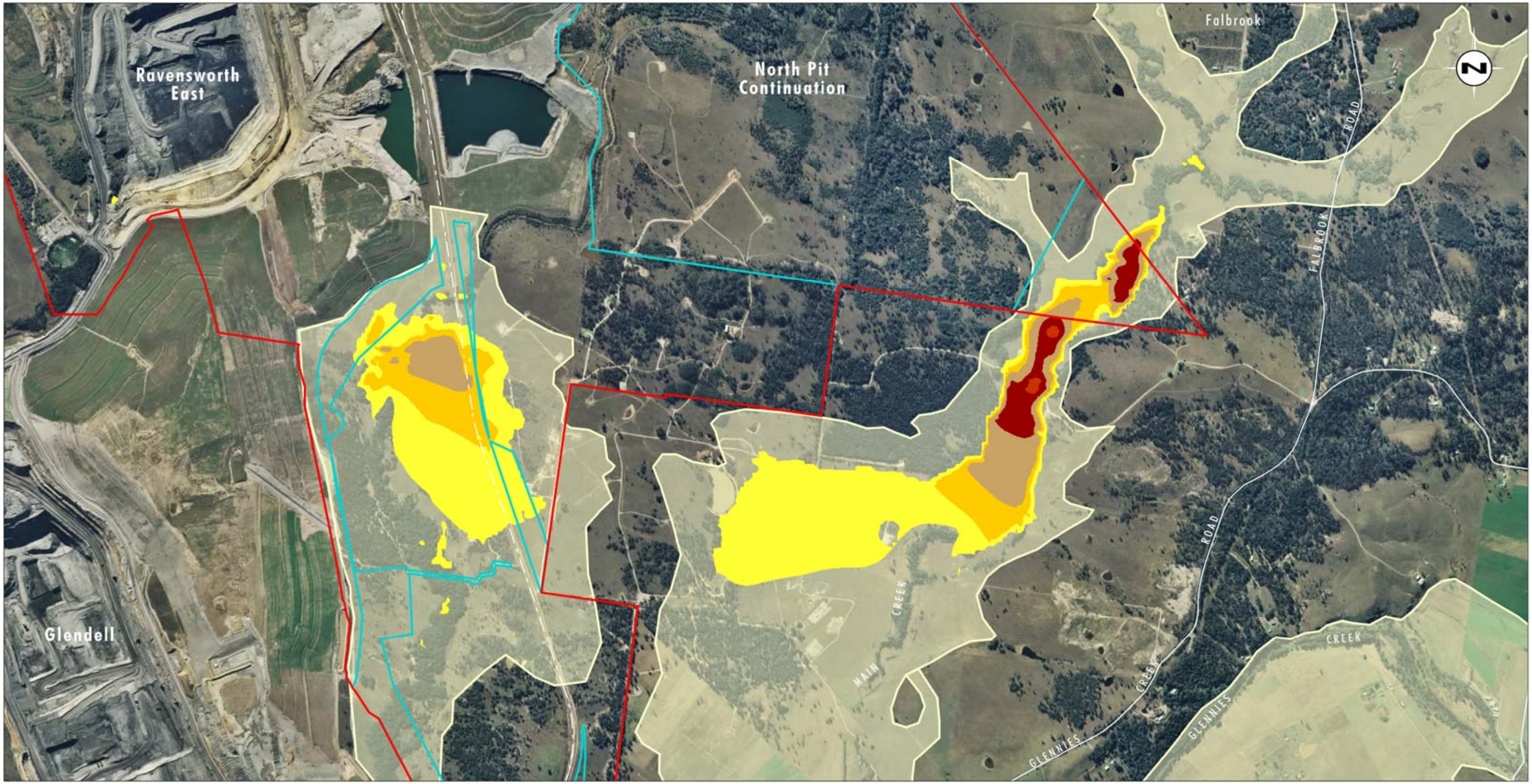

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent

Predicted Drawdown (m)

- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0

FIGURE 7

Predicted Median Plus 1 Standard Deviation Incremental Drawdown in Alluvial Aquifers in Year 2030

File Name (A4): R16/BriefingNote/3109_1020.dgn
20150709 9.05

As shown in **Figures 2** to **7**, and **Table 1**, the vast majority (84%) of the predicted drawdown impact associated with the Project will be less than 1 metre. All of the drawdown in the Bettys Creek alluvium will be less than 2 metres. Only approximately 0.34 Ha of the Bettys Creek alluvium is predicted to experience drawdown of up to 4 metres. The areas of higher predicted drawdown on Main Creek occur where there is a narrowing of the alluvium channel which amplifies the drawdown impact. The maximum predicted depressurisation (2030 Median prediction + 1 SD) is shown graphically in the long section of the alluvium closely aligning to channel of Main Creek shown in **Figure 8**. The alignment for the long section is shown in Figure 7 in **Appendix A.**

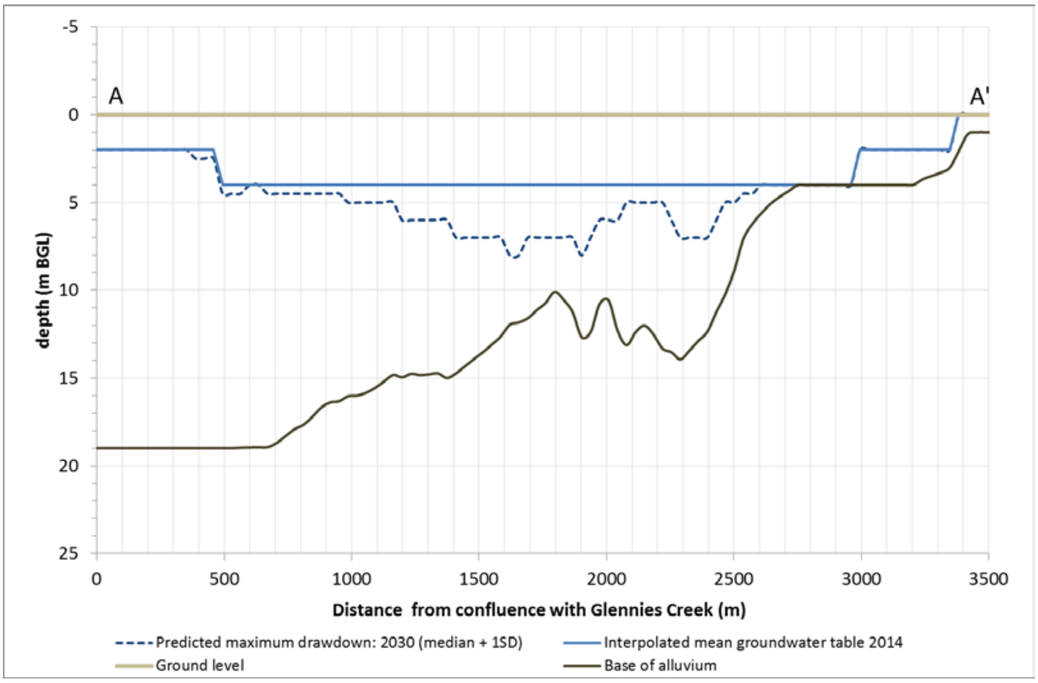

Figure 8 Cross-section depicting current and predicted maximum impact watertable depth and alluvium thickness along Main Creek

As can be seen from **Figure 8**, even under maximum predicted drawdown (a situation only likely to be observable during extended dry periods), groundwater will remain present in the alluvium below Main Creek in all locations where groundwater is currently present. Accordingly, connectivity between the alluvial aquifer in Main Creek and Glennies Creek will be maintained. A similar situation is expected in relation the predicted impacts in Bettys Creek where there the predicted drawdown of that aquifer is less than for Main Creek.

The predicted annual volume of drawdown in each of the alluvial systems (refer to **Figure 1**) will remain the same as identified in the Groundwater Impact Assessment contained in the EIS as the drawdown is induced through the depressurisation of sub-cropping seams associated with dewatering caused by the mining operations.

2.3 Impacts on Surface Flows

Both Bettys Creek and Main Creek are ephemeral however there are no stream gauges on these watercourses. Further, the groundwater model operates with annual time-steps and the resultant drawdowns represent potential incremental annual changes from the base case simulations and does not capture seasonal variability in the alluvial groundwater levels associated with rainfall. Accordingly, the seasonality of flows can only be estimated by reference to rainfall data, seasonality in other gauged watercourses in the area and monitored intra-annual variability in water tables in these aquifers and the inter-annual propensity for the aquifers to fill and spill with the weather and the variability in baseflow supporting stream flow.

As shown in **Figure 9,** intra-annual variability in alluvium aquifer water levels may range up to 1 metre each year, with greater ranges for shallow water tables in the headwaters (NPZ102, NPZ103). Bore NPZ101, is sighted within the zone of potential drawdown in the Main Creek alluvium and water tables at this site have been relatively constant at just over 4m below ground level over the past year. Peak predicted potential additional drawdown may result in an additional 1m watertable drop at this location. The alluvium at this location is approximately 13m thick.

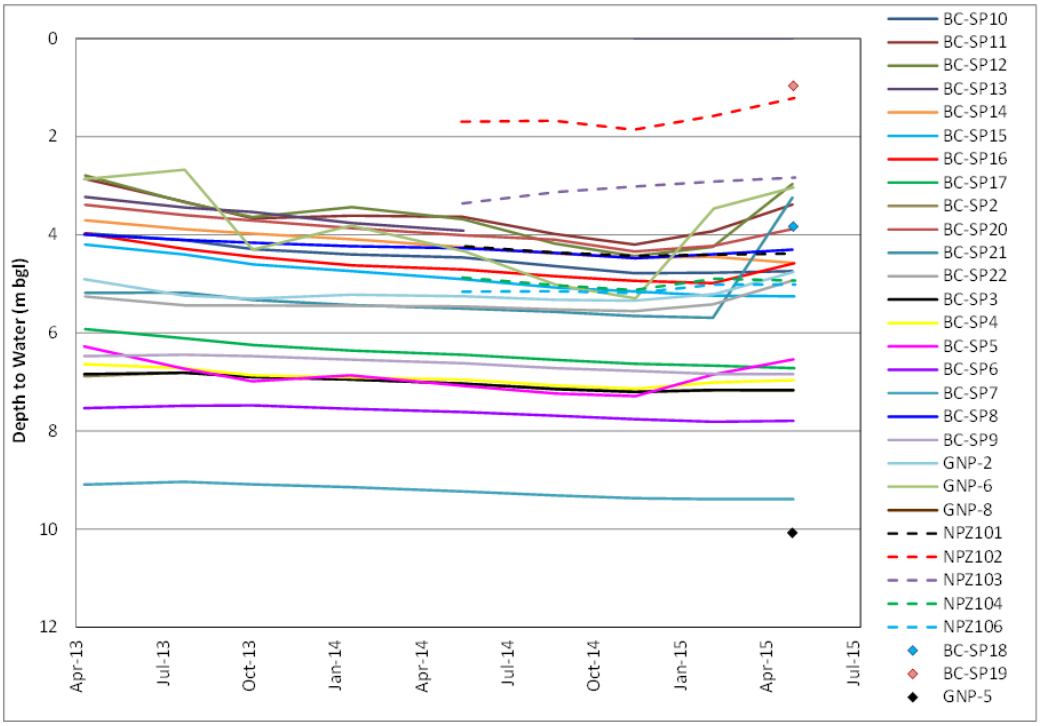

Figure 9 Alluvial groundwater levels across the regional model domain over the past two years. New standpipes within the refined model domain are indicated as dashed lines (NPZ101 – NPZ106)

The predicted drawdown in the Bettys Creek and Main Creek alluvial aquifers is limited to the upper reaches of these alluvial systems where the volume of alluvium is relatively small compared to downstream reaches of the creeks. The Main Creek channel is less than 2 metres in depth. All bores in the main channel of the alluvium record groundwater table depths in excess of 4 metres, indicating that the creeks are largely disconnected from the groundwater systems for these tributaries and will not contribute to baseflows in Main Creek or Bettys Creek. This will particularly be the case during drier periods when the water table in the alluvium will be even lower due to lower recharge rates.

As can be seen from **Figures 2** to **7**, there is no predicted drawdown in the Glennies Creek alluvium with the only predicted impact resulting from the drawdown in the alluvium associated with Main Creek. The predicted median reduction in groundwater flux in Main Creek (+1 SD) is 22ML/year (approximately 0.06ML.day). As detailed in Section 3.5.1.1 of the Groundwater Impact Assessment, this estimated leakage rate is equivalent to less than 0.3 per cent of the estimated baseflow contribution of Main Creek to Glennies Creek.

The catchment context of the Project relative to Glennies Creek is shown in the Surface Water Assessment and on **Figure 2.3**. Glennies Creek has a catchment area of approximately 523 square kilometres of which the upper half (i.e. 233 square kilometres, approximately 45 per cent of the total catchment area) is captured in the Glennies Creek Dam. Glennies Creek Dam is located approximately 17 kilometres upstream of the confluence of Main Creek with Glennies Creek.

The construction of Glennies Creek Dam was completed in 1983 and forms part of the Hunter Regulated River System. The Hunter Regulated River System is managed by the NSW Government as part of a Water Sharing Plan regulated under the NSW *Water Management Act 2000*. Water from Glennies Creek Dam is managed to meet downstream requirements for environment, irrigation, stock and domestic, town water and water conservation usages. As such the flow regimes downstream of Glennies Creek Dam are highly modified and are regulated by the NSW State Government.

An analysis of seasonal flows in Glennies Creek (Middle Falbrook 210044) (data from 1956 to 2014) is presented in **Figure 10**.

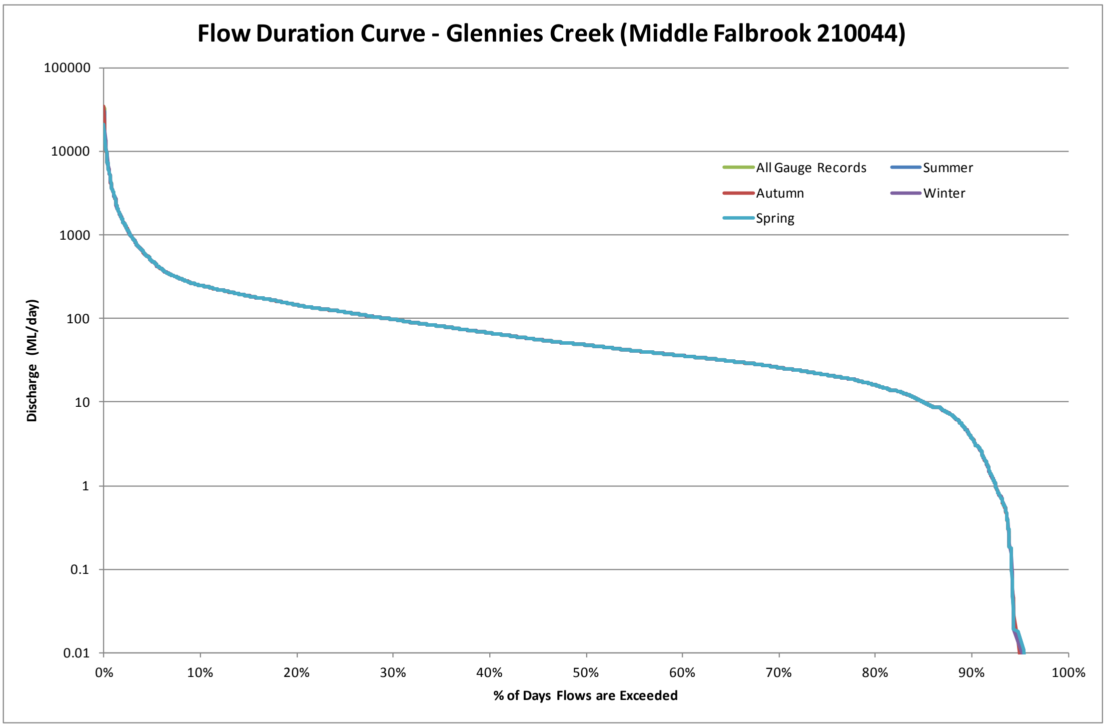

Figure 10 – Flow Duration Curve – Seasonal Analysis of Flows in Glennies Creek (Middle Falbrook 210044)

Due to it being a regulated system, Glennies Creek shows no seasonality in its flows. It follows that the level of predicted impact on base flows in Glennies Creek as a result of the predicted drawdown in Main Creek is considered to be negligible.

3.0 Impacts on Groundwater Dependant Ecosystems

The refined modelling indicates the predicted potential drawdown area within the alluvium is more constrained than was predicted in the model used for the Groundwater Impact Assessment in the EIS. This higher resolution modelling of predicted impacts enables a better understanding of potential impacts on existing ecological communities.

Ecological communities with potential to be impacted by changes in groundwater alluvium are:

- Aquatic fauna dependant on base flows lined to alluvial groundwater
- Stygofauna and hyporheic fauna present in the alluvium and alluvial aquifers
- Riparian vegetation or swamps reliant on alluvial groundwater.

The IESC advice included the following comments in relation to predicted impacts on water dependant ecological assets:

> *The effect on the Central Hunter Swamp Oak Forest GDE of lowering the Main Creek alluvial water table has not been addressed within the EIS.* [Paragraph 7]
>
> *The EIS states (App 10, p 92) that no GDEs are associated with Yorks Creek and Swamp Creek. However, the riparian zones of these watercourses are mapped as containing the Central Hunter Swamp Oak Forest which is considered to be a GDE (EIS, App 11, Figure 4.1). The proponent has not mapped or estimated the area inhabited by groundwater dependent riparian vegetation outside of the project area, including within the zone of predicted alluvial impact and downstream of the proposed project area.* [Paragraph 8]
>
> *The proponent states that ephemeral streams represent limited habitat opportunities for aquatic fauna. However, the EIS states in a number of places (for example App 10, p 26 and App 11, p 2.3-2.4) that pools of standing/stagnant water remain in ephemeral streams. These pools may be semi permanent and represent important refugia for aquatic fauna. The ecological assessment does not assess the habitat value, duration of persistence or map the extent or location of these pools.* [Paragraph 9]
>
> *Given the Main Creek alluvium supports known groundwater dependent riparian vegetation that is also habitat known to be utilised by the nationally listed endangered Spotted-tail quoll, information identified in paragraphs 8 and 9 is needed to determine the existing habitat conditions along this watercourse.* [Paragraph 10]
>
> *The proponent has undertaken sufficiently robust ecological stream habitat and aquatic fauna assessments for Bowmans Creek and Bettys Creek. However, equivalent assessments of Main Creek and Glennies Creek have not been provided within the EIS. To understand the existing ecological conditions within, and provide a robust assessment for Glennies and Main Creek, a description of the riparian, in-stream, and alluvial habitat for fauna and flora needs to be provided. This would include:*
>
> *a. mapping of vegetation including in riparian zones and areas of shallow groundwater*
> *b. sampling of GDEs including stygofauna and hyporheic fauna*
> *c. an in-stream aquatic fauna survey (e.g. fish, macroinvertebrates, amphibians)*
> *d. an existing conditions aquatic habitat assessment in line with a national standard (for example using the AUSRIVAS (2007) sampling protocols utilised for Bowmans Creek)*
> *e. the development of ecological conceptualisations using the method described in Commonwealth of Australia (2015) to identify the ecological and water relationships of the MOCO project area.* [Paragraph 14]

The Project's predicted impacts on GDEs (where present) is discussed further in **Sections 3.1** to **3.3**.

3.1 Aquatic Fauna

As discussed in **Sections 2.2** and **2.3**, the aquifers in the alluvium associated with Bettys Creek and Main Creek are considered unlikely to contribute to baseflows in the creeks themselves (i.e. the observed water tables are below the bed of creeks). Accordingly, depressurisation impacts associated with the Project will have no impact on aquatic fauna in Main Creek or Bettys Creek. As noted in **Section 2.3**, the Project will have a negligible impact on baseflows in Glennies Creek.

While not groundwater related, reductions in surface flows due to reduced catchment areas can impact on the volume of water and duration of flows in ephemeral systems. This remains relevant to the issues identified in paragraph 9 of the IESC advice.

Table 5.5.5 in the EIS (reproduced in **Table 2** below) shows that the catchment areas for each creek system impacted by the Project.

Table 2 – Predicted Impacts on Catchment Areas

Catchment	Pre-Mining (ha)	Current Area (2012) (ha)[1]	Current Approved Final Landform (ha)	Project		
				Year 5[1] (ha)	Proposed Final Landform[2]	
					Area (ha)	%[4]
Bowmans Creek[3]	**25,055**	**22,010**	**20,390**	**21,590**	**20,520**	**99.4%**
- Stringybark Creek	1,290	1,220	1,300	1,300	1,300	100%
- Yorks Creek	1,230	1,580	1,660	1,800	1,920	116%
- Swamp Creek	2,380	410	1,440	390	1,230	85%
- Bettys Creek	1,810	660	960	700	780	81%
Glennies Creek[3]	**52,335**	**50,265**	**50,405**	**50,215**	**50,255**	**99.7%**
- Main Creek	2,000	2,480	2,620[5]	2,430	2,470	94%

Notes:
1) Excluding water management system
2) Final Landform is when both the decommissioning of infrastructure and the rehabilitation of the post mining landform are completed.
3) Catchment areas modified to reflect changes due to the Project and approved and proposed Liddell Operations. This does not include impacts from other modifications (such as other mining operations) downstream of the Project Area.
4) Project final landform catchment area as a percentage of the current approved final landform.
5) Catchment area updated and larger than identified in Mount Owen Operations EIS, 2003 (previously 1,750 ha), as more accurate terrain data is now available (LiDAR) over entire catchment

As can be seen from **Table 2**, the catchment areas for the creeks impacted by the Project will remain similar to or be larger than the current catchment areas for these creeks during the life of the Project. Only Swamp Creek and Main Creek will experience a reduction in catchment area relative to existing conditions (approximately 5 per cent reduction in Year 5 in the case of Swamp Creek and approximately 2% reduction in the case of Main Creek).

As ephemeral systems, water flow in these systems is dependent on localised runoff. Accordingly, the Project is unlikely to have any negative impacts on the habitat value, duration of persistence of pools of standing/stagnant water present downstream of the Project in the creeks where there is an increase in catchment area. The predicted reduction in flows as a result of decreased catchment in Swamp Creek or Main Creek (relative to existing conditions) is unlikely to be observable given the significant natural variability already present in these ephemeral systems. Additionally, the previous diversion of the upper reaches of Bettys Creek into Main Creek means Main Creek currently has (and will continue to have) a larger catchment than existed prior to mining. Accordingly, the Project will have a negligible impact on the volume of water in, or the persistence of, pools in Main Creek and any potential impacts on aquatic fauna present in pools downstream as a result of the Project is likely to be negligible. The mapping of the extent or location of these pools or an assessment of their habitat value, area and duration of persistence is therefore not considered to be warranted.

An analysis of potential impacts on flows in Glennies Creek has been undertaken by adjusting the flow duration curve (for all periods) to consider predicted changes in catchment contribution and baseflow (refer to **Section 2.3**). The results are shown in **Figure 11**.

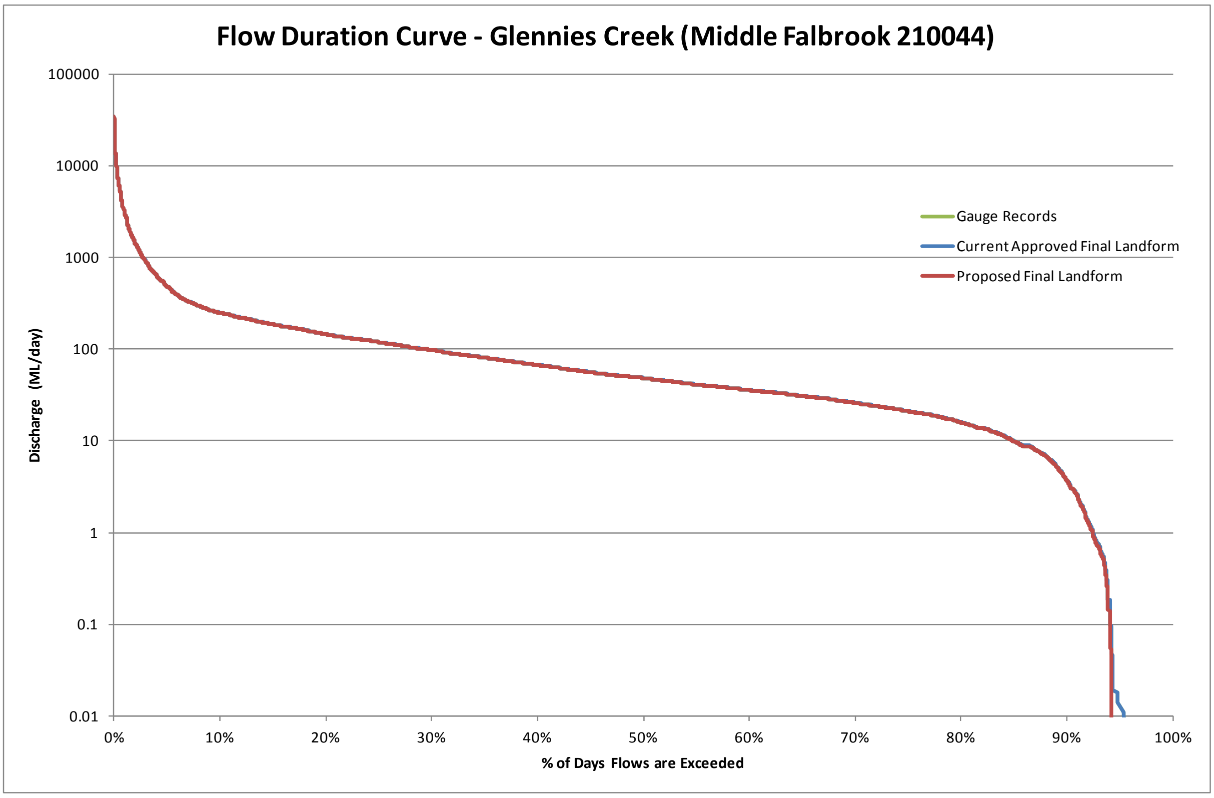

Figure 11 – Glennies Creek – Predicted Impacts

The flow duration curve indicates that the predicted flow impacts with the Project show little variation to both the gauge record and the current approved final landform. As shown on **Figure 11** the Project will impact not impact on baseflows in Glennies Creek due to the highly regulated processes within Glennies Creek. The mapping of the extent or location of pools or assessment of habitat value, in and adjacent to Glennies Creek is therefore not considered to be warranted.

3.2 Stygofauna and Hyporheic Fauna

As shown in **Figure 8**, the predicted drawdown in the Main Creek alluvial aquifer will not result in a permanent draining of the alluvial aquifer at any point. Even if depressurisation did result in a loss of connectivity between parts of the alluvial aquifers in the upper reaches of the Main Creek alluvium (for example during extreme drought periods), the natural flux in the alluvial system and the higher permeability of the alluvium relative to the premeabilities of the sub-cropping strata means this connectivity (and thus connectivity with the Glennies Creek alluvial aquifer) would be re-established during wetter periods when the alluvium 'fills and spills' (refer to **Figure 1**).

The connectivity between the Glennies Creek alluvium and the Main Creek alluvium means there is a strong likelihood that stygofauna and hyporheic fauna in these areas are similar or identical. Any impacts on stygofauna and hyporheic fauna as a result of depressurisation will be localised and in the unlikely event that there is a complete drainage of the alluvial aquifer in isolated areas of the alluvium where there is a predicted drawdown, stygofauna and hyporheic fauna populations will re-establish when connectivity is re-established during wetter periods. Accordingly, no significant impact on stygofauna or hyporheic fauna would be expected and no specific sampling of hyporheic or stygofauna is considered to be warranted either as part of the assessment of the Project or as part of the Surface Water and Groundwater Response Plan.

3.3 Riparian Vegetation

Mapped vegetation types and the location of standpipes recently installed in the alluvium in the areas of Main Creek and Bettys Creek where there are predicted drawdown impacts are shown on **Figure 12** with the extent of the predicted potential maximum drawdown (2030 Median + 1SD).

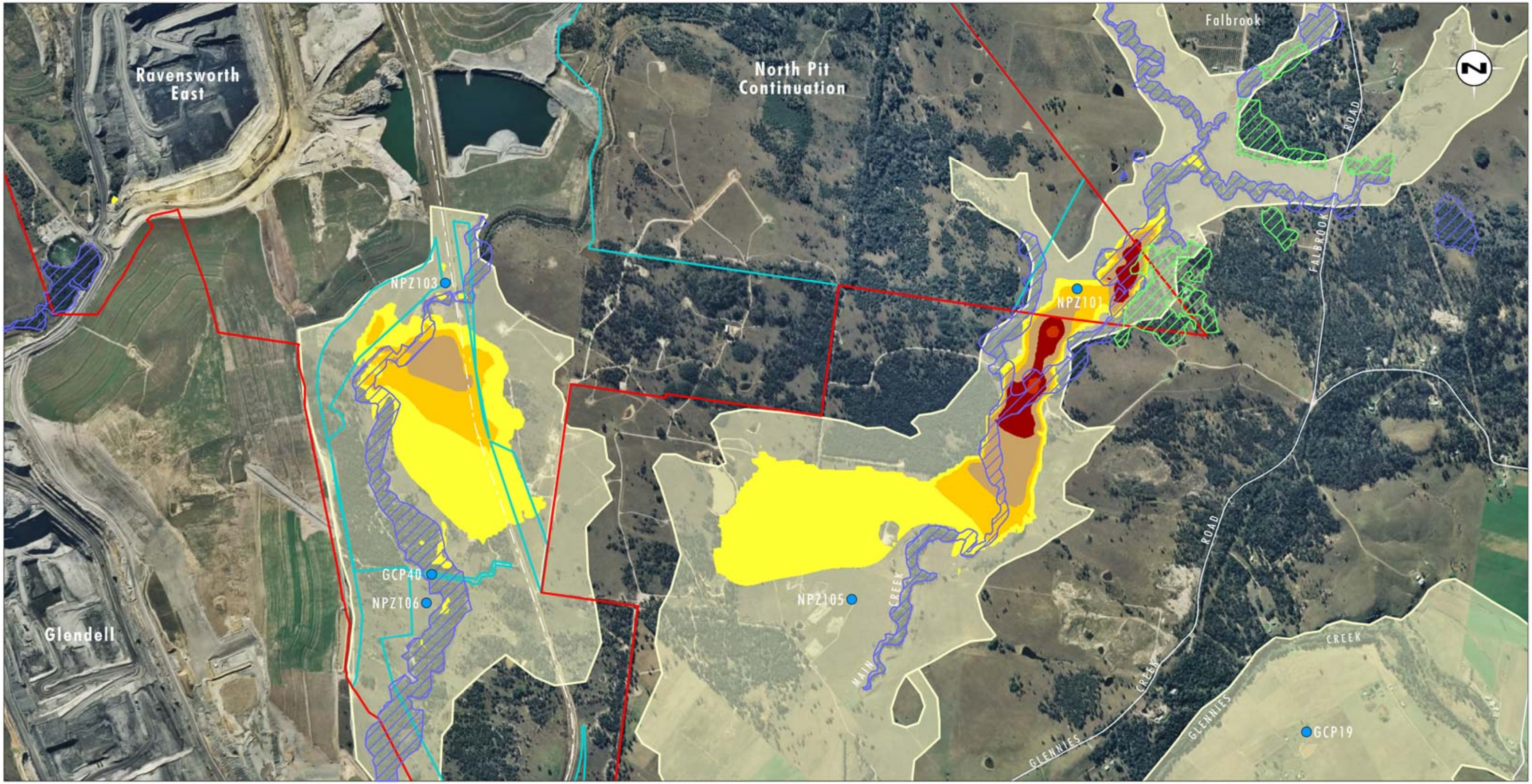

Image Source: Mount Owen (2013)
Data Source: Mount Owen (2014)

0 0.25 0.5 1.0km
1:25 000

Legend

- Project Area
- Proposed Disturbance Area
- Alluvium Extent
- Central Hunter Swamp Oak Forest
- Hunter Lowland Red Gum Forest
- Alluvial Groundwater Monitoring Bore Locations

Predicted Drawdown (m)

- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0

FIGURE 12

Predicted Median Plus 1 Standard Deviation Incremental Drawdown in Alluvial Aquifers in Year 2030 with Vegetation

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The area of Central Hunter Swamp Oak Forest located over areas of predicted groundwater drawdown is shown in **Table 3**.

Table 3 Area of Central Hunter Swamp Oak Forest Located in Areas of Predicted Drawdown in Alluvium (2030 Median + 1 SD)

Alluvial System	Area (Ha)					
	Predicted Drawdown (m)					Total
	0 – 0.5	0.5 - 1	1 - 2	2 - 3	3-4	
East - Central Hunter Swamp Oak Forest	13.68	10.49	8.36	3.86	0.34	36.73
West - Central Hunter Swamp Oak Forest	4.85	2.17	0.60	0	0	7.62
Total	18.53	12.66	8.96	3.86	0.34	44.35
Percentage of community in area of predicted drawdown	42%	29%	20%	9%	<1%	

As noted above in **Section 2.2.1**, the drawdown caused by the depressurisation of the underlying aquifers will be slow, with the effect only likely to be noticeable during extended dry periods.

The Central Hunter Swamp Oak Forest community (the main community present in the areas of predicted drawdown in Main Creek and Bettys Creek) and a small area of Hunter Lowland Red Gum Forest mapped as occurring on Main Creek to the east of the North Pit Continuation may be considered to be groundwater dependent due to reliance in some circumstances on groundwater in periods of drought. However, similar vegetation exists further upstream and in other creek systems where there is unlikely to be any significant alluvial groundwater present. This is particularly the case with the Hunter Lowland Red Gum Forest which is mapped as extending well into areas where there is little or no alluvium (refer to **Figure 12**) and vegetation in this area would be reliant on soil moisture and rainfall.

The dependence of the Central Hunter Swamp Oak Forest (and in particular, Swamp Oak (*Casuarina glauca*) which is the only species in the Hunter Swamp Oak Forest community present in the area of impact which is likely to have a root system deep enough to be in contact with the alluvial groundwater at present), on groundwater in this location will depend on the depth of the root system of the vegetation and it ability to maximise use of rainfall and surface moisture. A review of literature indicates that *C. glauca* can have a strong reliance (Cramer, 1999) or little reliance (Wei et al, 2013) on groundwater. Most studies of the species have focussed on *C. glauca* growing in swamp like conditions or areas with elevated water tables (0 to 3 metres below ground level) were there is a clear connectivity between the root system and alluvial groundwater. However, in the Hunter Valley, the species is considered to be opportunistic and readily colonises areas with little or no groundwater present; for example, the species has been observed growing on roadsides where it can utilise runoff water and it has also been observed growing up hill slopes.

Without excavation of trees to determine rooting depth or detailed isotype studies, it will not be possible to determine the likely extent of groundwater use of *C. glauca* present along Main Creek and Bettys Creek. However based on the current depth of the water table along Main Creek and Bettys Creek (refer to **Figures 8** and **9**) it is expected that the species, which is typically shallow rooted, will have little direct connectivity with the alluvium and is more likely to be reliant on soil moisture. This view accords with the findings in Wei *et al* (2013). During extended dry periods however, the reliance on groundwater in the alluvium is likely to increase. As discussed above, it is during extended dry periods when the drawdown effects in Main Creek and Bettys Creek are likely to be more evident.

As can be seen from **Figures 8** and **10**, approximately 1 kilometre of the Central Hunter Swamp Oak Forest along Main Creek is located over the area of proposed drawdown of more than 1 metre (i.e greater drawdown than has been observed in natural fluctuations over the 12 month period to April 2015).

The level of groundwater observed at piezometer NPC40 (located on Bettys Creek in Central Hunter Swamp Oak Forest) when installed in 2008 was approximately 8 to 9 metres below ground level, a similar level to the lowest predicted water table (medium +1 SD) along Main Creek. It would be expected that the level of the water table on Bettys Creek at this location would have been even lower during the drought ending in mid 2007, as indicated by the fluctuations observed at piezometer North (refer to Figure 2.11 in the Groundwater Impact Assessment). Piezometer NPC40 is no longer functional, however NPZ106 is located in a similar location and indicates the current water table at that location is approximately 5 metres below ground level. The Swamp Oak community along Bettys Creek in this area remain healthy indicating an ability to survive in areas where groundwater is more than 5 metres below the surface and a tolerance to fluctuations of a further 3-4 metres below this during period of drought. This level of natural fluctuation and depth to groundwater is similar to or greater than that predicted to occur in Main Creek under the Project scenario (refer to **Figure 8**).

To the extent that there is groundwater dependence by *C. glauca*, the plants in the immediate area have a demonstrated tolerance to lower water tables than are predicted to result from the Project and can handle large fluctuations in groundwater levels. Additionally, it is noted that the drawdown will occur over an extended period (approximately 15 years) at a steady rate that would enable root growth in the *C. glauca* to adapt to the change and 'follow' the water to greater depths. Accordingly, it is not expected that the predicted drawdowns in the Main Creek and Bettys Creek alluvium will have a significant impact on either individual trees, the species more broadly or the communities present.

Approximately 70% of area of Central Hunter Swamp Oak Forest in the area of impact is predicted to experience drawdowns less than the fluctuations observed in these systems over the past 12 months (i.e. up to 1 metre). The impact on the community in this area will be negligible. Approximately 13 hectares of Central Hunter Swamp Oak Forest community is located in areas of predicted groundwater drawdown of between 1 and 4 metres, however, less than 0.5 hectares is predicted to experience drawdowns of more than 3 metres. The long timeframe for drawdown impacts greater than 1 metre to occur (>10 years) is considered to be sufficient to allow the *C. glauca* to adapt to lower groundwater levels to the extent that it is reliant on them.

It should be stressed that the Central Hunter Swamp Oak Forest community is not listed as a threatened ecological community, nor is *C. glauca* listed as a threatened species. The area of Central Hunter Swamp Oak Forest potentially impacted is not large in the regional and local context and even if the community was lost or diminished in size in the area of predicted impact, this loss would not be significant given the broader occurrence of the community and species and community both locally and regionally. Further, any decline in the community would be limited to the overstorey of *C.glauca* and this would occur slowly, enabling other, less groundwater dependant tree species, to invade the area of impact. The understorey would remain largely unaffected by any changes in groundwater levels. As noted in the IESC advice, the significance of any impact on this community is though the potential impacts to terrestrial fauna movement and any potential impacts on the Central Hunter Swamp Oak Forest associated with groundwater impacts from the Project are unlikely to have a significant impact on habitat connectivity for terrestrial fauna. This is discussed further in **Section 3.4**.

3.4 Ecological Conceptualisations to Justify Assessment Approach and Findings

It is noted that the document *Modelling water-related ecological responses to coal seam gas extraction and coal mining* (Commonwealth of Australia 2015) was released during finalising of preparation of the EIS for the Project and accordingly was not considered as part of the assessment process.

Notwithstanding, as discussed above**,** the predicted impacts on GDEs (including stygofauna and hyporheic fauna) are expected be minimal in both scale and magnitude based on an understanding of both hydrogeological systems and ecological functioning in the area of impact.

While it is recognised that an ecological conceptualisations approach is appropriate for Projects with larger predicted impacts, or potential impacts on particularly sensitive or vulnerable communities, this additional level of assessment suggested in the IESC advice in relation to surface water ecological communities and stygofauna and hyporheic fauna is not considered to be warranted in the present circumstances for the reasons identified in **Sections 3.1** to **3.3** above.

As noted in **Section 2.3**, the Project's predicted impacts on groundwater are not expected to have a significant impact on riparian vegetation present in the area of predicted drawdown. The potential (but unlikely) impacts are associated with reduced water availability to *C. glauca* present in the area of predicted impact as a result of the groundwater drawdown. These impacts are associated with water stress and are reversible through the application of water. As these consequences are effectively reversible through watering, appropriate monitoring and management practices can mitigate the significance of any potential impact. Given the impacts on water levels in the alluvium will not occur for 5 years from commencement of the Project and the impacts (if any) are reversible, the vegetation assessment identified in the IESC advice is not considered warranted at this stage of the development assessment process. However, due to the uncertainties regarding the extent of *C. glauca* reliance on alluvial groundwater, some level of monitoring will be required as the Project progresses to identify any unexpected consequences and appropriate mitigation measures.

As is recognised in the IESC advice, the key concerns regarding any impacts on *C. glauca* and the Central Hunter Swamp Oak community are the implications for fauna movement which may rely on the connectivity provided by this riparian vegetation. The spotted-tailed quoll is the key species of concern in this regard.

In the worst case scenario, the reduced water table in parts of the Main Creek and Swamp Creek alluvium may result in some localised dieback of *C. glauca*. Even if this unlikely scenario eventuated, it would not result in the loss of all vegetation along the creek and understorey species are likely to increase in abundance in the absence of *C. glauca* and continue to provide habitat for ground species such as the spotted-tailed quoll. Other tree species, less reliant on groundwater, would replace the *C. glauca* along the creek line and habitat connectivity would be maintained with little impact on spotted-tail quoll movement. Increased abundance of the Hunter Lowland Red Gum Forest could be expected with potentially greater ecological benefits than that provided by *C. glauca* and the Central Hunter Swamp Oak Forest community (noting that the Hunter Lowland Red Gum Forest is present in the less disturbed upper reaches of Swamp Creek and Main Creek and it is likely was more abundant in lower sections prior to clearing activities in the 19^{th} and 20^{th} centuries). Accordingly, management measures focussed on retaining the habitat connectivity are considered to be more important than maintaining the Central Hunter Swamp Oak Forest community whose presence in the area may be an artefact of opportunistic colonisation following clearing rather than historical presence in the area.

4.0 Mitigation and Monitoring Measures

As stated in the EIS, the Mount Owen Complex Water Management Plan and associated sub plans, which includes a Surface Water and Groundwater Response Plan, will be updated to reflect management commitments and water management system described in the EIS if the Project is approved.

The existing *Mount Owen Complex Surface Water and Groundwater Response Plan* (July 2014) (refer to **Appendix B**) includes a protocol for the investigation, notification and mitigation of any exceedance of surface water, stream health and groundwater impact assessment criteria, and procedures that would be followed if any unforeseen impacts are detected during the development; in accordance the existing consents for Mount Owen, Ravensworth East and Glendell mines.

As discussed in Section 6.0 of the EIS, Mount Owen is committed to updating the *Mount Owen Complex Surface Water and Groundwater Response Plan* within 12 months of Project Approval to include the additional management requirements identified as part of the Project and any other monitoring locations identified during the Project. The revised Surface Water and Groundwater Response Plan will developed in consultation with relevant government agencies. Specific additional monitoring related to the issues discussed above, are outlined in the following sections.

4.1.1 Water Quality

As noted in Section 8.1.4 of the Surface Water Assessment and Section 5.5.7 of the EIS, an additional water monitoring point will be implemented on Main Creek to monitor changes in water quality parameters and identify any changes to water quality that may arise as a result of the project. Trigger Action Response Plans (TARP) will be developed (or where already present, revised) to deal with the unlikely eventuality that the Project impacts on water quality in all downstream creek systems (which has existing monitoring points located on it).

4.1.2 Impacts on Riparian Vegetation

The Surface Water and Groundwater Response Plan will also be updated to include monitoring requirements for both alluvial groundwater levels and ecological condition of vegetation communities potentially impacted by changes in alluvial groundwater levels.

Due to the potential (albeit low) for impacts on *C. glauca* associated with drawdowns in the alluvial aquifers in Bettys Creek and Main Creek, the *Mount Owen Complex Surface Water and Groundwater Response Plan* will include monitoring of both hard rock and alluvial aquifers and the identification of triggers that may indicate greater than predicted impacts.

Vegetation along Main Creek and Bettys Creek downstream of the Project (including in areas predicted to experience drawdowns in alluvial groundwater) will continue to be monitored and control sites will be identified outside the area of predicted impact to enable any impacts on vegetation within the area of predicted impact associated with the Projects impact on groundwater to be identified.

TARPs will be developed for any unexpected impacts on groundwater systems as well as impacts on riparian vegetation. As there is only a year of data in most areas of Bettys Creek and Main Creek alluviums, the ongoing collection of baseline data in the future will further inform the development of TARPs regarding observed impacts on the alluvial aquifers. Based on groundwater modelling predictions, there is sufficient time to collect additional baseline data to better inform TARPs relying on changes in groundwater levels prior to any impacts occurring. Interim TARPs developed in the early stage of the Project will focus on impacts on hard rock aquifers where there is a longer period of baseline data.

In the event of an observable impact, reasonable and feasible management options would be implemented. As noted in Section 2.5, these management options would be focused on improving the resilience of existing riparian vegetation and the maintenance of habitat connectivity generally and may include:

- Planting of tree species less reliant on groundwater
- Additional vegetation planting adjacent to creek lines to reduce reliance on riparian vegetation for connectivity
- Fencing of riparian vegetation to remove grazing pressures on ground and understorey species during dry periods.

The monitoring and management measures that may be required in response to any potential groundwater impacts on the Main Creek and Bettys Creek alluvial systems (including TARPS) will developed in consultation with relevant government agencies and finalised and implemented prior to any predicted impacts on alluvial ground water levels (Year 5 of the Project).

5.0 References

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APPENDIX A

Jacobs Briefing Note

JACOBS

Technical Memorandum

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Date	22 July 2015
To	David Holmes (Umwelt)
Copy	Vicki McBride (Glencore), Susan Shield (Umwelt), Gary Boland (Glencore), Steve Downes (Glencore), Bret Jenkins (Glencore), Brian Rask (Jacobs)
From	Richard Cresswell
Subject	**Refined Numerical Groundwater Model**

Submissions to the Mount Owen Continued Operations Project (the Project) were generally positive regarding all water aspects of the EIS, with a few information and discussion requests, only. These have been addressed via a separate note prepared by Umwelt and Jacobs.

The IESC, however, suggested more detailed groundwater modelling should be carried out in areas where sensitive ecosystems (specifically Swamp Oak and Red Gum areas) may be impacted by groundwater drawdown in the alluvium, as indicated by the extreme impact scenario from the groundwater modelling reported in the Groundwater Impact Assessment (Jacobs, 2014 – EIS Appendix 10).

Jacobs undertook additional modelling in support of a response to comments from the IESC, specifically in relation to the potential inaccuracies that could arise due to the relatively coarse grid resolution for two alluvial aquifers in which drawdowns are predicted to occur, namely: Main and Bettys Creeks.

The model used in the Groundwater Impact Assessment in Appendix 10 of the EIS (v8.1) utilises a grid size of 100x100m, which is commensurate with the regional nature of the model and provides adequate resolution to understand and appreciate the potential impacts to groundwater of the proposed expansion. This current grid resolution is appropriate to model dewatering effects on the hard rock aquifers and this resolution can be maintained in the model for these deeper layers.

Many of the surficial alluvial aquifers, however, either reduce in extent to less than this dimension (i.e. <100 m wide), or consist of heterogeneities that are smaller than this grid size, and hence there are concerns that the grid size used in the model could introduce local inaccuracies, or not provide sufficient intra-alluvial resolution sufficient to isolate separate receptors (communities) potentially supported by groundwater within the alluvium extents.

There is no direct connection with the alluvial aquifers from the proposed mining operations, nor is there any predicted cracking of strata directly below the alluvium. Potential impacts to the alluvial aquifers, and any supported groundwater dependent ecosystems, however, may be expected to result from dewatering activities that depressurise hard rock (coal measures) aquifers and indirectly induce leakage from the alluvial aquifers.

Model refinement

The regional groundwater model used in support of the Project submission(s) was used as a basis to develop a refined grid model centred on Main and Bettys Creeks. The objective of the refined model was specifically to assess if the grid size of the regional model affected the extent and volume of groundwater losses from the alluvial aquifers. Therefore, to compare results between the regional model and the refined model all efforts were made to keep the two models as similar as possible, with the exception of increased spatial resolution, namely decreased grid spacing and refined alluvial aquifer delineation (i.e. surface elevation and isopach).

The following modifications were thus made to model:

- The model domain was reduced to approximately 50 km^2 (**Figure 1**).
- Grid spacing was reduced to 20mx20m uniformly across the alluvium layer of the new model domain, generating 345 rows by 360 columns.
- The surface elevation within the alluvium was refined using the latest LiDAR data.
- The base of the alluvium was refined, based upon a refined isopach map and the refined surface elevations.
- Constant head boundary conditions were input to all active cells in Layer 2. The actual head values at each cell corresponded to the predicted heads in Layer 2 for each stress period from the regional model to simulate transient conditions. These boundary conditions were created for each stochastic realisation.
- Because Layer 2 is entirely constant heads, there was no need for all subsequently deeper layers. Therefore all layers greater than 2 in the regional model were deleted.

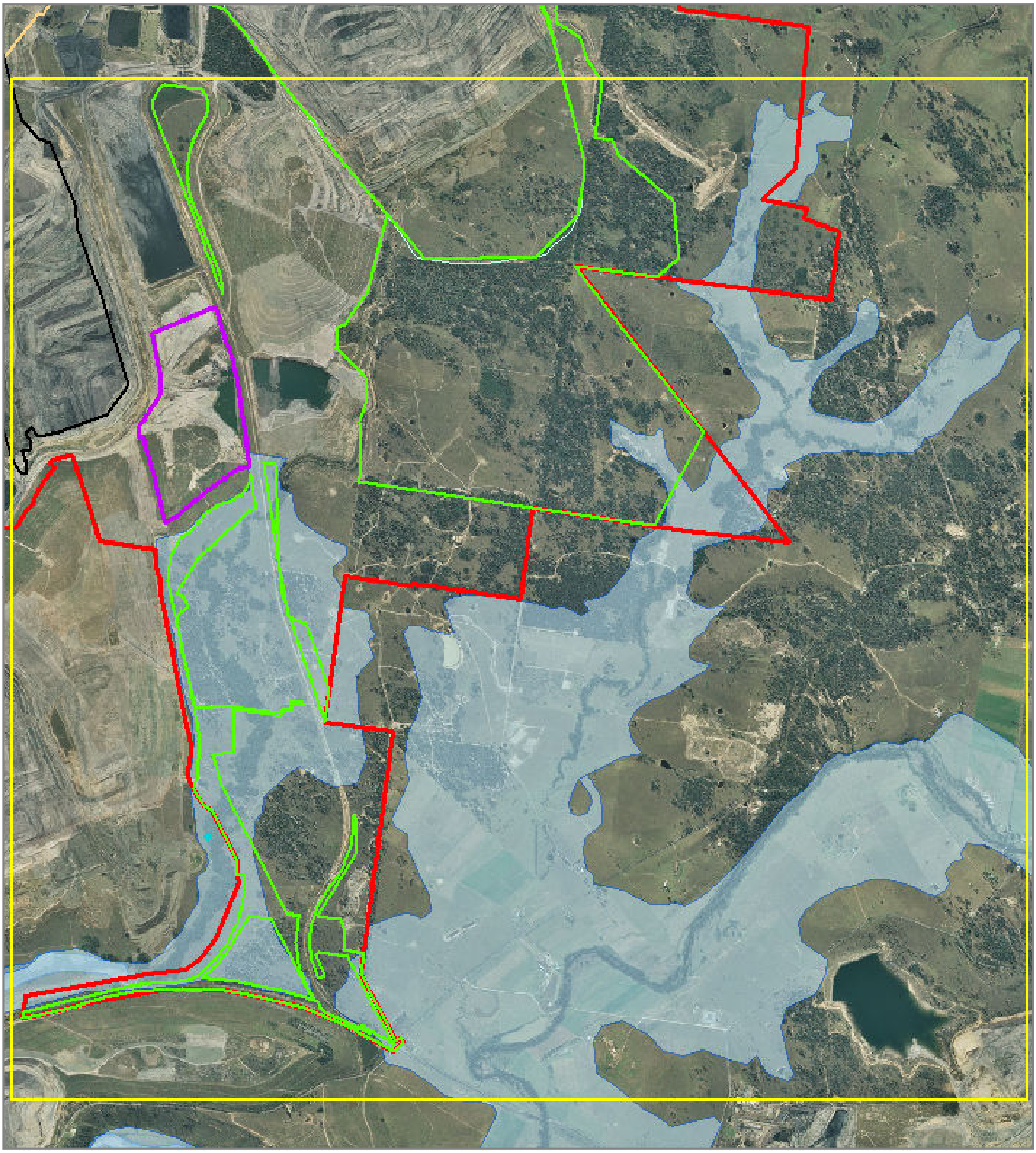
All other aspects of the model setup remained as per the regional model.

Model simulations

Model simulations were run using the same configuration and operations as the regional model and predictive scenarios were created from statistical analysis of the calibrated parameter sets generated from the regional model.

Median drawdown and 1 standard deviation results are presented for years 2020, 2025 and 2030; with the latter representing the maximum expected drawdown for the Project life. These are reproduced in **Figures 2** through **7**. The 2030 drawdown is also considered to represent the maximum long term impact of the Project as the final water level in the North Pit void is not predicted to rise to a level whereby the head pressure would be above that of the alluvium water table and reverse the direction of movement of water in the sub-cropping aquifers. That is, there will be a permanent hydraulic gradient away from the alluvium generating movement of water from the alluvium, through the coal seams and reporting as groundwater inflows to the North Pit void. As the void fills, this gradient will reduce and leakage from the alluvium will decrease.

For comparison, **Figure 8** shows the predicted maximum drawdown reported from the regional (100m x 100m grid) groundwater model (**Figure 3-21** in the Groundwater Impact Assessment in Appendix 10 of the EIS).



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Alluvium Extent
- IESC Modelling Extent

0 0.25 0.5 1 Kilometers

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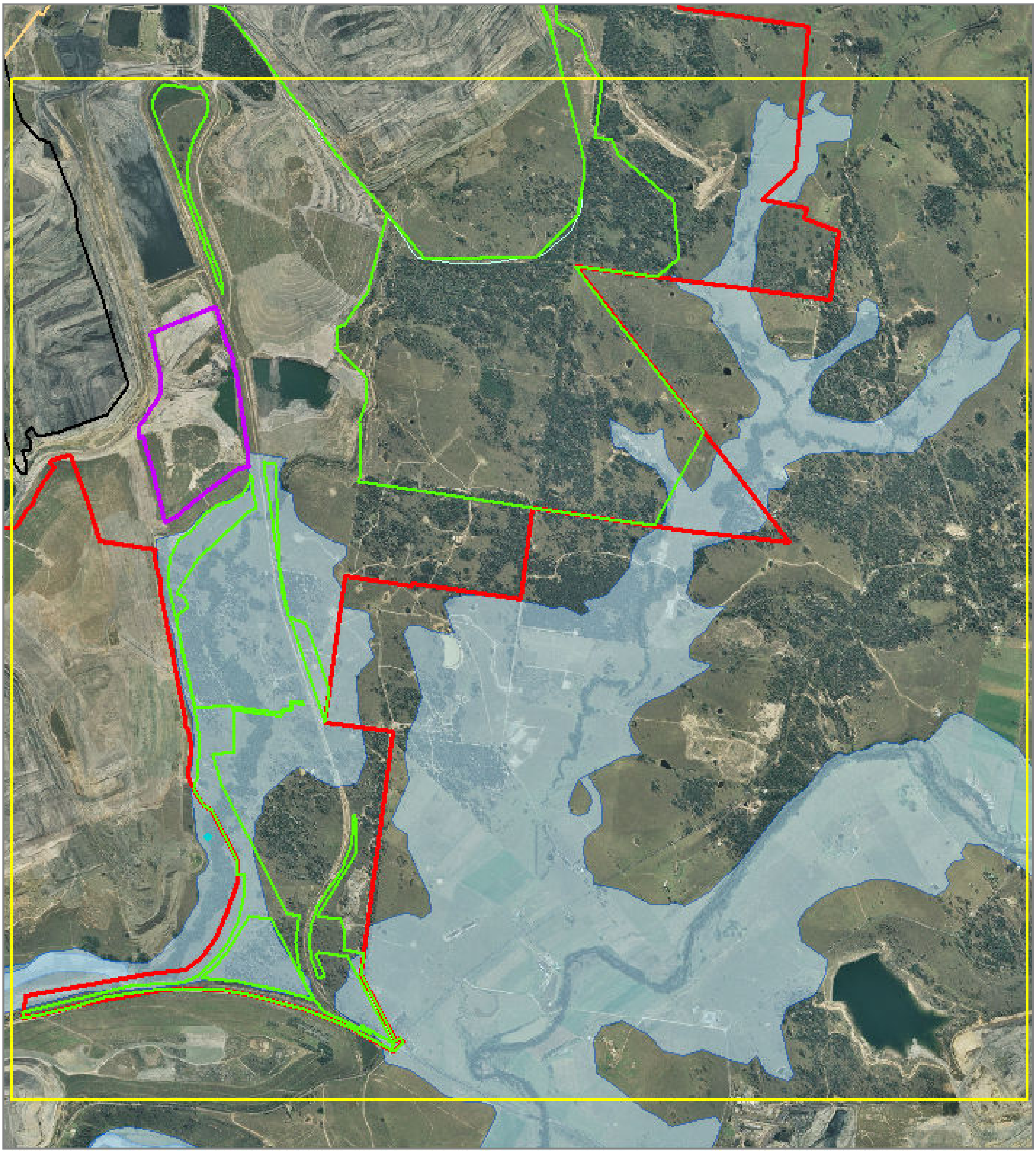
GDA 1994 MGA Zone 56

File Name: MOCO_DD_50percent_2016

Prepared by: LS
Checked by: RC

Figure 1 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2016

JACOBS



Predicted Drawdown (m)

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- 0.1 - 0.5
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0 0.25 0.5 1 Kilometers

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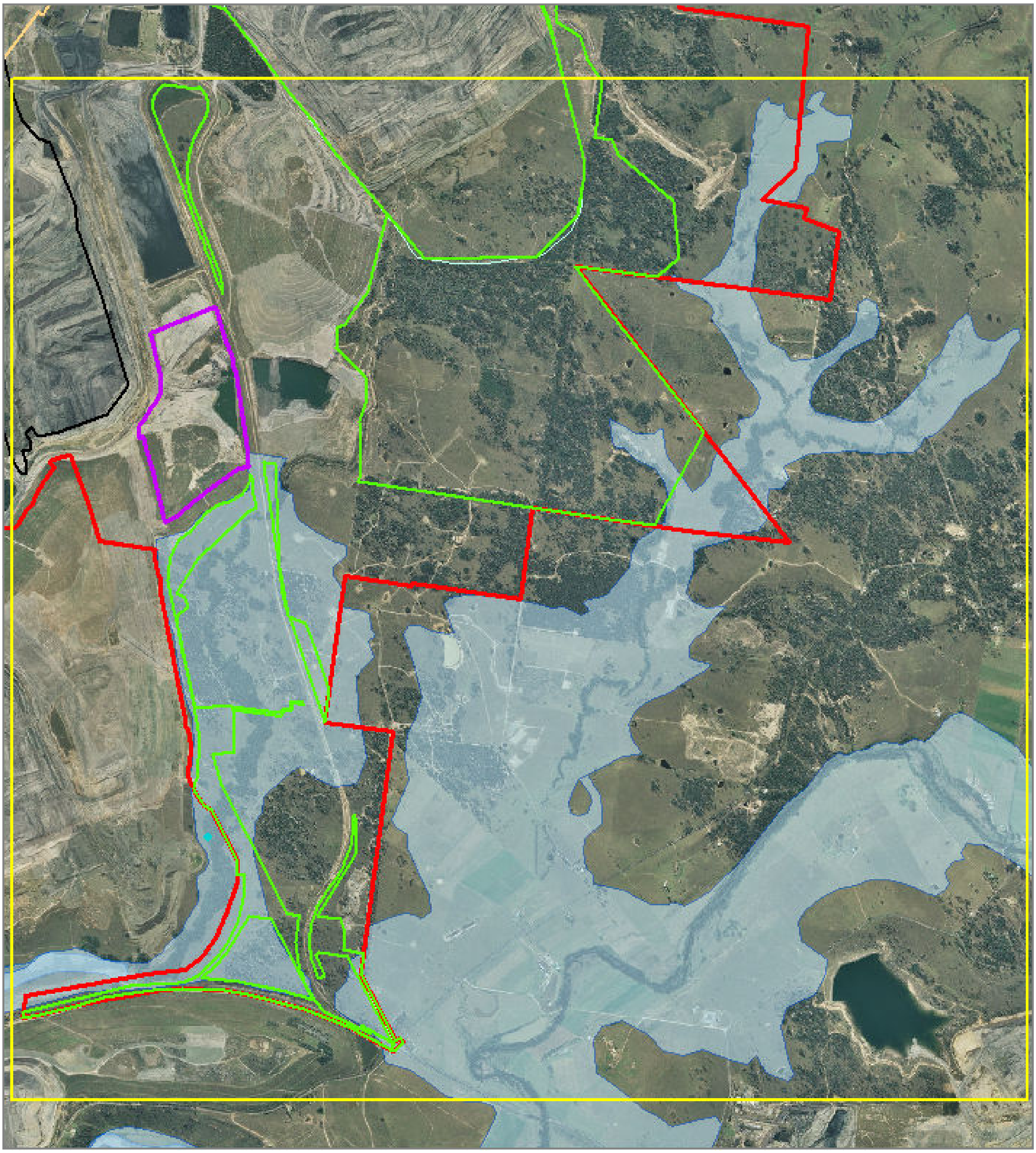
File Name: MOCO_DD_50percent_2020

Prepared by: LS
Checked by: RC

Figure 2 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2020

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
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- Alluvium Extent
- IESC Modelling Extent

0 0.3 0.6 1.2 Kilometers

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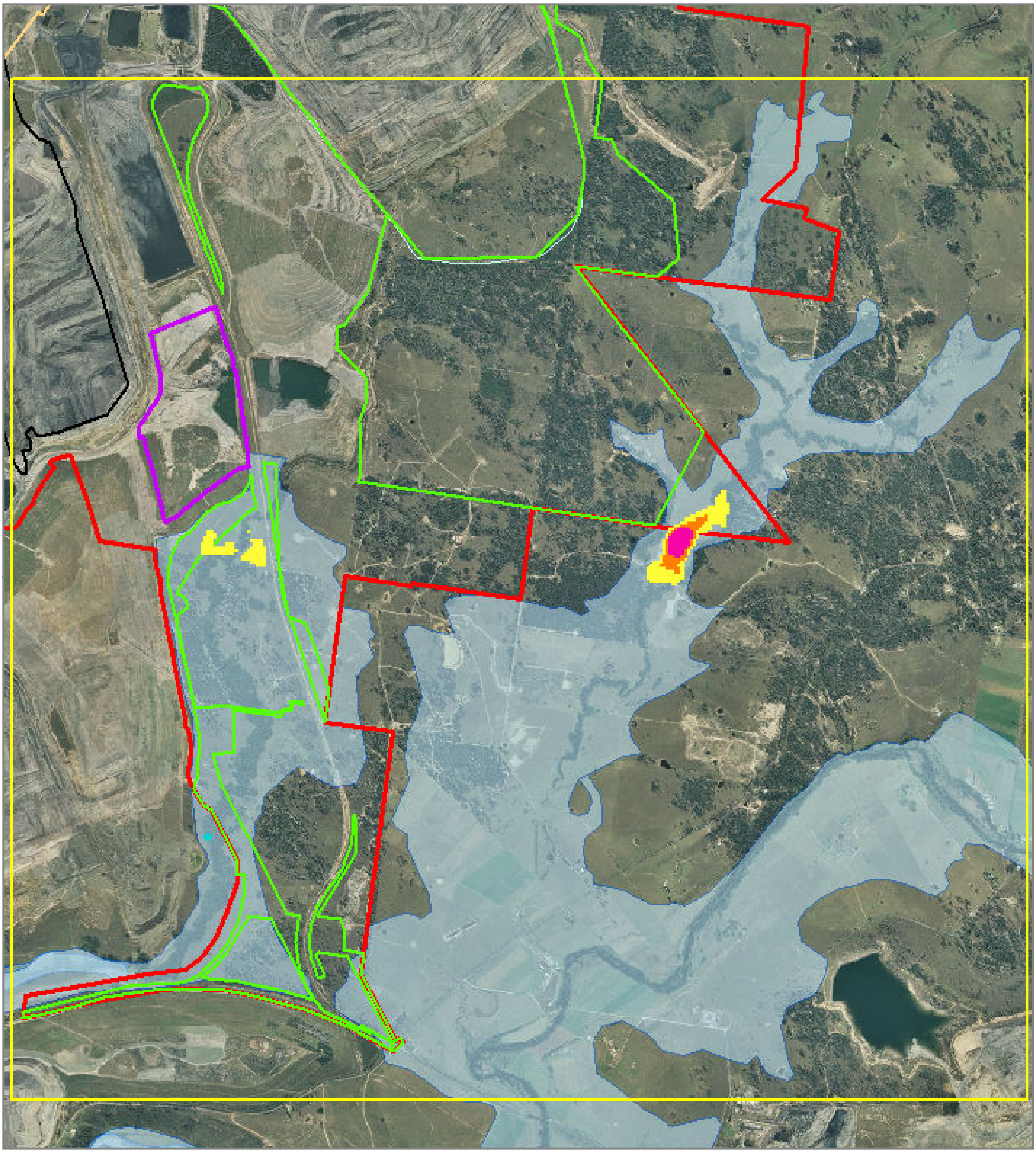
File Name: MOCO_DD_87percent_2020

Prepared by: LS
Checked by: RC

Figure 3 Predicted Median + 1SD Incremental Drawdown in Alluvial Aquifers in 2020

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
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- 3 - 4

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0 0.3 0.6 1.2 Kilometers

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File Name: MOCO_DD_50percent_2025

Prepared by: LS
Checked by: RC

Figure 4 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2025

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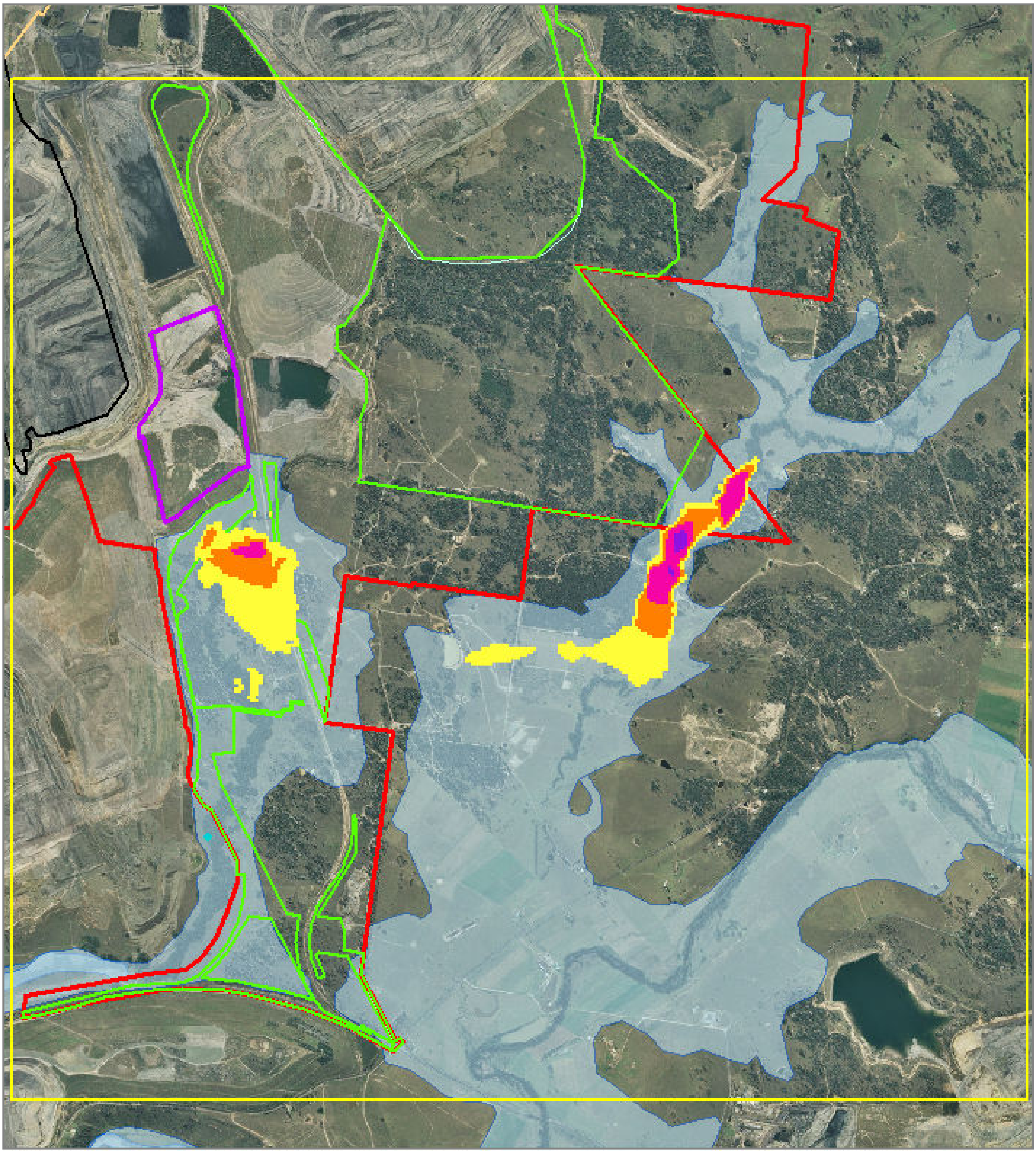

Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
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0 0.3 0.6 1.2 Kilometers

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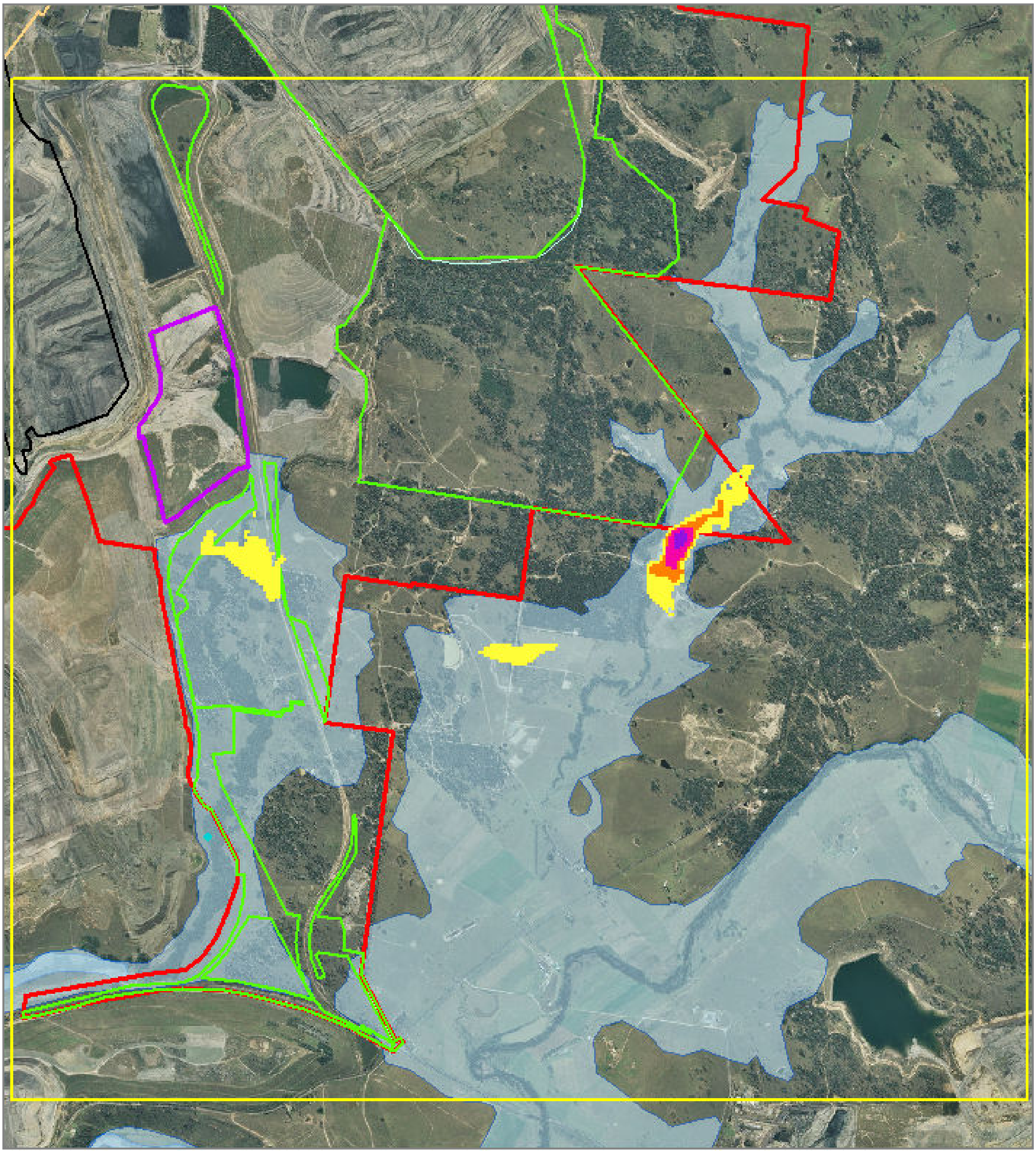
GDA 1994 MGA Zone 56

File Name: MOCO_DD_87percent_2025

Prepared by: LS
Checked by: RC

Figure 5 Predicted Median + 1SD Incremental Drawdown in Alluvial Aquifers in 2025

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
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- 2 - 3
- 3 - 4

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- Mount Owen Disturbance Area
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0 0.3 0.6 1.2 Kilometers

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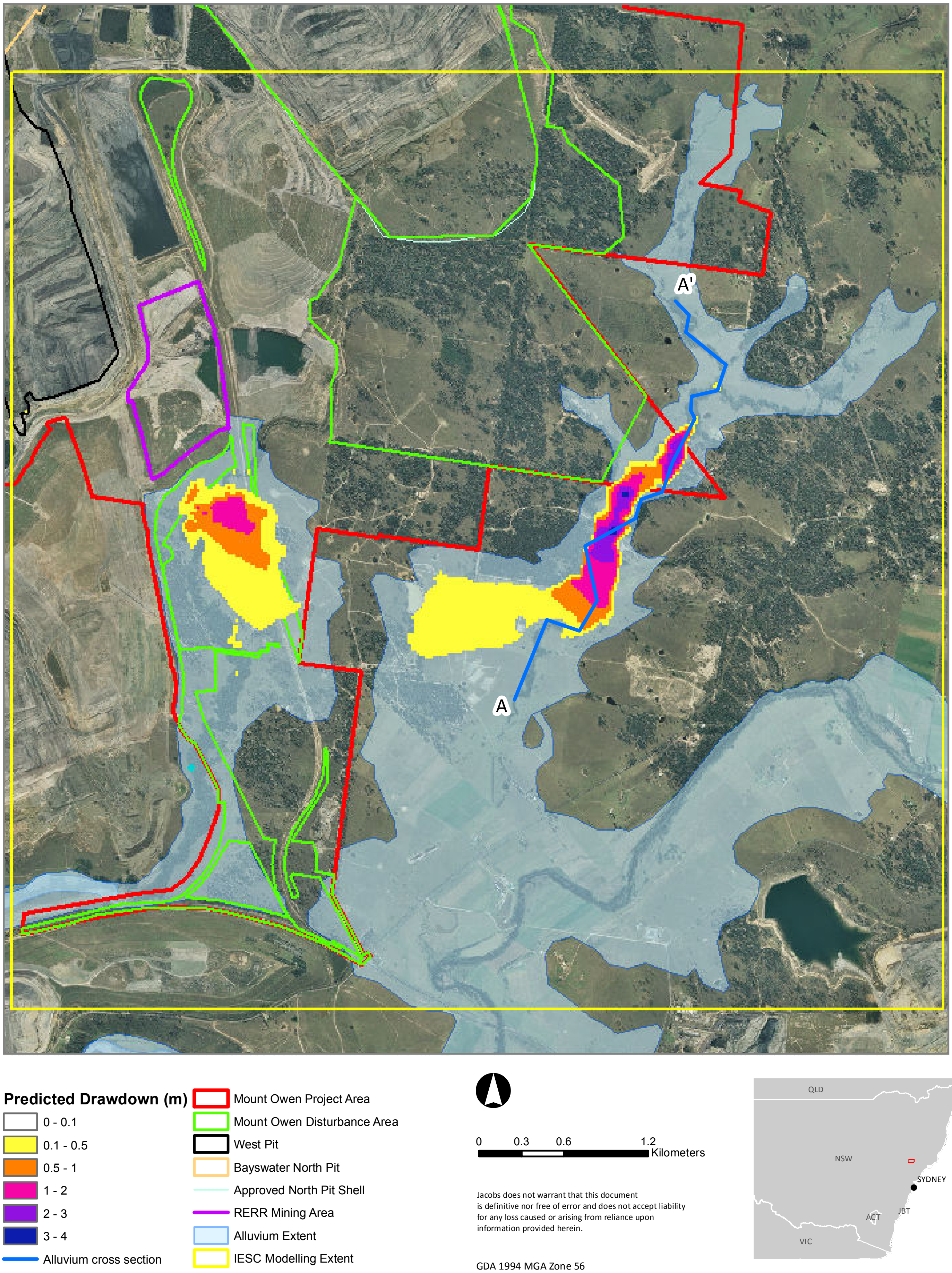
File Name: MOCO_DD_50percent_2030

Prepared by: LS
Checked by: RC

Figure 6 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2030

JACOBS



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File Name: MOCO_DD_87percent_2030

Prepared by: LS
Checked by: RC

Figure 7 Predicted Median + 1SD Incremental Drawdown in Alluvial Aquifers in 2030

JACOBS

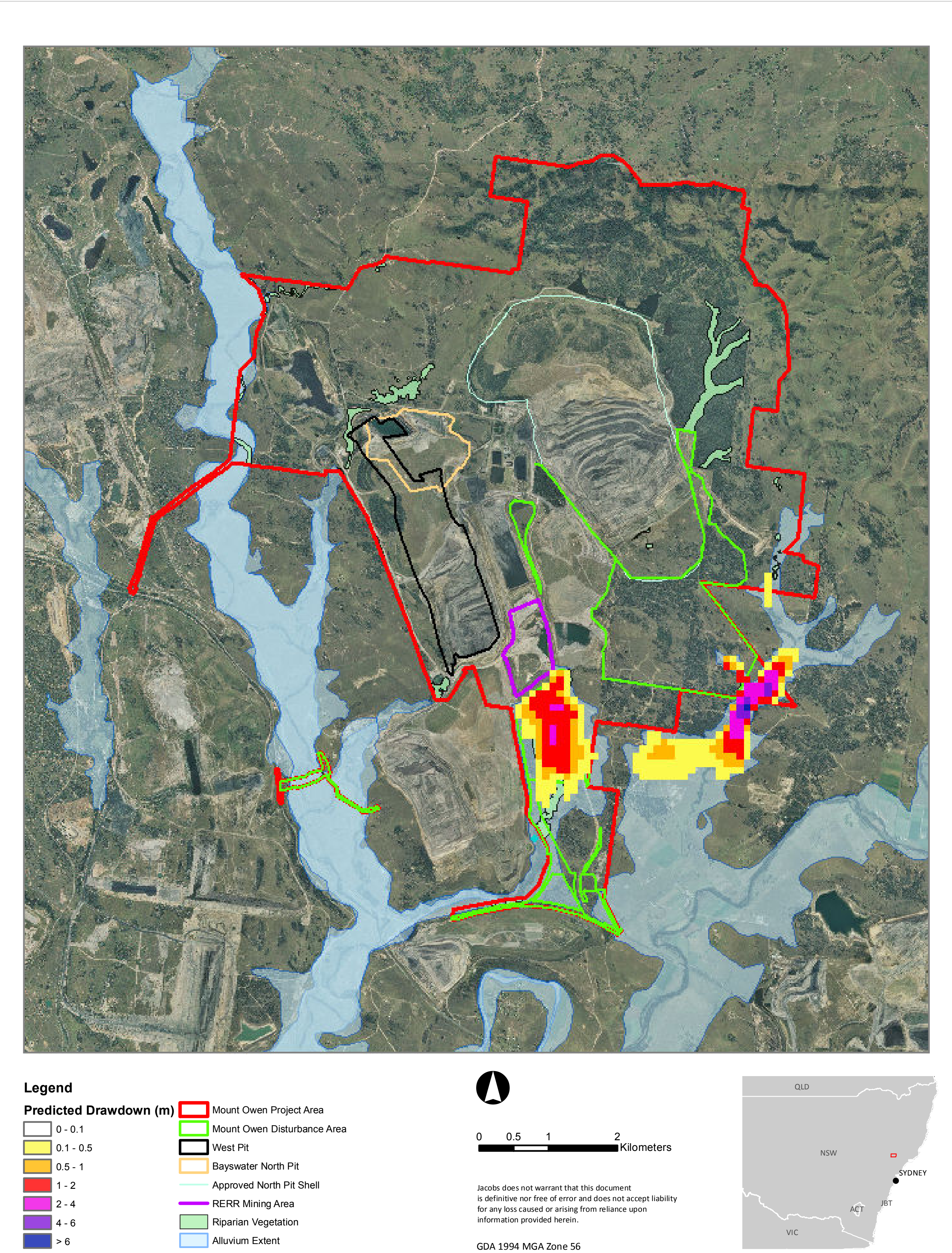


Figure 8 Predicted median +1SD incremental drawdown in alluvial aquifers in 2030 derived using the regional model (v8.1 resolution: 100x100m grid) domain, as reported for the EIS (Figure 3-21)

JACOBS

Prepared by: LS
Checked by: RC

File Name: Figure 3-21 MOCO GIA_AlluviumDDs_84per_2030

Implications for ecosystem impacts

It should be re-iterated that the model operates with annual time-steps and the resultant drawdowns represent potential incremental annual changes from the base case simulations. Comparison of results to the regional (100x100m grid) model results (as presented in the EIS and reproduced in **Figure 8**) shows that the revised extent and impact is comparable and likely to be less than previously described. That is, with refinement of the shallow layer grid to provide a more detailed representation of the alluvium systems, the actual area and magnitude of groundwater impact, and hence leakage and impact to the alluvial aquifer and surface water features, is reduced, confirming our previous assertion that the results presented in the EIS represent a conservative (maximum) estimate of impacts to the shallow systems.

