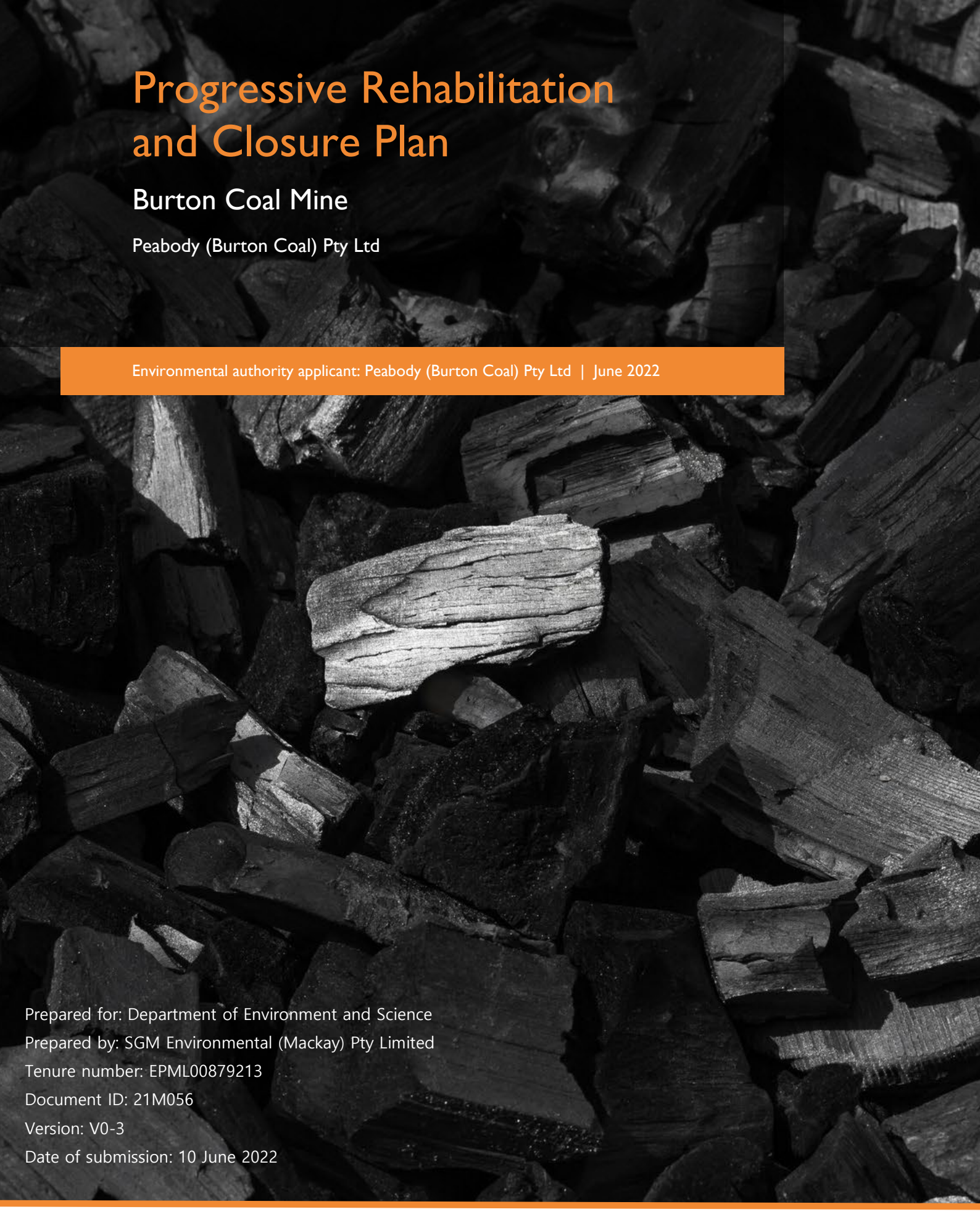
Progressive Rehabilitation and Closure Plan

Burton Coal Mine

Peabody (Burton Coal) Pty Ltd

Environmental authority applicant: Peabody (Burton Coal) Pty Ltd | June 2022



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Peabody

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This Report is given for the exclusive use of the Client pursuant to the Scope of Works dated 22 April 2022, which requires us to give Services relating to a *Progressive Rehabilitation and Closure Plan*.

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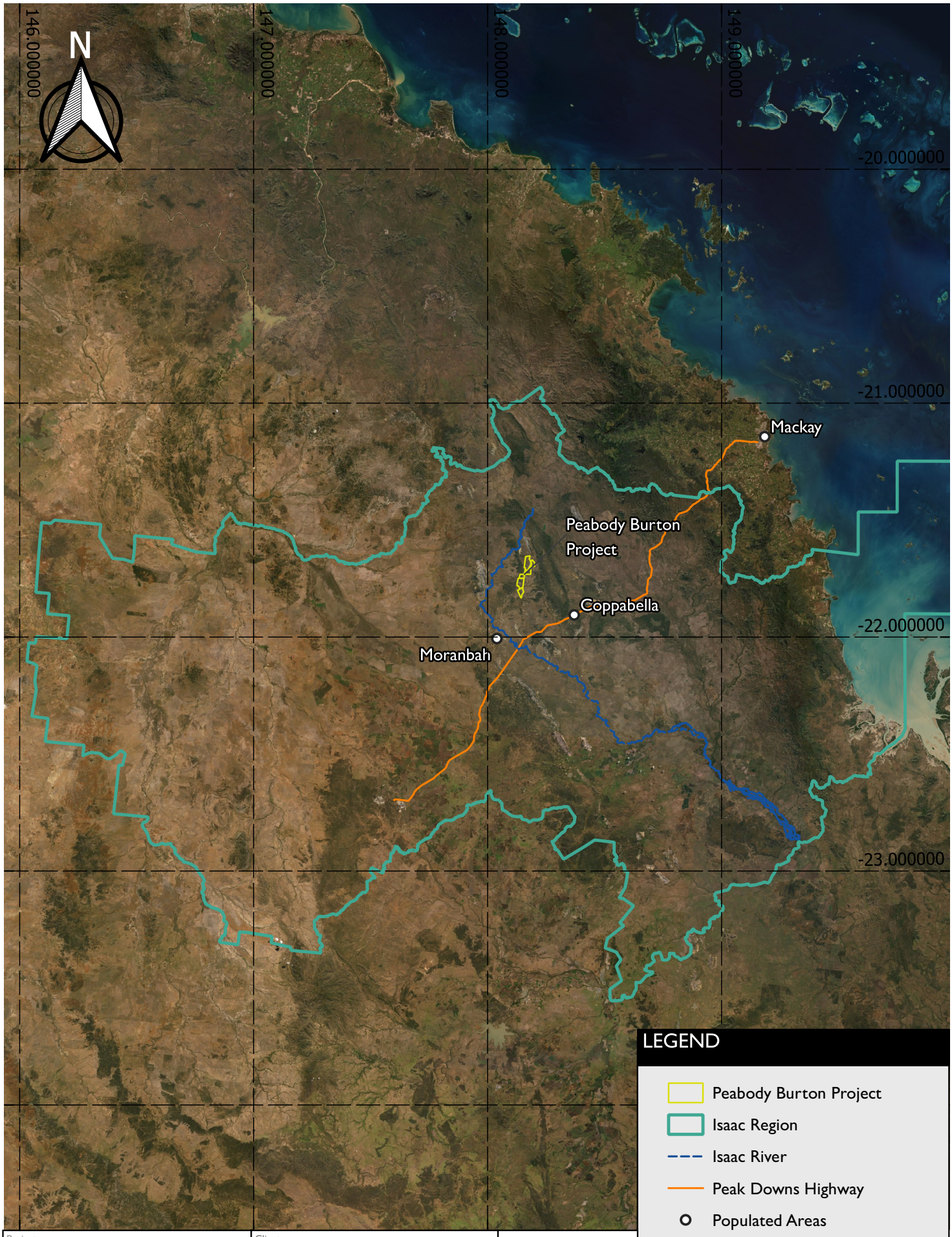
3.0 Rehabilitation planning part

3.1 Project planning

Peabody Burton Mine (the Mine) is a care, maintenance and rehabilitation site which is owned and operated by Peabody (Burton Coal) Pty Ltd (Peabody). The Mine ceased production in late 2016 and Peabody has been actively rehabilitating the Mine in accordance with environmental authority (EA) EPML00879213 and the Detailed Mine Closure Plan (DMCP) since that time.

3.1.1 Location details

The Mine is located in the Bowen Basin in Central Queensland within the Isaac Regional Council (IRC) Local Government Area (LGA). It is situated approximately (~) 90 kilometres (km) southwest of the city of Mackay, 67 km from Nebo and 36 km from Glenden (Figure 1).



LEGEND

- Peabody Burton Project
- Isaac Region
- Isaac River
- Peak Downs Highway
- Populated Areas

Scale 1 : 1 750 000

0 25 50 75 100 km

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Figure: 1	Title: Project Location	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 1,750,000 CRS: GDA94 / MGA zone 55	

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3.1.2 Project description

3.1.2.1 Mining tenements

The Mine EA has undergone three rounds of de-amalgamation. The first round of de-amalgamation excluded ML70109 and exploration permit coal (EPC)857 and mineral development lease (MDL)315, which were transferred to the New Hope Group.

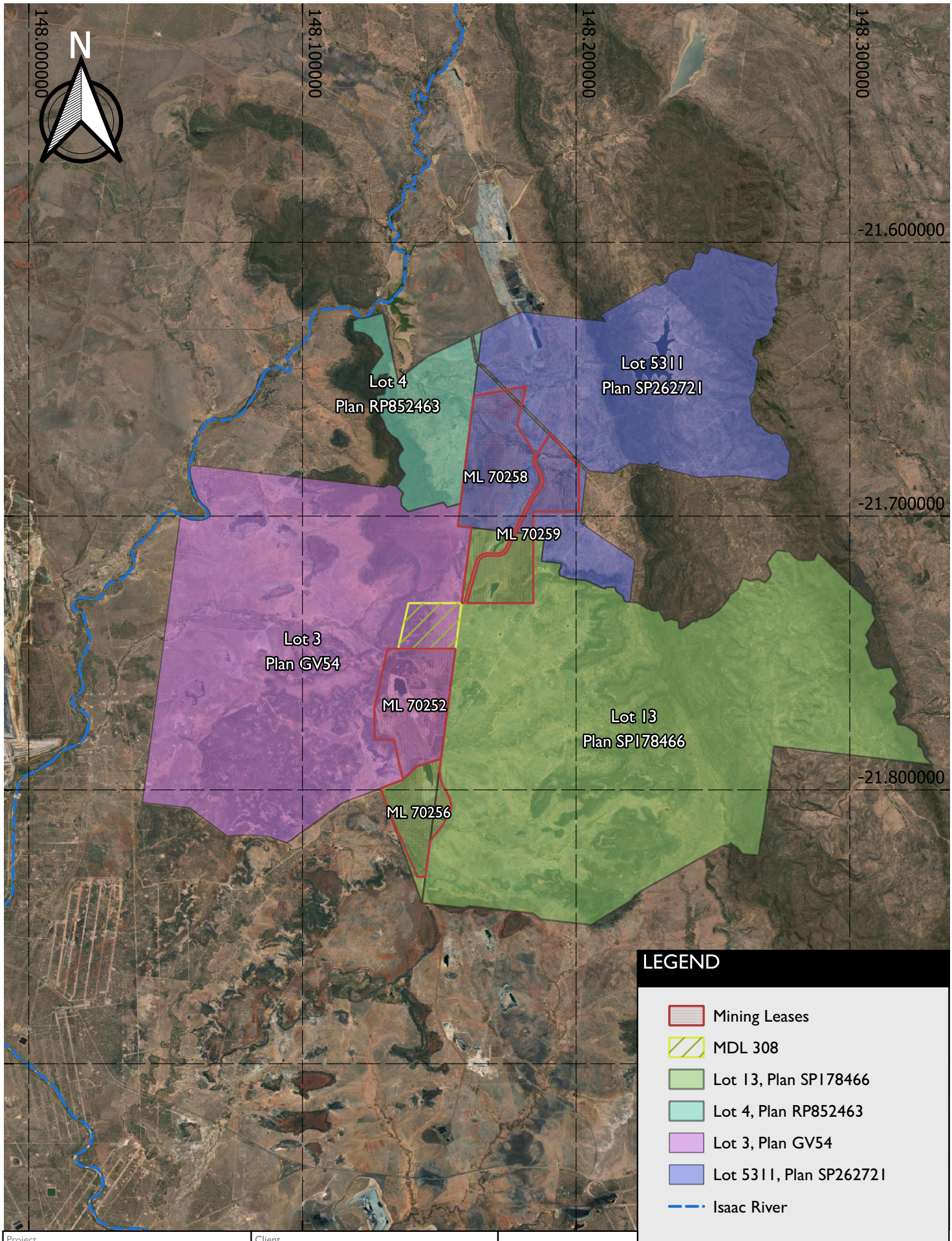
In 2016-17 a second round of de-amalgamation was done and EA EPML00879213 was issued (the reissued EA) in June 2018 excluding ML70260. A third round of de-amalgamation excluded ML70257. The current EA includes the land tenure described in Table 1 and Table 2 and given in Figure 2.

Table 1 EA land tenure

Tenure type	Number	Name	Area (ha)
ML	70258	Plumtree west	1,501.1
ML	70259	Plumtree east	956.4
ML	70252	Wallanbah	1,173.2
ML	70256	Broadmeadow west	676.8
MDL	308	-	383.4
Total	-	-	4,690.9

Table 2 Lot and plan numbers

Lot	Plan	Ownership
Lot 13	SP178466	Malcolm Burston
Lot 3	GV54	Allan Williams
Lot 5311	SP262721	Ganra Pty Ltd, Gaffwick Pty Ltd



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 2	Title: Tenure Boundaries	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 150,000 CRS: GDA94 / MGA zone 55	SGM environmental

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3.1.2.2 Environmentally relevant activities

Activities that will, or have the potential to, release contaminants into the environment which may cause environmental harm are defined as environmentally relevant activities (ERAs) (Table 3) in the *Environmental Protection Act 1994 (*EP Act). In accordance with the *Environmental Protection Regulation 2019* (EP Regulation), the Mine is a site-specific EA mining project for the mining of black coal.

Activities that have been identified as likely to cause land contamination are defined as notifiable activities in Schedule 3 of the EP Act. Any person undertaking these notifiable activities must tell the Department of Environment and Science (DES) and the land will be recorded in the *Environmental Management Register* (EMR). Potentially notifiable activities are listed in Table 4.

Table 3 Project ERAs

ERA number	Description of activity
Schedule 3, 13	Mining black coal
Schedule 3, 09	A mining activity involving drilling, costeaning, pitting or carrying out geological surveys causing significant disturbance
Schedule 2, 60	Waste disposal — 2: operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(b) — (c) more than 5,000 tonnes (t) but not more than 10,000 t
Schedule 2, 62	Resources recovery and transfer facility operation — 1: operating a facility for receiving and sorting, dismantling, baling or temporarily storing (c) category 2 regulated waste
Schedule 2, 63	Sewage treatment — 1: operating sewage treatment works, other than no-release works, with a total daily peak design capacity of, (b) more than 100 but not more than 1,500 EP, (i) if treated effluent is discharged from the works to an infiltration trench or irrigation scheme

Table 4 Project notifiable activities

Item number	Description of activity
7	Chemical storage (other than petroleum products or oil under item 29).
24	Mine wastes: storing hazardous mine or exploration wastes, including, for example, tailings dams, overburden or WRDs containing hazardous contaminants; and mining or processing, minerals in a way that exposes faces, or releases groundwater, containing hazardous contaminants.
29	Petroleum products or oil storage in above ground tanks.
37	Waste storage, treatment, or disposal — storing, treating, reprocessing or disposing regulated waste including operating a sewage treatment facility with on-site disposal facilities.

3.1.2.3 Primary mine features / infrastructure

a Plumtree

- one partially backfilled open-cut pit;
- two out-of-pit waste rock dumps (WRDs);
- mine industrial area (MIA) including:
  - administration offices;
  - petroleum, oil and lubricant storage and handling facilities;
  - vehicle and equipment wash down facilities;
  - vehicle fuelling facilities;
  - workshops and store facilities;
  - laydown and hardstand area;
  - water supply for firefighting; and
  - internal roads and carparking;
- haul roads and internal light vehicle (LV) and heavy vehicle (HV) roads (the roads);
- topsoil stockpiles; and
- water management and storage, supply and distribution:
  - northern sediment dams;
  - Plumtree south levee;
  - water distribution pipelines; and
  - surface water drainage structures.

b Bullock Creek

- one open-cut pit;
- two out-of-pit WRDs (north and low wall dumps);
- LV road and tracks;
- topsoil stockpile; and
- water management and storage, supply and distribution:
  - Mallawa haul road dam;
  - Bullock Creek levee;
  - Bullock Creek diversion;
  - Bullock Creek highwall drain;
  - water distribution pipelines; and
  - surface water drainage structures.

c Wallanbah

- one partially backfilled open-cut pit;
- two out-of-pit WRDs (eastern and western);
- LV road and tracks;
- topsoil stockpiles; and
- water management and storage, supply and distribution:
  - eastern sediment dam;
  - western sediment dam;
  - Wallanbah highwall drain;
  - water distribution pipelines; and
  - surface water drainage structures.

d Broadmeadow

- one partially backfilled open-cut pit with water filled voids at the northern and southern ends;
- one out-of-pit WRD (west);

- LV road and tracks;
- topsoil stockpiles; and
- water management and storage, supply and distribution:
  - western sediment dam;
  - Spade Creek diversion;
  - Broadmeadow north-west levee;
  - Broadmeadow south levee
  - water distribution pipelines; and
  - surface water drainage structures.

The primary Mine features are given in Figure 3.

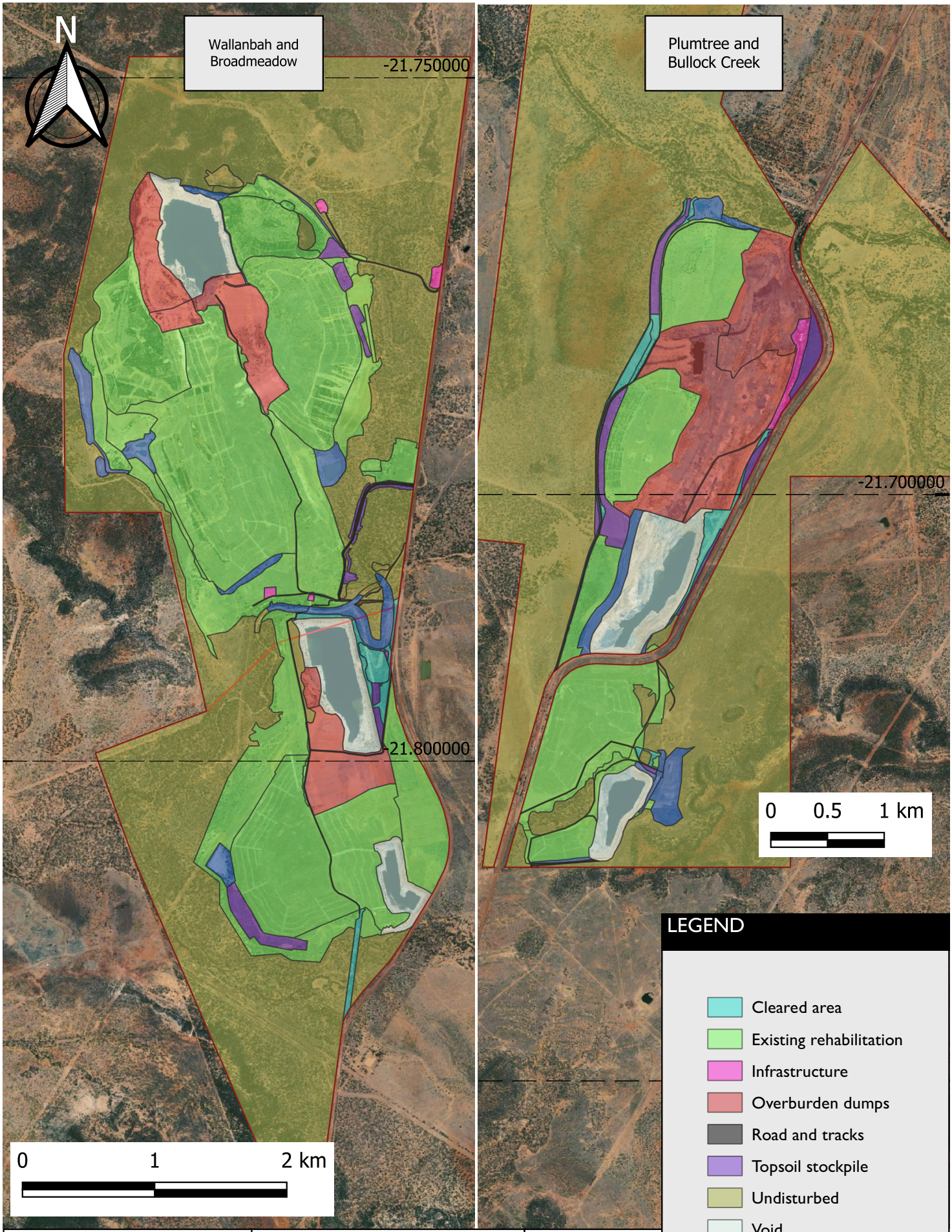

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Figure: 3	Title: Primary Features	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 30,000 (left) 1 : 35,000 (right) CRS: GDA2020 / MGA zone 55	

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3.1.2.4 Mining history

The site operational history is given in Figure 4 including the northern infrastructure areas which are no longer part of Peabody Burton Mine.

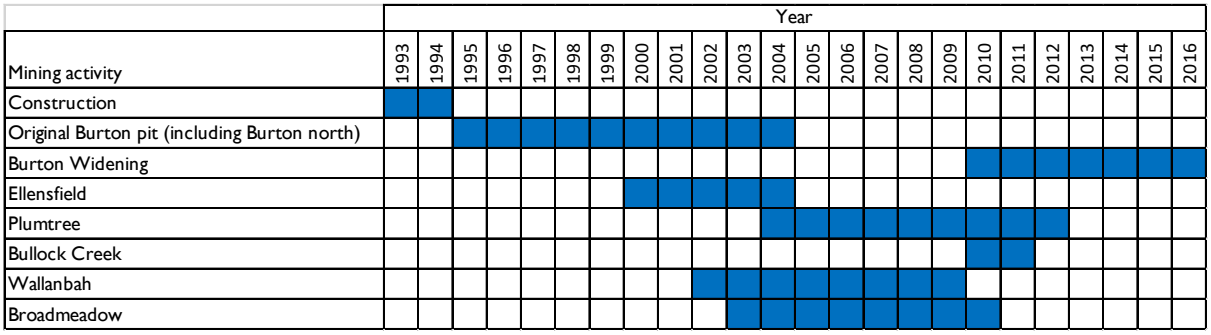

Figure 4 Site operational history

a Plumtree

Mining at Plumtree commenced in approximately 2004 and continued until about 2012. The northern half of the pit was backfilled as mining progressed. At the south, spoil was dumped against the western box-cut but did not reach to the highwall, leaving a 1.5km long void. Seams dipped at about 18 degrees (°) to the east resulting in a steep pit floor. After the main mining operation, the pit was extended southward past faulting running across the pit, however the area was not mined to completion leaving a section of highwall blasted but not removed. The remaining void is at the southern end of the pit, the northern part having being backfilled with spoil during mining. Coal was mined as Leichardt and Vermont seams, with dips steeper than 30° in the remaining void area. In this pit the Rewan Group sandstones were present above Rangal Coal Measure overburden.

b Bullock Creek

Open cut mining commenced in 2010 and was completed in October 2011 to a maximum pit depth of approximately 100m below ground level. The floor dips at 10-14° toward the highwall at the eastern side. Spoil was dumped against the low wall at the west, and the ramp entered from the south, along the highwall. Bullock Creek was diverted about 50m behind the low wall and a flood protection bund was constructed at the crest of the low wall. The highwall was auger mined from December 2011 to March 2012 but mining ceased when the pit was inundated following severe rain (a 1:20 annual exceedance probability (AEP) 72 hour rainfall event). The pit was mined to the Upper Vermont seam, which dipped at 10-14°. Rewan Group sandstone was present in the high wall but not along the box-cut.

c Wallanbah

Wallanbah was mined from approximately 2002 to 2009. The remaining void is at the northern end of the pit, the southern end having been backfilled with spoil during mining. The pit walls are unlike any other at Burton Mine because of the box-cut running along the Burton Range Fault and Tertiary age Suttor Formation overlying the Rewan formation. The Tertiary material comprises poorly consolidated and weathered clay, laterite and quartzose sandstone. The base of weathering is much deeper than in other pits, ranging from 16 - 65m with an average of 44m.

d Broadmeadow

Broadmeadow was mined from 2003 - 2010. The void is made up of a large void at the northern end and a smaller void toward the southern end, the middle section having been backfilled with spoil during mining. Up to 10 m depth of sand and gravel alluvium overlay the Rewan Group around the northern end, associated with the ephemeral Spade Creek.

3.1.3 Baseline information

3.1.3.1 Site topography

a Local

The Mine is generally flat to undulating and is surrounded by rocky hills to the east and west (Figure 5). Locally the hills are comprised of tertiary rocks and are vegetated with disturbed woodland. The Plumtree and Bullock Creek voids are generally flat to undulating with rocky hills to the south east and west. The eastern half of the Wallanbah void is generally flat to slightly undulating while the western half is characterised by rocky hills. The Broadmeadow void is generally flat to undulating with the south western corner comprising rocky hills.

b Regional

The Mine is in the Kerlong Valley. The Kerlong Valley is approximately 6-8 km wide and 26 km long. The area is relatively flat and is bounded by the Kerlong Range to the east and the Burton Range to the west. These generally rise to a maximum height of 210-220 m above the valley floor.

The main topographic variation at the Mine occurs in riparian areas ie the Isaac River, Sandy Creek, Spade Creek and Hat Creek.



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Figure: 5	Title: Topography	Design: SGM Environmental Pty Ltd 08.06.2022 Scale: 1 : 100,000 CRS: GDA94 / MGA zone 55	SGM environmental

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3.1.3.2 Climate

The climate of the Mine and surrounding areas is classified as BSh (hot semi-arid climate), according to the Köppen-Geiger climate classification. These climates tend to have hot summers and warm to cool winters with some to minimal rainfall. High variability in rainfall, temperature and evaporation are common in Central Queensland. The region experiences a predominance of southerly to south-easterly winds of low velocity (less than 10 km per hour).

Local rainfall, evaporation and temperature data has been sourced from surrounding Bureau of Meteorology weather stations:

- Moranbah Water Treatment Plant (station 034028) — operated from 1972 to March 2012. This station is located approximately 43 km south east of the Mine.
- Moranbah Airport (station 034035) — operational from March 2012. This station is located approximately 49 km south east of the Mine.

a Temperature

The mean annual maximum temperature is 29.7 degrees Celsius (˚C) with the hottest months being November through to February (over 33 ˚C). The mean annual minimum temperature is 16.7 ˚C. with the coolest months being June through to August (below 12 ˚C). Average monthly minimum and maximum temperature for both weather stations are given in Table 5.

b Rain

January, February and December exhibit the highest mean monthly rainfall, averaging above 100 millimetres (mm). The driest month of the year is September averaging under 10 mm of rainfall. The average annual rainfall for the region is 614.2 mm/year. Average monthly rainfall for both weather stations is given in Table 6

c Evaporation

The average annual potential evaporation at the Mine is estimated to be 2,306.4 mm, 3.8 times higher than annual rainfall. The evaporation rate varies seasonally, with the highest evaporation rates occurring in the months between October and March. Monthly average evaporation for the Moranbah Water Treatment Plant (not available for Moranbah Airport) is given in Table 7.

d Climate variability

Rain

The *State of the Climate Report* 2020 (CSIRO and BoM 2020) says that Australian rainfall is highly variable, which makes it difficult to identify significant trends over time. Northern Australian average annual rainfall has increased since national records began in 1900, largely due to increases in rainfall from October to April annually.

Temperature

The *State of the Climate Report* 2020 (CSIRO and BoM 2020) and the *Annual Climate Statement 2021* (BOM 2021) says Australia's weather and climate are changing in response to a warming global climate system. Australia has warmed by around 1 °C since 1910, with most warming since 1950. Eight of Australia's top ten warmest years have occurred since 2005. The warming trend occurs against a background of year-to-year climate variability, mostly associated with El Niño and La Niña in the tropical Pacific Ocean.

Sea surface temperatures in the Australian region have given a similar trend, warming by nearly 1 °C since 1910, with eight of the top ten warmest years occurring since 2005.

Table 5 Average monthly and annual temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temperature (°C) — Moranbah Water Treatment Plant	33.8	33.1	32.1	29.5	26.5	23.7	23.7	25.5	29.2	32.3	33.1	34	29.7
Mean minimum temperature (°C) — Moranbah Water Treatment Plant	21.9	21.8	20.2	17.6	14.2	11.2	9.9	11.1	14.1	17.6	19.4	21.1	16.7
Mean maximum temperature (°C) — Moranbah Airport	34.8	33.8	32.7	30.1	27	24.2	24.7	26.9	30.2	33.3	34.7	35.3	30.6
Mean minimum temperature (°C) — Moranbah Airport	21.5	21.4	20.3	16.9	12.8	9.9	8.7	8.8	12.6	16.2	18.9	20.6	15.7

Table 6 Average monthly and annual rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (mm) — Moranbah Water Treatment Plant	103.8	100.7	55.4	36.4	34.5	22.1	18	25	9.1	35.7	69.3	103.9	614.2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (mm) — Moranbah Airport	115.7	119.9	73	38.8	19.6	22.7	23.7	11.2	11.7	5	55.7	54.9	533.7

Table 7 Average monthly and annual evaporation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean evaporation (mm)	248	207.2	210.8	171	133.3	105.3	114.7	151.9	198	248	255	263.5	2,306.4

Bushfire

The *State of the Climate Report 2020* (CSIRO and BoM 2020) says Australia's shift to a warmer climate is accompanied by more extreme heat events on daily, multi-day and seasonal timescales. Australia-wide, increases in average temperature have been more notable across autumn, winter and spring, with the smallest trends in summer. The annual 90th percentile of daily McArthur Forest Fire Danger Index (FFDI) (ie the most extreme 10% of fire weather days), has increased in recent decades across much of eastern Australia.

The Bushfire Hazard Provision in the Queensland State Planning Policy 2013, identifies bushfire prone areas in Queensland and accounts for regional variability in bushfire weather severity. The mapping allows accurate identification of areas at risk from bushfire and allows greater confidence in design and mitigation strategies, proportional to the mapped risk level.

3.1.3.3 Geological setting

a Overview

The geology comprises an easterly dipping (between 15-25°) sequence of Permian sediments situated on the western flank of the Carborough Syncline in the Bowen Basin. The main coal bearing unit is the Rangal Coal Measures containing sandstone, siltstone, mudstone and coal. The sandstone, siltstone and mudstone occur as overburden and interburden units, which are generally weathered to an average depth of 25 m.

Overlying the Rangal Coal Measures are sediments of the Rewan Group, which is comprised of sandstone, siltstone and mudstone which sub-crop towards the eastern part of Burton. Resistant quartz sandstones, gritty conglomerates and siltstone overlay the Rewan Group and outcrop, forming escarpments to the east and west of Burton.

b Plumtree and Bullock Creek

Plumtree lies east of the Burton Range Fault and is an upthrown inlier of the Rangal Coal Measures. The Rangal and Fort Cooper Coal Measure sequences sub-crop within the Plumtree area. The Fort Cooper Coal Measures that overlie the Moranbah Coal Measures comprise grey lithic sandstones, conglomerate, siltstone, mudstone coal and tuffaceous sediments. The Girrah seam (uppermost seam in the Fort Cooper Coal Measures) is a thick banded sequence of coal, cream to brown tuffaceous claystones, mudstones and siltstones. The target seam (Leichardt and Vermont splits) occurs in the Rangal Coal Measures.

Overlying the Rangal Coal Measures are greenish sediments of the Rewan Group. Quaternary soil, alluvium and / or colluvium cover all of the Plumtree area, particularly where adjacent to Sandy Creek.

c Wallanbah

Wallanbah lies immediately east of the Burton Range Fault and is an upthrown inlier of the Rangal Coal Measures. To the west of the Burton Range Fault, the Wallanbah area is covered by Triassic Clematis Sandstone and at depth by red, brown and green mudstones and siltstones of the Triassic Arcadia Formation. The Rangal and Fort Cooper Coal Measure sequences sub-crop within the Wallanbah area. The Fort Cooper Coal Measures that overlie the Moranbah Coal Measures comprise grey lithic sandstones, conglomerate, siltstone, mudstone coal and tuffaceous sediments. The Girrah seam (uppermost seam in the Fort Cooper Coal Measures) is a thick banded sequence of coal, cream to brown tuffaceous claystones, mudstones and siltstones. The target seam (Burton seam and its splits) occurs in the Rangal Coal Measures.

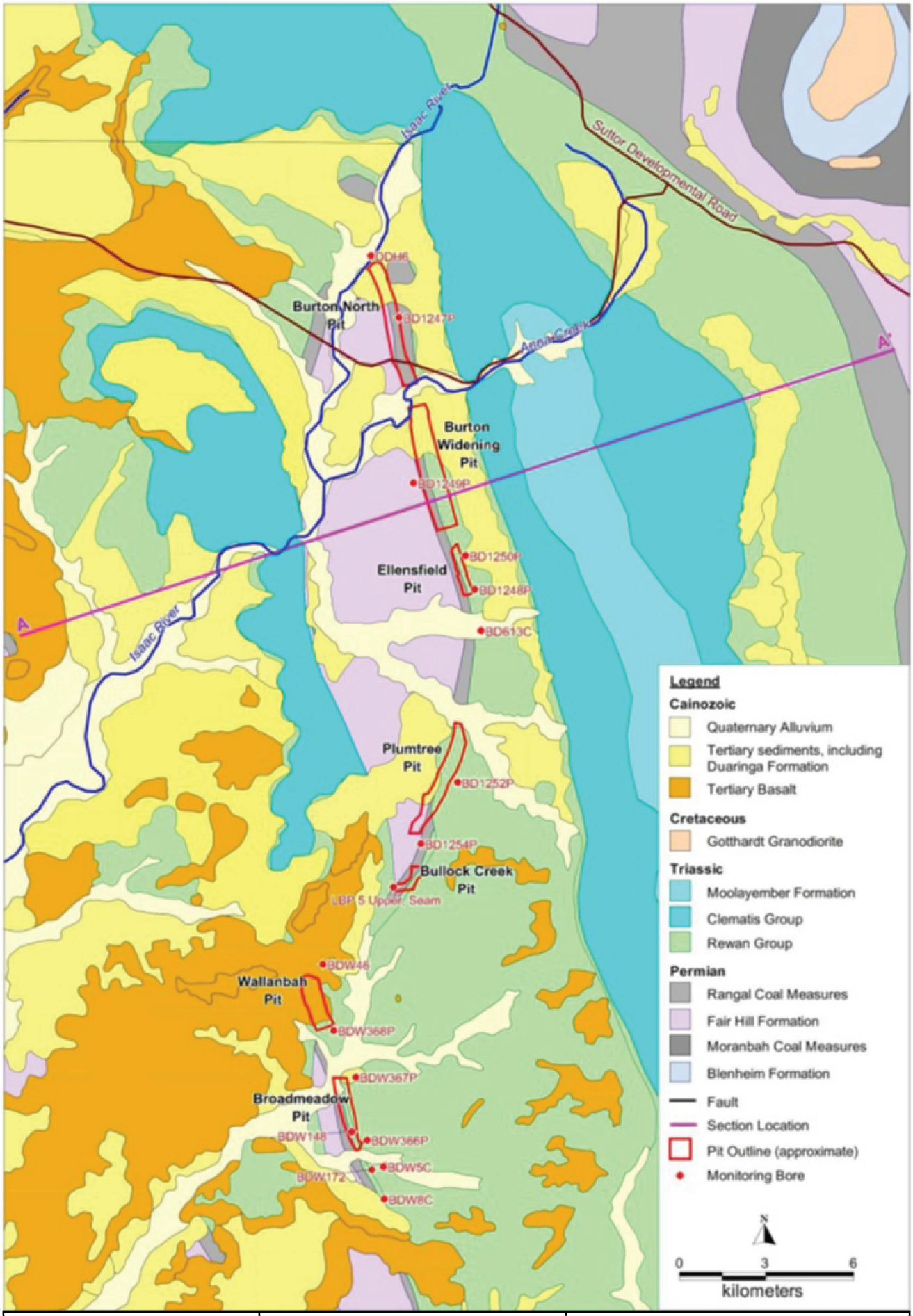
Overlying the Rangal Coal Measures are greenish sediments of the Rewan Group. Quaternary soil, alluvium and / or colluvium cover most of the eastern part of the Wallanbah area where adjacent to Bullock Creek and Spade Creek.

d Broadmeadow

Broadmeadow lies east of the Burton Range Fault and is an upthrown inlier of the Rangal Coal Measures. The Rangal and Fort Cooper Coal Measure sequences sub-crop within the Broadmeadow area. The Fort Cooper Coal Measures that overlie the Moranbah Coal Measures comprise grey lithic sandstones, conglomerate, siltstone, mudstone coal and tuffaceous sediments. The Girrah seam (uppermost seam in the Fort Cooper Coal Measures) is a thick banded sequence of coal, cream to brown tuffaceous claystones, mudstones and siltstones. The target seam (Burton seam and its splits) occurs in the Rangal Coal Measures.

Overlying the Rangal Coal Measures are greenish sediments of the Rewan Group. Quaternary soil, alluvium and / or colluvium cover most of the western part of the Broadmeadow area where adjacent to Hat Creek.

The site geological setting is given in Figure 6.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 6	Title: Surface Geology	Design: JBT Consulting Pty Ltd 26.09.2016 Scale: 1 : 100,000 CRS: GDA94 / MGA zone 55	SGM environmental

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3.1.3.4 Site hydrology and fluvial networks

a Catchment overview

The Burton Gorge Dam catchment is located in the northern area of the Mine. Sandy Creek is the southernmost tributary of the Burton Gorge Dam catchment and passes north of Plumtree Pit.

Teviot Brook catchment is located in the southern area of the Mine. Bullock Creek drains into Spade Creek (north of Broadmeadow) which in turn drains into Hat Creek on the western boundary of the MLs near Broadmeadow. These three waterways drain into Teviot Brook followed by the Isaac River. Spade and Bullock Creek have been diverted due to mine activity (water licence (WL)174800 and WL577239). The Mine has not released any water into Bullock or Spade Creek since mining operations ceased and no longer uses this release point.

b Hydrologic overview

Five named waterways pass through the MLs which drain to two local catchment systems and eventually the Isaac River (part of the Fitzroy Basin). The waterways all drain east to west through the mine lease. All the waterways have sand beds with banks forming flood channels. The waterways are all ephemeral with typical flow durations from a few hours to days after rainfall events.

c Water quality

Burton Gorge Dam catchment

Surface water quality data from the *Burton Coal Mine Water Management Plan 2022* (WMP) (Appendix B) for Sandy Creek, Burton Gorge Dam and Teviot Brook is given in Table 8 and Table 9.

Table 8 Burton Gorge Dam catchment water quality data

Parameter	Units	Sandy Creek	Burton Gorge Dam
Upper pH	pH units	8.1	7.9
Electrical conductivity (EC)	microsiemens per centimetre (us/cm)	239	264
Total nitrogen	Milligrams per litre (mg/l)	0.36	0.07
Nitrate + nitrite	mg/l	0.11	0.06
Phosphorus	mg/l	0.3	0.18
Dissolved metals			
Aluminium (Al)	mg/l	9.6	0.08
Arsenic (As)	mg/l	0.0014	0.001
Boron (B)	mg/l	0.09	0.10
Cadmium (Cd)	mg/l	0.00018	0.0001
Chromium (Cr)	mg/l	0.018	0.007
Copper (Cu)	mg/l	0.0076	0.0070
Lead (Pb)	mg/l	0.0070	0.0040
Manganese (Mn)	mg/l	0.16	0.15

Parameter	Units	Sandy Creek	Burton Gorge Dam
Mercury (Hg)	mg/l	0.0001	0.0001
Nickel (Ni)	mg/l	0.008	0.009
Selenium (Se)	mg/l	0.01	0.01
Silver (Ag)	mg/l	0.001	0.001
Zinc (Zn)	mg/l	0.025	0.019

Teviot Brook catchment

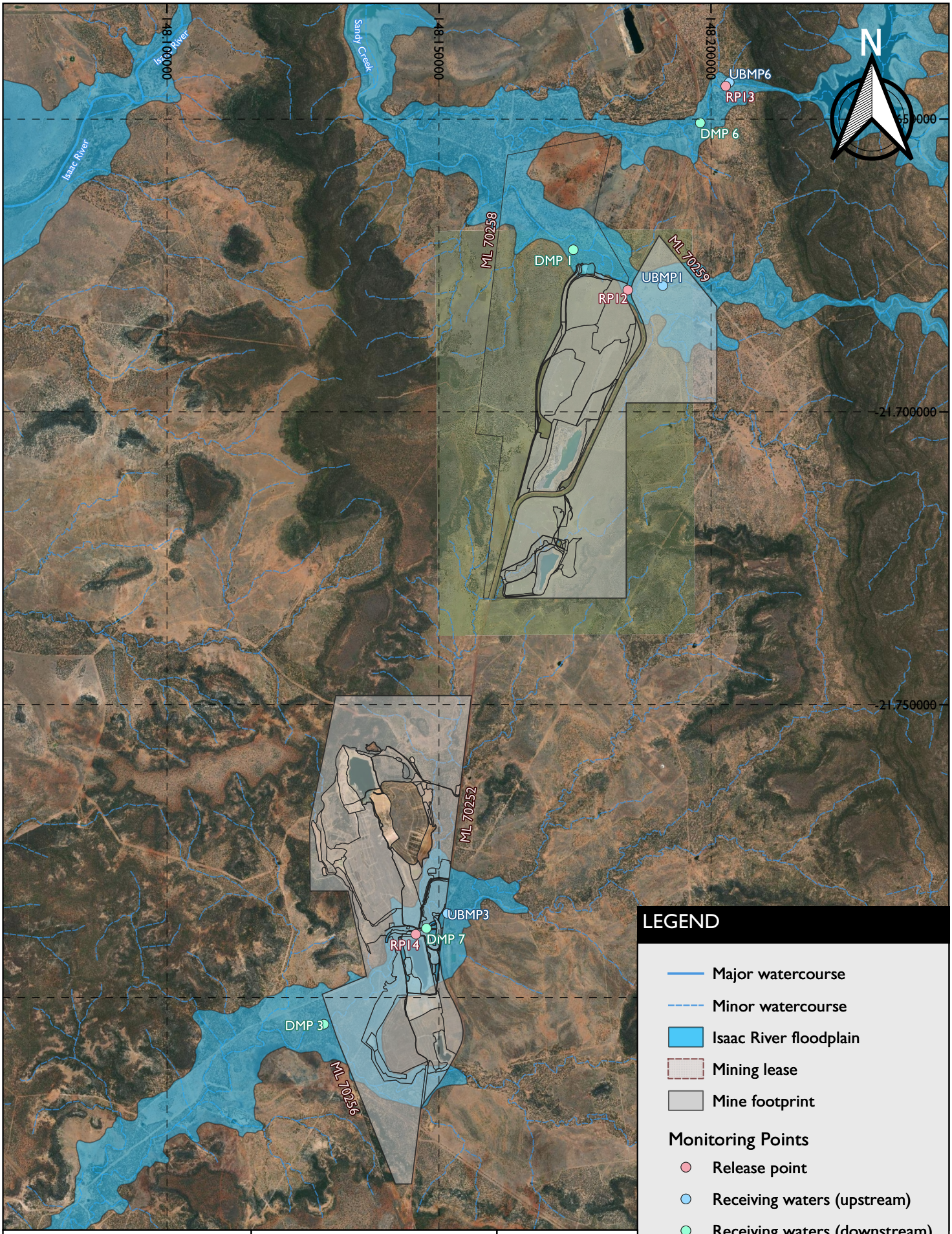
Table 9 Teviot Brook catchment water quality data

Parameter	Units	Spade Creek	Hat Creek
pH	pH units	7.1	7.1
EC	us/cm	110	110
Total dissolved solids (TDS)	mg/l	89	87
Ca	mg/l	3.8	4.2
Mg	mg/l	2.4	2.6
Na	mg/l	12.0	10.0
K	mg/l	2.2	3.8
Nitrate as N	mg/l	0.691	0.015
Dissolved metals			
Al	mg/l	132	78.8
Cd	mg/l	0.011	0.007
Cr	mg/l	0.128	0.083
Cu	mg/l	0.061	0.029
Mn	mg/l	1.595	0.089
Zn	mg/l	0.236	0.138

d Licensed diversions

The Mine has two licensed diversions at Bullock and Spade Creeks. The diversions are administered under IWL577149 and WL175610 respectively. The licenses are issued under the Department of Natural Resources and Mines (DNRM) and is administered by the Department of Natural Resources, Mines and Energy (DNRME). Monitoring, maintenance and relinquishment conditions are requirements of the licences.

The site fluvial network is given in Figure 7.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 7	Title: Fluvial Network	Design: SGM Environmental Pty Ltd 09.06.2022 Scale: 1 : 100,000 CRS: GDA94 / MGA zone 55	SGM environmental

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3.1.3.5 Groundwater levels and properties

a Overview

Three potential groundwater aquifer systems identified within the Mine include:

- unconfined fractured rock aquifers of the Triassic and Permian Coal sediments;
- confined aquifers within Permian Coal Measure sequences; and
- unconfined aquifers in unconsolidated Quaternary sand and gravel alluvium associated with creeks and rivers.

Recharge of the fractured rock aquifers (ie Blackwater Group sediments and Tertiary Sediments) is considered to occur regionally and to a lesser extent by flow within local drainage systems. The alluvial aquifers are recharged by direct infiltration of rainfall.

b Plumtree and Bullock Creek

Within the Plumtree area, the coal seams are the only permeable intervals and are considered to be the only aquifers. The coal seam has split into four seams with each believed to behave as a confined aquifer. Recharge for the aquifer system originates from Teviot Creek and Sandy Creek where they traverse the seam sub-crops and lie along the strike of the seam sub-crop. Significant quantities of groundwater could also be stored within the igneous sill intruding the Leichardt and Upper Vermont seam.

The overburden, interburden and floor strata are considered to behave as aquicludes due to their impermeability, with the exception being where fractures have formed.

c Wallanbah

The only aquifers in the Wallanbah area are the Rangal coal seams and the Girrah coal seam. Ephemeral streams traversing the Wallanbah area incise the sub-crops of Rangal's and Fort Cooper Coal Measures. It is likely that during the flow periods of these streams they could recharge the coal seam aquifer system. Generally, the amount of water transmitted from the aquifer would be low due to poor permeability.

d Broadmeadow

The only aquifers in the Broadmeadow area are the Burton Coal Seam, the two seams that originate from the Burton Seam, and the Girrah coal seam. Ephemeral streams traversing the Wallanbah area incise the sub-crops of Rangal's and Fort Cooper Coal Measures. It is likely that during the flow periods of these streams they could recharge the coal seam aquifer system. Generally, the amount of water transmitted from the aquifer would be low due to poor permeability.

e Chemistry

A program of groundwater sampling and analysis was completed at the Mine prior to 1996 to determine background water qualities. Sampling was done from four monitoring bores located within the Permian coal measure sequences. The results indicated that groundwater had the following characteristics:

- pH was neutral to alkaline;
- slightly to moderately saline, with higher salinities generally being encountered near the coal beds;
- groundwater samples collected near the coal beds generally did not meet the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC) stock water guidelines for total suspended solids (TSS) (ANZECC 2000);
- major ion analysis indicated sodium (Na) and chloride (Cl) as the dominant ions;
- samples from several bores returned calcium (Ca) and magnesium (Mg) concentrations exceeding the ANZECC (2000) guidelines for stock water.

- metal concentrations were generally below or close to laboratory detection limits including Cd, uranium (U), arsenic (As), selenium (Se), mercury (Hg), nickel (Ni), lead (Pb) and Zn.

Any impacts are expected to be minimal as there are no known groundwater users and groundwater quality is considered poor.

3.1.3.6 Soil types, properties and productivity

Soil surveys by AustralAsian Resource Consultants (AARC) (2000) identified Vertosols, Tenosols, Tenosols (alluvial), Chromosols and Sodosols at the Mine.

a Sodosols

Sodosols are soils that show strong texture contrast between the topsoil and subsoil, with highly sodic subsoil, but they are not highly acidic (pH > 5.5). Parent materials of Sodosols range from highly siliceous, siliceous to intermediate in composition. Generally, sodosols have very low agricultural potential. The high subsoil sodicity leads to high erodibility, poor structure and low permeability. These soils have low to moderate fertility and can be associated with soil salinity. Elevated sodium levels impose the primary limitation for this soil type, effectively limiting the potential for intensive land use due to the risk of erosion.

b Vertosols

Vertosols generally have high clay contents (>35%) of uniform texture. They have the potential for strong cracking and slickensides. These soils have high agricultural potential with high fertility and water-holding capacity, but they require significant amounts of rain before water is available to plants. Gypsum and / or lime may be required to improve their structure. Vertosols can be difficult to cultivate especially when they are wet. The primary limiting factor for this soil type is largely associated with the strongly seasonal climate of the region rather than soil characteristics. The highly seasonal rainfall presents an erosion risk due to the lack of vegetation cover present during the dry winter months, followed by relatively high intensity rainfall occurring during the remainder of the year.

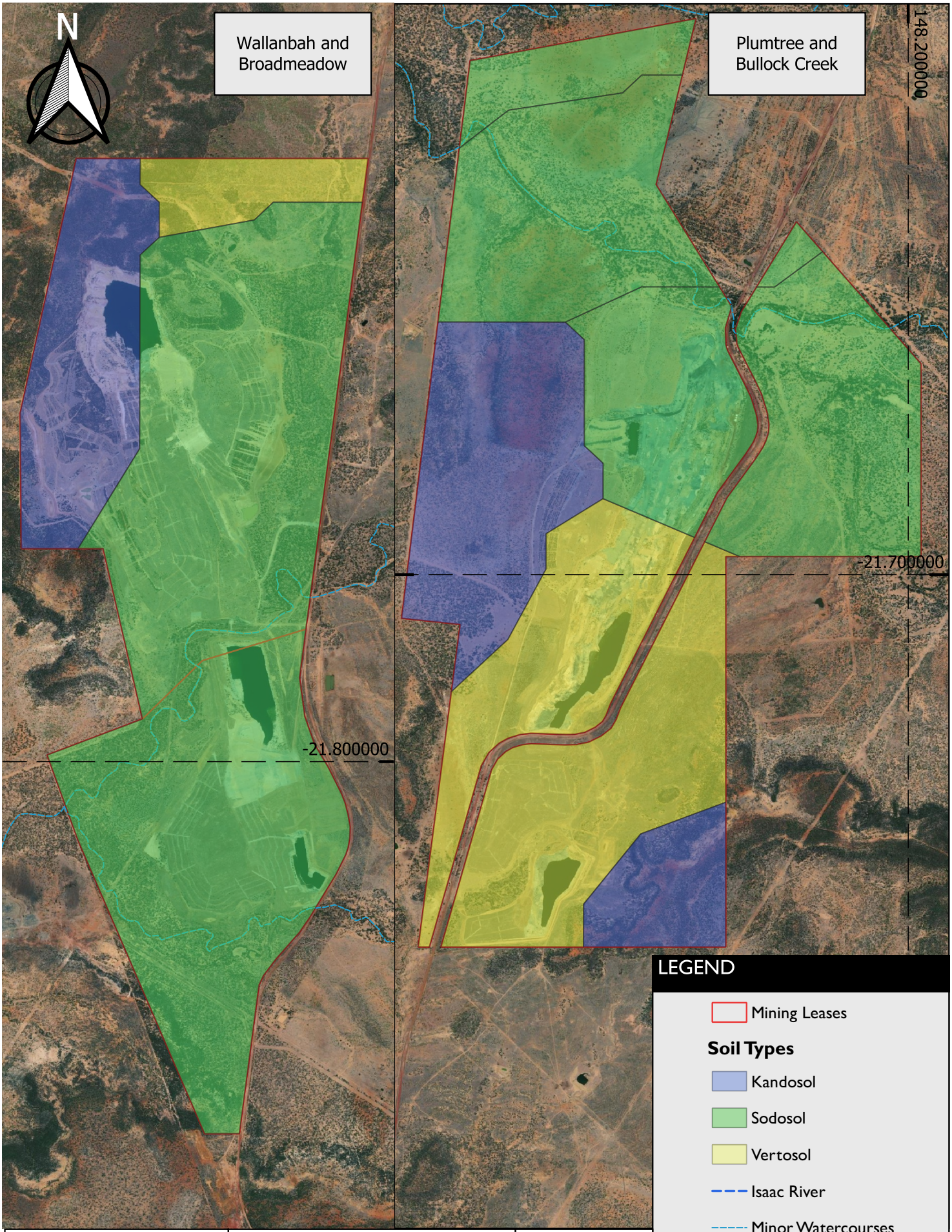
c Tenosols

Tenosols incorporate soils with generally weak pedologic organisation apart from the topsoil, encompassing a diverse range of soils. Tenosols generally have poor water retention, almost universal low fertility and occur in regions of low and erratic rainfall. They are mainly used for grazing based on native pastures and in better watered areas may support improved pastures or forestry. These soils are largely associated with escarpments at the Mine. The primary limitation is therefore slope angle and lack of effective rooting depth.

d Chromosols

Chromosols incorporate soils that show strong texture contrast with the subsoil which is generally not sodic especially in the upper 0.2 m. They are not highly acidic with pH generally above 5.5. Chromosols have moderate agricultural potential with moderate fertility and water-holding capacity. They can be susceptible to soil acidification and soil structure decline.

The soil distribution for the Mine is given in Figure 8.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	SGM environmental
Figure: 8	Title: Soil Distribution	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 35,000 CRS: GDA94 / MGA zone 55	

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3.1.4 Productivity

3.1.4.1 ALC class

The Guidelines for Agricultural Land Evaluation in Queensland (QDPI 1990) gives agricultural land classification (ALC) classes based on soil and landscape characteristics. The land ALC classes are given in Table 10.

Table 10 ALC classes

ALC class	Description
A	Land that is suitable for a wide range of current and potential crops with nil to moderate limitations to production.
B	Land that is suitable for a narrow range of current and potential crops. Land that is marginal for current and potential crops due to severe limitations but is highly suitable for pastures. Land may be suitable for cropping with engineering and / or agronomic improvements.
C	Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for production. Some areas may tolerate a short period of ground disturbance for pasture establishment.
D	Land not suitable for agricultural uses due to extreme limitations. This may be: undisturbed land with significant conservation and / or catchment values; land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop, poor drainage, salinity, acidic drainage; or is an urbanised area.

The soils in the project area were identified as ALC Class C1 and B land at the Mine (pre-mining) which meets the Belyando Shire Council criteria for GQAL (Table 11).

Table 11 ALC classes of soil orders

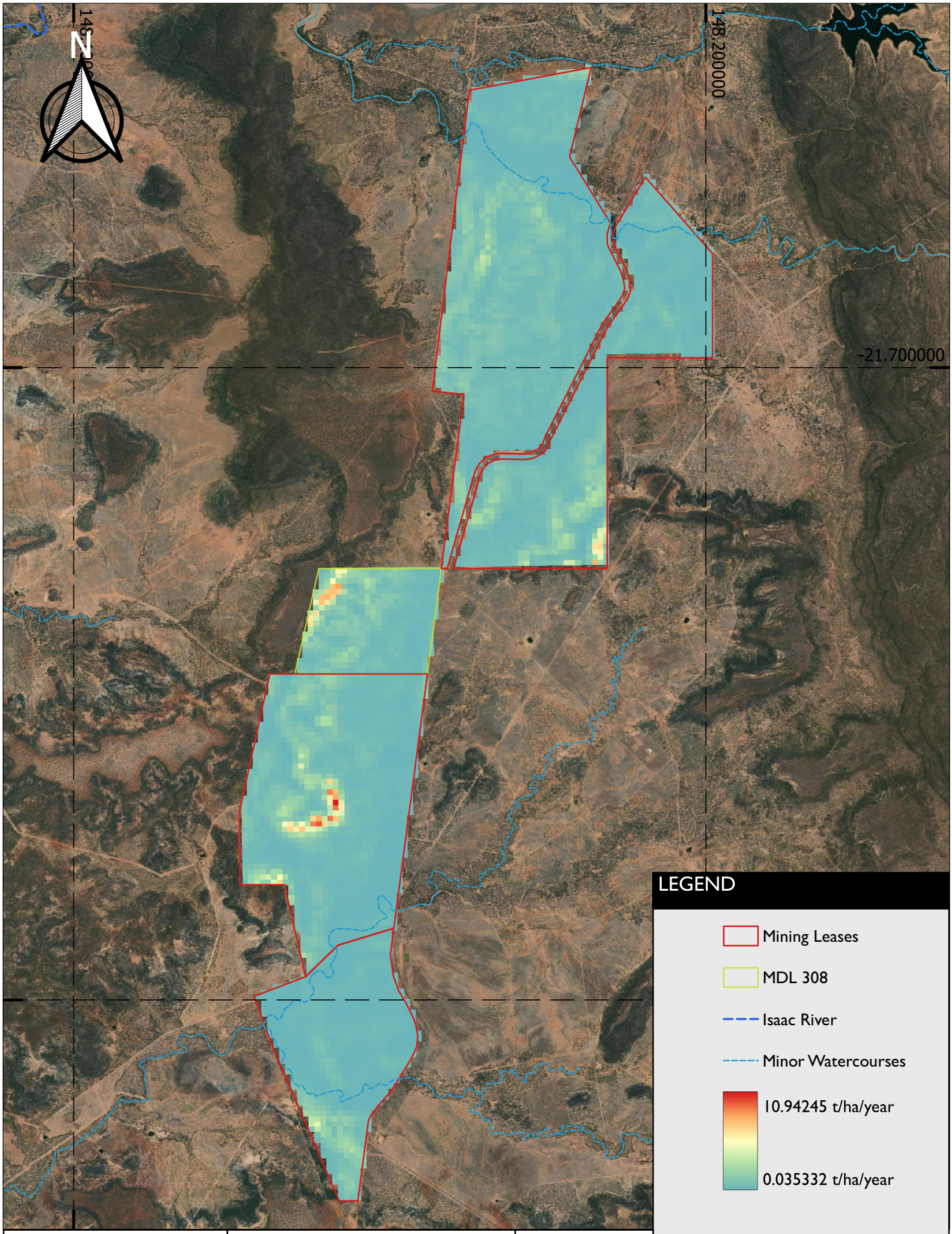
Soil type	ALC class
Vertosols	Class B (limited cropping) and Class B / C (equivalent to class C1) (improved pasture)
Chromosols	Class B / C (equivalent to class C1) (improved pasture)
Sodosols	Class C (pasture)
Tenosols (alluvial)	Class C (pasture)
Tenosols	Class D (non-agricultural land)

3.1.4.2 Belyando Shire Planning Scheme

The Belyando Shire Planning Scheme (2008) has mapped Good Quality Agricultural Land (GQAL) across the region. GQAL is land that is classified as ALC classes A to C1 (Table 11). The GQAL map prepared by the Belyando Shire Council indicates that there was some ALC Class C1 mapped at the Mine prior to mining.

3.1.4.3 Land stability

An assessment of pre-mining land stability is shown in Figure 9.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	SGM environmental
Figure: 9	Title: RUSLE Mapping	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 65,000 CRS: GDA94 / MGA zone 55	

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3.1.4.4 Vegetation communities and ecological data

a Matters of environmental significance

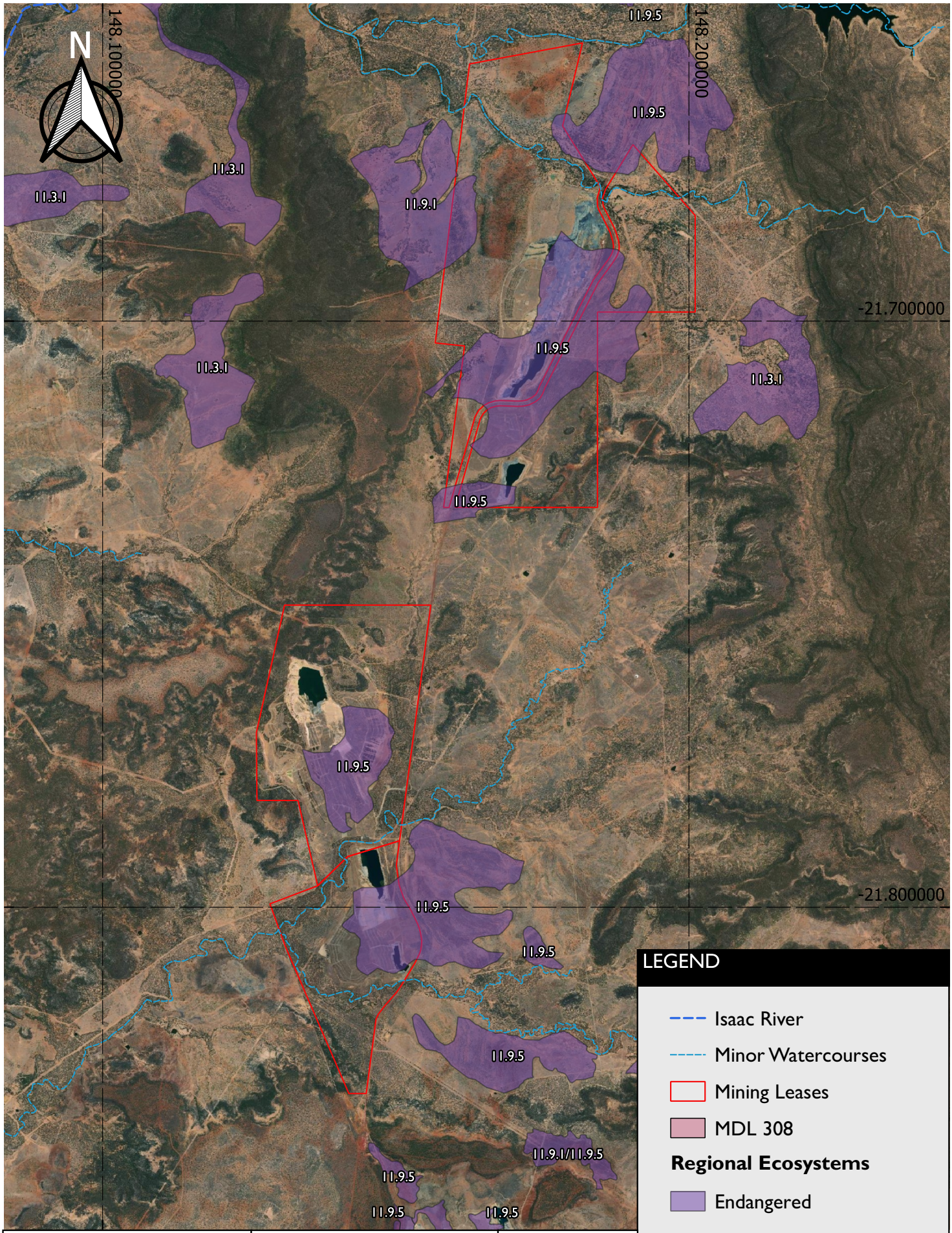
No matters of national environmental significance were identified in the MLs or the surrounding areas using the Department of the Environment and Energy protected matters search tool. No matters of local environmental significance were identified in *The Belyando Shire Planning Scheme* (2008).

The following matters of state environmental significance were identified in the MLs and surrounding areas:

- matter of state environmental significance (MSES) regulated vegetation (defined watercourse);
- MSES regulated vegetation (category B — endangered or of concern);
- MSES regulated vegetation (category C — endangered or of concern);
- MSES regulated vegetation (category R — GBR riverine); and
- MSES regulated vegetation (essential habitat).

b Environmentally sensitive areas

A search of the Department of Environment and Science (DES) Environmentally Sensitive Areas (ESAs) mapping tool for Category A and B ESAs, as described in the *Environmental Protection Regulation* (2008), identified small areas of Category A ESAs within the MLs (Figure 10). These areas have been largely undisturbed by mining operations.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 10	Title: Environmentally Sensitive Areas	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 55	SGM environmental

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c Significant flora

The protected matters search tool identified the following significant flora (as listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)) as occurring at the Mine or surrounds (within a 5 km radius) (Table 12).

Table 12 Significant flora that may occur

Scientific Name	Common Name	Class	Simple Presence	Threatened Category
Dichanthium queenslandicum	King Blue-grass	Plant	Likely	Endangered
Eucalyptus raveretiana	Black Ironbox	Plant	Likely	Vulnerable
Dichanthium setosum	bluegrass	Plant	Known	Vulnerable
Samadera bidwillii	Quassia	Plant	May	Vulnerable

Plumtree

Native vegetation communities have generally been cleared from much of the upland areas on the Plumtree, except for the hills in the south of the ML and small areas near Sandy Creek and Teviot Creek. The riparian zone along Teviot and Sandy Creek is comprised of a mature canopy layer dominated by Forest Blue Gum and Sally Wattle, and small stands of Paper-barked Teatree. The understorey and mid-layer are highly disturbed and are dominated by pasture species and a range of local and introduced species. The upland areas near the creeks are dominated by disturbed mixed Eucalypt woodland, comprised mainly of Forest Blue Gum, Moreton Bay Ash and Poplar Box. None of the flora species identified in these communities are listed as being conservation significance under any Local, State or Commonwealth Authority.

A remnant of Acacia harpophylla dominated community is located within the north west section of the ML. This community is noted as being an endangered regional ecosystem but has not been disturbed.

Bullock Creek

The Bullock Creek Coal Project contains three regional ecosystems: Brigalow-Dawson Gum Woodland, Poplar Box Woodland and Acacia Woodland. Most of the ML is covered in non-remnant grassland with Acacia Woodland along the hillside slopes. The Bullock Creek drainage line features Brigalow and Dawson Gum existing as co-dominant. A small section of Bullock Creek is identified as endangered regional ecosystem (ERE) being Brigalow — Dawson Gum woodland community (ERE 11.9.1).

Wallanbah

Much of Wallanbah has been cleared of vegetation for pastoral activities, except for the riparian zones and woodland along Spade and Bullock Creeks, and the escarpment and hills in the north west corner of the ML. The upland areas near the creeks are dominated by disturbed mixed Eucalypt woodland, comprised mainly of Forest Blue Gum, Poplar box and Moreton Bay Ash. The understorey is sparse, due to the disturbance caused by grazing.

The riparian zone along Spade and Bullock Creeks is comprised of a mature canopy layer dominated by Forest Blue Gum, Sally Wattle and small stands of White Flowered Bauhinia. The understorey and mid layer are highly disturbed and is dominated by pasture species and a range of local and introduced species. A small area of Poplar Box Woodland occurs within the western extent of Bullock Creek but is highly disturbed.

A small remnant of Acacia harpophylla dominated community is located to the south east in the ML. This community is noted as being an endangered regional ecosystem.

Broadmeadow

The native vegetation communities have generally been cleared for grazing purposes except for the hills in the south and small areas near Hat and Spade Creeks. The upland areas near the creeks are dominated by disturbed mixed Eucalypt woodland, comprised mainly of Forest Blue Gum, Poplar box, Brigalow and Moreton Bay Ash. Species such as Dark Wiregrass, Buffel grass, Kangaroo Grass and Red Natal Grass formed the ground cover. The riparian zone along Hat and Spade Creeks is comprised of a mature canopy layer dominated by Forest Blue Gum, Sally Wattle and small stands of White Flowered Bauhinia. The understorey and mid-layer are highly disturbed and are dominated by pasture species and a range of local and introduced species.

3.1.4.5 Fauna presence and populations

Surveys were completed by AARC from 1998–2000 to identify key fauna species in the area.

Over 30 species of birds were observed across the MLs. The most common bird species included Australian magpies, Torresian Crows, Noisy Friarbirds and Rainbow Lorikeets. A number of insignificant reptile species were observed and common mammal species including the Eastern Grey Kangaroo, Greater Glider and the Common Brushtail Possum.

A subspecies of the Squatter Pigeon was observed at the Plumtree Project on multiple occasions Bullock Creek. The bird species was seen at the Wallanbah Project in 2000 during another field survey and it was noted that it had been seen by environmental staff on site and at the Burton Coal residential village. Field staff were unable to determine which of the two subspecies of Squatter Pigeon was sighted however it is assumed that it was the southern subspecies *Geophaps. scripta scripta* due the northern species not being commonly found south of the Burdekin.

3.1.4.6 Significant fauna

The protected matters search tool identified the following significant fauna (as listed under the EPBC Act) within a 5 km radius of the Mine:

- 18 threatened fauna species; and
- 10 migratory bird species.

Table 13 lists the significant fauna that may occur.

Table 13 Significant fauna species that may occur in the Mine areas

Scientific Name	Common Name	Class	Simple Presence	Threatened Category
Elseya albagula	Southern Snapping Turtle, White-throated Snapping Turtle	Reptile	Likely	Critically Endangered
Calidris ferruginea	Curlew Sandpiper	Bird	May	Critically Endangered
Lerista allanae	Allan's Lerista, Retro Slider	Reptile	May	Endangered
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT)	Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory)	Mammal	Known	Endangered

Scientific Name	Common Name	Class	Simple Presence	Threatened Category
Poephila cincta cincta	Southern Black-throated Finch	Bird	May	Endangered
Rostratula australis	Australian Painted Snipe	Bird	May	Endangered
Dasyurus hallucatus	Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu]	Mammal	Likely	Endangered
Neochmia ruficauda ruficauda	Star Finch (eastern), Star Finch (southern)	Bird	Likely	Endangered
Geophaps scripta scripta	Squatter Pigeon (southern)	Bird	Known	Vulnerable
Rheodytes leukops	Fitzroy River Turtle, Fitzroy Tortoise, Fitzroy Turtle, White-eyed River Diver	Reptile	May	Vulnerable
Denisonia maculata	Ornamental Snake	Reptile	Known	Vulnerable
Erythrotriorchis radiatus	Red Goshawk	Bird	Likely	Vulnerable
Nyctophilus corbeni	Corben's Long-eared Bat, South-eastern Long-eared Bat	Mammal	May	Vulnerable
Furina dunmalli	Dunmall's Snake	Reptile	May	Vulnerable
Falco hypoleucos	Grey Falcon	Bird	May	Vulnerable
Egernia rugosa	Yakka Skink	Reptile	May	Vulnerable
Petauroides volans	Greater Glider	Mammal	Known	Vulnerable
Macroderma gigas	Ghost Bat	Mammal	May	Vulnerable

3.1.4.7 Aquatic flora and fauna

The waterways within the MLs are typical of smaller drainages in central Queensland, being ephemeral and generally only flowing for short periods after rain. The aquatic flora and fauna are not considered to be diverse or unique. Although macro invertebrates and fish may opportunistically move into the upstream drainages of ephemeral creeks to forage, the drainage lines within the MLs are considered poor habitat for macro invertebrates and are unlikely to harbour long-term fish populations.

3.1.4.8 Pre-mining land use

a Regional

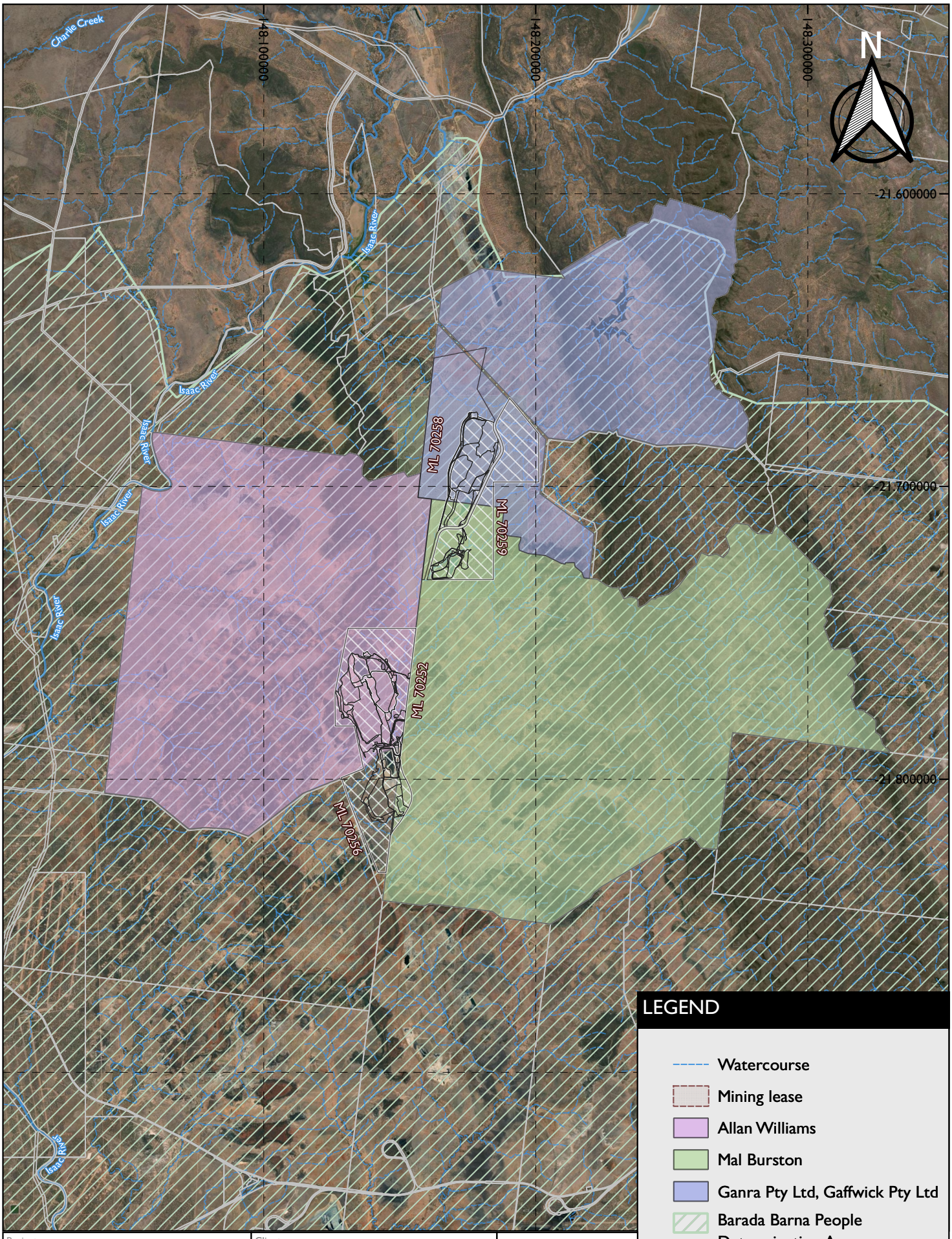
The Mine is located in a rural area typified by large holdings. Agricultural activities and coal mining are established in the locality. The nearest township is Moranbah, located approximately 14 km to the south-west. Nebo and Glenden are located 67 km and 36 km away respectively. Mackay (the regional centre) is 140 km to the north-east.

b Local

The pre-mining land use was low-intensity grazing and agricultural activity. Operational mines are located to the south, west and east. Extensive clearing for grazing and agriculture means that the remnant vegetation is mostly confined to riparian zones, predominantly along drainage lines.

3.1.4.9 Identification of underlying landholders

The underlying landholders are given in Figure 11.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 11	Title: Underlying Landholders	Design: SGM Environmental Pty Ltd 09.06.2022 Scale: 1 : 200,000 CRS: GDA94 / MGA zone 55	SGM environmental

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3.1.5 Project description

The Project description is given in Section 3.1.2.

3.1.6 Design for closure

In accordance with the PRC plan guideline, transitional PRC plans are not required to demonstrate how aspects of the Mine have been designed for existing or approved disturbance. However, any expansion to an existing site must demonstrate how it has been designed for closure.

No expansion or additional disturbance is planned.

3.1.7 Rehabilitation and improvement planning

3.1.7.1 Relevant activities

The Mine ceased production in 2016 and since that time has been progressively rehabilitating disturbed land. Current activities include:

- landform reshaping via dozer push;
- topsoiling of reshaped landforms;
- seeding of topsoiled areas with pasture/bushland seed mixes;
- maintenance of water management structures such as dams, diversions and levees;
- monitoring and maintenance of previously rehabilitated land; and
- grazing of cattle on suitable areas in partnership with neighbouring landholders.

3.1.7.2 Predicted duration and extent of activities

Earthworks associated with rehabilitation are scheduled to continue until mid-2028. Following this work the Mine will enter a monitoring and management phase. Progressive rehabilitation is being done as per the PRC schedule in Appendix A.

3.1.8 Existing rehabilitation

A total of ~ 1,735 ha of rehabilitation has been completed. Table 14–Table 17 outline completed rehabilitation.

3.1.8.1 Plumtree

Table 14 Completed rehabilitation for Plumtree

Location	Methodology	Year completed (approximate)
North dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2007
South dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2007

Location	Methodology	Year completed (approximate)
Rehabilitation maintenance	• dozer push; and • ripping and seeding.	2018
Western ROM	• remove rejects material and dump in void; • dozer reshaping; • deep ripping; • surface preparation; • topsoiling; and • rip and seed.	2022
In pit dump	• dozer reshaping.	In progress

3.1.8.2 Bullock Creek

Table 15 Completed rehabilitation for Bullock Creek

Location	Methodology	Year completed (approximate)
Out of pit dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2011
In pit dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2012 / 2013
ROM and workshop area	• dozer push; • backfill dam; • topsoiling; and • rip and seed.	2016
Sediment dam	• dozer push; • backfill dam; • topsoiling; and • rip and seed.	2017
Rehabilitation maintenance	• dozer push; and • ripping and seeding.	2017

Location	Methodology	Year completed (approximate)
Buttress	• load and haul spoil from in pit dump face to buttress; • reshape in-pit dump batter • reshape buttress; • topsoiling; and • rip and seed.	2018
ERE rehabilitation area	• dozer reshaping; • topsoiling; • ripping and seeding; and • tubestock planting.	2017 / 2018
ERE rehabilitation area	• ripping and seeding; and • tubestock planting.	2019

3.1.8.3 Wallanbah

Table 16 Completed rehabilitation for Wallanbah

Location	Methodology	Year completed (approximate)
Eastern out of pit dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2009
In-pit dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2011 / 2012
Western dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2011
South-west sediment dams	• dozer push; • backfill dams; • drainage installation; • topsoiling; and • rip and seed.	2016

Location	Methodology	Year completed (approximate)
Hardstand	• remnant infrastructure removed; • contaminated land assessment (desktop); • dozer reshaping; • dozer rip east/west; • topsoiling; and • rip (north/south) and seed.	2016
Rehabilitation maintenance	• dozer push; • reinstate failed drainage; • ripping and seeding.	2018
Eastern sediment dams	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2020

3.1.8.4 Broadmeadow

Table 17 Completed rehabilitation for Broadmeadow

Location	Methodology	Year completed (approximate)
Western out of pit dump	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2011
Broadmeadow ROM and ROM dam	• remove rejects material and dump in void; • backfill dam; • dozer reshaping; • deep ripping; • surface preparation; • topsoiling; and • rip and seed.	2018
Eastern drainage	• dozer push; • topsoiling; and • rip and seed.	2018
Rehabilitation maintenance	• dozer push; and • ripping and seeding.	2018

Location	Methodology	Year completed (approximate)
In pit spoil (south)	• dozer push; • drainage installation; • topsoiling; and • rip and seed.	2019
In pit spoil (south)	• dozer push.	2020

3.2 Post-mining land use

Mining is a temporary use of land. Suitable areas will be returned to grazing with areas of bushland habitat, which is consistent with EA conditions regarding rehabilitation, ie Conditions F1-F15.

The strategy for how this will be achieved is described in 3.6.8.3.

There will be areas of the disturbance area, ie riparian vegetation which will require an alternate land use.

The proposed final land uses are:

- grazing with areas of bushland habitat (disturbed and undisturbed);
- self-sustaining native vegetation (Bullock Creek ERE area); and
- riparian vegetation rehabilitation area (riparian area along the Spade Creek diversion).

The final landscape will be dominated by a mixture grazing and bushland. Table 18 gives the proposed area for each PMLU.

Table 18 PMLU

Final land use	Domains included in final land use	Area (ha)
Grazing with areas of bushland habitat	Includes areas to be rehabilitated, undisturbed, and completed rehabilitation	4,060.3
Self-sustaining native vegetation	Bullock Creek ERE area	10.6
Riparian	Re-established vegetation areas along Spade Creek diversion	12.6
NUMA	Voids	222.8
Total	**-**	**4,306.3**

3.2.1 Consistency with the outcome of community consultation

The PMLU is consistent with the outcome of community consultation because it:

- established that native habitat is not considered a good use of the land because it will be expensive to establish and will not be contiguous with any other native habitat;
- there is a preference for pasture grazing being a productive land use while recognising that the current surrounding areas contain a mixture of grazing and bushland areas which are productive for local graziers; and

- it is accepted that riparian areas along creek lines such as Bullock and Spade Creek require specific vegetation for stabilisation and habitat creation.

How underlying landholders and other stakeholders views have been addressed:

- all embankments / slopes are battered to 20% or less and is considered suitable for ingress and egress of grazing animals;
- species selected for seeding are consistent with surrounding grazing land with appropriate tree species included;
- a specific request for a legume (Butterfly pea) was made by a landholder and was subsequently included in the seed mix;
- grazing cattle will be excluded from void water which does not meet cattle drinking water guidelines;
- safety bunding will be placed around voids to protect against accidental vehicle access;
- salts are expected to accumulate over time due to evapo-concentration meaning voids are not suitable storage areas for cattle drinking water; and
- the results of cattle grazing trials have been successful in demonstrating the suitability of the PMLU (Section 3.8.4.3).

3.2.2 Consistency with local, State and Commonwealth requirements

3.2.2.1 Local government

The following review of the *Mackay, Isaac and Whitsunday Regional Plan* (DLGP 2012) and the *IRC 2035, our Community Strategic Plan* (IRC 2015) demonstrate that grazing with areas of bushland habitat is consistent with the strategies and plan outlined herein.

a Mackay, Isaac and Whitsunday Regional Plan

The *Mackay, Isaac and Whitsunday Regional Plan* (DLGP 2012) includes the following specific policies for PMLUs:

- identified valuable mineral and extractive resource areas within the region are protected from development that might adversely affect current or future extraction;
- the operation of extraction and processing activities does not compromise:
  - human health;
  - current and future resource use opportunities;
  - regional landscape values;
  - ecosystem function and services; and
  - must minimise its impact on primary production.
- once extraction ceases, former resource areas are rehabilitated to facilitate multiple end-uses, ensuring continuing contribution to the economic, community and EVs of the region; and
- innovative practices are encouraged, including local processing and value-adding activities, to maximise eco-efficiencies.

The *Mackay, Isaac and Whitsunday Regional Plan* is consistent with a PMLU of grazing with areas of bushland habitat because:

- the mine plan maximises the extraction of economic coal and therefore no potential resource will be sterilised from rehabilitation;
- the PMLU aligns with the regional landscape and will be returned to grazing with areas of bushland habitat ie rehabilitation minimises the impact to primary production; and
- rehabilitation of the land to grazing with areas of bushland habitat does not exclude other potential land uses such as solar farms or native habitat.

b 2035 Community Strategic Plan

Isaac 2035, our *2035 Community Strategic Plan* (the strategic plan), IRCs commitment to the long-term future of the region. It is the blueprint for the future, which gives how IRC will work towards enabling strong, vibrant, diverse, and sustainable communities for the community over the next 20 years.

Inevitable social, economic and political changes mean that IRC need to explore new ways of capitalising on opportunities and addressing challenges, to make sure the region reaches its full potential.

The aim of the strategic plan is to give clear goals and direction towards improving the future of the Isaac region through growth in four key themes:

- community — strong and diverse communities that support all to live, work and raise families;
- economy — continue to be Queensland's number one performing regional economy based upon a thriving, resilient and diverse mix of industry sectors;
- infrastructure — effective and sustainable infrastructure that supports the needs of the region's communities and its economic sectors; and
- environment — appropriate and sustainable balance between environment, economy and community to make sure our natural resources are sustainably managed and protected.

The strategic plan is consistent with a PMLU of grazing with areas of bushland habitat because:

- when rehabilitated the Mine will transition to grazing with areas of bushland habitat and continue to support the region's communities and its economic sectors as an agribusiness; and
- the inclusion of grazing with areas of bushland habitat represents a sustainable balance between business and the environment.

3.2.2.2 State and Commonwealth legislation

State and Commonwealth legislation that may be relevant to the PMLU and region is given in Table 19 including how the legislation relates to the Mine.

Table 19 State and Commonwealth legislation

Legislation	Objective	General application	How it relates to the Mine
Planning Act 2016	The principal objective of this Act is to achieve ecological sustainability.	Where land is included on a mining lease (ML) pursuant to the *Mineral Resources Act 1989*, closure and rehabilitation activities done under an EA do not require a planning approval from the local government.	The PMLU does not require local government approval.

Legislation	Objective	General application	How it relates to the Mine
Local Government Act 2009	The purpose of this Act is to give for the way a Local government is constituted and the nature and extent of its responsibilities and powers. Local laws are made under the Act.	Local laws may apply to the owner of land as defined under the *Mineral Resources Act 1989*.	The *Planning Act 2016* only applies if a built structure that is entered onto the *Queensland Heritage Register* is found. Therefore, the Planning Act does not apply to development in the ML authorised under the *Mineral Resources Act 1989*.
EP Act 1994	To protect the environment while allowing development that improves the total quality of life and ecologically sustainable development.	General environmental 'duty of care' to be observed to guarantee that any potential environmental impact from the Mine is minimised.	The potential impacts to EVs were assessed as part of the original EA application. Duty of care is demonstrated for rehabilitation by preparing the PRC plan in accordance with the PRC plan guideline.
State Development and Public Works Organisation Act 1971	To give state planning and organisational legislation that aids in the delivery of ecologically sustainable development.	Commitments during the environmental impact statement (EIS) phase may impact on closure and rehabilitation of the Mine.	The potential impacts to EVs have been assessed as part of the original EA application. Duty of care is demonstrated for rehabilitation by preparing the PRC plan in accordance with the PRC plan guideline.
Transport Infrastructure Act 1994	The overall objective of the Act is to give a regime that allows for and encourages effective integrated planning and efficient management of a system of transport infrastructure.	Approval from the Department of Transport and Main Roads (DTMR) is needed under the Act if the Mine interferes with a State Controlled Road.	The Project does not propose any modification to State Controlled Roads. Consequently, approvals for works under s33 of the Act is not needed.

Legislation	Objective	General application	How it relates to the Mine
Aboriginal Cultural Heritage Act 2003 which give rise to *Duty of Care Guidelines, 2004*	Provide effective recognition, protection and conservation of Aboriginal cultural heritage.	All practical measures need to be taken to make sure closure activities do not harm Aboriginal cultural heritage, ie demonstrate 'cultural heritage duty of care'.	The *Aboriginal Cultural Heritage Act 2003* (ACH Act) requires that, when carrying out an activity, all reasonable and practicable measures are taken to make sure that the activity does not harm Aboriginal cultural heritage. This is referred to as the cultural heritage duty of care. The Mine has a cultural heritage management plan (CHMP) with the Barada Barna People to manage the risk of harm to Aboriginal cultural heritage by activities associated with the Mine.
Land Act 1994	Relates to the administration and management of non-freehold land and deeds of grant in trust and the creation of freehold land, for related purposes.	Regulates the opening and closing of road reserves and land dealings relating to changes in land tenure.	The *Land Act 1994* gives a framework for the allocation of State land as leasehold, freehold or other tenure and gives for its management. The Act further regulates the grant, lease and permitting of Unallocated State Land and reserves and roads. No action is needed to satisfy this Act.
Stock Route Management Act 2002	The main purpose of this Act is to provide for stock route network management.	Regulates the management and use of stock routes.	The Project does not intersect existing stock routes. Consequently, no agreements to alter stock routes or reserves are needed.
Water Act 2000 (and Water Resource (Fitzroy Basin) Plan, 2011 Fitzroy Basin Resource Operations Plan, 2011)	Provide for the sustainable management of water and other resources and the establishment and operation of water authorities and for other purposes.	Utilisation of groundwater and rehabilitation of bore holes.	No make-good agreements associated with disturbance to water quality, volume or water supply infrastructure are anticipated and therefore do not impact on the proposed PMLU. Two existing creek diversions are currently licensed under the *Water Act 2000*
Nature Conservation Act 1992	To give a framework for the protection of state listed	Rehabilitation strategies may need to include any State listed	No threatened or endangered species have been identified on the Mine.

Legislation	Objective	General application	How it relates to the Mine
	threatened species	threatened species or communities that occur in the ML.	

3.3 Non-use management areas

Five NUMA's will remain being the residual voids at Plumtree, Bullock Creek, Wallanbah (including the Wallanbah void low wall), Broadmeadow (two water bodies separated by backfill material).

3.3.1 Legislative requirements

In accordance with sections 126C (1)(d), (g) and (h) of the EP Act, for each proposed NUMA, the rehabilitation planning part of the PRC plan must:

- state the reasons the applicant considers the area cannot be rehabilitated to a stable condition;
- include copies of reports or other evidence relied on by the applicant for each proposed NUMA;
- state the extent to which the proposed NUMA is consistent with the outcome of consultation with the community in developing the plan; and
- state the extent to which the NUMA is consistent with any strategies or plans for the land of a local government, the State or the Commonwealth.

Pursuant to section 754 (3) of the EP Act and section 6.3.2 of the PRC guideline, a NUMA will be taken to be pre-approved if a land outcome, the same or substantially similar to a NUMA, is contained in a LOD. LODs are defined in section 750 of the EP Act.

Where a NUMA has been pre-approved and is being translated into the PRC plan, the EA holder is not required to:

- justify the proposed NUMA;
- give evidence to support the justification of the NUMA;
- go through the Public Interest Evaluation process; or
- comply with the prohibition of voids located within a flood plain having to be rehabilitated to a stable condition.

However, pursuant to section 754 (4) (b) if the EA or any other LOD does not state sufficient detail to identify the location of the land to which the outcome relates, in this instance the residual void, the proposed PRC plan must state how the EA holder will ensure the location of the land to which the outcome relates minimises risks to the environment.

Table F1 and F3 (Bullock Creek only) of the EA states the final land use of final voids as:

Those not utilised for rejects tailings or pre-strip placement will remain as water storage bodies. Exposed coal seams may be sealed in areas not permanently or seasonally inundated to prevent spontaneous combustion. Its potential use will be dependent on the final water quality.

The *Detailed Mine Closure Plan* (DMCP) outlined the final land use of voids as water storage bodies while also including a description of the location and size of voids at Plumtree, Wallanbah and Broadmeadow (the Bullock Creek void is detailed in the EA). While water storage can be considered a valid PMLU as per Section 3.2 of the PRC plan guideline, the modelled water quality of water stored in residual voids at Burton significantly limits its

potential uses (section 3.6.3.9). The modelled increase in EC excludes the use of void water for irrigation and cattle water supply except in intermittent times of high rainfall input allowing adequate dilution. Void water may continue to be suitable for industrial use, specifically coal processing, while there is active coal mining in the region.

Given the limitations on long term use of final void water the use of final voids as water storage is considered *the same or substantially similar to a NUMA.* In this case the categorisation of the four final void areas as NUMAs is considered consistent with the requirements of section 6.3.2 of the PRC guideline as pre-approved NUMAs.

3.3.2 Description of the NUMAs

3.3.2.1 Plumtree

The NUMA at Plumtree void is inclusive of the pit lake, highwall, end wall, low wall and bunding at the southern end. The northern and central section of the void has been progressively backfilled during mining and will be rehabilitated to a PMLU of grazing with areas of bushland habitat. This has significantly reduced the area of the NUMA of 75.4 ha. The NUMA will be managed in accordance with the criteria outlined in section 3.3.6.

3.3.2.2 Bullock Creek

The NUMA at Bullock Creek void is inclusive of the pit lake, end walls, low wall, highwall and bunding. Given the proximity of surface water infrastructure to the void, including the Bullock Creek diversion, treatment of the low wall and end wall to an alternate PMLU is not considered feasible. The NUMA has a surface area of 28.1 ha and will be managed in accordance with the criteria outlined in section 3.3.6.

3.3.2.3 Wallanbah

The NUMA at Wallanbah void is inclusive of the pit lake, highwall, end wall, low wall and bunding at the northern end. The southern and central section of the void has been progressively backfilled during mining and will be rehabilitated to a PMLU of grazing with areas of bushland habitat. The low wall at the northern end will be stabilised through revegetation to ensure the void is effectively managed. The area of the NUMA is 63.3 ha with the void being 39.1 ha and the low wall 24.2 ha. The NUMA will be managed in accordance with the criteria outlined in section 3.3.6.

The Wallanbah void low wall is part of the Wallanbah void NUMA but has been assigned as a separate 'improvement area' (IA3). This is because the works required for stabilisation are significantly different to the void itself.

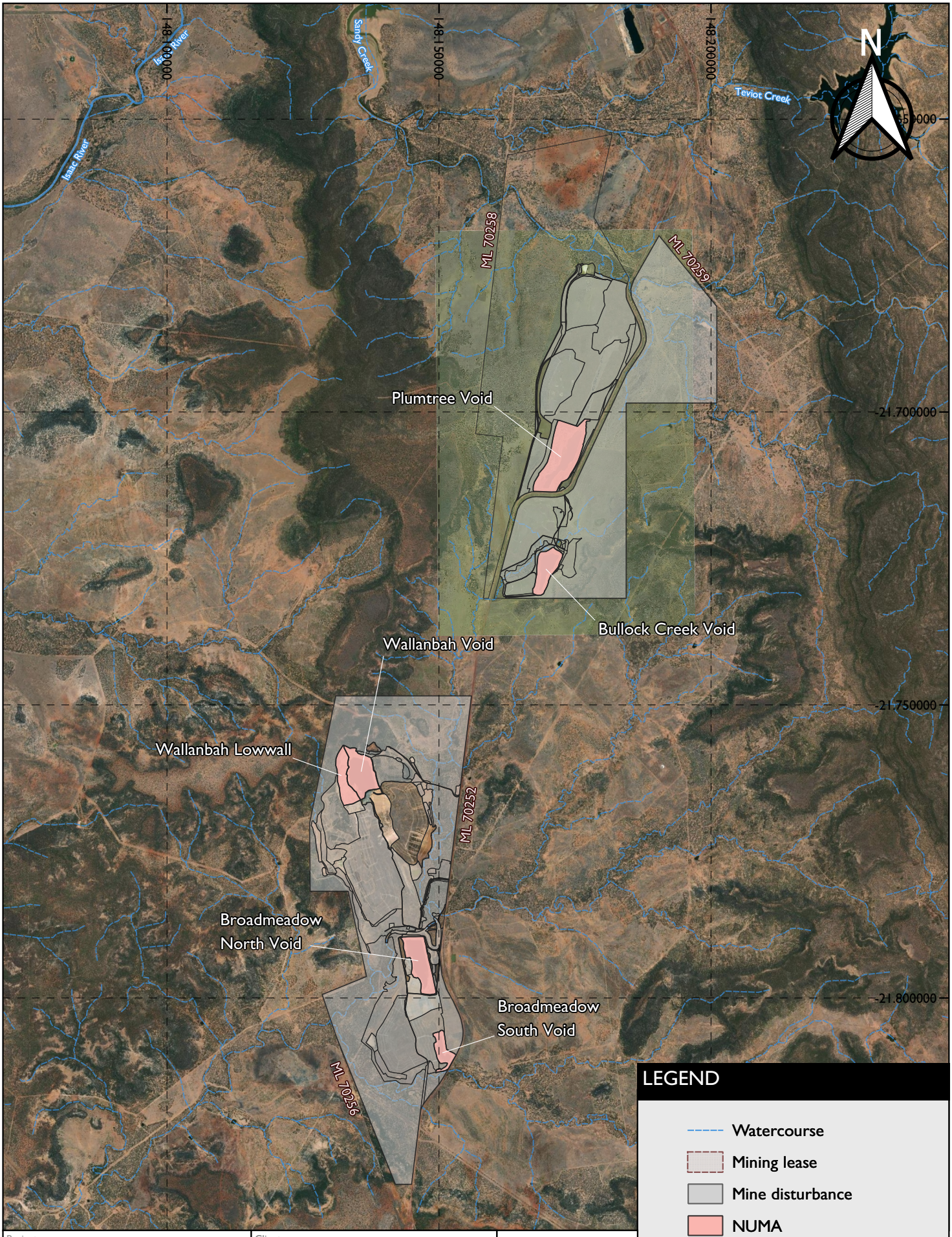
3.3.2.4 Broadmeadow

The NUMA at Broadmeadow void is inclusive of the pit lake, end wall, highwall, low wall and bunding in the northern section and the end wall, highwall, pit lake, bunding and Broadmeadow South levee in the southern section. The central area of the void has been progressively backfilled during mining and will be rehabilitated to a PMLU of grazing with areas of bushland habitat. This has significantly reduced the area of the NUMA to 55.9 ha being 39.2 ha in the north and 16.7 ha in the south. The NUMA will be managed in accordance with the criteria outlined in section 3.3.6.

The Broadmeadow South levee is located in close proximity to the Broadmeadow void end wall to the north and Hat Creek to the south. The levee was constructed to protect the void from potential flood waters and is required to remain for this purpose. The levee also acts as a physical barrier to the void. While the void is partially backfilled, an exposed section of end wall exists adjacent to the levee. Being a pit edge, an abandonment bund (section 3.3.5.1) is required to protect future land users from accidental access as per other areas of the Mine. Given the area available it is not possible to construct the bund. No structures may be built on the pit side due to the nominated geotechnical standoff while the opposite side can be extended no further due to Hat Creek. In this instance the retention of the levee is required for both purposes.

Given the safety risk it is not considered feasible to allow access to grazing animals as per the surrounding land. For this reason, the Broadmeadow south levee has been included in the area of the void which is a designated NUMA.

The location of the NUMAs is given in Figure 12.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 12	Title: Non Use Management Areas	Design: SGM Environmental Pty Ltd 09.06.2022 Scale: 1 : 100,000 CRS: GDA94 / MGA zone 55	SGM environmental

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3.3.3 Consistency with the outcome of community consultation

The outcome of residual voids remaining in the landscape is well known and communicated throughout the Mine's life. Original approvals allowed for residual voids and mine planning and operation progressed on this assumption. Consultation with community members included the retention of final voids. The potential use of the water contained in final voids for cattle supply was raised by neighbouring landholders. It was explained that due to increasing salinity levels the pit water would only meet cattle water guidelines intermittently (during times of high rainfall dilution) with the overall quality deteriorating over time. Landholders accepted this outcome with the option of potentially retaining other surface water infrastructure seen as a mitigating factor. Other community members have not raised concerns with the retention of residual voids.

3.3.4 Consistency with local, State and Commonwealth requirements

3.3.4.1 Local government

The following review of the *Mackay, Isaac and Whitsunday Regional Plan* (DLGP 2012) and the *IRC 2035, our Community Strategic Plan* (IRC 2015) demonstrates that the proposed NUMAs are not inconsistent with the strategies and plan outlined herein.

a Mackay, Isaac and Whitsunday Regional Plan

The *Mackay, Isaac and Whitsunday Regional Plan* (DLGP 2012) includes the following specific policies for PMLUs:

- identified valuable mineral and extractive resource areas within the region are protected from development that might adversely affect current or future extraction;
- the operation of extraction and processing activities does not compromise:
  - human health;
  - current and future resource use opportunities;
  - regional landscape values;
  - ecosystem function and services; and
  - must minimise its impact on primary production.
- once extraction ceases, former resource areas are rehabilitated to facilitate multiple end-uses, ensuring continuing contribution to the economic, community and EVs of the region; and
- innovative practices are encouraged, including local processing and value-adding activities, to maximise eco-efficiencies.

The *Mackay, Isaac and Whitsunday Regional Plan* is consistent with the nomination of NUMAs because:

- the mining voids are remnants of the economic extraction of coal ensuring no potential resource was sterilised;
- void water may be used for coal washing and other industrial activities in the short term which gives an asset and reduces the use of raw water;
- the NUMAs do not have an impact to the surrounding environment outside of their own area;
- the retention of NUMAs does not impact the overall PMLU of grazing with areas of bushland habitat as the area occupied by the NUMAs is minor compared to the overall area available for grazing. This minimises the impact to primary production; and
- retention of NUMAs does not exclude the area from future land uses which may become apparent with advances in technology.

b 2035 Community Strategic Plan

Inevitable social, economic and political changes mean that IRC need to explore new ways of capitalising on opportunities and addressing challenges, to make sure the region reaches its full potential.

The aim of the strategic plan is to give clear goals and direction towards improving the future of the Isaac region through growth in four key themes:

- community — strong and diverse communities that support all to live, work and raise families;
- economy — continue to be Queensland's number one performing regional economy based upon a thriving, resilient and diverse mix of industry sectors;
- infrastructure — effective and sustainable infrastructure that supports the needs of the region's communities and its economic sectors; and
- environment — appropriate and sustainable balance between environment, economy and community to make sure our natural resources are sustainably managed and protected.

The strategic plan is consistent with the retention of NUMAs because:

- the NUMAs are still able to supply void water for the purposes of coal washing and other industrial uses in the short term which gives an asset to support the region's communities and its economic sectors; and
- the use of pit water reduces the use of raw water for industrial processes representing a positive environmental benefit.

3.3.4.2 State and Commonwealth legislation

State and Commonwealth legislation that may be relevant to the NUMAs and region is given in Table 20 including how the legislation relates to the Mine.

Table 20 State and Commonwealth legislation

Legislation	Objective	General application	How it relates to the Mine
Planning Act 2016	The principal objective of this Act is to achieve ecological sustainability.	Where land is included on a ML pursuant to the *Mineral Resources Act 1989*, closure and rehabilitation activities done under an EA do not require a planning approval from the local government.	The NUMAs do not require local government approval.
Local Government Act 2009	The purpose of this Act is to give for the way a Local government is constituted and the nature and extent of its responsibilities and powers. Local	Local laws may apply to the owner of land as defined under the *Mineral Resources Act 1989*.	The *Planning Act 2016* only applies if a built structure that is entered onto the *Queensland Heritage Register* is found. Therefore, the Planning Act does not apply to development in the ML authorised under the *Mineral Resources Act 1989*.

Legislation	Objective	General application	How it relates to the Mine
	laws are made under the Act.		
EP Act 1994	To protect the environment while allowing development that improves the total quality of life and ecologically sustainable development.	General environmental 'duty of care' to be observed to guarantee that any potential environmental impact from the Mine is minimised.	The potential impacts to EVs due to the retention of NUMAs (water storages) were assessed as part of the original EA application. Duty of care is demonstrated for rehabilitation by preparing the PRC plan in accordance with the PRC plan guideline.
State Development and Public Works Organisation Act 1971	To provide state planning and organisational legislation that aids in the delivery of ecologically sustainable development.	Commitments during the EIS phase may impact on closure and rehabilitation of the Mine.	The potential impacts to EVs due to the retention of NUMAs (water storages) were assessed as part of the original EA application. Duty of care is demonstrated for rehabilitation by preparing the PRC plan in accordance with the PRC plan guideline.
Transport Infrastructure Act 1994	The overall objective of the Act is to give a regime that allows for and encourages effective integrated planning and efficient management of a system of transport infrastructure.	Approval from the DTMR is needed under the Act if the Mine interferes with a State Controlled Road.	The Project does not propose any modification to State Controlled Roads. Consequently, approvals for works under s33 of the Act is not needed.
Aboriginal Cultural Heritage Act 2003 which give rise to *Duty of Care Guidelines, 2004*	Provide effective recognition, protection and conservation of Aboriginal cultural heritage.	All practical measures need to be taken to make sure closure activities do not harm Aboriginal cultural heritage, ie demonstrate 'cultural	The ACH Act requires that, when carrying out an activity, all reasonable and practicable measures are taken to make sure that the activity does not harm Aboriginal cultural heritage. This is referred to as the cultural heritage duty of care. The Mine has a cultural heritage management plan (CHMP) with the Barada Barna People to manage the risk of harm to Aboriginal cultural heritage by activities associated with the Mine.

Legislation	Objective	General application	How it relates to the Mine
		heritage duty of care'.	
Land Act 1994	Relates to the administration and management of non-freehold land and deeds of grant in trust and the creation of freehold land, for related purposes.	Regulates the opening and closing of road reserves and land dealings relating to changes in land tenure.	The *Land Act 1994* gives a framework for the allocation of State land as leasehold, freehold or other tenure and provides for its management. The Act further regulates the grant, lease and permitting of Unallocated State Land and reserves and roads. No action is needed to satisfy this Act.
Stock Route Management Act 2002	The main purpose of this Act is to provide for stock route network management.	Regulates the management and use of stock routes.	The Mine does not intersect existing stock routes. Consequently, no agreements to alter stock routes or reserves are needed.
Water Act 2000 (and Water Resource (Fitzroy Basin) Plan, 2011 Fitzroy Basin Resource Operations Plan, 2011)	Provide for the sustainable management of water and other resources and the establishment and operation of water authorities and for other purposes.	Utilisation of groundwater and rehabilitation of bore holes.	No make-good agreements associated with disturbance to water quality, volume or water supply infrastructure are anticipated and therefore do not impact on the proposed retention of NUMAs
Nature Conservation Act 1992	To give a framework for the protection of state listed threatened species	Rehabilitation strategies may need to include any State listed threatened species or communities that occur in the ML.	No threatened or endangered species have been identified on the Mine.

3.3.5 Relevant safety features

3.3.5.1 Bunding

Post-mining, abandonment bunding will be constructed at the Mine with permanent earthfill bunding designs used. Figure 13 below shows the design and dimensions of a standard permanent earthfill bund. The bund has a total width of 14m (toe to toe), a slightly sloped (1% gradient) platform 2m in width and height, and impervious clay or other suitable material situated beneath the centre of the bund.

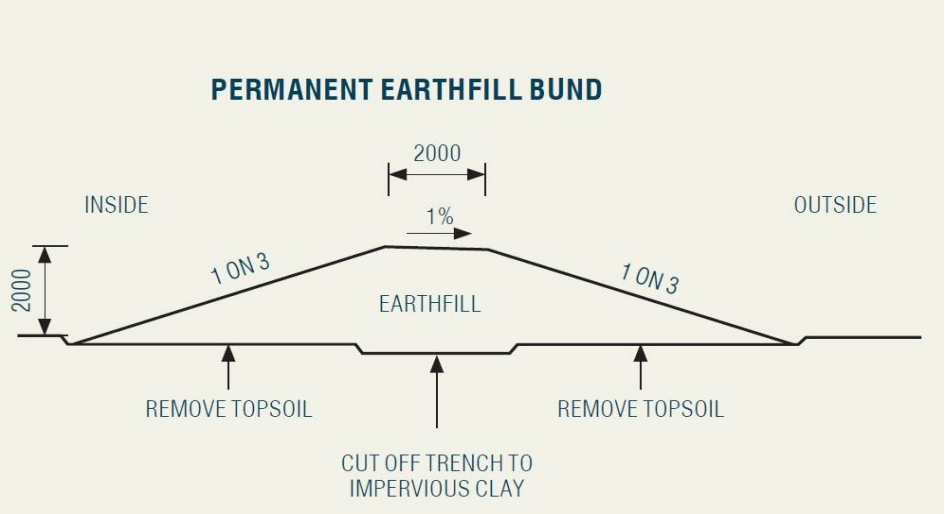


Figure 13 Abandonment bund dimensions

Note that units in Figure 13 *are in centimetres (cm).*

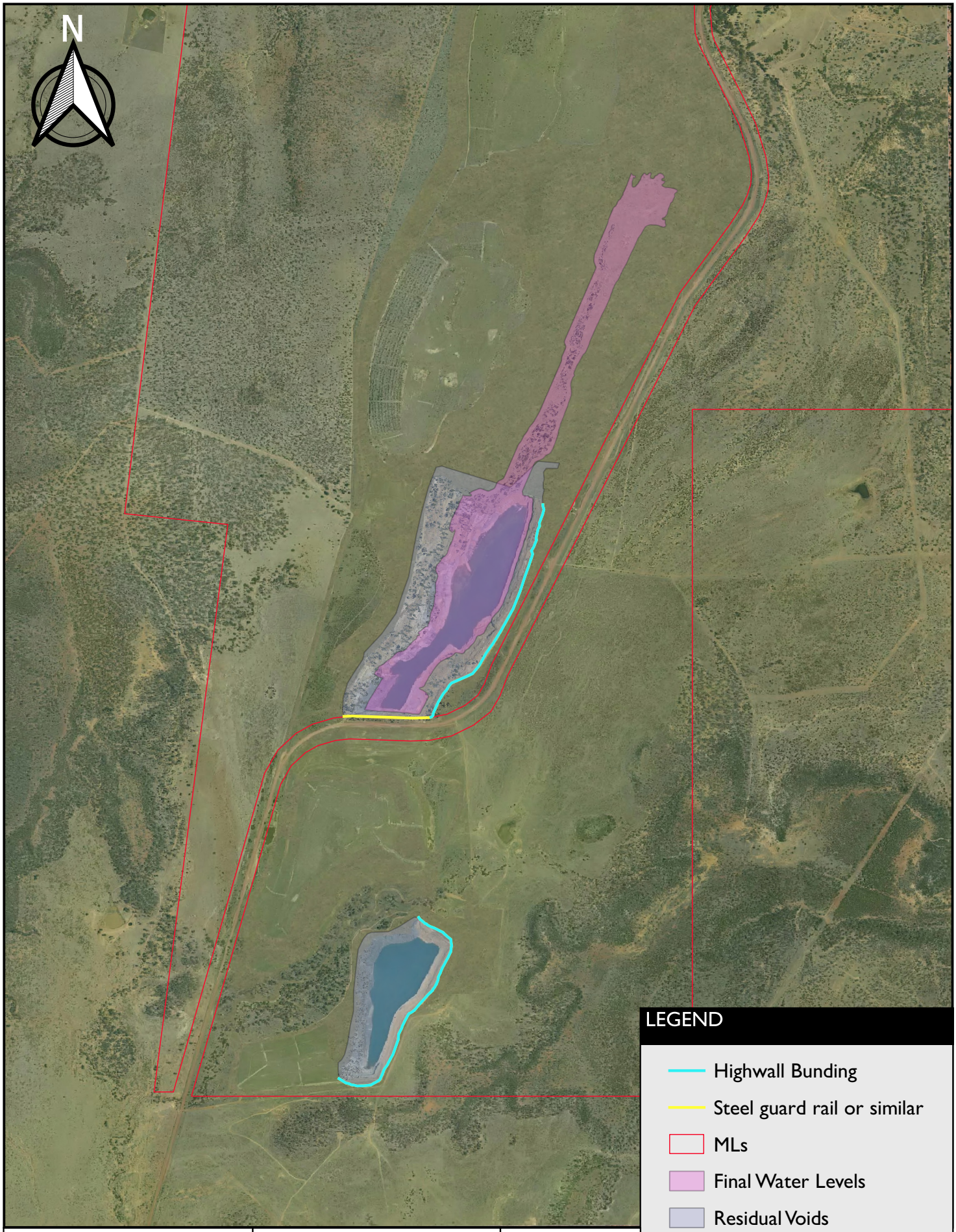
Drainage slots should be cut into the bund and spaced at regular intervals and low points to allow the discharge of surface water during rainfall events. Discharge spillways should be installed following the inflow of water into the pit from diversion drains. The distance between these spillways along the bund should be spaced in regular intervals or based on discharged volumes.

All bunding should be certified by an appropriately qualified person (AQP) to ensure the safety of personnel.

a Plumtree end wall

The area required to build the abandonment bund is not available at the Plumtree end wall due to the pit wall stand off and lease boundary. This short section of wall will be replaced with an alternate means of preventing vehicular access. This is planned to be a permanent infrastructure arrangement ie. steel guard rail.

The location of bunding across the site is shown in Figure 14 and Figure 15.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 14	Title: Abandonment Bund Locations (North)	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 20,000 CRS: GDA94 / MGA zone 55	SGM environmental

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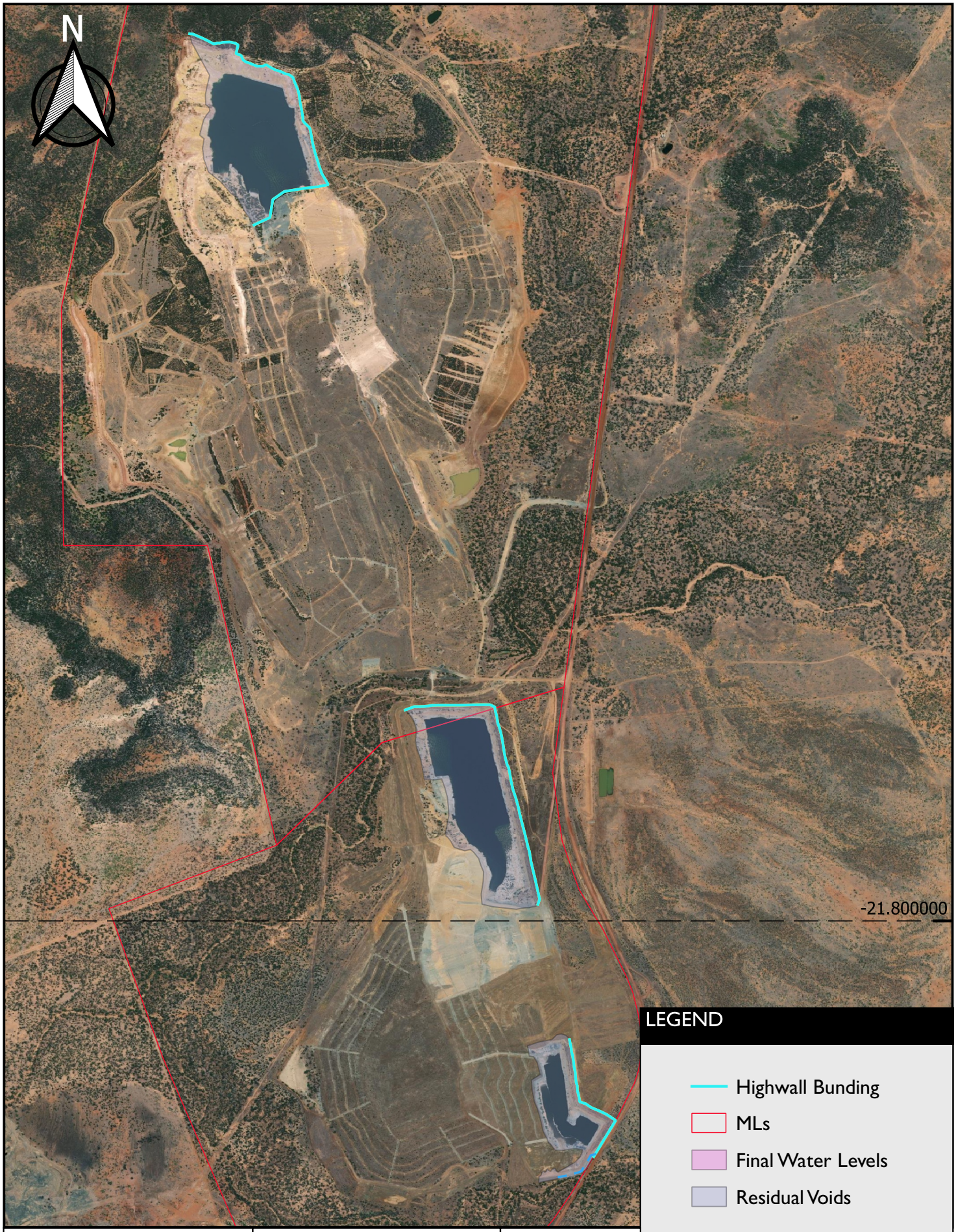

Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 15	Title: Abandonment Bund Locations (South)	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 20,000 CRS: GDA94 / MGA zone 55	SGM environmental

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3.3.5.2 Fencing

Fencing will be a four-strand barbed wire stock fence to restrict unauthorised persons, cattle and other fauna from accessing the final voids. Fencing is installed at a nominated distance offset from the outside of the safety bunding.

3.3.6 NUMA completion criteria

Table 21 gives the milestone criteria to be applied to NUMAs. The final milestone criteria will act as the completion criteria as per the PRC guideline.

Table 21 NUMA milestone criteria

Milestone criteria	Management milestone	Milestone criteria
MM1	Wall treatments	a) walls / slopes assessed as stable by an appropriately qualified person (AQP) (geotechnical engineer) and consistent with EA conditions.
MM2	Achievement of surface requirements / access controls	a) safety bund setback distance is in accordance with calculated geotechnical factor of safety; b) safety bund constructed at 2m high, base width of 14m and 1:3 batters; c) fencing installed at nominated offset from safety bund (nominally a four-strand barbed stock fence); and d) safety signage (design in accordance with Australian Standard) is erected at specified intervals along the fence.
MM3	Achievement of sufficient improvement	a) certification from an appropriately qualified person that the residual void will not cause environmental harm outside of the relevant tenure boundary; b) certification from an appropriately qualified person that the residual void is safe to humans and livestock; c) certification from an appropriately qualified person that the water level and quality in the void will not cause environmental harm to the surrounding environment; and d) regraded slopes with minimum 70% vegetation cover.

3.4 Voids in flood plains

3.4.1 Legislative requirements

Section 3.4 of the PRC plan guideline gives the information requirements for transitional PRC plans relating to voids in flood plains. This section states:

Where a land outcome document has a pre-approved land outcome for a void with a location specified, flood plain modelling is not required. If a void has been identified as a NUMA in a land outcome document but the location is not identified, the applicant is required to carry out flood plain modelling in accordance with this section of the guideline. While the provision in the EP Act relating to voids located within a floodplain having to rehabilitate to a stable condition does not apply, the PRC plan must include how the proposed location of the void minimises risks to the environment. Therefore, the flood plain modelling is required to support the assessment of the proposed location of the void.

The location of the voids has been given in the DMCP which is a LOD meaning flood plain modelling is not required. However, this section also states that flood plain modelling is required to show how the proposed location of the void minimises risk to the environment.

3.4.2 Flood plain modelling

Flood plain modelling was done to assist the design of flood protection levees during the transition to the regulated structures standard conditions. 0.1% AEP as well as probable maximum flood (PMF) modelling was done on Bullock, Spade and Hat Creeks (Appendix C). The results of this modelling were used to design and construct flood protection levees adjacent to the voids at Plumtree south, Bullock Creek, Broadmeadow north and Broadmeadow south.

The structures at Plumtree south, Bullock Creek and Broadmeadow north have been retained with works planned or completed to transition them into final landforms. The PMLU will be grazing with areas of bushland habitat to allow for a productive use and continued protection of voids from flooding. The Broadmeadow south levee will be retained as part of the final void and double as a safety bund to restrict access to the void.

While the locations of the voids are unable to be changed, the retention of flood protection structures minimises the risk to the environment by ensuring flood waters are not captured by voids. The capture of flood waters removes water from creek systems and could potentially alter final void water levels to a point of discharge to the natural environment.

3.5 Community consultation

3.5.1 Community consultation register

To comply with section 126C(1)(c)(iii) of the EP Act Peabody has completed a register to give a record of consultation and engagement outcomes. Community consultation that has been done is given in Table 22.

Table 22 Community consultation register

Consultation date(s)	Community member(s)	Description of consultation type (workshop, quarterly meetings, etc)	Information given to the community	Issues raised / discussed by the community	How the issues have been considered	Decisions / outcomes of engagement	Commitments made by Peabody
23 October 2018	Charles Williams (landholder) Jeanette Williams (landholder) Gillian Naylor (DES) Alison Sinclair (DES) Gemma McMahon (DES) Millicent Bradley Woods (IRC) Justin Vohland (PEA) Quentin Granger (PEA) Jamie Lees (PEA) Matt Lord (PEA) Suzanne Cryle (PEA) Paddy Kearney (PEA)	Workshop at Terowie Village and site visit to Burton Mine the following day	Detailed mine closure plan including timing and land outcomes	Discussion on: Final voids Potential water quality in voids Opportunity to graze cattle on completed rehab Timing of rehabilitation works Charles W asked for Butterfly pea seed to be used in rehabilitation	Indicate final voids will remain but will be fenced and bunded Water quality in voids is expected to deteriorate in the long term (high EC) Once current rehabilitation maintenance program was completed areas would be available for cattle, most likely in Wallanbah for Williams No issues with rehabilitation timeline proposed by Peabody	Continue to engage with updates on rehabilitation progress Move forward with plans to open up Wallanbah rehabilitation for grazing by the Williams	Issue 6-monthly newsletter with site updates on rehabilitation Continue to engage with landholders for cattle grazing opportunities Add butterfly pea to rehabilitation seed mix

Consultation date(s)	Community member(s)	Description of consultation type (workshop, quarterly meetings, etc)	Information given to the community	Issues raised / discussed by the community	How the issues have been considered	Decisions / outcomes of engagement	Commitments made by Peabody
February 2019-June 2019	Greg Smith	Informal discussion in person and via phone	Discussion on cattle grazing trials in Bullock Creek rehabilitation areas	Discussed use of GPS tracking collars for cattle grazing as a trial	Both parties committed to using the collars for a grazing trial	Cattle trials commenced in July 2019 Peabody to supply fencing, water, trough and storage tank	Ongoing water supply to Bullock Creek cattle
June 2019-August 2019	Charles Williams	Informal discussion in person and via phone	Discussion on cattle grazing trials in Wallanbah rehabilitation areas	Discussed use of GPS tracking collars for cattle grazing as used in Bullock Creek grazing trial	Both parties committed to using the collars for a grazing trial	Cattle trials commenced in August 2019	Committed to the supply of collars in exchange for access to data on cattle weights
March 2020-June 2020	Darren Gilliam	Informal discussion in person and via phone	Discussion on potential grazing in Plumtree areas	Darren inspected rehab and was happy to introduce cattle to the area	Both parties committed to the trial	Cattle trials commenced in June 2020	Committed to fencing and water supply for grazing cattle
17 February 2021	Mal Burston Daryn Railey	On site visit	Planned work Discussed recent sale of Wotonga to Mal Burston Potential pumping of water to CMJV including a new pipeline	No issues raised	No issues raised	Remain in contact and discuss future opportunities for grazing	Remain in contact and discuss future opportunities for grazing

Consultation date(s)	Community member(s)	Description of consultation type (workshop, quarterly meetings, etc)	Information given to the community	Issues raised / discussed by the community	How the issues have been considered	Decisions / outcomes of engagement	Commitments made by Peabody
			Positive feedback on rehabilitation with no suggestions for improvements				
19 April 2021	Mal Burston Charles Williams Janette Williams Alan Williams Daryn Railey	On site visit	-Overview of site works Future pumping of water from site to CMJV Discussions on fence boundaries and land ownership between landholders Discussion of possible lease realignment to allow landholders better access to rehabilitated areas	No issues raised Landholders were supportive of Peabody's plan	No issues raised	Remain in contact Discuss future opportunities for grazing	Remain in contact and discuss future opportunities for grazing
19 January 2022	Darren Gilliam	On site visit	Inspection of completed rehabilitation	Potential assistance with water supply Some weed spraying in Plumtree	Agreed to assist with water and weed spraying	Darren happy with current rehab and keen to continue using for grazing his cattle	Investigate water supply Organise weed spraying for Plumtree

Consultation date(s)	Community member(s)	Description of consultation type (workshop, quarterly meetings, etc)	Information given to the community	Issues raised / discussed by the community	How the issues have been considered	Decisions / outcomes of engagement	Commitments made by Peabody
03 February 2022	Brian Flannery and Darren Gilliam	Formal meeting	Presentation on potential mine lease realignments and landowner agreement on final rehabilitation/acceptance	No issues raised	-	Progress realignment as planned – continue to engage with Darren Gilliam	Continue to engage as planning realignment continues

3.5.2 Community engagement plan

The community consultation plan has been prepared in accordance with Section 126C(1)(c)(iv) of the EP Act and includes details of how Peabody has completed and will continue to undertake consultation.

The approach taken is based on locally-accepted standards of leading practice, international and Australian leading practices, particularly methods given in two publications by the *International Council on Mining and Metals — Planning for Integrated Closure Toolkit* (ICMM 2008) and the *ICMM Community Development Toolkit* (ICMM 2006). The specific methods follow those given in the *International Association for Impact Assessment* (IAIA) and the *International Principles for Social Impact Assessment* (Vanclay 2003). These methods have been adopted due to the IAIA's role in developing leading practices in community consultation. The community consultation plan also takes into consideration the *IAP2 Spectrum of Public Participation* (IAP2 Spectrum) (IAP2 2014) which defines five tiers for community consultation. Noting that only three tiers of community consultation will be used by Peabody.

3.5.3 Purpose and objectives

This community consultation plan has been developed to consult and inform community members who have been affected by the closure of the Mine or may be affected by rehabilitation activities. Through the community consultation process, Peabody will achieve the following objectives:

- identify all community members;
- keep identified community members informed of relevant activities and progress at the Mine;
- maintain and develop community relationships;
- identify community concerns about rehabilitation and closure of the Mine;
- consider and address community concerns where possible, as they arise; and
- give timely, accurate and credible information to the identified community members until relinquishment is achieved.

The community consultation plan forms part of the PRC Plan and will be applied by Peabody. The activities will be reviewed regularly to ensure their effectiveness and that the register is kept current.

3.5.4 Community profile

The Mine and other surrounding mines have influenced the local population. Prior to mining, regional residents had secondary school education, with a small proportion of the population being a skilled workforce. That is, 12% of residents had done apprenticeships to obtain trade skills and most of the population was defined as laborers.

70% of the workforce was used by the private sector in local authorities. Agriculture, mining and trade were the major employers in the region.

Since the Mine was developed the regional population has increased due to the expansion of mining including the development of several new mining projects. Noting that the Mine had its own accommodation infrastructure and the direct influence from the workforce on the surrounding towns eg Glenden has been minimal.

Regionally the population skill base has shifted (based on 2016 Census data) to a majority skilled workforce of which about 40% are directly used in mining.

Given the comparative size of the Mine to other mines in the region, the duration of its operations and the fact that many of the Mine employees resided outside of the local community. This community engagement strategy is a combination of targeted community consultation and broader community communication regarding the closure of the Mine and rehabilitation more generally.

3.5.5 Prior community consultation

Peabody and previous proponent and contractor employees have worked closely with neighbours and other key community members during it's the operational life of the mine, including the period of ownership by Peabody. Prior community consultation is given in Table 22.

3.5.6 Community identification and consultation

Potentially affected community members are both internal and external to Peabody. Community members will have varying levels of interest in and influence over the Mine closure and rehabilitation processes. Consequently, different communication approaches continue to be used for each community member (Table 23).

Community members include the Federal, State and Local Government; private landholders, Native Title party, community groups and non-government organisations, suppliers, internal community members and employees. The methods and level of engagement will vary for each of these groups. Over time the level of engagement of a community member may also vary. These concepts are demonstrated in the following sections, including categorising community members into different tiers of engagement.

Table 23 Community member interest levels and communication media

Tier	Level of Influence	Communication method
1 — Inform	Low	media articles.
2 — Consult	Medium	Newsletters, media articles
3 — Collaborate	High	Face to face meetings/dialogue, internal workshops, supplementary email updates / broadcasts.

3.5.7 Inform

The first tier of community members is those who should be 'informed'. These community members are typically local individuals or groups with a broader and more general interest in the future of the Mine. These community members only want to know 'what is going on' and newsletters and updates are suitable communications media. Peabody needs to give objective and balanced information to assist these community members to understand what is planned and the progress being made with these plans.

3.5.8 Consult

The second tier of community members is those who should be 'consulted'. They will have a direct interest and will want to both be informed and to give feedback. This tier includes selected internal business units, neighbouring operators and most Government stakeholders (excluding key regulators). Meetings will be held with these community members so that concerns and issues can be teased out and practical solutions or actions identified. Targeted supplementary email updates/broadcasts might also be utilised.

3.5.9 Collaborate

The third tier is those community members who need to be 'engaged' and who have the potential to be directly impacted. This tier is those who have a direct and influential role in Local Government, key State Government agencies, Members of Parliament, cultural heritage groups, adjacent land holders and selected internal business units. The best method of engagement for this tier is regular, face to face meetings enabling candid discussions to occur. With some internal business units, meetings or workshops could be followed by regular targeted supplementary internal email updates / broadcasts.

3.5.10 Identified community members

An initial listing of all potential internal and external community members has been compiled following consultation with a wide range of internal company representatives. These community members and their suggested tier of engagement are given in Table 24.

Table 24 Community members and tiers of engagement

Key community members	Tier of engagement
Internal	
Senior management	
St Louis	Collaborate
Vice President Technical Services	Collaborate
Director Safety, Health and Environment	
Key business units	
Human resources	Collaborate
Communications/Community relations	Collaborate
Corporate sustainable development team	
Commercial	
Other business units	
Site team	Collaborate
External stakeholders	
Federal Member	Inform
State Members	Consult
Mayor	Consult
Councillors	Inform
Government agencies (regulators)	Collaborate
Neighbours	Collaborate
Media	Inform
Investors	Inform
Queensland Resource Council	Inform
Service givers	Inform
New Hope Group	Inform
Barada Barna Traditional Owners	Collaborate

3.5.11 Information provision and resource requirements

The community consultation plan ensures Peabody gives clear, concise and credible information to identified community members at appropriate intervals suited to each group and / or individual. The plan identifies the key personnel who are required to give input into the preparation and or delivery of communication materials into the community consultation plan.

3.5.12 Proposed consultation frequency

Consultation should occur prior to any PRC plan schedule amendments that are likely to impact the community and the register should be updated when this consultation is finished.

Ongoing community consultation will continue throughout the stages of progressive rehabilitation so that the socio-economic and environmental impacts related to mine closure can be discussed with the community. Consultation frequency should be annually at a minimum or as issues or opportunities arise.

3.5.13 How feedback/comments will be considered

All engagement activities with external, ie non-Peabody, community members are to be recorded using Consultation Manager. The following minimum information needs to be recorded:

- invitations, attendance lists and minutes for site inspections;
- invitations, attendance lists and minutes for meetings;
- summaries of informal community interactions, eg with neighbours;
- copies of email updates, eg broadcasts;
- records of discussions (for opportunistic or planned face to face dialogue); and
- copies of any media statements.

Once feedback / comments have been received and logged, Peabody will make an initial assessment to identity classify and / or investigate the root cause and identify any actions needed to address it. Post-workshop updates and newsletters to be distributed to the appropriate community groups when required.

3.5.14 Review and revise

The community engagement plan and register of community engagement activities should be reviewed regularly and revised as required.

3.6 Rehabilitation management methodology

3.6.1 General rehabilitation practices

3.6.1.1 Hydrogeology

Groundwater is largely confined to the coal seams acting as aquifers. Groundwater is generally saline and often highly saline and therefore makes groundwater usage in the district limited. A program of groundwater sampling and analysis was completed at the Mine prior to mining starting in 1996 to determine background water qualities. Sampling was done from four monitoring bores located within the Permian coal measure sequences. The results indicated that groundwater had the following characteristics:

- pH was neutral to alkaline;
- slightly to moderately saline, with higher salinities generally being encountered near the coal beds;
- groundwater samples collected near the coal beds generally did not meet the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC) stock water guidelines for TSS (ANZECC 2000)
- major ion analysis indicated Na and Cl as the dominant ions;
- samples from several bores returned Ca and Mg concentrations exceeding the ANZECC (2000) guidelines for stock water.
- metal concentrations were generally below or close to laboratory detection limits including Cd, U, As, Se, Hg, Ni, Pd and Zn.

The potential impacts on groundwater quality from mining activities include leachate to the groundwater containing dissolved salts and high or low pH from areas such as:

- pits containing water;
- spoil storage areas and stockpiles; and
- decant dams.

There is also potential for affecting the groundwater level as a result of pit dewatering operations.

A groundwater monitoring program for the operational phase of the mine has been developed. Recent amendments to the EA include the addition of groundwater locations relevant for post-mining and rehabilitation. Groundwater monitoring will continue during and post-rehabilitation until bores are closed and rehabilitated or until relinquishment.

3.6.1.2 Flooding

Flood plain modelling was done to assist the design of flood protection levees during the transition to the regulated structures standard conditions. 0.1% AEP as well as PMF modelling was done on Bullock, Spade and Hat Creeks (Appendix D). The results were used to design and construct flood protection levees adjacent to the voids at Plumtree south, Bullock Creek, Broadmeadow north and Broadmeadow south. These structures will be retained for ongoing flood protection.

Given the proximity of the voids to creek systems, the greatest risk is of flood waters entering voids. The Mine does not have vulnerable infrastructure which may be affected by flooding. No high-risk structures (tailings, hostile spoil emplacements etc.) are at the Mine which may be impacted by flood waters. Personnel are no longer routinely present in voids. Grazing cattle may be at risk during flood events if grazing is happening in partially backfilled voids; however, the size of the storm event to cause void inundation would likely result in many areas of surrounding land also being inundated.

While all flood protection levees are built to a minimum of a 0.1% AEP, some have been constructed to a PMF flood levels plus freeboard. While these structures are in place the risk of flooding is greatly reduced. The retention of flood protection structures minimises the risk to the environment by ensuring flood waters are not captured by voids. The capture of flood waters removes water from creek systems and could potentially alter final void water levels to a point of discharge to the receiving environment.

3.6.1.3 Soil and capping material assessment

A soil assessment was done in 2020 by SGME and is given in (Appendix E). The assessment involved the sampling and analysis of existing topsoil stockpiles proposed for use in rehabilitation. A summary of this assessment and other information relevant to soil and capping is given in the following sections.

a Quantity

The quantity of available topsoil and the volume needed for rehabilitation of the Mine is given in Table 25.

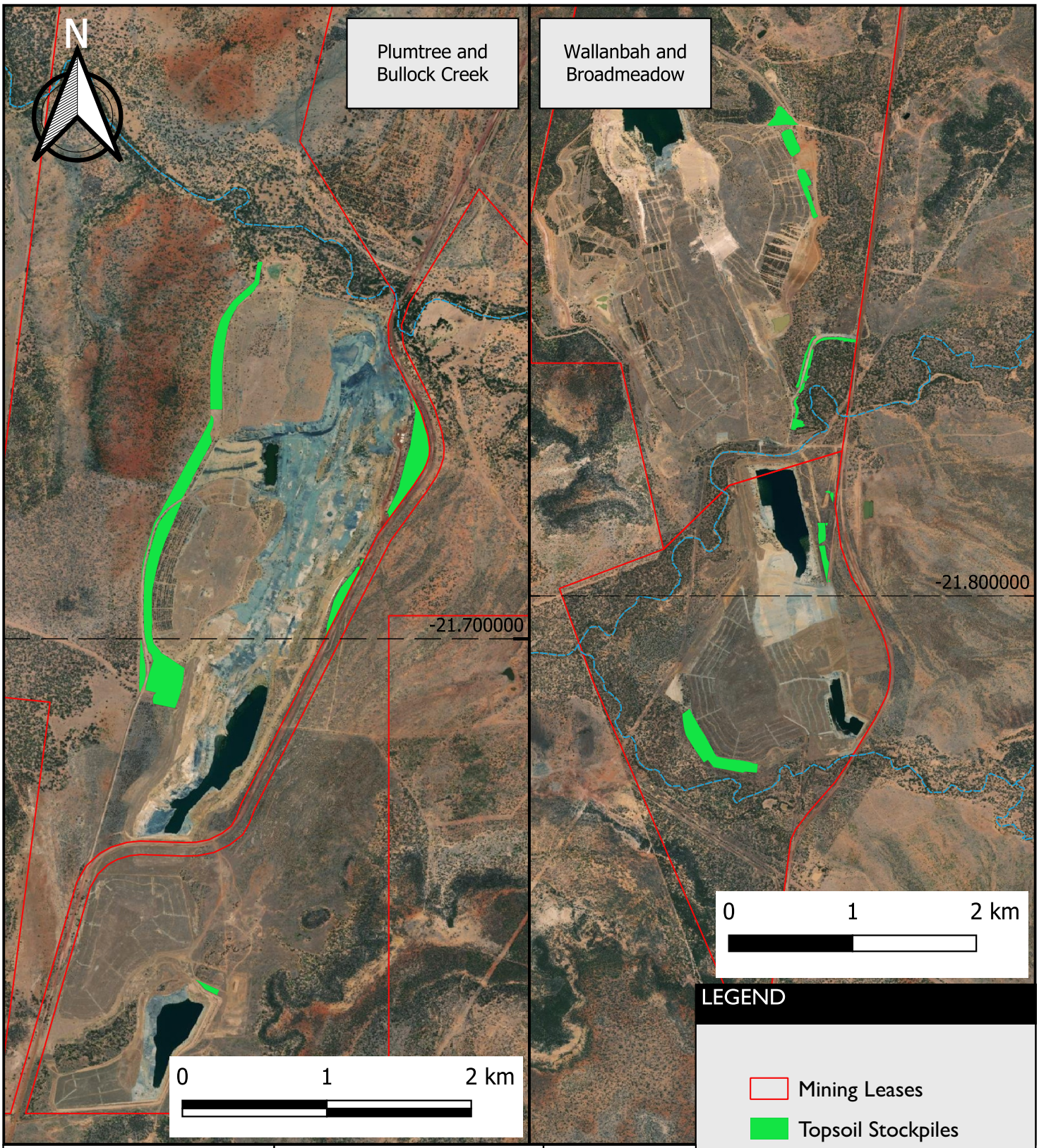
Table 25 Topsoil quantities

Location	Total volume available (m^3)	Volume required (cubic metres — m^3)
Plumtree	384,882	371,313
Bullock Creek	28,464	42,525
Wallanbah	163,024	159,800
Broadmeadow	148,470	146,263

Location	Total volume available (m^3)	Volume required (cubic metres — m^3)
Total	**724,840**	**719,901**

b Location

The location of topsoil stockpiles is given in Figure 16.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 16	Title: Topsoil Stockpiles	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 30,000 (left) 1 : 35,000 (right) CRS: GDA94 / MGA zone 55	SGM environmental

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c Quality

Fertility

Strong alkalinity, exchangeable cation imbalances, low N, P, total organic carbon (TOC) and cation exchange capacity (CEC) are the main restrictions to plant growth. Overall stockpiled soils exhibit low soil fertility.

- pH ranges from neutral to strongly alkaline;
- root exchangeable cations (ECe) is generally low indicating that majority of stockpiled soil is non-saline;
- water-soluble chloride is generally low;
- Total N is low indicating low reserves of N which may restrict plant growth;
- P (Colwell) is low in 89% of stockpiles. P deficiency may therefore restrict growth of some plant species (noting that most native plants are adapted to soils with low P concentrations);
- TOC is low across the majority of samples which can indicate poor structural condition, nutrient and moisture retention;
- exchangeable Ca is sufficient in 49% of stockpiles while exchangeable K is within the sufficiency range for 46%. Exchangeable cation imbalances may restrict plant growth;
- 81% of stockpiles have an exchangeable Mg percentage higher than the sufficiency range; all other soil samples are sufficient;
- 43% of soil samples have a CEC lower than the sufficiency range indicating a limited capacity to store nutrients. Soils with a low CEC are susceptible to leaching, leading to deficiencies in K and Mg; and
- Diethylenetriaminepentaacetic acid (DTPA) extractable Zn was low across majority of soil samples. Low concentrations are associated with soils with a high pH. DTPA extractable Cu was low across some soil samples (24% of soil samples). DTPA extractable Mn was largely sufficient. Micronutrients are unlikely to restrict plant growth.

Fertiliser may be required to ameliorate low macronutrients (N and P) in the soil prior to or during rehabilitation. Fertiliser is used to give a readily available source of nutrients to supplement fertility, maximise the growth of seeded areas and establish plants on rehabilitated land.

Erosion and dispersion potential

The structural stability of soil is heavily influenced by a combination of EC and exchangeable sodium percentage (ESP). Soil is considered sodic when the ESP is greater than 6 and highly sodic when the ESP is greater than 15. One stockpile in the Plumtree area is considered sodic while stockpiles in the Wallanbah and Broadmeadow areas are generally sodic or highly sodic.

Soils previously used in rehabilitation are also sodic or highly sodic. Despite this, existing rehabilitation is largely stable and displays adequate levels of vegetation cover.

If a soil is sodic, it is vulnerable to dispersion and structural instability. Dispersed soils have reduced infiltration and hydraulic conductivity leading to an increased potential for erosion and build-up of salts in the root zone. Dispersion declines as the EC of the soil solution increases.

Australian soils with an ESI less than 0.05 are potentially dispersive. 73% of stockpiles have an ESI less than 0.05 indicating they are potentially dispersive and have low structural stability. It is important to note that rainwater may leach salts from the soil over time, leading to a further increase in dispersion potential. All soil identified within spoil stockpiles have an ESI less than 0.05.

The Emerson aggregate test measures the instability of the soil structure when immersed in water. This test was used to predict the dispersive behaviour of the stockpiled soils. Emerson aggregate classes are consistent with the ESI results. Soil dispersion and loss of soil structure can cause poor water infiltration, water holding capacity, oxygen supply to roots and nutrient use efficiency.

Appropriate amelioration should be used to limit the dispersion potential of soil (ie minimising overhandling and gypsum application). Gypsum may be applied to decrease ESP, reduce dispersion and increase stability.

d Amelioration

The results of the soil assessment show the requirement for the addition of fertiliser to ameliorate low macronutrients (N and P) in the soil. Fertiliser application is currently used during rehabilitation.

Appropriate amelioration may be used to limit the dispersion potential of soil (ie minimising overhandling and gypsum application). Gypsum may be applied to decrease ESP, reduce dispersion and increase stability. Amelioration will be considered for rehabilitation around Wallanbah and other areas at risk of excessive erosion or dispersion.

e Soil application

Soil will be applied to landforms once they are re-contoured and any compacted zones (infrastructure and other hardstand areas) have been deep ripped. The soil application procedure has been designed to minimise any degradation of soil properties, aligning with industry leading practice.

Generally, soil will be applied with a minimum thickness of 0.2 m to give enough depth for ripping and vegetation growth.