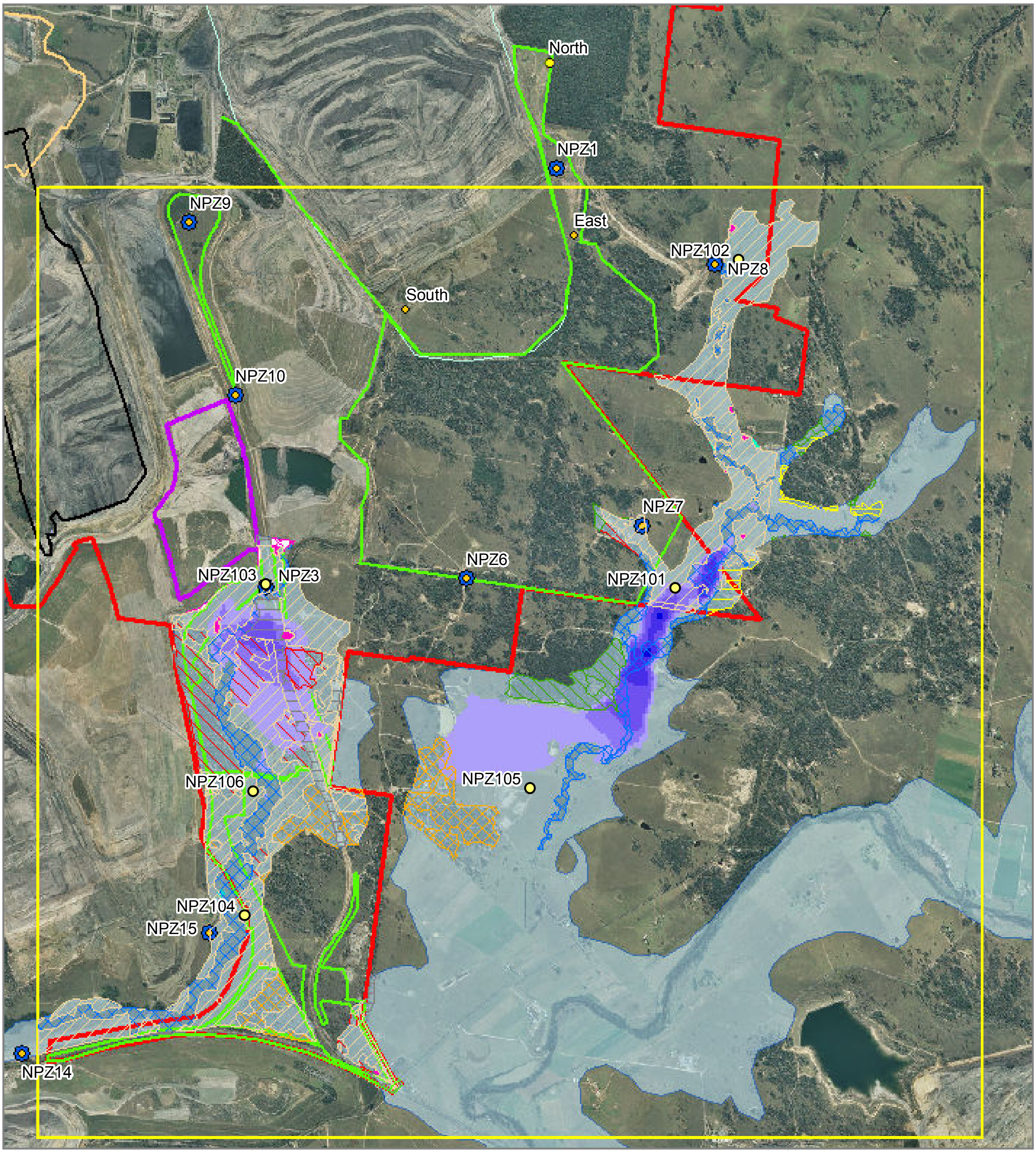
The extent of local vegetation communities on the alluvium is shown in **Figure 9**. Stands of ironbark, spotted gum and grey box exist in proximity to the area of maximum predicted drawdown, with the main river channels identified as swamp oak forest ecosystems. No other communities are identified to be within a potential impact area.

Standpipes NPZ101-NPZ106 were recently (2014) installed in the alluvial aquifers in this area (**Figure 9**), to provide monitoring of shallow alluvium water tables as an additional safeguard against future impact detection.

As can be seen in **Figure 10**, recent heavy rains do not appear to have had a significant impact on the alluvial aquifer water levels, except at the margins of the alluvium. Also of note, bore NPZ105, which is sighted in the deepest part of the Main Creek alluvium, has been dry since construction (sampling at a depth of 9.2m, above coarse gravels), indicating water levels are consistently lower than 9m below ground at this location. A single water level reading from a piezometer installed in 2008 along Bettys Creek (GPC40 – since de-commissioned) provided a reading of >9m below ground level in an area of healthy Swamp Oak community; recent readings at NPZ106 in the same location record groundwater levels at 5m below ground level (**Figure 10**).

All bores in the main channels record groundwater table depths in excess of 4m, indicating that the creeks are largely dis-connected from the groundwater systems for these tributaries. Maximum potential drawdown impacts to the alluvial aquifer of 2-3m along Main Creek occur where natural water tables are estimated to be 6-10m above the alluvium base. Hence, drawdown is unlikely to lead to local drying and significant saturated depth will remain available for migration of any local aquifer fauna (i.e. stygofauna).

These observations should also be considered in light of the large intra-annual variability in groundwater tables in the alluvial aquifers and their inter-annual propensity to rapidly fill and spill with the weather which naturally generates variability in baseflow that supports stream flow. The resilience of existing communities would indicate that they have adopted strategies that mitigate against drying climate events and consequent natural lowering of groundwater tables.



Predicted Drawdown (m)

- 0 - 0.1
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Vegetation type

- Central Hunter Bulloak Forest Regeneration
- Central Hunter Grey Box - Ironbark Woodland
- Central Hunter Ironbark - Spotted Gum - Grey Box Forest
- Central Hunter Swamp Oak Forest
- Dam
- Derived Native Grassland
- Disturbed Land
- Hunter Lowland Red Gum Forest
- Olive Plantation
- Rehabilitation

Existing Monitoring Network

- Alluvium
- Shallow Hard Rock
- Deep Hard Rock

File Name: Veg_MOCO_DD_87percent_2030

0 0.25 0.5 1 Kilometers

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GDA 1994 MGA Zone 56

Prepared by: LS
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Figure 9 Maximum predicted drawdown; potentially impacted vegetation types and new standpipe locations for Main and Bettys Creeks

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As shown in **Figure 10** intra-annual variability in alluvial aquifer water levels may range up to 1m each year, with greater ranges for shallow water tables in the headwaters (NPZ102, NPZ103). Bore NPZ101 is sighted within the zone of potential drawdown and water tables at this site have been relatively constant at just over 4m below ground level over the past year. Peak predicted potential additional drawdown may result in an additional 1m water table drop at this location. The alluvium at this location is approximately 13m thick.

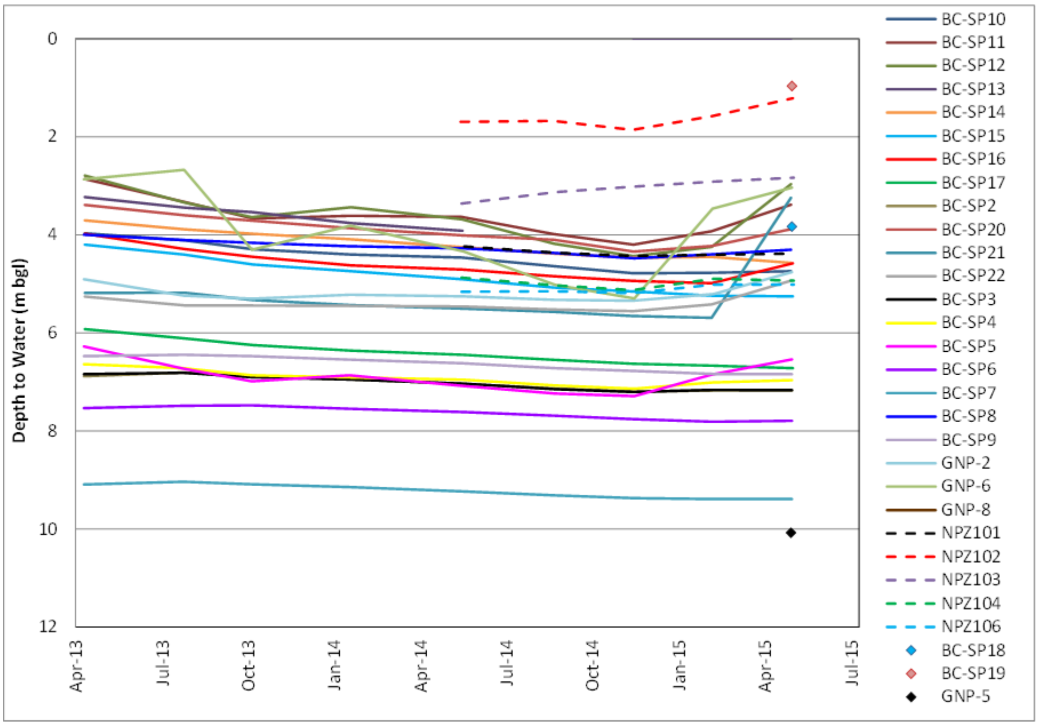

Figure 10 – Alluvium groundwater levels across the regional model domain over the past two years. New standpipes within the refined model domain are indicated as dashed lines (NPZ101 – NPZ106)

Figure 11 describes the section of the Main Creek alluvium defined in **Figure 7** and includes the interpolated average groundwater table depth for 2014. This section aligns with the location of Central Hunter Swamp Oak Forest present in the area of proposed drawdown. The maximum predicted drawdown (2030 median + 1 SD) shows that, even under a maximum depressurisation scenario, the alluvium will not dry and a saturated zone will be maintained throughout the alluvium system.

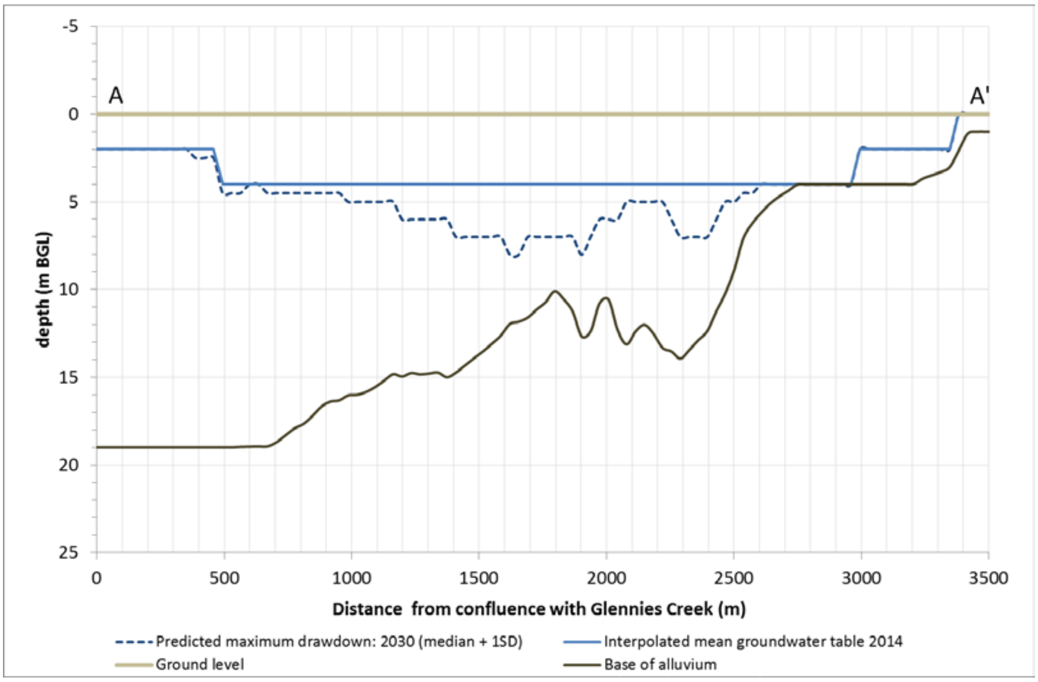

Figure 11 – Cross-section depicting current and predicted maximum impact groundwater table depth and alluvium thickness along Main Creek

The hydraulic characteristics of the alluvial aquifer and hard rock aquifers are significantly different. Hydraulic conductivity in the alluvium has been determined to be 3 orders of magnitude faster than the underlying hard rock, while specific yield is 2 orders of magnitude higher. Thus, it is expected that seasonal infiltration and flow through the alluvial aquifers will occur at a significantly faster rate than any variation in leakage driven by changes in water pressures in deeper formations. Further, while annual leakage from the alluvium predicted under the maximum impact scenario is estimated to be 15 ML/year from Main Creek and 6 ML/year from Bettys Creek, annual predicted recharge from rainfall is predicted to be more than an order of magnitude greater, with the bulk of water being transmitted downstream through the alluvium to the main systems of Glennies and Bowmans Creeks.

The relationship between the alluvium and hard rock aquifers is schematically illustrated in **Figure 12**. Annually, peak potential leakage impacts caused by drawdown induced from operations are less than 10% of mean annual expected recharge.

It is therefore unlikely that depressurisation will cause any observable effects under normal (average climate) conditions. During extended dry periods recharge may fall such that leakage (which will be unaffected by climate changes) may represent over 15% of infiltration from surface flows and rainfall. This may result in very localised stress on the groundwater-dependent systems, though the identified communities are likely to have strategies that manage dry conditions and only a prolonged drought may induce undue stress.

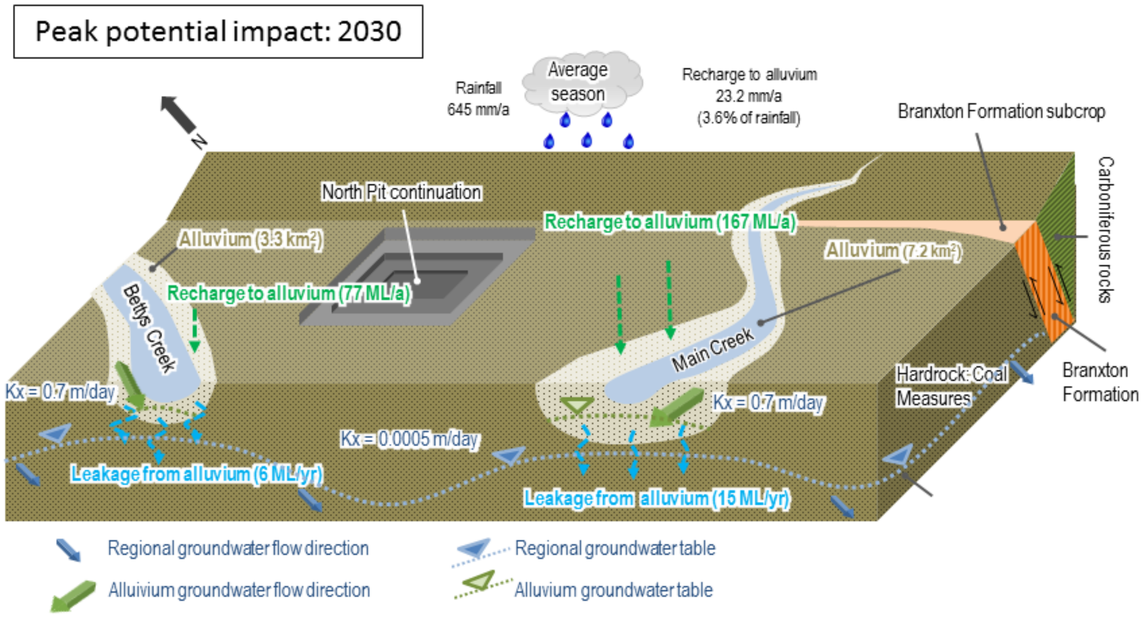

Figure 12 – Schematic representation of fluxes to and from the alluvium systems of Main and Bettys Creeks

As can be seen from Figure 9, approximately 1 km of the Central Hunter Swamp Oak Forest along Main Creek is located over the area of more than 1m potential drawdown (i.e. drawdown that may be greater than the observed natural fluctuations over the past 12 months). This level of drawdown is only likely to be observable in periods of prolonged drought. The Swamp Oak community along Bettys Creek in this area remains healthy indicating a tolerance to fluctuations of 3 to 4m. This level of natural fluctuation is in excess of the predicted potential impacts that may occur along Main Creek under the Project scenario.Summary and conclusions

Increased resolution of the regional numerical groundwater model in the vicinity of predicted potential maximum drawdown has refined our interpretation of the potential impacts to alluvial aquifers in this area. The overall conclusions from this additional work do not, however, change the conclusions from the previous modelling using the regional-scale model.

The predicted area of impact using the finer resolution grid is directly comparable to that determined from the coarser grid regional model. The added resolution, however, identifies that this impact is restricted to the central region of the alluvial extents only. Revised drawdown is comparable and slightly less than determined by the regional model, likely due to the improved resolution of the aquifer boundary and base, as defined using the recently installed standpipes along Bettys, Main and Glennies Creeks.

By considering a finer modelling grid and refining the extents and volume of the alluvial aquifer using LiDAR data and information from recently installed standpipes, the potential drawdown area within the alluvium appears to be more constrained and can be compared directly to the location of existing ecological communities.

As determined by the regional model, this modelling also predicts that there will be no impact to these alluvial aquifers for at least the next 5 years.

It should be noted that maximum potential impacts are comparable to inter-annual variability in alluvial aquifer water tables. Further, measured groundwater levels along the main channel of Main Creek indicate about 10m of saturated alluvial aquifer in the areas of maximum predicted impact (as determined from recent observations from newly installed standpipes for this purpose). Accordingly, the maximum predicted drawdown of around 4 m (occurring in only a very small section of the Main Creek Alluvium) will still leave in excess of 5 m of water in the alluvium at this point. Hence, the predicated drawdowns will not result in a complete drying of the alluvium at this location.

The predicted overall potential impacts to any vegetation communities that may result from the potential impacts to groundwater are therefore considered to be minimal and insignificant for any aquifer ecosystems (ie. stygofauna).

This additional modelling confirms the conclusions derived from the Groundwater Impact Assessment using the regional groundwater model.

APPENDIX B

Surface and Groundwater Response Plan

MT OWEN COMPLEX

SURFACE WATER AND GROUND WATER RESPONSE PLAN

July 2014

TABLE OF CONTENTS

1. COMMITMENT AND POLICY

1.1 Purpose

The Surface Water and Groundwater Response Plan is part of the Mt Owen Complex (MOC) Water Management Plan (WMP), which is required by the development consents for Mt Owen (DA 14-1-2004), Ravensworth East (DA 52-03-99) and Glendell Mine (DA 80/952). This Plan should be read in conjunction with the Water Management Plan.

The key functions of this document is to describe how MOC will respond to an incident regarding surface or groundwater.

1.2 Scope

The Surface Water and Groundwater Response Plan outlines the appropriate response protocols to be undertaken in the event that adverse impacts associated with the MOC mining operations on the surrounding surface and ground waters are identified. The plan outlines measures to mitigate impacts on downstream water users, minimise groundwater leakage from intercepted alluvials into open cut pits and response procedures to be followed in the event of any unforeseen impacts.

This Surface Water and Groundwater Response Plan is part of a set of documents prepared to support the MOC WMP required by the development consents for Mt Owen (DA 14-1-2004), Ravensworth East (DA 52-03-99) and Glendell Mines (DA 80/952). The plan aims to meet the requirements of the Mt Owen, Glendell and Ravensworth East Development Consents that require a surface and ground water response plan to be developed as part of the Water Management plan. The plan has also been developed to meet the requirements of condition 35, Schedule 3 of the Glendell Mine development consent (DA 80/952). **Table 1** outlines the development consent requirements for the complex and provides an indication of where each requirement is addressed in this plan.

Table 1 – Requirements for the Surface and Groundwater Response Plan

Mt Owen DA14-1-2004 Schedule 4 Condition:	Ravensworth East DA 52-03-99 Schedule 4 Condition:	Glendell DA 80/952 Schedule 3 Condition:	Consent Conditions	Relevant Section of this Plan
37	28	29	The Applicant shall prepare and implement a Water Management Plan that includes a Surface and Ground water response plan	Whole Document
		35	The Surface Water and Groundwater Response Plan must include:	
		a)	A protocol for the investigation, notification and mitigation of any exceedances of the surface water stream health and groundwater impact assessment criteria;	**Section 2.1**
		b)	Measures to mitigate and/or compensate potentially affected landowners for the loss of surface water flows in Bettys Creek, Swamp Creek, and Bowmans Creek downstream of the development;	**Section 2.3**
		c)	Measures to minimise prevent or offset groundwater leakage from the Bettys Creek and Swamp Creek alluvial aquifers;	Refer to Groundwater Monitoring Program
		d)	Measures to mitigate any direct hydraulic connection between the backfilled open cuts and the Bettys and Swamp Creek alluvium if the potential for adverse impacts is detected; and	**Section 2.4**
		e)	The procedures that would be followed if any unforeseen impacts are detected during the development.	**Section 2.5**

2. PLANNING

2.1 Management Response Actions

Appropriate response actions have been developed in the event that mining operations at the MOC result in adverse impacts to the surrounding surface waters and ground waters. **Table 2** summarises the potential water management issues that may arise and the appropriate response to be taken by relevant staff.

Table 2 – MOC Water Management Response Actions

Potential Water Management Issues	Response
Water monitoring reports results outside the surface water and stream health impact assessment criteria or maximum reported groundwater quality results (outlined in both the Surface Water and Groundwater Monitoring Plans respectively)	• investigate results and trends, considering any mitigating factors where applicable; • report results to senior management; and • where relevant initiate the criteria exceedance protocol.
Receipt of community complaint	• investigate complaint, considering any mitigating factors and provide feedback to complainant; • report complaint to senior management; • provide feedback to mine planning and production personnel, where relevant; and • where relevant initiate the complaints protocol.
Non-compliance with Hunter River Salinity Trading Scheme (HRSTS) discharge limits	• investigate non-compliance, considering any mitigating factors where applicable; and • report non-compliance to the Environment Protection Authority (EPA) in accordance with the Surface Water Monitoring Plan.
Unauthorised discharge	• investigate discharge, considering any mitigating factors where applicable; • report discharge as per EPA requirements for incident reporting; and • review adequacy of existing water management infrastructure and controls.
Loss of surface water availability for downstream water users	• investigate the cause of any losses in downstream surface water availability; and • where relevant initiate the Response Protocol for Adverse Impacts on Existing Surface Water and Groundwater Bores Supplies process.

Potential Water Management Issues	Response
Loss of groundwater availability at private licensed bore	• investigate loss of groundwater availability, considering any mitigating factors where applicable; • provide feedback to complainant; • report complaint to senior management; and • where relevant initiate the Response Protocol for Adverse Impacts on Existing Surface Water and Groundwater Bores Supplies process.
Increased seepage identified by changes in monitoring results or visual observations from the alluvial aquifers into open cut pits	• investigate the cause of any increased seepage from the alluvial aquifers into open cut pits; and • where relevant initiate the Response Protocol for Increased Leakage from Alluvium into Pits.

3 IMPLEMENTATION

3.0 Criteria Exceedence Protocol

MOC will monitor surface water and groundwater in accordance with the Surface Water and Groundwater Monitoring Program. If the surface water or groundwater monitoring reports/result(s) are outside the surface water and stream health impact assessment criteria or maximum reported groundwater quality results outlined in these programs, further investigations are required, MOC will:

- confirm the timing and general location of the exceedance(s);
- confirm the meteorological conditions at the time of the exceedance(s) (where relevant);
- identify any potential contributing factors;
- assess the monitoring results against background trends to identify any anomalies or causes;
- if the exceedance is not attributable to the MOC the routine monitoring program will be assessed for its effectiveness;
- where the exceedance is potentially attributable to the MOC appropriate mitigation and management strategies will be developed and implemented;
- where mitigation and management strategies have been implemented additional monitoring and regular reviews will be undertaken to measure the effectiveness of the strategies undertaken; and
- the exceedance will be reported in accordance with the reporting mechanisms outlined in the Surface Water and Groundwater Monitoring Programs.

3.1 Complaints Management Protocol

The MOC operates a dedicated complaints hotline. The details of this hotline are advertised in local newspapers, via a six monthly newsletter and on the MOC website.

A procedure for handling complaints has been implemented as part of the MOC Environmental Management System (EMS) to ensure a consistent approach to handling any complaint. All legitimate complaints will be thoroughly investigated by the MOC Environment and Community (E&C) Manager. With respect to complaints regarding surface water or groundwater the investigations will include, as a minimum:

- records of the timing and general location of the issue initiating the complaint;
- details of the meteorological conditions at the time of the issue initiating the complaint;
- identification of any potential contributing factors; and
- a review of any monitoring results relevant to the complaint.

Where the complaint is potentially attributable to the MOC appropriate mitigation and management strategies will be developed, implemented and monitored for the effectiveness of the strategies undertaken.

Feedback to the complainant will be provided within 24 hours of receiving the complaint.

Details of complaints relating to groundwater or surface water will be provided to relevant mine planning and production personnel, to assist in the improvement of management practices, where relevant. A summary of the complaints received by the community will be reported in the Annual Review.

If a landowner considers the operation to be in exceedance of the impact assessment criteria, they may request an independent review of the effects of the operation on their land. Such a request must be made in writing to the Director-General of the Department of Planning and Infrastructure (DP&I). If the Director-General determines that an independent review is to be undertaken, MOC must follow the procedures outlined in the relevant development consent.

3.2 Response Protocol for Adverse Impacts on Existing Surface Water and Groundwater Bores Supplies

The surface water available to adjacent landowners or storm water run-off flow rates may be affected by mining activities associated with the MOC. In the event that a complaint is received from a landowner regarding the loss of a surface water supply or of an unusual flooding event the Complaints Management Protocol will be implemented. If the initial investigations conclude the MOC has potentially contributed to the event(s), the following steps will also be implemented:

- provide a copy of the landowner complaint to the New South Wales Office of Water (NOW) and DP&I and inform both agencies of the intention to conduct independent review;
- commission an independent review including investigation (if applicable) of:
  - relevant surface water flow rates, surface water availability, meteorological conditions over the relevant period of record, storm events and/or flooding depths;
  - any changes to land use that may have affected surface water flow rates and quality over time; and
  - whether the event(s) is/are attributable solely to MOC operations.
- provide a copy of the independent review report to the landowner and NOW;
- if the investigation concludes that the event(s) are attributable to the MOC then appropriate mitigation and management strategies, where relevant, will be developed and implemented; and
- where mitigation and management strategies have been implemented additional monitoring and regular reviews will be undertaken to measure the effectiveness of the strategies undertaken.

The groundwater available to adjacent landowners may be affected by a loss of pressure in underlying aquifers. This depressurisation may occur as a result of mining activities in the area from mining operations including the MOC, and may affect all bores located within the depressurisation zone as discussed in the Groundwater Monitoring Program.

In the event that a complaint is received from a landowner regarding de-pressurisation of a water supply or bore the following protocol will be implemented:

- provide a copy of the landowner complaint to NOW and DP&I and inform both agencies of the intention to conduct an independent review;
- commission an independent review including investigation of:

  - relevant groundwater levels and groundwater quality monitoring results;
  - any changes to land use that may have affected groundwater levels and quality over time;
  - meteorological conditions over the relevant period of record; and
  - whether the loss of bore water is attributable solely to MOC operations
- provide a copy of the independent review report to the landowner and NOW;
- if the investigation concludes that the bores have been affected by mining at the MOC then, depending on the most appropriate response, the MOC will either:
  - rehabilitate the bore/well supply by deepening; or
  - replace the water supply with water of equivalent quality and quantity
- develop and implement appropriate mitigation and management strategies, where relevant; and
- implement additional monitoring as necessary to measure the effectiveness of the strategies undertaken.

3.3 Response Protocol for Increased Leakage from Alluvium into Pits

Excessive groundwater inflow from the alluvial aquifers into the Mt Owen, Ravensworth East and Glendell open cut pits has the potential to inhibit mining operations as well as remove groundwater from the surrounding environment. Continued monitoring of groundwater seepage from the alluvials will be undertaken as part of the Groundwater Monitoring Program.

To minimise the impacts on Swamp Creek alluvials, the western extent of the 1996 approved Glendell open cut mine has been moved approximately 350 metres to the east. As a result the western limit of the mine will now only intersect a small section of the eastern edge of Swamp Creek alluvium in the north western corner of the open cut pit area.

As outlined in the Groundwater Monitoring Program a series of test pits were excavated along the 400 metre intersection of the Swamp Creek alluvials and the Glendell Mine boundary prior to the commencement of mining to determine the presence of any areas of high permeability. The area was also regularly assessed during the first 18 months of mining with no significant inflows recorded from the Swamp Creek alluvials, which was in line with the predictions from the studies in the area.

To minimise the groundwater inflow from the Bettys Creek alluvium, a cut off embankment will be investigated and potentially constructed across Bettys Creek immediately to the east of the intersection of the approved open cut pit with the alluvium. This embankment will be constructed at the base of the alluvium and will prevent groundwater flowing into the alluvium to be mined. Groundwater that collects upslope of the embankment will be conveyed to the Bettys Creek diversion to be constructed to the south and south-east of the emplacement area

In the event that the monitoring programs identify increases in groundwater inflows from the interception of alluvials at Mt Owen, Ravensworth East or Glendell Mines, the responses outlined below will be implemented:

- initiate an investigation by suitably qualified personnel into the cause(s) and extent of the increase in groundwater inflow from the alluvium into the open-cut pits;
- where appropriate, identify contingency measures such as:
  - installation of a cut-off wall, grout curtain or measures performing a similar function to seal off areas of high permeability;
  - relocation of the pit boundary to avoid intersection of highly permeable areas; and
  - installation of diversion drains, where possible.

Further information on the impacts of the interception of alluvial aquifers at Glendell Mine and associated mitigation measures have been identified as part of the Part 5 licence for groundwater extraction from the Glendell open cut pit.

3.4 Unforeseen Impacts Protocol

In the event of unforeseen impacts associated with surface waters or ground waters at the MOC, the following protocol will be implemented:

- conduct a preliminary review of the nature of the impact, including:
  - any relevant monitoring data; and
  - current mine activities and land use practices;
- commission of an investigation by an appropriate qualified expert into the unforeseen impact to confirm cause and effect and consider relevant options for amelioration of impact(s) as appropriate;
- prepare an action plan in consultation with the appropriate regulatory agency;
- mitigate causal factors where possible; and
- implement additional monitoring as necessary to measure the effectiveness of the controls implemented.

The outcomes of this protocol will be reported in the Annual Review. The implementation of any mitigation measures will be undertaken in consultation with DP&I, NOW and the Environmental Protection Authority (EPA)and will be reported in the Annual Review.

4.0 MEASUREMENT AND EVALUATION

4.1 Monitoring and Maintenance Requirements

The Surface Water and Groundwater Response Plan will be addressed in the Annual Review. Monitoring and inspections of the site will include monthly reporting of water levels across mining operations including active pit areas and internal tracking of in pit groundwater seepage.

5.0 REVIEW AND IMPROVEMENT

5.1 Reporting and Review

The Surface Water and Ground water Response Plan will be reviewed every year. The review will include, but not be limited to, changes in the environmental requirements, advances in technology, and changes in operational or reporting procedures at the MOC. The effectiveness of the Surface and Groundwater Response Plan will be reported in the Annual Review.

6.0 DEFINITIONS

Term	Definition
Alluvim	Sediment deposited by a flowing stream, e.g. clay, silt, sand, etc.
Alluvium	Sediment deposited by a flowing stream e.g. clay, silt, sand and gravel.
Aquifer	A water bearing rock formation
DA	Development Application
DP&I	NSW Department of Planning and Infrastructure
E&C	Environmental and Community
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
Groundwater	Sub-surface water which is within the saturated zone and can supply wells and springs. The upper surface of this saturated zone is called the water table.
HRSTS	Hunter River Salinity Trading Scheme
MOC	Mt Owen Complex
MOP	Mining Operations Plan
NOW	NSW Office of Water
WMP	Water Management Plan

7.0 ACCOUNTABILITIES

Role	Accountabilities for this document
E&C Manager	Responsible for ensuring that the protocols in the Surface Water and Groundwater Response Plan are followed in response to any adverse impacts potentially caused by the MOC operations
Operations Manager	Responsible for providing adequate resources to undertake the activities required by this Plan

Role	Accountabilities for this document
E&C Coordinator	Responsible for ensuring that monitoring, periodic environmental inspections and inspections after high rainfall events are undertaken

8.0 REFERENCES

8.1 Legislation

8.2 Glencore

8.3 Other

- Umwelt (Australia) Pty Limited, 2003. *Environmental Impact Statement Mt Owen Operations*. Prepared for Xstrata Mt Owen Pty Limited.
- Golder Associates Pty Ltd 2002. Glendell Project Geotechnical Evaluation for Open Pit Mining. Prepared for Glendell Joint Venture.
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9.0 APPENDICES

Appendix 1 – Correspondence with Regulatory Agencies

10.0 CONTROL AND REVISION HISTORY

10.1 Document information

Property	Value
Approved by	MOC E&C Manager
Document Owner	MOC E&C Manager
Effective Date	N/A
Keywords	Groundwater, Surface Water

10.2 Revisions

Version	Date reviewed	Review team (consultation)	Nature of the amendment
1	Nov 2008	E&C Coordinator, HSEC Manager	Development of the Document
2	Nov 2011	E&C Coordinator, MOC E&C Manager	Updated the document in line with current practises and requirements
3	Nov 2012	MOC E&C Mgr; MOC Operations Manager; Glendell Operations Manager	Updated the document in line with current practises and requirements
4	Sept 2013	MOC E&C Manager	Removed references to Xstrata.
5	July 2014	MOC E&C Manager, Glendell ECC, Mt Owen & Glendell ECO's	Updated document in line with comments received from DP&I and current practices.

APPENDIX 1

Correspondence with Regulatory Agencies

NSW GOVERNMENT | Planning & Environment

Contact: Ann Hagerthy
Phone: 6575 3403
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Email: ann.hagerthy@planning.nsw.gov.au
Our ref: DA 80/952
DA 14-1-2004
DA 52-03-99

Glenn Cook
Environment and Community Manager
Mt Owen Complex
PO Box 320
SINGLETON NSW 2330

Dear Glenn

Mt Owen Complex – Approval of Surface Water and Groundwater Response Plan

Thank you for forwarding the Mt Owen Complex Surface Water and Groundwater Response Plan to the Department of Planning & Environment (the Department or DP&E), as required by Conditions 29 and 35, Schedule 5 of DA 80/952; Condition 37, Schedule 6 of DA 14-1-2004; and Condition 28, Schedule 6 of DA 52-03-99.

The Department has conducted a review and wishes to advise that the Secretary has approved the Surface Water and Groundwater Response Plan (Version 5, dated July 2014).

The Department requests that you place the approved plan, along with a copy of this letter, on your website in accordance with Condition 10, Schedule 5 of DA 80/952; Condition 10, Schedule 6 of DA 14-1-2004; and Condition 11, Schedule 6 of DA 52-03-99.

If you require further information please do not hesitate to contact me on 6575 3403 or ann.hagerthy@planning.nsw.gov.au.

Yours sincerely

Scott Brooks
Team Leader Compliance
13-10-2014
As Nominee for the Secretary

Singleton Office: P.O. Box 3145, Suite 14, Level 1, 1 Civic Avenue Singleton NSW 2330
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APPENDIX D

Umwelt Briefing Note on EPBC Offset Calculator Assumptions

Briefing Note

To: Department of the Environment
cc: Vicki McBride (Glencore)
From: Umwelt
Author: Kate Connolly, Travis Peake
Date: 24 June 2015
Subject: Umwelt's Review of DotE EPBC Offset Calculator Assessments

Purpose

In response to comments from the Department of the Environment (DotE) on the adequacy of the Mount Owen Continued Operations Project (the Project) Biodiversity Offset Strategy, Umwelt has prepared this briefing note for discussion on the key points of difference in Umwelt's and DotE's EPBC Offset Calculator assessment.

Outcomes/Key messages

Umwelt prepared the Ecology Assessment and EPBC Offset Calculator Assessment to assess the value of the proposed offsets sites for Matters of National Environmental Significance likely to be impacted by the Project. The Umwelt calculator assessment indicated that the proposed offset sites provide in excess of the 100 per cent of the offsetting requirements for the predicted impacts of the Project. Additionally, comments from the submission received from the NSW Office of Environment and Heritage (OEH) show that the OEH are satisfied that the proposed offsets adequately address the impacts associated with the Project on threatened species and communities.

DotE and Umwelt have undertaken different approaches in assessing impacts of the Project on particular habitat types. The DotE assessment shows deficits in offsets for the spotted-tailed quoll, regent honeyeater and swift parrot for mature (57 year old) woodland habitat.

Umwelt has applied elements of DotE's approach and then amended these assessments by adding in the restoration of habitats (to 57 years) at the Stringybark Creek and Esparanga offset sites and the inclusion of all eucalypt habitat as habitat for the swift parrot and regent honeyeater to the offset calculations, which provides offsets over the 90% threshold for koala, spotted-tailed quoll, swift parrot and regent honeyeater.

Additional information on the current management of the proposed offset sites and the expected risk of loss of these sites without the establishment of an offset is also provided.

Recommendations

It is recommended that:

- DotE review this briefing note and consider the amended application of the calculator based on Umwelt's changes and considering further justification provided for our approach; and
- Umwelt and Glencore meet with DotE to discuss these outcomes for the Project.

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Dedicated Team.
Quality Outcomes.

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1.0 Introduction

According to DotE's submission for the Project, the Department considers that significant impacts are likely to occur for the:

- spotted-tailed quoll;
- regent honeyeater;
- swift parrot; and
- koala.

It is understood that the Department has run an indicative assessment based on their interpretation of the information provided in the Ecological Assessment. Their assessment concluded that the offsets proposed (Cross Creek Offset Site, Esparanga Offset Site and the Stringybark Creek Habitat Corridor Regeneration Strategy) meet approximately 75%, 34%, 28% and 110% of the EPBC Act Offset Policy requirements for the spotted-tailed quoll, regent honeyeater, swift parrot and koala, respectively.

DotE have provided Umwelt with their calculator spreadsheets and documents outlining the parameters they entered into the calculator. Some methods used by DotE have not been provided explicitly and therefore Umwelt has had to interpret the results to determine these methods in our response. Each section below provides commentary on the DotE assessment in relation to the assessment approach undertaken by Umwelt and recommended changes or considerations for DotE.

The Department notes that the final percentages output from the EPBC Act Offsets Policy are likely to increase marginally with greater confidence in results based on the provision of further information relating to the risks of loss associated with the offset sites and the provision of information on the current management of the proposed offset sites.

2.0 Risk of Loss and Current Management of the Offset Sites

2.1 Cross Creek Offset Site

The Cross Creek property is not adjacent to the Glencore (or any) mining lease. The likelihood of the area containing coal is very low as it is located in a barren area east of the Hunter Thrust Fault. The tenure of this site is freehold and privately owned by Glencore. The site is zoned RU1 – Primary Production under the Singleton LEP 2013. The Cross Creek Offset Site is currently managed under licence agreements covering grazing, noxious weed control and pest management. If not used as an offset site, it is likely the area would be sold by Glencore with the land likely to be used agricultural purposes. Potential clearing and increased grazing intensity in woodland areas would be required to make this property commercially viable as a farming enterprise. This would likely result in the loss of some of the woodland habitats on the site.

Given that the likelihood of future economic extraction of coal is minimal, but the potential for woodland habitat clearance is moderate, the Umwelt calculator assessment scored the risk of loss without the establishment of the offset site at 20% for all the species assessments, with a confidence in this score of 90%. This risk of loss score is considered to be conservative given the potential for agricultural improvements without the establishment of the offset and there is a high level of confidence for this score. Conversely, DotE scored the risk of habitat loss without the establishment of the offset site at only 10% for all of the species assessments, with a confidence score of only 40%.

2.2 Esparanga Offset Site

The area is not within or adjacent to the Glencore mining lease. The site lies approximately 10km northwest of Mangoola within AUTH 286. Although there is some potential for coal in this area they are at depths exceeding 500m (based on inferred depths from a borehole >5km distant) which is currently not viable for extraction. The eastern boundary abuts Manobalai Nature Reserve. The tenure of this site is freehold and privately owned by Glencore. The site is mainly zoned RU1 – Primary Production and E3 – Environmental Management with the eastern boundary to Manobalai Nature Reserve zoned as E1 – National Parks and Nature Reserves under the Muswellbrook LEP 2009. Extensive agriculture (grazing) is permissible without consent in both the RU1 and E3 zones . The Esparanga Offset Site is currently managed under licence agreements covering grazing, noxious weed control and pest management.

Given that the likelihood of future economic extraction of coal is minimal and the site is located adjacent to a conservation area and zoned mainly for environmental purposes, the Umwelt calculator assessment scored the risk of loss without the establishment of the offset site at 10% for all the species assessments, with a confidence in this score of 90%. As with the Cross Creek offset site, this land would be used for grazing and/or other agricultural purposes that may require woodland clearance if not set aside for offsetting. Given the likely improvements to the land necessary to make the property commercially viable as a grazing enterprise, the assumed risk of loss of 10% is considered to be conservative and the high confidence score is considered to be appropriate. DotE also scored the risk of habitat loss without the establishment of the offset site at only 10% for all of the species assessments, but with a confidence score of only 40%.

2.3 Stringybark Creek Habitat Corridor Site

The Stringybark Creek Habitat Corridor site is adjacent to the Glencore mining lease and a portion of it (13%) falls within AUTH 423. There is a moderate likelihood of the area containing coal as there is potential for the eastern portion of the area to be intersecting the Greta Coal Measures, the Maitland Group and/or the Wittingham Coal Measures. It is also is contiguous with areas that are already considered to preclude mining such as the Yorks Creek VCA to the south, the New Forest Area to the north and east and the North West Offset Area to the east. The tenure of this site is freehold and privately owned by Glencore. The site is zoned RU1 – Primary Production under the Singleton LEP 2013. This site is managed under the current Mount Owen Complex Biodiversity Management Plan which includes a range of management strategies implemented across the Mount Owen Complex.

Given this, the Umwelt calculator assessment scored the risk of habitat loss without the establishment of the offset site at 40% for all the species assessments, with a confidence in this score of 90%. The assumed risk of loss of 40% and the confidence score is considered to be appropriate given the potential for future extraction of coal and degradation of the existing ecological values due to likely clearance of woodland habitats to enable economically viable grazing. Conversely, DotE scored the risk of habitat loss without the establishment of the offset site at only 10% for all of the species assessments, with a confidence score of only 40%.

3.0 Commentary on DotE Calculator Assessments

3.1 Koala (*Phascolarctos cinereus*)

- Umwelt identified that 163.7 hectares of koala habitat would be impacted as a result of the Project. Umwelt has used the existing woodland on the offset sites and the proposed restoration of woodland from existing grassland to offset the 163.7 hectares of suitable koala habitat to be impacted.

- It appears that DotE have separated the assessments based on the age of impacted woodland. Central Hunter Ironbark – Spotted Gum – Grey Box Forest (131.9 ha) is noted to be approximately 57 years old, and Central Hunter Grey Box – Ironbark Woodland (4.4 ha) and the planted Central Hunter Ironbark – Spotted Gum – Grey Box Forest (27.4 ha) is noted to be approximately 30 years old. DotE have used the existing woodland in the offset sites to offset the area for the 131.9 ha of Central Hunter Ironbark – Spotted Gum – Grey Box Forest to be impacted and the proposed restoration of woodland from existing grassland at Cross Creek to offset the impacts on 4.4 ha of Central Hunter Grey Box – Ironbark Woodland and 27.4 ha of the planted Central Hunter Ironbark – Spotted Gum – Grey Box Forest. It is not known why this approach was taken and why the restoration of woodland at Stringybark Creek and Esparanga were not also included the DotE offset assessment.

- **The DotE assessment results in a 110% offset for 57 year old woodland impacts and a 429% offset for 30 year old woodland impacts** (Cross Creek restoration only – note that restoration is also to be undertaken at Stringybark Creek (43.8 ha of Central Hunter Ironbark – Spotted Gum – Grey Box Forest and 15 ha of River-flat Eucalypt Forest) and Esparanga (85.1 ha of White Box Woodland and 5.9 ha of Red Gum Open Forest)).

- It is not known why DotE assumed that all the Central Hunter Ironbark – Spotted Gum – Grey Box Forest in the disturbance footprint was up to 57 years old and all the Central Hunter Grey Box – Ironbark Woodland and the planted Central Hunter Ironbark – Spotted Gum – Grey Box Forest was up to 30 years old. This may have been carried out from reviewing historic aerial photos from Figures 2.2a and 2.2b of the Ecological Assessment. DotE have used this to note that the 'Time until ecological benefit' for restored grasslands to woodland will be 30 years (i.e. to meet the same quality score of the impact area).

- The restoration of grassland into woodland at Stringybark Creek and Esparanga could have been used to increase the scores for offsetting mature woodland habitat by entering 57 years into the 'Time until ecological benefit'. Based on the DotE assessment however, this is not required as the existing woodland offsets already provide 110% offset for mature woodland impacts.

- Umwelt scored the impact area as a 4/10 for koala habitat, whereas DotE scored 5/10.

- For the offset sites for koala, Umwelt's 'Confidence in the Risk of Loss' rating is 90%, whereas DotE scored this only 40%. DotE requested more information regarding risk, including site tenure, of the offset sites if this score is to improve. This is discussed further in **Section 2.0** above.

- For koala habitat, DotE expected the Cross Creek offset quality to start at 3/10, to decline to 2/10 without the offset and increase to 6/10 with the offset. Umwelt scored this 4/10, 3/10, 5/10 respectively, which is a similar decrease and increase in score. Both Umwelt and DotE gave high scores (90% and 85%) for the confidence in quality change.

3.2 Spotted-tailed Quoll (*Dasyurus maculatus maculatus*)

- Umwelt identified that 223.7 hectares of spotted-tailed quoll woodland habitat would be impacted as a result of the Project. This included all woodland and forest vegetation within the project area. Umwelt used the existing woodland on the offset sites and the residual proposed restoration of woodland from existing grassland to offset the 223.7 hectares of suitable spotted-tailed quoll habitat to be impacted. DotE (as consistent with the approach at Liddell) have excluded grassland as habitat for the quoll.

- DotE have separated the assessments based on the age of impacted woodland. Central Hunter Ironbark – Spotted Gum – Grey Box Forest (131.9 ha) is noted to be approximately 57 years old, and an assessment for the other woodland/forest communities (totalling 91.8 ha) is noted to be approximately 30 years old. DotE have used the existing woodland in the offset sites to offset the area for the 131.9 ha of Central Hunter Ironbark – Spotted Gum – Grey Box Forest to be impacted and the proposed restoration of woodland from existing grassland at Cross Creek to offset the impacts on 91.8 ha of other 30 year old woodland/forest habitat.

- **The DotE assessment results in a 75% offset for 57 year old woodland impacts and a 117% offset for 30 year old woodland impacts** (Cross Creek restoration only – see below).

- DotE has not included the restoration of grassland to woodland at Stringybark Creek or Esparanga in the calculation of offsetting scores, notwithstanding that the species has been recorded in Esparanga and is likely to occur within the Stringybark Creek area. Stringybark Creek will include the restoration of 43.8 ha of Central Hunter Ironbark – Spotted Gum – Grey Box Forest and 15 ha of River-flat Eucalypt Forest, and Esparanga will include 85.1 ha of White Box Woodland and 5.9 ha of Red Gum Open Forest. If these areas are included in the offset for 57 year old woodland (same parameters entered into the DotE calculator assessment as for Cross Creek restoration except the 'Time until ecological benefit' is entered as 57 years), the Stringybark Creek restoration adds 12% and Esparanga adds 22% to the existing 75% offset gained from the existing woodland habitats at the offset sites (totalling 109% offset).

- DotE and Umwelt both scored the impact area as a 5/10.

- For the spotted-tailed quoll, Umwelt's 'Confidence in the Risk of Loss' rating is 90%, whereas DotE scored this as only 40%. DotE requested more information regarding risk, including site tenure, of the offset sites if this score is to improve. This is discussed further in **Section 2.0** above.

- Umwelt rated the 'Time until ecological benefit' as 10 years (DoE rated this 30 years for regeneration and 20 years for existing woodland) based on the spotted-tailed quoll being recorded frequently over the period 1995 to 2013 in rehabilitation sites and regeneration sites of 6-15 years old in the Mount Owen Complex.

- Umwelt included the African Olive infestation at the Stringybark Creek site as existing suitable habitat for the quoll, despite its exotic status. DotE excluded this and calculated only the woodland habitat (27.8 ha).

3.3 Regent Honeyeater (*Anthochaera phrygia*)

- Umwelt identified that 163.7 hectares of regent honeyeater habitat would be impacted as a result of the Project. Umwelt used the existing woodland on the offset sites and the proposed restoration of woodland from existing grassland to offset the 163.7 hectares of suitable regent honeyeater habitat to be impacted.

- DotE have separated the assessments based on the age of impacted woodland. Central Hunter Ironbark – Spotted Gum – Grey Box Forest (131.9 ha) is noted to be approximately 57 years old, and Central Hunter Grey Box – Ironbark Woodland (4.4 ha) and the planted Central Hunter Ironbark – Spotted Gum – Grey Box Forest (27.4 ha) noted to be approximately 30 years old. DotE used the existing woodland in the offset sites to offset the area for the 131.9 ha of Central Hunter Ironbark – Spotted Gum – Grey Box Forest to be impacted and the proposed restoration of woodland from existing grassland at Cross Creek to offset the impacts on 4.4 ha of Central Hunter Grey Box – Ironbark Woodland and 27.4 ha of the planted Central Hunter Ironbark – Spotted Gum – Grey Box Forest. It is not known why this approach was taken and why the restoration of woodland at Stringybark Creek and Esparanga were not included the DotE offset assessment.

- **The DotE assessment results in a 33% offset for 57 year old woodland impacts and a 358% offset for 30 year old woodland impacts** (Cross Creek restoration only – see below).

- Umwelt identified 211 hectares of potential regent honeyeater habitat on the Esparanga Offset Site. This includes all eucalypt-dominated woodland and forest being Upper Hunter White Box – Ironbark Grassy Woodland (46 ha), Spotted Gum Open Forest Complex on Sandstone (3.2 ha), Shrubby White Box Woodland (9.2 ha), Red Gum Open Forest on Alluvium/Colluvium (2.7 ha), Narrabeen Sheltered Dry Forest (59.3), Narrabeen Ironbark Woodland (91 ha). It appears that DotE only included 58.4 ha being Upper Hunter White Box – Ironbark Grassy Woodland,and Spotted Gum Open Forest Complex on Sandstone, Shrubby White Box Woodland. The Red Gum Open Forest, Narrabeen Sheltered Dry Forest and Narrabeen Ironbark Woodland still contain potential roosting habitat therefore would be suitable habitat for the species.

- Umwelt identified 51.7 hectares of potential regent honeyeater habitat on the Cross Creek Offset Site. This includes all eucalypt-dominated woodland and forest being Central Hunter Ironbark – Spotted Gum – Grey Box Forest (37.2 ha) and the Red Gum variant on this community (14.5 ha). It appears DotE excluded the variant community in their calculations. The variant community still contains winter-flowering species and potential roosting habitat and therefore would also be suitable habitat for the species.

- The inclusion of all eucalypt-dominated woodland and forest in the offset sites increases the offset score of 11% for Cross Creek and 17% for Esparanga to 15% and 62%, respectively.

- DotE has not included the restoration of grassland to woodland at Stringybark Creek or Esparanga in the calculation of offsetting scores. Stringybark Creek will include the restoration of 43.8 ha of Central

Hunter Ironbark – Spotted Gum – Grey Box Forest and 15 ha of River-flat Eucalypt Forest, and Esparanga will include 85.1 ha of White Box Woodland and 5.9 ha of Red Gum Open Forest – all potential habitat for these species. If these areas are included in the offset for 57 year old woodland (same parameters entered into the DotE calculator assessment as for Cross Creek restoration except the 'Time until ecological benefit' is entered as 57 years), the Stringybark Creek restoration adds 12% and Esparanga adds 22% to the existing 33% offset gained from the existing woodland habitats at the offset sites (totalling 67% offset). It is noted that the calculation for restoring woodland at Cross Creek comes to an offset for regrowth (30 year) woodland is 358%. Taking the residual of this and applying to an outcome for 57 year old regeneration (as per the impact area) adds 43% offset.

- DotE and Umwelt both scored the impact area as a 5/10 for regent honeyeater.

- Umwelt's 'Confidence in the Quality Change' score for Stringybark Creek was 90%. DotE only scored this to be 50% due to the African Olive infestation, however management of the African Olive infestations is proposed as part of the management actions for this offset area.

- For the offset sites, Umwelt's 'Confidence in the Risk of Loss' rating is 90%, whereas DotE scored this only 40%. DotE request more information regarding risk, including site tenure, of the offset sites.

3.4 Swift Parrot (*Lathamus discolor*)

- Umwelt identified that 163.7 hectares of swift parrot habitat would be impacted as a result of the Project. Umwelt used the existing woodland on the offset sites and the proposed restoration of woodland from existing grassland to offset the 163.7 hectares of suitable swift parrot habitat to be impacted.

- DotE have separated the assessments based on the age of impacted woodland. Central Hunter Ironbark – Spotted Gum – Grey Box Forest (131.9 ha) is noted to be approximately 57 years old, and Central Hunter Grey Box – Ironbark Woodland (4.4 ha) and the planted Central Hunter Ironbark – Spotted Gum – Grey Box Forest (27.4 ha) noted to be approximately 30 years old. DotE used the existing woodland in the offset sites to offset the area for the 131.9 ha of Central Hunter Ironbark – Spotted Gum – Grey Box Forest to be impacted and the proposed restoration of woodland from existing grassland at Cross Creek to offset the impacts on 4.4 ha of Central Hunter Grey Box – Ironbark Woodland and 27.4 ha of the planted Central Hunter Ironbark – Spotted Gum – Grey Box Forest. It is not known why this approach was taken and why the restoration of woodland at Stringybark Creek and Esparanga were not included the DotE offset assessment.

- **The DotE assessment results in a 28% offset for 57 year old woodland impacts and a 286% offset for 30 year old woodland impacts** (Cross Creek restoration only – see below).

- Umwelt identified 211 hectares of potential swift parrot habitat on the Esparanga Offset Site. This includes all eucalypt-dominated woodland and forest being Upper Hunter White Box – Ironbark Grassy Woodland (46 ha), Spotted Gum Open Forest Complex on Sandstone (3.2 ha), Shrubby White Box Woodland (9.2 ha), Red Gum Open Forest on Alluvium/Colluvium (2.7 ha), Narrabeen Sheltered Dry Forest (59.3), Narrabeen Ironbark Woodland (91 ha). It appears that DotE only included 58.4 ha being Upper Hunter White Box – Ironbark Grassy Woodland, Spotted Gum Open Forest Complex on Sandstone, Shrubby White Box Woodland. The Red Gum Open Forest, Narrabeen Sheltered Dry Forest and Narrabeen Ironbark Woodland still contain potential roosting habitat and therefore would be suitable habitat for the species.

- Umwelt identified 51.7 hectares of potential swift parrot habitat on the Cross Creek Offset Site. This includes all eucalypt-dominated woodland and forest being Central Hunter Ironbark – Spotted Gum – Grey Box Forest (37.2 ha) and the Red Gum variant on this community (14.5 ha). It appears DotE excluded the variant community in their calculations. The variant community still contains winter-flowering species and potential roosting habitat and therefore would also be suitable habitat for the species.

- The inclusion of all eucalypt-dominated woodland and forest in the offset sites increases the offset score of 9% for Cross Creek and 14% for Esparanga to 12% and 51%, respectively.

- DotE has not included the restoration of grassland to woodland at Stringybark Creek or Esparanga in the calculation of offsetting scores. Stringybark Creek will include the restoration of 43.8 ha of Central Hunter Ironbark – Spotted Gum – Grey Box Forest and 15 ha of River-flat Eucalypt Forest, and Esparanga will include 85.1 ha of White Box Woodland and 5.9 ha of Red Gum Open Forest – all potential habitat for these species. If these areas are included in the offset for 57 year old woodland (same parameters entered into the calculator as for Cross Creek restoration except the 'Time until ecological benefit' is entered as 57 years), the Stringybark restoration adds 12% and Esparanga adds 18% to the existing 28% offset gained from the existing woodland habitats at the offset sites (totalling 58% offset). It is noted that the calculation for restoring woodland at Cross Creek comes to an offset for regrowth (30 year) woodland is 286%. Taking the residual of this and applying to an outcome for 57 year old regeneration (as per the impact area), adds 41% offset.

- DotE and Umwelt both scored the impact area as a 6/10 for swift parrot.

- Umwelt's 'Confidence in the Quality Change' score for Stringybark Creek was 90%. DotE only scored this to be 50% due to the African Olive infestation, however management of the African Olive infestations is proposed as part of the management actions for this offset area.

- For the offset sites, Umwelt's 'Confidence in the Risk of Loss' rating is 90%, whereas DotE scored this only 40%. DotE request more information regarding risk, including site tenure, of the offset sites. This is discussed further in **Section 2.0** above.

- Umwelt's risk of loss for Stringybark Creek is higher (40%) than DotE's assessment (10%) due to its locality to mining and mining leases.

3.5 Key Differences across the DotE and Umwelt Assessments

- Umwelt considered grassland as habitat for quoll whereas DotE do not consider this habitat for the impact calculations. Umwelt assessed the impacts on woodland and grassland separately for the quoll. Spotted-tailed quolls are likely to utilise open grassland habitats to transverse between areas of higher quality woodland habitat (as per radio-tracking data from Mount Owen). Consequently, Umwelt acknowledged that this habitat is not of high quality for the species by rating it low (quality score of 3 out of 10). This was also the original method used to assess the offset requirements for the species for the adjacent Liddell Coal Operations Extension Project. Glencore and DotE have since negotiated the Liddell assessment approach and agreed that impacts on grassland were not to be considered in the EPBC Offsets Calculator for the spotted-tailed quoll. For the purposes of the assessment comparison below, Umwelt have adopted DotE approach of not including grassland in the impact calculation (refer to **Section 4.0**).

- Across all species, DoE separated impacts to younger (30 year) and more mature (57 year) vegetation in the impact area. This is a holistically different approach to Umwelt who included all woodland (regardless of broad age classes) as one assessment. For the purposes of the comparison below, Umwelt have adopted the 30/57 year age approach (refer to **Section 4.0**).

- DotE excluded any regeneration and restoration works at Stringybark Creek and Esparanga in the calculations for all species. This is presumably because the younger vegetation offset (30 year) (using the DotE method) is covered for all species through the regeneration of grassland at Cross Creek, however this regeneration is still relevant for habitat gains for mature woodland and should not be disregarded. For the purposes of the assessment comparison below, Umwelt have included the restoration of these sites in the calculations for 57 year old woodland offsets (refer to **Section 4.0**).

- Differences in what is considered habitat. Umwelt concluded that all eucalypt-dominated woodland would be suitable habitat for swift parrot and regent honeyeater, however DotE restricted this to just spotted gum-ironbark woodlands. Along with spotted gum-ironbark woodlands, Birdlife Australia (2013) notes in *Swift Parrots and Regent Honeyeaters in the Lower Hunter Region of NSW* that these species are known to utilise other vegetation communities including Hunter Lowland Red Gum Forest and River-flat Eucalypt Forest including important foraging species being flowering forest red gum (*Eucalyptus tereticornis*) and narrow-leaved ironbark (*Eucalyptus crebra*) for lerps. Additionally, regent honeyeaters are known to occupy of grey gum (*Eucalyptus punctata*) and broad-leaved ironbark (*Eucalyptus fibrosa*). In the case of this assessment, one or more of these species has been recorded to occur in the Red Gum Open Forest, Narrabeen Sheltered Dry Forest and Narrabeen Ironbark Woodland on Esparanga and within the River-flat Eucalypt Forest in the Stringybark Creek Corridor. For the purposes of the assessment comparison below, Umwelt have included these eucalypt-dominated woodlands and forests as suitable offset habitat for these species.

- For the offset sites, Umwelt's 'Confidence in the Risk of Loss' rating is 90%, whereas DotE scored this only 40%. DotE requests more information regarding risk, including site tenure, of the offset sites. This is discussed further in **Section 2.0** above.

4.0 Key Findings and Summary

In summary, Umwelt have reviewed the DotE assessment and applied many of the parameters entered as being appropriate and/or similar to that of the Umwelt assessment. Some key differences in approaches have been noted above that outline why the results of the DotE assessment and Umwelt assessment differ. This includes the exclusion of restoration works at the Stringybark and Esparanga offset sites and what is considered suitable habitat for swift parrot and regent honeyeater are key points of disagreement between the assessments.

Umwelt have taken the assessments by DotE (refer to **Table 1**) and applied the restoration of Stringybark and Esparanga grasslands to the offsets for mature (57 year old) woodland for the species with offset deficits and included all eucalypt-dominated woodland habitat to the offset calculations for swift parrot and regent honeyeater. These amendments are shown in **Table 2** which indicates that the provision of the three offset sites, including the restoration of woodland and forest habitat, would provide sufficient offsetting for the koala, spotted-tailed quoll, swift parrot and regent honeyeater using the EPBC Act Offset Calculator. Note: the 'Risk of Loss' scores in these tables use the DotE approach.

Table 1 - DotE Assessment

	Calculated Proportion of Impact Addressed by Offsets							
	Cross Creek		Stringybark Corridor		Esparanga		Total Value of Offset Sites	
	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)
Koala	429%	24%	-	10%	-	76%	429%	110%
Spotted-tailed quoll	118%	16%	-	7%	-	52%	118%	75%
Regent honeyeater	358%	11%	-	5%	-	17%	358%	33%
Swift parrot	287%	9%	-	5%	-	14%	287%	28%

Table 2 – Umwelt Application of DotE Assessment (with the inclusion of restoration at Stringybark Creek and Esparanga toward 57 year old mature woodland impacts and all eucalypt-dominated woodland/forest as suitable habitat for swift parrot and regent honeyeater)

	Calculated Proportion of Impact Addressed by Offsets							
	Cross Creek		Stringybark Corridor		Esparanga		Total Value of Offset Sites	
	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)	Regrowth (30 y/o)	Mature (57 y/o)
Koala	429%	24%	-	10% + 26% from restoration	-	76% + 38% from restoration	429%	174%
Spotted-tailed quoll	118%	16%	-	7% + 12% from restoration	-	52% + 22% from restoration	118%	109%
Regent honeyeater	102%^	15% + 43%* from residual restoration	-	5% + 11% from restoration	-	62% + 22%+ from restoration	102%	158%
Swift parrot	100%#	12% + 41%† from residual restoration	-	5% + 11% from restoration	-	51% + 18%+ from restoration	100%	138%

Notes: ^ 90 hectares of restoration
*225.3 hectares of restoration
#110 hectares of restoration
†205.3 hectares of restoration
+91 hectares of restoration

5.0 Recommendations

It is recommended that:

- DotE review this briefing note and consider the amended application of the calculator based on Umwelt's changes and our justification provided; and
- Umwelt and Glencore meet with DotE to discuss these outcomes for the Project.

APPENDIX E

IESC Advice Checklist

Question 1 - Do the groundwater and surface water assessments, including numerical modelling therein, provide reasonable estimations of the risk (including likelihood, extent and significance) to water resources, with particular reference to Bowmans Creek, Glennies Creek and the Hunter River, in the short and long term?	
IESC Response	**Report B Point of Reference**
1) The project specific risks to Bowmans Creek provided within the EIS appear to be reasonably estimated, except with regard to quantification of seasonal flow regimes and water quality other than total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC) and pH. Limited information on the potential hydrological and ecological risks to Glennies Creek and the Hunter River has been provided in the EIS. A reasonable estimation of the risks to Glennies Creek and the Hunter River would need to include quantitative flow regime data (including seasonal, high flow and contribution to the Hunter River), existing water quality data and ecological assessments (in-stream, hyporheic and riparian zones).	Section 2.1 Section 2.2.1 Section 2.2.2 Section 2.2.5 Section 2.2.6 Section 2.2.7 Section 2.4
2) Apart from the uncertainties raised in paragraphs 3 and 4, identification and assessments of the existing hydrological conditions along Bowmans Creek (including its tributaries, Stringybark Creek, Yorks Creek, Swamp Creek and Bettys Creek) are reasonable. Based on the assessment, risks within these watercourses are unlikely to significantly change compared to those from the existing mining operations.	Comment Noted
3) Information on existing water quality conditions within Bowmans Creek (and tributaries) and the assessment of potential impacts to water quality as a result of the project in all watercourses includes TDS, TSS, EC and pH, but would need to include metals, metalloids, polycyclic aromatic hydrocarbons (PAHs) and ionic compositions.	Section 2.2.5 Section 2.2.6 Section 2.2.7
4) The current seasonal flow regime has not been described or quantified for all watercourses in the area. The assessment of existing hydrological, geomorphological and ecological conditions along Glennies Creek is minimal throughout the assessment documentation. The limited data and information presented with regards to Glennies Creek makes it difficult to assess the proponent's estimation of risk, including downstream risks to the Hunter River.	Section 2.2.1 Section 2.2.2
5) The proponent states that "due to the limited localised impact, it is anticipated that the Project will have negligible impact on major downstream watercourses including Bowmans Creek, Glennies Creek and the Hunter River" (EIS, App 9, p 6.4). The assessment of potential surface water flow impacts is based on contributing catchment area losses within Yorks Creek, Bettys Creek, Swamp Creek and Main Creek and by inferring potential flow volumes using historical rainfall records from Jerrys Plains (approximately 19 km to the south). Flow within the tributaries was monitored visually though this data was not provided. The assessment of existing flows within Bowmans Creek and Glennies Creek was not supported by quantitative seasonal flow data from existing flow gauges on these two watercourses (for example, Bowmans Creek gauge 210130 and Glennies Creek gauge 210044 where presumably there is existing data). A discussion on the uncertainties and assumptions associated with this method of assessment, including the potential impact of using the Bowmans Creek (Grenell) (station number 61270) meteorological station for the rainfall source, is needed.	Section 2.2.2 Section 2.2.4.1
6) The numerical groundwater model has a cell size of 100 m by 100 m which is adequate for estimating regional groundwater behavior, though is too large to predict fine scale groundwater and surface water interactions. Nevertheless, the groundwater model predicts baseflow reductions to surface watercourses as follows (with results from the 'plus one standard deviation' model run in brackets): 6 ML/year (9 ML/year) decrease to Bettys Creek, 15 ML/year (22 ML/year) decrease to Main Creek and "negligible" losses from Bowmans and Glennies Creeks. Seasonal quantification or estimation of baseflow within each of the surface watercourses has not been provided. Baseflow analysis was only described as an annual percentage and therefore the importance of baseflow contribution to Bowmans and Glennies Creeks during seasonal or climatic low flow periods is unknown.	Section 2.3 Section 2.2.2.2
7) The groundwater model predicts drawdown within the Main Creek alluvium of between 2m and greater than 6 m (for the plus one standard deviation model run). Within the predicted zone of impact this would lower the Main Creek alluvial water table to between 4 m and 8 m below the surface. The effect on the Central Hunter Swamp Oak Forest GDE of lowering the Main Creek alluvial water table has not been addressed within the EIS.	Section 2.3 Section 2.4.3 Section 2.5

Question 1 - Do the groundwater and surface water assessments, including numerical modelling therein, provide reasonable estimations of the risk (including likelihood, extent and significance) to water resources, with particular reference to Bowmans Creek, Glennies Creek and the Hunter River, in the short and long term?	
IESC Response	**Report B Point of Reference**
8) The EIS states (App 10, p 92) that no GDEs are associated with Yorks Creek and Swamp Creek. However, the riparian zones of these watercourses are mapped as containing the Central Hunter Swamp Oak Forest which is considered to be a GDE (EIS, App 11, and Figure 4.1). The proponent has not mapped or estimated the area inhabited by groundwater dependent riparian vegetation outside of the project area, including within the zone of predicted alluvial impact and downstream of the proposed project area.	Section 2.4.3 Figure 2.20
9) The proponent states that ephemeral streams represent limited habitat opportunities for aquatic fauna. However, the EIS states in a number of places (for example App 10, p 26 and App 11, p 2.3-2.4) that pools of standing/stagnant water remain in ephemeral streams. These pools may be semi permanent and represent important refugia for aquatic fauna. The ecological assessment does not assess the habitat value, duration of persistence or map the extent or location of these pools.	Section 2.4.1 Section 2.4.4
10) Given the Main Creek alluvium supports known groundwater dependent riparian vegetation that is also habitat known to be utilised by the nationally listed endangered Spotted-tail quoll, information identified in paragraphs 8 and 9 is needed to determine the existing habitat conditions along this watercourse.	Section 2.4.3

Question 2: If not, what additional information would be required to provide a sufficiently robust assessment of the likelihood, extent and significance of potential impacts on water resources resulting from the project?	
IESC Response	**Report B Section Number**
11) The assessment of risk to Glennies Creek needs to include data and information that describes the existing hydrological (water quality, flow quantity, seasonal regime) and ecological (presence of fauna, habitat quality/quantity) conditions within the Glennies Creek system, including its tributary Main Creek.	Section 2.1 Section 2.2.1.2 Section 2.2.2.2 Section 2.2.5 Section 2.2.6 Section 2.4.1
12) Water quality monitoring within receiving surface water systems needs to include contaminants such as metals, PAHs and ionic composition to determine the potential downstream project specific and cumulative water quality impacts to the Hunter River.	Section 2.2.5 Section 2.2.6 Section 2.2.7
13) While the assessments of the majority of surface watercourses within the vicinity of the proposed project area are sufficiently robust, the assessment of existing conditions within Glennies Creek is limited. An assessment of the following is needed to understand the existing conditions within Glennies Creek and provide a robust assessment: a. Flow data, including seasonal and annual quantities, and details of Main Creek's alluvial groundwater and surface water contribution to flows in Glennies Creek. b. Water quality data above and downstream of Main Creek. Data needs to include the full range of contaminants such as those already considered within existing monitoring (paragraph 3) as well as metals, metalloids, PAHs and ionic compositions. c. An assessment of surface water contaminant contribution to cumulative impacts on downstream environments within Glennies Creek and the Hunter River.	Section 2.2.1.2 Section 2.2.2.2 Section 2.2.5 Section 2.2.6 Section 2.5
14) The proponent has undertaken sufficiently robust ecological stream habitat and aquatic fauna assessments for Bowmans Creek and Bettys Creek. However, equivalent assessments of Main Creek and Glennies Creek have not been provided within the EIS. To understand the existing ecological conditions within, and provide a robust assessment for Glennies and Main Creek, a description of the riparian, in-stream, and alluvial habitat for fauna and flora needs to be provided. This would include: a. mapping of vegetation including in riparian zones and areas of shallow groundwater b. sampling of GDEs including stygofauna and hyporheic fauna c. an in-stream aquatic fauna survey (e.g. fish, macroinvertebrates, amphibians) d. an existing conditions aquatic habitat assessment in line with a national standard (for example using the AUSRIVAS (2007) sampling protocols utilised for Bowmans Creek) e. the development of ecological conceptualisations using the method described in Commonwealth of Australia (2015) to identify the ecological and water relationships of the project area.	Section 2.4 Section 2.5
15) The geochemical characterisation study needs to be included as a component of the EIS. The document is referenced in the Mine Closure and Rehabilitation Strategy (EIS, Appendix 18) as Environmental Geochemistry International Pty Ltd, 2013 *Geochemical Assessment of the Mount Owen Optimisation Project*. This is an important document to allow a thorough assessment of the potential geochemical risks posed by the final landform including the three final voids.	Section 2.2.6.1 Appendix D

Question 3: Has the proponent provided effective strategies to avoid, mitigate, and / or reduce the likelihood, extent and significance of these impacts?	
IESC Response	**Report B Section Number**
16) The potential to implement avoidance measures is limited by the large scale of the project, compared to the size of the proponent's mining leases. However, where possible the proponent has attempted to reduce the project's disturbance footprint by proposing development on existing disturbed sites and has increased the setback for the NPE to 450 m from Main Creek's central flow channel.	Comment Noted
17) Mitigation measures are proposed to be implemented through existing management plans which have not been included within the assessment documentation. It is not possible to determine how effective the measures have been, or would be, at mitigating or reducing impacts from the existing operations as this information has not been provided within the EIS.	Section 2.5 Table 2.13
18) The proponent commits to continue utilising various approved plans, programs and strategies to mitigate potential impacts to water resources, including the Landscape Management Plan, Erosion and Sediment Control Plan, Water Management Plan and the Flora and Fauna Management Plan. These plans are not included as a component of the EIS, though are available on the proponent's website. The proposed mitigation measures that have been described broadly include ongoing review of groundwater modelling, biodiversity offsetting, rehabilitation, the addition of new monitoring locations, surface water diversions and erosion and sediment control techniques. The ongoing effectiveness or results of these measures within the existing operations have not been clearly stated. Water quality within existing stream diversions (including metals, PAHs and ionic compositions), as well as their habitat values and geomorphological stability has not been provided.	Section 2.5 Table 2.13
19) The groundwater impact assessment states (EIS, App 10, p 128) that, if necessary, the proponent would adjust mining and dewatering plans to mitigate unacceptable actual or predicted impacts on the alluvial systems of Glennies Creek and Bowmans Creek. The criteria to be used to determine an unacceptable impact should be provided in relation to the alluvial systems (or impacts to riparian GDEs) associated with the tributaries of Glennies Creek or Bowmans Creek.	Section 2.5 Table 2.13
20) Given the predicted drawdown in the Main Creek alluvium of between 2 m and up to greater than 6 m (for the plus one standard deviation prediction), there is a risk of impact to the riparian Central Hunter Swamp Oak Forest GDE along this watercourse. Mitigation, rehabilitation or vegetation improvement is not proposed, or has not been described within the EIS, to compensate for the predicted drawdown impacts to riparian vegetation along Main Creek.	Section 2.4.3 Section 2.5.1.3 Section 2.5.1.4

Question 4: If not, what additional measures should be recommended to avoid, mitigate, reduce or remediate the likelihood, extent and significance of these impacts?	
IESC Response	**Report B Section Number**
21) The proponent's mitigation strategy should consider the potential impacts to riparian vegetation affected by but outside of the proposed project area, such as along reaches of Bettys Creek and Main Creek. Stream diversion specifications as well as construction and performance criteria should be provided to determine the diversion's ability to avoid or mitigate potential downstream surface water impacts. The legacy risks associated with the three final voids need to be identified and mitigated or managed, including those associated with potential post mining contamination of aquifers and connectivity with the underlying longwall mine.	Section 2.2.3 Section 2.4.1 Section 2.4.3 Section 2.5.1.3 Section 2.5.1.4 Section 2.5.1.6
22) Given the riparian Central Hunter Swamp Oak Forest community is a GDE and a known habitat corridor for the nationally listed endangered Spotted-tail quoll, the application of mitigation or remediation measures along Main Creek (including outside of the proposed project boundary) within the zone of impact is warranted. These measures would need to include improved mapping of riparian vegetation potentially affected by drawdown but outside of the project boundary as well as ongoing monitoring of condition to determine if mitigation or remediation is required. If required, mitigation measures could include provision of additional water to the Main Creek alluvium, improvement of bank stability and water quality as well as vegetation remediation, rehabilitation and Spotted-tail quoll habitat improvement.	Section 2.4.2 Section 2.5.1.4 Figure 2.20
23) Ongoing monitoring and refined mapping of GDEs that occur outside of the project boundary, which may be impacted by the proposed project, is also needed to determine the extent of the potential impacts of the proposed project.	Section 2.4.2 Section 2.4.3 Section 2.5.1.3 Section 2.5.1.4
24) Specifications for surface water diversions as well as construction and performance criteria are needed to determine the effectiveness of each diversion in mitigating surface water quality and quantity impacts to downstream watercourses, particularly within Glennies Creek and the Hunter River. These specifications need to include: construction materials and geochemistry, meander length, in-stream flow velocities, shear stresses within flow channels, sediment control measures as well as modeled performance under a variety of flow velocities and vegetation establishment.	Section 2.2.3
25) The final landform, in its current conceptual form, following the completion of the proposed project contains three final voids. The proponent has identified the key rehabilitation and final landform design criteria in their Mine Closure and Rehabilitation Strategy. This report will need to be updated to demonstrate that the legacy issues and risks to water resources as a result of the final landform have been assessed and will be adequately mitigated and managed. This will need to include: a. the design of a post-mining groundwater and surface water monitoring network to provide a representative indication of groundwater and surface water quality to identify any leaching of saline or acidic material b. an assessment of the potential risks to regional hydrogeological units and surface watercourses caused by potential leakage or connectivity from the NPE final void into the underlying goaf of the Integra underground operations.	Section 2.5.1.5

Question 5: Does the EIS provide a reasonable consideration of the potential for discharges (including salt) to nearby watercourses and the significance of any resulting impacts to water quality and the downstream environment? If not, what additional information would be required to provide a sufficiently robust assessment of these matters?	
IESC Response	**Report B Section Number**
26) The EIS does not provide reasonable consideration of the potential for discharges. The water balance model predicts spillages to occur twice a year however the locations of receiving surface water systems are not identified. The water quality impacts of spillages to the downstream watercourses for a variety of contaminants have not been considered. The EIS inconsistently states that discharges will occur under the HRSTS, when the proponent's Environmental Protection License (EPL) EPL 4460 has been varied to remove conditions relating to discharges under the HRSTS.	Section 2.2.7
27) The proponent's water balance modeling results indicate that the frequency of spills from sediment dams following rainfall events is twice a year. Average spill volumes caused by rainfall events are predicted to be between 478 ML/ year and 534 ML/year, with maximum spill volumes between 3,765 ML/year and 4,173 ML/year (EIS, App. 9, App. B, p 14). Spills from water management system (WMS) dams may occur more regularly than predicted given the water balance model utilises the lower average annual rainfall values from the Jerrys Plains meteorological station, rather than the 35 per cent greater average annual rainfalls observed at the Bowmans Creek (Grenell) meteorological station.	Section 2.2.4
28) The Mount Owen EPL 4460 was varied in November 2014, removing conditions regarding the proponent's license to discharge water under the HRSTS to Swamp Creek (NSW EPA, 2014a). Additionally, the Ravensworth East EPL does not contain conditions that relate to water discharges (NSW EPA, 2014b). The EIS consistently states that, if required, excess mine water will be discharged to the HRSTS under EPL 4460. The proponent will need to clarify whether discharges to the Hunter River will actually occur or provide details of an alternative method of containing their excess saline water.	Section 2.2.4.2 Section 2.2.7.1
29) The WMS for the proposed project is based on the existing systems in place at the Mount Owen and Ravensworth East mines. However, detailed information has not been provided for the WMS currently implemented at the existing operations. With regards to the project's WMS, the following information is needed: a. A water management schematic, illustrating water transfers between stores, under a range of climatic scenarios and including licensed surface water and groundwater extraction/discharge quantities b. The location of particular sediment dams or water storages that are considered most at risk of regular spills c. Identification of receiving watercourses of spills d. Water quality monitoring of the full range of contaminants (including metals/metalloids, ionic composition and PAHs) prior to, during and following spills, consistent with the recent findings of Krogh et al. (2013), to provide evidence that spills have negligible impacts on the downstream water resources, including the Hunter River e. Alternative options, including redesign of dams and their storage capacity within the WMS, to avoid bi-annual spills, or mitigate their impacts.	Section 2.1 Section 2.2.4 Section 2.2.5 Section 2.2.6 Section 2.2.7 Section 2.5 Figure 2.10
30) The Northern Sydney Basin bioregion which includes the Hunter subregion has been identified as a Bioregional Assessment priority region. It is anticipated that the Bioregional Assessment programme will deliver a regional groundwater model for the Hunter subregion which will include the project, the adjacent coal mines and coal mine hydrogeological processes. Data and relevant information from the proposed project should be made accessible to this Bioregional Assessment and other research projects.	Comment Noted

APPENDIX F

Geochemical Assessment of the Mount Owen Optimisation Project

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Geochemical Assessment of the Mount Owen Optimisation Project

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List of Abbreviations

ARD	Acid Rock Drainage
ABA	Acid Base Account
$pH_{1:2}$	pH of a sample slurry with a solid to water ratio of 1:2 (w/w)
$EC_{1:2}$	EC of a sample slurry with a solid to water ratio of 1:2 (w/w)
ANC	Acid Neutralising Capacity in kg H_2SO_4/t
CNV	Carbonate Neutralising Value
MPA	Maximum Potential Acidity, calculated from total S in kg H_2SO_4/t
NAPP	Net Acid Producing Potential, calculated from ANC and total S (or MPA) in kg H_2SO_4/t.
NAG	Net Acid Generation (test)
NAGpH	pH of NAG solution before titration
$NAG_{(pH4.5)}$	NAG acidity titrated to pH 4.5 in kg H_2SO_4/t
$NAG_{(pH7.0)}$	NAG acidity titrated to pH 7.0 in kg H_2SO_4/t
ABCC	Acid Buffering Characteristic Curve
GAI	Geochemical Abundance Index based on multi-elements of solids
PAF	Potentially Acid Forming
PAF-LC	Potentially Acid Forming - Low Capacity
NAF	Non Acid Forming
UC	Uncertain

Executive Summary

Environmental Geochemistry International Pty Ltd (EGi) were commissioned by Mount Owen Pty Limited (Mount Owen) to carry out a geochemical assessment of the Mount Owen Optimisation Project, a multi seamed Permian coal resource within the Hunter Coalfield located approximately 25 kilometres northwest of Singleton, NSW. Development would produce mainly thermal coal and around 20% soft coking coal. The Mount Owen Optimisation Project has two components:

- Mount Owen Continued Operations Project (MOCO) - a southern extension to the existing North Pit being developed as part of the Mount Owen Operations; and
- Glendell Continued Operations Project (GCO) - a northern extension to the existing Barrett Pit being developed as part of the Glendell Operations.

The target seams of the current Mount Owen Operations and Glendell Operations comprise mainly from the Hebden up to the Lemington Seam groups. The MOCO would generally target coal from the base of the Bayswater Seam (BAY5 Seam) up to the Ravensworth (RY) Seam groups. The GCO would include seams from the Lower Hebden up to the Ravensworth Seam groups.

The objectives of the work were to: assess the acid rock drainage (ARD), salinity and elemental solubility (neutral mine drainage, NMD), and sodicity potential of the proposed mine materials; identify any geochemical issues; and provide recommendations for materials management and any follow up test work required. This report will contribute to an environmental impact statement (EIS) for the MOCO. Findings in the report also have implications for the GCO, but additional investigations are planned at a later date to support the GCO EIS.

A total of 525 overburden/interburden and coal samples were tested at EGi, collected from from 3 MOCO cored holes and 1 GCO cored hole. In addition, 194 rejects samples were collected over 6 months from the current Mount Owen coal handling and preparation plant (CHPP), of which 46 samples tested in more detail, to provide an indication of the geochemical characteristics of rejects to be produced from MOCO and GCO.

Results indicate that the vast bulk of overburden/interburden materials for the MOCO represented by the samples tested are likely to be non acid forming (NAF), with a significant excess of acid neutralising capacity and low leachable salinity. Occasional thin (less than 0.2m) zones of elevated S were identified close to coal seams, but dilution and mixing during mining should be sufficient to mitigate any ARD generation.

Final pit floor materials for the MOCO are understood to mainly comprise the Bayswater Seam floor. Results to date suggest the pit floor and margins of the MOCO pits are likely to be NAF with possible portions of low capacity potentially acid forming (PAF-LC) materials.

MOCO coal materials represented by the samples tested appear to be mainly NAF, but may include potentially acid forming (PAF) and PAF-LC portions.

MOCO coarse and fine rejects represented by the materials tested are expected to be NAF.

Kinetic NAG testing indicates that PAF materials are reactive and can rapidly generate ARD within weeks to a couple of months after exposure to atmospheric oxidation conditions. Constituents associated with ARD are likely to include Al, Co, Fe, Mn, Ni, SO_4 and Zn.

Although the occurrence of PAF materials is expected to be minor and mitigated through mining dilution, it is important to review this issue to identify any need for additional mitigation actions.

Water extracts from NAF overburden/interburden and rejects indicated that neutral mine drainage was unlikely to contain significant metal/metalloid concentrations. Results did not indicate potential for alkaline mine drainage.

Results of exchangeable cation and dispersion percent testing indicates that weathered Permian materials represented by the samples tested are likely to be sodic and dispersive, and may be subject to surface crusting and high erosion rates. Finer grained fresh Permian materials may also be partly sodic.

Results have the following implications for mine materials management:

- The vast majority of overburden/interburden, coal and washery rejects for the MOCO are expected to be NAF with excess ANC and will not require special handling. Dilution and mixing during mining is expected to be sufficient to mitigate ARD from any occasional thin zones of pyrite that may be present.
- Weathered Permian materials are likely to be NAF, but appear to be sodic and dispersive, and may need to be treated with gypsum or lime if used as a plant growing horizon, exposed on dump surfaces or used in engineered structures. Finer grained fresh Permian materials may also be partly sodic and require treatment.
- Regular review with sampling and testing of overburden/interburden, coal and washery wastes should be carried out during operations to confirm the low salinity and low risk of neutral mine drainage and ARD indicated by testing to date.
- Routine site water quality monitoring programmes should include monitoring of seepage and runoff from pit walls and floors, waste rock dumps, coal stockpiles and washery waste disposal areas to check for any evidence of ARD and metalliferous drainage and identify any need for additional controls. Parameters should include pH, EC, acidity/alkalinity, SO_4, Ca, Mg, K, Na, Cl, Al, As, Co, Cu, Fe, Mn, Ni and Zn.

It is recommended that additional investigations be carried out as follows:

- Continued testing of overburden/interburden, coal to confirm the continuity of NAF materials across the deposit.
- Opportunistic testing of rejects from Bayswater and Ravensworth Seam groups to better represent these materials.

- Consider leach column testing of NAF materials to better evaluate neutral and alkaline mine drainage chemistry.
- Further assessment of sodic/dispersive materials and management requirements.

1.0 Introduction

Environmental Geochemistry International Pty Ltd (EGi) were commissioned by Mount Owen Pty Limited (Mount Owen) to carry out a geochemical assessment of the Mount Owen Optimisation Project, located approximately 25 kilometres northwest of Singleton, NSW. The Mount Owen Optimisation Project has two components:

- Mount Owen Continued Operations Project (MOCO) - a southern extension to the existing North Pit being developed as part of the Mount Owen Operations; and
- Glendell Continued Operations Project (GCO) - a northern extension to the existing Barrett Pit being developed as part of the Glendell Operations.

The objectives of the work were to: assess the acid rock drainage (ARD), salinity and elemental solubility (neutral mine drainage, NMD), and sodicity potential of the proposed mine materials; identify any geochemical issues; and provide recommendations for materials management and any follow up test work required. This report will contribute to an environmental impact statement (EIS) for the MOCO. Findings in the report also have implications for the GCO, but additional investigations are planned at a later date to support the GCO EIS.

The scope of work comprised the following:

- an initial scoping phase involving liaison with relevant project personnel, compilation of background project data, and a site visit in June 2011 to examine representative core through the proposed mine stratigraphic sequence;
- preparation of an overburden and interburden sampling programme in conjunction with site geologists to represent the mine stratigraphy and expected geochemical variation of overburden;
- selection of appropriate washery waste materials for geochemical testing in consultation with relevant project personnel;
- collection of samples and arrangement of sample preparation by site personnel with advice from EGi;
- laboratory testing of samples; and
- assessment of results and reporting.

2.0 Background and Geology

The Mount Owen Optimisation Project is a multi-seamed resource within the Hunter Coalfield. The coal seams are Permian in age and are part of the Wittingham Coal Measures, which is in turn part of the Singleton Super-Group.

The MOCO is centred on a broad syncline, and the GCO is centred on a north west trending broad anticline (Camberwell Anticline), with dips in both proposed pits ranging from flat to greater than 30°. The expansion incorporates a broad stratigraphic sequence, which is the same as that mined by current operations.

The target seams of the current Mount Owen Operations and Glendell Operations comprise mainly from the Hebden up to the Lemington Seam groups. The MOCO would generally target coal from the base of the Bayswater Seam (BAY5 Seam) up to the Ravensworth (RY) Seam groups, with the Hebden to the Lemington Seam groups mined in only minor amounts due to lease depth restrictions associated with underground mining. The GCO would include seams from the Lower Hebden up to the Ravensworth Seam groups, but mining of the Ravensworth seam group would only occur in limited locations.

Figure 1 is a typical stratigraphic section for the region showing the stratigraphic range for each project. The Archerfield Sandstone is devoid of coal and separates coal seams from the Jerrys Plains Sub Group (Ravensworth to Bayswater Seam groups) from those in the underlying Vane Sub Group (Lemington to Hebden Seam groups). Non-coal sedimentary materials are predominantly (in decreasing order of abundance) sandstones, siltstones, conglomerate, carbonaceous claystones and tuffaceous claystones.

Mining would involve continuation of truck and excavator methods currently being used, and reach a final pit depth of approximately 300m from surface. Overburden and interburden would be progressively backfilled into the existing Barrett Pit and North Pit with some out of pit dumping as required. Most spoil will be placed within the pit development footprint, with final dump heights exceeding the original topography. At the end of mining there will be a pit void in the southern part of the MOCO, and in the northern part of the GCO.

All coal would be washed at the existing Mount Owen Coal Handling and Preparation Plant (CHPP) to produce mainly thermal coal and around 20% soft coking coal, and coarse and fine rejects streams. Product coal would be transported to the Port of Newcastle via the existing Mount Owen rail spur and the Main Northern Line. Coarse rejects would be placed in pit with the overburden/interburden, and fine rejects thickened and deposited into tailings storage facilities.

Cored holes SMC001 and MOD784 from the MOCO, and GNC002 from the GCO were examined during the June 2011 site visit as examples of interburden and overburden (coal quality samples were generally already sampled) through the proposed the mine stratigraphy. The focus of the core inspection was to check for evidence of pyrite and neutralising carbonate occurrence, and obtain a better understanding of the continuity and variation of the major rock types.

Pyrite appeared to be generally very minor throughout the stratigraphy, occurring mainly as traces and as thin veneers on bedding surfaces associated with carbonaceous partings and plant fossils (Plate 1), fractures in sandstone (Plate 2), carbonaceous wisps in sandstone (Plate 3), occasionally as small lenses and veinlets (Plate 4) and disseminated pyrite spheroids in sandstone (Plate 5). Significant pyrite was only observed between LDA and LCJ Seams at 75 to 76m and 80 to 81m depths in hole MOD784 (example shown in Plate 5). Note that only minor pyrite as thin veins were observed in the Archerfield Sandstone in hole SMC001 (Plate 6), which is known to be pyritic at some locations.

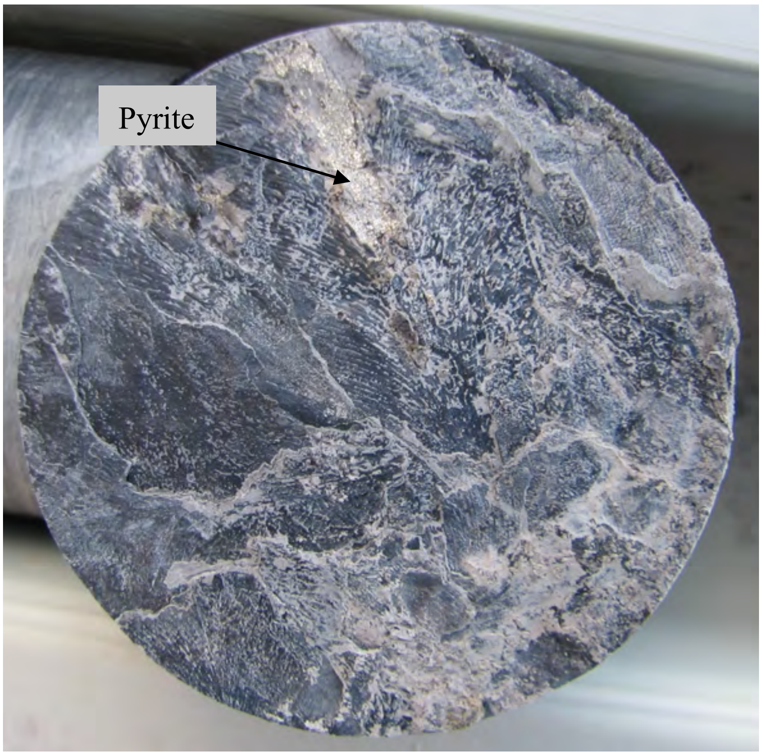

Plate 1: Carbonaceous parting with thin pyrite coating associated with leaf fossil. Hole SMC001, depth 30.40m.

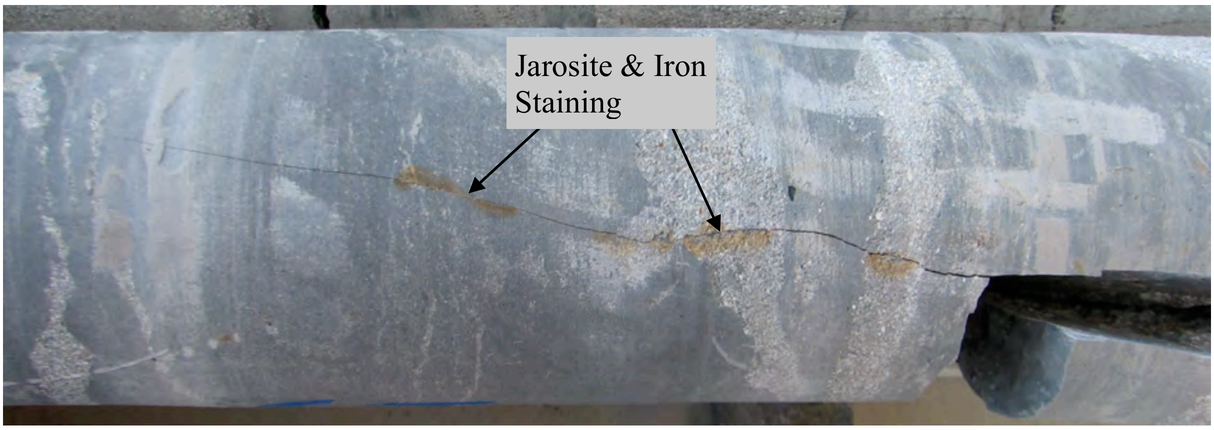

Plate 2: Minor pyrite on fracture surface in sandstone. Hole SMC001, depth 124.2m.

Plate 3: Examples of jarosite and iron oxide staining due to partial oxidation of minor pyrite in carbonaceous wisps and lenses in sandstone. Top photo hole SMC001, depth 57m. Bottom photo hole MOD784, depth 33.1m.

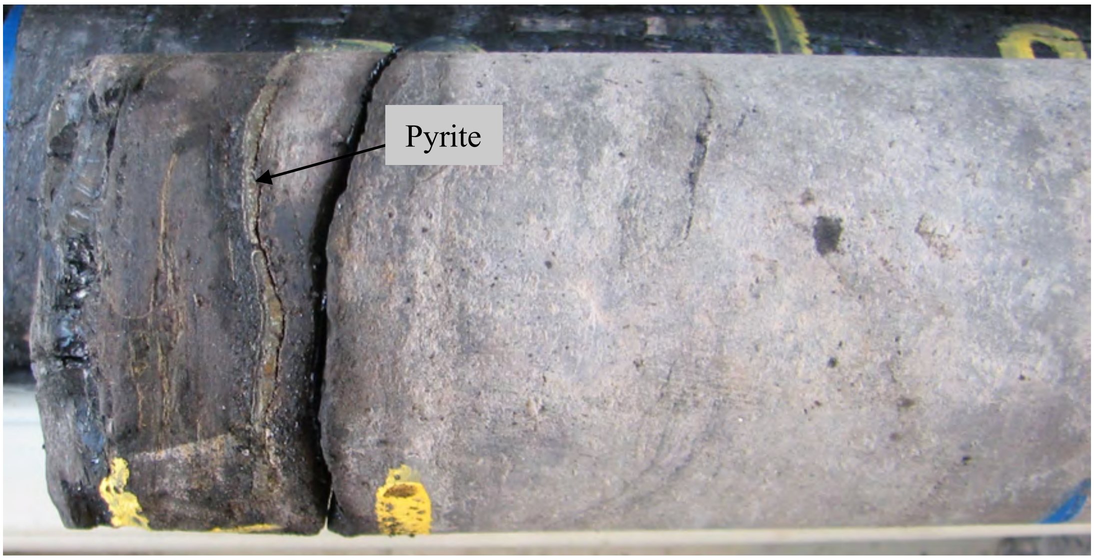

Plate 4: Thin pyrite vein in carbonaceous mudstone/siltstone. Hole SMC001, depth 207.8m.

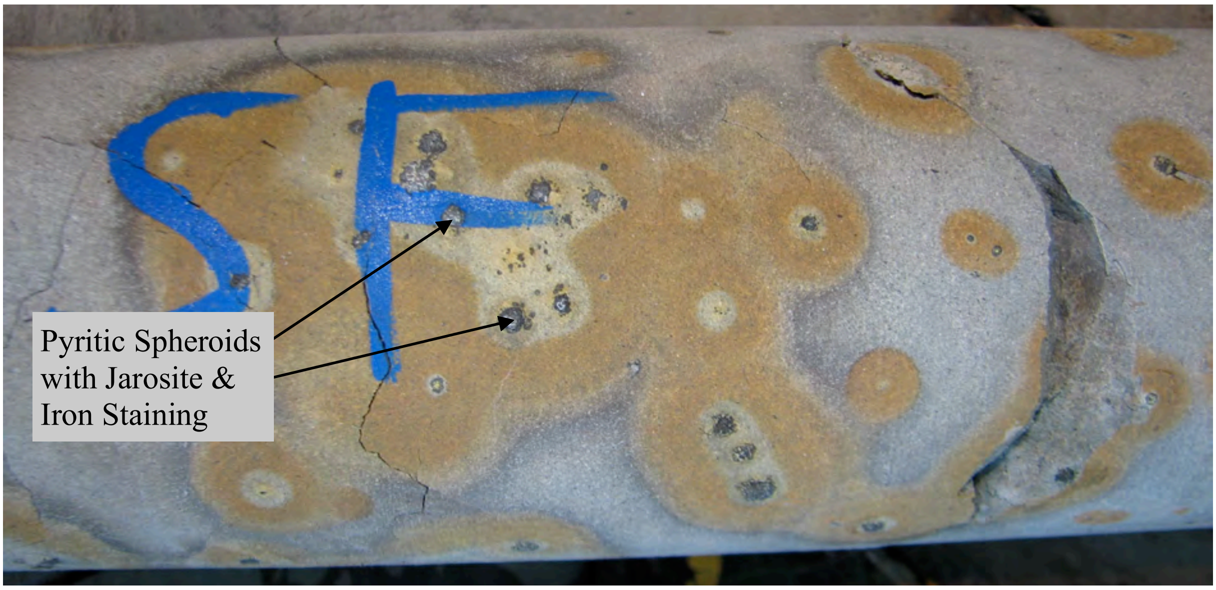

Plate 5: Disseminated pyrite spheroids in sandstone with associated iron staining, jarosite and sulphate salts due to partial pyrite oxidation. Hole MOD784, depth 75.5m.

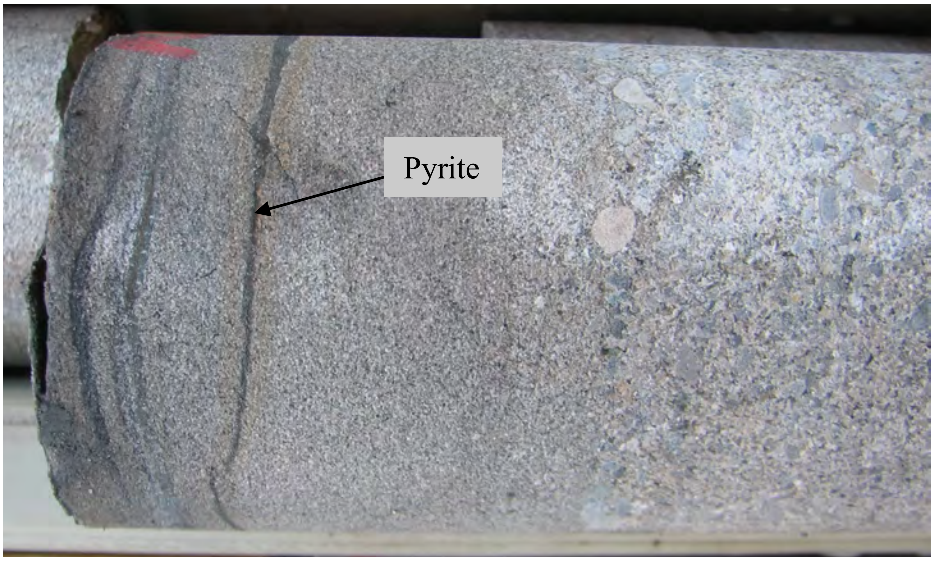

Plate 6: Thin pyrite vein in Archerfield Sandstone with associated iron staining. Hole SMC001, depth 233.7m.

During inspection of the core, 15% HCl was applied to the core intermittently to provide an indication of the presence of reactive carbonate such as calcite and dolomite. Results showed common faint fizzing throughout the core, with occasional zones of strong fizzing indicting the presence of calcitic carbonate. The calcitic carbonate occurred in the matrix and as veins in sandstone horizons (Plate 7) and some siltstone and conglomerate, as veins in coal, as veinlets and in matrix associated with siderite lenses, and in a few instances as calcitic/sideritic layers with cone-in-cone textures (Plate 8).

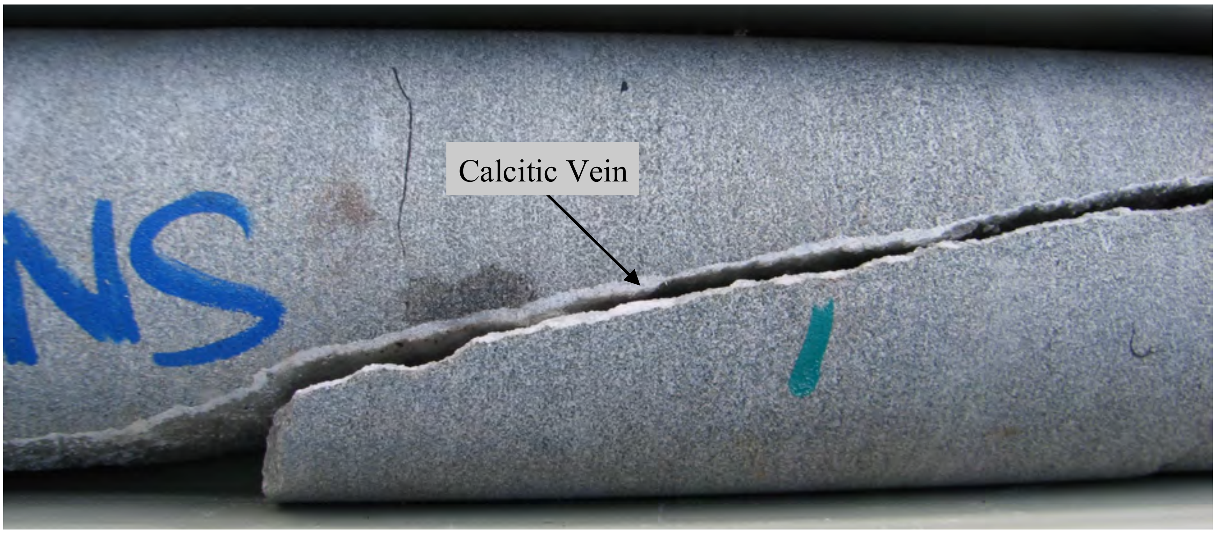

Plate 7: Sandstone with calcitic carbonate in the matrix and veins. Hole SMC001, 51.5m depth.

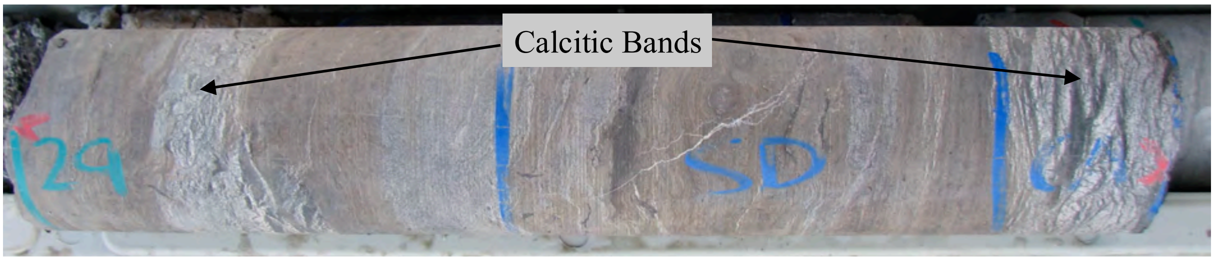

Plate 8: Calcitic bands with cone-in-cone texture within a sideritic layer. Hole SMC001, 29.15m depth.

In summary, examination of the core shows that pyrite generally occurs in low abundances in overburden and interburden, apart from some isolated pyritic zones. The acid generation potential from any pyrite in overburden and interburden is likely to be mostly offset by an excess of reactive acid neutralising calcitic/dolomitic carbonate.

Coal seam intervals had already been removed from most of the core examined, and no judgement could be made on pyrite occurrence in coal materials.

3.0 Sample Collection and Preparation

The distribution and abundance of pyrite in coal bearing sedimentary sequences are largely controlled by the original depositional environment, with influences such as seawater incursions and presence of organic matter key to pyrite formation. As a result of these controls, pyrite is usually preferentially distributed in particular lithologies (such as carbonaceous mudstones) and stratigraphic horizons. Coal sequences usually have high lithological variation in the vertical sense, but tend to show lateral continuity, and hence sampling for ARD assessment needs to take this into account by obtaining detailed continuous samples in individual holes spaced at wide intervals. The sampling strategy carried out for the Mount Owen Optimisation Project aimed to screen the entire mine stratigraphy for acid potential and identify horizons of concern, and rely on geological controls to help predict the distribution of potentially acid forming (PAF) and non-acid forming (NAF) rock types. This approach results in better representation of mine materials in coal deposits than purely lithological based sampling.

The proposed Mount Owen Optimisation Project incorporates a broad stratigraphic sequence, none of which had been previously geochemically assessed in detail. Four cored holes from the MOCO were selected for sampling to represent the entire proposed mine stratigraphic sequence (from the upper half of the Ravensworth RVY Seam to the base of the Hebden HEB Seam) as follows:

SMC001 – Roof RVY Seam to floor of BAY5 Seam

SMC011 – Roof BY3 Seam to floor of LDF Seam

SMC009 – LDK Seam to floor of LCE Seam

SMC006 – Roof LCJ Seam to floor of HEB Seam

Hole GNC004 was selected for sampling from the GCO to represent most of the stratigraphy to be mined, which covered from the roof of LCB Seam to the floor of Lower Hebden (LHB).

The original open hole pre-collars (12 to 40m depth) of the weathered portions for these diamond holes were not available for sampling. Pre-collars for holes SMC001, SMC011 and SMC009 were re-drilled by Mount Owen to complete the stratigraphic coverage across the MOCO. A further three shallow open holes were drilled at the GCO across the proposed mine area to represent weathered material in this location.

Hole locations are shown in Figure 2 and 3.

Sampling involved collection of detailed continuous samples in all holes, except where there were missing intervals or samples had been collected for other testing (such as geotechnical). Intervals were selected by site geologists in conjunction with EGi to match geological boundaries, with intervals ranging from less than 0.5m to over 5m. All samples were collected by site personnel. Selected coal quality samples were also provided by Mount Owen for a more complete representation of the coal, roof and floor materials.

A total of 525 overburden/interburden and coal samples were tested at EGi. The sampling programme was designed for a first pass assessment of the relative ARD potential of overburden/interburden and focus any required follow up work, but was not sufficient to accurately represent the variation and distribution of problematic materials from the entire proposed mine.

Sample preparation of core was arranged by Mount Owen with advice from EGi, and carried out by Coal Seam Gas (CSG) Services, which involved drying (as required), crushing to a nominal -4mm, splitting, pulverising a 500g split to -212μm, and dispatch of 500g of -212μm pulverised samples and 500g of -4mm crushed samples to EGi.

In addition to the overburden/interburden and coal samples described above, Mount Owen arranged intermittent collection of rejects and tailings discharged from the existing coal handling and preparation plant (CHPP). A total of 194 samples were sent to ALS Laboratory Group (Muswellbrook) for preparation and total S analysis, of which 46 samples were selected for further geochemical characterisation by EGi. EGi were provided with pulverised (-212μm) material for all samples and crushed material for selected samples.

4.0 Methodology

All 525 overburden/interburden and coal samples were analysed for total S (Leco equivalent), acid neutralising capacity (ANC) and net acid producing potential (NAPP, calculated from total S and ANC). Total S results were also provided by Mount Owen for 301 coal quality samples, not subject to further geochemical testing, to improve continuity of test results and assist interpretation. In addition, a total of 194 rejects samples were analysed for total S, of which 46 samples were also analysed for ANC and NAPP.

A smaller sub set was subjected to the following:

- pH and electrical conductivity (EC) of deionised water extracts at a ratio of 1 part solid to 2 parts water ($pH_{1:2}$ and $EC_{1:2}$) (348 overburden/interburden and coal samples and 34 washery waste samples); and
- single addition net acid generation (NAG) testing (321 overburden/interburden and coal samples and all washery waste samples).

Further testing was carried out on selected samples to help resolve uncertainties in the above test results, as follows:

- extended boil and calculated NAG testing to account for high organic carbon contents (23 overburden/interburden and coal samples and 4 washery waste samples);
- sulphur speciation to obtain a guide to the proportion of pyritic S (13 overburden/interburden and coal samples and 11 washery waste samples);
- kinetic NAG testing of higher S samples to check pyrite reactivity and to indicate lag times (8 overburden/interburden and coal samples and 4 washery waste samples); and
- acid buffering characteristic curve (ABCC) testing to define the relative availability of the ANC measured (28 overburden/interburden and coal samples and 12 washery waste samples).

A general description of ARD test methods and calculations used is provided in Appendix A.

In addition, selected samples were assayed for the following to identify any potential elemental concerns and to provide initial elemental solubility data:

- multi-element testing of solids (25 overburden/interburden and coal samples and 12 washery waste samples); and
- multi-element testing of deionised water extracts at a ratio of 1 part solid to 2 parts water (25 overburden/interburden and coal samples and 12 washery waste samples).

Fifty selected overburden/interburden samples were also tested for soluble and exchangeable cations and dispersion percent to provide an initial indication of sodicity and dispersion potential.

Water extractions for $pH_{1:2}$ and $EC_{1:2}$ and multi-element testing, soluble and exchangeable cations, and dispersion percent were carried out on -4mm crushed samples. Pulverised samples were used for all other tests.

The sulphur speciation procedure involved Leco total S, chromium reducible sulphur (CRS) and KCl digestion to help differentiate pyritic S, acid forming sulphate, non-acid forming sulphate and other S forms (including organic S, jarosite S and elemental S).

Standard multi-acid digest for elemental analysis could not be carried out directly on washery waste and coal samples due to the high carbon content, which can cause explosions during digestion. To overcome this issue, the samples were ashed to remove the organic component and ICP-AES and ICP-MS analysis performed on the ash, with concentrations calculated relative to the original sample weight. However, due to the potential loss of some volatile elements during ashing, element specific coal analysis methods were carried out on splits of the original solid to provide a more reliable measure of As, B, F, Hg, Sb and Se as follows:

As, Sb, Se by Eschka hydride ICP-OES
B by Eschka ICP-OES
F by Pyrohydrolysis/ISE
Hg by Leco direct combustion

Total sulphur assays were carried out by ALS Laboratory Group (Muswellbrook) for the washery waste samples, and CSG for the overburden/interburden and coal samples. CRS analyses of sample solids were carried out by ALS Laboratory Group (Brisbane). Multi-element analyses of solids from lower organic carbon samples and ash from high organic carbon samples were carried out by ALS Laboratory Group (Brisbane). Coal specific elemental analyses of solids for high organic carbon samples were carried out by ALS Laboratory Group (Maitland). Multi-element analyses of water extracts were carried out by ALS Laboratory Group (Sydney). Soluble and exchangeable cation testing and dispersion precent tests were carried out by Sydney Environmental and Soil Laboratory (SESL). Analyses of NAG solutions and S analysis of KCl digest solutions were carried out by Levay & Co. Environmental Services (Adelaide). All other analyses were carried out by EGi.

5.0 Overburden/Interburden and Coal Results

Acid forming characteristics of the 525 overburden/interburden and coal samples are presented in Table 1, comprising pH and EC of water extracts, total S, maximum potential acidity (MPA), ANC, NAPP, ANC/MPA ratio and single addition NAG. This table also includes total S results from 301 coal quality samples not available for testing.

5.1 pH and EC

The $pH_{1:2}$ and $EC_{1:2}$ results were determined by equilibrating the sample in deionised water for approximately 16 hours at a solid to water ratio of 1:2 (w/w). This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

The $pH_{1:2}$ values ranged from 4.1 to 9.4, with the vast majority (98%) of samples showing no inherent acidity with a pH greater than 6. Only 6 of the samples tested had a slightly acidic pH of less than 6.0.

$EC_{1:2}$ values ranged from 0.02 to 2.11 dS/m, with the vast majority (98%) falling within the non-saline to slightly range with an EC of 0.8 dS/m or less. Only 6 samples had an EC of greater than 0.8 dS/m, of which 5 were moderately saline (0.8 to 1.6 dS/m) and 1 was saline (>1.6 dS/m) with an EC of 2.11 dS/m.

Figure 4 is a plot of $pH_{1:2}$ and $EC_{1:2}$ versus total S, which shows that the lower $pH_{1:2}$ values (< pH 5) and the higher $EC_{1:2}$ values (>1 dS/m) are associated with higher S (>0.4%S) samples. This indicates that lower $pH_{1:2}$ and higher $EC_{1:2}$ values are primarily the result of partial pyrite oxidation occurring between sample collection and sample testing.

Results indicate low leachable acidity and salinity in overburden/interburden materials represented by these samples except where pyrite is present and it has partially oxidised.

5.2 Acid Base (NAPP) Results

Total S results ranged from below detection to 4.16%S, with most samples (65%) having low S values of less than 0.1%S. Figure 5 is a box plot of the distribution of S, split by lithology. The plot highlights the lack of S in most lithologies, but coal has a distinctly higher S distribution with a median of 0.6%S, compared to medians of less than 0.2 %S in other lithologies. Weathered zone materials have particularly low total S values, with most samples having total S of less than 0.05%S, and medians below detection. The other non coal lithologies show a range of S values, including some samples with S values greater than 0.5%S.

ANC ranges up to 295 kg H_2SO_4/t, with a moderate median ANC of 25 kg H_2SO_4/t. Figure 6 is a box plot of the distribution of ANC split by lithology. The weathered zone materials have a low median ANC of 10 kg H_2SO_4/t. The median ANC values for other lithologies are moderate, ranging from around 15 to 35 kg H_2SO_4/t. The ANC distribution in the sandstone materials appear to be higher than other lithologies and have the broadest range.

Results are consistent with the apparent general lack of pyrite and excess reactive carbonate observed during inspection of core (see Section 2).

The NAPP value is an acid-base account calculation using measured total S and ANC values. It represents the balance between the MPA and ANC. A negative NAPP value indicates that the sample may have sufficient ANC to prevent acid generation. Conversely, a positive NAPP value indicates that the material may be acid generating.

Figure 7 is an acid-base account plot of ANC versus total S. Figure 8 is the same as Figure 7, but re-scaled to better represent S values below 1.5%S and ANC values below 100 kg H_2SO_4/t. The NAPP zero line is shown which defines the NAPP positive and NAPP negative domains, and the line representing an ANC/MPA value of 2 is also plotted. Note that the NAPP = 0 line is equivalent to an ANC/MPA of l. The ANC/MPA value is used as an indication of the relative factor of safety within the NAPP negative domain. Usually a ratio of 2 or more signifies a high probability that the material will remain circum-neutral in pH and thereby should not be problematic with respect to ARD.

The results show that the majority (90%) of samples tested plot in the NAPP negative domain with ANC/MPA ratios of 2 or more, indicating a high factor of safety. Thirty two samples plot in the NAPP positive domain of which 27 samples are coal.

5.3 Single Addition NAG Results

Generally a NAGpH value less than 4.5 indicates a sample may be acid forming. However, samples with high organic carbon contents (such as coal and carbonaceous sedimentary materials) can cause interference with standard NAG tests due to partial oxidation of carbonaceous materials. This can lead to low NAGpH values and high acidities in standard single addition NAG tests unrelated to acid generation from sulphides.

Most samples (90%) had NAGpH values of 4.5 and greater, indicating they are likely to be non acid forming (NAF). Thirty one samples had a NAGpH less than 4.5, but most of these were associated with carbonaceous horizons and coal seams, and results are inconclusive in isolation due to potential organic acid effects.

NAG test results are used in conjunction with NAPP values to classify samples according to acid forming potential. Figure 9 is an ARD classification plot showing NAGpH versus NAPP value. Figure 10 is the same as Figure 9, but with an expanded NAPP axis to better represent the range -100 to 60 kg H_2SO_4/t. Potentially acid forming (PAF), NAF and uncertain (UC) classification domains are indicated. A sample is classified PAF when it has a positive NAPP and NAGpH < 4.5, and NAF when it has a negative NAPP and NAGpH ≥ 4.5. Samples are classified uncertain when there is an apparent conflict between the NAPP and NAG results, i.e. when the NAPP is positive and NAGpH ≥ 4.5, or when the NAPP is negative and NAGpH < 4.5.

The plot shows that most samples (85%) plot in the NAF domain, with 23 samples plotting in the PAF domain, 8 samples plotting in the lower left uncertain domain and 9 samples plotting in the upper right uncertain domain.

A total of 282 samples plot in the NAF domain, and all except 9 samples have a relatively low total S of 0.5%S or less. Samples 3816, 5294, 3883, 5297, 5300, 5303, 5304, 5305 and 4079 had higher total S values of 0.52%S to 0.76%S and moderate to high ANC values of 20 to 74 kg H_2SO_4/t, and further testing was carried out to confirm that buffering was sufficient to account for acid generated from these samples.

Seventeen of the PAF domain samples are coal or carbonaceous sediments showing organic acid effects in the NAG test, indicated by a large difference between the $NAG_{(pH4.5)}$ and $NAG_{(pH7.0)}$ values, and $NAG_{(pH4.5)}$ values that exceed the MPA. In these samples the NAG results overestimate the acid potential. Samples showing organic acid effects are highlighted yellow in Table 1. Specialised testing was carried out to help resolve uncertainties in classification of these samples. The remaining samples are expected to be PAF, with samples 5331 and 3954 likely to have a low acid generating capacity of less than 5 kg H_2SO_4/t.

Three samples of the 8 samples plotting in the lower left uncertain domain had low total S of 0.05%S and were classified NAF due to the negligible risk of acid formation. Follow up testing to check for organic acid effects was carried out to resolve the classification of the remaining samples.

The samples plotting in the upper right uncertain domain are coal samples with moderate total S of 0.4 to 1.5%S, low to moderate ANC values of less than 10 to 39 kg H_2SO_4/t, and NAGpH values greater than 4.5. The NAG test would normally account for most of the pyritic S in these samples and they are expected to be NAF. ABCC and S speciation testing was carried out to confirm a NAF classification.

5.4 Extended Boil and Calculated NAG Results

Extended boil and calculated NAG testing was carried out on 23 selected samples to help resolve uncertainties in ARD classification based on standard NAG test results, as discussed in the previous section. Results are shown in Table 2.

Results show that the NAGpH value for most samples increases 2 to 4 pH units after the extended boiling step. The increase in NAGpH confirms the effects of organic acids. The extended boil NAGpH of samples 5333, 3954, 5298, 3996, 4078 and 4080 remained less than 4.5, indicating these samples are likely to be acid producing.

Note that the extended boil NAGpH value can be used to confirm samples are PAF, but an extended boil NAGpH value greater than 4.5 does not necessarily mean that samples are NAF, due to some loss of free acid during the extended boiling procedure. To address this issue, a calculated NAG value is determined from assays of anions and cations released to the NAG solution. A calculated NAG value of less than or equal to 0 kg H_2SO_4/t indicates the sample is likely to be NAF, and a value of more than 0 kg H_2SO_4/t indicates the sample may be PAF.

The calculated NAG values for 5 of the samples (3813, 5290, 5324, 5338 and 4056) were negative, indicating that all acid generated in the standard NAG test for these samples is organic, and that materials represented by these samples are unlikely to be acid producing under field conditions. The remaining 18 samples had positive calculated NAG values, indicating these samples are likely to be acid producing. Samples 5291, 5292, 5330, 3882, 5336, 3907 and 3996 had acid potentials of less than 5 kg H_2SO_4/t, and are classified as potentially acid forming with a low capacity (PAF-LC).

5.5 Acid Buffering Characteristic Curve (ABCC) Testing

Acid buffering characteristic curve (ABCC) testing was carried out on 28 selected samples to evaluate the availability of the ANC measured. The ABCC test involves slow titration of a sample with acid while measuring the solution pH. The acid buffering of a sample to pH 4 can be used as an estimate of the proportion of readily available ANC. Results are presented in Figures 11 to 23, with calcite, dolomite, ferroan dolomite and siderite standard curves as reference. Calcite and dolomite readily dissolve in acid and exhibit strongly buffered pH curves in the ABCC test, rapidly dropping once the ANC value is reached. The siderite standard provides very poor acid buffering, exhibiting a very steep pH curve in the ABCC test. Ferroan dolomite is between siderite and dolomite in acid buffering availability.

The ABCC profile for sample 3804 plots between the siderite and ferroan dolomite standard curves (Figure 12), indicating slow reactivity and with only 30% likely to be effective.

Samples 5225 (Figure 13) and 5242 (Figure 11) have profiles that plot close to the ferroan dolomite standard curves. Results indicate slow reactivity with an effective ANC of around 70% of the total ANC. Sample 5225 shows initial strong buffering, indicating a portion of the ANC is in calcitic/dolomitic form.

Four samples, 3850, 3880, 4057 and 4480 have profiles that plot between the dolomite and ferroan dolomite standard curves (Figures 22, 12 and 14). The readily available ANC portion ranges from 50% to 100% of the total ANC, with reaction rates likely to be slower than dolomite.

The ABCC profiles for the remaining 21 samples show strong buffering, with profiles plotting close to those of calcite and dolomite standard curves and indicating 70% to 100% of the ANC is readily available.

Overall, ABCC results suggest that most of the ANC measured is likely to be fast reacting and effective. Results also show that the ANC is readily available in elevated S (>0.5%S) samples plotting in the NAF domain (see Section 5.3), confirming the NAF classification.

5.6 Kinetic NAG Testing

Kinetic NAG tests provide an indication of the kinetics of sulphide oxidation and acid generation for a sample. Kinetic NAG testing was carried out on 8 selected samples. Results are presented in Figures 24 to 31.

Typically, there will be a distinct temperature peak of 50°C or more in the kinetic NAG profile for samples with pyritic S greater than 0.7%S and low ANC. The kinetic NAG temperature profiles for samples 5290 (Figure 24), 5330 (Figure 25), 5298 (Figure 28), and 4025 (Figure 29) do not have distinct temperature peaks, and sample 5333 (Figure 26) has a subdued temperature peak, indicating that these samples have pyritic S contents of less than 0.7%S and a significant proportion of non acid generating S forms. Samples 5314 (Figure 27) and 4080 (Figure 31) showed distinct temperature peaks typical of pyritic samples. Note that sample 4079 (Figure 30) has a moderate and reactive ANC of 44 kg H_2SO_4/t, which results in reduced oxidation rates and only partial pyrite oxidation in the NAG test, and the temperature profile is not a valid indicator of pyritic S content.

The time to pH 4 in the kinetic NAG test can be used to estimate the lag time before acid conditions develop in a sample under atmospheric oxidation conditions.

Sample 4079 was expected to be NAF, and kinetic NAG testing was carried out to check if rates of acid buffering would match rates of acid generation in higher S samples. The pH profile (Figure 30) remained above 4.5 for the duration of the test, confirming matching rates of buffering and acid generation and the NAF classification.

Samples 5290 and 5330 did not produce acid in the time of the NAG test (Figures 24 and 25), indicating lag times of many years if they are acid forming.

Sample 4025 shows a significant delay of 150 minutes before dropping below pH 4, indicating a lag time of 1 to 2 years before onset of acid conditions after exposure to atmospheric conditions.

The remaining 4 samples 5333, 5314, 5298 and 4080 show relatively fast reaction rates, dropping below pH 4 in 9 minutes or less, and indicating lag times of one month or less.

Overall, results indicate that PAF materials are likely to have short lags of a month or less before onset of acid conditions after exposure to atmospheric conditions.

5.7 Sulphur Speciation

Sulphur speciation testing was carried out on 13 selected samples. Results are shown in Table 3. Note that the pyritic S value should only be treated as a guide to the pyrite content in the sample due to issues with repeatability in the chromium reducible sulphur (CRS) method[1].

Results for 5 of the 7 coal samples (5297, 5299, 5301, 5307 and 5321) indicate that most of the S measured (60% to 90%) is in non pyritic forms and most likely occurs as organic S. Two of the Lemington coal samples (3883 and 5333) have mainly pyritic S, accounting for 75% and 60% of the total S, respectively. Samples 5299, 5301 and 5307 had positive NAPP values but NAGpH values greater than 4.5. The S speciation testing shows that the NAPP value based on total S overestimates the acid forming potential for these coal samples, and ABCC testing (see Section 5.5) shows that all of the ANC is readily available. Results indicate that NAPP positive coal samples with NAGpH values of 4.5 and above are likely to be NAF, consistent with the NAGpH results.

The carbonaceous claystone sample 3882 has a low total S of 0.32%, and results indicate around half of this is in pyritic form. The S in the remaining 5 non coal samples is mostly (>60%) in pyritic form.

Results suggest that the total S in non coal samples is likely to be mainly pyritic, and that coal samples are likely to include a higher proportion of non pyritic S forms. Sulphur speciation results in conjunction ABCC testing show that coal samples plotting in the upper right hand uncertain domain are likely to be NAF.

[1] Environmental Geochemistry International, Levay and Co. and ACeSSS, 2008. *ACARP Project C15034: Development of ARD Assessment for Coal Process Wastes*, EGi Document No. 3207/817, July 2008. www.acarp.com.au.

5.8 Multi-Element Analysis of Solids and Water Extracts

Results of multi-element scans of solids from 25 selected samples were compared to the median soil abundance (from Bowen, 1979[2]) to highlight enriched elements. The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration with an average or median abundance on a log 2 scale. The GAI is expressed in integer increments where a GAI of 0 indicates the element is present at a concentration similar to, or less than, median soil abundance; and a GAI of 6 indicates approximately a 100-fold enrichment above median soil abundance. As a general rule, a GAI of 3 or greater signifies enrichment that warrants further examination.

Results of multi-element analysis of solids are presented in Table 4, and the corresponding GAI values are presented in Table 5.

Many of the samples are slightly enriched in Be relative to median soils, but they are within normal ranges for sedimentary rock. Sample 4025 showed enrichment in As, but is also enriched in S. The As enrichment is likely to be due to small amounts arsenopyrite associated with pyrite. A number of samples also showed enrichment in S, which was already discussed in relation to acid forming potential. Other individual samples show enrichment of W and Tl.

The same sample solids were subjected to water extraction at a solids:liquor ratio of 1:2. Results are shown in Table 6. Sample 4080 had elevated S of 1.26%S and produced a slightly acidic water extract pH value of 4.9, due to partial oxidation of pyrite between sampling and testing. The acidic pH is associated with elevated Fe, Mn and SO_4, and slightly elevated Co, Ni and Zn. Sample 3954 has a slightly acidic pH of 5.5, but did not produce significant metal/metalloid concentrations.

The remaining samples had circum-neutral to slightly alkaline pH extracts and there were no elevated metals/metalloids evident.

Results indicate that significant metal/metalloid release from materials represented by the samples tested would only be associated with generation of ARD. The solubility of metals/metalloids will largely be determined by pH and therefore control of acid generation will effectively control metal leaching. Water extracts from NAF materials indicated that neutral mine drainage is unlikely to contain significant metal/metalloid concentrations, but elevated SO_4 may occur where there is significant pyrite present. Extracts show that initial metal/metalloid release associated with any ARD generated from pyritic materials would include Co, Fe, Mn, Ni, and Zn.

5.9 Sodicity and Dispersion

Soluble and exchangeable cations and dispersion percent testing was carried out on 50 selected overburden/interburden samples to provide a preliminary indication of any sodicity and dispersion issues. Results are presented in Table 7.

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[2] Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, New York, p 36-37.

Sodic materials tend to form low permeability soil horizons, accelerating erosion and inhibiting plant growth. Sodic soils are also dispersive and should not be used as construction materials since they are prone to tunnelling and collapse. The exchangeable sodium percentage (ESP) is a measure of exchangeable Na as a percentage of the total effective cation exchange capacity (ECEC). The ESP can be used to classify samples according to sodicity as follows:

ESP < 6% - Non-Sodic

ESP 6-15% - Sodic

ESP 15-30% - Strongly Sodic

ESP >30% - Very Strongly Sodic

The dispersive properties of materials can also be measured more directly using a dispersion percent test. The test represents the ratio of clay dispersed in deionised water as a percentage of the total sample mass. A dispersion percent above 50% is considered high.

Most (37) of the samples have ESP values of greater than 6%, and vary from sodic to very strongly sodic with ESP values up to 74%. Most (80%) of the weathered samples are sodic to strongly sodic. Around half the fresh samples are sodic to very strongly sodic, mainly comprising claystone, siltstone and tuff samples, with the coarser grained sandstone and conglomerates tending to be non-sodic. Eighteen samples are classified dispersive according the dispersion percent test, which are all weathered, and all except 2 (5221 and 5222) are also sodic.

Results indicate that weathered Permian materials represented by the samples tested are likely to be sodic and dispersive, and may be subject to surface crusting and high erosion rates. Finer grained fresh Permian materials may also be partly sodic. Materials with sodic/dispersion potential may need to be treated with gypsum or lime if used as a plant growing horizon, exposed on dump surfaces or used in engineered structures.

More detailed testing would be required to accurately define the distribution and extent of sodic/dispersive materials.

5.10 Sample Classification and Distribution of ARD Rock Types

The results and discussions presented above were used to classify samples as NAF, PAF, PAF low capacity (PAF-LC) or UC in Table 1. PAF-LC samples are defined as having an acid capacity of 5 kg H_2SO_4/t or less. All samples with S values of less than or equal to 0.05%S were classified NAF due to the negligible risk of acid formation.

The following table shows the approximate breakdown of geochemical rock types based on the sample intervals tested to date (not taking spatial distribution or mining blocks into account) for overburden/interburden and coal:

Material Type	NAF inc. UC(NAF)	PAF-LC inc. UC(PAF-LC)	PAF
Overburden/Interburden	99.6%	0.1%	0.3%
Coal	78%	9%	13%

The estimated proportions of ARD classes indicate the vast majority of overburden/interburden is likely to be NAF, with PAF-LC/PAF materials estimated to be less than 1%. Coal materials are likely to be mainly NAF, but coal tends to be more elevated in S than other lithologies (See Figure 5) and coal materials include a greater proportion of PAF.

Figures 32 to 36 show down hole profiles of total S, ANC and NAPP values for each of the holes tested, with the stratigraphic position of coal seams plotted for reference. The plots also show sample ARD classifications for total S, ANC and NAPP profiles, with NAF (including UC(NAF)) samples represented as blue symbols, PAF-LC (including UC(PAF-LC)) samples as orange symbols, and PAF (including UC(PAF)) samples as red symbols. Note that many of the coal quality samples were not tested and classified by EGi, but total S results were available, providing a guide to the presence of pyritic horizons. These samples are shown as black symbols on the total S profiles.

The stratigraphic order from youngest to oldest for the MOCO holes starts from the Ravensworth Seams to the base of the Archerfield Sandstone in SMC001, through the Archerfield Sandstone in hole SMC011, through the Lemington Seams in SMC009, and from the Lemington Seams to the base of the Hebden Seams in SMC006. The GCO hole GNC004 covers from the roof of Lemington (LCB) Seam to the floor of Lower Hebden Seam.

The profiles emphasise the preferential distribution of higher total S and PAF/PAF-LC samples in distinct zones associated with coal seams. The vast majority of overburden/interburden is NAF with low S (most less than 0.2%S) and generally has an excess ANC of 20 kg H_2SO_4/t or more. These trends are consistent with core observations detailed in Section 2.

There are a number of thin (less than 0.2m) intercepts of seam roof, partings and floor that have slightly to moderately elevated S values throughout the stratigraphy, and particularly associated with Lemington Group Seams to Liddell Group Seams. This is consistent with the observed pyrite in hole MOD784 (Section 2) between the Lemington LDA and LCJ Seams. However, dilution and mixing during mining should be sufficient to negate any serious ARD risk from these thin horizons. Only 2 significant zones of PAF were identified in the overburden/interburden; one within 1m of the Lemington LBLM Seam floor, and the other within 0.5m of the Liddell LID5B Band 2 Seam roof. It is not known whether these intercepts represent continuous horizons. Further work would be required to define the acid potential, distribution and continuity of these higher ARD risk materials.

There is also a zone of elevated S (0.75% to 1.26%S) 3m below an unknown seam (UNK) at 351.06m in hole SM006, but this occurs 8m below the Hebden HEB Seam, and it is assumed this would not be mined.

Note that although the Archerfield Sandstone is known to be pyritic at other mine sites, the Archerfield Sandstone intercepts tested from holes SMC001 and SMC011 generally had low S, with one minor 0.14m intercept of PAF-LC material just below the Bayswater BAY5 Seam floor.

It is understood the final pit floor material in the MOCO will mainly comprise the Bayswater (BAY5) Seam floor. The base of the BAY5 Seam was intercepted in SMC001 and SMC011, and was classified NAF in the former and PAF-LC in the latter. Results to date suggest the pit floor and margins of the MOCO pit is likely to be NAF with possible PAF-LC portions.

Figure 37 is a box plot showing the total S distribution in raw coal from the Mount Owen CHPP raw coal S database (from Feb 2009 t March 2013) for each of the main seam groups. The Ravensworth and Bayswater Seam groups have a distinctly lower median total S at around 0.4%S and lower upper range of S values than most other seam groups. The Aries Seam group has a similar median S but a higher upper range. The Lemington Seam group has the highest median S at 0.65%S, with the remaining seams having medians of between 5%S and 6%S. Development of the MOCO will focus on the Ravensworth and Bayswater Seam groups, whereas current operations at Mount Owen and Glendell are focused on the Lemington Seam down. The results suggest that the S content of coal from the MOCO will be less than the coal currently being mined.

The Ravensworth and Bayswater Seam groups were intercepted in holes SMC001 and SMC011, and 19 intermittent samples were geochemically characterised to represent the range of raw coal values represented in Figure 37 for these seams. Most samples tested were classified NAF, 4 were classified PAF and 3 PAF-LC. The 4 PAF samples had relatively low acid capacities of 10 kg H_2SO_4/t or less (based on calculated NAG values). Overall, results indicated that most of the MOCO coal from the Ravensworth and Bayswater Seam represented by the samples tested is likely to be NAF, but with PAF/PAF-LC portions.

6.0 Washery Wastes Results

Washery waste samples from the current Mount Owen and Glendell operations CHPP were geochemically tested to provide an indication of the characteristics of washery wastes to be produced by development of MOCO and GCO. A total of 194 samples of coarse rejects and fine rejects were collected from October 2012 to March 2013 to represent washery wastes from a range of seam groups, raw coal S values, and pit locations. Total S was carried out on all 194 samples and results are shown in Table 8. A subset of 46 selected samples were subjected to standard ARD characterisation comprising pH/EC (15 samples excluded due to insufficient sample), total S, MPA, ANC, ANC/MPA, NAPP, and single addition NAG, with results shown in Table 9.

The $pH_{1:2}$ values were circum-neutral to slightly alkaline, ranging from 7.8 to 9.4. $EC_{1:2}$ values were non saline (0.4 dS/m or less) to slightly saline (0.4 to 0.8 dS/m), and range from 0.21 to 0.48 dS/m. Results show a lack of immediately available acidity and salinity in these samples.

Total S values (Table 8) for the rejects vary from 0.03% to 4.57%S. Figure 38 is a plot showing the S distribution for the coarse and fine rejects. The S distribution in the fine rejects is distantly higher than the coarse rejects, with a median of 0.7%S in the fine rejects compared to 0.2%S in the coarse. Results indicate that S minerals preferentially report to the fine rejects stream.

ANC values range from 13 to 140 kg H_2SO_4/t but are generally moderate to high, with all but 3 samples having ANC values greater than 20 kg H_2SO_4/t. Figure 39 is a plot showing the ANC distribution for the coarse and fine rejects. Although Figure 38 indicated S preferentially reported to the fine rejects stream, Figure 39 shows that this is balanced by the tendency for ANC minerals to also report to the fine rejects.

Figure 40 is an acid-base account plot of ANC versus total S for the rejects samples. Results show that all but 2 samples are NAPP negative, and most samples (65%) have an ANC/MPA of 2 or more, indicating a high factor of safety. The plot highlights the higher S and ANC in the fine rejects relative to the coarse rejects, as described above.

Figure 41 is an ARD classification plot for the rejects samples. Forty two samples plot in the NAF domain, but 16 of these have elevated S of over 0.5%S and pyrite oxidation may not have completed in single addition NAG testing of some of these samples. Sulphur speciation and ABCC testing was carried out to confirm the NAF classification for these samples. Two samples plot in the PAF domain and 2 samples plot in the lower left uncertain domain. Calculated NAG, sulphur speciation and ABCC testing was carried out to confirm the classification of these 4 samples.

Extended boil and calculated NAG testing results for the 4 samples plotting in the PAF and lower left uncertain domains are shown in Table 9. The calculated NAG values were positive, indicating these samples are likely to be PAF.

ABCC testing was carried out 12 selected samples and results are shown in Figures 42 to 48. The ABCC profile for coarse rejects sample 6131 plots close to the ferroan dolomite standard curve (Figure 45), and indicates slow reactivity with an effective ANC of around 70% of the total ANC. Samples 6126, 6145 and 6158 have profiles that plot between the dolomite and ferroan dolomite standard curves (Figures 42, 44 and 46), indicating reaction rates slower than dolomite and a readily available ANC portion of 60% to 80% of the total ANC. The ABCC profiles for the remaining 8 samples show strong buffering, with profiles plotting close to those of calcite and dolomite standard curves and indicating 60% to 100% of the ANC is readily available. ABCC results suggest that most of the ANC measured is likely to be fast reacting and effective.

Sulphur speciation test results for 11 selected rejects samples with elevated total S of 0.5%S or more are shown in Table 10. Results indicate that the total S in the rejects will include a significant portion of pyritic S, with the acid generating S content estimated at over 50% for all samples. Table 10 includes a re-calculated NAPP value based on the proportion of acid generating S and readily available ANC estimated from ABCC testing. The recalculated

NAPP values for samples 6126, 6148 and 6158 are close to the calculated NAG value, and the samples are classified PAF and PAF-LC according to the later test result. The recalculated NAPP value for sample 6145 is marginal at 0 kg H_2SO_4/t, but has a calculated NAG value of 2 kg H_2SO_4/t and is classified PAF-LC. The calculated NAPP value for sample 6164 is 10 kg H_2SO_4/t, but the single addition NAGpH is 6. Sulphur speciation confirms most of the total S is pyritic, and the sample is assumed to be PAF consistent with calculated NAPP results. The remaining calculated NAPP results were negative, consistent with original NAPP and NAGpH values, and were classified NAF.

Kinetic NAG tests were carried out 4 selected rejects samples with total S of 0.9% and above. Results are shown in Figures 49 to 52. The pyritic nature of these samples was confirmed by sulphur speciation testing. The samples have varying ANC from 13 to 49 kg H_2SO_4/t, but all show a relatively rapid drop with time, reaching pH 4 in 15 minutes or less, and indicating lag times of 1 to 2 months before onset of acid conditions after exposure to atmospheric oxidation.

Most samples (90%) were classified NAF based on results discussed above. Although the fine rejects tended to have elevated S, this was offset by elevated and generally readily available ANC. Two samples were classified PAF and 3 samples PAF-LC. Four of the PAF/PAF-LC samples were from the Liddell Seam group and one from Hebden, none of which would be mined as part of the MOCO. Overall, results indicate that the MOCO rejects represented by the samples tested are likely to be NAF.

Multi-element scans were carried out on 12 selected rejects samples solids. Results of multi-element analysis of solids are presented in Table 11 and the corresponding GAI values in Table 12. A number of samples showed enrichment to slight enrichment in S (already discussed above in regards to acid forming potential) and slight enrichment in Be. Although slightly enriched relative to soils, Be contents are within the typical range for coal and carbonaceous materials. Liddell coarse rejects sample 6145 is elevated in S and also has elevated Tl and slightly elevated As. The elevated Tl and As are likely to be associated with pyrite in this sample. One sample is enriched in Ba, but this has low solubility in sulphate solutions and is not expected to be of environmental concern.

The same rejects samples were subjected to water extraction at a solids:liquor ratio of 1:2. Results are shown in Table 13. The extracts have slightly alkaline pH of 8.5 to 9.3, and apart from sample 6136, show low concentrations of major cations/anions and metals/metalloids. Coarse rejects sample 6136 has slightly elevated Al, As and Mo, but also has elevated Si of 27 mg/L, and the slightly elevated metals/metalloids in this sample are most likely due to the presence of fine particulates in the solution after filtering.

Results indicate that the MOCO rejects represented by the samples tested are likely to be NAF, and were not significantly enriched in elements of environmental concern. Water extracts indicate metals and metalloids are unlikely to be mobilised to any significant extent from circum-neutral to slightly alkaline leachates.

7.0 Conclusions and Recommendations

Results indicate that the vast bulk of overburden/interburden materials for the MOCO represented by the samples tested are likely to be NAF, with a significant excess of acid neutralising capacity and low leachable salinity. Occasional thin (less than 0.2m) zones of elevated S were identified close to coal seams, but dilution and mixing during mining should be sufficient to mitigate any ARD generation.

More significant zones of PAF were identified associated with the Lemington LBLM Seam floor and Liddell LID5B Band 2 Seam roof, but these will not significantly contribute to the MOCO development, and are more relevant to the GCO.

Fresh overburden/interburden had a moderate median ANC of 30 kg H_2SO_4/t, providing a potential source of buffering to help mitigate the onset of ARD from PAF materials. Fresh sandstone tended to have higher ANC higher than other lithologies, having a median of 36 kg H_2SO_4/t, and is also the most common lithology. Note that weathered overburden/interburden had a relatively low median ANC of 10 kg H_2SO_4/t and is unlikely to be a source of significant buffering.

Final pit floor materials for the MOCO are understood to mainly comprise the Bayswater Seam floor. Results to date suggest the pit floor and margins of the MOCO pits are likely to be NAF with possible portions of low capacity potentially acid forming (PAF-LC) materials.

MOCO coal materials represented by the samples tested appear to be mainly NAF, but may include potentially acid forming (PAF) and PAF-LC portions.

MOCO coarse and fine rejects represented by the materials tested are expected to be NAF.

Kinetic NAG testing indicates that PAF materials are reactive and can rapidly generate ARD within weeks to a couple of months after exposure to atmospheric oxidation conditions. Constituents associated with ARD are likely to include Al, Co, Fe, Mn, Ni, SO_4 and Zn.

Although the occurrence of PAF materials is expected to be minor and mitigated through mining dilution, it is important to review this issue to identify any need for additional mitigation actions.

Water extracts from NAF overburden/interburden and rejects indicated that neutral mine drainage was unlikely to contain significant metal/metalloid concentrations. Results did not indicate potential for alkaline mine drainage.

Results of exchangeable cation and dispersion percent testing indicates that weathered Permian materials represented by the samples tested are likely to be sodic and dispersive, and may be subject to surface crusting and high erosion rates. Finer grained fresh Permian materials may also be partly sodic.

Results have the following implications for mine materials management:

- The vast majority of overburden/interburden, coal and washery rejects for the MOCO are expected to be NAF with excess ANC and will not require special handling. Dilution and mixing during mining is expected to be sufficient to mitigate ARD from any occasional thin zones of pyrite that may be present.
- Weathered Permian materials are likely to be NAF, but appear to be sodic and dispersive, and may need to be treated with gypsum or lime if used as a plant growing horizon, exposed on dump surfaces or used in engineered structures. Finer grained fresh Permian materials may also be partly sodic and require treatment.
- Regular review with sampling and testing of overburden/interburden, coal and washery wastes should be carried out during operations to confirm the low salinity and low risk of neutral mine drainage and ARD indicated by testing to date.
- Routine site water quality monitoring programmes should include monitoring of seepage and runoff from pit walls and floors, waste rock dumps, coal stockpiles and washery waste disposal areas to check for any evidence of ARD and metalliferous drainage and identify any need for additional controls. Parameters should include pH, EC, acidity/alkalinity, SO_4, Ca, Mg, K, Na, Cl, Al, As, Co, Cu, Fe, Mn, Ni and Zn.

It is recommended that additional investigations be carried out as follows:

- Continued testing of overburden/interburden, coal to confirm the continuity of NAF materials across the deposit.
- Opportunistic testing of rejects from Bayswater and Ravensworth Seam groups to better represent these materials.
- Consider leach column testing of NAF materials to better evaluate neutral and alkaline mine drainage chemistry.
- Further assessment of sodic/dispersive materials and management requirements.