The following measures are proposed to minimise the loss of soil during respreading and promote successful vegetation:

- a soil management strategy will be prepared before soil is spread, which confirms the depths and volume of soils to be reapplied to each feature;
- features will be re-contoured before any soil is spread;
- soil will be spread in even layers 0.2m across the feature;
- soils will be lightly scarified on the contour to encourage rainfall infiltration and minimise runoff.
- pasture will be seeded as soon as practicable after respreading; and
- erosion and sediment controls will be used where necessary before establishing vegetation.

f Erosion and sediment control

During operation of the Mine, erosion and sediment control plans have been developed following Peabody's *Erosion and Sediment Control Guideline*. General principles for erosion and sediment control have drawn from the International Erosion Control Association's (IECA) *Best Practice Erosion and Sediment* Control (IECA 2008). Erosion and sediment control at the Mine follow the hierarchy of control outlined below:

- prevent and minimise disturbance and progressively rehabilitate disturbed land to reduce the catchment size of any surface water catchment;
- surface water from rehabilitated land can drain off the MLs so long as it does not cause any erosion, through installation of erosion protection as per the erosion and sediment control procedure; and
- any surface water catchments that discharge sediment are directed through an erosion and sediment control structure, such as sediment basins to remove sediment loading.

The erosion and sediment control plan will be adapted for the post operational monitoring phase of the Mine to ensure they remain applicable to the rehabilitated landforms.

g Relationship between soil and vegetation ecosystems

Reference sites (often illustrating pre-mining conditions) give useful comparisons to determine the composition, structure and function of the desired rehabilitation outcome. Noting that reference sites should be used for guidance and not as firm targets.

Rehabilitated areas are trending towards composition, structure and function of reference sites for pasture and bushland based on completed rehabilitation monitoring.

h Stockpiled rock

There is one current rock stockpile at the Mine situated in the Wallanbah area. This rock has been stockpiled for future drainage works in Wallanbah and is ~ 2,300 m^3 in volume. If further rock is required it will be recovered during dozer pushing operations.

3.6.1.4 Waste characterisation

The following sections give a summary of the *Spoil Characterisation Assessment* report prepared by SGME in 2020 (Appendix F). The assessment aimed to determine:

- volumes of out-of-pit spoil;
- justification that the characterisation has been done to a high level of confidence;
- chemical and physical properties of the spoil under stored conditions including:
  - classification of spoil based on the potential for acid mine drainage (AMD), neutral mine drainage
  - (NMD) and / or saline drainage (SD);
  - elemental composition and future speciation and mobility; and
  - fertility;
- assessment of the suitability as a growth medium beneath the topsoil (cover); and
- management recommendations.

a Sampling regime

The International Network for Acid Prevention (INAP) *Global Acid Rock Drainage (GARD) Guide* (2014) does not contain clear guidance on sampling densities for out-of-pit spoil dump characterisation. Within Australia, the *Preventing Acid and Metalliferous Drainage: Leading Practice Sustainable Development Program for the Mining Industry* (2016) also does not give clear guidance on sampling densities for out-of-pit spoil dump characterisation. The Department of Mines and Energy (DME) 1995 guideline *Assessment and Management of Acid Drainag*e, describes sampling density based on volume of spoil. Notwithstanding, sampling density was selected based on the *Guidelines for Surveying Soil and Land Resources* (McKenzie et al. 2008) for field level and detailed project planning (ie one sample per 5-25 hectares (ha) or 4-20 samples per square kilometre (km^2) of spoil). The sampling density is spatially representative of the spoil stockpiles because sampling was done at a rate of one sample per 9 ha.

Sampling of coal waste was not necessary given the Mine is no longer in production and does not store coarse or fine coal rejects.

b Mine waste streams

Mine waste streams are restricted to spoil emplacements as the Mine is no longer operational and stores no coarse or fine coal rejects. Spoil waste was assessed for Geochemical characterisation suggests that spoil at the Mine is largely acid neutralising. Plumtree 14 had a net acid generation (NAG)pH less than 4.5. However, this is likely a result of the organic acids dissolved in the NAG procedure and are not going to contribute to AMD.

Spoil with an acid neutralising capacity to maximum potential acidity (ANC/MPA) mass ratio greater than two is considered to have a negligible to low risk of acid generation and a high factor of safety in terms of potential for AMD. All samples have an ANC/MPA ratio greater than two except for Wallanbah 34, 40 and 52. These samples have a reactive S of less than 0.1% and can therefore be considered barren. Barren spoil has almost no capacity to generate acidity even in the absence of significant ANC. Further, any acidity generated would quickly be neutralised by the ANC of the surrounding spoil.

Net acidity is negative for all samples, except Wallanbah 40 and 52, indicating sufficient ANC to neutralise any acid released. Actual and retained acidity are low for all samples indicating minimal past oxidation.

Water-soluble metal and metalloid concentrations are low for the majority of samples. Al, Ba, Fe and Mn were elevated in some samples. It is expected that further dilution effects from rainfall and natural attenuation would occur prior to any spoil drainage arriving at a receptor. Seepage from the spoil is therefore likely to contain very low concentrations of metals and metalloids.

Most samples are expected to have low salinity based on the DME (1995) soil salinity classification. It is unlikely that surface runoff and seepage from the spoil will be saline. Accordingly, water-soluble sulfate (SO_4) is low.

Strong alkalinity may be a restriction to plant growth; however, vegetation and groundcover did not appear to be limited / restricted at any of the test pit locations.

Actual acidity is low across all samples (less than 0.06%). pH (potassium chloride (KCl)) is greater than 4.5, indicating that any retained acidity present is very low.

The 2020 assessment suggests that spoil is largely acid neutralising. Spoil has a low chromium reducible sulfur (CRS), EC and negligible soluble metal profile indicating that it is barren. Notwithstanding, spoil salinity ranged from very low to medium. Therefore, there is a negligible chance of AMD / NMD or SD developing from the spoil. Based on this assessment, spoil is considered suitable for use in the construction of the final landform and as a growth medium beneath a topsoil layer (cover).

c Waste volumes

The calculated volume of mine waste spoil stored at the Mine is given in Table 26.

Table 26 Spoil volumes

Project area	Volume (bank cubic metres (BCM))
Plumtree	39,164,040
Bullock Creek	9,308,031
Wallanbah	33,000,000
Broadmeadow	23,400,237
Total	**104,872,308**

d Management and mitigation

Based on the 2020 assessment results there were no AMD / NMD or SD issues observed. Further, progressive rehabilitation at the Mine has been successful. Therefore, no actions or changes were recommended for the rehabilitation strategy.

3.6.1.5 Landform design

The final landform design is a key component of rehabilitation and closure planning. This section describes how land will be rehabilitated to a safe and structurally stable condition that supports the PMLU.

a Three-dimensional design plans

Three-dimensional design plans were produced by Minserve for the community consultation process. The plans are given in Figure 17–Figure 21.



Figure 17 Plumtree final landform design plan

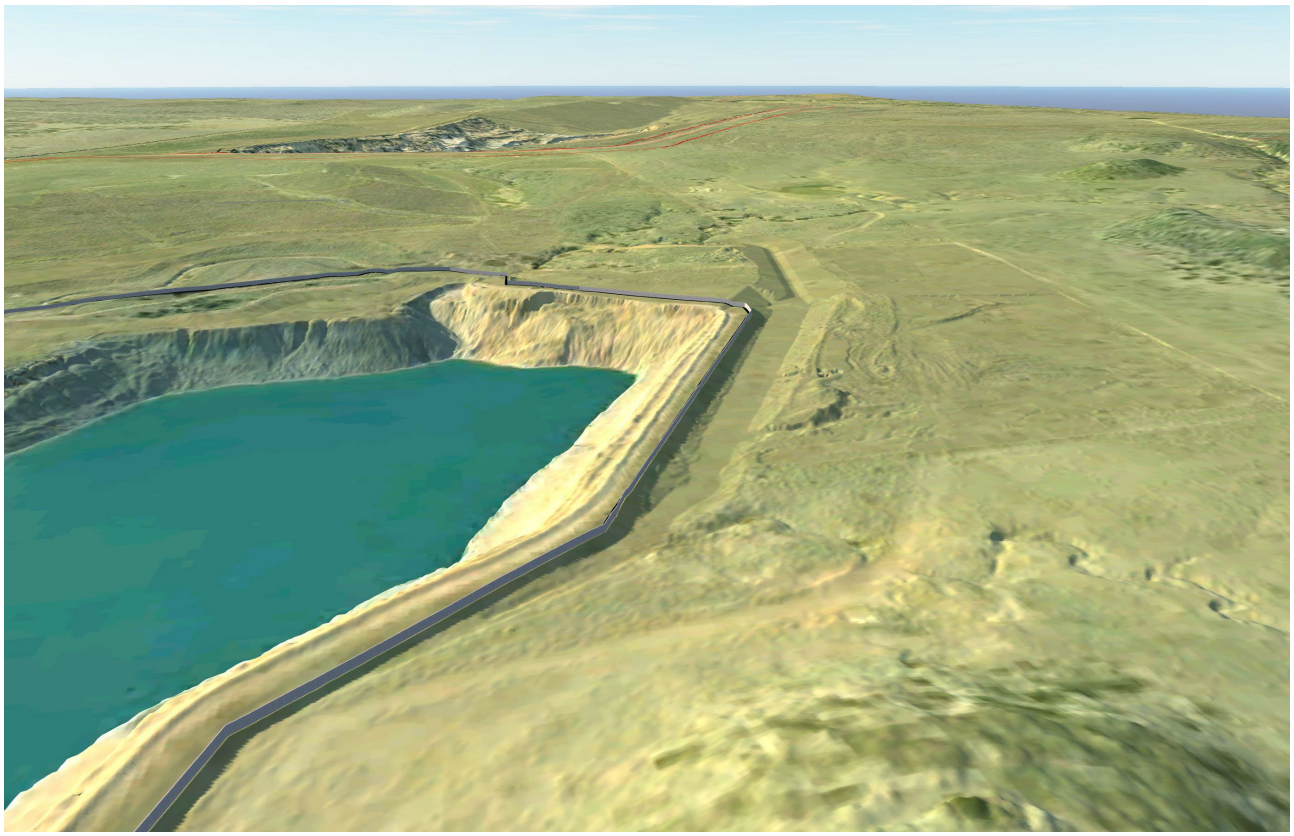


Figure 18 Bullock Creek final landform design plan (low wall and completed highwall drain)

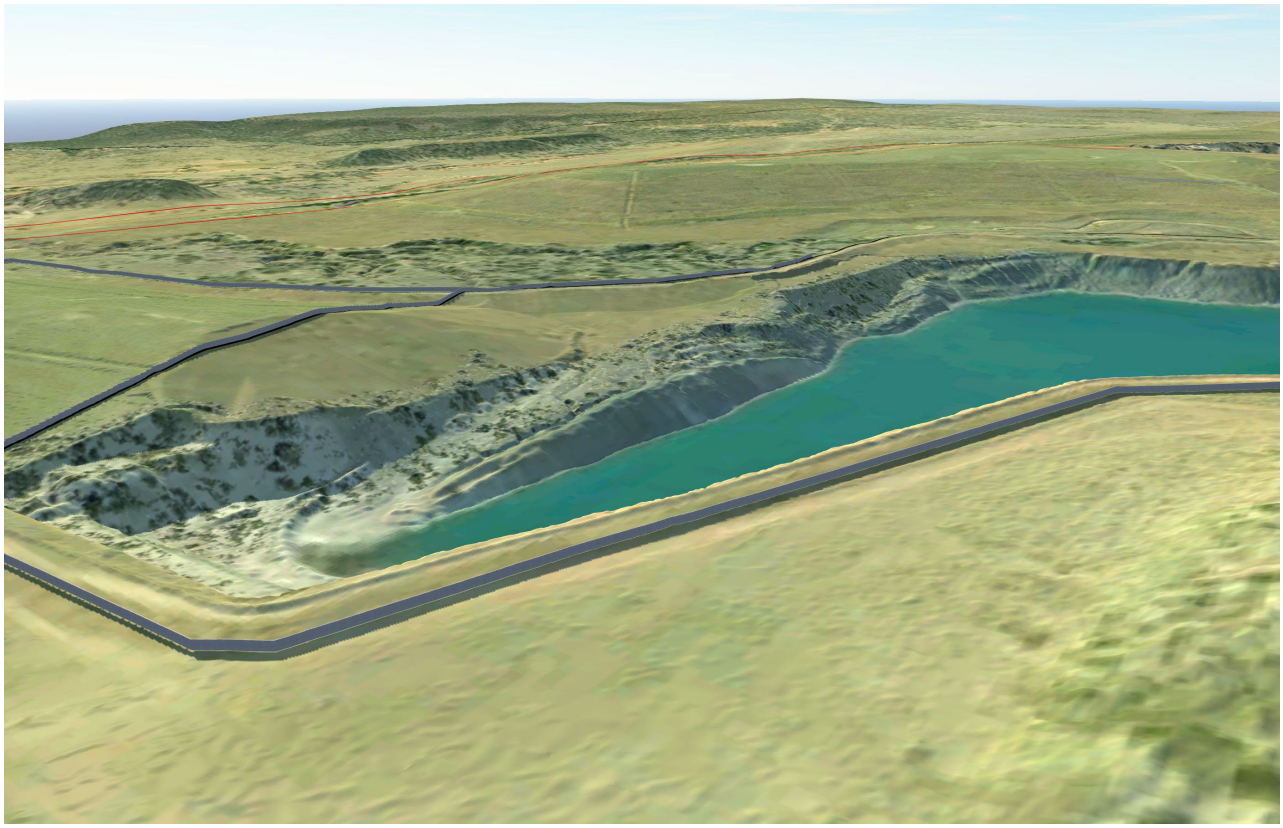


Figure 19 Bullock Creek final landform design plan (southern highwall and in-pit dump)

1. Note the bund located across the in-pit dump is no longer planned

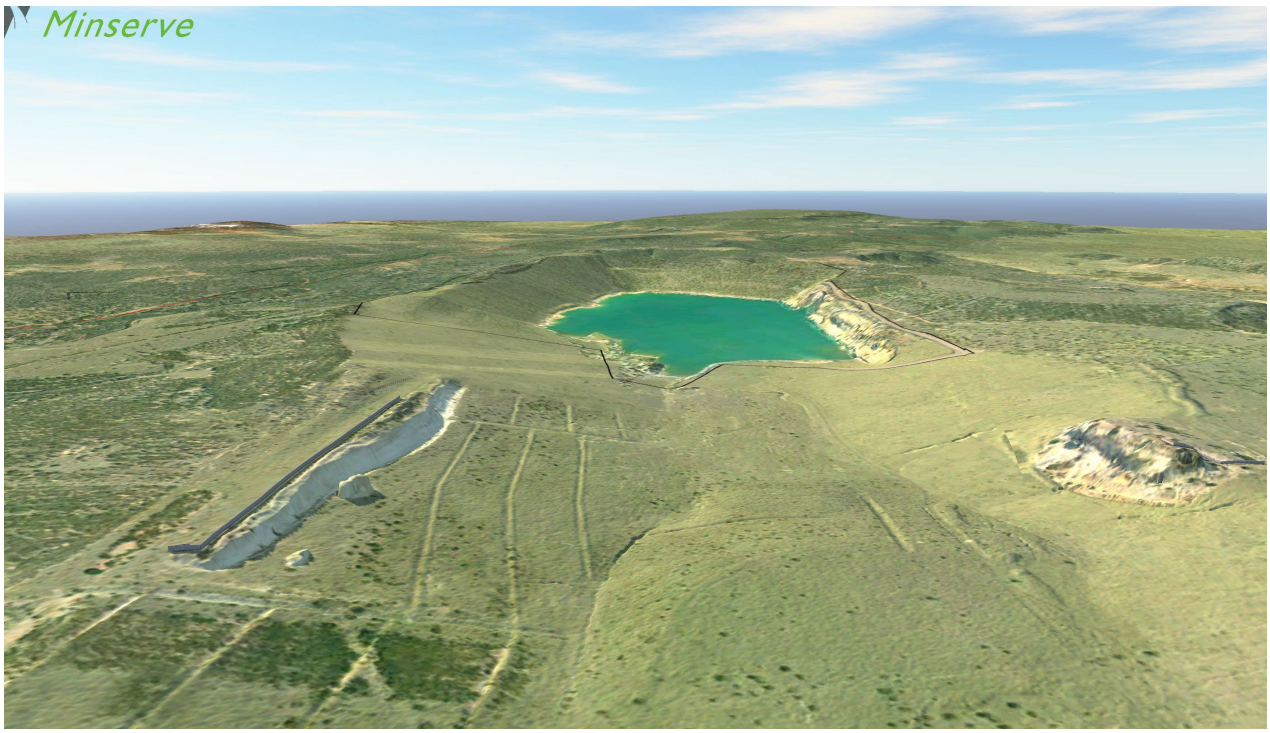


Figure 20 Wallanbah final landform design plan (in-pit dump and revegetated low wall)

1. Note the end wall is no longer planned to be reshaped



Figure 21 Broadmeadow final landform design plan (in-pit rehabilitation and completed Spade Creek diversion works)

b Method for determining final landform design

Final landform design, particularly for out of pit dumps, has traditionally been based on the requirements of the EA. Following the end of production, a detailed assessment of rehabilitation options for the remaining areas of disturbance was conducted by site personnel and Minserve. This assessment is given in section 3.6.3.1.

c Long-term stability

The objective of final landform design is to achieve long-term stability. To demonstrate that the final landform design can achieve long-term stability, Water Erosion Prediction Program (WEPP) and landform evolution modelling (LEM) (SIBERIA) was done (Appendix G).

Bulk samples of topsoil and spoil were taken. The erodibility parameters of the materials for the WEPP model were determined using measurements of runoff, erosion and sediment properties from rainfall simulator plots. WEPP simulations based on site landforms were run for a 100-year climate file prepared to simulate climate at Burton, with daily outputs of runoff and erosion. SIBERIA parameters were then derived from the WEPP time series data. Simulations were run on bare soil and 60% grass cover.

Landloch (2013) have given that rehabilitated mine slopes have a low tendency to rill with an average erosion rate of <5 t/ha/yr. Avoiding rill formation will ensure landform stability and reduce the likelihood of excessive erosion. The elimination of rilling will also reduce the potential of channelised flow, which can result in gully erosion. Therefore, an average erosion rate of <5 t/ha/yr is considered acceptable for long term stability.

The results for each project area are given below.

Plumtree

With 60% vegetation cover, the internal batters showed acceptable levels of erosion after 300 years with an average soil loss of approximately 50-60 mm which is equivalent to a loss of ~2.5 t/ha/yr. The western batter had an average erosion rate of ~1.4 t/ha/yr with 60% cover.

Bullock Creek

With 60% vegetation cover, the southern batter showed acceptable levels of erosion after 300 years with an average soil loss of approximately 20 mm which is equivalent to a loss of < 1 t/ha/yr. The out of pit dump to the north of the pit had an average erosion rate of ~1.44 t/ha/yr with 60% cover.

Wallanbah

With 60% vegetation cover, the internal batter of the eastern dump showed acceptable levels of erosion after 300 years with an average soil loss of ~2.5 t/ha/yr. The western batter had an average erosion rate of ~1.4 t/ha/yr with 60% cover. The western batters had an average erosion rate of ~1 t/ha/yr with 60% cover.

Tertiary material in the eastern dump required 70% vegetation cover to achieve an acceptable level of erosion after 300 years with an average soil loss of ~4 t/ha/yr. This slope drains to a void so overall the erosion rate is considered acceptable given the 70% vegetation cover can be achieved.

Broadmeadow

With 60% vegetation cover, the internal face of the western dump showed acceptable levels of predicted erosion after 300 years with an average soil loss of approximately 60 mm which is equivalent to a loss of ~2.6 t/ha/yr on the eastern batter. The western (external) batter had a predicted erosion rate of ~2.8 t/ha/yr with 60% cover.

d Quality assurance / quality control requirements

Key risks associated with final landform construction include a failure to follow the design, construction materials not conforming to specifications, poor or inadequate construction quality and the failure of quality assurance and quality control (QA/QC) to identify construction inadequacies. Final landform construction management, technical supervision and QA/QC will be done by an AQP who can make sure that construction is done in accordance with the design plan. GPS machine guidance will assist during landform construction and reshaping while LiDAR, aerial or on-ground surveys will be used to periodically monitor construction against design. Construction quality will be managed through effective mine planning and field supervision during construction.

A QA/QC document will be prepared by an AQP to verify final landform design has been done in accordance with the design plan and is stable.

e Methodology to verify the predicted success

The LEM has shown that slopes will achieve an acceptable erosion rate when groundcover reaches 60-70%. Measures to ensure stability of placed topsoil during vegetation establishment are given in section 3.6.1.8 and include:

- deep ripping of surface material prior to topsoiling to reduce compaction, encourage water infiltration and give surface roughness for better adhesion of topsoil to the contoured surface;
- scarifying placed topsoil along the contour to reduce compaction, encourage water infiltration, create rills to slow water flow downslope and create furrows and depressions for water collection to enhance seed germination;
- appropriate scheduling of topsoil / seeding to ensure sufficient subsoil moisture levels and favourable weather conditions for germination; and
- selected cover crop species in seed mixes to give fast vegetation cover for erosion protection.

f Limitations and assumptions of the final landform design

The final landform design has the following limitations:

- the accuracy of soil availability and quality at closure;
- effects of climate change on future rainfall event intensities, durations and / or frequencies; and
- nature of the final waste material.

The final landform design has the following assumptions:

- the materials tested are representative of the general lithologies;
- the nature of the waste material is like the current assessments; and
- progressive rehabilitation will continue using similar methodology to completed rehabilitation.

3.6.1.6 Cover design

Cover design will be limited to the remnant coal material that was stripped from ROM stockpiles and disposed of in Broadmeadow and Plumtree voids. Remnant coal or rejects material was capped with a minimum of 1m of spoil material and topsoiled as per the requirements of Table F1 in the EA. The locations and cross sections for the coal disposal locations is given in Figure 22 – Figure 25. Note that the stockpile locations were designed with a minimum of 2m of spoil to ensure adequate cover. Given the small volumes and benign nature of the material the disposal locations are considered low risk in terms of cover design. Each location is at the base of a spoil dump to ensure maximum coverage with spoil and to minimise the risk of erosion. All areas will be topsoiled and seeded as per EA requirements.

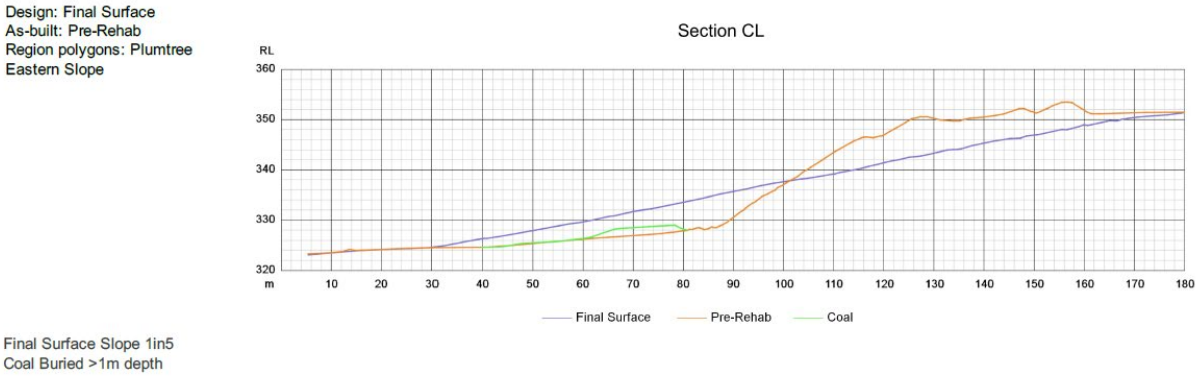


Figure 22 Plumtree eastern slope in-pit coal disposal

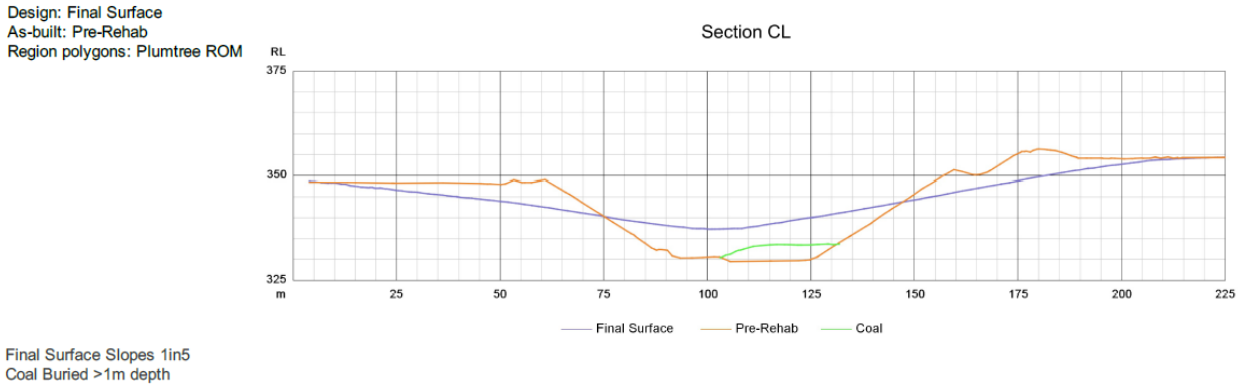
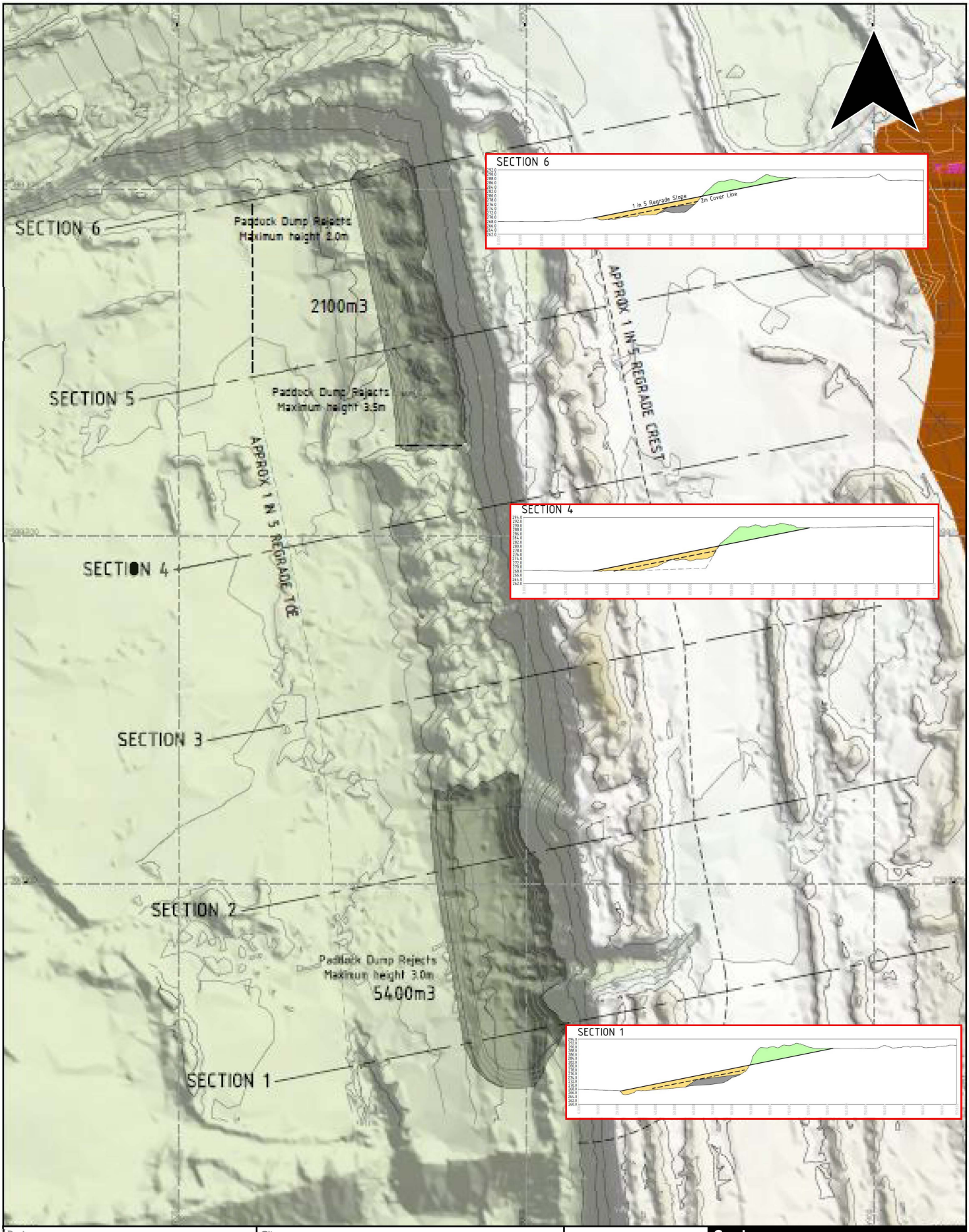


Figure 23 Plumtree ROM in-pit coal disposal



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	Scale: 0 – 25m
Figure: 24	Title: ROM Coal Placement Area 1 & 2	Design: Peabody Energy Australia 10.06.2022 Scale: 1 : 1,000 CRS: AMG84 - 55	SGM environmental

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Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	Scale: 0 — 25m
Figure: 25	Title: ROM Coal Placement Area 3	Design: Peabody Energy Australia 10.06.2022 Scale: 1 : 1,000 CRS: AMG84 - 55	SGM environmental

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3.6.1.7 Water management

a Groundwater

Groundwater at the Mine typically observes EC ranging between 1,800–32,600µS/cm (JBT 2016) with coal seams contributing to the higher concentrations. Groundwater is primarily sourced from coal seams (Peabody 2022).

Potential Contaminants

The potential exists for contaminants to enter groundwater via inflows to pits and drainage from emplacement dumps. The following potential contaminants identified in C50 (Table C3) of the EA pose a risk to EVs:

- Cr;
- Cu;
- Zn;
- Se;
- U;
- nitrate;
- petroleum hydrocarbons;
- Na; and
- Ba.

Release trigger levels for potential contaminants can also be seen in C50 (Table C3) of the EA.

Tributaries around the Mine have water quality that previously exceeded the ANZECC guidelines and background monitoring was done for all controlled releases during commencement and cessation. Weekly monitoring was implemented to verify if any exceedances in water quality limits downstream was a consequence of background conditions or the controlled release.

The Mine has no obligations under the EA to complete monitoring of stored water. Notwithstanding, voids are field sampled for EC and pH periodically for quality.

b Surface water

The WMP describes a surface water drainage system that captures water from disturbed areas. It also describes the ability of the system to shed clean water from undisturbed areas.

The water management system has been designed so that:

- worked water that has runoff from disturbed land is stored in designated worked water dams or pits;
- surface water runoff from disturbed areas but not in a worked water area, is captured in sediment dams; and
- diverted water runoff undisturbed areas is diverted away from disturbed land with no impact on water quality.

The only potential contaminant in surface water runoff is TSS, and this is controlled through the erosion and sediment control system. Surface water catchments only drain off the mls via control structures. Any water that is captured in dams or pits (worked water) is only released in accordance with the EA or reused for site activities.

The surface water management system will continue to control runoff until inspection by an AQP deems that rehabilitation is well established and catchment of runoff is no longer required.

Infiltration and seepage intervention and collection controls

SD can be a consequence of surface runoff and seepage through out-of-pit spoil emplacements. The Mine has not recorded any incidence of saline seepage since 2016 however inspections are done routinely in accordance with the WMP. The controls implemented to manage seepage includes:

- undertaking routine monitoring of out-of-pit spoil dump toe drains for signs of seepage;
- tracking all sources of seepage in the GIS database;
- appropriate response to identification of seepage (as per the seepage trigger action response program (TARP)); and
- report seepage as per the seepage TARP.

If saline seepage is identified it enacts the SD TARP identified in the WMP and reporting is completed in accordance with the actions outlined in the TARP.

Dewatering

Voids will not be dewatered. Water may be taken and stored in mining voids in accordance with the site WMP.

Ongoing water management and reduction

No treatment is planned for water stored in voids. The WBM discussed previously shows the active management of pit water volumes is unlikely to be required. No controlled releases are planned to occur due to:

- high EC of stored pit water;
- limited flow in ephemeral creek systems to allow release; and
- limited access to release points during rain events.

3.6.1.8 Revegetation

a Objectives

The revegetation objectives for the site are as follows;

- to establish self-sustaining vegetation consistent with the PMLU and nominated completion criteria;
- to establish self-sustaining vegetation in grazing areas that is productive, comparable to surrounding grazing areas and supports the commercial interest of future land holders;
- to establish self-sustaining vegetation of bushland areas that supports endemic species but is also productive for cattle grazing; and
- to monitor and manage weed and pest species which are detrimental to the establishment and persistence of key flora and fauna species.

b Key flora species

Key flora species for each PMLU are given in section g and Table 27 to Table 29.

c Species of conservation significance

Species of conservation significance have not been routinely identified on site however potential species are listed in Section 3.1.4.4c and Section 3.1.4.6

d Fauna habitat and use

The majority of fauna habitat occurs within the riparian vegetation corridors which were not impacted by mining operations. The Mine will establish riparian vegetation along the Spade Creek and Bullock Creek diversions. The Bullock Creek diversion is within the Bullock Creek ERE rehabilitation areas while the revegetation of the Spade Creek diversion will be as per the detailed *Spade Diversion Revegetation Plan* (Appendix H).

e Analogues sites

Rehabilitation monitoring is conducted in accordance with the *Peabody Energy Australia Rehabilitation Monitoring Manual* (2015) (Appendix I). Analogue sites have been established in areas dominated by pasture grass, areas dominated by native vegetation and areas with a mixture of both vegetation types.

f Management of revegetation

Revegetation is planned in advance of earthworks. If areas are reshaped and particularly if they are topsoiled, seeding should occur immediately to minimise the risk of erosion. Seed will be ordered in advance to ensure adequate supply. If tubestock are to be planted, preparations for adequate watering will be used.

g Seed mixes

The seed mix for each PMLU is given in Table 27-Table 29. Seed will be sourced through local suppliers where possible. Given the variability of supply, particularly with natives, some species may not be available when required for rehabilitation. In these cases, similar, suitable species may be substituted. Alternatively, the seeding rate of other species may be adjusted.

Table 27 Grazing with areas of bushland habitat PMLU seed mix

Scientific name	Common name	Seeding rate (kg/ha)	Properties
Cenchrus ciliaris	American buffel	4	• responds quickly and establishes after limited rainfall; • drought tolerant; • dominant grazing species in the surrounding area; and • palatable to grazing cattle.
Bothriochloa pertusa	Creeping blue grass	2	• good ground coverage for erosion protection; • drought tolerant; • tolerates heavy grazing; and • palatable to grazing cattle.
Urochloa mosambicensis	Sabi grass	3	• fast growing; • drought tolerant; • tolerates heavy grazing; and • palatable to grazing cattle.
Echinochloa esculenta	Japanese millet	3	• fast growing cover crop; and • palatable to grazing cattle.
Clitoria ternatea	Butterfly pea	3	• nitrogen fixing legume used to improve soil fertility; • palatable to grazing cattle; and • suggested as an addition to grazing seed mixes by landholders during community consultation and adopted by site.
Eucalyptus crebra	Narrow leaved ironbark	1	• endemic to area; and • potential shade tree.
Eucalyptus populnea	Poplar box	1	• endemic to area; and • potential shade tree.
Acacia Salicina	Sally wattle	1	• fast growing; and • endemic to area.

Scientific name	Common name	Seeding rate (kg/ha)	Properties
Corymbia citriodora	Spotted gum	1	• hardy; • adaptable; • occurs locally; and • as per recommendations from rehabilitation monitoring.

Table 28 Riparian PMLU seed mix

Scientific name	Common name
Overstorey trees and large shrubs (8–20cm)	
Acacia harpophylla	Brigalow
Angophora floribunda	Rough-barked apple
Brachychiton rupestris	Narrow-leaved bottle tree
Casuarina cunninghamiana	River oak
Eucalyptus camaldulensis	River red gum
Eucalytpus coolabah	Coolibah
Eucalyptus tereticornis	Queensland blue gum
Mid-storey shrubs (1–8m)	
Acacia salicina	Sally wattle
Acacia stenophylla	River cooba
Cappris lasiantha	Bush caper
*Carissa ovata^*	Currant bush
Lysiphyllum carronii	Red Bauhinia
Melaleuca bracteata	Black tea-tree
Melaleuca viminalis	Weeping bottlebrush
Terminalia oblongata	Yellow wood
Ground-storey grasses and tussocks (0.2–2m)	
Bothriochloa bladhii	Forest bluegrass
Brothriochloa ewartiana	Desert bluegrass
Chrysopogon fallax	Golden beard grass
Cyperus dactylotes	Flat-sedge
Cyperus difformis	Variable flat-sedge
Cyperus exaltatus	Giant sedge

Scientific name	Common name
Cyperus gracilis	Slender flat-sedge
Cyperus iria	Rice flat-sedge
Cyperus rigidellus	Whisker flat-sedge
Cyperus victoriensis	Yelka flat-sedge
Dichanthium sericeum	Queensland bluegrass
Imperata cylindrica	Blady grass
Leptochloa digitata	Whorled cane grass
Lomandra longifolia	Spiny-head mat-rush
Panicum decompositum	Native millet
Non-native cover crop species	
Echinochloa esculenta	Japanese millet
Lolium multiflorum	Annual ryegrass

Table 29 Self-sustaining native vegetation PMLU seed mix

Scientific name	Common name	Seeding rate (kg/ha)
Acacia harpophylla	Brigalow	2.267
Eucalyptus cambageana	Dawson gum	0.5
Lysiphyllum carronii	Red bauhinia	5.711
Terminalia oblongata	Yellow wood	1
Acacia salicina	Sally wattle	0.459
Acalypha eremorum	Soft acalypha	0.001
Alectryon diversifolius	Scrub boonaree	0.108
Diospyros humilis	Queensland ebony	0.403
Ehretia membranifolia	Peach bush	0.042
Eremophila mitchellii	False sandalwood	0.002
Pittosporum spinescens	Orange thorn	0.03
Psydrax odorata	Canthium	0.06
Geijera parviflora	Wilga	0.06
Flindersia dissosperma	Leopardwood	0.03
Carissa ovata	Conkerberry	0.225
Capparis lasiantha	Bush caper	0.069

Scientific name	Common name	Seeding rate (kg/ha)
Eucalyptus populnea	Poplar box	0.5
Echinochloa esculenta	Japanese millet	5

h Seed application

The seeding density is given in Table 27 and Table 29. The seeding density for riparian zones will be further refined based on seed availability at the time of planting. Revegetated areas are generally planted to coincide with the onset of annual high rainfall periods to avoid the need for watering. If tube stock is used some initial watering may be required to establish seedlings. Weed inspections and control will be done regularly until vegetation cover criteria are met. The area of ERE reinstatement at Bullock Creek and riparian areas at Spade Creek will be a combination of seed and tube stock and as such watering may be required.

i Infrastructure for revegetation protection

Fencing of the Bullock Creek ERE is required as per table F2 of the EA. Fencing of the ERE rehabilitation areas have been completed while the existing ERE will require permanent fencing as part of rehabilitation works.

j Growth media

Stockpiled topsoil is suitable and sufficient in quantity to sustain the PMLUs. Topsoil placed in the Bullock Creek ERE rehabilitation area was sourced from stockpiled soil from the cleared ERE as per table F2 of the EA.

k Topsoil depths

A nominal depth of 200mm of soil is used.

3.6.2 Tailings storage facilities

No tailings storage facilities are located on the Mine.

3.6.3 Voids

The final voids have been classified as NUMAs as per 3.3.2

3.6.3.1 Options for minimising final void area

Minserve (2018) has done detailed volumetric studies to identify a preferred closure option for the voids. Table 30 gives each option analysed and the final disturbed surface area and estimated cost of delivery.

Table 30 Void rehabilitation options

Void	Option 0	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Broadmeadow	Strip ROM pad. Create levee bank at north and south end-wall	Rehabilitate eastern face of out-of-pit storage area to 1(V):6(H) slope. Fence and bund end-wall and high-wall. Stabilise north end-wall by backfill the pit. Levee battered at 1(V):6(H) outer side and 1(V):2(H) on the inner side.	All of Option 1 plus drill and blast to stabilise high-wall.	All Option 1 plus rehabilitation of low-wall side and in-pit spoil storage area at 1(V):6(H) slope. Rehabilitation of the high-wall side by push spoil into the pit.	All Option 1plus rehabilitation of the low-wall. Rehabilitation of the high-wall and in-pit spoil storage area at 1(V):6(H) slope.	Rehabilitation of the low-wall, high wall and in-pit spoil storage area at 1(V):6(H) slope. Levee battered at 1(V):6(H)	Rehandle all out-of-pit spoil storage area and return to pit. Resulting landform will be approximately 1 m above natural topography.
Surface area (ha)	18.5	45.76	45.76	155.24	164.31	162.5	228.2
Plumtree	Strip ROM pad and dam, construct north and west levee bank, bund and fence.	Rehab north west and south west face of out of pit spoil storage area to 1(V):6(H) slope. Fence and bund end-wall and high-wall.	All of Option 1 plus drill and blast to stabilise high-wall.	All Option 1 plus rehabilitation of low-wall side and in-pit spoil storage area at 1(V):6(H) slope. Rehabilitation of the high-wall side by push spoil into the pit.			
Surface area (ha)	30.07	152.74	152.74	269.47			

Void	Option 0	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Bullock Creek	Bund and fence.	All Option 0 plus drill and blast to stabilise high-wall.	All Option 1 plus rehabilitation of low-wall side and in-pit spoil storage area at 1(V):6(H) slope. Rehabilitation of the high-wall side by push spoil into the pit.				
Surface area (ha)	-	-	-				
Wallanbah	Bund and fence.		All of Option 0 plus rehabilitation of the low wall side and in-pit spoil storage area to 1(V):6(H) slope.				
Surface area (ha)	-		64.4				

The Minserve (2018) options analysis gives guidance on the minimum and maximum, or 'book-end' options, which were considered. That is, filling the pits versus the minimum rehabilitation required to meet the EA.

The fill void option, EA option and preferred options are outlined in the following sections.

3.6.3.2 Fill void option

a Broadmeadow

An analysis of the Broadmeadow Pit shows that 22.8 million cubic metres (Mm^3) of spoil is required to fill the pit back to original topography. Spoil could be taken from the existing western out-of-pit spoil storage area and would require all the out-of-pit spoil to be completely rehandled and placed in the pit.

Filling of the pit was not considered viable due to:

- the pit contains 5,485 million litres (ML) of water which would need to be removed and stored elsewhere or treated for release.
- most of the spoil for rehandling would need to be moved via truck and shovel due to the distances involved. Truck and shovel is significantly more expensive than dozer pushing.
- all the external slopes and the top of the out-of-pit spoil storage area have been previously rehabilitated and are stable. Filling the pits would disturb the rehabilitated landform and leave the remaining area unstable; and
- re-work of rehabilitated spoil to win pit fill will result in the loss of the topsoil that has been applied to rehabilitation resulting in a shortfall for future rehabilitation.

b Plumtree

An analysis of Plumtree Pit shows that 39.1 Mm^3 of spoil is required to fill the pit back to original topography. The spoil source would be from the existing western out-of-pit spoil storage area and would require all of the spoil to be completely rehandled and placed in the pit.

Filling of the pit was not considered viable due to several factors:

- the pit contains 4,620 ML of water which would need to be removed and stored elsewhere or treated for release
- most of the spoil for rehandling would need to be moved via truck and shovel due to the distances involved. Truck and shovel is significantly more expensive than dozer pushing.
- all the external slopes and the top of the out-of-pit spoil storage area have been previously rehabilitated and are stable. Filling the pits would disturb the rehabilitated landform and leave the remaining area unstable; and
- re-work of rehabilitated spoil to win pit fill will result in the loss of the topsoil that has been applied to rehabilitation resulting in a shortfall for future rehabilitation.

c Bullock Creek

An analysis of the Bullock Creek Pit shows that 9.2 Mm^3 of spoil is required to fill the pit back to original topography. The spoil source would be from the northern out-of-pit spoil storage area (8.4 Mm^3), and the western end of the in-pit spoil storage area (0.8 Mm^3).

Filling of the pit was not considered viable due to several factors:

- the pit contains 2,544 ML of water which would need to be removed and stored elsewhere or treated for release;
- most of the spoil for rehandling would need to be moved via truck and shovel due to the distances involved. Truck and shovel is significantly more expensive than dozer pushing;

- all the external slopes and the top of the out-of-pit spoil storage area have been previously rehabilitated and are stable. Filling the pits would disturb the rehabilitated landform and leave the remaining area unstable; and
- re-work of rehabilitated spoil to win pit fill material will result in the loss of the topsoil that has been applied to rehabilitation resulting in a shortfall for future rehabilitation.

d Wallanbah

An analysis of Wallanbah Pit shows that 32.4 Mm^3 of spoil is required to fill the pit back to original topography. The spoil source would be from the existing eastern out-of-pit spoil storage area and would require all spoil to be completely rehandled and placed in the pit. Additional volumes would also need to be sourced from the rehabilitated western out-of-pit spoil storage area.

Filling of the pit was not considered viable due to several factors:

- the pit contains 5,893 ML of water which would need to be removed and stored elsewhere or treated for release
- most of the spoil for rehandling would need to be moved via truck and shovel due to the distances involved. Truck and shovel is significantly more expensive than dozer pushing.
- all the external slopes and the top of the out-of-pit spoil storage area have been previously rehabilitated and are stable. Filling the pits would disturb the rehabilitated landform and leave the remaining area unstable; and
- re-work of rehabilitated spoil to win pit fill will result in the loss of the topsoil that has been applied to rehabilitation resulting in a shortfall for future rehabilitation.

3.6.3.3 EA option

The following sections summarise the main elements of rehabilitation of the pits to meet the (minimum) requirements of the EA. For each pit the EA option has not been adopted because it did not minimise the pit area. Further, the EA option did not adequately address all risks.

a Broadmeadow

The main elements of rehabilitation in the Broadmeadow Pit to meet the EA are:

- incorporate required water infrastructure (levees);
- address remnant ROM pad;
- removal of old storage dams on western side which have no catchment and are not suitable for retention;
- incorporate remediation of Spade Creek diversion to facilitate licence surrender; and
- address highwall erosion.

b Plumtree

The main elements of rehabilitation in the Plumtree Pit to meet the EA are:

- the pit has been partially backfilled which minimises volume of the pit;
- limit catchment area due to elevated final water level;
- address ROM pads ensuring minimum of 2 m cover with inert spoil;
- incorporate required water infrastructure (levees) excluding the northern out-of-pit spoil storage area which acts as a levee;
- do not disturb the low-wall below the southern levee; and
- divert surface flows away from the pit where possible.

c Bullock Creek

The main elements of rehabilitation in the Bullock Creek Pit to meet the EA are:

- the pit has been partially backfilled which minimises the volume of the pit;
- incorporate required water infrastructure (levees and high-wall drain);
- include ERE as per EA requirements;
- protect undisturbed riparian vegetation; and
- treat area of low wall slippage — buttress has already been built.

d Wallanbah

The main elements of rehabilitation in the Wallanbah Pit to meet the EA are:

- previously partially backfilled which minimises volume of the pit;
- address low-wall and end-wall instability;
- address erodible tertiary layer;
- high wall, end wall and low wall drainage;
- remnant high wall on eastern side — difficult to remove (hard rock) for small benefit; and
- remnant low wall on western side — would need to cut-back into the hill to get enough fill, disturbing existing rehabilitated areas.

3.6.3.4 Preferred option

a Plumtree

Rehabilitation of the Plumtree Pit involve backfilling and removal of the western ROM stockpile, and grading the in-pit spoil, resulting in 129 ha of the pit rehabilitated to grazing until long-term water levels are reached. This approach links the rehabilitation on the eastern infrastructure areas to rehabilitated in-pit spoil storage areas, and the western out-of-pit spoil storage areas. The southern end of the low-wall will be left intact to stop erosion undermining the existing water management structure adjacent to the pit, while the rest of the low-wall will be re-graded. Safety bunds will be moved closer to the high-walls and end-walls to avoid erosion particularly to the upper tertiary slopes (as per geotechnical recommendations).

b Bullock Creek

To address long-term erosion and low wall stability that could potentially impact the Bullock Creek Pit, two new levees have been constructed. A revised drainage structure around the high-wall and backfilling of existing drains will be done. The upper part of the in-pit spoil storage area has been re-graded and rehabilitated to 1(V):5(H) and the spoil above natural topography is not visible. The lower section of the low-wall will remain at angle of repose, as analysis shows regrading this section to achieve a lower slope would be offset by disturbance of the existing rehabilitation. The remaining pit is currently projected to be approximately 31 ha which is well within the area permitted by the EA of 42.1 ha, including the rehabilitated upper areas of the low-wall spoil.

c Wallanbah

The remnant low wall and high-walls in the east and west of the pit will be left as rocky outcrops that will in time replicate the geomorphic features of the Burton and Kerlong Ranges. The current high wall and end wall will be left at its current angle and the high wall drain will be reinstated to direct water south to a new spine drain that will take water to the pit.

Geotechnical reports indicate there is a need for continued monitoring and maintenance of the end wall and low walls. For the end wall and low walls, additional studies and modelling for erosion will be done to determine the final specifications, locations of contour drains and spine drains, and lengths of slopes for 1(V):3(H) re-grades. Further investigation and modelling of the long-term erodibility of tertiary spoil may also be required. The outcomes of this work may help inform the potential for methods to promote vegetation and limit erosion during high rainfall and runoff events.

d Broadmeadow

The western spoil storage area of Broadmeadow Pit has been linked to the eastern infrastructure areas (ROM pad and assorted drainage structures) via the rehabilitated in-pit spoil storage area, resulting in an additional 26 ha of potential grazing land. Approximately half of this area still requires topsoiling and seeding. This addresses the rehabilitation of the remnant ROM pad and allows for in-pit management of coal contaminated earth from the ROM pad and Mine water dams. Safety bunds will be moved to an appropriate offset from the high-walls and end-walls to avoid erosion, particularly to the upper tertiary slopes. The southern low-wall of Broadmeadow Pit will be rehabilitated improve visual amenity. It is worth noting that this is possible due to safe access for machinery (ie only a short section of low wall is above the pit water storage). Some areas of pit low walls, rehabilitation works cannot be safely completed (eg pushing areas of low wall above deep bodies of water).

3.6.3.5 Void dimensions

The void dimensions are given in Figure 26

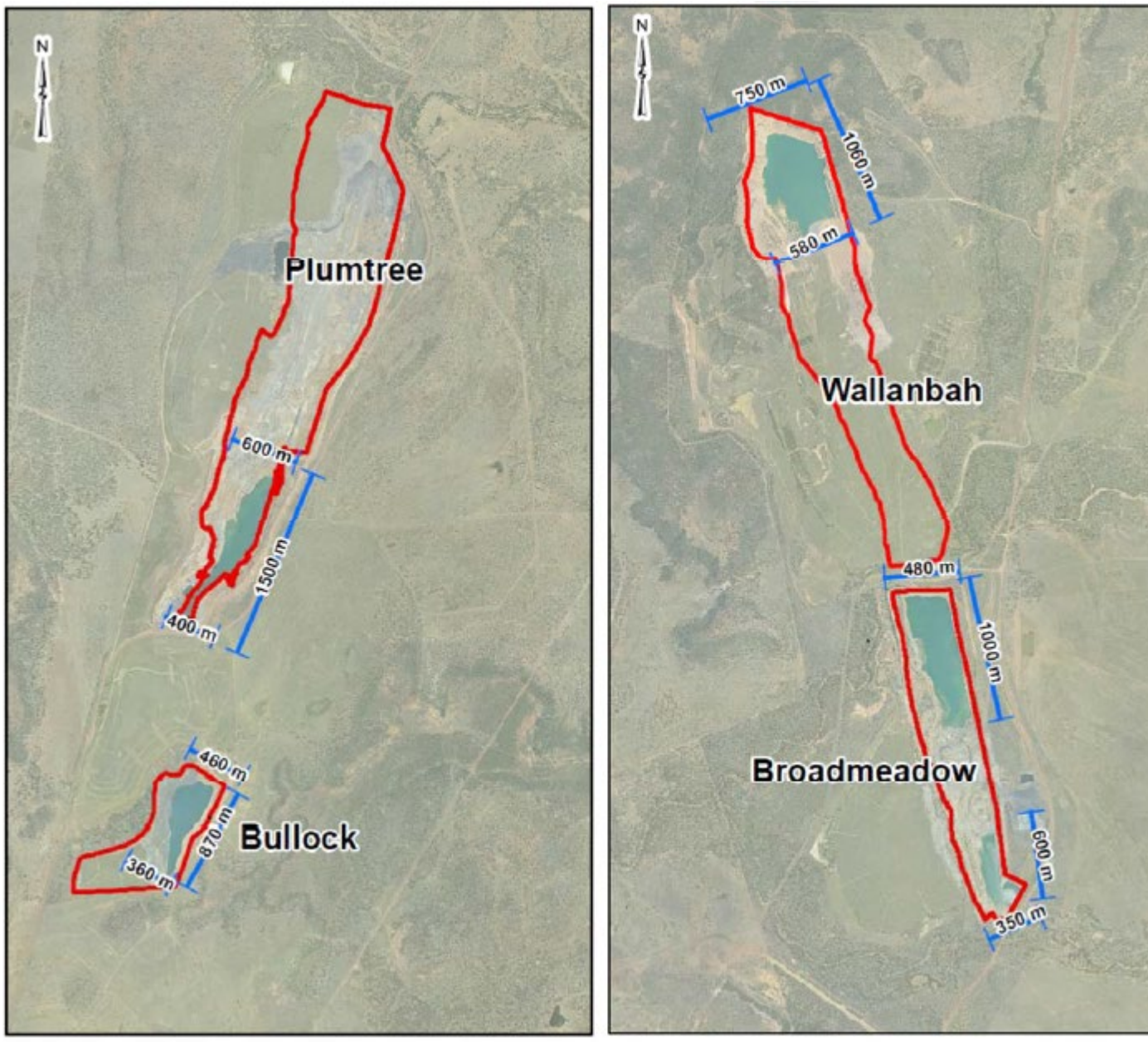

Figure 26 Final void dimensions

3.6.3.6 Void stability

Geotechnical assessments have been completed for the four pits. These assessments have been done by AQPs at different stages over the past few years. Monitoring has been done as per recommendations contained in the reports.

The geotechnical monitoring and associated report must investigate pit geotechnical stability and make recommendations to address any safety issues prior to ML surrender, ie restriction of human and animal access. Safety recommendations in the geotechnical monitoring report must be incorporated into closure planning. A summary of the geotechnical reports is listed for each pit below.

a Plumtree Pit

A stability assessment of the Plumtree Pit was completed by Henderson Geotech Pty Ltd in May 2015 (Appendix J). The assessment provided a pit-wall stability study and considered the effects of long-term erosion and weathering of the pit-wall and the effects of significant hydrological events.

Henderson (2015) concluded that:

- Based on water balance modelling, the water level in the pit is expected to range between 282-301 mRL. It is intended that the pit will continue as a water storage facility during the remaining life of mine, with a maximum operating level of 300 mRL which is 5 m below the bed level in nearby Sandy Creek. The critical water level (and saturation level) assumed for pit stability was therefore 301 mRL.
- For long-term stability of the high-wall, the condition with the lowest FoS (1.92) was a dry pit. As the maximum water level was below the base of weathering, the minimum FoS for the weathered zone was the same as for current conditions. A faulted section at the northern end of the remaining pit was not separately analysed - further large slippage was unlikely, but the back-scarp could cut-back further. A 30 degrees batter projected up from the base of weathering would accommodate any such geo-mechanical degradation. The actual wall crest, behind the slip scarp, is already at that projected stable slope line.
- As the rock mass profile and properties of the end-wall are essentially the same as for the high-wall, the stability analyses that have demonstrated long-term stability for the high-wall can be applied to the end-wall.
- A 10 m erosion margin is proposed for the pit high-wall and end-wall.
- The low-wall is expected to be stable into the future, because it has already slipped to a more stable geometry. The worst case for stability, but still with an acceptable minimum FoS, was again if the pit was pumped dry during its operational life as a water storage, leaving spoil up to the previous maximum water level with reduced strength properties. Some further scarping may occur as the rising pit water level causes in-pit spoil to saturate and settle, but no significant regression of the current wall crest is anticipated.
- When comparing stable long-term cross-sections with current sections, the expected changes are small, partly because previous slips have already created more stable geometry. As the weathered overburden has not shown to be severely erodible, the potentially affected margin is expected to be quite narrow behind the high-wall and end-wall. A conservative wider buffer has been allowed along the low-wall covering the area that has already been stripped and disturbed.
- There are no assets or areas of significant value within the area of the post-mining pit. Other considerations such as safety and surface drainage may dictate a need for other works or buffers, but from a stability perspective, the pit would have minimal additional long-term impact.

b Bullock Creek Pit

Several reports and reviews have been prepared for the pit at Bullock Creek. A summary of key findings for each one is given below.

In October 2012 and October 2013, GeoTek Solutions Pty Ltd completed inspections of the Bullock Creek Pit, in order to make geotechnical observations and give preliminary recommendations in relation to final rehabilitation.

GeoTek (2013) (Appendix K) documents the results of the inspection and assessment, and concludes:

- In terms of both current and long-term stability, the high-wall is considered stable. No evidence has been observed of any unfavourable structures that may lead to premature failure.
- Following a series of failures involving the northern end-wall and the western low-wall, at the date of the report, they were geotechnically stable under normal, dry conditions. However, if the Mine experiences soaking rains which have the effect of raising the phreatic surface to approximately 310 mRL, that would be enough to induce further movement in the spoil and the toppled end-wall material.
- Ongoing failures will progressively encroach on the perimeter flood bund and drain. However, instability will not impact on the functionality of the pit as a water storage;
- Raising the water level in the pit temporarily to 310 mRL or, permanently to 270 mRL, is unlikely to have any significant geotechnical impacts.
- The unbuttressed spoil will experience episodic conditions that may lead to it progressively sliding towards the bottom of the pit. In between, it is likely to become vegetated by rehabilitation or purely self-reporting species and this will assist in stabilising the spoil. The exposed back scarps will erode and flatten to quasi stable slopes on the order of 20°.
- The northern end-wall failure is likely to progressively flatten given that it has already failed and is therefore more exposed to weathering and erosion. Again, a long-term stable angle could be on the order of 20 °.

Henderson (2015) also gives a stability assessment of the Bullock Creek Pit. This assessment concluded that:

- Based on water balance modelling, the water level in the pit is expected to range between 263 mRL and 278 mRL. The pit material has already been saturated higher than the long-term level. It is intended to continue to use the pit for water storage during the remaining life of mine, with a maximum operating level of 315 mRL which is 5m below the bed level in nearby Bullock Creek. This was the critical water level (and saturation level) assumed for pit stability.
- With long-term water level ranges included, the least stable condition for whole slope failures on the high-wall was with the pit dry, and without any buttressing effect from water (FoS 2.26). For upper bench slips, the FoS occurred at the proposed maximum operational water level, with material at the base of the bench saturated (FoS 1.28). As the factors of safety are higher than the acceptable minimum for current and worst-case conditions, the Bullock Creek Pit high-wall is geomechanically stable in the long-term. A 7 m buffer is a conservative forecast of the band that might be significantly erosion-affected post-mining.
- For the end-wall, as was the case for the high-wall, the highest factor of safety for the weathered bench occurred at maximum water level, while the lowest FoS for the whole wall and the spoil bench occurred with no water in the pit. Results for the spoil bench suggested that slip failure was likely for the current geometry — iterations of slope angle found that a batter of about 25° was required to meet the adopted FoS (>1.2). The impact of a perched water table in the weathered overburden, fed by flow in the runoff capture drain, was again considered, but for long-term conditions the additional water was applied on top of the maximum pit water level. A scenario of 15 m extra height of water below the drain would require prolonged severe wet weather but might be feasible, and the resultant analyses suggested likelihood of slip failure. The slope angle was again iterated and found to give an acceptable outcome at 30°.
- The low-wall is considered stable under current conditions, largely because the slips that have occurred have resulted in a more stable geometry. Further slips are likely over the long-term, caused by extremes of variation in water conditions. Any large slips will be confined to spoil contained within the pit, but there could be local instability in the exposed top of the box-cut.
- When comparing stable long-term cross-sections with current sections, the predicted changes are relatively minor, because there have already been significant slips that shifted wall material into more stable geometries. The area expected to be affected by erosion is also limited, because the weathered Permian overburden does not appear to be particularly erodible. Both the runoff capture drain, where it passes behind the end-wall, and the Bullock Creek bund are within the margin that could be impacted

by future pit instability. Protection of the drain and bund, for example by relocation, needs to be addressed.

As part of final landform design and remedial works, flood modelling identified the need for a levee in the north western corner of the Bullock Creek Pit, within the existing 30 m geotechnical stand-off recommended in GeoTek 2013.

Cartledge and Geotechnics (2016) included a review of the stand-off, to allow design and construction of the preferred levee. Cartledge and Geotechnics (2016) concludes that:

- The end-wall is not at risk of large-scale global failure, and the failure on the northern end-wall is prevented from progressing east and west by the high-wall and slope height.
- The pit adjacent to the proposed levee has been backfilled and is therefore not susceptible to slope failure.
- It is expected that the current scarp will retreat northwards into the adjacent water diversion drain due to progressive slope failure. The currently proposed location of the levee is about 75 m from the edge of the expected scarp position and is therefore outside of the currently recommended 30 m stand-off.
- A revised stand-off should be adopted to allow the construction of the levee.
- Erosion of the end-wall due to mechanical and chemical means is likely and could undermine the levee if water flow is not managed well. As suggested in the May 2015 report by Henderson Geotech Pty Ltd, a 7 m buffer should be left around the edge of the pit as an erosion buffer. It is recommended that appropriate slope contouring and surface water management be implemented in the vicinity of the pit crest as part of the levee design and construction works.

The levee has been constructed as part of planned rehabilitation activities during 2018. Slope stability analysis completed by Cartledge and Geotechnics (2018) (Appendix L) focused on the failed low-wall slope in the Bullock Creek Pit and assessed the potential impact of a buttress on pitwall stability.

Cartledge and Geotechnics (2018) concludes that:

- Under current conditions, and assumed material parameters and ground conditions, the failure scarp is generally stable (FoS 1.6).
- Localised erosion and scouring is likely and has the potential to undermine the low-wall pit slope, leading to progressive failure. Further, variations to the assumed ground model and material parameters may present a decrease in slope stability.
- Where elevated (fully saturated) in-pit water levels are encountered, like those that could be expected following a heavy rainfall event, the pitwall is likely to be unstable (ie FoS <1.0). The construction of the minimum proposed in-pit buttress sees a resultant FoS >1.2 for the failure scarp, when considering an elevated water table. As these water conditions are transient, these FOS are considered appropriate.
- The results of the analysis indicate that the scarp is adequately supported for any buttress design considered, eg 10 m wide (at toe) buttress to 35 m wide (at crest).
- Rehabilitation (ie in-pit buttress) should be done to prevent erosion and scouring of the exposed scarp. The buttress should be constructed from free draining spoil.
- Consistent with previous analysis, a monitoring program should be developed and implemented, to update the analysis of the report, as required.
- The stability analysis should be reviewed and updated when new geological and geotechnical data becomes available, or as material changes are made to existing data.

As recommended by Cartledge (2018), the construction of the in-pit buttress is complete. Some settling occurred during construction, however, a regular survey of the area was done and reviewed by Cartledge. Since the completion of construction, the area has settled, with no further movement recorded.

c Wallanbah Pit

On 16 November 2017, a site inspection of the Wallanbah Pit was completed by Blackrock Mining Solutions Pty Ltd, to observe the geotechnical stability of pit-walls and spoil storage areas with respect to pit conditions.

The objective of the assessment was to identify areas of concern related to geotechnical stability of spoil slopes, and to give recommendations for the long-term stability of slopes to meet residual pit design criteria in the EA.

Blackrock 2018 (Appendix M) documents the geotechnical assessment, and concludes that:

- The high-walls are stable, and no large-scale wall failures are anticipated. There is a low probability that wall instability can occur where geological structures form geometries which daylight on the slope face.
- Large rotational failures observed on the low-wall and end-wall are confined to the Tertiary horizons. They are a function of inadequate slope design and poor surface water management.
- Wall instability of Tertiary overburden will continue along the low-wall and end-wall if nothing is done or until a stable slope configuration is reached.
- The low-wall is potentially unstable due to the proximity of the Burton Range Fault. A large deep-seated low-wall failure is feasible for slope segments north of the buttressed low-wall slope.
- Slopes constructed in the fresh overburden formations on the high-wall and end-wall follow the EA requirements for as-built pit slopes.
- Except for the over-steepened upper Tertiary slope sections along the low-wall and end-wall, the as-built slopes in fresh rock mass are generally in compliance with residual pit design guidelines set in the EA.
- The rehabilitated external spoil dumps have been re-graded to have a gradient of 1(V):6(H). The EA requirement specifies a slope gradient of 1(V):5(H).
- The in-pit low-wall spoil storage areas are stable.
- Any sudden drop in the pit water level would result in a perched water table in the formation which will affect the long-term stability of the walls. This is a critical observation for the marginally stable low-wall.

d Broadmeadow Pit

On 1 September 2017, a site inspection of the Broadmeadow Pit was completed by Blackrock Mining Solutions Pty Ltd, to observe the geotechnical stability of pit-walls and spoil storage areas with respect to pit conditions.

The objective of the assessment was to identify areas of concern for geotechnical stability of excavated and spoil slopes, and give recommendations for the long-term stability of slopes to meet residual pit design criteria in the EA. Further, appropriate high-wall crest stand-off distances were recommended for the certified construction of a levee system offset from the corner of the northern end-wall and low-wall, and southern end-wall.

Blackrock (2017) (Appendix N) documents the geotechnical assessment, and concludes that:

- The high-walls of the pit are inherently stable against mass failure, but local instability can occur where geological structures daylight on the pit face and form geometries that are kinematically unstable. In this case, the bench scale wedge failures in the southern high-wall block are unlikely to prejudice the long-term stability of the high-wall. However, these failures may continue to occur as the high-wall erodes.
- The standard slope designs meet the EA requirements for as-constructed pit slopes to be geotechnically stable.
- The as-constructed slopes follow residual pit design, except for the low-wall side of the out-of-pit spoil storage area which has yet to be re-graded. This would need to be tied into the low-wall in accordance with the EA requirements, which is planned as part of rehabilitation activities.
- In-pit low-wall spoil storage areas are stable, with a more than adequate long-term FoS, including a condition of partial submergence to the predicted 10 year water level.
- There is no potential risk of geotechnical instability due to water runoff entering the pit.

As the high-wall and end-wall slopes are assessed as geotechnically stable, the inside edge of the levee system and perimeter bunding should be offset at 15 m from the crest line. The same offset could be applied to the low-

wall, with the possibility of levee construction on filled spoil, given the amount of settlement that has occurred over time.

3.6.3.7 Void hydrology

A final void hydrology study and water balance model (WBM) was prepared by Klohn Crippen Berger Ltd (KCB) in December 2018 (Appendix O). The WBM was developed using the OPSIM software package which simulated the generation, movement and loss of water on a daily time-step within each final void over a 1,000 year period. The report concluded that:

- all voids will maintain a permanent pit lake which will fluctuate around a steady state equilibrium level in response to periods of flood and drought;
- during periods of floods, no final voids are expected to reach levels that would result in overflow to the environment via surface overflow;
- long term equilibrium conditions will generally be reached over an 80-year period within all four final voids; and
- predicted pit lake water qualities (assessed as electrical conductivity), are expected to support native flora and fauna and not affect fringing vegetation. The permanent pit lakes should provide a permanent aquatic habitat to serve as a wildlife refuge in an otherwise ephemeral system. The aquatic community will be limited in diversity to those species with at least a moderate salt tolerance.

3.6.3.8 Groundwater interaction

The final void hydrology and WBM prepared by KCB in 2018 also included a groundwater interaction study report (Appendix O as above). The report concluded that:

- most of the pits showed a strong correlation between void water levels and the groundwater levels in close proximity to the pits, with less than 10 m difference between void water levels and surrounding bore water levels. This implies relatively low hydraulic gradients between the void water levels and the surrounding groundwater system and therefore low groundwater inflow rates should be expected under current conditions;
- a slight increasing trend was observed in void water levels and some bore water levels after 2012 which indicates a slow rebound of groundwater levels after cessation of mining activities;
- based on the EC values of surrounding bores ranging from 9,420-31,400 uS/cm, groundwater quality is considered poor, and not suitable for livestock watering.
- 2D numerical groundwater model simulations, using various combinations of groundwater levels and void water levels, confirmed that in general, low inflow rates (0.2-8.6 L/s) are likely under existing aquifer and void conditions. Only two cases for the Wallanbah pit precited outflow may occur (2.5-3.3 L/s);
- as expected, sensitivity simulations using higher permeability values for the Rangal Coal Measures and Triassic Rewan Formation resulted in increased flow rates. Inflow rates increased to between 1.1-26.5 L/s and predicted outflow rates increased to 16.7-23.7 L/s;
- groundwater modelling inflow results were reported to the surface water team to model the final void water levels under various hydrologic conditions. The maximum final void water levels were simulated to vary from 260-307 mRL;
- based on the maximum void water levels and the available geology information, Plumtree pit, where the simulated void maximum water levels (maximum catchment yield case — 307 mRL) showed potential risk for void water escaping to the surrounding formation at the north and northeast sides of Plumtree Pit. At the northeast corner, the topographic elevation is around 310 mRL, which implies a resulting void water level of 3 m below surface and likely reaching the base of Quaternary deposits. Also, a 1: 100,000 scale geology map indicate Quaternary deposits associated with Sandy Creek. More detailed information regarding the base of the alluvial deposits would enable the potential risk to be further evaluated;
- the maximum final void water level (304 mRL) of the Bullock pit simulated under maximum groundwater inflow case is generally below the base of weathering and therefore not considered a risk;
- the maximum final void water level of the Wallanbah Pit was simulated below 274 mRL and therefore below the base of Tertiary deposits (>287 mRL). The potential risk of void water escaping from the

Wallanbah Pit was evaluated as low. The potential risk that void water escaping from the south side through the spoils to the weathered rock / Quaternary deposits is considered as high. The modelled void water level (274 mRL) is about 10 m above the base of weathering (around 263-265 mRL) at the south side of the Wallanbah pit. Further information regarding the base of the alluvial deposits would enable the potential risk to be further evaluated;

- there is also a potential of pit water flowing from the south side of Wallanbah Pit to the north of Broadmeadow Pit through spoils and the coal measures; and
- the final void water levels of Broadmeadow pit were simulated generally below the base of weathering and therefore outflow risk is low.

3.6.3.9 Water balance and long-term water quality

The 2018 KCB report modelled the long-term void water levels and predicted qualities as given below. Section 3.6.3.6e gives a further study done in response to the seepage risk presented by Wallanbah and Plumtree voids.

a Plumtree

Water level within Plumtree Pit is expected to increase until it reaches equilibrium after around 80 years. The increase in water level is largely due to the geometry of the final landform. As detailed in the final void data sheet, up to a level of around 309 mRL the final void is relatively narrow. From 309 mRL upwards, the surface area increases significantly and allows the balance of inflows and outflows to be achieved. Once equilibrium conditions are reached:

- expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 306 mRL and 277 mRL, respectively;
- expected water level fluctuations are below the original natural ground level and spoil crest level. As such, release of water via surface overflow is not predicted; and
- expected water level fluctuations are above the control. As such, there is potential for water to seep through the weathered or tertiary layers. This potential seepage is expected to be limited to the northern eastern end of the pit where the Quaternary deposits are evident. once equilibrium conditions are reached (ie after 80 years), the EC level fluctuates with seasonal variance and ranges from:
  - 4,570 µS/cm after prolonged periods of above average wet conditions; and
  - 11,670 µS/cm after prolonged dry periods.

b Bullock Creek

Water level within Bullock Pit is expected to decrease for the next 50 years and reaches equilibrium after around 80 years. The reduction in water level is due to the reduced catchment area with the final landform designed to direct surface runoff of nearby rehabilitated spoil dumps away from the void and no additional mine water being transferred into the pit. Once equilibrium conditions are reached:

- expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 290 mRL and 271 mRL, respectively;
- expected water level fluctuations are below the original natural ground level / nominal spoil crest level and the control level. As such, release of water via surface or subsurface overflow is not predicted;
- once equilibrium conditions are reached (ie after 80 years), the EC level fluctuates with seasonal variance and ranges from:
  - 16,430 µS/cm after prolonged periods of above average wet conditions; and
  - 61,850 µS/cm after prolonged dry periods;
- the high EC ranges relate to the lower volume of water expected to be retained within Bullock Pit (ie ranging from around 1,600-500 ML of free water) in comparison with the three other final voids.

c Wallanbah

Water level within Wallanbah Pit already appears to be very close to reaching equilibrium and is expected to remain relatively stable. Once equilibrium conditions are reached:

- expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 274 mRL and 254 mRL, respectively;
- expected water level fluctuations are below the original natural ground level / nominal spoil crest level and control level. As such, release of water via surface or sub-surface overflow is not predicted;
- expected water level fluctuations are above the base of weathered material in the southern side of the pit. Release of water may occur through the spoil and weathered rock / Quaternary deposits with flow directed towards the south and Broadmeadow pit. Further information regarding the base of the alluvial deposits would enable the potential risk to be further evaluated; and
- once equilibrium conditions are reached, the EC level fluctuates with seasonal variance. As the point of equilibrium is not as easily defined for Wallanbah Pit, EC ranges have been developed at 30, 50 and 80 years as detailed in Table 31.

Table 31 EC range for Wallanbah void

Time to equilibrium (years)	EC (µS/cm)	
	Wet periods	Dry periods
30	4,300	10,570
50	4,370	10,730
80	4,590	11,280

d Broadmeadow

Water level within Broadmeadow Pit is expected to decrease for the next 50 years and reaches equilibrium after around 80 years. The reduction in water level is due to the reduced catchment area with the final landform design. Once equilibrium conditions are reached:

- expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 249mRL and 228mRL, respectively;
- expected water level fluctuations are below the original natural ground level / nominal spoil crest level and the control level. As such, release of water via surface or subsurface overflow is not predicted;
- once equilibrium conditions are reached (ie after 80 years), the EC level fluctuates with seasonal variance and ranges from:
  - 6,740 µS/cm after prolonged periods of above average wet conditions; and
  - 16,190 µS/cm after prolonged dry periods.

e Pit evaporation study

Potential seepage from Wallanbah and Plumtree voids via shallow alluvial aquifers was outlined in the 2018 WBM report. In response to this report further investigation was done in 2020 by KCB. The report, *Burton Coal Mine Pit Evaporation Factor Investigation* (Appendix P) included sensitivity analysis based on adopting higher pit evaporation rates than the base case factor of 0.7. Studies done at Norwich Park showed similarly shaped final voids to Burton, (long, rectangular-box-shaped voids), had greater wind speeds at the pit lake surface than at land level possibly because of the long-narrow shape of the coal pits funnelling the wind into the pit. This resulted in an acceleration of airflow. Accordingly, actual evaporation rates were found to be substantially higher when compared to modelled rates, derived through the application of measured pan evaporation rates at the nearest BOM site and a pan evaporation coefficient of 0.7.

This research has further highlighted the uncertainty of the pit evaporation factor and suggested that the pit evaporation factors may range up to a factor of 1. To further understand the uncertainty that the pit-evaporation

factor has on the fluctuation of the long-term-equilibrium-water levels within the final voids, pit evaporation factors of 0.6, 0.7, 0.8, 0.9 and 1.0 were applied to the previous WBM.

Results

The study concluded that:

For the final voids of Bullock, Wallanbah and Broadmeadow Pits, the simulated variance in long-term water levels due to changing pit evaporation factors is not expected to result in any overflow or seepage to the environment (ie above original natural ground or control levels). Within Plumtree Pit, no overflow to the receiving environment is expected, however, the simulated long-term water levels may reach above the control level for lower pit evaporation factors of 0.6 and 0.7 with no groundwater and 0.6 to 0.9 with groundwater. Above the control level seepage to the receiving environment may occur via shallow alluvial aquifers.

Further investigation

To better understand the impact of pit evaporation factor at the Mine, wind monitoring stations were installed to collect data on wind speed and direction at pit lake and natural ground level. The monitor was placed in Wallanbah with plans to be relocated to Plumtree void in the future. The data collected for a six-month period in 2020 showed a negligible difference with wind speeds at ground level being only 3.2% higher than at the pit lake surface (1.63 m/s vs 1.59 m/s). Data collected to date supports the use of a higher evaporation rate in the Wallanbah void WBM. It is expected that data from the Plumtree void will show similar results.

f Stratification

A site investigation was undertaken around June 2020 to understand potential stratification of water in the Mine voids. Samples were taken from all four voids at 10m increments to the bottom using a Van Dorn sampler. Sediment samples were also taken from the bottom of the void using a ponar grab sampler. Samples were field measured and then sent to a National Association of Testing Authorities (NATA) laboratory for further testing. The results to date have not shown a significant difference in water quality across the four voids at varying depths. Further testing in the summer months is required to remove seasonal variability from the results.

3.6.3.10 Rehabilitation strategies

a Plumtree

Rehabilitation of Plumtree void involves backfilling and removal of the western ROM stockpile, and grading the in-pit spoil, resulting in 129 ha of the pit rehabilitated to grazing until long-term water levels are reached. This links the rehabilitation on the eastern infrastructure areas to rehabilitated in-pit spoil storage areas, and the western out-of-pit spoil storage areas. The southern end of the low-wall will be left intact to minimise the risk of erosion undermining the existing water management structure adjacent to the pit, while the rest of the low-wall will be re-graded. Safety bunds will be located outside of the nominated offset distance as per the geotechnical investigations in Section 3.6.3.3.

b Bullock Creek

To protect the pit from potential flooding that could potentially impact the Bullock Creek pit, two levees were constructed with one of these at ground level (ie a backfilled trench) and the other effectively forms part of the diversion bank. These levees have been incorporated into the final landform at Bullock Creek and will remain post closure. A redesigned and constructed drainage structure around the high wall and backfilling of the existing drain will be undertaken for the long-term management of surface water. The upper part of the in-pit spoil storage area has been re-graded and rehabilitated to 1(V):5(H) and the spoil above natural topography is not visible. The lower section of the low-wall will remain as is, as analysis shows regrading this section to achieve a lower slope would be offset by disturbance of the existing rehabilitation. The remaining pit is currently projected to be approximately 28ha which is well within the area permitted by the EA of 42.1 ha, including the rehabilitated upper areas of the low-wall spoil.

c Broadmeadow

The western spoil storage area of Broadmeadow will be linked to the eastern infrastructure areas (ROM pad and assorted drainage structures) via the rehabilitated in-pit spoil storage area, resulting in an additional 26 ha of potential grazing land. This addresses the rehabilitation of the remnant ROM pad and allows for in-pit management of coal contaminated earth from the ROM pad and mine water dams. Safety bunds will be located outside of the nominated offset distance as per the geotechnical investigations in section 3.6.3.3. The southern low-wall of Broadmeadow Pit will be rehabilitated to increase potential grazing land and minimise the NUMA area.

d Wallanbah

The remnant low-wall and high-walls in the east and west of the pit will be left as rocky outcrops that will in time replicate the geomorphic features of the Burton and Kerlong Ranges. The remnant high-wall will be left at its current angle and the high-wall drain will be reinstated to direct water south to a new spine drain that will take water to the pit. The drain behind the end wall will also be regraded and stabilised to direct water to the reinstated highwall drain.

The Wallanbah low wall is designated as a NUMA in keeping with the classification of the Wallanbah void. The low wall will undergo stabilisation works to ensure it can be managed in a way that minimises risk to the environment. The methodology for the low wall remediation will be:

- dozer to clear existing vegetation ~ 80m from the crest of the low wall to the west;
- topsoil to be stripped and retained in temporary stockpiles;
- blast holes drilled to ~ 40–60m depth and loaded for blasting;
- blasted material to be dozer pushed between 1:5 (min) and 1:3 (max) slope grade to form a continuous slope from the crest to a bench above the existing water level;
- safety bund (dimensions are likely up to 2m high and 10m wide) to be installed at the toe of the slope once dozer push is completed;
- a contour bank to be installed by dozer and ~ 6.4m wide (1 x D11 blade width) that allows water to drain to the south and then into a drop structure that enters into the final void at water level;
- topsoil will be spread from the crest to the bench above the water level (excluding the toe bund);
- the dozer will deep rip (0.8–1m), fertilise and seed (pasture and trees) along the contour of the slope; and
- low wall crest fence (4 x strand barbed wire) will be installed that joins the northern end wall and current southern low wall fence.

3.6.3.11 Ability of pits to support aquatic communities

As part of the KCB final void hydrology study and WBM report, GAUGE prepared a high-level discussion on the capability of the final voids to support flora and fauna. This report is a requirement of condition F7 of the EA. Key outcomes of the pit study are outlined below.

- four pits within Broadmeadow, Bullock, Plumtree and Wallanbah Pits are proposed to remain as part of the final landform and are expected to maintain permanent pit lakes;
- water levels within the pits are expected to reach equilibrium in approximately 80 years time, however, equilibrium may be reached sooner in Wallanbah Pit;
- once equilibrium has been reached, the pit lakes are expected to fluctuate around a steady-state equilibrium level in response to periods of flood and drought. No pits are expected to reach levels that would result in overflow into downstream watercourses via surface pathways (ie no water levels above the original natural ground level and spoil crest level);
- fluctuations in the pit lake water quality (ie EC levels) will continue to occur and be driven by climatic variability as cycles of above and below average rainfall result in rapid water quality fluctuations (ie timeframe of years to tens of years) when compared with long-term trends of gradual accumulation of metals and metalloids (ie timeframes of hundreds of years);

- the predicted salinity of the pits is expected to support native flora and fauna, including fish, invertebrates, macrophytes, algae, amphibians and birdlife, and not affect fringing vegetation;
- the pits will provide a permanent aquatic habitat to serve as a wildlife refuge in an otherwise highly ephemeral system;
- the aquatic community will be limited in diversity to those species with at least a moderate salt tolerance. The more saline Bullock Creek Pit will primarily support highly salt tolerant species and is likely to have very low diversity. The variety of species and the number of individuals present will be cyclical in nature, with more diverse taxa recruited when salinities are lowest, and transitioning to a less diverse, salt tolerant community during extended dry periods when salinities increase to maximum concentrations and with seasonal changes from salinity stratification;
- structural features of the pits enhance the aquatic habitat by providing a more suitable and diverse physico-chemical and physical habitat. The key features for improvement are the inclusion of:
  - significant areas of shallow, littoral zones;
  - a stable and vegetated riparian zone;
  - the presence of water plants in the littoral zone;
  - the presence of diverse aquatic structures; and
  - access to periodic fresh water inputs, preferably with connection to local waterways if practical and safe.

3.6.4 Underground mining

No underground mining has occurred or is planned.

3.6.5 Built infrastructure

3.6.5.1 Decommissioning and removal

All infrastructure will be removed from the Mine prior to relinquishment unless a written agreement is obtained from a future land holder stating that they will accept the asset. For example, the demountable buildings that make up the Mine office will be removed from their current location and remaining hard pads including vehicle park-ups will be de-compacted and rehabilitated.

Once infrastructure has been removed the area will be remediated (if required) and rehabilitated to grazing land with areas of bushland habitat. The following decommissioning strategy will be used:

- review of services plan to identify underground services;
- isolation of all energy sources;
- all chemical and materials storages and services emptied and decontaminated;
- completion of contaminated land assessment (phase 1 and phase 2 assessment); and
- removal and appropriate re-use, recycling or disposal of all dangerous goods and hazardous substances.

At the end of decommissioning a report will be prepared verifying that potentially contaminated land has been remediated as required.

Where practicable, consideration will be given to *Waste — Everyone's responsibility: Queensland Waste Avoidance and Resource Productivity Strategy* (2014–2024) (EHP 2014) waste and resource management hierarchy, in decreasing order of preference as shown in Figure 27.

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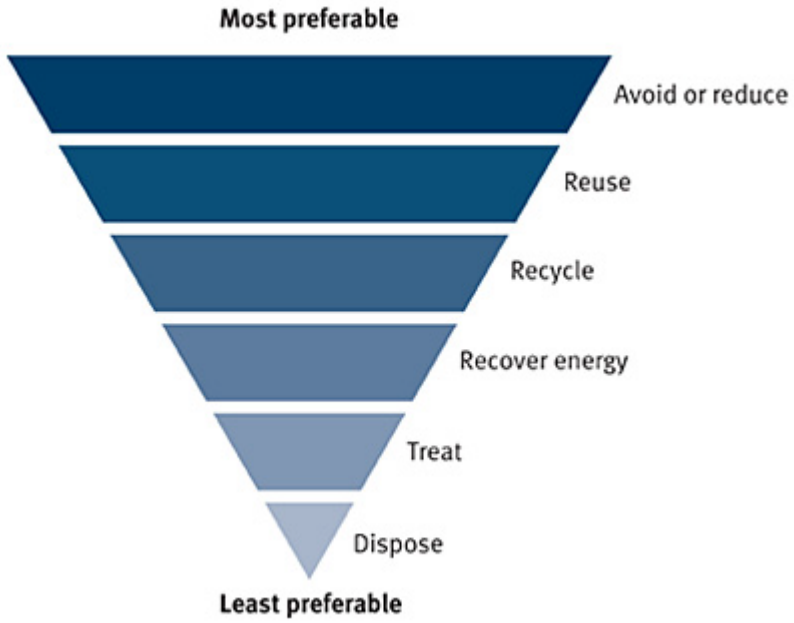

Figure 27 Waste and resource management hierarchy

3.6.5.2 Contaminated land management

A desktop assessment since ML de-amalgamation has been completed by GHD in 2017 (Appendix Q). The GHD assessment found very little potential for land contamination within the land that was retained by Peabody. There however, remains limited potential for contamination at the fuel storage and in the land immediately surrounding the current administration buildings.

If contaminated soils or other potential sources of contamination are found during the decommissioning and removal of buildings it will be preferentially treated at the Mine. If contamination cannot be treated, then it may be disposed of at an authorised facility. Treatment versus off-site disposal will depend on whether the land is listed on the *Contaminated Land Register* (CLR) and *Environmental Management Register* (EMR) (administered by the Qld Government) and whether it is deemed appropriate to have them removed from the registers as part of the rehabilitation process.

The process for assessing and adding / removing land from the CLR will need to be confirmed with DES at the time of rehabilitation.

Under the current Qld Government system, the following general phases will need to be completed by an appropriately qualified person (AQP):

- have a suitable qualified person complete a stage 1 and / or stage 2 contaminated land assessment;
- if there is no contamination then the suitably qualified person will produce a report for submission to DES requesting that the land be removed from the CLR; or
- if the contaminated site still contains contaminated soil, but it is being appropriately managed then the suitably qualified person can reflect this in their report — this may still allow the land to be removed from the CLR.

Should a significant area of contamination be identified a review of ground and surface water data will be completed and a source, pathway, receptor and fate model to demonstrate that contamination of surface water and groundwater is not occurring.

The process for assessing and removing land from the EMR will need to be confirmed with DES at the time of rehabilitation as this system is currently under review. It is however likely that in addition to a report from a

suitably qualified person an additional review and report will be required from one of DES's authorised third-party-reviewers to verify the AQP report.

3.6.5.3 Visual

De-amalgamated sections of the Mine, under the management of New Hope Group are visible from Suttor development Road. However, rehabilitation within the Peabody ML's is not readily visible. Notwithstanding the Mine does contain several elevated and rehabilitated spoil storage areas. The ground cover on the spoil storage areas has resulted in these landforms looking like the surrounding undisturbed grazing land.

3.6.5.4 Heritage

Cultural heritage material such as individual stone artefacts, artefact scatters and scarred trees will not be damaged in the rehabilitation process.

Plans for the management of the scar tree and artefacts garden post-relinquishment will be addressed through the consultation with the Traditional Owners.

3.6.6 Bushfire and spontaneous combustion

Spontaneous combustion of coal is a chemical fire which requires oxygen to fuel the fire and moisture to transfer heat, ie spread the fire. There is no recorded history of spontaneous combustion at the Mine.

Methods for bushfire management will be addressed as part of the post-closure management plan.

3.6.7 Methods to rehabilitate land to a stable condition

3.6.7.1 Voids

The rehabilitation methodology for voids is given in section 3.6.3.10.

3.6.7.2 ROM coal stockpiles

There are no remaining ROM coal stockpiles at the Mine. All ROM stockpiles have had coal material removed and disposed of as per section 3.6.1.6.

3.6.7.3 WRDs

Most WRDs at the Mine have been previously rehabilitated. Some areas of dump are still to be reshaped at Plumtree and Wallanbah. These areas will be reshaped to design using a dozer. The remaining faces will be re-contoured to a maximum stable slope angle of (20% (11.3°) or less) which will resemble the surrounding landscape. Once re-contoured the feature will be ripped, soiled and seeded.

3.6.7.4 MIA and hardstands

Actions to rehabilitate the MIA are:

- do a potential contamination assessment to see if there is any actual contamination;
- remove any remaining infrastructure, materials or equipment for their salvage and scrap value;
- treat contaminated soils if required and dispose of any remaining infrastructure and contamination to a licensed off-site facility;
- do a clean-up validation assessment having regard for *National Environment Protection measures* (NEPM);
- scrape and deep rip the feature; and
- spread soil and seed.

3.6.7.5 Roads

All dirt roads will have gravel sheeting removed (if needed), followed by re-contouring to the surrounding gradient, ripped, soiled and seeded.

Bitumen roads will have the pavement removed and disposed of according to licence conditions prior to being rehabilitated in the same manner as dirt roads.

3.6.7.6 Topsoil stockpiles

Topsoil stockpiles will be rehabilitated as they become available during other rehabilitation activities. Topsoil is not removed prior to stockpiling of soil meaning the original layer of topsoil will be present at the base of stockpiles. Depending on the depth of stockpiled soil, this base layer may require the addition of organic matter for effective vegetation establishment. The base layer will be treated (if necessary), ripped and seeded to a PMLU of grazing with areas of bushland habitat.

3.6.7.7 Water storage, supply and distribution

a Dams

All stored water in dams will be removed by solar evaporation. The structures will be backfilled using their embankments or other clean fill back to natural ground level. The feature will be ripped, soiled and seeded.

Once the Mine is rehabilitated there will be a potential for sediment to end up in the receiving environment after rainfall events. Sediment will likely discharge to Hat, Bullock or Sandy Creek which could impact the receiving environment; however, due to the ephemeral nature of the creeks and the fact that discharged sediment will not be contaminated, the impact of any discharge is likely to be small. Notwithstanding, mitigation by erosion and sediment control (ESC) structures, may be needed prior to relinquishment to further reduce this potential risk.

b Drains

Structures required for long term water management ie. permanent drains will be rehabilitated to blend in with the surrounding landscape and sustain a PMLU of grazing with areas of bushland habitat. This includes permanent drainage at Plumtree west, Bullock Creek highwall and Wallanbah highwall and end wall.

c Levees

The transition of levees into final landforms will be undertaken using the following methodology:

- existing flood models to be updated as per current guidelines to a 0.1% AEP;
- updated flood models to be used for a new Consequence Category Assessment (CCA) for each existing levee; and
- if one or all levees are re-classified as "low consequence" structures, and the current crest levels are above the 0.1% AEP an assessment will be conducted to determine if the levee walls can be re-graded from 1:3 to 1:5 as to achieve the final landform criteria. If successful, the regrading will be conducted by the onsite dozer(s) using GPS guidance.

Plumtree south

The Plumtree south levee will be regraded to achieve a 1:5 final landform criteria. This may also require the import of clean fill material to ensure the clay core of the constructed levee is not compromised. The surface will then be soiled and seeded. The levee will then remain as a final landform which aides in flood protection of the Plumtree void.

Bullock Creek

Two small levees (north and south) are constructed at Bullock Creek. The northern levee involved the backfilling of an excavation with competent, compacted material as the in-situ material was not considered suitable. This means the levee is actually below ground with the top being level with the current ground level. The area has been topsoiled and seeded to a PMLU of grazing with areas of bushland habitat.

The southern levee is adjacent to the Bullock Creek diversion and essentially forms part of the diversion bank. The levee currently has 1:4 batters and is less than 150m in length. Options to widen the levee to a 1:5 batter are limited due to the Bullock Creek diversion banks. Given the dimensions and location of the southern levee no further works are planned. The levee has been topsoiled and seeded to a PMLU of grazing with areas of bushland habitat and is considered rehabilitated.

Broadmeadow north-west

The Broadmeadow north-west levee will be regraded to achieve a 1:5 final landform criteria. Excess fill from the Spade Creek diversion works will be used to expand the current levee structure to the required final landform. The surface will then be soiled and seeded. The clay core of the levee will remain intact to continue to provide flood protection to the Broadmeadow void.

Broadmeadow south

The Broadmeadow south levee has been included in the area of the Broadmeadow void and designated as a NUMA as per section 3.3.2.4.

d Distribution

Water distribution equipment, including pipelines, will be removed and disposed of in accordance with licence conditions or reused off-site.

3.6.7.8 Riparian areas

The riparian PMLU around Spade Creek will be carried out in accordance with the *Spade Creek Diversion Project — Revegetation Plan* (Alluvium, 2020) (Appendix H).

3.6.7.9 Self-sustaining native vegetation

The revegetation of the Bullock Creek ERE area (self-sustaining native vegetation) has been carried out in accordance with the *Burton ERE Revegetation Management Plan* (AECOM, 2018) (Appendix R).

3.6.7.10 Exploration

The closure and rehabilitation of all exploration activities including drill holes, sumps, exploration tracks, and gridlines will be done in accordance with Section 16 of the EP Act, provisions under the *Water Act 2000* and *Eligibility criteria and standard conditions for exploration and mineral development projects — Version 2*.

Due to limited exploration activity exploration rehabilitation is expected to be minimal. Areas will be progressively rehabilitated where practicable.

3.6.7.11 Rehabilitation maintenance

Maintenance of rehabilitated areas must take place to ensure and demonstrate:

- stability of landforms;
- erosion control measures remain effective;
- stormwater runoff and seepage from rehabilitated areas does not impact the environmental values of any waters; and
- vegetation show healthy growth and recruitment is occurring and rehabilitated areas are managed regarding declared pest plants.

Maintenance activities on rehabilitation areas will be guided by general site inspections and rehabilitation monitoring results. Maintenance activities may include:

- maintenance of new vegetation, eg addition of fertiliser, re-planting of significant areas of failed vegetation, etc, prior to its establishment within the ecosystem;
- repair of failed drainage or significantly eroded areas;
- modifications to landforms or structures to improve management of surface water runoff;
- upkeep of water management structures;
- removal of temporary drainage structures not required for long-term stability; and
- replacement and repairs to fencing and signage.

3.7 Risk assessment

Identifying environmental, community, social and economic impacts and risks associated with closure and rehabilitation is critical for effective closure and rehabilitation planning. The overall objective of the closure and rehabilitation risk assessment (the risk assessment) is to identify risks of a stable condition for land not being achieved and how BCC intends to manage or mitigate the identified risks in accordance with Section 126C(1)(f) of the EP Act. The meaning of a 'stable condition' is given in Section 111A of the EP Act:

111A Meaning of a stable condition

Land is in a stable condition if —

a) the land is safe and structurally stable; and

b) there is no environmental harm being caused by anything on or in the land; and

c) the land can sustain a post-mining land use.

The risk assessment was developed considering the standard *AS ISO 31000:2018 Risk Management — Guidelines*. Risks and opportunities were identified for all decommissioning, demolition and closure and rehabilitation related activities that are yet to have occurred, or already have occurred at the Project. The post closure and rehabilitation monitoring periods were also included. The risk management process is shown in Figure 28.

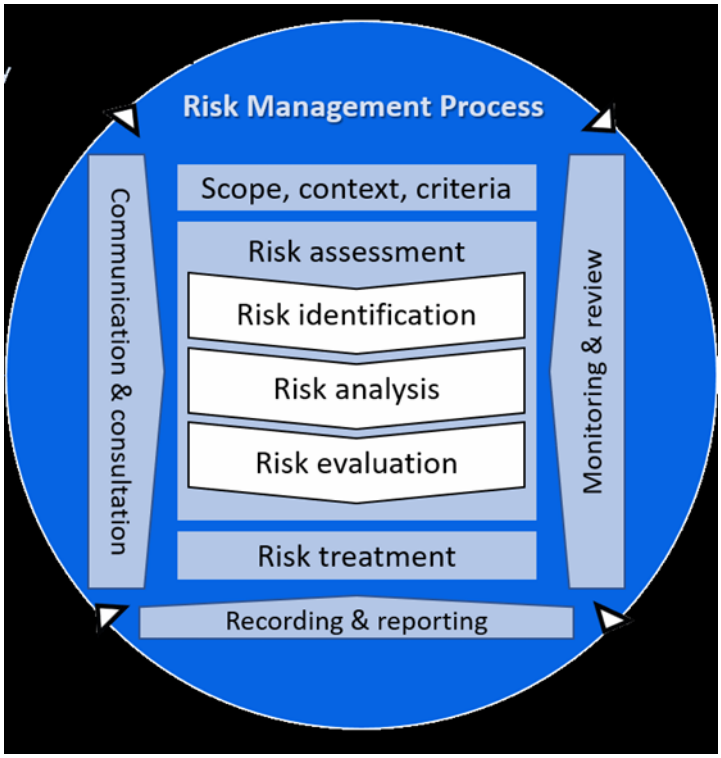

Figure 28 Risk management process overview

3.7.1 Risk identification

The risk identification step was used to:

- identify and define risks to land being safe and structurally stable;
- identify and define risks which have the potential to adversely affect EVs; and
- identify and define risks to land sustaining the PMLU.

3.7.2 Risk analysis

The risk analysis process considered the maximum probable outcome for each identified risk with the current control measures in place. Each identified risk was then analysed using the consequence categories and associated criteria given in Figure 29 and the likelihood categories in Figure 30. This determined the risk rankings also given in Figure 30.

The 'Environmental' consequence category from the Peabody standard consequence table was the only category considered during the risk assessment process. This is to ensure that only environmental risks associated with land not achieving a stable condition are considered, as per the requirements of the PRC guideline. This consequence category was further broken down into three broad categories based on the EP Act definition of a 'stable condition'. These categories are:

- safe and stable;
- impact to environmental values (EV's); and
- impact to the potential PMLU.

	Consequence descriptions					
Consequence Category	1 - Low	2 - Minor	3 - Moderate	4 - Significant	5 - Major	6 - Catastrophic
Harm to People	Near miss, near hit, no medical treatment, report only (RO)	Slightly injured, first aid treatment (FAI)	Medical treatment (MTI), disabling reversible impairment, restricted work (RWI) or lost time (LTI)	Serious bodily injury or disabling irreversible impairment, permanent partial disability (PPD)	Single fatality incident. Total and permanent disability (TPD). Major irreversible health effects	Multiple fatality incident. Major injury / disease among multiple employees
Environmental	• Negligible or reversible environmental impact • Nil to minor remediation (typically a shift) • No breach of regulations or requirement to report to regulators	• Minor reversible environmental impact • minor remediation (typically< 5 days) • Non-compliances and breaches of regulation that may result in a citation (NOV) • May require reporting to the regulators	• Incident resulting in moderate reversible onsite and/or off-site impact causing short term effect • Moderate remediation required (typically a month) • Non-compliances and breaches of regulation that may result in prosecution or citation or punitive fine. • Requirement or obligation to report to the regulators	• Incident resulting in significant onsite or off-site environmental impact causing medium to long term environmental harm • Significant remediation required (typically less than 12 months) • Significant legal issues, non-compliances and breaches of regulation that results in a prosecution or citation or fine • Moderate litigation issues involving many weeks of senior management time	• A major incident resulting in regional environmental impact causing long term environmental harm • Major long term remediation required (greater than 12 months) • Major litigation or prosecution resulting in long term interruption to operations or loss of licence at a site	• Incident resulting in catastrophic widespread regional environmental harm causing disastrous effect • Major long term remediation required (over multiple years) • Major litigation or prosecution , Loss of License to operate at Multiple sites
Finance (higher of cost or NPV)	<$10,000	$10,000 - $100,000	$100,000 - $1 mil	$1 mil - $20 mil	$ 20 mil-$100 mil	>$100 mil
Impact on reputation	Minor impact, no public concern; Market cap impact < $20 M (< $0.07 per share)	Local media or public concern; Market cap impact $20 M - $30 M ($0.07 - $0.12 per share)	Regional media or public concern. Local criticism; Market cap impact $30 M - $100 M ($0.12 - $0.40 per share)	National adverse media or public criticism; Market cap impact $100 M - $250 M ($0.40 - $1.00 per share)	International adverse media or public criticism. International public concern; Market cap impact $250 M - $500 M ($1.00 - $1.85 per share)	Significant international public or media criticism or condemnation; Market cap impact > $500 M (> $1.85 per share)
Law / Compliance / regulatory	Minor, one-off violations of law, regulation, permit or policy; minimal fines, penalties or costs.	Recurring or systemic minor violations of law, regulation, permit or policy.	Violations of law, regulation, permit or policy with moderate fines or penalties, Moderate Litigation, MSHA imminent danger order or similar	Significant violation of law or permit with material fines, penalties or costs. Serious dispute with strategic customer. Major Litigation.	Material Litigation. Serious investigation by SEC, DOJ or foreign equivalent. Code of Conduct violations.	Criminal investigation or proceedings involving officers or directors. Litigation with allegations of executive fraud or misappropriation
Strategic risk	Event does not have a meaningful impact to Strategic Outlook	Event does not have meaningful impact to Strategic Outlook, but may require further monitoring	Event may have a material impact on near-term outlook for a region or mine	Event has a material impact on strategic outlook for a region or basin that may require a change to operations to mitigate risk	Event causes mines in a region or basin to cease current operations	Event or threat such that BTU would cease to exist as an ongoing concern in coal operations

Figure 29 Consequence table

			Consequence					
Likelihood	Likelihood description	Probability	1 - Low	2 - Minor	3 - Moderate	4 - Significant	5 - Major	6 - Catastrophic
5 - Very Likely	Likely to occur repeatedly - Expected in the work team	10% - 100%	5	10	25	50	125	250
4 - Likely	Probably will occur several times - Expected at this location	1% - 10%	4	8	20	40	100	200
3 - Possible	Could occur intermittently - Expected within Peabody	0.1% - 1%	3	6	15	30	75	150
2 - Unlikely	Could occur but hardly ever - Expected within the mining industry	0.01% - 0.1%	2	4	10	20	50	100
1 - Rare	Improbable or unrealistic - Not expected in the mining industry but seen in other industries	< 0.01%	1	2	5	10	25	50

Figure 30 Likelihood table and risk matrix

3.7.3 Risk evaluation

Risk evaluation involves comparing the results of the risk analysis with the establishment of risk criteria to determine where additional action is required. Additional actions may include:

- do nothing further;
- consider risk treatment options;
- undertake further analysis;
- maintain existing controls; or
- reconsider objectives.

Additional controls are always applied for calculated risk scores of 20 or above. Additional controls may also be applied for lower calculated scores as required. The results of the risk assessment are given in Table 32 and Table 33.

3.7.4 Risk treatment

Risk treatment involves evaluating options for the management or mitigation of identified risks. The most appropriate risk treatment options (proposed actions) have been selected based on multiple criteria including cost benefit, regulatory obligations, community responsibility and protection of EVs. Actions to apply these options have been allocated to the appropriate work parties, scheduled and performance measures and constraints identified.

3.7.4.1 Residual risk

The nominated treatment options have been assessed as adequate in reducing the original risk ranking to an acceptable level. The risk treatments and the remaining risk should be monitored and reviewed regularly with any significant changes or emerging issues communicated with relevant parties. Treatments may be modified, replaced, or complemented with additional treatments as needed to make sure an acceptable level of risk is maintained.

Table 32 Risk identification, analysis and evaluation — PMLU

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
RM1 - Infrastructure decommissioning and removal	Inadequate removal of infrastructure	Safe and stable	Infrastructure may create erosion points causing instability Remnant infrastructure is a hazard to fauna or grazing animals	2	3	6	Current mine plans show locations of planned infrastructure PRC plan includes infrastructure removal Infrastructure may only be retained with written landholder approval Infrastructure included in ERC	Including in PRC and ERC ensures a documented and auditable record of infrastructure removal requirements and provides direction for planning and provisioning.	Site management team	Survey support GIS support	Decommissioning checklist (to be developed)	Visual inspection	Following removal	2	2	4
RM2 – Remediation of contaminated land	Residual contamination of land	Impact to EV's	Contaminated soil and / or impacts to downstream water quality	4	2	20	PRC plans for identification, assessment and proper disposal of contaminated soil Allow for contaminated soil disposal in ERC Monitor incidents involving hydrocarbon or chemical spills Utilise site Spill Response Plan AS1940 audits and inspections Contaminated land assessment	The inclusion in PRC/ERC allows for proper budgeting and planning of contaminated soil disposal/treatment. Effective spill controls and auditing allows for high-risk areas to be identified and prioritised for treatment. A contaminated land assessment will verify if contamination has been appropriately remediated	Site management team	SAP EHSM system (incident recording) Spill response procedure Auditing and inspection tools - Contaminated land assessment (by AQP)	Contaminated land assessment	Contaminated land assessment to be completed post operations and included in the final relinquishment report	Prior to further earthworks	2	2	4
		PMLU	Contamination impacts PMLU	3	2	10								2	2	4

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
RM3 - Landform reshaping and final contouring	Excessive slope on landform	Safe and stable	Increased erosion risk if slope exceeds material limits	4	2	20	Current final landform slope designs within material limitations GPS guidance and survey control during landform construction GPS guidance and survey control during landform reshaping	Current slopes have been designed with regard to material limitations. GPS and survey controls will ensure the landform is constructed as per design.	Site management team	Survey support GPS machine guidance	Review of survey data vs design	As per section 3.8.3.4	During construction / annually	3	2	10
		PMLU	Steep slopes not suitable for cattle and / or landholder access	3	2	10	Current design slope within accepted limits for grazing / landholder access GPS guidance and survey control during landform reshaping Grazing trials	Landform slopes of equal to or less than 20% for grazing is well within limits for cattle and landholder access. GPS and survey controls will ensure the landform is constructed as per design. Rehabilitation monitoring to demonstrate suitability	Site management team	Survey support GPS machine guidance Rehabilitation monitoring data	Review of survey data vs design	As per section 3.8.3.4	Annually	2	2	4
	Structural stability of landforms not achieved	Safe and stable	Constructed landforms not geotechnically stable	4	2	20	Current design assessed as geotechnically stable Geotechnical monitoring during operations Ensure deviations from design are reassessed by a geotechnical engineer (AQP)	Landforms slopes are designed to be geotechnically stable for the construction (dumped) material. Monitoring during operations can be used to validate the proposed design and update if required.	Site management team	Geotechnical monitoring data	Review of monitoring data vs predicted behaviour	As per section 3.8.3.4	During construction / annually	3	2	10
	Ineffective drainage on final landform	Safe and stable	Damage to previously completed rehabilitation Increased likelihood of erosion	3	3	15	Drainage requirements included in final landform design Rehabilitation monitoring Erosion and sediment control (ESCP) monitoring	Rehabilitation planning and methodology includes effective drainage. Rehabilitation and ESCP monitoring will monitor effectiveness of landform drainage	Site management team	Rehabilitation monitoring program ESCP monitoring program	Monitoring data	As per section 3.8.4 and section 3.8.3.4	As per section 3.8.4 and section 3.8.3.4	3	2	10

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
			Ponding causes instability				-Receiving environment monitoring program (REMP)			REMP monitoring						
		Impact to EV's	Increased risk of downstream sedimentation	3	3	15								3	2	10
RM4 - Surface preparation	Insufficient topsoil reserves	PMLU	Inadequate topsoil to establish vegetation and support PMLU	4	3	30	Projected inventory of stripped topsoil adequate for rehabilitation Topsoil inventory and mapping to be maintained during operations Review of topsoil inventory against rehabilitation requirements Topsoil volumes and requirements will be included in ERC	Available volume of topsoil is adequate for rehabilitation of disturbed areas. Maintaining a topsoil inventory and mapping allows for regular checks against requirements including ERC.	Site management team	Survey support Topsoil inventory tool ERC calculator	Topsoil inventory tool and ERC volumes Survey support	Survey checks	After use of stockpile in rehabilitation	3	2	10
	Inadequate topsoil cover	PMLU	Failed vegetation establishment not supporting PMLU	3	2	10	Projected inventory of stripped topsoil adequate for rehabilitation GPS and survey control during topsoiling Supervision during topsoiling Test-pitting of topsoil depths prior to seeding	Survey and test -pitting checks to ensure minimum topsoil depth is applied	Site management team	Survey support Topsoil inventory tool	Topsoil depths (field verified) Survey data (eg. LiDAR)	Survey checks	Immediately following topsoiling	2	2	4
	Topsoil not suitable for target vegetation	PMLU	Topsoil unable to support target rehabilitation species	3	2	10	Topsoil management plan outlines topsoil stripping, handling and storage requirements Amelioration rates determined by an AQP	Rehabilitation species selected grow in surrounding areas and are suitable for the soil type. Appropriate management will maintain the integrity of the topsoil resource. Rehabilitation monitoring	Site management team	Topsoil management plan Survey support Topsoil inventory tool	Rehabilitation monitoring data	Rehabilitation monitoring report		2	2	4

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
							Rehabilitation monitoring includes soil analysis Rehabilitation trials	and trials will inform success		Rehabilitation monitoring program Rehabilitation trials						
RM5 - Revegetation (grazing with areas of bushland habitat)	Inadequate ripping (not completed, downslope or insufficient depth)	Safe and stable	Topsoil not keyed into subsoil allows excessive erosion or downslope rip lines create erosion channels	3	2	10	Rehabilitation methodology includes cross slope ripping Supervision during ripping operations Visual inspection of ripped surface ESCP monitoring	Supervision during ripping to ensure correct direction and depth is achieved. Inspections following ripping provide visual confirmation.	Site management team	Rehabilitation monitoring program ESCP monitoring	Rehabilitation monitoring data ESCP monitoring data	Visual inspection	Immediately after ripping	2	2	4
	Heavy rainfall prior to vegetation establishment	PMLU, safe and stable	Loss of topsoil resource preventing adequate vegetation establishment, excessive erosion and instability of slope	3	3	15	Seeding to be scheduled immediately following surface preparation Seeding not scheduled prior to large rain events Cover crop included in seed mix	Appropriate timing of topsoiling/seeding reduces the risk of weather impacting vegetation establishment	Site management team	PRC schedule	PRC schedule audits	As required	As required	2	3	6
	Seed quality or application not sufficient for vegetation establishment	PMLU	Vegetation does not adequately establish to support PMLU	3	3	15	Seed mix and rate based on local conditions Seed quality and viability testing included in procurement Rehabilitation monitoring	AQP input into seed mixes allows for a better chance of successful rehab Seed quality testing will allow for better strike rate Rehabilitation monitoring will inform success of methodology	Site management team	Seed quality and validation tests Rehabilitation monitoring program	- Test results	Monitor prior to seeding	Prior to seeding	2	3	6
RM6 - Revegetation (self-sustaining native vegetation and	Heavy rainfall prior to vegetation establishment	PMLU, safe and stable	Loss of topsoil resource preventing adequate vegetation establishment,	3	3	15	Seeding to be scheduled immediately following surface preparation Seeding not scheduled prior to large rain events	Appropriate timing of topsoiling/seeding reduces the risk of weather impacting vegetation establishment.	Site management team	PRC schedule ESCP controls	PRC schedule audits ESCP monitoring / inspections	ESCP inspections and monitoring	Periodically during works or before forecast rain	2	3	6

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
RM7 - Achievement of surface requirements (riparian)	Seed quality or application not sufficient for vegetation establishment		Excessive erosion and instability				Cover crop included in seed mix Employ appropriate erosion and sediment controls	ESCP controls to manage the risk of soil loss during establishment								
		Impact to EV's	Increased sediment in downstream environment	4	3	30								3	3	15
		PMLU	Vegetation does not adequately establish to support PMLU	3	3	15	Seed mix and rate based on local conditions Seed quality and viability testing included in procurement Rehabilitation monitoring	AQP input into seed mixes allows for a better chance of successful rehab Seed quality testing will allow for better strike rate Rehabilitation monitoring will inform success of methodology	Site management team	Seed quality and validation tests Rehabilitation monitoring program	Test results	Monitor prior to seeding	Prior to seeding	2	3	6
		Impact to EV's	Increased sediment in downstream environment	3	3	15	Seeding not scheduled prior to large rain events Cover crop included in seed mix Employ appropriate erosion and sediment controls	ESCP controls to manage the risk of soil loss during establishment	Site management team	PRC schedule ESCP controls	PRC schedule audits ESCP monitoring / inspections	ESCP inspections and monitoring	Periodically during works or before forecast rain	2	3	6
	Tubestock does not establish	PMLU, impact to EVs	Vegetation does not adequately establish to support PMLU Long term stability issues	4	3	30	Tubestock sourced locally if possible Watering system for tubestock Rehabilitation monitoring	Local tubestock better suited to conditions Waster required for effective establishment Rehabilitation monitoring	Site management team	Water system and reliable water source	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	3	6
	Inadequate vegetation cover for riparian	PMLU	Vegetation not sufficient for / consistent with the PMLU Excessive grass growth inhibits tree	3	3	15	Seed mix and rate based on local conditions and PMLU Minimal grass in seed mix Rehabilitation monitoring to inform potential changes to mix or application rate	Seeding mix is specific to the establishment of riparian zones. Monitoring will inform success and potential changes to methodology.	Site management team	Rehabilitation monitoring program	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	3	6

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
			and shrub establishment													
	Groundcover not sufficient for surface stabilisation	Safe and stable	Inadequate groundcover establishment causes excessive erosion rates	3	2	10	Seed mix and rate based on local conditions Cover crop included in seed mix Rehabilitation monitoring	Species selection includes appropriate groundcover species. Rehabilitation monitoring will inform success.	Site management team	Rehabilitation monitoring program	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	3	6
	Revegetated areas dominated by weeds	PMLU	Weeds	3	3	15	Seed testing included in procurement Weed inspections of rehabilitation machinery Rehabilitation monitoring Weed management plan to be implemented	Seed testing to verify the quality of seed and the absence of weed species. Inspection and cleaning of equipment to help stop spread of weed species. Weed management plan to outline management options.	Site management team	Rehabilitation monitoring program Equipment inspection checklist Weed management plan	Rehabilitation monitoring data	As per section 3.8.5	As per section 3.8.5	2	3	6
		Impact to EV's	Untreated weed outbreaks impact surrounding land	3	2	10	Weed inspections of rehabilitation machinery Rehabilitation monitoring							2	2	4
RM8 – Achievement of surface requirements (grazing with areas of bushland habitat)	Inadequate vegetation cover for grazing with areas of bushland habitat	PMLU	Vegetation cover insufficient to support the PMLU	3	3	15	Seed mix and rate based on local conditions and PMLU Rehabilitation monitoring to inform potential changes to mix or application rate	Seed mix is consistent with surrounding grazing land and other mine rehabilitation in the Bowen Basin.	Site management team	Rehabilitation monitoring program	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	3	6

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
RM9 - Achievement of surface requirements (self-sustaining native vegetation)	Groundcover not sufficient for surface stabilisation	Safe and stable	Inadequate groundcover establishment causes excessive erosion rates	3	2	10	Seed mix and rate based on local conditions Cover crop included in seed mix Rehabilitation monitoring	Species selection includes appropriate groundcover species. Rehabilitation monitoring will inform success.	Site management team	Rehabilitation monitoring program	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	3	6
	Revegetated areas dominated by weeds	PMLU	Weeds	3	3	15	Seed testing included in procurement Weed inspections of rehabilitation machinery Rehabilitation monitoring Weed management plan to be implemented	Seed testing to verify the quality of seed and the absence of weed species. Inspection and cleaning of equipment to help stop spread of weed species. Weed management plan to outline management options.	Site management team	Rehabilitation monitoring program Equipment inspection checklist Weed management plan	Rehabilitation monitoring data	As per section 3.8.5	As per section 3.8.5	2	3	6
	Erosion rates exceed accepted levels	Safe and stable	Excessive erosion causes instability of landform	3	3	15	Landforms designed based on erosion modelling Landform constructed to specification Revegetation plan to establish cover ESCP and drainage controls	Landforms are designed and constructed with appropriate slope angles for material type. Establishment of vegetation and monitoring are strong controls for remediating erosion before it starts	Site management team	LiDAR survey	As per section 3.8.3.4	As per section 3.8.3.4	As per section 3.8.3.4	2	3	6
	Inadequate vegetation cover for grazing with areas of bushland habitat	PMLU	Vegetation cover insufficient to support the PMLU	3	3	15	Seed mix and rate based on local conditions and PMLU Rehabilitation monitoring to inform potential changes to mix or application rate	Seed mix is consistent with surrounding grazing land and other mine rehabilitation in the Bowen Basin.	Site management team	Rehabilitation monitoring program	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	3	6

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
RM10 & RM11 - Achievement of PMLU to a stable condition (grazing with areas of bushland habitat, riparian and self-sustaining native vegetation)	Groundcover not sufficient for surface stabilisation	Safe and stable	Inadequate groundcover establishment causes excessive erosion rates	3	2	10	Seed mix and rate based on local conditions Cover crop included in seed mix Rehabilitation monitoring	Species selection includes appropriate groundcover species. Rehabilitation monitoring will inform success.	Site management team	Rehabilitation monitoring program	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	3	6
	Revegetated areas dominated by weeds	PMLU	Weeds	3	3	15	Seed testing included in procurement Weed inspections of rehabilitation machinery Rehabilitation monitoring Weed management plan to be implemented	Seed testing to verify the quality of seed and the absence of weed species. Inspection and cleaning of equipment to help stop spread of weed species. Weed management plan to outline management options.	Site management team	Rehabilitation monitoring program Equipment inspection checklist Weed management plan	Rehabilitation monitoring data	As per section 3.8.5	As per section 3.8.5	2	3	6
	Erosion rates exceed accepted levels	Safe and stable	Excessive erosion causes instability of landform	3	3	15	Landforms designed based on erosion modelling Landform constructed to specification Revegetation plan to establish cover ESCP and drainage controls	Landforms are designed and constructed with appropriate slope angles for material type. Establishment of vegetation and monitoring are strong controls for remediating erosion before it starts	Site management team	LiDAR survey	As per section 3.8.3.4	As per section 3.8.3.4	As per section 3.8.3.4	2	3	6
	Lack of rehabilitation maintenance ie. repair of significant erosion	Safe and stable	Excessive erosion progressively impacts stability of final landform	4	3	30	Rehabilitation monitoring determines maintenance requirements Rehabilitation maintenance program	Regular monitoring and maintenance of rehabilitation allows issues to be addressed promptly.	Site management team	Rehabilitation monitoring and maintenance program	As per section 3.8.3.4	As per section 3.8.3.4	As per section 3.8.3.4	3	3	15
	Inappropriate final land use	PMLU	Loss of land resource and conflict with stakeholder engagement outcomes	3	2	10	Soils and rehabilitation design assessed as suitable for the PMLU's PMLU's compatible with surrounding land uses Rehabilitation monitoring	The selected PMLU's are consistent with surrounding land uses and would be expected to be suitable	Site management team	Rehabilitation monitoring program	Rehabilitation monitoring data	As per section 3.8.4	As per section 3.8.4	2	2	4

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
	Rehabilitation vegetation lost or damaged due to bushfire	Impact to EV's	- Loss of biodiversity - Damage to previously completed rehabilitation	3	3	15	Rehabilitation monitoring Bushfire management Selective grazing	Rehabilitation monitoring will identify areas requiring grazing or fire management to reduce fuel load	Site management team	Rehabilitation monitoring program Bushfire management plan	Visual inspection and as per section 3.8.4	Visual inspection and as per section 3.8.4	Visual inspection and as per section 3.8.4	2	3	6
	Surface water runoff causes environmental harm	Impacts to EV's	Environmental harm from contaminated runoff	4	2	20	Surface water monitoring	Monitoring to provide early indication of potential contamination	Site management team	Surface water monitoring program	As per section 3.8.2	As per section 3.8.2	As per section 3.8.2	3	2	10
	GW contamination from rehabilitated area	Impacts to EV's	Contamination of groundwater	4	3	30	GW monitoring	Monitoring to confirm modelling predictions of low risk to groundwater or to provide an early indication of potential issues	Site management team	GW monitoring program	As per section 3.8.3	As per section 3.8.3	As per section 3.8.3	3	2	10
	Area does not meet same condition as reference sites	PMLU	Delay in achievement of stable condition	3	2	10	-BioCondition monitoring	BioCondition monitoring provides a quantitative measure of rehabilitation performance against reference sites	Site management team	BioCondition monitoring program	As per section 3.8.4	As per section 3.8.4	As per section 3.8.4	2	2	4
	Failure of levee – Plumtree	Safe and stable	Flood waters enter void causing wall instability	4	2	20	Levee designed and certified by an AQP Levee designed for a PMF flood event Ongoing monitoring of flood levels against levee design height	Levees are designed and constructed for rare flood events expected in the area. Ongoing inspection by AQP to confirm stability assumptions	Site management team	Revised flood modelling Inspection program	Assess levee height against recalculated flood heights As per section 3.8.3.4 AQP inspections	As required As per section 3.8.3.4 AQP inspections	Annually As per section 3.8.3.4 As per AQP recommendations	3	2	10
	Failure of levee – Bullock Creek	Safe and stable		4	2	20								3	2	10
	Failure of levee – Broadmeadow	Safe and stable		4	2	20	Monitoring of levee stability by AQP							3	2	10

Table 33 Risk identification, analysis and evaluation — NUMA

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
MM1 - Wall treatments	Highwall (HW) and / or low wall (LW) and / or end wall (EW) does not achieve geotechnical stability	Safe and stable	HW, LW or EW not geotechnically stable and not considered safe	5	3	75	Current pit structures assessed as geotechnically stable by an AQP Ongoing monitoring and assessment	Current configuration assessed as geotechnical stable by an AQP. Pit structures have been in place for a long time and have been monitored in that time. No major failures have been recorded in recent monitoring	Site management team	Geotechnical monitoring program	Review of monitoring data vs predicted behaviour	As per section 3.8.3.4	Annually	5	2	50
	HW drain failure – Bullock Creek	Safe and stable	Capture of overland flow into Bullock Creek void impacting stability of highwall	5	2	50	HW drain designed by an AQP HW drain outside of geotechnical standoff area	Drain designed by an AQP for local flood events. Drain has been positioned outside of zone of potential instability	Site management team	Monitoring data	Monitoring program	As per section 3.8.3.4	Annually	3	2	10
	HW / EW drain failure - Wallanbah	Safe and stable,	Capture of overland flow into Wallanbah void impacting stability of highwall	5	3	75	-HW / EW drain designed by an AQP HW / EW drain outside of geotechnical standoff area	Drain designed by an AQP for local flood events. Drain has been positioned outside of zone of potential instability	Site management team	Monitoring data	Monitoring program	As per section 3.8.3.4	Annually	5	2	50

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
MM2 – Achievement of surface requirements / access controls		Impact to EV's	Capture of overland flow into Wallanbah void impacts water balance and causes seepage through southern alluvial material	4	2	20	HW / EW drain designed by an AQP HW / EW drain outside of geotechnical standoff area	Drain designed by an AQP for local flood events. Drain has been positioned outside of zone of potential instability	Site management team	Monitoring data	Monitoring program	As per section 3.8.3.4	Annually	3	2	10
	Fencing / bunding not installed r ineffective	Safe and stable	Un-bunded / unfenced areas pose a risk humans or livestock	4	3	30	Abandonment bund setback distance is in accordance with calculated geotechnical factor of safety Abandonment bund constructed of competent material and to geometry specified to prevent traversing by vehicles Fencing erected on the outside of the abandonment bund to specification (nominally four strand barbed stock fencing) Safety signage (design in accordance with Australian Standard) erected at specified intervals along the	Sufficient abandonment bund, fencing and signage is an effective method of reducing potential interaction with the residual void	Site management team	Final bunding and fencing plan	Visual inspection	Visual inspection	Regularly during construction / post rain events / monthly	3	2	10

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
							fence line (nominally one sign every 100m) Bunding, fencing and signage provisioned in ERC									
	Flood impacts on final void - Plumtree	Impact to EV's	Capture of overland flow and potential release of contaminants	5	2	50	PMF levee on the north (spoil dump) and western sides	Levees are designed and constructed for rare flood events expected in the area. Ongoing inspection by AQP to confirm stability assumptions	Site management team	Revised flood modelling Inspection program	Assess levee height against recalculated flood heights As per section 3.8.3.4 AQP inspections	As required As per section 3.8.3.4 AQP inspections	Annually As per section 3.8.3.4 As per AQP recommendations	4	2	20
	Flood impacts on final void – Bullock Creek	Impact to EV's	Capture of overland flow and potential release of contaminants	5	3	75	PMF levee adjacent to Bullock Creek	Levees are designed and constructed for rare flood events expected in the area. Ongoing inspection by AQP to confirm stability assumptions	Site management team	Revised flood modelling Inspection program	Assess levee height against recalculated flood heights As per section 3.8.3.4 AQP inspections	As required As per section 3.8.3.4 AQP inspections	Annually As per section 3.8.3.4 As per AQP recommendations	4	2	20
	Flood impacts on final void - Wallanbah	Impact to EV's	Capture of overland flow and potential release of contaminants	5	3	75	End wall and highwall drain take overland flow away Not in a flood plain	-Not impacted by floodwaters but overland flow Drains divert water into void in a controlled manner	Site management team	Inspection program	Drainage performance	As per section 3.8.3.4 AQP inspections (water / drainage expert)	Annually / Regularly during and before wet season	4	2	20

Milestone	Risk / threat	Consequence category	Impact	Risk evaluation			Proposed controls	Justification of treatment option	Responsibility	Resource requirements	Performance measures	Reporting and monitoring	Timing and scheduling	Residual risk		
				Consequence	Likelihood	Risk score								Consequence	Likelihood	Risk score
MM3 – Achievement of sufficient improvement	Flood impacts on final void - Broadmeadow	Impact to EV's	Capture of overland flow and potential release of contaminants	5	3	75	PMF levee on southern end wall 0.1% AEP levee on western low wall	Levees are designed and constructed for rare flood events expected in the area. Ongoing inspection by AQP to confirm stability assumptions	Site management team	Revised flood modelling Inspection program	Assess levee height against recalculated flood heights As per section 3.8.3.4 AQP inspections	As required As per section 3.8.3.4 AQP inspections	Annually As per section 3.8.3.4 As per AQP recommendations	4	2	20
	Residual void water quality causes environmental harm	Impact to EV's	Residual void water causes harm to environmental values	5	3	75	- Final void water modelling indicates minimal risk to receiving environment No identified users of groundwater in the area GW monitoring	Modelling indicates minimal risk which will be validated by ongoing monitoring	Site management team	GW monitoring program	GW monitoring data	As per section 3.8.3	As per section 3.8.3	4	2	20
	Inadequate vegetation / stabilisation of Wallanbah LW	Safe and stable	Wall continues to erode into void	4	4	40	LW to be reshaped to a more stable angle Successful vegetation will help stabilise slope Ongoing monitoring	Successfully establishing vegetation is the most effective method for minimising erosion	Site management team	Specialised revegetation plan	LiDAR Geotechnical inspections Rehabilitation monitoring	As per section 3.8.3.4 and section 3.8.6	As per section 3.8.3.4 and section 3.8.6	4	3	30

3.8 Monitoring and maintenance

3.8.1 Milestone monitoring

The following sections of the PRC plan describe monitoring and maintenance activities that will be done post-rehabilitation. Information collected during monitoring will demonstrate that the rehabilitation criteria have been met and contribute to satisfying DES's decision to progress surrender of the EA.

The post-rehabilitation phase will start when all rehabilitation activities specified in section 3.6 of this PRC plan are finished. Rehabilitation monitoring will be conducted to assess whether the closure objectives and rehabilitation criteria are being met, while maintenance will be done to address where the objectives and rehabilitation criteria remain incomplete or unsatisfactory. Data collected during this time will enhance monitoring data requirements for the post-closure monitoring period.

3.8.2 Surface water

Surface water will be monitored for run-off water quality during rehabilitation monitoring and maintenance.

Surface water samples will be tested against the following surface water quality parameters as per **RM10** to track milestone success:

- pH is between 6.5 and 9.0;
- EC is 20th of downstream monitoring points and 80th percentile of upstream monitoring points;
- suspended solids (TSS) are <1,000mg/L;
- SO4 is 20th of downstream monitoring points and 80th percentile of upstream monitoring points;
- Cr is <1 µg/L;
- Cu is <2 µg/L;
- Zn is <8 µg/L;
- Se is <10 µg/L;
- U is <1 µg/L;
- nitrate is <1,100 µg/L;
- petroleum hydrocarbons (C6-C9) is <20 µg/L;
- petroleum hydrocarbons (C10-C36) is <100 µg/L;
- Na is <180 mg/L;
- B is <2,000 µg/L.

Non-compliant results will be investigated as required and surface water quality at the Project will be reviewed annually. If a review of groundwater quality monitoring data indicates the potential deterioration in water quality, Peabody must complete an investigation into the potential for environmental harm.

3.8.2.1 Mine affected water release points, source and receiving waters

Monitoring of mine affected water will only occur during controlled release events or opportunistically during natural flow events. Surface water samples of mine affected water will be collected in accordance with the EA conditions for the Mine.

- maintain and implement a monitoring and evaluation program that quantifies that the outcomes of the approved design of the interference authorised under this WL are being achieved; or
- maintain and implement a monitoring and evaluation program that quantifies that the interference authorised under this WL is meeting or progressing towards achieving the following outcomes:
- developing features (including geomorphic and vegetation) present in the landscape and in local watercourses.

- the watercourse diversion maintains a sediment transport regime that allows the diversion to be self-sustaining and not directly impact on upstream and downstream reaches.
- the watercourse diversion and associated structures maintain equilibrium and functionality and do not require ongoing maintenance.

The Mine routinely samples surface water runoff from rehabilitated areas to determine water quality and suitability for reuse.

Routine analysis occurs opportunistically both upstream and downstream in Sandy Creek, Spade Creek and Teviot Creek during periods of natural flow to maintain a record of background data. The Mine weather station records daily rainfall.

Table 34 summarises where surface water samples will be collected for mine affected water release points, source and receiving waters.

Table 34 Surface water sample locations

Release point	Latitude (GDA 94)	Longitude (GDA 94)	Mine affected water source location	Monitoring point	Receiving waters description
RP12	21.679175	148.184726	Mine affected water — Pit distribution network	End of pipe	Sandy creek
RP13	21.644339	148.202723	Mine affected water — Pit distribution network	End of pipe	Teviot creek
RP14	21.789179	148.14575	Mine affected water — Pit distribution network	End of pipe	Spade creek

Mine affected water samples are collected daily for the following parameters, with the first sample taken within two hours of a release or natural flow event commencing:

- EC;
- pH; and
- turbidity.

For the following parameters surface water samples are collected weekly with the first sample taken within two hours of a release or during a natural flow event commencing:

- TSS;
- SO4;
- Cr;
- Cu;
- Zn;
- Se;
- U;
- NO3;
- petroleum hydrocarbons (C6-C9) and (C10-C36);
- Na; and
- B.

Surface water quality characteristics will be reviewed in accordance with EA condition C6 including the trigger levels shown in Schedule C — Table C3 of the EA conditions.

For rehabilitated domains surface water samples will be collected opportunistically and the following parameters will be measured:

- EC; and
- pH.

Surface water runoff from rehabilitated land will be clean water. Monitoring of this water will provide representative samples with enough regulatory, spatial and temporal replication to make statistically valid conclusions about the suitability of the water for reuse as either stock water or for irrigation in line with the water quality conditions prescribed in the EA, ie condition C24, including limits shown in Schedule C — Tables C7 and C8. In accordance with EA condition C21(f) and (h), the suggested sampling methods and water quality criteria have been prepared with reference to ANZECC guidelines.

3.8.2.2 Receiving water upstream and downstream of the Mine

Water upstream, ie background sites, and downstream, ie receiving sites, of the Mine will also be monitored. Table 35 identifies the locations of the surface water monitoring points.

Table 35 Upstream and downstream surface water monitoring points

Monitoring points	**Receiving water location description**		
Upstream background monitoring points		Easting (GDA94)	Northing (GDA94)
UBMP 1	Sandy Creek 60 m upstream of RP 12	7602294	623234
UBMP 3	Spade Creek 1,500 m upstream of RP 14, 620 m upstream of RP 3	7590458	619050
UBMP 6	Teviot Creek 150 m upstream of RP 13	7606129	624528
Downstream background monitoring points		Latitude (GDA 94)	Longitude (GDA 94)
DMP 7	Spade Creek via Bullock Creek, 650 m downstream of confluence	21.788163	148.147705
DMP 1	Sandy Creek 2,500 m downstream of RP 12	21.672291	148.174706
DMP 6	Teviot Creek 1200 m downstream of RP 13	21.650606	148.19804
DMP 3	Spade Creek 4000 m downstream of RP 14	21.804535	148.128847

Receiving water samples are collected daily for the following parameters, with the first sample being taken within two hours of a release or natural flow event commencing:

- EC;
- pH; and
- turbidity.

For the following parameters samples are collected weekly with the first sample being taken within two hours of a release or during a natural flow event commencing:

- TSS;
- SO4; and
- Na.

The monitoring described above will provide representative surface water samples from Spade Creek, Sandy, Creek and Teviot Creek with enough regulatory, spatial and temporal replication to make statistically valid conclusions about surface water quality.

3.8.3 Groundwater

Groundwater monitoring will occur during the rehabilitation and post-closure phases of the Mine. Table 36 outlines the monitoring points and frequencies required in accordance with Table C8 from the EA.

3.8.3.1 Standing water levels

The standing groundwater levels that will be monitored are shown in Table 36. To comply with the WL conditions, standing groundwater levels must be taken quarterly.

Table 36 Standing water level and groundwater quality monitoring locations

Monitoring point	Easting	Northing	Monitoring frequency
BD1252P	622294	7600039	Quarterly
BD1253P	622751	7601157	Quarterly
BD1254P	621022	7597920	Quarterly
BDW172 (54)	619333	7586689	Quarterly — water levels only
BDW 172 (32)	619333	7586689	Quarterly — water levels only
BDW366P	619163	7587710	Quarterly
BDW368P	618017	7591478	Quarterly — water levels only
BDW5C	619731	7586791	Quarterly
BDW8C	619762	7585670	Quarterly
LBP 5 Seam	620080	7596430	Quarterly
LBP 5 Upper	620080	7596430	Quarterly
Drill_1A	617744	7589588	Quarterly
Drill_2A	618269	7592774	Quarterly

The standing groundwater level monitoring described in **Table 36** will provide representative levels with enough regulatory detail and replication to make statistically valid conclusions about the standing groundwater level.

Standing groundwater level monitoring will identify any drawdown at monitoring points and will enable Peabody to make management decisions to ensure other lawful users of groundwater are not adversely impacted by drawdown. Drawdown fluctuations of two metres per year, not resulting from the pumping of licensed bores, will be reported to DES to comply with condition C48.

3.8.3.2 Groundwater quality

Groundwater quality samples will be taken from the same locations as the standing water monitoring points. Groundwater samples will be taken quarterly and tested for:

- EC; and
- pH.

In accordance with EA condition C50, the method of groundwater sampling will comply with that set out in the latest edition of the DES Monitoring and Sampling Manual Environmental Protection (Water) Policy 2009 (2018). The groundwater quality monitoring program is designed to detect changes in groundwater composition in aquifers potentially affected by Mine operations and rehabilitation. Groundwater data will be reviewed annually in accordance with **RM10**. If a review of groundwater quality monitoring data indicates the potential deterioration in water quality, Peabody must complete an investigation into the potential for environmental harm.

3.8.3.3 Soil

The objectives of soil monitoring are to:

- guarantee maximum value to the rehabilitation process;
- measure the performance of stockpile storage and soil reuse; and
- improve the management and reuse of stockpiled soils.

A soil monitoring program will:

- update soil inventories after use;
- periodic testing of stockpiled soil prior to use in rehabilitation; and
- investigate instances of poor revegetation performance.

3.8.3.4 Erosion

Erosion monitoring will occur using visual investigation by site personnel and formally during rehabilitation monitoring. LiDAR imagery will also be used to monitor annual erosion trends. Erosion and erosion control systems will be reviewed annually to assist with determining the progress of **RM3, RM8** and **RM10**.

Remedial works will generally be needed for any erosion that is increasing in size.

All drainage, erosion and sediment control measures will be maintained until their function is no longer needed to achieve the associated rehabilitation milestone.

3.8.4 Vegetation

Vegetation monitoring will be completed in accordance with the *Peabody Energy Australia Rehabilitation Monitoring Manual* (2015) and the methodology from the *BioCondition Assessment Manual* (DSITIA 2015).

Recognising that vegetation development is most rapid in the early stages of establishment and slows as the community matures, rehabilitation will be assessed: one, two and five years after establishment. Initial monitoring will enable potential areas of improvement to be identified.

3.8.4.1 Reference sites

Vegetation monitoring will be undertaken for both rehabilitated areas and reference sites outside the area of direct disturbance.

Table 37 summarises reference site vegetation monitoring locations and vegetation characteristics, eg regional ecosystems (RE) and vegetation community structure. Reference sites have been chosen on the basis that they are representative of woodland or grassland vegetation communities. The locational coordinates are based on the most recent monitoring transects in the areas.

The aim is to use the reference sites as indicators (species and community structure) for rehabilitation activities but not as sites to be replicated. The limitations to using reference sites will also need to be acknowledged, such as differing soil profiles and differing community structure of regrowth.

Table 37 Vegetation reference monitoring sites

Reference site	Regional ecosystem	Final land use	Easting GDA94	Northing GDA94
BAS-PAS-01	Adjacent property	Pasture Baseline	619761	7592660
BAS-NAT-01	Remnant RE 11.3.2	Native Ecosystem (Populanae) Baseline	618588	7590866
BAS-NAT-02	Remnant RE 11.9.1	Native Ecosystem (Brigalow) Baseline	620610	7597053
BAS-PAS-02	Adjacent property	Pasture Baseline	619388	7591343
BAS-NAT-04	Remnant Eucalyptus Crebra	Native Ecosystem (E. crebra) Baseline	618474	7585626
BAS-NAT-05	Remnant RE 11.3.2	Native Ecosystem (Populanae) Baseline	618550	7586075

3.8.4.2 Rehabilitation monitoring locations

Table 38 summarises where rehabilitation monitoring has been undertaken. As rehabilitation is completed additional monitoring sites will be added.

Table 38 Vegetation rehabilitation monitoring sites

Location	Easting1 ADG84Z55	Northing ADG84Z55	Year rehabilitated	Final land use	Years assessed
BCIPD01	620608	7596683	2013	Grazing	2018
BCCOPD06	620370	7597131	2010	Grazing	2017
BCIPD01	Not available	Not available	2012	Grazing	2017
BCIPD02	620315	7596597	2013	Pasture	2018, 2017

Location	Easting1 ADG84Z55	Northing ADG84Z55	Year rehabilitated	Final land use	Years assessed
BCOOPD01	Not available	Not available	2010	Grazing	2017
BCOOPD02	Not available	Not available	2010	Grazing	2017
BCOOPD03	Not available	Not available	2010	Grazing	2017
BCOOPD04	620704	7597514	2010	Grazing	2017
BCOOPD05	620219	7597070	2010	Grazing	2017
BCOOPD07	620824	7598072	2017	Grazing	2018
BCOOPD07	620938	7598252	2016	Grazing	2017
BMWOOPD01	618169	7588816	2011	Pasture	2018, 2017, 2016
BMWOOPD02	618009	7588435	2011	Pasture	2018, 2017, 2016
BMWOOPD03	618276	7588382	2011	Pasture	2018, 2017, 2016
BMWOOPD04	617756	7588142	2011	Pasture	2018, 2017, 2016
BMWOOPD05	618065	7588113	2011	Pasture	2018, 2017, 2016
BMWOOPD06	618269	7588231	2011	Pasture	2018, 2017, 2016
BMWOOPD07	617800	7587856	2011	Pasture	2018, 2017, 2016
BMWOOPD08	618112	7597739	2011	Pasture	2018, 2017, 2016
BMWOOPD09	618112	7587739	2011	Pasture	2018, 2017, 2016
BMWOOPD10	618044	7587532	2011	Pasture	2018, 2017, 2016
PTNOOPD01	621502	7602137	2007	Grazing	2017
PTNOOPD02	621679	7602076	2007	Grazing	2017
PTNOOPD03	621384	7601791	2007	Grazing	2017
PTNOOPD04	621588	7601854	2007	Grazing	2017
PTNOOPD05	621455	7601419	2007	Grazing	2017
PTNOOPD06	621627	7601597	2007	Grazing	2017
PTNOOPD07	621946	7601846	2007	Grazing	2018, 2017, 2016
PTNOOPD08	621780	7601493	2017	Grazing	2018, 2017, 2016
PTNOOPD09	621979	7302139	2007	Grazing	2018, 2017, 2016
PTSOOPD01	621118	7600525	2007	Grazing	2017
PTSOOPD02	621415	7600689	2007	Grazing	2017
PTSOOPD03	620852	7600233	2007	Grazing	2017
PTSOOPD04	621029	7600172	2007	Grazing	2017

Location	Easting1 ADG84Z55	Northing ADG84Z55	Year rehabilitated	Final land use	Years assessed
PTSOOPD05	621320	7600336	2007	Grazing	2017
PTSOOPD06	620846	7599887	2007	Grazing	2017
PTSOOPD07	621189	7599988	2007	Grazing	2017
WBEOOPD01	617768	7593135	2009	Grazing woodland	2017, 2016
WBEOOPD02	618064	7593138	2009	Grazing woodland	2017, 2016
WBEOOPD03	617813	7592932	2009	Grazing woodland	2017, 2016
WBEOOPD04	618089	7592776	2009	Grazing	2017, 2016
WBEOOPD05	618277	7592921	2009	Grazing	2017, 2016
WBEOOPD06	618031	7592626	2009	Grazing woodland	2017, 2016
WBEOOPD07	618346	7592583	2009	Grazing	2017, 2016
WBEOOPD08	618073	7592323	2009	Grazing	2017, 2016
WBEOOPD09	618317	7592148	2009	Grazing	2017, 2016
WBEOOPD10	618106	7592008	2009	Grazing	2017, 2016
WBEOOPD11	618484	7591785	2009	Grazing	2017, 2016
WBEOOPD12	618611	7592041	2009	Grazing	2017, 2016
WBEOOPD13	618221	7591660	2009	Grazing	2017, 2016
WBEOOPD14	618299	7591262	2009	Grazing	2017, 2016
WBEOOPD15	618989	7591243	2017	Grazing	2018, 2017
WBEOOPD22	617460	7589930	2017	Grazing	2018, 2017
WBIPD01	617489	7592283	2012	Pasture	2018, 2017, 2016
WBIPD02	617287	7592127	2012	Pasture	2018, 2017, 2016
WBIPD03	617861	7591391	2012	Pasture	2018, 2016
WBIPD04	618071	7591179	2011	Pasture	2018, 2016
WBIPD05	618055	7591038	2011	Pasture	2018, 2016
WBIPD06	618263	7590886	2011	Pasture	2018, 2016
WBIPD07	681347	7590716	2011	Pasture	2018, 2016
WBIPD08	618255	7590213	2011	Pasture	2018, 2016
WBROM01	617823	7590128	2011	Pasture	2018, 2016
WBWOOP01	616661	7592425	2011	Pasture	2018, 2016
WBWOOP02	616912	7592287	2011	Pasture	2018, 2016

Location	Easting1 ADG84Z55	Northing ADG84Z55	Year rehabilitated	Final land use	Years assessed
WBWOOP03	616604	7592007	2011	Pasture	2018, 2016
WBWOOP04	616872	7592013	2011	Pasture	2018, 2016
WBWOOP05	616661	7591693	2011	Pasture	2018, 2016
WBWOOP06	616821	7591773	2011	Pasture	2018, 2016
WBWOOP07	616975	7591408	2011	Pasture	2018, 2016
WBWOOP08	616775	7591448	2011	Pasture	2018, 2016
WBWOOP09	616672	7591099	2011	Pasture	2018
WBWOOP10	617069	7591325	2011	Pasture	2016
WBWOOP11	617238	7591442	2011	Pasture	2018, 2016
WBWOOP12	617289	7591636	2011	Pasture	2018, 2016
WBWOOP13	617655	7591328	2011	Pasture	2018, 2016
WBWOOP14	617649	7591128	2011	Pasture	2018, 2016
WBWOOP15	617301	7591053	2011	Pasture	2018, 2016
WBWOOP16	617329	7590853	2011	Pasture	2018, 2016
WBWOOP17	617569	7590739	2011	Pasture	2018, 2016
WBWOOP18	617872	7590402	2011	Pasture	2018, 2016
WBWOOP19	617621	7590459	2011	Pasture	2018, 2016
WBWOOP20	617346	7590453	2011	Pasture	2018, 2016
WBWOOP21	617558	7590191	2011	Pasture	2018, 2016

Notes: 1. Locations note a position within the transect surveyed.