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m)			Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					SINGLE ADDITION NAG			ARD Classification
	From	To	Interval											Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
SMC001	0.00	1.00	1.00	Soil/Conglomerate			CW			SMC001-1	5207	7.4	0.25	0.01	0	2	-1	5.34				NAF
SMC001	1.00	2.00	1.00	Claystone/Conglomerate			HW			SMC001-2	5208	8.2	0.35	<0.01	0	3	-2	16.86				NAF
SMC001	2.00	3.00	1.00	Claystone/Conglomerate			HW/MW			SMC001-3	5209	7.5	0.42	<0.01	0	8	-8	51.67				NAF
SMC001	3.00	7.00	4.00	Conglomerate			MW			SMC001-4	5210	7.8	0.33	<0.01	0	38	-38	249.72				NAF
SMC001	7.00	12.00	5.00	Conglomerate			MW			SMC001-5	5211	8.1	0.38	<0.01	0	21	-20	134.21				NAF
SMC001	12.00	13.50	1.50	Conglomerate			MW			SMC001-6	5212	7.9	0.41	<0.01	0	44	-44	285.49				NAF
SMC001	13.50	14.91	1.41	Claystone			FR	Not Available														
SMC001	14.91	15.00	0.09	Claystone			FR		6301					0.01	0							NAF
SMC001	15.00	15.59	0.59	Coal	RVY	Ravensworth	FR		6302					0.53	16							
SMC001	15.59	15.70	0.11	Claystone/Siltstone			FR		6303					<0.01	0							NAF
SMC001	15.70	17.50	1.80	Sandstone/Siltstone			FR			184501	3769	8.8	0.28	<0.01	0	11	-11	71.74	7.8	0	0	NAF
SMC001	17.50	18.90	1.40	Claystone/Sandstone			FR			184502	3770	8.2	0.31	<0.01	0	13	-13	88.01	7.7	0	0	NAF
SMC001	18.90	20.23	1.33	Sandstone			FR	Minor CY		184503	3771	8.4	0.28	0.01	0	8	-8	27.39	7.3	0	0	NAF
SMC001	20.23	20.34	0.11	Claystone			FR		6305					<0.01	0							NAF
SMC001	20.34	20.82	0.48	Coal	RVX	Ravensworth	FR		6306					0.65	20							
SMC001	20.82	20.94	0.12	Sandstone			FR		6307					<0.01	0							NAF
SMC001	20.94	21.95	1.01	Siltstone/Sandstone			FR			184504	3772	8.5	0.21	<0.01	0	12	-12	81.25	6.4	0	1	NAF
SMC001	21.95	22.95	1.00	Sandstone/Siltstone			FR			184505	3773	7.9	0.33	<0.01	0	19	-19	122.43	7.2	0	0	NAF
SMC001	22.95	23.59	0.64	Siltstone/Claystone			FR			184506	3774	8.7	0.49	0.04	1	11	-10	8.77	4.4	0.4	7	NAF
SMC001	23.59	23.71	0.12	Claystone			FR		6308					0.07	2							
SMC001	23.71	24.02	0.31	Coal	RVW	Ravensworth	FR		6309					0.52	16							
SMC001	24.02	24.14	0.12	Claystone			FR		6310					<0.01	0							NAF
SMC001	24.14	24.57	0.43	Siltstone/Claystone			FR			184507	3775	8.2	0.38	<0.01	0	11	-11	74.24	6.9	0	0	NAF
SMC001	24.57	26.27	1.70	Sandstone/Claystone			FR			184508	3776	7.9	0.41	<0.01	0	76	-76	499.96	7.9	0	0	NAF
SMC001	26.27	27.59	1.32	Sandstone/Siltstone			FR	Siderite		184509	3777	8.4	0.39	<0.01	0	59	-59	384.73	8.3	0	0	NAF
SMC001	27.59	28.23	0.64	Tuff			FR			184510	3778	7.6	0.33	<0.01	0	21	-21	136.92	7.9	0	0	NAF
SMC001	28.23	29.85	1.62	Claystone/Sandstone/Tuff			FR	Siderite, Calcite		184511	3779	8.8	0.30	<0.01	0	67	-67	436.93	8.4	0	0	NAF
SMC001	29.85	31.19	1.34	Siltstone			FR			184512	3780	8.7	0.28	<0.01	0	21	-21	138.57	8.1	0	0	NAF
SMC001	31.19	33.59	2.40	Sandstone/Claystone			FR			184513	3781	7.6	0.27	<0.01	0	59	-59	387.77	8.7	0	0	NAF
SMC001	33.59	36.36	2.77	Sandstone/Claystone			FR			184514	3782	8.5	0.34	<0.01	0	18	-18	119.83	7.7	0	0	NAF
SMC001	36.36	39.59	3.23	Sandstone/Siltstone			FR	Calcite		184515	3783	8.4	0.38	<0.01	0	69	-69	449.57	8.9	0	0	NAF
SMC001	39.59	44.93	5.34	Sandstone/Siltstone			FR	Two bags		184516 & 184517	3784	7.8	0.36	<0.01	0	17	-17	113.19	7.5	0	0	NAF
SMC001	44.93	47.54	2.61	Sandstone/Siltstone			FR			184518	3785	8.3	0.26	<0.01	0	49	-49	323.38	8.6	0	0	NAF
SMC001	47.54	52.71	5.17	Sandstone/Siltstone			FR	Two bags		184519 &184520	3786	8.2	0.24	<0.01	0	78	-78	508.94	8.8	0	0	NAF
SMC001	52.71	56.74	4.03	Sandstone/Siltstone			FR			184521	3787	7.8	0.23	<0.01	0	19	-19	124.37	7.5	0	0	NAF
SMC001	56.74	58.64	1.90	Sandstone/Siltstone			FR	Siderite, Calcite		184522	3788	9.1	0.35	<0.01	0	75	-75	491.25	8.2	0	0	NAF
SMC001	58.64	61.49	2.85	Sandstone			FR			184523	3789	8.8	0.34	<0.01	0	32	-32	207.80	8.3	0	0	NAF
SMC001	61.49	63.59	2.10	Sandstone/Siltstone			FR	Siderite		184524	3790	8.7	0.32	<0.01	0	99	-99	645.86	8.5	0	0	NAF
SMC001	63.59	65.40	1.81	Siltstone/Claystone			FR			184525	3791	8.6	0.35	<0.01	0	17	-17	112.21	8.1	0	0	NAF
SMC001	65.40	65.87	0.47	Claystone/Carb Claystone			FR			184526	3792	9.0	0.34	0.01	0	7	-7	24.37	5.2	0	4	NAF
SMC001	65.87	66.00	0.13	Claystone			FR		184806					<0.01	0							NAF
SMC001	66.00	66.59	0.59	Coal	RVU	Ravensworth	FR		184808		5286	7.5	0.10	0.42	13	2	11	0.13	2.2	73	106	PAF
SMC001	66.59	67.06	0.47	Tuff/Claystone	RVLP	Ravensworth	FR	Coally	6313					0.01	0							NAF
SMC001	67.06	68.09	1.03	Coal	RVL	Ravensworth	FR		6314		5287	4.5	0.13	0.45	14	2	12	0.11	2.2	88	124	PAF
SMC001	68.09	68.23	0.14	Claystone			FR		184811					0.02	1							NAF
SMC001	68.23	69.77	1.54	Sandstone/Siltstone			FR			184527	3793			<0.01	0	16	-16	107.42				NAF
SMC001	69.77	73.38	3.61	Sandstone/Siltstone			FR			184528	3794			<0.01	0	91	-91	594.32				NAF
SMC001	73.38	74.67	1.29	Sandstone/Claystone			FR			184529	3795			<0.01	0	38	-37	245.58				NAF
SMC001	74.67	75.53	0.86	Claystone/Sandstone			FR	Siderite, Calcite, Core loss of 0.15m		184530	3796			<0.01	0	20	-20	129.66				NAF
SMC001	75.53	75.60	0.07	Claystone			FR		6316					<0.01	0							NAF
SMC001	75.60	76.38	0.78	Coal	RUU	Ravensworth	FR	Calcite	6317		5288	6.8	0.12	0.35	11	55	-44	5.11	7.2	0	0	NAF
SMC001	76.38	76.97	0.59	Claystone	RULP	Ravensworth	FR	Siderite, Calcite	6318					0.01	0							NAF
SMC001	76.97	77.60	0.63	Coal	RUL	Ravensworth	FR		6319					0.43	13							
SMC001	77.60	77.71	0.11	Sandstone			FR		6320					0.01	0							NAF
SMC001	77.71	78.64	0.93	Sandstone/Siltstone			FR	Geotech Sample Removed		184531	3797	7.8	0.30	<0.01	0	16	-16	103.71	7.3	0	0	NAF
SMC001	78.64	80.90	2.26	Sandstone/Claystone			FR	Calcite		184532	3798	9.3	0.33	<0.01	0	53	-53	347.10	7.8	0	0	NAF
SMC001	80.90	83.39	2.49	Sandstone/Claystone			FR	Siderite, Calcite		184533	3799	9.2	0.26	<0.01	0	56	-55	363.60	8.5	0	0	NAF
SMC001	83.39	84.66	1.27	Siltstone/Claystone			FR			184534	3800	8.6	0.30	<0.01	0	47	-47	309.38	7.9	0	0	NAF
SMC001	84.66	87.62	2.96	Sandstone/Siltstone			FR			184535	3801	8.7	0.34	<0.01	0	24	-23	153.95	8.3	0	0	NAF
SMC001	87.62	90.69	3.07	Sandstone			FR			184536	3802	8.4	0.39	<0.01	0	35	-35	227.77	8.2	0	0	NAF
SMC001	90.69	93.21	2.52	Conglomerate/Sandstone			FR			184537	3803	8.5	0.31	<0.01	0	59	-58	383.12	8.5	0	0	NAF
SMC001	93.21	93.93	0.72	Claystone			FR			184538	3804	8.9	0.31	0.02	1	16	-15	25.61	5.9	0	1	NAF
SMC001	93.93	94.03	0.10	Claystone			FR		6321					0.01	0							NAF
SMC001	94.03	94.34	0.31	Coal	RTU	Ravensworth	FR		6322					0.57	17							
SMC001	94.34	94.45	0.11	Claystone			FR		6323					<0.01	0							NAF
SMC001	94.45	94.82	0.37	Claystone			FR			184539	3805			<0.01	0	19	-19	124.57				NAF
SMC001	94.82	94.93	0.11	Claystone/Carb Claystone			FR		6324					<0.01	0							NAF
SMC001	94.93	95.59	0.66	Coal	RTL	Ravensworth	FR		6325					0.65	20							
SMC001	95.59	95.71	0.12	Siltstone			FR		6326					<0.01	0							NAF
SMC001	95.71	96.65	0.94	Sandstone/Siltstone			FR			184540	3806			<0.01	0	23	-23	150.45				NAF
SMC001	96.65	100.05	3.40	Sandstone/Siltstone			FR	Calcite		184541	3807			<0.01	0	57	-57	375.80				NAF
SMC001	100.05	102.62	2.57	Sandstone			FR			184542	3808			<0.01	0	51	-50	330.94				NAF
SMC001	102.62	106.13	3.51	Sandstone/Siltstone			FR	Siderite		184543	3809			<0.01	0	59	-59	386.91				NAF
SMC001	106.13	108.93	2.80	Sandstone/Claystone			FR	Minor Calcite		184544	3810			<0.01	0	117	-117	762.92				NAF
SMC001	108.93	110.58	1.65	Sandstone/Siltstone			FR			184545	3811			<0.01	0	21	-20	134.45				NAF
SMC001	110.58	110.80	0.22	Claystone			FR			184546	3812			0.03	1	18	-17	19.12				NAF
SMC001	110.80	110.91	0.11	Coal/Carb Siltstone	BAND		FR	Calcite		184547	3813	9.1	0.20	0.23	7	38	-31	5.43	4.4	3	19	NAF
SMC001	110.91	112.55	1.64	Sandstone/Siltstone			FR			184548	3814	8.8	0.28	<0.01	0	26	-26	171.17	7.8	0	0	NAF
SMC001	112.55	113.01	0.46	Claystone/Carb Claystone			FR			184549	3815	8.9	0.21	0.03	1	19	-18	20.42	4.7	0	8	NAF
SMC001	113.01	113.19	0.18	Coal	RSU	Ravensworth	FR			184550	3816	8.5	0.14	0.65	20	74	-54	3.72	6.1	0	5	NAF
SMC001	113.19	113.97	0.78	Sandstone/Siltstone/Claystone			FR	Geotech Sample Removed		184551	3817	8.4	0.24	0.04	1	19	-18	15.76	7.1	0	0	NAF
SMC001	113.97	115.46	1.49	Sandstone/Siltstone			FR	Geotech Sample Removed		184552	3818	7.9	0.20	<0.01	0	105	-104	683.83	8.4	0	0	NAF
SMC001	115.46	115.56	0.10	Sandstone/Siltstone			FR		6332					<0.01	0							NAF

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m) From	Depth (m) To	Depth (m) Interval	Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS Total %S	MPA	ANC	NAPP	ANC/MPA	SINGLE ADDITION NAG NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	ARD Classification
SMC001	115.56	115.66	0.10	Coal	RS1	Ravensworth	FR		6333					0.97	30							
SMC001	115.66	115.78	0.12	Claystone			FR		6334					0.02	1							NAF
SMC001	115.78	116.64	0.86	Coal	RS	Ravensworth	FR		6335		5289	6.7	0.11	0.57	17	1	16	0.07	2.3	133	184	PAF
SMC001	116.64	116.78	0.14	Sandstone/Siltstone			FR		6336					<0.01	0							NAF
SMC001	116.78	117.83	1.05	Sandstone			FR			184553	3819			<0.01	0	14	-14	94.26				NAF
SMC001	117.83	120.18	2.35	Siltstone/Sandstone			FR			184554	3820			<0.01	0	25	-25	165.56				NAF
SMC001	120.18	124.49	4.31	Sandstone/Siltstone			FR	Siderite, Calcite, Two bags		184555	3821			<0.01	0	70	-70	458.31				NAF
SMC001	124.49	126.68	2.19	Sandstone			FR			184556	3822			0.01	0	53	-53	173.18				NAF
SMC001	126.68	129.71	3.03	Sandstone			FR	Pyrite		184557	3823			<0.01	0	139	-139	907.81				NAF
SMC001	129.71	131.94	2.23	Sandstone			FR	Siderite		184558	3824			<0.01	0	84	-84	550.20				NAF
SMC001	131.94	132.64	0.70	Siltstone/Claystone			FR			184559	3825			<0.01	0	22	-22	144.96				NAF
SMC001	132.64	132.75	0.11	Claystone/Carb Claystone			FR		6337					<0.01	0							NAF
SMC001	132.75	133.25	0.50	Coal	RQ	Ravensworth	FR		6338					0.53	16							
SMC001	133.25	133.37	0.12	Claystone/Tuff			FR		6339					<0.01	0							NAF
SMC001	133.37	134.43	1.06	Claystone/Siltstone/Sandstone			FR			184560	3826			<0.01	0	19	-18	121.27				NAF
SMC001	134.43	139.22	4.79	Sandstone			FR	Two bags		184561	3827			<0.01	0	99	-98	644.52				NAF
SMC001	139.22	140.09	0.87	Siltstone/Claystone			FR			184562	3828			0.01	0	17	-17	55.53				NAF
SMC001	140.09	140.20	0.11	Claystone/Carb Siltstone			FR		6340					<0.01	0							NAF
SMC001	140.20	140.75	0.55	Coal	RP	Ravensworth	FR		6341					0.51	16							
SMC001	140.75	140.83	0.08	Carb Claystone			FR		6342					<0.01	0							NAF
SMC001	140.83	141.09	0.26	Sandstone			FR			184563	3829	7.8	0.19	0.01	0	16	-15	51.18	5.4	0	4	NAF
SMC001	141.09	141.75	0.66	Claystone/Coal			FR			184564	3830	8.6	0.46	<0.01	0	39	-39	257.24	7.4	0	0	NAF
SMC001	141.75	145.71	3.96	Sandstone/Siltstone			FR			184565	3831	8.3	0.23	<0.01	0	32	-31	206.06	8.3	0	0	NAF
SMC001	145.71	149.00	3.29	Sandstone			FR	Siderite		184566	3832	8.4	0.28	<0.01	0	63	-63	413.79	8.4	0	0	NAF
SMC001	149.00	154.20	5.20	Sandstone			FR	Calcite, Two bags		184567	3833	8.2	0.29	<0.01	0	63	-63	413.60	8.6	0	0	NAF
SMC001	154.20	155.88	1.68	Sandstone/Claystone			FR			184568	3834	8.5	0.44	<0.01	0	15	-15	96.24	7.3	0	0	NAF
SMC001	155.88	156.13	0.25	Claystone/Coal	BAND		FR			184569	3835	8.8	0.47	0.16	5	17	-12	3.44	5.5	0	5	NAF
SMC001	156.13	159.92	3.79	Sandstone/Siltstone			FR			184570	3836	7.8	0.31	<0.01	0	58	-58	377.43	8.1	0	0	NAF
SMC001	159.92	164.39	4.47	Sandstone/Siltstone			FR	Two bags		184571	3837	8.3	0.43	<0.01	0	145	-145	946.91	8.4	0	0	NAF
SMC001	164.39	164.82	0.43	Siltstone/Claystone/Coal			FR			184572	3838	9.2	0.49	0.03	1	16	-15	17.34	6.9	0	0	NAF
SMC001	164.82	166.64	1.82	Sandstone/Siltstone			FR	Calcite		184573	3839	8.8	0.48	<0.01	0	40	-40	261.77	8.5	0	0	NAF
SMC001	166.64	166.95	0.31	Claystone/Siltstone			FR			184574	3840	8.7	0.39	<0.01	0	11	-11	73.95	6.9	0	0	NAF
SMC001	166.95	167.04	0.09	Carb Claystone/Claystone			FR		6343					<0.01	0							NAF
SMC001	167.04	167.75	0.71	Coal	RO	Ravensworth	FR		6344					0.56	17							
SMC001	167.75	167.84	0.09	Claystone			FR		6345					0.01	0							NAF
SMC001	167.84	168.49	0.65	Siltstone/Claystone			FR	Siderite		184575	3841	7.6	0.37	<0.01	0	123	-123	806.09	7.9	0	0	NAF
SMC001	168.49	169.53	1.04	Sandstone			FR			184576	3842	7.8	0.34	<0.01	0	110	-110	718.62	8.4	0	0	NAF
SMC001	169.53	169.61	0.08	Carb Siltstone			FR		6346					2.48	76							
SMC001	169.61	169.90	0.29	Coal	RNT	Ravensworth	FR		6347					0.63	19							
SMC001	169.90	171.17	1.27	Coal	RNU	Ravensworth	FR		6375		5290	6.6	0.12	0.71	22	20	1	0.94	2.9	25	43	UC(NAF)
SMC001	171.17	171.92	0.75	Coal	RNL	Ravensworth	FR		184809					0.60	18							
SMC001	171.92	171.99	0.07	Sandstone			FR		184810					0.01	0							NAF
SMC001	171.99	173.26	1.27	Sandstone/Siltstone			FR	Calcite		184577	3843	9.2	0.44	<0.01	0	81	-81	531.02	8.7	0	0	NAF
SMC001	173.26	173.36	0.10	Claystone			FR		6352					0.03	1							NAF
SMC001	173.36	174.20	0.84	Coal	RLU/RLL	Ravensworth	FR	Incudes 6cm TF parting	6353_55		5291	7.3	0.13	0.48	15	7	8	0.48	2.5	30	46	PAF-LC
SMC001	174.20	174.29	0.09	Sandstone/Claystone			FR		6356					0.10	3							
SMC001	174.29	175.54	1.25	Sandstone			FR			184578	3844			<0.01	0	68	-68	446.36				NAF
SMC001	175.54	177.10	1.56	Sandstone/Siltstone/Claystone			FR	Siderite, Calcite		184579	3845			<0.01	0	80	-79	519.83				NAF
SMC001	177.10	177.19	0.09	Siltstone/Claystone			FR		6357					<0.01	0							NAF
SMC001	177.19	177.61	0.42	Coal	RJU/RJM	Ravensworth	FR	Calcite, Incudes 4cm ST parting	6358_60					0.39	12							
SMC001	177.61	177.72	0.11	Tuff/Carb Claystone			FR		6361					0.14	4							
SMC001	177.72	178.51	0.79	Sandstone			FR			184580	3846			<0.01	0	18	-18	115.53				NAF
SMC001	178.51	180.02	1.51	Sandstone/Claystone			FR	Siderite		184581	3847			<0.01	0	63	-63	414.35				NAF
SMC001	180.02	180.14	0.12	Claystone			FR		6362					<0.01	0							NAF
SMC001	180.14	180.58	0.44	Coal	RJL	Ravensworth	FR		6363					0.49	15							
SMC001	180.58	180.67	0.09	Claystone			FR		6364					<0.01	0							NAF
SMC001	180.67	182.15	1.48	Sandstone/Siltstone			FR			184582	3848	8.7	0.43	<0.01	0	113	-112	735.40	8.8	0	0	NAF
SMC001	182.15	185.48	3.33	Sandstone/Siltstone			FR			184583	3849	8.2	0.43	<0.01	0	47	-47	307.58	8.5	0	0	NAF
SMC001	185.48	186.86	1.38	Siltstone			FR	Siderite, Calcite		184584	3850	8.3	0.41	<0.01	0	109	-109	715.04	8.6	0	0	NAF
SMC001	186.86	186.96	0.10	Siltstone			FR		6365					0.01	0							NAF
SMC001	186.96	187.29	0.33	Coal	RHU	Ravensworth	FR	Calcite	6366					0.38	12							
SMC001	187.29	187.59	0.30	Siltstone	RHLP	Ravensworth	FR	Coally	6367					<0.01	0							NAF
SMC001	187.59	188.04	0.45	Coal	RHL	Ravensworth	FR	Calcite	6368					0.59	18							
SMC001	188.04	188.12	0.08	Claystone/Siltstone			FR		6369					0.11	3							
SMC001	188.12	189.66	1.54	Sandstone			FR	Siderite, Calcite		184585	3851	8.1	0.44	<0.01	0	97	-97	633.94	8.6	0	0	NAF
SMC001	189.66	194.10	4.44	Sandstone			FR	Siderite, Two bags		184586	3852	7.8	0.50	<0.01	0	128	-128	835.75	8.8	0	0	NAF
SMC001	194.10	198.69	4.59	Sandstone/Siltstone			FR	Siderite, Calcite, Two bags, Core loss16cm		184587	3853	7.7	0.47	0.22	7	65	-58	9.67	8.5	0	0	NAF
SMC001	198.69	199.40	0.71	Siltstone/Claystone/Coal			FR			184588	3854	8.9	0.54	<0.01	0	32	-32	206.88	7.5	0	0	NAF
SMC001	199.40	199.53	0.13	Siltstone			FR		6370					0.08	2							
SMC001	199.53	200.14	0.61	Coal	RF	Ravensworth	FR		6371					0.60	18							
SMC001	200.14	200.60	0.46	Siltstone/Claystone	RFLP	Ravensworth	FR		6372					0.02	1							NAF
SMC001	200.60	200.95	0.35	Coal	RFL	Ravensworth	FR		6373					0.35	11							
SMC001	200.95	201.06	0.11	Siltstone/Coal			FR		6374					0.10	3							
SMC001	201.06	202.19	1.13	Sandstone/Siltstone			FR			184589	3855	8.5	0.38	<0.01	0	15	-15	97.31	7.8	0	0	NAF
SMC001	202.19	205.91	3.72	Sandstone			FR			184590	3856	8.4	0.39	<0.01	0	42	-41	271.51	8.3	0	0	NAF
SMC001	205.91	206.53	0.62	Siderite/Sandstone/Claystone			FR	Siderite, Calcite		184591	3857	8.6	0.39	<0.01	0	95	-95	622.44	8.4	0	0	NAF
SMC001	206.53	206.62	0.09	Claystone/Carb Claystone			FR		184812					0.18	6							
SMC001	206.62	207.46	0.84	Coal	BAY1	Bayswater	FR		184814		5292	7.1	0.13	0.44	13	2	12	0.14	2.3	39	60	PAF-LC
SMC001	207.46	207.58	0.12	Siltstone/Carb Claystone			FR		184813					0.83	25							
SMC001	207.58	207.80	0.22	Sandstone			FR			184592	3858	8.3	0.44	<0.01	0	12	-11	76.00	7.6	0	0	NAF
SMC001	207.80	209.29	1.49	Siltstone/Claystone/Coal			FR			184593	3859	8.7	0.36	0.02	1	14	-14	23.43	6.9	0	0	NAF
SMC001	209.29	210.07	0.78	Sandstone			FR	Calcite		184594	3860	8.6	0.30	<0.01	0	295	-295	1930.12	8.5	0	0	NAF
SMC001	210.07	210.55	0.48	Siltstone/Coal			FR			184595	3861	8.8	0.31	<0.01	0	26	-25	166.70	7.3	0	0	NAF

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m)			Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					SINGLE ADDITION NAG			ARD Classification
	From	To	Interval											Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
SMC001	210.55	210.67	0.12	Carb Claystone			FR		184815					<0.01	0							NAF
SMC001	210.67	210.90	0.23	Coal	BAY2AU	Bayswater	FR		184816					0.30	9							
SMC001	210.90	210.96	0.06	Siltstone			FR		184817					<0.01	0							NAF
SMC001	210.96	212.11	1.15	Sandstone/Siltstone			FR			184596	3862	8.5	0.34	0.01	0	37	-36	119.93	8.4	0	0	NAF
SMC001	212.11	212.20	0.09	Claystone			FR		184818					0.10	3							
SMC001	212.20	212.74	0.54	Coal	BAY2AL	Bayswater	FR		184819		5293	7.2	0.13	0.42	13	25	-12	1.95	6.9	0	0	NAF
SMC001	212.74	212.83	0.09	Claystone			FR		184820					0.01	0							NAF
SMC001	212.83	213.32	0.49	Claystone/Sandstone			FR			184597	3863	8.4	0.33	<0.01	0	18	-18	119.15	7.7	0	0	NAF
SMC001	213.32	213.45	0.13	Claystone/Siltstone			FR		184821					<0.01	0							NAF
SMC001	213.45	213.69	0.24	Coal	BAY2BU	Bayswater	FR		184822					0.30	9							
SMC001	213.69	213.81	0.12	Siltstone/Sandstone			FR		184823					<0.01	0							NAF
SMC001	213.81	214.31	0.50	Siltstone			FR			184598	3864	9.0	0.18	<0.01	0	32	-32	208.25	8.1	0	0	NAF
SMC001	214.31	214.42	0.11	Claystone/Siltstone			FR		184824					<0.01	0							NAF
SMC001	214.42	214.65	0.23	Coal	BAY2BM	Bayswater	FR		184825					0.30	9							
SMC001	214.65	214.93	0.28	Sandstone/Claystone	BAY2BLP	Bayswater	FR		184826					<0.01	0							NAF
SMC001	214.93	215.19	0.26	Coal	BAY2BL	Bayswater	FR	Calcite	184827					0.33	10							
SMC001	215.19	215.30	0.11	Claystone			FR	Calcite	184828					<0.01	0							NAF
SMC001	215.30	216.22	0.92	Sandstone/Siltstone			FR			184599	3865	8.9	0.24	<0.01	0	22	-22	141.79	7.8	0	0	NAF
SMC001	216.22	217.27	1.05	Sandstone/Siltstone/Carb Claystone			FR			184600	3866	8.8	0.23	<0.01	0	119	-119	780.89	8.5	0	0	NAF
SMC001	217.27	217.40	0.13	Carb Claystone			FR		184829					<0.01	0							NAF
SMC001	217.40	217.56	0.16	Coal	BAY3U	Bayswater	FR	Calcite	184830					0.37	11							
SMC001	217.56	217.67	0.11	Siltstone			FR		184831					0.02	1							NAF
SMC001	217.67	219.19	1.52	Siltstone/Sandstone/Carb Claystone			FR			186410	3867	8.4	0.25	<0.01	0	24	-24	157.65	7.6	0	0	NAF
SMC001	219.19	219.35	0.16	Carb Claystone			FR		184832					0.06	2							
SMC001	219.35	219.46	0.11	Coal	BAY3L	Bayswater	FR	Calcite	184833					0.36	11							
SMC001	219.46	219.60	0.14	Carb Claystone/Tuff			FR		184834					0.10	3							
SMC001	219.60	220.39	0.79	Siltstone/Sandstone			FR			186411	3868	8.2	0.26	<0.01	0	62	-62	407.67	8.4	0	0	NAF
SMC001	220.39	220.51	0.12	Sandstone/Carb Claystone			FR		184835					<0.01	0							NAF
SMC001	220.51	221.26	0.75	Coal	BAY4AU/BAY4A	Bayswater	FR		184836_37		5294	6.8	0.12	0.56	17	34	-17	1.99	7.3	0	0	NAF
SMC001	221.26	221.32	0.06	Carb Claystone	BAY4ALP	Bayswater	FR		184838					0.61	19							
SMC001	221.32	221.73	0.41	Coal	BAY4AL	Bayswater	FR		184839					0.44	13							
SMC001	221.73	222.31	0.58	Tuff/Carb Claystone	BAY4P	Bayswater	FR		184840					<0.01	0							NAF
SMC001	222.31	223.42	1.11	Coal	BAY4	Bayswater	FR		184841		5295	6.9	0.11	0.35	11	39	-28	3.62	7.5	0	0	NAF
SMC001	223.42	223.91	0.49	Conglomerate/Carb Claystone/Tuff	BAY5AUP	Bayswater	FR		184842					<0.01	0							NAF
SMC001	223.91	224.21	0.30	Coal	BAY5AU	Bayswater	FR		184843					0.41	13							
SMC001	224.21	224.57	0.36	Sandstone	BAY5AP	Bayswater	FR		184844					0.01	0							NAF
SMC001	224.57	225.16	0.59	Coal	BAY5A	Bayswater	FR		184845					0.49	15							
SMC001	225.16	225.25	0.09	Carb Claystone			FR		184846					0.31	9							
SMC001	225.25	225.74	0.49	Sandstone/Siltstone/Carb Claystone			FR			186412	3869	7.9	0.27	0.07	2	19	-17	9.10	5.3	0	5	NAF
SMC001	225.74	227.68	1.94	Sandstone			FR			186413	3870	7.6	0.28	0.01	0	22	-21	70.40	8.1	0	0	NAF
SMC001	227.68	228.59	0.91	Conglomerate/Carb Siltstone			FR			186414	3871	7.5	0.29	<0.01	0	127	-127	828.38	8.6	0	0	NAF
SMC001	228.59	228.71	0.12	Sandstone/Carb Siltstone			FR		184847					0.35	11							
SMC001	228.71	230.11	1.40	Coal	BAY5U/BAY5	Bayswater	FR		184848_49		5296	6.8	0.13	0.75	23	1	22	0.06	2.5	70	102	PAF
SMC001	230.11	230.22	0.11	Sandstone		Archerfield Sandstone	FR		184850					<0.01	0							NAF
SMC001	230.22	231.73	1.51	Sandstone		Archerfield Sandstone	FR			186415	3872	7.8	0.29	<0.01	0	18	-18	115.67	8.5	0	0	NAF
SMC001	231.73	235.61	3.88	Sandstone		Archerfield Sandstone	FR	Two bags		186416	3873	7.9	0.38	<0.01	0	16	-16	106.59	8.1	0	0	NAF
SMC001	235.61	239.70	4.09	Sandstone		Archerfield Sandstone	FR	Two bags		186417	3874	8.9	0.45	<0.01	0	34	-34	220.49	8.4	0	0	NAF
SMC001	239.70	241.25	1.55	Sandstone		Archerfield Sandstone	FR	Siderite, Calcite		186418	3875	8.7	0.41	<0.01	0	104	-104	682.63	8.7	0	0	NAF
SMC001	241.25	243.74	2.49	Sandstone/Siltstone/Claystone		Archerfield Sandstone	FR	Calcite		186419	3876	8.2	0.48	<0.01	0	44	-44	286.42	8.6	0	0	NAF
SMC011	0.00	1.00	1.00	Claystone			CW			SMC011-1	5213	8.3	0.29	<0.01	0	5	-5	31.60	4.6	0	13	NAF
SMC011	1.00	2.00	1.00	Sandstone			CW			SMC011-2	5214	7.7	0.29	<0.01	0	15	-15	97.02	7.7	0	0	NAF
SMC011	2.00	3.00	1.00	Sandstone			CW			SMC011-3	5215	7.6	0.33	<0.01	0	8	-8	52.14	7.9	0	0	NAF
SMC011	3.00	5.00	2.00	Claystone			EW			SMC011-4	5216	6.4	0.31	0.04	1	10	-9	8.33	7.5	0	0	NAF
SMC011	5.00	8.00	3.00	Sandstone			HW			SMC011-5	5217	8.2	0.42	<0.01	0	24	-23	154.49	7.8	0	0	NAF
SMC011	8.00	9.00	1.00	Sandstone			FR			SMC011-6	5218	7.5	0.53	<0.01	0	9	-9	59.63	7.1	0	0	NAF
SMC011	9.00	13.00	4.00	Sandstone			HW			SMC011-7	5219	7.6	0.38	<0.01	0	26	-26	170.57	8.2	0	0	NAF
SMC011	13.00	16.00	3.00	Sandstone			HW			SMC011-8	5220	7.7	0.36	<0.01	0	19	-19	123.53	8.2	0	0	NAF
SMC011	16.00	20.00	4.00	Conglomerate/Sandstone			HW			SMC011-9	5221	8.3	0.24	<0.01	0	52	-52	340.87	8.1	0	0	NAF
SMC011	20.00	25.00	5.00	Sandstone/Conglomerate			HW			SMC011-10	5222	7.7	0.25	<0.01	0	23	-22	147.20	8.3	0	0	NAF
SMC011	25.00	26.00	1.00	Sandstone/Claystone			HW/FR			SMC011-11	5223	7.8	0.26	0.01	0	15	-14	48.17	8.4	0	0	NAF
SMC011	26.00	27.00	1.00	Claystone			FR			SMC011-12	5224	8.2	0.28	0.03	1	36	-35	39.44	8.2	0	0	NAF
SMC011	27.00	29.00	2.00	Claystone/Siltstone			FR			SMC011-13	5225	7.9	0.29	<0.01	0	19	-19	122.07	7.8	0	0	NAF
SMC011	29.00	30.00	1.00	Claystone/Siltstone/Conglomerate			FR			SMC011-14	5226	7.8	0.29	0.01	0	13	-13	41.95	6.4	0	1	NAF
SMC011	30.00	32.00	2.00	Conglomerate			MW			SMC011-15	5227	7.7	0.35	<0.01	0	58	-57	376.26	8.1	0	0	NAF
SMC011	32.00	33.80	1.80	Conglomerate			MW			SMC011-16	5228	7.6	0.31	0.10	3	9	-6	2.82	7.8	0	0	NAF
SMC011	32.00	94.05	62.05				FR	Not Sampled														
SMC011	94.05	94.15	0.10	Claystone	BY3R	Bayswater	FR		186127		5323	7.6	0.23	<0.01	0	36	-36	237.43	7.7	0	0	NAF
SMC011	94.15	96.37	2.22	Coal	BY3/BY4U2/BY4U1	Bayswater	FR		186128_132		5324	7.4	0.25	0.48	15	10	5	0.66	3.3	9	28	UC(NAF)
SMC011	96.37	96.75	0.38	Tuff			FR		186133		5325	7.5	0.25	0.16	5	38	-33	7.70	7.1	0	0	NAF
SMC011	96.75	98.56	1.81	Coal	BY4	Bayswater	FR		186134		5326	7.4	0.15	0.38	12	32	-21	2.77	7.3	0	0	NAF
SMC011	98.56	98.86	0.30	Tuff	BY4LP	Bayswater	FR		186135		5327	7.6	0.13	<0.01	0	39	-39	252.73	7.7	0	0	NAF
SMC011	98.86	100.00	1.14	Coal	BY4L/BY5U3	Bayswater	FR		186136_138		5328	7.3	0.16	0.42	13	24	-11	1.89	7.9	0	0	NAF
SMC011	100.00	100.18	0.18	Coal/Carb Siltstone	BY5U2	Bayswater	FR		186139		5329	7.4	0.17	0.20	6	17	-10	2.70	7.8	0	0	NAF
SMC011	100.18	102.81	2.63	Coal	BY5U1/BY5	Bayswater	FR		186140_142		5330	7.2	0.18	0.69	21	9	12	0.44	2.8	25	56	PAF-LC
SMC011	102.81	102.95	0.14	Sandstone		Archerfield Sandstone	FR		186143		5331	6.8	0.40	0.13	4	1	3	0.16	3.8	1	3	PAF-LC
SMC011	102.95	104.32	1.37	Sandstone		Archerfield Sandstone	FR			186441	3877	8.3	0.51	<0.01	0	11	-11	71.60	7.2	0	0	NAF
SMC011	104.32	108.58	4.26	Sandstone/Conglomerate		Archerfield Sandstone	FR			186442	3878	8.0	0.49	<0.01	0	22	-22	145.16	7.9	0	0	NAF
SMC011	108.58	111.43	2.85	Sandstone		Archerfield Sandstone	FR	Geotech Sample Removed		186443	3879	7.8	0.44	<0.01	0	25	-25	166.31	8.4	0	0	NAF
SMC011	111.43	115.92	4.49	Sandstone		Archerfield Sandstone	FR			186444	3880	8.1	0.47	0.22	7	13	-6	1.93	7.2	0	0	NAF
SMC011	115.92	117.82	1.90	Sandstone/Siltstone		Archerfield Sandstone	FR			186445	3881	7.9	0.46	<0.01	0	29	-29	190.62	8.1	0	0	NAF
SMC011	117.82	117.97	0.15	Carb Claystone/Claystone			FR			186446	3882	8.4	0.65	0.32	10	9	1	0.89	3.1	20	44	PAF-LC
SMC011	117.97	118.20	0.23	Coal/Claystone/Carb Claystone	LEF	Lemington	FR	Pyrite		186447	3883	8.2	0.61	0.55	17	24	-7	1.43	6.9	0	0	NAF
SMC011	118.20	118.30	0.10	Claystone			FR		186144		5332	7.1	0.21	0.10	3	6	-3	1.95	5.5	0	1	NAF

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m)			Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					SINGLE ADDITION NAG			ARD Classification
	From	To	Interval											Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
SMC011	118.30	118.80	0.50	Coal	LEE	Lemington	FR	Pyrite	186145		5333	7.3	0.15	1.25	38	13	25	0.33	3.5	5	16	PAF
SMC011	118.80	118.90	0.10	Sandstone			FR		186146		5334	6.6	0.27	0.15	5	6	-1	1.32	6.9	0	0	NAF
SMC011	118.90	119.38	0.48	Sandstone			FR			186448	3884	8.5	0.57	0.05	2	18	-16	11.63	7.2	0	0	NAF
SMC011	119.38	119.48	0.10	Sandstone/Claystone	LEDR	Lemington	FR		186147		5335	4.6	0.67	1.13	35	2	33	0.05	2.5	24	30	PAF
SMC011	119.48	120.95	1.47	Coal/Tuff	LED/C/B/A/AL	Lemington	FR	Pyrite	186148_156		5336	7.2	0.24	0.70	22	8	14	0.35	3.1	7	21	PAF-LC
SMC011	120.95	121.05	0.10	Sandstone/Carb Claystone			FR		186157		5337	7.3	0.25	0.11	3	6	-3	1.90	5.3	0	1	NAF
SMC011	121.05	121.81	0.76	Sandstone			FR			186449	3885	8.0	0.53	<0.01	0	50	-49	324.35	8.3	0	0	NAF
SMC011	121.81	123.39	1.58	Sandstone			FR			186450	3886	7.6	0.41	<0.01	0	95	-94	617.74	8.7	0	0	NAF
SMC011	123.39	123.49	0.10	Sandstone/Claystone			FR		186158		5338	7.4	0.31	0.16	5	9	-4	1.84	3.7	2	8	NAF
SMC011	123.49	126.09	2.60	Coal	LDK/J/H/G/F	Lemington	FR		186159_167		5339	7.2	0.28	0.45	14	20	-6	1.4547555	6.5	0	1	NAF
SMC011	126.09	126.22	0.13	Sandstone			FR		186168		5340	7.2	0.14	0.02	1	6	-5	9.36	7.2	0	0	NAF
SMC009	0.00	1.00	1.00	Sandstone/Conglomerate/Soil			CW			SMC009-1	5229	8.3	0.27	<0.01	0	3	-3	21.27				NAF
SMC009	1.00	2.00	1.00	Sandstone			CW			SMC009-2	5230	8.2	0.26	<0.01	0	3	-3	22.47				NAF
SMC009	2.00	3.00	1.00	Sandstone			HW			SMC009-3	5231	8.1	0.25	<0.01	0	4	-4	25.60				NAF
SMC009	3.00	5.00	2.00	Conglomerate			HW			SMC009-4	5232	8.0	0.24	<0.01	0	4	-4	29.07				NAF
SMC009	5.00	6.00	1.00	Sandstone/Conglomerate			HW			SMC009-5	5233	7.8	0.23	<0.01	0	4	-4	25.11				NAF
SMC009	6.00	8.00	2.00	Conglomerate			MW			SMC009-6	5234	7.9	0.32	<0.01	0	4	-3	23.87				NAF
SMC009	8.00	9.00	1.00	Sandstone/Conglomerate			MW			SMC009-7	5235	7.8	0.35	<0.01	0	4	-4	24.86				NAF
SMC009	9.00	11.00	2.00	Sandstone			MW			SMC009-8	5236	6.7	0.42	<0.01	0	5	-5	34.63				NAF
SMC009	11.00	12.50	1.50	Conglomerate/Tuff			PW			SMC009-9	5237	7.2	0.28	0.03	1	5	-5	5.96				NAF
SMC009	12.50	12.72	0.22	Conglomerate/Tuff			PW	Not Available														
SMC009	12.72	13.18	0.46	Coal	LDK	Lemington	FR		184135					0.48	15							
SMC009	13.18	13.65	0.47	Tuff/Coal			FR		184136					0.28	9							
SMC009	13.65	14.80	1.15	Coal	LDJ	Lemington	FR		184144		5311	6.6	0.13	0.58	18	2	16	0.11	2.3	66	94	PAF
SMC009	14.80	15.58	0.78	Tuff/Carb Claystone			FR		184145					0.29	9							
SMC009	15.58	16.98	1.40	Coal	LDGH	Lemington	FR		184146					0.49	15							
SMC009	16.98	17.05	0.07	Tuff			FR		184147					<0.01	0							NAF
SMC009	17.05	17.23	0.18	Coal	LDE	Lemington	FR		184148					0.48	15							
SMC009	17.23	17.28	0.05	Carb Claystone			FR		184149					0.21	6							
SMC009	17.28	17.83	0.55	Coal	LDD	Lemington	FR		184150					0.48	15							
SMC009	17.83	17.87	0.04	Tuff			FR		184151					0.35	11							
SMC009	17.87	18.41	0.54	Coal	LDC	Lemington	FR		184152					0.54	17							
SMC009	18.41	18.65	0.24	Tuff			FR		184153					0.16	5							
SMC009	18.65	19.70	1.05	Coal	LDB	Lemington	FR		184154		5312	6.9	0.13	0.47	14	3	11	0.24	2.2	69	103	PAF
SMC009	19.70	19.75	0.05	Core Loss			FR															
SMC009	19.75	21.00	1.25	Coal	LDA	Lemington	FR		184156					0.66	20							
SMC009	21.00	21.10	0.10	Sandstone			PW		184157					0.21	6							
SMC009	21.10	21.80	0.70	Sandstone			PW	Minor Coal, Geotech Sample Removed		186420	3887	7.3	0.40	0.07	2	32	-30	15.12	8.1	0	0	NAF
SMC009	21.80	24.76	2.96	Sandstone			SW			186421	3888	7.5	0.44	<0.01	0	7	-7	47.24	7.4	0	0	NAF
SMC009	24.76	28.06	3.30	Sandstone			SW	Inc. TF		186422	3889	7.6	0.42	<0.01	0	25	-25	165.62	8.0	0	0	NAF
SMC009	28.06	30.93	2.87	Sandstone			SW	Siderite		186423	3890	7.7	0.40	<0.01	0	65	-65	424.52	8.3	0	0	NAF
SMC009	30.93	32.51	1.58	Sandstone			SW			186424	3891	7.8	0.42	<0.01	0	74	-74	482.16	9.0	0	0	NAF
SMC009	32.51	32.67	0.16	Tuff/Conglomerate			FR		184158					0.40	12							
SMC009	32.67	32.87	0.20	Coal	LCG	Lemington	FR		184159					1.87	57							
SMC009	32.87	32.93	0.06	Tuff			FR		184160					0.79	24							
SMC009	32.93	33.76	0.83	Coal	LCF	Lemington	FR		184161		5313	4.1	0.46	1.27	39	1	38	0.02	2.3	25	28	PAF
SMC009	33.76	33.92	0.16	Claystone			FR		184162					<0.01	0							NAF
SMC009	33.92	34.20	0.28	Claystone			FR			186425	3892			0.01	0	6	-6	19.39				NAF
SMC009	34.20	36.54	2.34	Sandstone/Siltstone			FR			186426	3893			0.01	0	16	-16	51.70				NAF
SMC009	36.54	38.42	1.88	Claystone/Sandstone			FR			186427	3894			0.03	1	15	-14	16.26				NAF
SMC009	38.42	39.73	1.31	Sandstone			FR	Siderite		186428	3895			<0.01	0	125	-125	819.35				NAF
SMC009	39.73	42.74	3.01	Core Loss			FR	Geotech Sample Removed		186429	3896			<0.01	0	30	-29	193.09				NAF
SMC009	42.74	45.74	3.00	Sandstone			FR			186430	3897			<0.01	0	68	-68	446.96				NAF
SMC009	45.74	48.74	3.00	Conglomerate			FR			186431	3898	7.7	0.45	<0.01	0	37	-37	243.81	8.9	0	0	NAF
SMC009	48.74	51.72	2.98	Conglomerate			FR			186432	3899	7.6	0.38	<0.01	0	21	-21	138.35	8.5	0	0	NAF
SMC009	51.72	54.74	3.02	Conglomerate			FR			186433	3900	7.8	0.55	<0.01	0	23	-23	152.71	8.3	0	0	NAF
SMC009	54.74	57.74	3.00	Conglomerate			FR			186434	3901	7.5	0.53	<0.01	0	20	-20	133.96	8.4	0	0	NAF
SMC009	57.74	60.76	3.02	Conglomerate			FR			186435	3902	7.4	0.49	<0.01	0	18	-18	117.60	8.2	0	0	NAF
SMC009	60.76	63.74	2.98	Conglomerate			FR			186436	3903	7.7	0.50	<0.01	0	32	-32	209.15	8.3	0	0	NAF
SMC009	63.74	64.47	0.73	Conglomerate			FR			186437	3904	8.1	0.55	<0.01	0	59	-59	387.15	8.6	0	0	NAF
SMC009	64.47	64.85	0.38	Siltstone/Coal	LCEBAND	Lemington	FR	Minor Pyrite		186438	3905	8.2	0.56	<0.01	0	14	-14	89.99	4.0	3	13	NAF
SMC009	64.85	65.54	0.69	Claystone			FR			186439	3906	8.0	0.59	0.02	1	11	-10	17.61	6.1	0	2	NAF
SMC009	65.54	65.68	0.14	Claystone			FR		184163					0.19	6							
SMC009	65.68	66.43	0.75	Coal	LCE	Lemington	FR	Calcite	184164		5314	6.6	0.36	3.54	108	17	91	0.16	2.2	61	67	PAF
SMC009	66.43	66.56	0.13	Claystone			FR		184165					0.27	8							
SMC009	66.56	66.96	0.40	Claystone/Sandstone			FR			186440	3907	7.3	0.57	0.09	3	11	-9	4.16	4.2	1	9	PAF-LC
SMC009	66.96	67.12	0.16	Claystone/Sandstone			FR		184166					0.14	4							
SMC006	0.00	0.20	0.20	Soil			EW	Open Hole - No Sample														
SMC006	0.20	2.00	1.80	Claystone			CW	Open Hole - No Sample														
SMC006	2.00	3.00	1.00	Claystone/Sandstone			EW	Open Hole - No Sample														
SMC006	3.00	9.00	6.00	Sandstone			MW	Open Hole - No Sample														
SMC006	9.00	10.00	1.00	Coal/Sandstone			SW	Open Hole - No Sample														
SMC006	10.00	11.00	1.00	Sandstone			FR	Open Hole - No Sample														
SMC006	11.00	11.80	0.80	Siltstone			FR	Open Hole - No Sample														
SMC006	11.80	13.26	1.46	Claystone/Sandstone/Conglomerate			FR	NR 0.12m		186451	3908	8.6	0.61	0.05	2	26	-25	17.21	8.3	0	0	NAF
SMC006	13.26	13.81	0.55	Siderite/Siltstone/Tuff			FR	Siderite		186452	3909	8.4	0.43	<0.01	0	51	-51	331.52	8.4	0	0	NAF
SMC006	13.81	13.88	0.07	Tuff			FR		184001					0.11	3							
SMC006	13.88	14.17	0.29	Coal	LCJ	Lemington	FR		184700					1.96	60							
SMC006	14.17	14.31	0.14	Claystone			FR		184699					0.30	9							
SMC006	14.31	15.92	1.61	Sandstone			FR	Minor coal		186453	3910	8.5	0.38	<0.01	0	58	-58	381.04	8.5	0	0	NAF
SMC006	15.92	17.22	1.30	Claystone			FR	Lesser SS		186454	3911	8.3	0.52	0.03	1	20	-19	21.86	8.2	0	0	NAF
SMC006	17.22	17.72	0.50	Sandstone			FR			186455	3912	8.2	0.42	0.03	1	24	-24	26.65	8.1	0	0	NAF
SMC006	17.72	17.85	0.13	Claystone/Sandstone			FR		184744					0.55	17							

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m) From	Depth (m) To	Depth (m) Interval	Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS Total %S	MPA	ANC	NAPP	ANC/MPA	SINGLE ADDITION NAG NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	ARD Classification
SMC006	17.85	18.13	0.28	Coal	LCH	Lemington	FR		184745					0.97	30							
SMC006	18.13	18.24	0.11	Tuff/Claystone			FR		184746					<0.01	0							NAF
SMC006	18.24	18.51	0.27	Coal/Tuff			FR			186456	3913	8.5	0.84	<0.01	0	19	-19	123.66	3.4	8	31	NAF
SMC006	18.51	18.74	0.23	Core Loss			FR															
SMC006	18.74	19.29	0.55	Siltstone/Claystone/Coal			FR			186457	3914	8.1	0.38	0.02	1	33	-32	53.69	7.5	0	0	NAF
SMC006	19.29	19.85	0.56	Tuff			FR	Minor Coal		186458	3915	7.8	0.38	<0.01	0	14	-13	89.23	7.2	0	0	NAF
SMC006	19.85	21.33	1.48	Siltstone			FR	Minor Coal		186459	3916	8.4	0.38	0.06	2	50	-48	26.99	7.6	0	0	NAF
SMC006	21.33	24.87	3.54	Sandstone/Siltstone			FR			186460	3917	8.3	0.29	<0.01	0	19	-19	126.16	7.9	0	0	NAF
SMC006	24.87	27.81	2.94	Sandstone/Claystone/Siltstone			FR			186461	3918	8.2	0.53	0.04	1	44	-43	36.11	7.8	0	0	NAF
SMC006	27.81	30.60	2.79	Sandstone/Siltstone			FR			186462	3919	8.5	0.43	0.09	3	18	-15	6.36	4.5	0	8	NAF
SMC006	30.60	30.92	0.32	Siltstone/Claystone			FR	Minor Coal		186463	3920	7.6	0.38	0.06	2	35	-33	19.16	7.6	0	0	NAF
SMC006	30.92	31.98	1.06	Sandstone			FR			186464	3921	8.4	0.51	<0.01	0	60	-60	390.56	7.7	0	0	NAF
SMC006	31.98	33.44	1.46	Claystone/Siltstone/Tuff			FR			186465	3922	7.8	0.42	0.06	2	17	-16	9.51	7.5	0	0	NAF
SMC006	33.44	35.79	2.35	Sandstone			FR			186466	3923			0.03	1	49	-48	53.40				NAF
SMC006	35.79	36.16	0.37	Claystone/Coal			FR			186467	3924			0.05	2	22	-21	14.68				NAF
SMC006	36.16	36.99	0.83	Sandstone/Siltstone			FR			186468	3925			0.01	0	15	-15	48.92				NAF
SMC006	36.99	38.86	1.87	Claystone/Siltstone			FR			186469	3926	8.3	0.39	0.07	2	28	-25	12.87	7.9	0	0	NAF
SMC006	38.86	41.95	3.09	Sandstone/Siltstone			FR			186470	3927	8.2	0.38	0.01	0	56	-56	183.09	8.5	0	0	NAF
SMC006	41.95	42.41	0.46	Siltstone/Claystone			FR			186471	3928	8.1	0.37	<0.01	0	45	-45	292.79	8.6	0	0	NAF
SMC006	42.41	43.91	1.50	Sandstone			FR			186472	3929	8.4	0.29	0.13	4	26	-22	6.52	8.3	0	0	NAF
SMC006	43.91	44.17	0.26	Claystone			FR			186473	3930	9.2	0.84	0.09	3	17	-14	6.14	7.5	0	0	NAF
SMC006	44.17	44.30	0.13	Claystone			FR		184747					0.06	2							
SMC006	44.30	44.54	0.24	Coal	LCG	Lemington	FR		184748					1.18	36							
SMC006	44.54	44.73	0.19	Carb Claystone/Claystone			FR		184749					0.67	21							
SMC006	44.73	45.23	0.50	Coal	LCFU	Lemington	FR		184750					1.53	47							
SMC006	45.23	45.73	0.50	Sandstone/Claystone			FR		184751					0.16	5							
SMC006	45.73	46.13	0.40	Coal	LCFL	Lemington	FR		184752					1.22	37							
SMC006	46.13	46.28	0.15	Claystone/Carb Claystone			FR		184754					0.64	20							
SMC006	46.28	47.17	0.89	Sandstone/Conglomerate			FR			186474	3931	8.2	0.72	0.09	3	26	-23	9.29	7.6	0	0	NAF
SMC006	47.17	49.60	2.43	Sandstone/Siltstone			FR			186475	3932	8.3	0.61	0.06	2	36	-34	19.52	7.8	0	0	NAF
SMC006	49.60	53.57	3.97	Sandstone/Claystone			FR	Siderite at base		186476	3933	8.2	0.67	0.10	3	38	-35	12.41	7.9	0	0	NAF
SMC006	53.57	54.11	0.54	Claystone			FR			186477	3934	8.5	0.57	0.10	3	16	-13	5.27	7.4	0	0	NAF
SMC006	54.11	56.15	2.04	Sandstone			FR			186478	3935			0.04	1	34	-33	27.68				NAF
SMC006	56.15	57.10	0.95	Claystone/Siltstone			FR			186479	3936			0.05	2	19	-18	12.67				NAF
SMC006	57.10	60.20	3.10	Sandstone			FR			186480	3937			0.05	2	61	-60	40.13				NAF
SMC006	60.20	61.07	0.87	Claystone/Siltstone/Sandstone			FR			186481	3938	8.4	0.50	0.06	2	52	-50	28.29	7.8	0	0	NAF
SMC006	61.07	61.21	0.14	Claystone/Siltstone			FR		184755					0.06	2							
SMC006	61.21	61.34	0.13	Coal	LCD	Lemington	FR		184756					0.90	28							
SMC006	61.34	61.49	0.15	Carb Claystone/Claystone			FR		184757					0.69	21							
SMC006	61.49	62.35	0.86	Claystone/Sandstone			FR			186482	3939	8.6	0.38	0.22	7	25	-18	3.71	7.5	0	0	NAF
SMC006	62.35	62.49	0.14	Claystone			FR		184758					0.57	17							
SMC006	62.49	62.81	0.32	Coal	LCC	Lemington	FR		184759					1.52	47							
SMC006	62.81	62.94	0.13	Tuff			FR		184760					1.13	35							
SMC006	62.94	63.54	0.60	Coal	LCB	Lemington	FR		184761					1.67	51							
SMC006	63.54	63.74	0.20	Tuff			FR		184762					0.39	12							
SMC006	63.74	64.69	0.95	Coal	LCA	Lemington	FR		184763		5297	7.2	0.12	0.77	24	45	-22	1.93	7.1	0	0	NAF
SMC006	64.69	64.81	0.12	Siltstone			FR		184764					0.59	18							
SMC006	64.81	65.64	0.83	Claystone/Sandstone			FR			186483	3940	8.4	0.30	0.16	5	31	-26	6.32	8.3	0	0	NAF
SMC006	65.64	67.11	1.47	Sandstone			FR			186484	3941			0.03	1	26	-25	28.58				NAF
SMC006	67.11	69.82	2.71	Claystone/Sandstone			FR			186485	3942			0.02	1	30	-30	49.79				NAF
SMC006	69.82	71.04	1.22	Claystone/Siltstone			FR			186486	3943			0.01	0	15	-15	49.61				NAF
SMC006	71.04	73.59	2.55	Sandstone/Claystone			FR			186487	3944			0.03	1	58	-57	63.42				NAF
SMC006	73.59	74.08	0.49	Claystone			FR			186488	3945			0.04	1	17	-16	14.06				NAF
SMC006	74.08	76.71	2.63	Sandstone			FR			186489	3946			0.03	1	24	-23	26.44				NAF
SMC006	76.71	82.06	5.35	Sandstone			FR	Two Bags		186490	3947			<0.01	0	42	-41	271.68				NAF
SMC006	82.06	83.15	1.09	Sandstone			FR			186491	3948			0.03	1	76	-75	82.59				NAF
SMC006	83.15	84.50	1.35	Claystone/Siltstone			FR			186492	3949			0.01	0	16	-15	51.38				NAF
SMC006	84.50	87.73	3.23	Claystone/Sandstone			FR			186493	3950			0.02	1	41	-40	66.39				NAF
SMC006	87.73	89.58	1.85	Sandstone			FR			186494	3951			<0.01	0	64	-64	417.77				NAF
SMC006	89.58	91.10	1.52	Conglomerate/Sandstone			FR			186495	3952			0.04	1	31	-29	24.97				NAF
SMC006	91.10	91.53	0.43	Claystone			FR			186496	3953	7.2	0.43	0.16	5	13	-8	2.59	7.1	0	0	NAF
SMC006	91.53	91.69	0.16	Claystone/Carb Claystone			FR		184765					0.52	16							
SMC006	91.69	92.35	0.66	Coal	LBLM	Lemington	FR		184766					1.13	35							
SMC006	92.35	92.46	0.11	Claystone/Siltstone			FR		184767					1.92	59							
SMC006	92.46	93.29	0.83	Sandstone/Claystone			FR			186497	3954	5.3	1.29	0.62	19	7	12	0.38	3.5	4	12	PAF-LC
SMC006	93.29	95.20	1.91	Sandstone/Claystone			FR			186498	3955	8.4	0.31	0.06	2	35	-33	18.81	7.5	0	0	NAF
SMC006	95.20	96.81	1.61	Sandstone/Claystone			FR			186499	3956	7.5	0.32	0.07	2	25	-23	11.80	7.4	0	0	NAF
SMC006	96.81	97.38	0.57	Siltstone/Claystone			FR			186500	3957	7.6	0.29	0.18	6	12	-7	2.19	5.8	0	1	NAF
SMC006	97.38	97.48	0.10	Claystone			FR		184768					0.22	7							
SMC006	97.48	97.68	0.20	Coal	LBK	Lemington	FR		184769					0.76	23							
SMC006	97.68	98.01	0.33	Siltstone/Tuff/Carb Siltstone			FR		184770					0.63	19							
SMC006	98.01	98.50	0.49	Coal	LBJU	Lemington	FR		184771					0.96	29							
SMC006	98.50	98.64	0.14	Carb Claystone			FR		184772					0.52	16							
SMC006	98.64	99.01	0.37	Coal	LBJL	Lemington	FR		184773					1.12	34							
SMC006	99.01	99.15	0.14	Siltstone			FR		184774					0.03	1							NAF
SMC006	99.15	100.14	0.99	Siltstone/Sandstone			FR			186501	3958	7.9	0.48	<0.01	0	64	-64	420.67	8.2	0	0	NAF
SMC006	100.14	100.69	0.55	Claystone			FR			186502	3959	7.8	0.45	0.01	0	25	-25	81.55	8.4	0	0	NAF
SMC006	100.69	100.78	0.09	Claystone			FR		184775					0.40	12							
SMC006	100.78	101.72	0.94	Coal	LBHU/LBHL	Lemington	FR	Incudes 8cm TF parting	184776_78					0.83	25							
SMC006	101.72	101.82	0.10	Sandstone			FR		184779					0.48	15							
SMC006	101.82	102.74	0.92	Sandstone			FR			186503	3960	7.6	0.32	0.24	7	83	-76	11.29	8.1	0	0	NAF
SMC006	102.74	102.83	0.09	Claystone			FR		184780					0.32	10							
SMC006	102.83	103.47	0.64	Coal	LBG	Lemington	FR		184781		5298	6.8	0.12	1.39	43	9	34	0.21	3.0	10	23	PAF

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m) From	To	Interval	Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS Total %S	MPA	ANC	NAPP	ANC/MPA	SINGLE ADDITION NAG NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	ARD Classification
SMC006	103.47	104.08	0.61	Coal	LBF	Lemington	FR		184782					0.59	18							
SMC006	104.08	104.23	0.15	Claystone			FR		184783					0.73	22							
SMC006	104.23	104.72	0.49	Sandstone			FR			186504	3961	7.8	0.37	0.01	0	9	-9	29.75	6.2	0	2	NAF
SMC006	104.72	105.85	1.13	Claystone			FR			186505	3962	8.1	0.41	0.03	1	26	-25	27.98	7.5	0	0	NAF
SMC006	105.85	106.20	0.35	Carb Claystone/Coal			FR	Not Available		186506												
SMC006	106.20	107.95	1.75	Sandstone			FR			186507	3964	8.0	0.36	0.04	1	42	-41	34.48	7.6	0	0	NAF
SMC006	107.95	108.18	0.23	Claystone/Coal			FR			186508	3965	7.4	0.35	0.11	3	23	-20	6.87	7.3	0	0	NAF
SMC006	108.18	108.27	0.09	Claystone			FR		184784					0.01	0							NAF
SMC006	108.27	108.71	0.44	Coal	LBE	Lemington	FR	Calcite	184785					0.71	22							
SMC006	108.71	108.78	0.07	Sandstone/Carb Claystone			FR		184786					0.08	2							
SMC006	108.78	109.50	0.72	Sandstone/Tuff			FR			186509	3966			0.04	1	21	-20	17.23				NAF
SMC006	109.50	109.63	0.13	Sandstone			FR		184787					0.01	0							NAF
SMC006	109.63	110.24	0.61	Coal	LBD	Lemington	FR		184788					0.63	19							
SMC006	110.24	110.33	0.09	Claystone			FR		184789					0.20	6							
SMC006	110.33	110.87	0.54	Sandstone			FR			186510	3967			<0.01	0	12	-12	79.67				NAF
SMC006	110.87	110.96	0.09	Claystone			FR		184790					0.07	2							
SMC006	110.96	111.46	0.50	Coal	LBC	Lemington	FR		184791					0.63	19							
SMC006	111.46	111.59	0.13	Claystone			FR		184792					0.13	4							
SMC006	111.59	112.99	1.40	Claystone/Sandstone			FR			186511	3968			0.05	2	32	-30	20.64				NAF
SMC006	112.99	113.07	0.08	Claystone			FR		184793					0.26	8							
SMC006	113.07	113.44	0.37	Coal	LBB	Lemington	FR		184794					0.81	25							
SMC006	113.44	113.58	0.14	Carb Claystone			FR		184795					0.60	18							
SMC006	113.58	114.23	0.65	Coal	LBA	Lemington	FR		184796					1.26	39							
SMC006	114.23	114.33	0.10	Siltstone			FR		184797					0.02	1							NAF
SMC006	114.33	115.32	0.99	Sandstone/Siltstone			FR			186512	3969			<0.01	0	20	-20	130.66				NAF
SMC006	115.32	117.98	2.66	Sandstone/Claystone			FR			186513	3970			0.03	1	31	-30	33.87				NAF
SMC006	117.98	123.79	5.81	Sandstone			FR			186514	3971			0.02	1	32	-31	52.36				NAF
SMC006	123.79	126.81	3.02	Sandstone			FR			186515	3972			0.02	1	30	-29	49.10				NAF
SMC006	126.81	130.80	3.99	Sandstone			FR			186516	3973			0.01	0	26	-26	86.13				NAF
SMC006	130.80	134.07	3.27	Sandstone/Conglomerate			FR			186517	3974			0.03	1	61	-60	66.01				NAF
SMC006	134.07	135.19	1.12	Siltstone			FR			186518	3975			<0.01	0	15	-15	100.46				NAF
SMC006	135.19	138.86	3.67	Conglomerate			FR			186519	3976			0.04	1	32	-31	26.26				NAF
SMC006	138.86	141.50	2.64	Conglomerate			FR			186520	3977			0.02	1	36	-35	58.12				NAF
SMC006	141.50	142.51	1.01	Conglomerate			FR			186521	3978	7.6	0.71	0.35	11	16	-6	1.52	7.8	0	0	NAF
SMC006	142.51	142.60	0.09	Siltstone/Claystone			FR		184798					0.86	26							
SMC006	142.60	143.17	0.57	Coal	LAM	Lemington	FR		184799					1.47	45							
SMC006	143.17	143.47	0.30	Coal	LAL	Lemington	FR		184800					0.97	30							
SMC006	143.47	143.87	0.40	Coal	LAK	Lemington	FR		184601					1.73	53							
SMC006	143.87	144.01	0.14	Sandstone/Claystone			FR		184602					1.27	39							
SMC006	144.01	145.02	1.01	Sandstone/Claystone			FR			186522	3979	7.9	0.63	0.05	2	62	-60	40.33	7.9	0	0	NAF
SMC006	145.02	146.43	1.41	Claystone/Sandstone/Siltstone			FR			186523	3980	7.7	0.56	0.04	1	36	-35	29.71	8.1	0	0	NAF
SMC006	146.43	146.58	0.15	Sandstone			FR		184603					<0.01	0							NAF
SMC006	146.58	146.92	0.34	Coal	LAJU	Lemington	FR		184604					0.78	24							
SMC006	146.92	147.05	0.13	Sandstone/Carb Claystone			FR		184605					0.29	9							
SMC006	147.05	148.48	1.43	Sandstone			FR			186524	3981	7.8	0.68	<0.01	0	32	-31	206.82	8.2	0	0	NAF
SMC006	148.48	149.05	0.57	Claystone			FR			186525	3982	7.6	0.49	0.09	3	25	-22	8.97	7.8	0	0	NAF
SMC006	149.05	149.18	0.13	Claystone/Carb Claystone			FR		184606					0.01	0							NAF
SMC006	149.18	149.57	0.39	Coal	LAJM	Lemington	FR		184607					0.88	27							
SMC006	149.57	149.71	0.14	Claystone			FR		184608					0.09	3							
SMC006	149.71	150.79	1.08	Sandstone/Siltstone			FR			186526	3983	7.7	0.47	<0.01	0	37	-37	242.88	7.6	0	0	NAF
SMC006	150.79	150.91	0.12	Siltstone			FR		184609					<0.01	0							NAF
SMC006	150.91	151.46	0.55	Coal	LAJ	Lemington	FR	Calcite	184610					0.74	23							
SMC006	151.46	151.59	0.13	Carb Claystone			FR		184611					0.48	15							
SMC006	151.59	152.33	0.74	Claystone			FR			186527	3984	8.5	0.37	0.05	2	7	-5	4.56	6.2	0	1	NAF
SMC006	152.33	153.07	0.74	Sandstone			FR			186528	3985	8.2	0.23	0.04	1	53	-52	43.39	7.5	0	0	NAF
SMC006	153.07	153.18	0.11	Sandstone/Carb Claystone/Tuff			FR		184612					0.23	7							
SMC006	153.18	153.62	0.44	Coal	LAHU	Lemington	FR		184613					1.52	47							
SMC006	153.62	153.72	0.10	Sandstone			FR		184614					0.15	5							
SMC006	153.72	154.17	0.45	Sandstone			FR			186529	3986	8.1	0.39	0.07	2	55	-52	25.50	7.6	0	0	NAF
SMC006	154.17	154.25	0.08	Claystone			FR		184615					0.71	22							
SMC006	154.25	154.61	0.36	Coal	LAH	Lemington	FR		184616					4.16	127							
SMC006	154.61	154.77	0.16	Claystone			FR		184617					0.95	29							
SMC006	154.77	154.98	0.21	Coal	LAG	Lemington	FR		184618					3.56	109							
SMC006	154.98	155.02	0.04	Claystone			FR		184619					0.26	8							
SMC006	155.02	155.35	0.33	Coal	LAF	Lemington	FR		184620					0.81	25							
SMC006	155.35	155.45	0.10	Sandstone			FR		184621					0.02	1							NAF
SMC006	155.45	156.91	1.46	Sandstone			FR			186530	3987	8.0	0.47	<0.01	0	28	-28	186.16	7.7	0	0	NAF
SMC006	156.91	158.39	1.48	Sandstone			FR			186531	3988	7.9	0.54	0.09	3	132	-130	48.11	7.9	0	0	NAF
SMC006	158.39	159.23	0.84	Claystone/Siltstone			FR	Minor Coal		186532	3989	7.8	0.30	<0.01	0	14	-14	91.98	6.9	0	0	NAF
SMC006	159.23	159.32	0.09	Claystone			FR		184623					0.26	8							
SMC006	159.32	159.81	0.49	Coal	LAE	Lemington	FR		184624					0.99	30							
SMC006	159.81	160.34	0.53	Claystone/Coal			FR		184625					0.18	6							
SMC006	160.34	160.61	0.27	Coal	LAD	Lemington	FR		184626					0.62	19							
SMC006	160.61	160.82	0.21	Tuff			FR		184627					0.01	0							NAF
SMC006	160.82	161.16	0.34	Coal	LAC	Lemington	FR		184628					1.83	56							
SMC006	161.16	161.34	0.18	Claystone			FR		184629					2.56	78							
SMC006	161.34	161.63	0.29	Coal	LAB	Lemington	FR		184630					3.02	92							
SMC006	161.63	162.12	0.49	Siltstone/Claystone			FR		184631					0.11	3							
SMC006	162.12	162.46	0.34	Coal	LAA	Lemington	FR		184632					0.96	29							
SMC006	162.46	162.57	0.11	Siltstone/Carb Siltstone			FR		184633					0.02	1							NAF
SMC006	162.57	162.99	0.42	Siltstone/Claystone			FR	Minor Coal		186533	3990	7.5	0.35	0.06	2	14	-12	7.43	5.2	0	3	NAF
SMC006	162.99	165.05	2.06	Sandstone/Siltstone/Claystone			FR			186534	3991	7.6	0.72	0.07	2	64	-61	29.68	8.1	0	0	NAF
SMC006	165.05	166.54	1.49	Sandstone/Siltstone			FR	Siderite Band		186535	3992			0.01	0	40	-40	130.51				NAF

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m)			Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					SINGLE ADDITION NAG			ARD Classification
	From	To	Interval											Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
SMC006	166.54	167.60	1.06	Claystone			FR			186536	3993			0.01	0	11	-11	37.57				NAF
SMC006	167.60	169.13	1.53	Sandstone			FR			186537	3994			<0.01	0	41	-41	269.08				NAF
SMC006	169.13	169.99	0.86	Claystone/Sandstone/Siltstone			FR			186538	3995			<0.01	0	12	-12	81.30				NAF
SMC006	169.99	170.16	0.17	Coal	PG3	Pikes Gully	FR			186539	3996	4.2	1.33	0.41	13	29	-16	2.27	2.8	14	37	PAF-LC
SMC006	170.16	171.03	0.87	Sandstone			FR			186540	3997	7.3	0.21	0.03	1	42	-41	45.73	7.6	0	0	NAF
SMC006	171.03	171.89	0.86	Sandstone			FR			186541	3998	7.4	0.25	<0.01	0	45	-45	292.47	7.8	0	0	NAF
SMC006	171.89	173.02	1.13	Sandstone/Claystone			FR			186542	3999	7.6	0.24	<0.01	0	56	-56	365.71	7.9	0	0	NAF
SMC006	173.02	175.37	2.35	Sandstone/Siltstone/Claystone			FR	Coally		186543	4000	7.8	0.28	0.07	2	34	-32	15.91	8.2	0	0	NAF
SMC006	175.37	177.68	2.31	Sandstone			FR			186544	4001			<0.01	0	72	-72	468.72				NAF
SMC006	177.68	177.80	0.12	Sandstone			FR		184622					0.09	3							
SMC006	177.80	177.99	0.19	Coal	PG2U	Pikes Gully	FR		184634		5299	6.9	0.13	1.50	46	39	7	0.84	7.2	0	0	UC(NAF)
SMC006	177.99	178.27	0.28	Claystone/Carb Claystone			FR		184635					1.45	44							
SMC006	178.27	178.42	0.15	Coal	PG2L	Pikes Gully	FR		184636					2.63	80							
SMC006	178.42	178.64	0.22	Claystone			FR		184637					1.28	39							
SMC006	178.64	180.04	1.40	Coal	PG1	Pikes Gully	FR		184638		5300	7.2	0.10	0.61	19	22	-4	1.19	6.5	0	1	NAF
SMC006	180.04	180.16	0.12	Sandstone			FR		184639					0.12	4							
SMC006	180.16	181.29	1.13	Siltstone/Sandstone/Claystone			FR			186545	4002			<0.01	0	10	-10	68.22				NAF
SMC006	181.29	183.84	2.55	Sandstone			FR			186546	4003			<0.01	0	38	-37	245.20				NAF
SMC006	183.84	186.88	3.04	Sandstone			FR			186547	4004			<0.01	0	27	-27	175.11				NAF
SMC006	186.88	189.73	2.85	Sandstone/Siltstone			FR			186548	4005			<0.01	0	13	-13	84.25				NAF
SMC006	189.73	191.92	2.19	Sandstone/Siltstone			FR	Siderite Band		186549	4006			<0.01	0	40	-39	258.70				NAF
SMC006	191.92	193.23	1.31	Sandstone			FR			186550	4007			0.01	0	12	-12	38.80				NAF
SMC006	193.23	197.23	4.00	Conglomerate			FR	Two Bags		186551	4008			0.01	0	28	-27	90.84				NAF
SMC006	197.23	198.71	1.48	Sandstone			FR			186552	4009			<0.01	0	31	-31	203.86				NAF
SMC006	198.71	202.11	3.40	Conglomerate			FR			186553	4010			0.03	1	24	-23	26.14				NAF
SMC006	202.11	203.46	1.35	Sandstone/Conglomerate			FR			186554	4011	8.1	0.20	0.07	2	81	-79	37.80	8.3	0	0	NAF
SMC006	203.46	204.40	0.94	Claystone/Siderite			FR	Siderite Band		186555	4012	7.5	0.18	0.14	4	12	-8	2.91	8.0	0	0	NAF
SMC006	204.40	204.56	0.16	Claystone			FR		184640					0.11	3							
SMC006	204.56	204.71	0.15	Coal	ARU3	Arties	FR		184641					0.61	19							
SMC006	204.71	205.01	0.30	Claystone			FR		184642					0.69	21							
SMC006	205.01	205.44	0.43	Coal	ARU2/ARU1	Arties	FR	Incudes 11cm CY/CS parting	184643_45					0.64	20							
SMC006	205.44	205.56	0.12	Siltstone			FR		184646					0.10	3							
SMC006	205.56	206.37	0.81	Coal	ART4	Arties	FR		184647		5301	7.3	0.09	0.81	25	23	1	0.94	7.5	0	0	UC(NAF)
SMC006	206.37	206.71	0.34	Claystone			FR		184648					0.02	1							NAF
SMC006	206.71	207.53	0.82	Coal	ART4L1/L2/L3	Arties	FR	Incudes ST partings	184649_53		5302	7.4	0.09	0.25	8	39	-31	5.06	7.6	0	0	NAF
SMC006	207.53	207.77	0.24	Tuff			FR		184654					0.64	20							
SMC006	207.77	209.12	1.35	Coal	ART3	Arties	FR		184655		5303	7.5	0.09	0.67	21	44	-24	2.15	7.4	0	0	NAF
SMC006	209.12	209.26	0.14	Tuff			FR		184656					<0.01	0							NAF
SMC006	209.26	209.65	0.39	Coal	ART2	Arties	FR		184657					0.41	13							
SMC006	209.65	209.72	0.07	Tuff/Carb Claystone			FR		184658					0.04	1							NAF
SMC006	209.72	210.27	0.55	Coal	ART1	Arties	FR		184659					0.41	13							
SMC006	210.27	210.39	0.12	Sandstone			FR		184660					0.10	3							
SMC006	210.39	211.79	1.40	Sandstone/Siltstone			FR			186556	4013	7.3	0.21	<0.01	0	75	-75	492.73	7.9	0	0	NAF
SMC006	211.79	212.48	0.69	Claystone			FR			186557	4014			0.01	0	13	-13	42.77				NAF
SMC006	212.48	215.24	2.76	Sandstone/Siltstone			FR			186558	4015			<0.01	0	31	-31	203.18				NAF
SMC006	215.24	219.97	4.73	Sandstone			FR	Two Bags		186559	4016			<0.01	0	50	-50	326.18				NAF
SMC006	219.97	222.22	2.25	Sandstone/Siderite/Claystone			FR	Siderite Band		186560	4017			0.01	0	49	-49	159.68				NAF
SMC006	222.22	224.32	2.10	Sandstone			FR			186561	4018			<0.01	0	44	-44	286.45				NAF
SMC006	224.32	225.00	0.68	Claystone			FR			186562	4019			0.03	1	13	-12	14.48				NAF
SMC006	225.00	225.07	0.07	Claystone			FR		184661					0.18	6							
SMC006	225.07	226.21	1.14	Coal	LID8	Liddell	FR		184662		5304	7.4	0.12	0.52	16	20	-4	1.24	7.1	0	0	NAF
SMC006	226.21	226.29	0.08	Tuff			FR		184663					0.32	10							
SMC006	226.29	227.47	1.18	Coal	LID7	Liddell	FR		184664		5305	7.8	0.13	0.66	20	39	-18	1.91	7.4	0	0	NAF
SMC006	227.47	228.34	0.87	Coal	LID6	Liddell	FR		184665					0.53	16							
SMC006	228.34	228.46	0.12	Sandstone			FR		184666					0.37	11							
SMC006	228.46	228.94	0.48	Sandstone			FR			186563	4020			<0.01	0	8	-8	51.94				NAF
SMC006	228.94	230.30	1.36	Sandstone/Siltstone			FR			186564	4021			0.03	1	41	-40	45.08				NAF
SMC006	230.30	234.93	4.63	Sandstone			FR	Lesser ST, Two Bags		186565	4022			0.03	1	19	-19	21.23				NAF
SMC006	234.93	236.10	1.17	Conglomerate/Sandstone			FR			186566	4023			0.02	1	63	-62	102.20				NAF
SMC006	236.10	239.15	3.05	Sandstone			FR			186567	4024			<0.01	0	104	-104	679.34				NAF
SMC006	239.15	239.52	0.37	Sandstone			FR			186568	4025	6.7	0.67	0.86	26	7	19	0.27	2.7	14	19	PAF
SMC006	239.52	239.68	0.16	Coal	LID5B BAND 2	Liddell	FR			186569	4026	8.3	0.16	<0.01	0	25	-24	160.97	6.2	0	2	NAF
SMC006	239.68	240.54	0.86	Claystone			FR			186570	4027	8.1	0.14	<0.01	0	12	-12	81.02	7.5	0	0	NAF
SMC006	240.54	240.73	0.19	Coal	LID5B BAND 1	Liddell	FR			186571	4028	8.2	0.12	<0.01	0	26	-26	170.36	5.8	0	3	NAF
SMC006	240.73	241.83	1.10	Sandstone/Siltstone			FR			186572	4029	8.1	0.23	<0.01	0	58	-58	378.30	7.6	0	0	NAF
SMC006	241.83	242.31	0.48	Claystone			FR			186573	4030			<0.01	0	13	-13	84.35				NAF
SMC006	242.31	242.44	0.13	Claystone			FR		184667					0.08	2							
SMC006	242.44	242.87	0.43	Coal	LID5B	Liddell	FR		184668					0.67	21							
SMC006	242.87	243.03	0.16	Sandstone			FR		184669					<0.01	0							NAF
SMC006	243.03	243.35	0.32	Sandstone			FR			186574	4031			<0.01	0	12	-12	77.67				NAF
SMC006	243.35	244.14	0.79	Claystone/Coal			FR			186575	4032			<0.01	0	54	-53	349.84				NAF
SMC006	244.14	244.25	0.11	Claystone			FR		184670					0.01	0							NAF
SMC006	244.25	245.09	0.84	Coal	LID5	Liddell	FR		184671					0.59	18							
SMC006	245.09	245.21	0.12	Claystone			FR		184672					0.34	10							
SMC006	245.21	246.58	1.37	Sandstone			FR	Coally		186576	4033			0.01	0	11	-11	35.39				NAF
SMC006	246.58	247.26	0.68	Claystone/Siltstone			FR			186577	4034			0.03	1	14	-13	15.50				NAF
SMC006	247.26	252.22	4.96	Sandstone			FR	Two Bags		186578	4035			<0.01	0	41	-41	269.13				NAF
SMC006	252.22	257.39	5.17	Sandstone			FR	Two Bags		186579	4036			<0.01	0	65	-65	422.88				NAF
SMC006	257.39	259.18	1.79	Sandstone			FR			186580	4037	7.7	0.28	0.01	0	121	-121	395.92	7.7	0	0	NAF
SMC006	259.18	259.82	0.64	Siltstone/Calcite/Siderite			FR	Calcite&Siderite, Band Not Available		186581												
SMC006	259.82	261.42	1.60	Siltstone			FR			186582	4039	7.8	0.29	0.20	6	11	-5	1.86	7.3	0	0	NAF
SMC006	261.42	261.54	0.12	Carb Claystone/Claystone			FR		184673					1.39	43							
SMC006	261.54	264.29	2.75	Coal	LID4	Liddell	FR		184674		5306	7.4	0.12	0.60	18	15	3	0.81	6.9	0	0	UC(NAF)