Soil analysis has occurred in the locations listed in Table 39

Table 39 Soil monitoring locations

Location	Easting ADG84Z55	Northing ADG84Z55	Year rehabilitated	Final land use	Years sampled
BAS-PAS-02	619388	7591337	Not available	Grazing	2017, 2016
BAS-PAS-04	621447	7598282	Not available	Grazing	2017
BAS-PAS-05	621617	7597592	Not available	Grazing	2017
BAS-PAS-06	618616	7593755	Not available	Grazing	2017
BCOOPD07	620938	7598252	2016	Grazing	2017
WBEOOPD-15	618988	7591242	2016	Grazing	2017
WBEOOPD-22	617581	7590107	2016	Grazing	2017
BMWOOPD02	618009	7588435	2011	Pasture	2016
BMWOOPD03	618276	7588382	2011	Pasture	2016
BAS-NAT-04	618474	7585626	Not available	Remnant Eucalyptus Crebra	2016
BAS-NAT-05	618550	7586075	Not available	Remnant RE 11.3.2	2016
PTNOOPD07	622049	7602011	2007	Grazing	2016
Bullock Ck Diversion	Not available	Not available	Not available	Not available	2016
BAS-NAT-01	618588	7590866	Not available	Remnant RE 11.3.2	2016
BAS-NAT-02	620610	7597053	Not available	Remnant RE 11.9.1	2016
BAS-PAT-01	Not available	Not available	Not available	Reference	2016
PTNOOPD09	621979	7302139	2007	Grazing	2016
BMWOOPD07	617800	7587856	2011	Pasture	2016
BMWOOPD08	618112	7597739	2011	Pasture	2016
BMWOOPD05	618065	7588113	2011	Pasture	2016
WBEOOPD07	618346	7592583	2009	Grazing	2015
WBEOOPD06	618031	7592626	2009	Grazing woodland	2015
WBEOOPD03	617813	7592932	2009	Grazing woodland	2015
BCOOPD01	Not available	Not available	2010	Grazing	2015

Location	Easting ADG84Z55	Northing ADG84Z55	Year rehabilitated	Final land use	Years sampled
WBEOOPD08	618073	7592323	2009	Grazing	2015
PTNOOPD03	621384	7601791	2007	Grazing	2015
WBEOOPD12	618611	7592041	2009	Grazing	2015
PTSOOPD01	621502	7602137	2007	Grazing	2015
BCIPD01	Not available	Not available	2012	Grazing	2015
BCOOPD02	Not available	Not available	2010	Grazing	2015
WBEOOPD13	618221	7591660	2009	Grazing	2015
PTNOOPD06	621627	7601597	2007	Grazing	2015
PTSOOPD05	621320	7600336	2007	Grazing	2015
BCOOPD04	620704	7597514	2010	Grazing	2015
BCOOPD05	620219	7597070	2010	Grazing	2015
PTNOOPD09	621979	7302139	2007	Grazing	2015
PTNOOPD03	621384	7601791	2007	Grazing	2015
PTNOOPD05	621455	7601419	2007	Grazing	2015
WBEOOPD14	618299	7591262	2009	Grazing	2015
WBIPD01	617489	7592283	2012	Pasture	2015
WBIPD02	617287	7592127	2012	Pasture	2015
BMWOOPD10	618044	7587532	2011	Pasture	2015
BMWOOPD01	618169	7588816	2011	Pasture	2015
BMWOOPD05	618065	7588113	2011	Pasture	2015

3.8.4.3 Grazing trials

Grazing has been carried out on rehabilitated land in three areas of the Mine.

a Plumtree

Grazing commenced on the northern and southern dumps at Plumtree in June 2020. Fencing was installed to keep cattle out of operational areas and raw water was supplied via an installed pipeline. These areas have been periodically grazed as agreed by a neighbouring landholder and site personnel. Average weight gains of cattle on rehabilitated land have been comparable to other nearby grazing areas. Grazed areas are included in rehabilitation monitoring to measure any impacts / benefits.

b Bullock Creek

Grazing commenced on the Bullock Creek out of pit dump and surrounding areas in July 2019. Fencing was installed to keep cattle out of the Bullock Creek ERE area and raw water was supplied via installed pipelines to a trough and another to an existing farm dam. The grazing trial involved the early adoption of commercial GPS

collar technology. GPS enabled collars were placed on cattle which allowed the animals to be tracked across the site. This also enabled the use of 'virtual fencing' where cattle are trained to recognise computer generated or virtual fences via the use of an audible tone and a mild electric current on the collars. The use of this technology allowed an accurate snapshot of cattle movements.

Cattle were observed to use the full extent of the grazing area, including the tops of rehabilitated landforms despite water only being available at ground level. Average weight gains of cattle on rehabilitated land have been comparable to other nearby grazing areas. Grazed areas are included in rehabilitation monitoring to measure any impacts / benefits.

Cattle movements are shown in Figure 31.



Figure 31 Bullock Creek cattle grazing area

c Wallanbah

Grazing started on the Wallanbah in-pit and western rehabilitation in August 2019. Existing farm dams were used for water supply while the cattle collar technology was used instead of permanent fencing. Average weight gains of cattle on rehabilitated land have been comparable to other nearby grazing areas. Grazed areas are included in rehabilitation monitoring to measure any impacts / benefits of grazing.

Cattle movements for two trials are shown in Figure 32 and Figure 33.

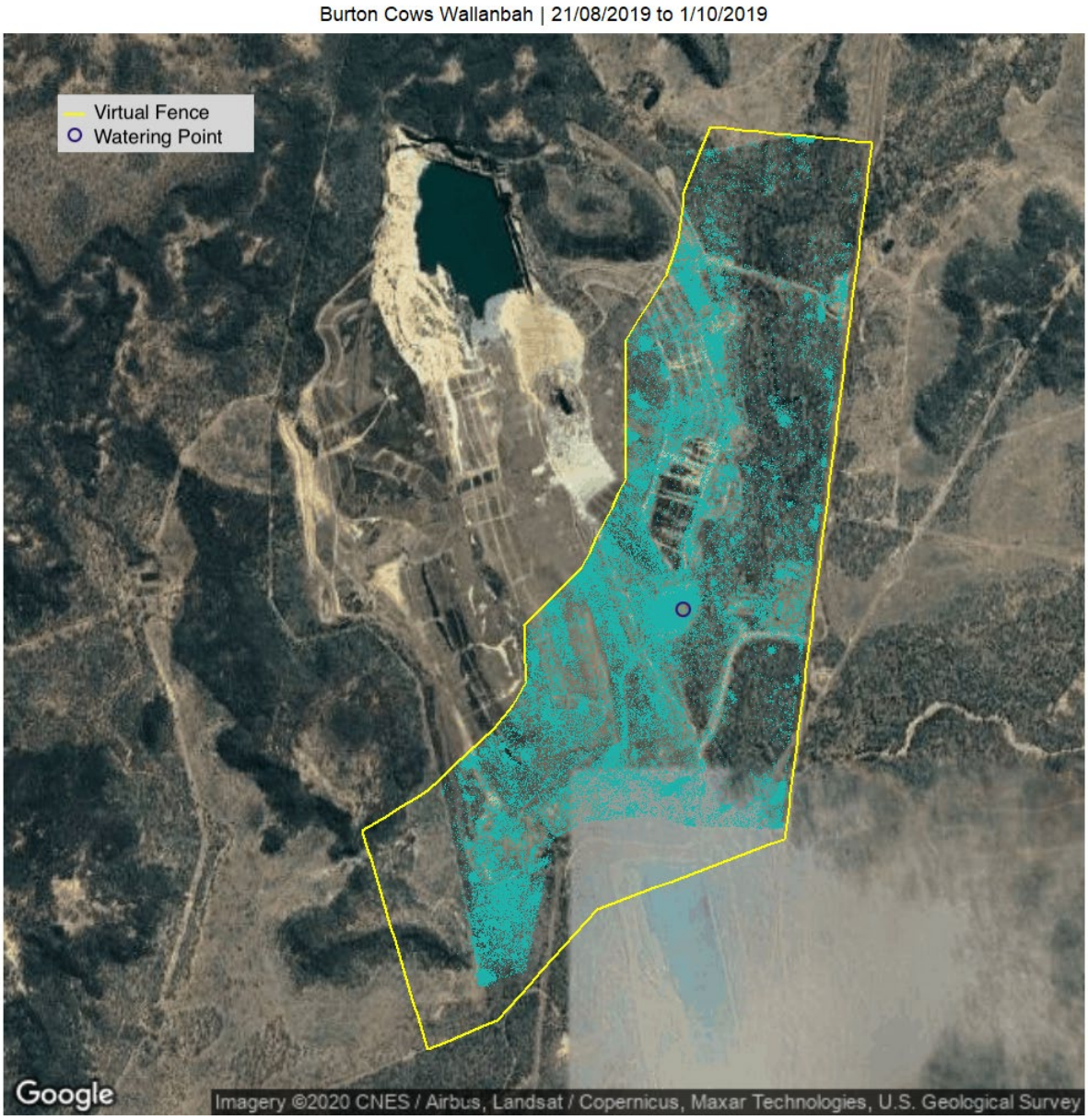

Figure 32 Cattle grazing trial one at Wallanbah

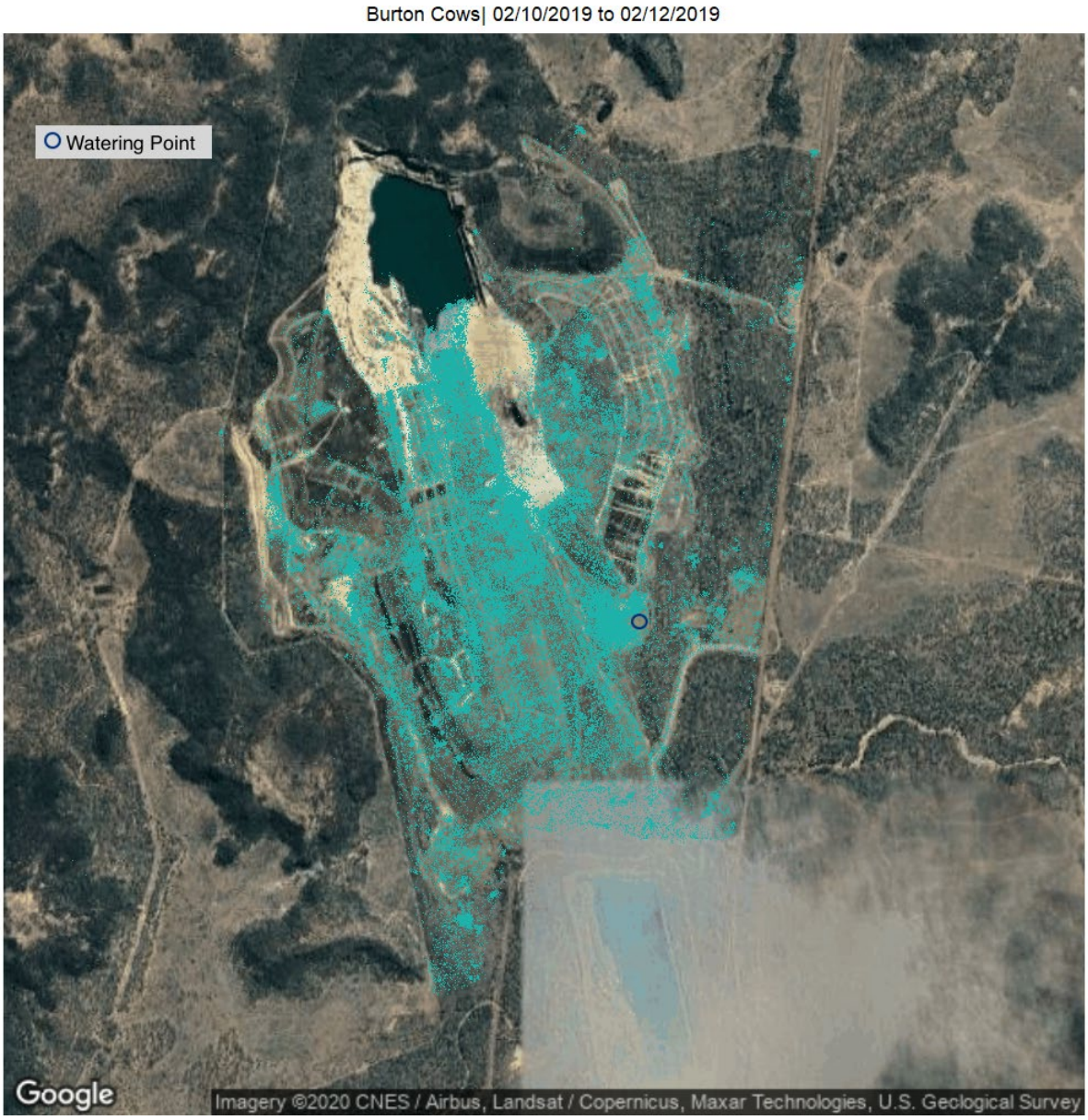

Figure 33 Cattle grazing trial two at Wallanbah

3.8.5 Weed and feral animal control and inspection

Weed and feral animal monitoring and control will be conducted as part of the rehabilitation monitoring. The surveys will be conducted in all areas of the Mine and control will be performed as required.

The objective of weed and feral animal monitoring and control is to manage the land in accordance with guidelines for the management of Class 1, Class 2 and Class 3 pests under the Qld Land Protection (Pest and Stock Route Management) Act 2002. These guidelines are available on the Qld Department of Agriculture and Fisheries website. It will also assist with neighbour relations, given weeds and feral animals are a landscape issue as opposed to being tenure specific.

3.8.6 Geotechnical monitoring

Geotechnical monitoring will be undertaken by a qualified geotechnical engineer who will assess the stability of post-rehabilitation features. Data collected will be used to assess the progress of the rehabilitation milestones and closure criteria.

3.8.6.1 Schedule

In accordance with legal obligations and best practice, rehabilitation monitoring will be done following the schedule given in Table 40.

Table 40 Proposed monitoring schedule

Name	Frequency	Duration (post-closure)
Analogue sites	Annually	Five years
Surface water / receiving environment	Twice yearly	10 years (then every five years for the following 20 years)
Groundwater	Annually	10 years (then every five years for the following 20 years)
Soil	Every two years	10 years (then every five years for the following 20 years)
Erosion / final landform stability	Every two years	10 years (then every five years for the following 20 years)
Vegetation	Annually	10 years (then every five years for the following 20 years)

3.8.6.2 Schedule of monitoring, reporting and review of each milestone

The rehabilitation monitoring program will help identify and quantify problems, risks and opportunities for corrective actions and adaptive management. A schedule of monitoring, reporting and review for each milestone is given in Table 41 to Table 51. A contingency strategy for each milestone is provided.

Table 41 RM1 (infrastructure decommissioning and removal) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
All site services disconnected and decommissioned	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review	Annually	Internal	Update mapping and records as required	At completion of works	Visual inspection and review of termination documentation	Organise disconnection
All road materials (bitumen and gravel) removed	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All above ground pipelines drained and removed	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All fencing not required by a subsequent landholder is removed	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All buildings not required by a subsequent landholder are demolished and removed	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All drillholes, sumps, exploration tracks and gridlines decommissioned	Monitor documentation of exploration works	Document review and site inspection	Annually	Internal	Update documentation as required	At completion of works	Site inspection Rehabilitation monitoring BioCondition monitoring	Review rehabilitation processes if criteria not being met

Table 42 RM2 (remediation of contaminated land) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Carry out preliminary and intrusive contaminated land investigations	Review infrastructure mapping for inclusion of potentially contaminated land sites Review incident reports for hydrocarbon and other spills Review adequacy of incident report actions and location details Identify high risk / regularly affected areas and proximity to sensitive receptors	Document review and site inspection	Annually	Internal	Update mapping as required Consider training on spill procedure as required Consider training on incident reporting (environment) as required Consider containment or mitigation strategies for identified areas	Following removal of contaminated material	Investigation as per NEPM legislation and sampling and analysis verification (SAP) standards	Prepare remediation plan for any remaining areas of contamination
Removal or on-site treatment of contaminated water	Review records / register / map files of potential contaminated areas	Document review and site inspection	Annually	Internal	Update register / records / mapping as required	Following removal / treatment of contaminated material	Document review and site inspection	Update remediation plan and update register / records
Removal or on-site treatment of contaminated material	Review records / register / map files of potential contaminated areas	Document review and site inspection	Annually	Internal	Update register / records / mapping as required	Following removal / treatment of contaminated material	Document review and site inspection	Update remediation plan and update register / records
Conduct validation testing to confirm that contaminated water / materials have been removed/remediated	Review records / register / map files of potential contaminated areas	Document review and site inspection	Annually	Internal	Update register / records / mapping as required	Following removal / treatment of contaminated material	Investigation as per NEPM legislation and sampling and analysis verification (SAP) standards	Review laboratory analysis and reports and update register / records
Certification from an appropriately qualified person (AQP) that all contaminated land has been remediated or removed and disposed of according to licence conditions.	Review records / register / map files of potential contaminated areas Review incident reports for evidence of significant spill events	Document review and site inspection	Annually	Internal	Update register / records / mapping as required	Following removal / treatment of contaminated material	Investigation as per NEPM legislation and SAP standards	Start remediation of failed areas

Table 43 RM3 (landform development and reshaping / re-profiling) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Finalise engineering and design plans	Monitor against PRCP schedule and milestones	LiDAR	Annually	Internal	Monitor against PRCP schedule and milestones	Following completion of design plans	LiDAR	Update schedule
Bulk earthworks to achieve required landform and slopes	Monitor against PRCP schedule and milestones	Ground survey and LiDAR	Annually	Internal	Update schedule if required	Following completion of works	Ground survey and LiDAR	Update schedule or accelerate works

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
General reshaping and pushing/trimming to achieve final landform	Monitor against PRCP schedule and milestones	Ground survey and LiDAR	Annually	Internal	Update schedule if required	Following completion of works	Monitor against PRCP schedule and milestones	Ground survey and LiDAR
Slope of constructed landforms is ⩽20% in at least 80% of the nominated area and verified by an AQP	Review landform designs to make sure slopes are planned as ≤ 20 % Review survey / LiDAR data for compliance with maximum slope angle	Document / design review Ground survey and LiDAR	Monthly during reshaping works	Internal	Update designs if required Remediate areas as required	Following completion of works	Ground survey and LiDAR	Remediate areas as required
Final highwall/end wall batters of voids meet EA requirements and verified by an AQP	Review landform designs Review survey / LiDAR data for compliance with maximum slope angle	Document / design review Ground survey and LiDAR	Monthly during reshaping works	Internal	Update designs if required Remediate areas as required	Following completion of works	Ground survey and LiDAR	Remediate areas as required
Sediment and mine water dams not required for sediment control or by a subsequent landholder are desilted and backfilled using their embankments	Review rehabilitation records for documentation of desilting and embankment removal	Document review and site inspection	Annually	Internal	Review and update design plans if required	At completion of works	Visual inspection	Assess impact of changed methodology on rehabilitation area
Install erosion and sediment control systems	Install and review erosion and sediment control installations	Visual inspection	Annually	Internal	Review appropriateness / effectiveness of controls	Pre and post wet season	Visual inspection	Remediate areas as required Alter control types as required

Table 44 RM4 (surface preparation) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Remediate excessive erosion or subsidence	Inspect erosion and subsidence areas	Visual inspection	Annually	Internal	Review appropriateness / effectiveness of controls	Pre and post wet season	Visual inspection	Remediate areas as required Alter control types as required
An assessment of soil health and suitability has been completed by an AQP to confirm soil is suitable for target vegetation establishment	Not applicable (N/A) — assessment completed prior to works starting	N/A	N/A	N/A	N/A	Prior to placement of soil	Soil sampling, laboratory analysis and results interpretation	Treat soil as required

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Application of ameliorants as per requirements of the soil health and suitability assessment	Review rehabilitation records for evidence of amelioration application	Visual inspection and document review Rehabilitation monitoring	Annually (document review) Ongoing during application works Annually (rehabilitation monitoring)	Internal	Update rehabilitation records as required Review rehabilitation methodology if amelioration not appearing to be effective	Prior to seeding	Visual inspection Test pitting, sampling and laboratory analysis if required	Complete amelioration
Deep ripping of compacted areas	Review rehabilitation records for evidence of deep ripping Inspect rehabilitation areas during ripping	Visual inspection and document review	Ongoing during works	Internal	Update rehabilitation records as required	Prior to seeding	Visual inspection	Remediate areas not adequately ripped
Placement of 0.2 metres (m) of soil	Review rehabilitation records for evidence of topsoil placement depth Inspect areas of topsoil placement during works	Visual inspection and document review Test pitting	Annually Ongoing during works	Internal	Review methodology if topsoil is too shallow in multiple areas Remediate isolated areas as required ie especially on slopes or in high-risk areas	Prior to seeding	Visual inspection Test pitting	Remediate areas as required

Table 45 RM5 (revegetation for grazing with areas of bushland habitat) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Completed seeding of target species at rate consistent with the revegetation plan	Review rehabilitation records for evidence of seed application rates Visual inspection during seeding works	Visual inspection and document review	Annually Ongoing during works	Internal	Update records as required	Annually	Rehabilitation monitoring BioCondition monitoring	Reseed as required Review seeding methodology, seeding rate, seed species, seed viability etc
Application of fertiliser as per requirements of the soil health and suitability assessment	Review rehabilitation records for evidence of fertiliser application Review effectiveness of fertiliser on rehabilitation	Visual inspection and document review Rehabilitation monitoring	Annually (document review) Ongoing during application works Annually (rehabilitation monitoring)	Internal	Update rehabilitation records as required Review rehabilitation methodology if fertiliser not appearing to be effective	Prior to seeding or when required	Visual inspection Test pitting, sampling and laboratory analysis if required	Investigate alternate fertiliser brands or rates
Deep ripping along the contour on slopes	Review rehabilitation records for evidence of ripping	Visual inspection and document review	Annually Ongoing during works	Internal	Update rehabilitation records as required	Prior to seeding	Visual inspection Test pitting	Remediate areas as required

Table 46 RM6 (revegetation for self-sustainable native vegetation and riparian areas) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Completed seeding of target species at rate consistent with the revegetation plan	Review rehabilitation records for evidence of seed application rates Visual inspection during seeding works	Visual inspection and document review	Annually Ongoing during works	Internal Internal	Update records as required	Annually	Rehabilitation monitoring BioCondition monitoring	Reseed as required Review seeding methodology, seeding rate, seed species, seed viability etc
Application of fertiliser as per requirements of the soil health and suitability assessment	Review rehabilitation records for evidence of fertiliser application Review effectiveness of fertiliser on rehabilitation	Visual inspection and document review Rehabilitation monitoring	Annually (document review) Ongoing during application works Annually (rehabilitation monitoring)	Internal	Update rehabilitation records as required Review rehabilitation methodology if fertilisation not appearing to be effective	Prior to seeding When required	Visual inspection Test pitting, sampling and laboratory analysis if required	Investigate alternate fertiliser brands or rates
Planting of tubestock	Review rehabilitation records	Visual inspection and document review Rehabilitation monitoring	Annually (document review) Ongoing during works	Internal	Update records as required Review rehabilitation methodology if growth not appearing to be effective	Annually When required	Rehabilitation monitoring BioCondition monitoring	Replant as required Review revegetation methodology, planting rate, species etc.
Install stock fencing to protect planting where required	Review rehabilitation records	Visual inspection and document review Rehabilitation monitoring	Ongoing during works Annually (rehabilitation monitoring)	Internal	Update records as required	Annually When required	Visual inspection	Install fencing as required

Table 47 RM7 (Achievement of surface requirements for riparian areas) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
No active areas of gully erosion	Inspect areas of active erosion	Visual inspection / LiDAR	Bi-annually or following rain events	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Investigate underlying cause of drainage issues eg design, construction, material types, ineffective maintenance etc Develop and carry out maintenance program for remediation
Certification from an AQP that weed and pest species are no greater than the nominated reference sites.	Inspect rehabilitation and undisturbed areas for presence of weeds	Visual inspection	Bi-annually	Internal and neighbouring landholders as required	Targeted treatment of weed outbreaks	Annually	Rehabilitation monitoring	Plan and execute weed treatment program

Table 48 RM8 (achievement of surface requirements for grazing with areas of bushland) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
80% of the nominated area has an average groundcover (consisting of standing live vegetation, attached litter, detached litter, rocks >5 cm and course woody debris) ≥70% as verified by an AQP	Inspection of rehabilitation areas	Visual inspections	Bi-annually	Internal	Remediate areas where minimal cover may pose a risk ie erosion, stability, sediment runoff etc	Annually	Rehabilitation monitoring BioCondition monitoring	Plan and execute remediation program
No active areas of gully erosion and drainage follows appropriate drainage paths	Inspect areas of active erosion Inspect drainage lines following rain events	Visual inspection LiDAR	Bi-annually or following rain events	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Investigate underlying cause of drainage issues eg design, construction, material types, ineffective maintenance etc Develop maintenance program for remediation Carry out remediation program
Certification from an AQP that weed and pest species are no greater than the nominated reference sites	Inspect rehabilitation and undisturbed areas for presence of weeds	Visual inspection	Bi-annually	Internal and neighbouring landholders as required	Targeted treatment of weed outbreaks	Annually	Rehabilitation monitoring	Plan and execute weed treatment program
Water control structures are either removed or are free from active erosion as verified by an AQP	Inspect water control structures	Visual inspection	Annually	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Remediate as required
Average erosion rate of ≥5 t/ha/year	Inspect areas of active erosion	Visual inspection LiDAR Calculation of average erosion rate	Annually	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Develop maintenance program for remediation Carry out remediation program
Erosion gullies are less than or equal to 1m deep	Inspect areas of active erosion	Visual inspection LiDAR	Bi-annually	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Investigate underlying cause of drainage issues eg design, construction, material types, ineffective maintenance etc Develop maintenance program for remediation Carry out remediation program
Certification form an AQP that rehabilitation is resilient to fire	Certification by AQP that rehabilitation is resilient to fire	Inspection of regrowth following fire events	Visual inspection	As required	Internal	Review seed mix if regrowth is insufficient Reseed if required	Annually	Rehabilitation monitoring

Table 49 RM9 (achievement of surface requirements for self-sustaining native vegetation) milestone criteria

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
No active areas of gully erosion	Inspect areas of active erosion	Visual inspection / LiDAR	Bi-annually or following rain events	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Investigate underlying cause of drainage issues eg design, construction, material types, ineffective maintenance etc Develop and carry out maintenance program for remediation
Certification from an AQP that weed and pest species are no greater than the nominated reference sites.	Inspect rehabilitation and undisturbed areas for presence of weeds	Visual inspection	Bi-annually	Internal and neighbouring landholders as required	Targeted treatment of weed outbreaks	Annually	Rehabilitation monitoring	Plan and execute weed treatment program

Table 50 RM10 (achievement of PMLU to a stable condition for grazing areas of bushland habitat) milestone criteria

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Certification from an AQP that the area has achieved stable condition	Monitoring of landform stability by geotechnical engineer Analysis of survey data by geotechnical engineer	Geotechnical inspections Ground survey / LiDAR	Annually	Internal	Remediate areas of instability Review and update design plans if required	Following completion of works	Geotechnical assessment	Remediate as advised or start redesign process
Certification from an AQP that the landform has achieved an acceptable factor of safety	Monitoring of landform stability by geotechnical engineer Analysis of survey data by geotechnical engineer	Geotechnical inspections Ground survey / LiDAR	Annually	Internal	Remediate areas of instability Review and update design plans if required	Following completion of works	Geotechnical assessment	Remediate as advised or start redesign process
Average erosion rate of ≥5 t/ha/year	Inspect areas of active erosion	Visual inspection LiDAR Calculation of average erosion rate	Annually	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Develop maintenance program for remediation Carry out remediation program

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
80% of the nominated area has an average groundcover (consisting of standing live vegetation, attached litter, detached litter, rocks >5 cm and course woody debris) ⩾70% as verified by an AQP	Inspection of rehabilitation areas	Visual inspections	Bi-annually	Internal	Remediate areas where minimal cover may pose a risk ie erosion, stability, sediment runoff etc	Annually	Rehabilitation monitoring BioCondition monitoring	Plan and execute remediation program
Biomass and cattle grazing indicators meet a minimum land suitability class of 4 and a minimum land capability class of VII as verified by an AQP	Inspection of rehabilitation areas	Visual inspections	Bi-annually	Internal	Remediate areas with reduced land suitability and capability class	Annually	Rehabilitation monitoring BioCondition monitoring Land suitability assessment	Plan and execute remediation program

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Surface water runoff quality from the area complies with the following: • pH is between 6.5 and 9.0; • EC is 20th of downstream monitoring points and 80th percentile of upstream monitoring points; • suspended solids are <1,000mg/L; • sulfate is 20th of downstream monitoring points and 80th percentile of upstream monitoring points; • Cr is <1 µg/L; • Cu is <2 µg/L; • Zn is <8 µg/L; • Se is <10 µg/L • U is <1 µg/L; • nitrate is <1,100 µg/L; • petroleum hydrocarbons (C6-C9) is <20 µg/L; • petroleum hydrocarbons (C10-C36) is <100 µg/L; • Na is <180 mg/L; • B is <2,000 µg/L.	Monitoring as per EA requirements	Sampling and laboratory analysis	As per EA	As per EA	Investigate non-compliant results as required	Annually	Sampling and laboratory analysis	Investigate cause of non-compliant results
Groundwater pH and electrical conductivity (EC) does not show a statistically significant change when compared to background data for a period of five years prior to relinquishment	Monitoring as per EA requirements	Sampling and laboratory analysis	As per EA	As per EA	Investigate non-compliant results as required	Annually	Sampling and laboratory analysis	Investigate cause of non-compliant results

Table 51 RM11 (achievement of PMLU to a stable condition for riparian and self-sustaining native vegetation) milestone criteria

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Certification from an AQP that the area has achieved stable condition	Monitoring of landform stability by geotechnical engineer Analysis of survey data by geotechnical engineer	Visual and BioCondition monitoring	Annually	Internal	Remediate areas of instability	Following completion of works	BioCondition monitoring	Develop and implement remediation strategy based on monitoring
Certification from an AQP that the self-sustaining vegetation areas are consistent with reference site BAS-NAT-02 based on BioCondition monitoring	Monitoring of diversion channel by an AQP	BioCondition monitoring	Annually	Internal	Investigate substandard vegetation causes	Following completion of works	BioCondition monitoring	Develop and implement remediation strategy based on monitoring
Certification from an AQP that riparian areas are consistent with reference sites based on BioCondition monitoring	Monitoring of diversion channel by an AQP	BioCondition monitoring	Annually	Internal	Investigate substandard vegetation causes	Following completion of works	BioCondition monitoring	Develop and implement remediation strategy based on monitoring

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Appendix A
PRC plan schedule



PRC plan schedule

The PRC plan schedule contains milestones and conditions that relate to the completion of progressive rehabilitation and closure. The PRC plan schedule has been prepared in accordance with section 126D of the EP Act and includes the final site design, rehabilitation areas, a schedule of land availability, rehabilitation milestones and milestone criteria. The PRC plan schedule applies to the entire life of the Project.

A.1 Final site design

The final site design (Figure 34) delineates the total area of the PRC plan as planned for surrender and includes the maximum disturbance footprint, MLA area as well as proposed PMLUs.

A.1.1 Rehabilitation areas

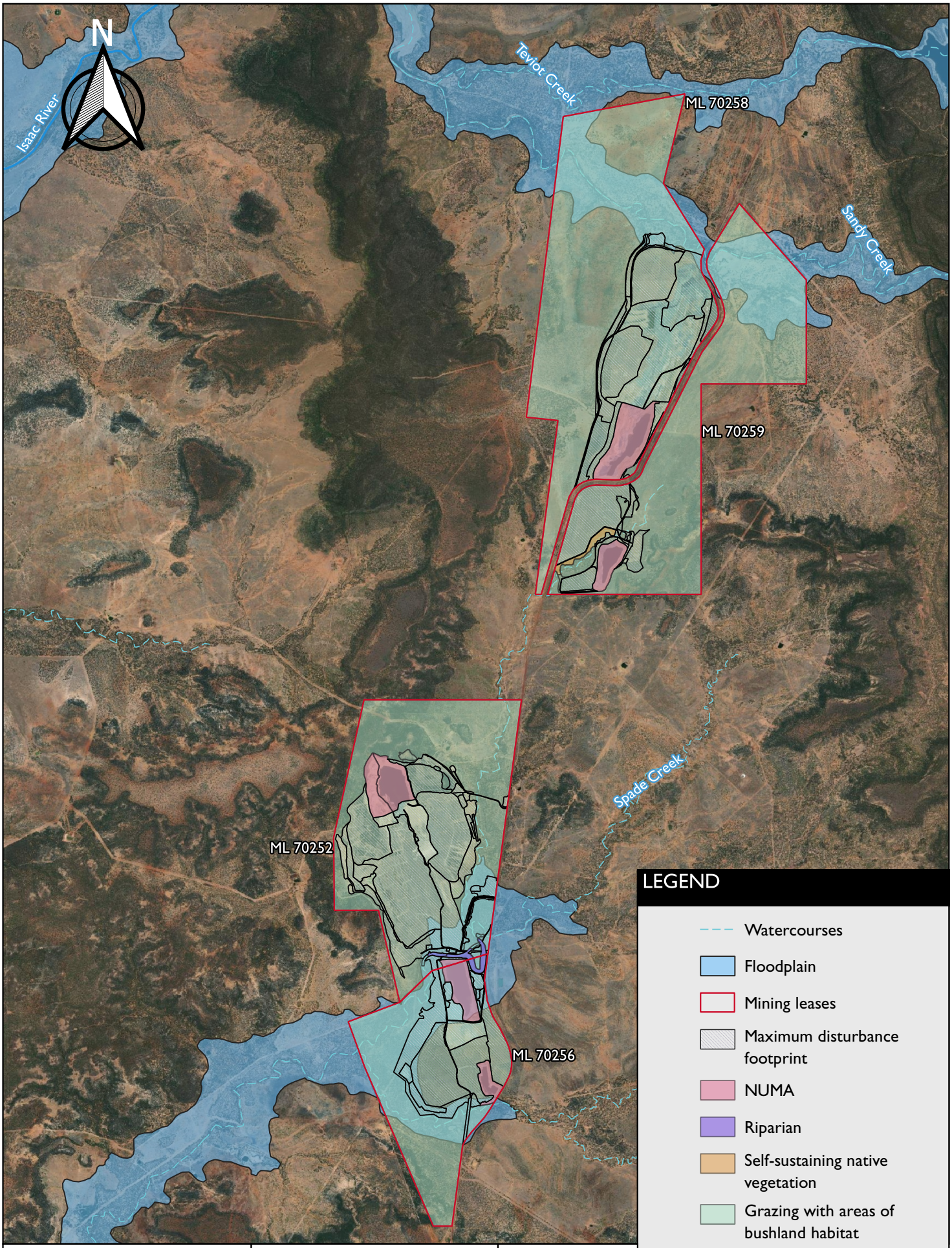
The disturbance areas identified in the final site design have been divided into the following rehabilitation and improvement areas (section 4.3), which have a common PMLU and rehabilitation methodology (Figure 35 and Figure 36):

- RA1 — Existing rehab south;
- RA2 — OB dumps and topsoil south;
- RA3 — Surface water management south;
- RA4 — Infrastructure south;
- RA5 — Existing rehab north;
- RA6 — OB dumps and topsoil north;
- RA7 — Surface water management north;
- RA8 — Infrastructure north;
- RA9 — Self-sustaining native ecosystem; and
- RA10 — Riparian veg Spade Creek.

A.1.2 Improvement areas

- IA1 — Broadmeadow voids

- IA2 — Wallanbah void;
- IA3 — Wallanbah void low wall;
- IA4 — Bullock Creek void; and
- IA5 — Plumtree void.



Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 34	Title: Final Site Design	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 65,000 CRS: GDA94 / MGA zone 55	SGMenvironmental

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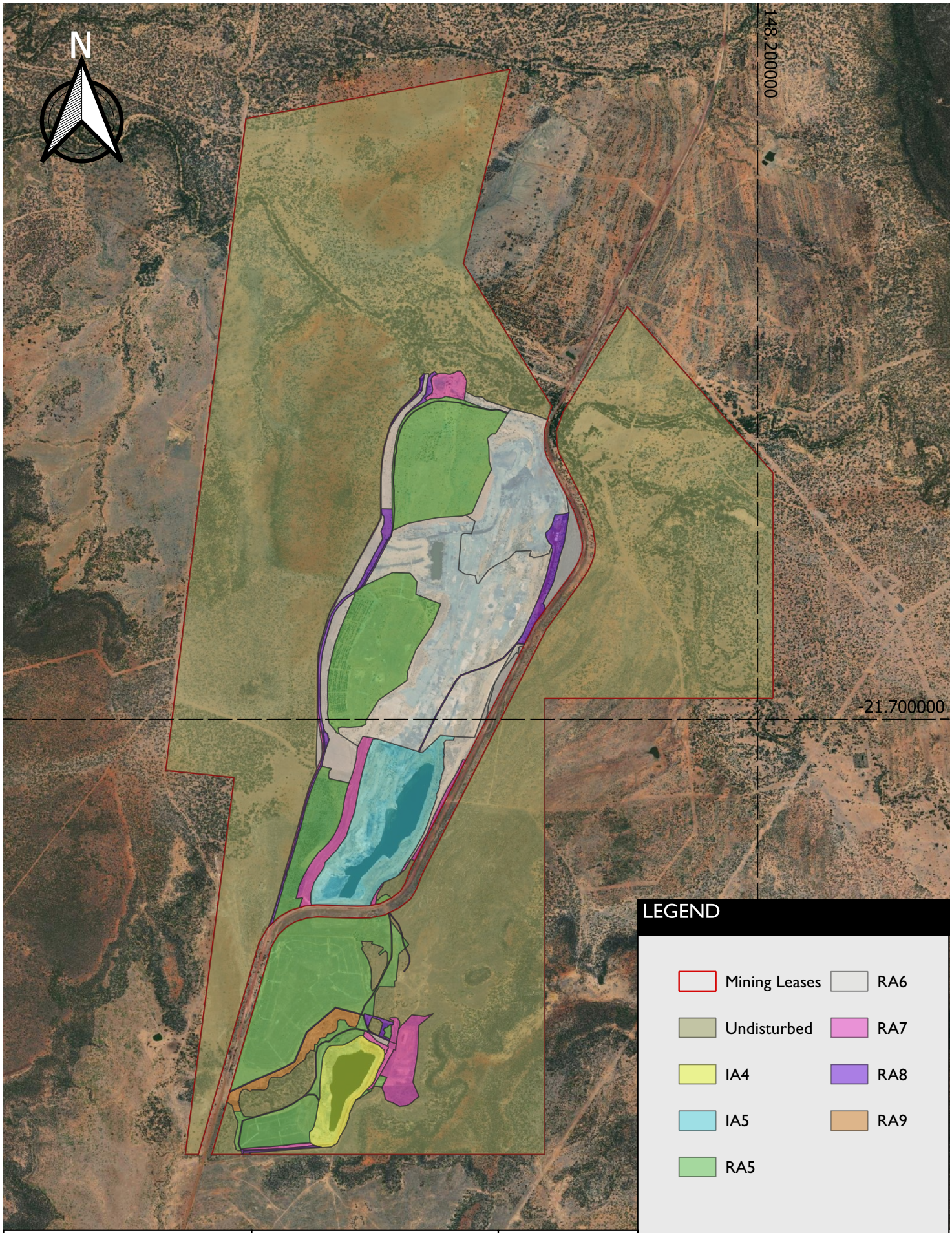

Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 35	Title: Rehabilitation Areas (North)	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 30,000 CRS: GDA94 / MGA zone 55	SGMenvironmental

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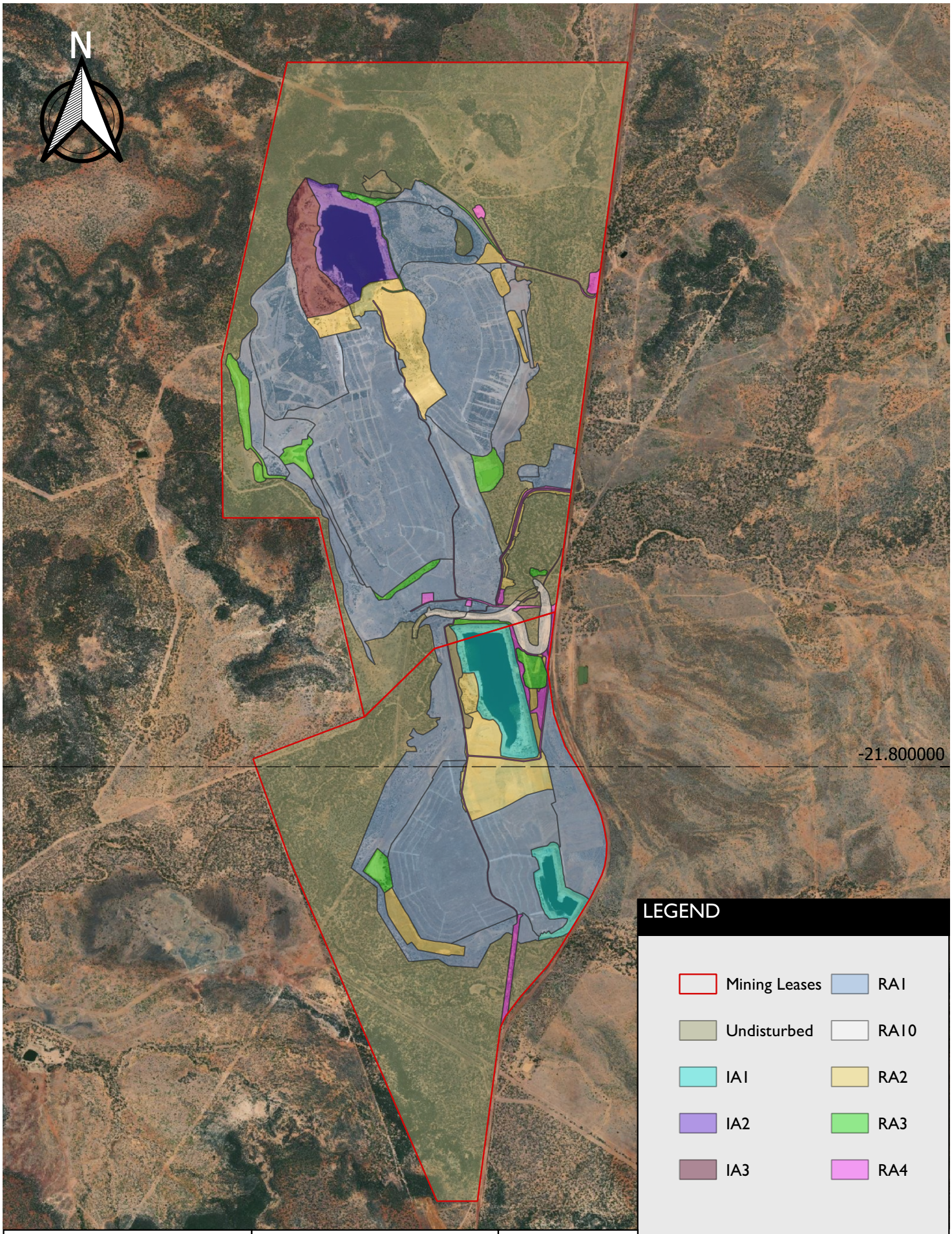

Project: Progressive Rehabilitation and Closure Plan		Client: Peabody (Burton Coal) Pty Ltd	
Figure: 36	Title: Rehabilitation Areas (South)	Design: SGM Environmental Pty Ltd 10.06.2022 Scale: 1 : 30,000 CRS: GDA94 / MGA zone 55	SGMenvironmental

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A.2 Schedule of land availability

Land will become progressively available for rehabilitation throughout the life of the Mine. Land is considered available for rehabilitation when:

- the land is no longer being mined;
- the land is no longer being used for operating infrastructure or machinery for mining including dam or water storage;
- the land is not needed for mining of a probable or proved ore reserve; or
- the land contains permanent infrastructure that will remain on the land for a PMLU.

The schedule of land availability for rehabilitation and improvement (NUMAs) is given in Table 52.

Table 52 Schedule of land availability for rehabilitation / improvement

		Land available for rehabilitation in each (ha)						
Feature		**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
RA1	Existing rehab south	694.7						
RA2	OB dumps and topsoil south	95.6						
RA3	Surface water management south	15.5						25.3
RA4	Infrastructure south							21.7
RA5	Existing rehab north	269.6						
RA6	OB dumps and topsoil north	259.5						
RA7	Surface water management north	18.8	24.3					

		Land available for rehabilitation in each (ha)						
RA8	Infrastructure north							25
RA9	Self-sustaining native vegetation — Bullock Creek	10.6						
RA10	Riparian veg — Spade Creek		12.6					
Sub-total		**1,364.3**	**36.9**	**-**	**-**	**-**	**-**	**72**
IA1	Broadmeadow voids	55.9						
IA2	Wallanbah void	39.1						
IA3	Wallanbah void low wall				6.8	7.5	7.5	2.4
IA4	Bullock Creek void	28.1						
IA5	Plumtree void	75.4						
Total		**198.5**	**-**	**-**	**6.8**	**7.5**	**7.5**	**2.4**

A.3 Rehabilitation milestones / criteria

Rehabilitation milestones are needed for each PMLU identified in accordance with section 126D of the EP Act. The purpose is to identify each significant event or step necessary to rehabilitate the land to a stable condition.

Land is in a stable condition if the land is safe and structurally stable, there is no environmental harm being caused by anything on or in the land and the land can sustain a PMLU (Section 11A of the EP Act).

Rehabilitation milestones and milestone criteria relevant to each rehabilitation area are listed in Table 53.

Table 53 Rehabilitation milestones and milestones criteria

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
RM1	Infrastructure decommissioning and removal	• All site services disconnected and decommissioned; • All road materials (bitumen and gravel) removed; • All above ground pipelines drained and removed; • All fencing not required by a subsequent landholder is removed; • All buildings not required by a subsequent landholder demolished and removed; and • All drillholes, sumps, exploration tracks and gridlines decommissioned.	RA2, RA3, RA4, RA6, RA7 and RA8
RM2	Remediation of contaminated land	• Carry out preliminary and intrusive contaminated land investigations; • Removal or on-site treatment of contaminated water; • Removal or on-site treatment of contaminated material; • Conduct validation testing to confirm that contaminated water / materials have been removed/remediated; and • Certification from an appropriately qualified person (AQP) that all contaminated land has been remediated or removed and disposed of according to licence conditions.	RA2, RA4, RA6 and RA8
RM3	Landform development and reshaping / re-profiling	• Finalise engineering and design plans; • Bulk earthworks to achieve required landform and slopes; • General reshaping and pushing/trimming to achieve final landform; • Slope of constructed landforms is ≤20% in at least 80% of the nominated area and verified by an AQP; • Final highwall/end wall batters of voids meet EA requirements and verified by an AQP; • Sediment and mine water dams not required for sediment control or by a subsequent landholder are desilted and backfilled using their embankments; and • Install erosion and sediment control systems.	RA2, RA3, RA4, RA6, RA7, RA8 and RA10

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
RM4	Surface preparation	• Remediate excessive erosion or subsidence; • An assessment of soil health and suitability has been completed by an AQP to confirm soil is suitable for target vegetation establishment; • Application of ameliorants as per requirements of the soil health and suitability assessment; • Deep ripping of compacted areas; and • Placement of 0.2 m of soil.	RA2, RA3, RA4, RA6, RA7, RA8 and RA10
RM5	Revegetation (grazing with areas of bushland habitat)	• Completed seeding of target species at rate consistent with the revegetation plan; • Application of fertiliser as per requirements of the soil health and suitability assessment; and • Deep ripping along the contour on slopes.	RA2, RA3, RA4, RA6, RA7 and RA8
RM6	Revegetation (self-sustaining native vegetation and riparian)	• Completed seeding of target species at rate consistent with the revegetation plan; • Application of fertiliser as per requirements of the soil health and suitability assessment; • Planting of tubestock; and • Install stock fencing to protect planting where required.	RA10
RM7	Achievement of surface requirements (riparian)	• No active areas of gully erosion; and • Certification from an AQP that weed and pest species are no greater than the nominated reference sites.	RA10

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
RM8	Achievement of surface requirements (grazing with areas of bushland habitat)	• 80% of the nominated area has an average groundcover (consisting of standing live vegetation, attached litter, detached litter, rocks >5 cm and course woody debris) ≥70% as verified by an AQP; • No active areas of gully erosion and drainage follows appropriate drainage paths; • Certification from an AQP that weed and pest species are no greater than the nominated reference sites; • Water control structures are either removed or are free from active erosion as verified by an AQP; • Average erosion rate of ≤5 t/ha/year; • Erosion gullies are less than or equal to 1m deep; and • Certification form an AQP that rehabilitation is resilient to fire.	RA1, RA2, RA3, RA4, RA5, RA6, RA7 and RA8,
RM9	Achievement of surface requirements (self-sustaining native vegetation)	• No active areas of gully erosion; and • Certification from an AQP that weed and pest species are no greater than the nominated reference sites.	RA9

RM10	Achievement of PMLU to a stable condition (grazing with areas of bushland habitat)	• Certification from an AQP that the area has achieved stable condition; • Certification from an AQP that the landform has achieved an acceptable factor of safety; • Average erosion rate of ≤5 t/ha/year; • 80% of the nominated area has an average groundcover (consisting of standing live vegetation, attached litter, detached litter, rocks >5 cm and course woody debris) ≥70% as verified by an AQP; • Biomass and cattle grazing indicators meet a minimum land suitability class of 4 and a minimum land capability class of VII as verified by an AQP; Surface water runoff quality from the area complies with the following: • pH is between 6.5 and 9.0; • EC is 20th of downstream monitoring points and 80th percentile of upstream monitoring points; • suspended solids are <1,000mg/L; • sulfate is 20th of downstream monitoring points and 80th percentile of upstream monitoring points • Cr is <1 µg/L; • Cu is <2 µg/L; Zn is <8 µg/L; • Se is <10 µg/L; • U is <1 µg/L; • nitrate is <1,100 µg/L; • petroleum hydrocarbons (C6-C9) is <20 µg/L; • petroleum hydrocarbons (C10-C36) is <100 µg/L; • Na is <180 mg/L; • B is <2,000 µg/L. Groundwater pH and EC does not show a statistically significant	RA1, RA2, RA3, RA4, RA5, RA6, RA7, RA8 and RA9

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
		change when compared to background data for a period of five years prior to relinquishment.	
RM11	Achievement of PMLU to a stable condition (riparian and self-sustaining native vegetation)	• Certification from an AQP that the area has achieved a stable condition; • Certification from an AQP that the self-sustaining vegetation areas are consistent with reference site BAS-NAT-02 based on BioCondition monitoring; and • Certification from an AQP that riparian areas are consistent with reference sites based on BioCondition monitoring.	RA10

A.4 Management milestones / criteria

Table 54 Management milestones and milestone criteria

Milestone criteria	Management milestone	Milestone criteria	Improvement area
MM1	Wall treatments	• walls / slopes assessed as stable by an appropriately qualified person (AQP) (geotechnical engineer) and consistent with EA conditions.	IA1, IA2, IA3, IA4 and IA5
MM2	Achievement of surface requirements / access controls	• safety bund setback distance is in accordance with calculated geotechnical factor of safety; • safety bund constructed at 2m high, base width of 14m and 1:3 batters; • fencing installed at nominated offset from safety bund (nominally a four-strand barbed stock fence); and • safety signage (design in accordance with Australian Standard) is erected at specified intervals along the fence.	IA1, IA2, IA3, IA4 and IA5
MM3	Achievement of sufficient improvement	• certification from an appropriately qualified person that the residual void will not cause environmental harm outside of the relevant tenure boundary; • certification from an appropriately qualified person that the residual void is safe to humans and livestock; • certification from an appropriately qualified person that the water level and quality in the void will not cause environmental harm to the surrounding environment; and • regraded slopes with minimum 70% vegetation cover.	IA1, IA2, IA3, IA4 and IA5

A.5 Proposed PRC plan schedule

The *Progressive Rehabilitation and Closure Plan Schedule template* is given on the following page.

A.5.1 Timing considerations

Revegetation and establishment (RM 5 — RM11) are strongly season-dependent.

All predictions of land availability within the calendar year are based on the current forecast projection date of the Project. This date is subject to change and government approval. Milestones (ie annual report of rehabilitation works) have a completion date of the 10 December of the calendar year.

Post-mining land uses (PMLU)											
Rehabilitation area				RA1							
Relevant activities				Existing Rehabilitation South							
Total rehabilitation area size (ha)				694.7							
Commencement of first milestone: RM8				10/06/2022							
PMLU				Grazing with Areas of Bushland Habitat							
Date area is available	10/06/2022										
Cumulative area available (ha)	694.7										
Milestone completed by	10/12/2025	10/12/2042									
Milestone Reference	**Cumulative area achieved (ha)**										
RM8	694.7										
RM10		694.7									

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)											
Rehabilitation area	RA2										
Relevant activities	Overburden Dumps and Topsoil Stockpiles South										
Total rehabilitation area size (ha)	95.6										
Commencement of first milestone: RM1	10/06/2022										
PMLU	Grazing with Areas of Bushland Habitat										
Date area is available	10/12/2022										
Cumulative area available (ha)	95.6										
Milestone completed by	10/12/2022	10/12/2024	10/12/2025	10/12/2026	10/12/2027	10/12/2028	10/12/2029	10/12/2030	10/12/2031	10/12/2032	10/12/2042
Milestone Reference	**Cumulative area achieved (ha)**										
RM1	95.6										
RM2	95.6										
RM3		51.5	63.8	76.2	88.5	95.6					
RM4			51.5	63.8	76.2	88.5	95.6				
RM5			51.5	63.8	76.2	88.5	95.6				
RM8						51.5	63.8	76.2	88.5	95.6	
RM10											95.6

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA3									
Relevant activities	Surface Water Management Infrastructure South									
Total rehabilitation area size (ha)	40.8									
Commencement of first milestone: RM1	10/06/2022									
PMLU	Grazing with Areas of Bushland Habitat									
Date area is available	10/06/2022									
Cumulative area available (ha)	40.8									
Milestone completed by	10/12/2024	10/12/2025	10/12/2026	10/12/2027	10/12/2028	10/12/2029	10/12/2030	10/12/2031	10/12/2032	10/12/2042
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	15.5	15.5	15.5	15.5	40.8					
RM3	15.5	15.5	15.5	15.5	40.8					
RM4		15.5	15.5	15.5	15.5	40.8				
RM5		15.5	15.5	15.5	15.5	40.8				
RM8					15.5	15.5	15.5	15.5	40.8	
RM10										40.8

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA4									
Relevant activities	Infrastructure South									
Total rehabilitation area size (ha)	21.7									
Commencement of first milestone: RM1	10/12/2028									
PMLU	Grazing with Areas of Bushland Habitat									
Date area is available	10/12/2028									
Cumulative area available (ha)	21.7									
Milestone completed by	10/12/2029	10/12/2030	10/12/2031	10/12/2034	10/12/2042					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	21.7									
RM2	21.7									
RM3		21.7								
RM4			21.7							
RM5			21.7							
RM8				21.7						
RM10					21.7					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA5									
Relevant activities	Existing Rehabilitation North									
Total rehabilitation area size (ha)	269.6									
Commencement of first milestone: RM8	10/06/2022									
PMLU	Grazing with Areas of Bushland Habitat									
Date area is available	10/06/2022									
Cumulative area available (ha)	269.6									
Milestone completed by	10/12/2025	10/12/2042								
Milestone Reference	**Cumulative area achieved (ha)**									
RM8	269.6									
RM10		269.6								

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA6									
Relevant activities	Overburden Dumps and Topsoil Stockpiles North									
Total rehabilitation area size (ha)	259.5									
Commencement of first milestone: RM1	10/06/2022									
PMLU	Grazing with Areas of Bushland Habitat									
Date area is available	10/12/2022									
Cumulative area available (ha)	259.5									
Milestone completed by	10/12/2022	10/12/2023	10/12/2024	10/12/2025	10/12/2026	10/12/2027	10/12/2028	10/12/2042		
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	259.5									
RM2	259.5									
RM3	82.9	207.2	259.5							
RM4		82.9	207.2	259.5						
RM5		82.9	207.2	259.5						
RM8					82.9	207.2	259.5			
RM10								259.5		

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA7									
Relevant activities	Surface Water Management Infrastructure North									
Total rehabilitation area size (ha)	43.1									
Commencement of first milestone: RM1	10/06/2022									
PMLU	Grazing with Areas of Bushland Habitat									
Date area is available	10/06/2022									
Cumulative area available (ha)	43.1									
Milestone completed by	10/12/2023	10/12/2024	10/12/2025	10/12/2027	10/12/2028	10/12/2042				
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	18.8	43.1								
RM3	18.8	43.1								
RM4		18.8	43.1							
RM5		18.8	43.1							
RM8				18.8	43.1					
RM10						43.1				

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA8									
Relevant activities	Infrastructure North									
Total rehabilitation area size (ha)	25.0									
Commencement of first milestone: RM1	10/12/2028									
PMLU	Grazing with Areas of Bushland Habitat									
Date area is available	10/12/2028									
Cumulative area available (ha)	25.0									
Milestone completed by	10/12/2029	10/12/2030	10/12/2031	10/12/2034	10/12/2042					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	25.0									
RM2	25.0									
RM3		25.0								
RM4			25.0							
RM5			25.0							
RM8				25.0						
RM10					25.0					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA9									
Relevant activities	Completed Riparian Vegetation Bullock Ck									
Total rehabilitation area size (ha)	10.6									
Commencement of first milestone:	10/06/2022									
PMLU	Self Sustaining Native Vegetation									
Date area is available	10/06/2022									
Cumulative area available (ha)	10.6									
Milestone completed by	10/12/2032	10/12/2042								
Milestone Reference	.									
RM9	10.6									
RM10		10.6								

1) Insert new columns to the <u>yellow table</u> to include further rehabilitation milestone dates.
2) Insert new columns to the <u>blue table</u> to match rehabilitation milestone dates.
3) Insert new rows to the <u>blue table</u> to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)											
Rehabilitation area				RA10							
Relevant activities				Riparian Vegetation Spade Ck							
Total rehabilitation area size (ha)				12.6							
Commencement of first milestone:				10/12/2023							
PMLU				Riparian							
Date area is available	10/12/2023										
Cumulative area available (ha)	12.6										
Milestone completed by	10/12/2024	10/12/2028	11/12/2042								
Milestone Reference	**Cumulative area achieved (ha)**										
RM3	12.6										
RM4	12.6										
RM6	12.6										
RM7		12.6									
RM11			12.6								

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Non-use management area (NUMA)										
Improvement area	IA1									
Relevant activities	Broadmeadow Voids									
Total size (ha)	55.9									
Commencement of first milestone: MM1	10/06/2022									
NUMA	Non Use Management Area associated with Pit Void									
Date area is available	10/06/2022									
Cumulative area available (ha)	55.9									
Milestone completed by	10/12/2025	10/12/2042								
Milestone Reference	**Cumulative area achieved (ha)**									
MM1	55.9									
MM2	55.9									
MM3		55.9								

1) Insert new columns to the yellow table to include further management milestone dates.
2) Insert new columns to the blue table to match management milestone dates.
3) Insert new rows to the blue table to include additional management milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. MM1).

Non-use management area (NUMA)										
Improvement area	IA2									
Relevant activities	Wallanbah Void									
Total size (ha)	39.1									
Commencement of first milestone: MM1	10/06/2022									
NUMA	Non Use Management Area associated with Pit Void									
Date area is available	10/06/2022									
Cumulative area available (ha)	39.1									
Milestone completed by	10/12/2025	10/12/2042								
Milestone Reference	**Cumulative area achieved (ha)**									
MM1	39.1									
MM2	39.1									
MM3		39.1								

1) Insert new columns to the yellow table to include further management milestone dates.
2) Insert new columns to the blue table to match management milestone dates.
3) Insert new rows to the blue table to include additional management milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. MM1).

Non-use management area (NUMA)										
Improvement area	IA3									
Relevant activities	Wallanbah Void Lowwall									
Total size (ha)	24.2									
Commencement of first milestone: MM1	10/06/2022									
NUMA	Non Use Management Area associated with Pit Void									
Date area is available	10/06/2022									
Cumulative area available (ha)	24.2									
Milestone completed by	10/12/2025	10/12/2026	10/12/27	10/12/28	10/12/29	10/12/42				
Milestone Reference	**Cumulative area achieved (ha)**									
MM1	6.8	14.3	21.8	24.2						
MM2					24.2					
MM3						24.2				

1) Insert new columns to the yellow table to include further management milestone dates.
2) Insert new columns to the blue table to match management milestone dates.
3) Insert new rows to the blue table to include additional management milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. MM1).

Non-use management area (NUMA)										
Improvement area	IA4									
Relevant activities	Bullock Ck Void									
Total size (ha)	28.1									
Commencement of first milestone: MM1	10/06/2022									
NUMA	Non Use Management Area associated with Pit Void									
Date area is available	10/06/2022									
Cumulative area available (ha)	28.1									
Milestone completed by	10/12/2024	10/12/2042								
Milestone Reference	**Cumulative area achieved (ha)**									
MM1	28.1									
MM2	28.1									
MM3		28.1								

1) Insert new columns to the yellow table to include further management milestone dates.
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3) Insert new rows to the blue table to include additional management milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. MM1).

Non-use management area (NUMA)										
Improvement area	IA5									
Relevant activities	Plumtree Void									
Total size (ha)	75.4									
Commencement of first milestone: MM1	10/06/2022									
NUMA	Non Use Management Area associated with Pit Void									
Date area is available	10/06/2022									
Cumulative area available (ha)	75.4									
Milestone completed by	10/12/2024	10/12/2042								
Milestone Reference	**Cumulative area achieved (ha)**									
MM1	75.4									
MM2	75.4									
MM3		75.4								

1) Insert new columns to the yellow table to include further management milestone dates.
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3) Insert new rows to the blue table to include additional management milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. MM1).

Appendix B
Water management plan



BURTON COAL MINE
WATER MANAGEMENT PLAN

BUR-ENV-EMPLAN-018

27 April 2022

Document Owner		Document Approver
Environment Manager		Environment Manager
Version	**Approval Date**	**Approver Name**
2.2	March 2015	John Merritt
3		
4	February 2017	Justin Vohland
5	December 2017	Justin Vohland
6	February 2019	Justin Vohland
7	March 2020	Justin Vohland
8	March 2021	Daryn Railey
9	April 2022	Daryn Railey

General Description of Changes from Previous Version

Updates to align with current operations
Updates for the Care and Maintenance Phase – Version 4
Updates for the sale of New Burton Mine – Version 5
Updates for saline drainage management – Version 6
Updated following annual review – Version 7
Annual review – Version 8 and Version 9

2020 Burton Water Management Plan Review

As per Section C32 of the Burton EA issued under the EP Act 1994, a review of Burton Coal Mine's (BCM) water management plan was undertaken on 18/2/2020. Suggested amendments and recommendations from the review have been provided to the Site Environmental Superintendent on the 18/02/2020. The expectation is that the 'plan' will be updated with the suggested amendments, and recommendations acted upon during the subsequent review period.

Name of Professional Person

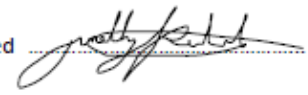
Timothy Kendrick
100 Melbourne St,
South Brisbane, 4101

Statement of Appropriate Qualification

Qualifications:
Bachelor of Science (Earth Sciences) (Honours) – Monash University, Victoria.

Experience:
I have 18 years' experience in water management in Australia and internationally in roles including consulting, operational and closed mine sites, water supply authorities, mineral exploration and corporate management. Areas of specialisation include groundwater exploration, groundwater and surface water supply, mine dewatering, mine water management planning, mine closure, water governance and environmental risk & compliance.

Statement
In my role as Senior Specialist, Environment and Water for Peabody I meet the definition of an 'appropriately qualified person'; where that definition is *"a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature"*; for the purposes of the review of a Water Management Plan.

Signed  Date 18/2/2020

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1 Introduction

Peabody (Burton Coal) Pty Ltd has prepared this Water Management Plan for the Burton Coal Mine (BCM) during its care, maintenance and rehabilitation phase, which commenced in November 2016 at the cessation of open cut operations.

The Water Management Plan (WMP) has been prepared in in compliance with BCM's environmental Authority (EPML00879213) Condition C32 and will be reviewed annually, with a view to revising it prior to the currently planned end of the care, maintenance and rehabilitation phase, which is likely to be completed by 1 April 2024 (subject to equipment and weather delays).

This plan is structured as follows:

- Section 2 gives the background to the operation, infrastructure and water management responsibilities during care and maintenance;
- Section 3 describes the environmental values of the regional and local drainage receiving surface waters;
- Section 4 presents the study of the source of contaminants on site;
- Section 5 presents the site water balance model and identifies performance criteria;
- Section 6 presents a description of the water management system for the site for managing the different water types on site;
- Section 7 presents the measures to manage and prevent saline drainage and acid rock drainage;
- Section 8 presents information on the Emergency Response Plan;
- Section 9 outlines the schedule for review of this WMP;
- Section 10 is a summary of the WMP provisions;
- Section 11 outlines the roles and responsibilities; and
- Section 12 gives a list of references and supporting documents.

2 Background

2.1 Description of Operations

BCM is owned by Peabody (Burton Coal) Pty Ltd (a wholly owned subsidiary of Peabody Australia Pty Ltd).

The mine site is located in the Bowen Basin QLD, approximately 150 km west of Mackay and 50 km north of Moranbah (**Figure 1**) and is operated under the BCM Environmental Authority (EA) EPML00879213.

Care and maintenance commenced in November 2016 with the cessation of all mining activity and coal processing onsite. The operation commenced in 1994 and was an open cut coal mine that utilised strip mining. In 2017, the northern portion of the mine site (ML 70109, EPC 857, MDL 349 and MDL 315) was transferred to New Hope Group via a sale agreement. This included the mine voids at Burton North, Burton Widening and Ellensfield and all associated infrastructure include the two co-disposal areas (CDA), the CHPP, the mine camp, Teviot Dam, the workshop and the administration area. The Mallawa Haul Road and train load out (TLO) facility were also transferred to New Hope Group (ML 70109). In December 2020, Broadmeadow East Mining Lease (ML70257), which was an undeveloped mining area, was sold by Peabody to Bowen Coking Coal.

BCM has four (4) mine voids which are shown in **Figure 2** and **Figure 3**. From north to south, they are:

- Plumtree;
- Bullock Creek;
- Wallanbah; and
- Broadmeadow.

The most recent mining area was Plumtree, which used Ellensfield void (New Lenton JV as part of New Hope Group) as a co-disposal facility and water storage. Ellensfield and the northern portion of the original BCM mining lease is no longer owned or operated by Peabody.

During the care and maintenance period, the following activities will occur:

- Rehabilitation of disturbed land; and
- Decommissioning and maintenance of site infrastructure.

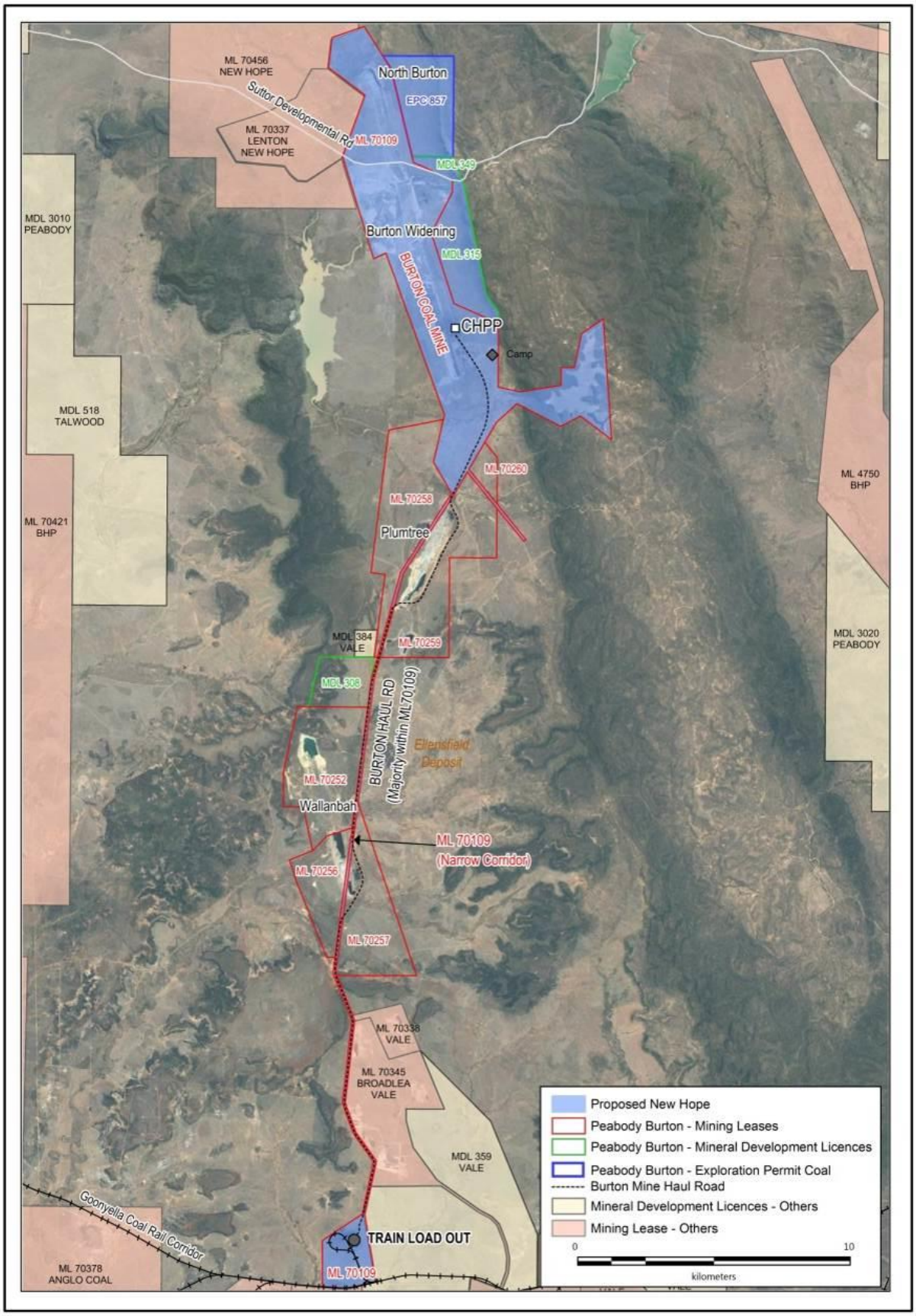

Figure 1: Burton Mining Lease and Tenements, showing the New Hope tenements at New Burton Coal Mine

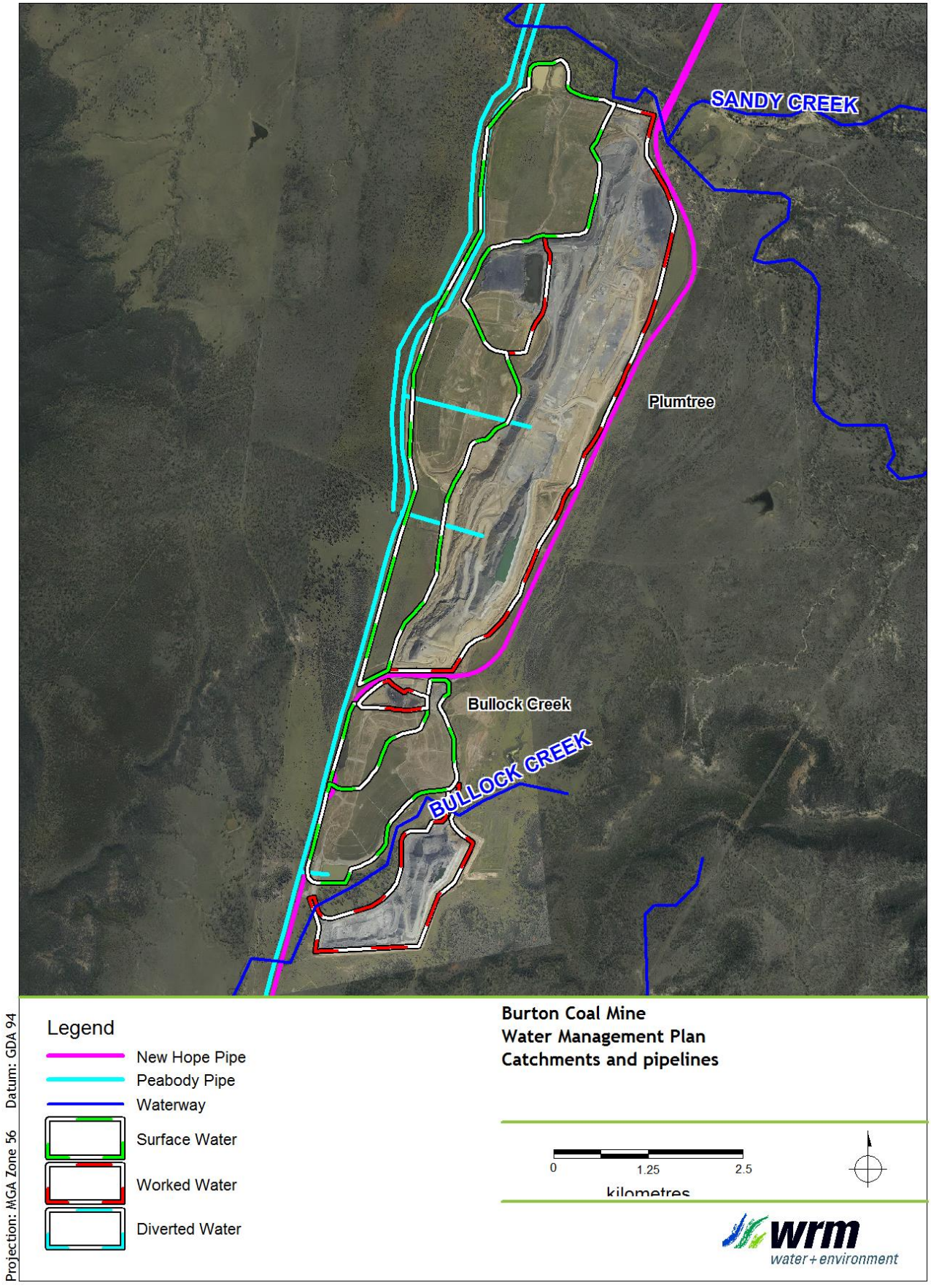

Figure 2: Plumtree and Bullock Creek catchment areas, mine voids and waterways

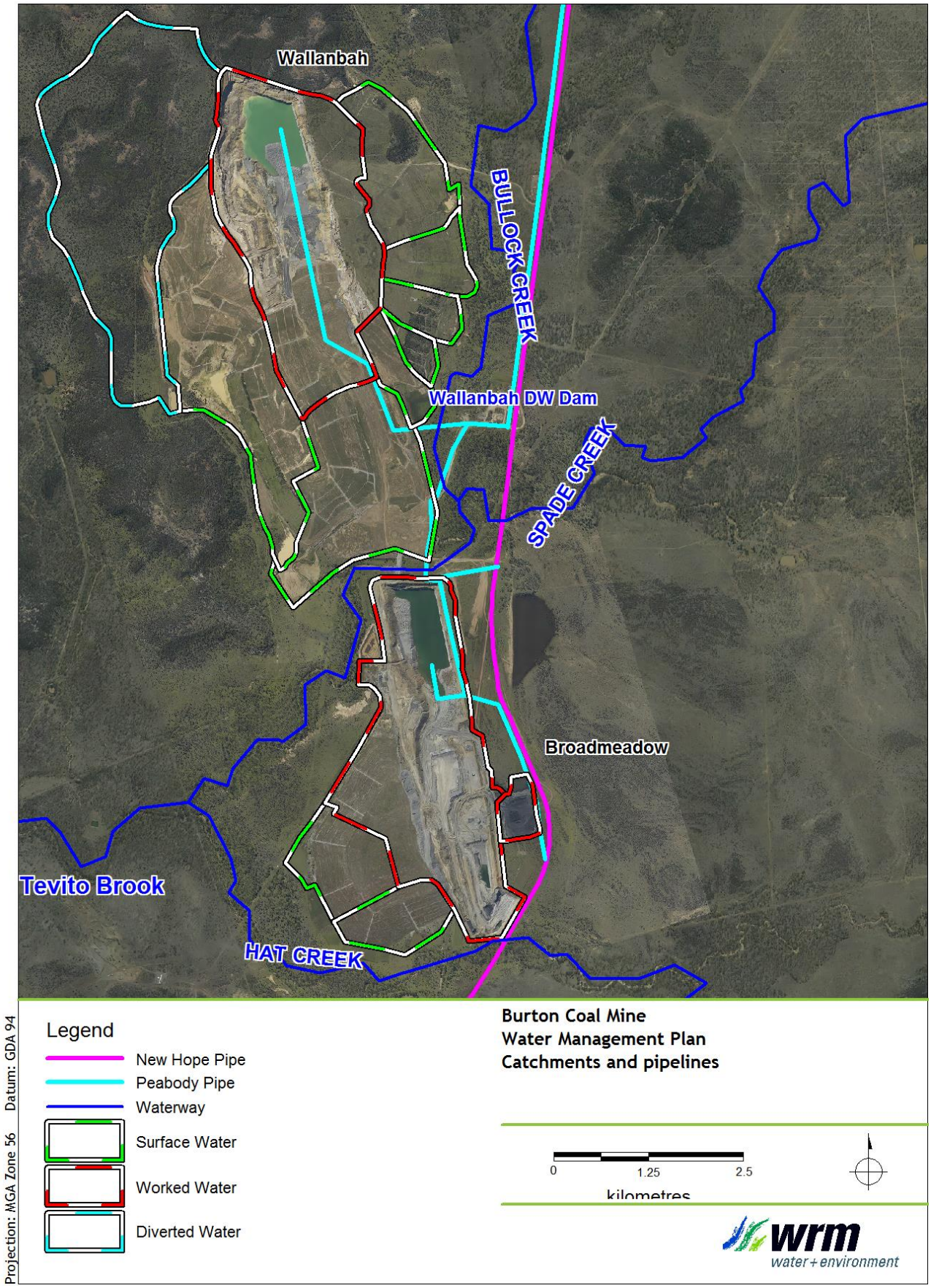

Figure 3: Wallanbah and Broadmeadow catchment areas, mine voids and waterways

2.2 Purpose and Scope

This WMP has been prepared to satisfy the conditions of the Burton Environmental Authority (EA) issued by the administering authority under Chapter 5 of the *Environmental Protection Act 1994* (EP Act). The WMP, in accordance with condition C32 of the BCM EA, must:

- Provide for effective management of actual and potential environmental impacts resulting from water management associated with the mining activity carried out under this environmental authority; and
- Be developed in accordance with the Department of Environment and Heritage Protection (DEHP) Guidelines on the Preparation of Water Management Plans for Mining Activities (DEHP, 2013a) including:
  - A study of the source of contaminants;
  - A water balance model for the site;
  - A water management system for the site;
  - Measures to manage and prevent saline drainage;
  - Measures to manage and prevent acid rock drainage;
  - Contingency procedures for emergencies; and
  - A program for monitoring and review of the effectiveness of the Water Management Plan.

The WMP examines and addresses all issues relevant to the importation, generation, use, and management of water on a mining project in order to minimise the quantity of water that is contaminated. During the care and maintenance phase, water will not be needed for operational use. The key goals of the water management system (WMS) will be:

- Maintain compliance with the BCM's EA;
- Minimise the generation of water on site, while maximizing the volume of water that runs off site in compliance with the *Burton Coal Mine Erosion and Sediment Control Plan* (ESCP); and
- Minimise the use of site resources for pumping.

The potential risks of environmental harm to natural waterways posed by mining activities have been identified and management actions that will effectively minimise these risks have been presented.

The WMP is a static compliance document. Yearly reviews will focus around the BCM's record of complying with this document and outlining actions for the year ahead to ensure continued compliance. The document will only be altered when changes occur to the site operations which will result in changes to the management of water. The yearly review will be completed by a competent person and will be responded to by site outlining the actions as required under the EA.

2.3 Related Documents

This WMP forms part of a BCM Environmental Management System and should be read in conjunction with the following documents:

- Burton Coal Mine - Hazardous Consequence Assessment – Dams (WRM 2014);
- Burton Coal Mine - Hazardous Consequence Assessment – Levees (WRM 2014);
- Burton Coal Mine - Consequence Category Assessments for Four Dams – (Henderson Geotech Pty Ltd, April 2016);
- Burton Coal Mine - Erosion and Sediment Control Standard (BUR-ENV-EMPLAN-017) ;
- Burton Coal Mine - Environmental Authority EPML00879213;
- Burton Coal Mine - Mine Water Release Procedure (BUR-ENV-EWI-001);

- Burton Coal Mine - Mine Water Release Flowchart (BUR-ENV-FC-001);
- Burton Coal Mine - Care and Maintenance Water Balance Modelling, Hatch, H351353-00000-228-230-0001);
- Burton Coal Mine - Receiving Environment Monitoring Plan (MNP_BUR_Receiving Environment Monitoring Program_v2_WRM)
- Burton Coal Mine - Regulated Structures Register and Operational Plans (REG_BUR_Regulated Structures Register_v1.7)

3 Environmental Values

3.1 Overview

This section of the WMP describes the environmental values and the regional drainage characteristics in the vicinity of BCM. The environmental values as defined by the *Environmental Protection Act 1994*, *Environmental Protection (Water) Policy 2009* and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000) and regulations of these waterways are described.

3.2 Receiving Water Environmental Values

The Environmental Protection Act 1994 aims to protect Queensland's water, whilst allowing ecologically sustainable development through the Environmental Protection (Water) Policy 2009 (EPP Water). The EPP Water achieves this within the following framework:

- Identifying environmental values for aquatic ecosystems and for human use; and
- Determine water Quality guidelines (WQGS) and water quality Objectives (WQOs) to enhance or protect the EVs

Environmental values are the qualities of waterways to be protected from activities in the catchment. Protecting environmental values aims to ensure healthy aquatic ecosystems and waterways that are safe and suitable for community use. Environmental values reflect the ecological, social and economic values and uses of the waterway, (such as stock water, swimming, fishing and agriculture).

The processes to identify EVs and determine WQGs and WQOs are based on the National Water Quality Management Strategy (ANZECC/ARMCANZ, 1994), Implementation Guidelines (1998) and further outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000). EVs and WQOs adopted for particular Queensland waters are included in Schedule 1 of the EPP Water. The waters in the connected waterways to BCM are scheduled in the Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011b).

The waterways within BCM are in the Isaac Northern Tributaries sub-region. The following EVs are identified under Schedule 1 of the EPP (Water) for this sub-region:

- Aquatic ecosystems;
- Irrigation;
- Farm supply/use;
- Stock water;
- Human consumer;
- Primary recreation;
- Secondary recreation;
- Visual recreation;
- Drinking water;
- Industrial use; and
- Cultural and spiritual values.

The indicators and water quality guidelines relevant to the above environmental values are listed in the Queensland Water Quality (QWQ) Guidelines (DEHP, 2009) and ANZECC Guidelines (2000). The conditions of waterways located in the vicinity of BCM are classified as Level 2: slightly to moderately disturbed ecosystems under the QWQ Guidelines. The downstream receiving waters for the three southern tributaries (Spade, Hat and Bullock Creek) do not include potable or irrigation water supply systems or National Parks within 100 km of the site.

The downstream catchment of Burton Gorge Dam (BGD) is used for potable water supply for North Goonyella Mine Camp. Mine activities within these catchments will be conducted in a manner to ensure minimal risk to water quality for downstream users.

3.3 Regional and Local Catchment Hydrology

Five (5) named waterways pass through the BCM mining lease which drain to two (2) local catchment systems and then Isaac River, which is part of the Fitzroy Basin. The two (2) local catchments are the BGD catchment, which is located in the northern section of the mine site, and the Teviot Brook catchment in the south. The waterways all drain east to west through the mine lease. All the waterways have sand beds with banks forming flood channels. The waterways are all ephemeral with typical flow durations from a few hours to days after rainfall events. Gauging stations are located on three (3) of the waterways to measure flow depth and linked via 4G mobile network to the Blomfield Environmental website as a 3rd party provided host.

3.3.1 Burton Gorge Dam Catchment

As shown in **Figure 2** Sandy Creek is the southernmost tributary of the BGD catchment and passes north of Plumtree Pit. Sandy Creek's catchment is grazing and bushland from the Kerlong Range. A gauging station is located both upstream and downstream of the mine to measure flow conditions of Sandy Creek.

3.3.2 Teviot Brook Catchment

Three (3) waterways pass through the BCM mine lease into Teviot Brook and then Isaac River. The waterways are Bullock Creek, which feeds into Spade Creek north of Broadmeadow, which in turn joins with Hat Creek on the western lease boundary near Broadmeadow. These three waterways all have grazing and bushland catchments within the Kerlong Range.

Spade and Bullock Creek have been diverted due to mine activity (WL 174800 & 577239). Both have gauging stations; the Bullock Creek station operates as the upstream gauging station for Spade Creek license discharge point. There are no Peabody owned gauging stations on Hat Creek as there are no licensed release points located on Hat Creek.

3.4 Water Quality

3.4.1 Burton Gorge Dam Catchment

Water quality characteristics of BGD and its associated waterways are listed below (**Table 1**), which was prepared for previous versions of this Plan based on historical water quality data. These table shows the 80th percentile water quality results compared with the default ANZECC Aquatic Ecosystem Trigger Values. The following is of note:

- All waterway samples were taken from upstream of the mine site, so there is no impact from mining;
- The cells highlighted red indicate 80th percentile values that are above the default ANZECC Aquatic Ecosystem Trigger Values;
- Water Quality parameters in the dam exceeding the default ANZECC values, are exceeding in the creek system, which indicates the exceedance being likely due to natural background conditions, with the exception of Electrical Conductivity (EC) which is above limits in BGD, but not the waterways;
- Records don't indicate significant accumulation of metals in the dam, with water quality parameters in the creeks generally similar to or exceeding those in BGD;

Release points for controlled discharges in the BGD catchment are located on Teviot Creek and Sandy Creek.

BGD is a source of drinking water and operational supply for Peabody North Goonyella Coal Mine (NGC) and accommodation camp. For this reason, release conditions into these waterways are to ensure no impact to drinking water quality values within BGD. Releases on the BGD spillway are downstream of any offtakes for drinking water, and therefore don't pose a risk to drinking water supply. The land surrounding BGD is also grazed by cattle, on land that is not owned by Peabody.

Table 1 : Burton Gorge Dam and tributaries 80th percentile water quality results compared to ANZECC Trigger values

Parameter	Units	Trigger	BGD	Anna	Teviot	Sandy	Isaac
pH Lower	pH units	6					
pH Upper	pH units	7.5	7.9	8.0	6.9	8.1	7.9
EC	µs/cm	250	264	156	116	239	160.6
Total Nitrogen	mg/L	0.15	0.07	0.12	0.04	0.36	0.1
Nitrate + nitrite	mg/L	0.03	0.06	0.30	0.03	0.11	0.06
Phosphorus	mg/L	0.01	0.18	0.12	0.07	0.30	0.64
Aluminium	mg/L	0.055	0.08	5.1	4.0	9.6	20.5
Arsenic	mg/L	0.024	0.001	0.0010	0.001	0.0014	0.001
Boron	mg/L	0.37	0.10	0.063	0.05	0.09	0.05
Cadmium	mg/L	0.0002	0.0001	0.0001	0.0001	0.00018	0.0001
Chromium	mg/L	0.001	0.007	0.005	0.003	0.018	0.017
Copper	mg/L	0.0012	0.0070	0.0040	0.0036	0.0076	0.0200
Lead	mg/L	0.0034	0.0040	0.0048	0.0020	0.0070	0.0098
Manganese	mg/L	1.9	0.15	0.08	0.03	0.16	0.54
Mercury	mg/L	0.0006	0.0001	0.0001	0.0001	0.0001	0.0001
Nickel	mg/L	0.011	0.009	0.004	0.004	0.008	0.019
Selenium	mg/L	0.011	0.01	0.01	0.01	0.01	0.01
Silver	mg/L	0.00005	0.001	0.001	0.001	0.001	0.001
Zinc	mg/L	0.008	0.019	0.014	0.007	0.025	0.040

All metals samples are dissolved

3.4.2 Teviot Brook Catchment

BCM has not released any water into Bullock or Spade Creek since mining operations ceased in the area and no longer uses these release points. This is due to the remote location, which isn't accessible during rainfall events large enough to create flows in the creek. Flow durations are short, lasting only hours to a day, so the only sampling option for background water quality is via rising stage samplers.

Water quality in the Isaac River downstream of BGD and Teviot Brook has been recorded at the DEHP stream gauging station #130414A (Isaac River at Goonyella). Review of the results indicates that the Isaac River downstream of BCM has the following characteristics:

- Fresh to brackish water salinity, with EC values ranging between 120 and 3,500 µS/cm;
- Slightly alkaline, with a mean pH of 7.6.

Mean values exceed the default ANZECC trigger values for the following parameters: conductivity, turbidity, pH, total nitrogen, NOx, total phosphorous, copper and zinc.

Note that the Isaac River water quality results are potentially affected by discharges from other mine sites in the region.

3.5 Geology and Soils

3.5.1 Geology

Burton Coal targets seams from the Rangal coal measures. In the southern mine area, the Leichardt and Vermont seams are present and join with the Burton Seam in the northern section. The Burton seam is 10 m thick and was the primary seam mined. The coal is mined along strike, with a steep down dip.

The Burton Range fault is a large structural feature and strikes north, north-west. The dominant rock types in the coal measures are sandstones, siltstones, mudstones and coal.

3.5.2 Topography

BCM is located in the Kerlong Valley. The valley floor is relatively flat, with the Kerlong range to the east of the site which rises 210 to 220 m above the valley floor. The valley is 6 to 8 km wide and 26 km long.

3.5.3 Soil Landscape

The mine lease is predominately composed of Land Zone 3 area, with small sections of Land Zone 4 and 9 at the southern extent of the site.

- Land Zone 3 - is quaternary alluvial systems, including floodplains, alluvial plains, alluvial fans, terraces, levees, swamps, channels and fine textured paleo-estuarine deposits. This includes areas under freshwater influence and inland lakes. The soils are predominantly Vertosol and Sodosol, also with Hydrosols in higher rainfall areas.
- Land Zone 4 - is Cainozoic clays deposits forming level to gently undulating plains over alluvial systems. Mainly Vertosols with areas of thin sandy or loamy surfaced Sodosol and Chromosols.
- Land Zone 9 - is fine rained sedimentary rocks, generally with little or no deformation. Undulating landscapes with a broad range of fine textured soils of moderate to high fertility. Siltstone's mudstones, shales, calcareous sediments, and lithic and labile sandstones are typical rock types although minor interbedded volcanic may occur. Diverse range of soils including Vertosols, sodosols and Chromosols with moderate to high fertility.

4 Contaminant Source Study

4.1 Overview

Activities at BCM during care and maintenance which have the potential to impact on the receiving environment by the introduction of contaminants are as follows:

- Runoff from disturbed land (e.g. from stockpiles, overburden dumps and rehabilitation);
- Saline drainage from overburden dumps;
- Groundwater inflows to the pits; and
- Runoff from chemical or fuel/oil spills.

4.2 Site Operating Activities

BCM was an open cut coal mining operation and is currently under care and maintenance. Under care and maintenance, permanent facilities (i.e., buildings) will not be operated. They will be continually maintained or decommissioned and removed from site.

There will be no traditionally open cut mining activities during the care and maintenance phase. Pit voids will be used as water storages as required and operated in compliance with EA conditions. The figures in the Appendix show the layout of the four (4) pits and any water monitoring locations within their vicinity.

4.3 Runoff Water Quality – Water types

BCM has monitored water quality in dams that capture surface runoff since mining commenced. The water quality results are all stored in the Peabody EQuIS water quality database. Due to BCM having previously had over 20 dams, which have had changing landforms during their lifetime, it is hard to define the water quality for each dam individually as they change significantly with landforms. A summary of water quality in dams with catchments of different water type is provided below.

For water management system purposes, the water generated at BCM is divided into five (5) types.

4.3.1 External or Raw Water

External or raw water is water brought onto site is usually of potable quality. Teviot Dam is owned and operated by New Hope Group, located within in the Kerlong Range. Teviot Dam water can be accessed from BCM, if required. Teviot Dam water may be supplied to BCM for fire and washdown water or for the filling of dams for cattle grazing. This water presents no potential for environmental harm.

On occasion BCM may receive other water from other mine sites or external third parties. This water may be raw or mine affected water. Most recently water was received from NGC and placed in Plumtree void. This water was mine affected but was monitored to ensure it posed no detrimental effect to BCM's water quality.

4.3.2 Diverted Water

Diverted water is runoff from areas surrounding the mine that is undisturbed and diverted away from the operations with no impact from the mine site. Diverted water is directed to one of the five waterways that run through the mine lease.

The effective operation of drainage structures diverting water away from disturbed area runoff water storages is critical to the effective management of disturbed area runoff in the site water containment systems.

4.3.3 Surface Water

Surface water is runoff from areas on the mine lease that have been disturbed but not in an active operational area or have been rehabilitated. The only potential contaminant is suspended solids, and this can be controlled through the Burton Coal Mine Erosion and Sediment Control Standard (BUR-ENV-EMPLAN-017). Any surface water that does accumulate in a dam shall only be discharged in compliance with BCM's EA conditions.

The water quality of dams with rehabilitated or undisturbed catchments is typically as follows:

- EC can vary from 200 to 700 µS/cm, this is highly dependent on the time of the rainfall event, with the first flush of a catchment yielding higher values then subsequent rainfall; and
- Other parameters are below EA trigger conditions or are similar to background receiving water levels.

Surface runoff to dams with catchments containing out of pit dumps (OOPD), have water quality which is typically:

- EC from 500 to 2,500 µS/cm during the wet season;
- pH typically ranges from 7.5 to 9;
- metals are below EA trigger values or similar to background receiving waters; and
- Suspended solids (TSS) can be higher than EA trigger values, however background monitoring of creeks has shown TSS to get to be above 2,000 mg/L in some events.

These catchments are directed to sediment dams and will not be allowed to drain directly off site until rehabilitated.

4.3.4 Mine Affected Water

Mine affected water is water that has come into contact with operational areas such as active mine areas, pits, operational areas such as the CHPP and Workshop or runoff from coal stockpiles. This water shall be stored in designated worked water dams or pit voids. Discharge of this water must be in compliance with BCM's EA conditions.

Worked water catchments typically have:

- EC values of up to 5,000 µs/cm;
- pH in the range of 8 to 8.5;
- Some metals such as Zinc and Uranium can be higher than trigger values in the EA, however this also occurs in the local creek systems;
- Sulfates are typically around 300 mg/L; and
- Sodium can also exceed trigger levels for the EA in some catchments.

BCM shall maximise the use of worked water for all operational purposes that don't require potable water and potential offsite transfer from BCM to other Peabody mines and/or 3rd parties under water transfer agreements.

4.3.5 Associated water

Associated water is water that drains into pits from groundwater sources. There is no dewatering of groundwater from bores. Associated water is managed as worked water on site due to its poor water quality.

4.4 Co-Disposal Runoff

BCM does not have any co-disposal facilities.

4.5 Groundwater

Groundwater at BCM can range in EC from 1,800 to 32,600 µS/cm (JBT, 2016) depending on the source, with higher values occurring from coal seams. However, the principal source of groundwater in the region is the coal seams. Once water levels in the pit are above the coal seams, inflows from groundwater have been observed to significantly reduce by site personnel. Under care and maintenance, pit voids will not be dewatered unless they reach their DSA.

Conditions C47 to C50 of the BCM EA outline the groundwater monitoring schedule for BCM. The majority of these bores are cased and in coal seams, which have water quality that is of no environmental or agricultural value. Additionally, due to the steeply dipping seams at BCM, most of the bores are located outside the area of influence of any pits. There are currently no groundwater bores being used for any production purposes at BCM.

The groundwater water quality that is suitable for use include:

- Tertiary basalt aquifers are within both livestock and drinking water limits;
- Permian sediments and coal seams at unfit for use with a median EC of 13,940 µS/cm and only 10 out of 191 sample below 5,970 µS/cm;

The locations of all sampling Bores are listed in Schedule 2 – Table 3 of the BCM EA. There are currently no monitoring sites that meet this criterion at BCM.

Post mining conceptual groundwater model by JBT (2016), suggests that groundwater inflows to pits will be less than evaporation, resulting in no impact to pit storage inventories.

4.6 Chemical and fuel Storage

Storage of all chemicals at BCM is within designated areas with bunds to the specifications of *AS1940 - Storage and Handling of Flammable and Combustible Liquids (2004)*. Spill response and procedures are managed under the Safety Health and Management System (SHMS) and Standard Operating Procedures (SOPs). An inventory and MSDS list of all chemicals are managed by site personnel. Chemical storage areas are all within the catchments of worked water dams. During care and maintenance minimal chemicals will be stored on site.

All fuel at site is stored within bunds in the workshop area. All tanks are maintained and operated as per of *AS1940 - Storage and Handling of Flammable and Combustible Liquids (2004)*. Spill response procedures are managed under the SHMS and SOPs. All fuel storages are located within worked water dam catchments.

4.7 Sewage Effluent

During care and maintenance, the sewage treatment plant will not be operated. Septic tanks will be used for the site administration building which will be emptied by licensed contractors.

5 Mine Site Water Balance

HATCH Pty Ltd (2018) updated the OPSIM water and solute balance model for BCM to reflect the water management strategy under care and maintenance. All details and assumptions are included in the *Burton Coal Mine – Final Void Modelling 2018* report. The model was developed to determine the following during care and maintenance:

- Frequency of uncontrolled releases from worked water dams;
- The pit storage inventories to determine pumping requirements; and
- Modelling of controlled releases at the BGD release point to understand their influence on mine site inventories.

The model is managed by site and is reviewed yearly to ensure the WMS is operated such that discharge risks are appropriately managed. Details of the water balance model are outlined in the following sections.

5.1 Uncontrolled Release from Worked Water Dams

Previous modelling of worked water dams was used to determine the Annual Exceedance Probability (AEP) of each dam spilling (Hatch, 2016). The following worked water dam spilled at a frequency greater than 10% AEP (though the modelling overestimated catchment areas in some instances, and the catchment is now fully rehabilitated):

- Wallanbah DW Dam which releases to Bullock Creek (shown in **Figure 3**);

During the care and maintenance phase, the runoff to and water stored in these dams is likely to have contaminant concentrations lower than during operational phases. Subsequently a history of water quality data was supplied to the regulator to allow the transition of the Wallanbah DW dam to a surface water dam for water management purposes. As such the pumping of surface water dams at BCM is currently not an operational requirement.

5.2 Pit Storage Inventory

During the care and maintenance phase, there will be no active mine pits. The modelled results indicate that while inventories are likely to remain steady over the next three (3) years, there is at least a 90% chance that no DSA, MRL or operating levels will be exceeded, so pumping or uncontrolled release from pits is highly unlikely. It should be noted that a review of the Consequence Category Assessment was completed by KCB in 2021 and all pits/voids at BCM have been classified as ‘low’ hazard and no longer require DSA or MRL.

5.3 Pumping Requirements

Care and maintenance pumping priorities will focus on monitoring the requirements of the regulated voids and the need for any water transfer. It should be noted that a review of the Consequence Category Assessment was completed by KCB in 2021 and all pits/voids at BCM have been classified as ‘low’ hazard and no longer require DSA or MRL.

5.4 Controlled Releases

It is planned that no controlled releases will occur during the care and maintenance phase. The water balance model indicates that during care and maintenance, the site inventory will decrease. The waterways around BCM are ephemeral with short flow durations.

6 Water Management System

The objective of the site water management system (WMS) is to manage all types of water on site to meet operational, social and environmental objectives encapsulated by BCM's Environmental Authority during care and maintenance.

Peabody has two key WMS objectives:

- Peabody minimises worked water uncontrolled releases and has sufficient worked and external water for operation in dry times; and
- The priority areas are the operation's impact on surface water and groundwater.

The water management system will be operated in a way to minimise uncontrolled releases, whilst minimising the volume of water accumulated through managing surface water catchment via the ESCP. Separation of water types is key to minimising water stored. Dams and their catchments are managed in accordance with the water type they store.

6.1 Worked Water Storages

6.1.1 Worked Water Hierarchy

The key objectives of the worked water system and managing pumping priorities are based on the worked water hierarchy:

- Minimise worked water catchment sizes to reduce the potential contamination of water and the accumulation of water on site;
- Reduce the water levels in worked water dams at risk of uncontrolled discharge; and
- Maintain requirements on all regulated structures, where required.

The details for achieving this hierarchy are detailed in the following sections.

6.1.2 Regulated Structures

BCM mine lease has nine regulated structures on site. Four of these structures are classed as dams and five are regulated levees to protect the pits from inundation. The dams include the four voids (Plumtree, Bullock Creek, Wallanbah and Broadmeadow).

These structures and their details are listed in the *Burton Coal Mine - Consequence Category Assessment (KCB 2021)*. A review of the Consequence Category Assessment was completed by KCB in 2021 and all pits/voids at BCM have been classified as 'low' hazard and no longer require DSA or MRL.

6.1.3 Worked Water Dams

Worked water dams at risk of uncontrolled releases at greater than 10% AEP are listed in **Section 5.1**. Pumping priority is to ensure that the less than 10% AEP can be achieved and to dewater the dams to mining voids with sufficient capacity over the dry season.

6.1.4 Pump and Pipe Network

The pump and pipe configuration were designed to meet the needs of BCM during coal mining operations. Under care and maintenance, pumping priorities will be based on the worked water hierarchy of control listed in **Section 6.1.1**.

The pipelines at BCM are shown in **Figure 2** and **Figure 3** with the pump assets at BCM and their respective utilisation shown in **Table 2**.

The BCM Care and Maintenance Water Balance Report shows that the pits on site had at least a 90% chance of not exceeding DSA or MRL prior to the 2021 review by KCB. Skid mounted

diesel pumps are available on site which can be connected to the pipe network to move water between pits if required.

Table 2: Pump assets and area of utilisation at Burton

Pump Asset list					
Asset ID	**Power supply**	**Supplier**	**Model**	**Specification/Capacity**	**Location**
Skid Pumps					
SP1	Diesel pump	Stalker	8400	~140 L/s	Not fixed
RTP15	Diesel pump	Pioneer	86C21	~140 L/s	Not fixed
Trailer Pumps					
TP3	Diesel pump	Sykes	CP-150		Not fixed
TP4	Diesel pump	Sykes	CP-150		Not fixed

6.2 Surface Water Storages

The BCM Erosion and Sediment Control Plan (ESCP) was developed by WRM in 2012 and most recently updated in 2022.

6.2.1 Surface Water ESCP Hierarchy

The ESCP for surface water catchments follows the hierarchy of control outlined below:

- Prevent and minimise disturbance and progressively rehabilitate disturbed land to reduce the catchment size of any surface water catchment;
- Any surface water catchments with disturbance that will generate sediment but not contaminants will be directed through an ESCP structure, such as sediment basins; and
- Existing surface water dams which capture surface water runoff shall be operated to only spill at a frequency less than 10% AEP to ensure sufficient flow in receiving catchment to minimise potential environmental harm.

Yearly inspections of surface water catchments and associated drainage will be conducted by site personnel to identify areas of erosion to plan remediation work and install ESCP structures. ESCP catchments are managed under the ESCP inspection template.

6.3 Raw Water Storages

BCM's raw water can be supplied from Teviot Dam, via New Hope Group. Due to the volume of water stored in pits, there is unlikely to be any need for raw water during care and maintenance, but the utilisation of the existing Plumtree ROM Dam will occur to allow for dust suppression water to be sourced whilst topsoil spreading is being undertaken onsite.

6.4 Haul Road and Work Area Dust Suppression

Dust suppression will only occur when required under care and maintenance, such as during rehabilitation works when spreading topsoil using a Scraper. Fast fill points are supplied from worked water storages or raw water storages, such as the Plumtree ROM Dam. All fast fill points drain internally to worked water dams so there is significantly reduced potential for fast fill point runoff to drain off site that may cause environmental harm.

6.5 Regulated Structures

BCM's Consequence Category Assessment was reviewed in 2021 by KCB and all final voids onsite have been classified as 'low' hazard.

BCM only has regulated levees onsite, which are:

- Plumtree Southern Levee;
- Bullock Creek Northwestern Levees;
- Broadmeadow Northwestern Levee;
- Broadmeadow Southwestern Levee; and
- Broadmeadow Southern Levee.

Regulated structures will all be managed in accordance with Section G of the BCM EA. The detail for each structure is kept in the *Regulated Structures Register and Operational Plans.*

6.6 Dam Maintenance and Monitoring

All regulated structures have yearly inspections as per Conditions G22 – G25 of the BCM EA. Any additional monitoring is outlined in each dam's operational plan. Additional water infrastructure is monitored periodically during the year in particular after large storm events. Yearly ESCP inspections are conducted and recorded in the ESCP inspection template.

6.7 Water Inventory Tracking

BCM monitors the site's water inventory through a water inventory account. This account is updated monthly (or as required/available) with:

- Survey pickups of RL's from all final voids/pits for volume calculations and to confirm volume;
- Recording of all flow meters for all pumps when pumping between final voids/pits, to a 3rd party or offsite;
- Rainfall runoff and evaporation estimates using site weather station data; and
- Water consumption estimates.

6.8 Water Quality Monitoring and Reporting

BCM undertakes water monitoring as per the conditions of the EA which includes:

- Monitoring of the end of pipe for controlled releases and the receiving waters both upstream and downstream of designated sampling points listed in the BCM's EA and detailed in **Appendix A**;
- Monitoring of uncontrolled release events from the source of the release and the receiving waters, in line with the sample requirements of the EA;
- Receiving Environment Monitoring Program (REMP) – background monitoring of waterways, this includes samples taken upstream of the mine site only during controlled discharge events of mine affected water and the use of rising stage samples (RSS);
- Gauging stations monitor stream flow in locations listed in BCM's EA. These stations are used to calculate the ability to make controlled releases and monitor compliance. These stations are linked via 4G to a website managed by Blomfield Environmental and are accessible 24/7; and
- Field monitoring – regular field samples are taken of storages and waterways on site to monitor EC and pH.

All water quality data for BCM is stored on the Peabody EQuIS database. Release event data is uploaded to the QLD government WaTERS websites. All sample points for release

points and receiving waters, along with access details are located in the *Peabody Burton Water Release Procedure* and maintained in the BCM's GIS system.

6.8.1 Controlled Releases

BCM has the capability to discharge water from multiple storages through its pipe network. The release rate and water quality parameters must be in compliance with Table C4 of the EA. The flow rates in the receiving waters for calculating the end of pipe release rates in Table C4 are based on the upstream gauging station for the waterway.

Due to the short flow durations of waterways and difficulty in accessing the release points (south of Sandy Creek) during wet weather, releases do not occur in these waterways.

6.8.2 Contaminant Release Limits

End of pipe release water quality is sampled at the locations defined in Table C1 of the EA. A summary of the conditions for monitoring end of pipe release water is listed below:

- **Table C4**: The end of pipe release rate is restricted by the receiving water flow rate and the release water EC and Sulfate concentrations. Receiving water flow rates are calculated by the upstream gauging station;
- **Table C2**: Daily field samples of pH and EC;
- **Table C2**: Lab samples of full sample list at commencement, cessation and weekly frequency;
- **Table C3**: Lab samples of full sample list at commencement, cessation and weekly frequency.

6.8.3 Receiving Waters Contaminant Limits

Receiving waters water quality is based on sampling at the locations defined in Table C5 of the EA. A summary of the conditions for monitoring receiving waters is listed below:

- **Table C4**: Flow rate is calculated from the gauging stations located in this table. The Bloomfield's website's alarms are set to notify the start and end of the specified flow regimes such as Low Flow, Medium flow etc;
- **Table C6**: Daily field samples of pH and EC;
- **Table C6**: Lab samples of full sample list at commencement, cessation and weekly frequency.

The tributaries around BCM have 80th percentile water quality that exceed the ANZECC guidelines (Table 2). Therefore, background monitoring of the sample suite in Table C3 is undertaken in all controlled releases at commencement, cessation and weekly to verify if an exceedance in water quality limits in the downstream sample is due to background conditions or the controlled release. In addition, the samples taken from the upstream samples shall be reported in the REMP.

6.8.4 Water Storages Monitoring

BCM has no EA conditions for the monitoring of stored water. However, dams are regularly field sampled for EC and pH and periodically sampled for parameters matching Table C3 of the EA.

7 Measures to manage and prevent Saline Drainage and Acid Rock Drainage

7.1 Seepage management

7.1.1 Overview

BCM shall take action to avoid or minimise the generation and/or release of saline drainage, in accordance with condition C37 of the BCM EA. Saline drainage can occur from both surface runoff and via seepage through out of pit spoil emplacements. BCM does not have a history of saline drainage from surface runoff. However, seepage from the toe of out of pit spoil dumps has been reported. The management strategy adopted by BCM to manage seepage includes:

- Undertake routine monitoring of out of pit spoil dump toe drains for signs of seepage;
- Track all sources of seepage in the BCM GIS database;
- Respond to the identification of seepage as per the seepage TARP; and
- Report seepage as per the seepage TARP;

7.1.2 Routine Monitoring

BCM will routinely monitor for seepage on an annual basis. Monitoring should occur within 3 months of the end of the wet season.

Identified seepage should be monitored monthly when flow is occurring. The following should be recorded:

- Field sampling of EC and pH;
- Estimated flow rates; and
- Photograph of the source, drainage path and destination.

If seepage is reporting to a dam, the dam shall also be monitored monthly. The following should be recorded:

- Field sampling of EC and pH; and
- Storage volume/water level.

7.1.3 Tracking

Identification of seepage will be tracked in the BCM GIS database. The following information shall be recorded in the GIS database:

- The location of the seepage from the dump toe;
- The drainage path and destination; and
- The location of any monitoring equipment.

7.1.4 Response plan

If saline seepage is identified, the saline drainage Trigger Action Response Plan (TARP) shown in Table 3 shall be used to manage actions at BCM.

7.1.5 Reporting

Reporting shall occur in accordance with the TARP shown in **Table 3**.

7.2 Acid Rock Drainage

Acid leachates have not been identified at BCM in its mining history.

Table 3: Saline Drainage TARP

LEVEL 1		
TRIGGER: *No reported saline drainage*		
No active seepage or signs of saline drainage (i.e. salt at dump toe)		
ACTION	**RESPONSE**	**PERSON RESPONSIBLE**
Normal operations	Annual Inspections as per WMP	Environmental Manager
LEVEL 2		
TRIGGER: *Seepage is Identified*		
Seepage is draining to a final void		
ACTION	**RESPONSE**	**PERSON RESPONSIBLE**
Tracking	Add details to the GIS database	Environmental Manager
Monitoring	Field sample pH and EC monthly during flow Record flow rate monthly, either visually (photographs) or estimate the flow rate by either measure depth/velocity of flow or with a flow meter	
Reporting	Report the first identification in the Peabody Incident management system	
LEVEL 3		
TRIGGER: S*eepage is Identified*		
Seepage is draining to a dam		
ACTION	**RESPONSE**	**PERSON RESPONSIBLE**
Tracking	Add details to the GIS database	Environmental Manager
Monitoring	Field sample seepage pH and EC monthly during flow Record flow rate monthly, either visually (photographs) or estimate the flow rate by either measure depth/velocity of flow or with a flow meter Monitor the surface water dam water level monthly Field sample the dam pH and EC monthly	
Reporting	Report the first identification in the Peabody Incident management system	
Divert Seepage	Where possible, divert the flow to a final void. This may require a dedicated sump and pump	
TRIGGER: Surface water dam spill risk		
Surface water dam exceeds 80% capacity or water quality is above 7,500 us/cm (not applicable to voids)		
ACTION	**RESPONSE**	**PERSON RESPONSIBLE**
Dewater the storage	Dewater the dam to the closest final void	Environmental Manager
Monitor	Monitor the water level and quality (pH and EC) weekly until below the trigger level In the event of a spill, refer to the BCM *Water Release Procedure (BU-ENV-PRO-002)*	
Reporting	Report the first identification in the Peabody Incident management system	
LEVEL 4		

TRIGGER: *Seepage has the potential to cause environmental harm*		
Seepage is not contained within the water management system		
ACTION	**RESPONSE**	**PERSON RESPONSIBLE**
Divert Seepage	Construct either: - Dedicated pump/sump to a dam or final void - Construct a drain to direct seepage to a dam or final void	Environmental Manager
Tracking	Add details to the GIS database	
Monitoring	Field sample pH and EC daily until diverted Record flow rate daily until diverted, either visually (photographs) or estimate the flow rate by either measure depth/velocity of flow or with a flow meter	
Reporting	In the event of potential environmental harm, notify the regulator and report as incident in Peabody SHMS	
TRIGGER: *Seepage is entering a watercourse or going off the mine lease*		
Seepage is not contained within the water management system		
ACTION	**RESPONSE**	**PERSON RESPONSIBLE**
Divert Seepage	Construct either: - Dedicated pump/sump to a dam or final void - Construct a drain to direct seepage to a dam or final void	Environmental Manager
Tracking	Add details to the GIS database	
Monitoring	Field sample pH and EC daily until diverted Record flow rate daily until diverted, either visually (photographs) or estimate the flow rate by either measure depth/velocity of flow or with a flow meter	
Reporting	Notify the regulator and report as incident in Peabody SHMS	

8 Emergency Response Plan

8.1 Overview

The proposed water management strategy under care and maintenance has been developed for both normal operation and during extreme wet weather events in order to:

- Minimise the risk of uncontrolled releases from worked water dams; and
- Ensure compliance with the BCM EA conditions.

The emergency response plan for site is managed in the site's Safety and Health Management System. A summary of the emergency response, should a failure of the water management strategy occur, is given below.

8.2 Uncontrolled Releases

All uncontrolled releases from site should follow the Mine Water Release Procedure and Flow Chart. These documents outline the actions to take and persons responsible for management of releases. Due to access restrictions during wet weather, inspections of storages can sometimes not occur until after the rainfall event, and potentially after a spill event has commenced/occurred. Unmonitored spill events from worked water storages will be handled under the incident reporting and investigation process. BCM aims to maintain at least a 10% AEP spill risk on all dams, to ensure that if a release occurs, it is during wet conditions so that the potential impact to the environment is minimal. This is outlined in the Water Balance Report (Hatch, 2016).

BCM procedures for worked water transfers require regular pipeline inspections by the pump crew. All discharges and leaks that are identified shall be reported immediately to the Peabody Burton Environment Manager, OCE and/or Supervisor and pumping is to cease immediately.

8.3 Dam and Levee Monitoring

The embankments of all levees and dams will be monitored annually before the wet season, and during and after flow events to ensure they are operating satisfactorily and have not been damaged through erosion. The gauging stations on each of the waterways measure water level, the Blomfield website has alarms set to report any high flow conditions to indicate water levels reaching the base of a levee.

Should a dam become damaged, the stored water will be pumped to the nearest void to minimise the risk of an uncontrolled release to the downstream waterway. The site Peabody Burton Environment Manager will be responsible for communicating with regulators. A suitably qualified person shall be used to inspect the dam. Repair work will occur as soon as practicable after damage has occurred.

8.4 Wet Weather Access

During wet weather, site access is restricted due to impassable dirt roads, flooding and safety issues. During care and maintenance there will be minimal staff on site, so extra precautions will be taken for safety. Waterways which have short duration flows and are inaccessible in wet conditions have rising stage samples which can be used to taken water samples, minimising exposure of personal to extreme weather events.

9 Water management plan yearly review and report

Condition C33 of the BCM EA states a review and report of the Water Management Plan must be prepared each year by an appropriately qualified person. The report must:

- Asses the plan against the requirements under Conditions C32 of this environmental Authority;
- Include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; and
- Identify any amendments made to the water management plan following the review.

The water management plan will be revised within 3 years, or if the care and maintenance phase ends at any part of the operation.

10 Summary

The BCM WMP has been prepared in accordance with the Guidelines on the Preparation of Water Management Plans for Mining Activities (DEHP, 2013) and the conditions of the Environmental Authority. It forms part of the Burton Environmental Management System, which is used to manage the potential risks to the environmental values of receiving waters.

The general principles to manage water for the site are as follows:

- Separation of runoff of water types worked, surface and diverted;
- Minimise the area of surface disturbance, thus minimising the volume of sediment or mine affected runoff;
- Worked water shall be used in any operational areas;
- Pumping hierarchy to focus on compliance and to minimise the potential for uncontrolled releases;
- Maximise runoff from surface water catchments to report offsite through ESCP to minimise water accumulation on site; and
- Controlled releases from site when in compliance with EA conditions.

11 Roles and Responsibilities

Table 4: Roles and Responsibilities

Role	Responsibilities
Environment Manager/SSE	Approval and implementation of the WMP and yearly review to ensure compliance and outline yearly actions in order to ensure continued compliance

12 Supporting Documents and References

12.1 Documents

Burton Coal Mine: Final Void Modelling Q1 2018 (Hatch 2018)

Burton Coal Mine - Hazardous Consequence Assessment – Dams (WRM 2014)

Burton Coal Mine - Hazardous Consequence Assessment – Levees (WRM 2014)

Burton Coal Mine – Erosion and Sediment Control Standard (BUR-ENV-EMPLAN-017)

Burton Coal Mine – Environmental Authority EPML00879213

Burton Coal Mine – Ellensfield Co-disposal Operational Plan

Burton Coal Mine - Mine Water Release Procedure (BUR-ENV-EWI-001)

Burton Coal Mine - Mine Water Release Flowchart (BUR-ENV-FC-001)

Burton Coal Mine – Controlled Release Modelling (WRM 2012)

Burton Coal Mine - Water Balance Model - Set-up (WRM 2012)

Burton Coal Mine - Water Balance Model (Hatch 2016)

Burton Coal Mine – Receiving Environment Monitoring Plan (

MNP_BUR_Receiving Environment Monitoring Program_V2_WRM)

Burton Coal Mine - Water Balance Model - Option Assessment (WRM 2012)

Burton Coal Mine - Post Wet Season Assessment 082014 HM

Burton Coal Mine – Regulated Structures Register and Operational Plans

12.2 Licenses

Bullock Creek Diversion WL 577239

12.3 References

ANZECC/ARMCANZ, 1994	*National Water Quality Management Strategy: Policy and Principles – A reference document,* Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, April 1994
ANZECC/ARMCANZ, 1998	*National Water Quality Management Strategy: Implementation Guidelines,* Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, 1998
ANZECC/ARMCANZ, 2000	*Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Volume 1, October 2000
DEHP, 2009	*Queensland Water Quality Guidelines 2009,* Department of Environment and Heritage Protection, Version 3, ISBN 978-0-9806986-0-2 September 2009 (republished in July 2013)
DEHP, 2012	*Guidelines on the Preparation of Water Management Plans for Mining Activities,* Department of Environment and Environment and Heritage Protection, July 2012
DEHP, 2013a	*Model Water Conditions for Coal Mines in the Fitzroy Basin,* Department of Environment and Heritage Protection, July 2013
DEHP, 2011	*Isaac River Sub-basin Environmental Values and Water Quality Objectives: Basin No. 130 (part), including all waters of the Isaac River Sub-basin (including Connors River),* Department of Environment and Heritage Protection, September 2011
DEHP, 2016	*Manual for Assessing Consequence Categories and Hydraulic Performance of Structures*, Department of Environment and Resource Management, Version 5.0, 2016
Hatch, 2016	*Burton Coal Mine - Care and Maintenance Water Balance Modelling*, Hatch, H351353-00000-228-230-0001
Henderson Geotech (2016)	*Burton Mine Consequence Category Assessments for Four Dams*, Henderson Geotech Pty Ltd, April 2016
JBT Consulting 2016	*Review and Assessment of the Groundwater Monitoring Network and Data for Burton Coal Mine*
Jeffrey et al. 2001	*Using spatial interpolation to construct a comprehensive archive of Australian climate data*, Environmental Modelling & Software, Jeffrey, S. J., Carter, J.O., Moodie, K.M. and Beswick, A. R., Vol. 16/4, pp 309-330, 2001

WRM	*Burton Mine Hazardous Consequence Assessment - Dams, 2014* *Burton Mine Hazardous Consequence Assessment - Levees, 2014* *Burton Mine, Erosion and Sediment Control Plan (ESCP) 2013*

13 Abbreviations & Definitions

Term	Definition
AEP	Annual Exceedance Probability
BGD	Burton Gorge Dam
CHPP	Coal Handling and Processing Plant
DEHP	Department of Environment and Heritage Protection
DERM	Department of Environment and Resource Management
DSA	Design Storage Allowance
EA	Environmental Authority
EC	Electrical Conductivity
EP Act	Environmental Protection Act
EPP	Environmental Protection Policy
ESCP	Erosion and Sediment Control Plan
EV	Environmental Values
MRL	Mandatory Reporting Level
MSDS	Material Safety and Data Sheet
OOPD	Out of Pit Dump
QLD	Queensland
SHMS	Safety and Health Management System
SOP	Standard Operating Procedure
TLO	Train Load Out
WL	Water License
WMP	Water Management Plan
WMS	Water Management System
WQG	Water Quality Guidelines
WQO	Water Quality Objectives

14 Appendices

Appendix 1 – Site Maps



Figure 4: Plumtree and Bullock



Figure 5: Wallanbah and Broadmeadow

Appendix C
Flood modelling for transitional assessments



alluvium

MODELLING REPORT:

Burton Mine Flood Modelling For Levees Required Under EA Transitional Assessments

June 2016

Peabody ENERGY

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Approved	Brett Twycross

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Acronyms

AEP	Annual Exceedance Probability.
AHD	Australian Height Datum
ARI	Average Recurrence Interval
GSDM	Generalised Short Duration Method
PMP	Probable Maximum Precipitation
PMF	Probably Maximum Flood

1 Introduction

In 2015, Peabody Energy (Peabody) engaged Alluvium Consulting Australia (Alluvium) to undertake an assessment of levees at Burton Mine, to determine the transitional timeframes to provide immunity to the 0.1% Annual Exceedance Probability (AEP) design flood event, in accordance with the latest model conditions from Queensland Government (2014).

In April 2016, Peabody appointed Alluvium to undertake work to follow on from that previous project. This new phase includes assessment of four sites to consider the final landforms required to provide flood immunity for the Probable Maximum Flood (PMF) and which would be suitable for future relinquishment.

Note that all modelling for this project has been undertaken with "glass walls" in place of the levee structures. This effectively prevents water from entering mine pits and assists with determining maximum water surface elevations without the need to account for water lost to pits.

1.1 Project objectives

The objectives of this new phase of work are to:

- determine the PMF water surface elevations at four specific sites at Burton Mine and also determine 0.1% AEP water surface elevations at two of these sites. The locations are listed below and shown in Figure 1-1:
    - BN_1, Burton North on the Isaac River (0.1% AEP and PMF)
    - PT_1, Plumtree North on Sandy and Plumtree creeks (PMF)
    - BC_1, Bullock Creek (note that modelling has been undertaken with the assumption the two haul road crossings have been removed – discussed further in Section 6.3) (0.1% AEP and PMF)
    - BM_3, Broadmeadow South on Hat Creek (PMF).

1.2 Report structure

This report is structured in three sections which include: project introduction and objectives; project output summary; and attachments, which include:

- Attachment A PMF Hydrology
- Attachment B Hydrodynamic modelling.

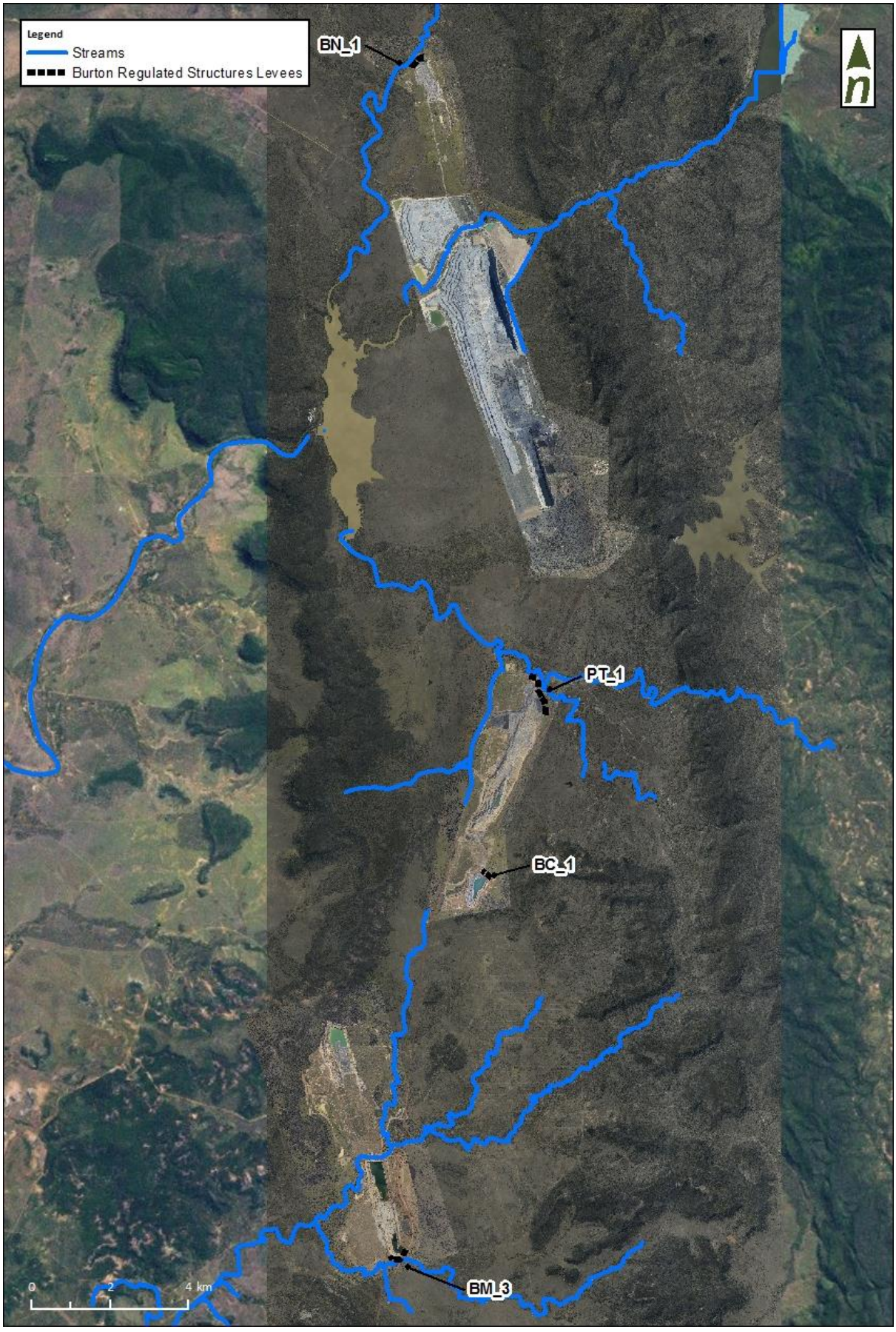

Figure 1-1. Overview of site

2 Project Outputs Summary

This section provides a brief summary of the key modelling outputs from the study. Further details can be found in the figures in Section 2.1. Please note that as the primary focus of this study has been to determine the maximum water surface elevations for the modelled flood events, and provide these in DXF contour format, this summary is intentionally kept brief. The maximum water surface elevations at each site are presented in Table 2-1.

Table 2-1. Maximum Water Surface Elevations at each site

Site	Maximum 0.1% AEP WSE (m AHD)	Maximum PMF WSE (m AHD)
BN_1	318.2 to 318.3m AHD See Figure 2-1	320.4 to 320.5m AHD See Figure 2-3
PT_1	N/A	317.5 to 320.3m AHD See Figure 2-4
BC_1	324.5 to 333.5m AHD See Figure 2-2	327.1 to 335.9m AHD See Figure 2-5
BM_3	N/A	286.0 to 287.9m AHD See Figure 2-6

Please note that the dxf files provided from the modelling outputs cover the full extent of the model. Care must be taken to focus only on using the results from adjacent the points of interest specific to this study. Contours from the areas upstream and downstream of these sites may not be as reliable as the hydrologic and hydraulic models have been developed specifically to produce accurate results at the points of interest of this study.

2.1 2D hydrodynamic modelling results

Flood depths for the 0.1% AEP design flood events modelled for BN_1 and BC_1 are presented in Figure 2-1 and Figure 2-2, respectively.

Flood depths for the PMF flood events modelled for all four sites are presented in Figure 2-3 to Figure 2-6.

All figures include the maximum water surface recorded by the model next to the structures.