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m)			Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					SINGLE ADDITION NAG			ARD Classification
	From	To	Interval											Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
SMC006	264.29	264.41	0.12	Siltstone			FR		184675					0.03	1							NAF
SMC006	264.41	266.25	1.84	Sandstone			FR			186583	4040	7.5	0.28	<0.01	0	66	-65	428.92	7.7	0	0	NAF
SMC006	266.25	267.34	1.09	Siltstone/Siderite			FR	Siderite Band		186584	4041			0.03	1	36	-35	39.33				NAF
SMC006	267.34	267.44	0.10	Carb Claystone			FR		184676					0.28	9							
SMC006	267.44	267.85	0.41	Coal	LID3	Liddell	FR		184677					0.71	22							
SMC006	267.85	267.96	0.11	Sandstone/Claystone			FR		184678					0.02	1							NAF
SMC006	267.96	269.59	1.63	Sandstone			FR	Siderite		186585	4042			0.03	1	31	-30	33.62				NAF
SMC006	269.59	270.99	1.40	Claystone/Sandstone			FR			186586	4043			<0.01	0	36	-36	236.04				NAF
SMC006	270.99	271.39	0.40	Claystone/Siderite			FR	Sideirte bands, coally		186587	4044			<0.01	0	128	-128	838.32				NAF
SMC006	271.39	274.43	3.04	Sandstone			FR	Lesser ST		186588	4045			<0.01	0	57	-57	372.09				NAF
SMC006	274.43	275.04	0.61	Claystone/Siderite/Siltstone			FR	Sideirte bands, coally		186589	4046			0.05	2	67	-65	43.80				NAF
SMC006	275.04	277.02	1.98	Sandstone			FR			186590	4047			0.01	0	38	-38	125.13				NAF
SMC006	277.02	277.64	0.62	Sandstone/Claystone			FR	Sideirte bands		186591	4048			0.01	0	40	-40	131.78				NAF
SMC006	277.64	280.23	2.59	Sandstone			FR			186592	4049			<0.01	0	66	-66	431.38				NAF
SMC006	280.23	281.42	1.19	Sandstone/Siltstone/Claystone			FR			186593	4050			0.03	1	11	-10	12.04				NAF
SMC006	281.42	283.01	1.59	Sandstone/Siltstone			FR			186594	4051			<0.01	0	31	-31	200.98				NAF
SMC006	283.01	284.35	1.34	Sandstone/Claystone			FR			186595	4052			0.01	0	15	-15	49.54				NAF
SMC006	284.35	288.33	3.98	Sandstone			FR	Two Bags		186596	4053			0.01	0	42	-42	137.13				NAF
SMC006	288.33	289.31	0.98	Siltstone			FR			186597	4054			0.01	0	20	-20	66.60				NAF
SMC006	289.31	290.34	1.03	Sandstone/Siltstone			FR			186598	4055	7.9	0.27	0.03	1	12	-11	13.50	7.5	0	0	NAF
SMC006	290.34	290.45	0.11	Sandstone/Carb Siltstone			FR		184679					0.64	20							
SMC006	290.45	291.73	1.28	Coal	LID12	Liddell	FR		184680					0.47	14							
SMC006	291.73	292.02	0.29	Carb Claystone/Siltstone			FR		184681					0.16	5							
SMC006	292.02	292.25	0.23	Siltstone/Coal			FR	Core Loss?		186599	4056	9.1	0.37	0.06	2	9	-7	4.82	3.6	5	17	NAF
SMC006	292.25	294.50	2.25	Siltstone			FR			186600	4057	8.7	0.33	0.01	0	23	-22	74.42	8.0	0	0	NAF
SMC006	294.50	295.56	1.06	Siltstone/Claystone			FR			186601	4058	8.8	0.41	0.02	1	46	-45	74.63	7.6	0	0	NAF
SMC006	295.56	295.68	0.12	Claystone/Carb Claystone			FR		184682					0.05	2							NAF
SMC006	295.68	298.38	2.70	Coal	BAR13/12	Barrett	FR		184687		5307	7.5	0.12	0.46	14	11	3	0.79	5.9	0	2	UC(NAF)
SMC006	298.38	298.50	0.12	Sandstone			FR		184686					<0.01	0							NAF
SMC006	298.50	299.60	1.10	Sandstone			FR			186602	4059			0.04	1	11	-9	8.66				NAF
SMC006	299.60	303.48	3.88	Sandstone			FR	Lesser ST, Two Bags		186603	4060			0.02	1	23	-23	37.98				NAF
SMC006	303.48	308.48	5.00	Sandstone			FR	Two Bags		186604	4061			0.02	1	37	-36	60.60				NAF
SMC006	308.48	313.65	5.17	Sandstone			FR	Two Bags		186605	4062			0.01	0	37	-37	120.82				NAF
SMC006	313.65	319.05	5.40	Sandstone			FR	Two Bags		186606	4063			<0.01	0	26	-26	172.65				NAF
SMC006	319.05	320.82	1.77	Sandstone			FR			186607	4064			<0.01	0	55	-54	356.93				NAF
SMC006	320.82	322.31	1.49	Siltstone			FR			186608	4065			0.01	0	22	-22	71.27				NAF
SMC006	322.31	322.53	0.22	Claystone/Coal			FR			186609	4066			0.04	1	9	-7	7.12				NAF
SMC006	322.53	322.63	0.10	Claystone			FR		184688					<0.01	0							NAF
SMC006	322.63	324.21	1.58	Coal	UH2	Hebden	FR		184689		5308	7.3	0.11	0.35	11	23	-13	2.18	7.2	0	0	NAF
SMC006	324.21	324.41	0.20	Tuff			FR		184690					<0.01	0							NAF
SMC006	324.41	326.15	1.74	Coal	UH1	Hebden	FR		184691		5309	7.4	0.10	0.46	14	8	6	0.57	5.1	0	6	UC(NAF)
SMC006	326.15	326.24	0.09	Siltstone			FR		184692					<0.01	0							NAF
SMC006	326.24	327.57	1.33	Siltstone			FR			186610	4067			0.04	1	17	-15	13.49				NAF
SMC006	327.57	331.03	3.46	Sandstone			FR	Two Bags		186611	4068			0.03	1	37	-37	40.81				NAF
SMC006	331.03	334.87	3.84	Sandstone			FR	Two Bags		186612	4069			<0.01	0	25	-25	165.09				NAF
SMC006	334.87	340.30	5.43	Sandstone			FR	Two Bags		186613	4070			<0.01	0	35	-35	227.59				NAF
SMC006	340.30	340.99	0.69	Siltstone/Claystone			FR			186614	4071	7.8	0.27	0.03	1	13	-12	14.26	7.2	0	0	NAF
SMC006	340.99	341.09	0.10	Claystone/Carb Claystone			FR	Calcite	184693					0.01	0							NAF
SMC006	341.09	342.81	1.72	Coal	HEB	Hebden	FR		184694		5310	7.2	0.10	0.46	14	30	-16	2.16	7.6	0	0	NAF
SMC006	342.81	342.92	0.11	Sandstone			FR		184695					<0.01	0							NAF
SMC006	342.92	343.75	0.83	Sandstone			FR			186615	4072	7.9	0.24	0.09	3	36	-33	13.05	7.6	0	0	NAF
SMC006	343.75	346.36	2.61	Sandstone/Siltstone			FR			186616	4073	7.6	0.23	<0.01	0	28	-28	180.98	8.2	0	0	NAF
SMC006	346.36	346.56	0.20	Coal/Claystone/Sandstone			FR			186617	4074	9.4	0.26	0.13	4	29	-25	7.28	8.3	0	0	NAF
SMC006	346.56	349.04	2.48	Sandstone/Siltstone			FR			186618	4075	8.3	0.26	<0.01	0	49	-49	320.02	8.1	0	0	NAF
SMC006	349.04	350.19	1.15	Sandstone			FR			186619	4076	8.2	0.27	<0.01	0	90	-90	588.42	8.2	0	0	NAF
SMC006	350.19	350.37	0.18	Claystone			FR			186620	4077	8.0	0.43	0.07	2	15	-13	6.97	7.7	0	0	NAF
SMC006	350.37	350.51	0.14	Claystone			FR		184696					<0.01	0							NAF
SMC006	350.51	350.94	0.43	Coal	UNK		FR	Calcite	184697					0.50	15							
SMC006	350.94	351.06	0.12	Claystone			FR	Calcite	184698					<0.01	0							NAF
SMC006	351.06	351.24	0.18	Carb Claystone			FR			186621	4078	7.2	0.83	0.75	23	7	16	0.32	3.1	6	21	PAF
SMC006	351.24	352.98	1.74	Sandstone			FR			186622	4079	7.3	0.29	0.96	29	44	-14	1.49	7.5	0	0	NAF
SMC006	352.98	354.25	1.27	Siltstone			FR			186623	4080	4.7	2.11	1.26	39	10	28	0.26	2.6	16	27	PAF
SMC006	354.25	358.04	3.79	Sandstone			FR	Two Bags		186625	4081	7.2	0.30	0.09	3	44	-41	15.93	8.1	0	0	NAF
SMC006	358.04	364.09	6.05	Sandstone			FR	Two Bags		186624	4082	7.1	0.20	0.08	2	50	-48	20.49	7.9	0	0	NAF
GNC004	0.00	4.75	4.75					Open Hole - No Sample														
GNC004	4.75	9.05	4.30	Sandstone			HW	Open Hole - No Sample														
GNC004	9.05	10.75	1.70	Carb Claystone			MW	Open Hole - No Sample														
GNC004	10.75	11.25	0.50	Weathered Coal				Open Hole - No Sample														
GNC004	11.25	12.82	1.57	Carb Siltstone				Open Hole - No Sample														
GNC004	12.82	13.65	0.83	Siltstone				Open Hole - No Sample														
GNC004	13.65	13.92	0.27	Coal				Open Hole - No Sample														
GNC004	13.92	16.75	2.83	Sandstone				Open Hole - No Sample														
GNC004	16.75	23.45	6.70	Sandstone				Open Hole - No Sample														
GNC004	23.45	23.75	0.30	Carb Claystone				Open Hole - No Sample														
GNC004	23.75	25.75	2.00	Sandstone				Open Hole - No Sample														
GNC004	25.75	27.00	1.25	Sandstone				Open Hole - No Sample														
GNC004	27.00	27.90	0.90	Sandstone				Open Hole - No Sample														
GNC004	27.90	28.90	1.00	Coal	LCF	Lemington		Open Hole - No Sample														
GNC004	28.90	33.08	4.18	Sandstone				Open Hole - No Sample														
GNC004	33.08	34.53	1.45	Sandstone				Open Hole - No Sample														
GNC004	34.53	36.55	2.02	Sandstone			FR			31106	4475	7.5	0.15	0.09	3	14	-11	4.93	8.2	0	0	NAF
GNC004	36.55	38.51	1.96	Sandstone			FR			31107	4476	8.1	0.22	0.06	2	58	-56	31.69	8.4	0	0	NAF
GNC004	38.51	39.76	1.25	Sandstone			FR			31108	4477	7.7	0.33	0.08	2	18	-15	7.29	8.5	0	0	NAF

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m) From	Depth (m) To	Depth (m) Interval	Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS Total %S	MPA	ANC	NAPP	ANC/MPA	SINGLE ADDITION NAG NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	ARD Classification
GNC004	39.76	39.88	0.12	Sandstone/Claystone			FR		184247					0.44	13							
GNC004	39.88	40.11	0.23	Coal	LCB	Lemington	FR		184248					1.67	51							
GNC004	40.11	40.26	0.15	Tuff			FR		184249					0.39	12							
GNC004	40.26	40.91	0.65	Coal	LCA	Lemington	FR		184250					1.60	49							
GNC004	40.91	41.02	0.11	Sandstone			FR		184251					0.17	5							
GNC004	41.02	41.93	0.91	Sandstone			FR			31109	4478	8.3	0.42	0.08	2	17	-14	6.81	8.2	0	0	NAF
GNC004	41.93	42.71	0.78	Carb Claystone			FR			31110	4479	8.2	0.32	0.17	5	18	-13	3.50	8.1	0	0	NAF
GNC004	42.71	48.49	5.78	Sandstone/Claystone/Siltstone			FR	Siderite (2 bags for NAG samples)		31111	4480	7.8	0.33	0.11	3	23	-20	6.86	8.0	0	0	NAF
GNC004	48.49	51.47	2.98	Sandstone			FR	Siderite		31112	4481	7.9	0.28	0.01	0	35	-34	113.04	7.8	0	0	NAF
GNC004	51.47	54.53	3.06	Sandstone			FR			31113	4482	6.8	0.02	<0.01	0	19	-18	121.51	7.9	0	0	NAF
GNC004	54.53	57.55	3.02	Sandstone			FR	Calcite		31114	4483	8.2	0.26	<0.01	0	72	-72	469.30	7.8	0	0	NAF
GNC004	57.55	59.06	1.51	Sandstone			FR			31115	4484	7.8	0.21	0.06	2	24	-22	13.06	8.1	0	0	NAF
GNC004	59.06	59.31	0.25	Siltstone			FR			31116	4485	7.9	0.20	0.05	2	16	-15	10.52	7.5	0	0	NAF
GNC004	59.31	59.35	0.04	Claystone			FR			31117	4486	8.2	0.19	0.21	6	26	-19	4.03	7.4	0	0	NAF
GNC004	59.35	59.49	0.14	Claystone/Siderite			FR	Siderite	184252					0.23	7							
GNC004	59.49	59.89	0.40	Coal	LBLM	Lemington	FR		184253					0.98	30							
GNC004	59.89	60.03	0.14	Sandstone			FR		184254					0.14	4							
GNC004	60.03	60.88	0.85	Sandstone			FR			31118	4487	7.7	0.20	0.10	3	11	-8	3.71	7.5	0	0	NAF
GNC004	60.88	64.21	3.33	Sandstone			FR			31119	4488	7.6	0.16	<0.01	0	32	-32	209.43	8.2	0	0	NAF
GNC004	64.21	65.58	1.37	Claystone/Siltstone/Sandstone			FR			31120	4489	7.5	0.20	0.01	0	17	-16	54.48	8.4	0	0	NAF
GNC004	65.58	69.56	3.98	Sandstone			FR	(2 bags for NAG samples)		31121	4490	7.7	0.17	<0.01	0	15	-15	96.10	8.3	0	0	NAF
GNC004	69.56	71.92	2.36	Sandstone			FR			31122	4491	7.8	0.16	0.02	1	15	-14	24.41	8.3	0	0	NAF
GNC004	71.92	72.65	0.73	Siltstone			FR			31123	4492	8.1	0.18	0.01	0	17	-17	56.48	8.1	0	0	NAF
GNC004	72.65	77.37	4.72	Sandstone			FR	(2 bags for NAG samples)		31124	4493	7.9	0.15	<0.01	0	29	-29	192.51	8.5	0	0	NAF
GNC004	77.37	77.59	0.22	Coal/Claystone			FR			31125	4494	8.2	0.18	0.17	5	13	-7	2.43	8.9	0	0	NAF
GNC004	77.59	80.01	2.42	Sandstone/Siltstone			FR			31126	4495			0.01	0	15	-15	48.74				NAF
GNC004	80.01	82.09	2.08	Sandstone/Claystone/Siltstone			FR			31127	4496			<0.01	0	36	-36	238.47				NAF
GNC004	82.09	84.95	2.86	Sandstone			FR	Siderite		31128	4497			<0.01	0	91	-91	597.76				NAF
GNC004	84.95	88.61	3.66	Sandstone			FR			31129	4498			0.02	1	41	-40	66.54				NAF
GNC004	88.61	93.64	5.03	Conglomerate			FR	(2 bags for NAG samples)		31130	4499			0.03	1	47	-46	51.43				NAF
GNC004	93.64	95.73	2.09	Conglomerate			FR			31131	4500			0.03	1	17	-16	18.20				NAF
GNC004	95.73	95.87	0.14	Conglomerate			FR		186054					0.75	23							
GNC004	95.87	96.08	0.21	Coal	BAND1		FR		186055					1.46	45							
GNC004	96.08	96.21	0.13	Carb Claystone/Sandstone			FR		186056					2.05	63							
GNC004	96.21	97.98	1.77	Sandstone			FR			31132	4501	6.8	0.22	0.11	3	16	-13	4.88	8.4	0	0	NAF
GNC004	97.98	98.71	0.73	Sandstone/Siltstone			FR			31133	4502	7.8	0.18	0.30	9	15	-6	1.60	5.9	0	1	NAF
GNC004	98.71	99.95	1.24	Siltstone/Carb Claystone			FR	Calcite		31134	4503			<0.01	0	24	-24	158.19				NAF
GNC004	99.95	100.05	0.10	Claystone			FR		184255					0.34	10							
GNC004	100.05	100.41	0.36	Coal	LAM	Lemington	FR	Pyrite	184256					0.93	28							
GNC004	100.41	100.72	0.31	Coal	LAL	Lemington	FR		184257					0.61	19							
GNC004	100.72	100.84	0.12	Claystone			FR		184258					0.10	3							
GNC004	100.84	101.00	0.16	Coal	LAK	Lemington	FR		184259					0.60	18							
GNC004	101.00	101.12	0.12	Claystone			FR		184260					0.01	0							NAF
GNC004	101.12	102.05	0.93	Claystone			FR			31135	4504			0.01	0	18	-17	57.47				NAF
GNC004	102.05	105.06	3.01	Sandstone			FR	Calcite		31136	4505	8.3	0.24	<0.01	0	80	-80	524.98	7.5	0	0	NAF
GNC004	105.06	107.82	2.76	Sandstone/Siltstone			FR			31137	4506	8.2	0.17	<0.01	0	15	-15	98.89	8.1	0	0	NAF
GNC004	107.82	109.52	1.70	Sandstone			FR			31138	4507	6.9	0.21	0.01	0	62	-61	201.30	7.8	0	0	NAF
GNC004	109.52	111.25	1.73	Siltstone/Sandstone			FR			31139	4508	6.8	0.15	0.01	0	16	-16	52.75	7.3	0	0	NAF
GNC004	111.25	117.20	5.95	Sandstone			FR	Siderite, minor calcite		31140	4509			<0.01	0	27	-27	179.65				NAF
GNC004	117.20	120.33	3.13	Conglomerate/Sandstone			FR	(2 bags for NAG samples)		31141	4510			<0.01	0	35	-34	225.96				NAF
GNC004	120.33	125.21	4.88	Sandstone			FR			31142	4511			<0.01	0	26	-26	170.15				NAF
GNC004	125.21	125.72	0.51	Siltstone			FR	Calcite, Siderite		31143	4512			0.01	0	202	-202	659.65				NAF
GNC004	125.72	128.46	2.74	Sandstone			FR			31144	4513			<0.01	0	40	-40	262.77				NAF
GNC004	128.46	131.37	2.91	Siltstone			FR	Siderite		31145	4514			0.01	0	90	-90	427.53				NAF
GNC004	131.37	132.54	1.17	Sandstone			FR			31146	4515			0.02	1	16	-16	26.46				NAF
GNC004	132.54	132.65	0.11	Sandstone			FR		184261					0.52	16							
GNC004	132.65	132.95	0.30	Coal	LAJU	Lemington	FR		184262					0.55	17							
GNC004	132.95	132.99	0.04	Carb Claystone/Claystone			FR		184263					0.27	8							
GNC004	132.99	133.55	0.56	Coal	LAJ	Lemington	FR		184264					0.53	16							
GNC004	133.55	133.99	0.44	Carb Claystone/Claystone			FR		184265					0.26	8							
GNC004	133.99	134.11	0.12	Coal	LAHU	Lemington	FR		184266					1.76	54							
GNC004	134.11	134.21	0.10	Siltstone			FR		184267					0.02	1							NAF
GNC004	134.21	135.01	0.80	Siltstone/Carb Claystone			FR			31147	4516			0.02	1	28	-27	45.79				NAF
GNC004	135.01	135.09	0.08	Claystone			FR		184268					0.01	0							NAF
GNC004	135.09	139.14	4.05	Coal/Claystone	LAHM/H/G/F/E/D/C/B/A	Lemington	FR	Calcite	184269_84		5315	6.7	0.28	0.42	13	24	-11	1.88	6.9	0	0	NAF
GNC004	139.14	139.24	0.10	Siltstone			FR		184285					0.01	0							NAF
GNC004	139.24	139.37	0.13	Siltstone/Carb Claystone			FR			31148	4517	6.7	0.15	0.18	6	12	-6	2.12	5.6	0	1	NAF
GNC004	139.37	141.68	2.31	Sandstone			FR			31149	4518	8.2	0.15	<0.01	0	41	-40	265.60	8.6	0	0	NAF
GNC004	141.68	142.55	0.87	Siltstone	BAND2		FR	Siderite, incl BAND2 10cm		31150	4519	7.5	0.22	<0.01	0	27	-26	173.45	8.3	0	0	NAF
GNC004	142.55	144.67	2.12	Sandstone			FR			31151	4520	8.1	0.22	<0.01	0	17	-17	110.30	8.1	0	0	NAF
GNC004	144.67	146.61	1.94	Siltstone/Claystone			FR			31152	4521			0.01	0	16	-16	52.04				NAF
GNC004	146.61	151.54	4.93	Sandstone/Siltstone			FR	Siderite, Calcite		31153	4522			0.02	1	47	-47	77.38				NAF
GNC004	151.54	153.66	2.12	Siltstone/Sandstone			FR	Siderite, Calcite		31154	4523			<0.01	0	39	-39	252.70				NAF
GNC004	153.66	156.64	2.98	Sandstone/Siltstone			FR			31155	4524			<0.01	0	16	-16	102.85				NAF
GNC004	156.64	159.67	3.03	Sandstone			FR			31156	4525			<0.01	0	87	-87	570.65				NAF
GNC004	159.67	162.66	2.99	Sandstone			FR	Siderite		31157	4526			<0.01	0	13	-13	86.17				NAF
GNC004	162.66	164.94	2.28	Sandstone/Siltstone			FR			31158	4527			<0.01	0	24	-23	154.32				NAF
GNC004	164.94	169.20	4.26	Sandstone			FR			31159	4528			<0.01	0	41	-41	270.75				NAF
GNC004	169.20	171.67	2.47	Conglomerate			FR			31160	4529	8.3	0.18	<0.01	0	78	-78	507.63	7.6	0	0	NAF
GNC004	171.67	173.56	1.89	Conglomerate/Sandstone			FR			31161	4530	7.6	0.19	<0.01	0	31	-31	200.54	8.5	0	0	NAF
GNC004	173.56	174.62	1.06	Sandstone			FR			31162	4531	7.7	0.20	<0.01	0	24	-24	159.90	8.5	0	0	NAF
GNC004	174.62	174.73	0.11	Sandstone			FR		184286					0.03	1							NAF
GNC004	174.73	176.14	1.41	Coal	PG3/2	Pikes Gully	FR	Calcite	184287_89		5316	7.3	0.28	0.51	16	10	6	0.64	5.9	0	1	UC(NAF)

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m)			Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					SINGLE ADDITION NAG			ARD Classification
	From	To	Interval											Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	
GNC004	176.14	176.68	0.54	Claystone/Siltstone			FR		184290					<0.01	0							NAF
GNC004	176.68	177.96	1.28	Coal	PG1	Pikes Gully	FR	Calcite	184291		5317	7.2	0.35	0.33	10	25	-15	2.52	7.4	0	0	NAF
GNC004	177.96	178.11	0.15	Claystone/Coal			FR		184292					0.21	6							
GNC004	178.11	178.92	0.81	Claystone/Carb Claystone			FR			31163	4532			0.03	1	22	-21	24.20				NAF
GNC004	178.92	182.49	3.57	Siltstone/Sandstone			FR	(2 bags for NAG samples)		31164	4533			0.03	1	45	-44	49.18				NAF
GNC004	182.49	183.11	0.62	Sandstone			FR	Minor Coal		31165	4534			0.03	1	39	-38	42.17				NAF
GNC004	183.11	183.23	0.12	Sandstone/Claystone			FR		184293					<0.01	0							NAF
GNC004	183.23	185.17	1.94	Coal/Tuff	ART3U/3/2/1	Arties	FR		184294_300		5318	6.8	0.31	0.35	11	18	-8	1.73	7.3	0	0	NAF
GNC004	185.17	185.32	0.15	Claystone			FR		186001					0.17	5							
GNC004	185.32	186.24	0.92	Claystone/Sandstone			FR			31166	4535			0.03	1	18	-18	20.09				NAF
GNC004	186.24	188.10	1.86	Sandstone/Siltstone			FR	Siderite, Calcite		31167	4536			0.01	0	23	-23	74.97				NAF
GNC004	188.10	192.69	4.59	Sandstone			FR	(2 bags for NAG samples)		31168	4537			<0.01	0	66	-65	428.81				NAF
GNC004	192.69	196.09	3.40	Sandstone/Siltstone			FR	Siderite (2 bags for NAG samples)		31169	4538			0.01	0	36	-36	118.59				NAF
GNC004	196.09	198.74	2.65	Sandstone/Siltstone			FR	Siderite		31170	4539			0.01	0	30	-30	99.34				NAF
GNC004	198.74	203.33	4.59	Sandstone/Siltstone			FR	(2 bags for NAG samples)		31171	4540			0.01	0	38	-38	123.85				NAF
GNC004	203.33	206.01	2.68	Sandstone/Siltstone			FR	Siderite		31172	4541			0.02	1	59	-58	96.58				NAF
GNC004	206.01	206.71	0.70	Claystone/Siltstone			FR	Siderite		31173	4542			0.02	1	15	-15	24.75				NAF
GNC004	206.71	206.79	0.08	Claystone			FR		186002					0.02	1							NAF
GNC004	206.79	209.97	3.18	Coal/Tuff	LID8/7/6/6L	Liddell	FR		186003_8		5319	7.2	0.26	0.35	11	14	-4	1.35	7.1	0	0	NAF
GNC004	209.97	210.09	0.12	Siderite/Carb Claystone			FR	Siderite	186009					0.02	1							NAF
GNC004	210.09	211.12	1.03	Siltstone/Claystone			FR	Siderite		31174	4543			0.01	0	98	-98	320.45				NAF
GNC004	211.12	214.79	3.67	Sandstone/Claystone			FR			31175	4544			0.01	0	30	-30	98.39				NAF
GNC004	214.79	217.66	2.87	Sandstone/Claystone			FR	Siderite, Calcite		31176	4545	7.5	0.17	<0.01	0	101	-101	658.44	8.9	0	0	NAF
GNC004	217.66	219.44	1.78	Sandstone			FR			31177	4546	7.4	0.15	<0.01	0	135	-134	879.22	8.6	0	0	NAF
GNC004	219.44	221.01	1.57	Siltstone/Claystone			FR	Siderite		31178	4547	8.0	0.15	<0.01	0	57	-57	373.40	8.3	0	0	NAF
GNC004	221.01	222.33	1.32	Sandstone/Carb Claystone			FR			31179	4548			0.04	1	25	-24	20.44				NAF
GNC004	222.33	222.46	0.13	Claystone			FR		186010					0.19	6							
GNC004	222.46	223.53	1.07	Coal/Claystone	LID5C	Liddell	FR		186011					0.62	19							
GNC004	223.53	223.64	0.11	Claystone			FR		186012					0.40	12							
GNC004	223.64	224.72	1.08	Sandstone/Claystone			FR			31180	4549	7.7	0.14	0.11	3	14	-11	4.21	8.2	0	0	NAF
GNC004	224.72	225.69	0.97	Claystone			FR			31181	4550	8.2	0.18	0.03	1	11	-10	12.12	8.1	0	0	NAF
GNC004	225.69	225.77	0.08	Core Loss			FR															
GNC004	225.77	230.92	5.15	Sandstone			FR	Siderite		31182	4551	7.8	0.23	0.03	1	22	-21	24.14	8.3	0	0	NAF
GNC004	230.92	232.77	1.85	Sandstone			FR			31183	4552	7.9	0.19	<0.01	0	141	-141	923.74	8.2	0	0	NAF
GNC004	232.77	234.26	1.49	Claystone/Sandstone			FR			31184	4553	7.7	0.18	<0.01	0	30	-30	194.09	8.4	0	0	NAF
GNC004	234.26	239.48	5.22	Siderite/Sandstone/Siltstone			FR	Siderite		31185	4554	8.2	0.24	0.04	1	33	-31	26.70	8.3	0	0	NAF
GNC004	239.48	240.78	1.30	Siltstone/Carb Claystone			FR			31186	4555	8.3	0.17	0.21	6	36	-29	5.54	8.7	0	0	NAF
GNC004	240.78	242.89	2.11	Claystone			FR			31187	4556			0.02	1	51	-51	83.72				NAF
GNC004	242.89	243.74	0.85	Claystone			FR	Siderite		31188	4557			0.05	2	76	-74	49.53				NAF
GNC004	243.74	243.86	0.12	Claystone			FR		186013					0.35	11							
GNC004	243.86	244.64	0.78	Coal	LID5B	Liddell	FR		186014					0.47	14							
GNC004	244.64	244.71	0.07	Tuff			FR		186015					0.01	0							NAF
GNC004	244.71	245.80	1.09	Coal	LID5A	Liddell	FR		186016					0.40	12							
GNC004	245.80	245.85	0.05	Tuff			FR		186017					0.05	2							NAF
GNC004	245.85	246.34	0.49	Coal	LID4B	Liddell	FR	Calcite	186018					0.40	12							
GNC004	246.34	246.46	0.12	Carb Claystone			FR		186019					0.15	5							
GNC004	246.46	246.85	0.39	Coal	LID4A	Liddell	FR		186020					0.84	26							
GNC004	246.85	247.00	0.15	Claystone/Carb Claystone			FR		186021					<0.01	0							NAF
GNC004	247.00	248.56	1.56	Claystone/Carb Claystone			FR			31189	4558			0.05	2	24	-22	15.70				NAF
GNC004	248.56	248.67	0.11	Carb Claystone			FR		186022					0.14	4							
GNC004	248.67	250.94	2.27	Coal/Tuff	LID3B/3A/2/1	Liddell	FR		186023_27		5320	6.7	0.42	0.43	13	12	1	0.92	5.7	0	1	UC(NAF)
GNC004	250.94	251.42	0.48	Carb Claystone			FR		186028					0.12	4							
GNC004	251.42	251.68	0.26	Coal	LID1L	Liddell	FR		186029					0.37	11							
GNC004	251.68	251.78	0.10	Claystone			FR		186030					0.10	3							
GNC004	251.78	252.75	0.97	Claystone/Siltstone			FR			31190	4559			0.01	0	14	-13	44.70				NAF
GNC004	252.75	255.80	3.05	Sandstone			FR			31191	4560			0.03	1	54	-53	58.61				NAF
GNC004	255.80	260.36	4.56	Sandstone			FR			31192	4561			<0.01	0	91	-91	593.06				NAF
GNC004	260.36	263.75	3.39	Siltstone/Sandstone			FR	Siderite		31193	4562			0.03	1	30	-30	33.19				NAF
GNC004	263.75	264.91	1.16	Claystone			FR			31194	4563			<0.01	0	13	-13	83.92				NAF
GNC004	264.91	265.06	0.15	Sandstone/Claystone			FR		186031					0.24	7							
GNC004	265.06	268.35	3.29	Coal	BAR3U/3/2/1/1L	Barrett	FR		186032_38		5321	7.5	0.22	0.47	14	19	-4	1.29	7.2	0	0	NAF
GNC004	268.35	268.46	0.11	Claystone			FR		186039					0.07	2							
GNC004	268.46	268.93	0.47	Siltstone/Carb Claystone			FR			31195	4564			0.03	1	13	-12	14.57				NAF
GNC004	268.93	270.68	1.75	Sandstone/Siltstone			FR			31196	4565			0.01	0	14	-14	46.74				NAF
GNC004	270.68	273.72	3.04	Sandstone			FR			31197	4566			<0.01	0	26	-26	169.07				NAF
GNC004	273.72	276.75	3.03	Sandstone			FR			31198	4567			<0.01	0	111	-111	724.24				NAF
GNC004	276.75	279.71	2.96	Sandstone/Siltstone			FR			31199	4568			<0.01	0	13	-13	83.13				NAF
GNC004	279.71	282.75	3.04	Sandstone			FR	Siderite, Calcite		31200	4569			<0.01	0	83	-82	539.22				NAF
GNC004	282.75	284.57	1.82	Sandstone			FR			31201	4570			<0.01	0	63	-63	410.73				NAF
GNC004	284.57	284.94	0.37	Siltstone			FR			31202	4571			0.01	0	12	-12	38.76				NAF
GNC004	284.94	285.04	0.10	Siltstone			FR		186040					0.04	1							NAF
GNC004	285.04	287.31	2.27	Coal	UH3/2/1	Hebden	FR	Calcite	186041_45		5322	7.3	0.23	0.55	17	11	6	0.64	5.7	0	1	UC(NAF)
GNC004	287.31	287.48	0.17	Carb Claystone			FR		186046					0.43	13							
GNC004	287.48	287.75	0.27	Coal	H1	Hebden	FR		186047					0.56	17							
GNC004	287.75	287.79	0.04	Claystone			FR		186048					0.16	5							
GNC004	287.79	288.01	0.22	Coal	H2	Hebden	FR		186049					0.36	11							
GNC004	288.01	288.17	0.16	Sandstone/Claystone			FR		186050					<0.01	0							NAF
GNC004	288.17	289.66	1.49	Siltstone/Claystone/Sandstone			FR			31203	4572			0.01	0	18	-17	57.34				NAF
GNC004	289.66	290.38	0.72	Sandstone/Coal	H3/H4	Hebden	FR	Incl H3(3cm)&H4(4cm) with SS parting		31204	4573			<0.01	0	14	-14	93.79				NAF
GNC004	290.38	291.83	1.45	Sandstone/Siltstone			FR			31205	4574			<0.01	0	14	-14	92.97				NAF
GNC004	291.83	294.81	2.98	Siltstone/Sandstone			FR			31206	4575	8.2	0.16	0.01	0	16	-16	52.99	8.1	0	0	NAF
GNC004	294.81	297.85	3.04	Sandstone			FR			31207	4576	8.1	0.22	<0.01	0	49	-49	321.60	8.6	0	0	NAF
GNC004	297.85	298.56	0.71	Siltstone			FR			31208	4577	7.8	0.17	<0.01	0	16	-15	101.35	8.5	0	0	NAF

Table 1: Acid forming characteristics of overburden/interburden and coal samples.

Hole Name	Depth (m) From	Depth (m) To	Depth (m) Interval	Lithology	Seam Name	Seam Group	Weathering	Comments	Coal Quality Sample No	Overburden/ Interburden Sample No	EGi Sample Number	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS Total %S	MPA	ANC	NAPP	ANC/MPA	SINGLE ADDITION NAG NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$	ARD Classification
GNC004	298.56	298.67	0.11	Claystone			FR		186051					0.02	1							NAF
GNC004	298.67	298.92	0.25	Coal	LHB	Hebden	FR		186052					0.69	21							
GNC004	298.92	299.06	0.14	Siltstone			FR		186053					0.55	17							
GNC004	299.06	299.57	0.51	Siltstone			FR	Siderite		31209	4578	8.2	0.28	0.07	2	17	-15	7.83	8.3	0	0	NAF
GNC004	299.57	300.84	1.27	Sandstone			FR			31210	4579	7.8	0.13	0.01	0	13	-13	42.23	8.2	0	0	NAF
GNC006	0.00	1.00	1.00	Claystone/Soil			CW			GNC006-1	5238	6.8	0.30	<0.01	0	4	-4	28.05				NAF
GNC006	1.00	2.00	1.00	Sandstone/Claystone			EW			GNC006-2	5239	7.4	0.29	<0.01	0	80	-80	520.66				NAF
GNC006	2.00	3.00	1.00	Sandstone			EW			GNC006-3	5240	8.5	0.34	0.03	1	102	-101	111.55				NAF
GNC006	3.00	6.00	3.00	Sandstone			EW			GNC006-4	5241	8.3	0.32	0.01	0	8	-8	27.64				NAF
GNC006	6.00	7.00	1.00	Sandstone			MW			GNC006-5	5242	7.6	0.32	<0.01	0	10	-10	63.98				NAF
GNC006	7.00	8.50	1.50	Sandstone			MW			GNC006-6	5243	8.2	0.29	<0.01	0	10	-10	66.26				NAF
GNC008	0.00	1.00	1.00	Sandstone			HW			GNC008-1	5244	8.1	0.29	<0.01	0	3	-3	21.78				NAF
GNC008	1.00	2.00	1.00	Sandstone			MW			GNC008-2	5245	7.8	0.31	0.01	0	11	-11	36.56				NAF
GNC008	2.00	3.00	1.00	Sandstone			MW			GNC008-3	5246	8.3	0.30	<0.01	0	39	-39	252.69				NAF
GNC008	3.00	7.00	4.00	Conglomerate			MW			GNC008-4	5247	7.7	0.28	<0.01	0	16	-16	107.42				NAF
GNC008	7.00	12.00	5.00	Conglomerate			MW			GNC008-5	5248	6.8	0.29	<0.01	0	19	-19	126.90				NAF
GNC008	12.00	13.50	1.50	Sandstone			MW			GNC008-6	5249	7.6	0.33	0.04	1	19	-18	15.42				NAF
GNC010	0.00	1.00	1.00	Conglomerate/Coal			HW			GNC010-1	5250	6.6	0.40	<0.01	0	5	-4	29.90	5.6	0	5	NAF
GNC010	1.00	2.00	1.00	Conglomerate			HW			GNC010-2	5251	7.2	0.38	0.01	0	23	-22	73.97	8.2	0	0	NAF
GNC010	2.00	3.00	1.00	Conglomerate			HW			GNC010-3	5252	8.4	0.24	<0.01	0	10	-10	63.25	6.9	0	0	NAF
GNC010	3.00	5.00	2.00	Conglomerate			HW			GNC010-4	5253	8.3	0.25	<0.01	0	26	-26	172.21	7.8	0	0	NAF
GNC010	5.00	6.00	1.00	Conglomerate/Coal			HW			GNC010-5	5254	7.8	0.31	0.03	1	29	-28	31.37	6.9	0	0	NAF
GNC010	6.00	7.00	1.00	Conglomerate/Claystone			HW			GNC010-6	5255	7.7	0.33	<0.01	0	9	-9	58.29	6.9	0	0	NAF
GNC010	7.00	10.00	3.00	Sandstone			FR/MW			GNC010-7	5256	8.0	0.42	<0.01	0	17	-17	110.73	7.8	0	0	NAF
GNC010	10.00	13.00	3.00	Sandstone			FR			GNC010-8	5257	6.7	0.39	0.02	1	38	-37	61.96	8.1	0	0	NAF
GNC010	13.00	14.00	1.00	Sandstone			FR			GNC010-9	5258	7.2	0.36	<0.01	0	15	-15	96.05	7.1	0	0	NAF
GNC010	14.00	16.00	2.00	Conglomerate			PW			GNC010-10	5259	6.8	0.32	0.01	0	36	-36	118.38	8.2	0	0	NAF

KEY

$pH_{1:2}$ = pH of 1:2 extract
$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)
MPA = Maximum Potential Acidity (kgH_2SO_4/t)
ANC = Acid Neutralising Capacity (kgH_2SO_4/t)
NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor
$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)
$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

NAF = Non-Acid Forming
PAF = Potentially Acid Forming
PAF-LC = PAF Low Capacity
UC = Uncertain Classification
(expected classification in brackets)

Coal seam interval

Missing interval or sample not available

Table 2: Extended boil and calculated NAG test results for selected overburden/interburden and coal samples.

EGi Code	Lithology	Seam Name	ACID-BASE ANALYSIS					STANDARD NAG TEST			Extended Boil NAGpH	Calculated NAG
			Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$		
5286	Coal	RVU	0.42	13	2	11	0.13	2.2	73	106	5.7	6
5287	Coal	RVL	0.45	14	2	12	0.11	2.2	88	124	5.6	6
3813	Coal	BAND	0.23	7	38	-31	5.43	4.4	3	19	7.6	-19
5289	Coal	RS	0.57	17	1	16	0.07	2.3	133	184	5.7	10
5290	Coal	RNU	0.71	22	20	1	0.94	2.9	25	43	7.4	-10
5291	Coal	RLU/RLL	0.48	15	7	8	0.48	2.5	30	46	7.1	1
5292	Coal	BAY1	0.44	13	2	12	0.14	2.3	39	60	6.9	5
5296	Coal	BAY5U/BAY5	0.75	23	1	22	0.06	2.5	70	102	4.9	10
5324	Coal	BY3/BY4U2/BY4U1	0.48	15	10	5	0.66	3.3	9	28	5.6	-3
5330	Coal	BY5U1/BY5	0.69	21	9	12	0.44	2.8	25	56	5.8	3
3882	Carb Claystone		0.32	10	9	1	0.89	3.1	20	44	7.1	1
5333	Coal	LEE	1.25	38	13	25	0.33	3.5	5	16	3.9	15
5336	Coal	LED/C/B/A/AL	0.70	22	8	14	0.35	3.1	7	21	6.3	3
5338	Sandstone		0.16	5	9	-4	1.84	3.7	2	8	7.1	-2
5311	Coal	LDJ	0.58	18	2	16	0.11	2.3	66	94	5.4	7
5312	Coal	LDB	0.47	14	3	11	0.24	2.2	69	103	5.9	6
3907	Claystone		0.09	3	11	-9	4.16	4.2	1	9	6.9	1
3954	Sandstone		0.62	19	7	12	0.38	3.5	4	12	4.2	6
5298	Coal	LBG	1.39	43	9	34	0.21	3.0	10	23	3.5	11
3996	Coal	PG3	0.41	13	29	-16	2.27	2.8	14	37	4.1	2
4056	Carb Siltstone		0.06	2	9	-7	4.82	3.6	5	17	7.1	-5
4078	Carb Claystone		0.75	23	7	16	0.32	3.1	6	21	3.6	9
4080	Siltstone		1.26	39	10	28	0.26	2.6	16.4	27	3.0	18

KEY

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

Extended Boil NAGpH = pH of NAG liquor after extended heating

Calculated NAG = The net acid potential based on assay of anions and cations released to the NAG solution (kgH_2SO_4/t)

Table 3: Sulphur speciation results for selected overburden/interburden and coal samples.

EGi Sample Number	Rock Type	Seam Name	Total %S	Pyritic S (%)	Acid Sulphate %S	Total Acid Generating S (%)	Non-Acid Sulphate %S	Other S Forms (%)	Proportion Total Acid Generating to Total S
3882	Carb Claystone		0.32	0.13	0.00	0.13	0.04	0.15	41%
3883	Coal	LEF	0.55	0.41	0.00	0.41	0.07	0.07	75%
5333	Coal	LEE	1.25	0.77	0.00	0.77	0.09	0.39	62%
5297	Coal	LCA	0.77	0.31	0.00	0.31	0.40	0.06	40%
3954	Sandstone		0.62	0.40	0.00	0.40	0.22	0.00	65%
5299	Coal	PG2U	1.50	0.46	0.00	0.46	0.53	0.51	31%
5301	Coal	ART4	0.81	0.11	0.00	0.11	0.06	0.64	14%
4025	Sandstone		0.86	0.77	0.00	0.77	0.08	0.01	90%
5307	Coal	BAR13/12	0.46	0.03	0.00	0.03	0.01	0.42	7%
4078	Carb Claystone		0.75	0.43	0.00	0.43	0.11	0.21	57%
4079	Sandstone		0.96	0.74	0.00	0.74	0.22	0.00	77%
4080	Siltstone		1.26	0.90	0.00	0.90	0.36	0.00	71%
5321	Coal	BAR3U/3/2/1/1L	0.47	0.10	0.00	0.10	0.02	0.35	21%

Pyritic S (%) = CRS (%)

Acid Sulphate S = KCl Acid Sulphate S

Total Acid Generating S = Pyritic S + Acid Sulphate S

Non-Acid Sulphate S = KCl S – KCl Acid Sulphate S

Other S Forms = Total S - (CRS + KCl S)

Table 4: Multi-element composition of selected overburden/interburden sample solids (mg/kg except where shown).

Element	Detection Limit	Lithology/Sample Number																								
		Tuff	Sandstone	Sandstone	Siltstone	Sandstone	Carb Siltstone	Weathered Zone	Weathered Zone	Sandstone	Sandstone	Weathered Zone	Conglomerate	Claystone	Sandstone	Claystone	Conglomerate	Sandstone	Siltstone	Sandstone	Siltstone	Carb Claystone	Sandstone	Sandstone	Siltstone	Weathered Zone
		3778	3831	3833	3850	3852	3859	5216	5221	3880	3886	5232	3900	3911	3954	3962	3978	4025	4057	4079	4080	4479	4480	4483	4547	5240
Ag	0.01	0.10	0.06	0.05	0.12	0.06	0.09	0.04	0.08	0.04	0.04	0.09	0.04	0.08	0.10	0.07	0.04	0.04	0.08	0.06	0.09	0.08	0.08	0.03	0.11	0.10
Al	0.01%	9.28%	8.45%	7.82%	8.50%	7.51%	9.77%	8.42%	6.33%	7.20%	7.11%	6.50%	6.41%	8.81%	9.98%	8.51%	6.21%	6.87%	8.74%	8.03%	9.38%	8.97%	8.20%	6.86%	7.79%	6.65%
As	0.2	3.3	7.6	5.6	4.9	9.8	8.2	8.6	5.8	19.2	3.8	9.2	13.3	15	36.6	3.8	20.5	301	11.4	31.9	22.8	18.2	9.8	4.8	15	5.4
B	10	20	10	10	10	10	20	40	30	10	10	30	10	20	10	10	10	<10	10	20	30	30	30	20	40	20
Ba	10	100	430	370	280	420	330	1090	500	500	350	690	520	300	420	350	580	620	290	310	330	330	380	510	390	490
Be	0.05	2	1.68	1.48	2.36	1.49	1.86	2.01	1.15	1.78	1.17	1.32	1.42	1.95	2.18	1.7	1.3	1.15	1.74	1.76	2	1.88	1.6	0.98	1.96	1.05
Bi	0.01	0.69	0.25	0.22	0.4	0.2	0.49	0.38	0.14	0.2	0.19	0.15	0.15	0.26	0.39	0.46	0.17	0.14	0.43	0.2	0.34	0.42	0.35	0.14	0.39	0.15
Ca	0.01%	0.66%	1.03%	2.20%	2.34%	3.57%	0.47%	0.29%	2.04%	0.35%	3.60%	0.19%	0.96%	0.44%	0.35%	0.68%	0.59%	0.38%	0.71%	1.96%	0.47%	0.32%	0.51%	2.87%	0.73%	4.06%
Cd	0.02	0.13	0.11	0.09	0.13	0.09	0.18	0.16	0.09	0.1	0.08	0.04	0.06	0.1	0.16	0.14	0.05	0.06	0.18	0.13	0.21	0.18	0.14	0.05	0.15	0.08
Ce	0.01	60	56.6	53.8	61.8	51.6	72.1	51.9	46.5	61.2	44.3	55.7	53.8	63.4	91.4	61.2	56.7	57.1	65.9	45.2	62.9	61.3	55.7	45.8	61.8	38.7
Co	0.1	2.4	10.8	10.4	13.7	11	11	15.2	8.3	10.1	9.3	5.9	7	19.4	28.2	16.2	6.8	15.4	10.1	13.4	14.1	15.1	13	6.5	16.9	5.5
Cr	1	6	58	59	39	57	45	41	65	114	51	82	88	82	99	36	90	94	34	35	43	34	45	78	34	65
Cs	0.05	9.04	6.31	5.60	9.21	4.70	12.20	10.00	3.15	5.54	4.16	2.73	3.03	6.16	9.49	11.80	2.63	2.67	10.60	5.43	7.34	11.00	9.06	2.71	9.23	2.82
Cu	0.2	6.4	19.8	17.9	31.7	15.7	39.8	31.3	9.7	14.2	12.5	9.5	8.6	36.5	46.9	36.4	8.8	6.5	34.9	15.9	29	62.2	26.8	8.8	29.9	9.4
F	20	720	330	330	390	270	350	760	410	270	270	440	260	330	680	870	400	360	700	570	700	860	800	360	700	480
Fe	0.01%	1.63%	3.47%	3.31%	8.14%	3.41%	2.26%	3.13%	2.14%	1.94%	2.32%	1.57%	1.58%	3.81%	2.83%	3.17%	2.06%	1.68%	3.24%	3.79%	4.05%	3.05%	4.56%	1.73%	8.62%	1.69%
Ga	0.05	26.7	20.0	19.7	22.2	17.4	26.1	22.7	14.9	17.5	15.9	16.0	16.1	23.9	26.0	23.8	15.6	15.8	23.4	19.3	23.3	24.9	20.9	15.6	21.0	15.7
Ge	0.05	0.31	0.21	0.19	0.16	0.15	0.2	0.22	0.19	0.21	0.2	0.19	0.21	0.28	0.28	0.25	0.24	0.18	0.25	0.21	0.22	0.22	0.25	0.22	0.27	0.26
Hf	0.01	5.8	3.4	3.4	3.7	3	4.2	4	3.2	3.4	2.9	3.6	3.7	4.9	5	4	3.2	3.2	3.8	3.4	4.7	4.1	3.3	2.6	3.2	2.6
Hg	0.005	0.019	0.019	0.011	0.033	0.022	0.018	0.047	<0.005	0.069	0.006	0.01	0.012	0.037	0.114	0.027	0.021	0.067	0.028	0.118	0.092	0.034	0.024	0.006	0.023	<0.005
In	0.005	0.065	0.065	0.058	0.069	0.053	0.09	0.076	0.048	0.061	0.048	0.046	0.05	0.089	0.083	0.085	0.048	0.043	0.081	0.057	0.078	0.088	0.074	0.039	0.071	0.04
K	0.01%	2.03%	1.89%	1.70%	1.66%	1.63%	1.97%	2.03%	1.83%	2.18%	1.34%	2.15%	2.00%	1.39%	1.74%	2.22%	1.63%	2.02%	1.71%	1.47%	1.77%	1.98%	1.88%	1.71%	1.81%	1.91%
La	0.5	25.1	28.1	26.7	29.8	24.6	33.9	22.8	22.7	30.3	20.5	28.4	26.5	29.9	42.4	28.9	28.9	28.5	31.4	20.7	31.9	28.4	26.9	22.6	29.4	18.4
Li	0.2	11	32.1	29.8	38.2	26.1	36.4	36.4	18.4	18.1	21.2	15.3	17.5	35.6	40.2	30	21.1	17.9	32.6	28	31.4	39.4	31.7	17.4	28.2	16.7
Mg	0.01%	1.17%	0.73%	0.69%	0.93%	0.81%	0.70%	0.77%	0.45%	0.38%	0.78%	0.26%	0.38%	0.76%	0.67%	0.94%	0.44%	0.27%	0.85%	0.47%	0.61%	0.92%	0.90%	0.44%	0.61%	0.42%
Mn	5	45	618	560	1730	587	184	211	365	177	421	440	287	749	79	357	411	107	515	756	359	209	863	503	1700	541
Mo	0.05	2.78	0.81	0.76	1.04	0.79	0.89	0.89	0.92	1.11	1.17	1.64	1.2	0.85	1.82	0.93	1.62	1.46	0.67	0.81	1.49	0.93	0.94	1.21	0.79	0.88
Na	0.01%	0.26%	1.46%	1.50%	0.77%	1.30%	0.30%	1.02%	1.51%	0.80%	1.63%	1.61%	1.99%	0.69%	0.77%	0.81%	1.44%	1.50%	0.89%	1.40%	1.38%	0.89%	1.16%	1.93%	1.11%	1.71%
Nb	0.1	8.8	6.5	6.6	7.1	5.7	8.1	7.7	6.2	7.5	5.3	6.9	6.4	8.3	10.5	7.8	6.6	5.5	7.5	6	7.5	7.2	6.5	5.1	6.8	5.1
Ni	0.2	4	14.9	13	19.5	13.3	20.8	20.6	10.6	14.3	10.3	11.3	9.1	47.8	73	24	10.8	15	17.2	13.7	18.3	19.3	16.9	7.2	18.3	6.6
P	10	120	410	450	800	460	310	260	310	250	360	270	410	520	540	480	380	310	450	370	470	470	430	340	570	340
Pb	0.5	36.1	14.1	13.2	17.8	12.5	21.8	17.2	11.3	14	12.5	11.4	11.4	16.6	20.5	17.4	10.7	18.6	17.7	12.5	18.6	18.2	16.2	11	16.8	11.4
Rb	0.1	80	96.2	81.4	97.3	80.5	120.5	117	75.4	107.5	60.6	87.7	86.1	76.8	112	135	70.9	81.4	107	73.7	99.4	113.5	102.5	73.1	101.5	75.4
Re	0.002	<0.002	0.002	0.002	0.004	0.002	0.003	0.004	0.003	0.003	0.002	0.002	0.004	0.003	0.005	<0.002	0.002	0.002	0.003	0.003	0.004	0.004	0.002	0.002	0.002	0.002
S	0.01%	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%	0.02%	0.04%	<0.01%	0.22%	<0.01%	<0.01%	<0.01%	0.03%	0.62%	0.03%	0.35%	0.86%	0.01%	0.96%	1.26%	0.17%	0.11%	<0.01%	<0.01%	<0.00
Sb	0.05	0.73	0.83	0.75	1.12	0.68	1.27	1.35	0.75	1	0.58	0.87	0.69	0.5	0.8	0.87	0.88	1.55	0.89	0.65	1.25	1.17	0.97	0.59	1.02	0.54
Sc	0.1	4.8	15.8	14.7	18.6	13	22.1	18	10.4	13	12	9.5	10.2	23.3	23.1	20.2	9.8	7	20.7	14.1	18.3	19	17.3	9.6	17.3	8.7
Se	1	2	2	2	3	2	2	2	2	2	1	2	2	3	3	3	2	2	2	2	2	2	2	1	3	1
Sn	0.2	5.6	2.1	2.1	2.5	1.8	3	2.6	1.8	2	1.6	2.2	1.9	2.5	3.3	2.8	1.9	1.7	2.8	2	2.5	2.7	2.3	1.6	2.4	1.5
Sr	0.2	234	292	307	232	321	123	167	177	138	538	103.5	204	229	404	178	142.5	201	410	238	243	214	206	258	246	179.5
Ta	0.05	1.01	0.54	0.56	0.59	0.47	0.72	0.64	0.52	0.55	0.48	0.58	0.54	0.62	0.83	0.7	0.55	0.5	0.63	0.49	0.63	0.62	0.56	0.42	0.56	0.41
Te	0.05	<0.05	0.05	<0.05	0.1	0.05	0.1	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	0.11	<0.05	<0.05	0.07	<0.05	0.08	0.1	<0.05	<0.05	0.07	0.05
Th	0.2	18.2	9.4	9	11.5	8	12.5	9.6	7.4	9.3	7.1	9.5	9.1	8.6	13.4	11.7	9.3	8.8	11.5	7.6	11.3	10.6	10.4	7	10.8	6.5
Ti	0.005%	0.07%	0.42%	0.45%	0.41%	0.35%	0.47%	0.44%	0.38%	0.36%	0.33%	0.30%	0.27%	0.58%	0.57%	0.43%	0.26%	0.24%	0.44%	0.38%	0.47%	0.47%	0.40%	0.30%	0.38%	0.30%
Tl	0.02	0.58	0.49	0.42	0.53	0.4	0.59	0.71	0.42	0.68	0.3	0.46	0.49	0.39	0.93	0.55	0.63	1.23	0.56	1.26	1.75	0.62	0.51	0.33	0.56	0.38
U	0.1	5	2.4	2.3	3.1	2	3.5	3.1	1.8	2.1	1.9	2	2.1	2.3	2.8	3.2	2.1	2	3.1	2	3.1	3.1	2.9	1.7	3	1.7
V	1	13	98	101	118	81	141	118	72	132	70	54	50	143	172	125	50	54	120	82	113	130	109	67	109	69
W	0.1	0.6	1.3	1.3	1.6	1.7	1.8	1.8	2.3	1.3	1.2	14	1.2	1.2	1.8	1.9	1.3	1.1	1.7	1.2	1.5	1.7	1.5	1	1.5	1.9
Y	0.1	29.6	22.9	21.5	30.9	21.6	29.1	25.3	19.2	20.4	17.4	22.1	22.5	29.3	27.7	26.3	21.5	18.7	25.5	21.7	26.1	26	25.3	18.2	27.2	17.2
Zn	2	72	79	74	98	65	98	94	52	69	65	46	50	91	121	100	44	50	105	73	90	110	93	49	92	50
Zr	0.5	137	107	109	120	98	132	128	105	111	88	112	113	185	177	121	100	100	119	112	149	120	108	87	106	88

< element at or below analytical detection limit.

Table 5: Geochemical abundance indices (GAI) of selected overburden/interburden sample solids.

Element	Median Soil Abundance*	Lithology/Sample Number																								
		Tuff	Sandstone	Sandstone	Siltstone	Sandstone	Carb Siltstone	Weathered Zone	Weathered Zone	Sandstone	Sandstone	Weathered Zone	Conglomerate	Claystone	Sandstone	Claystone	Conglomerate	Sandstone	Siltstone	Sandstone	Siltstone	Carb Claystone	Sandstone	Sandstone	Siltstone	Weathered Zone
		3778	3831	3833	3850	3852	3859	5216	5221	3880	3886	5232	3900	3911	3954	3962	3978	4025	4057	4079	4080	4479	4480	4483	4547	5240
Ag	0.05	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Al	7.1%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As	6	-	-	-	-	-	-	-	-	1	-	-	1	1	2	-	1	5	-	2	1	1	-	-	1	-
B	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ba	500	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Be	0.3	2	2	2	2	2	2	2	1	2	1	2	2	2	2	2	2	1	2	2	2	2	2	1	2	1
Bi	0.2	1	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-
Ca	1.5%	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Cd	0.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ce	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Co	8	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Cr	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cs	4	1	-	-	1	-	1	1	-	-	-	-	-	-	1	1	-	-	1	-	-	1	1	-	1	-
Cu	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F	200	1	-	-	-	-	-	1	-	-	-	1	-	-	1	2	-	-	1	1	1	2	1	-	1	1
Fe	4.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Ga	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ge	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hf	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
In	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	1.4%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
La	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Li	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg	0.5%	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mo	1.2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Na	0.5%	-	1	1	-	1	-	-	1	-	1	1	1	-	-	-	1	1	-	1	1	-	1	1	1	1
Nb	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ni	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rb	150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Re	0																									
S	0.07%	-	-	-	-	-	-	-	-	1	-	-	-	-	3	-	2	3	-	3	4	1	-	-	-	-
Sb	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sc	7	-	1	-	1	-	1	1	-	-	-	-	-	1	1	1	-	-	1	-	1	1	1	-	1	-
Se	0.4	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1
Sn	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sr	250	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ta	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Te	0																									
Th	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ti	0.50%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tl	0.2	1	1	-	1	-	1	1	-	1	-	1	1	-	2	1	1	2	1	2	3	1	1	-	1	-
U	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W	1.5	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zn	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zr	400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Bowen H.J.M.(1979) Environmental Chemistry of the Elements.

Table 6: Chemical composition of water extracts for selected overburden/interburden samples.

Parameter		Detection Limit	Lithology/Sample Number																								
			Tuff	Sandstone	Sandstone	Siltstone	Sandstone	Carb Siltstone	Weathered Zone	Weathered Zone	Sandstone	Sandstone	Weathered Zone	Conglomerate	Claystone	Sandstone	Claystone	Conglomerate	Sandstone	Siltstone	Sandstone	Siltstone	Carb Claystone	Sandstone	Sandstone	Siltstone	Weathered Zone
			3778	3831	3833	3850	3852	3859	5216	5221	3880	3886	5232	3900	3911	3954	3962	3978	4025	4057	4079	4080	4479	4480	4483	4547	5240
pH		0.1	7.9	8.5	8.6	8.7	8.5	8.6	7.2	8.5	8.0	8.2	8.3	8.1	8.7	5.5	8.2	7.8	7.2	8.9	7.8	4.9	8.4	8.2	8.5	8.4	8.7
EC	dS/m	0.01	0.35	0.24	0.29	0.48	0.41	0.65	0.28	0.23	0.45	0.33	0.25	0.43	0.50	0.99	0.45	0.68	0.69	0.42	0.33	1.96	0.34	0.25	0.28	0.17	0.32
Ag	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.010	<0.001	<0.010	<0.001
Al	mg/l	0.01	<0.10	0.28	0.14	0.3	0.12	0.05	0.02	0.06	<0.01	0.06	0.29	0.03	<0.10	<0.01	0.62	0.02	<0.10	0.04	<0.01	0.35	0.11	0.26	0.15	0.73	0.08
As	mg/l	0.001	0.084	0.066	0.030	0.020	0.044	0.017	<0.001	0.002	0.004	0.007	0.002	0.003	<0.010	<0.001	0.006	<0.001	0.046	0.021	0.002	0.002	0.010	0.015	0.017	0.106	0.002
B	mg/l	0.05	0.91	0.12	0.1	0.08	0.07	0.06	<0.05	0.06	0.06	0.06	0.1	0.06	<0.50	0.11	0.1	<0.05	<0.50	<0.05	0.1	0.12	<0.50	<0.50	0.07	<0.50	0.06
Ba	mg/l	0.001	0.012	0.05	0.066	0.064	0.104	0.25	<0.001	0.212	0.426	0.105	0.096	0.288	0.063	0.08	0.065	0.28	1.4	0.001	0.078	0.103	<0.010	<0.010	0.233	<0.010	0.169
Be	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	0.002	<0.010	<0.010	<0.001	<0.010	<0.001
Ca	mg/l	1	1	<1	1	<1	2	4	<1	2	24	2	<1	17	3	8	<1	14	18	1	107	68	<1	<1	2	<1	1
Cd	mg/l	0.0001	<0.0010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0010	0.0002	<0.0001	<0.0001	<0.0010	<0.0001	<0.0001	0.002	<0.0010	<0.0010	<0.0001	<0.0010	<0.0001
Cl	mg/l	1	47	8	10	6	9	11	72	11	10	7	40	8	15	5	8	7	41	11	7	4	11	17	13	<10	14
Co	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	0.069	0.001	0.003	0.127	<0.001	0.005	0.293	<0.010	<0.010	<0.001	<0.010	<0.001
Cr	mg/l	0.001	<0.010	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.010	<0.001	0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.010	<0.010	<0.001	<0.010	<0.001
Cu	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	0.004	<0.010	<0.010	<0.001	<0.010	<0.001
F	mg/l	0.1	1	0.9	0.7	0.7	0.8	1	0.8	0.5	0.5	0.6	1	0.4	0.7	0.1	0.8	0.4	0.3	0.3	0.6	0.3	0.8	0.6	0.6	0.6	1
Fe	mg/l	0.05	<0.50	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	<0.50	0.08	0.09	<0.05	<0.50	<0.05	<0.05	5.85	<0.50	<0.50	<0.05	<0.50	<0.05
Hg	mg/l	0.0001	<0.0010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0010	<0.0001	<0.0001	<0.0010	<0.0010	<0.0001	<0.0010	<0.0001
K	mg/l	1	3	2	3	3	3	4	<1	<1	11	3	<1	7	4	6	3	4	4	4	13	3	3	3	4	2	<1
Mg	mg/l	1	1	<1	<1	<1	<1	2	<1	<1	14	1	<1	8	3	9	<1	8	9	<1	9	24	<1	<1	<1	<1	<1
Mn	mg/l	0.001	0.4	0.035	0.036	0.03	0.037	0.093	<0.001	<0.001	0.367	0.017	0.004	0.054	0.024	0.033	<0.001	0.074	0.731	<0.001	0.468	4.15	<0.010	<0.010	0.012	<0.010	<0.001
Mo	mg/l	0.001	0.385	0.033	0.032	0.046	0.029	0.031	<0.001	0.002	0.009	0.046	0.006	0.004	0.016	0.001	0.049	0.006	0.075	0.005	0.005	<0.001	0.013	0.016	0.008	0.026	0.002
Na	mg/l	1	119	53	50	39	32	30	9	34	39	28	38	30	97	126	43	16	68	82	289	278	72	91	50	113	42
Ni	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	0.122	0.002	0.006	0.086	<0.001	0.006	0.258	<0.010	<0.010	<0.001	<0.010	<0.001
P	mg/l	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pb	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.010	<0.010	<0.001	<0.010	<0.001
Sb	mg/l	0.001	0.01	0.006	0.004	0.005	0.004	0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.010	<0.001	0.005	<0.001	0.017	<0.001	<0.001	<0.001	<0.010	<0.010	0.003	0.012	<0.001
Se	mg/l	0.01	<0.10	0.01	<0.01	0.03	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10	0.04	0.03	<0.01	<0.10	<0.01	<0.01	<0.01	<0.10	<0.10	<0.01	0.1	<0.01
Si	mg/l	0.1	76	4	4	4	4	3	148	5	3	4	6	2	49	4	6	2	2	49	3	5	45	42	3	125	4
Sn	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.010	<0.010	<0.001	<0.010	<0.001
SO4	mg/l	1	69	17	14	19	21	59	181	4	217	23	9	134	140	363	43	87	177	117	906	952	163	156	32	117	2
Sr	mg/l	0.001	0.129	0.034	0.068	0.053	0.098	0.172	<0.001	0.03	1.49	0.2	0.004	1.42	0.237	1.79	0.039	0.55	1.97	0.018	4.19	5.28	0.022	0.023	0.104	0.027	0.011
Th	mg/l	0.001	<0.010	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.010	<0.001	<0.010	<0.001
U	mg/l	0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.010	<0.001	<0.010	<0.001
Zn	mg/l	0.005	<0.050	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.050	0.163	<0.005	0.011	0.102	<0.005	0.017	0.467	<0.050	<0.050	<0.005	<0.050	<0.005

< element at or below analytical detection limit.

Table 7: Soluble/exchangeable cations and dispersion percent of selected overburden/interburden samples.

EGi Sample Code	Hole Name	Depth (m)			Lithology	Weathering	$pH_{1:2}$	$EC_{1:2}$	sol Na (meq%)	sol K (meq%)	sol Ca (meq%)	sol Mg (meq%)	ex Na (meq%)	ex K (meq%)	ex Ca (meq%)	ex Mg (meq%)	% ECEC Na (ESP)	% ECEC K	% ECEC Ca	% ECEC Mg	ECEC	Dispersion Percent	Classification
		From	To	Interval																			
5207	SMC001	0.00	1.00	1.00	Soil	Weathered	7.4	0.25	0.67	0.09	0.02	0.46	1.40	0.18	0.45	5.20	19.4	2.5	6.2	71.9	7.2	43%	Strongly Sodic
5208	SMC001	1.00	2.00	1.00	Claystone	Weathered	8.2	0.35	1.22	1.29	0.03	1.78	2.70	0.00	0.19	8.10	24.6	0.0	1.7	73.7	11.0	86%	Strongly Sodic, Dispersive
5209	SMC001	2.00	3.00	1.00	Claystone	Weathered	7.5	0.42	1.23	1.82	0.02	2.35	3.40	0.00	0.11	11.20	23.1	0.0	0.7	76.1	14.7	77%	Strongly Sodic, Dispersive
5210	SMC001	3.00	7.00	4.00	Conglomerate	Weathered	7.8	0.33	0.85	0.11	0.11	0.24	0.61	0.06	6.10	2.80	6.4	0.6	63.8	29.3	9.6	47%	Sodic
3778	SMC001	27.59	28.23	0.64	Tuff	Fresh	7.6	0.33	2.19	2.83	0.45	2.74	6.00	0.00	14.50	22.60	13.9	0.0	33.6	52.4	43.1	27%	Sodic
3830	SMC001	141.09	141.75	0.66	Carb Claystone	Fresh	8.6	0.46	1.43	0.23	0.12	0.38	1.20	0.14	9.10	5.10	7.7	0.9	58.6	32.8	15.5	27%	Sodic
3833	SMC001	149.00	154.20	5.20	Sandstone	Fresh	8.2	0.29	1.01	0.20	0.11	0.28	0.59	0.11	7.50	2.70	5.4	1.0	68.8	24.8	10.9	33%	Non Sodic
3850	SMC001	185.48	186.86	1.38	Siltstone	Fresh	8.3	0.41	1.15	0.17	0.08	0.23	1.10	0.22	7.60	4.00	8.5	1.7	58.8	31.0	12.9	18%	Sodic
3859	SMC001	207.80	209.29	1.49	Carb Siltstone	Fresh	8.7	0.36	0.91	0.22	0.09	0.28	0.73	0.22	7.70	5.20	5.3	1.6	55.6	37.5	13.9	13%	Non Sodic
5213	SMC011	0.00	1.00	1.00	Claystone	Weathered	8.3	0.29	0.54	0.21	0.05	0.71	2.00	0.10	3.30	11.40	11.9	0.6	19.6	67.9	16.8	56%	Sodic, Dispersive
5214	SMC011	1.00	2.00	1.00	Sandstone	Weathered	7.7	0.29	1.24	0.36	0.18	1.00	0.98	0.00	4.80	6.30	8.1	0.0	39.7	52.2	12.1	57%	Sodic, Dispersive
5216	SMC011	3.00	5.00	2.00	Claystone	Weathered	6.4	0.31	1.95	0.23	0.13	0.85	4.30	0.17	3.90	14.50	18.8	0.7	17.1	63.4	22.9	75%	Strongly Sodic, Dispersive
5217	SMC011	5.00	8.00	3.00	Sandstone	Weathered	8.2	0.42	1.65	0.31	0.15	0.74	1.80	0.21	6.10	7.80	11.3	1.3	38.3	49.0	15.9	53%	Sodic, Dispersive
5220	SMC011	13.00	16.00	3.00	Sandstone	Weathered	7.7	0.36	1.02	0.39	0.11	0.70	0.71	0.00	6.00	3.70	6.8	0.0	57.6	35.5	10.4	58%	Sodic, Dispersive
5221	SMC011	16.00	20.00	4.00	Conglomerate	Weathered	8.3	0.24	0.80	0.21	0.11	0.40	0.49	0.00	6.70	2.90	4.9	0.0	66.4	28.7	10.1	64%	Dispersive
5222	SMC011	20.00	25.00	5.00	Sandstone	Weathered	7.7	0.25	0.72	0.33	0.11	0.59	0.42	0.00	6.00	2.80	4.6	0.0	65.1	30.4	9.2	53%	Dispersive
5224	SMC011	26.00	27.00	1.00	Claystone	Fresh	8.2	0.28	0.97	0.47	0.11	0.67	0.87	0.00	6.40	6.30	6.4	0.0	47.2	46.4	13.6	40%	Sodic
5226	SMC011	29.00	30.00	1.00	Claystone	Fresh	7.8	0.29	0.63	0.37	0.07	0.54	0.85	0.00	2.60	5.10	9.9	0.0	30.4	59.6	8.6	42%	Sodic
5227	SMC011	30.00	32.00	2.00	Conglomerate	Weathered	7.7	0.35	0.57	0.10	0.10	0.21	0.30	0.03	6.60	2.70	3.1	0.3	68.5	28.0	9.6	37%	Non Sodic
3880	SMC011	111.43	115.92	4.49	Sandstone	Fresh	8.1	0.47	0.91	0.14	0.65	0.62	0.09	0.26	4.70	2.50	1.2	3.4	62.3	33.1	7.5	9%	Non Sodic
3886	SMC011	121.81	123.39	1.58	Sandstone	Fresh	7.6	0.41	0.78	0.14	0.09	0.15	0.20	0.14	6.30	2.00	2.3	1.6	72.9	23.1	8.6	33%	Non Sodic
5229	SMC009	0.00	1.00	1.00	Sandstone	Weathered	8.3	0.27	0.87	0.07	0.04	0.37	1.90	0.14	0.83	5.00	24.1	1.8	10.5	63.5	7.9	77%	Strongly Sodic, Dispersive
5231	SMC009	2.00	3.00	1.00	Sandstone	Weathered	8.1	0.25	0.60	0.13	0.01	0.17	0.96	0.00	0.43	2.10	27.5	0.0	12.3	60.2	3.5	23%	Strongly Sodic
5232	SMC009	3.00	5.00	2.00	Conglomerate	Weathered	8.0	0.24	0.70	0.19	0.02	0.23	1.10	0.00	0.70	2.10	28.2	0.0	17.9	53.8	3.9	47%	Strongly Sodic
5233	SMC009	5.00	6.00	1.00	Sandstone	Weathered	7.8	0.23	0.74	0.15	0.01	0.15	0.87	0.00	0.72	1.50	28.2	0.0	23.3	48.5	3.1	19%	Strongly Sodic
5237	SMC009	11.00	12.50	1.50	Conglomerate	Weathered	7.2	0.28	2.08	0.31	0.21	1.12	3.80	0.00	2.20	7.80	27.5	0.0	15.9	56.5	13.8	83%	Strongly Sodic, Dispersive
3887	SMC009	21.10	21.80	0.70	Sandstone	Weathered	7.3	0.40	0.56	0.13	0.09	0.18	0.01	0.06	1.10	1.40	0.4	2.1	42.9	54.6	2.6	44%	Non Sodic
3900	SMC009	51.72	54.74	3.02	Conglomerate	Fresh	7.8	0.55	0.63	0.09	0.48	0.35	0.06	0.14	4.80	1.20	0.9	2.3	77.5	19.4	6.2	0%	Non Sodic
3911	SMC006	15.92	17.22	1.30	Claystone	Fresh	8.3	0.52	2.16	0.19	0.20	0.70	3.20	0.46	8.10	12.10	13.4	1.9	33.9	50.7	23.9	17%	Sodic
3915	SMC006	19.29	19.85	0.56	Tuff	Fresh	7.8	0.38	3.85	0.74	0.83	6.21	15.10	0.00	13.60	15.40	34.2	0.0	30.8	34.9	44.1	34%	Very Strongly Sodic
3954	SMC006	92.46	93.29	0.83	Sandstone	Fresh	5.3	1.29	3.24	0.08	0.12	0.22	1.20	0.41	4.70	7.10	8.9	3.1	35.0	52.9	13.4	22%	Sodic
3962	SMC006	104.72	105.85	1.13	Claystone	Fresh	8.1	0.41	1.32	0.46	0.11	0.61	1.50	0.07	6.30	5.10	11.6	0.5	48.6	39.3	13.0	20%	Sodic
3978	SMC006	141.50	142.51	1.01	Conglomerate	Fresh	7.6	0.71	0.53	0.08	0.49	0.49	0.00	0.12	1.40	1.10	0.0	4.6	53.4	42.0	2.6	0%	Non Sodic
4079	SMC006	351.24	352.98	1.74	Sandstone	Fresh	7.3	0.29	5.72	0.13	2.56	0.38	0.68	0.29	9.80	0.89	5.8	2.5	84.0	7.6	11.7	0%	Non Sodic
4479	GNC004	41.93	42.71	0.78	Carb Claystone	Fresh	8.2	0.32	1.41	0.50	0.06	0.70	3.00	0.21	3.90	6.30	22.4	1.6	29.1	47.0	13.4	40%	Strongly Sodic
4480	GNC004	42.71	48.49	5.78	Sandstone	Fresh	7.8	0.33	1.69	0.76	0.11	1.19	2.80	0.00	4.10	4.40	24.8	0.0	36.3	38.9	11.3	44%	Strongly Sodic
4483	GNC004	54.53	57.55	3.02	Sandstone	Fresh	8.2	0.26	1.06	0.32	0.13	0.33	0.28	0.00	5.60	0.70	4.3	0.0	85.1	10.6	6.6	29%	Non Sodic
4547	GNC004	219.44	221.01	1.57	Siltstone	Fresh	8.0	0.15	2.56	0.68	0.18	0.42	5.10	0.00	5.60	0.41	45.9	0.0	50.4	3.7	11.1	47%	Very Strongly Sodic
4550	GNC004	224.72	225.69	0.97	Claystone	Fresh	8.2	0.18	1.67	0.62	0.15	0.40	9.30	0.30	2.60	0.35	74.1	2.4	20.7	2.8	12.6	34%	Very Strongly Sodic
5238	GNC006	0.00	1.00	1.00	Claystone	Weathered	6.8	0.30	1.54	0.10	0.18	0.78	1.60	0.16	1.90	6.20	16.2	1.6	19.3	62.9	9.9	73%	Strongly Sodic, Dispersive
5239	GNC006	1.00	2.00	1.00	Sandstone	Weathered	7.4	0.29	1.71	0.19	0.15	0.40	1.30	0.01	7.00	3.80	10.7	0.1	57.8	31.4	12.1	63%	Sodic, Dispersive
5240	GNC006	2.00	3.00	1.00	Sandstone	Weathered	8.5	0.34	0.99	0.16	0.10	0.27	0.67	0.00	7.40	2.70	6.2	0.0	68.7	25.1	10.8	59%	Sodic, Dispersive
5241	GNC006	3.00	6.00	3.00	Sandstone	Weathered	8.3	0.32	0.59	0.22	0.07	0.33	0.62	0.00	5.20	3.20	6.9	0.0	57.6	35.5	9.0	56%	Sodic, Dispersive
5244	GNC008	0.00	1.00	1.00	Sandstone	Weathered	8.1	0.29	1.65	0.07	0.11	0.80	1.70	0.07	1.00	5.10	21.6	0.9	12.7	64.8	7.9	82%	Strongly Sodic, Dispersive
5246	GNC008	2.00	3.00	1.00	Sandstone	Weathered	8.3	0.30	2.15	0.13	0.23	0.65	2.50	0.05	6.90	7.30	14.9	0.3	41.2	43.6	16.8	57%	Sodic, Dispersive
5248	GNC008	7.00	12.00	5.00	Conglomerate	Weathered	6.8	0.29	0.98	0.17	0.06	0.26	0.58	0.00	5.10	2.90	6.8	0.0	59.4	33.8	8.6	29%	Sodic
5250	GNC010	0.00	1.00	1.00	Conglomerate	Weathered	6.6	0.40	0.44	0.09	0.20	0.41	0.67	0.15	4.40	5.40	6.3	1.4	41.4	50.8	10.6	31%	Sodic
5253	GNC010	3.00	5.00	2.00	Conglomerate	Weathered	8.3	0.25	0.77	0.23	0.07	0.34	0.64	0.00	5.50	3.60	6.6	0.0	56.5	37.0	9.7	48%	Sodic
5255	GNC010	6.00	7.00	1.00	Conglomerate	Weathered	7.7	0.33	0.55	0.18	0.14	0.85	3.40	0.09	2.70	12.30	18.4	0.5	14.6	66.5	18.5	64%	Strongly Sodic, Dispersive
5259	GNC010	14.00	16.00	2.00	Conglomerate	Weathered	6.8	0.32	1.23	0.13	0.10	0.20	0.37	0.14	5.70	2.20	4.4	1.7	67.8	26.2	8.4	28%	Non Sodic

Table 8:Total S results for CHPP discharged rejects.

Date	Time	Seam	Seam Group	Raw Coal Total S (%)	Coarse Rejects Total S (%)	Fine Rejects Total S (%)
5/10/12	7:00am	Upper Hebden	Hebden	0.47	0.09	4.45
6/10/12	7:00am	Lem B	Lemington	0.68	1.39	3.81
7/10/12	7:00am	Upper Liddell/Upper Hebden	Liddell/Hebden	0.58	1.04	3.13
8/10/12	7:00am	AUL/RAV F	Arties/Ravensworth	0.47	0.03	0.54
9/10/12	7:00am	AUL	Arties	0.58	0.04	
10/10/12	7:00am	AUL/RAV F	Arties/Ravensworth			2.45
11/10/12	7:00am	Upper Hebden	Hebden	0.46	0.23	4.57
12/10/12	7:00am	Lem B	Lemington	0.71		0.58
13/10/12	7:00am	Rav F	Ravensworth	0.40	0.03	0.41
14/10/12	7:00am	Lem B	Lemington	0.88	0.36	4.14
22/10/12	7:00am	Lem B	Lemington	0.46	0.47	0.18
23/10/12	7:00am	LLD/Rav H	Liddell/Ravensworth	0.37	0.04	1.39
27/10/12	7:00am	LLD/Rav F	Liddell/Ravensworth	0.59	0.25	1.77
28/10/12	7:00am	LLD	Liddell	0.60	1.04	0.93
29/10/12	7:00am	ULD	Liddell	0.74	1.06	0.95
30/10/12	7:00am	LLD/Rav F	Liddell/Ravensworth	0.43	0.03	1.13
31/10/12	7:00am	Lem B	Lemington	0.57	0.42	1.99
9/11/12	7:00am	Bays 1-2	Bayswater	0.40	0.05	
10/11/12	7:00am	Bays 1-2	Bayswater		0.05	0.72
11/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	0.47	0.05	0.65
12/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	0.42	0.04	3.27
13/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	0.46		2.27
14/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	0.73	0.23	1.49
19/11/12	7:00am	ULD	Liddell	0.70		1.35
20/11/12	7:00am	Barrett/Rav F	Barrett/Ravensworth	0.52	0.06	1.58
21/11/12	7:00am	ULD/Upper Hebden	Liddell/Hebden	0.70	0.24	4.26
22/11/12	7:00am	Lem A	Lemington	0.51	0.23	0.23
23/11/12	0.50	Lem A, Arties	Lemington	0.46	0.05	0.41
24/11/12	7:00am	Lem A	Lemington	0.53	0.31	1.04
25/11/12	7:00am	Lem A	Lemington	0.38	0.84	1.20
26/11/12	7:00am	LLD	Liddell	0.49	0.05	1.11
27/11/12	7:00am	Lem B	Lemington	0.47	0.23	
28/11/12	7:00am	Lem B	Lemington	0.70	0.20	
30/11/12	7:00am	Lower Hebden	Hebden	0.48	0.24	
1/12/12	7:00am	Lower Hebden	Hebden		0.39	
3/12/12	0.58	AUL	Arties		0.66	0.87
4/12/12	7:00am	Lem A	Lemington	0.58	0.64	4.57
5/12/12	7:00am	Lem B	Lemington		0.06	1.14
6/12/12	7:00am	Lower Hebden	Hebden	0.75	0.07	
7/12/12	7:00am	MLD-B	Liddell	0.56	0.16	
8/12/12	7:00am	AUL	Arties	0.37	0.21	
9/12/12	7:00am	MLD-B	Liddell	0.51	0.23	
10/12/12	7:00am	MLA	Liddell	0.54	0.17	
12/12/12	7:00am	Lem A	Lemington	0.69	0.47	1.13
14/12/12	7:00am	MLA/Upper Hebden	Liddell/Hebden	0.65	0.21	1.57
17/12/12	7:00am	AUL/Barrett	Arties/Barrett	0.63	0.21	0.62
18/12/12	7:00am	ULD	Liddell	0.66	0.52	0.87
19/12/12	7:00am	ULD	Liddell	0.66	0.62	0.84
20/12/12	7:00am	LLD	Liddell	0.44	0.06	0.55
21/12/12	7:00am	LLD	Liddell	0.56	0.20	0.55
23/12/12	7:00am	Barrett/LLD	Barrett/Liddell	0.33	0.23	0.73
28/12/12	7:00am	AUL	Arties	0.39	0.21	0.84
29/12/12	7:00am	AUL	Arties	0.49	0.12	0.62
30/12/12	7:00am	Pikes Gully	Pikes Gully	0.74	0.20	0.65
4/01/13	7:00am	AUL	Arties	0.38	0.08	0.52
5/01/13	7:00am	Upper Hebden	Hebden	0.58	0.35	1.04

Table 8:Total S results for CHPP discharged rejects.

Date	Time	Seam	Seam Group	Raw Coal Total S (%)	Coarse Rejects Total S (%)	Fine Rejects Total S (%)
6/01/13	7:00am	Upper Hebden	Hebden	0.53	0.45	1.89
7/01/13	12:30pm	ULA	Liddell	0.72	0.78	0.68
9/01/12	7:00am	AUL	Arties	0.46	0.52	
14/01/13	7:00am	Barrett	Barrett	0.53	0.42	0.52
16/01/13	12:00md	Lem B	Lemington	0.53	0.21	0.40
17/01/13	7:00am	Barrett	Barrett	0.41	0.34	0.63
18/01/13	7:00am	Barrett	Barrett	0.53	0.36	0.66
19/01/13	7:00am	Upper Hebden	Hebden	0.57	0.68	0.80
20/01/13	12:30pm	MLA	Liddell	0.55	0.55	0.89
21/01/13	7:00am	MLA	Liddell	0.57	0.39	0.26
22/01/13	12:00md	Pikes Gully	Pikes Gully	0.52	0.16	0.26
23/01/13	7:00am	Barrett	Barrett	0.49	0.29	0.84
25/01/13	7:00am	Lower Hebden	Hebden	0.52	0.20	0.42
27/01/13	7:00am	Barrett	Barrett	0.64	0.23	0.42
30/01/13	7:00am	Bay 1-2	Bayswater	0.36	0.05	0.17
31/01/13	7:00am	Bay 1-3	Bayswater		0.20	
1/02/13	12:00pm	Arties 3	Arties	0.42	0.04	0.13
2/02/13	7:00am	Arties 3	Arties	0.38	0.03	0.23
3/02/13	7:00am	Bays 3-4	Bayswater	0.28	0.07	0.10
4/02/13	7:00am	Bays 3-4	Bayswater	0.28	0.04	0.12
5/02/13	7:00am	LMA	Lemington	0.52	0.51	0.24
6/02/13	7:00am	MLA/MLB	Liddell	0.65	0.25	1.49
8/02/13	7:00am	Bay 1-3	Bayswater	0.69	0.73	
11/02/13	7:00am	Barrett	Barrett	0.62	0.36	0.68
12/02/13	7:00am	MLT	Liddell	0.63	0.15	0.34
15/02/13	3:40pm	LMA	Lemington	0.52	0.22	0.41
16/02/12	1:40pm	LMA	Lemington	0.52	0.15	0.38
17/02/12	7:00pm	LMA	Lemington	0.56	0.22	0.32
18/02/12	7:00am	LMA	Lemington	0.59	0.24	0.27
19/02/12	7:00am	AUL	Arties		0.13	1.27
25/02/13	7:00am	AUL/Arties 3	Arties	0.80	0.57	1.26
26/02/13	7:00am	Arties 3	Arties	0.35	0.21	1.15
27/02/13	7:00am	MLA	Liddell	0.54	0.88	0.69
28/02/13	7:00am	ULD	Liddell	0.71	0.72	0.72
1/03/13	7:00am	AUL/Arties 3	Arties	0.56	0.03	0.78
4/03/13	7:00am	MLA	Liddell	0.63	1.07	0.58
5/03/13	7:00am	MLA/UHB	Liddell/Hebden	0.52	0.32	0.93
6/03/13	7:00am	MLT	Liddell	0.60	0.06	0.65
8/03/13	2:10pm	Lem B/Bay 3-4	Lemington/Bayswater	0.38	0.13	0.93
9/03/13	7:00am	Lem B/Bay 3-4	Lemington/Bayswater	0.57	0.15	0.32
10/03/13	7:00am	AUL	Arties	0.39	0.05	0.30
11/03/13	7:00am	UHB/MLA	Hebden/Liddell	0.48	0.59	0.79
12/03/13	7:00am	Lem B	Lemington	0.54	0.29	0.52
13/03/13	7:00am	AUL	Arties	0.45	0.14	0.54
14/03/13	7:00am	AUL	Arties	0.43	0.18	0.55
15/03/13	7:00am	LLD/AUL	Liddell/Arties	0.46	0.04	0.39
16/03/13	7:00am	LLD/AUL	Liddell/Arties	0.43	0.11	0.38
18/03/13	7:00am	PKG/BAYS	Pikes Gully/Bayswater		0.18	0.32
19/03/13	7:00am	ULD/MLB	Liddell	0.48	0.09	0.36
20/03/13	7:00am	MLB	Liddell	0.38	0.10	0.27

Table 9: Acid forming characteristics of CHPP discharged rejects.

Date	Time	Seam	Seam Group	Material Type	Raw Coal Total S (%)	EGi Sample No	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					STANDARD NAG TEST			Extended Boil NAGpH	Calculated NAG	ARD Classification
									Total %S	MPA	ANC	NAPP	ANC/MPA	NAGpH	$NAG_{(pH4.5)}$	$NAG_{(pH7.0)}$			
27/10/12	7:00am	LLD/Rav F	Liddell/Ravensworth	Coarse Rejects	0.59	6125			0.25	8	24	-16	3.13	7.6	0	0			NAF
28/10/12	7:00am	LLD	Liddell	Coarse Rejects	0.60	6126			1.07	33	13	20	0.39	3.7	1	14	4.2	10	PAF
31/10/12	7:00am	Lem B	Lemington	Coarse Rejects	0.57	6127			0.42	13	26	-13	1.99	6.9	0	0			NAF
10/11/12	7:00am	Bays 1-2	Bayswater	Coarse Rejects		6128			0.05	2	33	-31	21.27	7.3	0	0			NAF
11/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	Coarse Rejects	0.47	6129			0.05	2	33	-32	21.78	7.6	0	0			NAF
12/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	Coarse Rejects	0.42	6130			0.04	1	35	-34	28.65	7.7	0	0			NAF
12/12/12	7:00am	Lem A	Lemington	Coarse Rejects	0.69	6131	9.1	0.33	0.47	14	39	-25	2.72	7.8	0	0			NAF
21/12/12	7:00am	LLD	Liddell	Coarse Rejects	0.56	6132	8.4	0.35	0.20	6	22	-16	3.58	7.5	0	0			NAF
29/12/12	7:00am	AUL	Arties	Coarse Rejects	0.49	6133			0.12	4	42	-38	11.38	7.6	0	0			NAF
30/12/12	7:00am	Pikes Gully	Pikes Gully	Coarse Rejects	0.74	6134	8.6	0.28	0.20	6	27	-21	4.43	7.8	0	0			NAF
5/01/13	7:00am	Upper Hebden	Hebden	Coarse Rejects	0.58	6135	8.5	0.28	0.35	11	31	-20	2.86	7.3	0	0			NAF
16/01/13	12:00md	Lem B	Lemington	Coarse Rejects	0.53	6136	9.1	0.37	0.21	6	31	-25	4.87	7.7	0	0			NAF
18/01/13	7:00am	Barrett	Barrett	Coarse Rejects	0.53	6137	8.9	0.29	0.36	11	30	-19	2.70	7.9	0	0			NAF
22/01/13	12:00md	Pikes Gully	Pikes Gully	Coarse Rejects	0.52	6138	8.8	0.35	0.16	5	27	-22	5.53	7.8	0	0			NAF
25/01/13	7:00am	Lower Hebden	Hebden	Coarse Rejects	0.52	6139	8.7	0.30	0.20	6	30	-24	4.93	7.6	0	0			NAF
3/02/13	7:00am	Bays 3-4	Bayswater	Coarse Rejects	0.28	6140	7.9	0.34	0.07	2	33	-31	14.69	8.1	0	0			NAF
6/02/13	7:00am	MLA/MLB	Liddell	Coarse Rejects	0.65	6141	7.8	0.37	0.25	8	31	-23	4.01	7.3	0	0			NAF
11/02/13	7:00am	Barrett	Barrett	Coarse Rejects	0.62	6142	8.2	0.29	0.36	11	25	-14	2.29	7.5	0	0			NAF
25/02/13	7:00am	AUL/Arties 3	Arties	Coarse Rejects	0.80	6143	8.4	0.38	0.78	24	32	-8	1.32	7.6	0	0			NAF
26/02/13	7:00am	Arties 3	Arties	Coarse Rejects	0.35	6144	8.7	0.40	0.21	6	22	-15	3.35	7.8	0	0			NAF
4/03/13	7:00am	MLA	Liddell	Coarse Rejects	0.63	6145	9.0	0.45	0.93	28	31	-3	1.09	4.1	0.1	4	5.2	2	PAF-LC
8/03/13	2:10pm	Lem B/Bay 3-4	Lemington/Bayswater	Coarse Rejects	0.38	6146	8.6	0.43	0.13	4	41	-37	10.23	7.6	0	0			NAF
10/03/13	7:00am	AUL	Arties	Coarse Rejects	0.39	6147	8.8	0.41	0.05	2	38	-37	25.13	7.7	0	0			NAF
27/10/12	7:00am	LLD/Rav F	Liddell/Ravensworth	Fine Rejects	0.59	6148			3.21	98	48	50	0.49	3.5	2	9	4.0	5	PAF-LC
28/10/12	7:00am	LLD	Liddell	Fine Rejects	0.60	6149			0.93	28	48	-19	1.67	7.3	0	0			NAF
31/10/12	7:00am	Lem B	Lemington	Fine Rejects	0.57	6150			2.72	83	88	-5	1.06	7.6	0	0			NAF
10/11/12	7:00am	Bays 1-2	Bayswater	Fine Rejects		6151			0.72	22	56	-34	2.55	7.5	0	0			NAF
11/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	Fine Rejects	0.47	6152			0.65	20	84	-64	4.21	7.7	0	0			NAF
12/11/12	7:00am	AUL/RAV F	Arties/Ravensworth	Fine Rejects	0.42	6153			4.21	129	140	-11	1.09	7.4	0	0			NAF
12/12/12	7:00am	Lem A	Lemington	Fine Rejects	0.69	6154			1.13	35	44	-10	1.28	7.6	0	0			NAF
21/12/12	7:00am	LLD	Liddell	Fine Rejects	0.56	6155			0.50	15	29	-13	1.88	7.5	0	0			NAF
29/12/12	7:00am	AUL	Arties	Fine Rejects	0.49	6156	8.2	0.35	0.62	19	117	-98	6.17	7.9	0	0			NAF
30/12/12	7:00am	Pikes Gully	Pikes Gully	Fine Rejects	0.74	6157	7.8	0.32	0.65	20	61	-41	3.06	7.9	0	0			NAF
5/01/13	7:00am	Upper Hebden	Hebden	Fine Rejects	0.58	6158	8.8	0.32	1.45	44	49	-4	1.10	3.8	1	8	4.1	2	PAF-LC
16/01/13	12:00md	Lem B	Lemington	Fine Rejects	0.53	6159	8.3	0.31	0.40	12	57	-45	4.69	7.3	0	0			NAF
18/01/13	7:00am	Barrett	Barrett	Fine Rejects	0.53	6160	7.8	0.30	0.57	17	19	-2	1.11	7.6	0	0			NAF
22/01/13	12:00md	Pikes Gully	Pikes Gully	Fine Rejects	0.52	6161	7.9	0.29	0.26	8	18	-10	2.29	7.5	0	0			NAF
25/01/13	7:00am	Lower Hebden	Hebden	Fine Rejects	0.52	6162	8.4	0.41	0.42	13	47	-34	3.63	7.7	0	0			NAF
3/02/13	7:00am	Bays 3-4	Bayswater	Fine Rejects	0.28	6163	8.5	0.33	0.10	3	69	-66	22.61	7.6	0	0			NAF
6/02/13	7:00am	MLA/MLB	Liddell	Fine Rejects	0.65	6164	8.5	0.43	1.61	49	51	-2	1.04	6.0	0	1			PAF
11/02/13	7:00am	Barrett	Barrett	Fine Rejects	0.62	6165	8.6	0.35	0.68	21	47	-26	2.27	7.1	0	0			NAF
25/02/13	7:00am	AUL/Arties 3	Arties	Fine Rejects	0.80	6166	8.7	0.48	1.26	39	51	-12	1.32	7.1	0	0			NAF
26/02/13	7:00am	Arties 3	Arties	Fine Rejects	0.35	6568	8.9	0.23	1.04	32	49	-17	1.54	7.2	0	0			NAF
4/03/13	7:00am	MLA	Liddell	Fine Rejects	0.63	6569	9.0	0.32	0.58	18	22	-4	1.22	7.3	0	0			NAF
8/03/13	7:00am	Lem B/Bay 3-4	Arties	Fine Rejects	0.38	6570	9.1	0.38	0.93	28	100	-72	3.52	7.4	0	0			NAF
10/03/13	7:00am	AUL	Arties	Fine Rejects	0.39	6571	9.4	0.21	0.30	9	78	-69	8.55	7.5	0	0			NAF

KEY

$pH_{1:2}$ = pH of 1:2 extract

$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

Extended Boil NAGpH = pH of NAG liquor after extended heating

Calculated NAG = The net acid potential based on assay of anions and cations released to the NAG solution (kgH_2SO_4/t)

Standard NAG results overestimate acid potential due to organic acid effects

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

PAF-LC = PAF Low Capacity

UC = Uncertain Classification

(expected classification in brackets)

Table 10: Sulphur speciation results for selected rejects samples.

EGi Sample Number	Material Type	Seam Group	Total %S	Pyritic S (%)	Acid Sulphate %S	Total Acid Generating S (%)	Non-Acid Sulphate %S	Other S Forms (%)	Proportion Total Acid Generating to Total S	Original NAPP* (kg H_2SO_4/t)	Readily Available ANC** (kg H_2SO_4/t)	Re-calculated NAPP*** (kg H_2SO_4/t)
6126	Coarse Rejects	Liddell	1.07	0.70	0.00	0.70	0.06	0.31	65%	20	10	12
6143	Coarse Rejects	Arties	0.78	0.60	0.00	0.60	0.05	0.13	77%	-8	29	-11
6145	Coarse Rejects	Liddell	0.93	0.66	0.00	0.66	0.03	0.24	71%	-3	20	0
6148	Fine Rejects	Liddell/Ravensworth	3.21	1.77	0.00	1.77	0.42	1.02	55%	50	49	6
6150	Fine Rejects	Lemington	2.72	2.03	0.00	2.03	0.12	0.57	75%	-5	93	-31
6153	Fine Rejects	Arties/Ravensworth	4.21	2.82	0.00	2.82	0.23	1.16	67%	-11	99	-13
6155	Fine Rejects	Liddell	0.50	0.27	0.00	0.27	0.04	0.19	54%	-13	29	-21
6158	Fine Rejects	Hebden	1.45	1.03	0.00	1.03	0.04	0.38	71%	-4	30	1
6160	Fine Rejects	Barrett	0.57	0.41	0.00	0.41	0.04	0.12	72%	-2	23	-10
6164	Fine Rejects	Liddell	1.61	1.34	0.00	1.34	0.08	0.19	83%	-2	31	10
6568	Fine Rejects	Arties	1.04	0.85	0.00	0.85	0.04	0.15	82%	-3	52	-26

Pyritic S (%) = CRS (%)

Acid Sulphate S = KCl Acid Sulphate S

Total Acid Generating S = Pyritic S + Acid Sulphate S

Non-Acid Sulphate S = KCl S – KCl Acid Sulphate S

Other S Forms = Total S - (CRS + KCl S)

* standard NAPP value based on total S and standard ANC values

** estimated from ABCC testing

***based on acid generating S (pyrite and acid sulphate S) and readily available ANC

Table 11: Multi-element composition of selected rejects sample solids (mg/kg except where shown).

Element	Detection Limit	Rejects Type/Seam Group/Sample Number											
		Coarse Rejects						Fine Rejects					
		Hebden	Lemington	Bayswater	Liddell	Arties	Liddell	Hebden	Lemington	Bayswater	Liddell	Arties	Liddell
		6135	6136	6140	6141	6144	6145	6158	6159	6163	6164	6568	6569
Ag	0.01	0.10	0.10	0.11	0.11	0.11	0.11	0.05	0.06	0.08	0.06	0.09	0.08
Al	0.01%	6.54%	5.14%	6.55%	6.98%	7.15%	5.71%	4.82%	3.72%	4.40%	4.49%	5.03%	4.95%
As	0.2	13.13	16.49	6.81	15.52	7.77	40.70	9.52	9.91	4.86	15.94	9.10	11.38
B	10	20	31	22	22	18	21	16	31	20	10	16	21
Ba	10	7526	241	265	461	257	251	296	430	357	542	311	572
Be	0.05	1.34	1.26	1.93	1.37	1.34	1.34	1.11	1.22	1.43	0.99	1.11	1.36
Bi	0.01	0.40	0.37	0.48	0.44	0.43	0.44	0.29	0.29	0.40	0.29	0.35	0.41
Ca	0.01%	0.64%	0.64%	0.86%	0.62%	0.54%	0.37%	1.64%	1.81%	1.89%	1.15%	1.55%	0.77%
Cd	0.02	0.19	0.17	0.20	0.20	0.12	0.21	0.12	0.10	0.15	0.12	0.10	0.11
Ce	0.01	23.2	27.1	50.4	36.2	52.4	24.5	22.8	19.7	26.9	22.7	28.7	33.7
Co	0.1	8.4	10.9	5.5	10.3	6.6	10.2	6.6	10.2	5.3	8.3	7.7	7.7
Cr	1	32	33	27	36	39	27	28	19	29	29	33	40
Cs	0.05	6.91	4.17	5.96	7.26	7.85	6.47	4.10	2.83	2.61	4.07	5.87	7.57
Cu	0.2	41.2	52.5	58.7	61.4	47.0	65.1	29.2	31.1	27.3	24.4	34.5	36.0
F	20	430	470	440	525	435	460	315	280	470	300	260	225
Fe	0.01%	2.25%	1.50%	1.88%	2.58%	1.88%	2.99%	2.81%	1.58%	1.69%	4.99%	2.15%	1.63%
Ga	0.05	21.2	21.5	23.6	23.4	21.0	20.7	14.7	13.3	18.7	12.6	15.1	16.1
Ge	0.05	0.08	0.20	0.14	0.14	0.10	0.19	0.08	0.22	0.27	0.08	0.14	0.18
Hf	0.01	3.4	4.3	6.1	3.6	4.2	3.2	2.5	2.9	5.1	2.3	2.4	2.7
Hg	0.005	0.07	0.08	0.06	0.10	0.05	0.35	0.06	0.04	0.08	0.16	0.06	0.05
In	0.005	0.08	0.08	0.10	0.08	0.08	0.08	0.05	0.05	0.07	0.05	0.06	0.06
K	0.01%	1.60%	1.13%	1.31%	1.53%	1.36%	1.37%	0.98%	0.66%	0.79%	0.83%	0.97%	1.23%
La	0.5	9.3	11.0	21.9	14.6	23.4	9.3	9.5	8.0	10.6	9.4	12.3	14.6
Li	0.2	28.6	40.5	32.2	38.4	33.5	36.5	23.4	23.4	23.5	19.6	21.7	25.9
Mg	0.01%	0.50%	0.40%	0.45%	0.53%	0.50%	0.40%	0.42%	0.30%	0.39%	0.45%	0.41%	0.46%
Mn	5	253	129	268	416	192	408	261	135	219	684	198	153
Mo	0.05	2.33	2.45	1.91	2.75	2.67	3.35	2.05	2.38	2.08	2.87	2.79	2.61
Na	0.01%	0.60%	0.63%	0.61%	0.43%	0.38%	0.40%	0.33%	0.29%	0.38%	0.22%	0.17%	0.35%
Nb	0.1	7.0	8.2	11.9	6.9	6.8	6.0	4.5	4.8	7.8	3.8	4.8	5.0
Ni	0.2	16.6	25.8	12.9	20.6	20.6	17.5	14.8	15.2	14.9	38.1	19.3	24.0
P	10	460	434	341	841	560	574	343	205	305	431	380	450
Pb	0.5	18.9	20.3	21.0	21.9	18.3	23.3	13.4	12.9	15.8	12.4	11.2	13.7
Rb	0.1	46.4	36.8	61.2	65.3	73.3	53.6	27.6	13.3	14.3	27.1	35.3	61.4
Re	0.002	0.007	0.004	0.004	0.006	0.004	0.005	0.002	0.004	0.005	0.003	0.004	0.005
S	0.01%	0.35%	0.21%	0.07%	0.25%	0.21%	0.93%	1.45%	0.40%	0.10%	1.61%	1.04%	0.58%
Sb	0.05	0.97	0.72	0.81	1.00	0.58	1.20	1.18	0.92	0.76	0.96	0.83	1.03
Sc	0.1	11.5	8.1	12.1	11.9	12.4	8.8	8.7	7.1	7.5	8.2	10.7	10.5
Se	1	1.7	1.6	1.5	1.6	1.6	1.6	1.2	1.0	1.3	1.1	1.2	1.2
Sn	0.2	2.6	3.3	4.6	3.3	3.5	2.9	1.7	1.9	3.6	1.5	2.1	2.3
Sr	0.2	840	231	247	293	169	215	271	290	529	260	242	232
Ta	0.05	0.56	0.72	1.00	0.60	0.72	0.60	0.38	0.38	0.77	0.33	0.40	0.46
Te	0.05	0.10	0.08	0.11	0.11	0.12	0.17	0.08	0.09	0.06	0.07	0.07	0.09
Th	0.2	4.9	5.2	9.5	7.4	10.0	5.3	4.4	3.4	5.0	4.4	5.5	6.4
Ti	0.005%	0.47%	0.51%	0.39%	0.51%	0.40%	0.40%	0.31%	0.26%	0.27%	0.25%	0.27%	0.27%
Tl	0.02	0.77	0.64	0.48	0.99	0.57	2.19	0.89	0.45	0.40	0.99	0.64	0.74
U	0.1	2.8	2.9	3.3	3.4	3.2	3.0	1.8	1.2	1.6	1.6	1.6	2.2
V	1	98	88	76	91	75	80	69	68	62	60	77	77
W	0.1	1.4	3.4	4.9	2.4	2.7	2.6	1.0	2.2	3.0	0.9	3.4	5.4
Y	0.1	11.9	10.2	21.8	14.7	19.4	9.2	10.9	11.0	14.3	11.6	13.6	13.4
Zn	2	100	72	84	103	80	96	59	53	56	52	56	60
Zr	0.5	104.9	125.5	207.4	104.3	126.3	88.4	76.3	90.1	155.0	68.1	77.1	84.2

< element at or below analytical detection limit.

Table 12: Geochemical abundance indices (GAI) of selected rejects sample solids. Values 3 and over are highlighted in yellow.

Element	Median Soil Abundance*	Rejects Type/Seam Group/Sample Number											
		Coarse Rejects						Fine Rejects					
		Hebden	Lemington	Bayswater	Liddell	Arties	Liddell	Hebden	Lemington	Bayswater	Liddell	Arties	Liddell
		6135	6136	6140	6141	6144	6145	6158	6159	6163	6164	6568	6569
Ag	0.05	-	-	1	-	1	1	-	-	-	-	-	-
Al	7.1%	-	-	-	-	-	-	-	-	-	-	-	-
As	6	1	1	-	1	-	2	-	-	-	1	-	-
B	20	-	-	-	-	-	-	-	-	-	-	-	-
Ba	500	3	-	-	-	-	-	-	-	-	-	-	-
Be	0.3	2	1	2	2	2	2	1	1	2	1	1	2
Bi	0.2	-	-	1	1	1	1	-	-	-	-	-	-
Ca	1.5%	-	-	-	-	-	-	-	-	-	-	-	-
Cd	0.35	-	-	-	-	-	-	-	-	-	-	-	-
Ce	50	-	-	-	-	-	-	-	-	-	-	-	-
Co	8	-	-	-	-	-	-	-	-	-	-	-	-
Cr	70	-	-	-	-	-	-	-	-	-	-	-	-
Cs	4	-	-	-	-	-	-	-	-	-	-	-	-
Cu	30	-	-	-	-	-	1	-	-	-	-	-	-
F	200	1	1	1	1	1	1	-	-	1	-	-	-
Fe	4.0%	-	-	-	-	-	-	-	-	-	-	-	-
Ga	20	-	-	-	-	-	-	-	-	-	-	-	-
Ge	1	-	-	-	-	-	-	-	-	-	-	-	-
Hf	6	-	-	-	-	-	-	-	-	-	-	-	-
Hg	0.06	-	-	-	-	-	2	-	-	-	1	-	-
In	1	-	-	-	-	-	-	-	-	-	-	-	-
K	1.4%	-	-	-	-	-	-	-	-	-	-	-	-
La	40	-	-	-	-	-	-	-	-	-	-	-	-
Li	25	-	-	-	-	-	-	-	-	-	-	-	-
Mg	0.5%	-	-	-	-	-	-	-	-	-	-	-	-
Mn	1000	-	-	-	-	-	-	-	-	-	-	-	-
Mo	1.2	-	-	-	1	1	1	-	-	-	1	1	1
Na	0.5%	-	-	-	-	-	-	-	-	-	-	-	-
Nb	10	-	-	-	-	-	-	-	-	-	-	-	-
Ni	50	-	-	-	-	-	-	-	-	-	-	-	-
P	800	-	-	-	-	-	-	-	-	-	-	-	-
Pb	35	-	-	-	-	-	-	-	-	-	-	-	-
Rb	150	-	-	-	-	-	-	-	-	-	-	-	-
Re													
S	0.07%	2	1	-	1	1	3	4	2	-	4	3	2
Sb	1	-	-	-	-	-	-	-	-	-	-	-	-
Sc	7	-	-	-	-	-	-	-	-	-	-	-	-
Se	0.4	1	1	1	1	1	1	1	1	1	1	1	1
Sn	4	-	-	-	-	-	-	-	-	-	-	-	-
Sr	250	1	-	-	-	-	-	-	-	-	-	-	-
Ta	2	-	-	-	-	-	-	-	-	-	-	-	-
Te													
Th	9	-	-	-	-	-	-	-	-	-	-	-	-
Ti	0.50%	-	-	-	-	-	-	-	-	-	-	-	-
Tl	0.2	1	1	1	2	1	3	2	1	-	2	1	1
U	2	-	-	-	-	-	-	-	-	-	-	-	-
V	90	-	-	-	-	-	-	-	-	-	-	-	-
W	1.5	-	1	1	-	-	-	-	-	-	-	1	1
Y	40	-	-	-	-	-	-	-	-	-	-	-	-
Zn	90	-	-	-	-	-	-	-	-	-	-	-	-
Zr	400	-	-	-	-	-	-	-	-	-	-	-	-

*Bowen H.J.M.(1979) Environmental Chemistry of the Elements.

Table 13: Chemical composition of water extracts from selected rejects samples.

Parameter		Detection Limit	Rejects Type/Seam Group/Sample Number											
			Coarse Rejects						Fine Rejects					
			Hebden	Lemington	Bayswater	Liddell	Arties	Liddell	Hebden	Lemington	Bayswater	Liddell	Arties	Liddell
			6135	6136	6140	6141	6144	6145	6158	6159	6163	6164	6568	6569
pH		0.1	8.8	9.3	8.5	8.7	9.2	9.4	9.1	8.7	8.9	9.0	8.9	8.8
EC	dS/m	0.001	0.44	0.51	0.43	0.41	0.35	0.46	0.48	0.52	0.62	0.62	0.45	0.34
Ag	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Al	mg/l	0.01	0.22	0.78	0.50	0.32	0.29	0.32	0.22	0.39	0.36	0.06	0.05	0.12
As	mg/l	0.001	0.072	0.301	0.044	0.042	0.079	0.033	0.019	0.03	0.009	0.008	0.013	0.003
B	mg/l	0.05	0.1	0.32	0.2	0.18	0.11	0.15	0.18	0.29	0.32	0.1	0.11	0.06
Ba	mg/l	0.001	0.172	0.173	0.129	0.093	0.109	0.09	0.446	0.467	0.583	0.655	1.03	0.471
Be	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ca	mg/l	1	<1	<1	<1	<1	1	<1	2	1	1	2	3	5
Cd	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cl	mg/l	1	26	30	15	15	18	17	34	53	44	46	30	10
Co	mg/l	0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	mg/l	0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	0.001	0.001	0.002	<0.001	<0.001	<0.001
Cu	mg/l	0.001	<0.001	0.005	<0.001	0.001	0.002	<0.001	0.002	0.004	0.005	0.004	0.005	0.003
F	mg/l	0.1	0.6	1.0	0.7	0.6	1.3	0.9	0.6	1.0	1.2	0.6	1.1	1.1
Fe	mg/l	0.05	<0.05	0.23	0.07	0.06	<0.05	0.05	<0.05	0.06	0.06	<0.05	<0.05	<0.05
Hg	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/l	1	3	3	3	2	2	2	3	3	3	3	4	3
Mg	mg/l	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2	3	2
Mn	mg/l	0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Mo	mg/l	0.001	0.08	0.15	0.08	0.07	0.09	0.09	0.04	0.06	0.03	0.04	0.04	0.04
Na	mg/l	1	83	129	102	84	60	122	97	121	127	111	90	54
Ni	mg/l	0.001	<0.001	0.004	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001
P	mg/l	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pb	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sb	mg/l	0.001	0.004	0.004	0.003	0.004	0.002	0.005	0.003	0.003	0.002	0.002	0.001	0.001
Se	mg/l	0.01	0.02	0.03	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	<0.01
Si	mg/l	0.1	5.3	27.0	16.2	6.4	3.0	4.7	2.2	2.8	3.7	1.6	1.3	1.2
Sn	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/l	1	63	88	57	85	43	135	100	93	104	124	118	70
Sr	mg/l	0.001	0.147	0.094	0.068	0.117	0.078	0.045	0.285	0.192	0.184	0.435	0.286	0.255
Th	mg/l	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
U	mg/l	0.001	<0.001	0.002	<0.001	<0.001	0.001	0.002	<0.001	0.001	0.001	<0.001	<0.001	<0.001
Zn	mg/l	0.005	<0.005	0.006	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

< element at or below analytical detection limit.

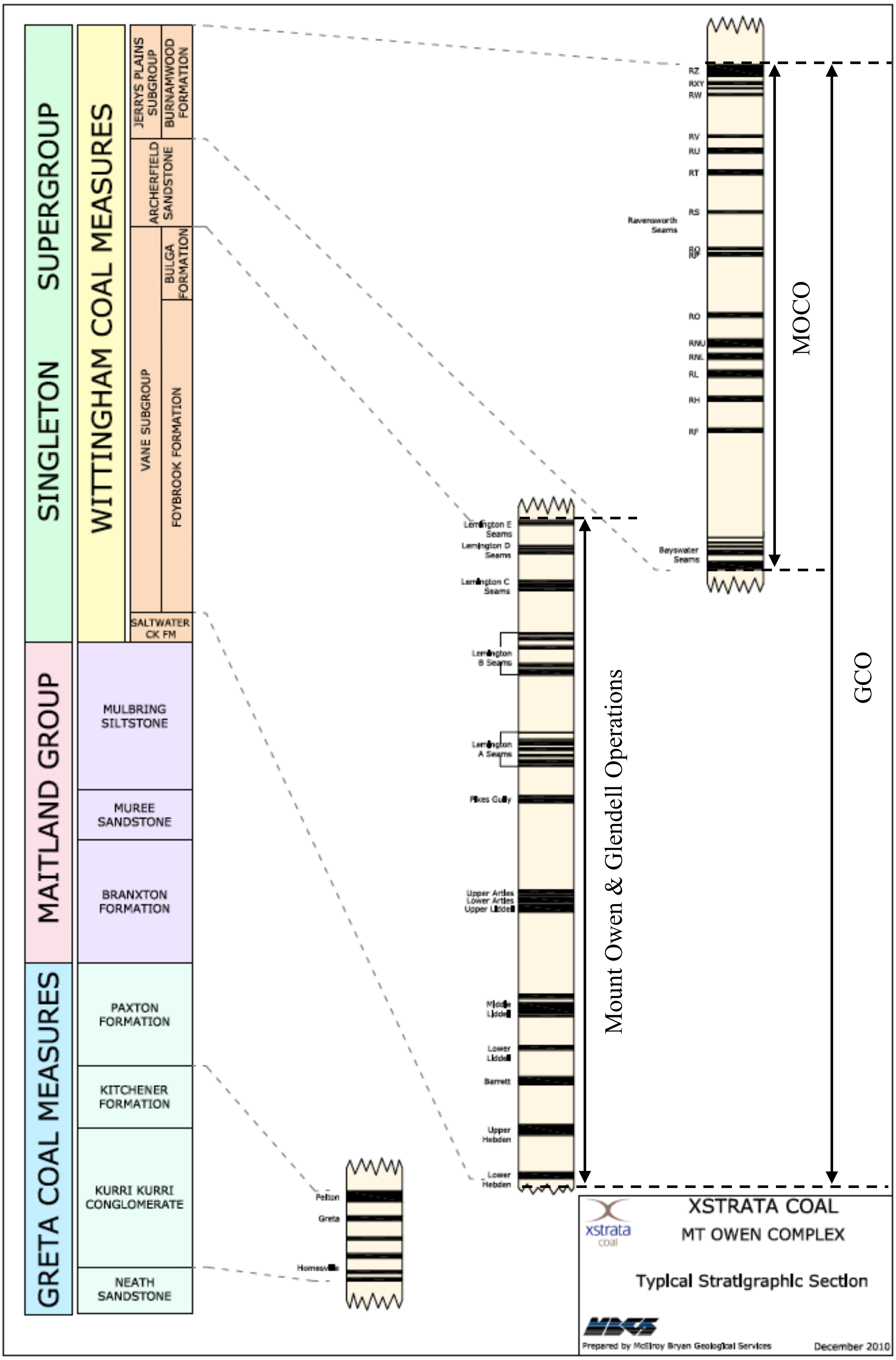


Figure 1: Typical stratigraphic section for the Mount Owen Optimisation Project, showing the target seams for the Mount Owen Continued Operations Project (MOCO), Glendell Continued Operations Project (GCO), and current operations at Mount Owen and Glendell.

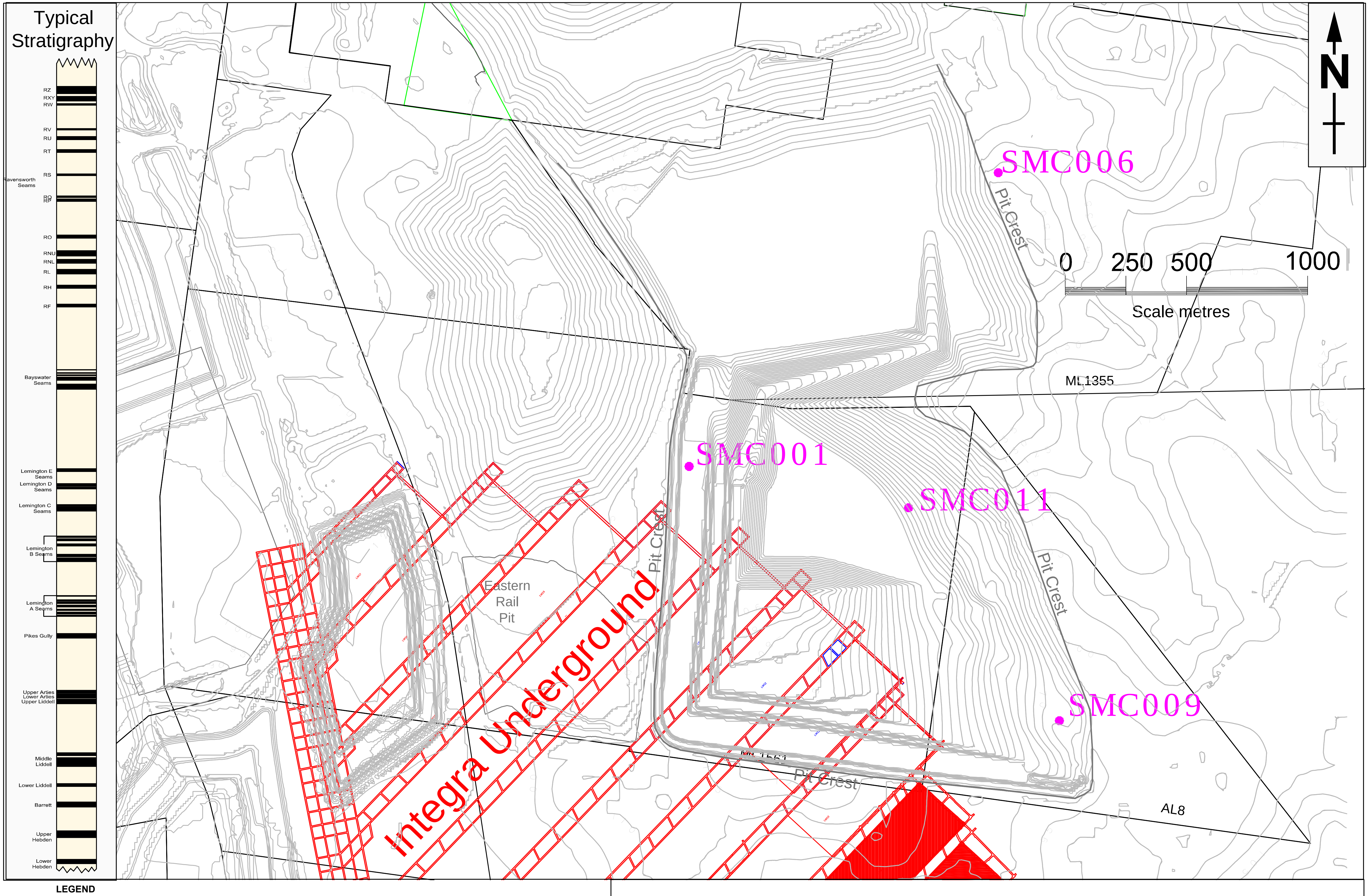


Figure 2: Location of drillholes from the • Mount Owen Continued Operations Project sampled for geochemical testing.

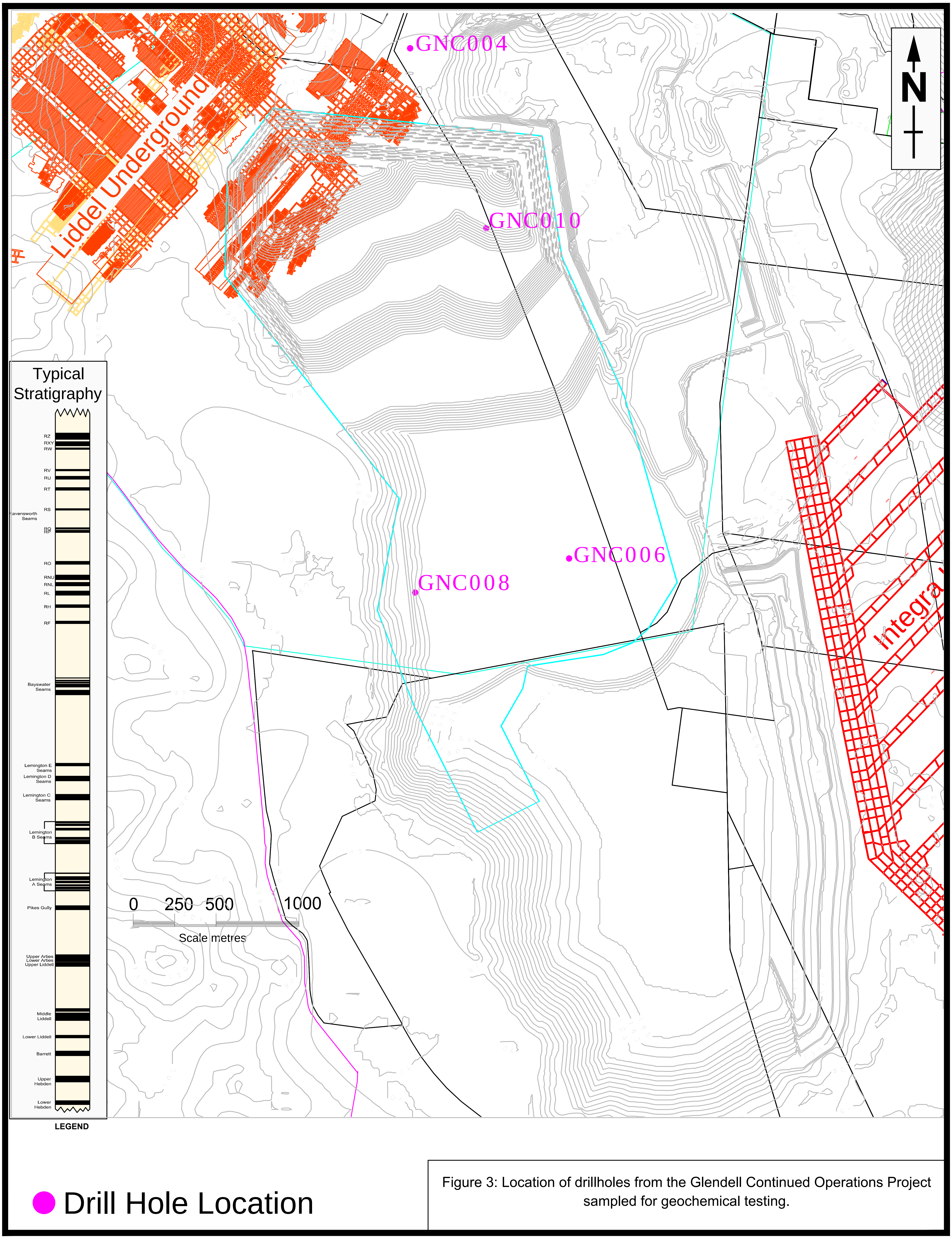


Figure 3: Location of drillholes from the Glendell Continued Operations Project sampled for geochemical testing.

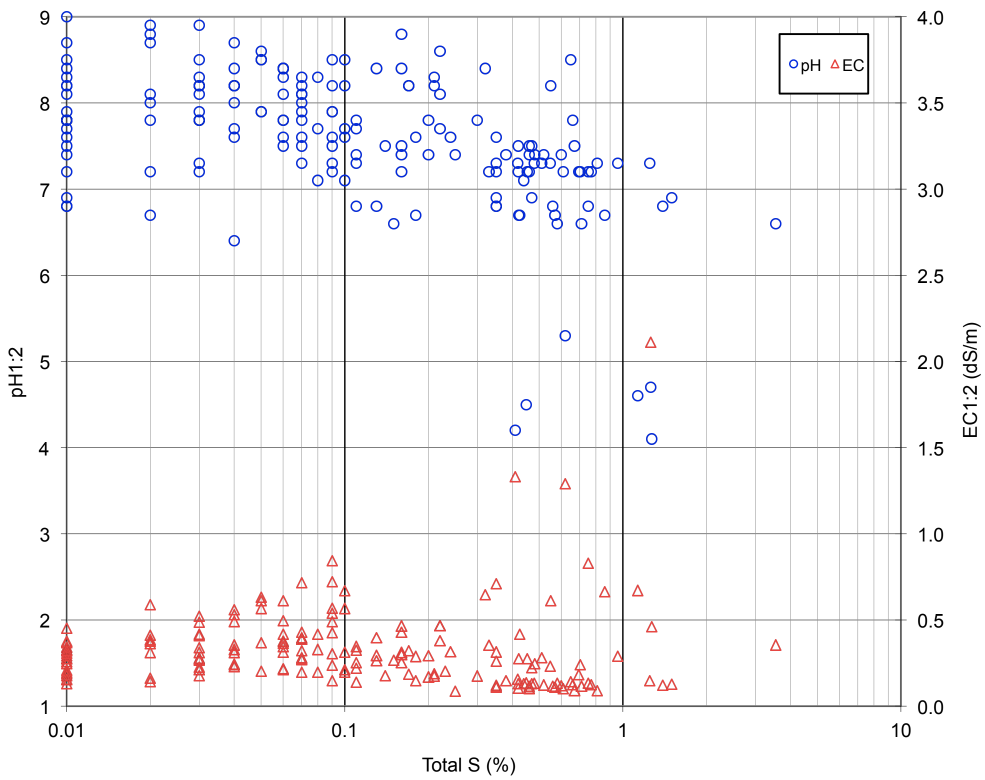


Figure 4: Plot showing $pH_{1:2}$ and $EC_{1:2}$ versus total S for overburden/interburden and coal samples.

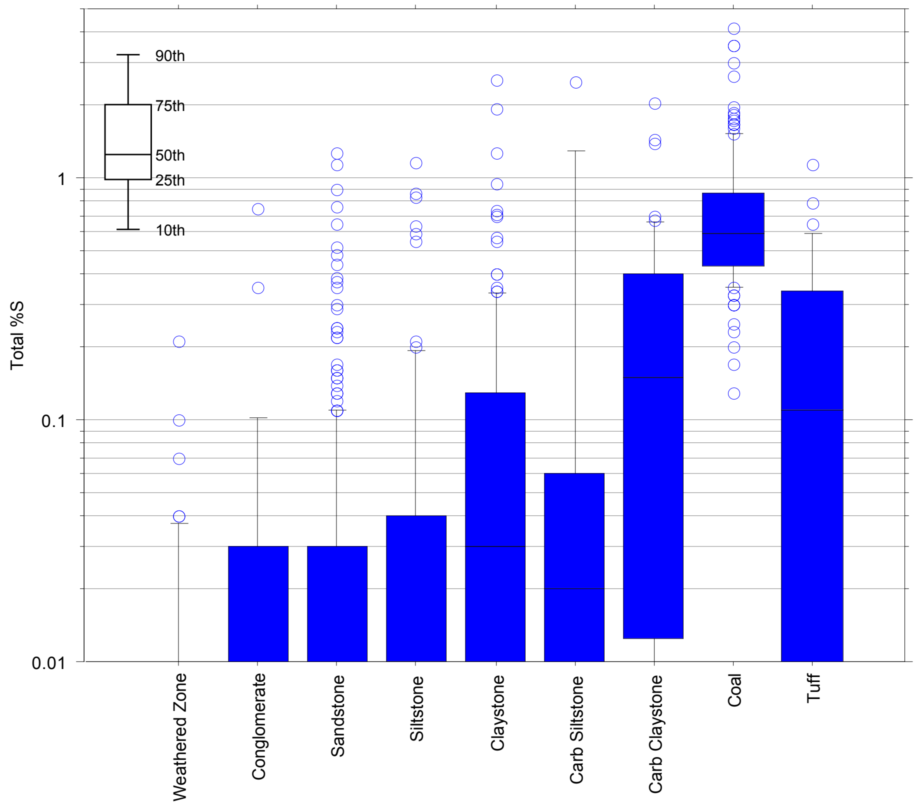


Figure 5: Box plot showing the distribution of S split by lithology for overburden/interburden and coal samples. Box plots have 10th, 25th, 50th (median), 75th and 90th percentiles marked.

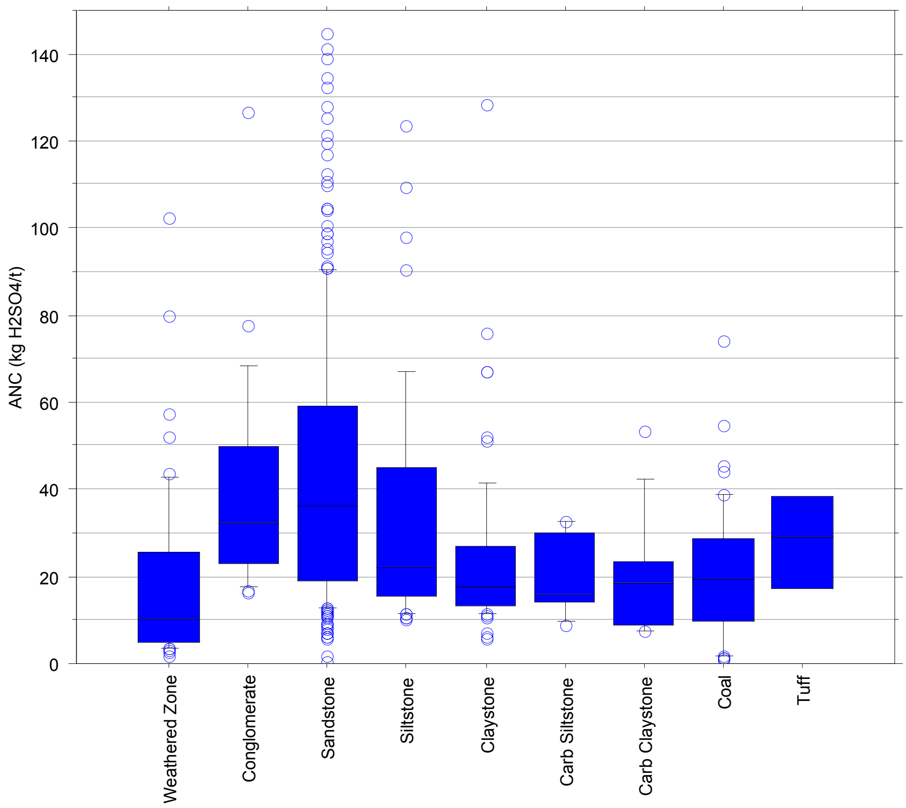


Figure 6: Box plot showing the distribution of ANC split by lithology for overburden/interburden and coal samples. Box plots have 10th, 25th, 50th (median), 75th and 90th percentiles marked.

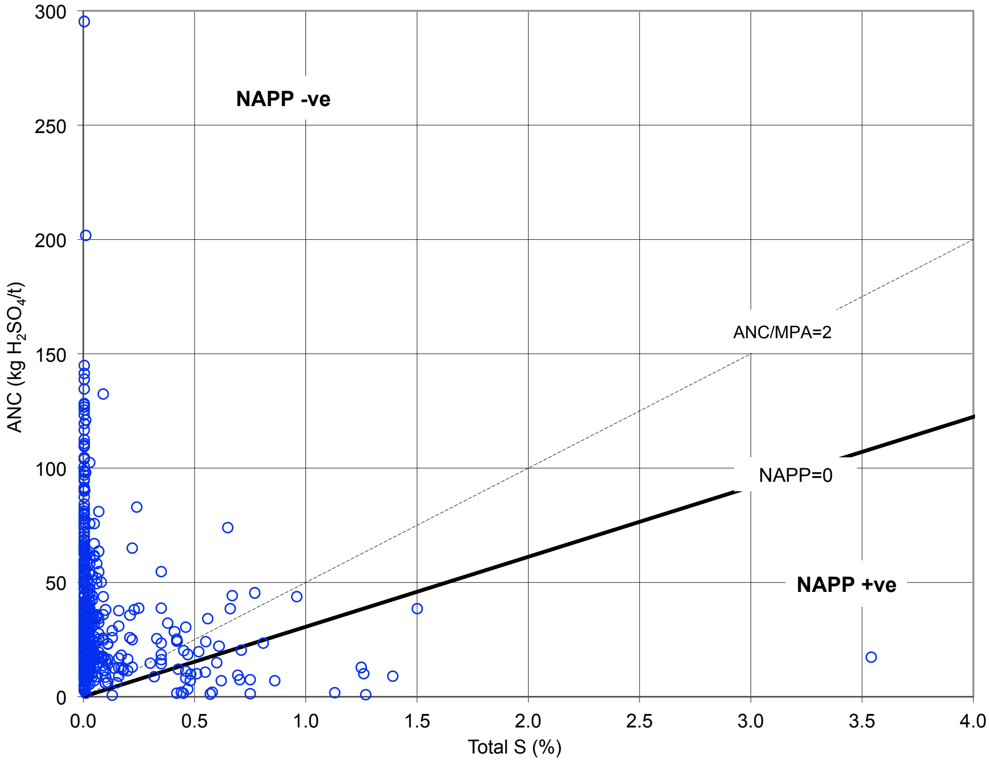


Figure 7: Acid-base account (ABA) plot showing ANC versus total S split by lithology for overburden/interburden samples.

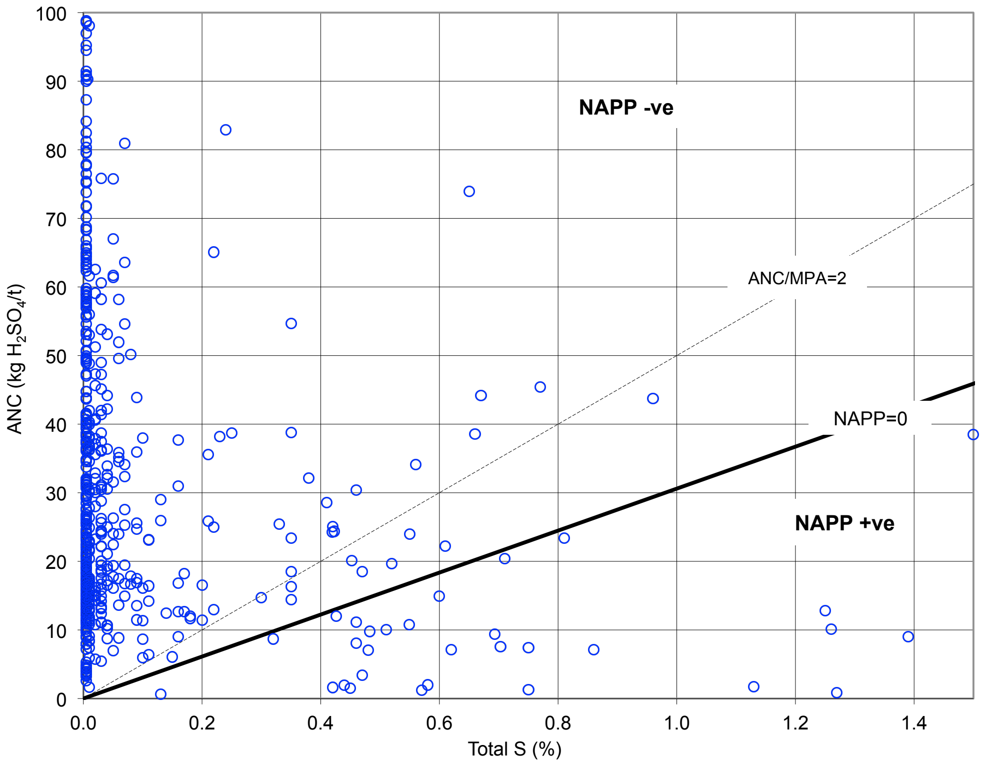


Figure 8: As for Figure 7 with expanded axes.

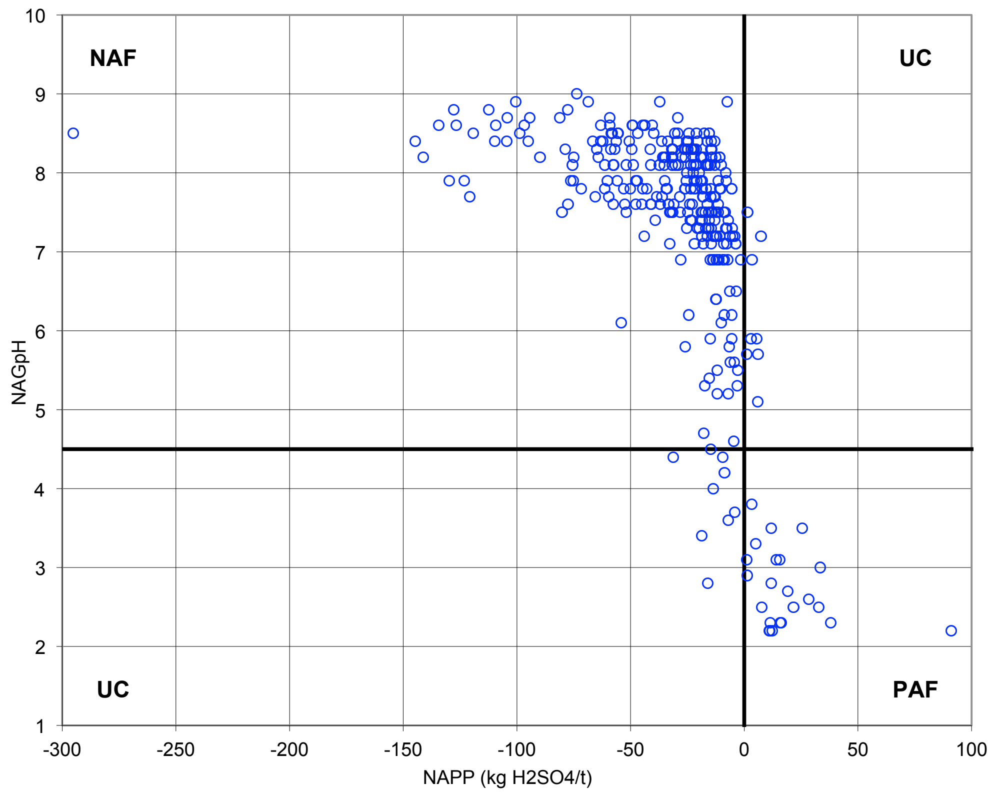


Figure 9: ARD classification plot showing NAGpH versus NAPP split by lithology for overburden/interburden samples, with ARD classification domains indicated.

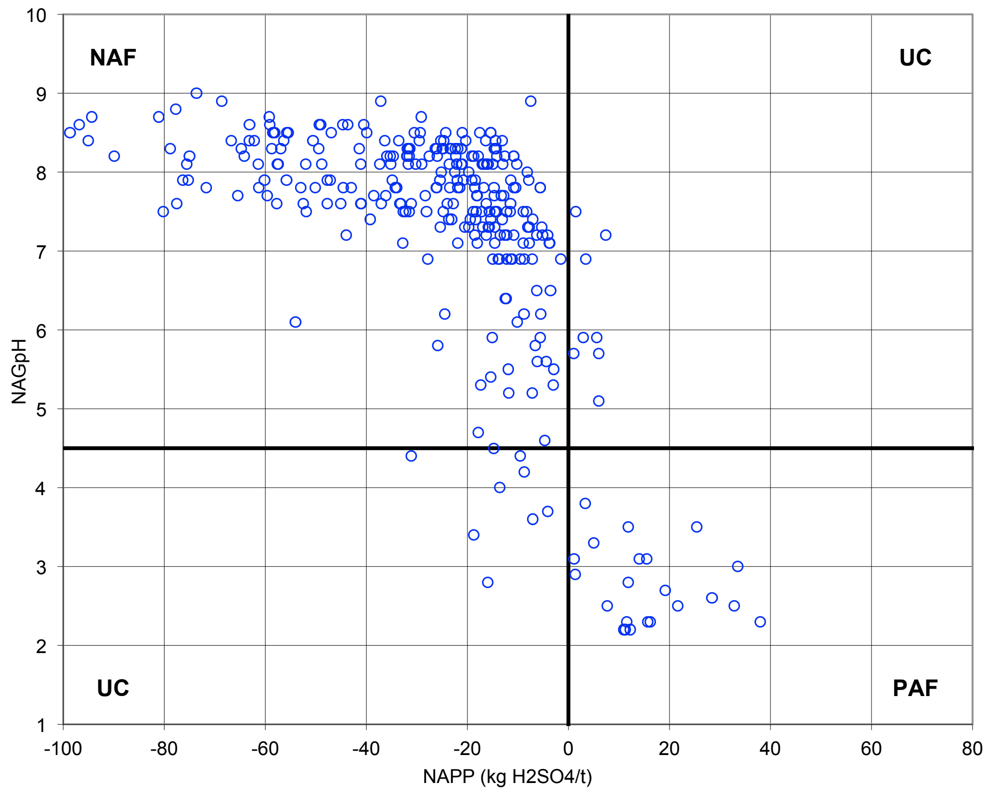


Figure 10: As for Figure 9 with expanded NAPP axis.

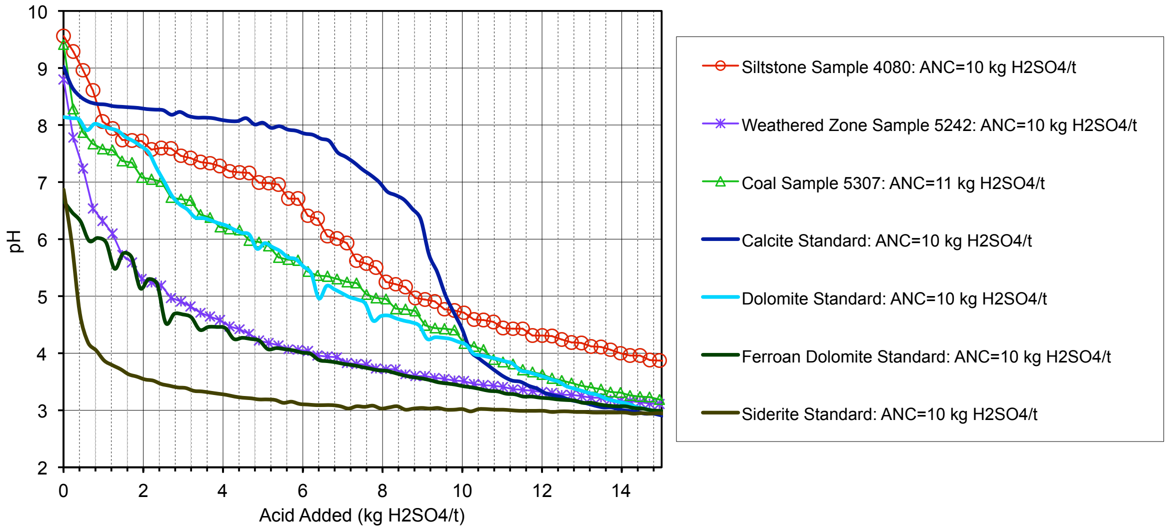


Figure 11: ABCC profile for samples with an ANC value close to 10 kg H_2SO_4/t. Carbonate standard curves are included for reference.

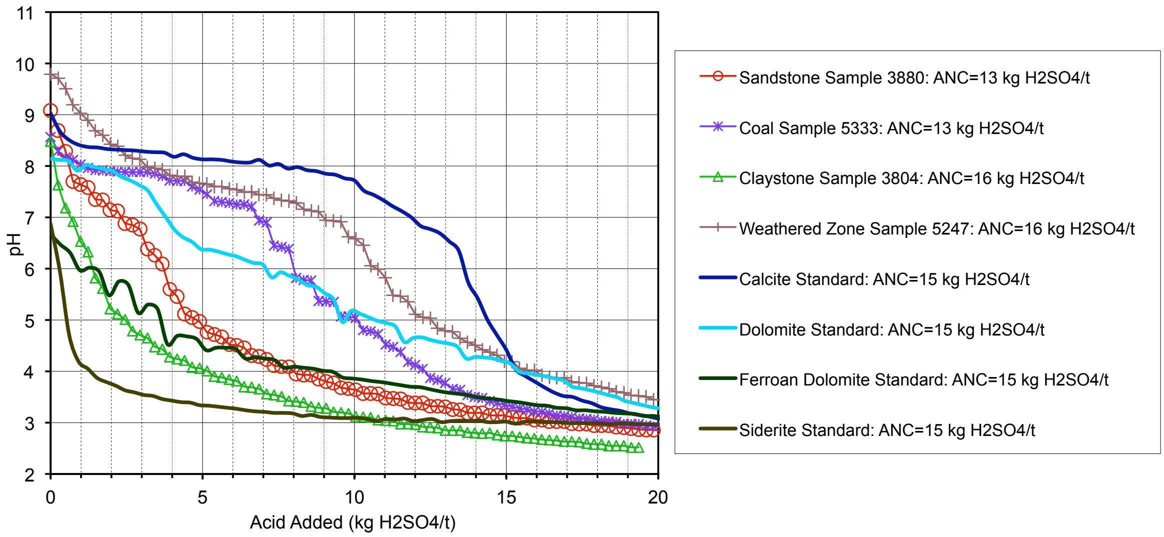


Figure 12: ABCC profile for samples with an ANC value of 15 kg H_2SO_4/t. Carbonate standard curves are included for reference.

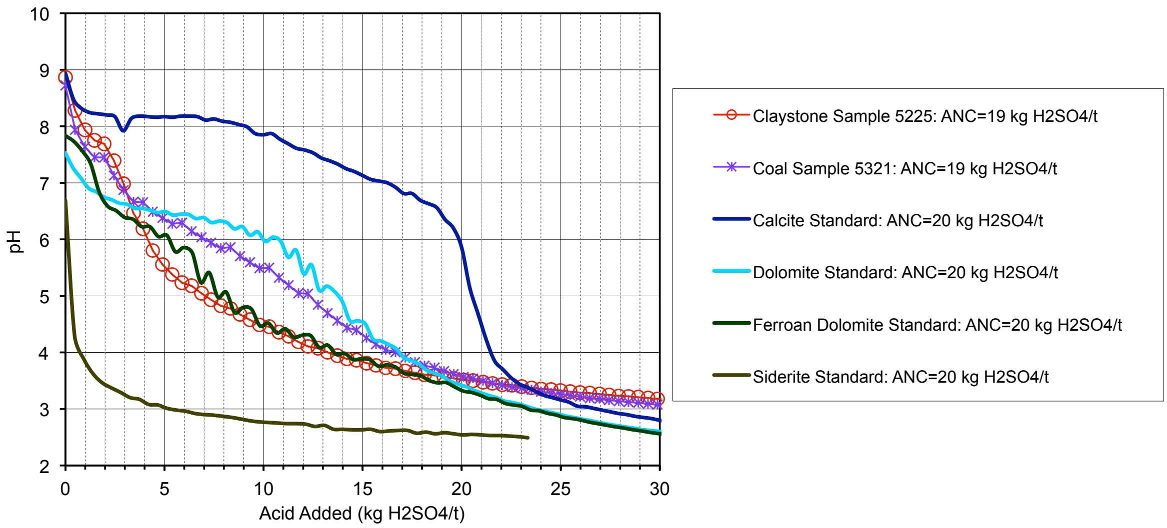


Figure 13: ABCC profile for samples with an ANC value close to 20 kg H_2SO_4/t. Carbonate standard curves are included for reference.

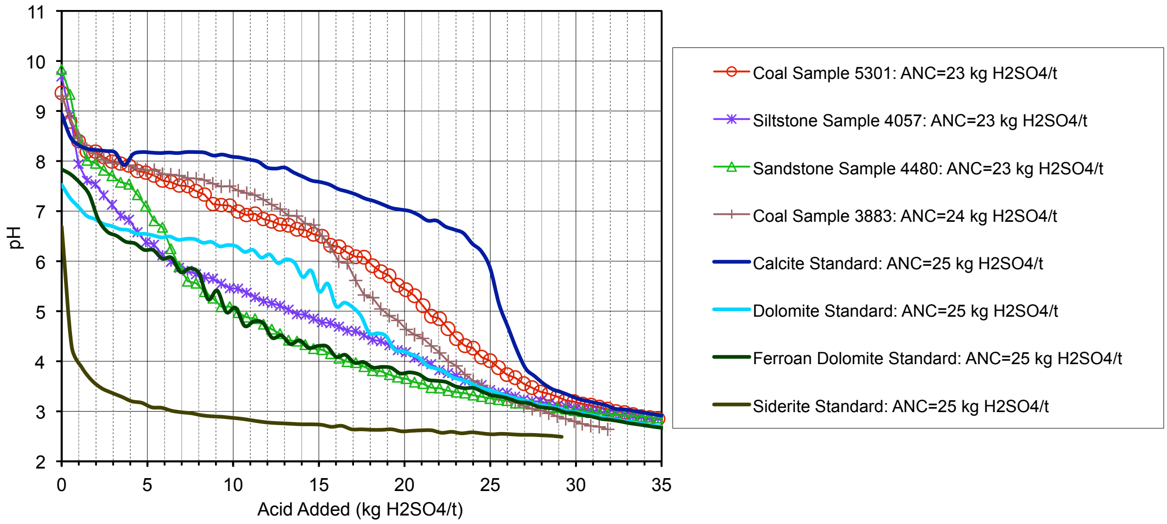


Figure 14: ABCC profile for samples with an ANC value close to 25 kg H_2SO_4/t. Carbonate standard curves are included for reference.

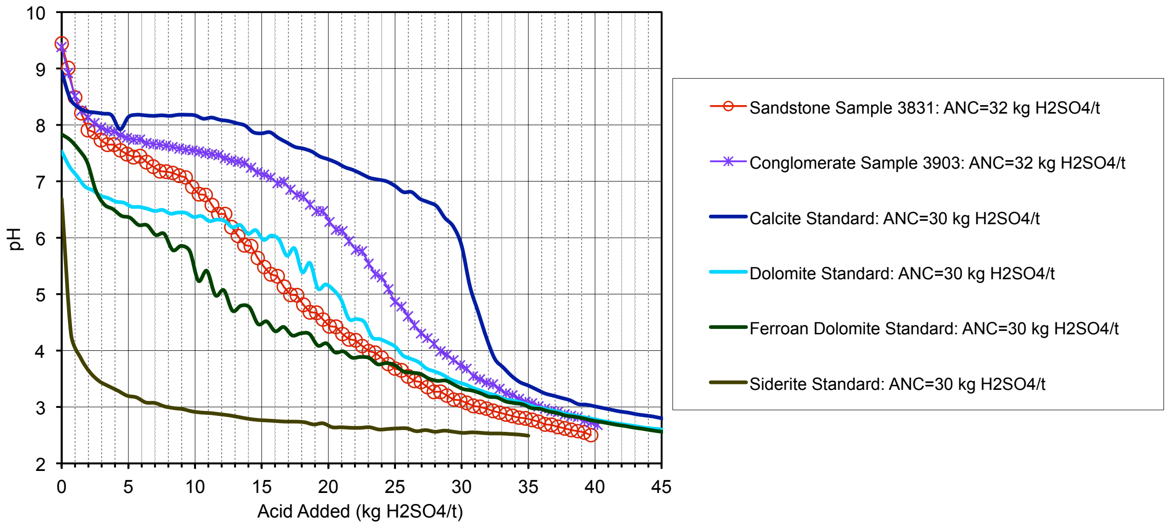


Figure 15: ABCC profile for samples with an ANC value close to 30 kg H_2SO_4/t. Carbonate standard curves are included for reference.