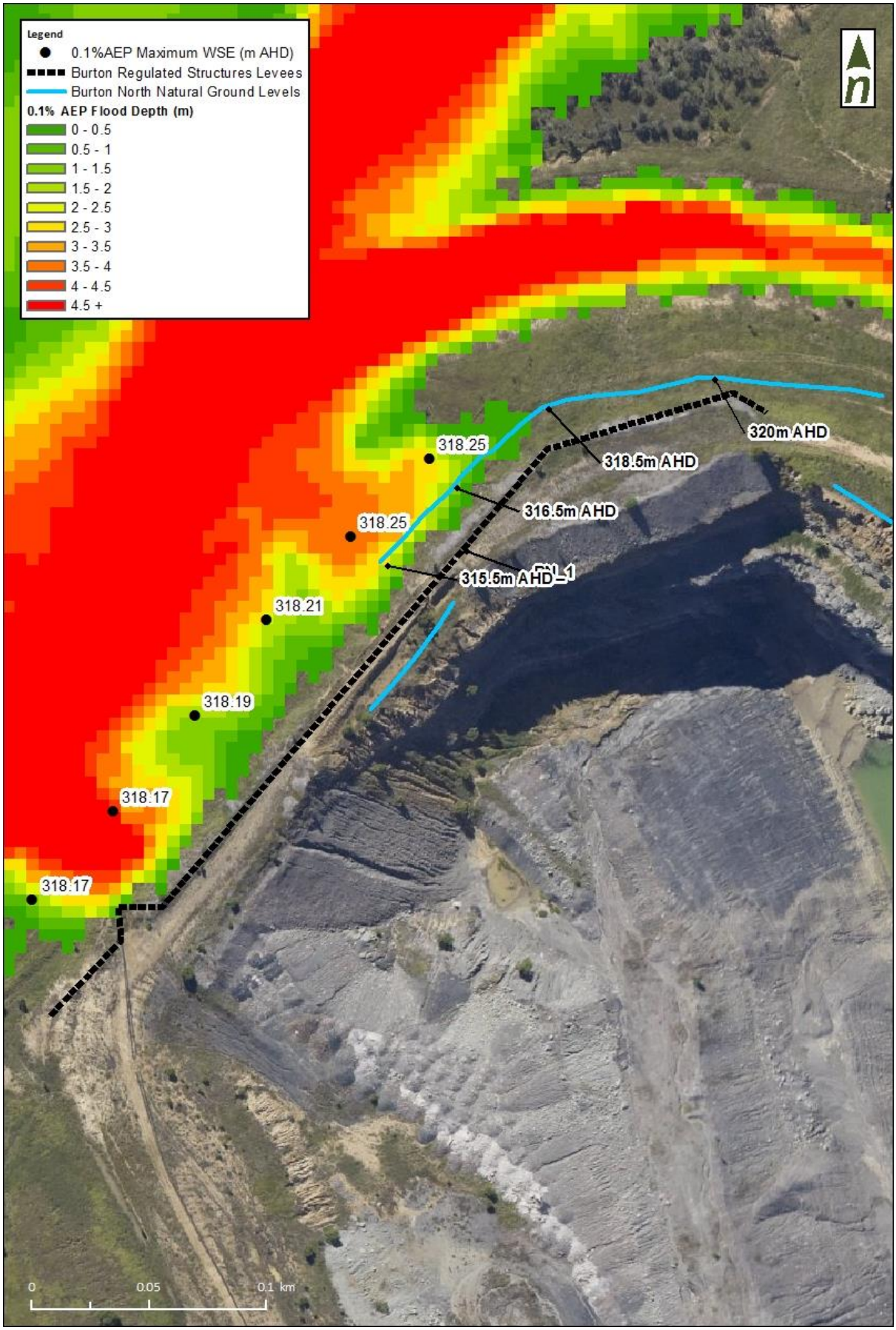

Figure 2-1. BN_1 0.1% AEP design event maximum flood depths

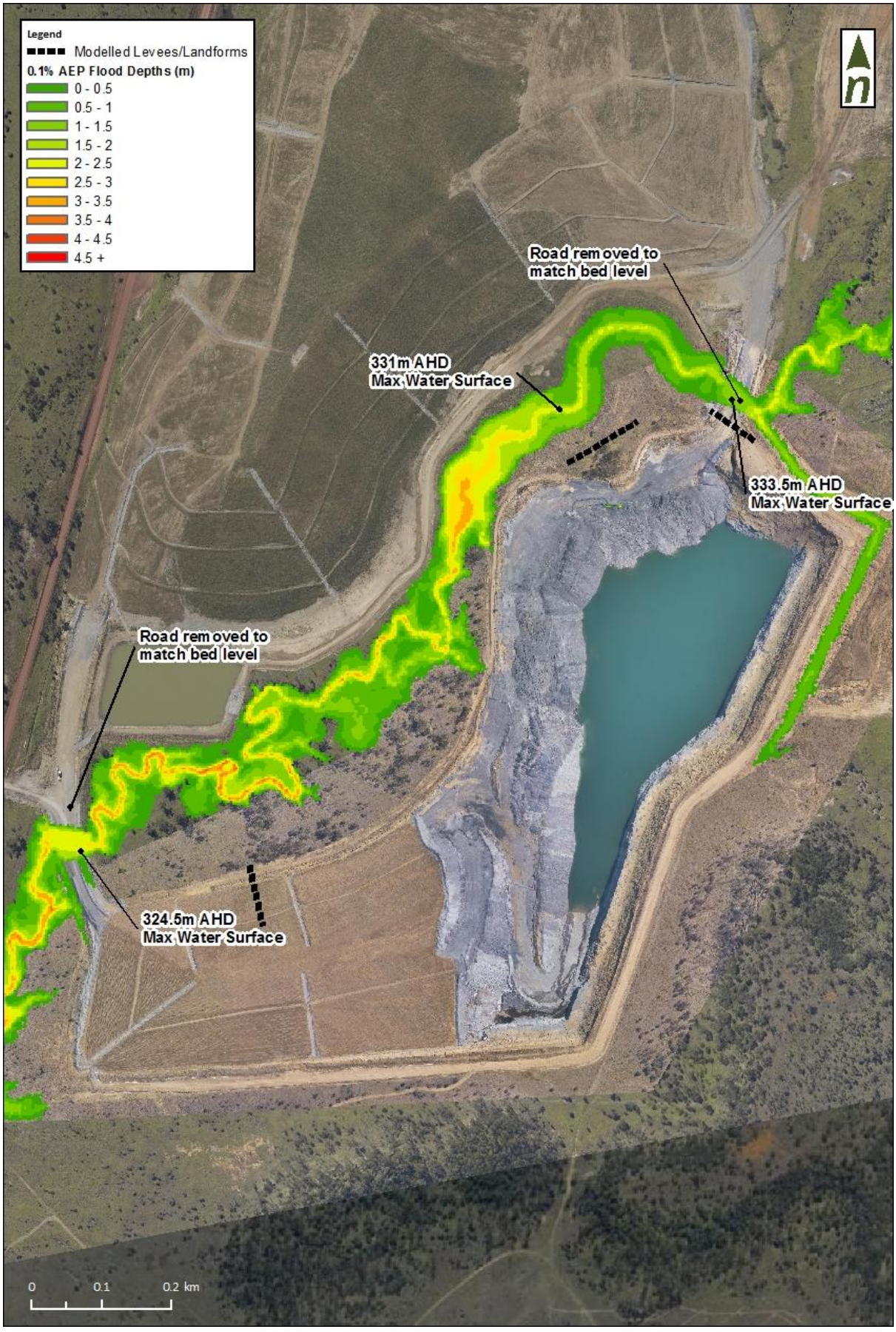

Figure 2-2. BC_1 0.1% AEP design event maximum flood depths

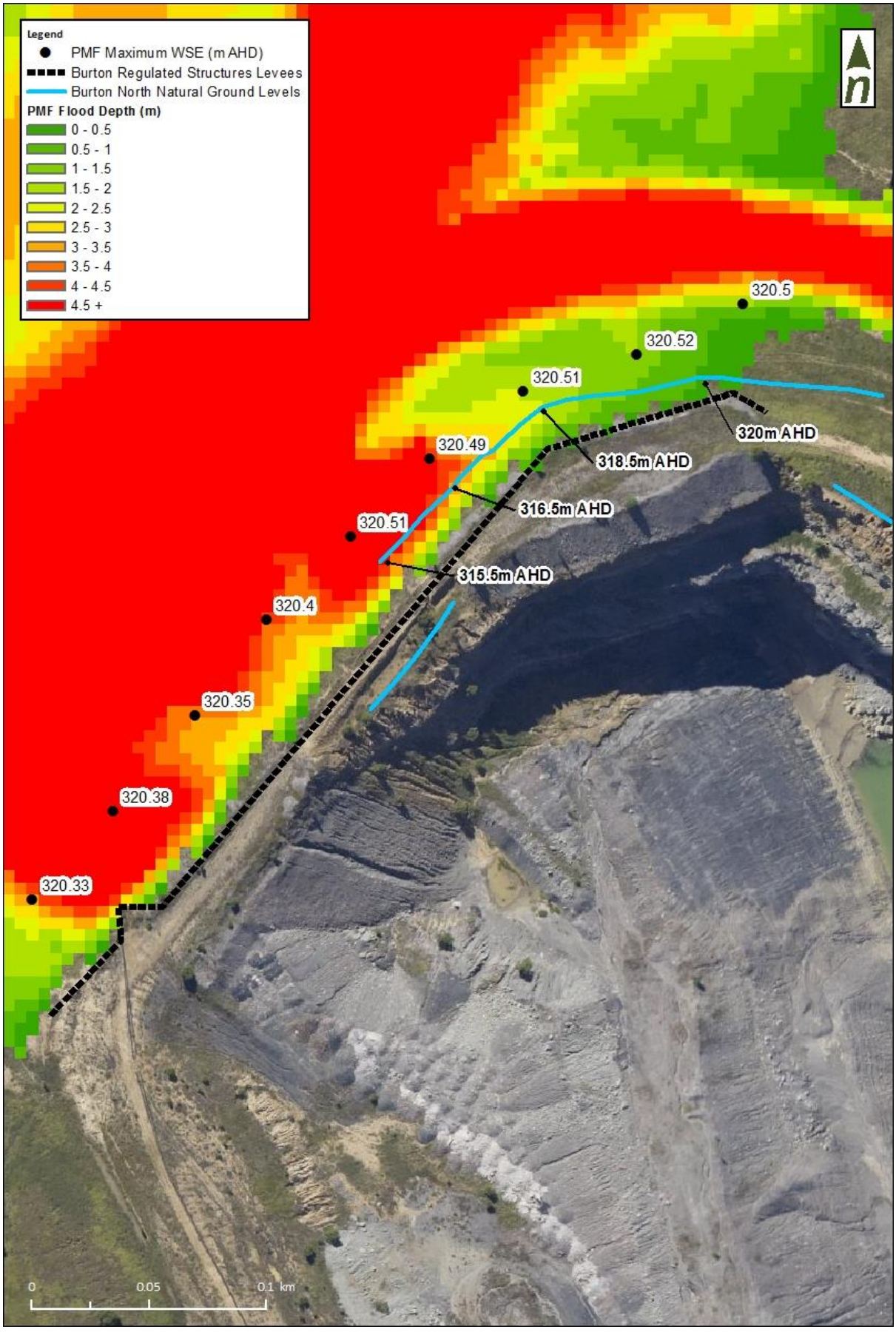

Figure 2-3. BN_1 PMF event maximum flood depths

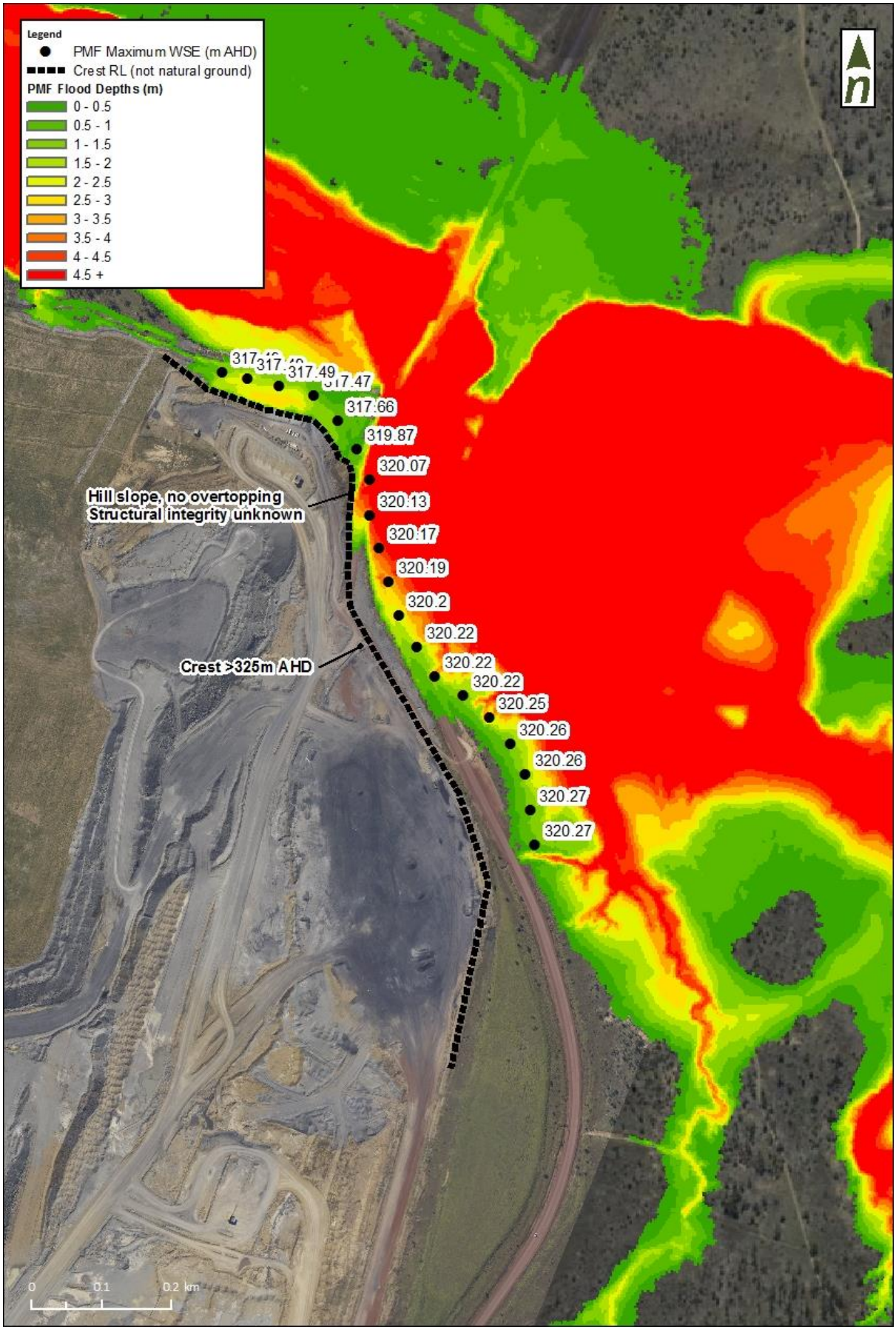

Figure 2-4. PT_1 PMF event maximum flood depths

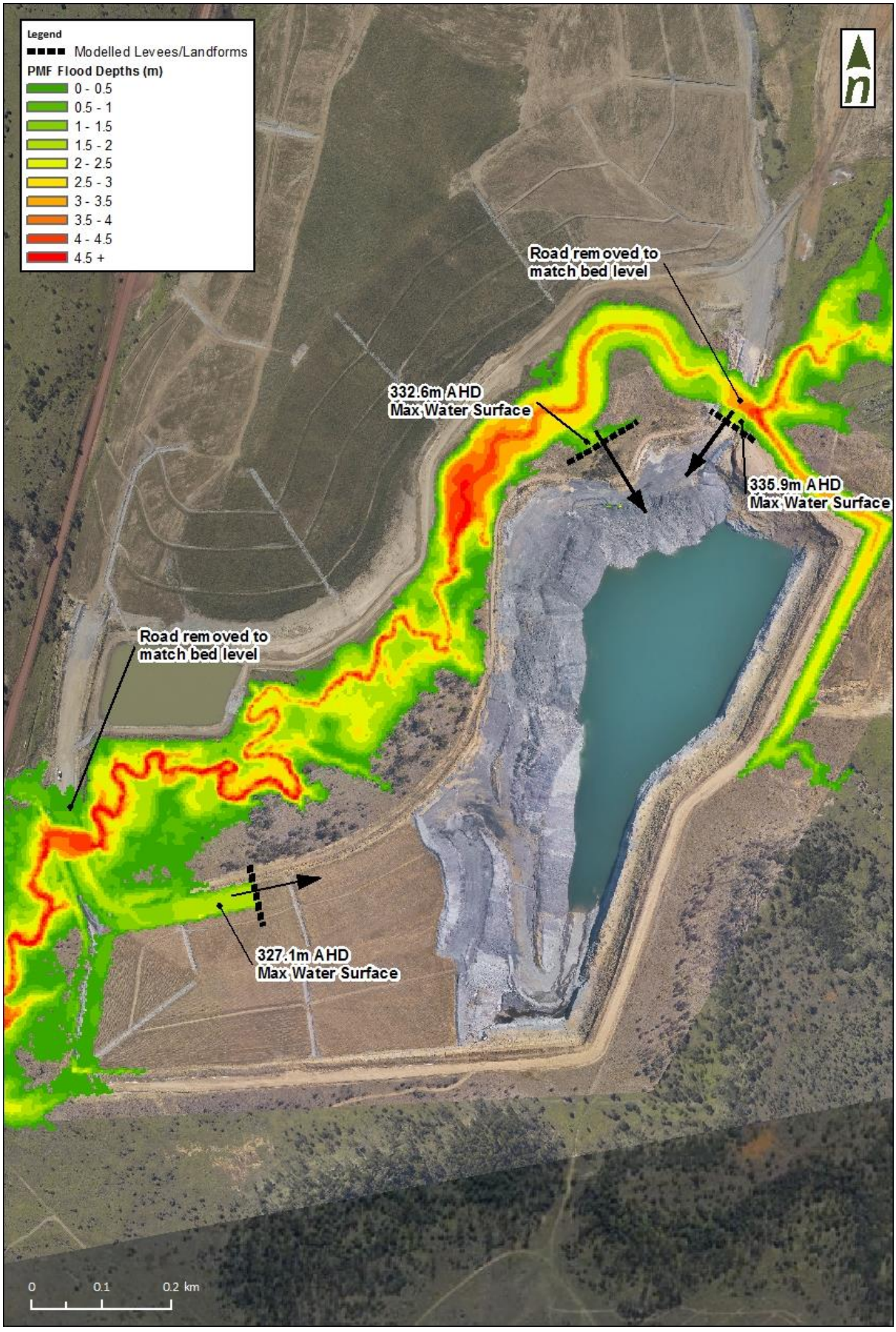

Figure 2-5. BC_1 PMF event maximum flood depths

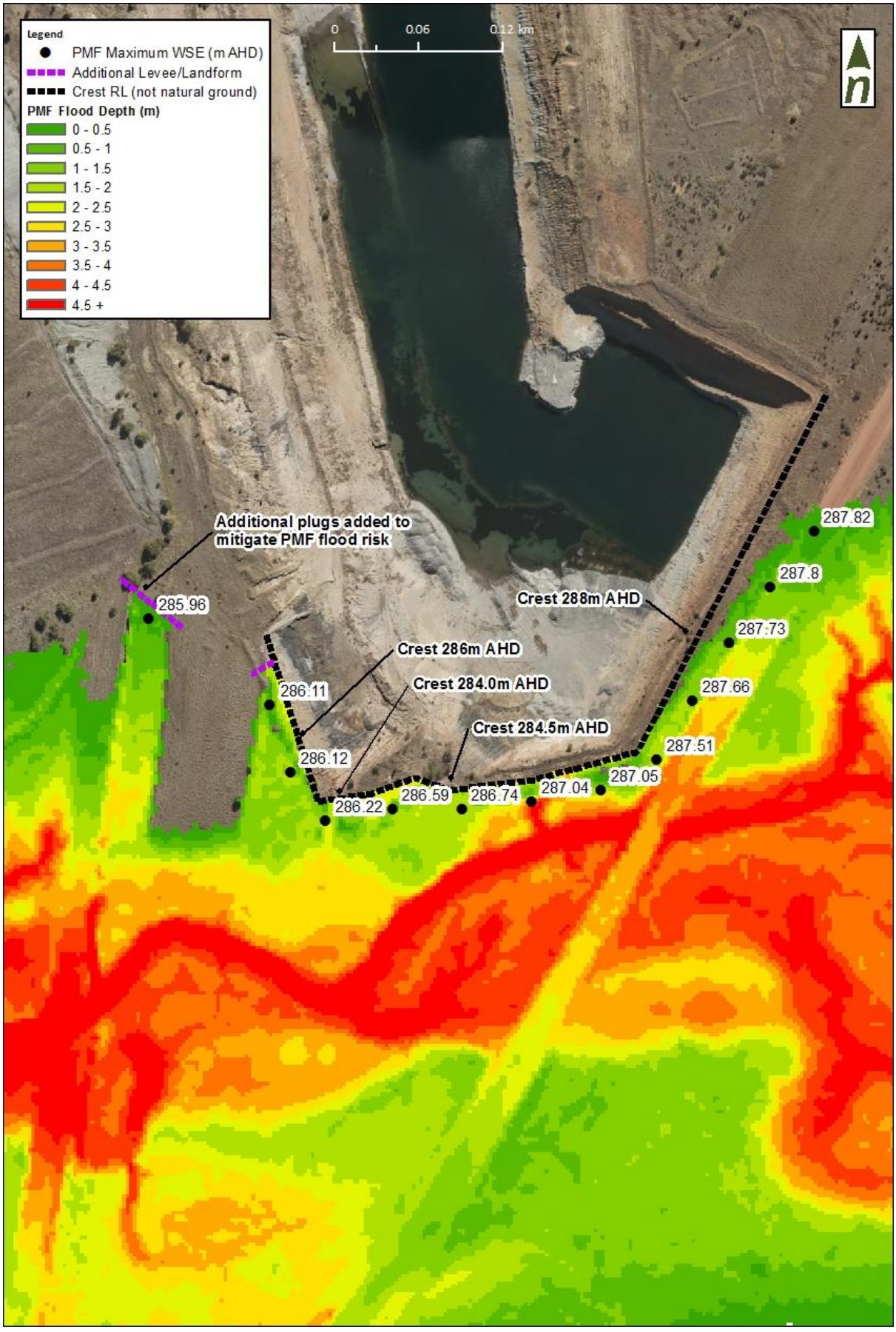

Figure 2-6. **BM_3 PMF event maximum flood depths**

3 Recommendations

The maximum water surface elevations presented in this report have been derived from conceptual levee configurations – an approach that is fit for purpose for the level of assessment undertaken for this project.

It is highly recommended that the modelling be revisited during the detailed design phase for any of the structures. Furthermore, the water surface elevations reported in this document make no allowance for freeboard. This must also be considered during the detailed design phase.

For the modelling undertaken for BN_1 and PT_1, the models developed for these sites will require further development during detailed design, particularly with focus on refinement of the land roughness.

For BC_1 the modelling has been undertaken with the two haul road crossings removed (see Section 6.3). Any departure, or even a minor variation, from this concept will yield different water surface elevations. The modifications made to the haul road crossings must be included in the detailed design modelling.

4 References

Alluvium Consulting (2012a). *Anna Creek Flood Risk Assessment*. Report by Alluvium Consulting for Burton Mine

Alluvium Consulting (2012b). *Hat, Spade and Bullock Creeks Flood Risk Assessment*. Report by Alluvium for Burton Mine.

Alluvium, (2015). *Burton Mine Transitional Assessment Levees*. Report by Alluvium for Peabody Energy.

Bureau of Meteorology (2003), *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*. Bureau of Meteorology.

Attachment A
PMF Hydrology

5 Hydrologic Modelling

Alluvium already possessed RORB hydrologic models for all sites assessed for this study. These models have been used previously to derive flow used for the 0.1% AEP (1000yr ARI) design flood modelling. For further details on this modelling refer to:

- BN_1 - *Anna Creek Flood Risk Assessment* (Alluvium 2012a)
- PT_1 - *Burton Mine Transitional Assessment Levees* (Alluvium 2015)
- BC_1 - *Hat, Spade and Bullock Creeks Flood Risk Assessment* (Alluvium 2012b)
- BM_3 - *Hat, Spade and Bullock Creeks Flood Risk Assessment* (Alluvium 2012b)

For the purpose of generating PMF flood hydrographs for each site, the models for BN_1, BC_1, and BM_3 were trimmed down to include only the area upstream of the points of interest. This was undertaken primarily for convenience to assist in reducing errors relating to the application of the areal reduction factors built into the Generalised Short Duration Method (GSDM) for the Probable Maximum Precipitation (PMP). In the case of PT_1, the model was considered fit for purpose as-is.

5.1 Catchment delineation and application of the PMP rainfall depths

The CatchmentSIM models developed previously for each site were modified to remove parts of the catchment downstream of the points of interest and then used to undertake the PMP calculations. The revised catchment areas and number of subcatchments are listed in Table 5-1

Table 5-1. PMF hydrologic model catchment areas and number of subcatchments

Site	Revised Catchment Area (km^2)	Number of subcatchments
BN_1	193	14
PT_1	95	57
BC_1	3.8	7
BM_3	38	69

The resulting layouts of each catchment are shown in Figures 5-1 to 5-4. The figures also show the spatial distribution of the PMP.

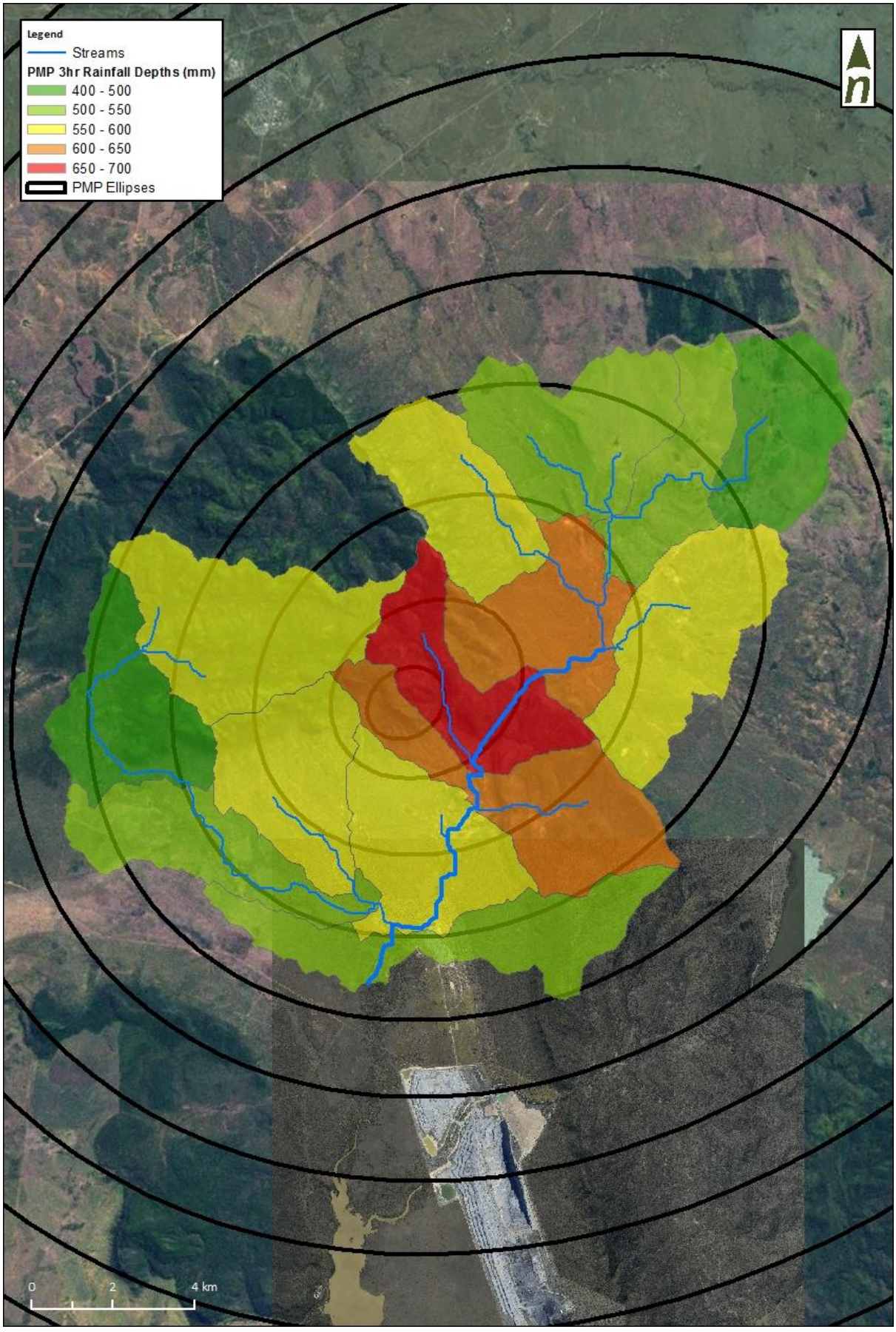

Figure 5-1. Isaac River at BN_1 PMF catchment model delineation and PMP spatial distribution

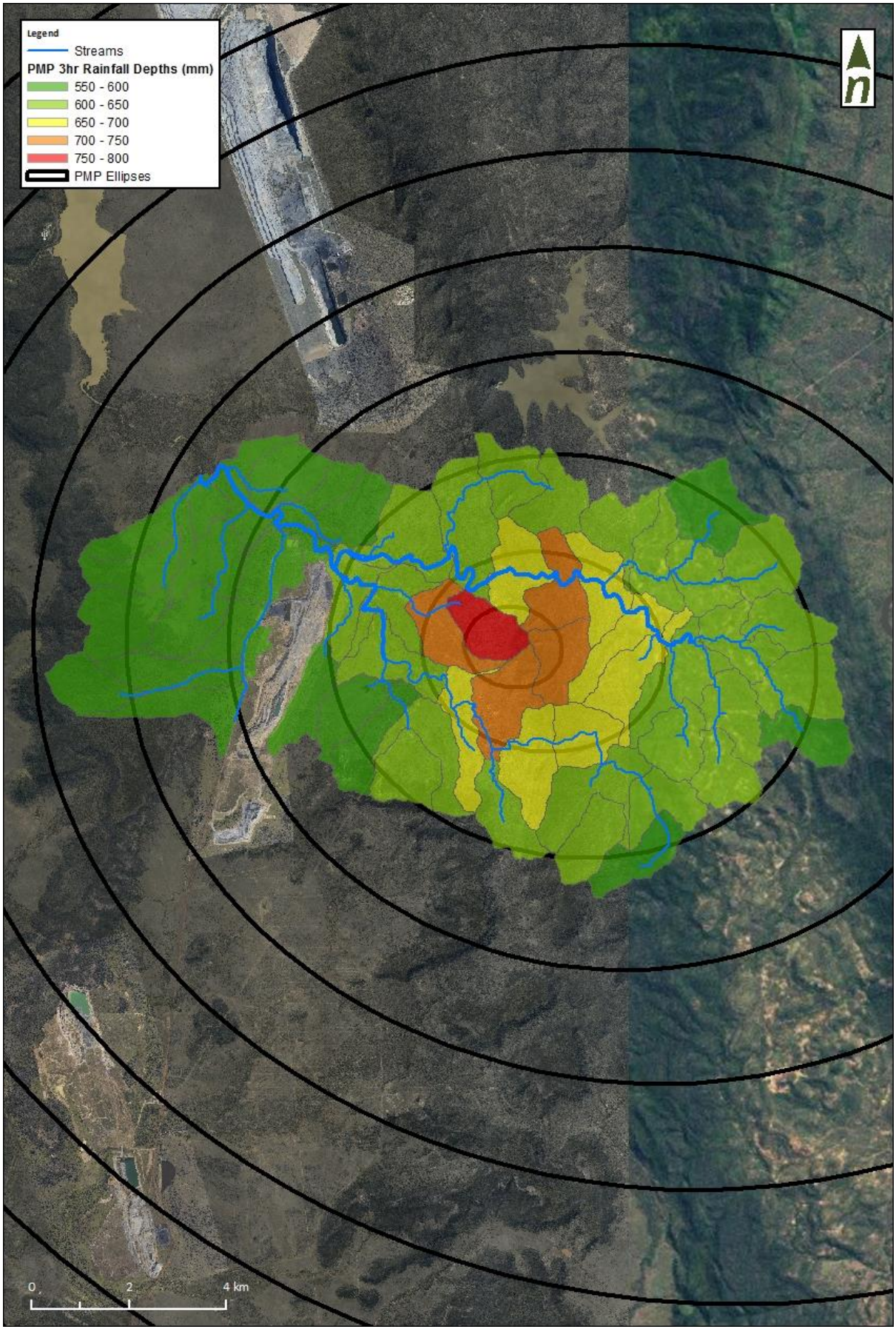

Figure 5-2. Sandy Creek at PT_1 PMF catchment model delineation and PMP spatial distribution

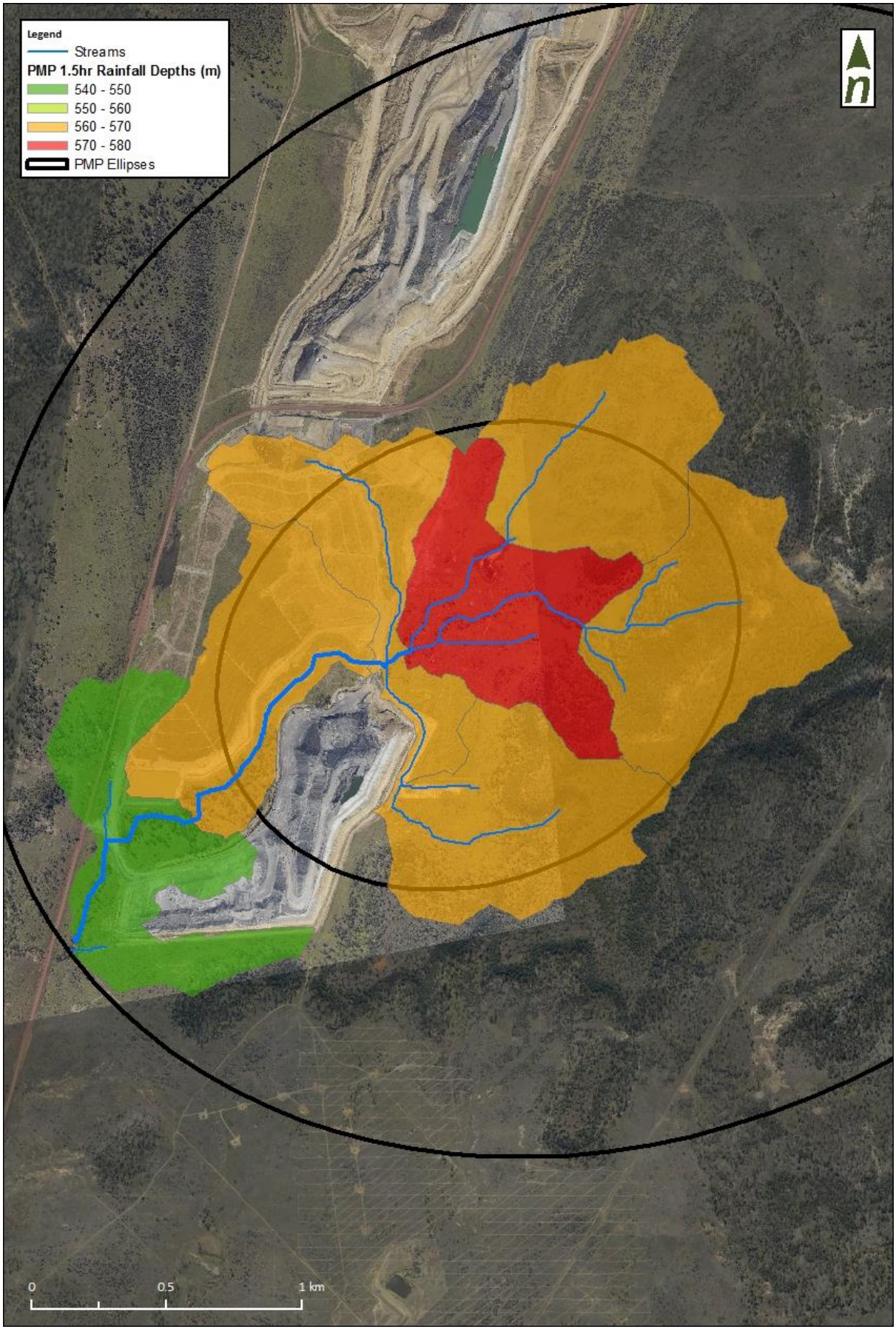

Figure 5-3. BC_1 PMF catchment model delineation and PMP spatial distribution

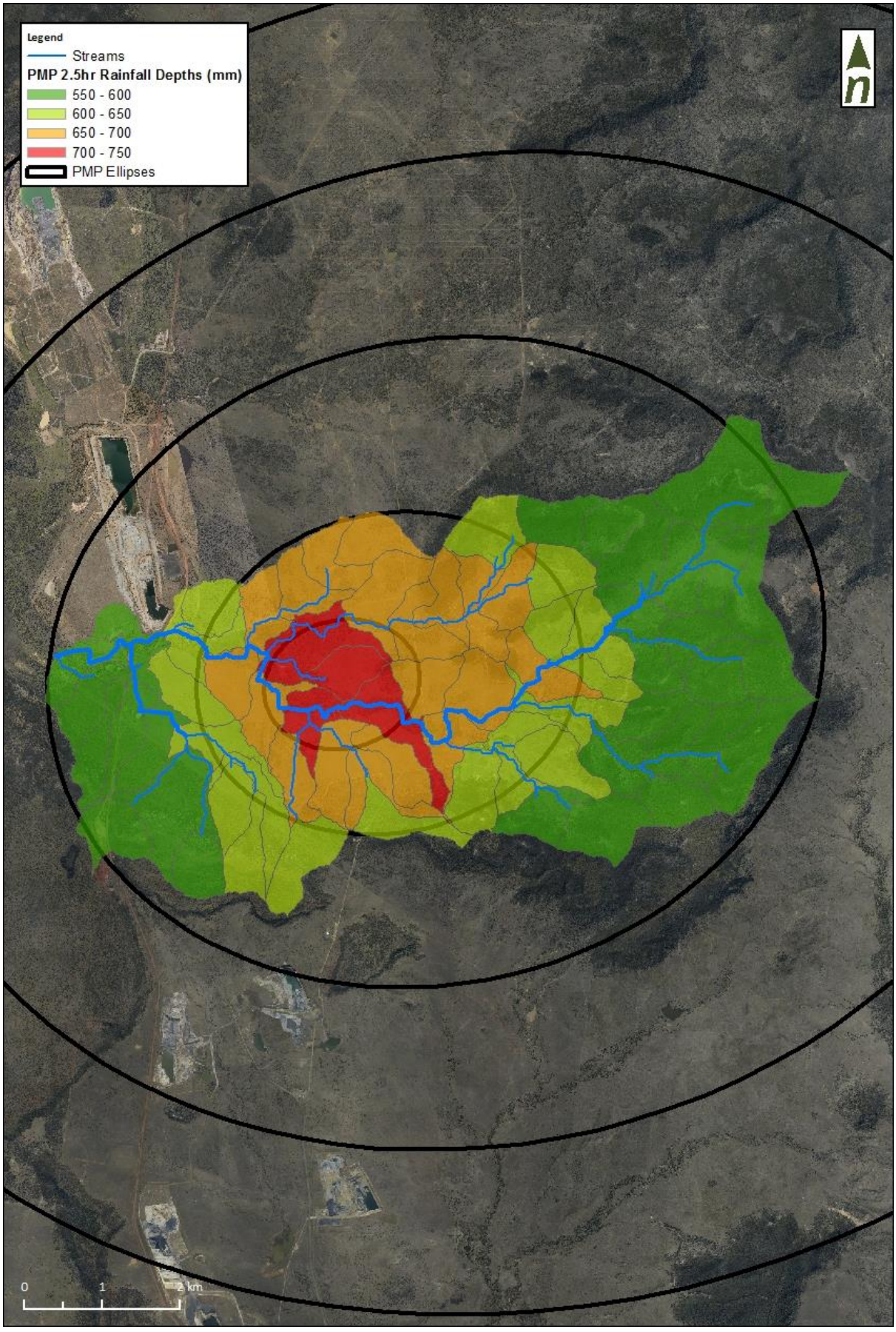

Figure 5-4. **Hat Creek at BM_3 PMF catchment model delineation and PMP spatial distribution**

5.2 Model parameter derivation

Due to the limited stream flow data available, it was not possible to directly calibrate the hydrologic models used for hydrologic modelling undertaken for Peabody. Therefore, it was necessary to use the Weeks method to develop the k_c values for the RORB models.

Weeks regional relationship method

Australian Rainfall and Runoff (ARR) outlines, in section 3.6.2, the regional relationships developed to calculate k_c for ungauged catchments. For Queensland, the relevant method was derived by Weeks and takes the form:

$$k_c = 0.88 * Area^{0.53}$$

Table 5-2, below, lists the Weeks derived k_c values for each model.

Table 5-2. Calculated Weeks values for each model

Scenario	Weeks k_c Value*	Comment
BN_1	14.33	
PT_1	9.83	No change from previous modelling
BC_1	1.78	
BM_3	6.04	

*Note, that the underlying assumption is that m = 0.8.

Other modelling parameters

As the hydrologic modelling undertake for this investigation has focused on the PMF flood event, the loss values recommended by the Bureau of Meteorology for the Probable Maximum Precipitation (PMP) were adopted. These are:

- Initial losses: 0 mm (for entire model)
- Continuing Losses: 1 mm/hr

5.3 PMP rainfall depths

PMP rainfall depths were generated for all catchments using the GSDM. From previous work undertaken at Burton Mine it was established that all sites had critical flood event durations of less than 6 hours – the upper limit of the GSDM. The rainfall depths for each catchment are presented in Table 5-3. The variations reflect the different catchment sizes.

Table 5-3. Table of PMP rainfall depths for each catchment

Event	BN_1	PT_1	BC_1	BM_3
15 minutes	140	150	200	170
30 minutes	200	220	300	250
45 minutes	250	280	380	320
1 hour	310	340	440	380
1.5 hours	400	440	560	480
2 hours	460	510	660	560
2.5 hours	520	570	730	630
3 hours	560	620	800	680
4 hours	640	700	910	770
5 hours	690	760	1000	850
6 hours	730	810	1060	910

Temporal pattern

Suitable temporal patterns were obtained from Bureau of Meteorology (2003) and are depicted in Figure 5-5. This temporal pattern has been used for all PMP durations.

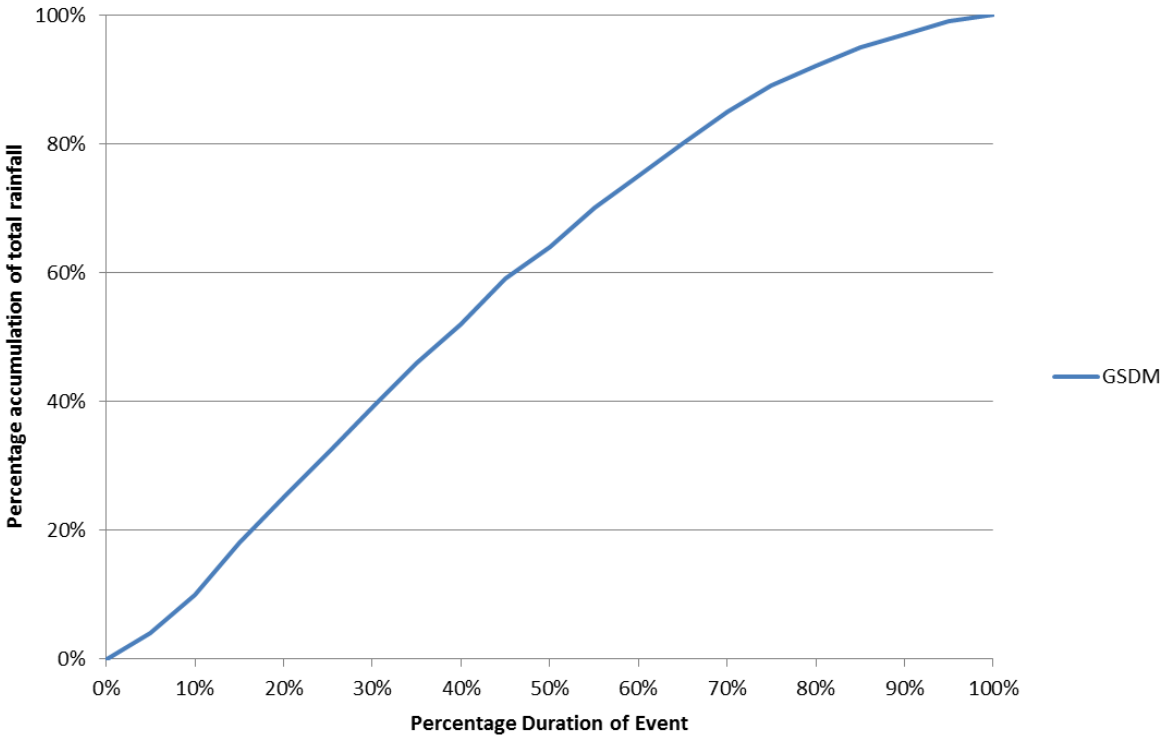

Figure 5-5. GSDM temporal pattern

5.4 RORB PMF model output flow

The RORB model PMF outputs at each site are presented in Table 5-4. The critical duration for all catchments varied between 1.5 and 3 hours.

Table 5-4. Design discharges generated from hydrologic modelling of the PMF

PMF Duration	Peak Discharge (m^3/s)			
	BN_1	**PT_1**	**BC_1**	**BM_3**
15 minutes	1813	817	218.6	637
30 minutes	2330	1321	328.9	1017
45 minutes	2677	1762	407.1	1353
1 hour	3047	2195	428.5	1645
1.5 hours	4136	2915	**444.6**	2168
2 hours	4810	3372	421.4	2440
2.5 hours	5248	3725	389.9	**2534**
3 hours	**5335**	**3832**	368.6	2519
4 hours	5194	3808	327	2384
5 hours	4836	3617	295.2	2220
6 hours	4504	3379	263.3	2060

Attachment B
Hydrodynamic Modelling

6 Hydrodynamic Modelling

6.1 2D hydrodynamic modelling overview

Alluvium already possessed 2D flood models for three of the four sites assessed for this study with the exception being BN_1, where a 1D HECRAS model had been used previously. The existing 2D models have been used with minimal modification, other than to alter the levee alignments where necessary and, in the case of BC_1 to remove the Haul Road crossings (see Section 6.3). All models have been run with PMF hydrology. At Peabody's request the models for BN_1 and BC_1 have also been run with the 0.1% AEP design flood event.

The original intent for BN_1 was to continue using the 1D HECRAS, however early modelling suggested that a 2D approach would provide a more reliable estimate of the water surface elevation for the events being modelled. Therefore, Alluvium has built a basic 2D model for this area. The model was developed to a point sufficient for this level of assessment.

The terrain model was built from LiDAR survey data supplied by Peabody Energy (flown July 2011 and May 2012) along with design rainfall hydrology (as discussed in Attachment A) to determine flood extents and depths along the Isaac River.

Modelling results are presented in Section 2.1.

6.2 BN_1 2D hydrodynamic model set-up

The 2D hydrodynamic model of the Isaac River catchment at BN_1 was built using XPSWMM, a hydrodynamic modelling software package which couples together the SWMM 1D model and the 2D finite difference model TUFLOW.

The hydrodynamic model outfalls on the Isaac River, approximately 2.5km southwest of the levee. The model extends 2km upstream into the catchment. See Figure 6-1.

The model was configured using a 10m cell size. The active extent of the model is shown in Figure 6-1.

A single Manning's n roughness coefficient was used for the entire modelled extent. As the majority of the catchment is similar density vegetation, and the flood risk is low, it was not considered necessary to further refine the roughness throughout the model. Note that if the model is to be used for a different purpose in the future it is recommended that this approach be reviewed.

Design hydrographs were input into the model at the locations shown in Figure 6-1 and represent inputs from both the catchments external to the area and runoff generated locally.

It should be noted that the XPSWMM hydrodynamic model does not predict erosion and sediment transport impacts. Dam and other embankment failure scenarios have not been modelled in this assessment and therefore results are based on stable topography over the full length of the modelled events – which is unlikely to occur during a large magnitude event.

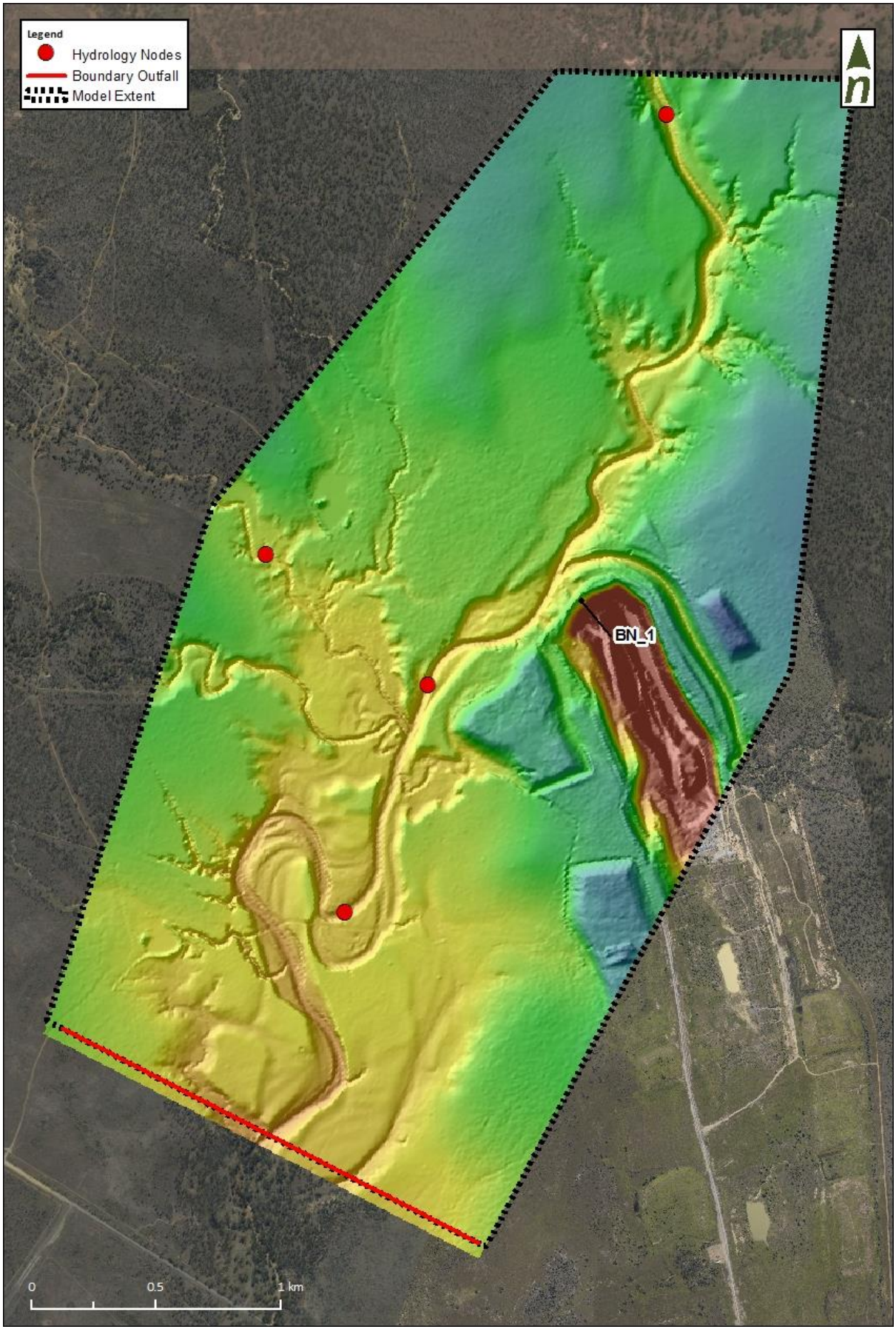

Figure 6-1. BN_1 2D model configuration

6.3 Modifications made to Bullock Creek model

Both haul roads crossing the Bullock Creek diversion were removed within the model to represent an approximation of the Bullock Creek channel post mine closure following removal of the haul roads. The changes to each haul road crossing are represented by the cross sections shown in Figure 6-2 and Figure 6-3 for the upstream and downstream haul road crossings respectively. Figure 6-4 shows the extent of the terrain modifiers used to remove the haul roads.

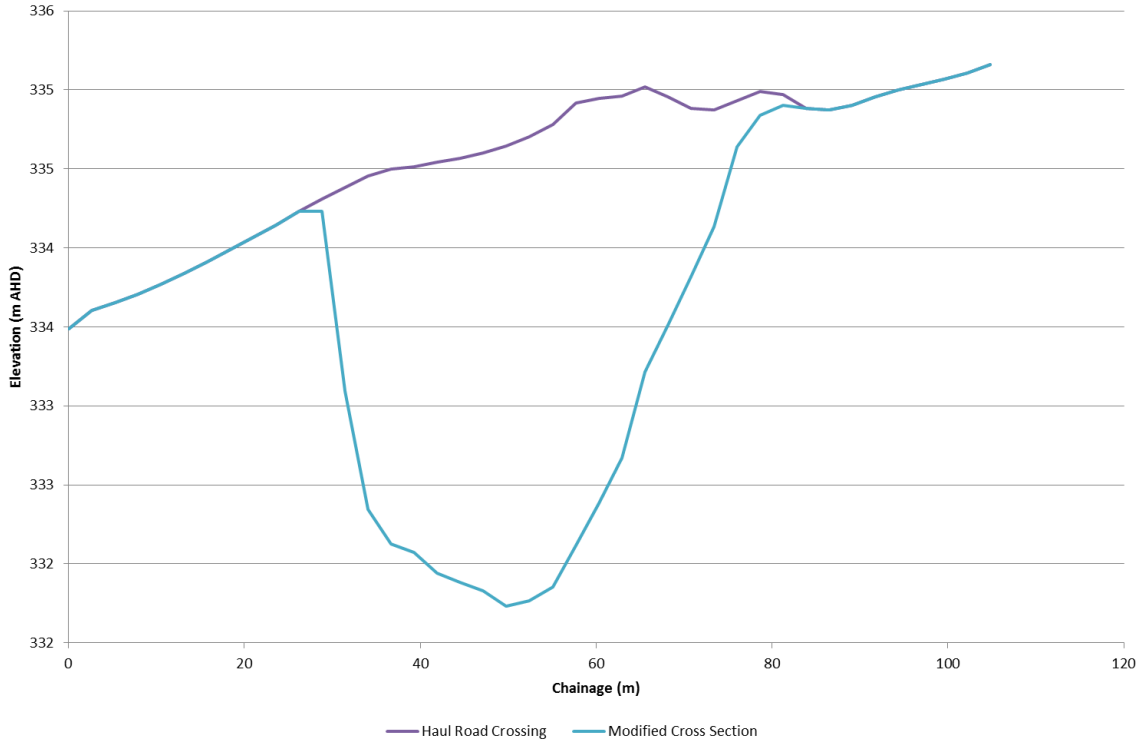

Figure 6-2. Upstream cross section, facing downstream

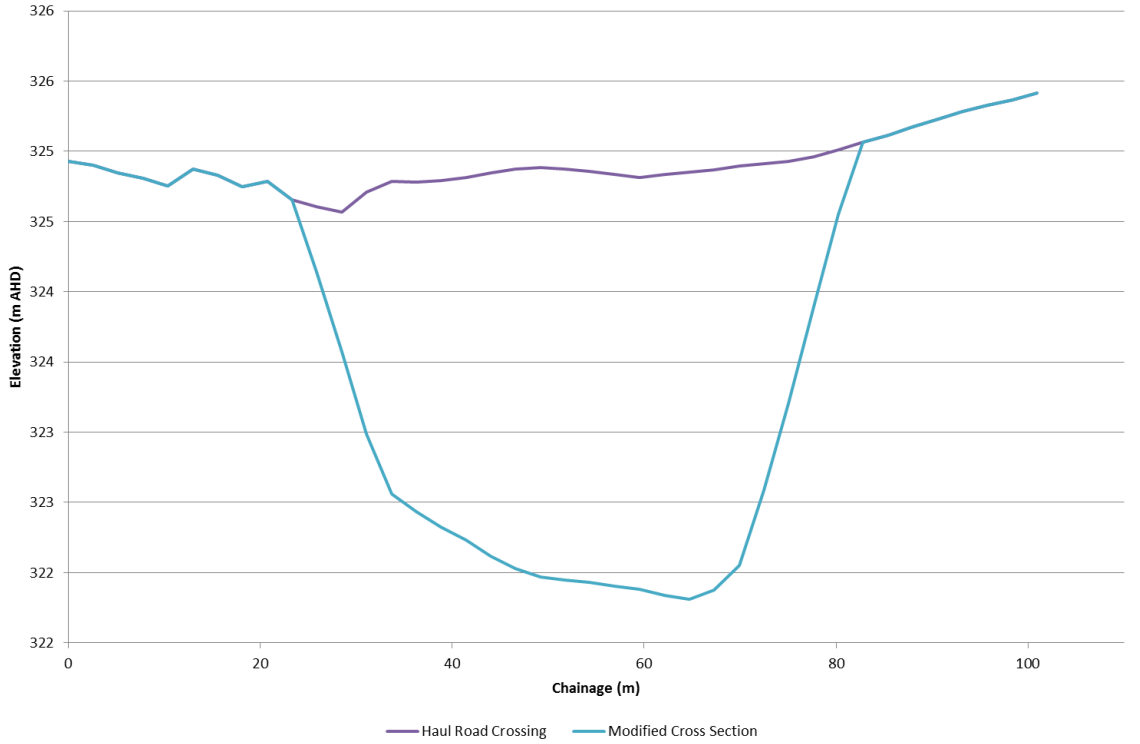

Figure 6-3. Downstream cross section, facing downstream

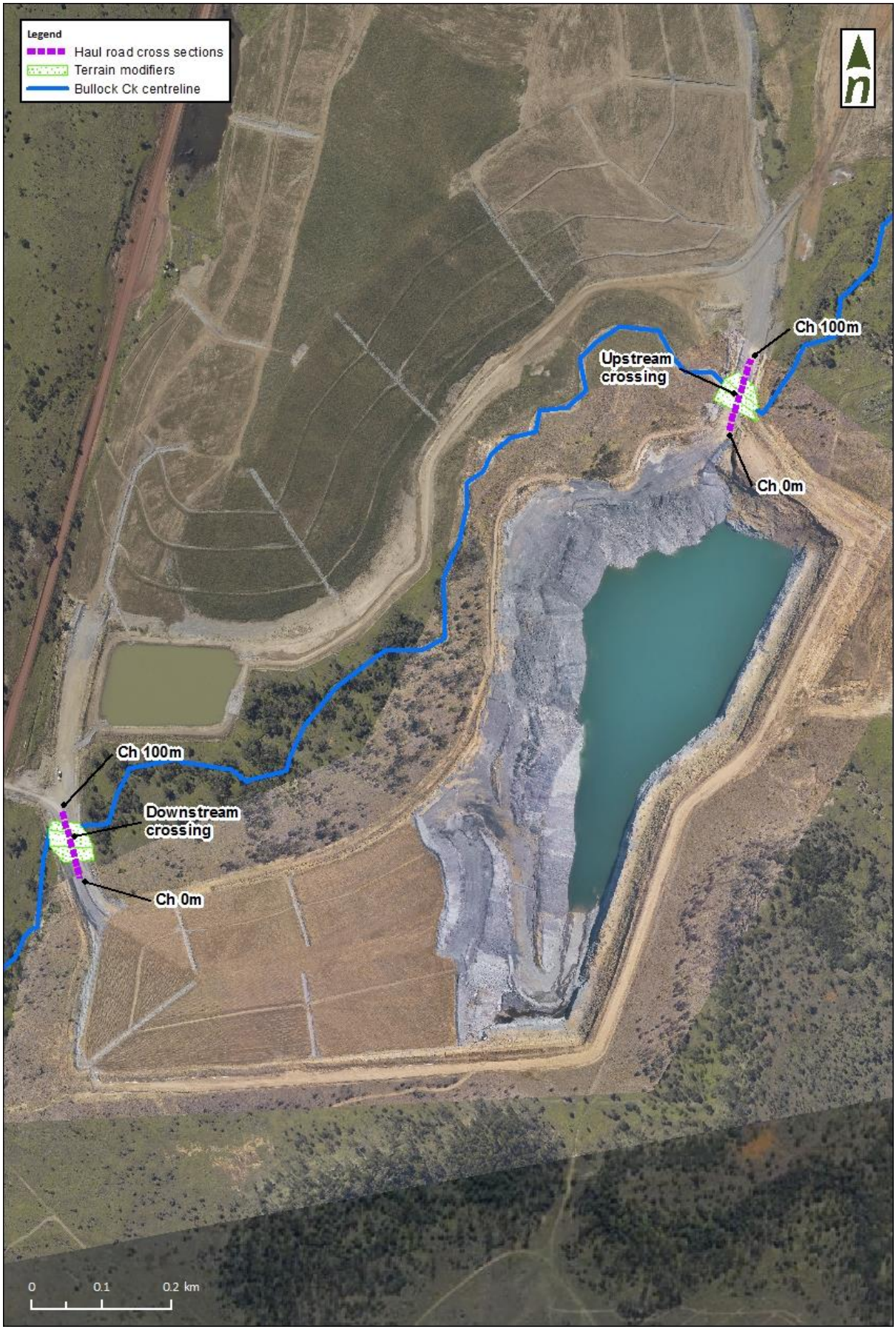

Figure 6-4. Haul road removal cross section locations

Appendix D
Flood risk assessment



alluvium

MODELLING AND ASSESSMENT REPORT:

Hat, Spade and Bullock Creeks Flood Risk Assessment

March 2013

Peabody ENERGY

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Acronyms and Glossary

Acronyms

ACARP	Australian Coal Association Research Program
AEP	Annual Exceedance Probability. The probability that a given rainfall total accumulated or peak flow rate for a given duration will be exceeded in any one year. See Table A-1 for conversion to ARI.
AHD	Australian Height Datum
ARI	Average Recurrence Interval. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated or peak flow rate for a given duration. See Table A-1 below for conversion to AEP.
ARR	Australian Rainfall and Runoff
CL	Continuing Loss
CMP	Corrugated Metal Pipe
CRCCH	Cooperative Research Centre - Catchment Hydrology
CRC-FORGE	Cooperative Research Centre - Focussed Rainfall Growth Estimation
DEHP*	Department of Environment and Heritage Protection
DNRM*	Department of Natural Resources and Mines
DTM	Digital Terrain Model
DXF	Drawing Exchange Format
FRA	Flood Risk Assessment
GSDM	Generalised Short Duration Method
IFD	Intensity, Frequency, Duration
IL	Initial Loss
LiDAR	Light Detection And Ranging
OOP	Out Of Pit
PMP	Probable Maximum Precipitation
RCBC	Reinforced Concrete Box Culvert
WSE	Water Surface Elevation

*Following the election of the Queensland government on 30 March 2012, the functions of the former Department of Environment and Resources Management (DERM) will be delivered by the following departments:

- Department of Environment and Heritage Protection.
- Department of Natural Resources and Mines.
- Department of National Parks, Recreation, Sport and Racing.
- Department of Energy and Water Supply.

Throughout this report, the reference to DERM will now refer to one or more of these departments.

In accordance with the Bureau of Meteorology guidelines, AEP has been used throughout this report in preference to ARI. ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP. However, as ARI is used throughout the ACARP criteria, ARI has been used throughout the hydraulic analysis sections. In order to reduce confusion, ARI has been used for events up to the 50 year and for, higher magnitude events, the AEP has been adopted. This also assists in distinguishing between the event probabilities used for hydraulic design (high probability, low magnitude) and those used to quantify flood risk (low probability, high magnitude).

Table A-1. ARI to AEP conversion table

ARI (years)	AEP	AEP expressed as percentage (%)
2	0.393	39
5	0.181	18
10	0.095	10
20	0.049	5
50	0.020	2
100	0.010	1
200	0.005	0.5
500	0.002	0.2
1000	0.001	0.1
2000	0.0005	0.05

Glossary

Alluvium	Alluvium Consulting Australia
HEC-RAS	Hydraulic modelling software package
k_{en}	Entrance Loss Coefficient
RORB	Hydrological modelling software package
TUFLOW	1D/2D Hydrodynamic modelling software package
XPSWMM	1D/2D Hydrodynamic modelling software package

1 Introduction

Burton Coal Mine is located approximately 125km south-west of Mackay in Queensland. It is situated in the northern end of Queensland's Bowen Basin coalfields and stretches over 35km from north to south. The location of the Burton Mine lease is illustrated in Figure 1-1.

In September 2012, Burton Mine engaged Alluvium Consulting Australia (Alluvium) to undertake a number of desktop studies for the coal mine, primarily focusing on assessing flood risk. This report provides a summary of the tasks that were completed and delivers recommendations where appropriate.

In accordance with the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM 2012), which covers regulated dam and levee structures, the flood risk to the areas of interest to this report has been assessed and quantified for the 0.1% AEP event. This study has identified a number of areas where flood risk exists and provides recommendations for mitigating measures.

1.1 Project objectives

The objectives of the project are to:

- Derive hydrologic information for Hat, Spade and Bullock Creeks and complete a Flood Risk Assessment (FRA) of existing mining operations due to flooding arising from Hat, Spade and Bullock Creeks
- Develop rating curves (or stage discharge curves) for gauging stations on Teviot and Sandy Creeks
- Provide an assessment of in-channel hydraulic characteristics for Spade Creek and Bullock Creek diversions to determine whether or not these diversions are likely to be stable and meet current best practice hydraulic criteria for Bowen Basin diversions, and
- Deliver a compliance check for the Bullock Creek diversion constructed in 2010.

1.2 Report structure

This report is structured in three distinct sections which include: project background and objectives; summary of findings including an FRA of the relevant Burton Mine operations arising from Hat, Spade and Bullock Creeks respectively; and relevant attachments.

The series of attachments include:

- Attachment A Hydrologic modelling of the relevant catchments
- Attachment B Hydrodynamic modelling of Hat and Spade Creeks and Bullock Creek
- Attachment C Stage discharge curves for Teviot and Sandy Creeks
- Attachment D Spade Creek diversion hydraulic analysis
- Attachment E Bullock Creek diversion hydraulic analysis
- Attachment F Bullock Creek diversion compliance report

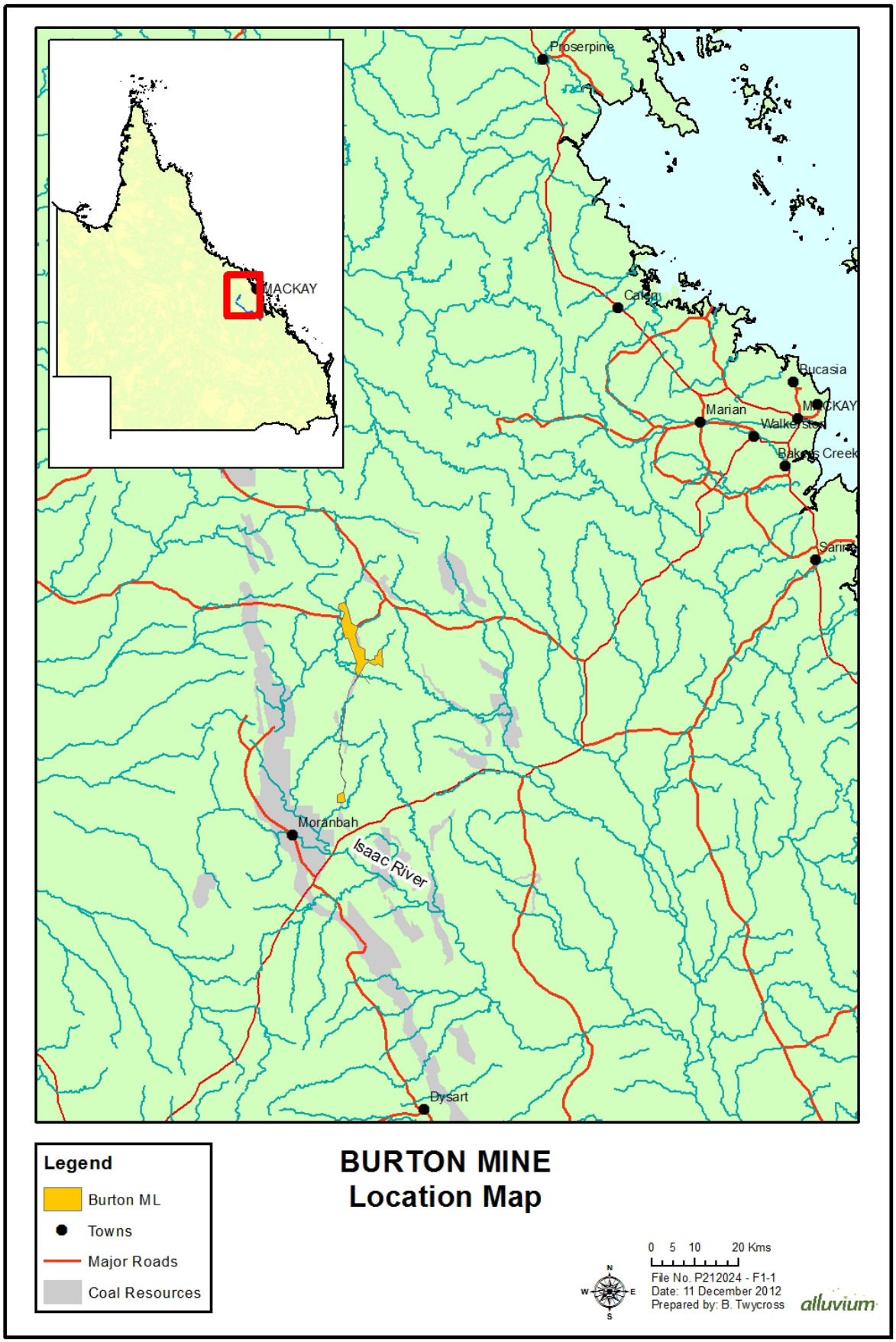

Figure 1-1. *Burton Mine location map*

2 Project Outputs Summary

The section below summarises the key findings of the study. Refer to the Attachments for further details.

2.1 Catchment hydrology

As delineated for this project, the Teviot Brook catchment extends from the headwaters of Bullock and Spade Creeks in the north, from Hat Creek in the south and outfalls to the west side of the northern end of Broadmeadow Pit, west of open cut operations. The Teviot Brook catchment, including the three tributaries, covers an area of approximately 131km^2.

A hydrologic model was built of the entire catchment and flows were generated for up to 0.05% AEP for existing conditions. The hydrologic models have not been calibrated as no observed flow data was available.

See Attachment A for further details.

2.2 Flood risk assessment Spade and Hat Creeks

Hydrodynamic modelling was undertaken to assess the existing conditions flood risk for mining activities adjacent to Hat and Spade Creeks to determine the following:

- Flood extents and risks, and
- Conceptual options to mitigate the flood risk.

The following section provides summary details of the project findings. See Attachment B for further details.

It should be noted that the XPSWMM hydrodynamic model does not predict erosion and sediment transport impacts. Dam and other embankment failure scenarios have not been modelled in this assessment and therefore results are based on stable topography over the full length of the modelled events. Therefore the predicted flood volumes entering the mining areas, in particular the pits, are likely to be higher than indicated.

2.2.1 Existing conditions

Modelling demonstrated that both the northern and southern ends of Broadmeadow Pit are vulnerable to flooding as a direct result of the lack of capacity in Hat and Spade Creeks. Table 2-1 presents the modelled volumes of water entering the pit for the 0.1% AEP event.

Table 2-1. Flood volumes (ML) entering Bullock Creek Pit for the 0.1% AEP event

Duration	Spade Creek Diversion	BM NW DW Dam	Hat Creek, at crossing
3 hour	0	160	6.7
6 hour	0.145	208	7.1

*Note – Hydrodynamic modelling does not account for the potential effect of rapid erosion of failing flood protection measures which would further increase the inundation volume.

For Hat Creek the pit ingress is primarily as a result of backwatering caused by the Broadmeadow OOP Dump restricting the flood plain, 650m downstream of the Hat Creek Mallawa Haul Road crossing. For Spade Creek Diversion the process is similar, with backwatering due to the hydraulic restriction imposed by the Spade Creek Diversion crossing and also the restricted channel 350m downstream of the crossing. Along the west side of the northern end of Broadmeadow Pit, the BM NW DW Dam is overtopped and water can enter the pit via the internal drainage network. The locations where flood water enters the pit are depicted in Figure 2-1 and the specific mechanisms which cause flooding are discussed in greater detail in Section 5.3.

The 0.1% AEP flood envelope and depths for the modelled area are shown in Figure 2-1. As the critical durations vary spatially the results from 3 hour and 6 hour events have been sampled to generate a single maximum flood extent.

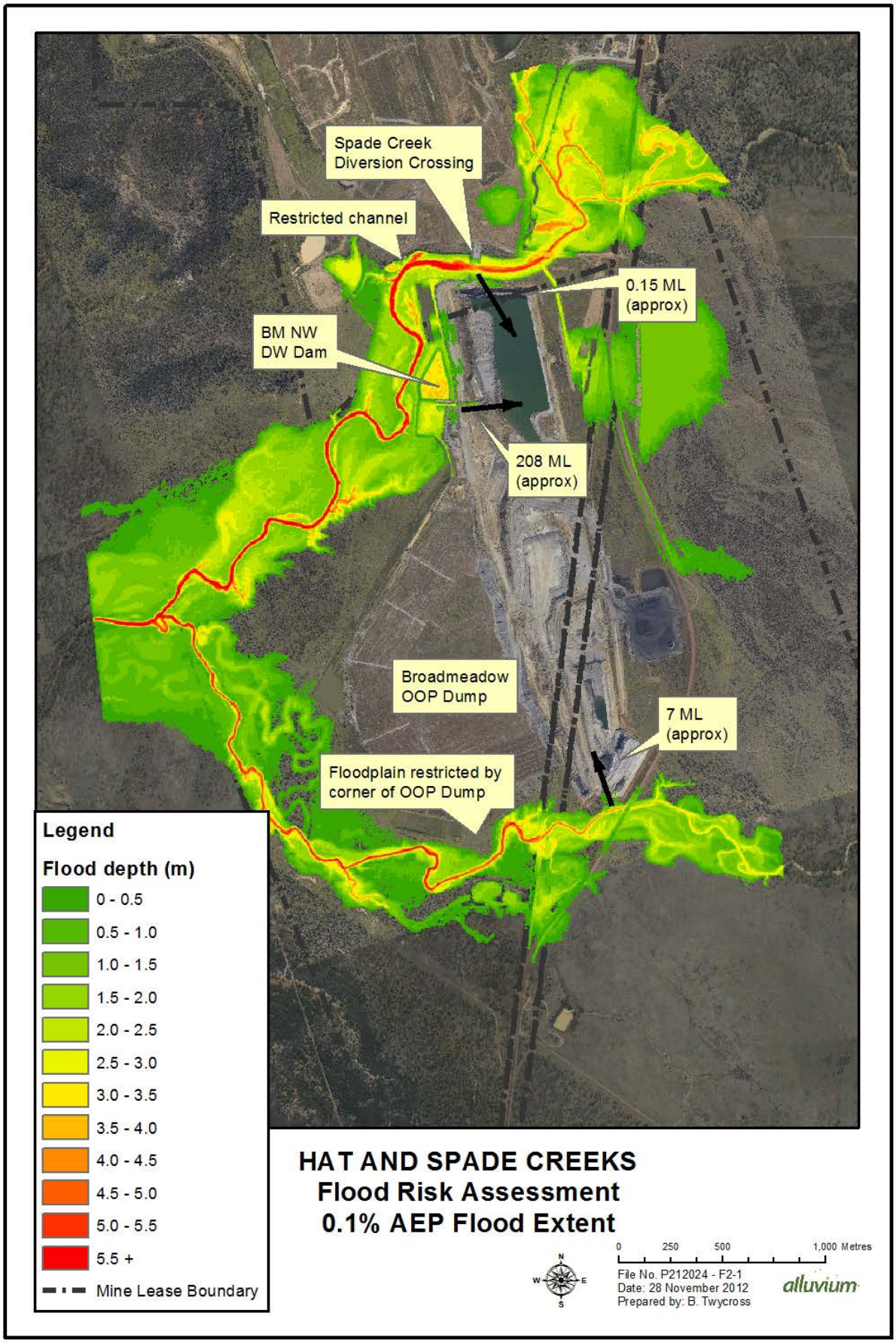

Figure 2-1. *0.1% AEP flood extents and depth for Hat and Spade Creeks (3 hour and 6 hour events combined)*

2.2.2 Flood mitigation options

As discussed in Section 2.2.1, the existing conditions Hat and Spade Creek flood modelling highlighted three locations where flood risk exists for the 0.1% AEP event.

All three locations will require modification to provide the required flood protection. Conceptual design details for the preferred options are provided in the following pages.

Levee protection is considered the most practical option for all three locations. In total, approximately 900m of levee is required although this will often only require that existing bunds be raised to provide sufficient levee protection – providing they are geotechnically suitable to be regarded as levees. Given the close proximity of pit end walls to these locations, pit wall stability is a further geotechnical risk to providing adequate, long term flood protection in these areas.

Following the development of each option, the existing conditions model was updated, to include the suggested levees, and the model was re-run. The resulting flood depth outputs are presented below in Figure 2-2.

Broadmeadow Pit (Northern End)

Flood waters enter the northern end of Broadmeadow Pit via the Spade Creek Diversion as a result of two flow restrictions or low capacity areas. One is the Spade Creek Diversion crossing and the other is caused by the constricted channel 350m downstream of the crossing (refer to Figure 2-1). The road crossing raises the bed level and subsequently the water surface elevation by approximately 1m while the downstream constriction causes a surcharge of approximately 0.8m.

The preferred option is to block off the road on the south side of the diversion by using a levee (see Section 5.5.1).

The conceptual design details for the Broadmeadow Pit (northern end) levee are summarised in Table 2-2 and the conceptual alignment is shown in Figure 2-2.

Table 2-2. Broadmeadow Pit (northern end) Levee, summary of preferred levee option

Parameter	Value
Water surface elevation (m AHD)	281.3 – 282.5
Total length of levee	~200m
Typical raise height	~0.0 to 2.0m*

* Assuming 0.5m freeboard

BM NW DW Dam

Flood waters enter the dam during the 0.1% AEP event and, once the dam is full, overtop and continue into the drainage network which outfalls into the northern end of Broadmeadow Pit (refer back to Figure 2-1).

The preferred option is to remove and rehabilitate the dams and build a levee alongside Broadmeadow Pit, in the location of the existing dam's eastern wall. In addition, a plug is required 200m north of the location to prevent ingress of water via the drainage channel. The conceptual design for the BM NW DW Dam levee and plug are summarised in Table 2-3 and the conceptual alignments are shown in Figure 2-2.

Table 2-3. BM NW DW Dam Levee, summary of preferred levee and plug option

Parameter		Value
Levee	Water surface elevation (m AHD)	278.7 – 280.0
	Total length of levee	~500m
	Typical raise height	~0.0 to 4m*
Plug	Water surface elevation (m AHD)	281.5
	Total length of levee	~30m
	Typical raise height	~4m*

* Assuming 0.5m freeboard

Broadmeadow Pit (Southern End)

Flood waters enter the southern end of Broadmeadow Pit as a result of a flow constriction approximately 600m downstream of the spill point caused by a smaller dump, on the south side of the Broadmeadow OOP Dump, which impinges on the Hat Creek flood plain (refer back to Figure 2-1). The restriction causes a 1.5m water surface elevation surcharge upstream.

A levee is the preferred option providing geotechnical conditions in relation to the pit end wall and geomorphic conditions in relation to channel migration can be satisfied.

The conceptual design details for the Broadmeadow Pit (southern end) levee are summarised in Table 2-4 and the conceptual alignment is shown in Figure 2-2.

Table 2-4. Broadmeadow Pit (Southern End) levee, brief summary of preferred levee option

Parameter	Value
Water surface elevation (m AHD)	284.4 – 284.9
Total length of levee	~200m
Typical raise height	~0.0 to 1.5m*

* Assuming 0.5m freeboard

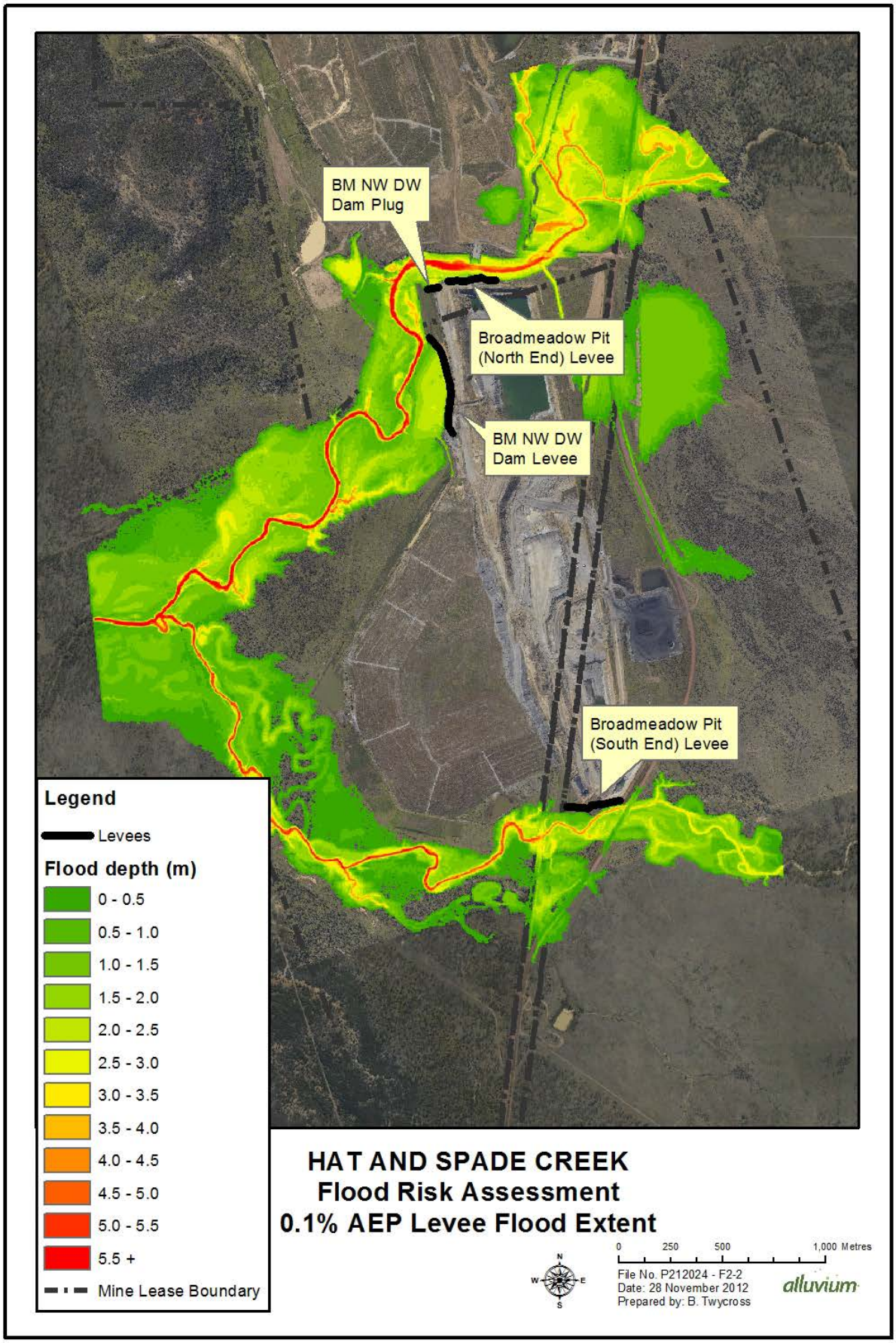

Figure 2-2. *0.1% AEP (with levees) flood depths for Hat and Spade Creeks (3 hour & 6 hour events combined)*

2.3 Flood risk assessment Bullock Creek

Hydrodynamic modelling was undertaken to assess the existing conditions flood risk for mining activities adjacent to Bullock Creek to determine the following:

- Flood extents and risks, and
- Conceptual options to mitigate the flood risk.

The follow section provides summary details of the project findings. See Attachment B for further details.

2.3.1 Existing conditions

Modelling demonstrated that mining activities on the south side of Bullock Creek are vulnerable to flooding as a result of the lack of culvert capacity under the two Bullock Creek haul road crossings, up and downstream of the diversion.

Table 2-5 details the volumes of water into the pit for the 0.1% AEP event.

Table 2-5. Flood volumes (ML) entering Bullock Creek Pit for the 0.1% AEP event

Duration	Upstream Bullock Creek HR Crossing	Downstream Bullock Creek HR Crossing
30 mins	104	0
1 hour	179	1
3 hour	250	7

Note – Hydrodynamic modelling does not account for the potential effect of rapid erosion of failing flood protection measures which would further increase the inundation volume.

Modelling indicates that pit flooding occurs as a direct result of each of the road crossings causing water surcharge upstream and effectively funnelling water directly into the pit at each location. This explains why the spill volumes continue increasing for increasing storm durations, despite the small catchment size.

The 0.1% AEP flood envelope and depths for the modelled area are shown in Figure 2-3. As the critical durations vary spatially the results from 30 minute, 1hour and 3 hour events have been sampled to generate a single maximum flood extent.

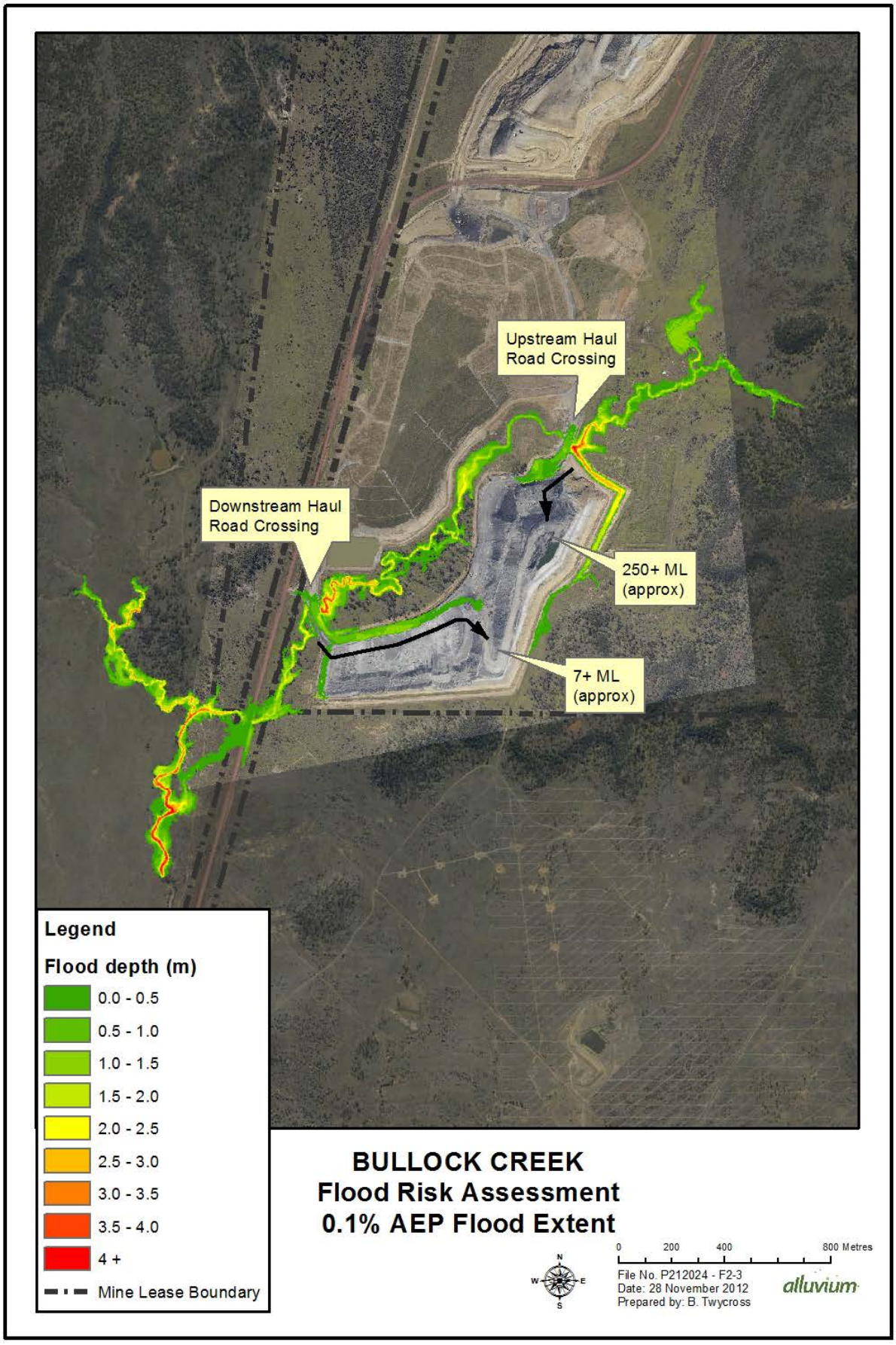

Figure 2-3. *0.1% AEP flood extents and depth for Bullock Creek (30 mins, 1 hour and 3 hour events combined)*

2.3.2 Flood mitigation options

As discussed in Section 2.3.1, the existing conditions Bullock Creek flood modelling highlighted two locations where flood risk exists for the 0.1% AEP event.

Three possible options were investigated:

- Increasing the culvert capacity to prevent backwatering upstream.
- Removal of the haul road crossings and restoration to natural surface.
- Providing levee protection.

Burton Mine has indicated that the second option is preferred. The pit is in the process of being rehabilitated and heavy vehicle access is not required. If light vehicle access is required then a creek crossing can be installed at the channel bed level.

Further details on all three options are provided in Attachment B.

The resulting flood depth outputs for the preferred option are presented in Figure 2-4.

2.4 Low flow release triggers for GST6 and GST1

In order to develop rating curves to provide flow depths corresponding to the low flow release triggers in Table 2-6 from Burton Mine's EA, hydraulic models were developed for the flow gauging stations at Teviot Creek (GST6) and Sandy Creek (GST1). The low flow release triggers flow rates and depths are provided below in Table 2-6.

Table 2-6. Low flow release triggers for GST6 and GST1

Flow Station	Release Trigger (m^3/s)	Corresponding WSE (m AHD)	Invert (m AHD)	Depth (m)
Teviot Creek (GST6)	0.5	315.04	314.45	0.59
Sandy Creek (GST1)	1.5	305.34	304.98	0.36

See Attachment C for further details on the development of the Teviot Creek flow gauging station (GST6) and Sandy Creek flow gauging station (GST1) rating curves, including development of the models and the separated curves for the channels and floodplains.

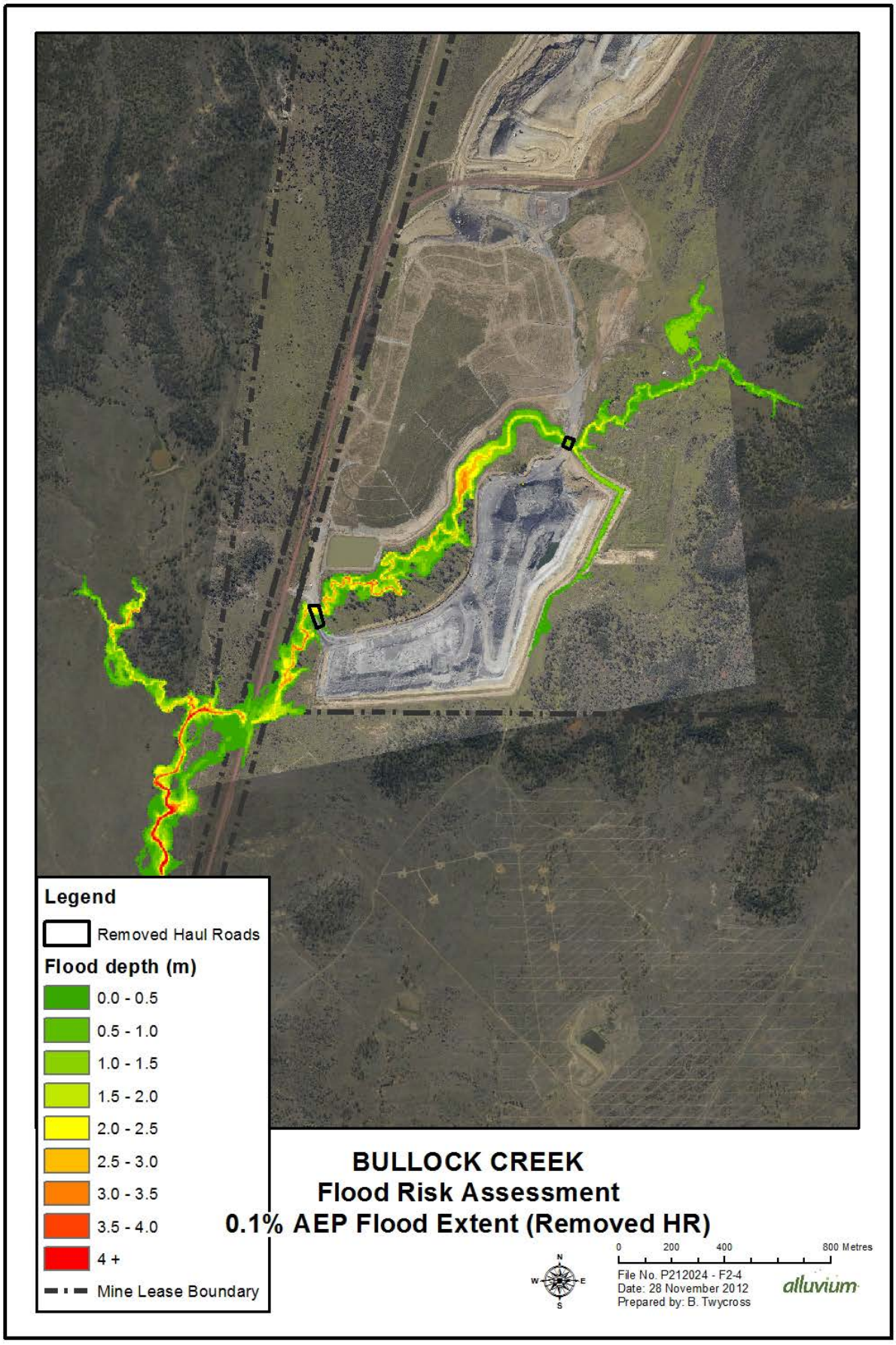

Figure 2-4. *0.1% AEP (upgraded culverts) flood depths for Bullock Creeks (1 hour and 3 hour events combined)*

2.5 Spade Creek diversion hydraulic assessment

Modelling has demonstrated that the average hydraulic parameter values for the reach upstream of the diversion are all within recommended thresholds for both the 1:2 and 1:50 ARI events.

Through the diversion reach, the average value of velocity for the 1:50 ARI and average values of velocity and stream power for the 1:2 ARI exceed recommended thresholds. Modelling indicates that this is primarily as a result of the steep (~10 times steeper than the upstream and downstream reaches) section associated Spade Creek Crossing which may have been a drop structure at some point in time. This causes significant spikes in the velocity and stream power, driving both averages above threshold. This is illustrated on Figure 2-5.

The average hydraulic parameter values for the reach of Spade Creek downstream of the diversion are generally below recommended thresholds for both the 1:2 and 1:50 ARI events. However, the recommended velocity threshold is exceeded for the 1:2 ARI event. Modelling indicates that this is not caused by any particular section of the reach; velocities are reasonably consistent along the reach.

The overall longitudinal gradient of the diversion is 0.00376m/m, approximately double the gradient of the adjoining upstream and downstream reaches. With this overall gradient it would not be unusual for the diversion to be subject to high hydraulic parameter values and substantial instabilities throughout the entire reach. However, the presence and continual maintenance, especially following flow events, of the two diversion road crossings prevents this from occurring. Maintenance of the crossings holds the upstream bed elevation in place and prevents deepening of the bed from occurring.

The crossings also have the impact of reducing sediment transport through the reach and have localised high flow energies on the downstream elevation drop of both crossings. Materials washed out of the haul road during each event are depositing downstream, providing some armouring of the bed and thus limiting the potential for deepening to occur.

If the two road crossings were removed (or maintenance ceased) the gradient along the diversion would be too steep, and significant erosion would be expected to progress upstream with substantial aggradation occurring downstream of the diversion.

In its current form, the diversion is not considered to be a self-sustaining waterway and not likely to be suitable for licence relinquishment in the future. Therefore, rehabilitation of the diversion is recommended to reduce potential risks to the Burton mining operation and the adjoining environment, and establish it on a condition trajectory that is self-sustaining and suitable for the prospect of licence relinquishment in the future. Rehabilitation of the diversion is likely to involve lengthening to establish a stable longitudinal gradient without the requirement for ongoing maintenance.

See Attachment D for further details.

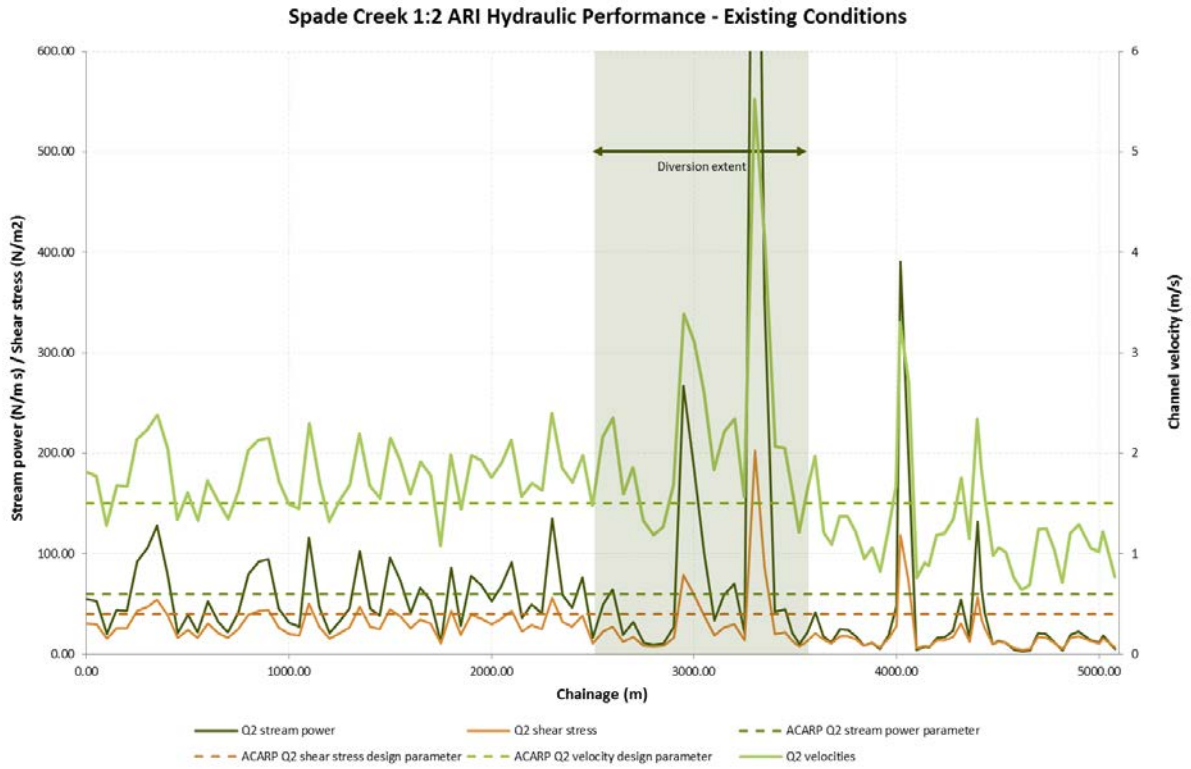

Figure 2-5. *1:2 ARI hydraulic parameters modelled for Spade Creek*

2.6 Bullock Creek hydraulic assessment

Modelling has demonstrated that the average hydraulic parameter values for the reach upstream of the Bullock Creek Diversion are all below recommended thresholds for both the 1:2 and 1:50 ARI events. Increased headwater elevation upstream of the Upstream Bullock Creek Haul Road Crossing results in a decrease in hydraulic parameter values for both the 1:2 and 1:50 ARI events for approximately 300m in the upstream reach.

Through the diversion reach, average hydraulic parameter values are mostly below recommended thresholds with the exception of the 1:2 ARI stream power. Modelling indicates that the high stream power value is largely a result of the overtopping of the Upstream Bullock Creek Haul Road Crossing which causes a large localised spike in all hydraulic parameter values. It should be noted that the overall longitudinal bed gradient of the diversion is 0.0060m/m, approximately double the gradient of the adjoining downstream reach and half the gradient of the adjoining upstream reach. Average hydraulic parameter values through the diversion reach are influenced by two backwater zones. A floodplain confinement just downstream of the diversion increases water surface elevations (which reduces hydraulic parameter values) through the downstream portion of the diversion. The haul road crossing has a similar effect at the upstream end of the diversion. The removal of the haul road may be a long term option to stabilise the hydraulic parameters.

The average hydraulic parameter values for the reach of Bullock Creek downstream of the diversion are all below recommended thresholds for both the 1:2 and 1:50 ARI events. As was the case for the upstream reach, these low hydraulic parameters are influenced by increased headwater elevations resulting from the respective road crossings: Downstream Bullock Creek Haul Road Crossing, and Mallawa Haul Road Crossing. Also associated with these crossings are localised elevated hydraulic parameter values which suggest that whilst the roads are in operation, continued maintenance will be required.

With these modelling results and limited on-ground assessment, it is difficult to draw accurate conclusions about the performance of the diversion and likely suitability for future licence relinquishment (assuming the haul road would be removed for the relinquishment scenario). It is recommended that the diversion be modelled without the haul road in place and further on-ground assessment be undertaken (if required) to better understand potential suitability for future licence relinquishment.

As highlighted in Section 11.4, vegetative rehabilitation of the diversion reach will assist by reducing stream parameters and providing increased resistance to erosion from stream flows.

See Attachment E for further details.

3 References

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Mathew Palmer Consulting Engineers (2009). *Burton Coal Mine: Bullock Creek Diversion #1 Design Report*, Tasmania, 27 October.

Hydrologic Engineering Centre (2010). *HECR-RAS Hydraulic Reference Manual Version 4.1*. US Army Corps of Engineers.

Attachment A
Hydrology

4 Hydrologic Modelling

As delineated for this project, the Teviot Brook catchment extends from the headwaters of Bullock and Spade Creeks in the north, from Hat Creek in the south and outfalls to the west side of the northern end of Broadmeadow Pit, in the west. The Teviot Brook catchment, including the three tributaries, covers an area of approximately 131km^2. See Figure 4-1.

As per the project objectives, hydrologic information for Hat, Spade and Bullock Creeks has been derived at relevant locations in order to facilitate a flood risk assessment of existing mining operations due to flooding arising from these watercourses.

A hydrologic model was built of the entire catchment and flows were generated for up to the 0.05% AEP for existing conditions. The hydrologic models have not been calibrated as no observed flow data was available for the catchment.

4.1 RORB model description

The hydrologic modelling software used in this study is RORBWin version 6.15 (Nathan 2010), a Windows version of the industry accepted RORB program (Laurenson & Mein 1997).

A RORB model represents the rainfall runoff process occurring in a catchment by:

- Conceptualising the catchment as a linked series of sub-catchments represented in the model by catchment storages and river reach storages;
- Applying rainfall excess (rainfall minus losses) to each sub-catchment (rainfalls are assumed to enter the sub-catchment at its centroid);
- Calculating the resulting runoff from each sub-catchment storage;
- Routing the runoff through the catchment system, combining flows at channel junctions; and
- Outputting flow hydrographs at points of interest in the catchment.

The model represents only the rapid flow or surface runoff component of stream flow, and the slow response or base flow component has not been included in the model.

Setting up the model comprises:

- Determining the catchment boundary and dividing the catchment into sub-catchments;
- Calculating the area of each sub-catchment;
- Placing model nodes at sub-catchment inflows and junctions;
- Placing reach storages between nodes; and
- Measuring the length of reach between adjacent nodes.

The RORB model requires four parameters to be specified which include k_c, m, initial loss (IL) and continuing loss (CL). The k_c and m parameters are factors in the storage discharge relationship.

The storage discharge relationship for the reach storages in the model has the general form:

$$S = 3600k\,Q^m$$

Where:

S is the volume of water in storage (m^3);
k is related to travel time of a particular reach and the characteristics of the whole catchment;
Q is outflow rate from the reach storage; and
m is a dimensionless exponent representing the non-linearity of catchment response. m varies in the range 0.6 to 1.0 with a value of 1 representing a linear response. Many studies adopt a value of 0.8.

The relationship between k and k_c is given by the equation:

$$k = k_{ri} k_c$$

Where:

k_{ri} is the relative delay time of reach i; and
k_c is an empirical coefficient applicable to the catchment and is a constant for the whole catchment.

The two rainfall loss parameters of initial loss and continuing loss are used in the generation of the rainfall excess hyetograph for the model. Initial loss is the rainfall at the start of a storm event which fills soil and groundwater storage, is intercepted by vegetation, or is lost by another process and does not contribute to runoff. Continuing loss is the ongoing portion of rainfall that falls after the initial loss that does not produce surface runoff. This could be due to deep soil storage, vegetation interception or evaporation. The loss parameters used in the model are storm and catchment specific.

4.2 Catchment delineation

Catchment delineation and subdivision was undertaken using the CatchmentSIM software program which delineates sub-catchments from a Digital Terrain Model (DTM), calculates their properties and creates output files for a range of hydrologic models including RORB.

For this project, two different data sources were used in the following order:

- LiDAR data collected in May 2012. This covered the area within the mine lease.
- LiDAR data collected in July 2011. This data covers the remainder of the catchment.

The catchment delineation and subdivision took account of all known diversions and waterways within the project area. Following delineation of the sub-catchments, the CatchmentSIM model was exported as a RORB catchment file using a CatchmentSIM-RORB macro (6.0 v3). This automatically sets up the connections between sub-catchments and reaches and calculates and assigns the sub-catchment areas, reach lengths and slopes in the RORB catchment file. This file was then modified to specify the locations where hydrograph outputs were required.

The existing conditions model for Teviot Brook has 230 subcatchments. The resulting layout of subcatchments and reaches is shown in Figure 4-2**.**

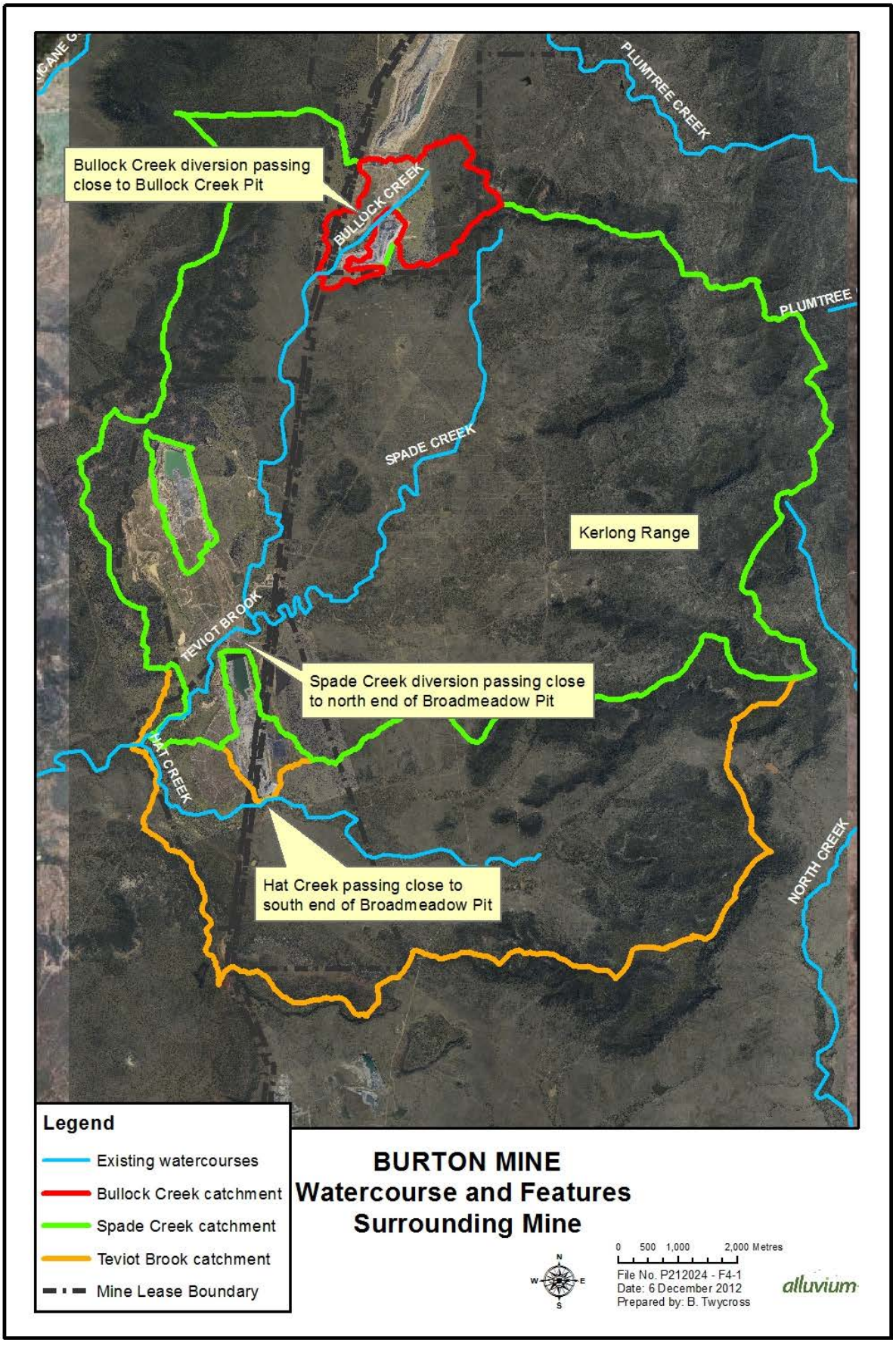


Figure 4-1. *Teviot Brook catchment watercourse and features surrounding mine*

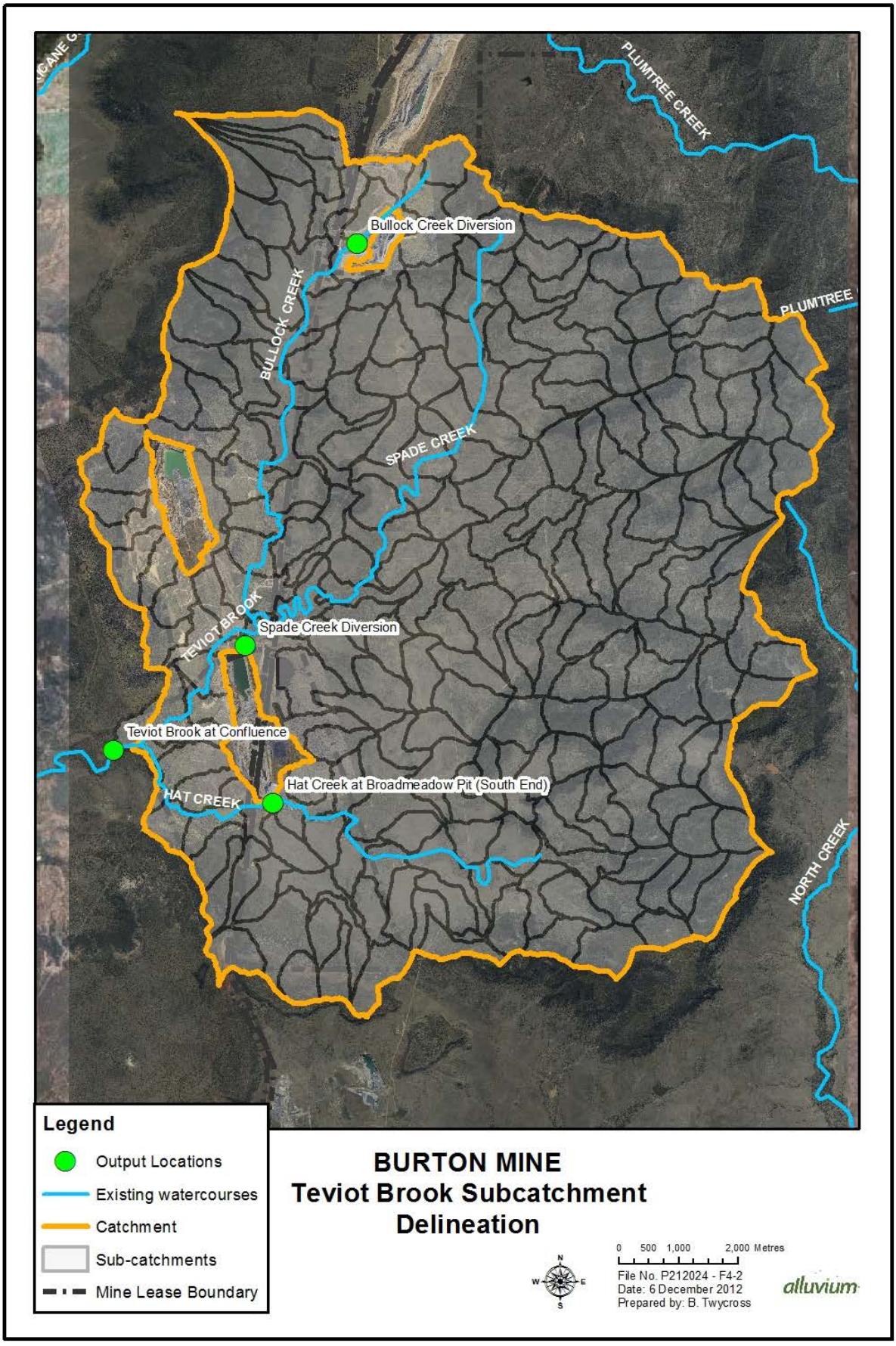


Figure 4-2. *Teviot Brook subcatchment delineation*

4.3 Model parameter derivation

Due to the lack of either stream flow data or a comparable sized catchment nearby, it was not possible to calibrate the model. Therefore, a regional method was used to derive the parameters required for the RORB model.

Weeks regional relationship method

Australian Rainfall and Runoff (ARR) outlines, in section 3.6.2, the regional relationships developed to calculate k_c for ungauged catchments. For Queensland, the relevant method was derived by Weeks and takes the form:

$$k_c = 0.88 * Area^{0.53}$$

Table 4-1, below, lists the Weeks derived k_c values for existing conditions.

Table 4-1. Calculated Weeks value based on existing conditions scenario

Scenario	Catchment Area (km^2)	Weeks k_c Value*
Existing Conditions	132.0	11.71

*Note, that the underlying assumption is that m = 0.8.

Other modelling parameters

For this project it was considered suitable to use typical Queensland design values for Initial Loss (IL) and Continuing Loss (CL). These are presented in Table 4-2.

Table 4-2. Adopted model parameters for initial loss and continuing loss

Parameter	All ARI and AEP
Initial Loss	25mm
Continuing Loss	2.5mm/hr

4.4 Design rainfall

Design rainfall depths for up to the 0.05% AEP events were generated for this study. The 1:2 ARI to the 1:50 ARI design rainfalls were determined using the ARR method inbuilt in RORB (with site parameters determined from ARR Vol 2).

The 1% to 0.05% AEP design rainfalls were determined using DERM design rainfall data (2005) for Queensland. This data was based on analysis of rainfall records on a regional basis using a technique developed by the CRCCH known as CRC-FORGE.

In order to generate appropriate design flood hydrographs for each of the two key mining areas within the catchment it was necessary to development Intensity, frequency, duration (IFD) data for each area separately to account for the spatial variation and differences in catchment size.

IFD tables for the Teviot Brook and the Bullock Creek catchment are presented in Table 4-3 and Table 4-4, respectively.

Table 4-3. IFD Table for Bullock Creek catchment, total rainfall depth in mm (includes Areal Reduction Factors)

Event	1:2 ARI	1:5 ARI	1:10 ARI	1:20 ARI	1:50 ARI	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP
15 min	20.62	25.73	28.72	32.83	38.25	53.39	60.87	71.74	80.80	90.66
30 min	30.01	36.92	40.89	46.42	53.69	74.90	85.40	100.65	113.36	127.18
1 hour	42.13	51.00	56.00	63.12	72.40	100.94	115.08	135.64	152.77	171.40
3 hours	56.32	70.62	79.03	90.51	105.73	142.64	162.62	191.67	215.88	242.20
6 hours	66.54	85.36	96.70	111.90	132.26	175.82	200.46	236.26	266.10	298.54
12 hours	78.82	103.41	118.60	138.65	165.80	217.21	247.64	291.88	328.74	368.82
18 hours	88.61	117.41	135.35	158.93	191.02	253.19	288.67	340.23	383.20	429.92
24 hours	96.04	128.13	148.28	174.67	210.69	281.33	319.36	372.90	416.77	462.70
48 hours	113.77	154.50	180.50	214.34	260.93	371.54	418.22	481.92	531.67	582.95
72 hours	121.82	167.33	196.69	234.77	287.49	419.37	473.18	548.19	607.39	668.92
96 hours	N/A					450.73	509.98	592.82	659.06	728.19
120 hours						471.21	533.59	620.43	690.35	763.73

Table 4-4. IFD Table for Teviot Brook catchment, total rainfall depth in mm (includes Areal Reduction Factors)

Event	1:2 ARI	1:5 ARI	1:10 ARI	1:20 ARI	1:50 ARI	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP	0.05% AEP
15 min	15.83	19.75	22.05	25.20	29.37	48.09	54.83	64.62	72.78	81.66
30 min	23.04	28.34	31.39	35.64	41.21	67.49	76.95	90.70	102.15	114.60
1 hour	36.18	43.79	48.08	54.20	62.16	91.00	103.75	122.28	137.73	154.52
3 hours	52.38	65.68	73.50	84.17	98.33	129.09	147.18	173.47	195.38	219.20
6 hours	63.21	81.09	91.87	106.31	125.65	159.53	181.88	214.37	241.45	270.88
12 hours	75.67	99.27	113.86	133.10	159.17	197.58	225.26	265.50	299.03	335.49
18 hours	85.07	112.71	129.94	152.57	183.38	229.89	262.10	308.92	347.94	390.35
24 hours	93.16	124.29	143.83	169.43	204.37	254.99	289.32	337.66	377.31	418.81
48 hours	110.36	149.87	175.09	207.91	253.10	342.29	385.12	443.65	489.36	536.45
72 hours	119.38	163.98	192.76	230.07	281.74	391.67	441.58	511.13	565.92	622.77
96 hours	N/A					424.23	479.61	556.83	618.50	682.81
120 hours						445.80	504.27	585.68	651.03	719.63

Temporal patterns

For events ranging from 1:2 to 1:50 ARI the standard ARR zone 3 temporal patterns were utilised.

A design temporal pattern suitable for all events greater than 1:50 ARI was derived from the 10 patterns provided in the Jordan et al. (2005) paper combined with the Bulletin 53 pattern from the Generalised Short Duration Method (GSDM) PMP. The resulting "Rare Design" temporal pattern is depicted in Figure 4-3.

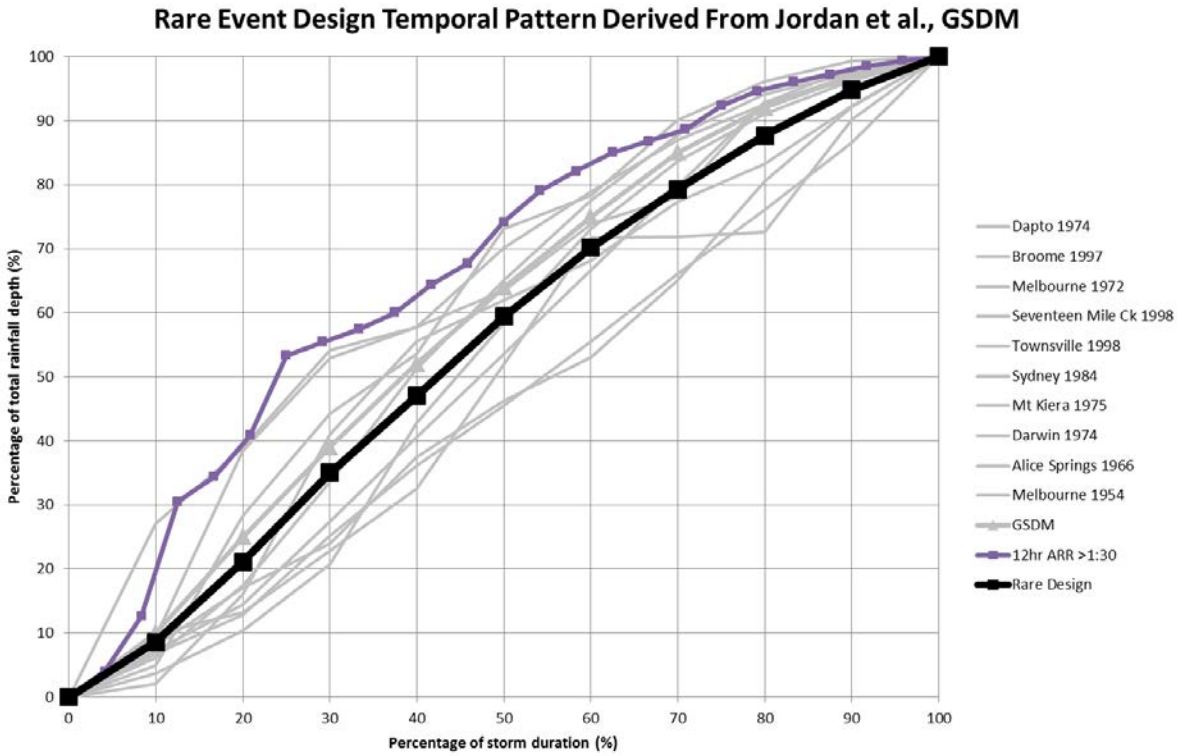


Figure 4-3. *Selection of the design temporal pattern for rare events*

4.5 RORB model output flow

Presented in Table 4-5 below are the RORB model outputs for existing conditions. The output locations are depicted in Figure 4-2 and have been chosen to facilitate reporting.

Note that the peak flow rates did not all coincide on the same duration storm event – overall the critical duration varied between the 1 hour and 6 hour events depending on event probability and location.

Table 4-5. Design discharges generated from hydrologic modelling of existing conditions

	Bullock Creek Diversion	Sandy Creek Diversion	Hat Creek at Broadmeadow	Teviot Brook Confluence
Upstream catchment (km^2)	26.2	80.4	88.8	93.5
ARI/AEP	**Peak Discharge (m^3/s)***			
1:2	9	86	32	116
1:50	27	359	130	492
1%	33	500	188	714
0.1%	61	877	326	1268
0.05%	73	1015	384	1477

* Please note that the peak flow rates will not necessarily match with the corresponding events modelled using 2D flood modelling software due to the differences in the modelling methods.

Attachment B
Hydrodynamic Modelling

5 Hydrodynamic Modelling of Hat and Spade Creeks Existing Conditions

5.1 2D hydrodynamic modelling overview

Hydrodynamic modelling was undertaken to assess the existing conditions flood risk for mining activities adjacent to Hat and Spade Creeks to determine the following:

- Flood extents and risks, and
- Conceptual options to mitigate the flood risk.

The model was built from LiDAR survey data along with design rainfall hydrology (as discussed in Attachment A) to determine flood extents and depths in the area surrounding the northern and southern ends of Broadmeadow Pit. The flood envelope was generated using the 2D hydrodynamic modelling package XPSWMM.

As is explained in Section 5.5, water levels were used to ascertain the necessary levee embankment elevations and extents to provide the required 0.1% AEP flood immunity for the mining activities. The model was then rerun to confirm the effectiveness of the recommendations.

5.2 2D hydrodynamic model set-up

A 2D hydrodynamic model of the Hat and Spade Creek catchments surrounding the northern and southern ends of Broadmeadow Pit was built using XPSWMM, a hydrodynamic modelling software package which couples together the SWMM 1D model and the 2D finite difference model TUFLOW.

The hydrodynamic model outfalls at Teviot Brook approximately 400m downstream of the confluence of Spade and Hat Creeks. The model is extended up into the catchment to approximately 500m upstream of the Spade Creek Mallawa Haul Road crossing (including Cockies Dam) and approximately 800m upstream of the Hat Creek Mallawa Haul Road crossing. See Figure 5-1.

The digital terrain model (DTM) used for the model consists of a processed amalgam of two LiDAR sources supplied by Burton Mine. Both sources were acquired by Atlass, one in July 2011 and the other in May 2012. The data used to generate the model and the source of the data is summarised in Table 5-1.

Table 5-1. Summary of data used in Hat and Spade Creeks 2D model

Data	Provider	Comments
LiDAR DTM of mine and surrounds	Burton Mine	Provides full coverage. Acquisition date May 2012 and June 2011 (Atlass)
Aerial of mine and surrounds	Burton Mine	Provides full coverage. Acquisition date May 2012 and June 2011 (Atlass)
Manning's delineation of site	Alluvium	Assessed from aerial image provided
Catchment Hydrology	Alluvium	Determined using RORB (see Attachment A)

The model was configured using a 5m cell size. The active area of the model is shown in Figure 5-1.

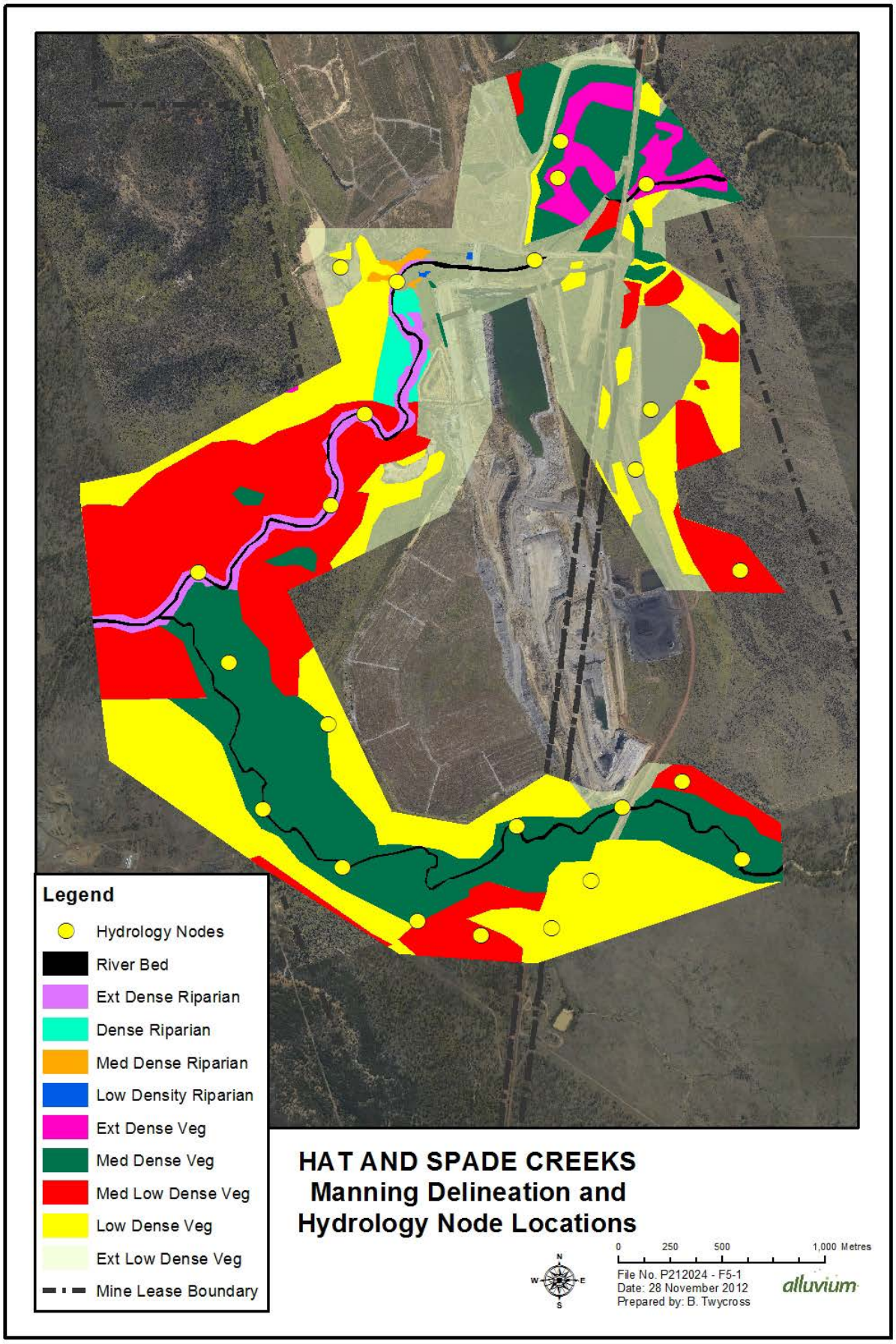


Figure 5-1. *XPSWMM Hat and Spade Creeks model set up*

Manning's n roughness coefficients for the model were set using polygons delineated from aerial imagery (without onsite verification). Manning's n values adopted for the different polygons are presented in Table 5-2 with the delineation of the Manning's n polygons shown in Figure 5-1.

Table 5-2. Manning's n roughness values for Bullock Creek 2D model

Land use/Vegetation Type	Roughness value
River bed	0.025
Extremely dense riparian	0.1
Dense riparian	0.065
Medium density riparian	0.05
Low density riparian	0.035
Extremely dense vegetation	0.1
Medium density vegetation	0.075
Medium low density vegetation	0.055
Low density vegetation	0.040
Extremely low density vegetation	0.025

Hydrologic inputs suitable for 2D modelling were developed for the 0.1% AEP event. This event was chosen based on guidance contained in the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2012).

Design hydrographs were input into the hydrodynamic model at the locations shown in Figure 5-1 to represent inputs from both the catchments external to the area and runoff generated locally.

The hydrodynamic model was tested with storm durations of 3 hours, 6 hours and 12 hours in order to confirm the critical duration which generated the greatest flood extents. It was determined that the 6 hour was the primary critical duration for Spade Creek and most of Hat Creek (as was found during hydrologic modelling) however for some areas of the catchment the 3 hour event was critical. This is shown in Figure 5-2.

It should be noted that the XPSWMM hydrodynamic model does not predict erosion and sediment transport impacts. Dam and other embankment failure scenarios have not been modelled in this assessment and therefore results are based on stable topography over the full length of the modelled events. Therefore the predicted flood volumes entering the mining areas, in particular the pits, are likely to be higher than indicated.

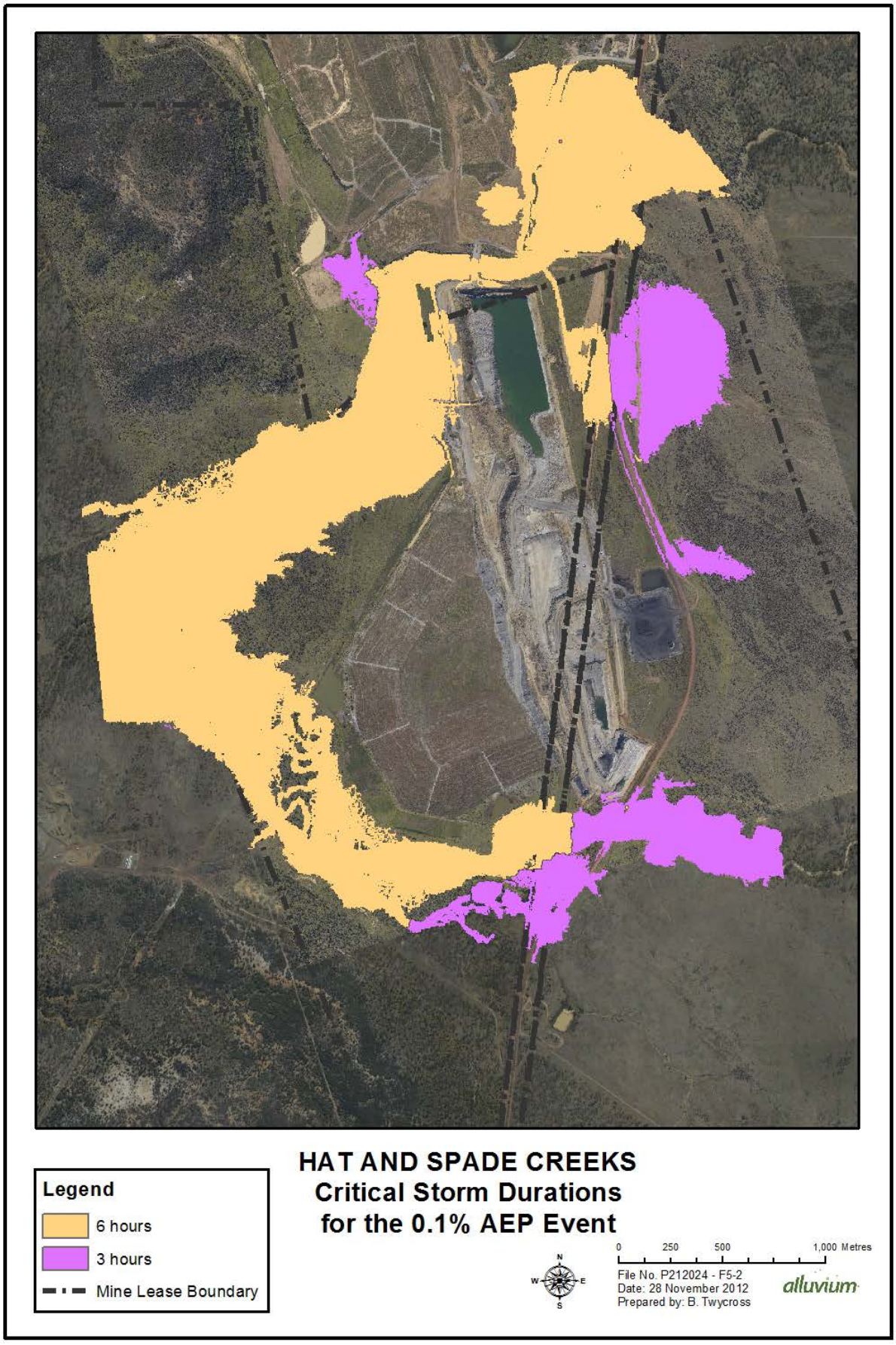


Figure 5-2. *Critical storm durations in the Hat and Spade Creeks area*

5.3 2D hydrodynamic modelling results

Modelling demonstrated that both the northern and southern ends of Broadmeadow Pit are vulnerable to flooding as a direct result of the lack of capacity in Hat and Spade Creeks. Table 5-3 presents the modelled peak flow rates and volumes of water entering the pit for the 0.1% AEP event.

Table 5-3. Flow rates and volumes entering Bullock Creek Pit for the 0.1% AEP event

	Spade Creek Diversion		BM NW DW Dam		Hat Creek, at crossing	
Duration	**Peak flow rate entering pit (m^3/s)**	**Volume entering pit (ML)**	**Peak flow rate entering pit (m^3/s)**	**Volume entering pit (ML)**	**Peak flow rate entering pit (m^3/s)**	**Volume entering pit (ML)**
3 hour	0	0	17.3	160	1.7	6.7
6 hour	0.1	0.145	18.3	208	1.5	7.1

Note – Hydrodynamic modelling does not account for the potential effect of rapid erosion of failing flood protection measures which would further increase the inundation volume.

Figure 5-3 illustrates the hydrographs corresponding to flow rates and volumes from Table 5-3. Due to the small flow rates and volumes entering the pit from the Spade Creek Diversion they are not depicted.

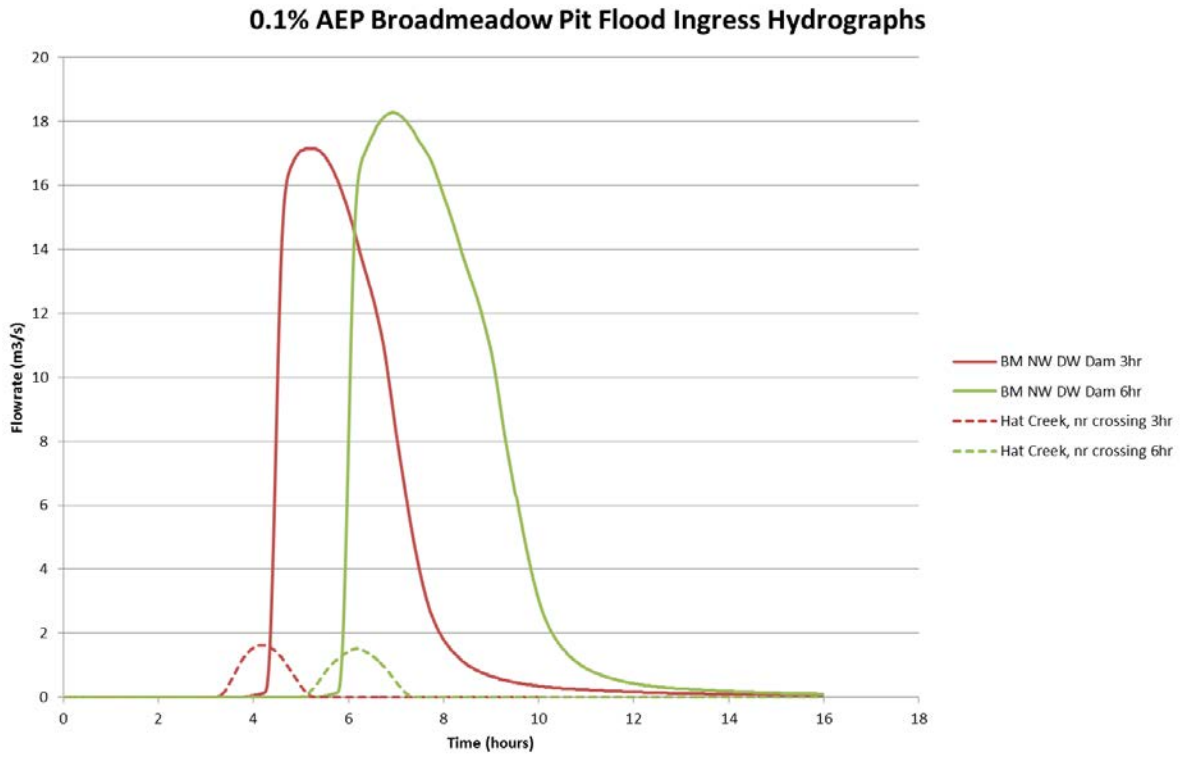


Figure 5-3. *0.1% AEP spill hydrographs into the northern and southern ends of Broadmeadow Pit*

For Hat Creek, the pit ingress is mainly due to backwatering caused by the Broadmeadow OOP Dump restricting the flood plain, 650m downstream of the Hat Creek Mallawa Haul Road crossing. For Spade Creek Diversion the process is similar, with backwatering due to the Spade Creek Diversion crossing and the restricted channel 350m downstream of the crossing. Along the west side of the north end of Broadmeadow Pit, the BM NW DW Dam overtops and water enters the pit via the drainage network. The sites where water enters the pit are depicted in Figure 5-4 and the flood mechanisms are discussed in Section 5.5.

The 0.1% AEP flood envelope and depths for the modelled area are shown in Figure 5-4. The corresponding velocities are shown in Figure 5-5. As the critical durations vary spatially the results from 3 hour and 6 hour events have been sampled to generate a single maximum flood extent.

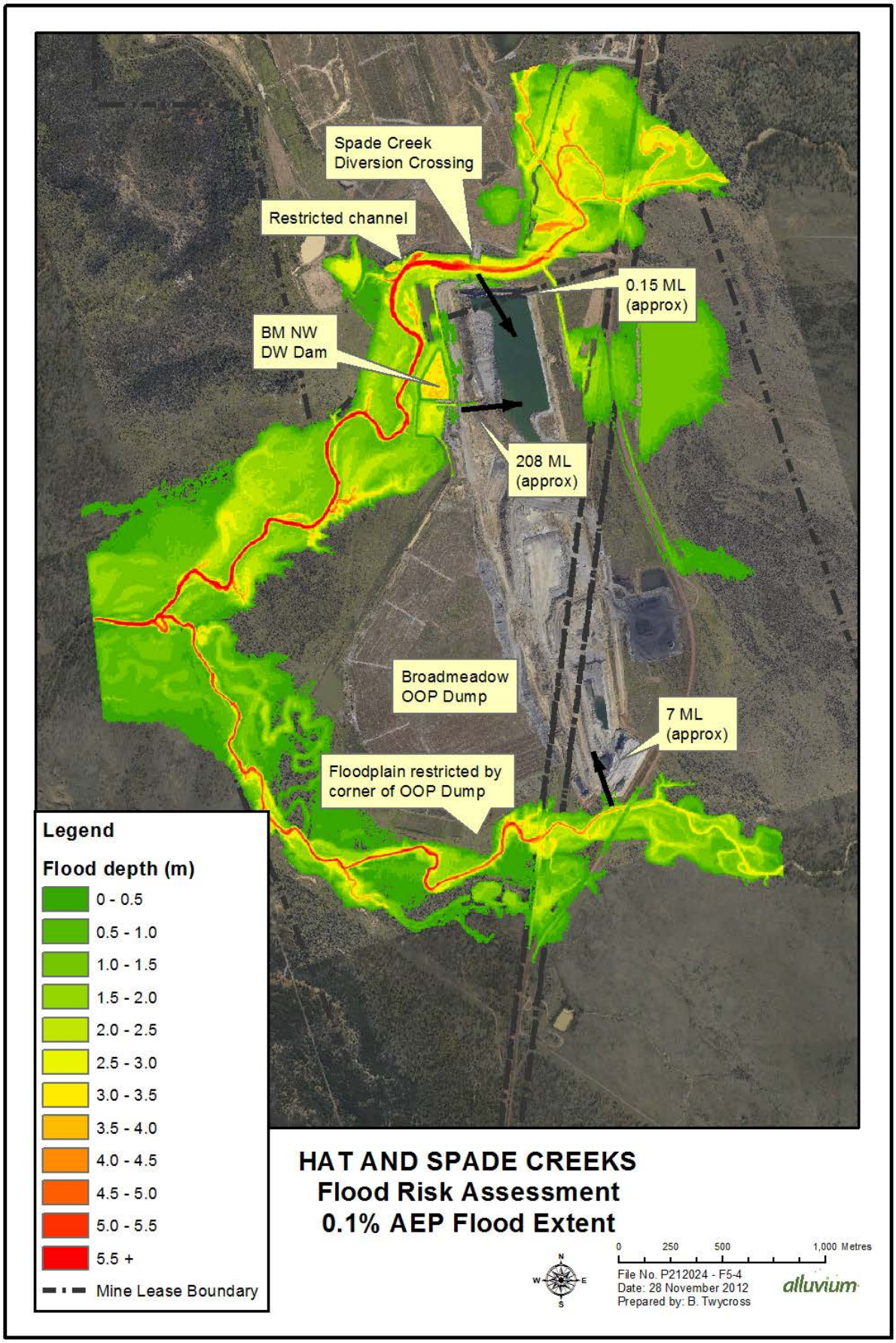


Figure 5-4. *0.1% AEP flood extents and depth for Hat and Spade Creeks (3 hour and 6 hour events combined)*

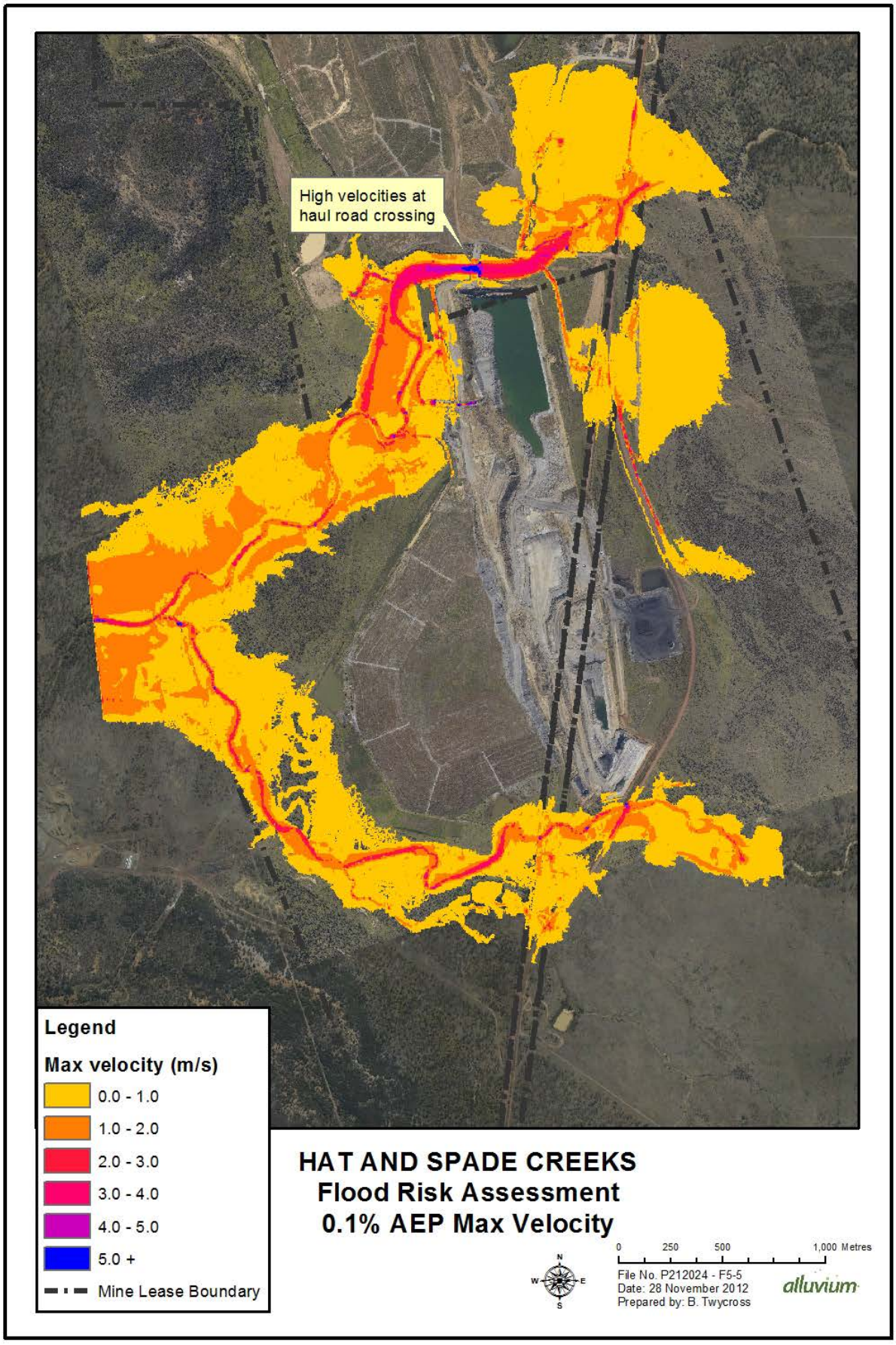


Figure 5-5. *0.1% AEP peak velocities for Hat and Spade Creeks (3 hour and 6 hour events combined)*

5.4 Sensitivity testing to model inputs

Sensitivity testing was undertaken for the following scenarios:

- Increase flows by 10%
- Vary the Manning's "n" roughness values by +/- 10%

Typical flood depth variations of up to 0.3m occurred throughout out the area modelled. The greatest variation occurred at and around the upstream end of the Spade Creek diversion. The least variation occurred around the Hat Creek Mallawa Haul Road crossing.

The changes in water surface elevation at various points throughout the model are listed below in Table 5-4, with each reporting point shown in Figure 5-6, below.

Table 5-4. Sensitivity testing and effect on water surface elevations throughout model

Point	Existing (m)	+10% Flow (m)	-10% 'n' (m)	+10% 'n' (m)	Maximum Difference (m)
1	283.06	283.31	282.99	283.13	0.25
2	283.00	283.24	282.92	283.07	0.24
3	282.77	283.05	282.69	282.86	0.28
4	281.19	281.37	281.09	281.31	0.18
5	281.32	281.48	281.26	281.38	0.16
6	280.16	280.25	280.10	280.22	0.09
7	278.86	278.93	278.81	278.91	0.07
8	285.17	285.25	285.12	285.23	0.09
9	284.86	284.96	284.78	284.94	0.11
10	284.35	284.45	284.27	284.42	0.10

Testing demonstrated that the peaks flow rates and volumes entering the pit were quite sensitive to input parameters. This is particularly the case for the Spade Creek Diversion and Hat Creek, where the flood mechanism is primarily the result of backwatering.

In the case of the water entering the northern end of Broadmeadow Pit via the BM NW DW Dam the sensitivity to inputs is approximately linear.

The percentage impacts on peak spill rates and volumes into the northern and southern ends of Broadmeadow Pit resulting from the altered input parameters are summarised below in Table 5-5.

Table 5-5. Sensitivity analysis and effect on peak flows and volumes spilling into Bullock Creek Pit

	Spade Creek Diversion	BM NW DW Dam	Hat Creek, at crossing
Original Model	100%	100%	100%
+10% Flow	Increases spill*	+12% to +24%	+94% to +153%
+ 10% Manning's	Increases spill*	-12% to -4%	-67% to -54%
-10% Manning's	No spill	+4% to +12%	+65% to +104%

* Providing meaningful results for the Spade Creek Diversion is problematic as the initial spill rates and volumes are very small therefore even small changes can have a large relative effect.

Overall, while the modelling results did exhibit some sensitivity to inputs, testing demonstrated that flood risk exists in all cases. Therefore, it is considered acceptable to use fixed input parameters.

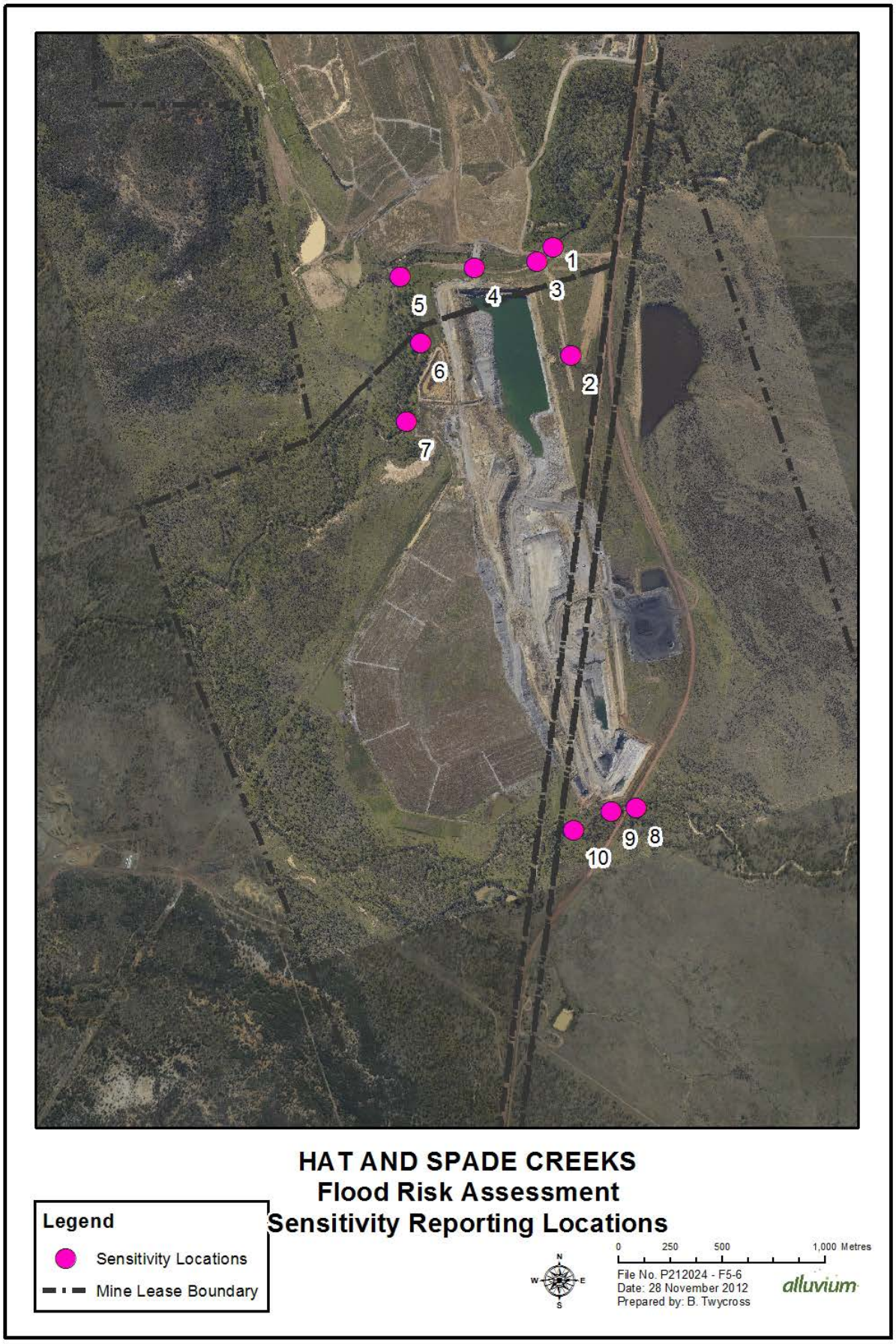


Figure 5-6. *Sensitivity testing output locations for Hat and Spade Creeks*

5.5 Flood mitigation options

As discussed in Section 5.3, the existing conditions Hat and Spade Creek flood modelling highlighted three locations where flood risk exists for the 0.1% AEP event.