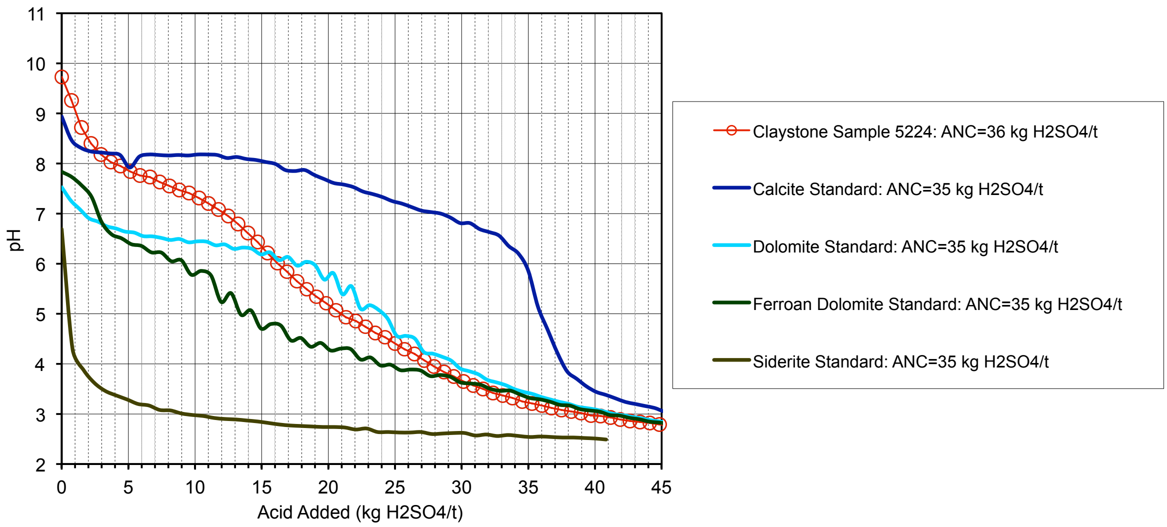


Figure 16: ABCC profile for sample 5224 with an ANC value close to 35 kg H_2SO_4/t. Carbonate standard curves are included for reference.

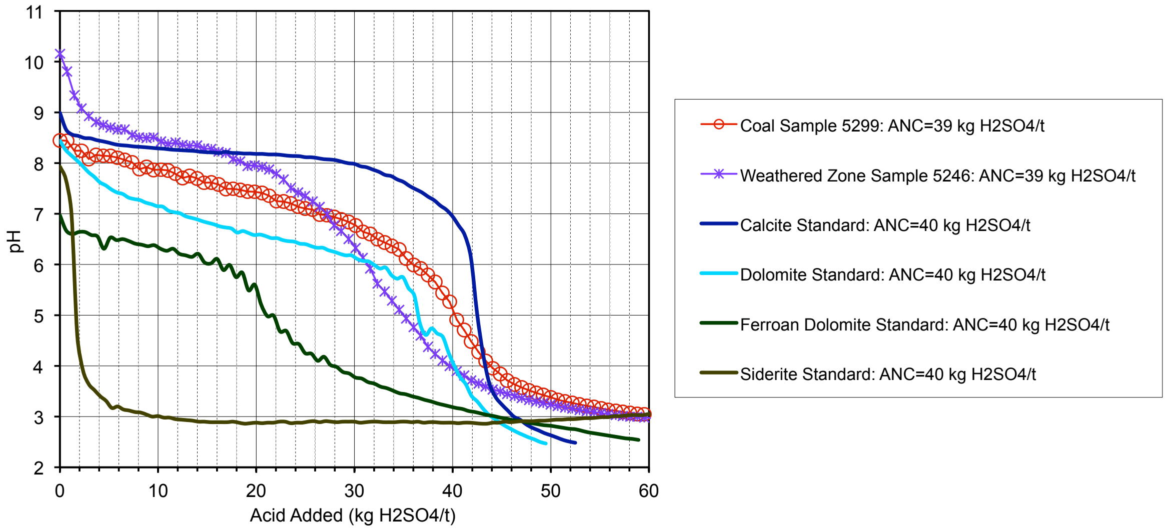


Figure 17: ABCC profile for samples with an ANC value close to 40 kg H_2SO_4/t. Carbonate standard curves are included for reference.

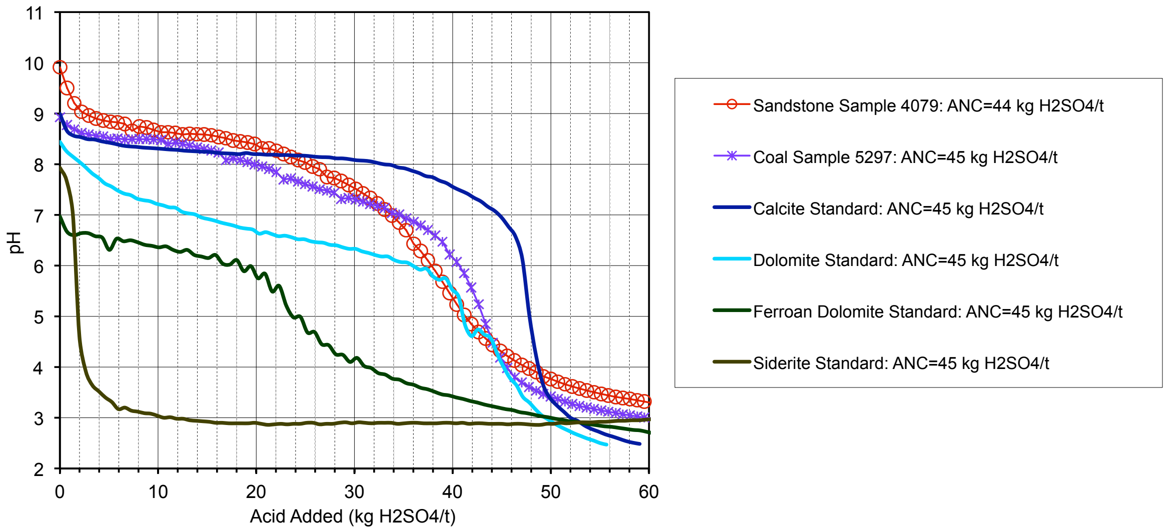


Figure 18: ABCC profile for samples with an ANC value close to 45 kg H_2SO_4/t. Carbonate standard curves are included for reference.

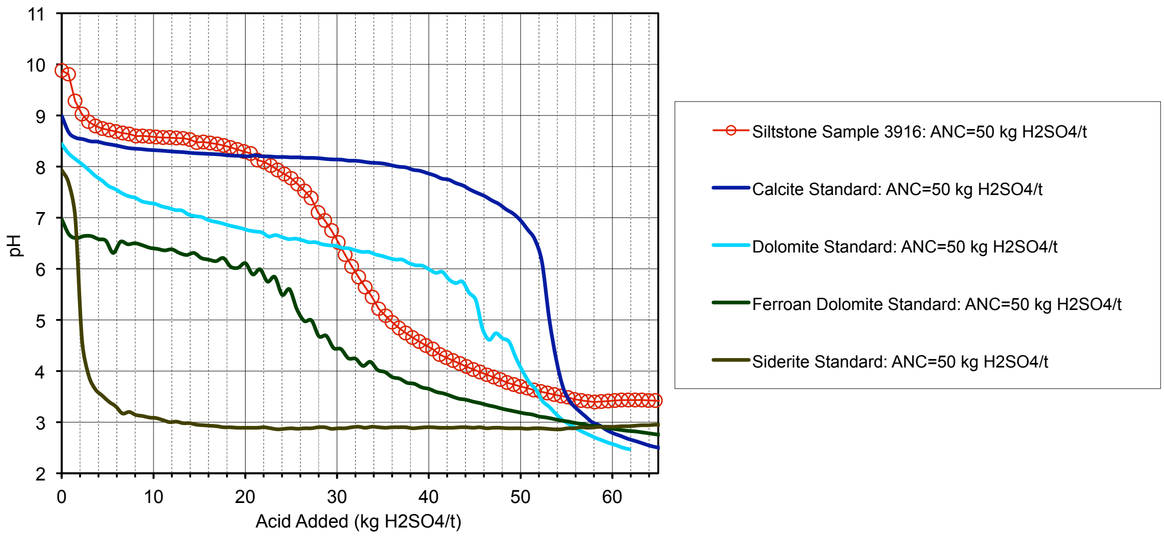


Figure 19: ABCC profile for sample 3916 with an ANC value close to 50 kg H_2SO_4/t. Carbonate standard curves are included for reference.

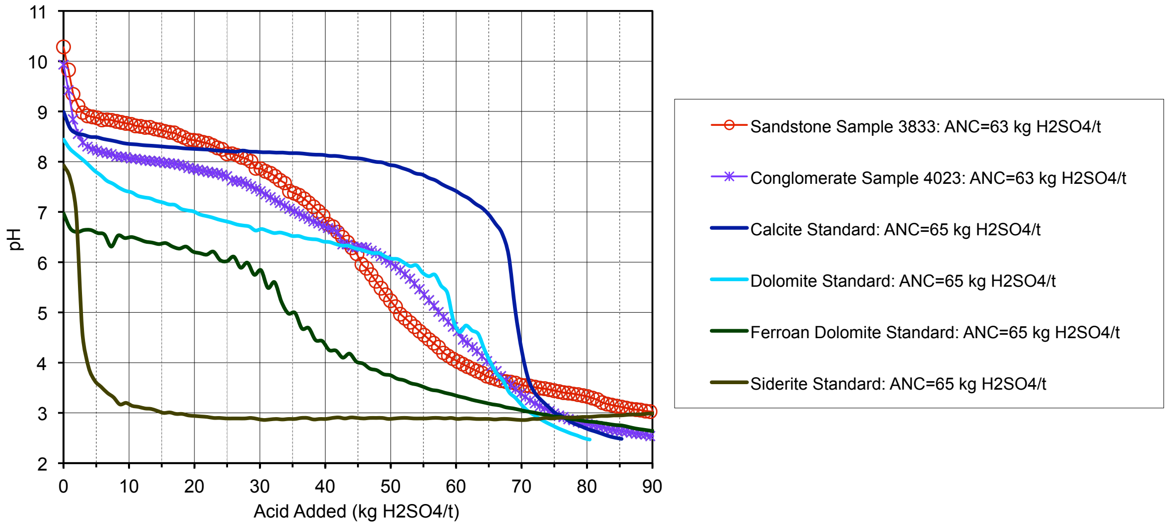


Figure 20: ABCC profile for samples with an ANC value close to 65 kg H_2SO_4/t. Carbonate standard curves are included for reference.

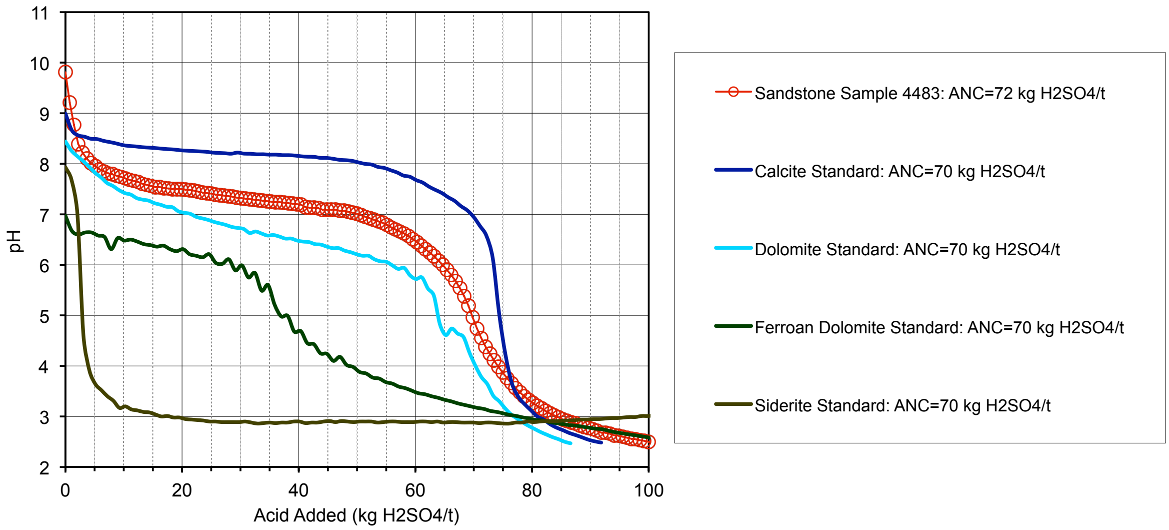


Figure 21: ABCC profile for sample 4483 with an ANC value close to 70 kg H_2SO_4/t. Carbonate standard curves are included for reference.

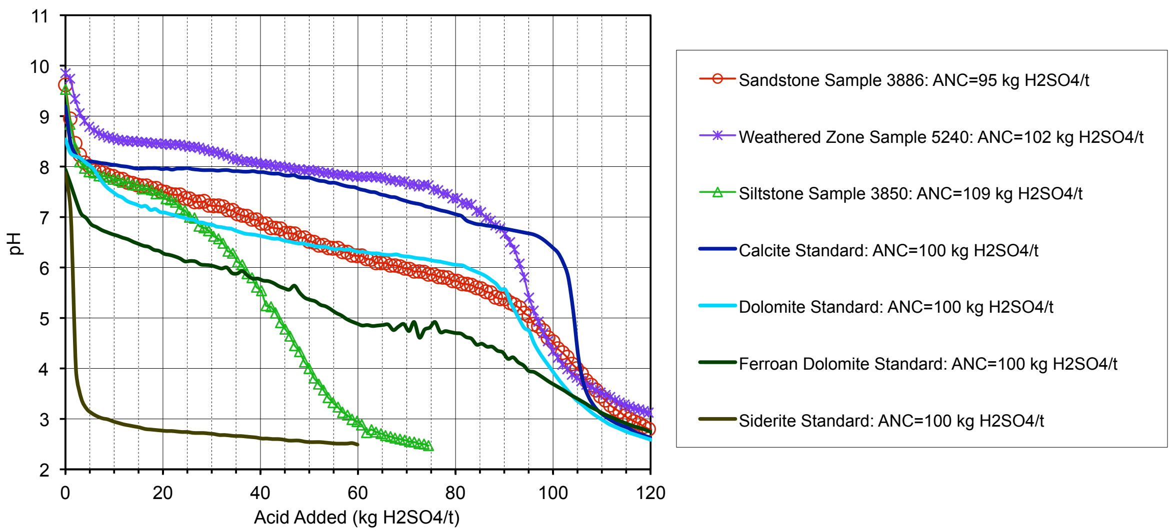


Figure 22: ABCC profile for samples with an ANC value close to 100 kg H_2SO_4/t. Carbonate standard curves are included for reference.

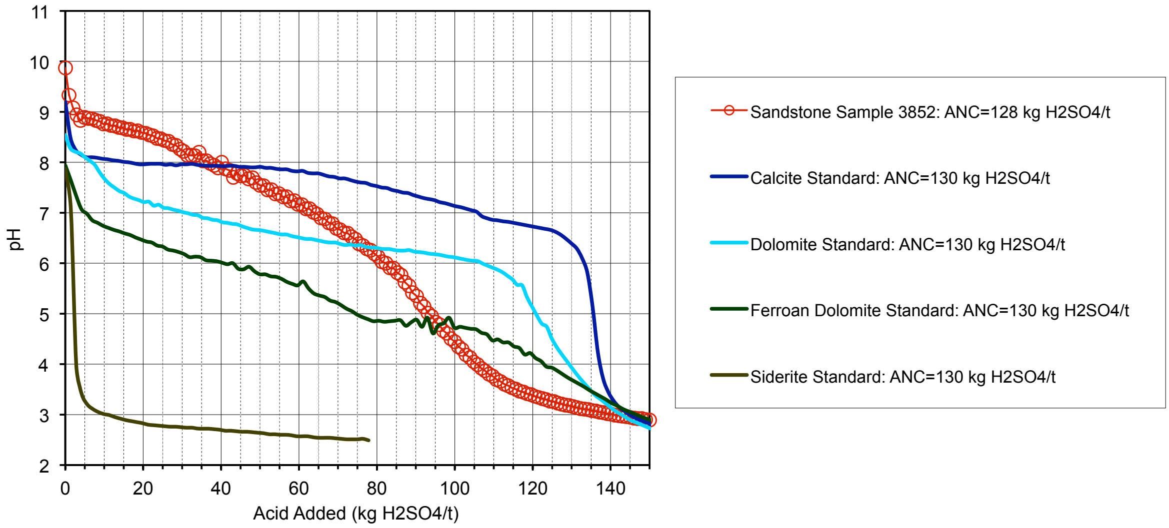


Figure 23: ABCC profile for sample 3852 with an ANC value close to 130 kg H_2SO_4/t. Carbonate standard curves are included for reference.

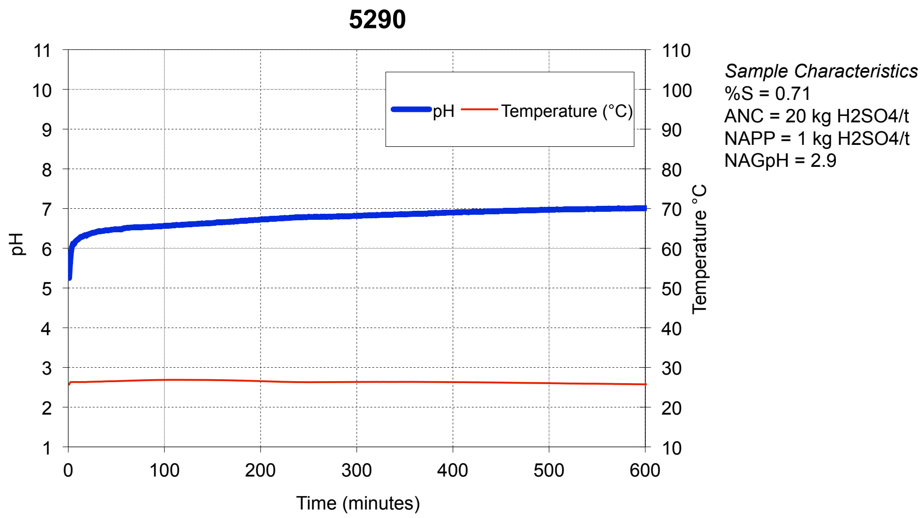


Figure 24: Kinetic NAG graph for coal sample 5290.

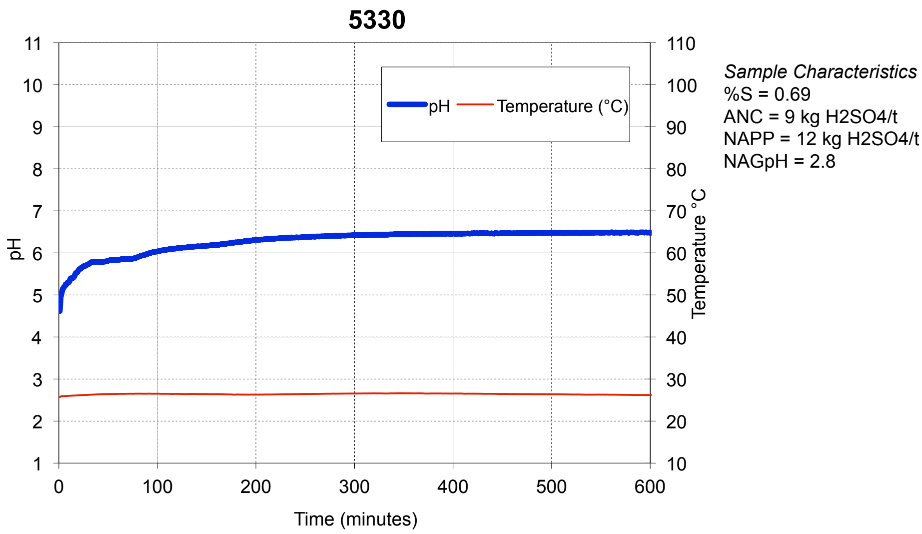


Figure 25: Kinetic NAG graph for coal sample 5330.

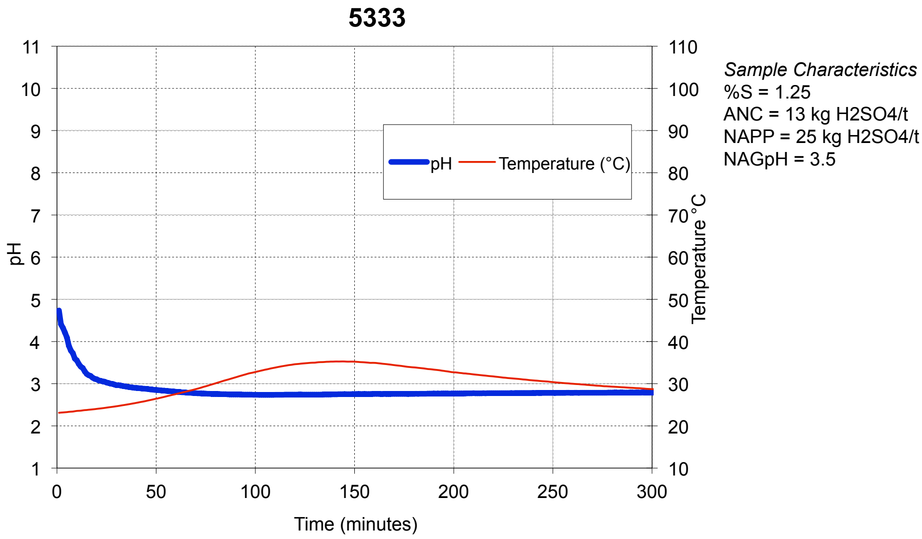


Figure 26: Kinetic NAG graph for coal sample 5333.

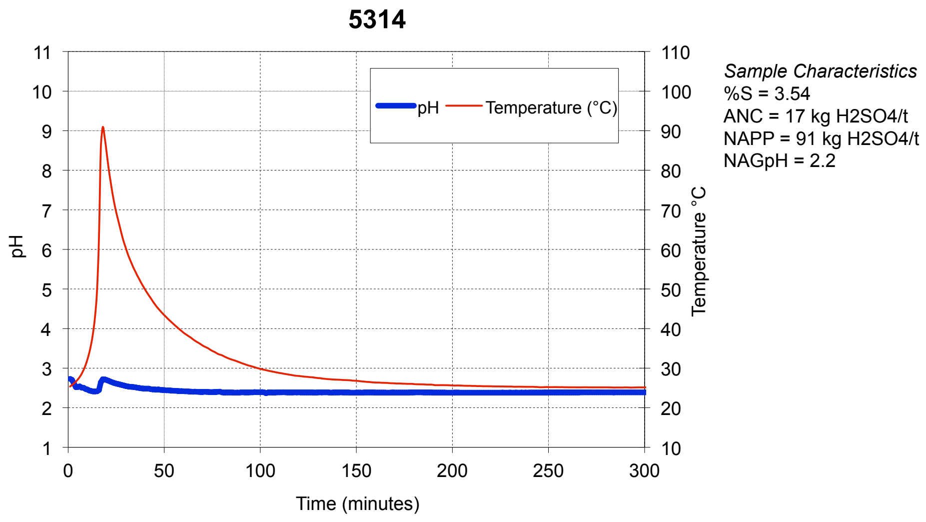


Figure 27: Kinetic NAG graph for coal sample 5314.

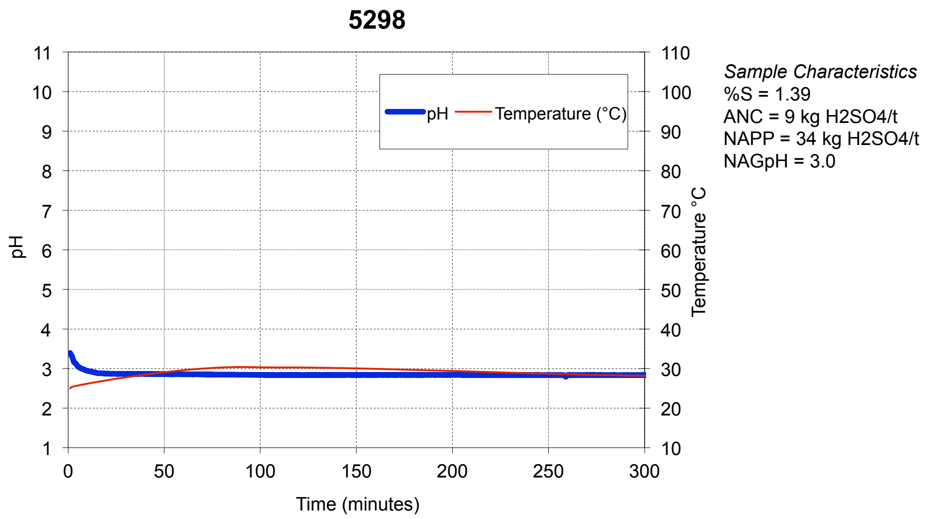


Figure 28: Kinetic NAG graph for coal sample 5298.

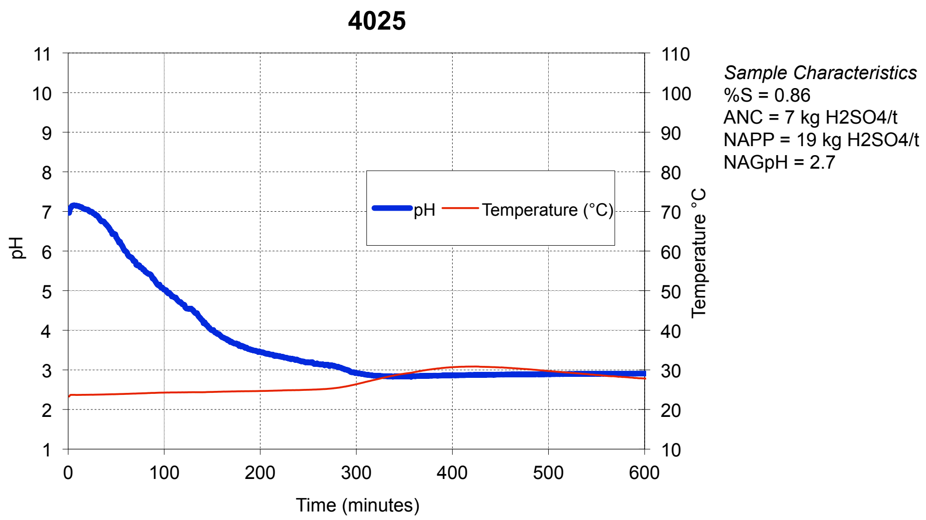
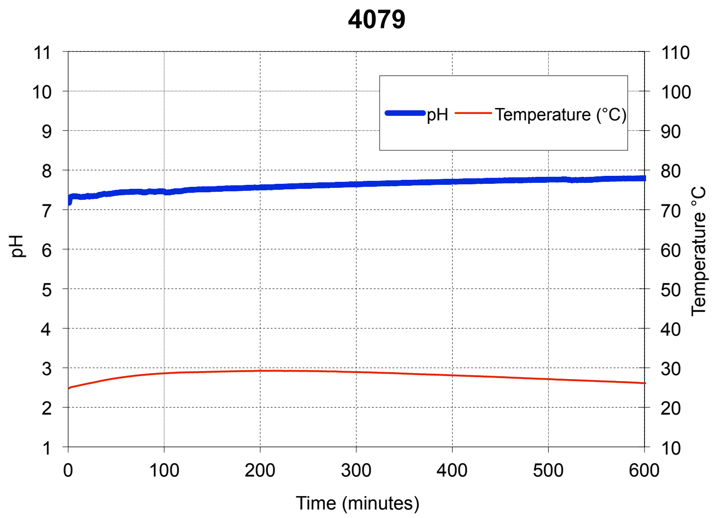
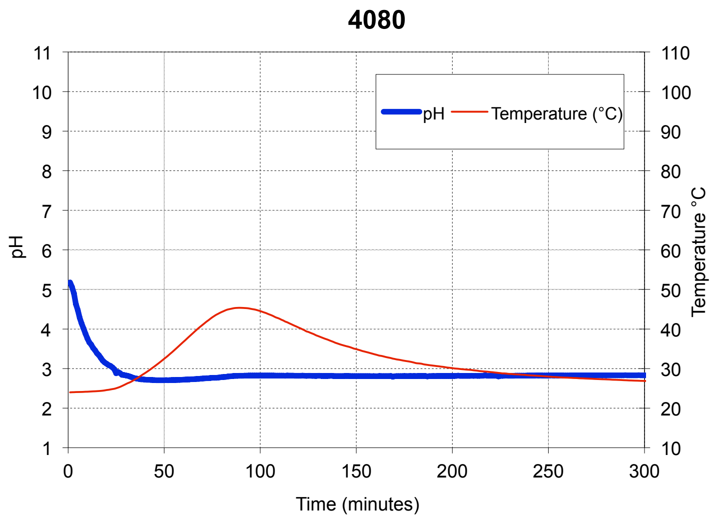


Figure 29: Kinetic NAG graph for sandstone sample 4025.



Sample Characteristics
%S = 0.96
ANC = 44 kg H2SO4/t
NAPP = -14 kg H2SO4/t
NAGpH = 7.5

Figure 30: Kinetic NAG graph for sandstone sample 4079.



Sample Characteristics
%S = 1.26
ANC = 10 kg H2SO4/t
NAPP = 28 kg H2SO4/t
NAGpH = 2.6

Figure 31: Kinetic NAG graph for siltstone sample 4080.

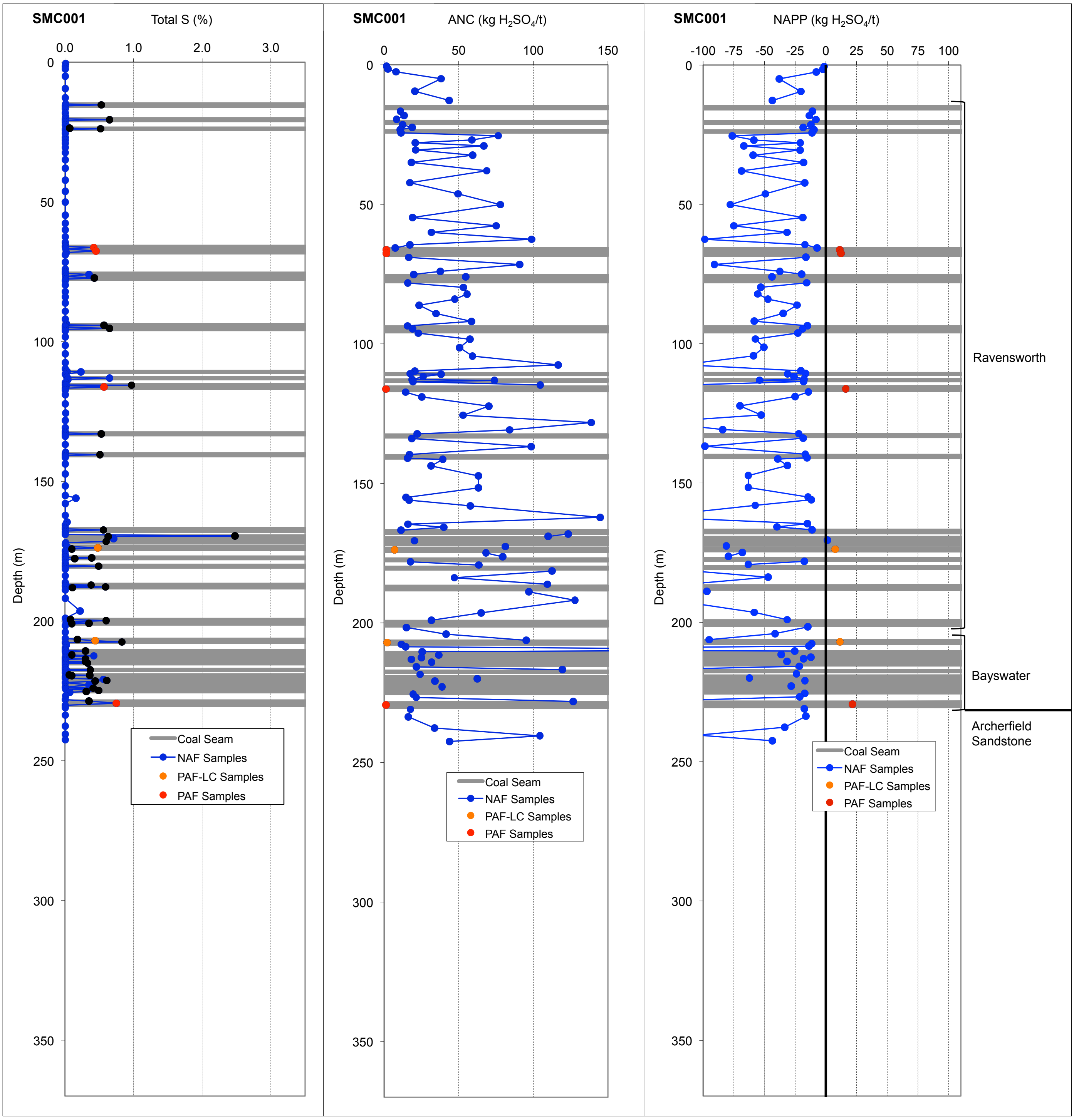


Figure 32: Total S, ANC and NAPP profiles for hole SMC001.

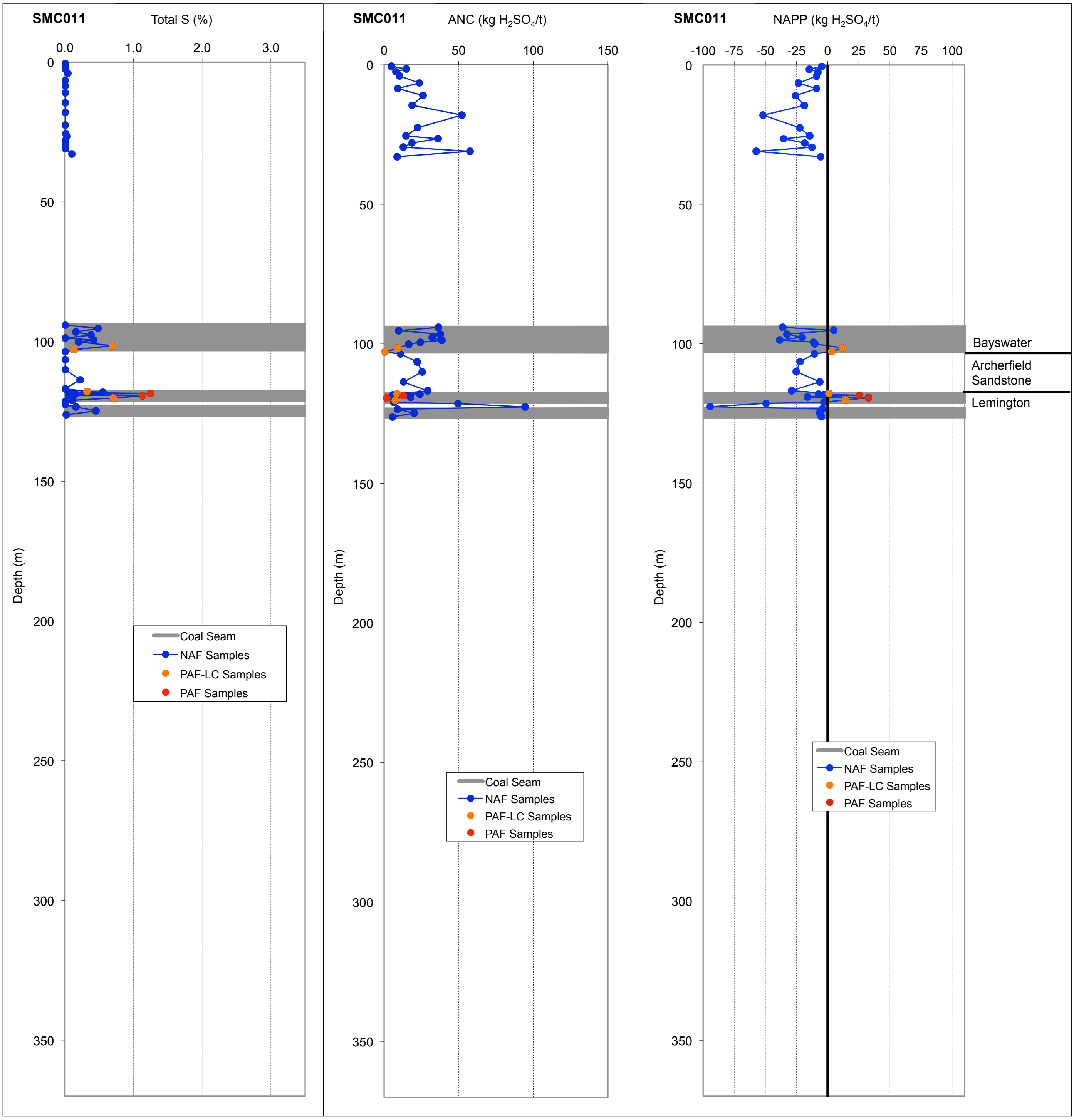


Figure 33: Total S, ANC and NAPP profiles for hole SMC011.

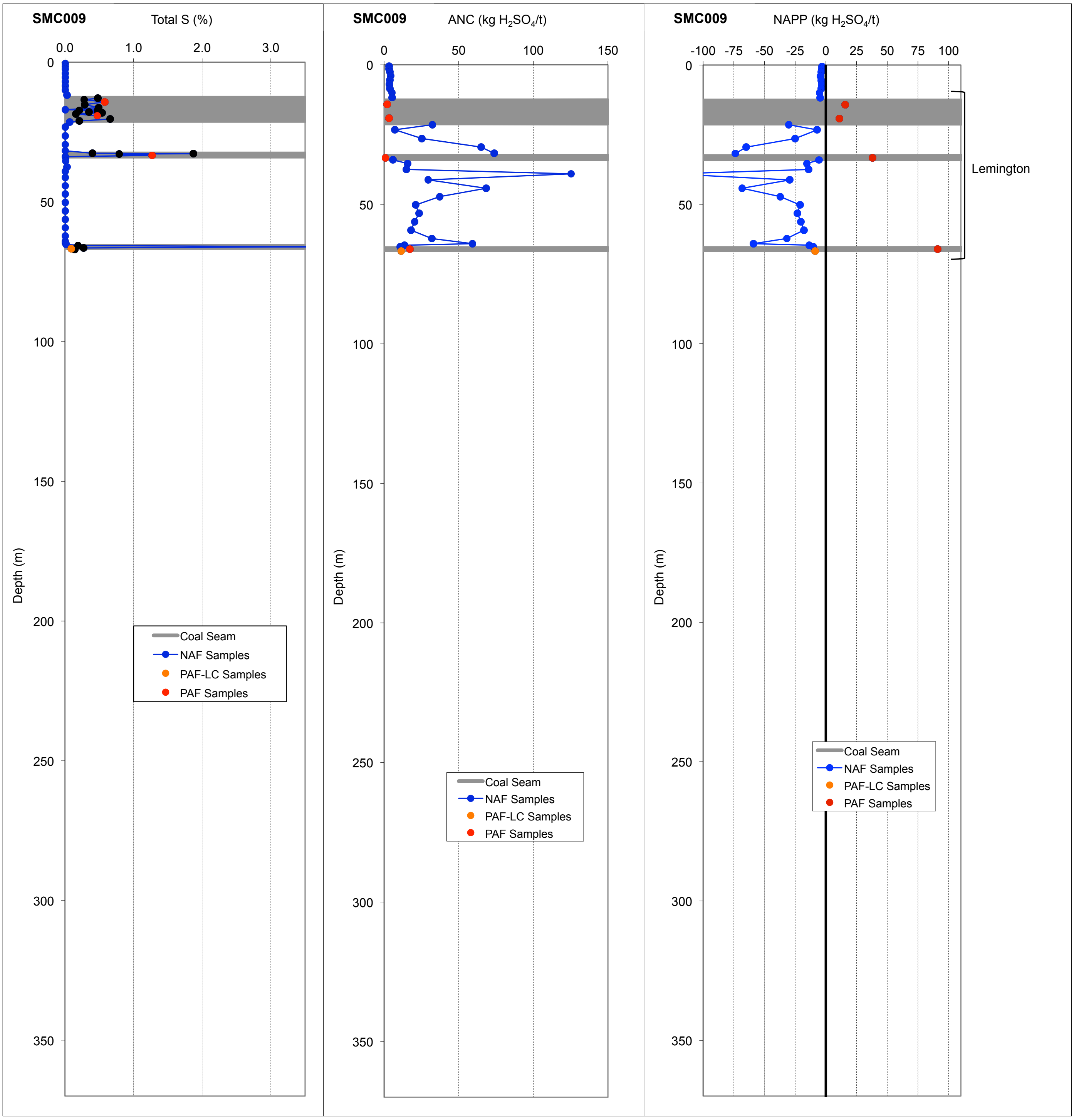


Figure 34: Total S, ANC and NAPP profiles for hole SMC009.

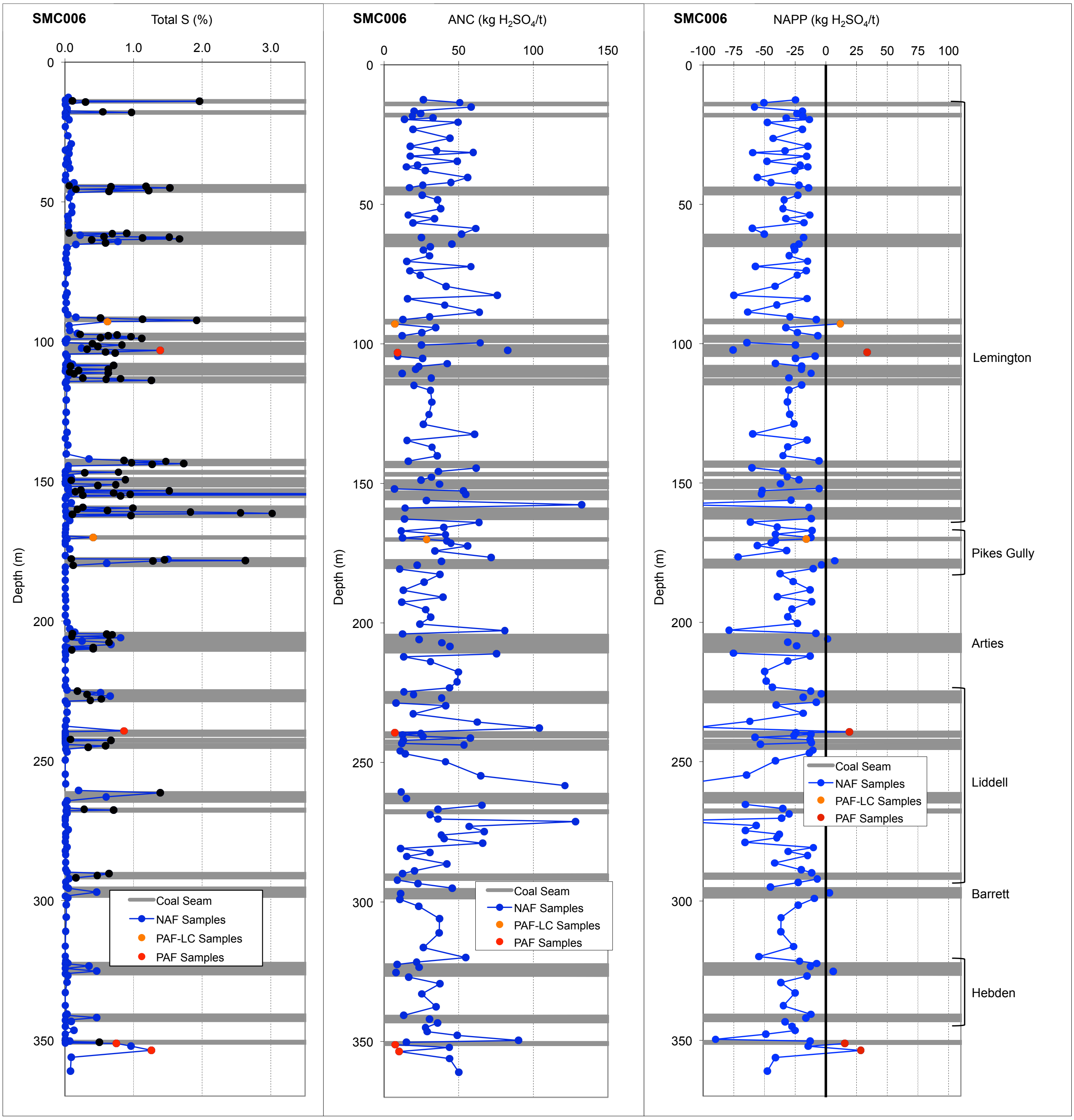


Figure 35: Total S, ANC and NAPP profiles for hole SMC006.

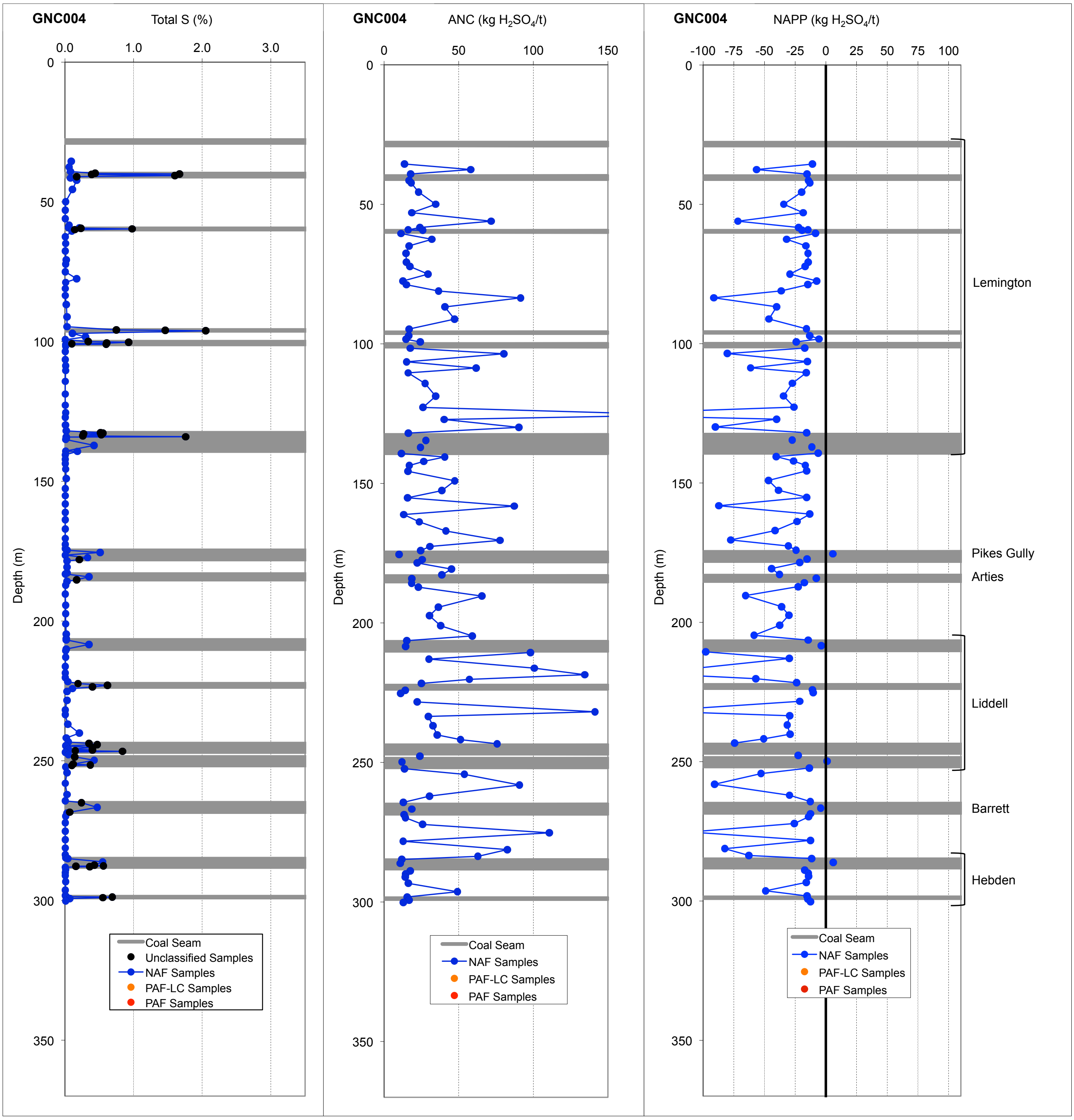


Figure 36: Total S, ANC and NAPP profiles for hole GNC004.

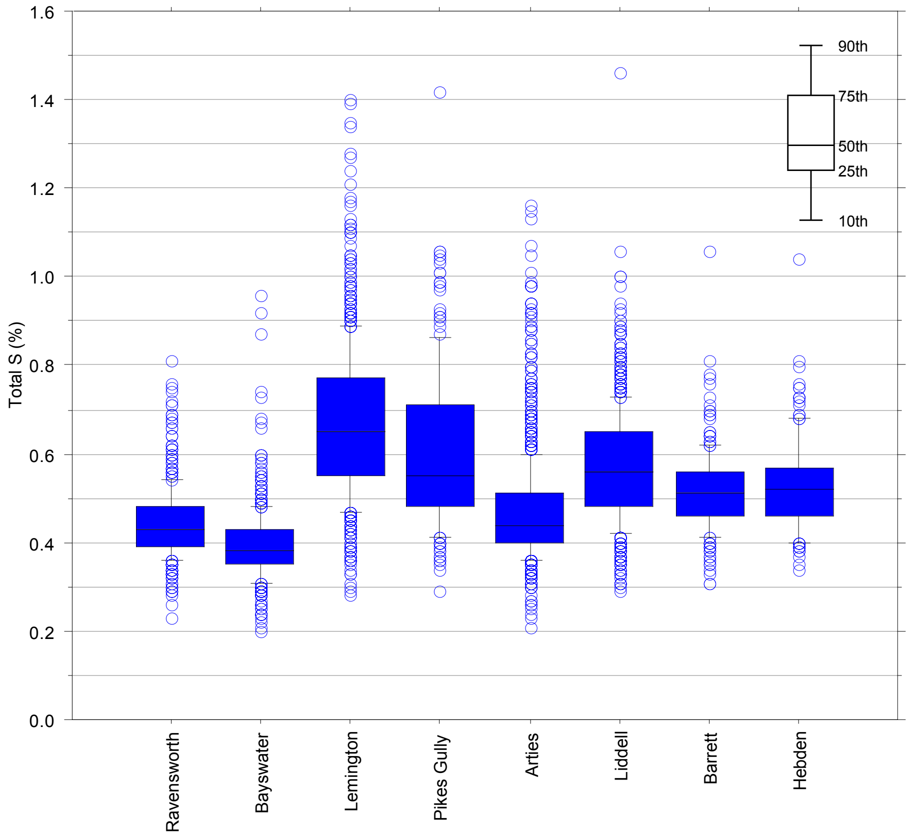


Figure 37: Box plot showing the distribution of raw coal total S for the main seam groups. Box plots have 10th, 25th, 50th (median), 75th and 90th percentiles marked.

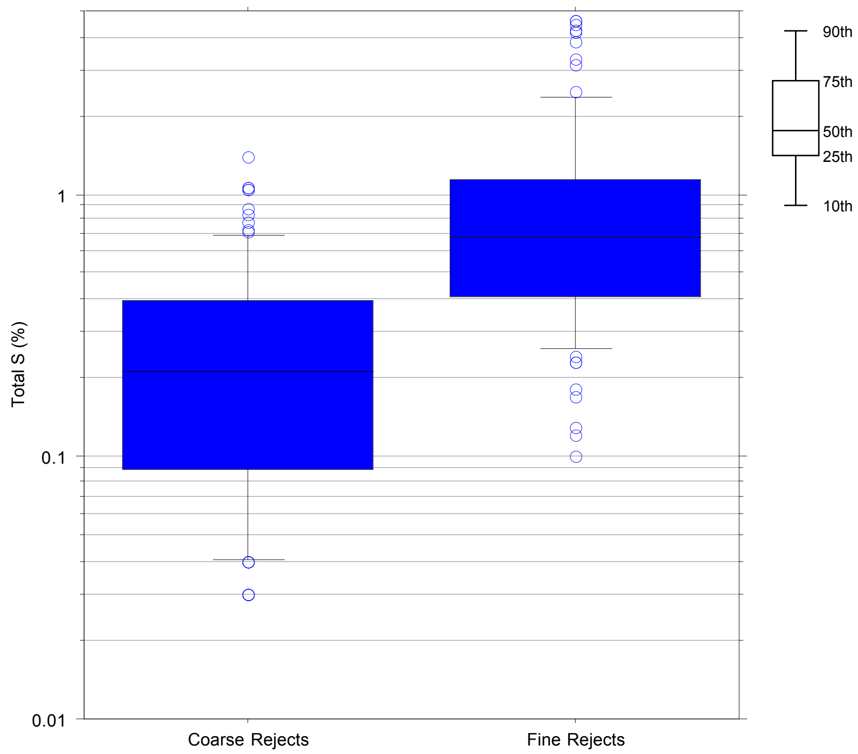


Figure 38: Box plot showing the distribution of total S for coarse and fine rejects. Box plots have 10th, 25th, 50th (median), 75th and 90th percentiles marked.

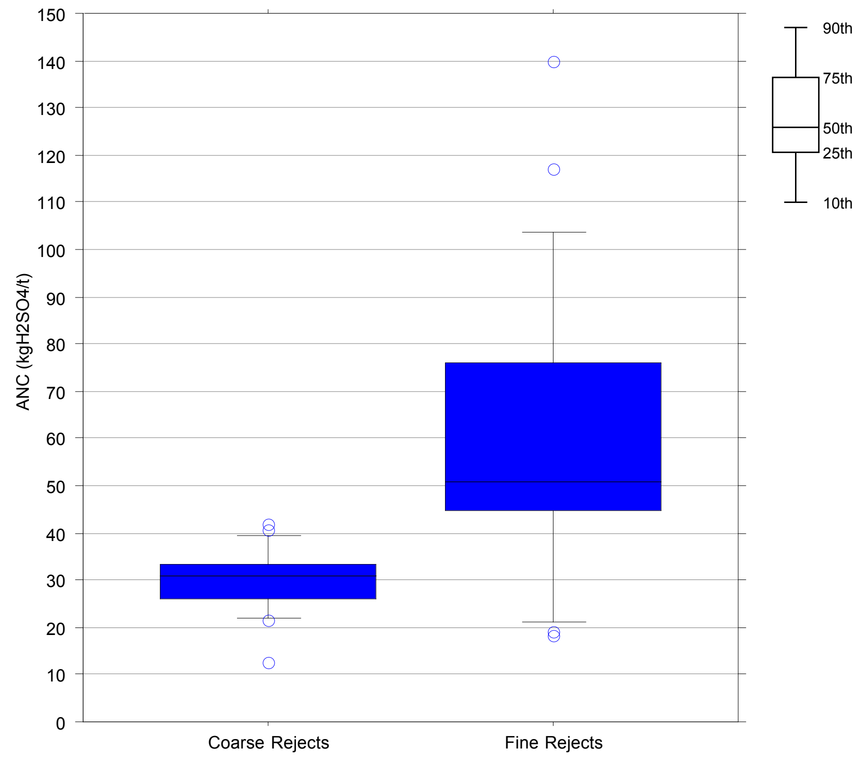


Figure 39: Box plot showing the distribution of ANC for coarse and fine rejects. Box plots have 10th, 25th, 50th (median), 75th and 90th percentiles marked.

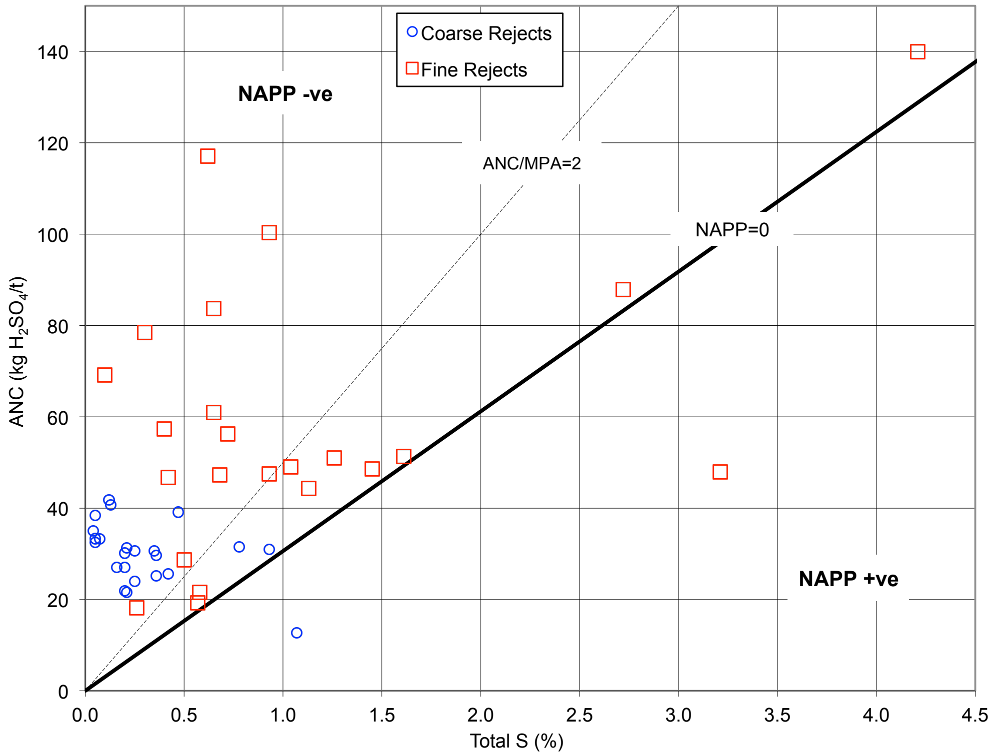


Figure 40: Acid-base account (ABA) plot showing ANC versus total S coarse and fine rejects samples.

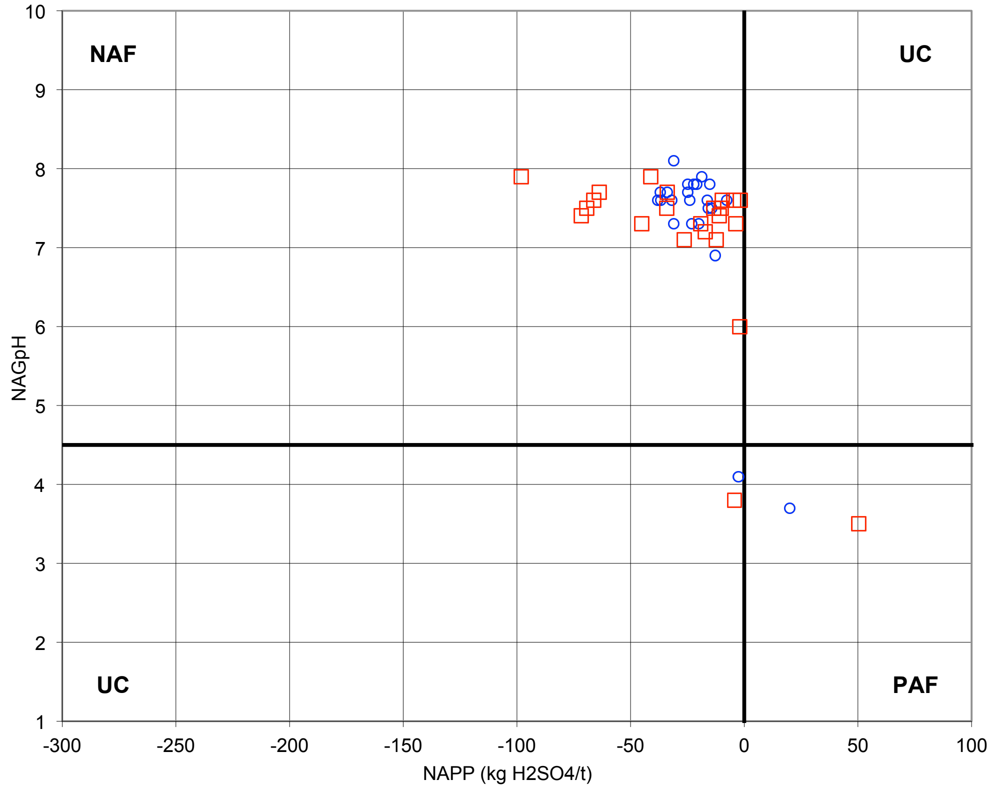


Figure 41: ARD classification plot showing NAGpH versus NAPP for rejects samples, with ARD classification domains indicated.

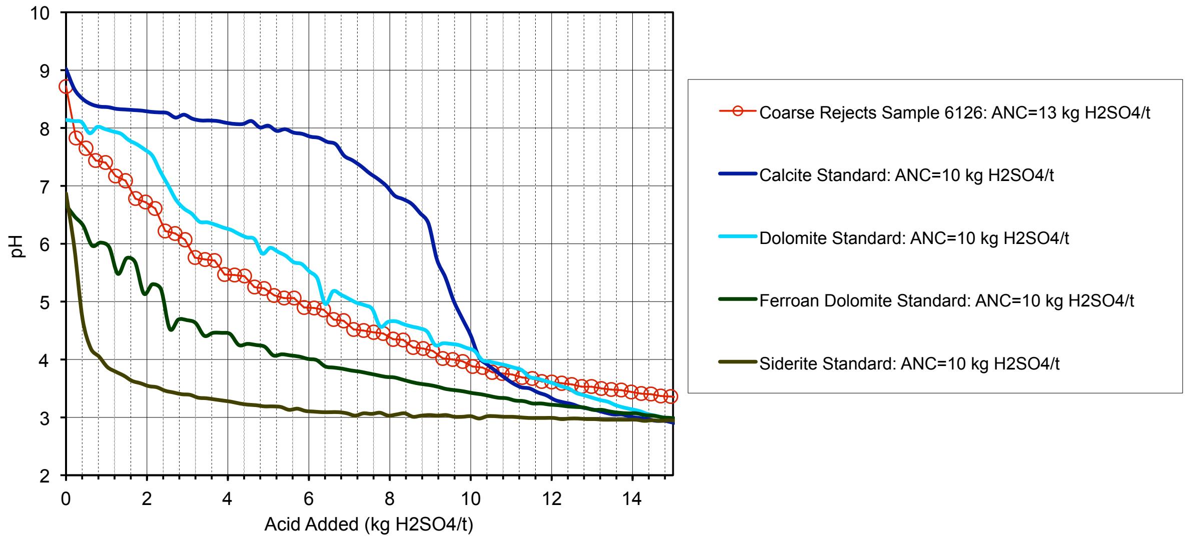


Figure 42: ABCC profile for rejects sample 6126 with an ANC value close to 10 kg H_2SO_4/t. Carbonate standard curves are included for reference.

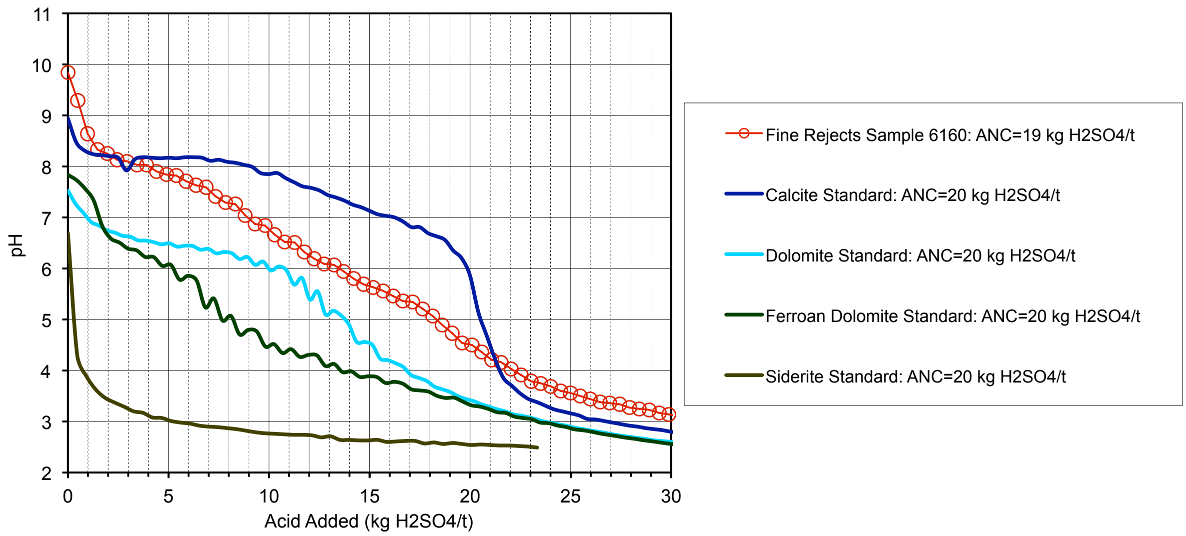


Figure 43: ABCC profile for rejects sample 6160 with an ANC value close to 20 kg H_2SO_4/t. Carbonate standard curves are included for reference.

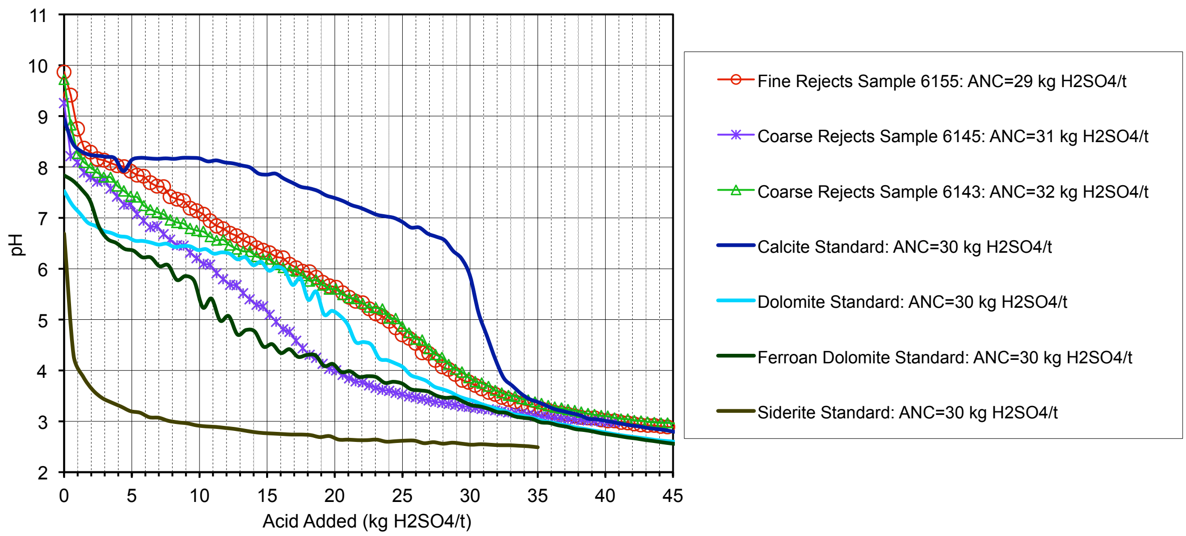


Figure 44: ABCC profile for rejects samples with an ANC value close to 30 kg H_2SO_4/t. Carbonate standard curves are included for reference.

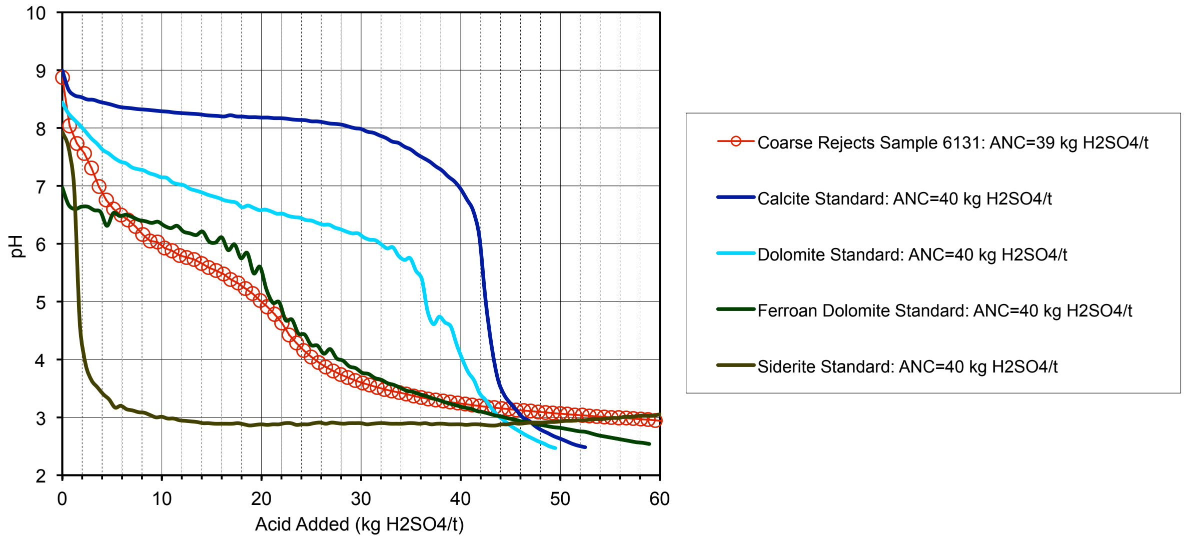


Figure 45: ABCC profile for rejects sample 6131 with an ANC value close to 40 kg H_2SO_4/t. Carbonate standard curves are included for reference.

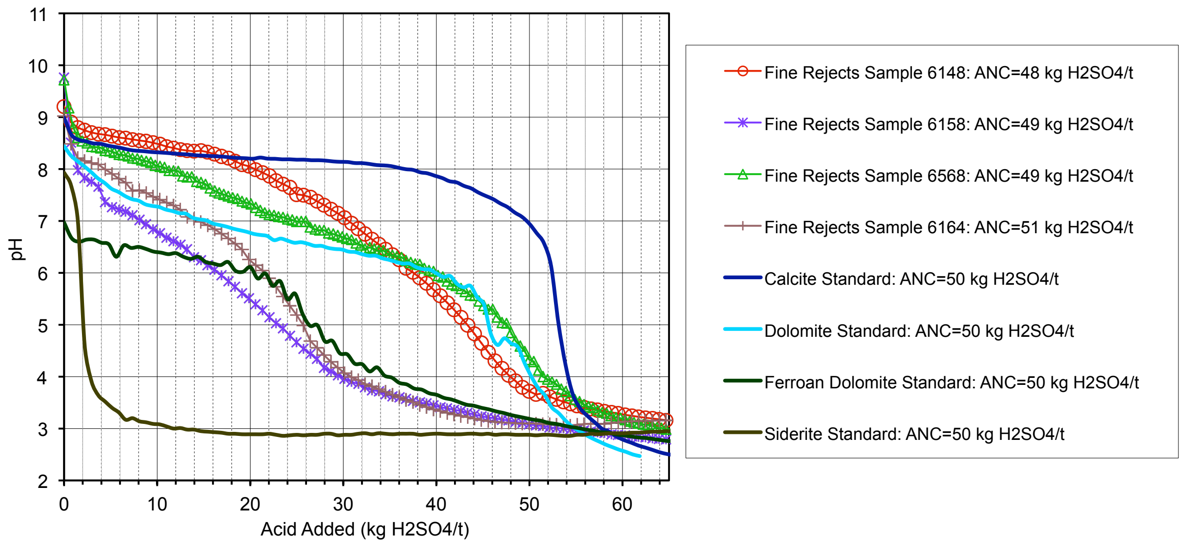


Figure 46: ABCC profile for rejects samples with an ANC value close to 50 kg H_2SO_4/t. Carbonate standard curves are included for reference.

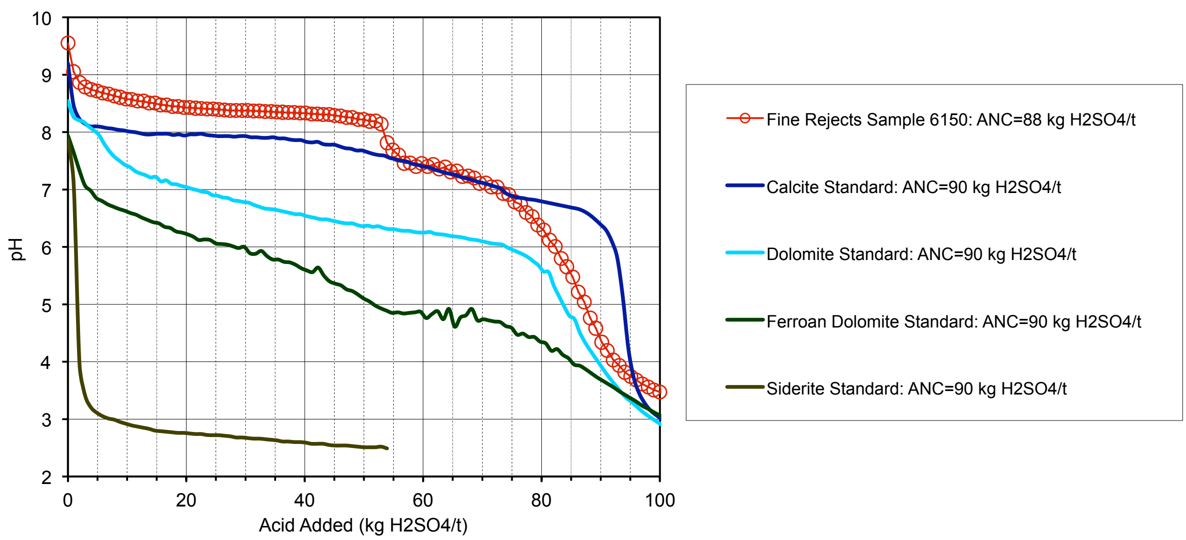


Figure 47: ABCC profile for rejects sample 6150 with an ANC value close to 90 kg H_2SO_4/t. Carbonate standard curves are included for reference.

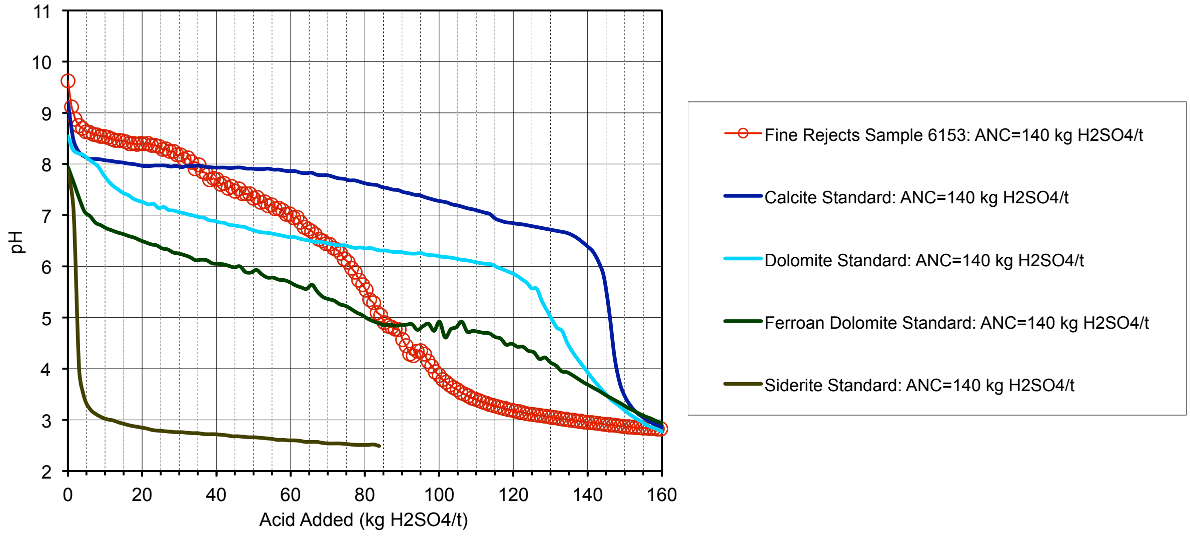


Figure 48: ABCC profile for rejects sample 6153 with an ANC value close to 140 kg H_2SO_4/t. Carbonate standard curves are included for reference.

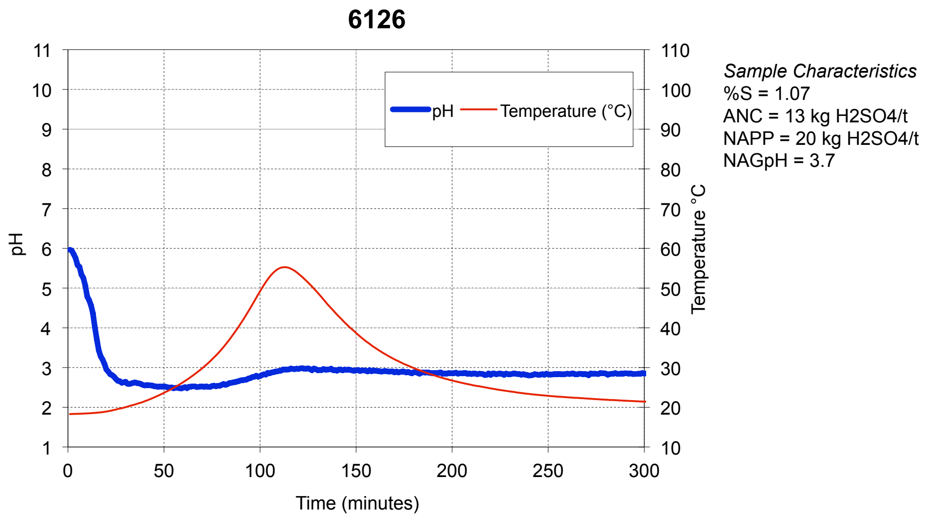


Figure 49: Kinetic NAG graph for coarse rejects sample 6126.