All three locations will require modification to provide the required flood protection and conceptual design details are provided over the following pages.

Levee protection is considered the most practical option for all three locations. In total, approximately 900m of levee is required though this will often only require that existing bunds be raised to provide sufficient levee protection – providing they are geotechnically suitable to be regarded as levees.

Following the development of each option the existing conditions model was updated to include the suggested levees and re-run. The resulting flood depth and velocity outputs are presented below in Figure 5-7 and Figure 5-8.

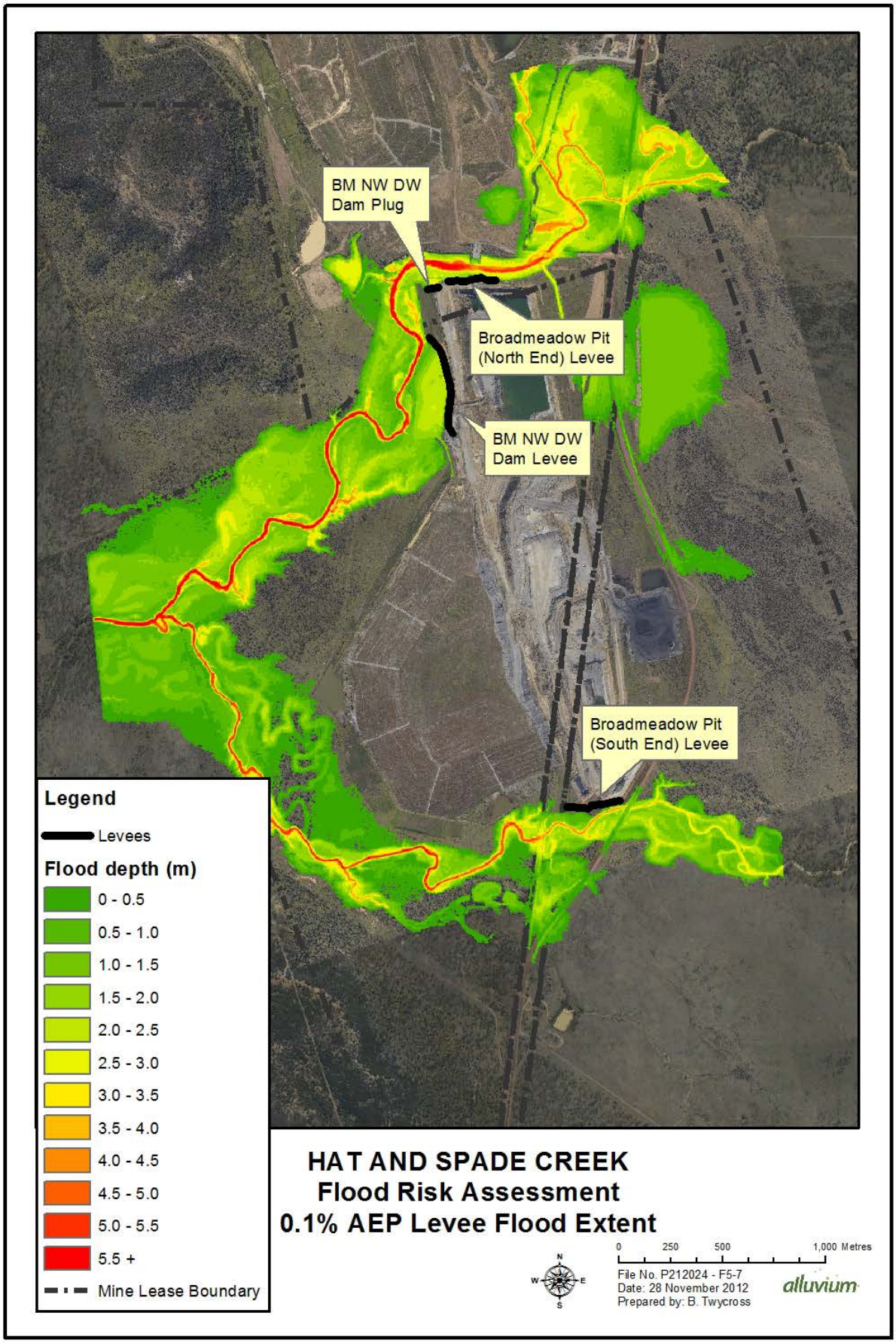


Figure 5-7. *0.1% AEP (with levees) flood depths for Hat and Spade Creeks (3 hour & 6 hour events combined)*

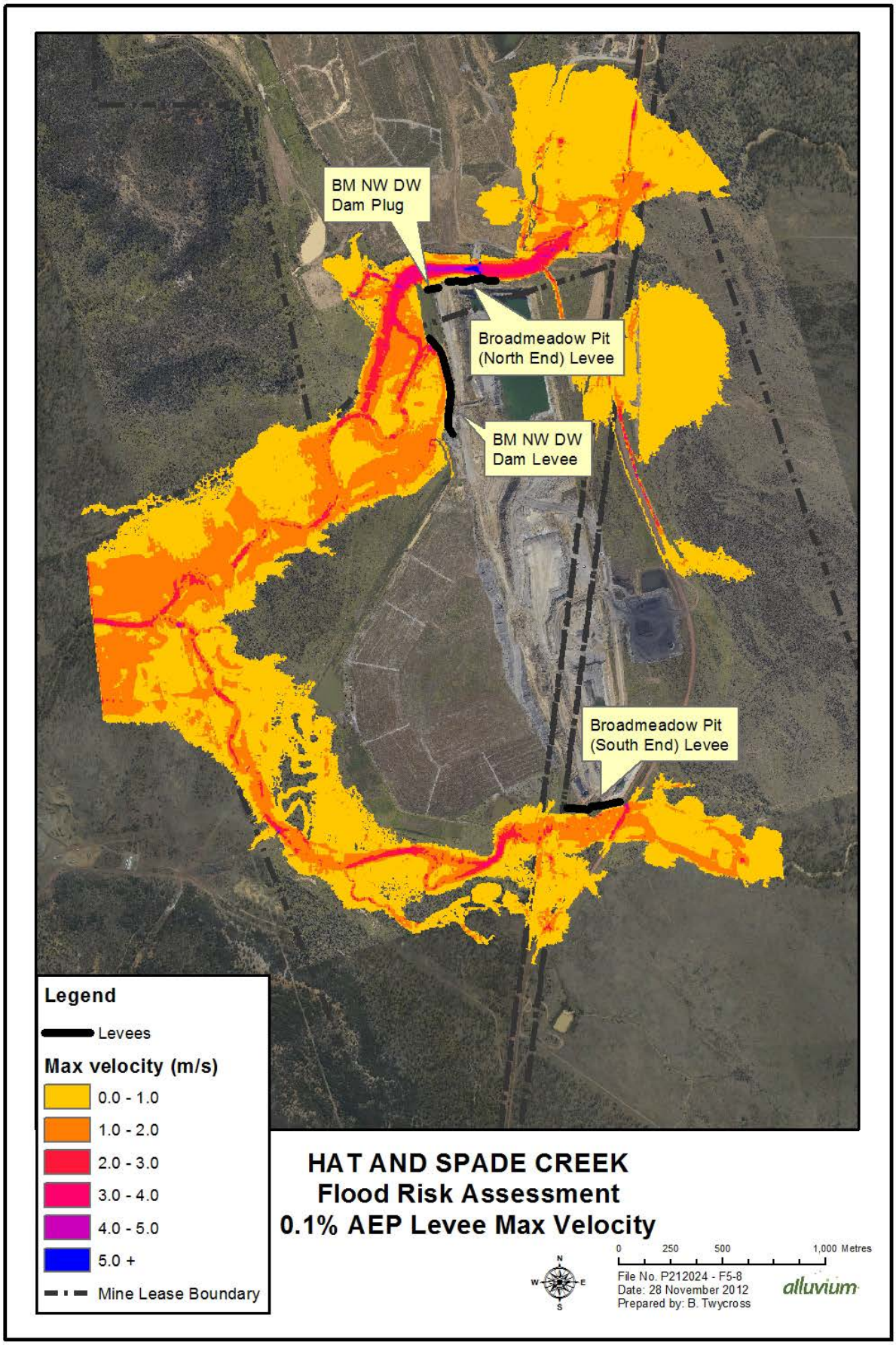


Figure 5-8. *0.1% AEP (with levees) peak velocities for Hat & Spade Creeks (3 hour & 6 hour events combined)*

5.5.1 Broadmeadow Pit (Northern End)

Flood waters enter the northern end of Broadmeadow Pit via the Spade Creek Diversion as a result of two flow restrictions, one caused by the Spade Creek Diversion crossing and the other by the constricted channel 350m downstream of the crossing (refer back to Figure 5-4). The road crossing raises the bed level and subsequently the water surface elevation by approximately 1m (see Figure 9-5 and Figure 9-6 in Section 9.4) while the downstream constriction causes a surcharge of approximately 0.8m.

Removing the restrictions may be possible as Burton Mine has indicated that heavy vehicle access is not required at the crossing. However, as highlighted in Section 9.5, the continued presence of the road crossing minimises the impact that that steep diversion has on erosion upstream and aggradation downstream. Therefore, the removal of the crossing is not a practical option without further work to stabilise the diversion.

The preferred option is to block off the road on the south side of the diversion by using a levee. The conceptual design details for the Broadmeadow Pit (northern end) levee are summarised in Table 5-6.

Table 5-6. Broadmeadow Pit (Northern End) Levee, brief summary of preferred levee option

Parameter	Value
Water surface elevation (m AHD)	281.3 – 282.5
Total length of levee	~200m
Typical raise height	~0.0 to 2.0m*

* Assuming 0.5m freeboard

A long section of the water surface with the levee in place is presented in Figure 5-9, and a plan view is presented in Figure 5-10, next page.

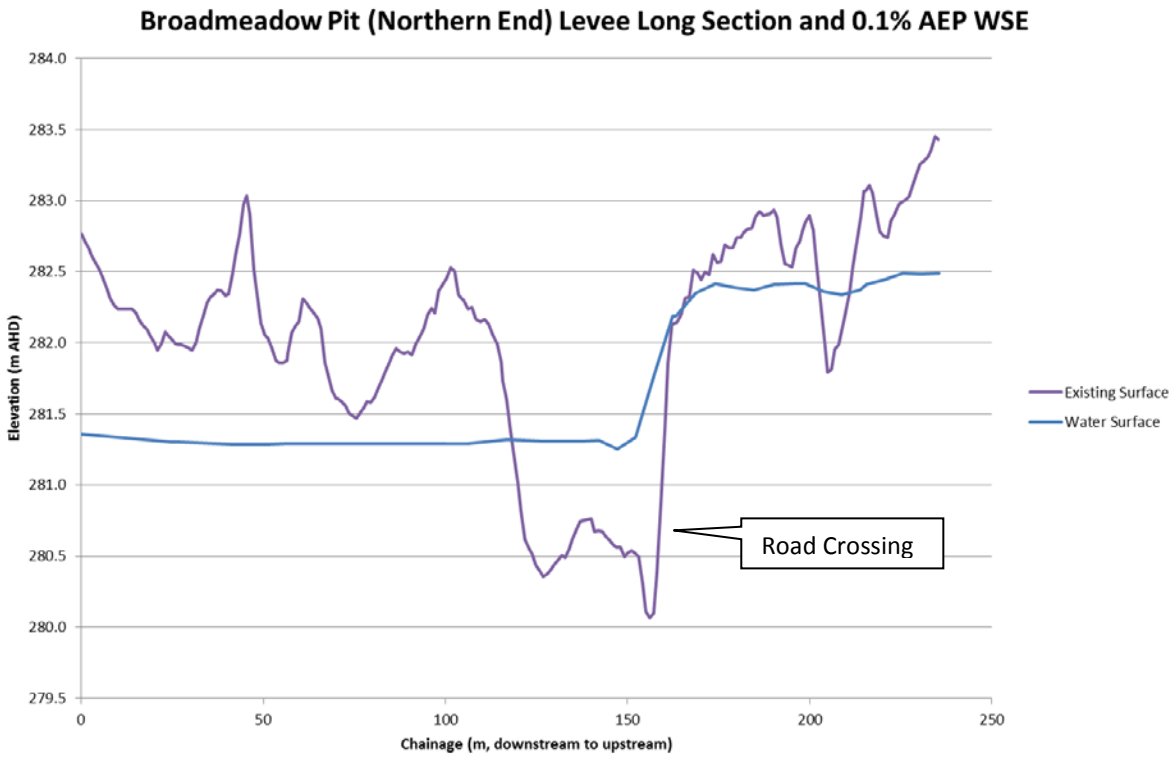


Figure 5-9. *Broadmeadow Pit (northern end) diversion levee long section*

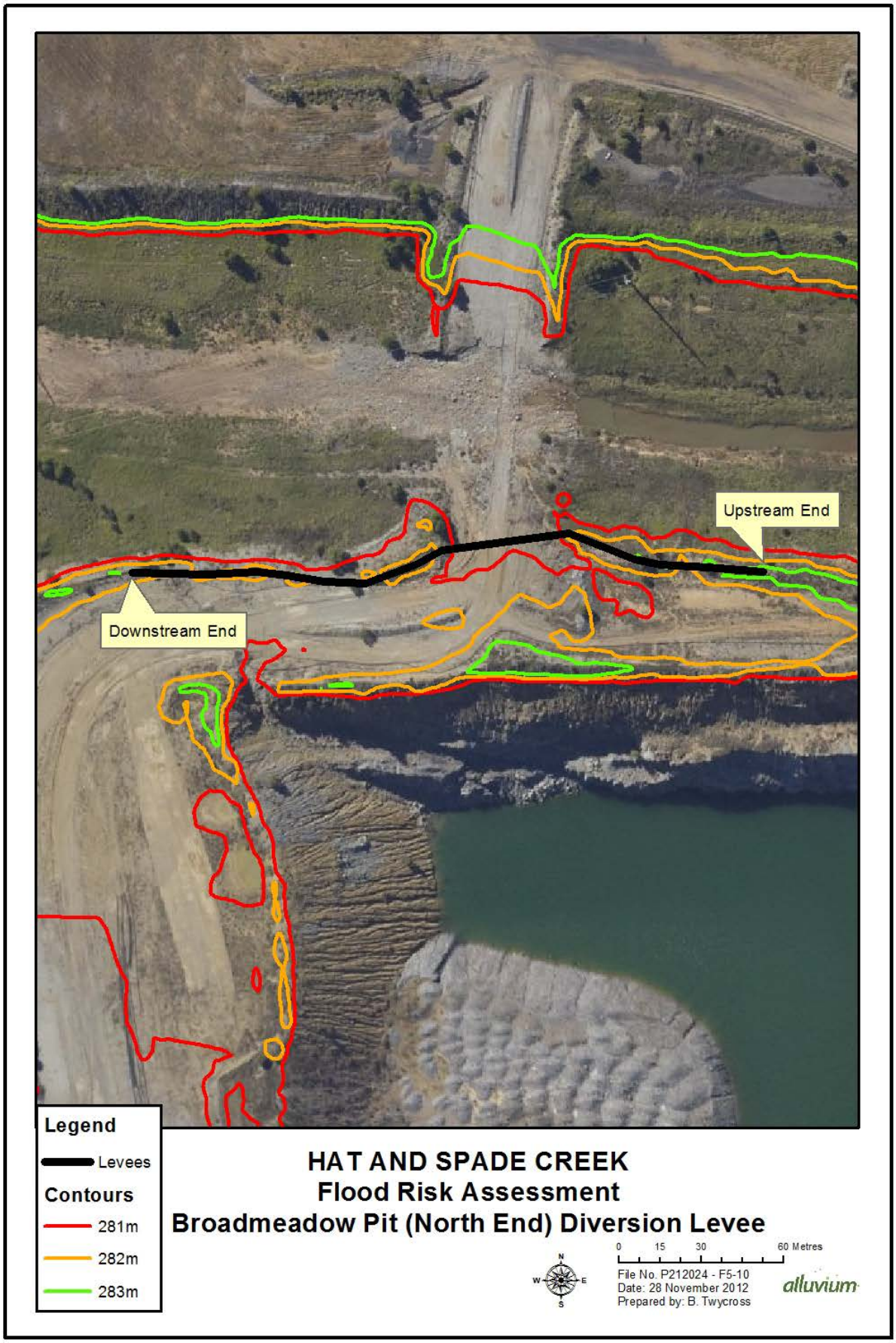


Figure 5-10. *Broadmeadow Pit (northern end) diversion levee plan view*

5.5.2 BM NW DW Dam

Flood waters enter the dam during the 0.1% AEP event and, once the dam is full, overtop and continue into the drainage network which outfalls into the northern end of Broadmeadow Pit (refer back to Figure 5-4).

While the dam does encroach into the flood plain and is located in close proximity to Spade Creek, the hydraulic gradient along Spade Creek suggests that, in this area, there is no specific flow restriction to which the overtopping can be attributed. Consequently, a levee is considered the only practical option to protect the pit.

The preferred option is to remove and rehabilitate the dams and build a levee alongside Broadmeadow Pit, in the location of the existing dam's eastern wall. In addition, a plug is required 200m north of the location to prevent ingress of water via the drainage channel.

The conceptual design details for the BM NW DW Dam levee and plug are summarised in Table 5-7.

Table 5-7. BM NW DW Dam Levee, brief summary of preferred levee and plug option

Parameter		Value
Levee	Water surface elevation (m AHD)	278.7 – 280.0
	Total length of levee	~500m
	Typical raise height	~0.0. to 4m*
Plug	Water surface elevation (m AHD)	281.5
	Total length of levee	~30m
	Typical raise height	~4m*

* Assuming 0.5m freeboard

A long section of the water surface with the levee in place is presented in Figure 5-11 and a plan view of both the levee and plug is presented in Figure 5-12.

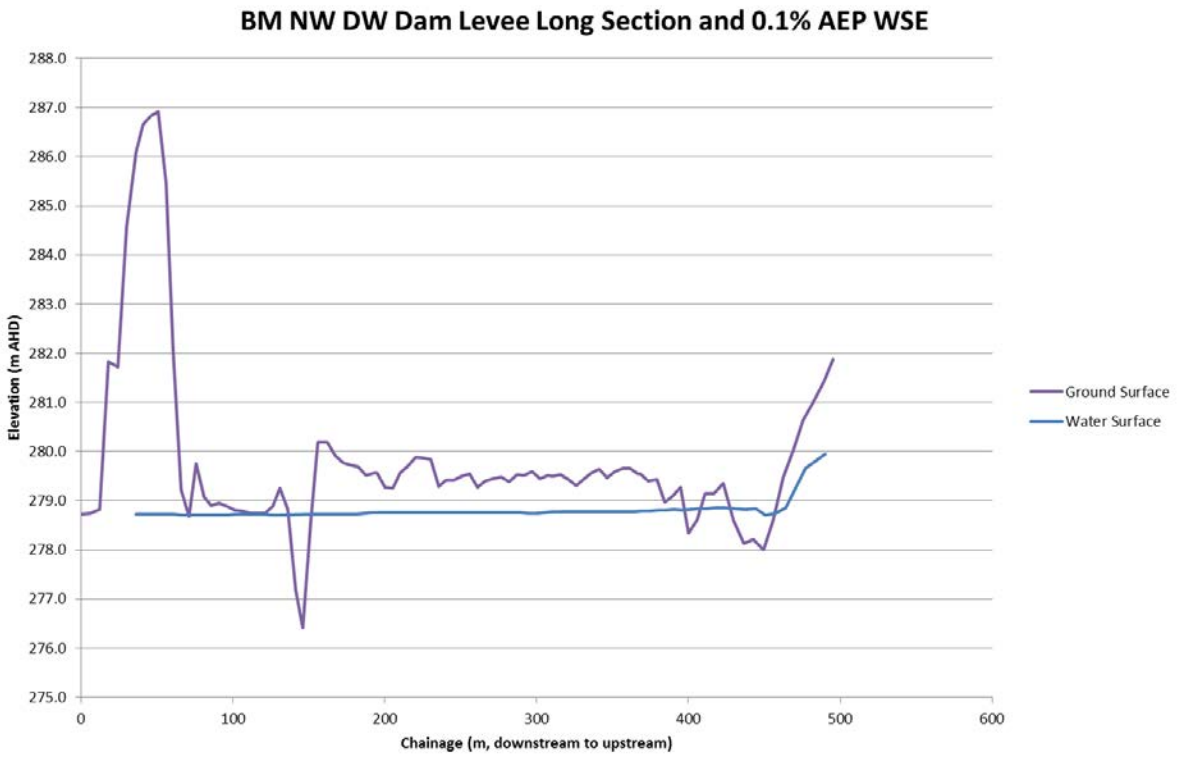


Figure 5-11. *BM NW DW Dam levee long section*

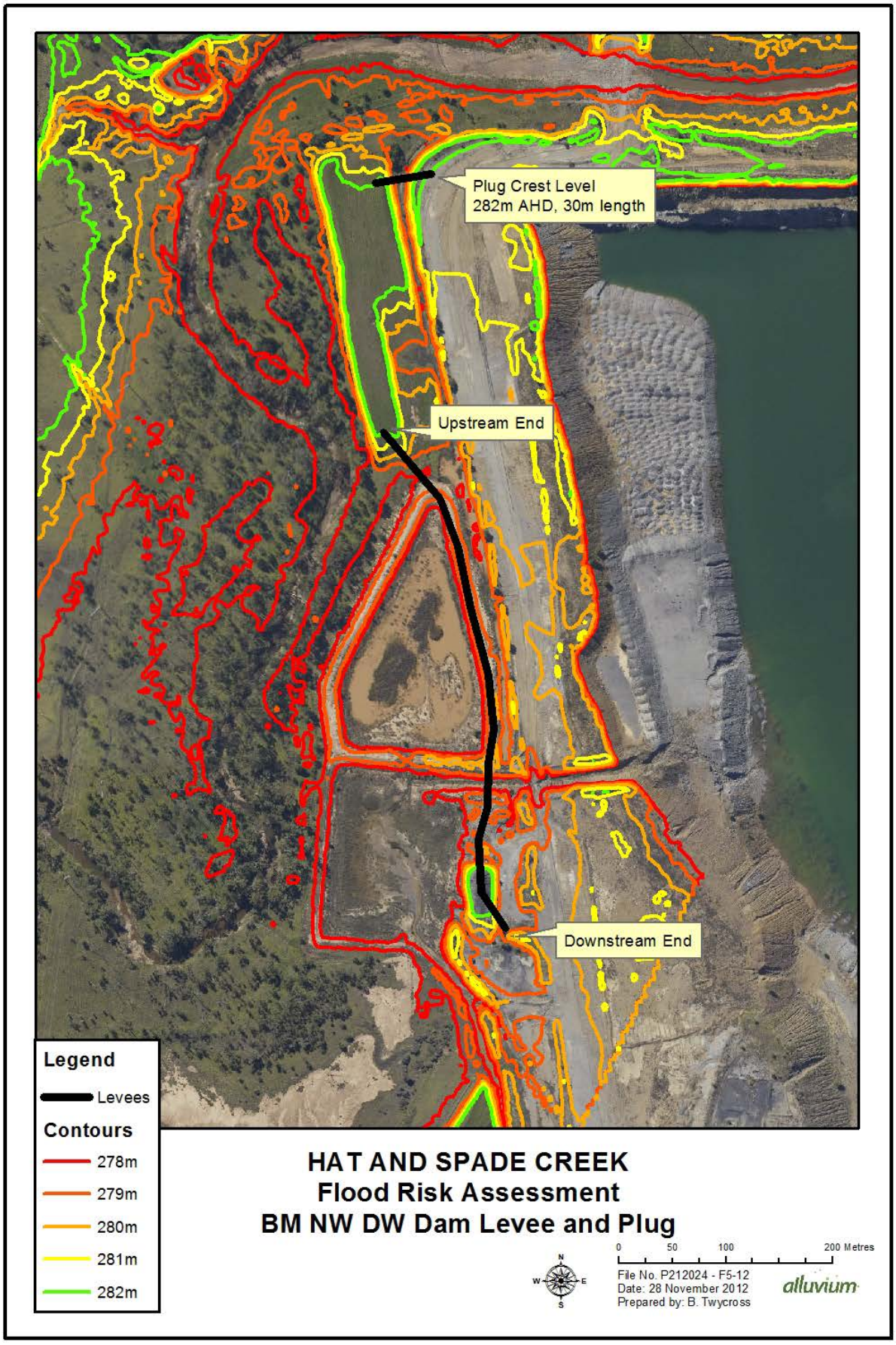


Figure 5-12. *BM NW DW Dam levee plan view*

5.5.3 Broadmeadow Pit (Southern End)

Flood waters enter the southern end of Broadmeadow Pit as a result of a flow constriction approximately 600m downstream of the spill point. This is caused by a smaller dump, on the south side of the Broadmeadow OOP Dump, which impinges on the Hat Creek flood plain (refer back to Figure 5-4). The restriction causes a 1.5m water surface elevation surcharge upstream.

While the removal of the restriction may result in the water surface dropping and eliminating, or at least reducing, flood water ingress to the pit, the scope of earthworks required to implement this option is estimated to require relocation of an estimated 50,000m^3 of ground material. This would most likely exceed the cost of the option of constructing a levee across the southern edge of the pit to achieve the same objective. Consequently, a levee is the preferred option.

The conceptual design details for the Broadmeadow Pit (southern end) levee are summarised in Table 5-8.

Table 5-8. Broadmeadow Pit (southern end) levee, brief summary of preferred levee option

Parameter	Value
Water surface elevation (m AHD)	284.4 – 284.9
Total length of levee	~200m
Typical raise height	~0.0 to 1.5m*

* Assuming 0.5m freeboard

A long section of the water surface with the levee in place is presented in Figure 5-13, below, and a plan view is present in Figure 5-14, next page.

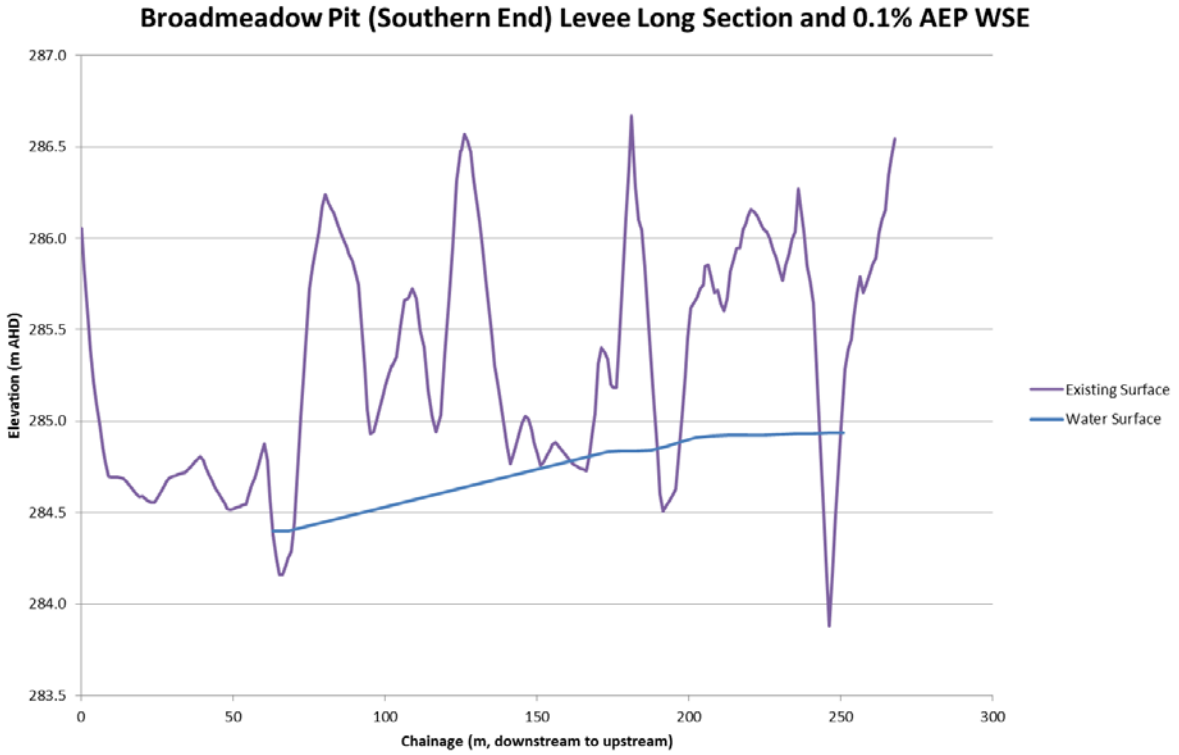


Figure 5-13. *Broadmeadow Pit (southern end) diversion levee long section*

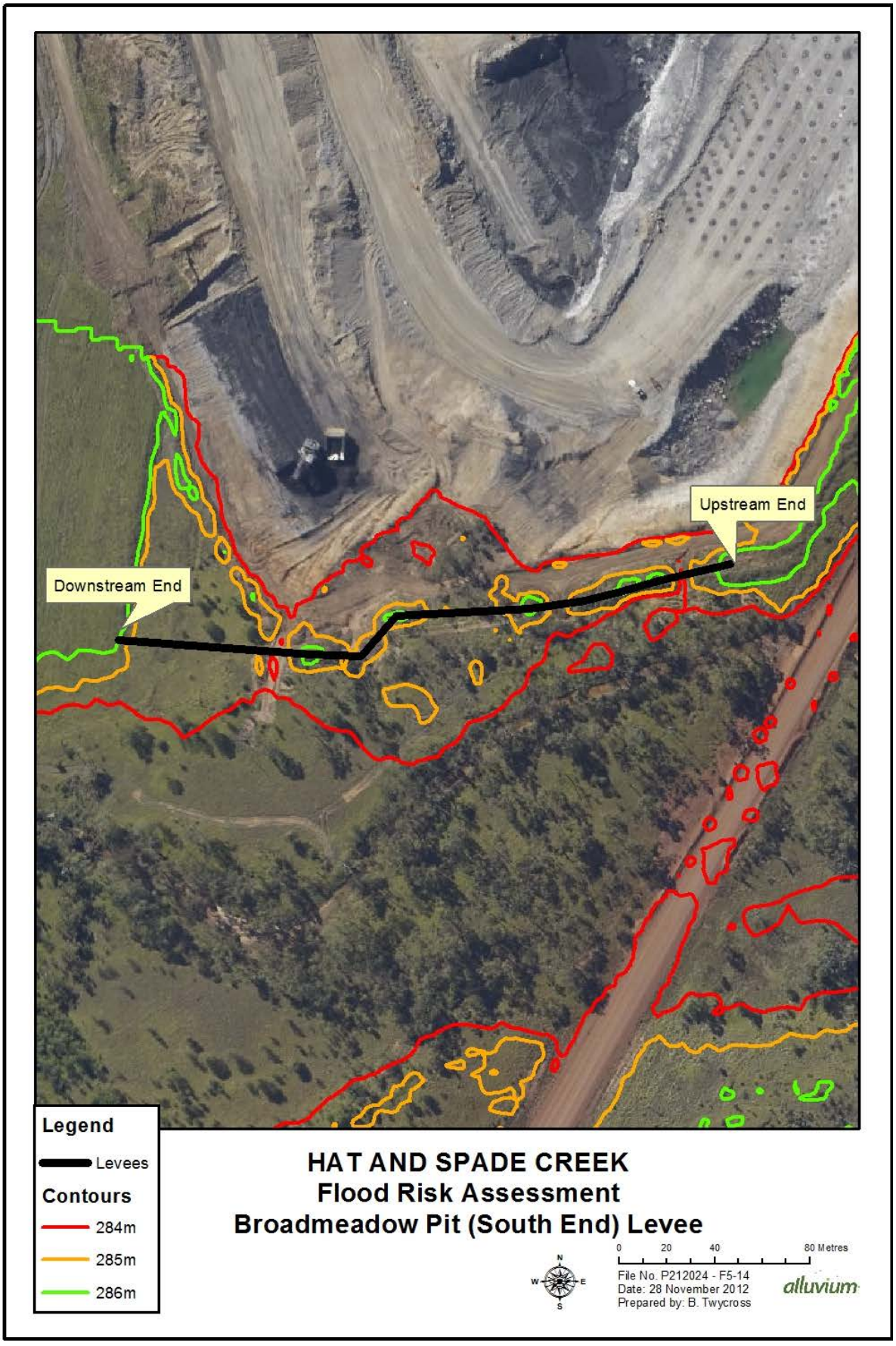


Figure 5-14. *Broadmeadow Pit (southern end) levee plan view*

6 Hydrodynamic Modelling of Bullock Creek Existing Conditions

6.1 2D hydrodynamic modelling overview

Hydrodynamic modelling was undertaken to assess the existing conditions flood risk for mining activities adjacent to Bullock Creek to determine the following:

- Flood extents and risks, and
- Conceptual options to mitigate the flood risk.

The model was built from LiDAR survey data along with design rainfall hydrology (as discussed in Attachment A) to determine flood extents and depths in the Bullock Creek diversion area. The flood envelope was generated using the 2D hydrodynamic modelling package XPSWMM.

As will be explained in Section 6.5, water levels were then used to ascertain the necessary levee embankment elevations and extents to provide the required 0.1% AEP flood immunity for the mining activities. The model was then rerun to confirm the effectiveness of the recommendations.

6.2 2D hydrodynamic model set-up

A 2D hydrodynamic model of the Bullock Creek catchment surrounding Bullock Creek Pit was built using XPSWMM, a hydrodynamic modelling software package which couples together the SWMM 1D model and the 2D finite difference model TUFLOW.

The model starts on Bullock Creek approximately 800m upstream of the upstream tie-in of the Bullock Creek diversion and continues to approximately 700m downstream of the Mallawa Haul road crossing.

The digital terrain model (DTM) used for the model consists of a processed amalgam of two LiDAR sources supplied by Burton Mine. Both sources were acquired by Atlass, one in July 2011 and the other in May 2012. The data used to generate the model and the source of the data is summarised in Table 6-1.

Table 6-1. Summary of data used in Bullock Creek 2D model

Data	Provider	Comments
LiDAR DTM of mine and surrounds	Burton Mine	Provides full coverage. Acquisition date May 2012 and June 2011 (Atlass)
Aerial of mine and surrounds	Burton Mine	Provides full coverage. Acquisition date May 2012 and June 2011 (Atlass)
Manning's delineation of site	Alluvium	Assessed from aerial image provided
Catchment Hydrology	Alluvium	Determined using RORB (see Attachment A)

The model was configured using a 5m cell size.

The active area of the model is shown in Figure 6-1.

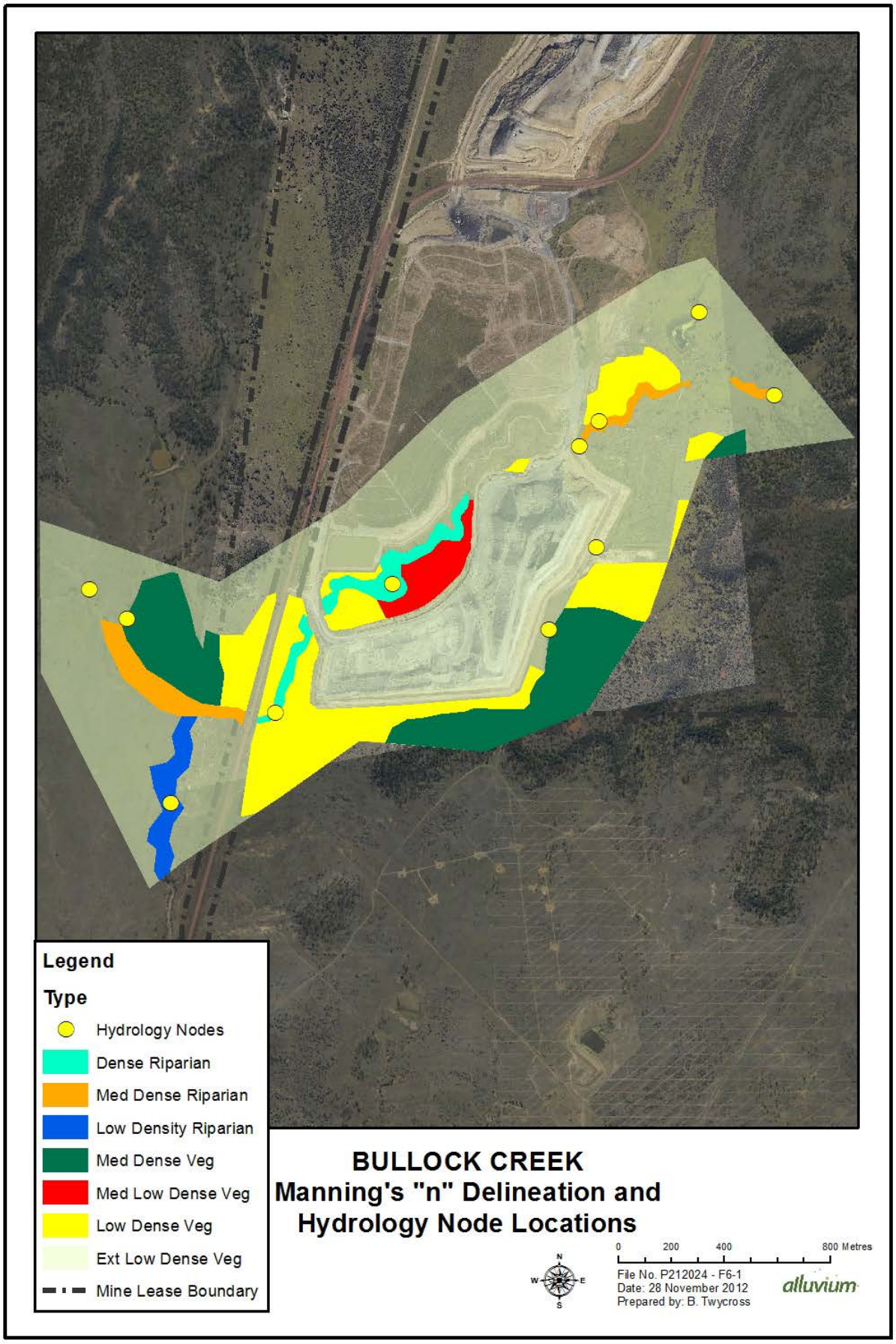


Figure 6-1. *XPSWMM Bullock Creek model set up*

Manning's n roughness coefficients for the model were set using polygons delineated from aerial imagery (without onsite verification). Manning's n values adopted for the different polygons are presented in Table 6-2 with the delineation of the Manning's n polygons shown in Figure 6-1.

Table 6-2. Manning's n roughness values for Bullock Creek 2D model

Land use/Vegetation Type	Roughness value
Dense riparian	0.070
Medium density riparian	0.045
Low density riparian	0.035
Medium density vegetation	0.075
Medium low density vegetation	0.055
Low density vegetation	0.040
Extremely low density vegetation	0.030

Hydrologic inputs suitable for 2D modelling were developed for the 0.1% AEP. This event was chosen based on guidance contained in the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM, 2012).

Design hydrographs were input into the hydrodynamic model at the locations shown in Figure 6-1 to represent inputs from both the catchments external to the area and runoff generated locally.

The hydrodynamic model was tested with storm durations of 30 minutes, 1 hour and 3 hours in order to confirm the critical duration which generated the greatest flood extents. It was determined that the 1 hour was the primary critical duration for Bullock Creek (as was found during hydrologic modelling) however this did vary spatially, as shown in Figure 6-2.

As discussed in Section 5.2, the inability for the model to predict erosion means that the predicted flood volumes entering the pit are likely to be underestimates.

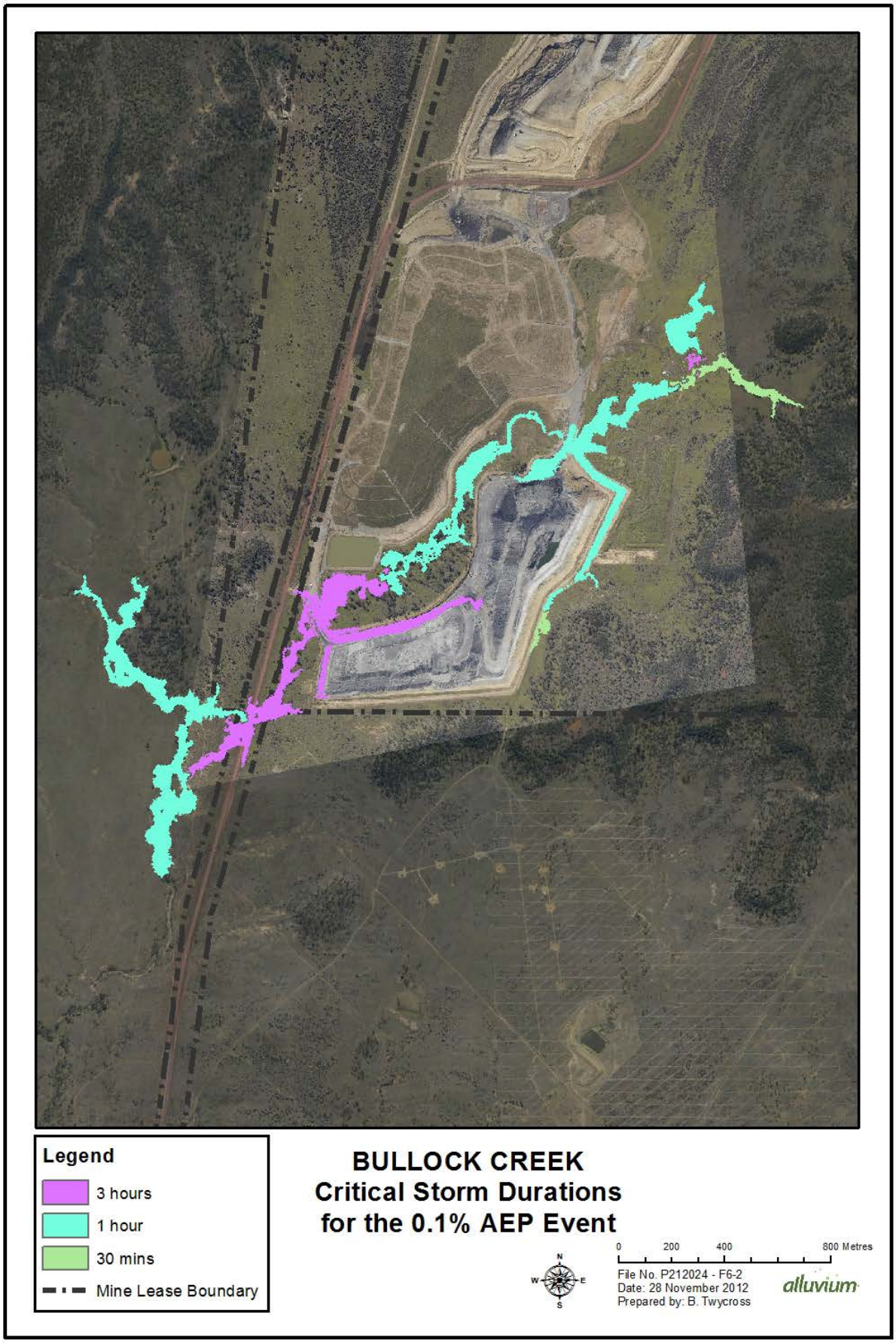


Figure 6-2. *Critical storm durations in the Bullock Creek area*

6.3 2D hydrodynamic modelling results

Modelling demonstrated that mining activities on the south side of Bullock Creek are vulnerable to flooding as a result of the lack of culvert capacity under the two Bullock Creek haul road crossings, up and downstream of the diversion. Table 6-3 details the peak flow rates and volumes of water into the pit for the 0.1% AEP event. Figure 6-3 depicts the hydrographs corresponding to flow rates and volumes from Table 6-3.

Table 6-3. Flow rates and volumes entering Bullock Creek Pit for the 0.1% AEP event

	Upstream Bullock Creek HR Crossing		Downstream Bullock Creek HR Crossing	
Duration	**Peak flow rate into pit (m^3/s)**	**Volume entering pit (ML)**	**Peak flow rate into pit (m^3/s)**	**Volume entering pit (ML)**
30 mins	58.6	104	0	0
1 hour	72.5	179	0.4	1
3 hour	43.6	250	1.5	7

Note – Hydrodynamic modelling does not account for the potential effect of rapid erosion of failing flood protection measures which would further increase the inundation volume.

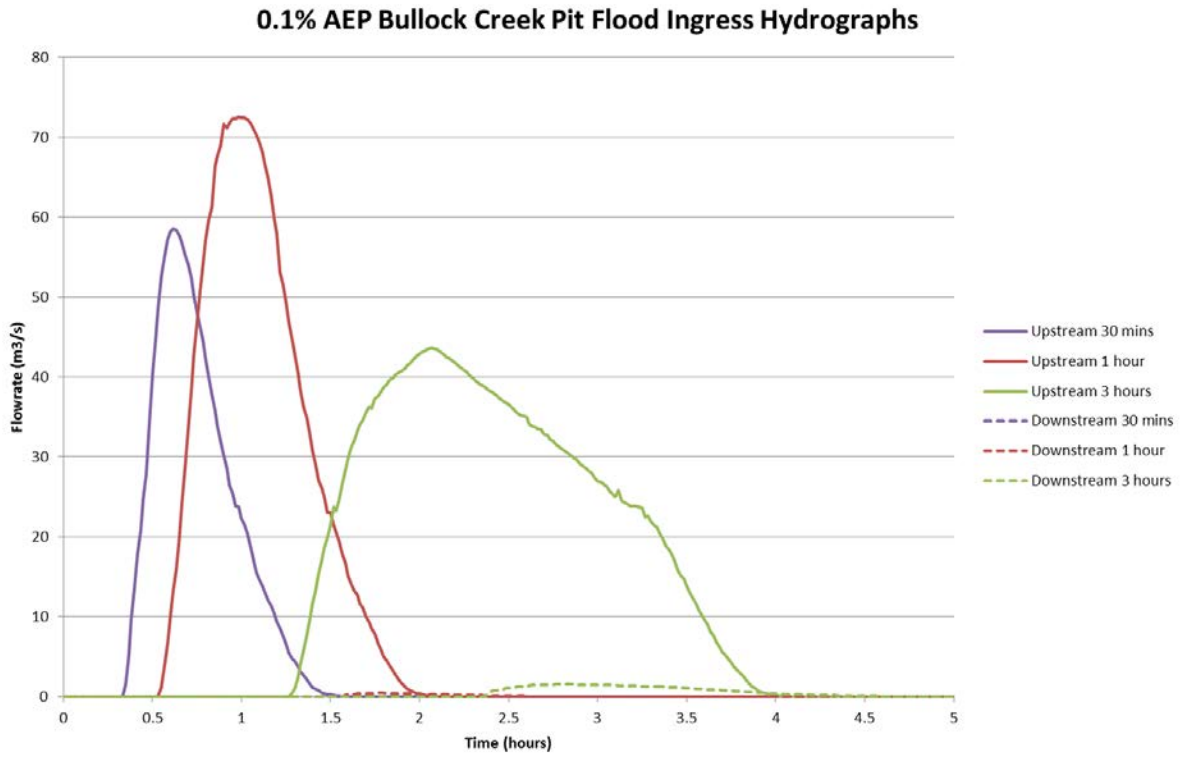


Figure 6-3. *0.1% AEP spill hydrographs into Bullock Creek Pit*

Modelling indicates that pit flooding occurs as a direct result of each of the road crossings causing water surcharge upstream and effectively funnelling water directly into the pit at each location. This explains why the spill volumes continue increasing for increasing storm durations, despite the small catchment size.

Historically, water has entered the pit immediately west of upstream haul road crossing as a result of the diversion channel overtopping. While modelling did not exactly replicate this flow path this is most probably as a result of earthworks to repair road damage.

The 0.1% AEP flood envelope and depths for the modelled area are shown in Figure 6-4. The corresponding velocities are shown in Figure 6-5. As the critical durations vary spatially the results from 30 minute, 1hour and 3 hour events have been sampled to generate a single maximum flood extent.

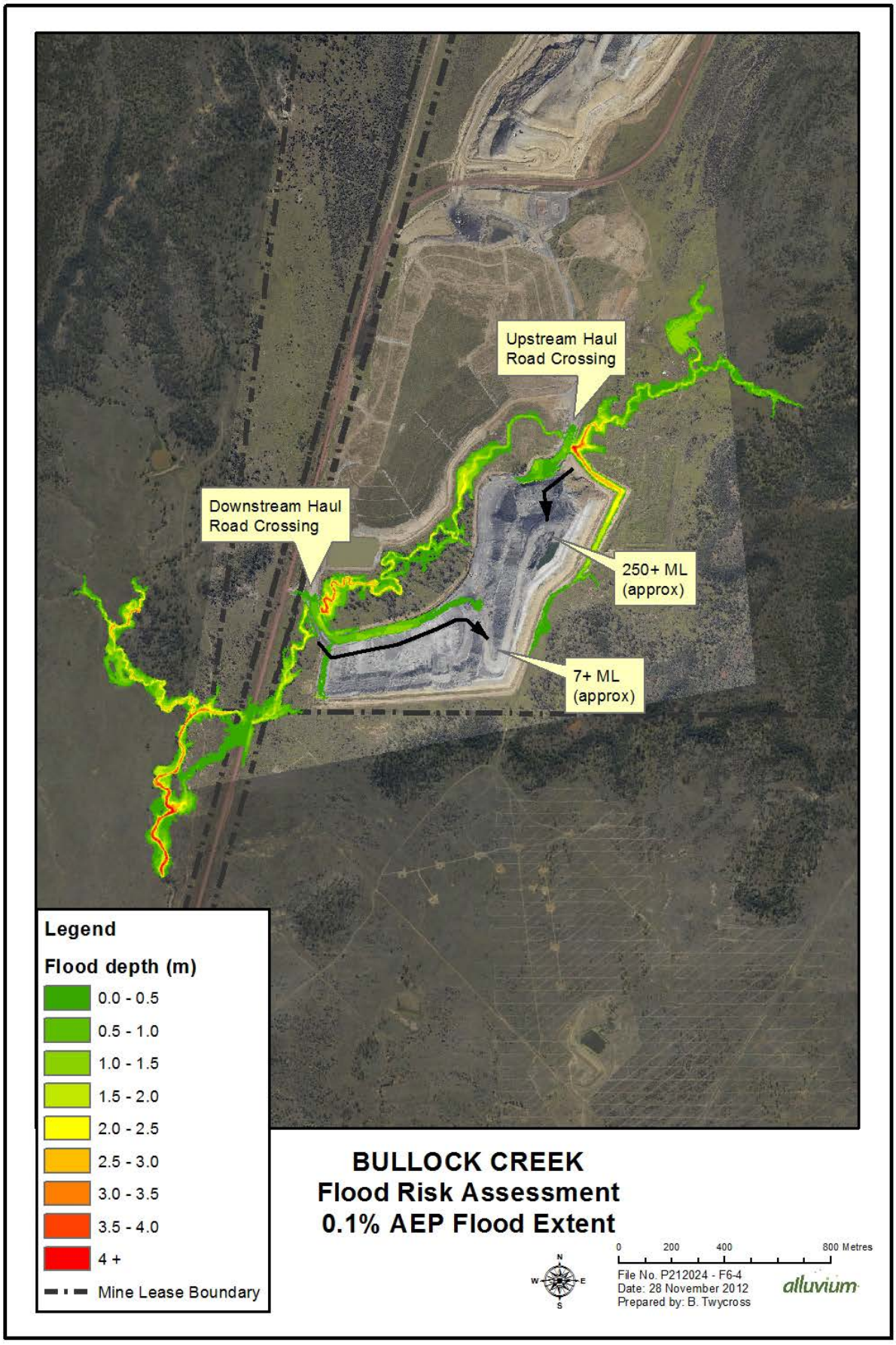


Figure 6-4. *0.1% AEP flood extents and depth for Bullock Creek (30 mins, 1 hour and 3 hour events combined)*

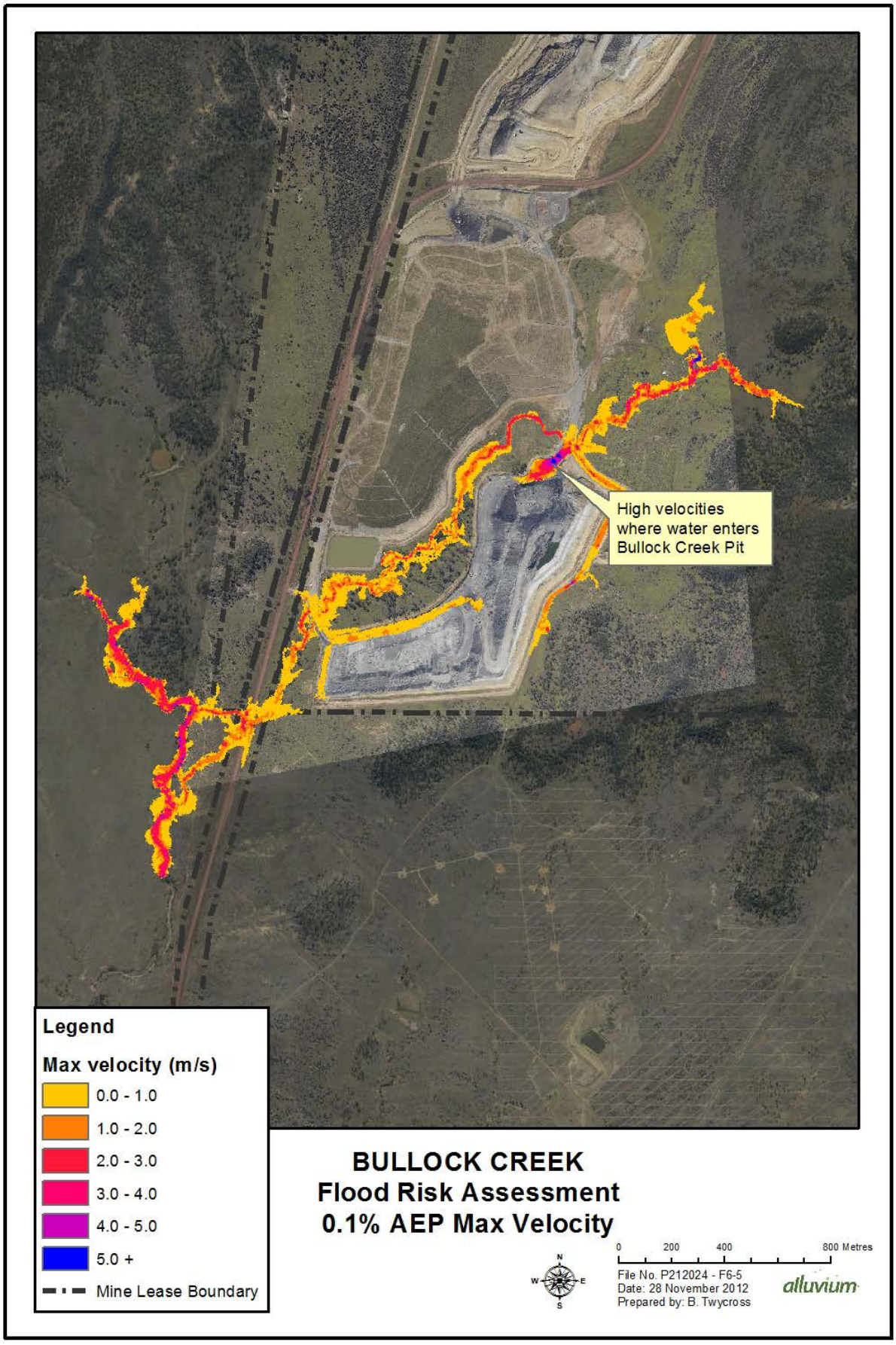


Figure 6-5. *0.1% AEP peak velocities for Bullock Creek (30 mins, 1 hour and 3 hour events combined)*

6.4 Sensitivity testing to model inputs

Sensitivity testing was undertaken for the following scenarios:

- Increase flows by 10%
- Vary the Manning's "n" roughness values by +/- 10%
- Removal of the bunds on either side of the haul roads
- Blocked culverts

Typical flood depth variations of up to 0.4m occurred throughout out the area modelled. The greatest variation occurred between the two haul road crossings, particularly at the start of the Bullock Creek diversion (point 2) during the "No bunds over Haul Roads" scenario where the flow rate over the Haul Road increased due to the removal of the bunds – resulting in a higher downstream water surface elevation.

The changes in water surface elevation at various points throughout the model are listed below in Table 6-4, with each reporting point shown in Figure 6-6, below.

Table 6-4. Sensitivity testing and effect on water surface elevations throughout model

Point	Existing (m)	No Bunds over Haul Roads (m)	+10% Flow (m)	-10% 'n' (m)	+10% 'n' (m)	Maximum Difference (m)	Blocked Culverts (m)	Difference (m)
1	335.73	335.62	335.81	335.73	335.73	0.12	335.94	0.21
2	330.87	331.24	330.97	330.84	330.97	0.37	330.05	0.82
3	329.69	330.03	329.73	329.64	329.74	0.33	328.28	1.41
4	327.29	327.47	327.30	327.27	327.31	0.17	N/A	N/A
5	325.67	325.37	325.69	325.67	325.68	0.30	325.64	0.03
6	321.49	321.71	321.52	321.43	321.53	0.23	320.85	0.64
7	320.65	320.72	320.67	320.65	320.66	0.06	320.58	0.07
8	317.59	317.60	317.71	317.57	317.59	0.12	317.44	0.15

The percentage impacts on peak spill rates and volumes into Bullock Creek Pit resulting from the altered input parameters are summarised below in Table 6-5.

Table 6-5. Sensitivity analysis and effect on peak flows and volumes spilling into Bullock Creek Pit

	Bullock Creek Haul Road Crossing (upstream)	Bullock Creek Haul Road Crossing (downstream)
Original Model	100%	100%
No Bunds over Haul Roads	-20% to -4%	No spill
+10% Flow	+11% to +17%	+15% to +82%
+ 10% Manning's	-3% to +2%	-3% to +8%
-10% Manning's	-2% to -1%	-11% to -3%
Blocked Culverts	+31% to +102%	-25% to +90%

Overall, the greatest impact was caused by blocking the haul road culverts. This demonstrates the benefit of maintaining the culverts in good condition, though in this instance water will still enter the pit for a 0.1% AEP event regardless of culvert condition.

While the modelling results did exhibit some sensitivity to inputs, testing demonstrated that flood risk exists in all cases. Therefore, it is considered acceptable to use fixed input parameters.



Figure 6-6. *Sensitivity testing output locations for Bullock Creek*

6.5 Flood mitigation options

As discussed in Section 6.3, the existing conditions Bullock Creek flood modelling highlighted two locations where flood risk exists for the 0.1% AEP event.

Three possible options were investigated:

- Increasing the culvert capacity to prevent backwatering upstream.
- Removal of the haul road crossings and restoration to natural surface.
- Providing levee protection.

Following the development of each option the existing conditions model was updated and re-run. The overall model outputs are presented below.

Figure 6-7 and Figure 6-8 show the respective flood depths and velocities for the upgraded culvert option.

Figure 6-9 and Figure 6-10 show the respective flood depths and velocities for the option of lowering the haul roads.

Figure 6-11 and Figure 6-12 show the respective flood depths and velocities for the levee option.

The conceptual design details are provided over the following pages. While each option has been modelled as being applied to each of the two haul roads the options can be mixed and matched as required though it is recommended that the final option be modelled so confirm its validity.

Burton Mine has indicated that the second option, that of haul road removal is the preferred option. The pit is in the process of being rehabilitated and heavy vehicle access is not required. If light vehicle is required then a creek crossing can be installed at the natural ground level.

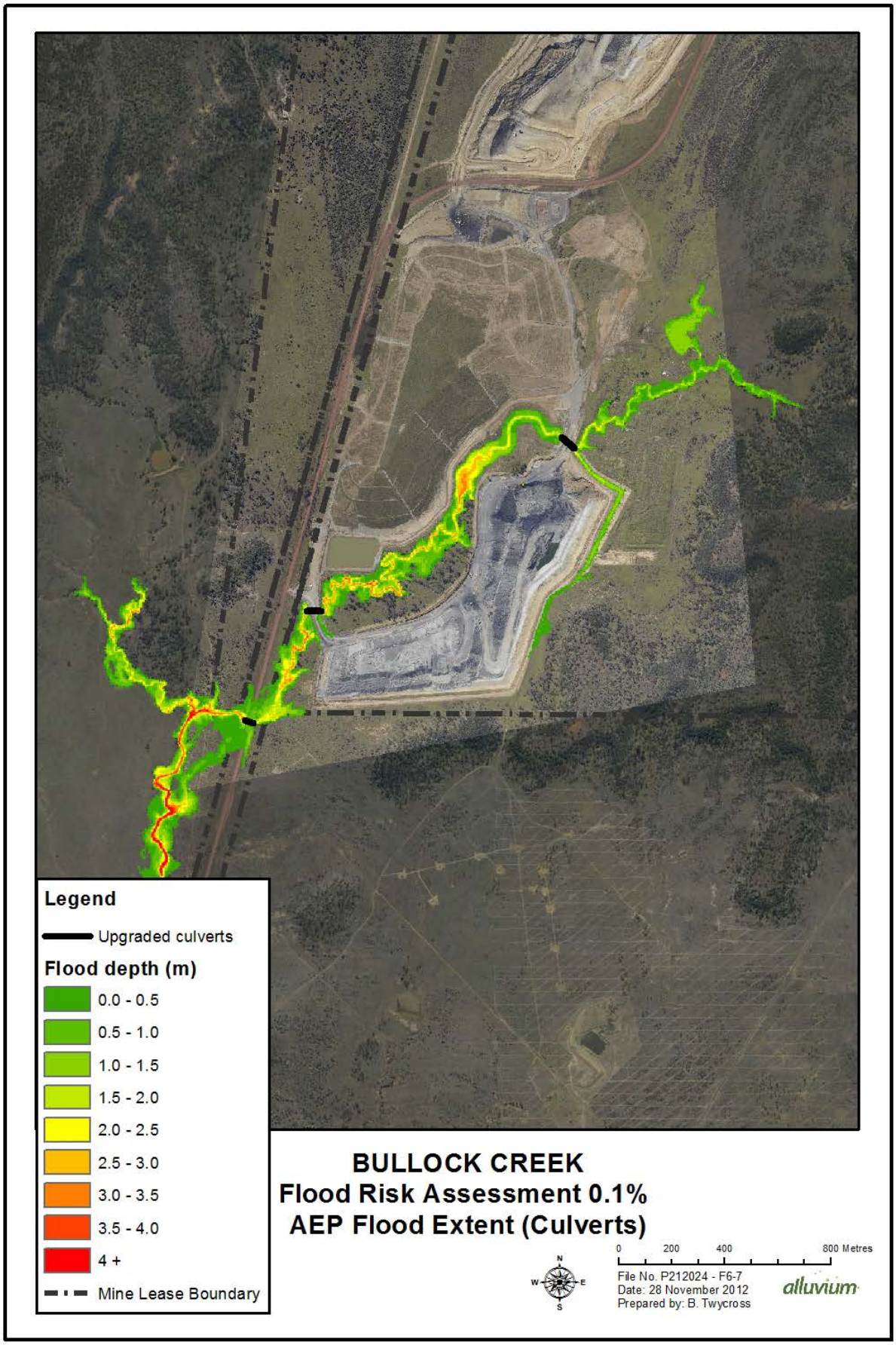


Figure 6-7. *0.1% AEP (upgraded culverts) flood depths for Bullock Creeks (1 hour and 3 hour events combined)*

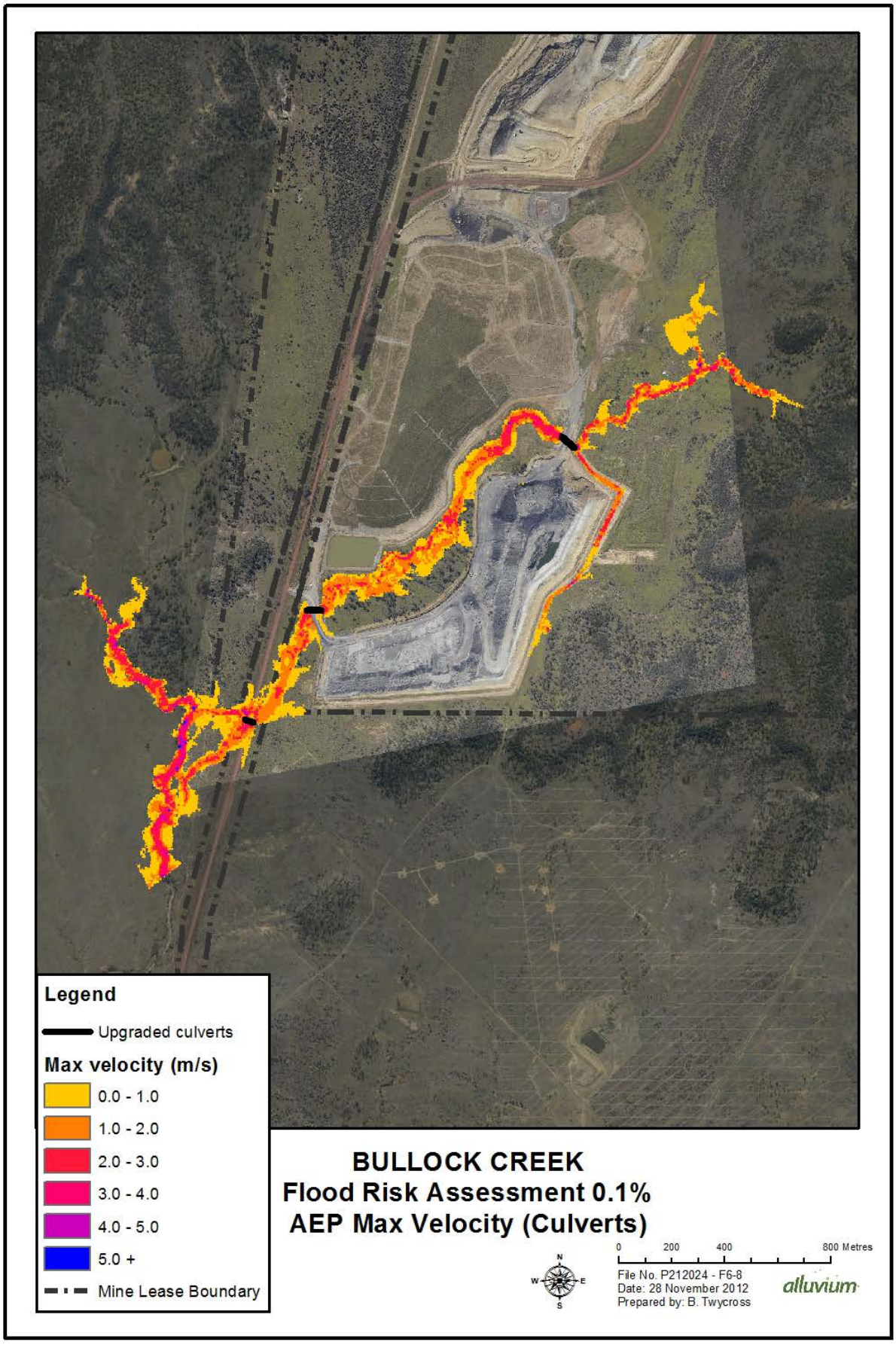


Figure 6-8. *0.1% AEP (upgraded culverts) peak velocities for Bullock Creek (1 hour & 3 hour events combined)*

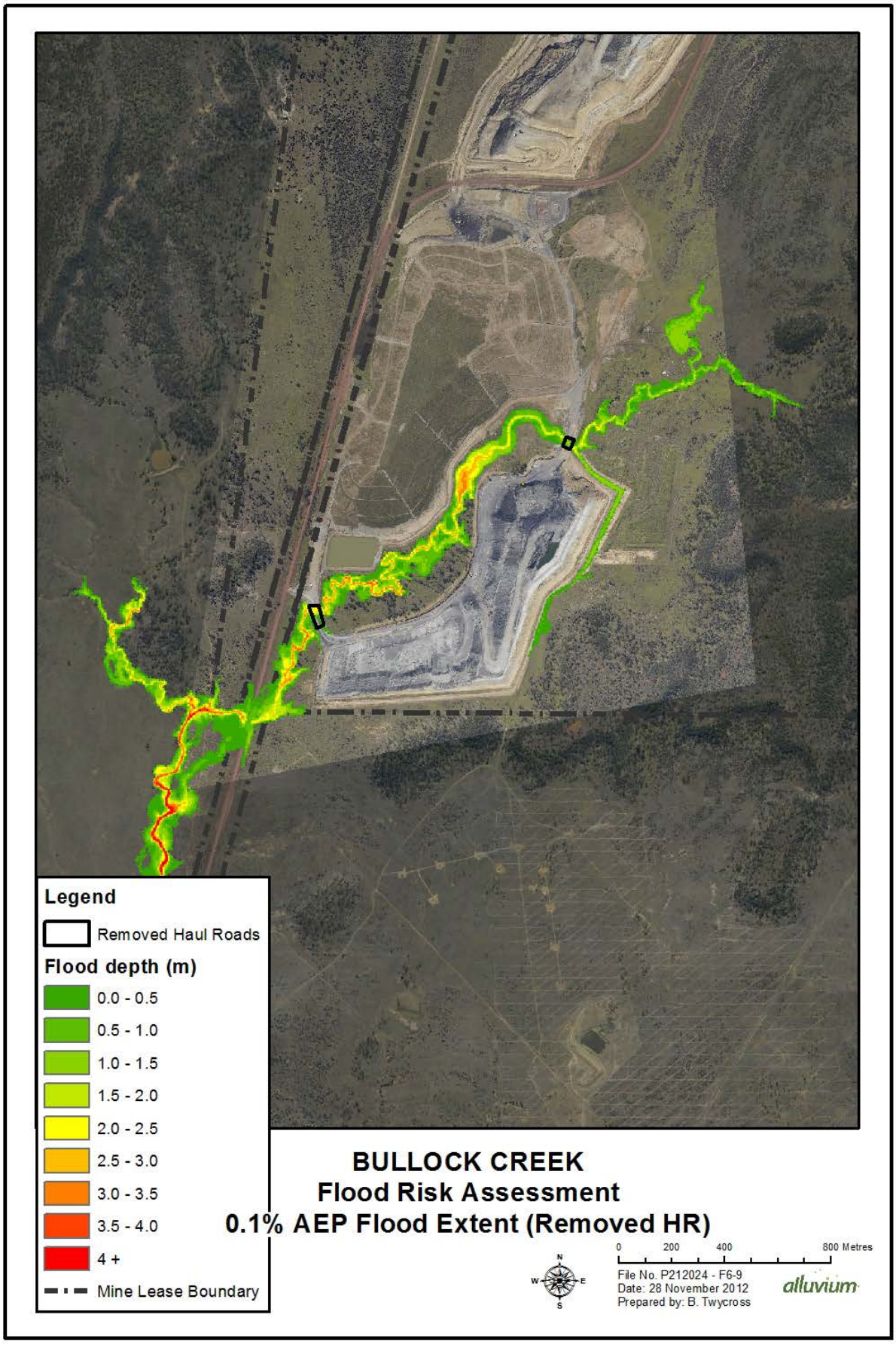


Figure 6-9. *0.1% AEP (removed haul roads) flood depths for Bullock Creeks (1 hour & 3 hour events combined)*

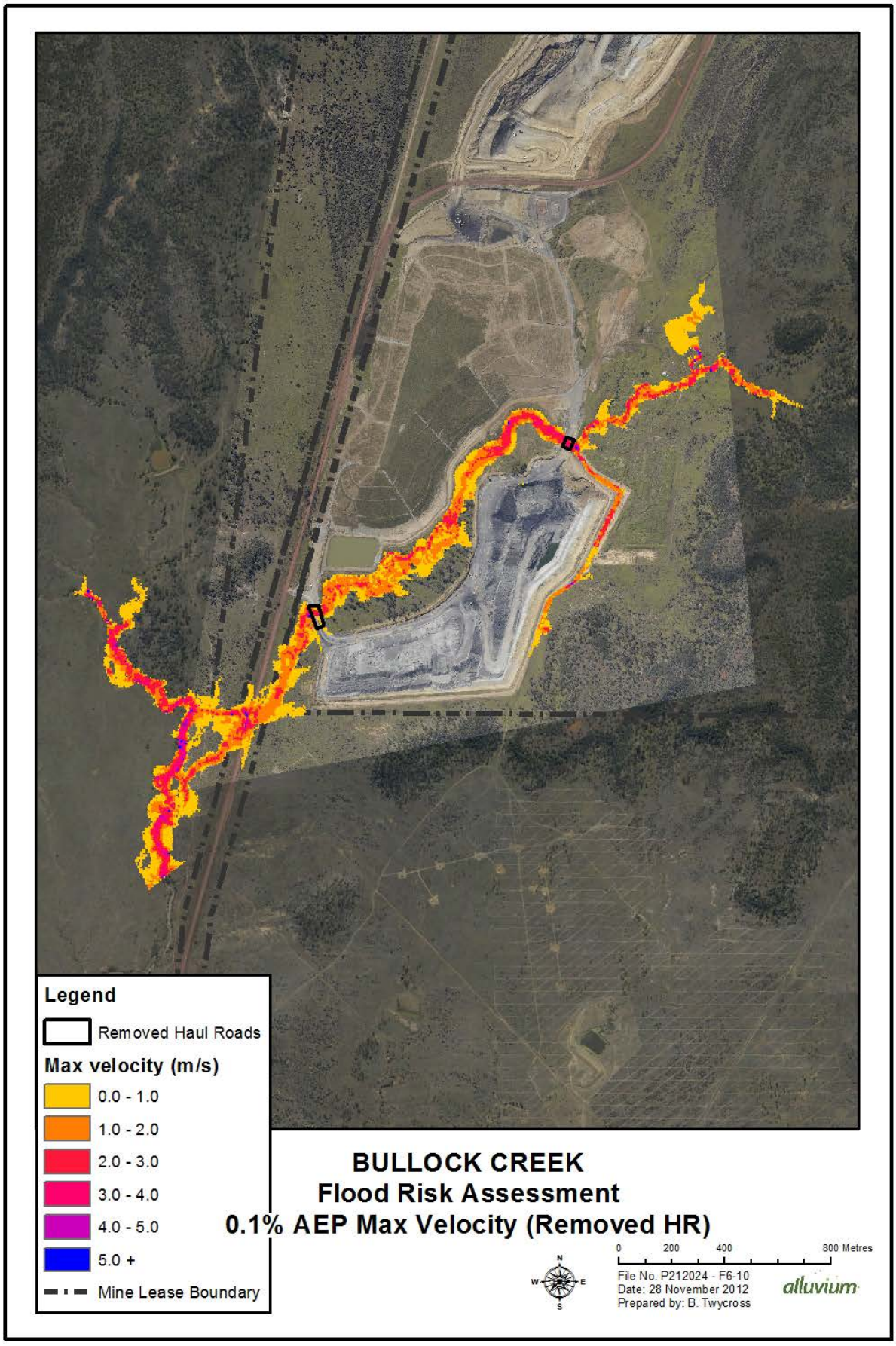


Figure 6-10. *0.1% AEP (removed haul roads) peak velocities for Bullock Creek (1 and 3 hour events combined)*

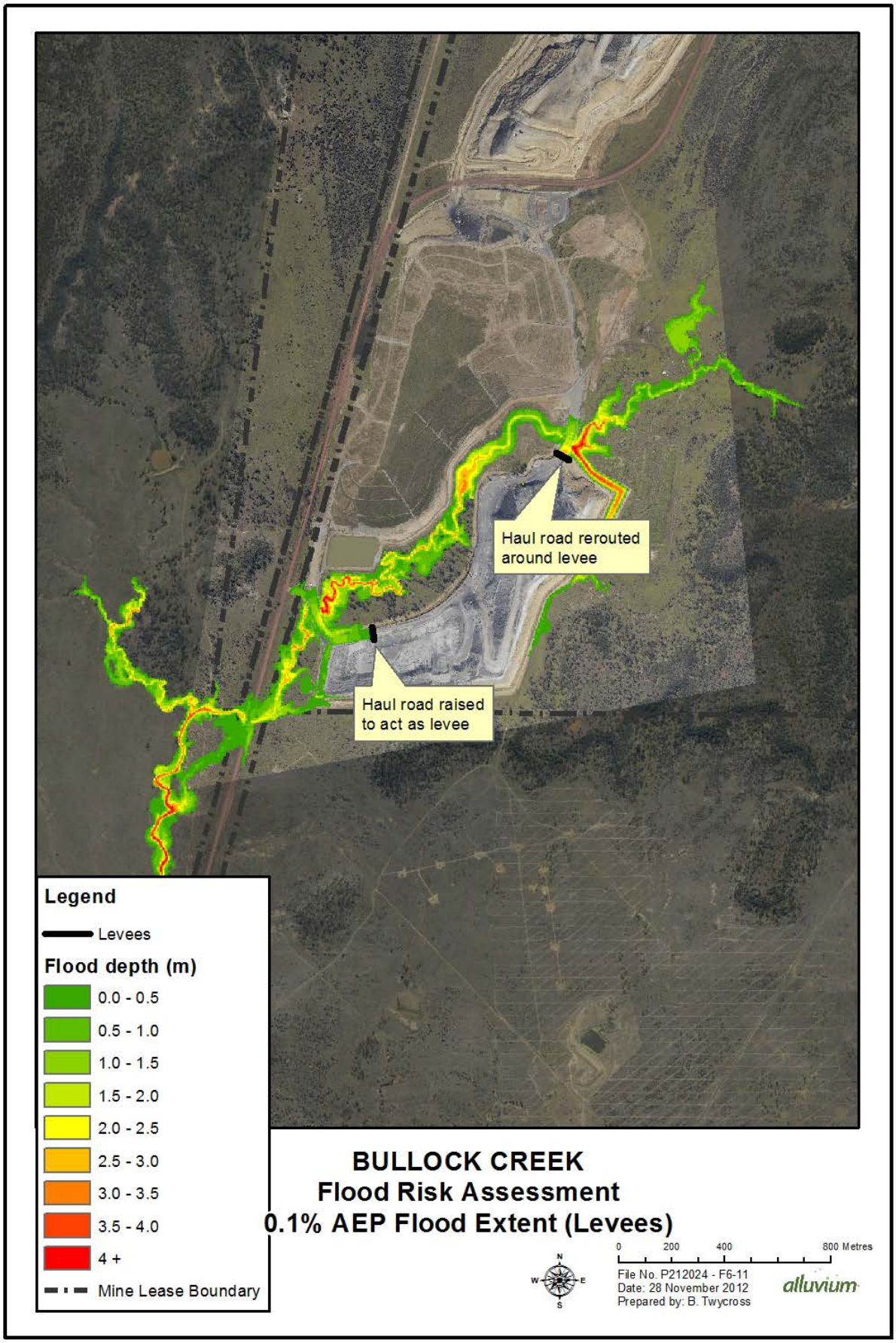


Figure 6-11. *0.1% AEP (with levees) flood depths for Bullock Creeks (1 and 3 hour events combined)*

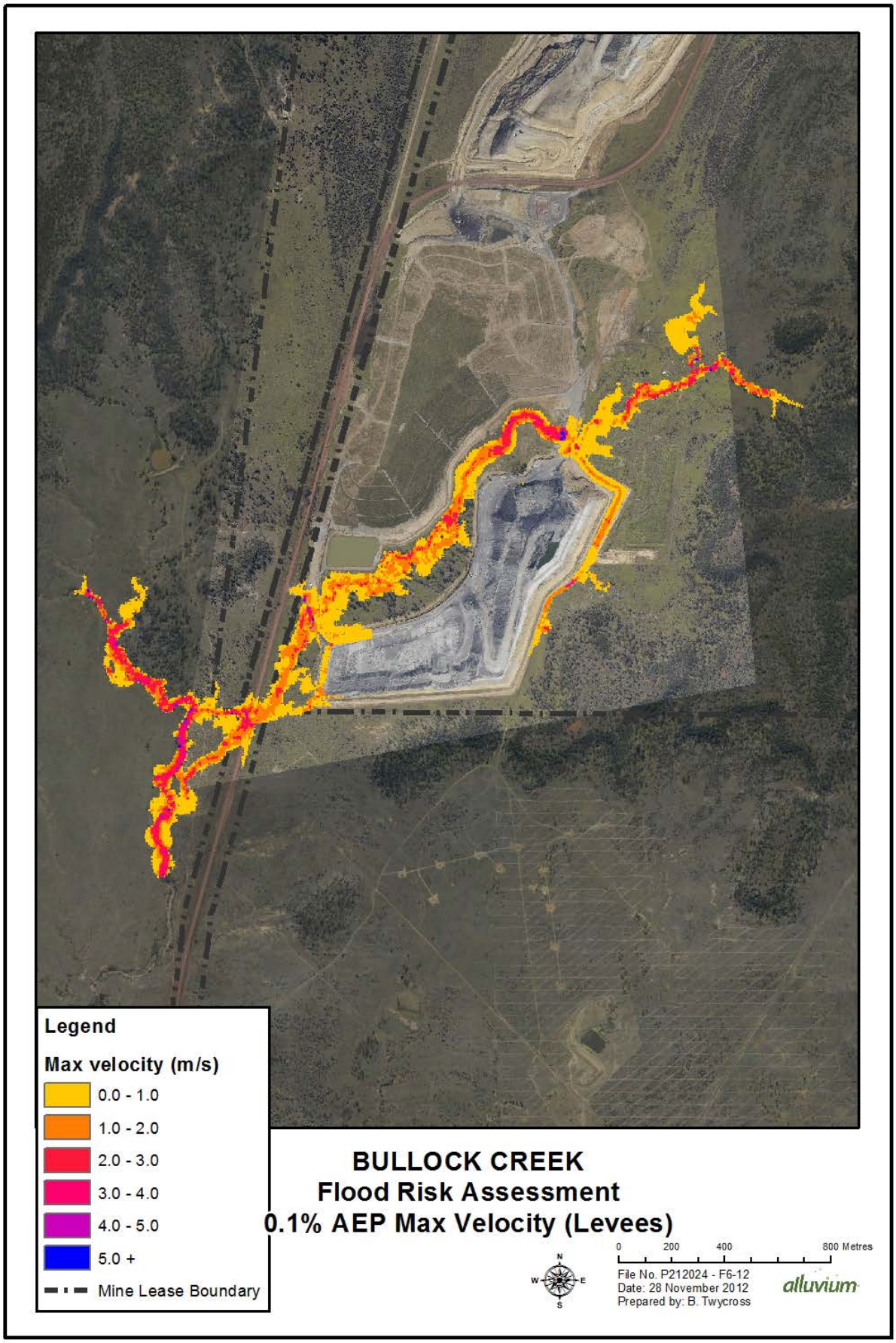


Figure 6-12. *0.1% AEP (with levees) peak velocities for Bullock Creek (1 hour and 3 hour events combined)*

6.5.1 Upstream Bullock Creek Haul Road Crossing

Upgraded culverts
The upstream haul road crossing is culverted by a pair of 1.6m diameter corrugated metal pipes (CMPs). Culvert capacity peaks at 23m^3/s compared to the incoming flowrate of between 60 and 100 m^3/s.

The Haul Road sits clear of the channel bed by approximately 3.5 to 4m and bridges the 80m wide diversion. This provides considerable scope to increase the culvert capacity with minimal reconfiguration of the existing road crossing other than during construction.

Modelling determined that 4 large capacity Reinforced Concrete Box Culverts (RCBC) would be capable of passing the required flow while maintaining at least 0.5m of freeboard below the haul road crest. The conceptual details of the culvert design are provided in Table 6-6.

Table 6-6. Upstream Bullock Creek Haul Road Crossing levee, culvert upgrade details

Parameter	Existing	Upgrade
Material and type	CMP	RCBC
Diameter (or width/height)	1.6m	3.6m/3m
Length	30m	30m
# of barrels	2	4

The resulting effect the upgrade would have on the water surface elevation can be seen in Figure 6-13.

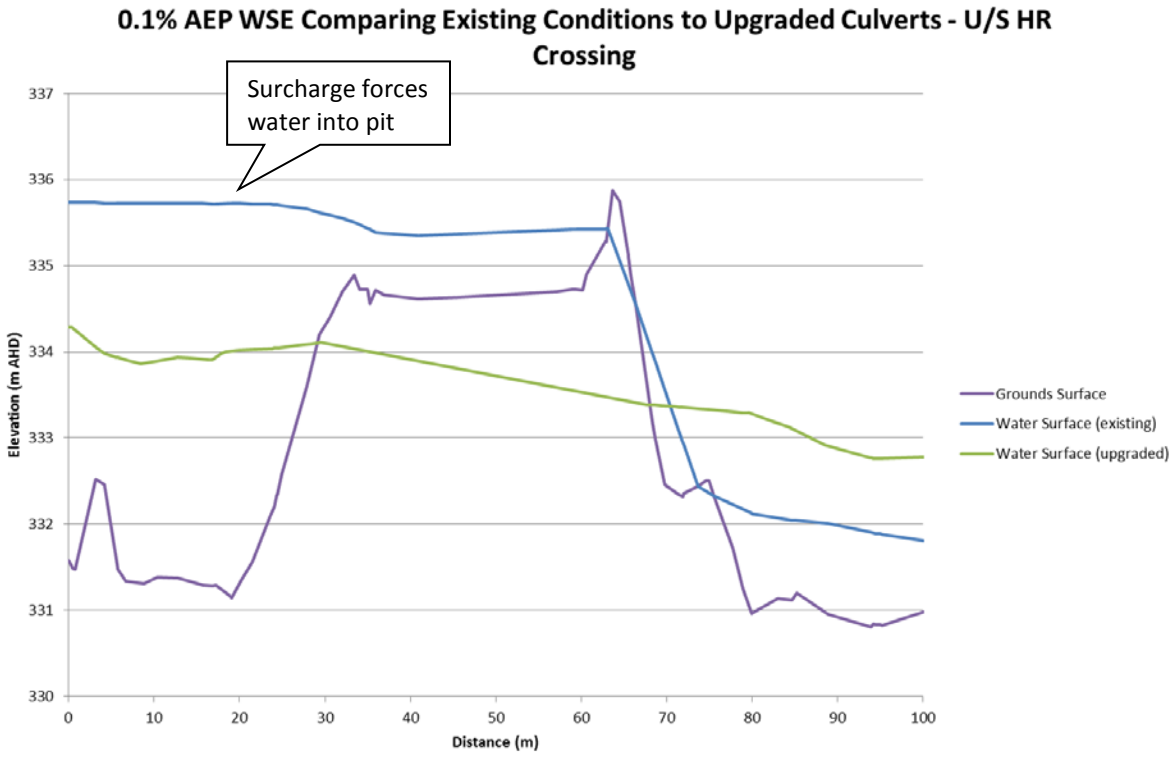


Figure 6-13. *Long section comparing effect of upstream haul road crossing culvert upgrade on WSE*

Remove haul road crossing
While increasing culvert capacity is one method of decreasing the flow restriction caused by the haul road, an alternative is to remove the haul road entirely and increase the reach conveyance capacity by removing the hydraulic restriction.

Burton Mine has indicated that this is the preferred option as the pit is in the process of being rehabilitated and heavy vehicle access is not required. If light vehicle access is required then a creek crossing can be installed at the natural ground level.

Levee protection
While raising the existing levee along the south bank of the diversion will effectively prevent flood water ingress to the pit, being able to do so while maintaining effective use of the haul road would be problematic.

Modelling suggested the water surface elevation for this scenario would be approximately 336.5m AHD for the 0.1% AEP event. As the terrain slopes sharply downwards from north to south and the existing haul road surface on the south side of the diversion is approximately 333.5m AHD, the resulting levee crest would be at least 3.5m high. Consequently, it would be necessary to reroute the haul road to avoid the obstacle, as would be required for the option of lowering the haul road crossing.

Overall, this option is not recommended as it does not address the underlying issue of the flow restriction caused by the haul road.

6.5.2 Downstream Bullock Creek Haul Road Crossing

Upgraded culverts
The downstream haul road crossing is culverted by a pair of 1.6m diameter CMPs. Culvert capacity peaks at 20m^3/s compared to the incoming flowrate of over 30m^3/s.

The Haul Road sits clear of the channel bed by approximately 3 to 3.5m and bridges a 160m crossing over the diversion. This provides considerable scope to increase the culvert capacity with minimal reconfiguration of the existing road crossing (other than to facilitate construction).

Modelling determined that 5 large capacity RCBCs would be capable of passing the required flow while maintaining approximately 0.5m of freeboard below the spill crest into the pit. Note that with the upgraded culverts at the upstream Bullock Creek Haul Road crossing, the incoming flow rate increases from approximately 30m^3/s to over 100m^3/s.

The conceptual details of the culvert design are provided below in Table 6-7.

Table 6-7. Downstream Bullock Creek Haul Road Crossing levee, culvert upgrade details

Parameter	Existing	Upgrade
Material and type	CMP	RCBC
Diameter (or width/height)	1.6m	3.6m/3m
Length	30m	30m
# of barrels/cells	2	5

The resulting effect the upgrade would have on the water surface elevation can be seen in Figure 6-14.

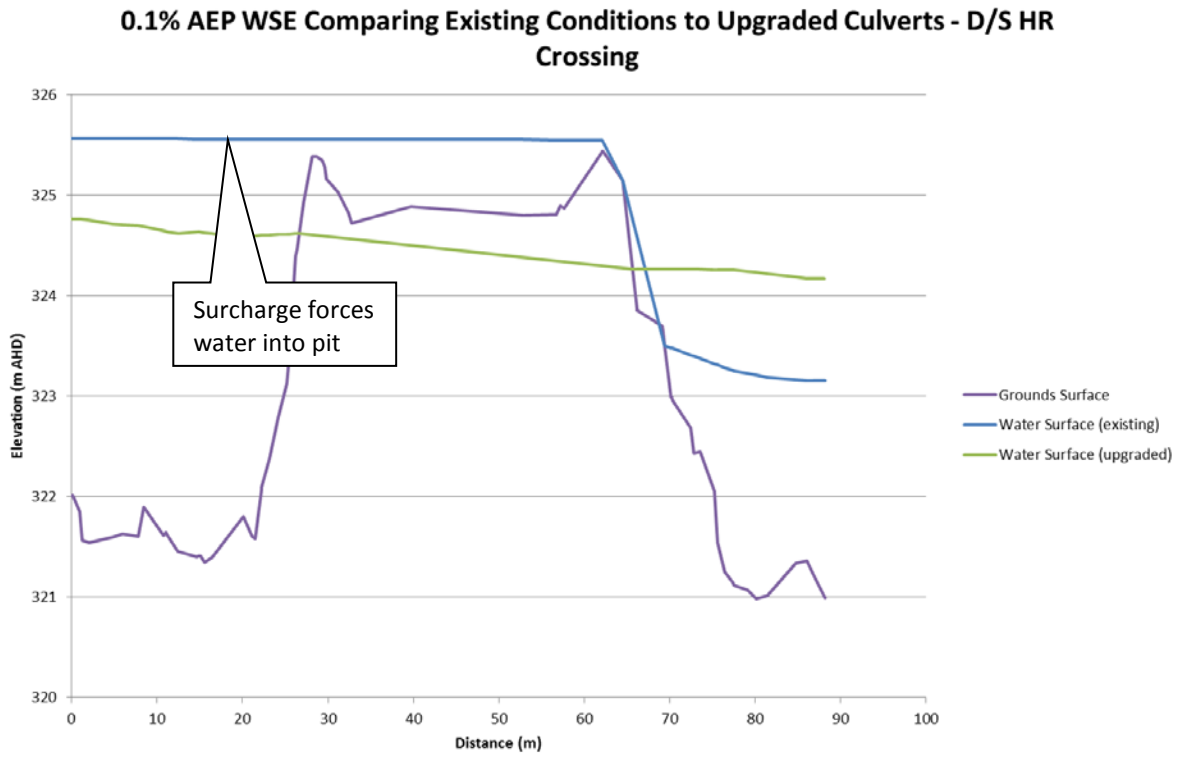


Figure 6-14. *Long section comparing effect of downstream haul road crossing culvert upgrade on WSE*

Remove haul road crossing

As is the case for the upstream Bullock Creek Haul Road crossing, while increasing culvert capacity is one way of decreasing the flow restriction from the road, an alternative is to remove the road entirely and increase capacity by removing the hydraulic restriction

Burton Mine has indicated that this is the preferred option as the pit is in the process of being rehabilitated and heavy vehicle access is not required. If light vehicle is required then a creek crossing can be installed at the natural ground level.

Levee protection

While the two options of increasing the capacity through the downstream Bullock Creek Haul Road crossing will prevent flood waters entering Bullock Creek Pit during the 0.1% AEP event, the conventional option of levee protection is the simplest alternative.

As the Haul Road itself has been identified as the conveyor of flood flows, it is not possible to directly protect the road. Instead, the road must be raised to a sufficient elevation to prevent flood ingress.

The conceptual design details for modifying the haul road are summarised in Table 6-8.

Table 6-8. Downstream Bullock Creek Haul Road raising, brief summary of conceptual option

Parameter	Value
Water surface elevation (m AHD)	326.2
Total length of levee	~400m
Typical raise height	~0.5. to 2.0m*

* Allowing for 0.5m freeboard

A long section of the raised haul road is presented in Figure 6-15, below, and a plan view is presented in Figure 6-16, next page.

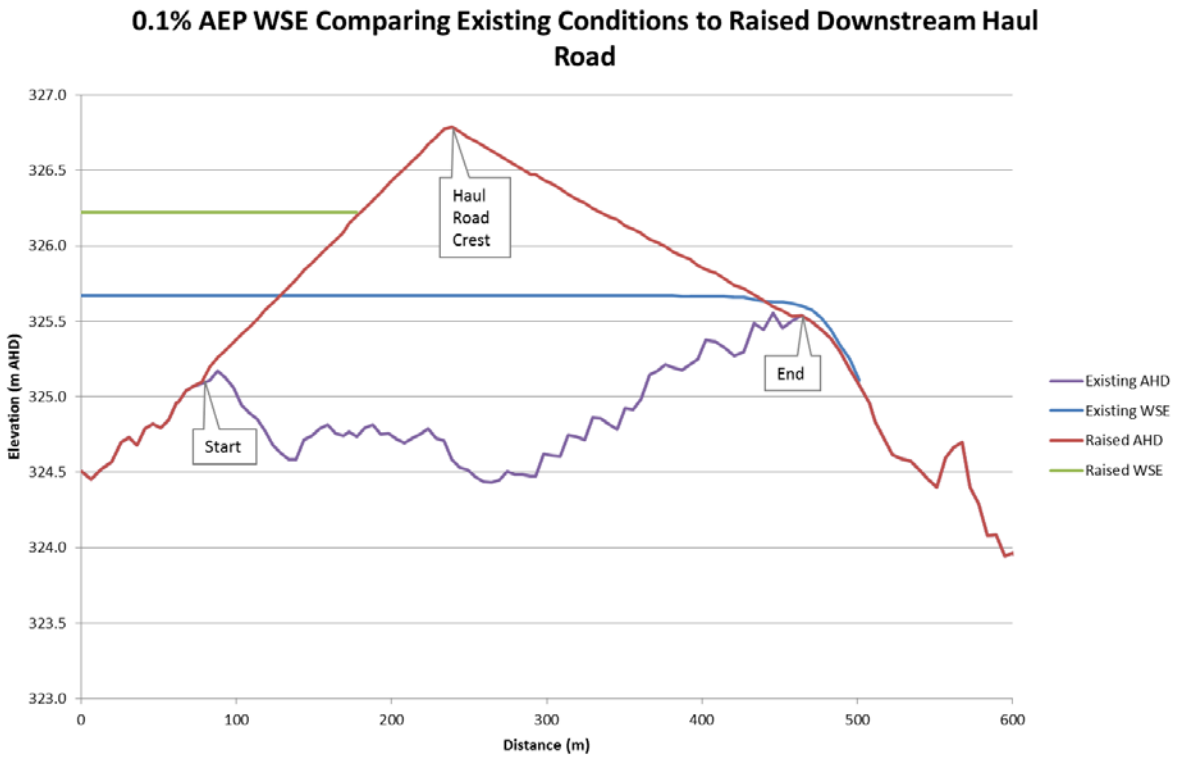


Figure 6-15. *Downstream Bullock Creek Haul Road Crossing levee long section*

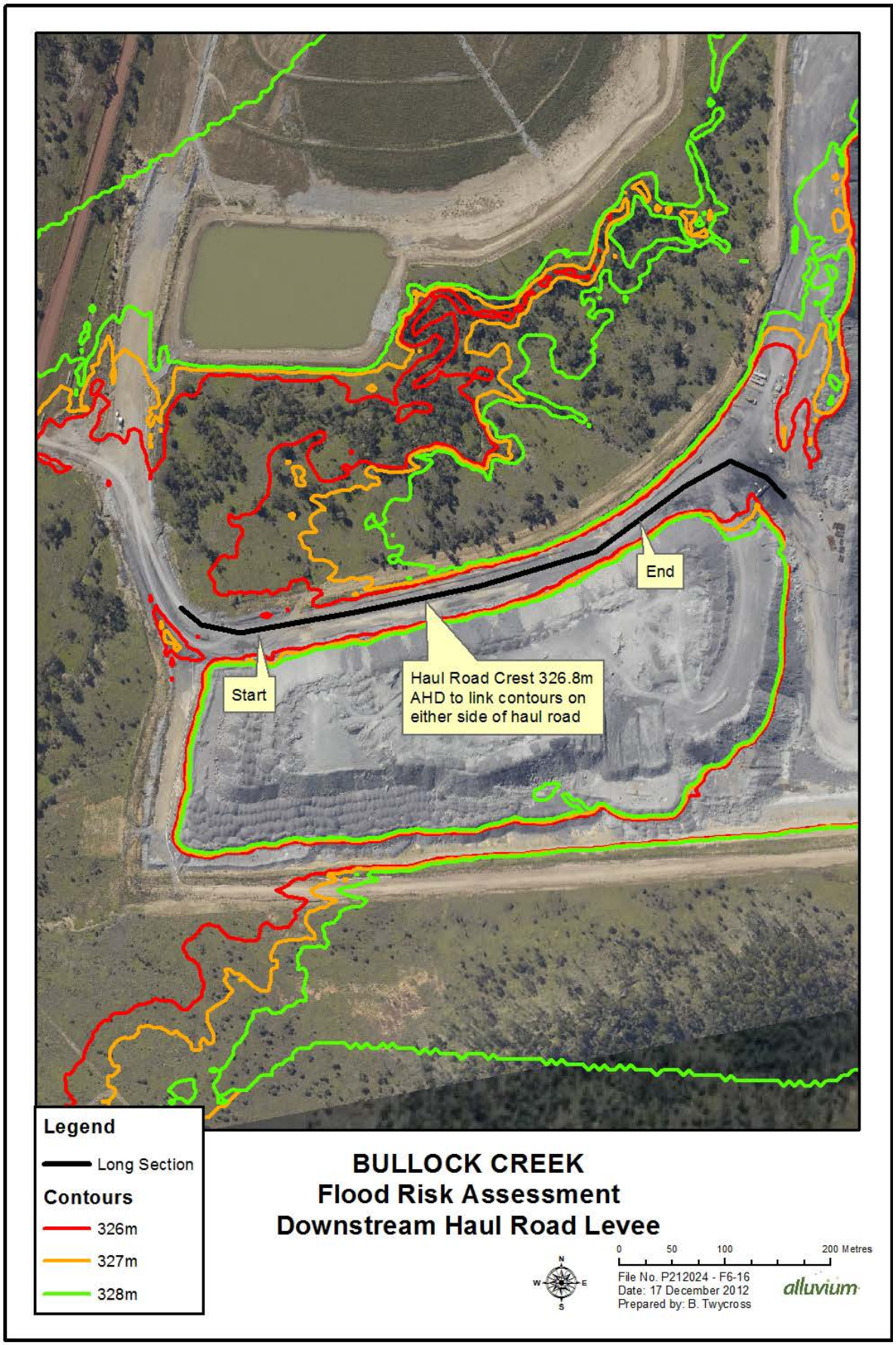


Figure 6-16. *Downstream Bullock Creek Haul Road Crossing levee plan view*

Attachment C
Stage Discharge Curves

7 Stage Discharge Curve Development for Teviot Creek Flow Gauging Station (GST6)

Burton Mine operates a pressure sensing gauging station on Teviot Creek (GST6). In order to determine the relevant low flow release trigger, it is necessary to convert flow rates into water depth estimates using a stage discharge curve for the location. Alluvium has undertaken the hydraulic analysis and produced a stage-discharge curve at the location of the gauging station. This chapter provides a brief description of the hydraulic analysis undertaken, and presents the resultant stage discharge curves and relates the EA low flow release trigger back to a measurable depth in the channel.

7.1 Teviot Creek gauge location

The Teviot Creek flow gauging station is located approximately 55m upstream of the Mallawa Haul road culvert crossing, as shown in Figure 7-1. The presence of the culverts causes backwater upstream of the gauge station location. This will introduce additional complexity to the hydraulic behaviour in the area surrounding the site. The close proximity of the culvert crossing to the location of the gauge is not ideal, particularly for high flow events. Confidence in the results reduces as flows, and hence the influence of the haul road and culvert, increase. The stage discharge curve will need to be updated regularly, following flow events which change the channel form (mobile sand bed).

Although modelling has been undertaken based on the location of GST6, it is suggested that the gauging station be relocated approximately 400m upstream to avoid backwater impacts from the culverts for flows less than $3m^3/s$. For flows greater than $3m^3/s$, the gauging station will need to be relocated even further upstream to avoid influence from the culvert.

7.2 Teviot Creek model setup

One dimensional, steady state modelling has been undertaken using HEC-RAS to develop the stage discharge curves required for the Teviot Creek gauging station. Water levels were determined by the model at the location of the gauging station for a range of flows, allowing a stage discharge curve to be defined.

The model was built for an approximate 1500m length of Spade Creek with cross sections at 50m spacing with the exception of the 500m section of channel closest to the gauging station, where 25m spacing was used for increased accuracy. See Figure 7-2.

In the absence of any specific stage/flow data, the boundary conditions were set to normal depth, as measured from the supplied DTM; see Table 7-1.

Table 7-1. Upstream and downstream settings adopted for the Teviot Creek rating curve hydraulic model

Boundary	Adopted normal depths
Upstream	0.00198 m/m
Downstream	0.00349 m/m

Roughness, represented in the form of Manning's "n" values, was selected and applied to the model using an aerial image to determine vegetation cover and channel form. Identified vegetation types and corresponding roughness's are detailed below in Table 7-2.

Table 7-2. Vegetation types and adopted Manning's "n" values

Vegetation Category	Description	Assigned Manning's "n" Value
Medium dense	Woodland with medium dense cover	0.075
Medium Density Riparian/Clean, Straight	Sections of diversion where some regeneration has occurred, or natural creek with medium cover	0.040

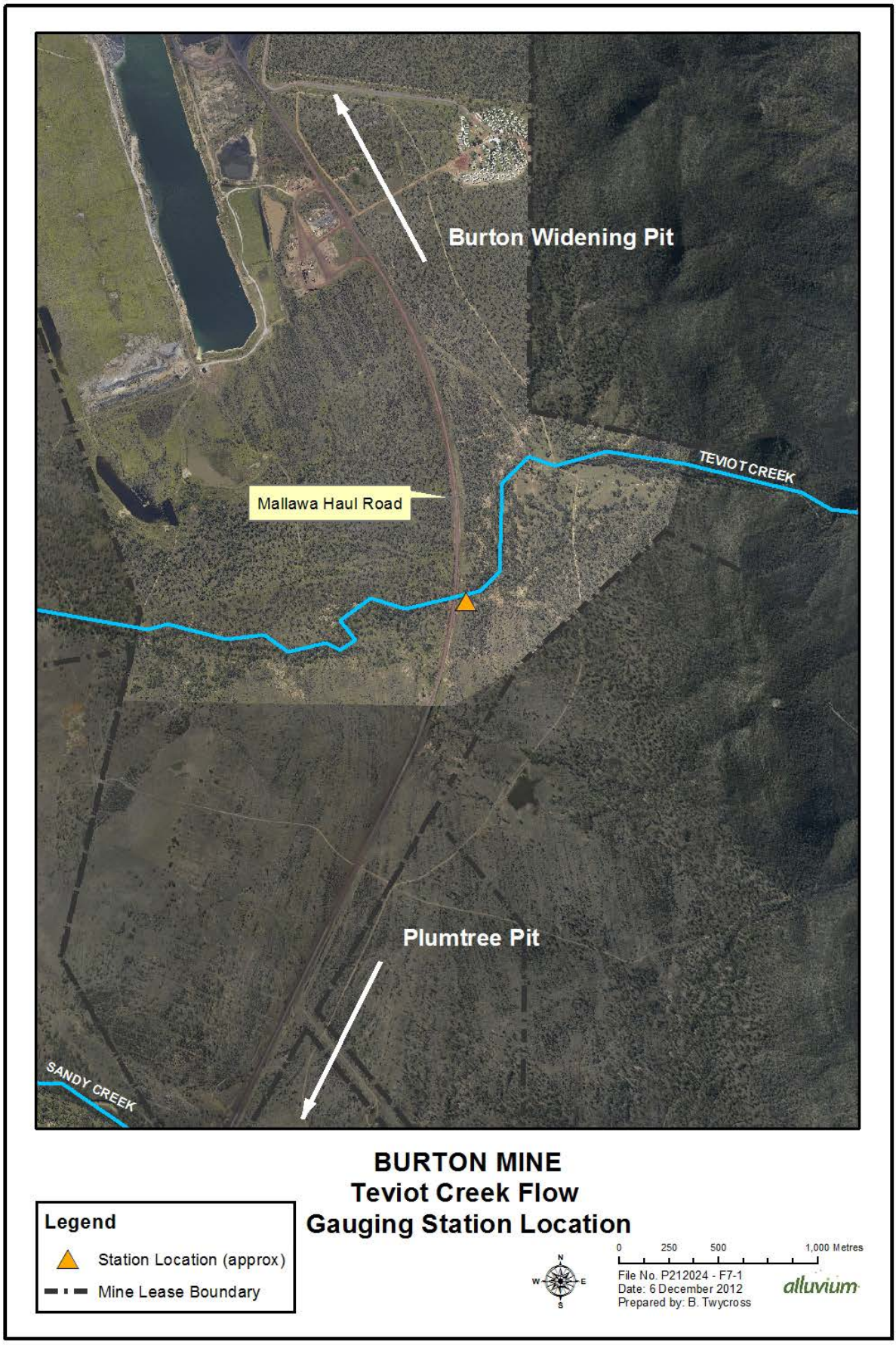


Figure 7-1. *Teviot Creek flow gauging station location map*

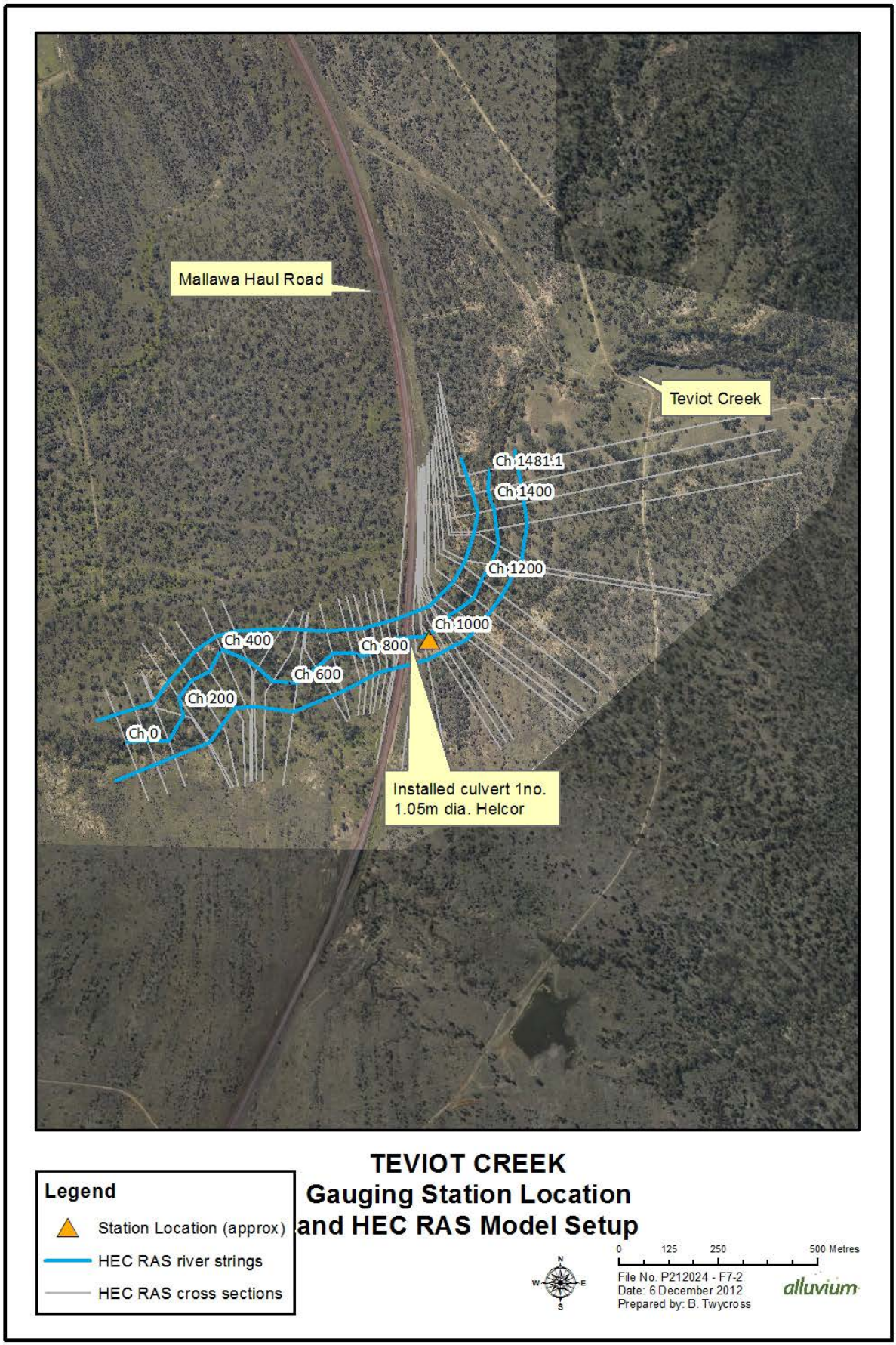


Figure 7-2. *Location of Teviot Creek flow gauging station and HEC RAS model setup*

The topographic data used to undertake this analysis included the haul road crossing over the Teviot Creek subject reach. Alluvium was provided with information on the size of the culverts in an email from Burton Mine on 7 September 2012. Given Alluvium was not provided with details on the end conditions of the culvert, it was assumed that the culvert is configured as a pipe projecting from fill with no headwall

Table 7-3 provides detail on the culverts that were included in the model and Table 7-4 outlines the parameters that were adopted for the culvert.

Table 7-3. Mallawa Haul Road culvert details

Culvert type	Number of culverts	Diameter (mm)	U/s invert level (m AHD)	D/s invert level (m AHD)
Helcor	1	1050	314.4	314.25

Table 7-4. Mallawa Haul Road culvert crossing adopted parameters

Parameter	Adopted value
Entrance loss coefficient (k_{en})	0.9 (Table 6-3 HEC RAS Reference Manual, CMP projecting from fill)
Manning's "n" value	0.024 (Table 6-1 HEC RAS Reference Manual, applied to top and bottom of culvert)

The model was tested for sensitivity to the end wall configured. The model results were compared against a model configured with the pipes conforming to the fill slope. As outlined in Table 6-3 of the HEC RAS Hydraulic Reference Manual (2008), CMPs that conform to the fill slope are allocated an k_{en} value of 0.7. It determined that the model was largely insensitive to the entrance loss coefficient adopted.

7.3 Teviot Creek subject reach modelling results

Flows ranging from 0.25m^3/s to 1000m^3/s were applied to the model.

Due to the presence of the haul road embankment approximately 55m downstream of the gauge location, backwater influence and hydraulic complexity increases with flow rate, with a corresponding reduction in confidence in modelling results. It is therefore considered appropriate to separate the curves for flow "through culvert" and flow "overtopping haul road" as the trajectories are different, and as a result a more accurate fit is possible.

It is not applicable in this case to provide a combined stage discharge curve for the full range of flows. It was found that if the combined flows were plotted, for both through the culvert and overtopping the haul road, that an appropriately fitted curve is not possible. This is due to the overtopping of Mallawa Haul road, which occurs between 2m^3/s and 3m^3/s, for which HEC-RAS uses an alternative equation.

Stage discharge curves are presented in Figure 7-3 and Figure 7-4, next page, for the "through culvert" only and the "overtopping haul road" only, respectively.

The tables used to plot the figures are provided in the accompanying Excel spreadsheet named "Teviot Creek Stage Discharge Curve.xlsx".

The polynomial equations used to define the stage discharge curves for the Teviot Creek gauging station are presented in Table 7-5.

Table 7-5. Teviot Creek stage discharge curve equations and associated R^2 values

Curve	Equation (based on 314.45m AHD invert)	R^2 Value	Applicable Range
Through culvert only	$y = -0.1872x^4 - 0.0255x^3 + 1.183x^2 + 0.1941x + 0.00004$	1.00	0.25 – 2 m^3/s
Overtopping haul road only	$y = 0.0177x^4 - 0.8407x^3 + 15.227x^2 - 32.868x + 16.69$	1.00	3 – 1000 m^3/s

The decision as to which equation to use should reflect the range of flows which need to be most accurately gauged.

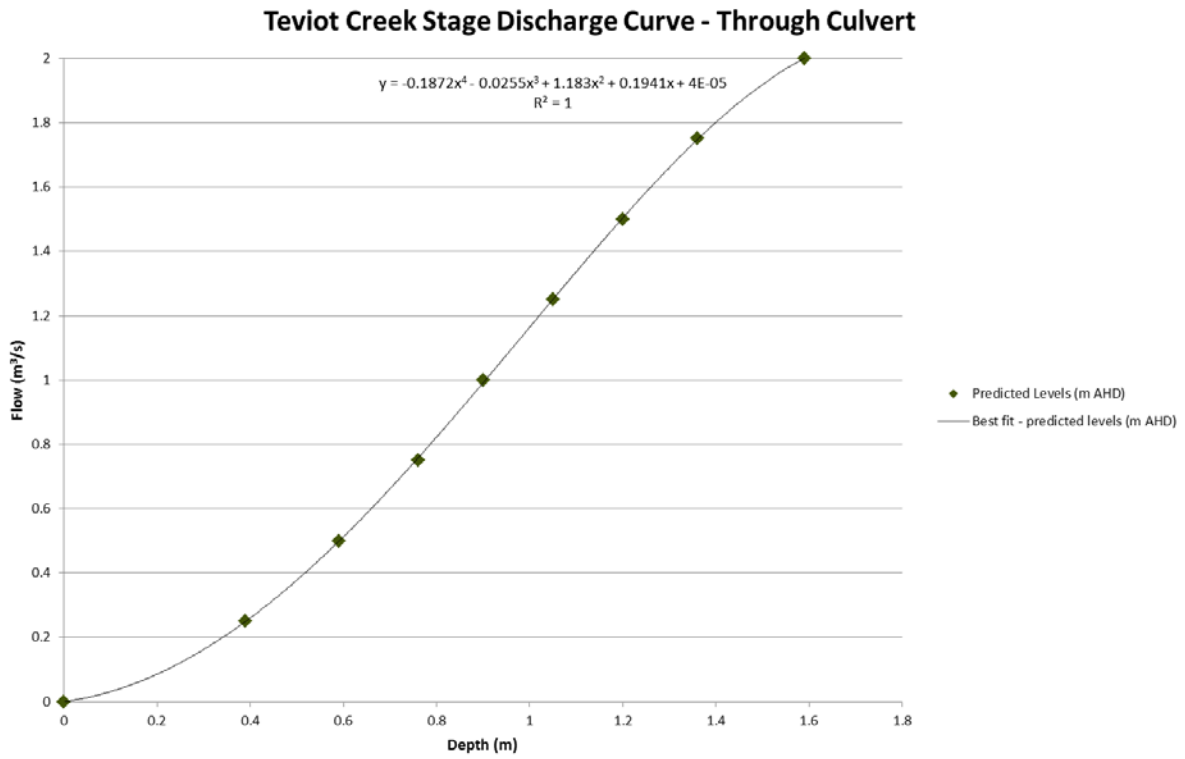


Figure 7-3. *Teviot Creek stage discharge curve – through culvert only*

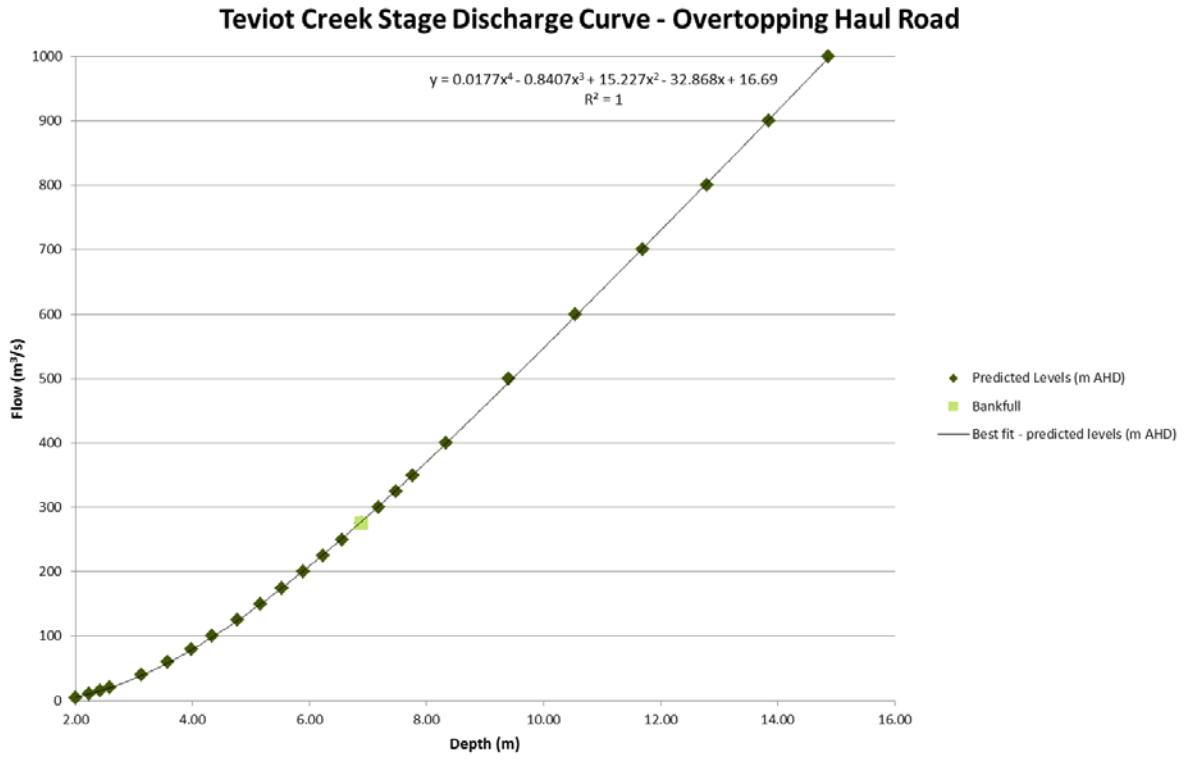


Figure 7-4. *Teviot Creek stage discharge curve – overtopping haul road only*

7.4 EA Conditions for GST6

The low flow release trigger flow rate, water surface elevation (WSE) and depth is provided in Table 7-6.

Table 7-6. Low flow release trigger for GST6

Flow Station	Release Trigger (m^3/s)	Corresponding WSE (m AHD)	Invert (m AHD)	Depth (m)
Teviot Creek (GST6)	0.5	315.04	314.45	0.59

7.5 Summary and limitations

The stage discharge curves developed during this analysis have been produced through 1D hydraulic modelling, based on the assumptions outlined in this report. This allows recorded depths to be converted into flow rate estimates using the equations provided.

The selection of Manning's "n" values and other design coefficients are based on review of aerial photography and experience. No calibration or validation of the hydraulic model has been undertaken and as a result, the stage discharge curves can only be considered approximate.

Due to the presence of the Mallawa haul road across Teviot Creek, as well as the culvert, confidence in the results reduces as flows increase. Given that the haul road overtops for flows between $2m^3/s$ and $3\ m^3/s$ and greater, the channel rating curve should be used with caution.

If the rating curves is intended to build a flow data set for the purposes of hydrologic analysis, in which case lower probability flow rates are of importance, a more suitable gauge location should be considered.

Another limitation of the Teviot Creek flow gauging station is that the culvert opening is relatively small, and may become blocked during a high flow event. This will result in erroneous flow rates measured at the gauge. This should be considered when processing and checking data from high flow events.

Given the presence of the haul road and the culvert crossing, in conjucnition with high sediment inputs from upstream channel cross section will change from event to event. It is therefore essential that the stage discharge curve is updated following each substantial flow event to ensure the validity of calculated flow data.

8 Stage Discharge Curve Development for Sandy Creek Flow Gauging Station (GST1)

Burton Mine currently operates a gauging station on Sandy Creek (GST1) which records water height and electrical conductivity. In order to determine the relevant low flow release trigger, it is necessary to convert flow rates into water depth estimates using a stage discharge curve for the location.

Alluvium has undertaken hydraulic analysis and produced a stage discharge curve at the location of the gauging station. This chapter provides a brief description of the hydraulic analysis undertaken, and presents the resultant stage discharge curves and relates the EA low flow release trigger back to a measurable depth in the channel.

8.1 Sandy Creek gauge location

The Sandy Creek flow gauging station is located approximately 1500m downstream, and to the northwest, of the Mallawa Haul road crossing as shown in Figure 8-1. The station is located on a high angle meander in the Sandy Creek watercourse. Whilst lower flows contained within the channel (160m^3/s and less) are unlikely to be influenced by the location of the gauging station on the meander, the higher out of bank flows (greater than 160 m^3/s) are likely to introduce additional complexity to the hydraulic behaviour surrounding the site.

The location of the gauging station on the meander is not ideal, particularly for high flow events. Confidence in modelling results reduces as flows, and hence the influence of the out of bank flows through the neck of the meander, increase. The stage discharge curve will need to be updated regularly, following events which change the channel form.

8.2 Sandy Creek model setup

One dimensional, steady state modelling has been undertaken using HEC-RAS to develop the stage discharge curves required for the Sandy Creek gauging station. Water levels are predicted by the model at the location of the gauging station for a range of flows, allowing a stage discharge curve to be defined.

The model was built for approximately 1800 m of Sandy Creek with cross sections at 50m spacing except for the 300m section of channel closest to the gauging station, where approximately 25m spacing was used for increased accuracy. Figure 8-2 presents the model setup and the location of the gauging station. In the absence of any specific stage/flow data, the boundary conditions were set to normal depth, as measured from the supplied DTM and as outlined in Table 8-1.

Table 8-1. Upstream and downstream settings adopted for the Sandy Creek rating curve hydraulic model

Boundary	Adopted normal depths
Upstream	0.00155 m/m
Downstream	0.00166 m/m

Roughness, represented in the form of Manning's "n" values, was selected and applied to the model using an aerial image to determine vegetation cover and channel form. Identified vegetation types and corresponding roughness coefficients are detailed below in Table 8-2. Sensitivities of the different Manning's value on the depth of flow are outlined in section 8.3.

Table 8-2. Vegetation types and adopted Manning's "n" values

Vegetation Category	Description	Assigned Manning's "n" Value
Medium dense	Woodland with medium dense cover	0.065
Medium Density Riparian/Clean, Straight	Sections of diversion where some regeneration has occurred, or natural creek with medium cover	0.040

The topographic data used to undertake this analysis did not include any road or culvert crossings.

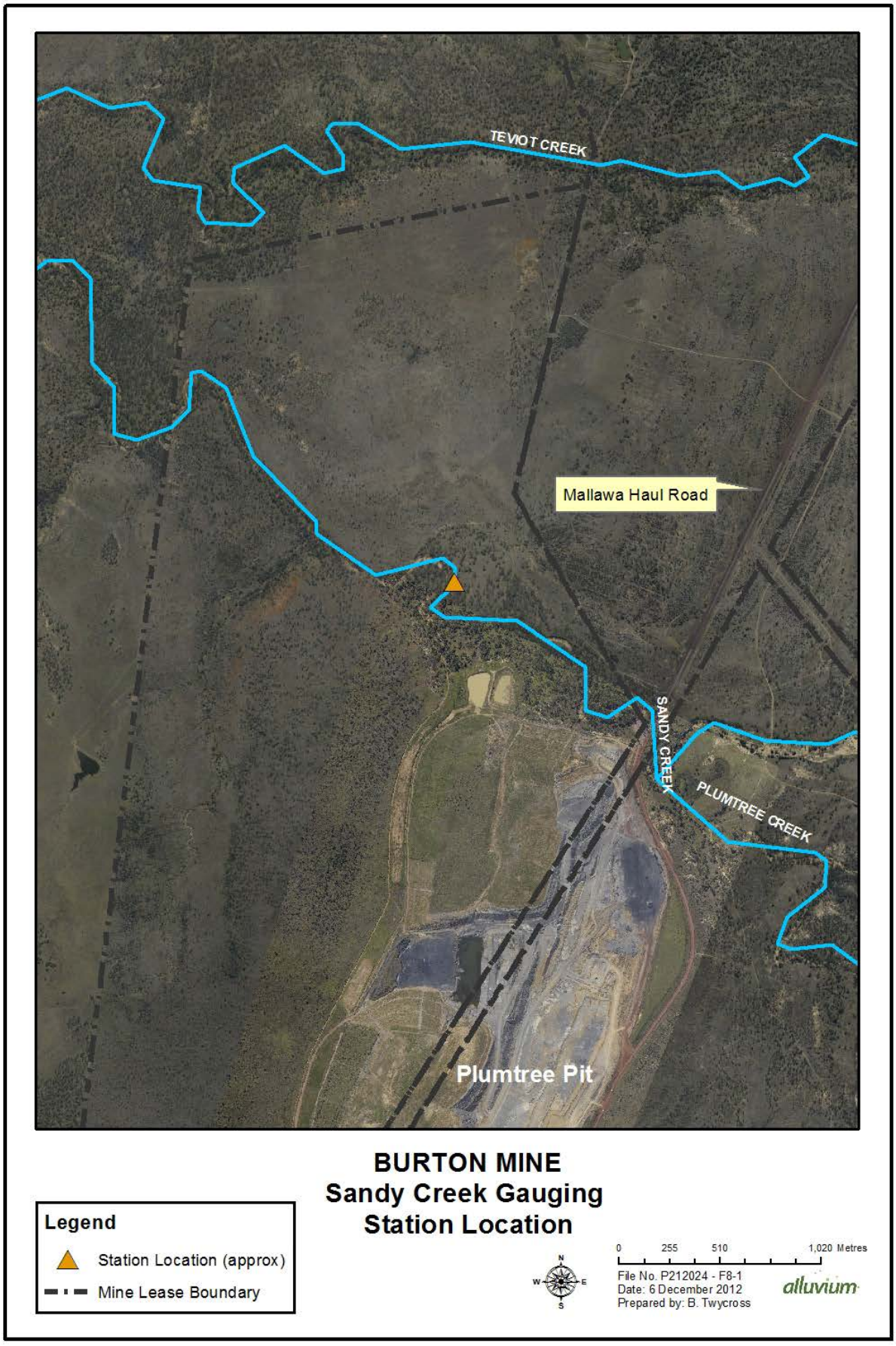


Figure 8-1. *Sandy Creek flow gauging station location map*

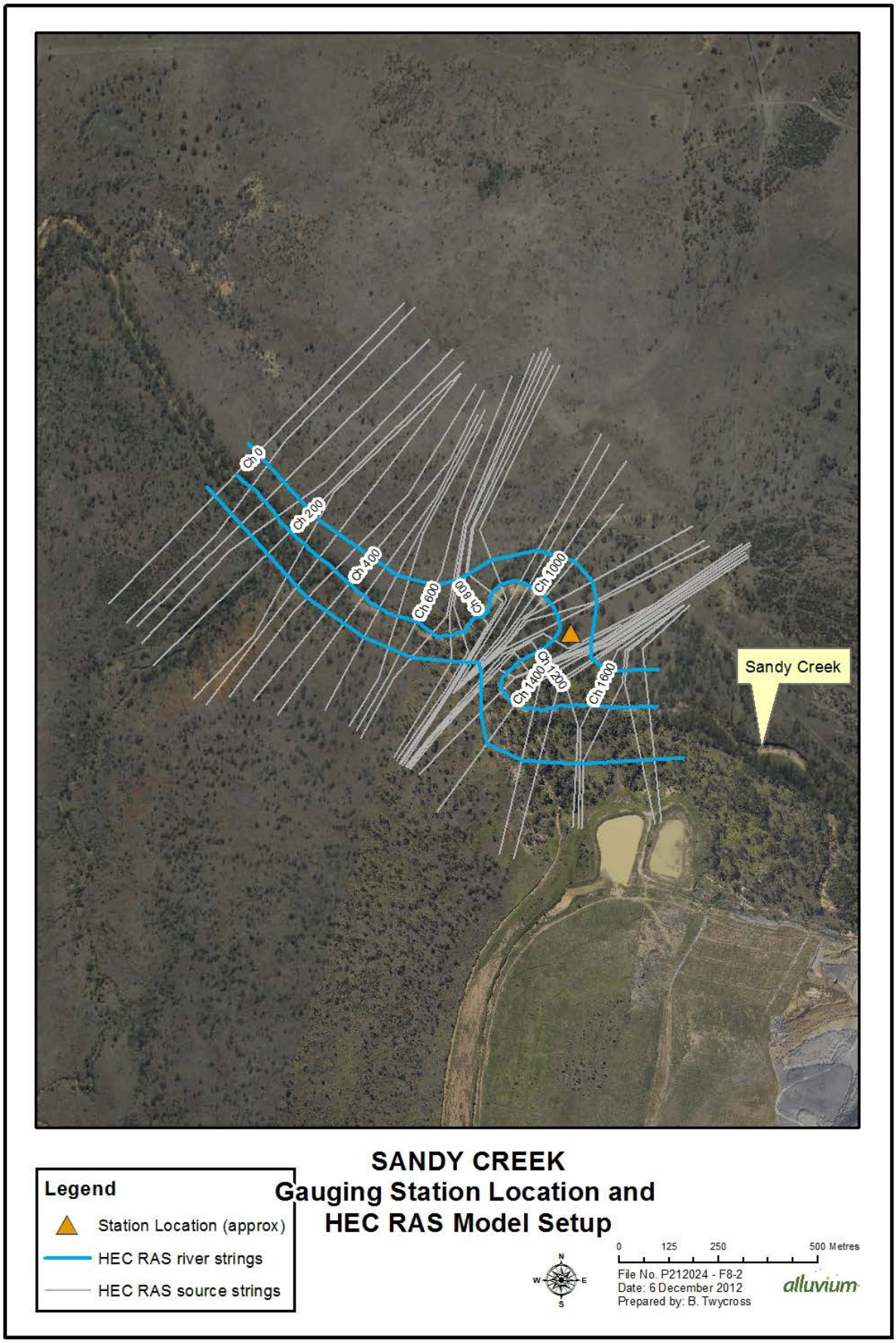


Figure 8-2. *Location of Sandy Creek flow gauging station and HEC RAS model setup*

8.3 Sandy Creek subject reach modelling results

Flows ranging from 0.25m^3/s to 1000m^3/s were applied to the model. Stage discharge curves are presented in Figure 8-3 and Figure 8-4 for the channel only and the floodplain only, respectively.

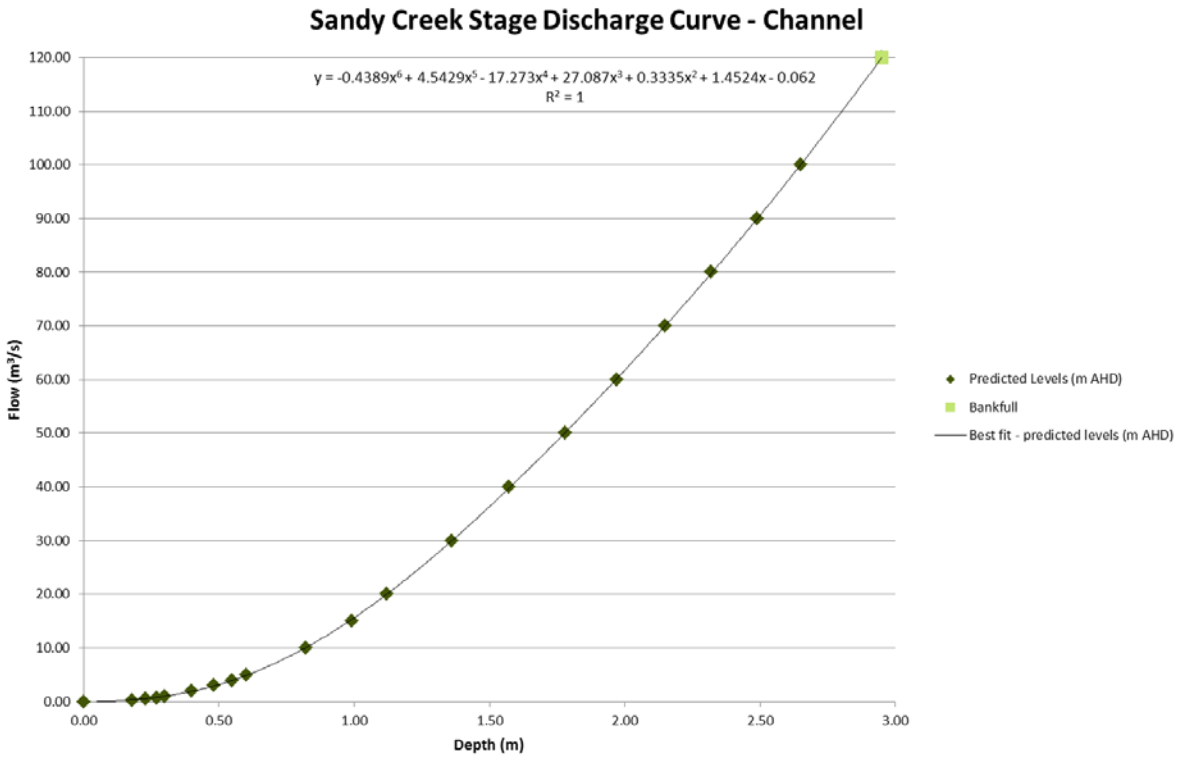


Figure 8-3. *Sandy Creek stage discharge curve – channel only*

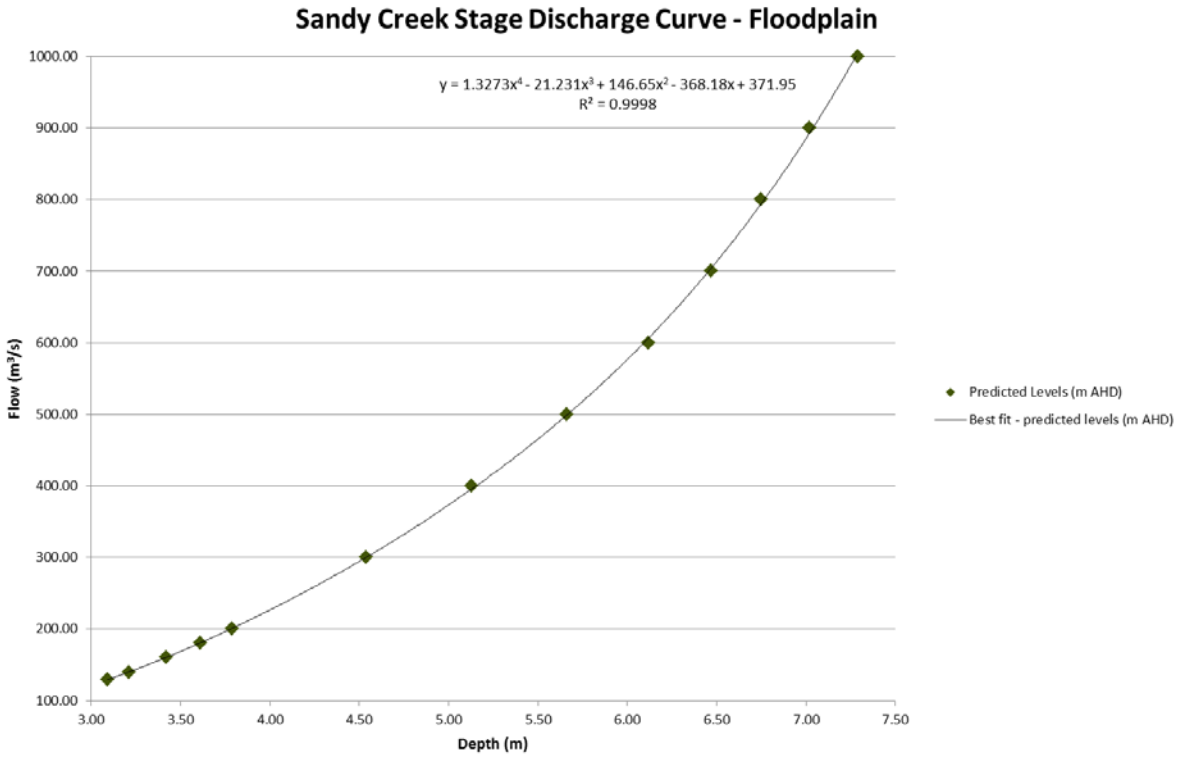


Figure 8-4. *Sandy Creek stage discharge curve – floodplain only*

Due to the location of the station on the meander of the watercourse, complexity increases as the flow rate increases. As a one-dimensional modelling program, HEC RAS is unable to simulate the lateral diffusion of a flood wave, as it represents topographic input as cross sections rather than as a surface. Therefore, in the case of modelling the outputs of flow data on the meander, the increasing complexity corresponds with a reduction in confidence in modelling results. Consequently, it is considered appropriate to separate the curves for channel and floodplain as the trajectories are different, and as a result a more accurate fit is possible.

In this instance, it is expected that out-of-bank flows will occur for flows of greater than 120 m^3/s. As a result, flows analysed in this range should be assessed and utilised with caution.

The tables used to plot the above figures are provided in the accompanying Excel spreadsheet named "Sandy Creek Stage Discharge Curve.xlsx".

The equations used to define the stage discharge curves for the Sandy Creek gauging station are shown in Table 8-3. To obtain a better fit for the channel curve, it was necessary to use a sixth order polynomial.

Table 8-3. Sandy Creek stage discharge curve equations and associated R^2 values

Curve	Equation (based on 304.98m AHD invert)	R^2 Value	Applicable Range
Channel only	$y = -0.4389x^6 + 4.5429x^5 - 17.273x^4 + 27.087x^3 + 0.3335x^2 + 1.4524x - 0.062$	1.0000	0.25 – 120 m^3/s
Floodplain only	$y = 1.3273x^4 - 21.231x^3 + 146.65x^2 - 368.18x + 371.95$	0.9998	120 – 1000 m^3/s

The decision as to which equation to use should reflect the range of flows which need to be most accurately gauged. In this instance it is recommended to use the "Channel only" equation due to the location of the flow gauging station on the meander and the lack of confident in the stage discharge curve for higher flow rates.

8.4 EA Conditions for GST1

The low flow release trigger flow rate, water surface elevation (WSE) and depth is provided in Table 8-4.

Table 8-4. Low flow release trigger for GST1

Flow Station	Release Trigger (m^3/s)	Corresponding WSE (m AHD)	Invert (m AHD)	Depth (m)
Sandy Creek (GST1)	1.5	305.34	304.98	0.36

8.5 Summary and limitations

The stage discharge curves developed during this analysis have been produced through 1D hydraulic modelling, based on the assumptions outlined in this report. This allows recorded depths to be converted into flow rate estimates using the equations provided.

The selection of Manning's "n" values and other design coefficients are based on review of aerial photography and experience. No calibration or validation of the hydraulic model has been undertaken and as a result, the stage discharge curves can only be considered approximate.

Given that the flow gauging station is located on a sharp meander in the Sandy Creek watercourse, higher out of bank flows (greater than 120m^3/s) are likely to skew results in the area surrounding the gauging site. If the rating curves is intended to build a flow data set for the purposes of hydrologic analysis, in which case lower probability flow rates are of importance, a more suitable gauge location should be considered.

Channel migration and aggradation provide a mechanism for cross section change at this therefore it is essential that the stage discharge curve be updated following each substantial flow event to ensure the validity of calculated flow data.

Attachment D
Spade Creek Hydraulic Analysis

9 Overview of Spade Creek Hydraulic Assessment

Spade Creek is a watercourse within the Teviot Brook catchment. The section of the Spade Creek under investigation in this hydraulic analysis is 5100m long (hereafter "subject reach"). It is located at the southern end of the Teviot Brook catchment and encompasses the Spade Creek diversion, which is approximately 1060m long, and is diverted around the northern end of Broadmeadow Pit. See Figure 9-1.

The Spade Creek diversion is licenced under the *Water Act 2000* in accordance with Water Licence Reference number 175670.

A one-dimensional steady state hydraulic model of the Spade Creek diversion encompassing the reach constructed for the diversion was developed using the US Army Corps Hydrologic Engineering Centre's River Analysis System (HEC-RAS).

This section outlines the design methodology for this process and offers some recommendations to manage the stream processes resulting from the operation of the Spade Creek diversion.

9.1 Hydraulic modelling overview

During a hydraulic assessment of a watercourse, a number of key hydraulic parameters are analysed which includes stream power, velocity, and shear stress. These parameters allow for comparative assessment between waterways and against diversion design criteria established in ACARP (2002).

The diversion design criteria established by ACARP (2002) is based on reach average parameter values of existing creeks within the Bowen Basin in Central Queensland and is detailed in Table 9-1.

Table 9-1. Bowen Basin diversion design criteria (reach average) (ACARP 2002)

Scenario	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
1:2 ARI event in channel with vegetation	20 to 60	1.0 to 1.5	<40
1:50 ARI event in channel with vegetation	100 to 150	1.5 to 2.5	<80

This design criterion can be used as threshold design levels for rehabilitation works, and is described in more detail below.

Stream power

Stream power is a product of channel slope and discharge that represents the excess energy available to do work in and on the channel. Recovery usually involves a balance of deposition and erosion. If the flow is too powerful, then the channel erosion may persist or increase.

Stream Power $\omega = \frac{\rho g Q S}{W}$

ρ = density of water (kg/m^3)

g = gravitational acceleration constant (m^2/s)

Q = discharge (m^3/s)

S = hydraulic gradient (m/m)

W = water surface top width (m)

Velocity

Stream velocity is the speed at which water flows through a stream. The higher the velocity, the greater the erosive force of the stream. Stream velocity is calculated by dividing total flow by the cross-sectional area.

Velocity $v = \frac{Q}{A}$

Q = discharge (m^3/s)

A = cross sectional area (m^2)

Shear stress

Shear stress, otherwise known as tractive force, is described as the force exerted on the channel bed and banks by the action of flowing water. It is also a function of channel slope and discharge.

Shear Stress $\tau = (\rho g d s)$

ρ = density of water (kg/m^3)

g = gravitational acceleration constant (m^2/s)

d = depth of water (m)

s = water surface slope (m/m)

9.2 Catchment hydrology

A hydrologic assessment of the Spade Creek catchment is presented in Attachment A. The estimated flow rates for the 1:2 and 1: 50 ARI events through the Spade Creek diversion are shown in Table 9-2.

Table 9-2. Estimated flow rates for 1:2 and 1:50 ARI events through Spade Creek diversion

Flow Change Location	Chainage (m)	ARI	Peak Flow Rate (m^3/s)
A	5086	2	54
		50	223
B	4540	2	86
		50	359

The extent of the Spade Creek hydraulic model and the flow change locations are illustrated in Figure 9-1.

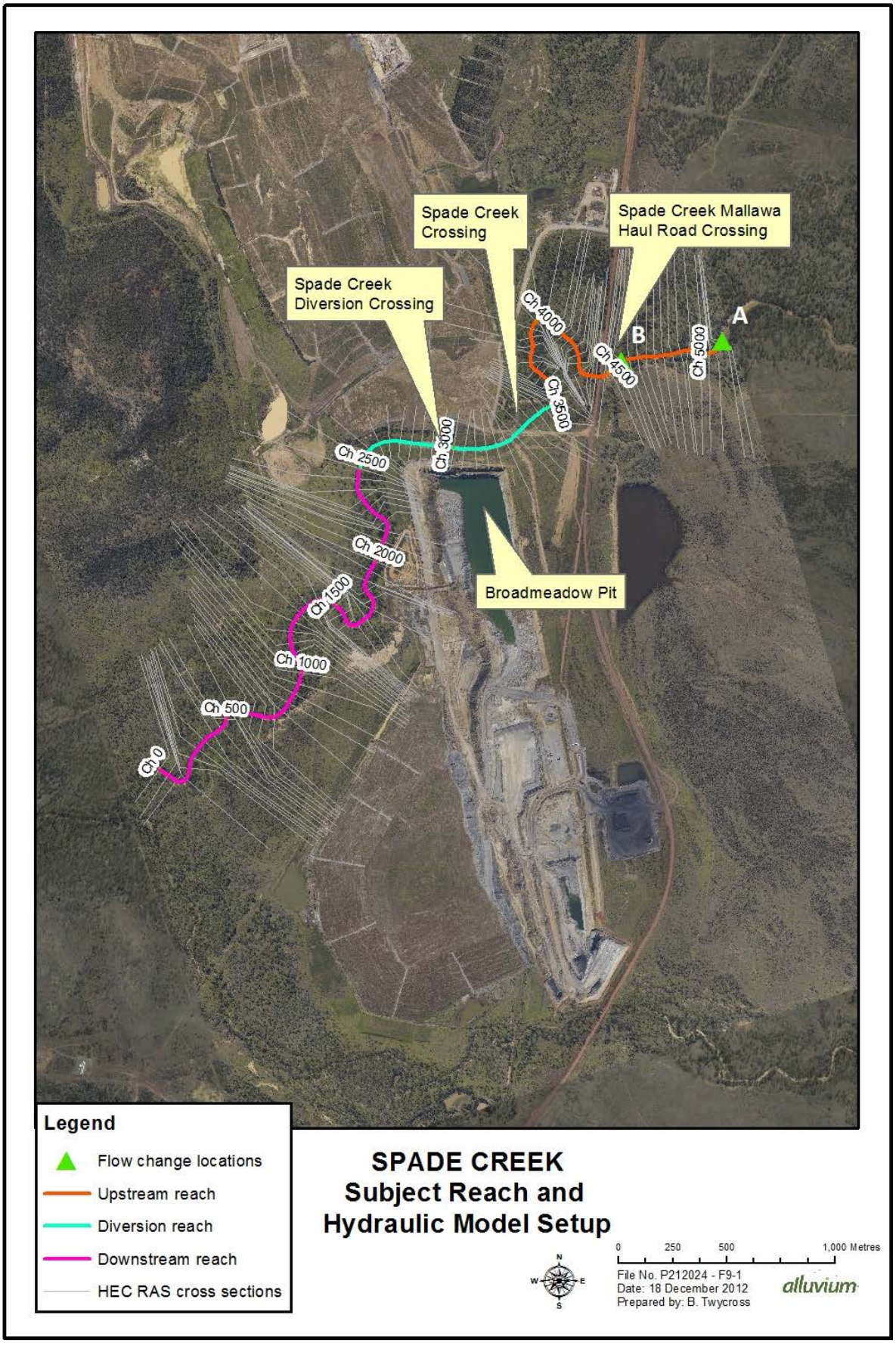


Figure 9-1. *Spade Creek subject reach and hydraulic model setup*

9.3 Model setup

The HEC RAS model is formed by creating a series of cross-sections, extracted from the digital terrain model (DTM), which extend across the channel and onto the floodplain on either side. Other inputs into the model include the Manning's roughness coefficient (n), model boundary conditions, topographic data, and flow estimates for the main channel as outlined in section 9.2.

The subject reach was divided into three sections for the HEC RAS assessment: upstream reach; diversion reach; and downstream reach. Cross sections for the model were typically created at 50m intervals for the entire length of the subject reach. This is with the exception of areas of interest, such as steeper sections and road crossings, where finer spacing was used.

Manning's roughness coefficient (n) varies between the channel and floodplain and represents the frictional resistance to flow provided by the surface and shape of the bed and banks, vegetation and debris of the channel and floodplain. Typically, these values would vary considerably across the extent of the model at a local scale.

The values were selected and applied to the model using an aerial image to determine vegetation cover and channel form. Identified vegetation types and corresponding roughnesses are detailed in Table 9-3.

Table 9-3. Vegetation types and adopted manning's "n" value's for Spade Creek hydraulic model

Category	Description	n Value
Dense Riparian/ Clean, Winding, Sand Bed	Dense vegetation along the majority of Spade Creek. An average of bed and banks.	0.065
Medium Density Riparian/Clean, Straight	Sections of diversion where some regeneration has occurred, or natural creek with medium cover	0.035
Low Density Riparian/Clean, Straight	Sections of diversion where negligible regeneration has occurred.	0.025

The boundary conditions for the model were determined using the known upstream and downstream normal depths for the model, as outlined in Table 9-4.

Table 9-4. Upstream and downstream setting adopted for Spade Creek hydraulic model

Boundary	Adopted normal depth slope (m/m)
Upstream	0.00291
Downstream	0.00140

The topographic data used to undertake this analysis included the three road crossings over Spade Creek:

- Spade Creek Mallawa Haul Road Crossing (culvert crossing)
- Spade Creek Crossing (culvert crossing), and
- Spade Creek Diversion Crossing (no culverts present).

Table 9-5 provides detail on the culverts that were included in the model and Table 9-6 outlines the parameters that were adopted for both of the culverted crossings.

Table 9-5. Spade Creek culvert details for hydraulic assessment

Culvert crossing	Culvert type	Number of culverts	Diameter (mm)	Upstream invert level (m AHD)	Downstream invert level (m AHD)
Mallawa Haul Road	Helcor	6	1050	279.90	279.50
Spade Creek Crossing	Helcor	2	1600	277.40	277.10

Table 9-6. Spade Creek culvert parameters adopted for hydraulic assessment

Parameter	Adopted value
Entrance loss coefficient (k_{en})	0.9 (Table 6-3 HEC RAS Reference Manual, CMP projecting from fill)
Manning's "n" value	0.024 (Table 6-1 HEC RAS Reference Manual, applied to top and bottom of culvert)

9.4 Results

In order to assess the existing hydraulic conditions of Spade Creek, the subject reach has been divided into three separate reaches: upstream of the diversion off take (upstream of chainage 3600); the diversion (chainage 2500 to 3600); and downstream of the constructed diversion tie-in (at chainage 2500).

The tabulated results for each reach are presented below in Table 9-7 for the upstream reach, Table 9-8 for the diversion reach and Table 9-9 for the downstream reach.

Hydraulic parameter plots for the entire subject reach for the 1:2 and 1:50 ARI events are presented below in Figure 9-3 and Figure 9-4, respectively. The graphs of each parameter must be understood in context of local and reach scale geomorphic characteristics due to the dramatic appearance of spikes that exceed threshold levels. If these spikes are localised and not in consecutive cross sections then they do not necessarily represent an area of instability.

Upstream reach

The upstream reach is characterised by a sharp meander and a culvert crossing at the Spade Creek Mallawa Haul Road Crossing at chainage 4475. There is also the risk of development of a high flow cut off connecting chainage 4400 almost directly to 3500.

Overall, as demonstrated in Table 9-7, Figure 9-3 and Figure 9-4, the average hydraulics of the upstream reach were all within threshold.

Table 9-7. Spade Creek upstream reach hydraulic characteristics

Parameter	Units	ARI	Bowen Basin diversion criteria (reach average)	Modelled parameters		
				Minimum	Maximum	Average
Shear Stress	N/m^2	1:2	<40	4.05	118.42	18.91
		1:50	<80	3.46	69.16	21.39
Stream Power	N/m.s	1:2	with vegetation <60	2.59	390.39	34.21
		1:50	<150*	2.22	189.01	39.72
Velocity	m/s	1:2	with vegetation<1.5	0.65	2.79	1.19
		1:50	<2.5	0.62	2.74	1.49

Diversion reach

Modelling confirmed that the average shear stress throughout the diversion reach is below the ACARP thresholds. However, modelling showed that average velocities are higher than threshold for both the 1:2 and 1:50 ARI events and that stream power substantially exceeds threshold for the 1:2 ARI event. See Table 9-8.

Given that the channel is largely confined and vegetation has yet to establish, higher velocities and stream power in this area would be expected. Furthermore, immediately downstream of the Spade Creek Diversion Crossing, the diversion drops by 1.7m over 65m, at a gradient of 0.026m/m (see Figure 9-5 and Figure 9-6). High stream power immediately downstream of this location is likely to cause erosion and deepening of the channel bed if the weak armouring present continues getting mobilised and is not replenished.

Modelling shows that overtopping of the Spade Creek Crossing, at chainage 3375, is occurring for both the 1:2 and 1:50 ARI events. As a result, backwater is providing drowned out conditions for part of the reach

upstream of this location. As would be expected, the results show low hydraulics for approximately 500 metres upstream of this location.

Table 9-8. Spade Creek diversion reach hydraulic characteristics

Parameter	Units	ARI	Bowen Basin diversion criteria (reach average)	Modelled parameters		
				Minimum	Maximum	Average
Shear Stress	N/m^2	1:2	<40	7.50	202.18	33.20
		1:50	<80	12.75	159.84	38.64
Stream Power	N/m.s	1:2	no vegetation <35	8.91	1,118.17	112.74
		1:50	<150*	22.58	854.60	136.09
Velocity	m/s	1:2	no vegetation <1.0	0.71	5.53	2.25
		1:50	<2.5	1.75	5.35	2.90



Figure 9-2. *Spade Creek diversion crossing*

Downstream reach

Aggradation of sediment has been occurring in the channel through the downstream reach and high flows are engaging the floodplain. Modelling suggests that these floodplain flows have resulted in lower hydraulics in the downstream reach. However sections of excessive hydraulics were modelled at chainages 350, 850 and 1150 which may be due to the presence of localised bed grade changes at these locations. Overall, average hydraulic parameters are below threshold with the exception of velocity which exceeds the threshold for the 1:2 ARI event. See Table 9-9.

Table 9-9. Spade Creek downstream reach hydraulic characteristics

Parameter	Units	ARI	Bowen Basin diversion criteria (reach average)	Modelled parameters		
				Minimum	Maximum	Average
Shear Stress	N/m2	1:2	<40	10.52	56.15	31.12
		1:50	<80	6.52	240.15	38.24
Stream Power	N/m.s	1:2	with vegetation <60	11.31	134.92	58.60
		1:50	<150*	5.56	1,255.45	108.28
Velocity	m/s	1:2	with vegetation<1.5	1.08	2.75	1.91
		1:50	<2.5	0.85	5.18	1.94

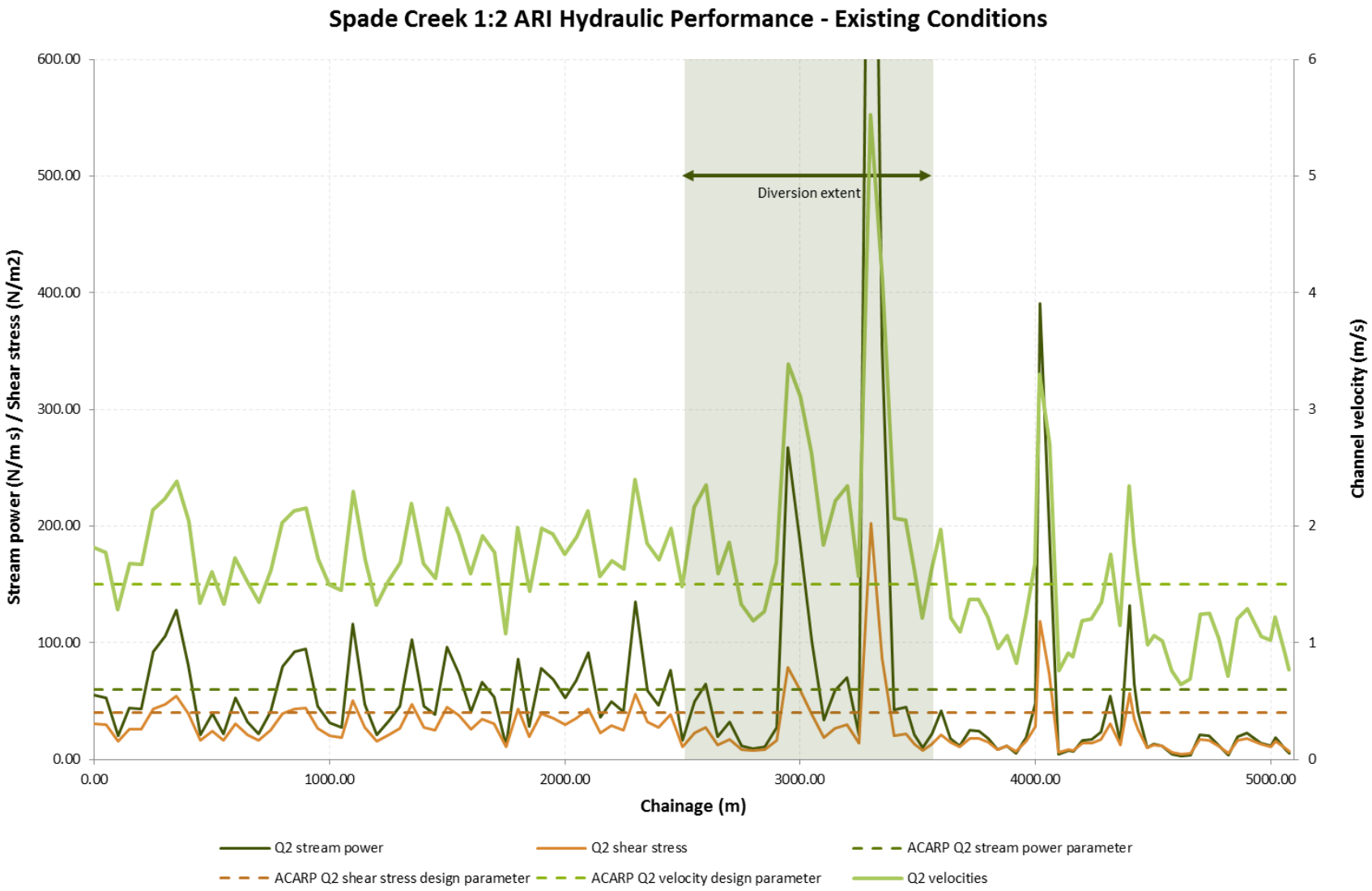


Figure 9-3. *Modelled 1:2 ARI hydraulic parameters for Spade Creek*

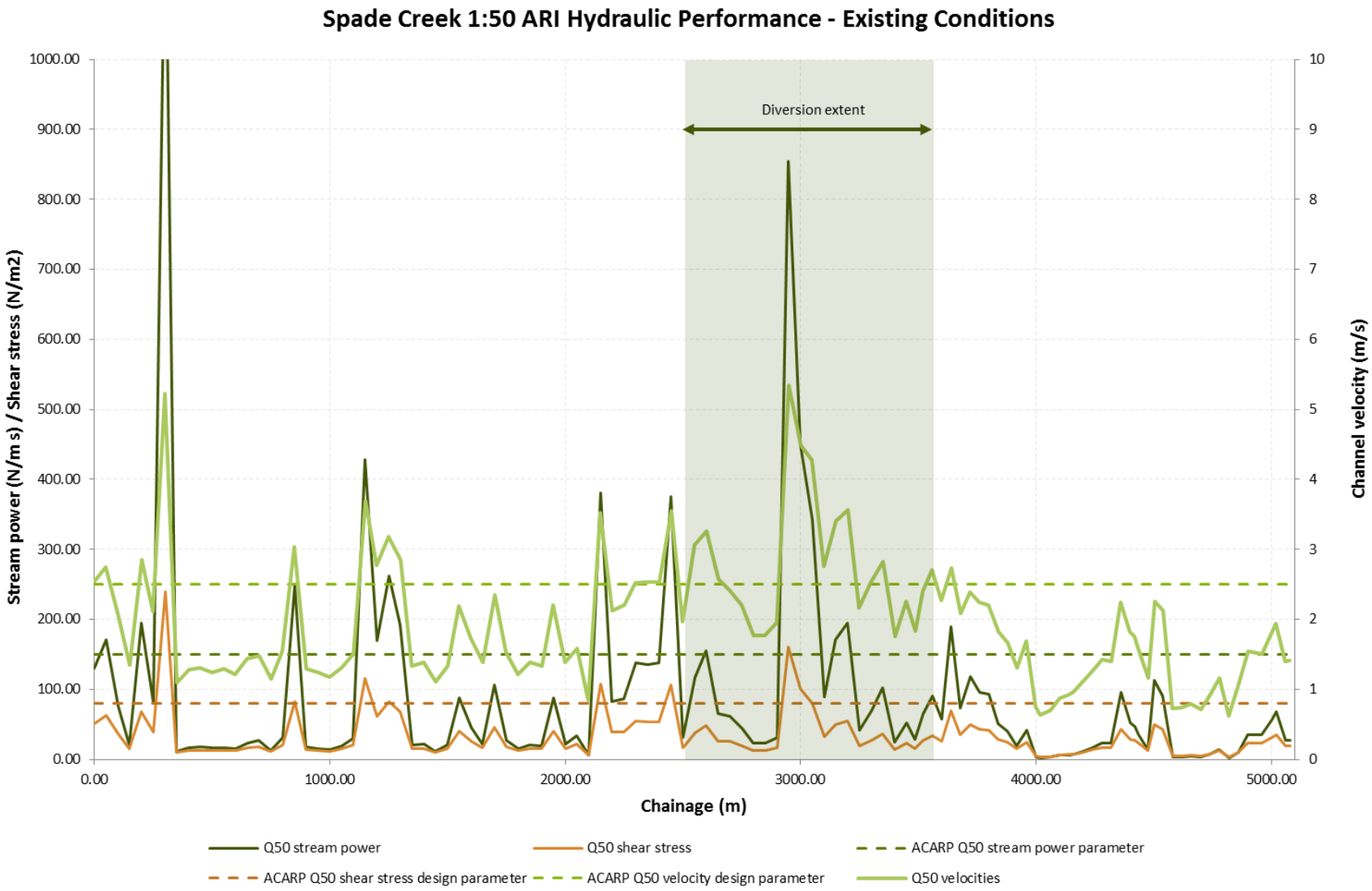


Figure 9-4. *Modelled 1:50 ARI hydraulic parameters for Spade Creek*

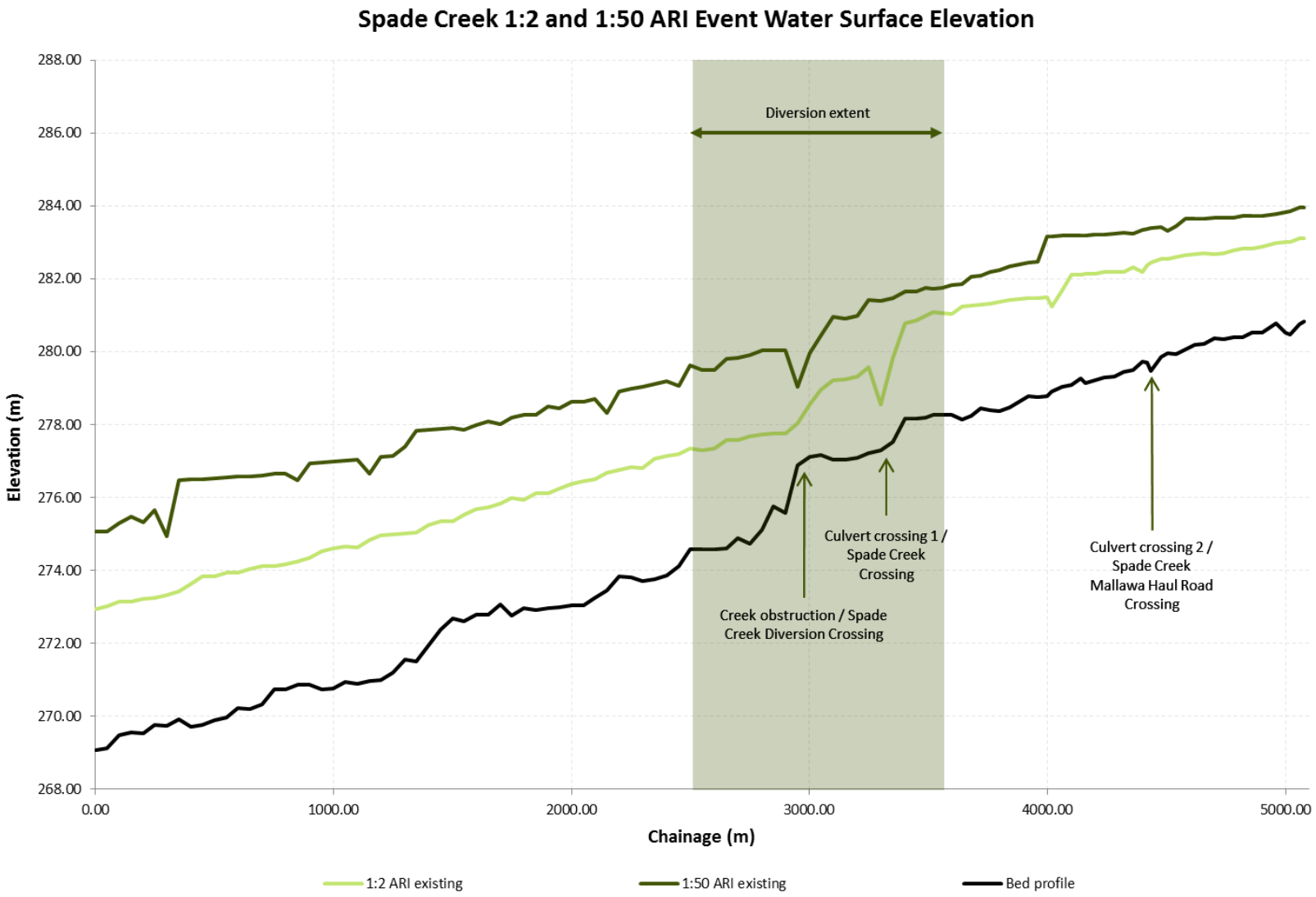


Figure 9-5. *Spade Creek water surface elevation existing conditions for 1:2 and 1:50 ARI events*

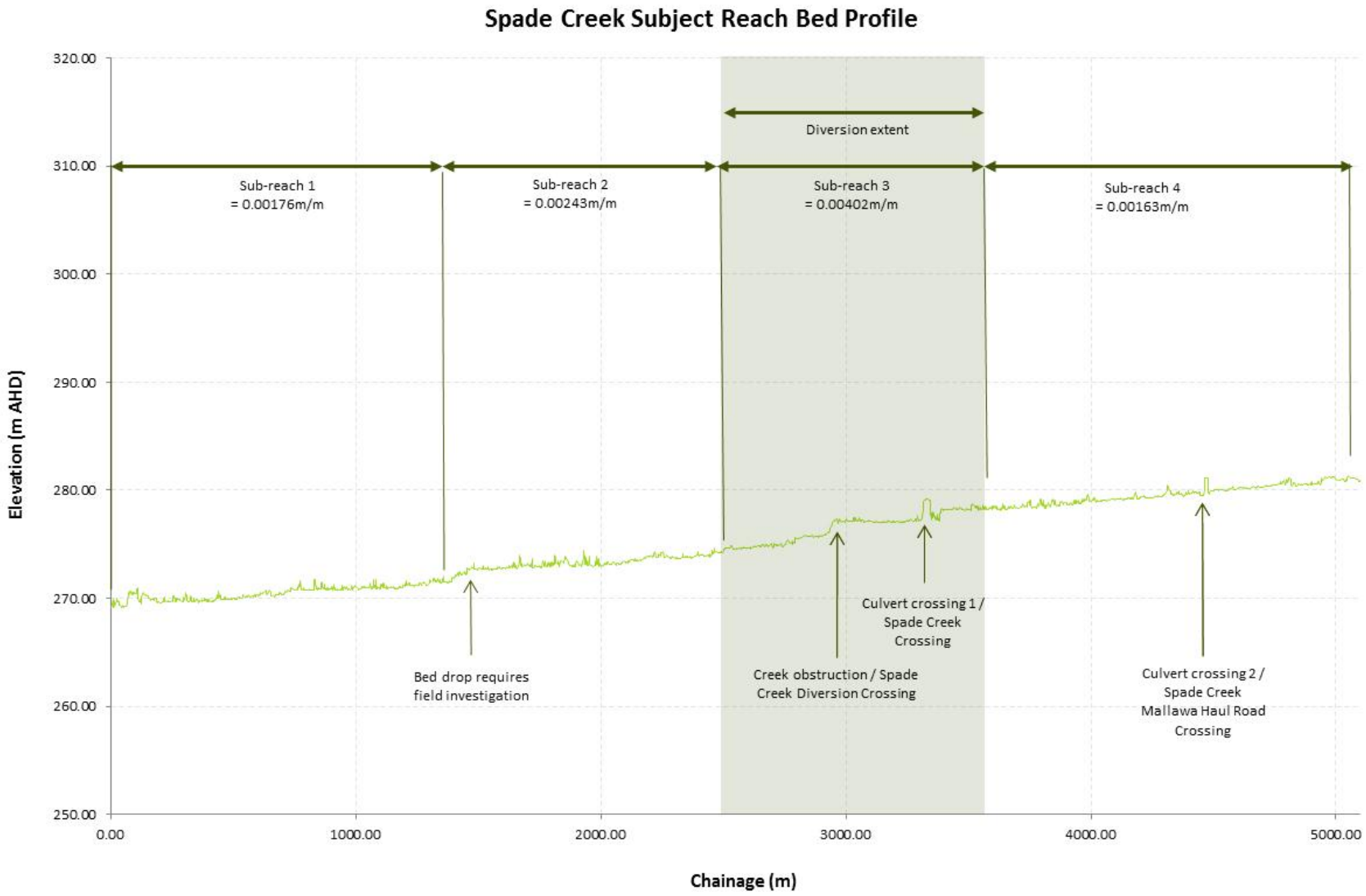


Figure 9-6. *Bed grade analysis of Spade Creek subject reach*

9.5 Summary and Recommendations

Modelling has demonstrated that the average stream parameter values for the reach upstream of the diversion are all below the recommended thresholds for diversions for both the 1:2 and 1:50 ARI events.

Through the diversion reach, the average value of velocity for the 1:50 ARI and average values of velocity and stream power for the 1:2 ARI exceed recommended thresholds. This is primarily as a result of the Spade Creek Crossing and associated steep gradient downstream of it which causes significant spikes in the velocity and stream power, driving both averages above threshold.

The average stream parameter values for the reach of Spade Creek downstream of the diversion are generally below recommended diversion thresholds for both the 1:2 and 1:50 ARI events. However, the recommended velocity threshold is exceeded for the 1:2 ARI event. This is not caused by any particular section of the reach; it is as a result of consistently high velocities along the entire reach. No field assessment to investigate stability and presence/absence of bedrock controls in this reach has been undertaken.

The overall longitudinal gradient of the diversion is 0.00402m/m, approximately double the gradient of the adjoining upstream and downstream reaches. With this overall gradient it would not be unusual for the diversion to be subject to high stream parameter values and substantial instabilities throughout the entire reach. However, the presence and continual maintenance, especially following flow events, of the two diversion road crossings presently mitigates this risk. Maintenance of the crossings holds the upstream bed elevation in place and prevents deepening of the bed from occurring. Materials washed out of the haul road during each event are depositing downstream, providing some armouring of the bed and thus limiting the potential for deepening to occur.

If the two road crossings were removed (or maintenance ceased) the gradient along the diversion would be too steep, and significant erosion would be expected to progress upstream with potential for substantial aggradation downstream of the diversion.

In its current form, the diversion is not considered to be a self-sustaining waterway and not likely to be suitable for licence relinquishment in the future. Therefore, rehabilitation of the diversion is recommended to reduce potential risks to the Burton Mining operation and environment, and establish it on a condition trajectory that is self-sustaining and suitable for the prospect of licence relinquishment in the future. Rehabilitation of the diversion is likely to involve lengthening to establish a stable longitudinal gradient without the requirement for ongoing maintenance of structures such as crossings.

Attachment E
Bullock Creek Diversion Compliance Report

10 Bullock Creek Diversion Overview

Alluvium has undertaken a diversion compliance assessment of the Bullock Creek diversion. The Bullock Creek diversion is approximately 650m in length and is located between the Bullock OOP Dump and Bullock Creek Pit, starting at the upstream Bullock Creek Haul Road crossing and extending downstream partway towards to the downstream Bullock Creek Haul Road crossing.

The Bullock Creek diversion is licenced under the *Water Act 2000* in accordance with Water Licence Reference number 577239.

10.1 Background

As the original Bullock Creek alignment intercepted the proposed Bullock Creek Pit, a watercourse diversion was required to undertake mining at that location.

The Bullock Creek diversion was designed by Mathew Palmer Consulting Engineers in 2009. Construction of the diversion was completed by Windsor Earthmoving Contractors in 2010.

Figure 10-1 illustrates the general arrangement of works for the Bullock Creek diversion as constructed.

10.2 Task objectives

The objective of this component of the report is to deliver a compliance check of construction against the proposed design for the Bullock Creek diversion.

The report provides a comparison of horizontal alignments, longitudinal profiles, cross sections, and other points of interest for the following sets of data:

- Bullock Creek diversion design strings created by Mathew Palmer Consulting Engineers (provided to Alluvium on 15 November 2012), and
- Bullock Creek diversion As Constructed survey compiled by Windsor Earthmoving Contractors (provided to Alluvium on 9 October 2012).

10.3 Bullock Creek diversion design

The Bullock Creek diversion report, completed by Mathew Palmer Consulting Engineers in October 2009, was commissioned by Burton Mine to carry out an evaluation of the channel requirements for the diversion of a section of Bullock Creek through their Burton Coal mining lease.

The Bullock Creek diversion report was provided to Alluvium on 24 September 2012 by Burton Mine. The following drawings, which formed part of Appendix B in the design report, have formed the basis for this comparative assessment:

- G0909-1-01 – General arrangement
- G0909-1-02 – Plan & longitudinal section
- G0909-1-03 – Cross sections sheet 1 of 3
- G0909-1-04 – Cross sections sheet 2 of 3
- G0909-1-05 – Cross sections sheet 3 of 3, and
- G0909-1-06 – Construction tables sheet 1 of 2, and Construction tables sheet 2 of 2.

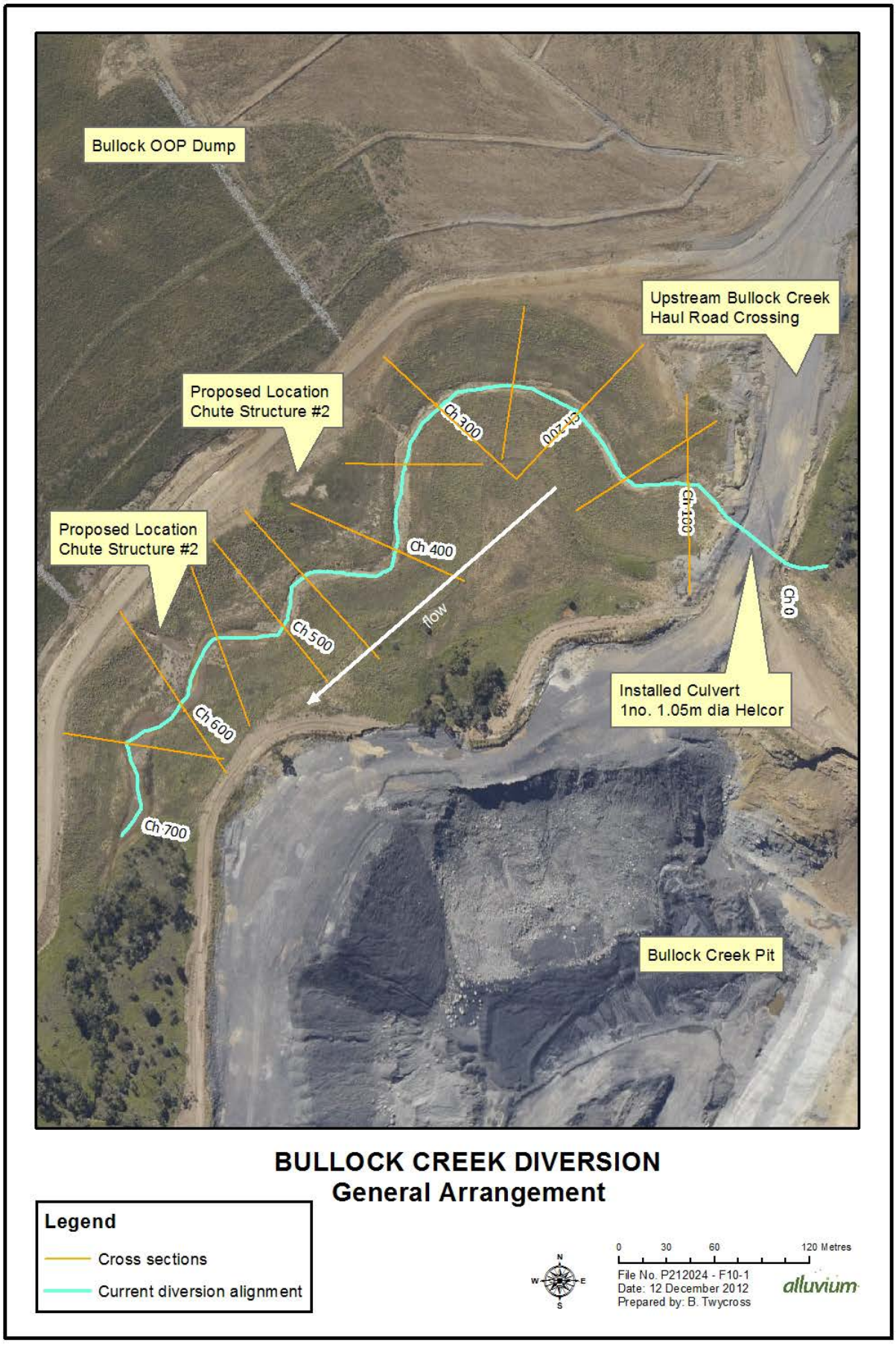


Figure 10-1. *Bullock Creek diversion general arrangement*

The typical section illustrated in Figure 10-2 was adopted for the design of the diversion and was used as a basis of comparison against the constructed works.

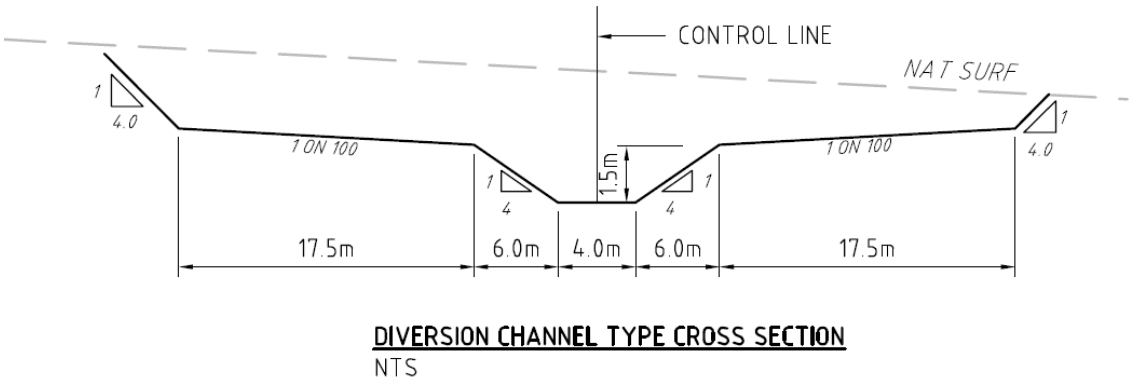


Figure 10-2. *Bullock Creek diversion typical cross section taken from Mathew Palmer Consulting Engineers (2009)*

The electronic design strings (in DXF form) were also provided to Alluvium by Burton Mine. These electronic design strings were used to generate a longitudinal profile and cross sections for comparison against the as constructed survey data. The data has been tabulated for comparison and is provided in Table 10-1.

Typically, the zero chainage for a watercourse would be located downstream of the reach. However, the design was completed with the zero chainage at the upstream section. Based on this, and for ease of comparing the as constructed report with the design report, the cross sections for comparison were cut using the design string provided, i.e. “cross section 0” is located at the most upstream point along the design reach.

10.4 Construction tolerances

For construction compliance, it is generally accepted that earthworks shall conform to the lines, grades and cross-sections shown on the drawings or as directed by the superintendent/designer. Design lines and levels define the required finished surface profile, inclusive of any surface treatments as specified on the drawings.

Given that Alluvium did not have access to the technical specification for the design of the Bullock Creek diversion, it is assumed that the following tolerances were applied to the construction works:

- **Formation width:** the widths measured on each side from the specified control-line to the toes of cut batters and/or tops of fill batters should not be less than the widths specified, and no portion of cut batters should encroach within these widths.
- **Batter slopes:** at all levels the average plane of the batters should not be steeper than the slope specified, within a vertical tolerance of 150mm, and shall have a neat and natural appearance.
- **Batter line**:

  Cut batters should be constructed so that the top of the batter is not more than 600 mm outside the planned batter line in the case of batters less than 3m high or 20% of the batter height in the case of higher batters. In sections where the width of work area is limited, batters should be constructed so that the tops of cut batters are not more than 300mm outside the planned batter line, and the toes of fill batters are not more than 600mm outside the planned batter line.

  Similarly, **fill batters** should be constructed so that the toe of the batter is not more than 1.2 m outside the planned batter line in the case of batters less than 6m high or 20% of the batter height in the case of higher batters.

Cut batters and fill batters typically should not be constructed to grades steeper than shown on the project drawings without the approval of the designer/superintendent.

10.5 Comparison results

Longitudinal and cross sectional profiles have been produced comparing the design surface with the As Constructed surface of the all the major features including: diversion channel and rock chutes.

Diversion channel

The diversion channel has been constructed along the design alignment, achieving the desired length and overall bed grade. See Figure 10-3 for a photo of the general diversion and floodplain.

A plan view was prepared to compare the design and As Constructed alignment; see Figure 10-4.

Longitudinal and cross sectional profiles have been produced comparing the design surface with the As Constructed surface and the 2012 LiDAR data set. The cross sections, attached at the end of the report, were taken at regular chainages which correspond with the design cross section profiles. A longitudinal section profile has also been provided and is attached at the end of the report.

Table 10-1 provides a summary and comparison of the Bullock Creek Diversion design longitudinal section against the As Constructed surface and 2012 LiDAR surface.

Table 10-1. Comparison of Bullock Creek Diversion design longitudinal section using various data sets

	Data set	2009 design surface	As Con survey surface	2012 LiDAR surface
	Method of capture / development	Design strings	Topographic survey	LiDAR
	Acquired / Designed	27/10/2009	6/05/2010	04/05/2012
	Units	m AHD	m AHD (Diff. to 2009 surface)	m AHD (Diff. to 2009 surface)
Chainage (m) – see Figure 10-4	50	330.73	330.95 (0.21)	336.72 (5.99)
	100	330.37	330.36 (-0.01)	331.16 (0.79)
	150	330.02	329.84 (-0.18)	330.22 (0.20)
	200	329.66	329.60 (-0.06)	330.13 (0.47)
	250	329.30	329.14 (-0.16)	329.54 (0.25)
	300	328.95	328.87 (-0.07)	329.36 (0.42)
	350	328.58	328.41 (-0.18)	329.05 (0.46)
	400	328.22	328.01 (-0.21)	328.75 (0.53)
	450	327.86	327.82 (-0.04)	328.47 (0.62)
	500	327.50	327.27 (-0.23)	328.20 (0.70)
	550	327.14	326.96 (-0.17)	327.94 (0.81)
	600	326.77	326.62 (-0.15)	327.83 (1.06)
	650	326.41	326.38 (-0.03)	327.58 (1.17)
	700	326.05	325.68 (-0.37)	327.43 (1.38)

In general, the following observations were made regarding the comparison of the available information:

- The constructed alignment is generally along the proposed design alignment. At approximate chainages 200, 270, 550, 600 and 650 the constructed alignment is slightly straighter than the design alignment and is approximately offset by three metres at these points.
- The longitudinal profile shows small fluctuations in the As Constructed survey with the creation of small pools in some sections and small sediment deposits in other sections. The As Constructed bed surface is slightly lower than the proposed design surface from chainage 450 to 700 which possibly demonstrates slight erosion following lower flows in this area. The higher levels in the survey are likely to represent minor sediment deposits following local sediment inputs from the diversion batters.

- Bed width and overall channel dimensions meet design intent based on the cross sections, despite slight variations in the horizontal alignment of the diversion channel.
- Bench height and cross fall toward the low flow channel meet design intent. There are some local variances in bench width and height, particularly at cross section 150, 350, 400 and 450.
- In general, the 2012 LiDAR data surface shows that significant aggradation has occurred since construction was completed in mid-2010.

It was not confirmed at the time of this report, whether the Bullock Creek diversion channel was topsoiled, deep ripped and revegetated.

10.6 Construction of chutes

The designer proposed the construction of two rock chute structures approximately at chainages 350 and 600, respectively. Based on aerial photography of the diversion, it shows that the rock chute structures were constructed in approximately the locations that were proposed. Given that a site inspection was not carried out by Alluvium engineers as part of this compliance report, a detail assessment cannot be made of the construction of the rock chutes.

10.7 Design compliance and summary

Based on the assumed construction tolerances set out in section 10.4, the construction of the Bullock Creek diversion tends to comply with the proposed design. It appears that either minor modifications to design were made during construction or small changes have occurred since the operation of the diversion.

It should be noted that while the dimensions of levee construction can be confirmed as part of this report, confirmation of suitable construction with regards to materials and standards should be supplied by a suitably qualified engineer or the project superintendent.



Figure 10-3. *Bullock Creek diversion and floodplain*



Figure 10-4. *Bullock Creek diversion plan view comparison of design and as constructed*

Attachment F
Bullock Creek Hydraulic Analysis

11 Overview of Bullock Creek Hydraulic Assessment

Bullock Creek is a watercourse within the Teviot Brook catchment. The section of the Bullock Creek under investigation in this hydraulic analysis is 3630m long (hereafter "subject reach"). It is located at the northern end of the Teviot Brook catchment and encompasses the Bullock Creek diversion, which is approximately 860m long and diverts water around the Bullock Creek Pit. See Figure 11-1.

The Bullock Creek diversion is licenced under the *Water Act 2000* in accordance with Water Licence Reference number 577239.

HEC RAS modelling of the Bullock Creek diversion has been undertaken to determine the existing conditions hydraulic parameters.

This section outlines the methodology for this process and offers some recommendations to manage the stream processes resulting from the operation of the Bullock Creek diversion.

11.1 Hydraulic modelling overview

During a hydraulic assessment of a watercourse, a number of key hydraulic parameters are analysed which includes stream power, velocity, and shear stress. These parameters allow for comparative assessment between waterways and against diversion design criteria established in ACARP (2002).

The diversion design criteria established by ACARP (2002) is based on reach average parameter values of actual existing creeks within the Bowen Basin in Central Queensland and is detailed in Table 11-1.

Table 11-1. Bowen Basin diversion design criteria (reach average) (ACARP 2002)

Scenario	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
1:2 ARI event in channel with vegetation	20 to 60	1.0 to 1.5	<40
1:50 ARI event in channel with vegetation	100 to 150	1.5 to 2.5	<80

This design criterion can be used as threshold design levels for rehabilitation works, and are described in more detail in Section 9.1.

11.2 Catchment hydrology

A detailed hydrologic assessment of Bullock Creek catchment was undertaken by Alluvium and is presented in Attachment A. The estimated flow rates for the 1:2 ARI and 1:50 ARI events through Bullock Creek diversion are shown in Table 11-2.

Table 11-2. Estimated flow rates for 1:2 and 1:50 ARI events through Bullock Creek

Flow Change Location	Chainage (m)	ARI	Peak Flow Rate (m^3/s)
A	3618	2	5
		50	16
B	3078	2	9
		50	27

The extent of the Spade Creek hydraulic model and the flow change locations are illustrated in Figure 11-1.

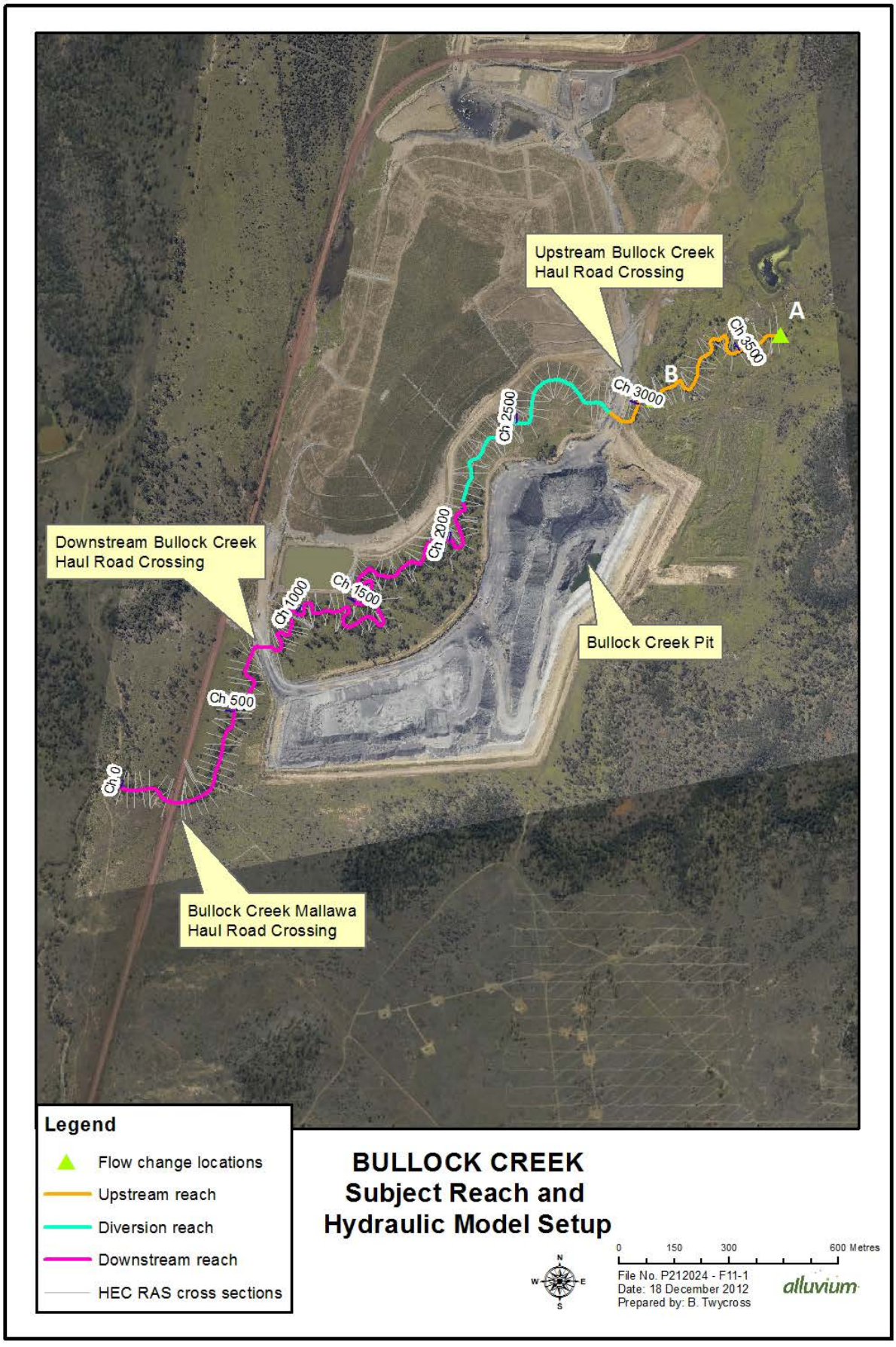


Figure 11-1. *Bullock Creek subject reach and hydraulic model setup*

11.3 Model setup

The HEC RAS model is formed by creating a series of cross-sections, extracted from the digital terrain model (DTM), which extend across the channel and onto the floodplain on either side. Other inputs into the model include the Manning's roughness coefficient (n), model boundary conditions, topographic data, and flow estimates for the main channel as outlined in section 11.2.

The subject reach was divided into three sections for the HEC RAS assessment: upstream reach; diversion reach; and downstream reach. Cross sections for the model were typically created at 20m intervals for the entire length of the subject reach. This is with the exception of areas of interest, such as steep sections and road crossings, where finer accuracy was used.

Manning's roughness coefficient (n) varies between the channel and floodplain and represents the frictional resistance to flow by the surface and shape of the bed and banks, vegetation and debris of the channel and floodplain. Typically, these values would vary considerably across the model extents at a local scale.

The values were selected and applied to the model using an aerial image to determine vegetation cover and channel form. Identified vegetation types and corresponding roughness are detailed in Table 11-3.

Table 11-3. Vegetation types and adopted manning's "n" value's for Bullock Creek hydraulic model

Category	Description	n Value
Dense Riparian/ Clean, Winding, Sand Bed	Dense vegetation along the majority of Bullock Creek. An average of bed and banks.	0.065
Medium Density Riparian/Clean, Straight	Sections of diversion where some regeneration has occurred, or natural creek with medium cover	0.035
Low Density Riparian/Clean, Straight	Sections of diversion where negligible regeneration has occurred.	0.025

The boundary conditions for the model were determined using the known upstream and downstream normal depths for the model, as outlined in Table 11-4.

Table 11-4. Upstream and downstream setting adopted for Bullock Creek hydraulic model

Boundary	Adopted normal depth slope (m/m)
Upstream	0.0117
Downstream	0.0020

The topographic data used to undertake this analysis included the three road crossings over Bullock Creek:

- Upstream Bullock Creek Haul Road Crossing
- Downstream Bullock Creek Haul Road Crossing, and
- Bullock Creek Mallawa Haul Road Crossing.

Table 11-5 provides detail on the culverts that were included in the model and Table 11-6 outlines the parameters that were adopted for the three culverted crossings.

Table 11-5. Bullock Creek culvert details for hydraulic assessment

Culvert crossing	Culvert type	Number of culverts	Diameter (mm)	Upstream invert level (m AHD)	Downstream invert level (m AHD)	Other details
Bullock Creek HR Upstream	CMP	2	1600	332.00	331.80	Highly damaged; 75% blocked
Bullock Creek HR Downstream	CMP	2	1600	321.40	321.00	Damaged in centre; 25% blocked

Culvert crossing	Culvert type	Number of culverts	Diameter (mm)	Upstream invert level (m AHD)	Downstream invert level (m AHD)	Other details
Mallawa Haul Road	Helcor	2	1050	318.50	317.00	-

Table 11-6. Bullock Creek culvert crossing adopted parameters for hydraulic assessment

Parameter	Adopted value
Entrance loss coefficient (k_{en})	0.9 (Table 6-3 HEC RAS Reference Manual, CMP projecting from fill)
Manning's "n" value	0.024 (Table 6-1 HEC RAS Reference Manual, applied to top and bottom of culvert)

11.4 Results

In order to assess the existing hydraulic conditions of Bullock Creek, the subject reach has been divided into three separate reaches: upstream of the diversion off take (upstream of chainage 3040); the diversion (chainage 2170 to 3040); and downstream of the constructed diversion tie-in (at chainage 2170).

The tabulated results for each reach are presented below in Table 11-7 for the upstream reach, Table 11-8 for the diversion reach and Table 11-9 for the downstream reach.

Hydraulic parameter plots for the entire subject reach for the 1:2 and 1:50 ARI events are presented below in Figure 11-2 and Figure 11-3, respectively. The graphs of each parameter must be understood in context of local and reach scale geomorphic characteristics due to the dramatic appearance of spikes that exceed threshold levels. If these spikes are localised and not in consecutive cross sections then they do not necessarily represent an area of instability.

Upstream reach

Table 11-7, Figure 11-2 and Figure 11-3 demonstrate that the average hydraulic parameter values of the upstream reach are mostly below recommended threshold levels for diversions. For the 1:2 ARI event the stream power and velocity parameters exceed the "no vegetation" threshold however the reach is moderately vegetated so can probably be considered acceptable.

It should be noted that the Upstream Bullock Creek Haul Road Crossing acts as a weir (see Figure 11-4) and supresses stream parameters for 200m upstream. This issue is addressed in more detail in Section 11.5.

Table 11-7. Upstream Bullock Creek reach hydraulic characteristics

Parameter	Units	ARI	Bowen Basin diversion criteria (reach average)	Modelled parameters		
				Minimum	Maximum	Average
Shear Stress	N/m^2	1:2	<40	0.41	78.60	30.20
		1:50	<80	3.54	114.85	50.47
Stream Power	N/m.s	1:2	no vegetation <35 with vegetation <60	0.08	177.34	53.61
		1:50	<150*	2.11	327.80	114.77
Velocity	m/s	1:2	no vegetation <1.0 with vegetation<1.5	0.20	2.26	1.23
		1:50	<2.5	0.59	2.85	1.82

Diversion reach

Table 11-8, Figure 11-2 and Figure 11-3 demonstrate that the average hydraulics of the diversion reach are mostly below recommended threshold levels for diversions.

Average stream power and velocity both exceed threshold for the 1:2 ARI event however this is primarily as a result of the Upstream Bullock Creek Haul Road Crossing overtopping. The very high peak velocities and stream power (for both the 1:2 and 1:50 ARI) are likely to cause erosion and deepening of the channel bed.

At the downstream end of the diversion reach, higher WSEs for both the 1:2 and 1:50 ARI are most likely the result of a confinement of the floodplain where the diversion ties-in with the downstream reach. This is resulting in lower stream parameters at this section.

Sensitivity testing demonstrated that restoring culvert capacity did little to change the hydraulics through the diversion reach. This issue is addressed in more detail in Section 11.5. Alternatively, revegetation of the diversion reach would be sufficient to increase the allowable threshold to the point where only the stream power would exceed threshold however this would not address the issue of water overtopping the haul road.

Table 11-8. Bullock Creek diversion reach hydraulic characteristics

Parameter	Units	ARI	Bowen Basin diversion criteria (reach average)	Modelled parameters		
				Minimum	Maximum	Average
Shear Stress	N/m^2	1:2	<40	0.09	285.98	23.22
		1:50	<80	0.51	334.45	35.98
Stream Power	N/m.s	1:2	no vegetation <35 with vegetation <60	0.01	1452.32	66.95
		1:50	<150*	0.16	2133.21	135.23
Velocity	m/s	1:2	no vegetation <1.0 with vegetation<1.5	0.14	5.08	1.32
		1:50	<2.5	0.31	6.38	1.85

Downstream reach

Table 11-9, Figure 11-2 and Figure 11-3 demonstrate that the average hydraulics of the downstream reach are all below recommended threshold levels for diversions. However, it should be noted that both the Downstream Bullock Creek Haul Road Crossing and Mallawa Haul Road Crossing act as weirs (see Figure 9-5) and supress stream parameters for some distance upstream. In the case of the Mallawa Haul Road, sedimentation has occurred upstream of the crossing part way up to the Downstream Bullock Creek Haul Road Crossing and creates a disconnect with the longitudinal profile of the downstream reach (see Figure 11-4 and Figure 11-5). Haul Road failure would most likely result in deepening and widening of the reach upstream and poses a long term threat to the stability of the diversion and may threaten levee integrity and increase the flood risk to the mine.

Table 11-9. Bullock Creek downstream reach hydraulic characteristics

Parameter	Units	ARI	Bowen Basin diversion criteria (reach average)	Modelled parameters		
				Minimum	Maximum	Average
Shear Stress	N/m2	1:2	<40	0.33	136.37	24.24
		1:50	<80	0.68	173.50	34.13
Stream Power	N/m.s	1:2	no vegetation <35 with vegetation <60	0.06	382.65	43.87
		1:50	<150*	0.19	614.16	78.97
Velocity	m/s	1:2	no vegetation <1.0 with vegetation<1.5	0.18	2.81	1.17
		1:50	<2.5	0.29	3.54	1.50

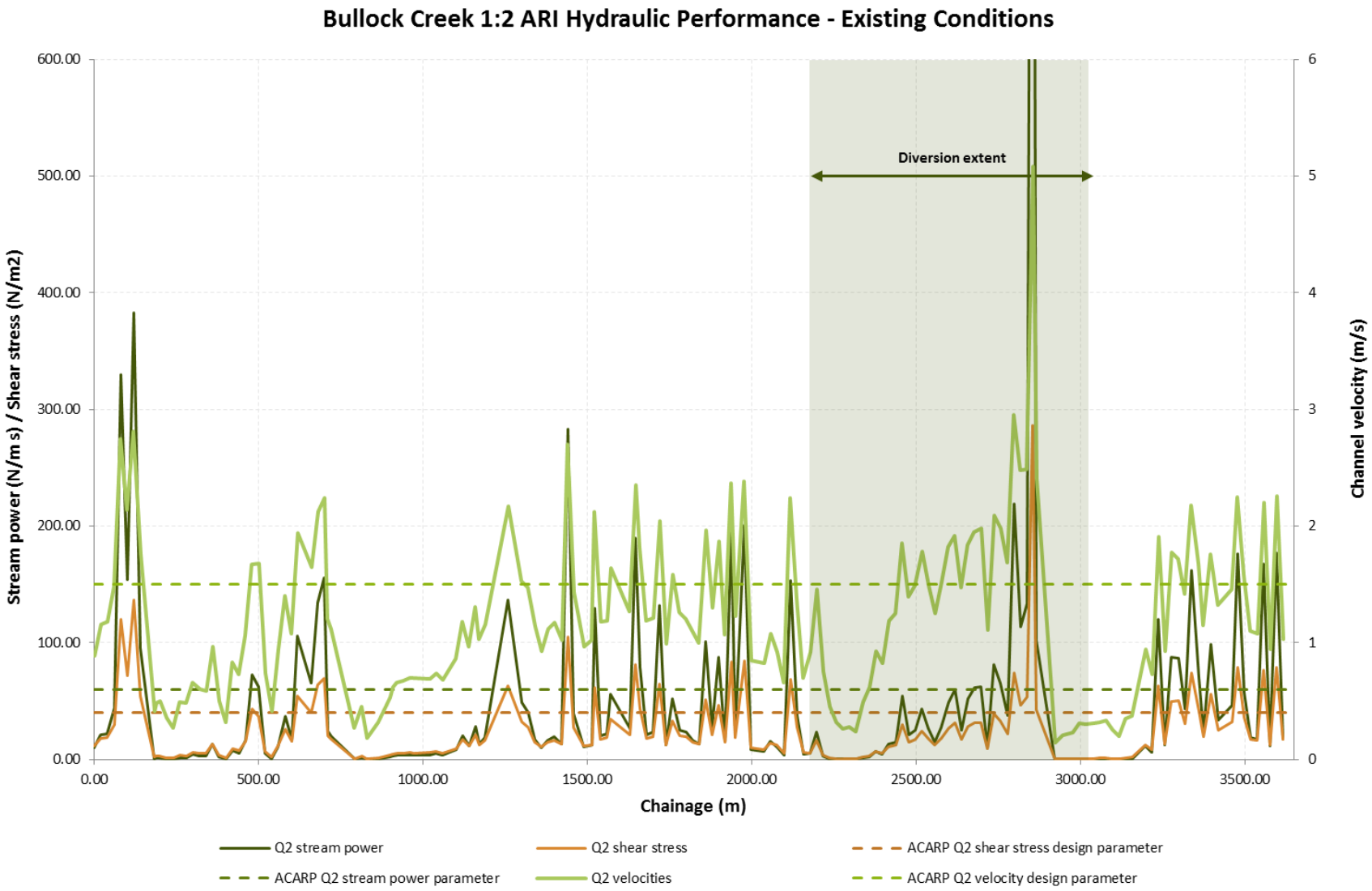


Figure 11-2. *Modelled 1:2 ARI hydraulic parameters for Bullock Creek*

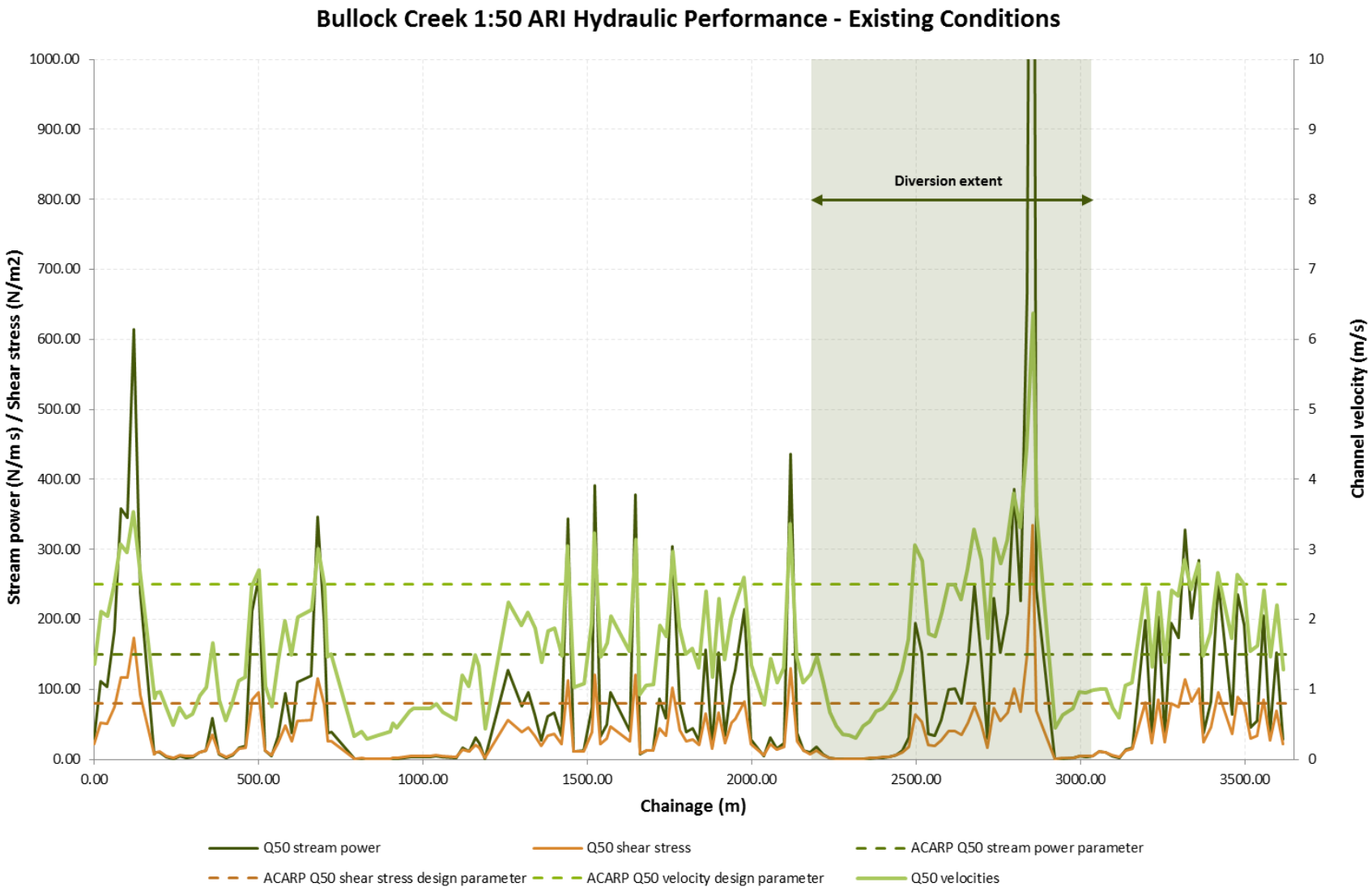


Figure 11-3. *Modelled 1:50 ARI hydraulic parameters for Bullock Creek*

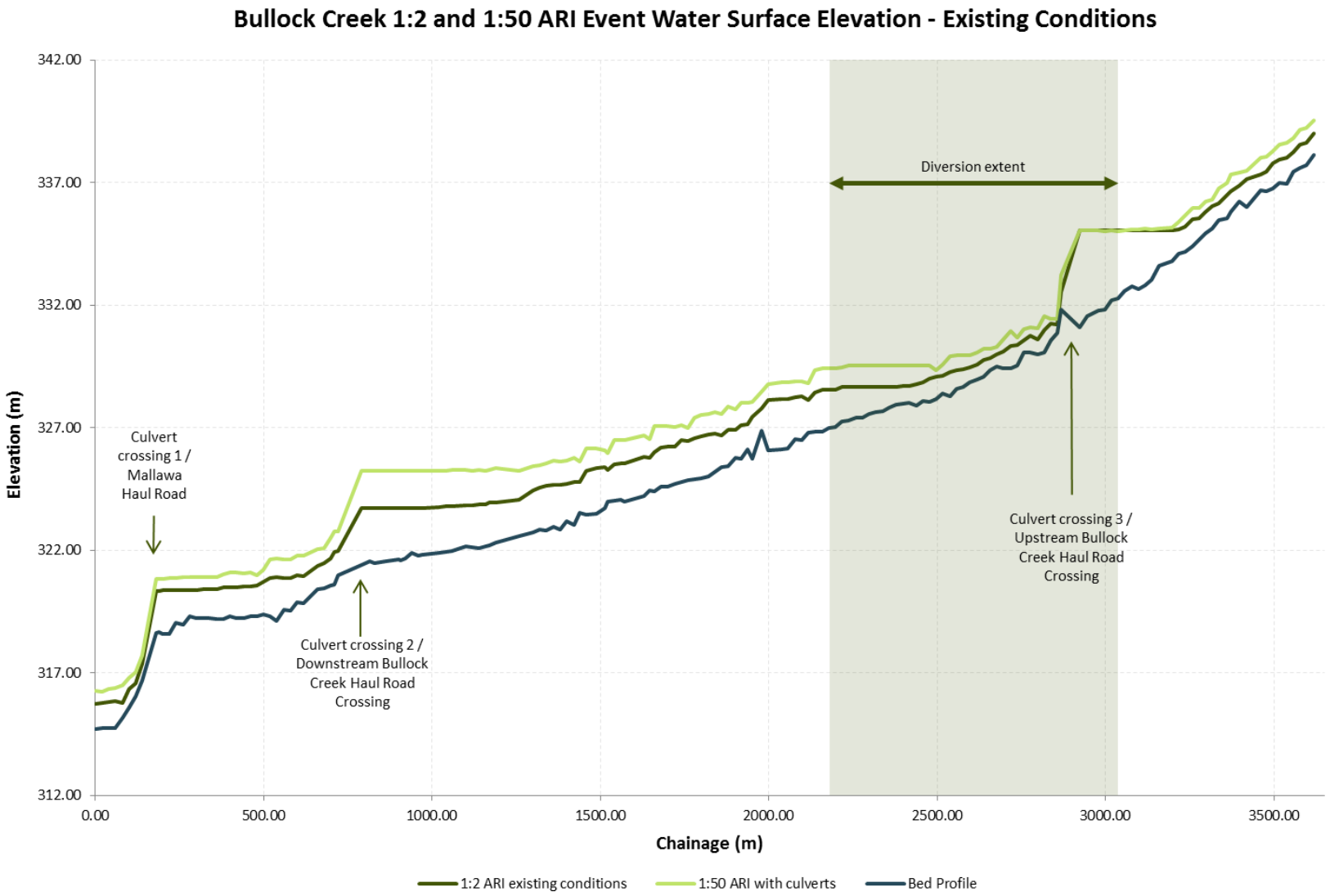


Figure 11-4. *Bullock Creek water surface elevation existing conditions for the 1:2 and 1:50 ARI events*

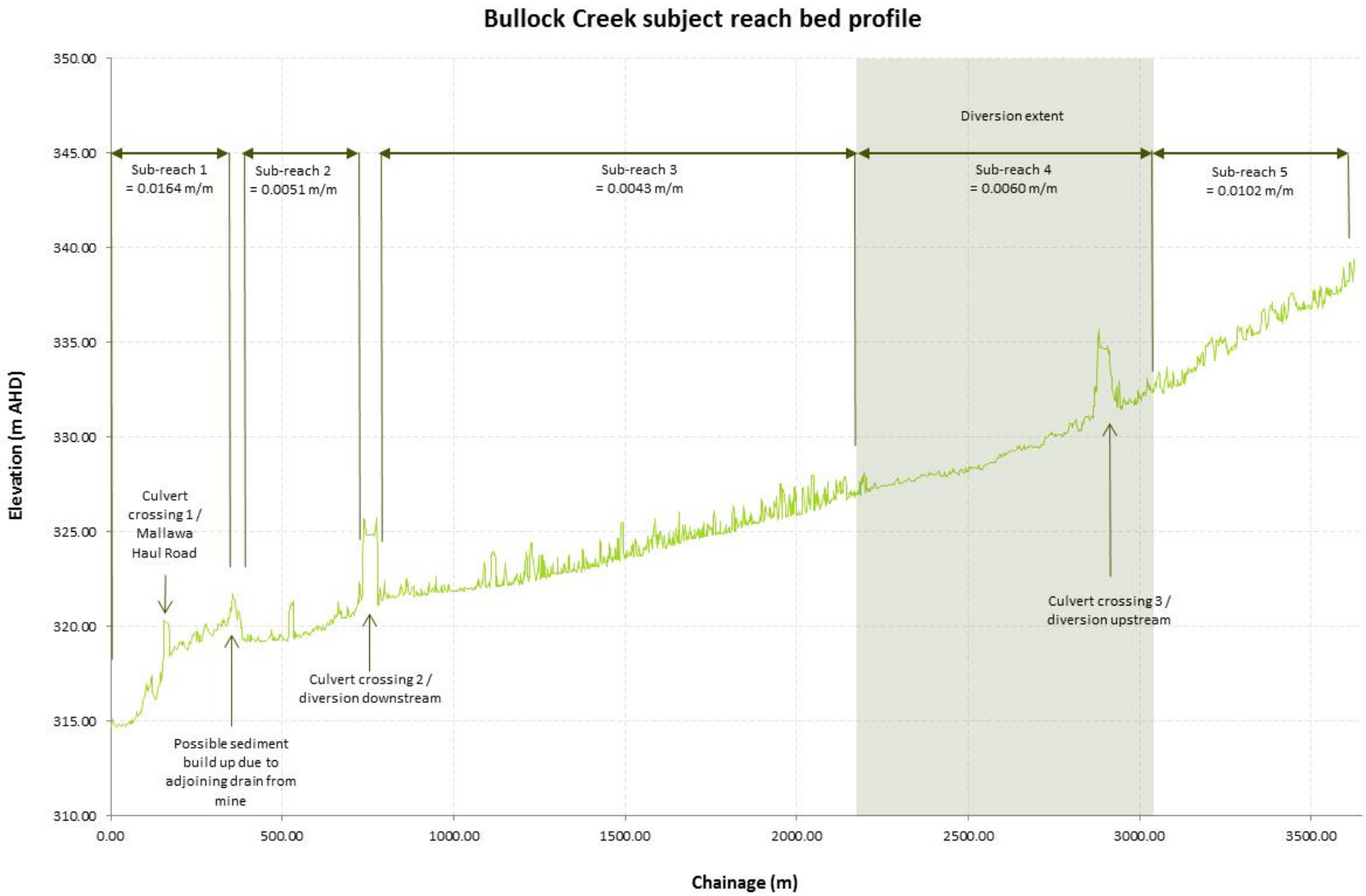


Figure 11-5. *Bed grade analysis of Bullock Creek subject reach*

11.5 Model sensitivity to Upstream Bullock Creek Haul Road Crossing culvert blockage

The culverts passing under the Upstream Bullock Creek Haul Road Crossing (at chainage 2900) are highly damaged and have been assumed to be approximately 75% blocked (refer to Table 11-5).

In order to quantify the impact of this assumption, sensitivity testing was undertaken to compare the effect of completely restoring culvert capacity and it was determined that, as a result of the reduced backwater effect, this scenario tended to increase parameters upstream and downstream of the crossing but reduced parameters directly at the crossing.

In the case of the 1:2 ARI, little impact occurred at, or downstream of, the crossing. However, the parameters upstream, in the 200m length which backwaters due to the mostly blocked culverts, increased to meet or slightly exceed the recommended threshold levels for diversions.

For the 1:50 ARI, unblocking the culverts had a very limited effect upstream but did increase parameters downstream. As a result of the increased capacity, the hydraulics over the road itself dropped noticeably, particularly for velocity and shear stress. However, the reach average hydraulics did not exceed threshold and the peaks value over the road crossing did not decrease enough to reduce the likelihood of erosion.

The differences for stream power, velocity and shear stress are illustrated from Figure 11-6 to Figure 11-8, respectively.

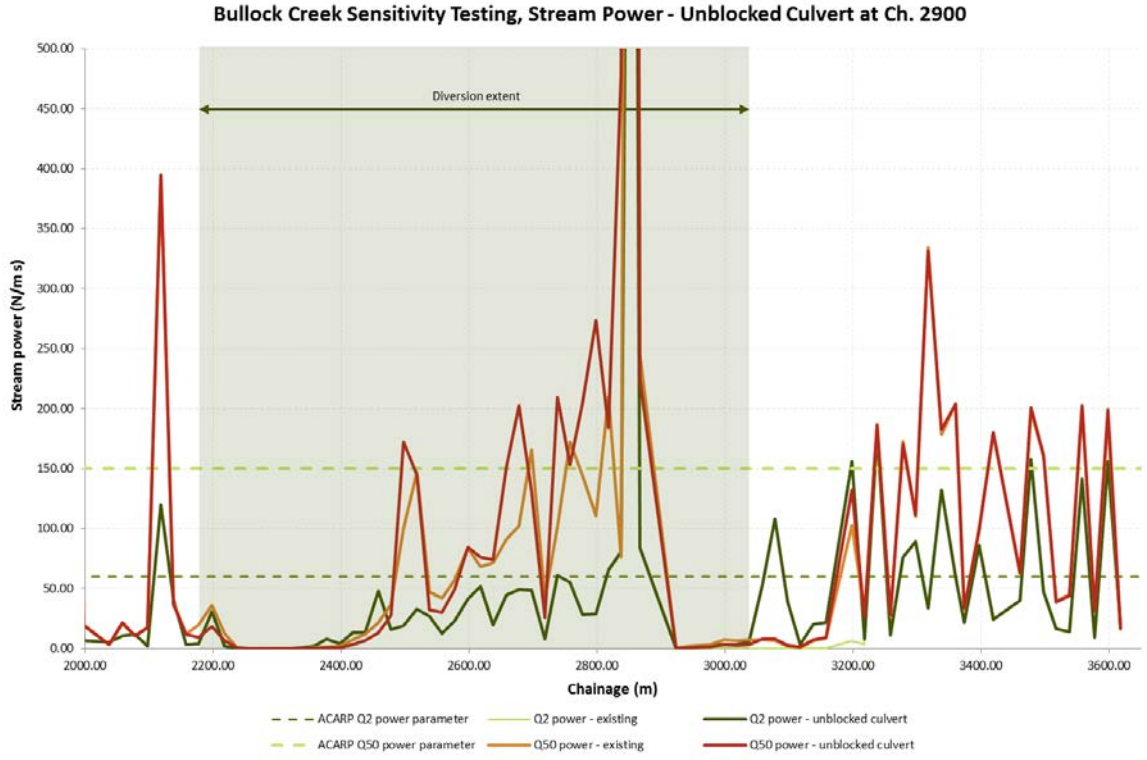


Figure 11-6. *Sensitivity testing, effect of unblocking the culverts at chainage 2900 on stream power*

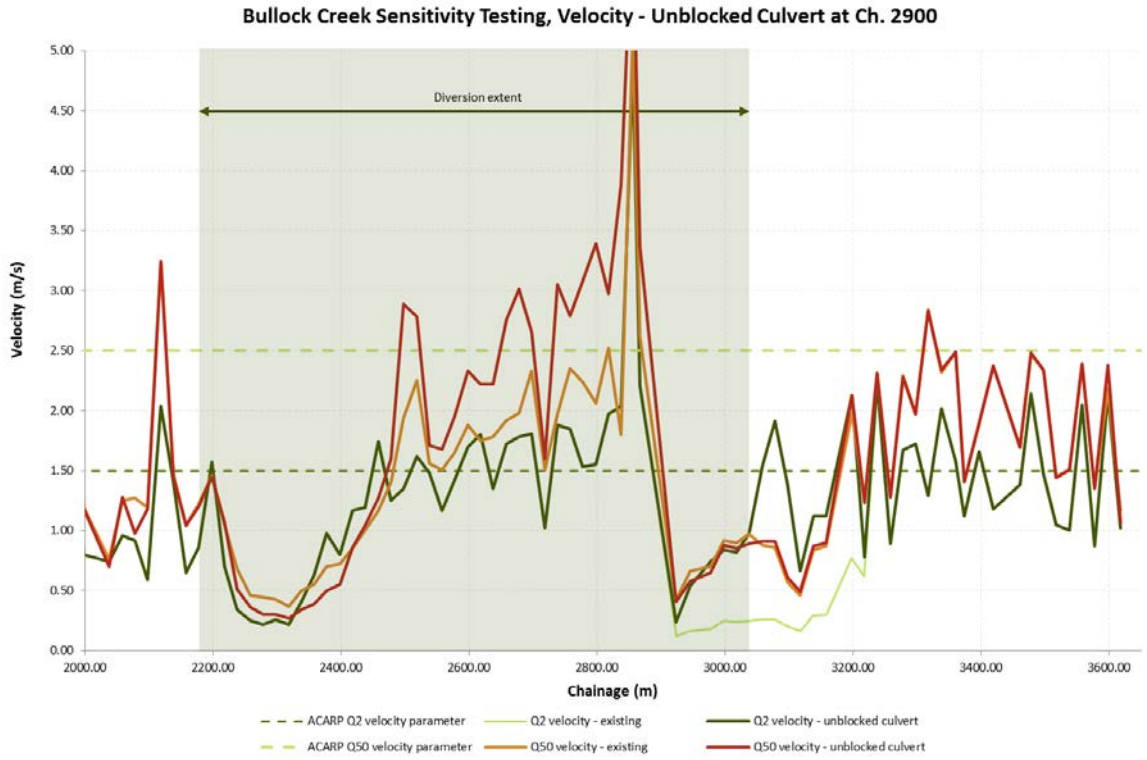


Figure 11-7. *Sensitivity testing, effect of unblocking the culverts at chainage 2900 on velocity*

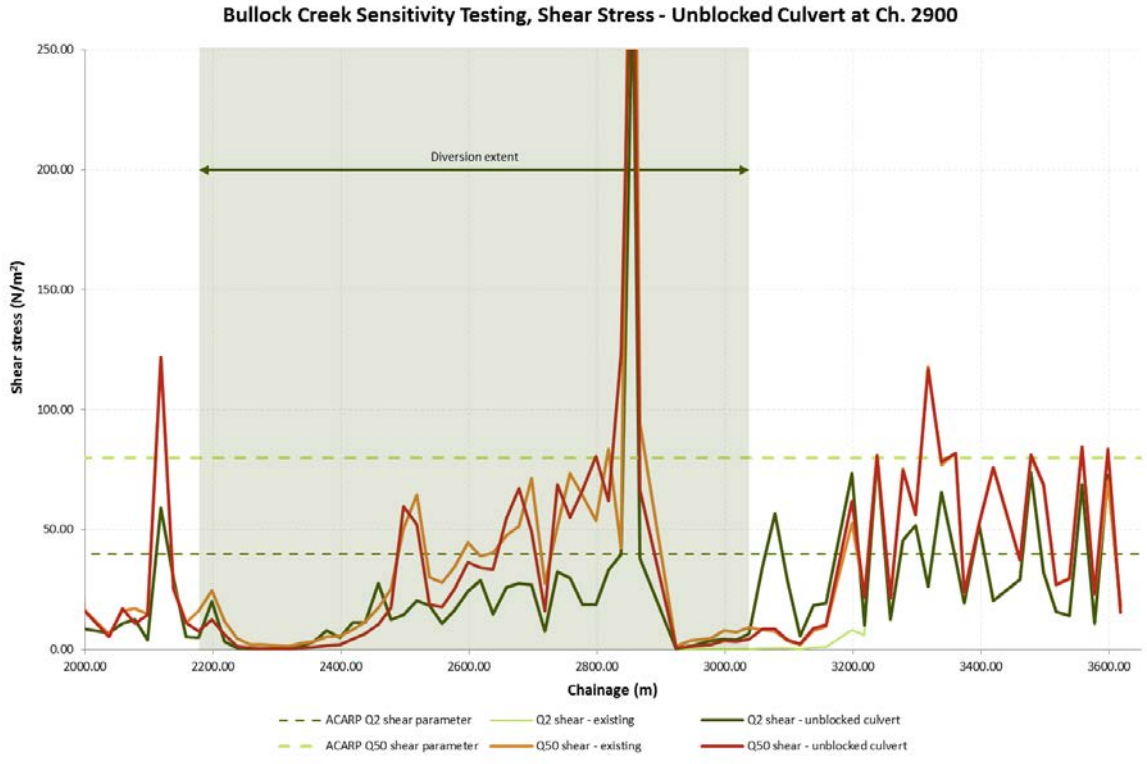


Figure 11-8. *Sensitivity testing, effect of unblocking the culverts at chainage 2900 on shear stress*

11.6 Summary and Recommendations

Modelling has demonstrated that the average stream parameter values for the reach upstream of the Bullock Creek Diversion are all below recommended threshold levels for diversions for both the 1:2 and 1:50 ARI events. Increased headwater elevation upstream of the Upstream Bullock Creek Haul Road Crossing is resulting in a decrease in stream parameter values for both the 1:2 and 1:50 ARI events for approximately 300m in the upstream reach.

Through the diversion reach, average parameter values are mostly below recommended thresholds with the exception of the 1:2 ARI stream power. The high stream power value is largely a result of the overtopping of the Upstream Bullock Creek Haul Road Crossing which causes a large localised spike in all stream parameter values. It should be noted that the overall longitudinal bed gradient of the diversion is 0.0060m/m, approximately double the gradient of the adjoining downstream reach and half the gradient of the adjoining upstream reach, and average stream parameter values through the diversion reach are influenced by two backwater zones. A floodplain confinement just downstream of the diversion increases water surface elevations (and thus reduces stream parameter values) through the downstream portion of the diversion and the haul road crossing has a similar effect at the upstream end of the diversion. The removal of the haul road may be a long term option to stabilise the hydraulic parameters.

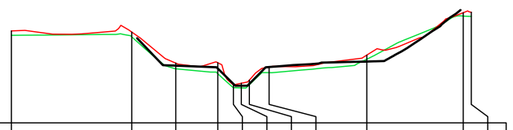
The average stream parameter values for the reach of Bullock Creek downstream of the diversion are all below recommended thresholds for both the 1:2 and 1:50 ARI events. As was the case for the upstream reach, these low stream parameters are influenced by increased headwater elevations resulting from the respective road crossings: Downstream Bullock Creek Haul Road Crossing, and Mallawa Haul Road Crossing. Also associated with these crossings are localised elevated parameter values which suggest that whilst the roads are in operation, continued maintenance will be required. The difference in bed level upstream and downstream of the Mallawa Haul Road crossing requires further investigation as the risk of major bed deepening upstream of it appears substantial.

With these modelling results and limited on-ground assessment, it is difficult to draw accurate conclusions about the performance of the diversion and likely suitability for future licence relinquishment (assuming the haul road would be removed for the relinquishment scenario). It is recommended that the diversion be modelled without the haul road in place and further on-ground assessment be undertaken (if required) to better understand potential suitability for future licence relinquishment.

As highlighted in Section 11.4, vegetative rehabilitation of the diversion reach will assist by reducing stream parameters and providing increased resistance to erosion from stream flows.

NOTES

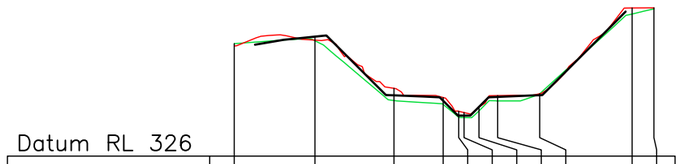
1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.



Datum RL 327

2009 DESIGN				331.66	331.42	330.17	330.02	330.18	331.54	331.99	
2012 LIDAR	334.49	334.39	331.86	331.89	330.09	330.22	330.48	331.54	332.52	335.97	336.01
ASCON	334.13	334.00	331.40	331.00	329.86	329.84	330.11	331.09	332.19	335.69	335.67
OFFSET FROM DESIGN CL	-75.00	-35.71	-21.38	-7.65	-2.60	0.00	2.61	9.06	40.92	72.40	75.00

CH 150.00



Datum RL 326

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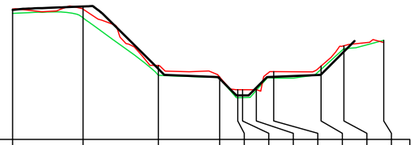
ASCON	335.16	335.39	330.53	330.21	329.15	329.14	329.68	330.50	331.08	337.58	338.00
OFFSET FROM DESIGN CL	-75.00	-48.67	-22.90	-6.82	-1.75	0.00	4.84	10.94	24.66	54.80	61.90

CH 250.00



Datum RL 325

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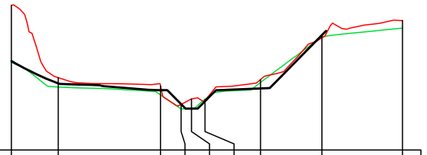

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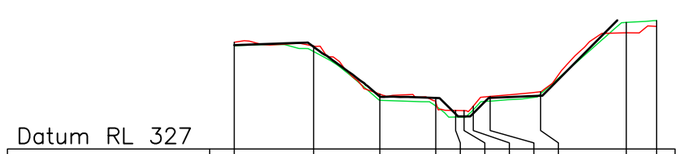

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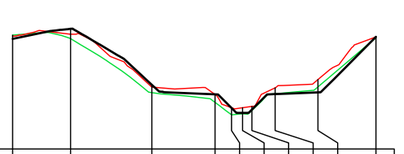

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CH 300.00

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BURTON MINE

BULLOCK CREEK DIVERSION

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CROSS SECTIONS 1 OF 2

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Sheet No. 1 File Name: P212024_001-003.dwg
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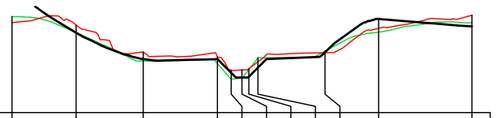

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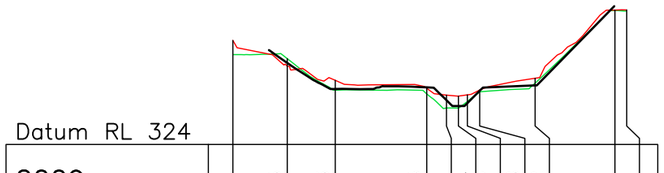

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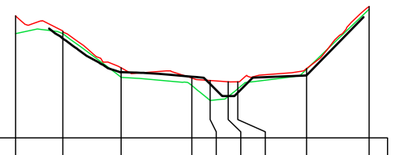

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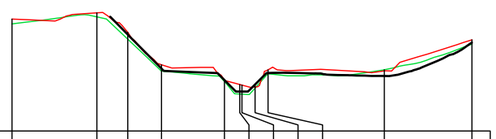

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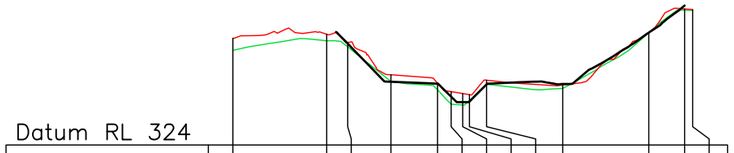

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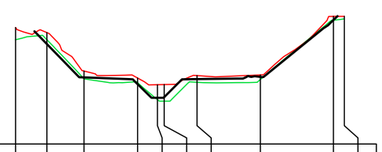

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Sheet No. 2 File Name: P212024_001-003.dwg
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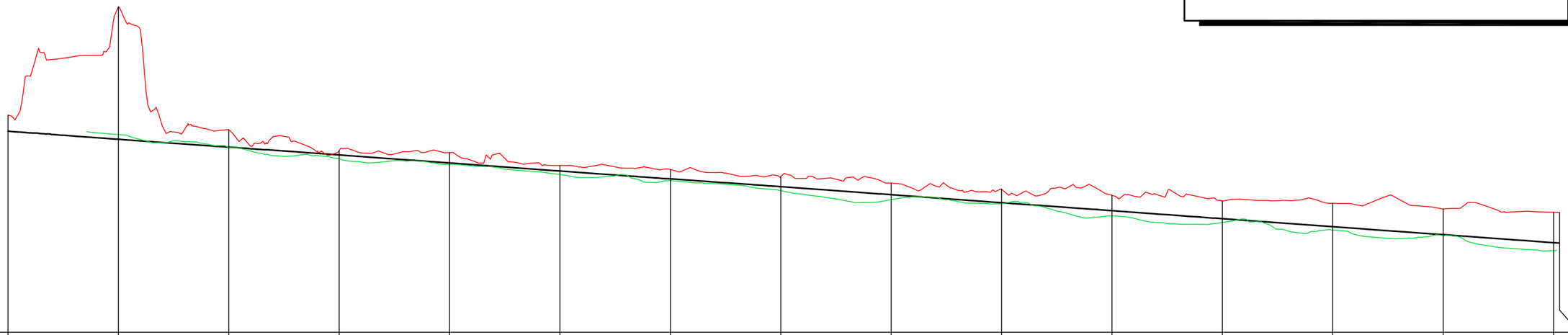

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Appendix E
Soil assessment



Soil Assessment

Peabody Burton Mine

Prepared for Peabody (Burton) Pty Limited | October 2020



Peabody

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Soil Assessment

Peabody Burton Mine

Prepared for Peabody (Burton) Pty Limited | 16 October 2020

Project number:	19016
Document title:	Soil Assessment | Peabody Burton Mine
Revision:	V1-4
Date:	16 October 2020
Client:	Peabody (Burton) Pty Limited
Project manager:	T Rohde
Author:	G Greening / A Costin

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Document history and status

Revision	Date	Description	By	Review	Approved
V0-1	10/06/20	Draft	G Greening	T Rohde	T Rohde
V0-3	23/06/20	Draft	G Greening	T Rohde	N Jamson
V1-4	16/10/20	Final	A Costin	T Rohde	T Rohde

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Executive summary

Peabody Burton Mine (the Mine) commenced care, maintenance and rehabilitation in November 2016 with the end of mining and coal processing. Peabody (Burton) Pty Limited (Peabody) aims to return the land to a safe, stable, self-sustaining and non-polluting landform capable of achieving an agreed post mining land use (PMLU).

SGM environmental Pty Limited (SGME) was engaged by Peabody to undertake soil sampling and characterisation for the remaining stockpiles in accordance with the requirements of the *Guideline: Progressive rehabilitation and closure plans* (the PRC plan guideline) (the soil assessment). The soil assessment supports the *Progressive Rehabilitation and Closure Plan* (PRC plan) being prepared by SGME for the Mine.

Soils play an important role in plant community structure and diversity as they determine the availability of nutrients including, nitrogen (N), phosphorous (P) and micronutrients. The nutrient content of soil can decline while it is stored in stockpiles; decreasing fertility and reducing post-mining land suitability.

Peabody has been monitoring rehabilitation at the Mine since 2015 to investigate plant and ground cover condition, pasture productivity and landform stability. Rehabilitation monitoring was undertaken by AECOM Australia Pty Limited (AECOM) (2015), AECOM (2016), WSP Pty Limited (WSP) (2017) and WSP (2018). Reference sites were selected based on vegetation composition, condition and land use. Rehabilitation monitoring shows that rehabilitation is trending towards reference sites.

The soil assessment has found that soil at the Mine has low fertility because of strong alkalinity, exchangeable cation imbalances, low N, P, total organic carbon (TOC) and cation exchange capacity (CEC) and is also expected to be dispersive. Low fertility and soil dispersion can be overcome by adding fertilisers and ameliorants (gypsum) prior to or during rehabilitation.

Soil identified within the Broadmeadow project spoil stockpile is not recommended for use in rehabilitation as it has high electrical conductivity (EC) in the form of chloride salinity.

Notwithstanding, the soil assessment has found that the soil can support the proposed PMLU; that is largely grazing and bushland.

The following recommendations are made for the amelioration of soil for use in rehabilitation:

- It is recommended that fertiliser is applied before or during rehabilitation to ameliorate low macronutrients (N and P). Suitable fertilisers to use include monoammonium P (MAP), diammonium P (DAP) or equivalent.
- It is recommended (but not essential) that elemental sulfur or iron sulfate are used if alkaline soil conditions are impacting plant growth. Bacteria in the soil will oxidise with the sulfur, forming sulfuric acid, which will then lower soil pH. Noting that some plants are able to tolerate alkaline soils.
- It is recommended that gypsum is applied to soil to decrease the exchangeable sodium percentage (ESP), reduce dispersion potential and increase stability. The likely gypsum application rate will be between 1.2 to 2.4 tonnes per hectare for the top 10 centimetres of soil. Noting that the effectiveness of gypsum will be dependent on the properties of the soil. Additional testing would be required at the time of application to verify gypsum as an appropriate management option.

1.0 Introduction

Peabody Burton Mine (the Mine) is located approximately (~) 90 kilometres (km) southwest of the city of Mackay, 67 km from Nebo and 36 km from Glenden. The Mine commenced care, maintenance and rehabilitation in November 2016 with the end of mining and coal processing.

This report has been completed to support the *Progressive Rehabilitation and Closure Plan* (PRC plan) which is currently being prepared by SGM environmental Pty Limited (SGME) in accordance with the *Guideline: Progressive rehabilitation and closure plans* (the PRC plan guideline).

1.1 Scope

The scope of this report is to complete soil sampling and field characterisation for the remaining stockpiles (the soil assessment) while meeting the requirements of the PRC plan guideline.

1.1.1 PRC plan guideline

The PRC plan guideline states that the PRC plan must include all supporting information required by the Department of Environment and Science (DES) to reach a decision on the 'soundness' of the proposed rehabilitation strategies and delivery techniques to meet the approved land outcomes.

The soil assessment will form an appendix in the PRC plan. How the requirements of the PRC plan guideline have been addressed is summarised in Table 1.

Table 1 How the PRC plan guideline has been addressed

Requirements	Report section
Quantity of soil available to complete rehabilitation	Section 1.2.1.1 b
Chemical and physical properties of stockpiled soil including fertility and erosion and dispersion potential	Section 4.1 and 4.2 respectively
Location (ie with respect to haul distance) and accessibility of cover material (soil)	Section 1.2.1.1 a
An assessment of the need for ameliorants and / or fertilisers and the suitability as a growth medium	Section 4.1
The relationship between soils and vegetation ecosystems for the PMLU and rehabilitation methodology	Section 4.3

1.2 Review of progressive rehabilitation

1.2.1 Rehabilitation strategy and objectives

Mining is a temporary use of land. Peabody (Burton) Pty Limited (Peabody) aims to return all areas disturbed by mining activities to a condition that is safe, stable, self-sustaining and non-polluting. Suitable areas will be returned to grazing while other areas will be covered with soil and seeded with trees, shrubs and grasses in a manner which is consistent with environmental authority (EA) EMPL00879213.

The proposed post mining land use (PMLU) includes:

- water storage;
- pit water storage (pits including Broadmeadow pit, Plumtree pit, Bullock Creek pit, Wallanbah pit and farm dams);
- grazing;
- bushland (disturbed and undisturbed areas);
- riparian (riparian areas along Bullock Creek and Spade Creek diversion);
- infrastructure (including laydowns, hardstands, roads and loading ramps); and
- undisturbed (pre-existing land uses).

1.2.1.1 Soil stockpiles

Soil stockpiles will be removed by using the soil in rehabilitation. Where final landforms need to be constructed, they will be built by excavating and / or dozer pushing suitable materials for the landform (spoil) and loading and hauling material for the cover (soil).

a Location

Plumtree has large soil stockpiles located to the east and west of the run of mine pad and out of pit spoil storage areas. Several other soil stockpiles exist within the Wallanbah and Broadmeadow project areas.

The soil assessment considers only the remaining soil stockpiles that will be used in rehabilitation (ie shortest haul). Other stockpiles were excluded based on distance (cost).

b Material balance

The volume of soil available / required for rehabilitation is listed in Table 2, noting that there will be a soil inventory surplus of 136,599 metres cube (m^3).

Table 2 Soil inventory

Project area	Amount available (m^3)	Amount required (m^3)
Plumtree	430,415	297,000
Bullock Creek	-	10,000
Wallanbah	163,024	180,000
Broadmeadow	110,160	80,000
Total	703,599	567,000

1.2.2 Progressive rehabilitation monitoring history

Peabody have been monitoring the progressive rehabilitation at the Mine since 2015 to investigate plant and ground cover condition, pasture productivity and landform stability. Rehabilitation monitoring has been completed in accordance with the methods detailed in the *Peabody Rehabilitation Monitoring Manual*.

1.2.2.1 Monitoring events

Progressive rehabilitation monitoring events are summarised in Table 3. AECOM Australia Pty Limited (AECOM) monitored 83 transects across numerous landforms in 2015 and 107 rehabilitated transects with an additional 9 transects in reference sites for grazing and open woodland in 2016. In 2017, WSP Pty Limited (WSP) monitored 50 rehabilitated transects with no additional reference sites. The transects were revisited in 2018 and assessed against the results obtained in the 2017 and 2016 assessment.

Reference sites were established in areas that most accurately match conditions (slope length, angle, plant communities and land use) at the Mine. Pasture reference sites are located in the adjacent land holder properties. A number of native ecosystem (bushland) reference sites were also established. These are located in areas of remnant regional ecosystems adjacent to the Mine.

Table 3 Progressive rehabilitation monitoring events

Monitoring event	Location	Rehabilitation year
2015[1]	Burton north	1999-2005
	Burton widening east out of pit dump	2014
	Ellensfield south out of pit dump	2014
	Ellensfield west out of pit dump	2003, 2014
	Plumtree south out of pit dump	2007
	Plumtree north out of pit dump	2011
	Bullock Creek in pit dump	2013
	Wallanbah east out of pit dump	2009
	Wallanbah in pit dump	2011
	Broadmeadow west out of pit dump	2011
2016[1]	Broadmeadow west out of pit dump	2011
	Burton widening east out of pit dump	2014
	Burton widening west out of pit dump	2015
	Ellensfield east out of pit dump	2003
	Ellensfield west out of pit dump	2003, 2014
	Plumtree north out of pit dump	2011
	Wallanbah east out of pit dump	2009
	Wallanbah in pit dump	2011
	Wallanbah run of mine	2011
	Wallanbah west out of pit dump	2011
2017[2]	Broadmeadow west out of pit dump	2011
	Bullock Creek out of pit dump	2010

Monitoring event	Location	Rehabilitation year
	Bullock Creek in pit dump	2013
	Wallanbah east out of pit dump	2009
	Wallanbah in pit dump	2012
	Plumtree south out of pit dump	2007
	Plumtree north out of pit dump	2007
2018[2]	Plumtree north out of pit dump	2007
	Broadmeadow west out of pit dump	2011
	Wallanbah west out of pit dump	2011
	Wallanbah in pit dump	2011
	Wallanbah in pit dump	2012
	Wallanbah in pit dump	2013
	Bullock Creek out of pit dump	2017
	Wallanbah east out of pit dump	2017

1. Undertaken by AECOM.
2. Undertaken by WSP.

1.2.2.2 Rehabilitated landform development

Rehabilitation monitoring has shown that landforms at Bullock Creek, Broadmeadow, Plumtree and Wallanbah are performing reasonably well with an adequate plant cover and diversity. Sites that recorded high to very high plant cover were dominated by high biomass pasture grasses such as *Cenchrus ciliaris* (WSP 2018). Species richness varied across sites, noting that species richness is highly responsive to available soil moisture. Overstorey richness and density is variable ranging from low to moderate. The highest transect average was the Plumtree south landform recording a total of 11 species. By comparison the youngest site, Bullock Creek, recorded the lowest woody species (zero) (WSP 2018). It is important to note that areas that have a PMLU of open woodland had higher woody species richness than sites which have a grazing PMLU.

Rehabilitation monitoring indicates sites are generally stable. Noting that several active rills and minor erosion gullies were observed in 2018; particularly on slopes at Wallanbah west out of pit dump rehabilitation area completed in 2011 (WSP 2018).

Average transect yields for understory biomass show that rehabilitated areas recorded moderate to high biomass yields (WSP 2018). Biomass trends show that pasture productivity correlated with pasture vegetation cover rather than the age of rehabilitation (WSP 2018).

The seed mix used to establish the rehabilitated landforms largely comprised of introduced pasture grass and legume species including *Bothriochloa pertusa* (Indian Blue Grass — Coated), *Melinis repens* (Ref Natal Grass), *Urochloa mosambicensis* (Sabi Grass) and *Cenchrus ciliaris* (American Buffel). All species mentioned above were recorded in varying densities and abundances across rehabilitated landforms suggesting that the establishment of seeded species was generally successful (WSP 2018). Noting that the most successful species was *Cenchrus ciliaris* (American Buffel).

2.0 Method

2.1 Soil sample sites

Soil samples were collected from 15 locations (one location per hectare (ha) of soil stockpile) (Figure 1).

Additional soil was identified and collected from the following Mine spoil locations (Figure 2):

- Plumtree project area (site 12, 25 and 28);
- Broadmeadow project area (site 5 and 8); and
- Bullock Creek project area (site 42).

2.2 Sampling method

A minimum of three composite soil samples were collected per location. Soil samples were collected from a depth of 1-1.5 metres (m) below the surface of the stockpile using a hand auger.

The *Guidelines for Surveying Soil and Land Resources: 2nd edition* (McKenzie et al. 2008) advocate one sample per horizon. However, as the soil stockpiles are a mix of topsoil and subsoil, the top, middle and bottom were sampled to adequately reflect soil stockpiles.

Sampling was completed also having regard for the following guidelines:

- *Australian Soil and Land Survey Handbook: 3rd Edition* (NCST 2009); and
- *The Australian Soil Classification* (Isbell & NCST 2016).

2.3 Field testing

All soil samples were analysed in the field for pH and electrical conductivity (EC). These are screening tests for acidic / alkaline soils and saline soils respectively. The tests were used to select soil samples for laboratory analysis.

2.4 Field observations

Field observations were made including:

- soil texture;
- soil colour; and
- soil surface condition.



Client: Peabody (Burton) Pty Limited	Project: Soil Assessment | Peabody Burton Mine		
Design: SGM environmental Pty Limited | 16.10.2020 Scale: 1:65,000	Title: Sample site locations	FIGURE: 1	

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Client: Peabody (Burton) Pty Limited	Project: Soil Assessment | Peabody Burton Mine	SGM environmental	
Design: SGM environmental Pty Limited | 16.10.2020 Scale: 1:70,000	Title: Spoil stockpile sample locations	FIGURE 2	

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2.5 Laboratory testing

A National Association of Testing Authorities (NATA) accredited laboratory was used to ensure testing was undertaken using correct methods.

The following tests were completed by SGS on 37 soil samples:

- pH (1:5) and EC (1:5);
- water-soluble chloride and sulfate;
- exchangeable cations (calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), aluminium (Al) and cation exchange capacity (CEC));
- organic matter and total organic carbon (TOC);
- total nitrogen (N) including total Kjeldahl N (TKN) and nitrate plus nitrite as N;
- Colwell phosphorous (P (Colwell));
- Emerson aggregate test; and
- Diethylenetriaminepentaacetic acid (DTPA) extractable metals (copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn)).

2.6 Assessment criteria

Soil used for rehabilitation must be able to support plant establishment and continued growth. Soil has been assessed against sufficiency values from APAL (2017), Baker and Eldershaw (1993), DERM (2011) and Perverill et al. (1999) for pasture and food crops (Table 4). Noting that sufficiency values represent 'best case' criteria and may be overly conservative for the establishment of native plants.

Table 4 Sufficiency for common plant nutrition indicators

Constituent	Unit	Sufficiency
pH	pH unit	6.0-7.5
ECe	deciSiemens per metre (dS/m)	<1.9
Chloride	Milligrams per kilogram (mg/kg)	<800
CEC	Milliequivalent per 100 grams (meq/100g)	12-25
Exchangeable Ca	%	60-75
Exchangeable Mg	%	10-20
Exchangeable K	%	3-8
ESP	%	<6
Ca:Mg	-	>2
Total N	mg/kg	>1,500
P (Colwell)	mg/kg	>10
Organic carbon	%	>1.2
DTPA extractable metals		
Cu	mg/kg	>0.3

Constituent	Unit	Sufficiency
Zn	mg/kg	>0.8
Mn	mg/kg	>2

3.0 Results

3.1 Field observations

Field observations were made regarding soil texture, soil colour and soil surface condition (Table 5). Detailed field sheets can be found in Appendix A.

Table 5 Summary of field observations

Project area	Location	Hand texture	Field colour
Plumtree	TS1	Clay loam	Brown
	TS2	Loamy sand (0-10 centimetres below ground level (cm bgl)) to clayey sand (70-85 cm bgl) to loamy sand (90-100 cm bgl)	Reddish brown (0-10 cm bgl) to dark brown (70-80 cm bgl) to reddish brown (90-100 cm bgl)
	TS3	Loamy sand	Reddish brown
	TS4	Loamy sand	Reddish brown
	TS5	Clay	Very dark grey
Wallanbah	TS6	Sandy loam	Dark reddish brown (0-10 cm bgl) to dark brown (90-100 cm bgl)
	TS7	Sandy loam (0-10 cm bgl) to clay loam (90-100 cm bgl)	Brown
	TS8	Clay loam (0-10 cm bgl) to sandy clay loam (90-100 cm bgl)	Dark brown
	TS9	Sandy clay loam	Dark brown
	TS10	Loamy sand	Brown
	TS11	Loamy sand	Brown
	TS12	Loamy sand	Brown
Broadmeadow	TS13	Clay	Very dark grey
	TS14	Clay	Very dark grey
	TS15	Loamy sand (0-10 cm bgl) to clay (90-100 cm bgl)	Brown (0-10 cm bgl) to very dark grey (90-100 cm bgl)

3.2 Laboratory

Laboratory analysis was completed by SGS. The certificate of analysis is presented in Appendix B.

Fertility and DTPA extractable metals are presented in Table 6 and Table 7. Erosion and dispersion potential results are presented in Table 8.

Table 6 Fertility assessment

Analyte	$pH_{1:5}$	ECe	Water-soluble sulfate	Water-soluble chloride	Total N	P (Colwell)	TOC	Organic Matter	ESP	Exchangeable Ca	Exchangeable K	Exchangeable Mg	CEC
Units	pH Units	dS/m	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%	meq/100g
Sample Sufficiency	6-7.5	<1.9	-	<800	>1,500	>10	>1.2	-	<6	60-75	3-8	10-20	12-25
Plumtree project area													
TS1 0-10	**8.1**	1.03	6	<5	**570**	**2**	**0.71**	1.2	1.8	72.8	**1.6**	**23.8**	16
TS1 140-150	**8.3**	1.03	21	26	**740**	**2**	**1.1**	1.8	**6.3**	66.7	**1.1**	**25.9**	**29**
TS2 0-10	7.3	**2.62**	3	<5	**230**	**2**	**0.39**	0.67	1.3	69.1	**12.8**	16.8	**3**
TS2 70-85	**7.6**	0.400	33	<5	**380**	**2**	**0.53**	0.92	0.9	66.3	4	**28.8**	12
TS2 90-100	7	0.447	11	<5	**240**	**2**	**0.37**	0.64	1.3	68.8	6.8	**23.1**	**3.8**
TS3 0-10	7	0.221	<3	<5	**360**	**2**	**0.62**	1.1	0.7	74.2	6.7	18.3	**5.5**
TS3 90-100	7.4	0.359	<3	<5	**260**	**2**	**0.26**	0.46	1	**76.7**	6.4	15.9	**2.5**
TS4 0-10	7.4	0.331	<3	<5	**270**	**2**	**0.36**	0.62	0.7	**58.9**	**22.5**	18	**2.8**
TS4 100-110	7.5	0.166	<3	<5	**230**	**1**	**0.26**	0.45	0.5	**78.5**	5.2	15.8	**3.9**
TS5 0-10	**8.2**	1.12	11	<5	1,500	**8**	1.7	2.9	0.5	**78.3**	**2.6**	18.6	**36**
TS5 100-110	**8.2**	**2.06**	32	94	**710**	**5**	**1.1**	1.8	5	66.2	**2.1**	**26.7**	20
Plumtree 12	**9.4**	**3.08**	20	290	**390**	**2**	**0.28**	0.5	**16.1**	**56**	**0.8**	**27.2**	**26**
Plumtree 25	**9.3**	**5.42**	180	440	**220**	**1**	**0.13**	0.2	**14.5**	60	**0.9**	**24.8**	**41**
Plumtree 28	**9.4**	**2.57**	6	31	**160**	**2**	**0.14**	0.2	**19.8**	**46**	**0.9**	**33.6**	18
Wallanbah project area													
TS6 0-10	6.6	0.607	10	19	**550**	**4**	**0.9**	1.6	5.7	**50.9**	**9.7**	**33.8**	**4.2**
TS6 90-100	6.1	**2.48**	65	190	**460**	**6**	**0.8**	1.4	**18.4**	**44.8**	3.6	**33.2**	**4.6**
TS7 0-10	6.9	0.856	9	9	**490**	**9**	**0.98**	1.7	1.4	**47.6**	6.4	**44.5**	**9.8**
TS7 90-100	7.5	1.38	56	110	**460**	**9**	**0.76**	1.3	**9.7**	**59**	3.2	**28.1**	**9**
TS8 0-10	**7.8**	0.636	6	9	**980**	10	**1.1**	1.8	1.8	61.4	4.3	**32.5**	19
TS8 90-100	**7.9**	**5.13**	150	530	**770**	**7**	**0.83**	1.4	**10**	**58.8**	**1.9**	**29.3**	19
TS9 0-10	**8.6**	1.14	11	7	**800**	**2**	**1**	1.7	5.1	**55.4**	**2**	**37.5**	**27**
TS9 90-100	**7.9**	**4.09**	120	400	**1,100**	**8**	**1.2**	2.1	**14.3**	**50.1**	**2.3**	**33.2**	**26**
TS10 0-10	7.4	0.152	<3	<5	**230**	**3**	**0.26**	0.45	0.7	68.2	3.9	**27.2**	**5.2**
TS10 90-100	**7.6**	0.196	4	<5	**180**	**4**	**0.2**	0.35	1.2	64.7	4.2	**29.9**	**5.8**
TS11 0-10	7.5	0.621	5	5	**540**	16	**0.66**	1.1	0.6	60.7	**16.3**	**22.3**	**9.5**

Analyte	$pH_{1:5}$	ECe	Water-soluble sulfate	Water-soluble chloride	Total N	P (Colwell)	TOC	Organic Matter	ESP	Exchangeable Ca	Exchangeable K	Exchangeable Mg	CEC
Units	pH Units	dS/m	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	%	meq/100g
Sample Sufficiency	6-7.5	<1.9	-	<800	>1,500	>10	>1.2	-	<6	60-75	3-8	10-20	12-25
TS11 90-100	7.4	0.759	15	12	**280**	17	**0.4**	0.69	3.6	63.7	4.9	**27.8**	**7.3**
TS12 0-10	**8.3**	1.38	19	<5	**380**	11	**0.44**	0.75	3.3	64.5	4.2	**28**	**11**
TS12 90-100	**7.9**	0.359	10	<5	**180**	**5**	**0.14**	0.24	5.1	**58.1**	3.9	**32.8**	**6**
Broadmeadow project area													
TS13 0-10	**8.2**	1.20	5	<5	**1,200**	**3**	1.6	2.8	0.3	74.8	4.7	**20.2**	**29**
TS13 90-100	**8.5**	1.46	11	<5	**870**	**4**	**1.1**	1.9	3.6	70.8	**1.2**	**24.4**	**31**
TS14 0-10	**8.3**	1.29	9	<5	**1,200**	16	1.6	2.8	0.3	**84.2**	3.8	11.7	**35**
TS14 90-100	**8.7**	**1.98**	40	<5	**1,000**	**5**	**1.2**	2	**6.1**	68	**1.2**	**24.7**	**33**
TS15 0-10	**7.9**	**9.11**	46	620	**1,200**	**4**	**1.2**	2	**6.3**	69.9	3.5	**20.3**	**37**
TS15 90-100	**8**	**15.5**	3,900	650	**1,000**	**2**	1.3	2.3	**10.8**	61.8	**0.6**	**26.8**	**53**
Broadmeadow 5	**8.8**	**10.5**	190	**1,400**	**480**	**2**	**0.65**	**1.1**	**25.2**	**45**	**0.9**	**29.1**	**31**
Broadmeadow 8	**9.1**	**10.5**	110	**1,400**	**370**	**<1**	**0.26**	0.5	**27.9**	**46**	**0.7**	**25**	**31**
Bullock Creek project area													
Bullock Creek 42	**9.2**	**4.9**	200	450	**320**	**1**	**0.48**	0.8	**12.5**	**58**	**1.2**	**28.6**	**30**

1. Bold indicates value did not meet sufficiency criteria.

Table 7 DTPA extractable metals

	Analyte	Cu	Zn	Mn	Fe
	Units	mg/kg	mg/kg	mg/kg	mg/kg
Sample	**Sufficiency**	>0.3	>0.8	>2	-
Plumtree project area					
TS1 0-10		0.48	**0.11**	6	5.2
TS1 140-150		0.91	**0.17**	8.1	8
TS2 0-10		**0.26**	**0.1**	8.3	8.4
TS2 70-85		0.78	**0.14**	14	8
TS2 90-100		0.47	**0.07**	14	10
TS3 0-10		0.42	**0.23**	12	9.9
TS3 90-100		**0.15**	**0.09**	5.4	5.4
TS4 0-10		**0.21**	**0.08**	4.5	19
TS4 100-110		**0.25**	**0.06**	5.1	5.2
TS5 0-10		0.84	**0.47**	6.2	6.6
TS5 100-110		1	**0.49**	15	13
Plumtree 12		**0.17**	**0.10**	2.1	2.3
Plumtree 25		0.48	**<0.05**	**1.7**	1.7
Plumtree 28		**0.18**	**0.06**	**1.5**	2.0
Wallanbah project area					
TS6 0-10		0.36	0.98	17	20
TS6 90-100		0.72	0.9	46	100
TS7 0-10		0.75	1.5	15	6.1
TS7 90-100		0.49	**0.56**	15	8
TS8 0-10		0.65	0.82	7.9	5.9
TS8 90-100		0.52	**0.36**	8.6	4.6
TS9 0-10		0.8	**0.19**	3.4	8.1
TS9 90-100		0.8	**0.34**	5.9	8.7
TS10 0-10		**0.26**	**0.07**	9.3	4.9
TS10 90-100		**0.24**	**0.05**	9.7	4.1
TS11 0-10		0.5	**0.16**	14	8.5
TS11 90-100		0.43	**0.18**	12	10

	Analyte	Cu	Zn	Mn	Fe
	Units	mg/kg	mg/kg	mg/kg	mg/kg
Sample	**Sufficiency**	>0.3	>0.8	>2	-
TS12 0-10		0.33	**0.43**	6.7	4.1
TS12 90-100		0.4	**0.12**	7.8	8.2
Broadmeadow project area					
TS13 0-10		0.58	**0.46**	3.5	3.6
TS13 90-100		0.8	**0.24**	5.7	5.8
TS14 0-10		0.38	**0.39**	3.6	3.2
TS14 90-100		1.1	**0.28**	7	7.6
TS15 0-10		1.3	**0.06**	13	2.7
TS15 90-100		0.94	**0.17**	5.9	3.3
Broadmeadow 5		0.47	**0.19**	**2.0**	2.4
Broadmeadow 8		**0.12**	**0.05**	**1.1**	1.7
Bullock Creek project area					
Bullock Creek 42		0.80	**0.49**	2.9	4.4

1. Bold indicates value did not meet sufficiency criteria.

Table 8 Erosion and dispersion potential

Analyte		Emerson Class Number	$EC_{1:5}$	CEC	Exchangeable Ca	Exchangeable K	Exchangeable Mg	ESP	ESI
Units		-	Microsiemens per centimetre (µS/cm)	meq/100 g	%	%	%	%	-
Sample	**Sufficiency**	-	-	12-25	60-75	3-8	10-20	<6	-
Plumtree project area									
TS1 0-10		3	120	16	72.8	**1.6**	**23.8**	1.8	0.07
TS1 140-150			120	**29**	66.7	**1.1**	**25.9**	**6.3**	0.02
TS2 0-10		3	190	**3.0**	69.1	**12.8**	16.8	1.3	0.15
TS2 90-100			29	**3.8**	68.8	6.8	**23.1**	1.3	0.02
TS2 70-85			52	12	66.3	4.0	**28.8**	0.9	0.06
TS3 0-10		3	16	**5.5**	74.2	6.7	18.3	0.7	0.02
TS3 90-100			26	**2.5**	76.7	6.4	15.9	1.0	0.03
TS4 0-10		2	24	**2.8**	**58.9**	**22.5**	18.0	0.7	0.03
TS4 100-110			12	**3.9**	**78.5**	5.2	15.8	0.5	0.02
TS5 0-10		3	130	**36**	**78.3**	**2.6**	18.6	0.5	0.26
TS5 100-110			240	20	66.2	**2.1**	**26.7**	5.0	0.05
Plumtree 12		2	400	**26**	**55.8**	**0.8**	**27.2**	**16.1**	0.02
Plumtree 25		2	570	**41**	**59.9**	**0.9**	**24.8**	**14.5**	0.04
Plumtree 28		2	270	18	**45.7**	**0.9**	**33.6**	**19.8**	0.01

Analyte		Emerson Class Number	$EC_{1:5}$	CEC	Exchangeable Ca	Exchangeable K	Exchangeable Mg	ESP	ESI
Units		-	Microsiemens per centimetre (µS/cm)	meq/100 g	%	%	%	%	-
Sample	**Sufficiency**	-	-	12-25	60-75	3-8	10-20	<6	-
Wallanbah project area									
TS6 0-10		2	44	**4.2**	**50.9**	**9.7**	**33.8**	5.7	0.01
TS6 90-100			180	**4.6**	**44.8**	3.6	**33.2**	**18.4**	0.01
TS7 0-10		2	62	**9.8**	**47.6**	6.4	**44.5**	1.4	0.04
TS7 90-100			160	**9.0**	**59.0**	3.2	**28.1**	**9.7**	0.02
TS8 0-10		3	74	19	61.4	4.3	**32.5**	1.8	0.04
TS8 90-100			540	19	**58.8**	**1.9**	**29.3**	**10.0**	0.05
TS9 0-10		3	120	**27**	**55.4**	**2.0**	**37.5**	5.1	0.02
TS9 90-100			430	**26**	**50.1**	**2.3**	**33.2**	**14.3**	0.03
TS10 0-10		2	11	**5.2**	68.2	3.9	**27.2**	0.7	0.02
TS10 90-100			14	**5.8**	64.7	4.2	**29.9**	1.2	0.01
TS11 0-10		2	45	**9.5**	60.7	**16.3**	**22.3**	0.6	0.08
TS11 90-100			55	**7.3**	63.7	4.9	**27.8**	3.6	0.02
TS12 0-10		2	100	**11**	64.5	4.2	**28.0**	3.3	0.03
TS12 90-100			26	**6.0**	**58.1**	3.9	**32.8**	5.1	0.01
Broadmeadow project area									

Analyte	Emerson Class Number	$EC_{1:5}$	CEC	Exchangeable Ca	Exchangeable K	Exchangeable Mg	ESP	ESI
Units	-	Microsiemens per centimetre (µS/cm)	meq/100 g	%	%	%	%	-
Sample **Sufficiency**	-	-	12-25	60-75	3-8	10-20	<6	-
TS13 0-10	3	140	**29**	74.8	4.7	**20.2**	0.3	0.47
TS13 90-100		170	**31**	70.8	**1.2**	**24.4**	3.6	0.05
TS14 0-10	3	150	**35**	**84.2**	3.8	11.7	0.3	0.50
TS14 90-100		230	**33**	68.0	**1.2**	**24.7**	**6.1**	0.04
TS15 0-10	3	660	**37**	69.9	3.5	**20.3**	**6.3**	0.10
TS15 90-100		1,800	**53**	61.8	**0.6**	**26.8**	**10.8**	0.17
Broadmeadow 5	2	1,100	**31**	**44.9**	**0.9**	**29.1**	**25.2**	0.04
Broadmeadow 8	2	1,100	**31**	**46.4**	**0.7**	**25**	**27.9**	0.04
Bullock Creek project area								
Bullock Creek 42	2	520	**30**	**57.6**	**1.2**	**28.6**	**12.5**	0.04

1. Bold indicates value did not meet sufficiency criteria.

3.3 Rehabilitation monitoring

AECOM undertook soil sampling for the 2016 monitoring event (AECOM 2017). Soil properties are presented in Table 9. Noting that no soil sampling was undertaken by WSP (2017) and WSP (2018).

Table 9 Progressive rehabilitation monitoring results

Analyte	Units	Sufficiency	Median (and range) rehabilitated sites	Median (and range) pasture reference sites	Median (and range) bushland reference sites
pH	pH units	6-7.5	**8.2** (5.3-8.9)	6.5 (6.3-7.7)	6.5 (6.2-7.1)
EC	µS/cm	-	96 (18-273)	30 (22-51)	12 (6-32)
ECe	dS/m	<1.9	0.82 (0.17-2.6)	0.37 (0.21-0.44)	0.20 (0.10-0.32)
Total N	mg/kg	>1,500	**635** (310-1,040)	**1,320** (1,100-1,460)	**580** (260-1,820)
P (Colwell)	mg/kg	>10	**5** (5-38)	18 (14-31)	**5** (5-15)
CEC	meq/100g	12-25	16 (2-42)	12.6 (8.8-16.6)	**3.9** (1.7-13.1)
Exchangeable cations					
Ca	%	60-75	67 (29-81)	63 (56-82)	67 (59-75)
Mg	%	10-20	**29** (16-55)	**25** (21-26)	**22** (21-29)
K	%	3-8	3 (2-15)	5 (3-6)	5 (4-12)
ESP	%	<6	0.5 (0.1-5.5)	0.1	0.1

1. Bold indicates median value did not meet sufficiency criteria.

4.0 Discussion

4.1 Fertility

Fertility results are presented in Table 6 and Table 7:

- pH ranges from neutral to strongly alkaline. 22% of soil samples (eight samples) are considered strongly alkaline. Noting that these were largely soil identified within the spoil stockpiles (six samples). Alkaline soils may restrict the growth of some plant species sensitive to alkalinity.
- ECe is generally low indicating that majority of stockpiled soil is non-saline. Five soil samples are considered slightly saline (TS2, TS5, TS6, Plumtree 12 and Plumtree 28). Four soil samples are considered moderately saline (TS8, TS9, Plumtree 25 and Bullock Creek 42). TS15, Broadmeadow 5 and Broadmeadow 8 are considered highly saline. Saline soils inhibit the growth of some plant species.
- Water-soluble chloride is low except for elevated concentrations at Broadmeadow 5 and Broadmeadow 8. Water soluble sulfate is elevated at TS15 and therefore is likely the main contributor to the elevated ECe.
- Total N is low indicating low reserves of N. This may restrict plant growth.
- P (Colwell) is low in 89% of soil samples. P deficiency may therefore restrict growth of some plant species (noting that most native plants are adapted to soils with low P concentrations).
- TOC is low across the majority of samples which can indicate poor structural condition, nutrient and moisture retention. TOC for soil stockpiles at Broadmeadow (TS14 and TS15) are above the sufficiency value.
- Exchangeable Ca is sufficient in 49% of soil samples. 40% have an exchangeable Ca slightly lower than the sufficiency range while 11% of soil samples are slightly higher. Exchangeable K is within the sufficiency range for 46% of soil samples. 43% of soil samples are lower than the sufficiency range. 11% are higher than the sufficiency range. Exchangeable cation imbalances may restrict plant growth.
- 81% of soil samples have an exchangeable Mg percentage higher than the sufficiency range; all other soil samples are sufficient.
- 43% of soil samples have a CEC lower than the sufficiency range indicating a limited capacity to store nutrients. Soils with a low CEC are susceptible to leaching, leading to deficiencies in K and Mg.
- DTPA extractable Zn was low across majority of soil samples. Low concentrations are associated with soils with a high pH. DTPA extractable Cu was low across some soil samples (24% of soil samples). DTPA extractable Mn was largely sufficient. Micronutrients are unlikely to restrict plant growth.

It is expected that the soil will exhibit low soil fertility. Strong alkalinity, exchangeable cation imbalances, low N, P, TOC and CEC are the main restrictions to plant growth. Soil identified within the Broadmeadow spoil stockpiles (Broadmeadow 5 and Broadmeadow 8) have high EC in the form of chloride salinity and therefore are not recommended for use in rehabilitation.

Fertiliser may be required to ameliorate low macronutrients (N and P) in the soil prior to or during rehabilitation. Fertiliser is used to provide readily available source of nutrients to supplement fertility, maximise the growth of seeded areas and establish plants on rehabilitated land.

4.2 Erosion and dispersion potential

The structural stability of soil is heavily influenced by a combination of EC and ESP. Soil is considered sodic when the ESP is greater than 6 and highly sodic when the ESP is greater than 15. TS1, TS7, TS8, TS9, TS14, TS15 at a depth between 90-100 cm and TS15 at the surface (ie 0-10 cm) have an ESP greater than 6 but less than 15, indicating the soil samples are sodic (Table 8). TS6 at a depth between 90-100 cm has an ESP greater than 15% (18.4%) indicating that it is highly sodic (Table 8). Plumtree 25 and Bullock Creek 42 have an ESP greater than 6% but less than 15%. Plumtree 12, Plumtree 28, Broadmeadow 5 and Broadmeadow 8 have an ESP greater than 15%. If a soil is sodic, it is vulnerable to dispersion and structural instability. Dispersed soils have reduced infiltration and hydraulic conductivity leading to an increased potential for erosion and build-up of salts in the root zone.

Dispersion declines as the EC of the soil solution increases. The Electrochemical Stability Index (ESI) expresses the relationship between sodicity and salinity (EQN1).

$$ESI = EC_{1:5}/ESP \qquad [EQN1]$$

Australian soils with an ESI less than 0.05 are potentially dispersive. 73% of soil samples (27 samples) have an ESI less than 0.05 indicating they are potentially dispersive and have low structural stability (**Error! Reference source not found.**). It is important to note that rainwater may leach salts from the soil over time, leading to a further increase in dispersion potential. All soil identified within spoil stockpiles have an ESI less than 0.05 (Table 8).

The Emerson aggregate test measures the instability of the soil structure when immersed in water. This test was used to predict the dispersive behaviour of the soil samples. Emerson aggregate classes are consistent with the ESI results. Six soil samples were Class 2 indicating a moderate risk of dispersion (Table 8). All soil identified within spoil stockpiles were Class 2. 60% (9 samples) were Class 3, indicating that the remoulded soil (heavily trafficked) at the plastic limit will disperse in water (Table 8). Soil dispersion and loss of soil structure can cause poor water infiltration, water holding capacity, oxygen supply to roots and nutrient use efficiency.

Appropriate amelioration should be used to limit the dispersion potential of soil (ie minimising overhandling and gypsum application). Gypsum may be applied to decrease ESP, reduce dispersion and increase stability.

4.3 Compatibility with the PMLU

Reference sites (often illustrating pre-mining conditions) provide useful comparisons to determine the composition, structure and function of the desired rehabilitation outcome. Noting that reference sites should be used for guidance and not as firm targets.

Rehabilitated areas are trending towards composition, structure and function of reference sites for pasture and bushland (WSP 2018).

4.3.1 Reference site comparison

The soil properties of the soil stockpiles were compared to the reference sites monitored in 2016 (AECOM 2017).

Table 10 Pasture reference site comparison

Analyte	Pasture reference site	Soil
pH	Sufficient	Sufficient
ECe	Sufficient	Sufficient
Total N	Slightly lower than sufficiency value	Low
P (Colwell)	Sufficient	Low
CEC	Sufficient	Sufficient
Exchangeable cations		
Ca	Sufficient	Sufficient
Mg	Slightly higher than sufficiency range	Slightly higher than sufficiency range
K	Sufficient	Sufficient
ESP	Sufficient	Sufficient (noting that some samples are considered sodic)

Alkalinity may be a restriction to some plant species. However, given the similar pH of rehabilitated areas, it is unlikely to be an issue (Table 9). The soil at pasture reference sites is not sodic. Gypsum may be applied to reduce the ESP in stockpiled soil. Soil used in to rehabilitate areas to grazing may require fertiliser to ameliorate very low total N and low P (Colwell). Noting that pasture reference sites were slightly below the sufficiency value for total N. It is expected that soil at the Mine can support pasture if ameliorated with gypsum and fertiliser.

Table 11 Bushland reference site comparison

Analyte	Bushland reference site	Soil
pH	Sufficient	Alkaline
ECe	Sufficient	Sufficient
Total N	Low	Low
P (Colwell)	Low	Low
CEC	Low	Sufficient
Exchangeable cations		
Ca	Sufficient	Sufficient
Mg	Slightly higher than sufficiency range	Slightly higher than sufficiency range
K	Sufficient	Sufficient
ESP	Sufficient	Sufficient (noting that some samples are considered sodic)

Alkalinity may be a limitation for areas returned to bushland. However, it is unlikely given the similar pH of rehabilitated areas. Gypsum may be required to reduce ESP. It is expected that soil can support bushland if ameliorated with gypsum. Noting that bushland reference sites are also low in total N and P (Colwell).

5.0 Conclusions and recommendations

It is expected that the soil will exhibit low soil fertility. Strong alkalinity, exchangeable cation imbalances, low N, P, TOC, CEC and dispersion potential are the main restrictions to plant growth. Soil identified within Mine spoil stockpiles is also expected to have low soil fertility. Soil identified within the Broadmeadow project spoil stockpile has high EC in the form of chloride salinity and therefore is not recommended for use in rehabilitation.

Peabody's aim is to return the land to a safe, stable, self-sustaining and non-polluting final landform that is consistent with an agreed PMLU. Based on the chemical properties, soil can support the PMLUs if appropriately amended with fertiliser and gypsum.

5.1 Recommendations

5.1.1 Fertiliser

It is recommended that fertiliser is used to ameliorate low macronutrients (N and P) in the soil. Fertiliser is used to provide a readily available source of nutrients to supplement fertility, maximise the growth of seeded areas and establish plants on rehabilitated land. Suitable fertilisers to use include monoammonium P (MAP), diammonium P (DAP) or equivalent with the main nutrients added to the soil being N and P.

5.1.2 Elemental sulfur and iron sulfate

It is recommended (but not essential) that elemental sulfur or iron sulfate are used if alkaline soil conditions are impacting plant growth. Bacteria in the soil will oxidise with the sulfur, forming sulfuric acid, which will then lower soil pH. Noting that some native species are able to tolerate alkaline soils.

5.1.3 Gypsum application

Adding gypsum to dispersive soils may decrease the ESP, reduce dispersion and increase stability. The effectiveness of gypsum will be dependent on the properties of the soil. Gypsum application rates were calculated from the observed pH, EC and exchangeable cations and is adjusted for a target ESP (ie <6%). The likely gypsum application rate will be between 1.2 to 2.4 tonnes per hectare for the top 10 cm of soil. While applying gypsum to stockpiled dispersive soil may provide some benefit, this would likely be contained to the top 0.2 m of soil. It is therefore recommended to wait until after the soil has been spread before adding any amelioration.

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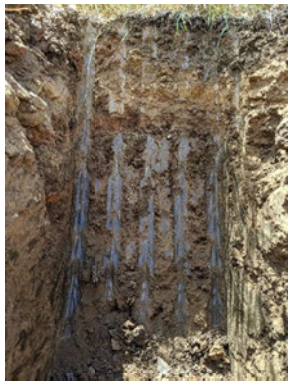
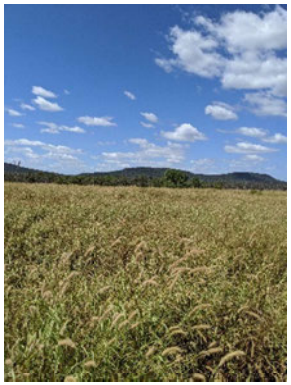
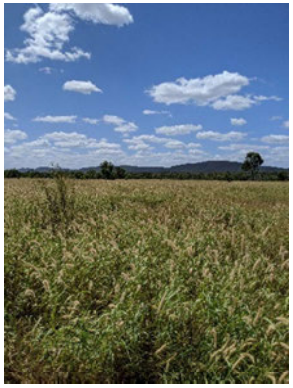
Appendix A
Field sheets



Location: TS1

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

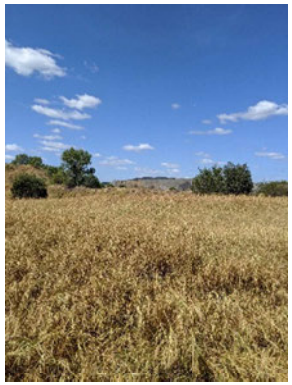
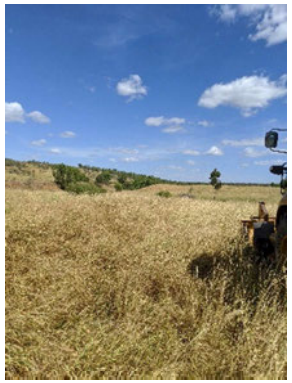
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Clay Loam	7.5YR 4/3 Brown	8.1	16
30					
50					
90					
140-150		Clay Loam	7.5YR 4/3 Brown	8.3	29

Location: TS2

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

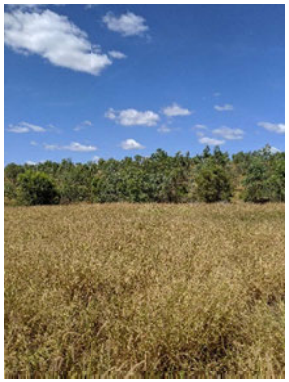
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Loamy Sand	5YR 5/3 Reddish Brown	7.3	3
30					
50					
70-85		Clayey Sand	7.5YR 3/3 Dark Brown	7.6	12
90-100		Loamy Sand	5YR 5/3 Reddish Brown	7.0	3.8

Location: TS3

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

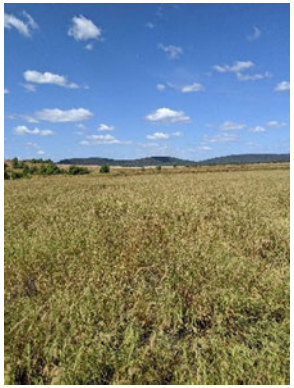
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Loamy Sand	5YR 4/3 Reddish Brown	7.0	5.5
30					
50					
90-100		Loamy Sand	5YR 4/3 Reddish Brown	7.4	2.5

Location: TS4

Soil profile	**Landscape**				**Ground surface**
	North	*South*	*East*	*West*	
					

Soil description	**Field**			**Laboratory**	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Loamy Sand	5YR 4/3 Reddish Brown	7.4	2.8
30					
50					
90					
100-110		Loamy Sand	5YR 4/3 Reddish Brown	7.5	3.9

Location: TS5

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

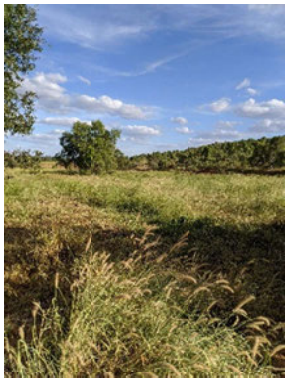
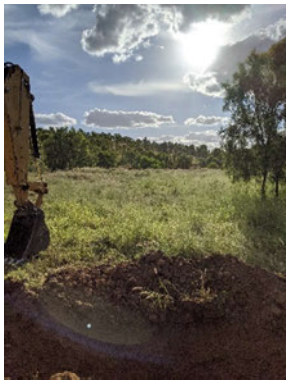
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Clay	7.5YR 3/1 Very Dark Grey	8.2	36
30					
50					
90					
100-110		Clay	7.5YR 3/1 Very Dark Grey	8.2	20

Location: TS6

Soil profile	**Landscape**				**Ground surface**
	North	*South*	*East*	*West*	
					

Soil description	**Field**			**Laboratory**	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Sandy Loam	5YR ¾ Dark Reddish Brown	6.6	4.2
30					
50					
90-100		Sandy Loam	7.5YR 3/3 Dark Brown	6.1	4.6

Location: TS7

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Sandy Loam	10YR 4/3 Brown	6.9	9.8
30					
50					
90-100		Clay Loam	10YR 4/3 Brown	7.5	9

Location: TS8

Soil profile	**Landscape**				**Ground surface**
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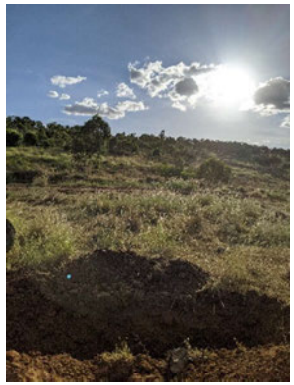
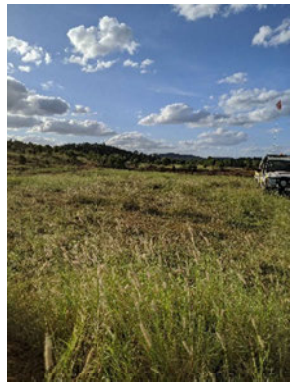
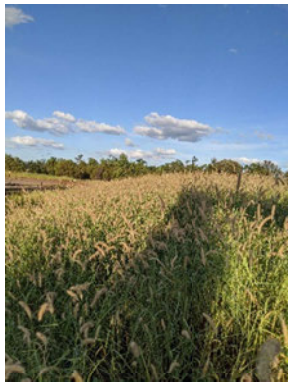
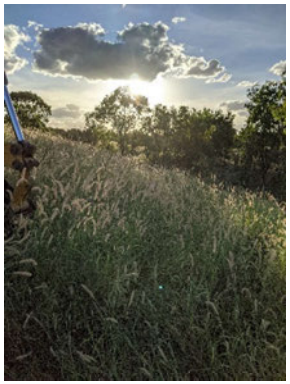
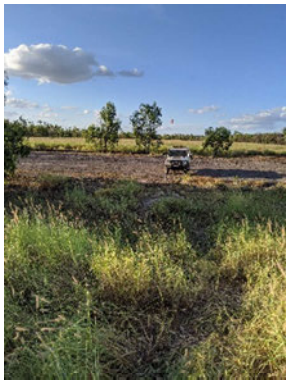
					

Soil description	**Field**			**Laboratory**	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Clay Loam	7.5YR 3/3 Dark Brown	7.8	19
30					
50					
90-100		Sandy Clay Loam	7.5YR 3/3 Dark Brown	7.9	19

Location: TS9

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Sandy Clay Loam	7.5YR 3/3 Dark Brown	8.6	27
30					
50					
90-100		Sandy Clay Loam	7.5YR 3/3 Dark Brown	7.9	26

Location: TS10

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

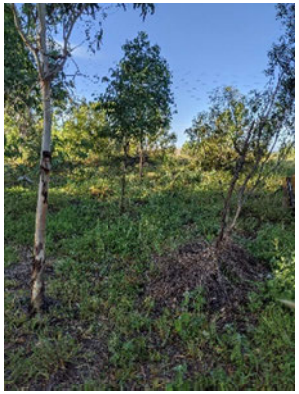
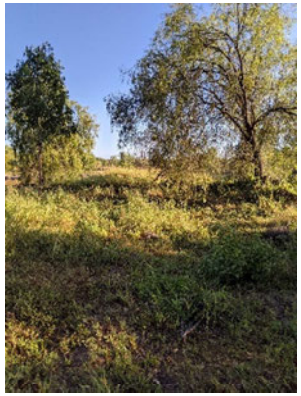
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Loamy Sand	5YR 5/3 Brown	7.4	5.2
30					
50					
90-100		Loamy Sand	5YR 5/3 Brown	7.6	5.8

Location: TS11

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

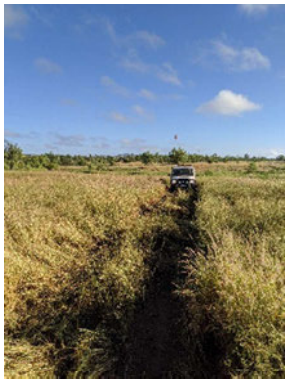
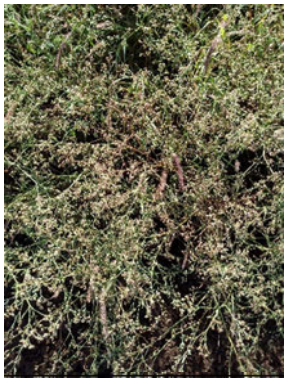
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Loamy Sand	5YR 5/3 Brown	7.5	9.5
30					
50					
90-100		Loamy Sand	5YR 5/3 Brown	7.4	7.3

Location: TS12

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Loamy Sand	5YR 5/3 Brown	8.3	11
30					
50					
90-100		Loamy Sand	5YR 5/3 Brown	7.9	6

Location: TS13

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

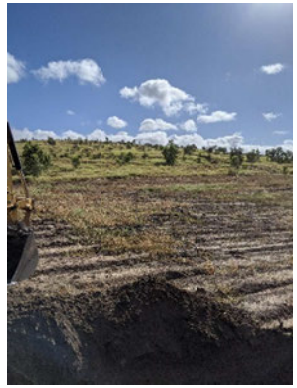
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Clay	7.5 YR 3/1 Very Dark Grey	8.2	29
30					
50					
90-100		Clay	7.5 YR 3/1 Very Dark Grey	8.5	31

Location: TS14

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Clay	7.5 YR 3/1 Very Dark Grey	8.3	35
30					
50					
90-100		Clay	7.5 YR 3/1 Very Dark Grey	8.7	33

Location: TS15

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

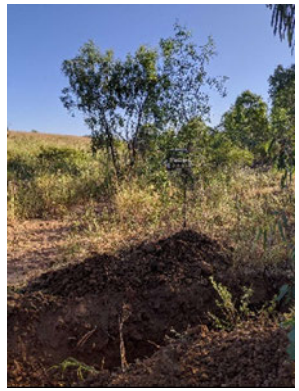
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**Hand texture**	**Colour**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-100	Soil				
0-10		Loamy Sand	5 YR 5/3 Brown	7.9	37
30					
50					
90-100		Clay	7.5 YR 3/1 Very Dark Grey	8.0	53

Location: Plumtree 12

Soil profile	**Landscape**				**Ground surface**
	North	*South*	*East*	*West*	
					

Soil description	**Field**			**Laboratory**	
Depth (cm)	**Description**	**$pH_{1:5}$**	**EC (µS/cm)**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-150	Soil	9.38	429.4	9.4	26
0-10					
30					
50					
90					
100-150					

Location: Plumtree 28

Soil Profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

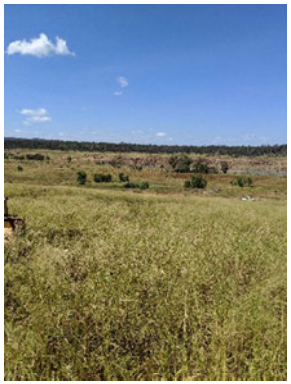
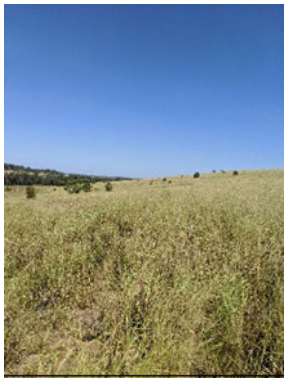
Soil description	Field			Laboratory	
Depth (cm)	**Description**	**$pH_{1:5}$**	**EC (µS/cm)**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-150	Soil	9.39	203.5	9.4	18
0-10					
30					
50					
90					
100-150					

Location: Broadmeadow 5

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description	Field			Laboratory	
Depth (cm)	**Description**	**$pH_{1:5}$**	**EC (µS/cm)**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-200	Spoil / Soil (grey)	8.63	1,183.0	8.8	31
0-10					
30					
50					
90					
100-200					

Location: Bullock Creek 42

Soil profile	**Landscape**				**Ground surface**
	North	*South*	*East*	*West*	
					

Soil description	**Field**			**Laboratory**	
Depth (cm)	**Description**	**$pH_{1:5}$**	**EC (µS/cm)**	**$pH_{1:5}$**	**CEC (meq/100g)**
0-150	Soil	9.32	482.9	9.2	30
0-10					
30					
50					
90					
100-150					

Appendix B
Laboratory results



ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Timothy Rohde
Client	SGM ENVIRONMENTAL
Address	PO BOX 5622 STAFFORD HEIGHTS QLD 4053
Telephone	0488 111 722
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Email	trohde@sgmenvironmental.com
Project	**19016 Soil**
Order Number	(Not specified)
Samples	37

LABORATORY DETAILS

Manager	Anthony Nilsson
Laboratory	SGS Cairns Environmental
Address	Unit 2, 58 Comport St Portsmith QLD 4870
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Email	AU.Environmental.Cairns@sgs.com
SGS Reference	**CE145676 R0**
Date Received	20 Apr 2020
Date Reported	01 May 2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(3146).