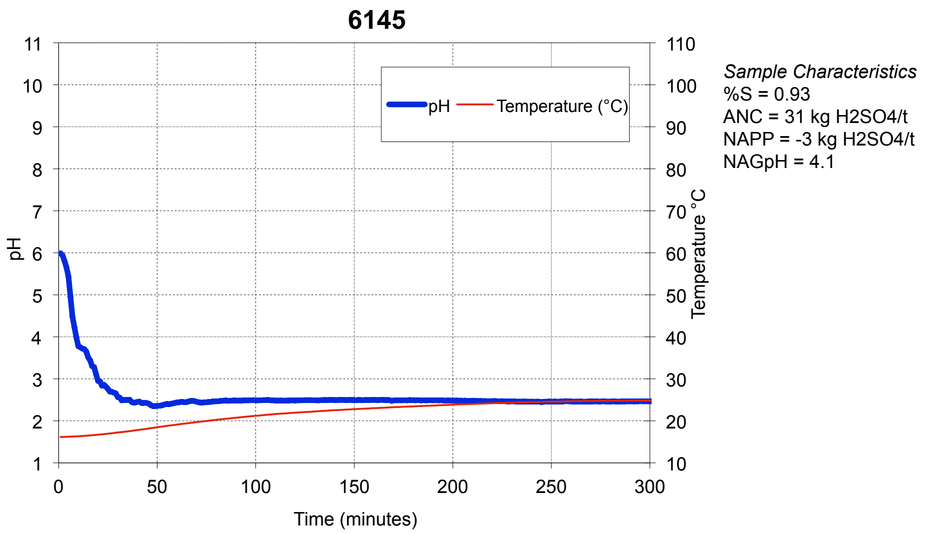


Figure 50: Kinetic NAG graph for coarse rejects sample 6145.

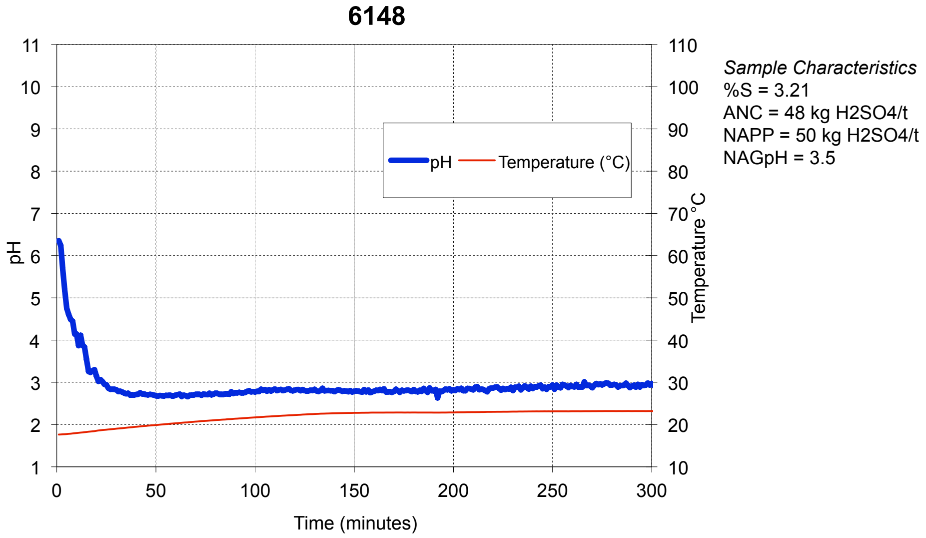


Figure 51: Kinetic NAG graph for fine rejects sample 6148.

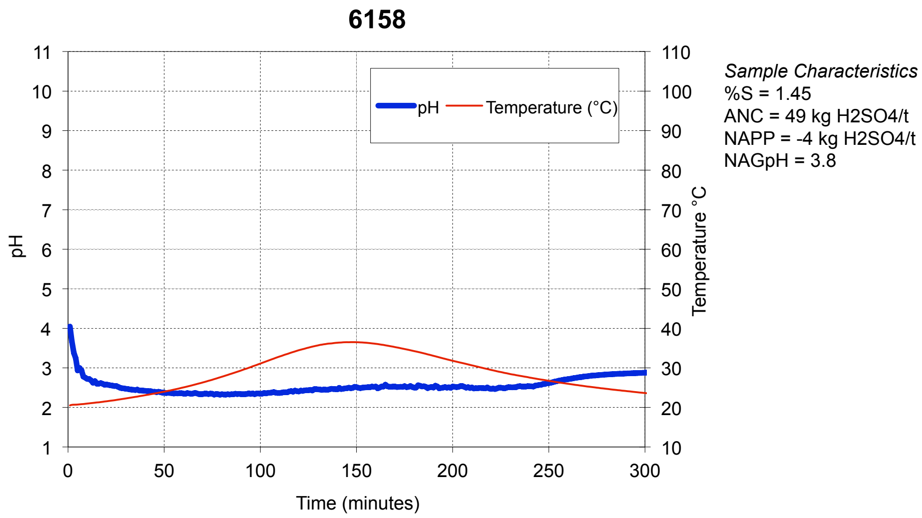


Figure 52: Kinetic NAG graph for fine rejects sample 6158.

APPENDIX A

Assessment of Acid Forming Characteristics

Assessment of Acid Forming Characteristics

Introduction

Acid rock drainage (ARD) is produced by the exposure of sulphide minerals such as pyrite to atmospheric oxygen and water. The ability to identify in advance any mine materials that could potentially produce ARD is essential for timely implementation of mine waste management strategies.

A number of procedures have been developed to assess the acid forming characteristics of mine waste materials. The most widely used methods are the Acid-Base Account (ABA) and the Net Acid Generation (NAG) test. These methods are referred to as static procedures because each involves a single measurement in time.

Acid-Base Account

The acid-base account involves static laboratory procedures that evaluate the balance between acid generation processes (oxidation of sulphide minerals) and acid neutralising processes (dissolution of alkaline carbonates, displacement of exchangeable bases, and weathering of silicates).

The values arising from the acid-base account are referred to as the potential acidity and the acid neutralising capacity, respectively. The difference between the potential acidity and the acid neutralising capacity value is referred to as the net acid producing potential (NAPP).

The chemical and theoretical basis of the ABA are discussed below.

Potential Acidity

The potential acidity that can be generated by a sample is calculated from an estimate of the pyrite (FeS_2) content and assumes that the pyrite reacts under oxidising conditions to generate acid according to the following reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

Based on the above reaction, the potential acidity of a sample containing 1 %S as pyrite would be 30.6 kilograms of H_2SO_4 per tonne of material (i.e. kg H_2SO_4/t). The pyrite content estimate can be based on total S and the potential acidity determined from total S is referred to as the maximum potential acidity (MPA), and is calculated as follows:

$$\text{MPA (kg } H_2SO_4\text{/t)} = \text{(Total \%S)} \times 30.6$$

The use of an MPA calculated from total sulphur is a conservative approach because some sulphur may occur in forms other than pyrite. Sulphate-sulphur, organic sulphur and native sulphur, for example, are non-acid generating sulphur forms. Also, some sulphur may occur as other metal sulphides (e.g. covellite, chalcocite, sphalerite, galena) which yield less acidity than pyrite when oxidised or, in some cases, may be non-acid generating. The total sulphur content is commonly used to assess potential acidity because of the difficulty, costs and uncertainty involved in routinely determining the speciation of sulphur forms within samples, and determining reactive sulphide-sulphur contents. However, if the sulphide mineral forms are known then allowance can be made for non- and lesser acid generating forms to provide a better estimate of the potential acidity.

Acid Neutralising Capacity (ANC)

The acid formed from pyrite oxidation will to some extent react with acid neutralising minerals contained within the sample. This inherent acid buffering is quantified in terms of the ANC.

The ANC is commonly determined by the Modified Sobek method. This method involves the addition of a known amount of standardised hydrochloric acid (HCl) to an accurately weighed sample, allowing the sample time to react (with heating), then back-titrating the mixture with standardised sodium hydroxide (NaOH) to determine the amount of unreacted HCl. The amount of acid consumed by reaction with the sample is then calculated and expressed in the same units as the MPA (kg H_2SO_4/t).

Net Acid Producing Potential (NAPP)

The NAPP is a theoretical calculation commonly used to indicate if a material has potential to produce acidic drainage. It represents the balance between the capacity of a sample to generate acid (MPA) and its capacity to neutralise acid (ANC). The NAPP is also expressed in units of kg H_2SO_4/t and is calculated as follows:

$$\text{NAPP} = \text{MPA} - \text{ANC}$$

If the MPA is less than the ANC then the NAPP is negative, which indicates that the sample may have sufficient ANC to prevent acid generation. Conversely, if the MPA exceeds the ANC then the NAPP is positive, which indicates that the material may be acid generating.

ANC/MPA Ratio

The ANC/MPA ratio is frequently used as a means of assessing the risk of acid generation from mine waste materials. The ANC/MPA ratio is another way of looking at the acid base account. A positive NAPP is equivalent to an ANC/MPA ratio less than 1, and a negative NAPP is equivalent to an ANC/MPA ratio greater than 1. A NAPP of zero is equivalent to an ANC/MPA ratio of 1.

The purpose of the ANC/MPA ratio is to provide an indication of the relative margin of safety (or lack thereof) within a material. Various ANC/MPA values are reported in the literature for indicating safe values for prevention of acid generation. These values typically range from 1 to 3. As a general rule, an ANC/MPA ratio of 2 or more signifies that there is a high probability that the material will remain circum-neutral in pH and thereby should not be problematic with respect to acid rock drainage.

Acid-Base Account Plot

Sulphur and ANC data are often presented graphically in a format similar to that shown in Figure A-1. This figure includes a line indicating the division between NAPP positive samples from NAPP negative samples. Also shown are lines corresponding to ANC/MPA ratios of 2 and 3.

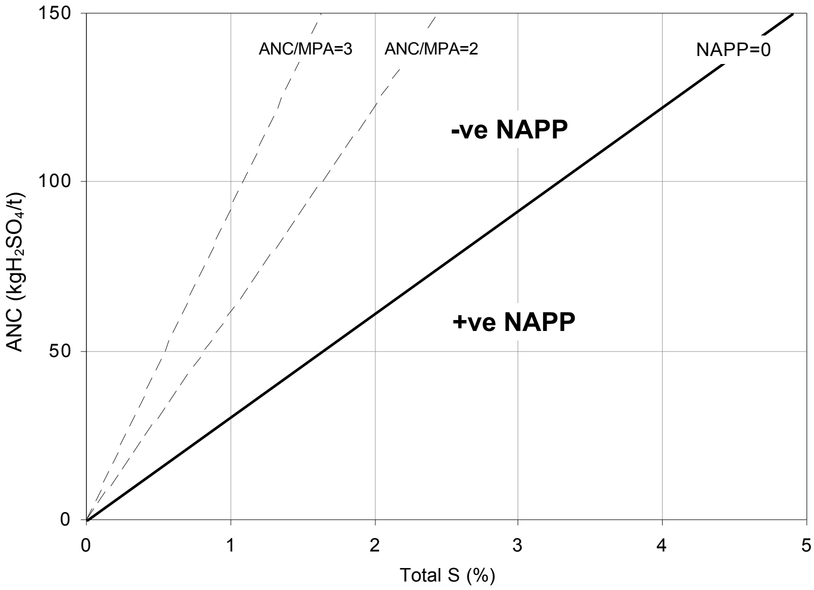


Figure A-1: Acid-base account (ABA) plot

Net Acid Generation (NAG) Test

The NAG test is used in association with the NAPP to classify the acid generating potential of a sample. The NAG test involves reaction of a sample with hydrogen peroxide to rapidly oxidise any sulphide minerals contained within a sample. During the NAG test both acid generation and acid neutralisation reactions can occur simultaneously. The end result represents a direct measurement of the net amount of acid generated by the sample. The final pH is referred to as the NAGpH and the amount of acid produced is commonly referred to as the NAG capacity, and is expressed in the same units as the NAPP (kg H_2SO_4/t).

Several variations of the NAG test have been developed to accommodate the wide geochemical variability of mine waste materials. The four main NAG test procedures currently used by EGi are the single addition NAG test, the sequential NAG test, the kinetic NAG test, and the extended boil and calculated NAG test.

Single Addition NAG Test

The single addition NAG test involves the addition of 250 ml of 15% hydrogen peroxide to 2.5 g of sample. The peroxide is allowed to react with the sample overnight and the following day the sample is gently heated to accelerate the oxidation of any remaining sulphides, then vigorously boiled for several minutes to decompose residual peroxide. When cool, the NAGpH and NAG capacity are measured.

An indication of the form of the acidity is provided by initially titrating the NAG liquor to pH 4.5, then continuing the titration up to pH 7. The titration value at pH 4.5 includes acidity due to free acid (i.e. H_2SO_4) as well as soluble iron and aluminium. The titration value at pH 7 also includes metallic ions that precipitate as hydroxides at between pH 4.5 and 7.

Sequential NAG Test

When testing samples with high sulphide contents it is not uncommon for oxidation to be incomplete in the single addition NAG test. This can sometimes occur when there is catalytic breakdown of the hydrogen peroxide before it has had a chance to oxidise all of the sulphides in a sample. To overcome this limitation, a sequential NAG test is often carried out. This test may also be used to assess the relative geochemical lag of PAF samples with high ANC.

The sequential NAG test is a multi-stage procedure involving a series of single addition NAG tests on the one sample (i.e. 2.5 g of sample is reacted two or more times with 250 ml aliquots of 15% hydrogen peroxide). At the end of each stage, the sample is filtered and the solution is used for measurement of NAGpH and NAG capacity. The NAG test is then repeated on the solid residue. The cycle is repeated until such time that there is no further catalytic decomposition of the peroxide, or when the NAGpH is greater than pH 4.5. The overall NAG capacity of the sample is then determined by summing the individual acid capacities from each stage.

Kinetic NAG Test

The kinetic NAG test is the same as the single addition NAG test except that the temperature and pH of the liquor are recorded. Variations in these parameters during the test provide an indication of the kinetics of sulphide oxidation and acid generation. This, in turn, can provide an insight into the behaviour of the material under field conditions. For example, the pH trend gives an estimate of relative reactivity and may be related to prediction of lag times and oxidation rates similar to those measured in leach columns. Also, sulphidic samples commonly produce a temperature excursion during the NAG test due to the decomposition of the peroxide solution, catalysed by sulphide surfaces and/or oxidation products.

Extended Boil and Calculated NAG Test

Organic acids may be generated in NAG tests due to partial oxidation of carbonaceous materials[1] such as coal washery wastes. This can lead to low NAGpH values and high acidities in standard single addition NAG tests unrelated to acid generation from sulphides. Organic acid effects can therefore result in misleading NAG values and misclassification of the acid forming potential of a sample.

The extended boil and calculated NAG tests can be used to account for the relative proportions of pyrite derived acidity and organic acidity in a given NAG solution, thus providing a more reliable measure of the acid forming potential of a sample. The procedure involves two steps to differentiating pyritic acid from organic derived acid:

Extended Boil NAG	decompose the organic acids and hence remove the influence of non-pyritic acidity on the NAG solution.
Calculated NAG	calculate the net acid potential based on the balance of cations and anions in the NAG solution, which will not be affected by organic acid.

The extended boiling test is carried out on the filtered liquor of a standard NAG test, and involves vigorous boiling of the solution on a hot plate for 3-4 hours. After the boiling step the solution is cooled and the pH measured. An extended boil NAGpH less than 4.5 confirms the sample is potentially acid forming (PAF), but a pH value greater than 4.5 does not necessarily mean that the sample is non acid forming (NAF), due to some loss of free acid during the extended boiling procedure. To address this issue, a split of the same filtered NAG solution is assayed for concentrations of S, Ca, Mg, Na, K and Cl, from which a calculated NAG value is determined[2].

The concentration of dissolved S is used to calculate the amount of acid (as H_2SO_4) generated by the sample and the concentrations of Ca, Mg, Na and K are used to estimate the amount of acid neutralised (as H_2SO_4). The concentration of Cl is used to correct for soluble cations associated with Cl salts, which may be present in the sample and unrelated to acid generating and acid neutralising reactions.

The calculated NAG value is the amount of acid neutralised subtracted from the amount of acid generated. A positive value indicates that the sample has excess acid generation and is likely to be PAF, and a zero or negative value indicates that the sample has excess neutralising capacity and is likely to be NAF.

[1] Stewart, W., Miller, S., Thomas, J.E., and Smart R. (2003), 'Evaluation of the Effects of Organic Matter on the Net Acid Generation (NAG) Test', in *Proceedings of the Sixth International Conference on Acid Rock drainage (ICARD), Cairns, 12-18th July 2003*, 211-222.

[2] Environmental Geochemistry International, Levay and Co. and ACeSSS, 2008. *ACARP Project C15034: Development of ARD Assessment for Coal Process Wastes*, EGi Document No. 3207/817, July 2008.

Sample Classification

The acid forming potential of a sample is classified on the basis of the acid-base and NAG test results into one of the following categories:

- Barren;
- Non-acid forming (NAF);
- Potentially acid forming (PAF); and
- Uncertain (UC).

Barren

A sample classified as barren essentially has no acid generating capacity and no acid buffering capacity. This category is most likely to apply to highly weathered materials. In essence, it represents an 'inert' material with respect to acid generation. The criteria used to classify a sample as barren may vary between sites, but for hard rock mines it generally applies to materials with a total sulphur content ≤ 0.1 %S and an ANC ≤ 5 kg H_2SO_4/t.

Non-acid forming (NAF)

A sample classified as NAF may, or may not, have a significant sulphur content but the availability of ANC within the sample is more than adequate to neutralise all the acid that theoretically could be produced by any contained sulphide minerals. As such, material classified as NAF is considered unlikely to be a source of acidic drainage. A sample is usually defined as NAF when it has a negative NAPP and the final NAG pH ≥ 4.5.

Potentially acid forming (PAF)

A sample classified as PAF always has a significant sulphur content, the acid generating potential of which exceeds the inherent acid neutralising capacity of the material. This means there is a high risk that such a material, even if pH circum-neutral when freshly mined or processed, could oxidise and generate acidic drainage if exposed to atmospheric conditions. A sample is usually defined as PAF when it has a positive NAPP and a final NAGpH < 4.5.

Uncertain (UC)

An uncertain classification is used when there is an apparent conflict between the NAPP and NAG results (i.e. when the NAPP is positive and NAGpH > 4.5, or when the NAPP is negative and NAGpH ≤ 4.5). Uncertain samples are generally given a tentative classification that is shown in brackets e.g. UC(NAF).

Figure A-2 shows the format of the classification plot that is typically used for presentation of NAPP and NAG data. Marked on this plot are the quadrats representing the NAF, PAF and UC classifications.

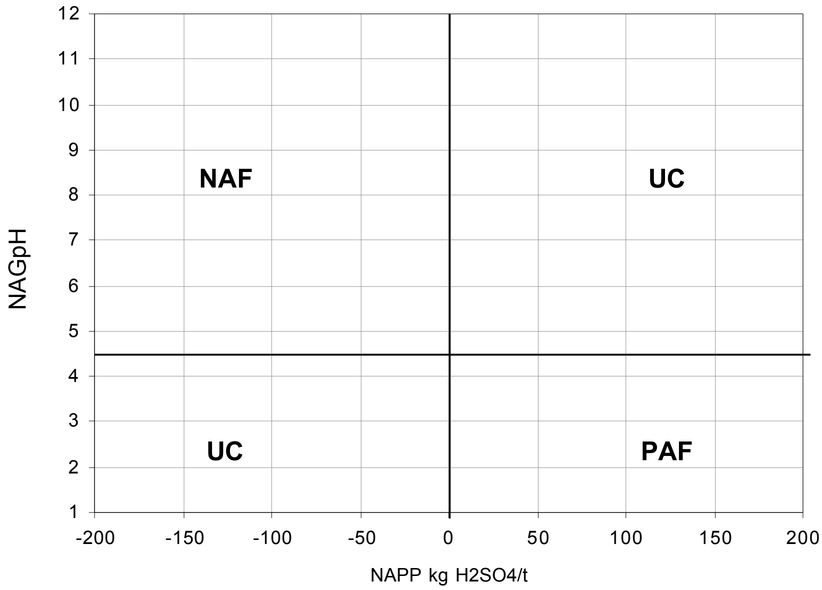


Figure A-2 ARD classification plot

Other Methods

Other test procedures may be used to define the acid forming characteristics of a sample.

pH and Electrical Conductivity

The pH and electrical conductivity (EC) of a sample is determined by equilibrating the sample in deionised water for a minimum of 12 hours (or overnight), typically at a solid to water ratio of 1:2 (w/w). This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Acid Buffering Characteristic Curve (ABCC) Test

The ABCC test involves slow titration of a sample with acid while continuously monitoring pH. These data provides an indication of the portion of ANC within a sample that is readily available for acid neutralisation.

APPENDIX G

Groundwater Model of predicted impacts
from Mount Owen Continued Operations
Project on Alluvial Aquifers

Technical Memorandum

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Date	22 July 2015
To	David Holmes (Umwelt)
Copy	Vicki McBride (Glencore), Susan Shield (Umwelt), Gary Boland (Glencore), Steve Downes (Glencore), Bret Jenkins (Glencore), Brian Rask (Jacobs)
From	Richard Cresswell
Subject	**Refined Numerical Groundwater Model**

Submissions to the Mount Owen Continued Operations Project (the Project) were generally positive regarding all water aspects of the EIS, with a few information and discussion requests, only. These have been addressed via a separate note prepared by Umwelt and Jacobs.

The IESC, however, suggested more detailed groundwater modelling should be carried out in areas where sensitive ecosystems (specifically Swamp Oak and Red Gum areas) may be impacted by groundwater drawdown in the alluvium, as indicated by the extreme impact scenario from the groundwater modelling reported in the Groundwater Impact Assessment (Jacobs, 2014 – EIS Appendix 10).

Jacobs undertook additional modelling in support of a response to comments from the IESC, specifically in relation to the potential inaccuracies that could arise due to the relatively coarse grid resolution for two alluvial aquifers in which drawdowns are predicted to occur, namely: Main and Bettys Creeks.

The model used in the Groundwater Impact Assessment in Appendix 10 of the EIS (v8.1) utilises a grid size of 100x100m, which is commensurate with the regional nature of the model and provides adequate resolution to understand and appreciate the potential impacts to groundwater of the proposed expansion. This current grid resolution is appropriate to model dewatering effects on the hard rock aquifers and this resolution can be maintained in the model for these deeper layers.

Many of the surficial alluvial aquifers, however, either reduce in extent to less than this dimension (i.e. <100 m wide), or consist of heterogeneities that are smaller than this grid size, and hence there are concerns that the grid size used in the model could introduce local inaccuracies, or not provide sufficient intra-alluvial resolution sufficient to isolate separate receptors (communities) potentially supported by groundwater within the alluvium extents.

There is no direct connection with the alluvial aquifers from the proposed mining operations, nor is there any predicted cracking of strata directly below the alluvium. Potential impacts to the alluvial aquifers, and any supported groundwater dependent ecosystems, however, may be expected to result from dewatering activities that depressurise hard rock (coal measures) aquifers and indirectly induce leakage from the alluvial aquifers.

Model refinement

The regional groundwater model used in support of the Project submission(s) was used as a basis to develop a refined grid model centred on Main and Bettys Creeks. The objective of the refined model was specifically to assess if the grid size of the regional model affected the extent and volume of groundwater losses from the alluvial aquifers. Therefore, to compare results between the regional model and the refined model all efforts were made to keep the two models as similar as possible, with the exception of increased spatial resolution, namely decreased grid spacing and refined alluvial aquifer delineation (i.e. surface elevation and isopach).

The following modifications were thus made to model:

- The model domain was reduced to approximately 50 km^2 (**Figure 1**).
- Grid spacing was reduced to 20mx20m uniformly across the alluvium layer of the new model domain, generating 345 rows by 360 columns.
- The surface elevation within the alluvium was refined using the latest LiDAR data.
- The base of the alluvium was refined, based upon a refined isopach map and the refined surface elevations.
- Constant head boundary conditions were input to all active cells in Layer 2. The actual head values at each cell corresponded to the predicted heads in Layer 2 for each stress period from the regional model to simulate transient conditions. These boundary conditions were created for each stochastic realisation.
- Because Layer 2 is entirely constant heads, there was no need for all subsequently deeper layers. Therefore all layers greater than 2 in the regional model were deleted.

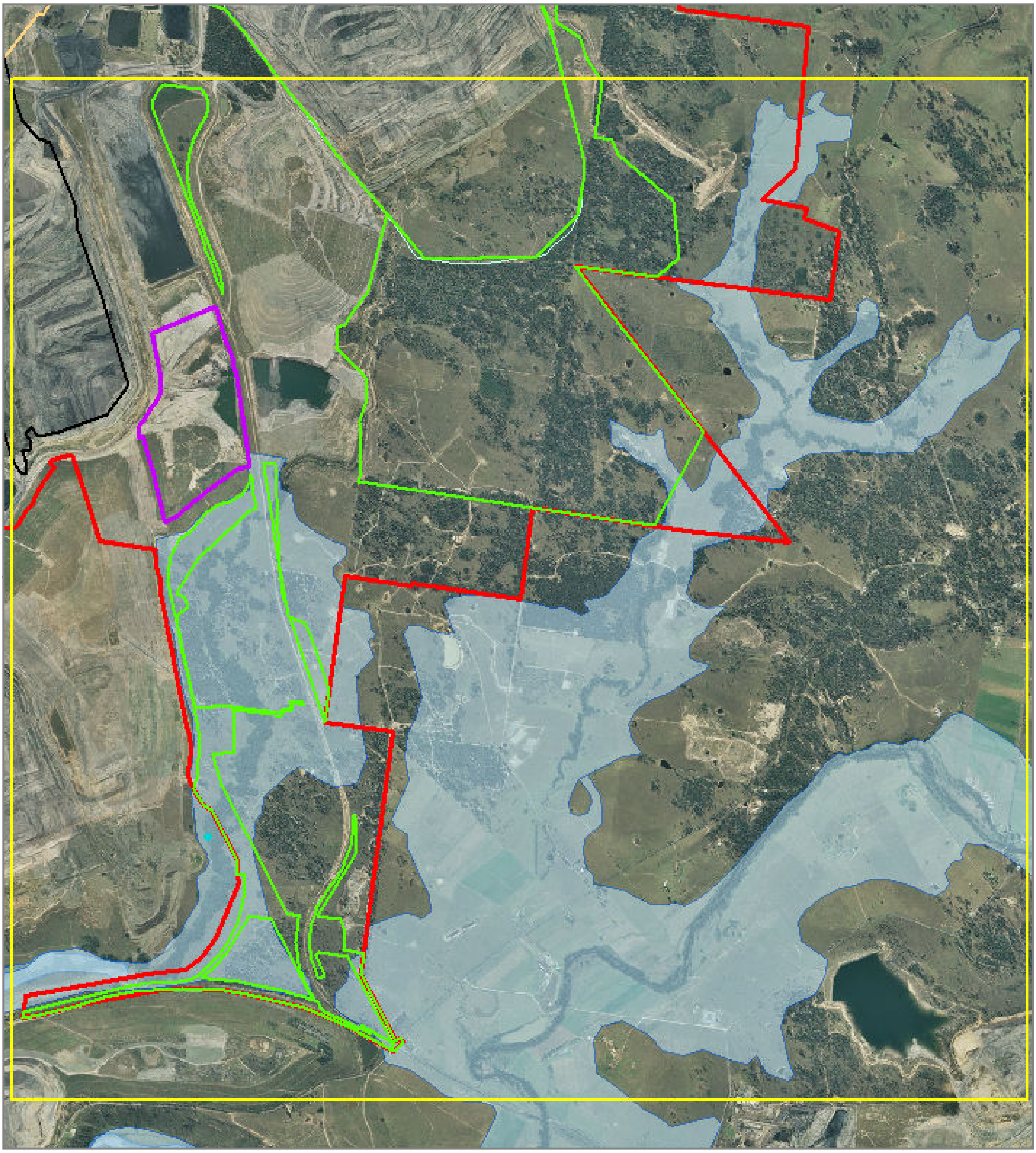
All other aspects of the model setup remained as per the regional model.

Model simulations

Model simulations were run using the same configuration and operations as the regional model and predictive scenarios were created from statistical analysis of the calibrated parameter sets generated from the regional model.

Median drawdown and 1 standard deviation results are presented for years 2020, 2025 and 2030; with the latter representing the maximum expected drawdown for the Project life. These are reproduced in **Figures 2** through **7**. The 2030 drawdown is also considered to represent the maximum long term impact of the Project as the final water level in the North Pit void is not predicted to rise to a level whereby the head pressure would be above that of the alluvium water table and reverse the direction of movement of water in the sub-cropping aquifers. That is, there will be a permanent hydraulic gradient away from the alluvium generating movement of water from the alluvium, through the coal seams and reporting as groundwater inflows to the North Pit void. As the void fills, this gradient will reduce and leakage from the alluvium will decrease.

For comparison, **Figure 8** shows the predicted maximum drawdown reported from the regional (100m x 100m grid) groundwater model (**Figure 3-21** in the Groundwater Impact Assessment in Appendix 10 of the EIS).



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Alluvium Extent
- IESC Modelling Extent

0 0.25 0.5 1 Kilometers

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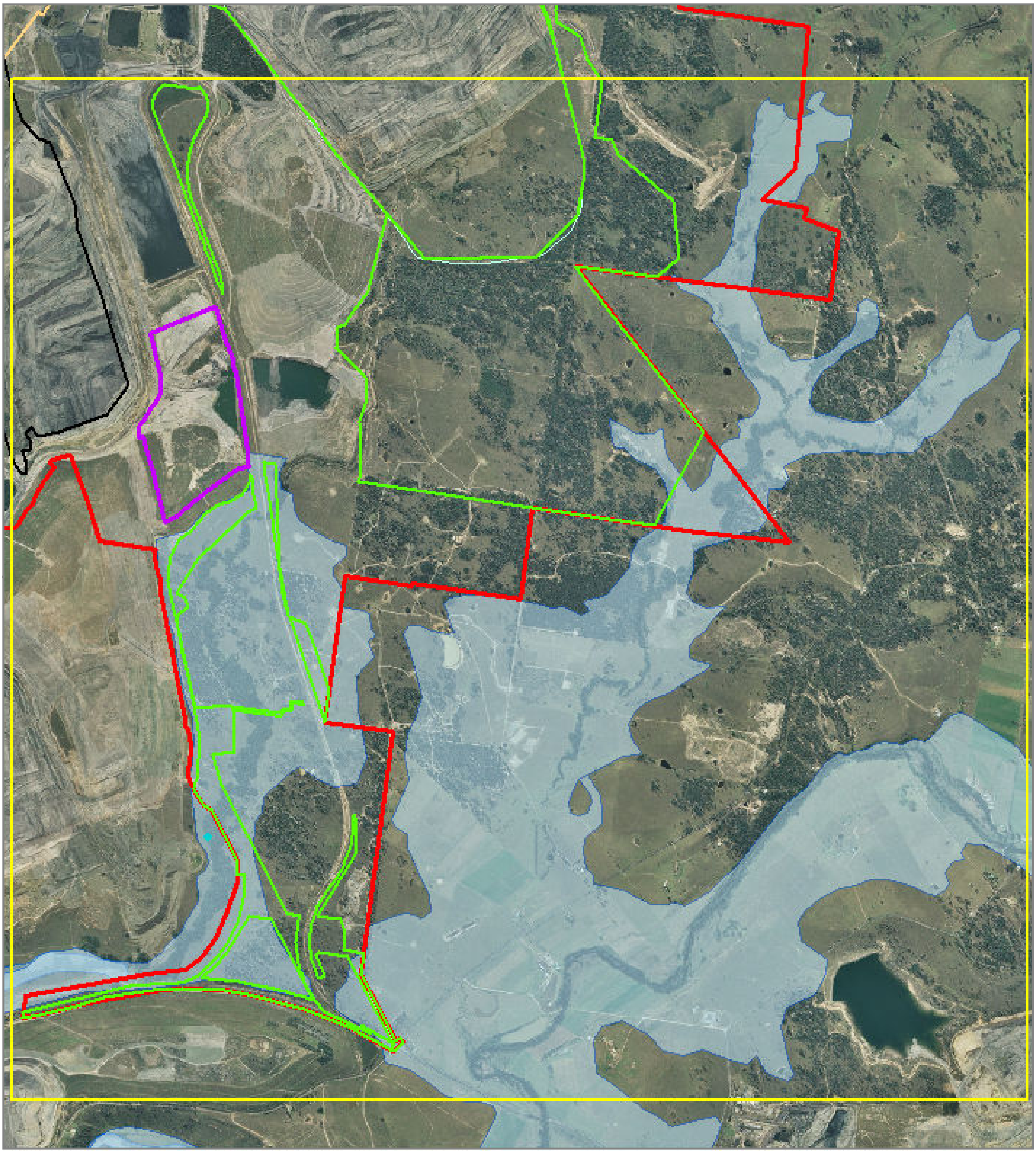
GDA 1994 MGA Zone 56

File Name: MOCO_DD_50percent_2016

Prepared by: LS
Checked by: RC

Figure 1 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2016

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Alluvium Extent
- IESC Modelling Extent

0 0.25 0.5 1 Kilometers

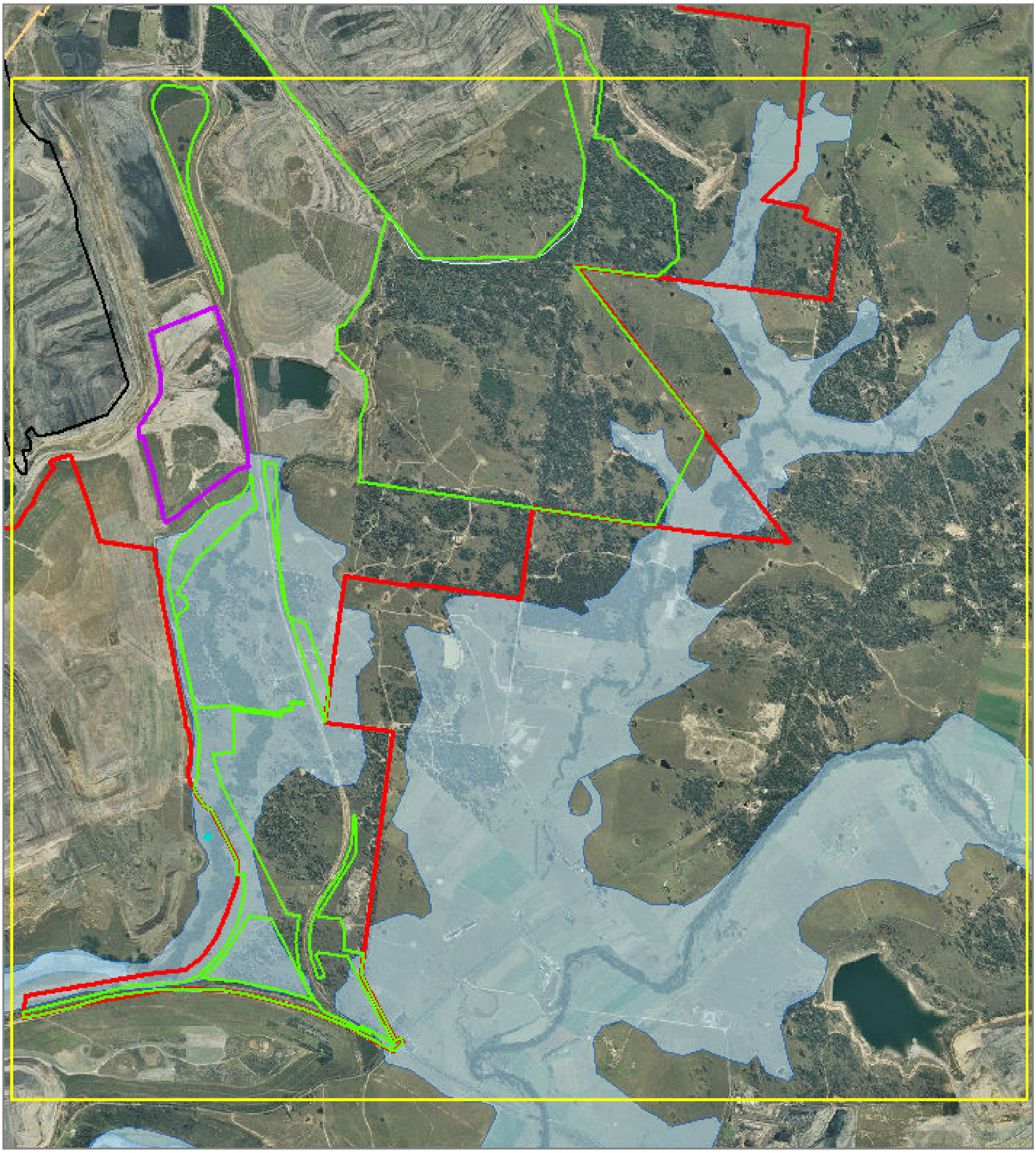
GDA 1994 MGA Zone 56

File Name: MOCO_DD_50percent_2020

Prepared by: LS
Checked by: RC

Figure 2 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2020

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Alluvium Extent
- IESC Modelling Extent

0 0.3 0.6 1.2 Kilometers

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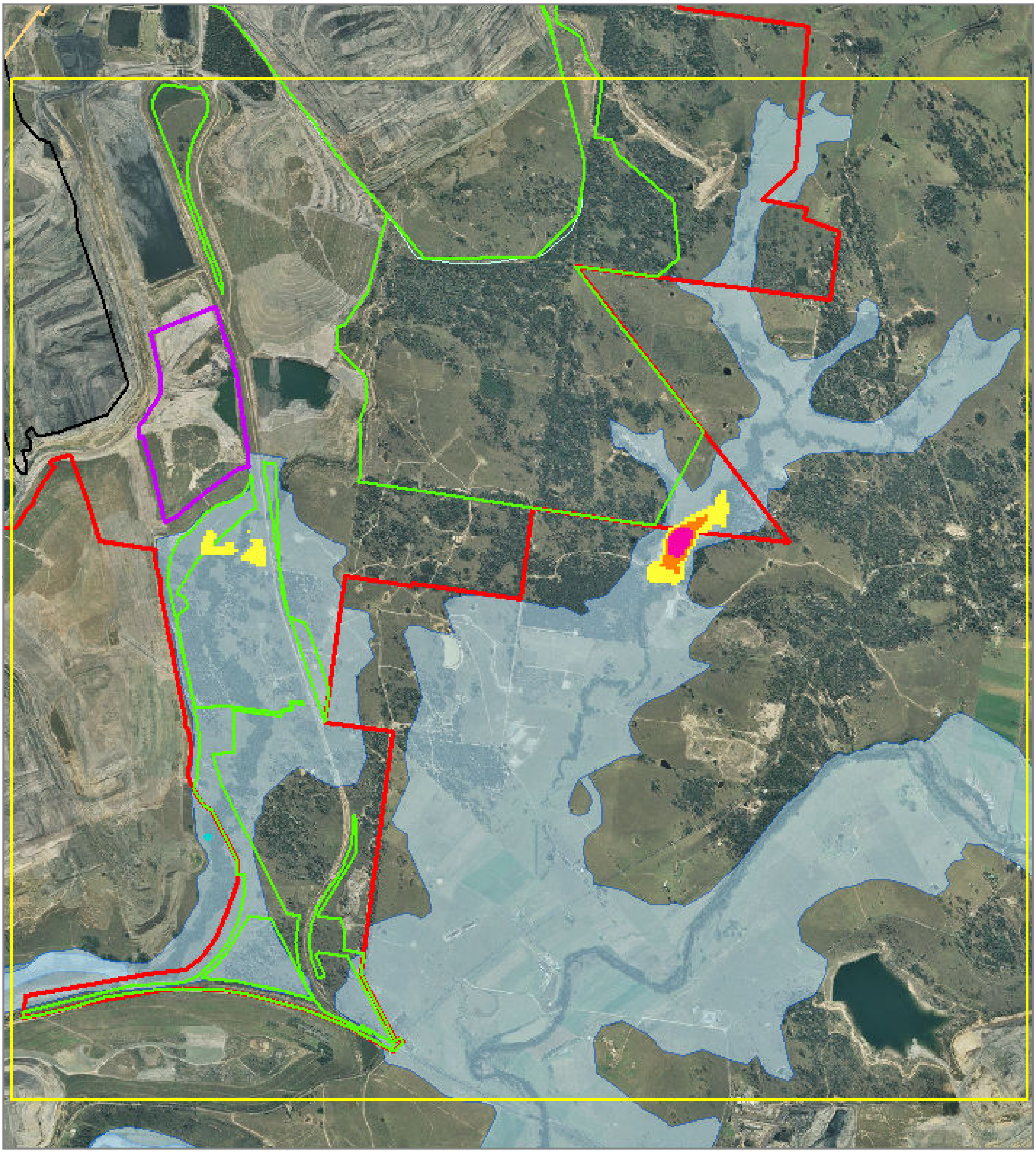
GDA 1994 MGA Zone 56

File Name: MOCO_DD_87percent_2020

Prepared by: LS
Checked by: RC

Figure 3 Predicted Median + 1SD Incremental Drawdown in Alluvial Aquifers in 2020

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Alluvium Extent
- IESC Modelling Extent

0 0.3 0.6 1.2 Kilometers

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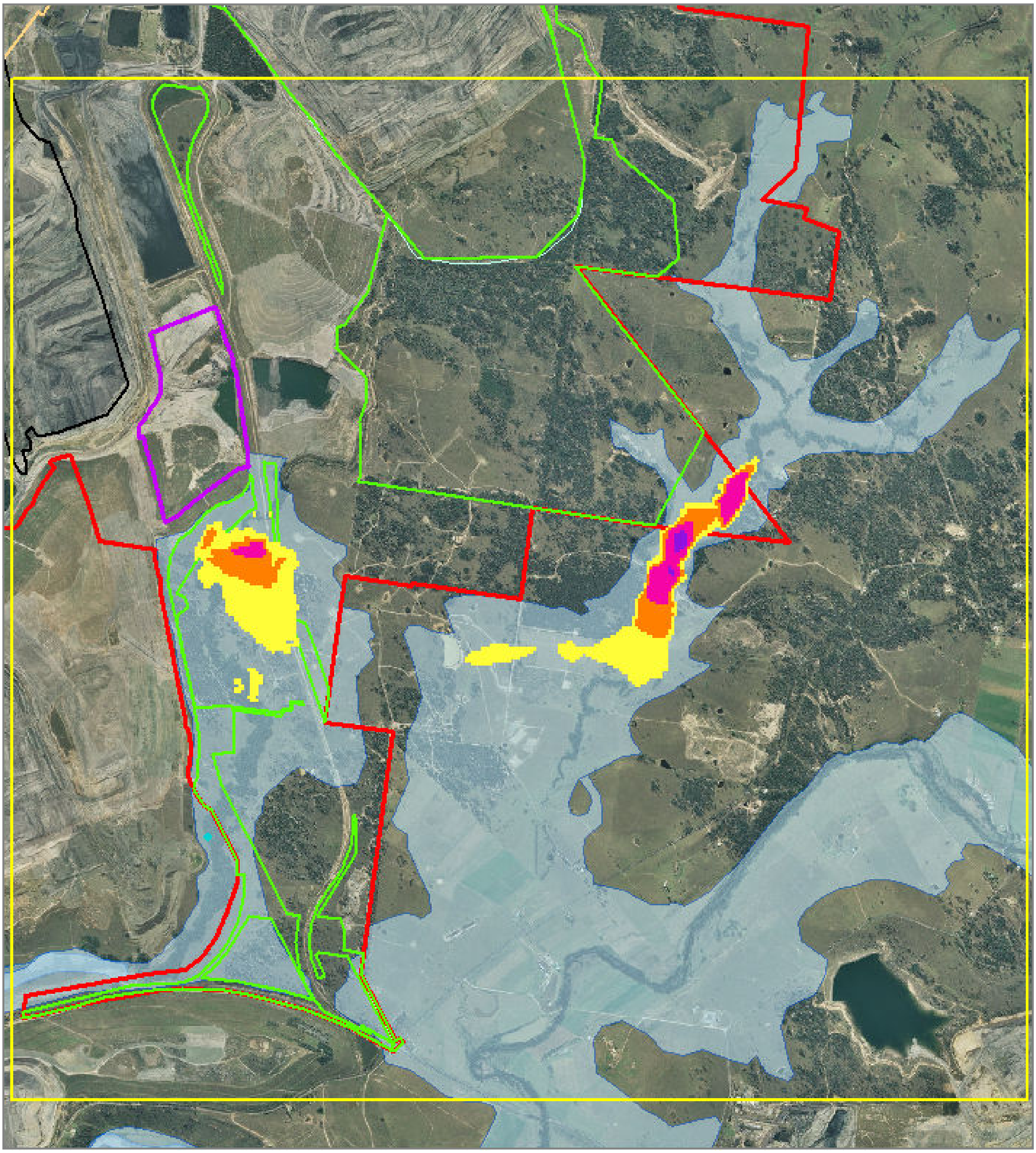
GDA 1994 MGA Zone 56

File Name: MOCO_DD_50percent_2025

Prepared by: LS
Checked by: RC

Figure 4 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2025

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Alluvium Extent
- IESC Modelling Extent

0 0.3 0.6 1.2 Kilometers

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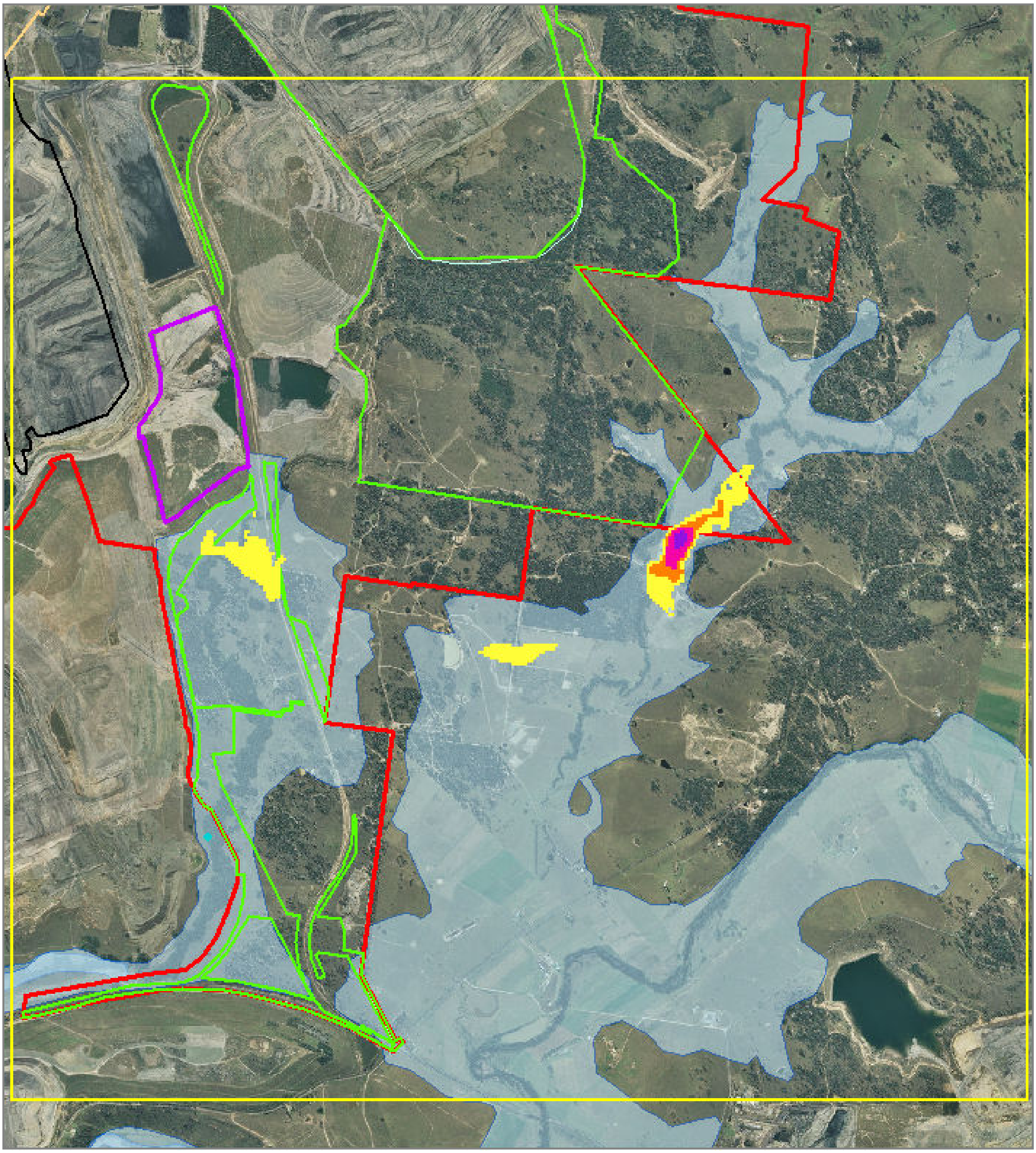
GDA 1994 MGA Zone 56

File Name: MOCO_DD_87percent_2025

Prepared by: LS
Checked by: RC

Figure 5 Predicted Median + 1SD Incremental Drawdown in Alluvial Aquifers in 2025

JACOBS



Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Alluvium Extent
- IESC Modelling Extent

0 0.3 0.6 1.2 Kilometers

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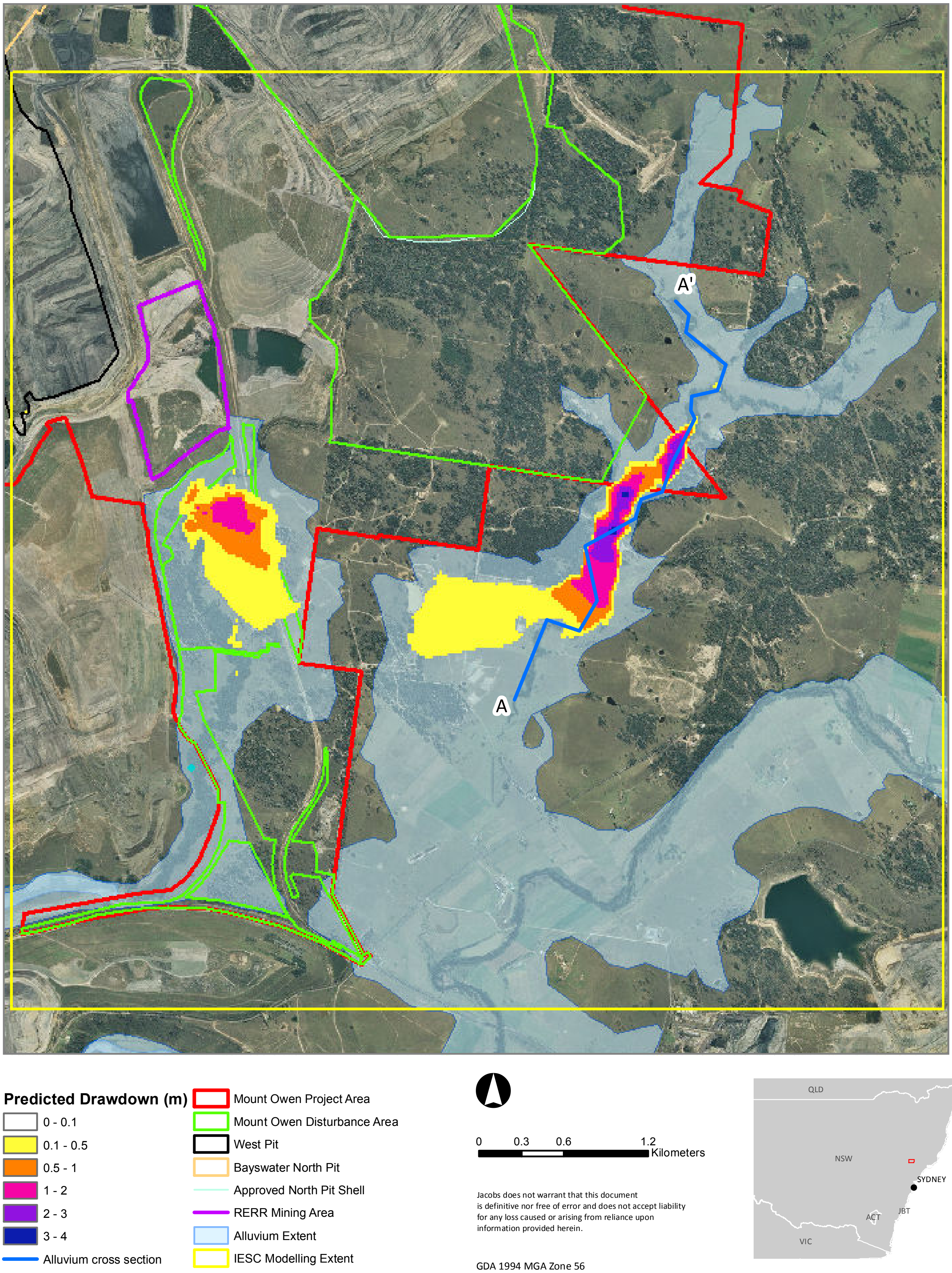
GDA 1994 MGA Zone 56

File Name: MOCO_DD_50percent_2030

Prepared by: LS
Checked by: RC

Figure 6 Predicted Median Incremental Drawdown in Alluvial Aquifers in 2030

JACOBS



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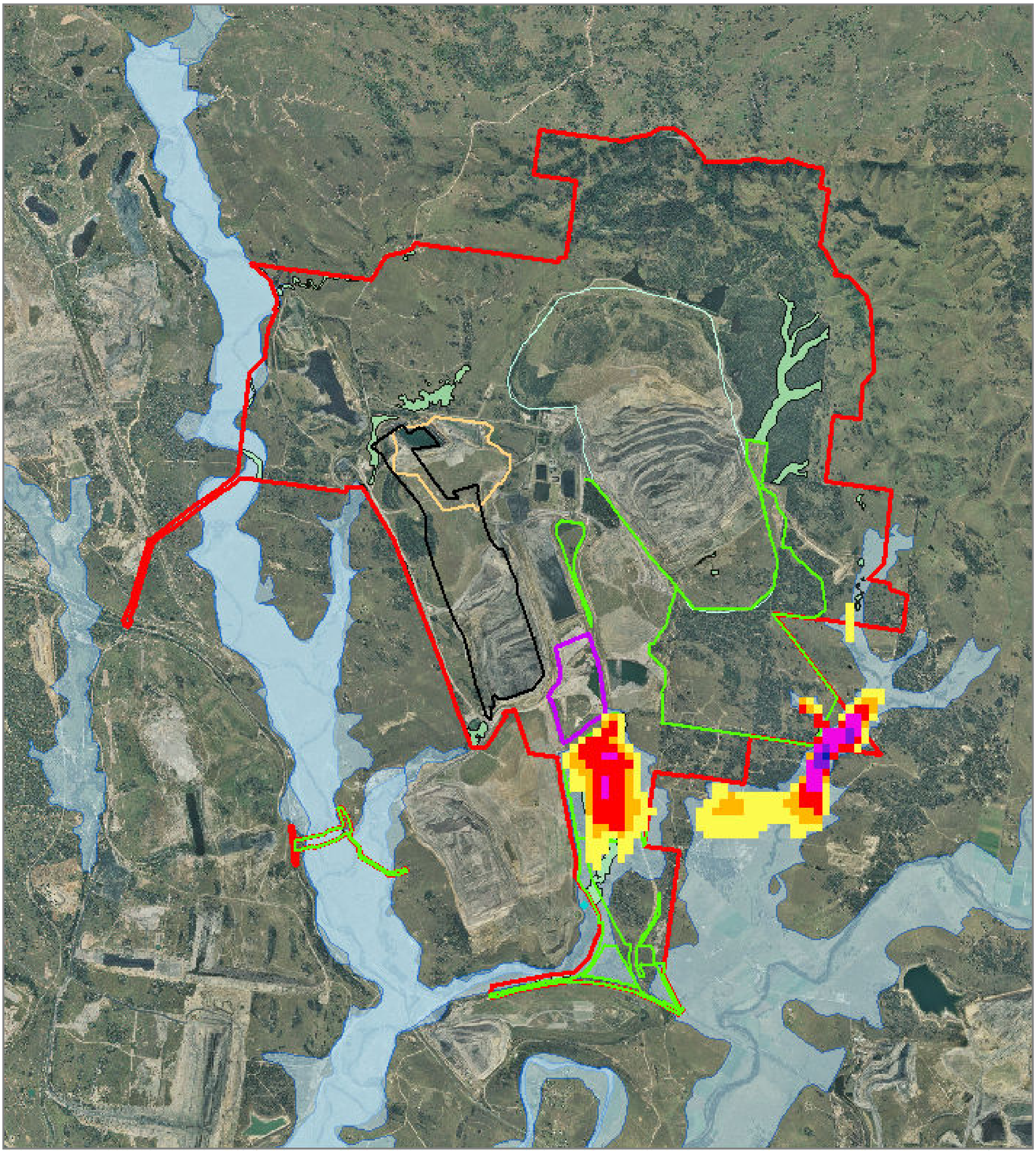
File Name: MOCO_DD_87percent_2030

Prepared by: LS
Checked by: RC

Figure 7 Predicted Median + 1SD Incremental Drawdown in Alluvial Aquifers in 2030

JACOBS

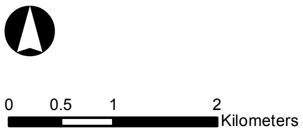


Legend

Predicted Drawdown (m)

- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4
- 4 - 6
- > 6

- Mount Owen Project Area
- Mount Owen Disturbance Area
- West Pit
- Bayswater North Pit
- Approved North Pit Shell
- RERR Mining Area
- Riparian Vegetation
- Alluvium Extent



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GDA 1994 MGA Zone 56

Figure 8 Predicted median +1SD incremental drawdown in alluvial aquifers in 2030 derived using the regional model (v8.1 resolution: 100x100m grid) domain, as reported for the EIS (Figure 3-21)

JACOBS

Prepared by: LS
Checked by: RC

File Name: Figure 3-21 MOCO GIA_AlluviumDDs_84per_2030

Implications for ecosystem impacts

It should be re-iterated that the model operates with annual time-steps and the resultant drawdowns represent potential incremental annual changes from the base case simulations. Comparison of results to the regional (100x100m grid) model results (as presented in the EIS and reproduced in **Figure 8**) shows that the revised extent and impact is comparable and likely to be less than previously described. That is, with refinement of the shallow layer grid to provide a more detailed representation of the alluvium systems, the actual area and magnitude of groundwater impact, and hence leakage and impact to the alluvial aquifer and surface water features, is reduced, confirming our previous assertion that the results presented in the EIS represent a conservative (maximum) estimate of impacts to the shallow systems.

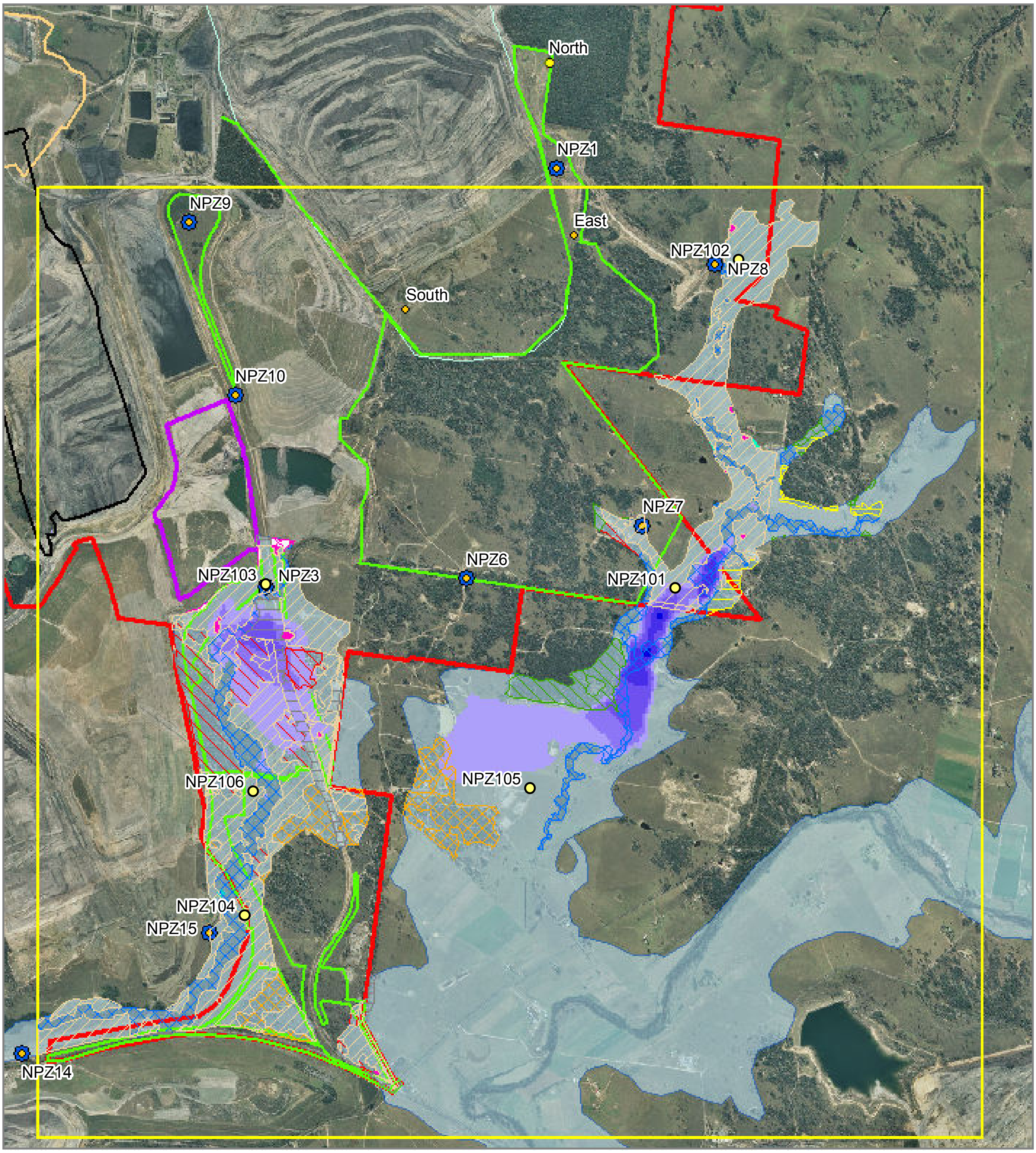
The extent of local vegetation communities on the alluvium is shown in **Figure 9**. Stands of ironbark, spotted gum and grey box exist in proximity to the area of maximum predicted drawdown, with the main river channels identified as swamp oak forest ecosystems. No other communities are identified to be within a potential impact area.

Standpipes NPZ101-NPZ106 were recently (2014) installed in the alluvial aquifers in this area (**Figure 9**), to provide monitoring of shallow alluvium water tables as an additional safeguard against future impact detection.

As can be seen in **Figure 10**, recent heavy rains do not appear to have had a significant impact on the alluvial aquifer water levels, except at the margins of the alluvium. Also of note, bore NPZ105, which is sighted in the deepest part of the Main Creek alluvium, has been dry since construction (sampling at a depth of 9.2m, above coarse gravels), indicating water levels are consistently lower than 9m below ground at this location. A single water level reading from a piezometer installed in 2008 along Bettys Creek (GPC40 – since de-commissioned) provided a reading of >9m below ground level in an area of healthy Swamp Oak community; recent readings at NPZ106 in the same location record groundwater levels at 5m below ground level (**Figure 10**).

All bores in the main channels record groundwater table depths in excess of 4m, indicating that the creeks are largely dis-connected from the groundwater systems for these tributaries. Maximum potential drawdown impacts to the alluvial aquifer of 2-3m along Main Creek occur where natural water tables are estimated to be 6-10m above the alluvium base. Hence, drawdown is unlikely to lead to local drying and significant saturated depth will remain available for migration of any local aquifer fauna (i.e. stygofauna).

These observations should also be considered in light of the large intra-annual variability in groundwater tables in the alluvial aquifers and their inter-annual propensity to rapidly fill and spill with the weather which naturally generates variability in baseflow that supports stream flow. The resilience of existing communities would indicate that they have adopted strategies that mitigate against drying climate events and consequent natural lowering of groundwater tables.



Predicted Drawdown (m)
- 0 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- Mount Owen Disturbance Area
- Approved North Pit Shell
- West Pit
- Bayswater North Pit
- RERR Mining Area
- Mount Owen Project Area
- Alluvium Extent
- IESC Modelling Extent

Vegetation type
- Central Hunter Bulloak Forest Regeneration
- Central Hunter Grey Box - Ironbark Woodland
- Central Hunter Ironbark - Spotted Gum - Grey Box Forest
- Central Hunter Swamp Oak Forest
- Dam
- Derived Native Grassland
- Disturbed Land
- Hunter Lowland Red Gum Forest
- Olive Plantation
- Rehabilitation

Existing Monitoring Network
- Alluvium
- Shallow Hard Rock
- Deep Hard Rock

File Name: Veg_MOCO_DD_87percent_2030

0 0.25 0.5 1 Kilometers

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GDA 1994 MGA Zone 56

Prepared by: LS
Checked by: RC

Figure 9 Maximum predicted drawdown; potentially impacted vegetation types and new standpipe locations for Main and Bettys Creeks

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As shown in **Figure 10** intra-annual variability in alluvial aquifer water levels may range up to 1m each year, with greater ranges for shallow water tables in the headwaters (NPZ102, NPZ103). Bore NPZ101 is sighted within the zone of potential drawdown and water tables at this site have been relatively constant at just over 4m below ground level over the past year. Peak predicted potential additional drawdown may result in an additional 1m water table drop at this location. The alluvium at this location is approximately 13m thick.

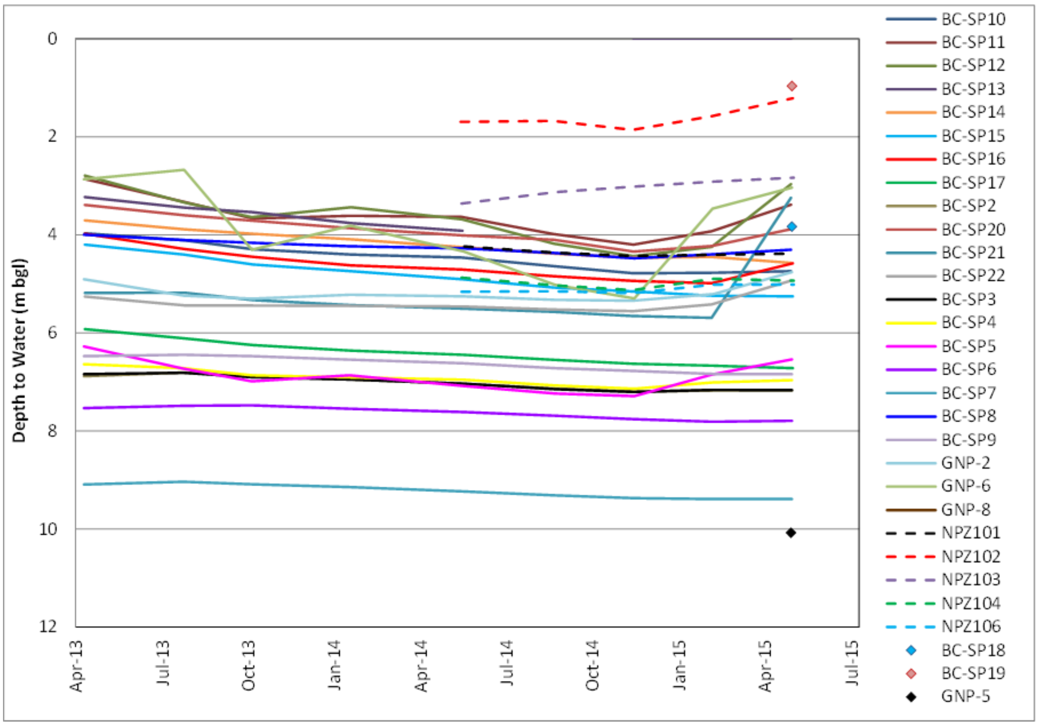

Figure 10 – Alluvium groundwater levels across the regional model domain over the past two years. New standpipes within the refined model domain are indicated as dashed lines (NPZ101 – NPZ106)

Figure 11 describes the section of the Main Creek alluvium defined in **Figure 7** and includes the interpolated average groundwater table depth for 2014. This section aligns with the location of Central Hunter Swamp Oak Forest present in the area of proposed drawdown. The maximum predicted drawdown (2030 median + 1 SD) shows that, even under a maximum depressurisation scenario, the alluvium will not dry and a saturated zone will be maintained throughout the alluvium system.

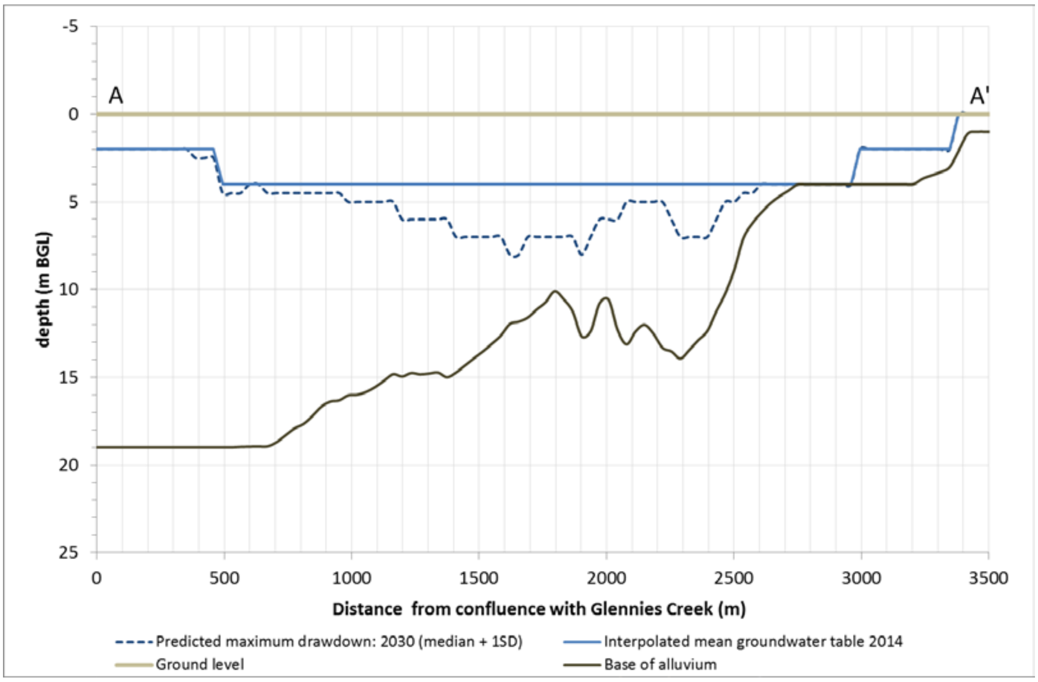

Figure 11 – Cross-section depicting current and predicted maximum impact groundwater table depth and alluvium thickness along Main Creek

The hydraulic characteristics of the alluvial aquifer and hard rock aquifers are significantly different. Hydraulic conductivity in the alluvium has been determined to be 3 orders of magnitude faster than the underlying hard rock, while specific yield is 2 orders of magnitude higher. Thus, it is expected that seasonal infiltration and flow through the alluvial aquifers will occur at a significantly faster rate than any variation in leakage driven by changes in water pressures in deeper formations. Further, while annual leakage from the alluvium predicted under the maximum impact scenario is estimated to be 15 ML/year from Main Creek and 6 ML/year from Bettys Creek, annual predicted recharge from rainfall is predicted to be more than an order of magnitude greater, with the bulk of water being transmitted downstream through the alluvium to the main systems of Glennies and Bowmans Creeks.

The relationship between the alluvium and hard rock aquifers is schematically illustrated in **Figure 12**. Annually, peak potential leakage impacts caused by drawdown induced from operations are less than 10% of mean annual expected recharge.

It is therefore unlikely that depressurisation will cause any observable effects under normal (average climate) conditions. During extended dry periods recharge may fall such that leakage (which will be unaffected by climate changes) may represent over 15% of infiltration from surface flows and rainfall. This may result in very localised stress on the groundwater-dependent systems, though the identified communities are likely to have strategies that manage dry conditions and only a prolonged drought may induce undue stress.

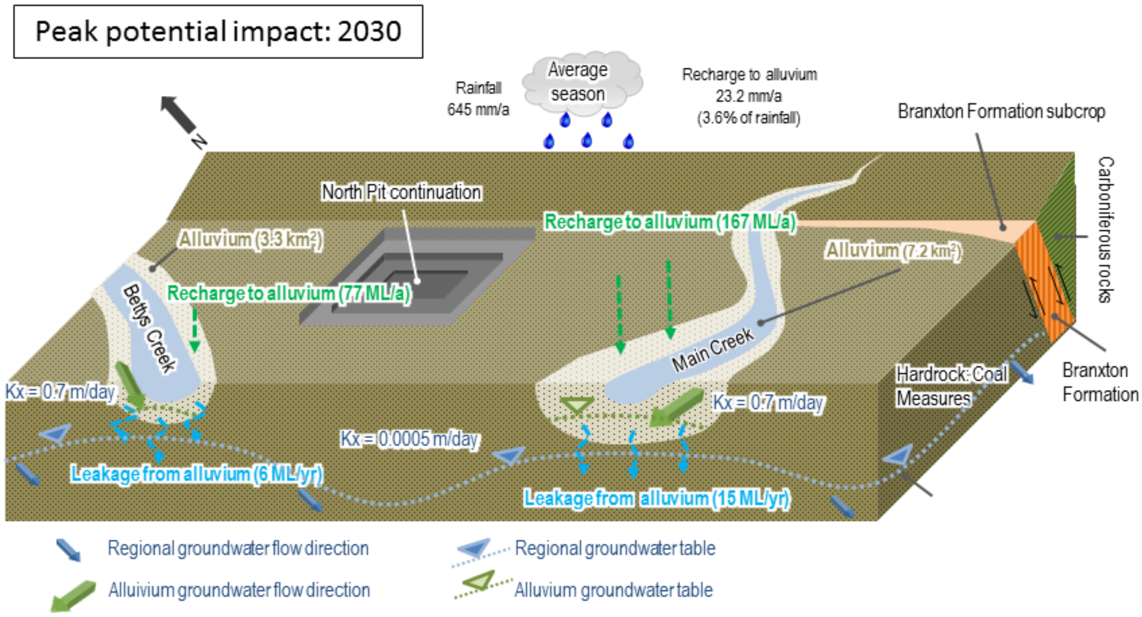

Figure 12 – Schematic representation of fluxes to and from the alluvium systems of Main and Bettys Creeks

As can be seen from Figure 9, approximately 1 km of the Central Hunter Swamp Oak Forest along Main Creek is located over the area of more than 1m potential drawdown (i.e. drawdown that may be greater than the observed natural fluctuations over the past 12 months). This level of drawdown is only likely to be observable in periods of prolonged drought. The Swamp Oak community along Bettys Creek in this area remains healthy indicating a tolerance to fluctuations of 3 to 4m. This level of natural fluctuation is in excess of the predicted potential impacts that may occur along Main Creek under the Project scenario.Summary and conclusions

Increased resolution of the regional numerical groundwater model in the vicinity of predicted potential maximum drawdown has refined our interpretation of the potential impacts to alluvial aquifers in this area. The overall conclusions from this additional work do not, however, change the conclusions from the previous modelling using the regional-scale model.

The predicted area of impact using the finer resolution grid is directly comparable to that determined from the coarser grid regional model. The added resolution, however, identifies that this impact is restricted to the central region of the alluvial extents only. Revised drawdown is comparable and slightly less than determined by the regional model, likely due to the improved resolution of the aquifer boundary and base, as defined using the recently installed standpipes along Bettys, Main and Glennies Creeks.

By considering a finer modelling grid and refining the extents and volume of the alluvial aquifer using LiDAR data and information from recently installed standpipes, the potential drawdown area within the alluvium appears to be more constrained and can be compared directly to the location of existing ecological communities.

As determined by the regional model, this modelling also predicts that there will be no impact to these alluvial aquifers for at least the next 5 years.

It should be noted that maximum potential impacts are comparable to inter-annual variability in alluvial aquifer water tables. Further, measured groundwater levels along the main channel of Main Creek indicate about 10m of saturated alluvial aquifer in the areas of maximum predicted impact (as determined from recent observations from newly installed standpipes for this purpose). Accordingly, the maximum predicted drawdown of around 4 m (occurring in only a very small section of the Main Creek Alluvium) will still leave in excess of 5 m of water in the alluvium at this point. Hence, the predicated drawdowns will not result in a complete drying of the alluvium at this location.

The predicted overall potential impacts to any vegetation communities that may result from the potential impacts to groundwater are therefore considered to be minimal and insignificant for any aquifer ecosystems (ie. stygofauna).

This additional modelling confirms the conclusions derived from the Groundwater Impact Assessment using the regional groundwater model.

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