SIGNATORIES

Anthony NILSSON
Operations Manager

Jon Dicker
Manager Northern QLD

Maristela GANZAN
Metals Team Leader

Parameter	Units	LOR	Sample Number: CE145676.001 Sample Matrix: Soil Sample Name: TS1 0-10	Sample Number: CE145676.002 Sample Matrix: Soil Sample Name: TS1 140-150	Sample Number: CE145676.003 Sample Matrix: Soil Sample Name: TS2 0-10	Sample Number: CE145676.004 Sample Matrix: Soil Sample Name: TS2 90-100
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**8.1**	**8.3**	**7.3**	**7.0**
pH (CaCl2)*	pH Units	0.1	**7.6**	**7.8**	**6.1**	**6.1**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**120**	**120**	**190**	**29**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	**26**	<5	<5
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**4.1**	**6.6**	**2.5**	**7.5**
Nitrate as NO_3*	mg/kg	0.2	**18**	**29**	**11**	**33**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**4.1**	**6.6**	**2.5**	**7.5**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**560**	**740**	**230**	**230**
Total Nitrogen	mg/kg	20	**570**	**740**	**230**	**240**

Parameter	Units	LOR	Sample Number: CE145676.001 Sample Matrix: Soil Sample Name: TS1 0-10	Sample Number: CE145676.002 Sample Matrix: Soil Sample Name: TS1 140-150	Sample Number: CE145676.003 Sample Matrix: Soil Sample Name: TS2 0-10	Sample Number: CE145676.004 Sample Matrix: Soil Sample Name: TS2 90-100
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	2	2	2	2
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.71	1.1	0.39	0.37
Organic Matter	%w/w	0.1	1.2	1.8	0.67	0.64
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	66	430	9	12
Exchangeable Potassium, K	mg/kg	2	98	120	150	100
Exchangeable Calcium, Ca	mg/kg	2	2300	3900	420	530
Exchangeable Magnesium, Mg	mg/kg	2	470	930	62	110
Exchangeable Sodium, Na	cmol (+)/kg	0.01	0.29	1.9	0.04	0.05
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.25	0.32	0.39	0.26
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	12	20	2.1	2.6
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	3.8	7.6	0.50	0.89
Exchangeable Sodium Percentage*	%	0.1	1.8	6.3	1.3	1.3
Exchangeable Calcium Percentage*	%	0.1	72.8	66.7	69.1	68.8
Exchangeable Potassium Percentage*	%	0.1	1.6	1.1	12.8	6.8
Exchangeable Magnesium Percentage*	%	0.1	23.8	25.9	16.8	23.1
Cation Exchange Capacity	cmol (+)/kg	0.02	16	29	3.0	3.8
Sodium Adsorption Ratio*	No unit	0.1	0.1	0.5	<0.1	<0.1
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	3.1	2.6	4.1	3.0
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.48	0.91	0.26	0.47
Zinc, Zn	mg/kg	0.05	0.11	0.17	0.10	0.07
Manganese, Mn	mg/kg	0.5	6.0	8.1	8.3	14
Iron, Fe	mg/kg	0.5	5.2	8.0	8.4	10
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	2	7	1	4
Sulphur as Sulfate, SO4	mg/kg	3	6	21	3	11

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.001 Soil TS1 0-10	CE145676.002 Soil TS1 140-150	CE145676.003 Soil TS2 0-10	CE145676.004 Soil TS2 90-100
Emerson Class Number Method: AN009 Tested: 24/4/2020						
Emerson Class Number	No unit	1	**3**	-	**3**	-

Parameter	Units	LOR	Sample Number: CE145676.005 Sample Matrix: Soil Sample Name: TS2 70-85	CE145676.006 Soil TS3 0-10	CE145676.007 Soil TS3 90-100	CE145676.008 Soil TS4 0-10
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**7.6**	**7.0**	**7.4**	**7.4**
pH ($CaCl_2$)*	pH Units	0.1	**6.0**	**6.8**	**6.6**	**6.3**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**52**	**16**	**26**	**24**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	<5	<5	<5
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**5.0**	**1.4**	**8.0**	**1.4**
Nitrate as NO_3*	mg/kg	0.2	**22**	**6.1**	**35**	**6.0**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**5.0**	**1.4**	**8.0**	**1.4**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**380**	**360**	**250**	**270**
Total Nitrogen	mg/kg	20	**380**	**360**	**260**	**270**

Parameter	Units	LOR	Sample Number: CE145676.005 Sample Matrix: Soil Sample Name: TS2 70-85	CE145676.006 Soil TS3 0-10	CE145676.007 Soil TS3 90-100	CE145676.008 Soil TS4 0-10
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	2	2	2	2
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.53	0.62	0.26	0.36
Organic Matter	%w/w	0.1	0.92	1.1	0.46	0.62
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	25	9	6	4
Exchangeable Potassium, K	mg/kg	2	180	140	63	250
Exchangeable Calcium, Ca	mg/kg	2	1600	820	380	330
Exchangeable Magnesium, Mg	mg/kg	2	410	120	48	62
Exchangeable Sodium, Na	cmol (+)/kg	0.01	0.11	0.04	0.03	0.02
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.47	0.37	0.16	0.63
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	7.8	4.1	1.9	1.7
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	3.4	1.0	0.40	0.51
Exchangeable Sodium Percentage*	%	0.1	0.9	0.7	1.0	0.7
Exchangeable Calcium Percentage*	%	0.1	66.3	74.2	76.7	58.9
Exchangeable Potassium Percentage*	%	0.1	4.0	6.7	6.4	22.5
Exchangeable Magnesium Percentage*	%	0.1	28.8	18.3	15.9	18.0
Cation Exchange Capacity	cmol (+)/kg	0.02	12	5.5	2.5	2.8
Sodium Adsorption Ratio*	No unit	0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	2.3	4.0	4.8	3.3
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.78	0.42	0.15	0.21
Zinc, Zn	mg/kg	0.05	0.14	0.23	0.09	0.08
Manganese, Mn	mg/kg	0.5	14	12	5.4	4.5
Iron, Fe	mg/kg	0.5	8.0	9.9	5.4	19
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	11	<1	<1	<1
Sulphur as Sulfate, SO4	mg/kg	3	33	<3	<3	<3

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.005 Soil TS2 70-85	CE145676.006 Soil TS3 0-10	CE145676.007 Soil TS3 90-100	CE145676.008 Soil TS4 0-10
Emerson Class Number Method: AN009 Tested: 27/4/2020						
Emerson Class Number	No unit	1	-	**3**	-	**2**

Parameter	Units	LOR	Sample Number: CE145676.009 Sample Matrix: Soil Sample Name: TS4 100-110	CE145676.010 Soil TS5 0-10	CE145676.011 Soil TS5 100-110	CE145676.012 Soil TS6 0-10
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**7.5**	**8.2**	**8.2**	**6.6**
pH (CaCl2)*	pH Units	0.1	**6.5**	**7.5**	**7.5**	**5.4**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**12**	**130**	**240**	**44**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	<5	**94**	**19**
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**1.1**	**2.7**	**20**	**5.2**
Nitrate as NO_3*	mg/kg	0.2	**4.9**	**12**	**89**	**23**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**1.1**	**2.7**	**20**	**5.2**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**230**	**1500**	**690**	**540**
Total Nitrogen	mg/kg	20	**230**	**1500**	**710**	**550**

Parameter	Units	LOR	Sample Number: CE145676.009 Sample Matrix: Soil Sample Name: TS4 100-110	CE145676.010 Soil TS5 0-10	CE145676.011 Soil TS5 100-110	CE145676.012 Soil TS6 0-10
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	1	8	5	4
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.26	1.7	1.1	0.90
Organic Matter	%w/w	0.1	0.45	2.9	1.8	1.6
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	4	39	230	55
Exchangeable Potassium, K	mg/kg	2	79	360	160	160
Exchangeable Calcium, Ca	mg/kg	2	610	5700	2600	430
Exchangeable Magnesium, Mg	mg/kg	2	75	820	640	170
Exchangeable Sodium, Na	cmol (+)/kg	0.01	0.02	0.17	0.99	0.24
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.20	0.93	0.42	0.41
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	3.1	28	13	2.1
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	0.61	6.7	5.3	1.4
Exchangeable Sodium Percentage*	%	0.1	0.5	0.5	5.0	5.7
Exchangeable Calcium Percentage*	%	0.1	78.5	78.3	66.2	50.9
Exchangeable Potassium Percentage*	%	0.1	5.2	2.6	2.1	9.7
Exchangeable Magnesium Percentage*	%	0.1	15.8	18.6	26.7	33.8
Cation Exchange Capacity	cmol (+)/kg	0.02	3.9	36	20	4.2
Sodium Adsorption Ratio*	No unit	0.1	<0.1	<0.1	0.3	0.2
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	5.0	4.2	2.5	1.5
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.25	0.84	1.0	0.36
Zinc, Zn	mg/kg	0.05	0.06	0.47	0.49	0.98
Manganese, Mn	mg/kg	0.5	5.1	6.2	15	17
Iron, Fe	mg/kg	0.5	5.2	6.6	13	20
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	<1	4	11	3
Sulphur as Sulfate, SO4	mg/kg	3	<3	11	32	10

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.009 Soil TS4 100-110	CE145676.010 Soil TS5 0-10	CE145676.011 Soil TS5 100-110	CE145676.012 Soil TS6 0-10
Emerson Class Number Method: AN009 Tested: 27/4/2020						
Emerson Class Number	No unit	1	-	**3**	-	**2**

Parameter	Units	LOR	Sample Number: CE145676.013 Sample Matrix: Soil Sample Name: TS6 90-100	CE145676.014 Soil TS7 0-10	CE145676.015 Soil TS7 90-100	CE145676.016 Soil TS8 0-10
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**6.1**	**6.9**	**7.5**	**7.8**
pH ($CaCl_2$)*	pH Units	0.1	**5.2**	**6.1**	**6.7**	**7.1**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**180**	**62**	**160**	**74**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**190**	**9**	**110**	**9**
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**1.3**	**14**	**15**	**2.4**
Nitrate as NO_3*	mg/kg	0.2	**5.6**	**61**	**66**	**11**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**1.3**	**14**	**15**	**2.4**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**460**	**480**	**450**	**980**
Total Nitrogen	mg/kg	20	**460**	**490**	**460**	**980**

Parameter	Units	LOR	Sample Number: CE145676.013 Sample Matrix: Soil Sample Name: TS6 90-100	CE145676.014 Soil TS7 0-10	CE145676.015 Soil TS7 90-100	CE145676.016 Soil TS8 0-10
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	6	9	9	10
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.80	0.98	0.76	1.1
Organic Matter	%w/w	0.1	1.4	1.7	1.3	1.8
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	200	32	200	77
Exchangeable Potassium, K	mg/kg	2	65	250	110	310
Exchangeable Calcium, Ca	mg/kg	2	420	940	1100	2300
Exchangeable Magnesium, Mg	mg/kg	2	190	530	310	740
Exchangeable Sodium, Na	cmol (+)/kg	0.01	0.85	0.14	0.87	0.34
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.17	0.63	0.29	0.79
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	2.1	4.7	5.3	11
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	1.5	4.4	2.5	6.1
Exchangeable Sodium Percentage*	%	0.1	18.4	1.4	9.7	1.8
Exchangeable Calcium Percentage*	%	0.1	44.8	47.6	59.0	61.4
Exchangeable Potassium Percentage*	%	0.1	3.6	6.4	3.2	4.3
Exchangeable Magnesium Percentage*	%	0.1	33.2	44.5	28.1	32.5
Cation Exchange Capacity	cmol (+)/kg	0.02	4.6	9.8	9.0	19
Sodium Adsorption Ratio*	No unit	0.1	0.6	<0.1	0.4	0.1
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	1.3	1.1	2.1	1.9
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.72	0.75	0.49	0.65
Zinc, Zn	mg/kg	0.05	0.90	1.5	0.56	0.82
Manganese, Mn	mg/kg	0.5	46	15	15	7.9
Iron, Fe	mg/kg	0.5	100	6.1	8.0	5.9
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	22	3	19	2
Sulphur as Sulfate, SO4	mg/kg	3	65	9	56	6

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.013 Soil TS6 90-100	CE145676.014 Soil TS7 0-10	CE145676.015 Soil TS7 90-100	CE145676.016 Soil TS8 0-10
Emerson Class Number Method: AN009 Tested: 27/4/2020						
Emerson Class Number	No unit	1	-	**2**	-	**3**

Parameter	Units	LOR	Sample Number: CE145676.017 Sample Matrix: Soil Sample Name: TS8 90-100	CE145676.018 Soil TS9 0-10	CE145676.019 Soil TS9 90-100	CE145676.020 Soil TS10 0-10
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**7.9**	**8.6**	**7.9**	**7.4**
pH ($CaCl_2$)*	pH Units	0.1	**7.5**	**7.6**	**7.3**	**6.3**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**540**	**120**	**430**	**11**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**530**	**7**	**400**	<5
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**30**	**2.6**	**86**	**1.3**
Nitrate as NO_3*	mg/kg	0.2	**130**	**12**	**380**	**5.7**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**30**	**2.6**	**86**	**1.3**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**740**	**800**	**1000**	**230**
Total Nitrogen	mg/kg	20	**770**	**800**	**1100**	**230**

Parameter	Units	LOR	Sample Number: CE145676.017 Sample Matrix: Soil Sample Name: TS8 90-100	CE145676.018 Soil TS9 0-10	CE145676.019 Soil TS9 90-100	CE145676.020 Soil TS10 0-10
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	7	2	8	3
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.83	1.0	1.2	0.26
Organic Matter	%w/w	0.1	1.4	1.7	2.1	0.45
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	440	310	870	8
Exchangeable Potassium, K	mg/kg	2	140	210	240	78
Exchangeable Calcium, Ca	mg/kg	2	2300	3000	2600	700
Exchangeable Magnesium, Mg	mg/kg	2	690	1200	1100	170
Exchangeable Sodium, Na	cmol (+)/kg	0.01	1.9	1.4	3.8	0.03
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.36	0.55	0.61	0.20
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	11	15	13	3.5
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	5.6	10	8.7	1.4
Exchangeable Sodium Percentage*	%	0.1	10.0	5.1	14.3	0.7
Exchangeable Calcium Percentage*	%	0.1	58.8	55.4	50.1	68.2
Exchangeable Potassium Percentage*	%	0.1	1.9	2.0	2.3	3.9
Exchangeable Magnesium Percentage*	%	0.1	29.3	37.5	33.2	27.2
Cation Exchange Capacity	cmol (+)/kg	0.02	19	27	26	5.2
Sodium Adsorption Ratio*	No unit	0.1	0.7	0.4	1.1	<0.1
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	2.0	1.5	1.5	2.5
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.52	0.80	0.80	0.26
Zinc, Zn	mg/kg	0.05	0.36	0.19	0.34	0.07
Manganese, Mn	mg/kg	0.5	8.6	3.4	5.9	9.3
Iron, Fe	mg/kg	0.5	4.6	8.1	8.7	4.9
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	50	4	39	<1
Sulphur as Sulfate, SO4	mg/kg	3	150	11	120	<3

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.017 Soil TS8 90-100	CE145676.018 Soil TS9 0-10	CE145676.019 Soil TS9 90-100	CE145676.020 Soil TS10 0-10
Emerson Class Number Method: AN009 Tested: 27/4/2020						
Emerson Class Number	No unit	1	-	**3**	-	**2**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.021 Soil TS10 90-100	CE145676.022 Soil TS11 0-10	CE145676.023 Soil TS11 90-100	CE145676.024 Soil TS12 0-10
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**7.6**	**7.5**	**7.4**	**8.3**
pH (CaCl2)*	pH Units	0.1	**6.4**	**6.4**	**6.5**	**7.5**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**14**	**45**	**55**	**100**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	**5**	**12**	<5
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**1.0**	**3.9**	**12**	**1.5**
Nitrate as NO_3*	mg/kg	0.2	**4.4**	**17**	**53**	**6.7**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**1.0**	**3.9**	**12**	**1.5**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**180**	**530**	**270**	**370**
Total Nitrogen	mg/kg	20	**180**	**540**	**280**	**380**

Parameter	Units	LOR	Sample Number: CE145676.021 Sample Matrix: Soil Sample Name: TS10 90-100	CE145676.022 Soil TS11 0-10	CE145676.023 Soil TS11 90-100	CE145676.024 Soil TS12 0-10
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	4	16	17	11
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.20	0.66	0.40	0.44
Organic Matter	%w/w	0.1	0.35	1.1	0.69	0.75
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	16	14	61	87
Exchangeable Potassium, K	mg/kg	2	95	610	140	190
Exchangeable Calcium, Ca	mg/kg	2	750	1200	930	1500
Exchangeable Magnesium, Mg	mg/kg	2	210	260	250	390
Exchangeable Sodium, Na	cmol (+)/kg	0.01	0.07	0.06	0.26	0.38
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.24	1.6	0.35	0.48
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	3.7	5.8	4.6	7.4
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	1.7	2.1	2.0	3.2
Exchangeable Sodium Percentage*	%	0.1	1.2	0.6	3.6	3.3
Exchangeable Calcium Percentage*	%	0.1	64.7	60.7	63.7	64.5
Exchangeable Potassium Percentage*	%	0.1	4.2	16.3	4.9	4.2
Exchangeable Magnesium Percentage*	%	0.1	29.9	22.3	27.8	28.0
Cation Exchange Capacity	cmol (+)/kg	0.02	5.8	9.5	7.3	11
Sodium Adsorption Ratio*	No unit	0.1	<0.1	<0.1	0.1	0.2
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	2.2	2.7	2.3	2.3
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.24	0.50	0.43	0.33
Zinc, Zn	mg/kg	0.05	0.05	0.16	0.18	0.43
Manganese, Mn	mg/kg	0.5	9.7	14	12	6.7
Iron, Fe	mg/kg	0.5	4.1	8.5	10	4.1
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	1	2	5	6
Sulphur as Sulfate, SO4	mg/kg	3	4	5	15	19

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.021 Soil TS10 90-100	CE145676.022 Soil TS11 0-10	CE145676.023 Soil TS11 90-100	CE145676.024 Soil TS12 0-10
Emerson Class Number Method: AN009 Tested: 27/4/2020						
Emerson Class Number	No unit	1	-	**2**	-	**2**

Parameter	Units	LOR	Sample Number: CE145676.025 Sample Matrix: Soil Sample Name: TS12 90-100	CE145676.026 Soil TS13 0-10	CE145676.027 Soil TS13 90-100	CE145676.028 Soil TS14 0-10
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**7.9**	**8.2**	**8.5**	**8.3**
pH (CaCl2)*	pH Units	0.1	**6.5**	**7.6**	**7.8**	**7.6**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**26**	**140**	**170**	**150**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	<5	<5	<5
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**2.6**	**4.3**	**14**	**7.9**
Nitrate as NO_3*	mg/kg	0.2	**12**	**19**	**63**	**35**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**2.6**	**4.3**	**14**	**7.9**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**180**	**1200**	**850**	**1200**
Total Nitrogen	mg/kg	20	**180**	**1200**	**870**	**1200**

Parameter	Units	LOR	Sample Number: CE145676.025 Sample Matrix: Soil Sample Name: TS12 90-100	CE145676.026 Soil TS13 0-10	CE145676.027 Soil TS13 90-100	CE145676.028 Soil TS14 0-10
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	5	3	4	16
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.14	1.6	1.1	1.6
Organic Matter	%w/w	0.1	0.24	2.8	1.9	2.8
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	71	19	260	21
Exchangeable Potassium, K	mg/kg	2	93	540	140	520
Exchangeable Calcium, Ca	mg/kg	2	700	4400	4300	5800
Exchangeable Magnesium, Mg	mg/kg	2	240	720	910	490
Exchangeable Sodium, Na	cmol (+)/kg	0.01	0.31	0.08	1.1	0.09
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.24	1.4	0.35	1.3
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	3.5	22	22	29
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	2.0	5.9	7.5	4.0
Exchangeable Sodium Percentage*	%	0.1	5.1	0.3	3.6	0.3
Exchangeable Calcium Percentage*	%	0.1	58.1	74.8	70.8	84.2
Exchangeable Potassium Percentage*	%	0.1	3.9	4.7	1.2	3.8
Exchangeable Magnesium Percentage*	%	0.1	32.8	20.2	24.4	11.7
Cation Exchange Capacity	cmol (+)/kg	0.02	6.0	29	31	35
Sodium Adsorption Ratio*	No unit	0.1	0.2	<0.1	0.3	<0.1
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	1.8	3.7	2.9	7.2
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.40	0.58	0.80	0.38
Zinc, Zn	mg/kg	0.05	0.12	0.46	0.24	0.39
Manganese, Mn	mg/kg	0.5	7.8	3.5	5.7	3.6
Iron, Fe	mg/kg	0.5	8.2	3.6	5.8	3.2
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	3	2	4	3
Sulphur as Sulfate, SO4	mg/kg	3	10	5	11	9

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.025 Soil TS12 90-100	CE145676.026 Soil TS13 0-10	CE145676.027 Soil TS13 90-100	CE145676.028 Soil TS14 0-10
Emerson Class Number Method: AN009 Tested: 27/4/2020						
Emerson Class Number	No unit	1	-	3	-	3

Parameter	Units	LOR	Sample Number: CE145676.029 Sample Matrix: Soil Sample Name: TS14 90-100	CE145676.030 Soil TS15 0-10	CE145676.031 Soil TS15 90-100	CE145676.032 Soil Plumtree 25
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	**8.7**	**7.9**	**8.0**	**9.3**
pH (CaCl2)*	pH Units	0.1	**7.8**	**7.5**	**7.7**	**8.2**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**230**	**660**	**1800**	**570**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	**620**	**650**	**440**
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**28**	**81**	**5.9**	**1.3**
Nitrate as NO_3*	mg/kg	0.2	**120**	**350**	**20**	**5.8**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**28**	**80**	**4.5**	**1.3**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	**1.3**	**1.3**	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	**970**	**1100**	**1000**	**220**
Total Nitrogen	mg/kg	20	**1000**	**1200**	**1000**	**220**

Parameter	Units	LOR	Sample Number: CE145676.029 Sample Matrix: Soil Sample Name: TS14 90-100	CE145676.030 Soil TS15 0-10	CE145676.031 Soil TS15 90-100	CE145676.032 Soil Plumtree 25
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	5	4	2	1
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	1.2	1.2	1.3	0.13
Organic Matter	%w/w	0.1	2.0	2.0	2.3	0.23
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	460	530	1300	1400
Exchangeable Potassium, K	mg/kg	2	160	500	120	140
Exchangeable Calcium, Ca	mg/kg	2	4500	5100	6500	4900
Exchangeable Magnesium, Mg	mg/kg	2	990	910	1700	1200
Exchangeable Sodium, Na	cmol (+)/kg	0.01	2.0	2.3	5.7	5.9
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.41	1.3	0.31	0.35
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	22	26	33	24
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	8.2	7.4	14	10
Exchangeable Sodium Percentage*	%	0.1	6.1	6.3	10.8	14.5
Exchangeable Calcium Percentage*	%	0.1	68.0	69.9	61.8	59.9
Exchangeable Potassium Percentage*	%	0.1	1.2	3.5	0.6	0.9
Exchangeable Magnesium Percentage*	%	0.1	24.7	20.3	26.8	24.8
Cation Exchange Capacity	cmol (+)/kg	0.02	33	37	53	41
Sodium Adsorption Ratio*	No unit	0.1	0.5	0.6	1.2	1.4
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	2.7	3.4	2.3	2.4
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	1.1	1.3	0.94	0.48
Zinc, Zn	mg/kg	0.05	0.28	0.06	0.17	<0.05
Manganese, Mn	mg/kg	0.5	7.0	13	5.9	1.7
Iron, Fe	mg/kg	0.5	7.6	2.7	3.3	1.7
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	13	15	1300	58
Sulphur as Sulfate, SO4	mg/kg	3	40	46	3900	180

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.029 Soil TS14 90-100	CE145676.030 Soil TS15 0-10	CE145676.031 Soil TS15 90-100	CE145676.032 Soil Plumtree 25
Emerson Class Number Method: AN009 Tested: 27/4/2020						
Emerson Class Number	No unit	1	-	**3**	-	**2**

Parameter	Units	LOR	Sample Number: CE145676.033 Sample Matrix: Soil Sample Name: Bullock Creek 42	CE145676.034 Soil Plumtree 28	CE145676.035 Soil Plumtree 12	CE145676.036 Soil Broadmedow 5
pH in soil (1:5) Method: AN101 Tested: 27/4/2020						
pH	pH Units	0.1	9.2	9.4	9.4	8.8
pH ($CaCl_2$)*	pH Units	0.1	8.1	8.2	8.1	8.1
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	520	270	400	1100
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	450	31	290	1400
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020						
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	1.5	1.9	1.4	2.4
Nitrate as NO_3*	mg/kg	0.2	6.6	8.5	6.4	11
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	1.5	1.9	1.4	2.4
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020						
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020						
Total Kjeldahl Nitrogen	mg/kg	20	320	160	390	480
Total Nitrogen	mg/kg	20	320	160	390	480

Parameter	Units	LOR	Sample Number: CE145676.033 Sample Matrix: Soil Sample Name: Bullock Creek 42	CE145676.034 Soil Plumtree 28	CE145676.035 Soil Plumtree 12	CE145676.036 Soil Broadmedow 5
Colwell Phosphorus Method: AN015 Tested: 28/4/2020						
Colwell Phosphorus	mg/kg	1	1	2	2	2
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020						
Total Organic Carbon	%w/w	0.05	0.48	0.14	0.28	0.65
Organic Matter	%w/w	0.1	0.83	0.24	0.48	1.1
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020						
Exchangeable Sodium, Na	mg/kg	2	870	800	970	1800
Exchangeable Potassium, K	mg/kg	2	150	62	83	100
Exchangeable Calcium, Ca	mg/kg	2	3500	1600	2900	2700
Exchangeable Magnesium, Mg	mg/kg	2	1000	720	860	1100
Exchangeable Sodium, Na	cmol (+)/kg	0.01	3.8	3.5	4.2	7.7
Exchangeable Potassium, K	cmol (+)/kg	0.01	0.38	0.16	0.21	0.26
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	17	8.0	15	14
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	8.6	5.9	7.1	8.9
Exchangeable Sodium Percentage*	%	0.1	12.5	19.8	16.1	25.2
Exchangeable Calcium Percentage*	%	0.1	57.6	45.7	55.8	44.9
Exchangeable Potassium Percentage*	%	0.1	1.2	0.9	0.8	0.9
Exchangeable Magnesium Percentage*	%	0.1	28.6	33.6	27.2	29.1
Cation Exchange Capacity	cmol (+)/kg	0.02	30	18	26	31
Sodium Adsorption Ratio*	No unit	0.1	1.0	1.3	1.3	2.3
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	2.0	1.4	2.1	1.5
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020						
Exchangeable Aluminium*	mg/kg	1	-	-	-	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-	-	-	-
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020						
Copper, Cu	mg/kg	0.05	0.80	0.18	0.17	0.47
Zinc, Zn	mg/kg	0.05	0.49	0.06	0.10	0.19
Manganese, Mn	mg/kg	0.5	2.9	1.5	2.1	2.0
Iron, Fe	mg/kg	0.5	4.4	2.0	2.3	2.4
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020						
Sulfur, S	mg/kg	1	66	2	7	62
Sulphur as Sulfate, SO4	mg/kg	3	200	6	20	190

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145676.033 Soil Bullock Creek 42	CE145676.034 Soil Plumtree 28	CE145676.035 Soil Plumtree 12	CE145676.036 Soil Broadmedow 5
Emerson Class Number Method: AN009 Tested: 24/4/2020						
Emerson Class Number	No unit	1	**2**	**2**	**2**	**2**

Parameter	Units	LOR	Sample Number: CE145676.037 Sample Matrix: Soil Sample Name: Broadmedow 8
pH in soil (1:5) Method: AN101 Tested: 27/4/2020			
pH	pH Units	0.1	**9.1**
pH ($CaCl_2$)*	pH Units	0.1	**8.1**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 27/4/2020			
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**1100**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020			
Chloride (water extractable 1:5)	mg/kg	5	**1400**
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil Method: AN248 Tested: 27/4/2020			
Nitrate/Nitrite Nitrogen, NOx as N	mg/kg	0.05	**1.9**
Nitrate as NO_3*	mg/kg	0.2	**8.6**
Nitrate Nitrogen, NO_3 as N	mg/kg	0.05	**1.9**
Nitrite Nitrogen in Soil Method: AN277 Tested: 30/4/2020			
Nitrite, NO_2 as N in Soil	mg/kg	0.05	<0.05
Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges Method: AN281 Tested: 27/4/2020			
Total Kjeldahl Nitrogen	mg/kg	20	**370**
Total Nitrogen	mg/kg	20	**370**

Parameter	Units	LOR	Sample Number: CE145676.037 Sample Matrix: Soil Sample Name: Broadmedow 8
Colwell Phosphorus Method: AN015 Tested: 28/4/2020			
Colwell Phosphorus	mg/kg	1	<1
Total Organic Carbon by Heanes Oxidation Method: AN273 Tested: 28/4/2020			
Total Organic Carbon	%w/w	0.05	**0.26**
Organic Matter	%w/w	0.1	**0.45**
Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) Method: AN122 Tested: 27/4/2020			
Exchangeable Sodium, Na	mg/kg	2	**2000**
Exchangeable Potassium, K	mg/kg	2	**91**
Exchangeable Calcium, Ca	mg/kg	2	**2900**
Exchangeable Magnesium, Mg	mg/kg	2	**950**
Exchangeable Sodium, Na	cmol (+)/kg	0.01	**8.7**
Exchangeable Potassium, K	cmol (+)/kg	0.01	**0.23**
Exchangeable Calcium, Ca	cmol (+)/kg	0.01	**14**
Exchangeable Magnesium, Mg	cmol (+)/kg	0.02	**7.8**
Exchangeable Sodium Percentage*	%	0.1	**27.9**
Exchangeable Calcium Percentage*	%	0.1	**46.4**
Exchangeable Potassium Percentage*	%	0.1	**0.7**
Exchangeable Magnesium Percentage*	%	0.1	**25.0**
Cation Exchange Capacity	cmol (+)/kg	0.02	**31**
Sodium Adsorption Ratio*	No unit	0.1	**2.6**
Exchangeable Calcium/Exchangeable Magnesium Ratio*	No unit	0.1	**1.9**
Soil - Aluminium (KCL Extraction) Method: AN046 Tested: 29/4/2020			
Exchangeable Aluminium*	mg/kg	1	-
Exchangeable Aluminium*	cmol (+)/kg	0.01	-

Parameter	Units	LOR	Sample Number: CE145676.037 Sample Matrix: Soil Sample Name: Broadmedow 8
DTPA Extractable Metals in Soil Method: AN025/AN320 Tested: 27/4/2020			
Copper, Cu	mg/kg	0.05	**0.12**
Zinc, Zn	mg/kg	0.05	**0.05**
Manganese, Mn	mg/kg	0.5	**1.1**
Iron, Fe	mg/kg	0.5	**1.7**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 28/4/2020			
Sulfur, S	mg/kg	1	**35**
Sulphur as Sulfate, SO4	mg/kg	3	**110**
Emerson Class Number Method: AN009 Tested: 24/4/2020			
Emerson Class Number	No unit	1	**2**

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Chloride (water extractable) **Method: ME-(AU)-[ENV]AN274**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride (water extractable 1:5)	LB078234	mg/kg	5	<5	0 - 1%	108 - 109%

Colwell Phosphorus **Method: ME-(AU)-[ENV]AN015**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Colwell Phosphorus	LB078233	mg/kg	1	<1	0 - 5%	108 - 112%

DTPA Extractable Metals in Soil **Method: ME-(AU)-[ENV]AN025/AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Copper, Cu	LB078176	mg/kg	0.05	<0.05	0 - 3%	99 - 105%
Zinc, Zn	LB078176	mg/kg	0.05	<0.05	10 - 82%	86 - 90%
Manganese, Mn	LB078176	mg/kg	0.5	<0.5	1 - 6%	111 - 113%
Iron, Fe	LB078176	mg/kg	0.5	<0.5	0 - 6%	89 - 92%

Exchangeable Cations and Cation Exchange Capacity (CEC/ESP/SAR) **Method: ME-(AU)-[ENV]AN122**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Exchangeable Sodium, Na	LB078174	mg/kg	2		0 - 4%	97 - 101%
Exchangeable Potassium, K	LB078174	mg/kg	2		1 - 3%	105%
Exchangeable Calcium, Ca	LB078174	mg/kg	2		1 - 4%	101 - 102%
Exchangeable Magnesium, Mg	LB078174	mg/kg	2		1 - 3%	97 - 101%
Exchangeable Sodium, Na	LB078174	cmol (+)/kg	0.01	<0.01		
Exchangeable Potassium, K	LB078174	cmol (+)/kg	0.01	<0.01		
Exchangeable Calcium, Ca	LB078174	cmol (+)/kg	0.01	<0.01		
Exchangeable Magnesium, Mg	LB078174	cmol (+)/kg	0.02	<0.02		
Exchangeable Sodium Percentage*	LB078174	%	0.1	23.1 - 58.1		
Exchangeable Calcium Percentage*	LB078174	%	0.1	33.4 - 37.2		
Exchangeable Potassium Percentage*	LB078174	%	0.1	2.1 - 9.2		
Exchangeable Magnesium Percentage*	LB078174	%	0.1	2.6 - 34.3		
Cation Exchange Capacity	LB078174	cmol (+)/kg	0.02	<0.02		
Sodium Adsorption Ratio*	LB078174	No unit	0.1	<0.1		
Exchangeable Calcium/Exchangeable Magnesium Ratio*	LB078174	No unit	0.1	1.0 - 14.3		

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by Auto Analyser in Soil **Method: ME-(AU)-[ENV]AN248**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Nitrate/Nitrite Nitrogen, NOx as N	LB078204	mg/kg	0.05	<0.05	0 - 11%	98 - 99%

Nitrite Nitrogen in Soil **Method: ME-(AU)-[ENV]AN277**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Nitrite, NO_2 as N in Soil	LB078202	mg/kg	0.05	<0.05	0 - 35%	98 - 100%

Total Kjeldahl Nitrogen and Total Nitrogen in Soil/Sludges **Method: ME-(AU)-[ENV]AN281**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Kjeldahl Nitrogen	LB078197	mg/kg	20	<20	0 - 3%	117%

Total Organic Carbon by Heanes Oxidation **Method: ME-(AU)-[ENV]AN273**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MSD %RPD
Total Organic Carbon	LB078232	%w/w	0.05	<0.05	7 - 10%	98 - 104%	NA
Organic Matter	LB078232	%w/w	0.1	<0.10	7 - 10%	NA	NA

Water Soluble Metals in Soil by ICPOES **Method: ME-(AU)-[ENV]AN002/AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Sulfur, S	LB078209	mg/kg	1	<1	1 - 7%	NA
Sulphur as Sulfate, SO4	LB078209	mg/kg	3	<3	1 - 7%	NA

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN002/AN320/AN321	Soil sample is extracted in deionised water (1:2 or 1:5) and metals analysed by ICP OES, method AN320/AN321, with results reported on the dried sample basis.
AN009	The method follows AS1289 3.8.1 - 2006. Soils are divided into seven classes on the basis of their coherence in water, with one further class being distinguished by the presence of calcium-rich minerals. Class 1: Air-dried crumbs of soil show a strong dispersion reaction, i.e., a colloidal cloud covers nearly the whole of the bottom of the beaker, usually in a very thin layer. The reaction should be evident within 10min. In extreme cases all the water in the beaker becomes cloudy, leaving only a coarse residue in a cloud of clay.
AN009	Class 2: Air-dried crumbs of soil show a moderate to slight reaction. A moderate reaction consists of an easily recognisable cloud of colloids in suspension, usually spreading in thin streaks on the bottom of the beaker. A slight reaction consists of the bare hint of cloud in water at the surface of the crumbs. Class 3: The soil remoulded at the plastic limit disperses in water. Class 4: The remoulded soil does not disperse in water. Calcium carbonate (calcite) or calcium sulfate (gypsum) is present. Class 5: The remoulded soil does not disperse in water and the 1:5 soil/water suspension remains dispersed after 5 min.
AN009	Class 6: The remoulded soil does not disperse in water and the 1:5 soil/water suspension begins to flocculate within 5 min. Class 7: The air-dried crumbs of soil remain coherent in water and swells. Class 8: The air-dried crumbs of soil remain coherent in water and do not swell.
AN015	Soil sample is extracted in an end over end roller in 0.5 N sodium bicarbonate at pH 8.5 with the supernatant liquor analysed for Phosphorous. Orthophosphate anion (PO43-) is reacted with ammonium molybdate and potassium antimony tartrate in sulfuric acid solution. The resulting phospho-molybdate complex is reduced, using ascorbic acid, to an intense blue coloured complex Molybdenum Blue. The absorbance of this complex is measured at 880 nm by Discrete Analyser, and compared with calibration standards to obtain the concentration of orthophosphate in the sample. Based on Rayment & Higginson 9B1.
AN025/AN320	A chelating agent is used to complex metal ions in solution. The extracted elements are determined byICP OES.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode and is calibrated against 3 buffers purchased commercially. For soils, sediments and sludges, an extract with water (or 0.01M CaCl2) is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN103	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract of as received sample with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Salinity can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. Reference APHA 2510 B.
AN122	Exchangeable Cations, CEC and ESP: Soil sample is extracted in 1 M Ammonium Acetate at pH=7 (or 1M Ammonium Chloride at pH=7) with cations (Na, K, Ca & Mg) then determined by ICP OES/ICP MS and reported as Exchangeable Cations. For saline soils, these results can be corrected for water soluble cations and reported as Exchangeable cations in meq/100g or soil can be pre-treated (aqueous ethanol/aqueous glycerol) prior to extraction. Cation Exchange Capacity (CEC) is the sum of the exchangeable cations in meq/100g.

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN122	The Exchangeable Sodium Percentage (ESP) is calculated as the exchangeable sodium divided by the CEC (all in meq/100g) times 100. ESP can be used to categorise the sodicity of the soil as below: ESP < 6% non-sodic ESP 6-15% sodic ESP >15% strongly sodic Method is referenced to Rayment and Lyons, 2011, sections 15D3 and 15N1.-
AN248	Nitrate / Nitrite in extract by Auto Analyser: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Reference APHA 4500-NO3- F.
AN273	The sample is digested in Dichromate / Sulfuric Acid to oxidise the organic carbon. The determination is completed colourimetrically by Aquakem Discrete Analyser at 600 nm. Based on Rayment & Higginson 6B1.
AN274	Chloride by Aquakem DA following 1:5 or 1:2 DI water extraction: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Results reported on dry sample basis. Reference APHA 4500Cl-
AN277	Nitrite on the extract is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The original nitrite is determined. Reference APHA 4500-NO2- B.
AN281	The sample is heated in the presence of Sulphuric acid, K2SO4 and CuSO4 for two and half hours using a temperature controlled digestion block. Amino Nitrogen of many organic materials is converted to ammonium ion. Free ammonia also is converted to ammonium. The digest is cooled and placed on the Aquakem 250 discrete analyser for Ammonia determination.
SOL061	Soil sample is extrcated 1:10 in 1MKCl with aluminium determined by ICP OES.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
		NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

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Appendix F
Spoil characterisation



Spoil Characterisation Assessment

Peabody Burton Mine

Prepared for Peabody (Burton) Pty Limited | June 2022



Peabody

SGMenvironmental

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Spoil Characterisation Assessment

Peabody Burton Mine

Prepared for Peabody (Burton) Pty Limited | 6 June 2022

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Executive summary

Peabody Burton Mine (the Mine) is located approximately (~) 90 kilometres (km) southwest of the city of Mackay, 67 km from Nebo and 36 km from Glenden. The Mine commenced care, maintenance and rehabilitation in November 2016 with the end of mining activity and coal processing.

SGM environmental Pty Limited (SGME) was engaged by Peabody (Burton) Pty Limited (Peabody) to prepare a spoil characterisation report for the Mine. This report is intended to support the Progressive Rehabilitation and Closure Plan (PRC plan) which is currently being prepared by SGME. This report is consistent with the requirements of the *Guideline: Progressive rehabilitation and closure plans* (the PRC plan guideline) and includes:

- volumes of out-of-pit spoil;
- justification that the characterisation has been done to a high level of confidence;
- chemical and physical properties of the spoil under stored conditions including:
  - classification of spoil based on the potential for acid mine drainage (AMD), neutral mine drainage (NMD) and / or saline drainage (SD);
  - elemental composition and future speciation and mobility; and
  - fertility;
- assessment of the suitability as a growth medium beneath the topsoil (cover); and
- management recommendations.

Geochemical characterisation suggests that spoil at the Mine is largely acid neutralising. Plumtree 14 had a net acid generation (NAG)pH less than 4.5. However, this is likely a result of the organic acids dissolved in the NAG procedure and are not going to contribute to AMD.

Spoil with an acid neutralising capacity to maximum potential acidity (ANC/MPA) mass ratio greater than two is considered to have a negligible to low risk of acid generation and a high factor of safety in terms of potential for AMD. All samples have an ANC/MPA ratio greater than two except for Wallanbah 34, 40 and 52. These samples have a reactive S of less than 0.1% and can therefore be considered barren. Barren spoil has almost no capacity to generate acidity even in the absence of significant ANC. Further, any acidity generated would quickly be neutralised by the ANC of the surrounding spoil.

Net acidity is negative for all samples, except Wallanbah 40 and 52, indicating sufficient ANC to neutralise any acid released. Actual and retained acidity are low for all samples indicating minimal past oxidation.

Water-soluble metal and metalloid concentrations are low for the majority of samples. Aluminium, barium, iron and manganese (Al, Ba, Fe and Mn) were elevated in some samples. It is expected that further dilution effects from rainfall and natural attenuation would occur prior to any spoil drainage arriving at a receptor. Seepage from the spoil is therefore likely to contain very low concentrations of metals and metalloids.

Most samples are expected to have low salinity based on the Department of Mines and Energy (DME) (1995) soil salinity classification. It is unlikely that surface runoff and seepage from the spoil will be saline. Accordingly, water-soluble sulfate is low.

Strong alkalinity may be a restriction to plant growth; however, vegetation and groundcover did not appear to be limited / restricted at any of the test pit locations.

Actual acidity is low across all samples (less than 0.06%). pH (potassium chloride (KCl)) is greater than 4.5, indicating that any retained acidity present is very low.

There were no AMD / NMD or SD issues observed during this assessment. Spoil is suitable for use in rehabilitation and as a growth medium beneath a topsoil layer (cover). Further, progressive rehabilitation at the Mine has been successful. Therefore, no changes are recommended to the rehabilitation strategy.

1.0 Introduction

Peabody Burton Mine (the Mine) is located approximately (~) 90 kilometres (km) southwest of the city of Mackay, 67 km from Nebo and 36 km from Glenden. The Mine commenced care, maintenance and rehabilitation in November 2016 with the end of mining activity and coal processing.

This report has been completed to support the *Progressive Rehabilitation and Closure Plan* (PRC plan) which is currently being prepared by SGM environmental Pty Limited (SGME) in accordance with the *Guideline: Progressive rehabilitation and closure plans* (the PRC plan guideline).

1.1 Scope

The scope of this report is to complete spoil sampling and field characterisation while meeting the requirements of the PRC plan guideline. The purpose is to characterise spoil and identify any contaminants that pose a risk to the environment for the following features:

- Broadmeadow out-of-pit spoil storage area;
- Plumtree out-of-pit spoil storage areas (two);
- Bullock Creek out-of-pit spoil storage area; and
- Wallanbah out-of-pit spoil storage areas (two).

1.1.1 PRCP plan guideline

The PRC plan guideline states that the PRC plan must include all supporting information required by the Department of Environment and Science (DES) to reach a decision on the 'soundness' of the proposed rehabilitation strategies and delivery techniques to meet the approved land outcomes. This report will form an appendix in the PRC plan.

How this report meets the requirements of the PRC plan guideline is addressed in Table 1.

Table 1 How the PRC plan guideline is addressed in this report

Requirements	Report section
Volumes of out-of-pit spoil	Section 1.2.2.1
Justification that the characterisation has been done to a high level of confidence	Section 2.0
Chemical and physical properties of the spoil under stored conditions including: • classification of spoil based on the potential for acid mine drainage (AMD), neutral mine drainage (NMD) and / or saline drainage (SD); • elemental composition and future specification and mobility; and • fertility.	Section 3.0 & 4.0
An assessment of the suitability as a growth medium beneath the topsoil	Section 4.5
Any management recommendations	Section 5.1

1.2 Review

1.2.1 Geology

1.2.1.1 Regional geology

The Mine is in the Bowen Basin which is an important Permian coal basin located in Central Queensland. The basin extends south in the subsurface beneath Mesozoic sediments of the Surat Basin and connects with the Gunnedah and Sydney Basins in New South Wales.

The stratigraphic sequence of the Bowen Basin can be summarised as Permo-Triassic sediments overlain by a thin covering of unconsolidated Quaternary alluvium and colluvium and poorly consolidated Tertiary sediments of the Tertiary Suttor and Duaringa formations as well as remnants of Tertiary basalt flows.

Coal seams in the Bowen Basin show major variations in rank and quality, reflecting both the depositional and tectonic history of the basin.

1.2.1.2 Mine geology

The Mine is located within the Rangal Coal Measures. The Rangal and Fort Cooper Coal Measure sequences sub crop within the Plumtree, Broadmeadow and Wallanbah Coal Project areas. The Fort Cooper Coal Measures that overlie the Moranbah Coal Measures comprise grey lithic sandstones, conglomerate, siltstone, mudstone coal and tuffaceous sediments. The Girrah seam (uppermost seam in the Fort Cooper Coal Measures) is a thick banded sequence of coal, cream to brown tuffaceous claystones, mudstones and siltstones. The target seam (Leichardt and Vermot splits) occurs in the Rangal Coal Measures.

Overlying the Rangal Coal Measures are greenish sediments of the Rewan Group. Quaternary soil, alluvium and / or colluvium cover:

- all of the Plumtree Coal Project area, particularly adjacent to Sandy Creek;
- most of the western part of the Broadmeadow Coal Project area adjacent to Hat Creek; and
- most of the eastern part of the Wallanbah Coal Project area adjacent to Bullock Creek and Spade Creek.

The Wallanbah Coal Project area lies to the west of the Burton Range Fault and is covered by Triassic Clematis Sandstone and at depth by red, brown and green mudstones and siltstones of the Triassic Arcadia Formation.

It is accepted that Tertiary sediments have low strengths, are dispersive in nature and highly erodible due to their physical and chemical characteristics. Weathered Rewan Formation is generally less susceptible to erosion. The interbedded sandstone layers are generally more slake resistant in comparison to the siltstone layers which tend to degrade rapidly.

1.2.2 Rehabilitation

1.2.2.1 Volume of out-of-pit spoil

The volume of out-of-pit spoil available for rehabilitation is presented in Table 2.

Table 2 Volume of out-of-pit spoil

Project area	Volume (bank cubic metres (BCM))
Broadmeadow	23,400,237
Plumtree	39,164,040

Project area	Volume (bank cubic metres (BCM))
Bullock Creek	9,308,031
Wallanbah	33,000,000
Total	**104,872,308**

1.2.2.2 Relinquishment goals and objectives

The general rehabilitation goals for the Mine include:

- the Mine will be safe to humans and livestock;
- disturbed land will be rehabilitated so that it is non-polluting;
- rehabilitation will aim to create a landform that is stable and conducive to the post-mining land use (PMLU); and
- rehabilitation will be completed to a standard that is conducive to the PMLU.

Peabody intends to return most of the disturbed area to grazing in a manner which is consistent with the PRC plan guideline and environmental authority (EA) EMPL00879213 conditions regarding rehabilitation (ie Conditions F1-F15).

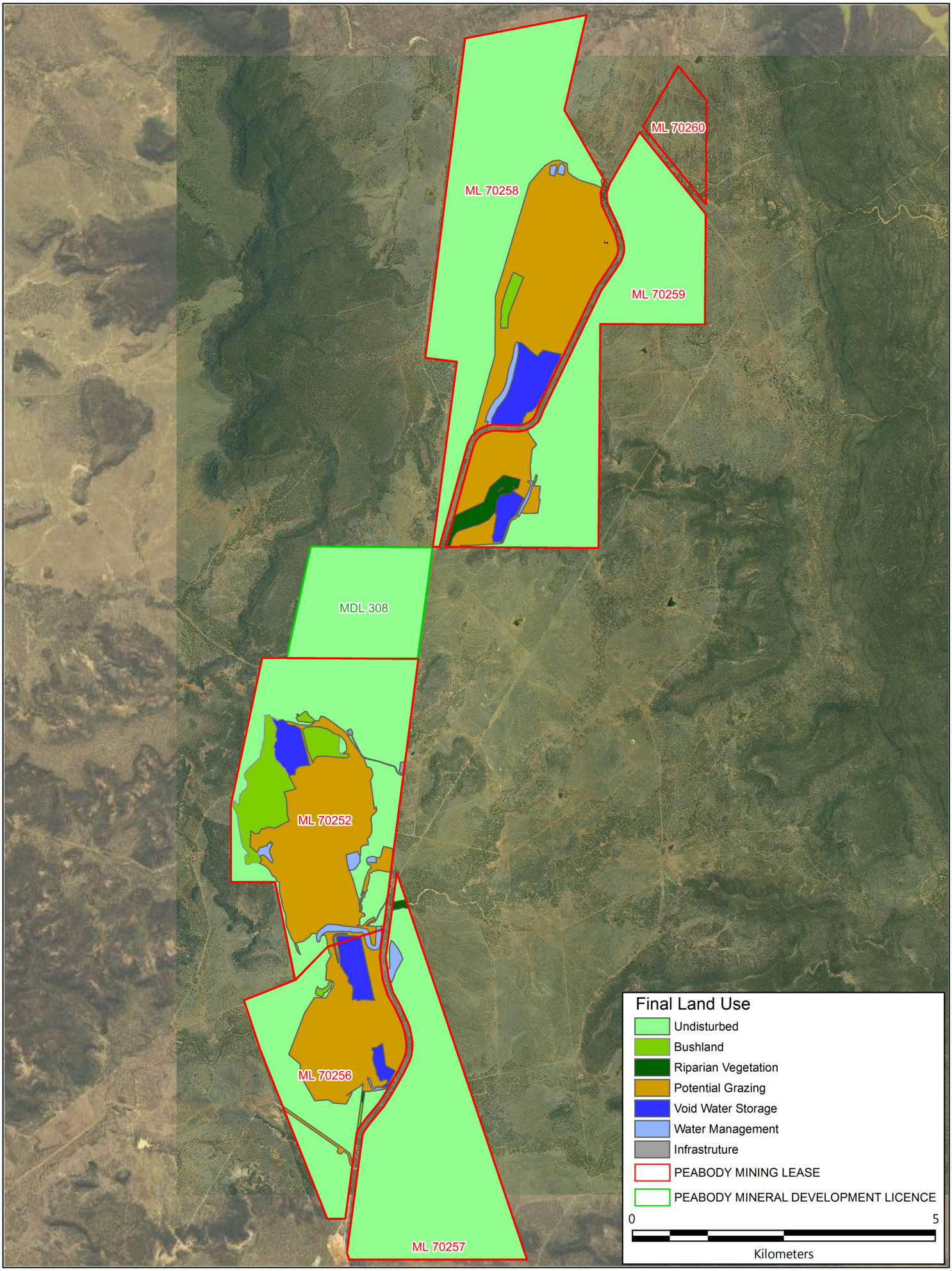
1.2.2.3 Post-mining land use

Mining is a temporary use of land. Suitable areas will be returned to grazing while other areas will be covered with soil and seeded with trees, shrubs and grasses in a manner which is consistent with EA conditions regarding rehabilitation (Conditions F1-F15).

The proposed PMLU comprises:

- water management;
- pit water storage (pits including Broadmeadow pit, Plumtree pit, Bullock Creek pit, Wallanbah pit and farm dams);
- grazing;
- bushland (disturbed and undisturbed areas);
- riparian (riparian areas along Bullock Creek and Spade Creek diversions);
- infrastructure (including laydowns, hardstands, roads and loading ramps); and
- undisturbed (pre-existing land uses).

Figure 1 shows the spatial distribution of PMLUs.



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Final Land Use

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Issued: 14/12/2018	Drawn: BL

2.0 Method

2.1 Sample sites

10 samples were collected at six out-of-pit storage areas (a total of 60 samples). Spoil sample locations are shown in Figure 2 and Figure 3.

2.2 Sampling density

The International Network for Acid Prevention (INAP) *Global Acid Rock Drainage (GARD) Guide* (2014) does not contain clear guidance on sampling densities for out-of-pit spoil dump characterisation. Within Australia, the *Preventing Acid and Metalliferous Drainage: Leading Practice Sustainable Development Program for the Mining Industry* (2016) also does not provide clear guidance on sampling densities for out-of-pit spoil dump characterisation.

The Department of Mines and Energy (DME) 1995 guideline *Assessment and Management of Acid Drainage*, describes sampling density based on volume of spoil. Notwithstanding, sampling density was selected based on the *Guidelines for Surveying Soil and Land Resources* (McKenzie et al. 2008) for field level and detailed project planning (ie one sample per 5-25 hectares (ha) or 4-20 samples per square kilometre (km^2) of spoil). The sampling density is spatially representative of the spoil stockpiles because sampling was done at a rate of one sample per 9 ha. Spatial representation is important when considering rooting depth.

2.3 Sampling method

1 metre (m) composite samples were collected from ground level (or the bottom of applied soil) down to 1 m below ground level (bgl) from a test pit dug by backhoe.

2.4 Field testing

All 60 samples were analysed in the field for pH and electrical conductivity (EC). These are screening tests for acidic / alkaline and saline spoil respectively. These tests were used to select samples for laboratory analysis.

2.5 Laboratory testing

A National Association of Testing Authorities (NATA) laboratory (SGS) was used to assess 35 samples for the following:

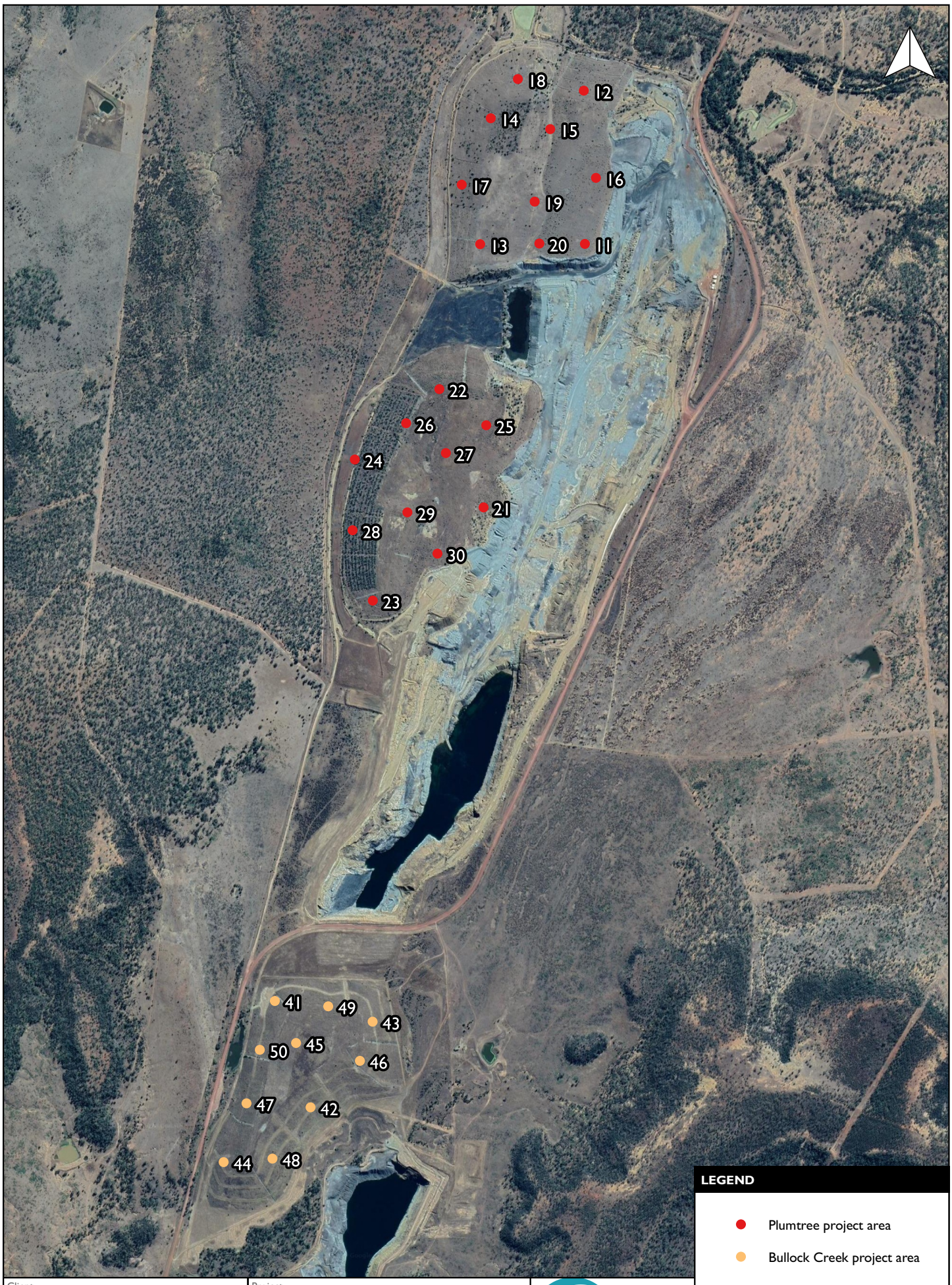
- $pH_{1:5}$ and $EC_{1:5}$;
- water-soluble chloride and sulfate;
- water-soluble metals (aluminium (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn));
- chromium reducible sulfur (CRS);
- pH (potassium chloride (KCl) and titratable actual acidity (TAA);
- acid neutralising capacity (ANC);
- potassium chloride (KCl) and hydrochloric acid (HCl) extractable sulfur; and
- net acid generation (NAG)pH and NAG7.0 and NAG4.5.

2.6 Screening criteria

The screening criteria used for determining AMD potential are listed in . These are taken from *Preventing Acid and Metalliferous Drainage: Leading Practice Sustainable Development Program for the Mining Industry* (DFAT 2016).

Table 3 AMD potential screening criteria

Classification	Net acid producing potential (NAPP) (kilograms of sulfuric acid per tonne (kg H_2SO_4/t))	NAGpH
Potentially acid forming (PAF)	>10	<4.5
PAF-low capacity (PAF-LC)	0-10	<4.5
Non-acid forming (NAF)	Negative	≥4.5
Acid-consuming (AC)	Less than -100	≥4.5
Uncertain (UC)	Positive	≥4.5
	Negative	<4.5



Client: Peabody (Burton) Pty Limited	Project: Spoil Characterisation Assessment | Peabody Burton Mine	SGM environmental
Design: SGM environmental Pty Limited | 16.10.2020 Scale: 1:25,000	Title: Sample site locations for Plumtree and Bullock Creek project areas	FIGURE 2

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Client: Peabody (Burton) Pty Limited	Project: Spoil Characterisation Assessment | Peabody Burton Mine	SGM environmental
Design: SGM environmental Pty Limited | 16.10.2020 Scale: 1:25,000	Title: Sample site locations for Wallanbah and Broadmeadow project areas	FIGURE 3

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3.0 Results

3.1 Field

Detailed field sheets can be found in Appendix A.

3.2 Laboratory

Geochemical analysis was completed by SGS. The certificate of analysis is presented in Appendix B.

Acid base accounting and NAGpH test results are shown in Table 4. Water-soluble metal and metalloid concentrations are presented in Table 5.

Table 4 Acid base accounting and NAGpH test results

Analyte		$pH_{1:5}$	$EC_{1:5}$	Water-soluble sulfate	TAA	CRS	Maximum potential acidity (MPA)[1]	ANC	Net acidity	Classification based on net acidity only	ANC/MPA	NAG ($pH_{4.5}$)	NAG (pH_7)	NAGpH	Classification based on MPA, ANC/MPA and NAGpH
Sample	Unit	pH units	Microsiemens per centimetre (µS/cm)	Milligrams per kilogram (mg/kg)	%	%	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t		-	kg H_2SO_4/t	kg H_2SO_4/t	pH units	
Broadmeadow 1		9.2	280	35	0.01	0.011	0.587	28	-27.4	NAF	47.7	<0.5	<0.5	8.7	NAF
Broadmeadow 2		9.4	370	170	0.01	0.009	0.525	29	-28.5	NAF	55.2	<0.5	<0.5	9.4	NAF
Broadmeadow 3		9.2	380	19	0.01	0.005	0.403	20	-19.6	NAF	49.6	<0.5	<0.5	8.9	NAF
Broadmeadow 4		8.7	460	600	0.01	0.025	1.015	36	-35.0	NAF	35.5	<0.5	<0.5	9.4	NAF
Broadmeadow 7		8.8	360	370	0.01	0.110	3.616	31	-27.4	NAF	8.6	<0.5	<0.5	8.6	NAF
Broadmeadow 9		9.1	700	100	0.01	0.005	0.403	44	-43.6	NAF	109.2	<0.5	<0.5	8.9	NAF
Plumtree 11		9.1	250	35	0.01	0.005	0.403	32	-31.6	NAF	79.4	<0.5	<0.5	9.7	NAF
Plumtree 13		8.4	340	440	0.01	0.034	1.290	18	-16.7	NAF	13.9	<0.5	<0.5	8.7	NAF
Plumtree 14		7.0	220	260	0.01	0.018	0.801	9.8	-9.0	NAF	12.2	3.2	12.0	3.6	UC (NAF)
Plumtree 16		9.0	510	180	0.01	0.007	0.464	51	-50.5	NAF	109.9	<0.5	<0.5	10.1	NAF
Plumtree 17		9.0	200	<3	0.01	0.005	0.403	32	-31.6	NAF	79.4	<0.5	<0.5	9.0	NAF
Plumtree 20		9.3	290	40	0.01	0.005	0.403	25	-24.6	NAF	62.0	<0.5	<0.5	9.5	NAF
Plumtree 21		9.1	800	75	0.01	0.005	0.403	72	-71.6	NAF	178.7	<0.5	<0.5	9.6	NAF
Plumtree 22		8.9	260	130	0.01	0.007	0.464	16	-15.5	NAF	34.5	<0.5	<0.5	8.3	NAF
Plumtree 25		8.9	300	200	0.01	0.007	0.464	27	-26.5	NAF	58.2	<0.5	<0.5	9.7	NAF
Plumtree 26		8.7	200	19	0.01	0.005	0.403	320	-319.6	NAF	794.0	<0.5	<0.5	9.9	NAF (AC)
Plumtree 30		8.6	570	10	0.01	0.005	0.403	8.6	-8.2	NAF	21.3	<0.5	<0.5	8.4	NAF
Bullock Creek 38		8.7	300	300	0.01	0.050	1.780	44	-42.2	NAF	24.7	<0.5	<0.5	9.5	NAF
Bullock Creek 41		8.9	760	99	0.01	0.007	0.464	110	-109.5	NAF	237.0	<0.5	<0.5	9.9	NAF (AC)
Bullock Creek 43		9.2	720	<3	0.01	0.005	0.403	28	-27.6	NAF	69.5	<0.5	<0.5	9.9	NAF
Bullock Creek 46		8.7	550	6	0.01	0.005	0.403	18	-17.6	NAF	44.7	<0.5	<0.5	8.7	NAF
Bullock Creek 47		9.1	510	57	0.01	0.005	0.403	20	-19.6	NAF	49.6	<0.5	<0.5	9.2	NAF
Bullock Creek 50		8.9	430	56	0.01	0.005	0.403	29	-28.6	NAF	72.0	<0.5	<0.5	9.4	NAF
Wallanbah 32		8.4	95	170	0.01	0.005	0.403	7.4	-7.0	NAF	18.4	<0.5	<0.5	7.6	NAF
Wallanbah 33		9.1	380	13	0.01	0.012	0.617	32	-31.4	NAF	51.8	<0.5	<0.5	9.6	NAF
Wallanbah 34		5.9	90	9	0.02	0.005	0.643	1.2	-0.6	NAF	1.87	<0.5	1.4	5.5	UC (NAF)
Wallanbah 35		9.1	380	140	0.01	0.018	0.801	13	-12.2	NAF	16.2	<0.5	<0.5	7.4	NAF

Analyte	$pH_{1:5}$	$EC_{1:5}$	Water-soluble sulfate	TAA	CRS	Maximum potential acidity (MPA)[1]	ANC	Net acidity	Classification based on net acidity only	ANC/MPA	NAG ($pH_{4.5}$)	NAG (pH_7)	NAGpH	Classification based on MPA, ANC/MPA and NAGpH
Wallanbah 38	7.2	300	51	0.01	0.005	0.403	1.2	-0.8	NAF	3.0	<0.5	<0.5	7.7	NAF
Wallanbah 40	6.5	70	41	0.01	0.007	0.464	0.1	0.4	PAF-LC	0.215	<0.5	1.4	5.0	UC (NAF)
Wallanbah 52	6.0	33	16	0.06	0.005	1.853	0.1	1.8	PAF-LC	0.054	<0.5	1.6	4.9	UC (NAF)
Wallanbah 54	7.5	180	18	0.01	0.005	0.403	1.2	-0.8	NAF	3.0	<0.5	<0.5	7.1	NAF
Wallanbah 56	9.0	230	<3	0.01	0.005	0.403	31	-30.6	NAF	76.9	<0.5	<0.5	9.3	NAF
Wallanbah 57	7.1	300	53	0.01	0.005	0.403	2.5	-2.1	NAF	6.2	<0.5	<0.5	6.1	NAF
Wallanbah 58	9.1	390	170	0.01	0.007	0.464	32	-31.5	NAF	68.9	<0.5	<0.5	8.9	NAF
Wallanbah 59	8.6	180	<3	0.01	0.005	0.403	16	-15.6	NAF	39.7	<0.5	<0.5	8.1	NAF

1. MPA = CRS multiplied by 30.6.

Table 5 Water-soluble metal and metalloid concentrations

Analyte	Al	As	Ba	Be	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Zn
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Broadmeadow 1	77	<0.2	6.7	0.06	<0.01	<0.05	0.3	1.6	38	0.7	28	<0.005	<0.1	0.2	0.2
Broadmeadow 2	48	<0.2	3	<0.05	<0.01	<0.05	0.2	1.1	37	0.5	16	<0.005	<0.1	0.15	0.2
Broadmeadow 3	60	<0.2	4.8	<0.05	<0.01	<0.05	0.2	0.28	9.4	0.2	11	<0.005	<0.1	0.11	0.2
Broadmeadow 4	63	<0.2	8	0.05	<0.01	<0.05	0.4	1.2	62	0.7	28	<0.005	<0.1	0.18	0.3
Broadmeadow 7	31	<0.2	4.2	<0.05	<0.01	<0.05	0.2	0.44	23	0.5	18	<0.005	<0.1	0.14	0.5
Broadmeadow 9	60	<0.2	4.2	<0.05	<0.01	<0.05	0.2	0.6	14	0.4	20	<0.005	<0.1	0.09	0.4
Plumtree 11	33	<0.2	9.2	<0.05	<0.01	<0.05	0.2	0.66	18	0.4	16	<0.005	<0.1	0.11	0.4
Plumtree 13	11	<0.2	1.1	<0.05	<0.01	<0.05	<0.1	0.2	9.8	<0.2	4.2	<0.005	<0.1	0.07	0.2
Plumtree 14	59	<0.2	13	0.05	<0.01	<0.05	0.5	2.2	24	1	12	<0.005	<0.1	0.22	1.4
Plumtree 16	48	<0.2	11	<0.05	<0.01	<0.05	0.2	0.68	36	0.6	23	<0.005	<0.1	0.09	0.5
Plumtree 17	49	<0.2	5.4	<0.05	<0.01	<0.05	0.2	0.22	6.5	<0.2	9.2	<0.005	<0.1	<0.05	0.2
Plumtree 20	52	<0.2	7.8	<0.05	<0.01	<0.05	0.2	0.72	26	0.6	19	<0.005	<0.1	0.1	0.3
Plumtree 21	50	<0.2	16	<0.05	<0.01	<0.05	0.3	0.34	8.9	0.2	11	<0.005	<0.1	0.13	0.2
Plumtree 22	40	<0.2	16	<0.05	0.01	<0.05	0.7	1.4	35	0.8	13	<0.005	<0.1	0.47	2.8
Plumtree 25	51	<0.2	13	<0.05	<0.01	<0.05	0.2	1.1	23	0.6	20	<0.005	<0.1	0.16	0.2
Plumtree 26	63	<0.2	8.4	<0.05	0.01	<0.05	0.2	2.1	19	2.1	21	<0.005	<0.1	0.09	0.3
Plumtree 30	120	<0.2	6.9	0.05	<0.01	<0.05	0.3	0.23	18	0.3	16	<0.005	<0.1	0.06	0.3
Bullock Creek 38	48	0.2	4.8	<0.05	<0.01	<0.05	0.6	1.2	51	0.9	24	<0.005	<0.1	0.46	1.6
Bullock Creek 41	84	<0.2	22	<0.05	0.01	<0.05	0.2	0.75	15	0.4	23	<0.005	<0.1	0.17	0.3
Bullock Creek 43	70	<0.2	2.1	<0.05	<0.01	<0.05	0.2	0.25	16	0.4	21	<0.005	<0.1	<0.05	0.2
Bullock Creek 46	60	<0.2	12	<0.05	<0.01	<0.05	0.1	0.38	8.6	<0.2	14	<0.005	<0.1	0.08	0.2
Bullock Creek 47	38	<0.2	7.2	<0.05	<0.01	<0.05	0.2	0.28	7.1	0.3	10	<0.005	<0.1	0.05	0.3
Bullock Creek 50	35	<0.2	6.9	<0.05	<0.01	<0.05	0.1	0.32	4.5	0.3	7.8	<0.005	<0.1	0.05	0.2
Wallanbah 32	41	<0.2	2.4	<0.05	<0.01	<0.05	0.2	0.59	26	0.6	18	<0.005	<0.1	0.11	0.3
Wallanbah 33	30	<0.2	6.5	<0.05	<0.01	<0.05	<0.1	0.28	2.5	<0.2	3.3	<0.005	<0.1	<0.05	0.2
Wallanbah 34	16	<0.2	27	<0.05	<0.01	<0.05	0.2	0.14	1.9	<0.2	1.6	<0.005	<0.1	0.37	0.3
Wallanbah 35	57	<0.2	22	<0.05	0.02	<0.05	0.2	1.2	36	1.8	17	<0.005	<0.1	0.06	0.3
Wallanbah 38	25	<0.2	5.7	0.11	<0.01	<0.05	0.5	0.12	4.1	<0.2	13	<0.005	<0.1	0.23	1.7
Wallanbah 40	19	<0.2	2.5	<0.05	<0.01	<0.05	<0.1	<0.05	8.2	<0.2	1.1	<0.005	<0.1	0.07	<0.1

Analyte	Al	As	Ba	Be	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Zn
Wallanbah 52	30	<0.2	14	<0.05	<0.01	<0.05	<0.1	0.06	20	<0.2	0.46	<0.005	<0.1	0.18	<0.1
Wallanbah 54	29	<0.2	23	0.05	<0.01	<0.05	0.3	0.15	2.6	<0.2	6.1	<0.005	<0.1	0.19	2
Wallanbah 56	56	<0.2	8	<0.05	<0.01	<0.05	0.1	0.23	6.9	<0.2	8.8	<0.005	<0.1	<0.05	0.2
Wallanbah 57	27	<0.2	5.1	<0.05	<0.01	<0.05	0.2	0.2	12	<0.2	8.1	<0.005	<0.1	0.17	0.4
Wallanbah 58	58	<0.2	4.6	0.06	<0.01	<0.05	0.3	0.78	22	0.8	20	<0.005	<0.1	0.22	0.4
Wallanbah 59	59	<0.2	13	<0.05	<0.01	<0.05	0.2	0.64	17	0.6	13	<0.005	<0.1	0.06	0.2

4.0 Discussion

4.1 AMD, NMD and SD

AMD occurs when reactive sulfides (mainly pyrite) contained in spoil are exposed to water and oxygen. Sulfide oxidation has the potential to produce sulfates, acidity and dissolved metals which can be transported by hydrological processes. NMD occurs when the acid generated is neutralised by dissolution of surrounding minerals such as dolomite. As the solubility of many metals is pH-dependent, the neutralisation process can lead to the precipitation of many metals. However, at near neutral pH, concentrations of metals can remain elevated. The drainage will also have high sulfate salinity. SD occurs when acidic drainage is completely neutralised by surrounding minerals and contains no significant concentrations of metals; leaving elevated calcium, magnesium, sulfate and salinity.

The potential for AMD can be assessed by the NAG test. This involves reaction of the sample with hydrogen peroxide to rapidly oxidise any sulfides. It therefore incorporates both acid-generation and acid-neutralising reactions giving a net result of the amount of acid released. A pH after reaction (NAGpH) of less than 4.5 generally indicates that the sample is net acid generating. All samples, except Plumtree 14 (3.6), have a NAGpH greater than 4.5 indicating that the spoil is net acid neutralising (Table 4). Low NAGpH, in combination with high ANC is often characteristic of organic acids that get dissolved in the NAG procedure. These organic acids are not going to contribute to any AMD issues. Plumtree 14 is therefore classified as UC (NAF). There is potential for NAG tests to result in an overestimate of the extent of oxidation relative to field conditions (Stewart et al. 2003). NAG tests are therefore most useful when used in combination with other static and kinetic geochemical test methods.

The MPA for most of the samples is less than the ANC indicating that spoil has enough ANC to neutralise any acid generation. This may be due to naturally occurring calcium and magnesium carbonates or other acid neutralising material. Net acidity for Wallanbah 40 and 52 is 0.4 and 1.8 kg H_2SO_4/t respectively. Based on net acidity only, Wallanbah 40 and 52 are classified as PAF-LC (Table 4). Spoil with an ANC to MPA (ANC/MPA) mass ratio greater than two is considered to have a negligible to low risk of acid generation and a high factor of safety in terms of potential for AMD; that is, a high probability that it will remain neutral in pH (DITR 2007). All samples have an ANC/MPA ratio greater than two except for Wallanbah 34, 40 and 52 (1.870, 0.215 and 0.054 respectively) (Table 4). Wallanbah 34, 40 and 52 have a CRS (reactive sulfides) of less than 0.1% and can therefore be considered barren (Table 4). Barren spoil has negligible capacity to generate acidity, even in the absence of significant ANC. Further, any acidity generated would quickly be neutralised by the ANC of the surrounding spoil. Titration value at pH 7 is from less available metallic ions that precipitate as hydroxides and therefore these samples are likely NAF (Table 4). Based on the MPA, ANC/MPA and NAGpH, spoil at the Mine is NAF.

4.2 Existing acidity

Existing acidity is the acidity that has already been generated during past AMD activity. It is made up of actual acidity (readily water-soluble eg melanterite) and retained acidity (sparingly water-soluble eg jarosite). It is important to consider existing acidity in materials that have experienced high levels of oxidation as significant existing acidity is likely to be present. In material with low reactive sulfides and high existing acidity, existing acidity may be the primary driver for drainage water quality. The dissolution of these sulfates may also accelerate the oxidation of any remaining sulfides in PAF spoil by providing ferric iron as an oxidising agent. The solubility of sulfates is highly variable and dependent on factors such as rainfall, pH, redox potential and pore solution chemistry. Actual acidity generates acid proportionally with wetting-up (ie rainfall) while retained acidity will generate acid based on dissolution kinetics (unrelated to wetting-up). Actual acidity will continue to impact water quality until it is flushed from the system. If reactive sulfides and / or retained acidity is present, actual acidity will continue to be replenished until all reactive sulfides have oxidised and / or all retained acidity has dissolved.

TAA measures the readily-water soluble acidity (actual acidity). Actual acidity is low across all samples (<0.06%). pHKCl is >4.5, indicating that any retained acidity present is low. A low actual and retained acidity (ie existing acidity) indicates that minimal oxidation of reactive sulfides has occurred.

4.3 Metal leaching

Water-soluble metal and metalloid concentrations are low for most of the samples (). Al, Ba, Fe and Mn were elevated in some samples (). It is worth noting that water-soluble metals data represents pore water chemistry for pulverised samples and that further dilution effects from rainfall and natural attenuation would likely occur prior to any spoil drainage arriving at a receptor. Seepage from the spoil dumps is therefore likely to contain low concentrations of metals and metalloids.

4.4 Salinity

High salt levels can negatively affect spoil structure and water quality. Spoil salinity can be classified from the $EC_{1:5}$ results. $EC_{1:5}$ ranged from very low 33 µS/cm to medium 800 µS/cm with a median of 300 µS/cm (Table 4). Based on the DME (1995) soil salinity classification, spoil is expected to have very low to medium salinity. It is unlikely that surface runoff and seepage from the spoil will be saline.

Water-soluble sulfate ranged from 3 to 600 mg/kg with a median of 53 mg/kg (Table 4). $EC_{1:5}$ was largely consistent with water-soluble sulfate concentrations.

4.5 Fertility

Spoil that is proposed for use as growth media is equivalent to the B Horizon in the soil profile, with its primary function being plant available water. Therefore, its assessment for use as growth media has been limited to AMD, NMD and SD as these will influence the quality of plant available water and / or limit plant growth.

Strong alkalinity may be a restriction to plant growth (Table 4); however, vegetation and groundcover did not appear to be limited / restricted at any of the test pit locations.

5.0 Conclusions and recommendations

This assessment suggests that spoil at the Mine is largely acid neutralising. Spoil has a low CRS, EC and negligible soluble metal profile indicating that it is barren. Notwithstanding, spoil salinity ranged from very low to medium. Therefore, there is a negligible chance of AMD / NMD or SD developing from the spoil. Based on this assessment, spoil is considered suitable for use in the construction of the final landform and as a growth medium beneath a topsoil layer (cover).

5.1 Recommendations

There were no AMD / NMD or SD issues observed during this assessment. Further, progressive rehabilitation at the Mine has been successful. Therefore, no actions or changes are recommended to the rehabilitation strategy.

References

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DFAT 2016, *Preventing Acid and Metalliferous Drainage: Leading Practice Sustainable Development Program for the Mining Industry*, Department of Foreign Affairs and Trade.

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DME 1995, *Assessment and Management of Acid Drainage: Technical guidelines for the environmental management of exploration and mining in Queensland*, Department of Mines and Energy.

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McKenzie, N J, Grundy, M J, Webster R & Ringrose-Voase, A J 2008, *Guidelines for Surveying Soil and Land Resources: 2nd edition*, CSIRO Publishing, Australia.

Stewart, W, Miller, S, Thomas, J E & 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, pp. 211-222, 12-18 July 2003, Cairns.



Appendix A
Field sheets

Location: Broadmeadow 1

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (grey)	9.32	270.6
0-10			
30			
50			
90			
100-150			

Location: Broadmeadow 2

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (dark grey)	9.39	478.8
0-10			
30			
50			
90			
100-150			

Location: Broadmeadow 3

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

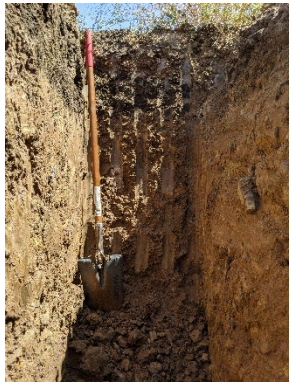
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (brown)	9.34	346
0-10			
30			
50			
90			
100-150			

Location: Broadmeadow 4

Soil profile	Landscape				Ground surface
	North	South	East	West	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (grey)	8.58	735.3
0-10			
30			
50			
90			
100-150			

Location: Broadmeadow 5

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-200	Spoil / Soil (grey)	8.63	1,183
0-10			
30			
50			
90			
100-200			

Location: Broadmeadow 7

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (dark grey)	8.76	506.2
0-10			
30			
50			
90			
140-150			

Location: Broadmeadow 8

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil / Soil (grey)	9.05	1,152
0-10			
30			
50			
90			
100-150			

Location: Broadmeadow 9

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					-

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (brown)	9.30	643.2
0-10			
30			
50			
90			
140-150			

Location: Plumtree 11

Soil profile	Landscape				Ground surface
	North	South	East	West	
					

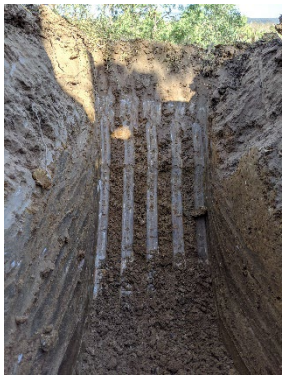
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	9.48	212.7
0-10			
30			
50			
90			
100-150			

Location: Plumtree 12

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil	9.38	429.4
0-10			
30			
50			
90			
100-150			

Location: Plumtree 13

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

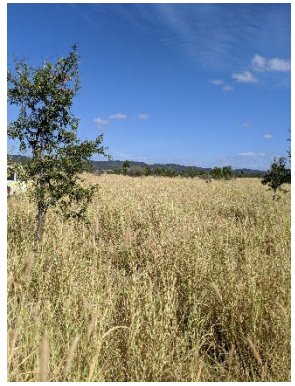
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil	8.15	495.3
0-10			
30			
50			
90			
100-150			

Location: Plumtree 14

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil / Coal reject	8.36	204.8
0-10			
30			
50	Soil		
90			
100-150	Coal reject		

Location: Plumtree 16

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

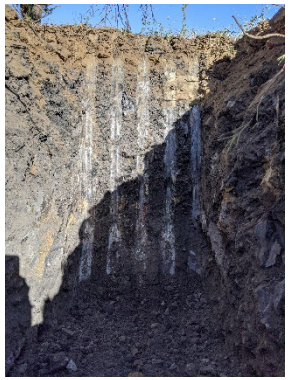
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	9.23	613.3
0-10			
30			
50			
90			
100-150			

Location: Plumtree 17

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

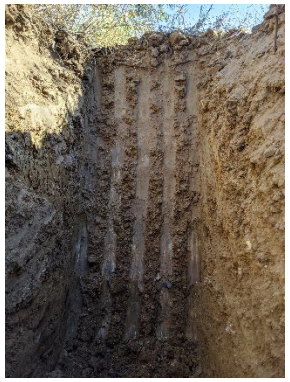
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Fresh brown oxide	9.45	177.4
0-10			
30			
50			
90			
100-150			

Location: Plumtree 20

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

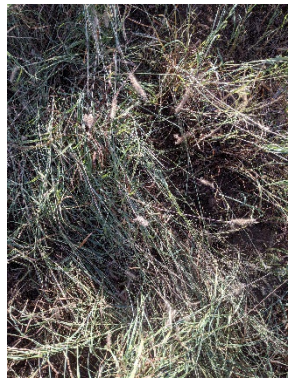
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	9.68	322.2
0-10			
30			
50			
90			
100-150			

Location: Plumtree 21

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (weathered brown)	9.38	614.5
0-10			
30			
50			
90			
100-150			

Location: Plumtree 22

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (coal reject?)	9.40	230.2
0-10			
30			
50			
90			
100-150			

Location: Plumtree 24

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

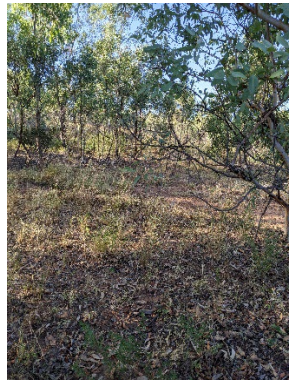
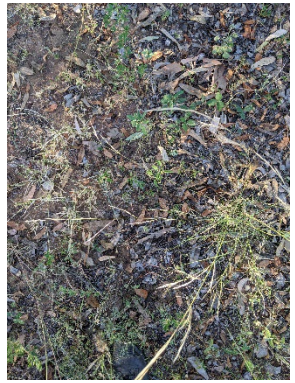
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil	9.40	500.8
0-10			
30			
50			
90			
100-150			

Location: Plumtree 26

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
-	-	-	-	-	-

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	9.18	137.6
0-10			
30			
50			
90			
100-150			

Location: Plumtree 28

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil	9.39	203.5
0-10			
30			
50			
90			
100-150			

Location: Plumtree 30

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	8.53	670.1
0-10			
30			
50			
90			
100-150			

Location: Bullock Creek 38

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil / Spoil	8.87	440.5
0-10			
30			
50			
90			
100-150			

Location: Bullock Creek 41

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

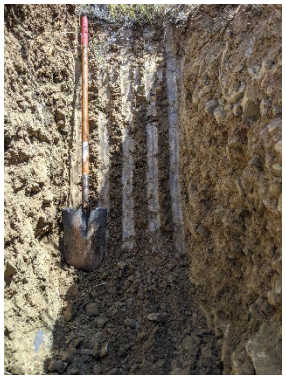
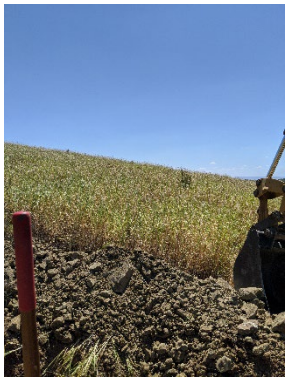
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil / Spoil	9.17	752.8
0-10			
30			
50			
90			
100-150			

Location: Bullock Creek 42

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Soil	9.32	482.9
0-10			
30			
50			
90			
100-150			

Location: Bullock Creek 43

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					-

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	9.42	873.4
0-10			
30			
50			
90			
100-150			

Location: Bullock Creek 46

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil / Soil	9.05	604.9
0-10			
30			
50			
90			
100-150			

Location: Bullock Creek 47

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

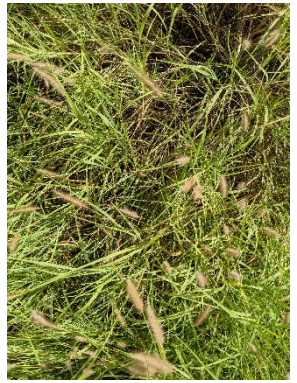
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	9.55	517.2
0-10			
30			
50			
90			
100-150			

Location: Bullock Creek 50

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

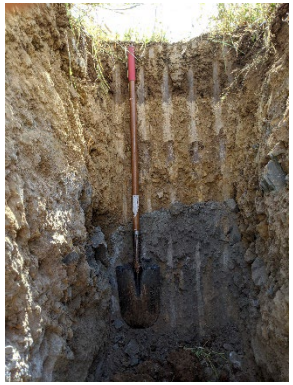
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil / Soil	9.42	400.8
0-10			
30			
50			
90			
100-150			

Location: Wallanbah 32

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (brown)	7.96	91.93
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 33

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (grey)	9.50	398.1
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 34

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

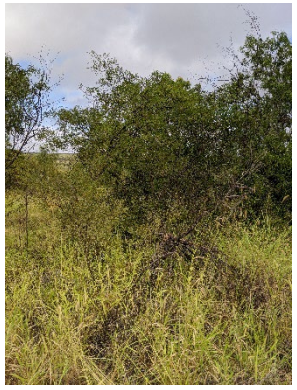
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (weathered brown)	5.89	85.58
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 35

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

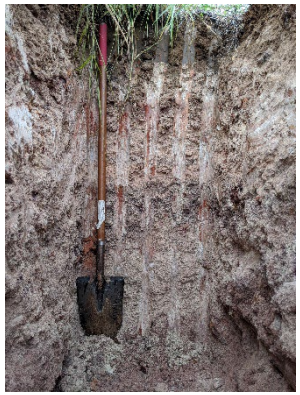
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (grey)	9.18	293.2
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 38

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (red)	6.67	273.4
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 40

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (red)	6.79	82.22
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 51

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					-

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (weathered brown)	6.64	303.5
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 52

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (red)	5.38	68.04
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 54

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

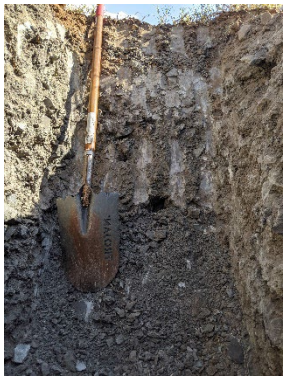
Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (weathered brown)	8.36	149.4
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 56

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC**
0-150	Spoil (weathered brown)	9.5	177.7
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 58

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil	9.24	409.1
0-10			
30			
50			
90			
140-150			

Location: Wallanbah 59

Soil profile	Landscape				Ground surface
	North	*South*	*East*	*West*	
					

Soil description		Field	
Depth (cm)	**Description**	**pH**	**EC (µS/cm)**
0-150	Spoil (brown)	8.03	162.0
0-10			
30			
50			
90			
140-150			



Appendix B
Laboratory results

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Timothy Rohde	Manager	Anthony Nilsson
Client	SGM ENVIRONMENTAL	Laboratory	SGS Cairns Environmental
Address	PO BOX 5622 STAFFORD HEIGHTS QLD 4053	Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	0488 111 722	Telephone	+61 07 4035 5111
Facsimile	(Not specified)	Facsimile	+61 07 4035 5122
Email	trohde@sgmenvironmental.com	Email	AU.Environmental.Cairns@sgs.com
Project	**19016 Geochemistry**	SGS Reference	**CE145677 R0**
Order Number	(Not specified)	Date Received	20 Apr 2020
Samples	35	Date Reported	01 May 2020

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(3146).

SIGNATORIES

Anthony NILSSON
Operations Manager

Jon Dicker
Manager Northern QLD

Maristela GANZAN
Metals Team Leader

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.001 Soil Plumtree 26	CE145677.002 Soil Plumtree 30	CE145677.003 Soil Plumtree 22	CE145677.004 Soil Plumtree 25
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**8.7**	**8.6**	**8.9**	**8.9**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**200**	**570**	**260**	**300**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**7**	**570**	**28**	**12**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**63**	**120**	**40**	**51**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**8.4**	**6.9**	**16**	**13**
Beryllium, Be	mg/kg	0.05	<0.05	**0.05**	<0.05	<0.05
Cadmium, Cd	mg/kg	0.01	**0.01**	<0.01	**0.01**	<0.01
Cobalt, Co	mg/kg	0.1	**0.2**	**0.3**	**0.7**	**0.2**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**2.1**	**0.23**	**1.4**	**1.1**
Iron, Fe	mg/kg	0.2	**19**	**18**	**35**	**23**
Lead, Pb	mg/kg	0.2	**2.1**	**0.3**	**0.8**	**0.6**
Manganese, Mn	mg/kg	0.05	**21**	**16**	**13**	**20**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	**0.09**	**0.06**	**0.47**	**0.16**
Sulfur, S	mg/kg	1	**6**	**3**	**42**	**66**
Sulphur as Sulfate, SO4	mg/kg	3	**19**	**10**	**130**	**200**
Zinc, Zn	mg/kg	0.1	**0.3**	**0.3**	**2.8**	**0.2**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**4.8**	**7.8**	**6.7**	**4.2**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.001 Soil Plumtree 26	CE145677.002 Soil Plumtree 30	CE145677.003 Soil Plumtree 22	CE145677.004 Soil Plumtree 25
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	<0.005	<0.005	**0.007**	**0.007**
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	<5	<5	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**8.8**	**7.7**	**8.9**	**9.0**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	<0.005	<0.005	**0.007**	**0.010**
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	<0.005	<0.005	**0.019**	**0.014**
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**33**	**0.9**	**1.6**	**2.8**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**33**	**0.9**	**1.6**	**2.8**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**320**	**8.6**	**16**	**27**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**6500**	**170**	**320**	**550**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**10**	**0.28**	**0.52**	**0.88**
ANC as % $CaCO_3$	% CaCO3	0.1	**33**	**0.9**	**1.6**	**2.8**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	<0.005	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	<0.005	<0.005	**0.007**	**0.007**
a-Net Acidity	moles H+/T	5	<5	<5	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-6.9**	**-0.19**	**-0.34**	**-0.58**
a-Net Acidity without ANCBT	moles H+/T	5	<5	<5	<5	<5
Liming Rate without ANCBT	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**130**	**79**	**180**	**140**
pHox (NAG pH)	No unit	-	**9.9**	**8.4**	**8.3**	**9.7**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.005 Soil Plumtree 17	CE145677.006 Soil Plumtree 20	CE145677.007 Soil Plumtree 21	CE145677.008 Soil Plumtree 13
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**9.0**	**9.3**	**9.1**	**8.4**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**200**	**290**	**800**	**340**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	**7**	**750**	**27**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**49**	**52**	**50**	**11**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**5.4**	**7.8**	**16**	**1.1**
Beryllium, Be	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Cadmium, Cd	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
Cobalt, Co	mg/kg	0.1	**0.2**	**0.2**	**0.3**	<0.1
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**0.22**	**0.72**	**0.34**	**0.20**
Iron, Fe	mg/kg	0.2	**6.5**	**26**	**8.9**	**9.8**
Lead, Pb	mg/kg	0.2	<0.2	**0.6**	**0.2**	<0.2
Manganese, Mn	mg/kg	0.05	**9.2**	**19**	**11**	**4.2**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	<0.05	**0.10**	**0.13**	**0.07**
Sulfur, S	mg/kg	1	<1	**13**	**25**	**150**
Sulphur as Sulfate, SO4	mg/kg	3	<3	**40**	**75**	**440**
Zinc, Zn	mg/kg	0.1	**0.2**	**0.3**	**0.2**	**0.2**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**5.7**	**4.9**	**9.4**	**6.4**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.005 Soil Plumtree 17	CE145677.006 Soil Plumtree 20	CE145677.007 Soil Plumtree 21	CE145677.008 Soil Plumtree 13
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	<0.005	**0.005**	<0.005	**0.034**
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	<5	<5	**21**
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**8.8**	**9.0**	**9.0**	**8.8**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	<0.005	<0.005	**0.006**	**0.017**
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	<0.005	<0.005	**0.013**	**0.021**
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**3.3**	**2.5**	**7.4**	**1.9**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**3.3**	**2.5**	**7.4**	**1.9**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**32**	**25**	**72**	**18**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**650**	**500**	**1500**	**370**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**1.0**	**0.80**	**2.4**	**0.60**
ANC as % $CaCO_3$	% CaCO3	0.1	**3.3**	**2.5**	**7.4**	**1.9**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	<0.005	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	<0.005	**0.005**	<0.005	**0.034**
a-Net Acidity	moles H+/T	5	<5	<5	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-0.69**	**-0.53**	**-1.6**	**-0.37**
a-Net Acidity without ANCBT	moles H+/T	5	<5	<5	<5	**21**
Liming Rate without ANCBT	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	**1.6**
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**98**	**110**	**150**	**140**
pHox (NAG pH)	No unit	-	**9.0**	**9.5**	**9.6**	**8.7**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.009 Soil Plumtree 14	CE145677.010 Soil Plumtree 16	CE145677.011 Soil Bullock Creek 50	CE145677.012 Soil Plumtree 11
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**7.0**	**9.0**	**8.9**	**9.1**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**220**	**510**	**430**	**250**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**81**	**280**	**310**	**9**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**59**	**48**	**35**	**33**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**13**	**11**	**6.9**	**9.2**
Beryllium, Be	mg/kg	0.05	**0.05**	<0.05	<0.05	<0.05
Cadmium, Cd	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
Cobalt, Co	mg/kg	0.1	**0.5**	**0.2**	**0.1**	**0.2**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**2.2**	**0.68**	**0.32**	**0.66**
Iron, Fe	mg/kg	0.2	**24**	**36**	**4.5**	**18**
Lead, Pb	mg/kg	0.2	**1.0**	**0.6**	**0.3**	**0.4**
Manganese, Mn	mg/kg	0.05	**12**	**23**	**7.8**	**16**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	**0.22**	**0.09**	**0.05**	**0.11**
Sulfur, S	mg/kg	1	**86**	**61**	**19**	**12**
Sulphur as Sulfate, SO4	mg/kg	3	**260**	**180**	**56**	**35**
Zinc, Zn	mg/kg	0.1	**1.4**	**0.5**	**0.2**	**0.4**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**5.2**	**5.5**	**7.7**	**4.3**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.009 Soil Plumtree 14	CE145677.010 Soil Plumtree 16	CE145677.011 Soil Bullock Creek 50	CE145677.012 Soil Plumtree 11
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	**0.018**	**0.007**	<0.005	**0.005**
Chromium Reducible Sulphur (Scr)	moles H+/T	5	**11**	<5	<5	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**6.2**	**9.0**	**8.9**	**9.0**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	**0.015**	**0.008**	<0.005	<0.005
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	**0.033**	**0.012**	**0.008**	<0.005
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**1.0**	**5.3**	**3.0**	**3.3**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**1.0**	**5.3**	**3.0**	**3.3**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**9.8**	**51**	**29**	**32**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**200**	**1000**	**600**	**650**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**0.32**	**1.7**	**0.96**	**1.0**
ANC as % $CaCO_3$	% CaCO3	0.1	**1.0**	**5.3**	**3.0**	**3.3**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	<0.005	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	**0.020**	**0.007**	<0.005	**0.005**
a-Net Acidity	moles H+/T	5	<5	<5	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-0.20**	**-1.1**	**-0.64**	**-0.69**
a-Net Acidity without ANCBT	moles H+/T	5	**12**	<5	<5	<5
Liming Rate without ANCBT	kg CaCO3/T	0.1	NA	<0.1	<0.1	<0.1
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**230**	**160**	**150**	**120**
pHox (NAG pH)	No unit	-	**3.6**	**10.1**	**9.4**	**9.7**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	**3.2**	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	**12**	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	**3.3**	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	**12**	<0.5	<0.5	<0.5

Parameter	Units	LOR	Sample Number: CE145677.013 Sample Matrix: Soil Sample Name: Bullock Creek 43	CE145677.014 Soil Bullock Creek 46	CE145677.015 Soil Bullock Creek 38	CE145677.016 Soil Bullock Creek 47
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**9.2**	**8.7**	**8.7**	**9.1**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**720**	**550**	**300**	**510**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**780**	**590**	**10**	**380**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**70**	**60**	**48**	**38**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	**0.2**	<0.2
Barium, Ba	mg/kg	0.05	**2.1**	**12**	**4.8**	**7.2**
Beryllium, Be	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Cadmium, Cd	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
Cobalt, Co	mg/kg	0.1	**0.2**	**0.1**	**0.6**	**0.2**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**0.25**	**0.38**	**1.2**	**0.28**
Iron, Fe	mg/kg	0.2	**16**	**8.6**	**51**	**7.1**
Lead, Pb	mg/kg	0.2	**0.4**	<0.2	**0.9**	**0.3**
Manganese, Mn	mg/kg	0.05	**21**	**14**	**24**	**10**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	<0.05	**0.08**	**0.46**	**0.05**
Sulfur, S	mg/kg	1	<1	**2**	**100**	**19**
Sulphur as Sulfate, SO4	mg/kg	3	<3	**6**	**300**	**57**
Zinc, Zn	mg/kg	0.1	**0.2**	**0.2**	**1.6**	**0.3**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**8.8**	**8.8**	**5.9**	**7.4**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.013 Soil Bullock Creek 43	CE145677.014 Soil Bullock Creek 46	CE145677.015 Soil Bullock Creek 38	CE145677.016 Soil Bullock Creek 47
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	<0.005	<0.005	**0.050**	<0.005
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	<5	**31**	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**8.9**	**8.8**	**9.0**	**8.9**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	<0.005	**0.83**	**0.013**	<0.005
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	<0.005	<0.005	**0.017**	**0.005**
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**2.9**	**1.9**	**4.5**	**2.0**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**2.9**	**1.9**	**4.5**	**2.0**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**28**	**18**	**44**	**20**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**570**	**370**	**900**	**400**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**0.92**	**0.60**	**1.4**	**0.64**
ANC as % $CaCO_3$	% CaCO3	0.1	**2.9**	**1.9**	**4.5**	**2.0**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	<0.005	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	<0.005	<0.005	**0.050**	<0.005
a-Net Acidity	moles H+/T	5	<5	<5	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-0.61**	**-0.40**	**-0.91**	**-0.42**
a-Net Acidity without ANCBT	moles H+/T	5	<5	<5	**31**	<5
Liming Rate without ANCBT	kg CaCO3/T	0.1	<0.1	<0.1	**2.3**	<0.1
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**150**	**120**	**150**	**110**
pHox (NAG pH)	No unit	-	**9.9**	**8.7**	**9.5**	**9.2**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.017 Soil Bullock Creek 41	CE145677.018 Soil Broadmedow 1	CE145677.019 Soil Broadmedow 2	CE145677.020 Soil Broadmedow 3
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**8.9**	**9.2**	**9.4**	**9.2**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**760**	**280**	**370**	**380**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**870**	**7**	**28**	**150**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**84**	**77**	**48**	**60**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**22**	**6.7**	**3.0**	**4.8**
Beryllium, Be	mg/kg	0.05	<0.05	**0.06**	<0.05	<0.05
Cadmium, Cd	mg/kg	0.01	**0.01**	<0.01	<0.01	<0.01
Cobalt, Co	mg/kg	0.1	**0.2**	**0.3**	**0.2**	**0.2**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**0.75**	**1.6**	**1.1**	**0.28**
Iron, Fe	mg/kg	0.2	**15**	**38**	**37**	**9.4**
Lead, Pb	mg/kg	0.2	**0.4**	**0.7**	**0.5**	**0.2**
Manganese, Mn	mg/kg	0.05	**23**	**28**	**16**	**11**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	**0.17**	**0.20**	**0.15**	**0.11**
Sulfur, S	mg/kg	1	**33**	**12**	**57**	**6**
Sulphur as Sulfate, SO4	mg/kg	3	**99**	**35**	**170**	**19**
Zinc, Zn	mg/kg	0.1	**0.3**	**0.2**	**0.2**	**0.2**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**9.2**	**6.3**	**5.2**	**7.8**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.017 Soil Bullock Creek 41	CE145677.018 Soil Broadmedow 1	CE145677.019 Soil Broadmedow 2	CE145677.020 Soil Broadmedow 3
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	**0.007**	**0.011**	**0.009**	<0.005
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	**7**	**6**	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**9.1**	**8.8**	**9.0**	**8.8**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	<0.005	<0.005	**0.007**	<0.005
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	**0.010**	<0.005	**0.008**	<0.005
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**11**	**2.9**	**3.0**	**2.0**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**11**	**2.9**	**3.0**	**2.0**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**110**	**28**	**29**	**20**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**2200**	**570**	**600**	**400**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**3.6**	**0.92**	**0.96**	**0.64**
ANC as % $CaCO_3$	% CaCO3	0.1	**11**	**2.9**	**3.0**	**2.0**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	<0.005	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	**0.007**	**0.011**	**0.009**	<0.005
a-Net Acidity	moles H+/T	5	<5	<5	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-2.4**	**-0.60**	**-0.63**	**-0.43**
a-Net Acidity without ANCBT	moles H+/T	5	<5	**7**	**6**	<5
Liming Rate without ANCBT	kg CaCO3/T	0.1	<0.1	NA	NA	<0.1
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**170**	**97**	**98**	**95**
pHox (NAG pH)	No unit	-	**9.9**	**8.7**	**9.4**	**8.9**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.021 Soil Broadmedow 9	CE145677.022 Soil Broadmedow 7	CE145677.023 Soil Broadmedow 4	CE145677.024 Soil Wallanbah 38
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**9.1**	**8.8**	**8.7**	**7.2**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**700**	**360**	**460**	**300**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**640**	**8**	**35**	**340**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**60**	**31**	**63**	**25**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**4.2**	**4.2**	**8.0**	**5.7**
Beryllium, Be	mg/kg	0.05	<0.05	<0.05	**0.05**	**0.11**
Cadmium, Cd	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
Cobalt, Co	mg/kg	0.1	**0.2**	**0.2**	**0.4**	**0.5**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**0.60**	**0.44**	**1.2**	**0.12**
Iron, Fe	mg/kg	0.2	**14**	**23**	**62**	**4.1**
Lead, Pb	mg/kg	0.2	**0.4**	**0.5**	**0.7**	<0.2
Manganese, Mn	mg/kg	0.05	**20**	**18**	**28**	**13**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	**0.09**	**0.14**	**0.18**	**0.23**
Sulfur, S	mg/kg	1	**33**	**120**	**200**	**17**
Sulphur as Sulfate, SO4	mg/kg	3	**100**	**370**	**600**	**51**
Zinc, Zn	mg/kg	0.1	**0.4**	**0.5**	**0.3**	**1.7**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**7.8**	**5.8**	**4.8**	**8.1**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.021 Soil Broadmedow 9	CE145677.022 Soil Broadmedow 7	CE145677.023 Soil Broadmedow 4	CE145677.024 Soil Wallanbah 38
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	<0.005	**0.11**	**0.025**	<0.005
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	**71**	**16**	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**9.0**	**9.1**	**9.0**	**5.7**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	**0.006**	**0.015**	**0.023**	<0.005
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	**0.008**	**0.021**	**0.033**	<0.005
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**4.5**	**3.1**	**3.6**	**0.1**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**4.5**	**3.1**	**3.6**	**0.1**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**44**	**31**	**36**	**1.2**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**900**	**620**	**720**	**25**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**1.4**	**1.0**	**1.2**	**0.040**
ANC as % $CaCO_3$	% CaCO3	0.1	**4.5**	**3.1**	**3.6**	**0.1**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	<0.005	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	<0.005	**0.11**	**0.025**	<0.005
a-Net Acidity	moles H+/T	5	<5	<5	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-0.96**	**-0.55**	**-0.75**	**-0.03**
a-Net Acidity without ANCBT	moles H+/T	5	<5	**71**	**16**	<5
Liming Rate without ANCBT	kg CaCO3/T	0.1	<0.1	**5.4**	NA	<0.1
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**130**	**180**	**130**	**56**
pHox (NAG pH)	No unit	-	**8.9**	**8.6**	**9.4**	**7.7**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.025 Soil Wallanbah 56	CE145677.026 Soil Wallanbah 33	CE145677.027 Soil Wallanbah 32	CE145677.028 Soil Wallanbah 54
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**9.0**	**9.1**	**8.4**	**7.5**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**230**	**380**	**95**	**180**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	**6**	**130**	**35**	**150**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**56**	**30**	**41**	**29**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**8.0**	**6.5**	**2.4**	**23**
Beryllium, Be	mg/kg	0.05	<0.05	<0.05	<0.05	**0.05**
Cadmium, Cd	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
Cobalt, Co	mg/kg	0.1	**0.1**	<0.1	**0.2**	**0.3**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**0.23**	**0.28**	**0.59**	**0.15**
Iron, Fe	mg/kg	0.2	**6.9**	**2.5**	**26**	**2.6**
Lead, Pb	mg/kg	0.2	<0.2	<0.2	**0.6**	<0.2
Manganese, Mn	mg/kg	0.05	**8.8**	**3.3**	**18**	**6.1**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	<0.05	<0.05	**0.11**	**0.19**
Sulfur, S	mg/kg	1	<1	**4**	**57**	**6**
Sulphur as Sulfate, SO4	mg/kg	3	<3	**13**	**170**	**18**
Zinc, Zn	mg/kg	0.1	**0.2**	**0.2**	**0.3**	**2.0**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**10**	**7.6**	**9.2**	**13**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.025 Soil Wallanbah 56	CE145677.026 Soil Wallanbah 33	CE145677.027 Soil Wallanbah 32	CE145677.028 Soil Wallanbah 54
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	**0.005**	**0.012**	<0.005	<0.005
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	**8**	<5	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**8.8**	**9.1**	**6.5**	**5.8**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	<0.005	**0.008**	<0.005	<0.005
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	<0.005	**0.009**	<0.005	**0.006**
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**3.1**	**3.3**	**0.8**	**0.1**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**3.1**	**3.3**	**0.8**	**0.1**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**31**	**32**	**7.4**	**1.2**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**620**	**650**	**150**	**25**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**1.0**	**1.0**	**0.24**	**0.040**
ANC as % $CaCO_3$	% CaCO3	0.1	**3.1**	**3.3**	**0.8**	**0.1**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	<0.005	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	**0.005**	**0.012**	<0.005	**0.006**
a-Net Acidity	moles H+/T	5	<5	<5	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	<0.1	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-0.66**	**-0.68**	**-0.16**	**-0.02**
a-Net Acidity without ANCBT	moles H+/T	5	<5	**8**	<5	<5
Liming Rate without ANCBT	kg CaCO3/T	0.1	<0.1	NA	<0.1	<0.1
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**91**	**110**	**47**	**56**
pHox (NAG pH)	No unit	-	**9.3**	**9.6**	**7.6**	**7.1**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.029 Soil Wallanbah 59	CE145677.030 Soil Wallanbah 40	CE145677.031 Soil Wallanbah 57	CE145677.032 Soil Wallanbah 34
pH in soil (1:5) Method: AN101 Tested: 28/4/2020						
pH	pH Units	0.1	**8.6**	**6.5**	**7.1**	**5.9**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020						
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**180**	**70**	**300**	**90**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020						
Chloride (water extractable 1:5)	mg/kg	5	<5	**32**	**370**	**72**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020						
Aluminium, Al	mg/kg	0.2	**59**	**19**	**27**	**16**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**13**	**2.5**	**5.1**	**27**
Beryllium, Be	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Cadmium, Cd	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
Cobalt, Co	mg/kg	0.1	**0.2**	<0.1	**0.2**	**0.2**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**0.64**	<0.05	**0.20**	**0.14**
Iron, Fe	mg/kg	0.2	**17**	**8.2**	**12**	**1.9**
Lead, Pb	mg/kg	0.2	**0.6**	<0.2	<0.2	<0.2
Manganese, Mn	mg/kg	0.05	**13**	**1.1**	**8.1**	**1.6**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	**0.06**	**0.07**	**0.17**	**0.37**
Sulfur, S	mg/kg	1	<1	**14**	**18**	**3**
Sulphur as Sulfate, SO4	mg/kg	3	<3	**41**	**53**	**9**
Zinc, Zn	mg/kg	0.1	**0.2**	<0.1	**0.4**	**0.3**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020						
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005	<0.005
Moisture Content Method: AN002 Tested: 20/4/2020						
% Moisture	%w/w	0.5	**7.2**	**10**	**9.9**	**12**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.029 Soil Wallanbah 59	CE145677.030 Soil Wallanbah 40	CE145677.031 Soil Wallanbah 57	CE145677.032 Soil Wallanbah 34
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020						
Chromium Reducible Sulphur (Scr)	%	0.005	**0.005**	**0.007**	<0.005	<0.005
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	<5	<5	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020						
pH KCl	pH Units	-	**8.5**	**5.3**	**6.4**	**4.7**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	<5	<5	<5	**10**
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	<0.01	<0.01	<0.01	**0.02**
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-	-
Sulphur (SKCl)	%w/w	0.005	<0.005	<0.005	**0.006**	<0.005
Titratable Actual Acidity	kg H2SO4/T	0.25	<0.25	<0.25	<0.25	**0.49**
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020						
Acid Soluble Sulfur (SHCl)	%w/w	0.005	<0.005	**0.008**	**0.010**	**0.005**
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020						
Lime Equivalence	% CaCO3	0.1	**1.6**	<0.1	**0.3**	**0.1**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	**1.6**	<0.1	**0.3**	**0.1**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	**16**	<0.1	**2.5**	**1.2**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	**320**	<5	**50**	**25**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	**0.52**	<0.005	**0.080**	**0.040**
ANC as % $CaCO_3$	% CaCO3	0.1	**1.6**	<0.1	**0.3**	**0.1**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020						
s-Net Acidity	%w/w S	0.005	<0.005	**0.015**	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	**0.005**	**0.015**	**0.006**	**0.020**
a-Net Acidity	moles H+/T	5	<5	**9**	<5	<5
Liming Rate	kg CaCO3/T	0.1	<0.1	NA	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**-0.34**	**0.01**	**-0.05**	**-0.02**
a-Net Acidity without ANCBT	moles H+/T	5	<5	**9**	<5	**12**
Liming Rate without ANCBT	kg CaCO3/T	0.1	<0.1	NA	<0.1	NA
Single Addition Net Acid Generation (NAG) Method: AN216 Tested: 28/4/2020						
ECox (NAG Conductivity)	µS/cm	1	**71**	**50**	**63**	**47**
pHox (NAG pH)	No unit	-	**8.1**	**5.0**	**6.1**	**5.5**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5	<0.5	**1.4**	<0.5	**1.4**
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5	<0.5	<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5	<0.5	**1.4**	<0.5	**1.4**

Parameter	Units	LOR	Sample Number: CE145677.033 Sample Matrix: Soil Sample Name: Wallanbah 52	CE145677.034 Soil Wallanbah 35	CE145677.035 Soil Wallanbah 58
pH in soil (1:5) Method: AN101 Tested: 28/4/2020					
pH	pH Units	0.1	**6.0**	**9.1**	**9.1**
Conductivity and TDS by Calculation - Soil Method: AN106 Tested: 28/4/2020					
Conductivity of Extract (1:5 dry sample basis)	µS/cm	2	**33**	**380**	**390**
Chloride (water extractable) Method: AN274 Tested: 28/4/2020					
Chloride (water extractable 1:5)	mg/kg	5	<5	**110**	**98**
Water Soluble Metals in Soil by ICPOES Method: AN002/AN320 Tested: 29/4/2020					
Aluminium, Al	mg/kg	0.2	**30**	**57**	**58**
Arsenic, As	mg/kg	0.2	<0.2	<0.2	<0.2
Barium, Ba	mg/kg	0.05	**14**	**22**	**4.6**
Beryllium, Be	mg/kg	0.05	<0.05	<0.05	**0.06**
Cadmium, Cd	mg/kg	0.01	<0.01	**0.02**	<0.01
Cobalt, Co	mg/kg	0.1	<0.1	**0.2**	**0.3**
Chromium, Cr	mg/kg	0.05	<0.05	<0.05	<0.05
Copper, Cu	mg/kg	0.05	**0.06**	**1.2**	**0.78**
Iron, Fe	mg/kg	0.2	**20**	**36**	**22**
Lead, Pb	mg/kg	0.2	<0.2	**1.8**	**0.8**
Manganese, Mn	mg/kg	0.05	**0.46**	**17**	**20**
Molybdenum, Mo	mg/kg	0.1	<0.1	<0.1	<0.1
Nickel, Ni	mg/kg	0.05	**0.18**	**0.06**	**0.22**
Sulfur, S	mg/kg	1	**5**	**48**	**56**
Sulphur as Sulfate, SO4	mg/kg	3	**16**	**140**	**170**
Zinc, Zn	mg/kg	0.1	<0.1	**0.3**	**0.4**
Water Soluble Mercury in Soil Method: AN002/AN311 Tested: 29/4/2020					
Mercury, Hg	mg/kg	0.005	<0.005	<0.005	<0.005

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name CE145677.033 Soil Wallanbah 52	CE145677.034 Soil Wallanbah 35	CE145677.035 Soil Wallanbah 58
Moisture Content Method: AN002 Tested: 20/4/2020					
% Moisture	%w/w	0.5	**8.8**	**7.9**	**7.1**
Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 28/4/2020					
Chromium Reducible Sulphur (Scr)	%	0.005	**0.005**	**0.018**	**0.007**
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	**11**	<5
TAA (Titratable Actual Acidity) Method: AN219 Tested: 27/4/2020					
pH KCl	pH Units	-	**4.5**	**8.7**	**8.9**
Titratable Actual Acidity (TAA) moles H+/tonne	moles H+/T	5	**35**	<5	<5
Titratable Actual Acidity (TAA) S%w/w	%w/w S	0.01	**0.06**	<0.01	<0.01
Net Acid Soluble Sulphur (Snas)	%w/w	0.005	-	-	-
Net Acid Soluble Sulphur (Snas) moles H+/tonne	moles H+/T	5	-	-	-
Sulphur (SKCl)	%w/w	0.005	<0.005	**0.008**	**0.007**
Titratable Actual Acidity	kg H2SO4/T	0.25	**1.7**	<0.25	<0.25
HCl Extractable S, Ca and Mg in Soil ICP OES Method: AN014 Tested: 30/4/2020					
Acid Soluble Sulfur (SHCl)	%w/w	0.005	<0.005	**0.017**	**0.010**
Acid Neutralising Capacity (ANC) Method: AN214 Tested: 28/4/2020					
Lime Equivalence	% CaCO3	0.1	<0.1	**1.4**	**3.3**
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	% CaCO3	0.1	<0.1	**1.4**	**3.3**
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	kg H2SO4/T	0.1	<0.1	**13**	**32**
Acid Neutralisation Capacity (ANCBT) as acidity units	moles H+/T	5	<5	**270**	**650**
Acid Neutralisation Capacity (ANCBT) as % S	%w/w S	0.005	<0.005	**0.44**	**1.0**
ANC as % $CaCO_3$	% CaCO3	0.1	<0.1	**1.4**	**3.3**
Chromium Suite Net Acidity Calculations Method: AN220 Tested: 30/4/2020					
s-Net Acidity	%w/w S	0.005	**0.061**	<0.005	<0.005
s-Net Acidity without ANC	%w/w S	0.005	**0.061**	**0.018**	**0.007**
a-Net Acidity	moles H+/T	5	**38**	<5	<5
Liming Rate	kg CaCO3/T	0.1	**2.9**	<0.1	<0.1
Verification s-Net Acidity	%w/w S	-20	**0.01**	**-0.28**	**-0.69**
a-Net Acidity without ANCBT	moles H+/T	5	**38**	**11**	<5
Liming Rate without ANCBT	kg CaCO3/T	0.1	**2.9**	NA	<0.1

Parameter	Units	LOR	Sample Number Sample Matrix Sample Name	CE145677.033 Soil Wallanbah 52	CE145677.034 Soil Wallanbah 35	CE145677.035 Soil Wallanbah 58
Single Addition Net Acid Generation (NAG) **Method: AN216** **Tested: 28/4/2020**						
ECox (NAG Conductivity)	µS/cm	1		**47**	**77**	**120**
pHox (NAG pH)	No unit	-		**4.9**	**7.4**	**8.9**
NAG as kg H_2SO_4/tonne to pH 4.5	kg H2SO4/T	0.5		<0.5	<0.5	<0.5
NAG as kg H_2SO_4/tonne to pH 7	kg H2SO4/T	0.5		**1.6**	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 4.5	kg CaCO3/T	0.5		<0.5	<0.5	<0.5
NAG as kg CaCO3/tonne to pH 7	kg CaCO3/T	0.5		**1.6**	<0.5	<0.5

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Acid Neutralising Capacity (ANC) Method: ME-(AU)-[ENV]AN214

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Lime Equivalence	LB078241	% CaCO3	0.1	<0.1		
Acid Neutralisation Capacity (ANCBT) as % $CaCO_3$	LB078241	% CaCO3	0.1	<0.1	0 - 4%	100%
Acid Neutralisation Capacity (ANCBT) as kg H_2SO_4/t	LB078241	kg H2SO4/T	0.1	<0.1	0 - 4%	NA
Acid Neutralisation Capacity (ANCBT) as acidity units	LB078241	moles H+/T	5	<5	0 - 4%	NA
Acid Neutralisation Capacity (ANCBT) as % S	LB078241	%w/w S	0.005	<0.005	0 - 4%	NA
ANC as % $CaCO_3$	LB078241	% CaCO3	0.1	<0.1	0 - 4%	NA

Chloride (water extractable) Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride (water extractable 1:5)	LB078235	mg/kg	5	<5	4 - 10%	107 - 108%

Chromium Reducible Sulphur (CRS) Method: ME-(AU)-[ENV]AN217

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chromium Reducible Sulphur (Scr)	LB078222	%	0.005	<0.005	0%	94%
Chromium Reducible Sulphur (Scr)	LB078222	moles H+/T	5	<5		

Single Addition Net Acid Generation (NAG) Method: ME-(AU)-[ENV]AN216

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
ECox (NAG Conductivity)	LB078240	µS/cm	1	40 - 42	0 - 4%	90%
pHox (NAG pH)	LB078240	No unit	-	6.0 - 6.1	0 - 1%	96%
NAG as kg H_2SO_4/tonne to pH 4.5	LB078240	kg H2SO4/T	0.5	<0.5	0 - 3%	108 - 109%
NAG as kg H_2SO_4/tonne to pH 7	LB078240	kg H2SO4/T	0.5	<0.5	0%	96 - 104%
NAG as kg CaCO3/tonne to pH 4.5	LB078240	kg CaCO3/T	0.5	<0.5	0 - 3%	108 - 109%
NAG as kg CaCO3/tonne to pH 7	LB078240	kg CaCO3/T	0.5	<0.5	0%	96 - 104%

TAA (Titratable Actual Acidity) Method: ME-(AU)-[ENV]AN219

Parameter	QC Reference	Units	LOR	DUP %RPD	LCS %Recovery
pH KCl	LB078182	pH Units	-	0%	101%
Titratable Actual Acidity (TAA) moles H+/tonne	LB078182	moles H+/T	5	0%	92%
Titratable Actual Acidity (TAA) S%w/w	LB078182	%w/w S	0.01	0%	92%
Sulphur (SKCl)	LB078182	%w/w	0.005	0 - 7%	88%
Titratable Actual Acidity	LB078182	kg H2SO4/T	0.25	0%	NA

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Water Soluble Mercury in Soil **Method: ME-(AU)-[ENV]AN002/AN311**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Mercury, Hg	LB078260	mg/kg	0.005	<0.005	0%	90 - 92%

Water Soluble Metals in Soil by ICPOES **Method: ME-(AU)-[ENV]AN002/AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Aluminium, Al	LB078258	mg/kg	0.2	<0.2	3 - 5%	NA
	LB078259	mg/kg	0.2	<0.2	9%	NA
Arsenic, As	LB078258	mg/kg	0.2	<0.2	0%	NA
	LB078259	mg/kg	0.2	<0.2	0%	NA
Barium, Ba	LB078258	mg/kg	0.05	<0.05	2 - 7%	NA
	LB078259	mg/kg	0.05	<0.05	15 - 77%	NA
Beryllium, Be	LB078258	mg/kg	0.05	<0.05	0%	NA
	LB078259	mg/kg	0.05	<0.05	0%	NA
Cadmium, Cd	LB078258	mg/kg	0.01	<0.01	0 - 2%	NA
	LB078259	mg/kg	0.01	<0.01	0%	NA
Cobalt, Co	LB078258	mg/kg	0.1	<0.1	4 - 5%	NA
	LB078259	mg/kg	0.1	<0.1	15 - 61%	NA
Chromium, Cr	LB078258	mg/kg	0.05	<0.05	0%	NA
	LB078259	mg/kg	0.05	<0.05	0%	NA
Copper, Cu	LB078258	mg/kg	0.05	<0.05	1 - 6%	NA
	LB078259	mg/kg	0.05	<0.05	18 - 71%	NA
Lead, Pb	LB078258	mg/kg	0.2	<0.2	2 - 4%	NA
	LB078259	mg/kg	0.2	<0.2	0 - 14%	NA
Manganese, Mn	LB078258	mg/kg	0.05	<0.05	3 - 7%	NA
	LB078259	mg/kg	0.05	<0.05	6 - 90%	NA
Molybdenum, Mo	LB078258	mg/kg	0.1	<0.1	0%	NA
	LB078259	mg/kg	0.1	<0.1	0%	NA
Nickel, Ni	LB078258	mg/kg	0.05	<0.05	3 - 7%	NA
	LB078259	mg/kg	0.05	<0.05	12 - 82%	NA
Sulfur, S	LB078258	mg/kg	1	<1	1%	NA
	LB078259	mg/kg	1	<1	3 - 12%	NA
Sulphur as Sulfate, SO4	LB078258	mg/kg	3	<3	1%	NA
	LB078259	mg/kg	3	<3	3 - 12%	NA
Zinc, Zn	LB078258	mg/kg	0.1	<0.1	2 - 3%	NA
	LB078259	mg/kg	0.1	<0.1	20 - 78%	NA

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN002	The test is carried out by drying (at either 40°C or 105°C) a known mass of sample in a weighed evaporating basin. After fully dry the sample is re-weighed. Samples such as sludge and sediment having high percentages of moisture will take some time in a drying oven for complete removal of water.
AN002/ AN311	Soil sample is extracted 1:5 in deionised water and mercury analysed by CVAAS, method AN311, with results reported on the dried sample basis.
AN002/AN320/AN321	Soil sample is extracted in deionised water (1:2 or 1:5) and metals analysed by ICP OES, method AN320/AN321, with results reported on the dried sample basis.
AN014	This method is for the determination of soluble sulfate (SO4-S) by extraction with hydrochloric acid. Sulphides should not react and would normally be expelled. Sulfur is determined by ICP.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode and is calibrated against 3 buffers purchased commercially. For soils, sediments and sludges, an extract with water (or 0.01M CaCl2) is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract of as received sample with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Salinity can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. Reference APHA 2510 B.
AN214	Acid Neutralising Capacity (ANC)or Neutralising Value (NV): The crushed or as received sample is reacted with excess normal acid (HCl) and then back titrated with standard sodium hydroxide to determine the acid consumed. The result is expressed as kg H2SO4/tonne or %CaCO3. Based on AS4969-13.
AN216	Pulverised sub-sample of a waste rock or an as received sample of filter cake, soil or sludge is subjected to an oxidising digest with 15% hydrogen peroxide adjusted to pH 4.5. The pH and EC of the NAG suspension is recorded at various stages in the digest. The acid produced (if any) is titrated using standardised NaOH to pH 7.0. NAG results are reported to 0.5 kg H2SO4/tonne.
AN217	Dried pulped sample is mixed with acid and chromium metal in a rapid distillation unit to produce hydrogen sulfide (H2S) which is collected and titrated with iodine (I2(aq)) to measure SCR.
AN219	Dried pulped sample is extracted for 4 hours in a 1 M KCl solution. The ratio of sample to solution is 1:40. The extract is titrated for acidity. Calcium, magnesium, and sulfur are determined by ICP-AES.
AN220	Chromium Suite: Scheme for the calculation of net acidities and liming rates using a Fineness Factor of 1.5.
AN274	Chloride by Aquakem DA following 1:5 or 1:2 DI water extraction: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Results reported on dry sample basis. Reference APHA 4500Cl-

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
		NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

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Appendix G
Landform evolution modelling



Landloch







Landform evolution study:

Burton Coal Mine

Prepared for Peabody Energy Australia

December, 2020

Disclaimer: All care and diligence has been exercised in testing, interpreting data and the development of recommendations presented in this report. The work has been undertaken in a skilled, professional manner, according to accepted practices. Specific circumstances and research findings after the date of publication may influence the accuracy of the data and recommendations within this report.

The landscape is not uniform. Because of this non-uniformity, no monitoring, testing or sampling technique can produce completely precise results for any site. Any conclusions based on the monitoring and/or testing presented in this report can therefore only serve as a 'best' indication of the environmental condition of the site at the time of preparing this document. It should be noted that site conditions can change with time.

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1 BACKGROUND

1.1 The Burton Coal Mine

The Burton Mine is an open-cut mine owned by Peabody. It is located 150 kilometres west of Mackay, and has been operating since 1995.

Between 1995 and 2016, mining was conducted by dragline and truck-shovel operations, mining coking coal. In 2017, the northern portion of the mine was taken over by New Hope Coal for continued operation as the New Lenton Coal Project. The part of the mine still under Peabody's management is now being rehabilitated for final closure.

There are four pits to be closed; Broadmeadow, Wallanbah, Bullock Creek, and PlumTree. Each pit includes highwalls, endwalls and lowwalls, as well as associated out-of-pit dumps.

Waste rock at Burton broadly consists of two dominant material types:

- a fine-textured Tertiary overburden that is commonly sodic, dispersive, and highly erodible, and
- Permian sandstones and mudstones of varying competence, but that are generally alkaline and dispersive.

1.2 Work scope

Burton Coal engaged Landloch Pty Ltd (Landloch) to undertake a review of waste material properties and landform design options for Burton Mine, using the following work program:

a) Review existing data and identify sampling locations;
b) Site visit to assess erosion mechanisms and key aspects of site rehabilitation and stability, and to collect initial material samples;
c) Interpretation of laboratory data and selection of bulk samples for erodibility measurement;
d) Erodibility measurement; and
e) Review existing and proposed landforms on site and explore options for modification of current practices and optimisation of designs.

2 SITE VISIT

Landloch staff conducted a site visit to Burton Mine in November 2018. With the assistance of site personnel, examples of the various topsoil and waste materials present on-site were identified and sampled for laboratory analysis.

Multiple examples of each identified material were recorded to provide some redundancy in case preferred locations for bulk sample collection were made inaccessible by mining operations.

3 MATERIAL SAMPLING AND CHARACTERISATION

3.1 Site geology and overburden types

The waste materials at Burton Mine can be broadly classified into two categories:

- Weathered zone materials: Cainozoic (Tertiary) clays, sands, claystones and sandstones. The Weathered Zone materials (referred to generally as Tertiary materials in this report) are typically sodic, highly erodible and prone to clay dispersion. These materials have varying levels of salinity, but their main constraint is their high erosion risk.
- Unweathered zone materials: Permian sandstones, siltstones, and mudstones. Carbonaceous zones are present close to the coal seams. These materials are referred to generally as Permian materials in this report. The physical properties of these materials are highly variable. They are generally sodic, alkaline and non-saline, although there are some materials with elevated salinity levels, and some with lower sodicity levels. Erosion risk varies, based on physical properties and sodicity, but generally the sandstones are somewhat more competent and resistant to weathering and erosion than are the siltstones and mudstones.

3.2 Initial sampling

Grab samples of a total of five topsoil and nine waste materials were taken for initial analysis. Sample locations are shown in Figure 1. Chemical properties of the materials selected for bulk sampling are presented in in Table 1.

3.3 Bulk samples for erodibility testing

Based on the data obtained, it was decided to take bulk samples of the topsoils represented by samples B04 and B07 to largely cover the range in clay contents in the stockpiled topsoils available for use on rehabilitation areas.

Wastes B02 and B10 were selected to cover the range of Permian materials onsite. However, due to accessibility difficulties, a bulk sample of the tertiary waste B03 was provided in lieu of the B02 Broadmeadow Permian material.

Access to sites for bulk sampling was constrained somewhat by wet weather, but samples of approximately 1 m^3 of each of these materials were collected and transported to Landloch's Toowoomba erosion laboratory.



Figure 1: Locations of initial samples collected during site visit.

Table 1: Laboratory analysis results for materials used for erodibility testing. Items that may impact stability or revegetation success are highlighted in yellow.

Analyses	Unit	Sample			
		Mudstone waste	Tertiary waste	B07 Clay topsoil	B04 Loam topsoil
pH - Water	pH units	9.46	6.26	8.56	8.05
Electrical Conductivity	dS/m	0.65	0.38	0.16	0.08
Chloride	mg/kg	260.0	416.0	16.5	7.7
Cation Extraction Method	Rayment& Lyons	15C1	15A2	15C1	15C1
Cation Exchange Capacity	meq/100g	21.5	10.0	37.6	9.6
Exch. Calcium Percent	%	57.17	19.69	72.0	77.99
Exch. Magnesium Percent	%	27.10	70.20	24.6	18.85
Exch. Potassium Percent	%	1.21	1.16	1.43	2.59
Exch. Sodium Percent	%	14.46	8.84	1.95	0.45
Exch. Aluminium Percent	%	0.05	0.11	0.03	0.12
Exchangeable Calcium	mg/kg	2454	395	5414	1496
Exchangeable Magnesium	mg/kg	698	845	1112	217
Exchangeable Potassium	mg/kg	101	45.4	210	96.9
Exchangeable Sodium	mg/kg	714	204	169	10
Exchangeable Aluminium	mg/kg	1.0	1.0	1.0	1.0
Calcium/Magnesium Ratio	-	2.1	0.3	2.9	4.1

4 EROSION AND LANDFORM EVOLUTION MODELLING

4.1 Soil loss targets

This study used runoff, erosion, and landform evolution modelling to identify landform options that would erode at rates low enough to provide long-term stability. Effectively, the landforms are planned to be consistent with **tolerable** rates of soil loss. Wischmeier and Smith (1978) defined tolerable soil loss for cropland as "*the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.*"

A value of 11.2 t/ha/y is often cited as a tolerable soil loss rate, but that value was derived by US soil conservation agencies for deep fertile cultivated soils, and has little relevance to most rehabilitated minesites. Using similar criteria to those applied for crop land, a lower soil loss tolerance value of 4.5 t/ha/y was developed by US agencies for erosion of rangeland soils and shallow cultivated soils (Wight and Siddoway 1979).

This latter value is more appropriate to minesite revegetation in Australia. A similar value of 5 t/ha/y has been widely used in planning by Landloch on the basis that – at that value – rilling is largely if not completely absent. The elimination of rilling greatly reduces the potential for channelised flow to form gullies, and experience to date with a large number of waste landforms designed by Landloch has shown that a tolerance soil loss value of 5 t/ha/y does achieve acceptable levels of stability to erosion.

4.2 Strategy adopted

In considering landform design, the strategy applied was to:

a) use the WEPP model to consider runoff and erosion from a range of landform and rehabilitation options as its flexibility and detailed output is ideal for that purpose.
b) generate time series data from WEPP which are then used to derive parameters for the SIBERIA landform evolution model.
c) run SIBERIA for 3-dimensional landforms to consider impacts of potential flow concentrations and of changes in landform profile through time.

WEPP is used to consider 2-dimensional slope profiles, and cannot, therefore, consider impacts of flow concentration over areas of tens of hectares. However, the detail provided by WEPP with respect to runoff and erosion and the location and timing of significant losses makes it an excellent design tool.

4.3 The WEPP model

The Water Erosion Prediction Program (WEPP) (Flanagan and Livingston 1995) was developed by the United States Department of Agriculture (USDA) to predict runoff, erosion, and deposition for hillslopes and watersheds. It is a simulation model with a daily input time step, but internal calculations can use shorter time steps. For example, the climate file (for each day) includes information on:

- Amount of rain
- Duration of the rain
- Time to peak intensity
- Ratio between peak intensity and average intensity.

This information is used in infiltration calculations, so that the model takes intensity and duration of rainfall into account. For every day, plant and soil characteristics important to erosion processes are updated. When rainfall occurs, those plant and soil characteristics are considered in determining whether runoff occurs. If runoff is predicted to occur, the model computes sediment detachment, transport, and

deposition at points along the slope profile, and, depending on the version used, in channels and reservoirs.

Conceptually, the WEPP model can be divided into six components: climate generation, hydrology, plant growth, soils, management, and erosion.

The erosion component uses a steady-state sediment continuity equation as the basis for the erosion computations. Soil detachment in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil detachment in rills is predicted to occur if the flow hydraulic shear stress is greater than critical shear and the flow sediment load is below transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

4.4 The SIBERIA model

The SIBERIA model simulates runoff and erosion from a landform that evolves in response to predicted erosion and deposition. It is a 3-dimensional topographic evolution model, which predicts the long-term evolution of channels and hillslopes in a catchment on the basis of runoff and erosion, and has been successfully applied to explain aspects of geomorphology of natural landforms (Willgoose 1994). The location and speed with which gullies develop are controlled by a channelisation function that is related to runoff and soil erodibility (Willgoose *et al.* 1989). The model solves for two variables; elevation, from which slope geometries are determined, and an indicator function that determines where channels exist. Channel growth is governed by an activation threshold. A surface may commence with no gullies, but when the activation threshold, which depends on discharge and slope gradient, is exceeded, a channel develops.

The SIBERIA model has been widely used for assessment of the evolution of constructed landforms on a range of minesites across Australia and overseas (Willgoose 1994, Willgoose and Riley 1995, Boggs *et al.* 2000, Hancock *et al.* 2003, Hancock and Willgoose 2004, Hancock 2004).

4.5 Validation of WEPP and SIBERIA

Both models can be considered "industry standard".

WEPP has been widely used and validated for application in agricultural situations (Nearing and Nicks 1998; Ghidey and Alberts 1996; Liu *et al.* 1997; Zhang *et al.* 1996; Tiwari *et al.* 2000; Yu and Rosewell 2001).

It has also been widely used in design of constructed landforms for minesites across Australia. Erosion of minesite landforms modelled with WEPP using parameters derived using Landloch's methods has shown extremely strong correlation with observed rates for the same time periods, rainfall and surface conditions (Howard and Roddy 2012), confirming the accuracy of WEPP simulations for waste landform designs.

SIBERIA has been extensively used by the Supervising Scientist Division of the Commonwealth Department of Sustainability, Environment, Water, Population and Communities, and subjected to extensive validation. In general, the tests indicate that – provided the model is adequately calibrated – SIBERIA predictions appear to be reasonable (Hancock *et al.* 2000, Hancock *et al.* 2002, Hancock *et al.* 2003, Willgoose *et al.* 2003).

4.6 Derivation of SIBERIA parameter values

WEPP simulations were run for a 100-year climate file prepared to simulate climate at Burton, for a range of slope lengths and gradients, with daily outputs of runoff and erosion.

SIBERIA parameters m_1 (a slope response parameter) and b_1 (an erosion rate parameter) were derived from those time series data.

5 ERODIBILITY MEASUREMENT

For the wastes and topsoils supplied, erodibility parameters for the WEPP model were determined using measurements of runoff, erosion, and sediment properties from:

- plots exposed to simulated rainfall to measure interrill erodibility and hydraulic conductivity (Figure 2 and Figure 3); and
- Flumes where soil samples were exposed to a range of overland flow conditions to measure critical shear and rill erodibility (Figure 4 and Figure 5).

These four parameters are used within the WEPP model to describe the erodibility of a soil.

5.1.1 Rainfall simulation

The rainfall simulator used is of the design described by Loch *et al.* (2001), and applies simulated rain with a kinetic energy equivalent to that of natural rainfall at intensities >40 mm/h. Simulated rain was applied to duplicate plots 0.75 m square and 0.2 m deep set at a 20% gradient for a period sufficient for the samples to reach steady infiltration/runoff rates.

Plots were lightly compacted during packing so that the re-packed samples were consistent with soil that had consolidated naturally under rainfall, and subject to wetting and drying to further consolidate the surface. Runoff generated by simulated rain was sampled at regular intervals (2-3 minutes), and sediment concentrations were measured gravimetrically.



Figure 2: Rainfall simulator plots immediately following application of rain, to samples of (L-R) tertiary waste (B03), and Wallanbah topsoil (B04).



Figure 3: Rainfall simulator plots immediately following application of rain, to samples of (L-R) Broadmeadow topsoil (B07), and Permian mudstone waste (B10).

The WEPP model version used also requires information on sediment size and density, which effectively control sediment settling velocity and – in some circumstances – sediment transport capacity. To measure properties of "sediment available for detachment" for the topsoil, samples of the surface seal layer were taken from plots immediately following application of simulated rain using the method outlined by Loch (1994). Settling velocity distributions of those samples were measured in a modified top entry tube (Loch 2001).

Rain water was used in all measurements to avoid any potential impacts of water quality on infiltration and on the disaggregation of sediment to finer sizes.

5.1.2 Overland flows in flumes

Studies of rill erodibility used flumes 2 m long and 0.4 m wide (Figure 4 and Figure 5). For all materials, three flumes were run, set at various gradients, ensuring that a wide range of flow tractive force was applied. In all cases, samples were lightly compacted during placement in the flumes (to achieve a field bulk density for the material), then exposed to several wetting and drying cycles over several days to develop a hard, cohesive soil surface crust (consistent with typical field conditions) prior to application of overland flow.

For each flume, a sequence of increasing overland flow rates was applied. Each flow rate was maintained for 5 minutes and samples of runoff were taken at 1, 2, 3, and 5 minutes from the commencement of each flow rate for sediment concentration measurement.



Figure 4: Flumes showing application of flow to samples of (L-R) tertiary waste (B03), and Wallanbah topsoil (B04). Note high suspended load of dispersed clay in runoff from the waste.



Figure 5: Flumes showing application of flow to samples of (L-R) Broadmeadow topsoil (B07), and Permian mudstone waste (B10).

5.2 WEPP parameter derivation

Erodibility parameters required for the WEPP model are K_i (interrill erodibility), K_R (rill erodibility - a detachment parameter), and τ_c (critical shear for rill initiation). These parameters are used to predict changes in erosion processes and rates in response to changes in runoff, slope length, and land management. Also important is the Hydraulic Conductivity parameter (K_e) used in the model to predict runoff.

5.3 SIBERIA parameter derivation

SIBERIA predicts the long-term average change in elevation of a point by predicting the volume of sediment lost from a node. The rate of sediment transport through a node (q_s in units of m^3/y) is determined by the equation:

$$q_s = \beta_1 \times q^{m_1} \times S^{n_1} \qquad 1)$$

where β_1 is the sediment transport rate coefficient, q is discharge (m^3/y), m_1 is the discharge exponent, S is the slope (m/m), and n_1 is the slope exponent.

SIBERIA does not directly model runoff, but uses sub-grid effective parameterisation which relates discharge to area draining through a point as:

$$q = \beta_3 \times A^{m_3} \qquad 2)$$

Where β_3 is the coefficient between discharge and area, A is area (m^2), and m_3 is the exponent of the area in discharge.

To run SIBERIA, the parameters β_1, m_1, n_1, β_3, and m_3 are usually needed. Effectively, the β_1 parameter could be described as an erosion "rate parameter", as it primarily controls the rate of sediment movement. The m_1 parameter could be described as primarily controlling slope length responses.

Input parameters for SIBERIA are derived by fitting the model to time series data for the field area of interest. However, as long periods of record are not available for landforms at Burton Mine, the approach used to estimate SIBERIA model parameters was to:

(a) Run the WEPP model to generate data sets of runoff and erosion for slopes and materials of interest; and

(b) Analyse the WEPP output to derive parameters for the SIBERIA model.

In this case, WEPP data were generated for bare and vegetated slopes at Burton Mine, for the local climate, and considering a range of slope lengths. Soil properties were adjusted so that their hydraulic conductivities were consistent with 60% grass cover, as the long-term simulations compared vegetated areas with bare areas.

Field observations found that the ripping and settling of rehabilitated surfaces resulted in the typically thin layer of topsoil being reasonably well mixed into the upper portion of the underlying waste, with no significant, distinct topsoil horizon present. For this reason, landforms have been modelled with erodibility parameters based on bare waste materials.

6 LANDFORM EVOLUTION SIMULATIONS

6.1 Landforms considered

Digital terrain models (DTMs) of the proposed final landforms for four pits and their associated waste dumps were provided by RACAD Pty Ltd for use in this study.

6.1.1 Wallanbah

Wallanbah pit has a large internally-facing slope on the eastern side of the pit which is variously comprised of the internal batter of the eastern ex-pit dump and the battered-down highwall, as shown in Figure 6.

The eastern ex-pit dump is constructed of a mix of Permian and tertiary materials, but is dominated by permian waste and has been modelled as such.

The battered down highwall is mostly cut and filled tertiary waste, and additional simulations were run using erodibility parameters for tertiary material and topsoil to specifically investigate the long-term stability of that slope.

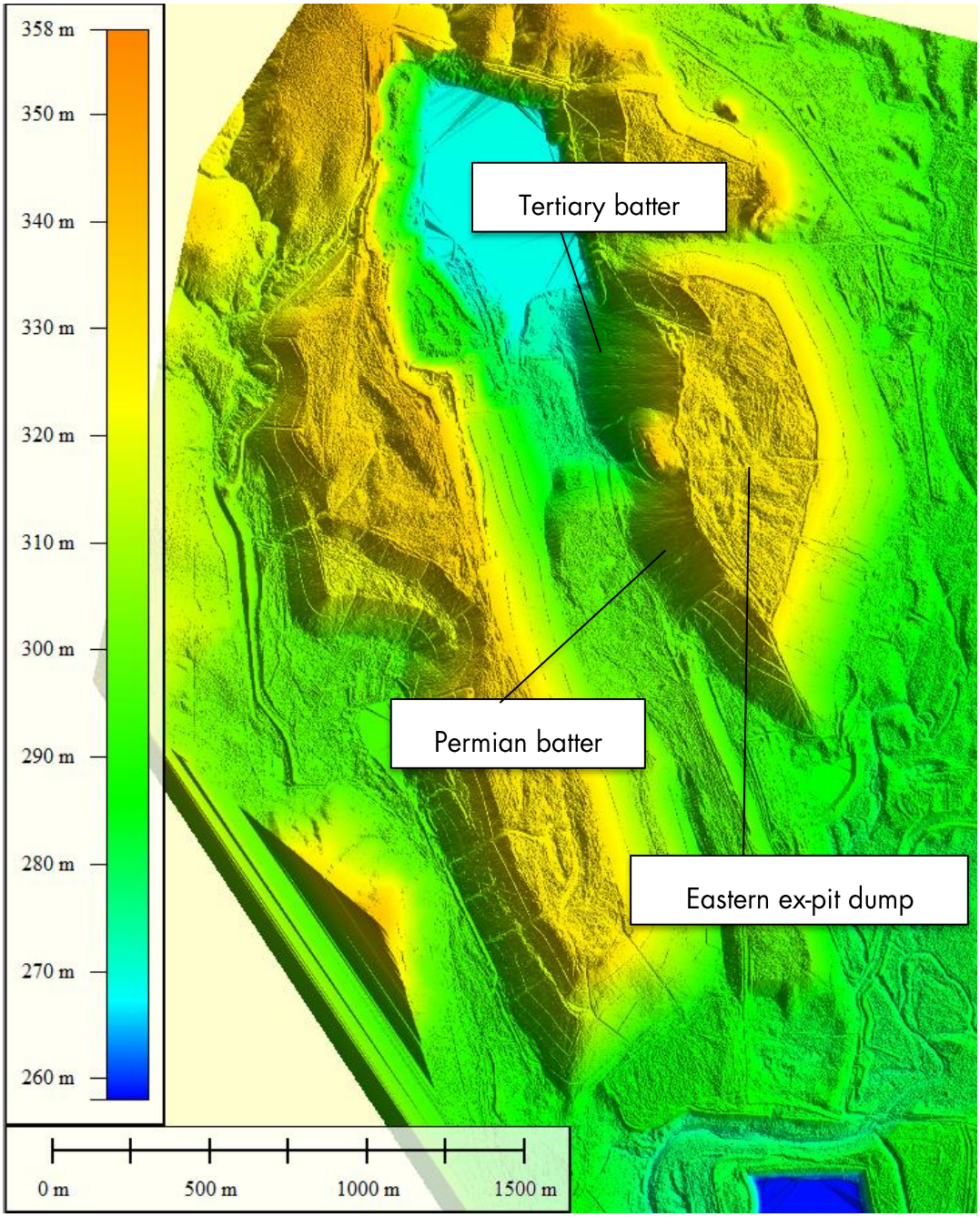

Figure 6: Wallanbah pit final landform, showing the two slopes assessed in this study.

6.1.2 Broadmeadow

The focus of simulations in the Broadmeadow pit is the inner face of the large western ex-pit dump. The current design for the slope is an approximately 300m long, 16.6% gradient slope. WEPP modelling was used to assess the likely stability of the slope with different contour bank spacings (e.g. 60-90m spacings), but SIBERIA modelling assessed the long-term stability of the slope in its final state, with contour banks removed. Figure 7 shows the study area.

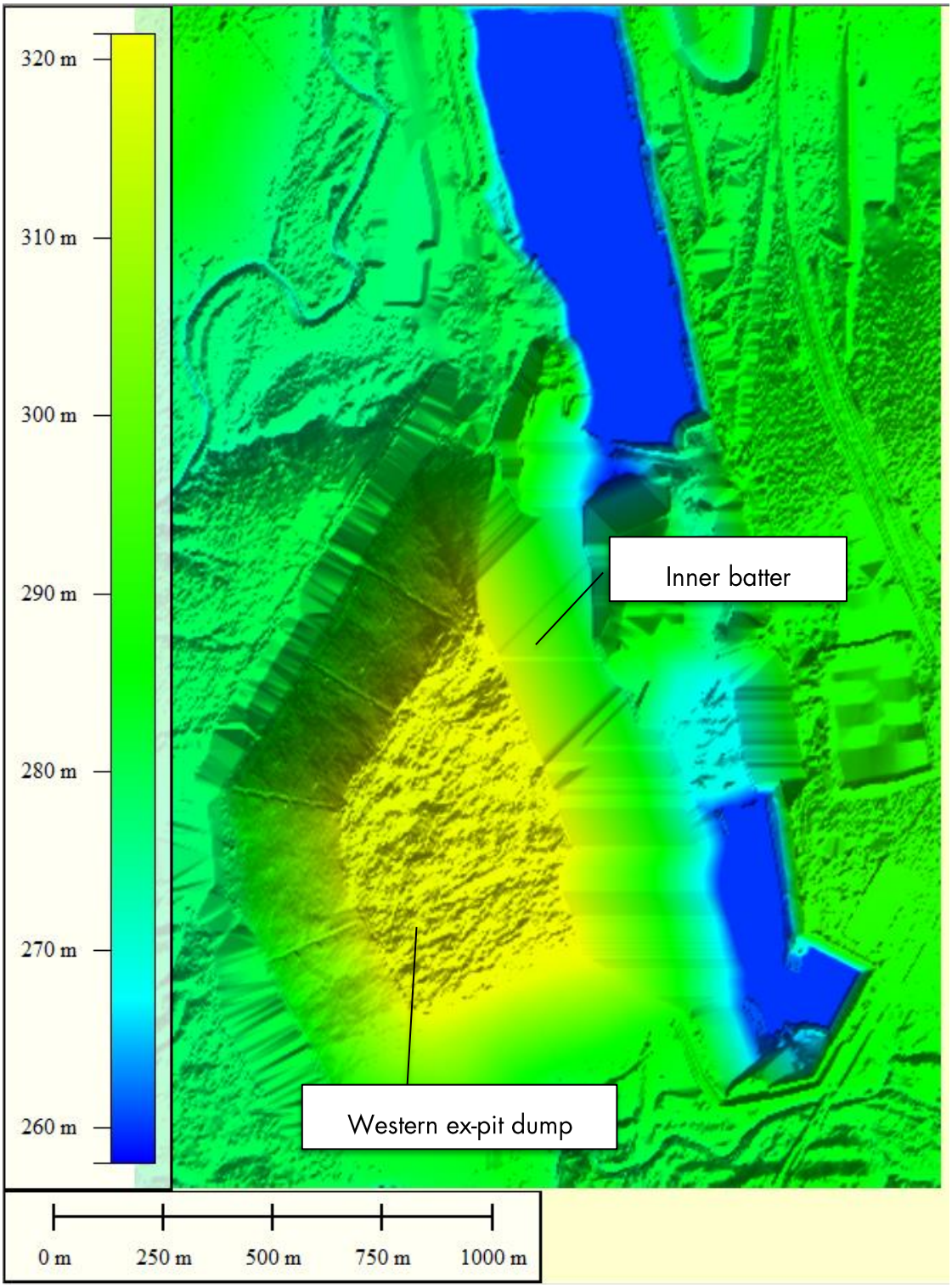

Figure 7: Broadmeadow pit final landform, showing inner batter assessed in this study.

6.1.3 Bullock Creek

The Bullock Creek pit has been mostly rehabilitated. The simulations assessed the long-term stability of the southern in-pit dump. The pit area and southern dump assessed in the erosion study are shown in Figure 8.

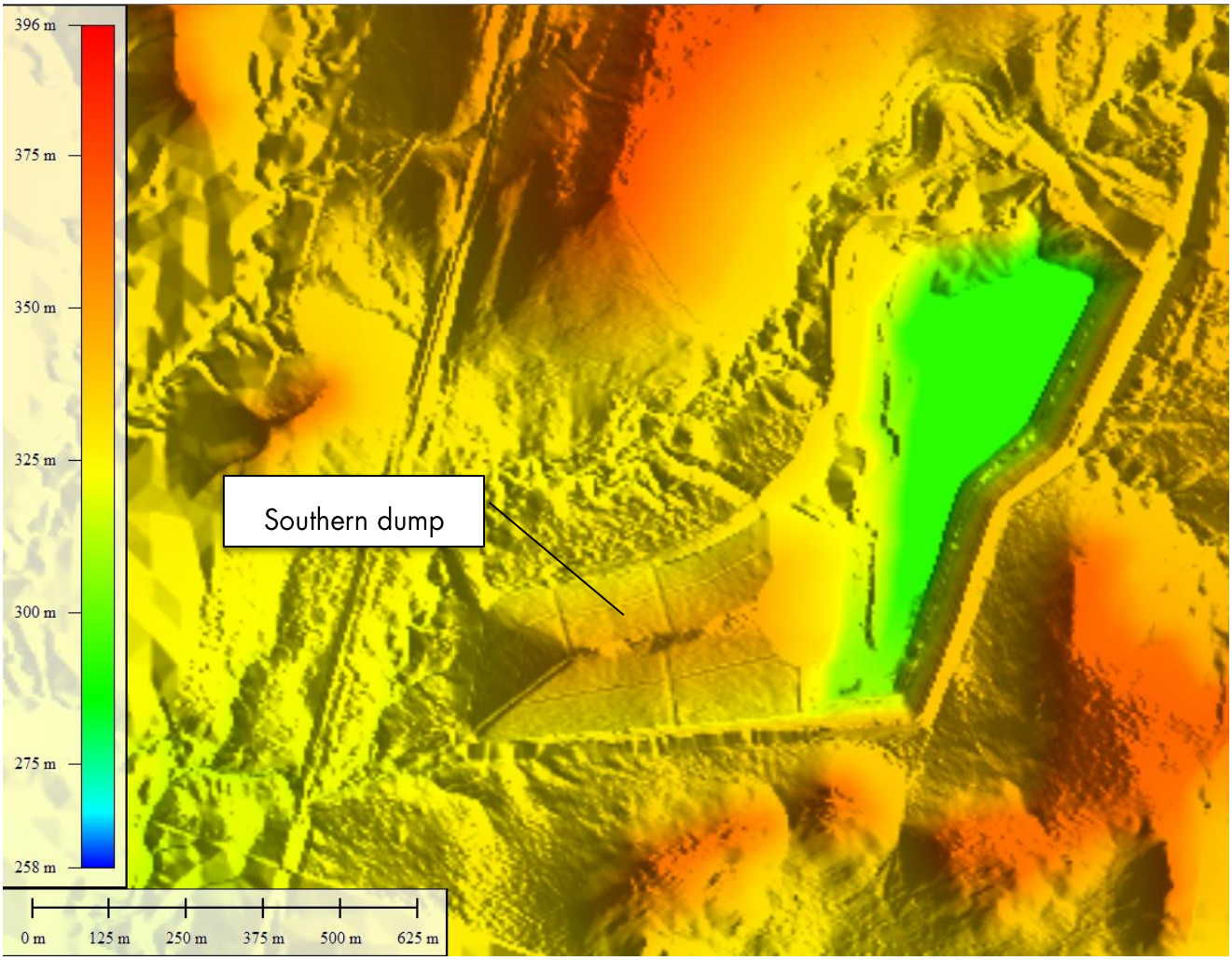

Figure 8: Bullock Creek pit final landform.

6.1.4 Plumtree

The Plumtree pit is the northernmost pit assessed in this study. The modelling focussed on the internal batters of the two large in-pit dumps. The pit area and slopes assessed are shown in Figure 9.

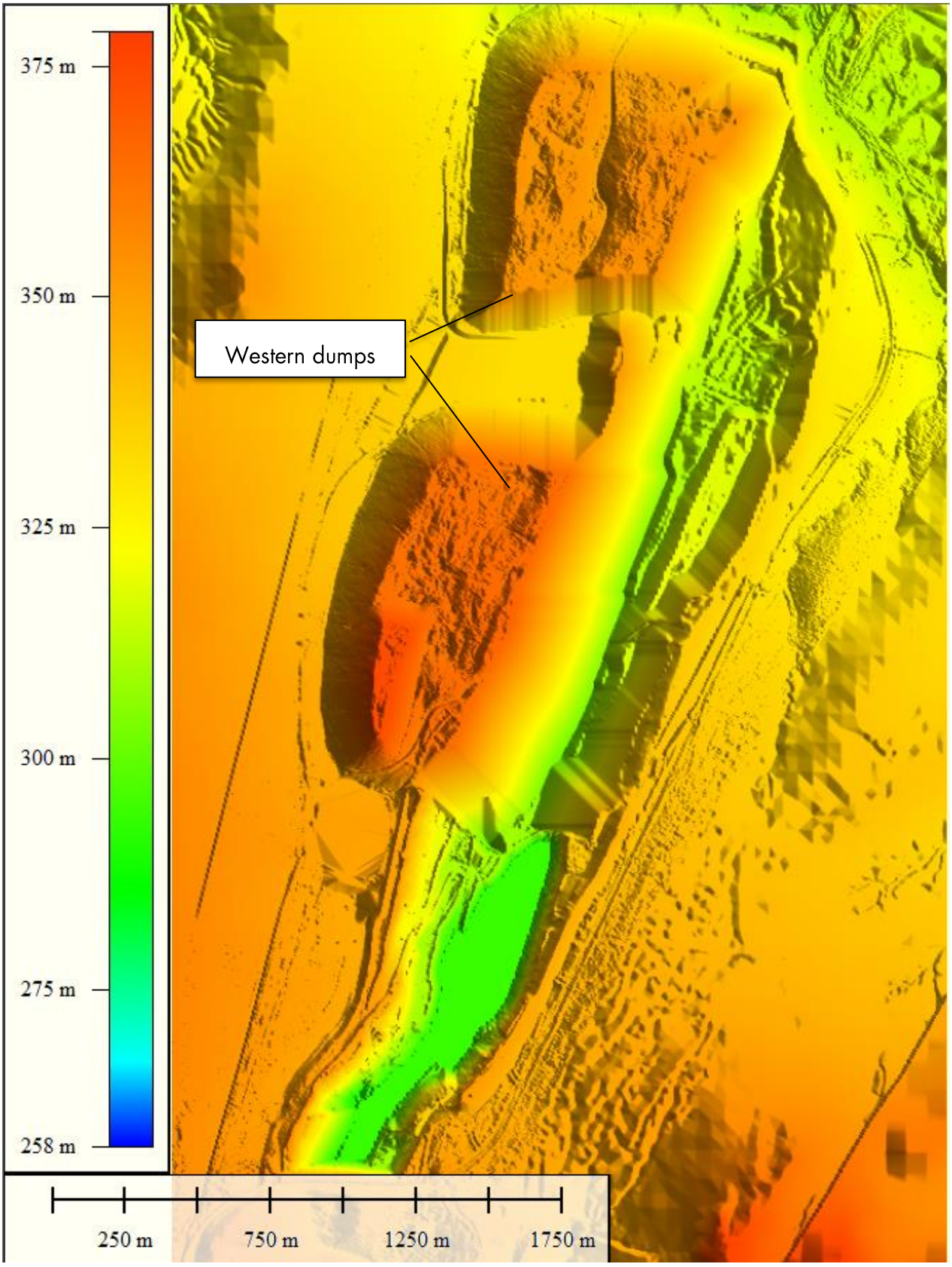

Figure 9: Plumtree pit final landform, showing western dumps assessed in this study.

6.1.5 Erodibility

Simulations were run on bare soil (C=1) and 60% grass cover (C=0.04) scenarios with erodibility parameters (β_1, m_1) derived from WEPP modelling as discussed above. A ground (contact) cover level of 60% was chosen as a realistic minimum cover level, based on observations of established rehabilitation made during the site inspection.

In considering surface cover, it should be noted that contact cover will include basal area of grass, litter, and rocks. For some grass species, standing cover may not be greatly different to contact cover, whereas for species such as buffel grass, standing cover may be considerably less than contact cover, and buffel is, consequently, widely recognised to be less effective in controlling erosion than some other species.

6.2 Model output

6.2.1 Overview

All landforms assessed showed major erosion under bare soil conditions, including severe gullying. Under 60% contact groundcover, erosion rates were generally lower and gullying less severe.

6.2.2 Wallanbah

For Permian material with 60% contact ground cover, 300 year simulations of erosion of the internal batter of the eastern dump (focus area shown in Figure 10) predicted acceptable rates of erosion (Figure 11), with an average erosion rate of ~2.5 t/ha/year.

Simulations on a bare Permian material surface show extensive gullying and severe overall soil loss where there is low surface cover (Figure 12, 13 and 14). Erosion rates on the Wallanbah Western dump batters were 21 t/ha where there was no vegetation cover and 1 t/ha where there was 60% vegetation cover.

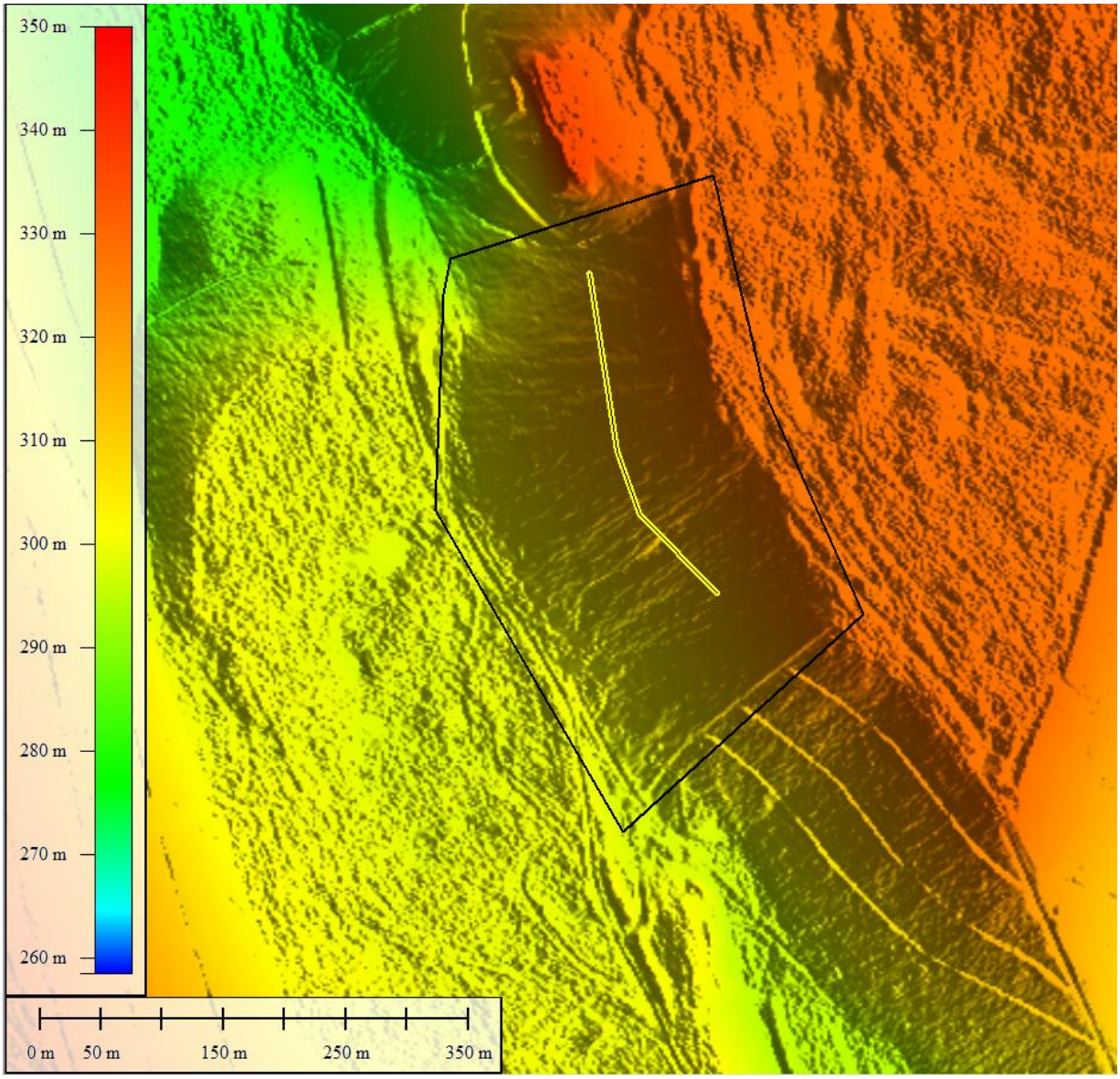

Figure 10: Wallanbah pit showing the slope assessed prior to simulated erosion, and cross section location (as shown in Figure 13).

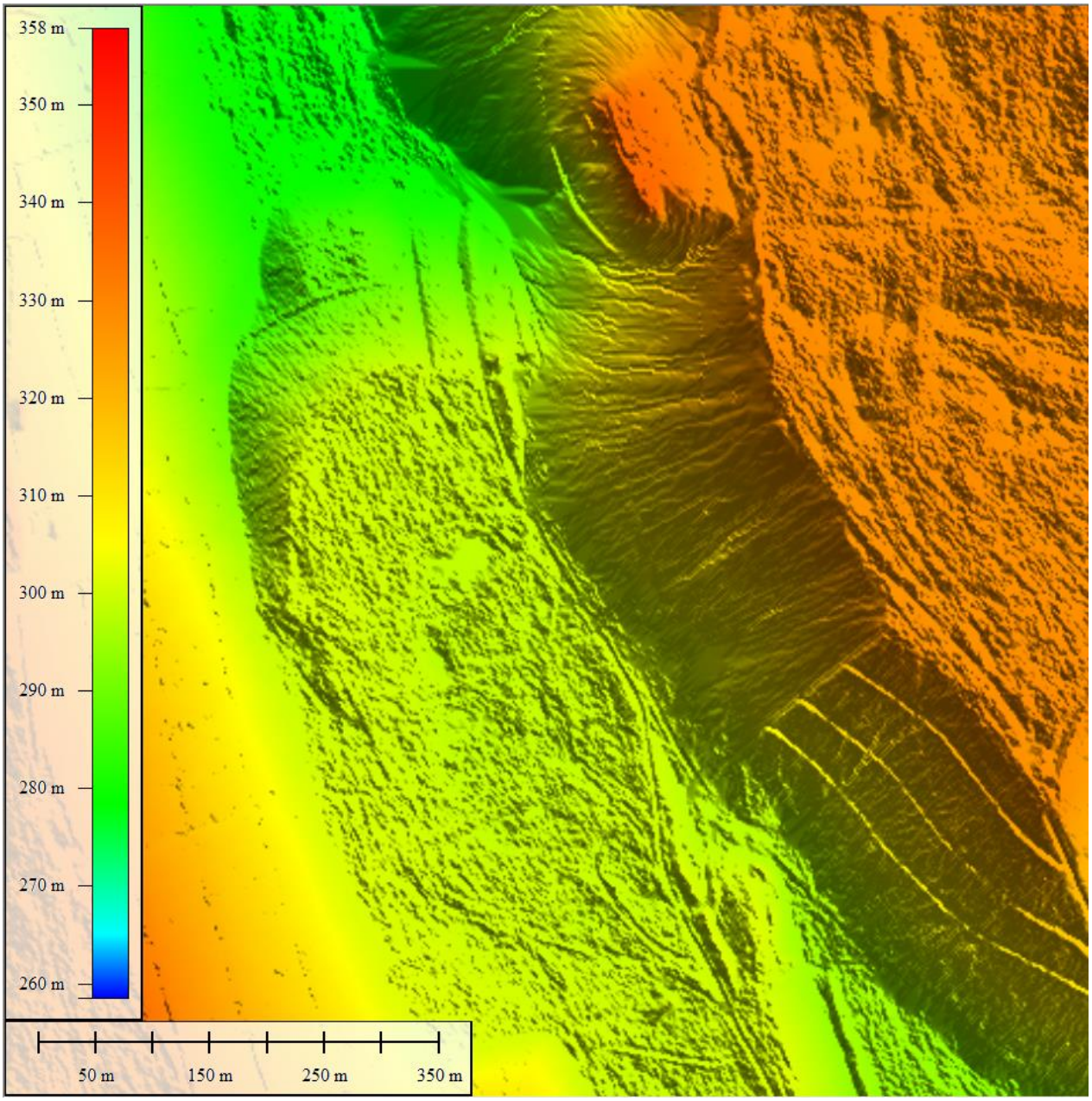

Figure 11: Wallanbah eastern dump internal batter after 300 years of simulated erosion on Permian material with 60% vegetation cover.

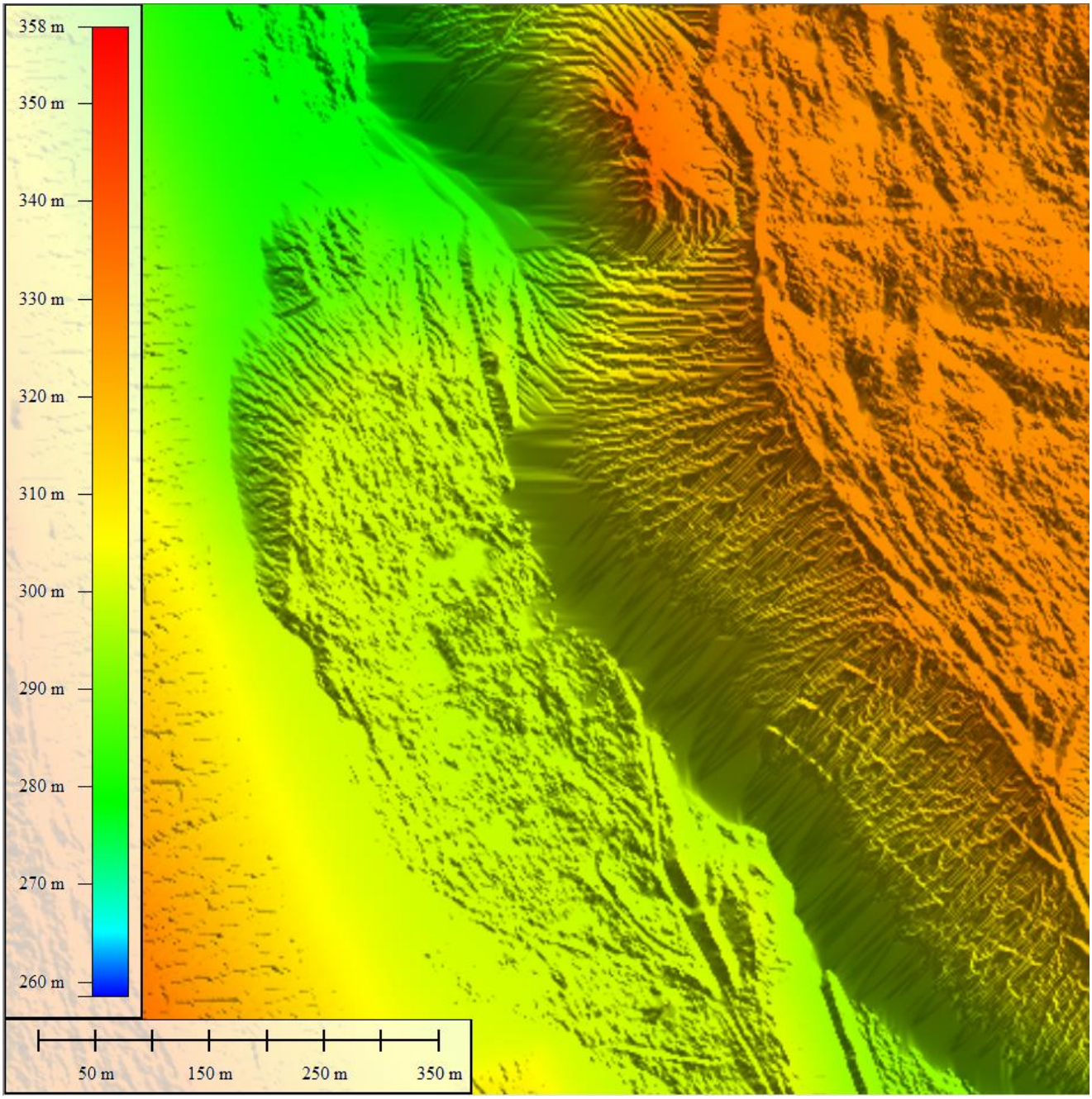

Figure 12: Wallanbah eastern dump internal batter after 300 years of simulated erosion on Permian material bare surface.

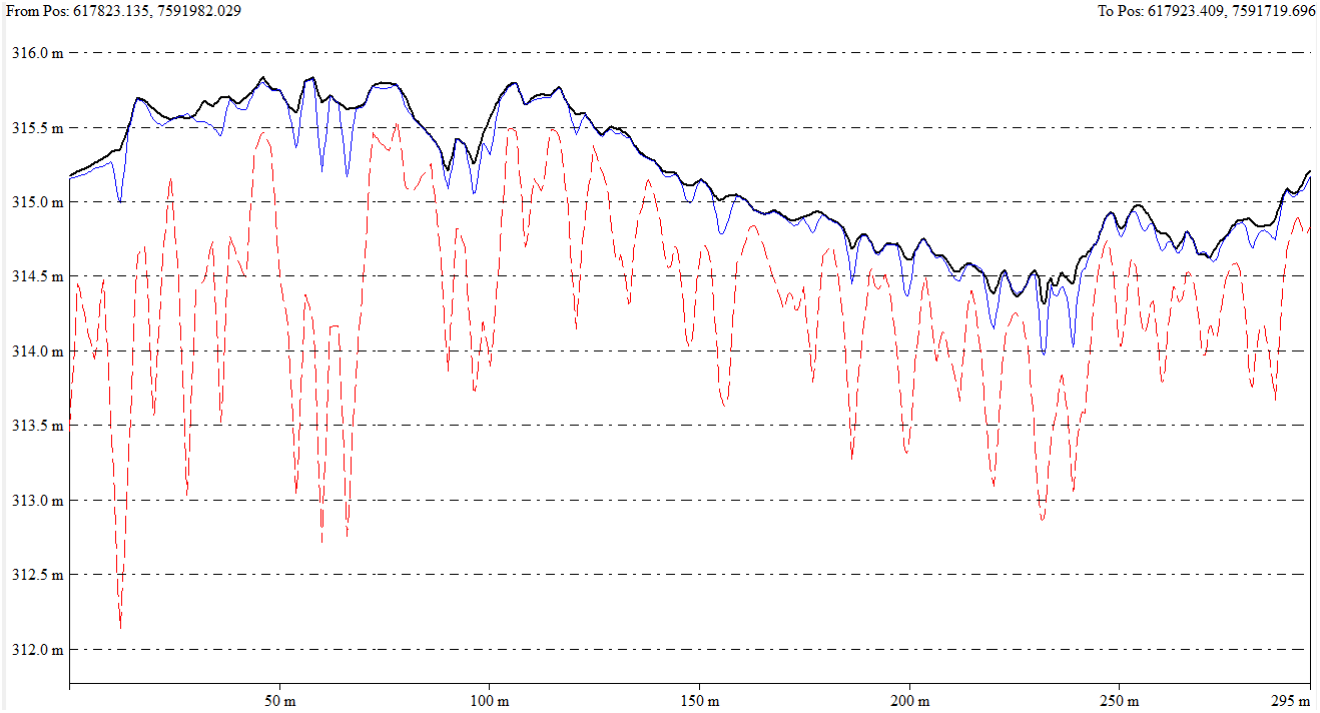

Figure 13: Example cross section showing gullying across the Wallanbah Eastern dump internal batter after 300 years of simulated erosion on bare soil (red dashed line) and 60% groundcover (blue line) compared with orginal surface (black solid line).

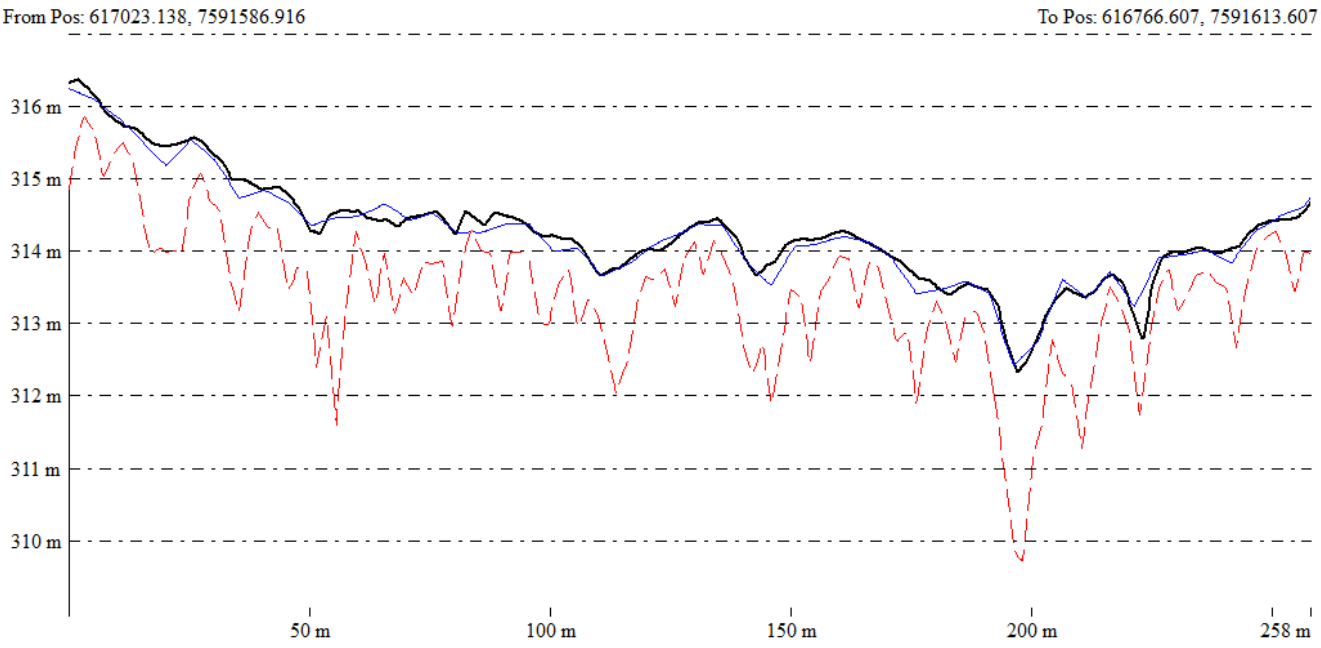

Figure 14: Example cross section showing gullying across the Wallanbah Western dump after 300 years of simulated erosion on bare soil (red dashed line) and 60% groundcover (blue line) compared with orginal surface (black solid line).

6.2.2.1 Tertiary highwall batter

A separate simulation was run to assess the extent of erosion and gullying on the tertiary material of the highwall batter over a 300 year period. Field observations indicated that the slope was already severely eroded and had negligible vegetation cover, so only a bare soil scenario was assessed using SIBERIA. As expected, based on current condition, predicted long-term erosion on the batter was extreme. Significant erosion was predicted after 25 years, with major erosion with gullies greater than 4 m deep predicted after 300 years (Figures 15 and 16). Average erosion rate over the 300 year simulation was ~140 t/ha/yr.

Subsequently, WEPP simulations were carried out to consider the option of toproiling and vegetating the highwall batter. Simulations considered:

- A 40 metre high slope on gradient 16.6%;
- Wallanbah B04 Loam topsoil; and
- Vegetation cover levels of 30%, 50%, and 70%, with infiltration rates adjusted to considervegetation impacts as well as adjustment of erosion rates in response to cover factors.

Rill spacings across slope were set to 3 metres for 30% cover, and 2 metres for the higher vegetation cover levels.

Results of the simulations are shown in Figure 17. They indicate that – at 70% vegetation cover – erosion rates on the slope will reach approximately 9 t/ha/y at the toe of the slope, with an average of 4 t/ha/y over the full slope length.

Overall, given this slope drains to a pit, the erosion rates modelled are considered acceptable, provided that the 70% cover level can be achieved sustainably. Some slight reduction in batter gradient over the final 40 metres of slope would also improve the slope's stability.

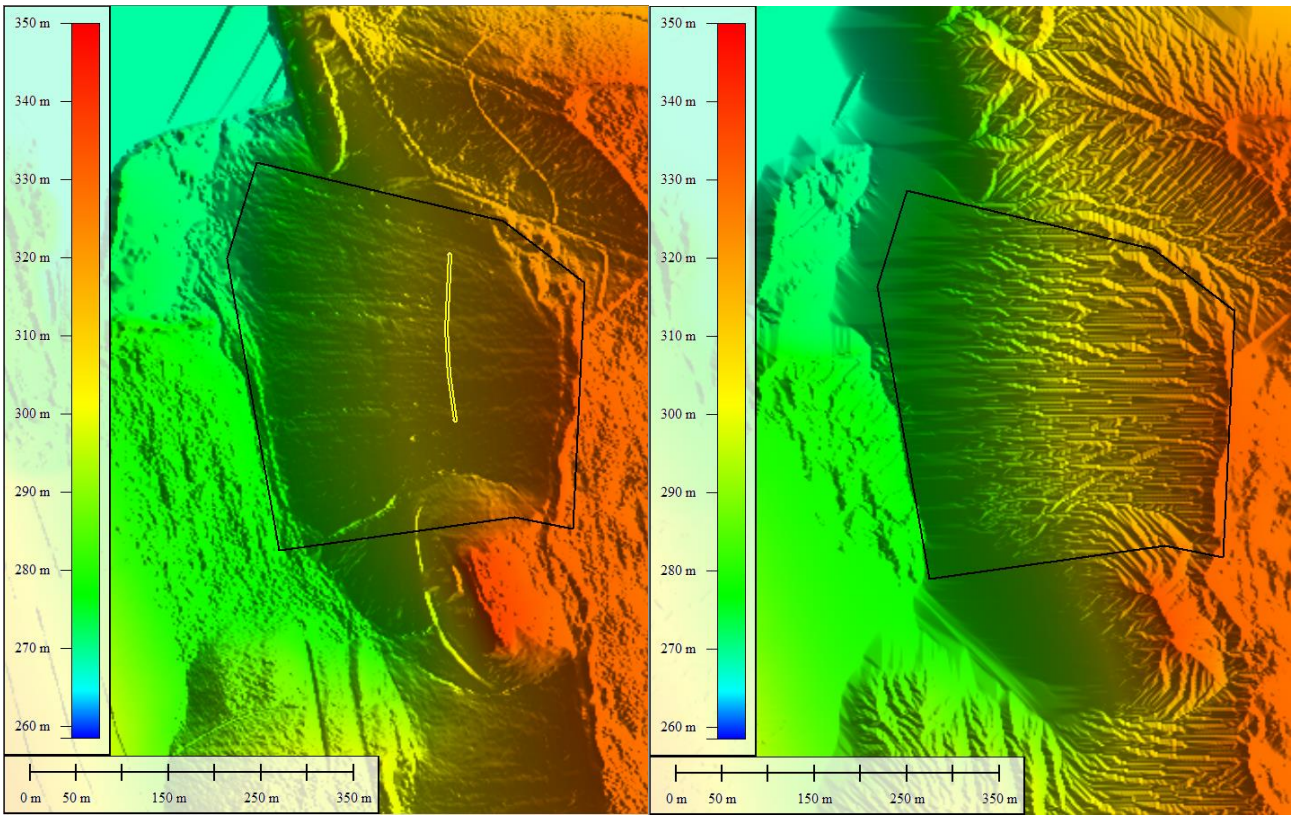

Figure 15: Wallanbah eastern tertiary batter before (left) and after (right) 300 years of simulated erosion, with target area and cross section location marked.

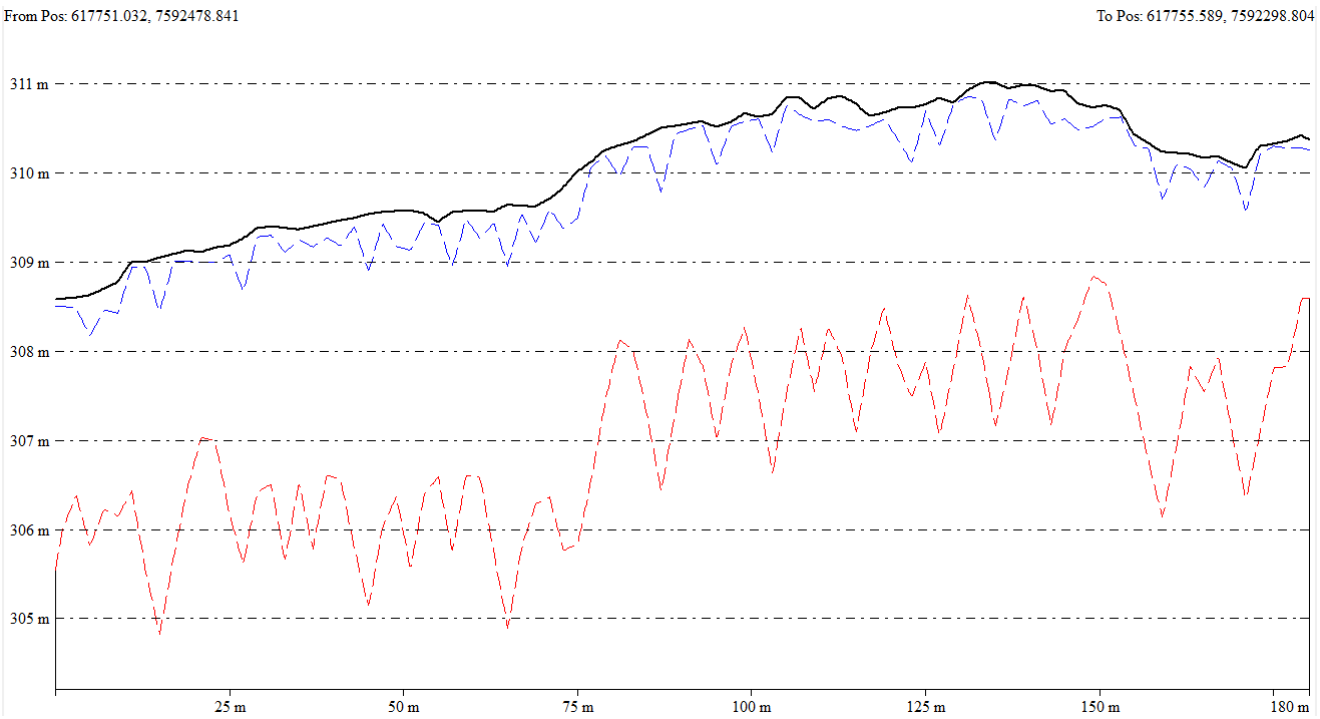

Figure 16: Example cross-section showing gully formation on Wallanbah tertiary batter at 25 years (blue line) and 300 years (red dashed line) compared with original surface (black solid line).

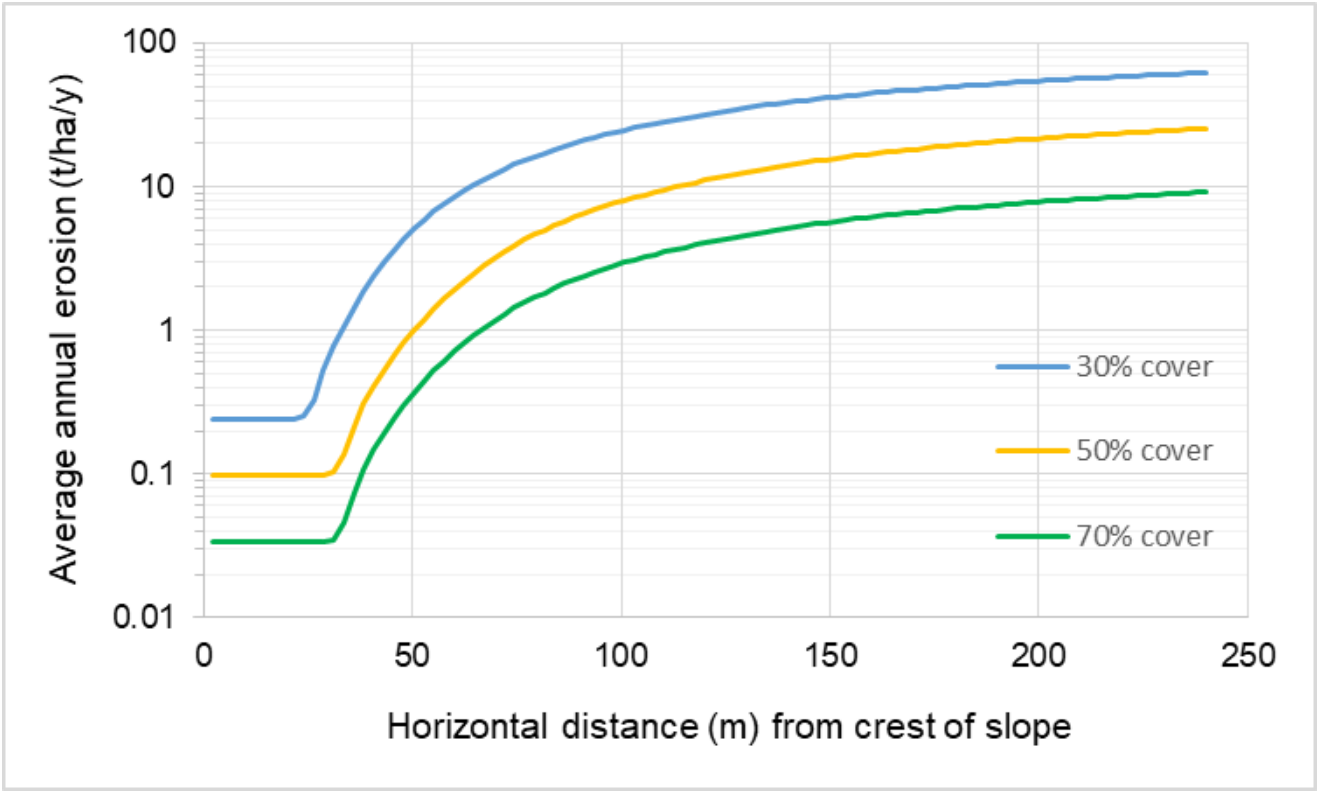

Figure 17: WEPP model output, showing impacts of vegetation cover and slope length on predicted erosion rates for a 40 m high slope on 16.6% gradient.

6.2.3 Broadmeadow

With 60% ground cover, the internal face of the western dump showed acceptable levels of predicted erosion after 300 years (Figure 18), with an average soil loss of approximately 60 mm over the 300 year period (~2.6 t/ha/year) on the eastern batter. The western batter had a predicted erosion rate of 2.8 t/ha/year with 60% cover. Bare soil was predicted to undergo extensive erosion and major gullying, as shown in Figures 19 and 20. The crossection of the eastern batter is presented in Figure 20 and the Western batter in Figure 21.

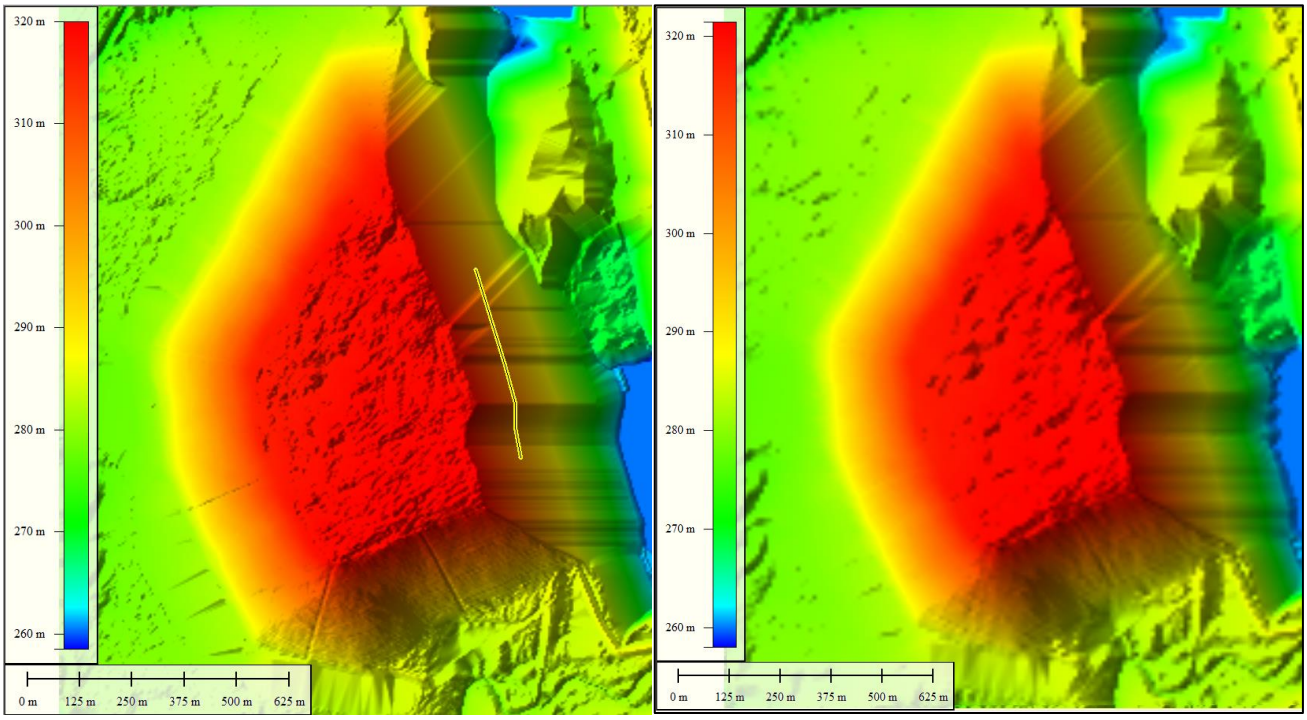

Figure 18: Broadmeadow ex-pit dump before (left, with cross section location marked) and after (right) 300 years simulated erosion on a surface with 60% ground cover.

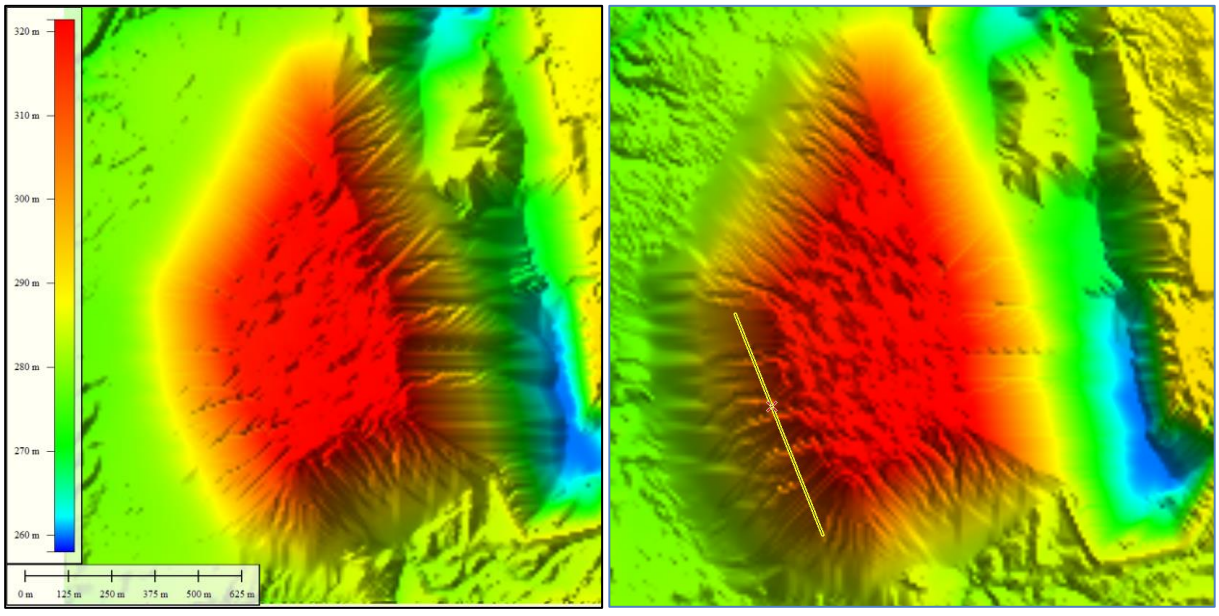

Figure 19: Broadmeadow ex-pit dump after 300 years of simulated erosion on a bare soil surface and transect location.

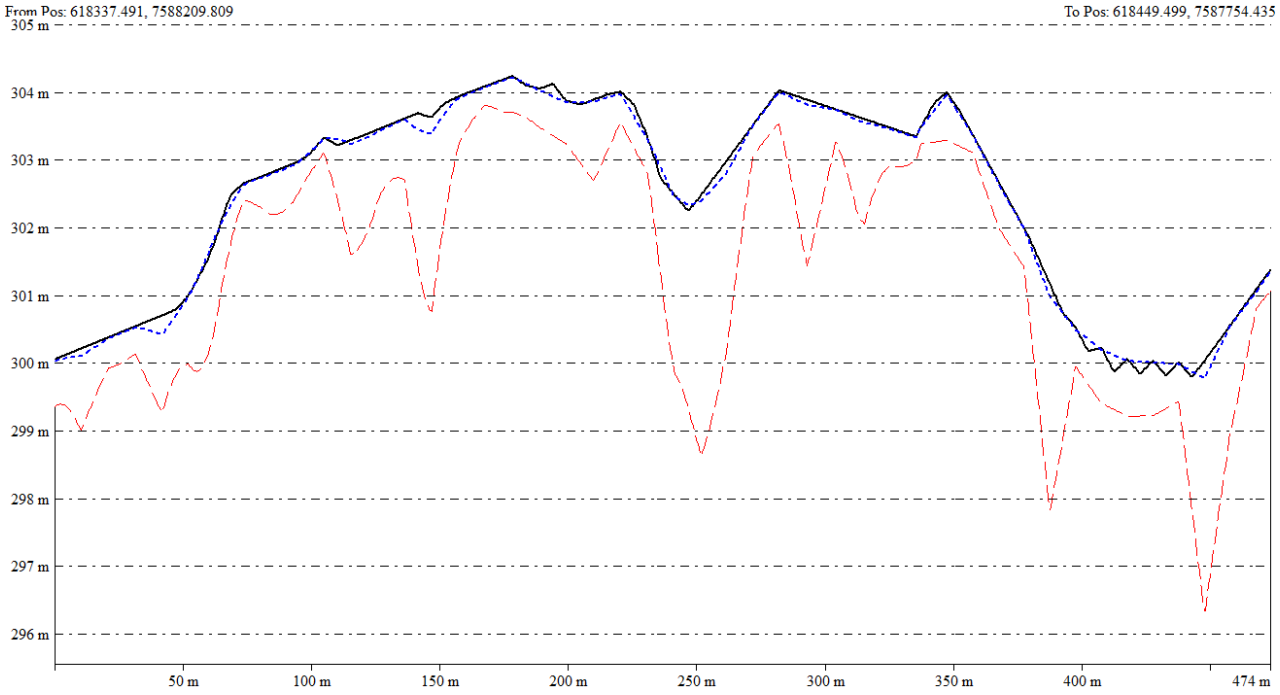

Figure 20: Cross-section of internal/eastern face of Broadmeadow western dump showing gullying after 300 years of simulated erosion on bare soil (red dashed line) and 60% cover (blue dashed line) compared with original surface (black solid line).

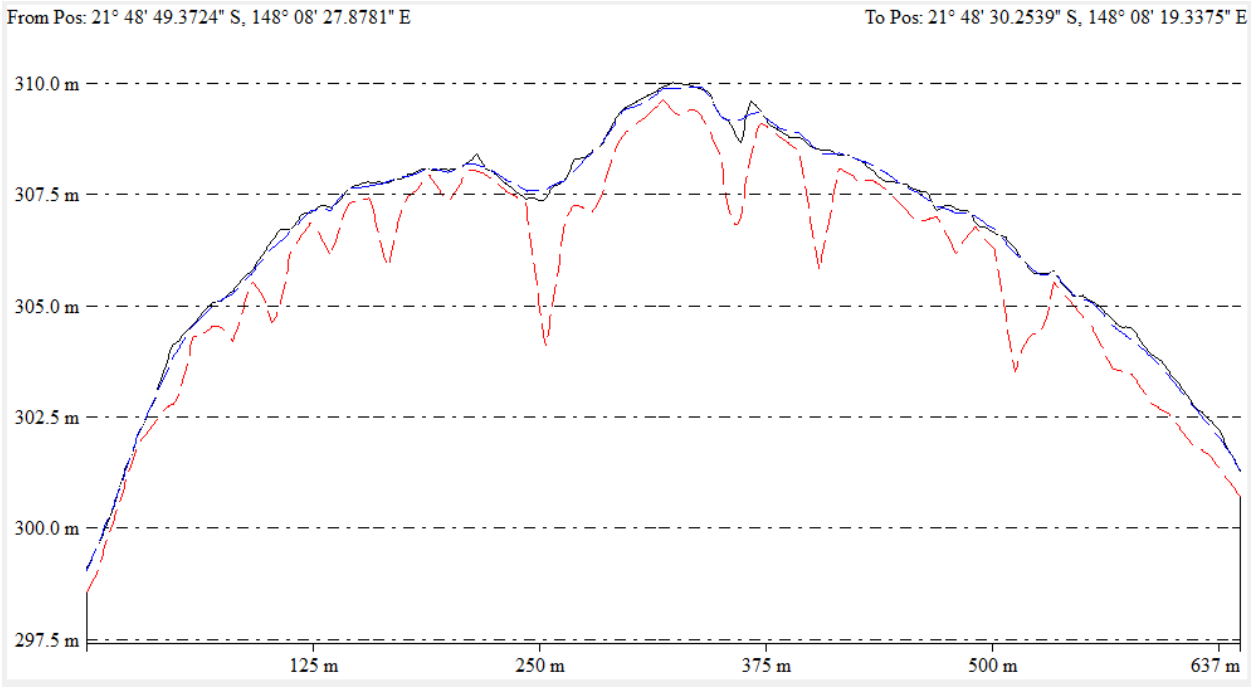

Figure 21: Cross-section of external/western face of Broadmeadow western dump showing gullying after 300 years of simulated erosion on bare soil (red dashed line) and 60% cover (blue dashed line) compared with original surface (black solid line).

6.2.4 Bullock Creek

With 60% vegetation cover, predicted erosion on the southern batter after 300 years was relatively minor (Figure 22), with average cumulative soil loss of approximately 20mm depth, equivalent to a removal rate of less than 1 t/ha/year. The out of pit dump to the north of the pit had an average erosion rate of 1.44 t/ha/yr under 60% cover which is acceptable.

Without adequate vegetation cover, the Bullock Creek in-pit dump was predicted to sustain severe erosion (Figure 23), with gullies 3-4 metres deep developing over a 300 year period (Figure 24 and 25).

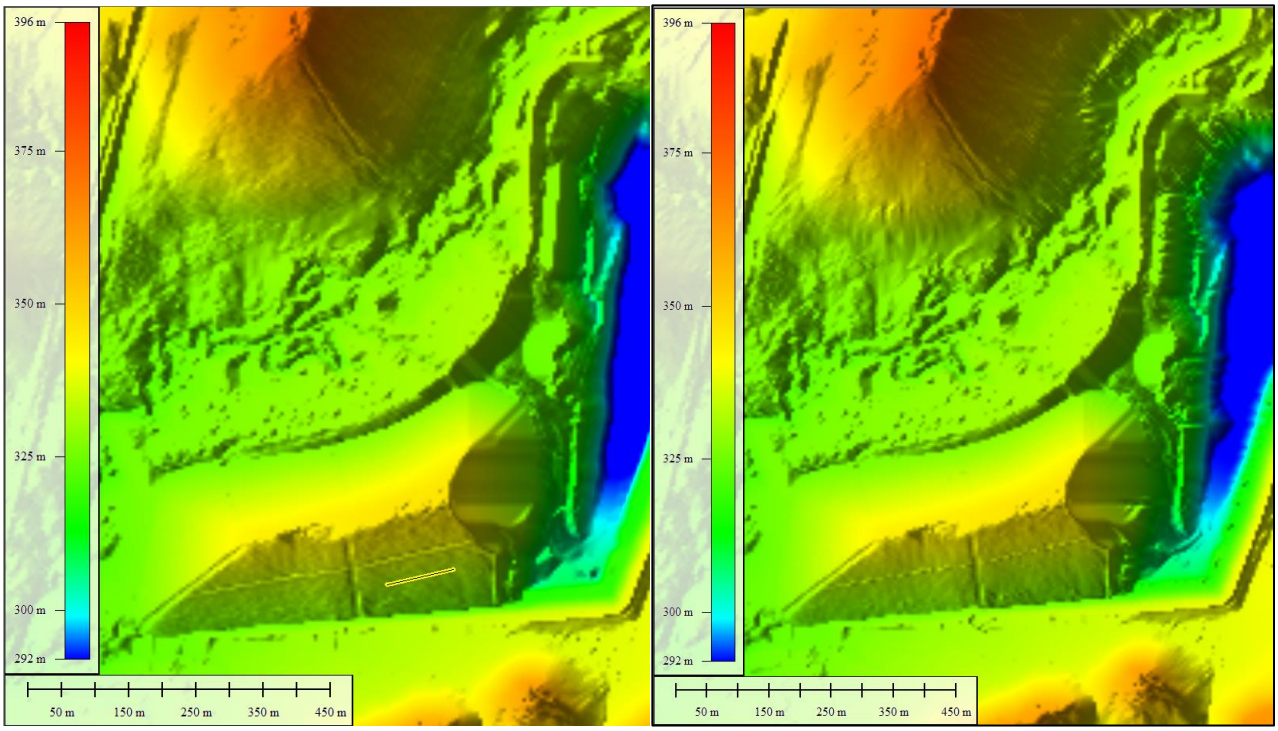

Figure 22: Bullock Creek in-pit dump before (left, showing cross section location) and after (right) 300 years of simulated erosion on a surface with 60% ground cover.

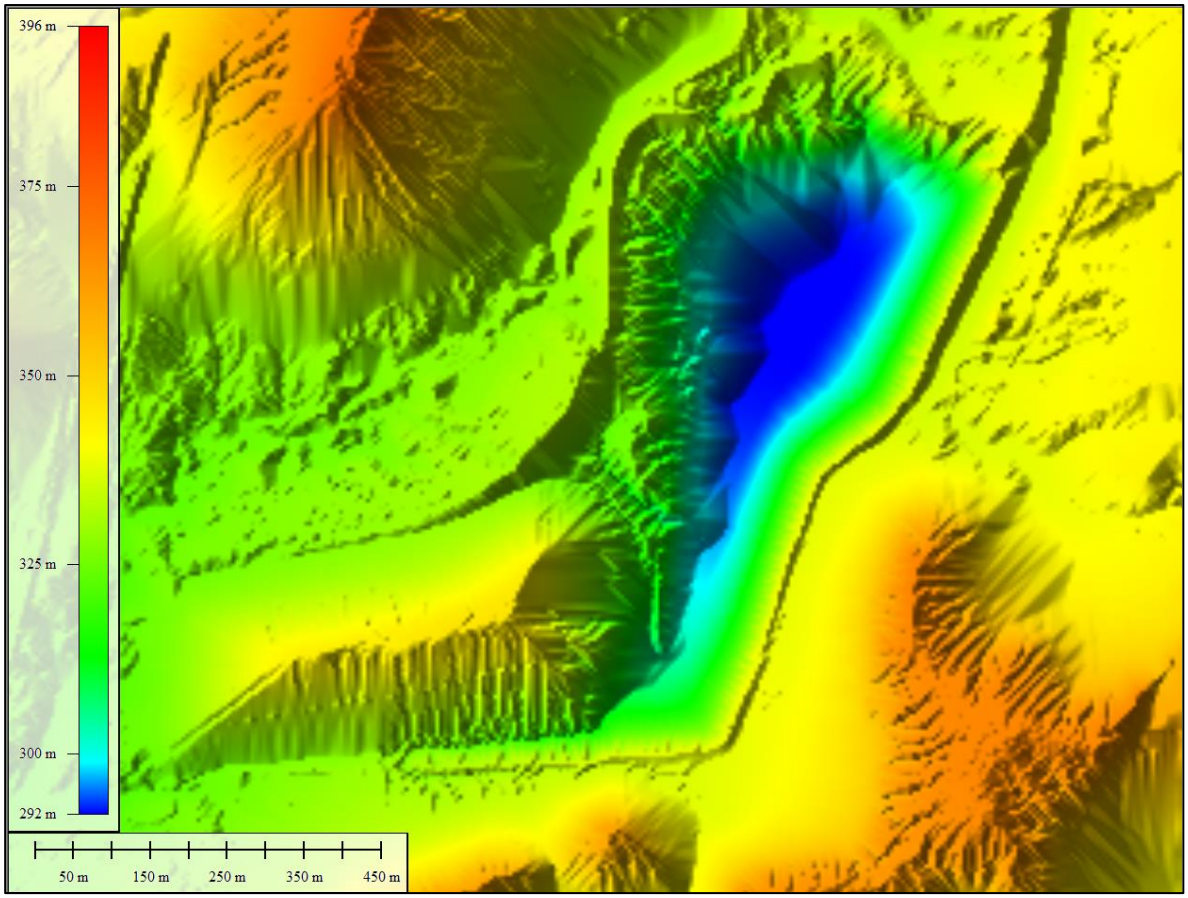

Figure 23: Bullock Creek in-pit dump after 300 years of simulated erosion on a bare soil surface.

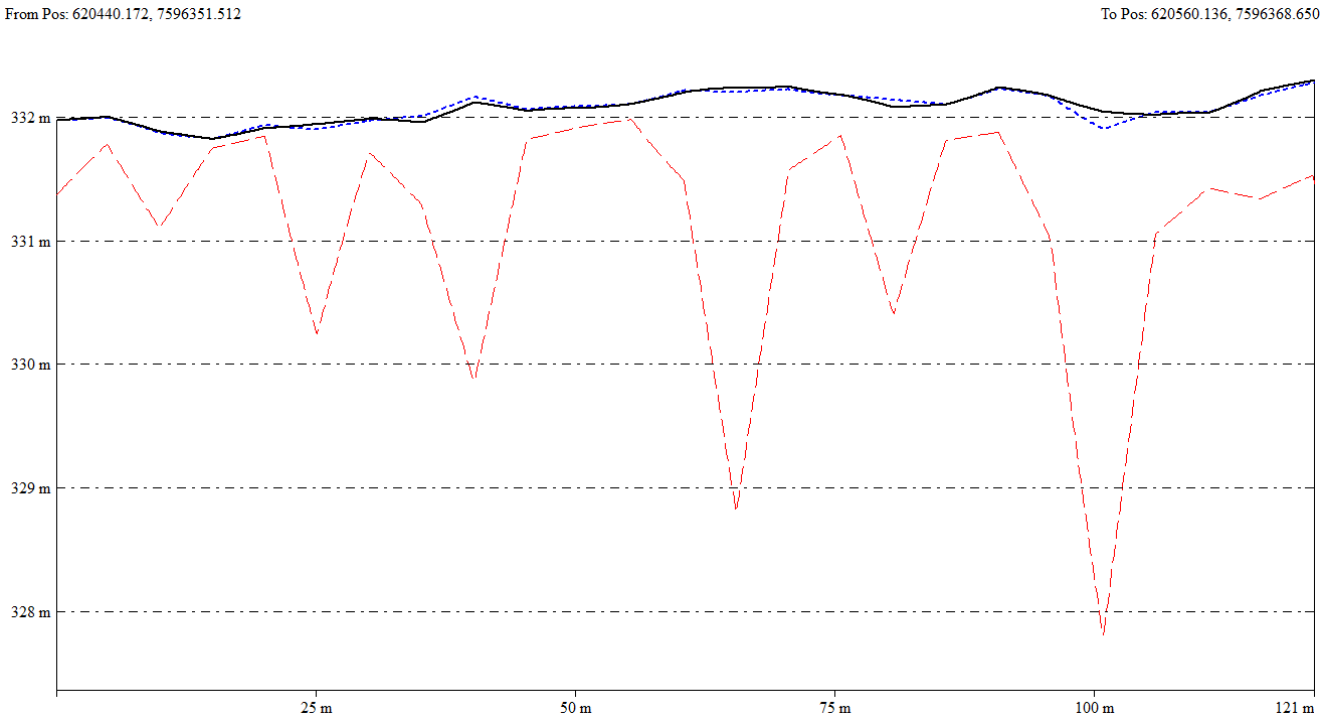

Figure 24: Cross-section of Southern face of Bullock Creek in-pit dump showing gullying after 300 years of simulated erosion on bare soil (red dashed line) and 60% cover (blue dashed line) compared with original surface (black solid line).

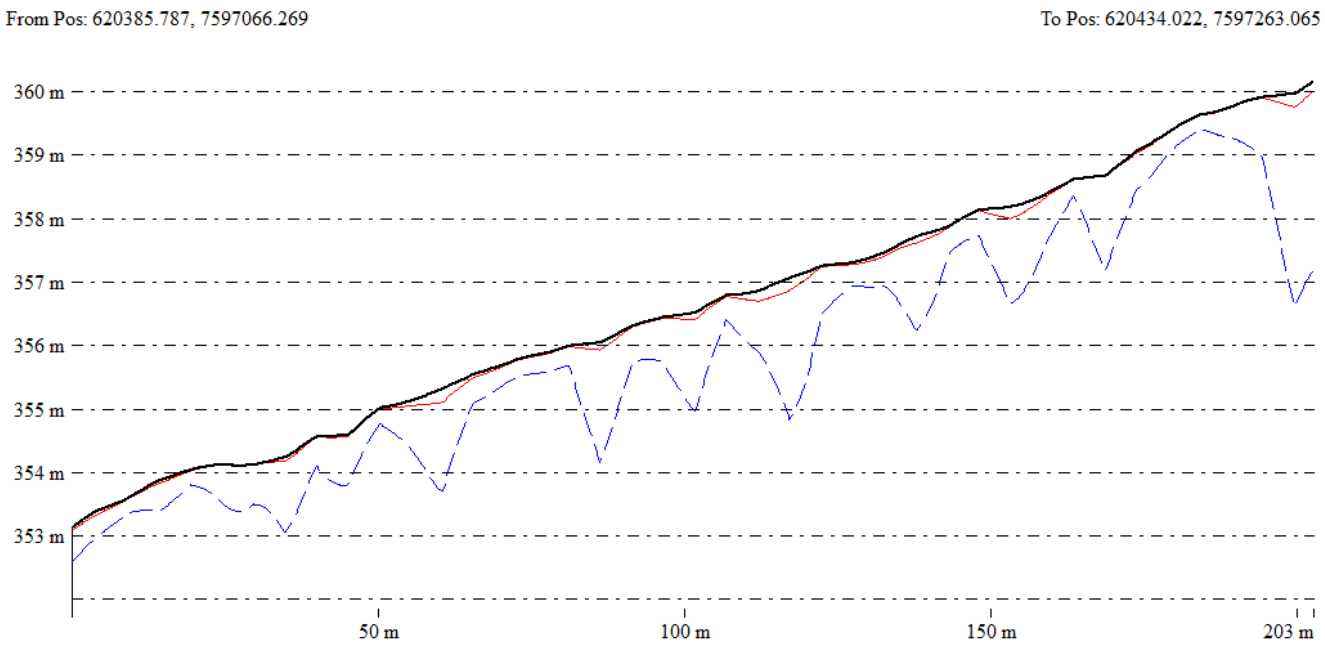

Figure 25: Cross-section of out-of-pit dump of Bullock Creek showing gullying after 300 years of simulated erosion on bare soil (blue dashed line) and 60% cover (red dashed line) compared with original surface (black solid line).

6.2.5 Plumtree pit

For a surface with 60% cover (Figure 6), 300 years of simulated erosion resulted in an average predicted cumulative soil removal of 50-60 mm on the internal batters (~2.5 t/ha/yr), and the western batter 1.4 t/ha/yr which are acceptable long-term erosion rates. Bare soil simulations showed severe erosion after 300 years, with gullies greater than 3 metres deep (Figure 26 to 29).

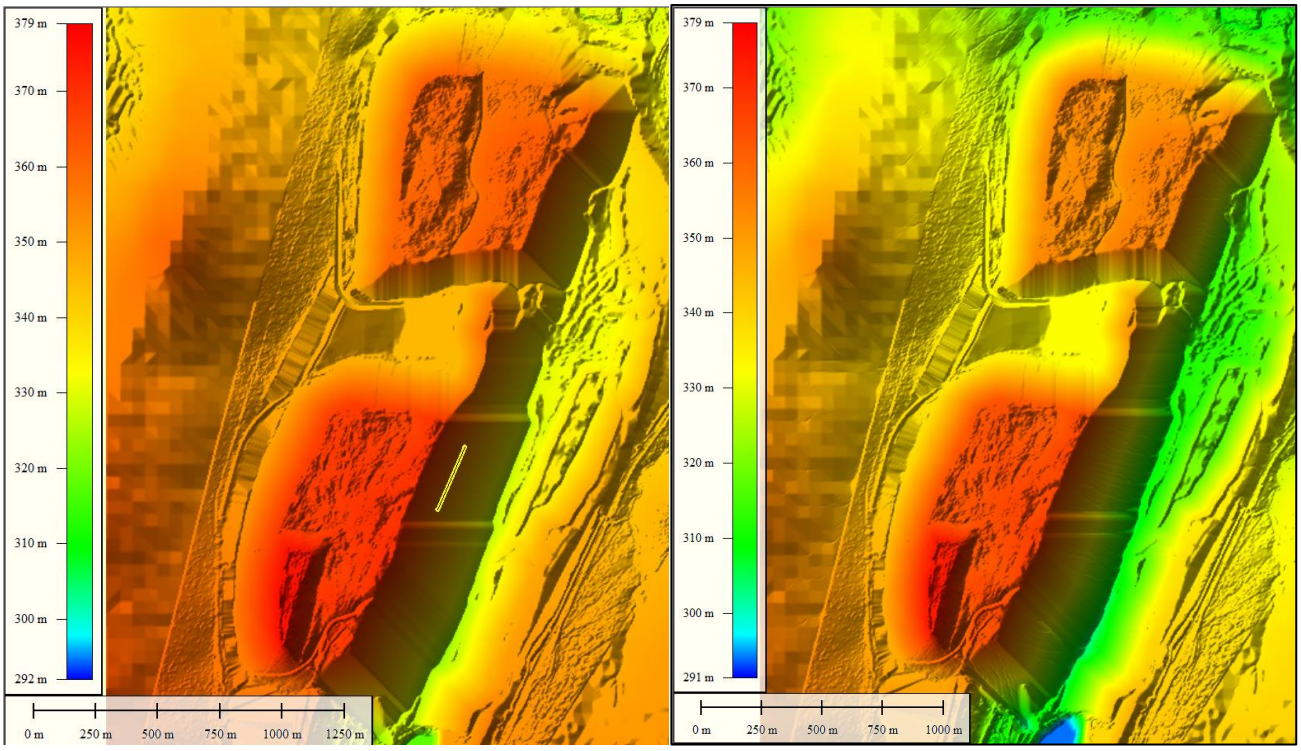

Figure 26: Plumtree pit and dumps before (left, showing cross section location) and after (right) 300 years of simulated erosion on a surface with 60% ground cover.

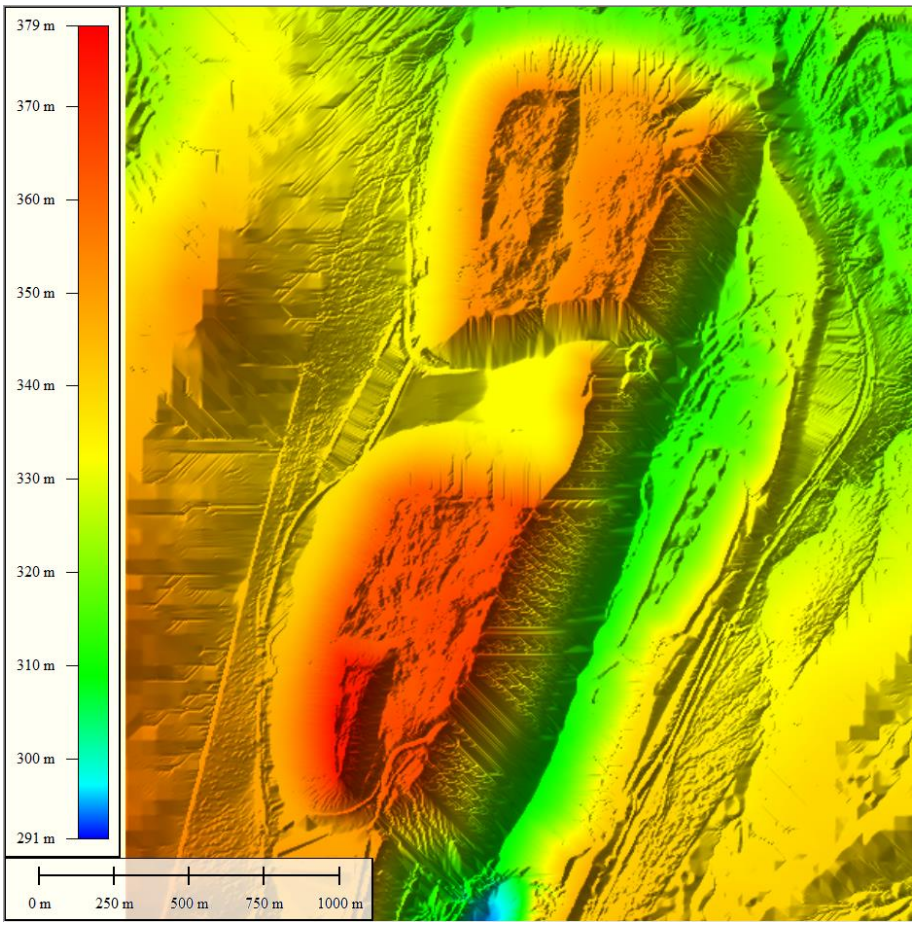

Figure 27: Plumtree pit and dumps after 300 years of simulated erosion on a bare soil surface.

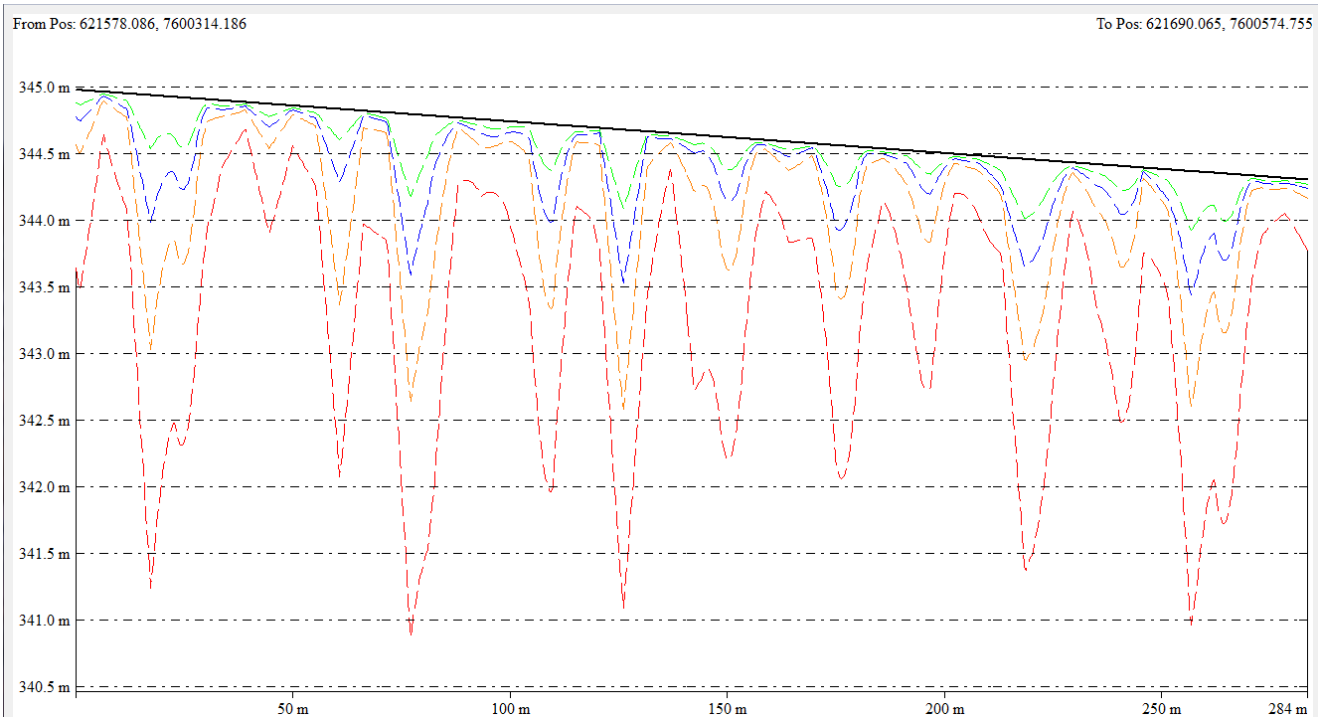

Figure 28: Example profile across Plumtree pit internal batter face showing gully development at 25 years (green), 50 years (blue), 100 years (orange), and 300 years (red), compared to orginal surface (black solid line).

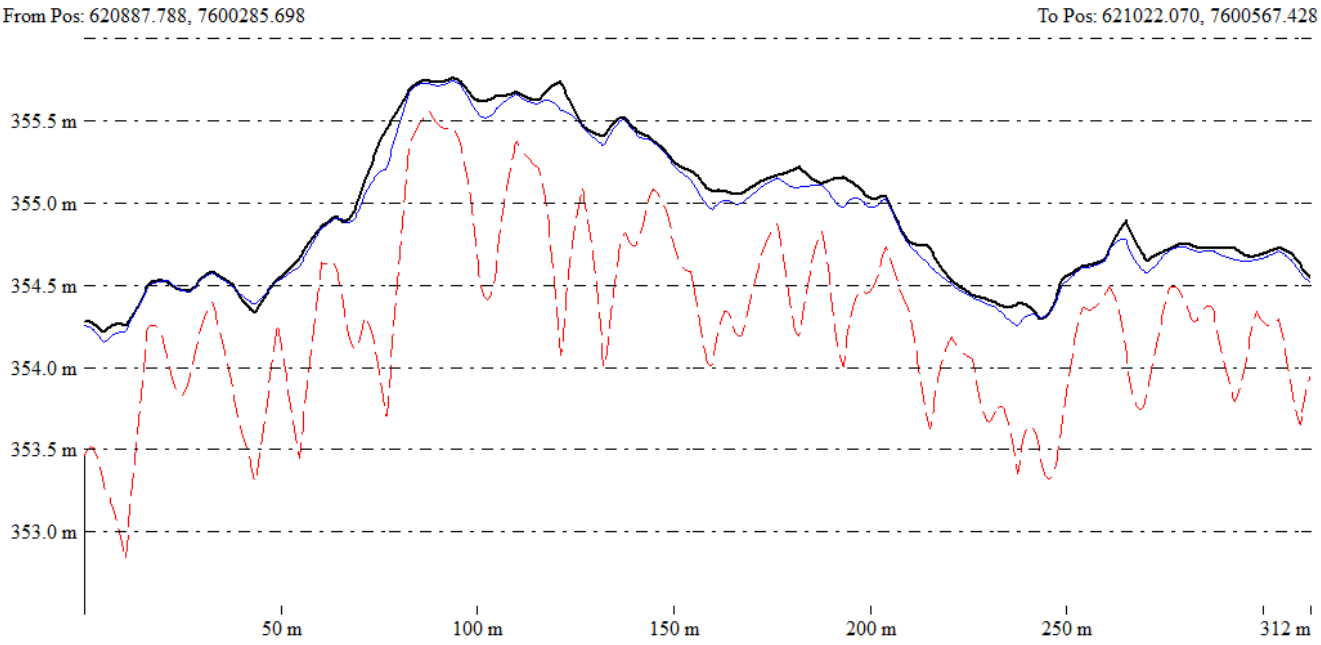

Figure 29: Example profile across Plumtree pit western batter face showing gully development at 300 years for no vegetation cover (red line) and 60% surface cover (blue line).

7 DISCUSSION AND CONCLUSIONS

With the exception of the battered down tertiary material on the Wallanbah highwall, the simulations all suggest that the slopes assessed can be expected to be erosionally stable in the long term, provided 60% vegetative cover can be achieved.

Based on site obervations and material chemical analysis, it is unlikely that the Wallanbah tertiary material will sustain sufficient vegetataion growth for long-term stability. The material itself is very highly erodible, and it is recommended that it is treated with gypsum and capped with a more stable material. A considerable depth of capping material is required to minimise infiltrated water reaching the underlying dispersive material, and reducing potential for surface erosion to incise to depth and expose the Wallanbah tertiary material. A depth of 1 metre of capping material has been recommended for such situations (Minserve 2004). Consideration should be given to reducing the slope gradient to reduce flow velocities on the slope.

For the remainder of the rehabilitation areas, it is recommended that efforts focus on on soil amelioration and improvement to encourage establishment and long-term sustainability of vegetation growth to achieve and maintain at least 60% cover.

7.1 Soil sampling, analysis, and amendment

It is recommended that comprehensive analysis of growth media be undertaken prior to commencement of rehabilitation works. An example analysis suite covering key properties for plant growth is:

- pH (1:5 water),
- electrical conductivity (EC) (1:5 water),
- chloride,
- total nitrogen,
- total Phosphorous,
- available (Colwell) phosphorus and potassium,
- organic carbon,
- available sulphur,
- trace metals (B, Cu, Zn, Mn and Fe), and
- exchangeable cations and cation exchange capacity (CEC),

The results of these analyses can be used to identify constraints to plant growth and calculate ameliorant (e.g. gypsum, lime) and fertiliser requirements.

Soil sampling should be undertaken at an intensity sufficient to characterise the range of materials present. For initial characterisation of stockpiled topsoil resources, it is recommended that one sample per hectare of stockpile area is collected, but initially only 50% of samples be analysed. If a high degree of variation is found within stockpiles, more samples can then be analysed to assist in differentiating materials or to gain more confidence in calculating universal or "blanket" treatment requirements.

This approach may need to be modified if several visibly distinct and practically seperable materials are present. In that case, representative sampling of the material types present may be warranted. For the analytical suite listed above, a sample size of 500 to 1000 g is generally sufficient.

Samples should be collected from a depth of 0.5 to 1m within stockpiles, and, preferably, composite samples should be created by combining material collected from multiple pits within a 5 to 10 m radius.

In Landloch's experience, many central Queensland soils are highly deficient in nitrogen, to the extent that a single addition of the amount of mineral nitrogen fertiliser required to correct the deficieny would actually be harmful to plant growth. In such cases, the use of slow-release products and organic amendments (e.g. composted manure) may be necessary to provide enough nitrogen without negatively impacting seedlings. The incorporation of a number of legume species into the seed mix will also be beneficial, as they provide an ongoing source of nitrogen.

7.2 Species selection

Vegetation species selected for rehabilitation should be tolerant of, or adapted to, soil properties such as texture. For example, in areas where sandy topsoil will be spread, species adapted to sandy soils should be favoured, and in areas where clay topsoil will be used, clay-adapted species should be favoured.

In addition, salt tolerance, drought tolerance, and stoloniferous growth habit (for grass, legume, and herbaceous species) should also be considered when selecting revegetation species to maximise persistence and erosion protection.

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APPENDIX 1 – LABORATORY ANALYSIS RESULTS

Project Number:	EW181787
Location:	Burton erodibility
Sample Collection Date:	20/11/2018
Sample Receival Date:	24/11/2018
Sample Analysis Date:	12/05/2018
Project Contact Person:	Tim Nash
East West Enviroag	
82 Plain St Tamworth NSW 2340	
ph:02 67621733	

Analyses	Unit	Lab No	181787-1	181787-2	181787-3	181787-4	181787-5	181787-6	181787-7	181787-8	181787-9	181787-10	181787-11	181787-12	181787-13	181787-14	181787-15	181787-16
		Order			Waste	Topsoil			Topsoil			Waste						
		Sample ID	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B12	B13	B14	B15	B16	B17
		Sample Depth																
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH - Water	pH units		6.82	9.83	6.26	8.05	9.52	9.41	8.56	8.33	8.42	9.46	9.56	9.35	8.16	4.86	8.57	8.86
Electrical Conductivity	dS/m		0.43	0.20	0.38	0.08	0.21	0.26	0.16	0.23	0.20	0.65	0.43	0.36	0.12	0.17	0.05	0.10
Chloride	mg/kg		486.0	6.7	416.0	7.7	48.3	24.6	16.5	57.6	38.6	260.0	140.0	132.0	35.8	176.0	5.5	9.5
Total Nitrogen - Kjeldahl	mg/kg		*	*	*	*	*	*	1174	*	*	*	*	*	*	*	*	*
Total Phosphorus - Nitric/Perchloric	mg/kg		*	*	*	*	*	*	252	*	*	*	*	*	*	*	*	*
Phosphorus - Colwell extr	mg/kg		*	*	*	*	*	*	21.3	*	*	*	*	*	*	*	*	*
Potassium - Colwell ext	mg/kg		*	*	*	*	*	*	135	*	*	*	*	*	*	*	*	*
Sulphur - KCl	mg/kg		*	*	*	*	*	*	18.1	*	*	*	*	*	*	*	*	*
Organic Carbon	%		*	*	*	*	*	*	1.09	*	*	*	*	*	*	*	*	*
Copper	mg/kg		*	*	*	*	*	*	1.35	*	*	*	*	*	*	*	*	*
Iron	mg/kg		*	*	*	*	*	*	24.4	*	*	*	*	*	*	*	*	*
Manganese	mg/kg		*	*	*	*	*	*	12.1	*	*	*	*	*	*	*	*	*
Zinc	mg/kg		*	*	*	*	*	*	0.33	*	*	*	*	*	*	*	*	*
Boron	mg/kg		*	*	*	*	*	*	1.04	*	*	*	*	*	*	*	*	*
Cation Extraction Method	Rayment& Lyons		15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1
Cation Exchange Capacity	meq/100g		9.7	26.3	12.6	11.2	30.3	25.5	40.9	34.9	19.3	26.2	27.6	31.9	18.3	6.0	31.2	20.7
Ex Calcium Percent	%		8.92	60.60	16.89	75.14	63.35	58.30	71.27	72.44	62.62	51.09	54.20	59.71	22.60	34.43	74.17	68.05
Ex Magnesium Percent	%		56.35	28.88	67.95	19.49	27.89	32.43	24.45	22.42	29.16	27.04	27.04	26.61	64.26	44.39	23.86	28.94
Ex Potassium Percent	%		3.46	1.55	1.63	3.90	0.96	1.77	2.07	1.37	2.57	2.16	1.15	0.93	1.70	8.81	1.33	1.77
Ex Sodium Percent	%		31.2	8.9	13.4	1.4	7.8	7.4	2.2	3.7	5.6	19.7	17.6	12.7	11.4	10.1	0.6	1.2
Ex Aluminium Percent	%		0.11	0.04	0.09	0.10	0.04	0.04	0.03	0.03	0.06	0.04	0.04	0.03	0.06	2.25	0.04	0.05
Exchangeable Calcium	mg/kg		173	3189	425	1690	3835	2969	5834	5056	2423	2680	2990	3814	827	411	4627	2822
Exchangeable Magnesium	mg/kg		656	912	1026	263	1013	991	1201	939	677	851	895	1020	1411	318	893	720
Exchangeable Potassium	mg/kg		131	159	79.9	171	113	176	331	187	194	221	124	116	121	205	162	143
Exchangeable Sodium	mg/kg		695	540	389	35.5	541	436	205	300	249	1186	1114	934	479	139	43.6	56.5
Exchangeable Aluminium	mg/kg		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.10	1.00	1.00
Exchangeable Calcium	meq/100g		0.87	15.95	2.13	8.45	19.18	14.85	29.17	25.28	12.12	13.40	14.95	19.07	4.14	2.06	23.14	14.11
Exchangeable Magnesium	meq/100g		5.47	7.60	8.55	2.19	8.44	8.26	10.01	7.83	5.64	7.09	7.46	8.50	11.76	2.65	7.44	6.00
Exchangeable Potassium	meq/100g		0.34	0.41	0.20	0.44	0.29	0.45	0.85	0.48	0.50	0.57	0.32	0.30	0.31	0.53	0.42	0.37
Exchangeable Sodium	meq/100g		3.02	2.35	1.69	0.15	2.35	1.90	0.89	1.30	1.08	5.16	4.84	4.06	2.08	0.60	0.19	0.25
Exchangeable Aluminium	meq/100g		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.13	0.01	0.01
Calcium/Magnesium Ratio	-		0.2	2.1	0.2	3.9	2.3	1.8	2.9	3.2	2.1	1.9	2.0	2.2	0.4	0.8	3.1	2.4
Cation Extraction Method	Rayment& Lyons		15A2	15C1	15A2	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	*	15C1	15C1
Cation Exchange Capacity	meq/100g		6.4	22.2	10.0	9.6	26.9	21.4	37.6	32.0	16.9	21.5	22.9	28.1	16.7	*	27.8	17.3
Ex Calcium Percent	%		7.83	64.73	19.69	77.99	66.28	57.89	71.95	73.49	65.46	57.17	56.74	60.70	22.22	*	79.44	70.70
Ex Magnesium Percent	%		64.98	28.23	70.20	18.85	27.83	34.89	24.63	22.79	29.47	27.10	29.40	28.39	69.93	*	19.75	28.32
Ex Potassium Percent	%		2.48	1.09	1.16	2.59	0.66	1.15	1.43	0.78	1.04	1.21	0.55	0.77	0.87	*	0.61	0.54
Ex Sodium Percent	%		24.54	5.90	8.84	0.45	5.18	6.01	1.95	2.91	3.96	14.46	13.27	10.11	6.91	*	0.16	0.37
Ex Aluminium Percent	%		0.17	0.05	0.11	0.12	0.04	0.05	0.03	0.03	0.07	0.05	0.05	0.04	0.07	*	0.04	0.06
Exchangeable Calcium	mg/kg		99.6	2874	395	1496	3569	2478	5414	4698	2214	2454	2596	3414	741	*	4412	2447
Exchangeable Magnesium	mg/kg		496	752	845	217	899	896	1112	874	598	698	807	958	1399	*	658	588
Exchangeable Potassium	mg/kg		61.4	94.8	45.4	96.9	69.8	96.2	210	96.8	68.7	101	48.9	84.1	56.8	*	66.5	36.6
Exchangeable Sodium	mg/kg		359	301	204	10	321	296	169	214	154	714	698	654	265	*	10	14.9
Exchangeable Aluminium	mg/kg		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	*	1.0	1.0
Exchangeable Calcium	meq/100g		0.50	14.37	1.98	7.48	17.85	12.39	27.07	23.49	11.07	12.27	12.98	17.07	3.71	*	22.06	12.24
Exchangeable Magnesium	meq/100g		4.13	6.27	7.04	1.81	7.49	7.47	9.27	7.28	4.98	5.82	6.73	7.98	11.66	*	5.48	4.90
Exchangeable Potassium	meq/100g		0.16	0.24	0.12	0.25	0.18	0.25	0.54	0.25	0.18	0.26	0.13	0.22	0.15	*	0.17	0.09
Exchangeable Sodium	meq/100g		1.56	1.31	0.89	0.04	1.40	1.29	0.73	0.93	0.67	3.10	3.03	2.84	1.15	*	0.04	0.06
Exchangeable Aluminium	meq/100g		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	*	0.01	0.01
Calcium/Magnesium Ratio	-		0.1	2.3	0.3	4.1	2.4	1.7	2.9	3.2	2.2	2.1	1.9	2.1	0.3	*	4.0	2.5
Gravel >2.0mm	%		7.1	16.8	0.1	4.6	1.4	1.4	0.8	*	*	3.7	7.3	3.0	2.4	*	6.9	7.6
Coarse Sand 0.2-2.0mm	%		15.0	25.7	38.9	21.0	21.7	16.6	15.8	*	*	18.7	15.5	19.4	24.2	*	22.6	12.7
Fine Sand 0.02-0.2mm	%		30.6	25.2	23.3	30.5	29.6	30.2	28.5	*	*	34.9	36.8	29.7	25.5	*	33.6	32.0
Silt 0.002-0.02mm	%		12.2	12.2	19.6	7.3	21.7	20.6	8.5	*	*	17.7	10.0	13.5	22.0	*	13.8	17.3
Clay <0.002mm	%		35.2	20.1	18.1	36.6	25.6	31.2	46.4	*	*	25.1	30.5	34.4	26.0	*	23.0	30.3
ADMC	%		4.2	3.1	1.6	3.0	3.4	2.5	7.5	*	*	3.0	2.2	3.1	3.0	*	3.5	1.7
Emerson Aggregate	Class		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Phosphorus Buffer Index	mg/kg		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Appendix H

Spade Creek diversion revegetation plan



alluvium

REVEGETATION PLAN AND TECHNICAL SPECIFICATIONS:

Burton Mine: Spade Creek Diversion – Revegetation Plan

February 2020

Peabody ENERGY

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1 Project description

This revegetation plan has been produced to accompany the Burton Mine: Spade Creek Diversion Detailed Design (Alluvium 2019a). Burton Mine is situated in the northern end of Queensland's Bowen Basin coalfields, approximately 125 km south-west of Mackay, and stretches over 35km from north to south. The detailed design is a rehabilitation design to modify an existing diversion such that its function and recovery place it on a trajectory that would make it suitable for relinquishment associated with mine closure.

This report provides methods and processes recommended for revegetating the Spade Creek Diversion and works associated with the detailed design. The purpose of this report is to provide:

1. A revegetation plan which replicates the native vegetation of the subject area
2. A plan for developing a long-term self-sustaining vegetation community
3. An approach that minimises potential for topsoil and subsoil loss, through increasing soil stability and reducing erosion risk
4. An outcome which facilitates rapid vegetation establishment.

The revegetation recommended in this plan is based on direct seeding of local native plant species (LNS). For this process to be successful significant seed will need to be collected and sown at the right depth at the correct time of year. Tubestock planting may also be applied to supplement direct seeding. Tubestock is proposed for species where seed availability is limited and/or the reliability of establishing a given species by direct seeding is low.

The revegetation plan is a required component of detailed design and will be essential in developing a stable diversion and landforms, which will be suitable for approvals relinquishment and mine closure in the long term. The aim of the revegetation plan is to enhance the diversion and landform rehabilitation works and:

1. Reduce erosion risks
2. Enhance vegetation establishment and survival
3. Aid rapid vegetation establishment of soil cover
4. Provide a guide to ongoing maintenance and improvement.

The recommended treatments are required to ensure vegetation establishment aligns with the aim of providing a long-term, self-sustaining vegetation community while minimising potential for topsoil loss.

1.1 Spade Creek Diversion detail design

The extent of works detailed in this report includes:

- Spade Creek diversion
- Redundant channel fill
- Land forming to direct flows into the channel
- Batter drains

Detailed documentation for these components is provided in

- The detailed design report (Alluvium, 2019a)
- Technical specification for diversion and associated works (Alluvium, 2019b)
- Revegetation plan for diversion (this report) (Alluvium, 2019)
- The project drawings (draft issue)

This revegetation plan should be read in conjunction with the detailed design (Alluvium 2019a) and detailed design technical specifications (Alluvium 2019b).

1.2 Revegetation objectives

The revegetation plan aims to establish, as far as practical, a self-sustaining native vegetation community along the diversion and adjacent landforms that is suited to the shallow soils to be placed on the excavated and filled surfaces of the construction footprint. The plan has the following objectives:

a) Provide a practical approach to restoration of a highly disturbed environment
b) To minimise potential for topsoil loss through increasing soil stability and reducing erosion risk
c) Use of methods that are economic and operationally practical
d) Addresses short and long-term risks to vegetation establishment
e) Satisfies any EA conditions regarding rehabilitation and revegetation
f) An outcome which facilitates approvals relinquishment by the time of mine closure
g) Provide technical information (guidance) for a successful deployment of the revegetation plan
h) Provide guidance to maintenance requirements.

The plan outlines a staged approach to revegetation aimed at delivering technical components:

a) Revegetation efforts should complement existing natural vegetation with LNS used where practicable
b) The vegetation community should aim to fit the modified landform
c) The revegetation outcome must achieve a long-term self-sustaining vegetation community.

1.3 Aspects that guide the revegetation plan

Development of the revegetation plan is influenced by the location of the works, climate, existing vegetation and features of the Spade Creek Diversion and associated works. The capacity to irrigate, monitor and undertake regular maintenance may influence the revegetation approach used. A mix of planting techniques is recommended for cost efficiency and to improve the chances of success. The main aspects that guide the revegetation plan are described below.

Soil properties

Soil properties of the topsoil and sub-soils play a critical role in the establishment and long-term viability of vegetation. The availability of topsoil is limited at site and the sub-soils are expected to be nutrient deficient with poor chemical and physical properties. Treatment of existing soils will likely be required to develop an adequate growing medium for successful vegetation establishment.

Soil attributes testing has been limited. Comprehensive information about current and desired soil condition was unavailable at the time of writing this revegetation plan. However, this need not be a blocker to commencing preparation and developing a plan. This plan assumes further testing and amelioration will take place independently of revegetation recommendations and prior to the delivery of on ground works recommended in this revegetation plan. It assumes that amelioration will be to a standard that maximises establishment success. Specific recommendations around soil amelioration will not be provided in this report. Soil amelioration requirements are to be provided by a consultant independently of this plan.

Soil testing requirements are discussed in Section 3.2.

Soil moisture

The availability of soil moisture will play a key role in the successful long-term establishment of vegetation. Regardless of the approach used (direct seeding, tubestock planting or natural regeneration), water/moisture availability is critical for plant establishment. Adequate water is required for at least the first two years to increase the chances of survival. The use of hay mulch is recommended to:

- retain soil moisture
- reduce erosion risk
- contribute organic matter
- suppress pest plants
- contribute to the development of the soil profile.

Vegetation
The use of local native vegetation is required to meet obligations to rehabilitate Regional Ecosystems (RE) impacted by this development. Local native vegetation provides the best chance of long-term rehabilitation success because it uses species best adapted to the soils and climate. Rehabilitation of REs is required to restore habitat function of the impacted area. The selection of species is largely based on RE mapping, previous vegetation surveys and monitoring of the site. RE mapping identifies the relationship between vegetation communities and landforms and is a valuable source of information when developing revegetation plans. Two exotic grass species are also included for their ability to rapidly form ground cover and prevent soil loss in the initial stages of rehabilitation.

Accessibility
Design batters enable machine access to the batters for seeding. Where access is limited, seeding may be supplemented by hand seeding.

Preparation and maintenance
Ground preparation and control of weeds play major roles in revegetation success. Maintenance should consider the control of competitive non-desired species and species where there is a legal obligation to manage and control. Weeds of National Significance such as Parthenium, *Parthenium hysterophorus,* require control.

Some exotic species such as Flaxleaf Fleabane, *Erigeron bonariensis,* may be abundant early colonisers of disturbed ground. While abundant it may not necessarily pose a threat to establishment of revegetation at Spade Creek. In some cases, it may be a useful contributor of organic matter to the site having a similar function to cover crops established to protect soil. Flaxleaf Fleabane will rapidly decline in abundance when vacant niches are absent or taken up by revegetation. It is a low priority for control and maintenance. Some discretion will need to be applied to the control of species performing a similar function to fleabane. Control of Fleabane during revegetation establishment is a low priority unless it can be demonstrated that it is significantly reducing the vigour of desired species. Fleabane is prevalent at the nearby Bullock Creek revegetation site where it does not appear to be substantially reducing the success of revegetation especially in areas where irrigation is supplied and supplements the vigorous growth of native species revegetation efforts.

The control of grazing and browsing pest animals may be required if they are having an adverse impact on vegetation establishment. Stock can be managed by appropriate fencing. Other grazers/browsers including rabbits, macropods and potentially feral pigs and goats may require control in the future. At the time of assessment there was no evidence of any substantial impact by these species. Ongoing monitoring of the impact of these species on establishment of vegetation will be required to determine the need for appropriate actions to maintain vegetation.

1.4 Regional Ecosystems

Regional Ecosystem (RE) mapping has been used to identify the most suitable vegetation community, however it is not always accurate at the site scale as much of it is estimated from aerial imagery and geological information at larger scales. The mapping is regularly reviewed and updated as on-ground observations are reported. Species recorded during diversion monitoring are also used to inform the selection of species.

EA requirements
EA item F9 states that:

> *"Areas which are to be progressively rehabilitated to land not suitable for grazing must demonstrate achieving the specified land suitability and ensure:*
> *(a) achieve a self-sustaining native ecosystem;*
> *(b) success criteria defined in the document entitled "Burton Coal Mine Environmental Management Plan" dated May 2010, Appendix 3 – Proposed rehabilitation success criteria - Bushland, are met;*
> *(c) all areas disturbed by mining activities must be rehabilitated to a stable landform and comply with the design criteria defined in Table F2 and Table F3".*

Current RE mapping

Version 11.0 of the Queensland EPA Regional Ecosystem (RE) Mapping (updated July 2019) indicates that the vegetation communities through which the Spade Creek Diversion works will be undertaken are mapped almost entirely as non-remnant Figure 1Table 1 except for a short section of RE11.5.9c/11.5.3 at the diversion start. Prior to clearance and other disturbance, RE11.5.9c/11.5.3 was the dominant RE with RE11.3.25 present where the diversion ties back into the original watercourse Figure 2.RE11.5.9c/11.5.3 has a Biodiversity status of *No concern at present* while RE11.3.25 has a Biodiversity status of *Of Concern*.

It is considered that reproduction of RE11.3.25 as the main vegetation community along the diversion is appropriate because the area is being changed into an alluvial landform (land zone 3) from a loamy or sandy plain (land zone 5). Since it will take some time for the alluvial landform and soils to develop we are including some of the species from RE11.5.9c/11.5.3 to provide the opportunity for greater diversity and increase the likelihood of successful vegetation establishment, particularly in the section of new channel. The typical species of the REs considered in developing this revegetation plan are presented in Table 1.

Table 1. Regional ecosystems encompassing the Burton High Wall Diversion

RE	Description	Typical species
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines. Mid-dense structure of open forest to woodland with tall shrub layer and fewer low shrubs. The ground layer is open to sparse and dominated by perennial grasses, sedges and forbs. Occurs on fringing levees and banks of rivers and drainage lines of alluvial plains. Occurs on a variety of deep alluvial soils.	Trees: *Eucalyptus tereticornis, E. coolabah, Casuarina cunninghamiana, Corymbia clarksoniana* Shrubs: *Acacia salicina, A. stenophylla, Lysiphyllum carronii, Melaleuca* spp. Ground cover: *Imperata cylindrica, Bothriochloa bladhii, B. ewartiana, Chrysopogon fallax, Cyperus* spp., *Dichanthium sericeum, Lomandra longifolia, Panicum* spp.
11.5.9c/11.5.3	*Eucalyptus crebra* and other *Eucalyptus spp.* and *Corymbia spp.* woodland on sand plains and/or remnant surfaces. The mid layer ranges from absent to a sparse to dense shrubland typically dominated by Acacia spp. Occurs on plateaus and broad crests of hills and ranges which are formed by Cainozoic sandplains. Soils are generally deep red earths.	Trees: *Eucalyptus crebra and/or Corymbia intermedia, C. dallachiana and E. moluccana.* Shrubs: *Acacia excelsa, A. leiocalyx, Petalostigma pubescens, Lysicarpus angustifolius, Alphitonia excelsa* and occasionally *Melaleuca nervosa* (on texture contrast soils).

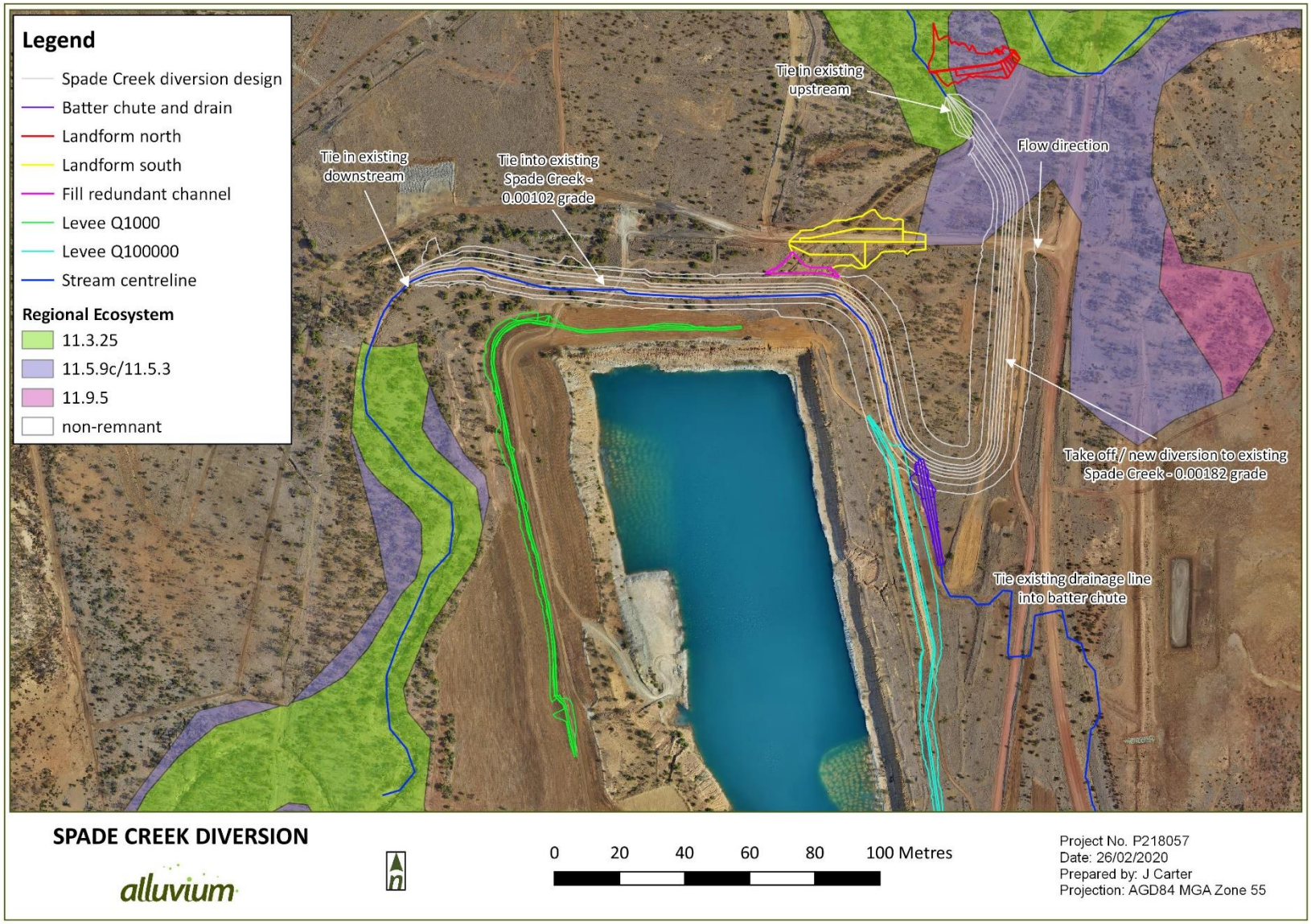

Figure 1. *Current Regional Ecosystem mapping of the Spade Creek Diversion and surrounds*

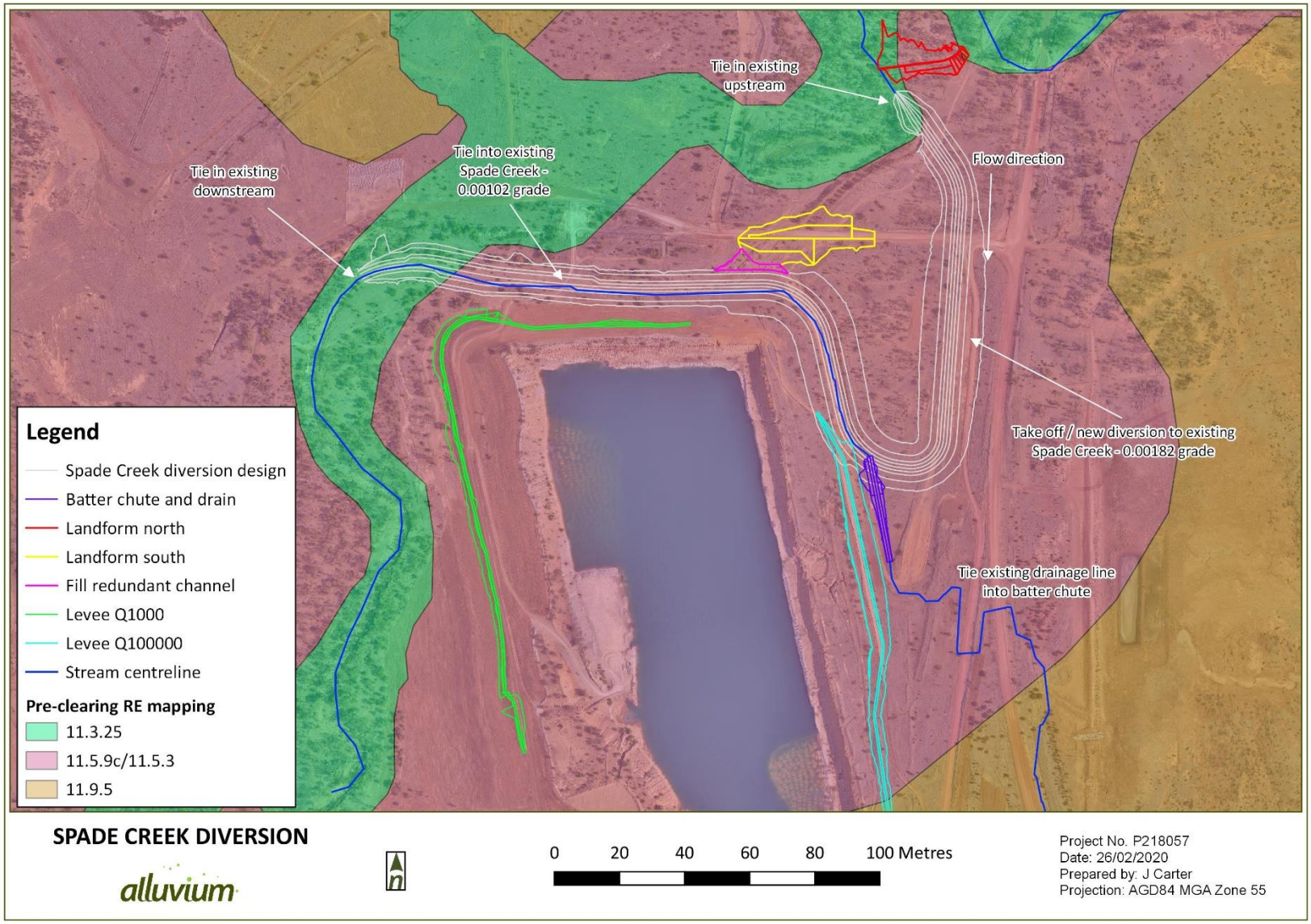

Figure 2. *Regional Ecosystem pre-clearance mapping of the Spade Creek Diversion and surrounds*

1.5 Climate

The wet and dry climate of central Queensland is a challenge to the timing of revegetation activities. Soil erosion is a risk at the site if revegetation isn't successfully established before seasonal rains. Cyclone related storms and localised storms can result in heavy rainfall and rill erosion prior to the establishment of good ground cover. This will require monitoring, especially in the early stages of revegetation works.

Conversely, lack of seasonal rain can limit the establishment and survival of vegetation. This will require monitoring, especially in the first two years following revegetation.

Climate data has been obtained from the Bureau of Meteorology (BOM) website. The closest available long-term monitoring station to Burton Mine is at Moranbah Water Treatment Plant (station no. 034038), which identifies the mean annual rainfall as 613 mm with December, January and February being the wettest months, each averaging over 100 mm (Figure 3).

The monthly mean minimum and maximum temperatures provide a guide to suitable planting periods. November to February are the warmest months with mean maximums from 33-35°C while June and July are the coolest months, sharing the lowest mean maximum temperature at 23.7°C (Figure 4).

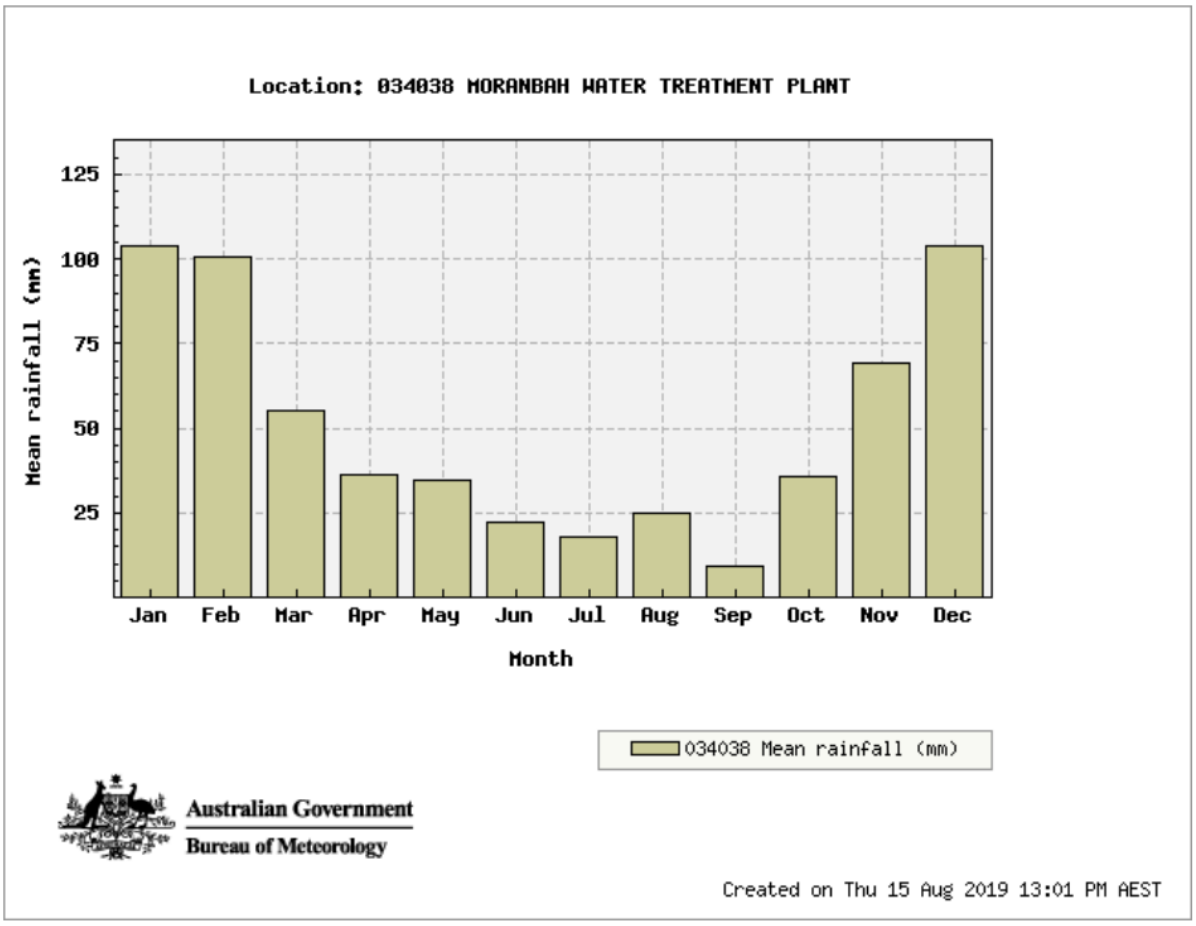

Figure 3. *Mean rainfall at Moranbah (accessed August 2019)*

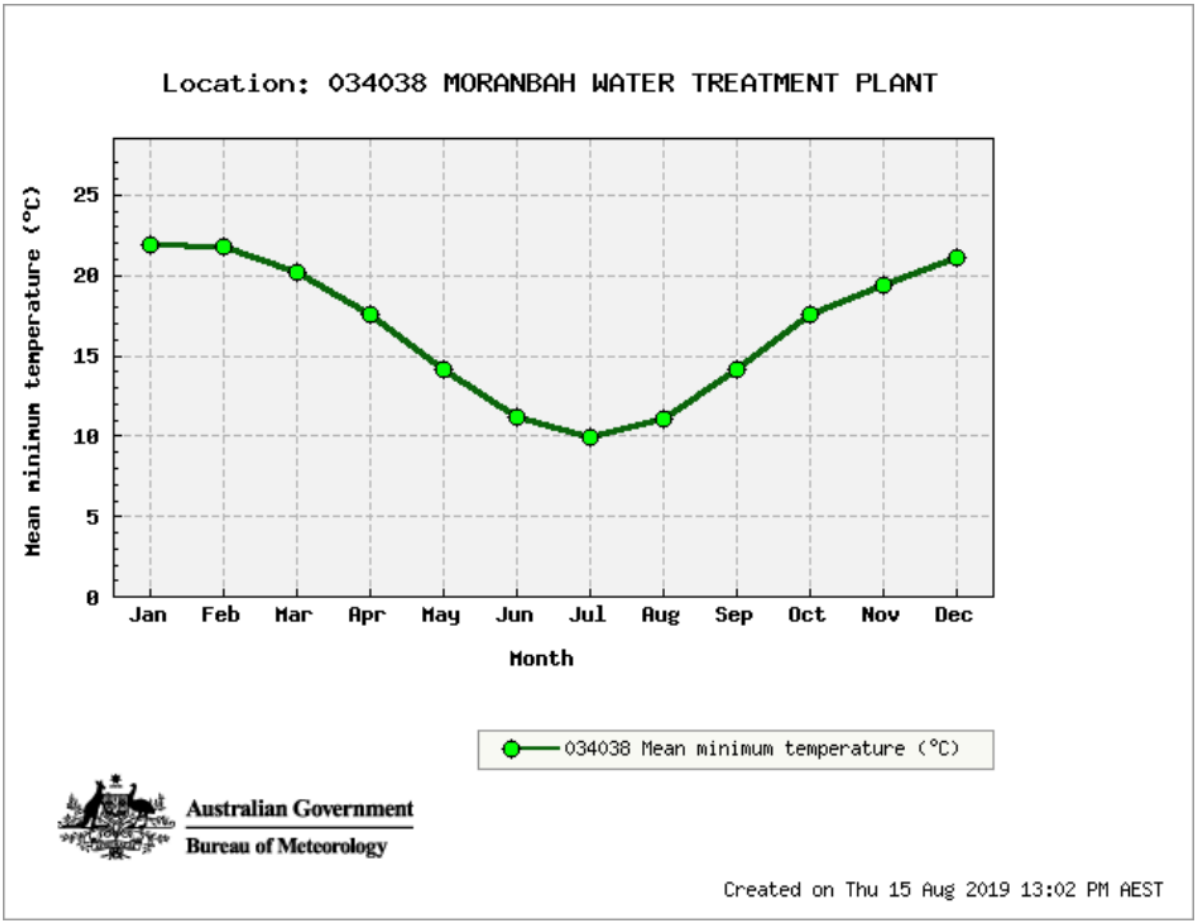

Figure 4. *Mean maximum temperatures at Moranbah (accessed August 2019)*

2 The revegetation process

Revegetation involves the covering of exposed or disturbed soils with topsoil and establishing a vegetative cover using a design seed mix, to achieve sustainable long-term stabilisation and ecological restoration. A combination of techniques may be employed and requires ongoing maintenance, particularly in the early years, to address competition from undesired species and ensure vegetation is on the desired trajectory.

2.1 General restoration process

Revegetation of disturbed land requires appropriate preparation and follow-up maintenance practices including:

a) Weed treatment prior to revegetation, if required and where possible
b) Respreading stockpiled or freshly stripped topsoil
c) Contour ripping to improve infiltration and tree root establishment. This action is normally undertaken immediately after surface preparation
d) Application of chemical treatment to improve soil structure, after soil chemical analysis, if required. NB this component is subject to a separate assessment and not covered within this plan
e) Application of appropriate fertiliser to improve soil nutrients, after soil chemical analysis, if required (as for point d)
f) Seeding with an appropriate seed mix of cover crop species as an interim measure to protect exposed substrate and soil which may include non-native and native species
g) Revegetate with seed mix containing local native grass, shrub and tree species to establish a sustainable vegetation cover in a one-pass operation
h) Regular watering of the initial treatment until the cover crop is well established; watering preferable in a pattern that mirrors seasonal rainfall distribution as required beyond that
i) Ongoing weed management until desired vegetation community is established
j) Seedling replacement (re-seeding), as required or selected instalment of tubestock to replace species or portions of the revegetation site that have not achieved sufficient establishment.

2.2 Revegetation techniques

A range of revegetation techniques are available. Using a combination of methods usually provides the best chance of long-term success and enables the most suitable approach to be used in different locations. Advantages and disadvantages for the revegetation techniques are summarised in Table 2.

Table 2. Revegetation techniques

Technique	Advantage	Disadvantage
Hydro-mulching (introduced grasses and selected LNS)	▪ Where large areas require quick soil erosion control. ▪ Pre-treated large native seeds may be added to the application process ▪ Fertilisers may be added to the mix ▪ Can be accurately applied across a desired treatment area	▪ Can be expensive ▪ May be restricted by access ▪ May require additional water during dry times ▪ May be susceptible to competition from undesired species if adequate preparation has not been undertaken
Seedling planting (tubestock)	▪ Select species can be used to target particular areas ▪ Uses less seed for plant numbers ▪ Suited to species that are unreliable or poor establishers via	▪ Very expensive per stem ▪ Safety can be an issue ▪ Takes a long time to implement ▪ May require additional water during dry times

	broad scale approaches such as hydro-mulching.	▪ Needs careful coordination over an extended period of time ▪ Can require many people to implement
Machine Direct Seeding	▪ Much less expensive than seedlings ▪ Quicker than seedlings ▪ Excellent structural outcome ▪ No initial watering required ▪ Can delay implementation if drought conditions occur ▪ Suited to areas where purpose-built direct seeding machines can be used. ▪ Ideal for correct seed depth placement of fine and fluffy seeds.	▪ Relies on rainfall for germination ▪ May require additional water during dry times ▪ Accurate seed depth placement is essential for germination ▪ Requires lots of local seeds to be collected ▪ Weed control at germination is essential for longevity ▪ Weed control at germination can be technically demanding and expensive ▪ Terrain may limit machine access
Hand Seeding	▪ Less expensive than seedlings ▪ Placement of species possible ▪ Controls seed depth ▪ Works very well on sites where machinery cannot get access ▪ Can delay implementation if drought conditions occur ▪ Where site is too steep for machine seeding ▪ When seed is in short supply ▪ Where accurate placement of plants is required if a particular species is desired.	▪ Takes time but quicker than seedlings ▪ Requires rainfall to germinate ▪ May require additional water during dry times ▪ Needs many people to implement ▪ Requires quality seed to be collected ▪ Requires sufficient quantity of seed and may require expert advice to suggest appropriate alternative species
Natural Regeneration	▪ Natural process ▪ Is generally triggered by suitable conditions for establishment ▪ Species most suited to conditions tend to prevail ▪ Produces strong, healthy plants ▪ Opportunistic ▪ Continuous over time ▪ Cheap ▪ Can be rapid in favourable years	▪ Requires existing remanet vegetation on good condition with sufficient seed to enable dispersal ▪ Does not distribute seed over large areas ▪ Does not control immediate erosion issues ▪ Does not control for pest plants

2.3 Quality controls

As part of the revegetation process the following quality control measures are essential and include:

Site controls

- Livestock must be excluded prior to seed application.
- Soil treatments are an essential completion item prior to seeding; soil treatment requirements will require defining once soil testing has been completed.
- Drought conditions should be referred to a site management technical group for decision prior to seeding.

Seed controls

- Order or collect required LNS seeds prior to any engineering works commencing (this may be required more than a year in advance due to seed availability), where possible.
- Insist on a seed viability and quality testing process for all batches of seeds ordered.
- Store seeds in dry, dark sealed containers in a temperature controlled cool room until required; this will maintain seed viability.
- Use pre-seeding treatments of native seeds prior to seeding application.

Implementation controls

- Contractors should be selected from experienced revegetation practitioners. These contractors must have a track record of delivering revegetation projects which establish a diversity of species.
- Control seed depth application to site; this may require the use of specific native seed seeding machines in the second year (refer Section 3.1) of the revegetation program.
- Regularly monitor vegetation establishment.
- Improve site knowledge regarding native seed germination by developing a seedling germination guide, which will assist others to identify germinates.

2.4 Local native seed

Direct seeding is the primary option in large-scale successful revegetation; however this is only possible if:

a. Large quantities of local native seeds are collected and stored appropriately prior to revegetation.
b. The seed collected is good quality; collected by an experienced seed collector.
c. The seed is stored in an appropriate manner under climate-controlled conditions.
d. The seeds are treated appropriately prior to seeding.
e. The seeds are sown at the correct depth.

It is possible to purchase seeds from suppliers. However, seed orders should be placed well in advance of intended planting. Advice should be sought from the authors of this plan prior to making any changes to the species or application method described herein.

2.5 Seed provenance (LNS)

Re-establishment of the required RE will draw upon appropriate species collected from an appropriate range of specimens from the project site and beyond. Sufficient genetic diversity of seed material is required to ensure that the vegetation that establishes is robust and capable of developing into a self-sustaining ecosystem. Providing material from across the range of a species is a prudent measure to mitigate against potential climate variability and the impact of climate change.

A 60/30/10 rule is broadly advised. Where possible 60% of material is to be sourced locally, 30% to be sourced regionally and 10% sourced from the broadest range of community. For the purposes of this project seed collected generally in the latitudes between Rockhampton and Townsville would be considered adequate and capable of representing genetic variability capable of adapting to current and future site conditions.

3 Revegetation of the Spade Creek Diversion

The revegetation program has been designed as a practical approach to a challenging environment. A combination of processes will be required over a 2-year period for the site to stabilise, develop, and provide the required outcome. The recommended strategy applies to all works associated with rehabilitation of the diversion.

3.1 Recommended strategy

Due to limited soil depth, level of expected disturbance and potential water scarcity, a minimum 2-pass operation is a preferred approach to manage erosion risk. Consideration should also be given to topping up seed supply in the third year if seedlings do not successfully establish. The revegetation process aims to initially establish adequate ground cover to minimise erosion and then improve species diversity and structure. This approach has two distinct revegetation phases, there may also be some natural regeneration occurring particularly of grasses, some regeneration from adjoining remnant vegetation and supply of propagules from upstream:

Table 3. Revegetation strategy

	Purpose	Process/method	Seed Mix	Desired Outcome	Other considerations
Year 1 Achieve initial soil cover	Control batter and rill erosion. Stabilise the site	Hydro mulching, seed broadcast or other methods, which includes applying bands of mulch along the contour to increase erosion protection and moisture retention	Introduced and native grasses, robust and reliable large seeded native trees and shrubs with selected "hard" coated native seeds.	Covering of robust reliable grasses and other plants that stabilise the site and control potential erosion.	May provide opportunity for weed species transported in soil to germinate and be controlled prior to further seeding and planting
Year 2 Increase species diversity	Increase species diversity and structure of the site	Deploy purpose built direct seeder to place fine seed on a stabilised bed along with a hand seeding technique developed for steep or difficult sites	A combination of all native plant seeds appropriately treated. Add fine native seeds to the mix (Eucalyptus, Melaleuca, etc.) increase the diversity of plants germinating #	As above but with increased diversity of species	Limited number of tube-stock planting may be considered. See comment #
Year 3 and ongoing. natural regeneration	Increase species abundance and diversity germinating on the site	Facilitate germination over the entire revegetation site by increasing the number and diversity of species contributing seeds.	Natural supply from surrounding remnant vegetation and mature planted species from Year 1 and Year 2	Further increase in plant diversity, habitat value, site stability and resilience.	Large woody debris, if available, can be placed outside the waterway channel to provide additional habitat.

Direct seeding is considered lower cost with higher chance of success than planting seedlings. However, if Burton Mine wishes, tubestock planting in strategic locations may be undertaken; this strategy is most appropriate for species where seed supply is limited and establishing via direct planting has a higher likelihood of success. Species such as *Brachychiton rupestris,* Narrow Leafed Bottle Tree, are suggested to be established via planting tubestock rather than direct seeding.

3.2 Soil management

Ripping
Ripping of soils makes planting easier and increases aeration and water infiltration, which improves root development by enabling deeper penetration and faster growth. On slopes, ripping should be done along the contour, though on flatter ground cross ripping on a grid layout should be used to prevent root development in one direction along a rip line. Soil should generally be ripped to a depth of at least 300 mm.

Sodic soils, if encountered, are more prone to structural degradation and should receive minimal cultivation. The aim is to preserve soil organic matter in the surface soil and leave the more sodic subsoil at depth.

Soil amelioration
Experience from previous rehabilitation works indicates that amelioration may be required, however, the result of soil testing will be needed to confirm this. Issues such as low Phosphorus (P) and high sodicity, if they prove to be a problem, can be treated by the application of a high-P fertiliser and gypsum to address sodicity. These treatments will also improve soil structure and reduce erosion risk. For sodic soils, beneficial techniques involve high application rates of gypsum before tillage or concentrating gypsum into rip lines and is most effective at sowing time.

Soil testing needs to be undertaken during rehabilitation works once the site has been disturbed. Treatments and application rates will then be determined prior to revegetation works.

Soil testing requirements
To inform recommendations for soil amelioration (if required) soil testing is required and can be undertaken prior to construction works. The same soil testing analysis that was undertaken for the Bullock Creek diversion (AECOM, 2017) can be applied to this project:

Soil samples should be collected from a representative area where soil will be sourced for this project (existing ground surface to be excavated and existing soil stockpiles). At each of 6 locations from where soil is to be sourced take samples from the top 0 - 10 cm of soil to ensure that they are representative of the topsoil profile. Care must be taken to ensure leaf litter and woody debris is not included. Approximately 500 g of material will be placed inside a zip lock bag. Samples should be double bagged to prevent cross contamination and stored on ice until they are sent for analysis at a NATA accredited laboratory. Analysis of the following chemical and physical properties should be undertaken:

- pH;
- Electrical Conductivity (µS/cm);
- Exchangeable Sodium Percent (%);
- Particle Size (Sand, Silt, Clay, Gravel and Cobbles);
- Soil Particle Density (g/cm^3);
- Cation Exchange Capacity (CEC) (meq/100 g);
- Sulphate (mg/kg);
- Chloride (mg/kg);
- Boron (mg/kg);
- Total metals (mg/kg);
- Nitrite and Nitrate (mg/kg);
- Total Nitrogen (mg/kg);
- Total Phosphorus (mg/kg);
- Extractable Phosphorus (mg/kg);
- Total Organic Carbon (%); and
- Particle size distribution (sand, silt and clay content).

Results can then be provided to Alluvium for assessment and recommendations for amelioration requirements, if any.

3.3 Weed management

Weed management prior to revegetation reduces competition for nutrients, water and light. A weed-free environment helps new seedlings develop a vigorous root system that can access nutrients and soil moisture. This is most critical during their initial development and establishment. Ideally, weed control is undertaken a year or more in advance, though this is risky in erodible soils. To minimise the risk of exposed soils a surface mulch (such as hay) may be used to reduce runoff and the loss of topsoil and soil moisture through evaporation.

Alternative non-chemical methods such as matting rely on smothering and usually require pinning in place to avoid disturbance from wind or water flow and are a high cost option. Chemical herbicides may be the most effective method but should be used carefully near waterways (as per labelled recommendations) and will likely need follow up applications to deplete the weed seedbank in the soil.

3.4 Use of a cover crop

The use of a non-invasive cover crop to control soil erosion is the first step in restoration. This process may be completed by broadcast measures or hydro mulching methodology.

The requirement of the cover crop is:

a. To cover the exposed and disturbed soils and retain soil moisture
b. To reduce the risk of soil erosion
c. To assist LNS germination.

The cover crop is not designed to be the final dominant plant species at the site.

Some LNS seeds can be added during the hydro-mulching application (Attachment B) however, fine seeds will be lost if added during this stage of the revegetation process.

3.5 Topsoil and erosion protection

Due to a paucity of quality topsoil on site, a combination of surface treatments is likely to be recommended (subject to soil testing results) to provide stability and minimise soil and moisture loss. Use of a hay mulch is recommended following seeding (and planting if undertaken) to reduce erosion risk, retain soil moisture and reduce weed germination. The mulch should be applied around the base of any seedlings planted but should be kept clear of the stem to avoid rot development.

3.6 Timing

Modification of the diversion channel and associated works may take several weeks/more than a month to complete. If more than a few weeks, the revegetation should be undertaken progressively as construction stages are completed. Progressive revegetation reduces exposure time of disturbed and unvegetated areas and spreads risk over time, minimising the impact of destructive weather events.

Rehabilitation and revegetation works should aim to be completed prior to the commencement of the wet season (ideally by end of October) to maximise the benefits of subsequent rainfall or following the heat of Summer (i.e. March onwards).

Construction works can improve the chance of success by:

a) Providing good compaction of disturbed surfaces
b) Maintaining communication to revegetation contractors regarding progress and soil issues
c) Identifying highly stable areas from where revegetation can be staged
d) Regular site reviews with revegetation contractors to enable final surface quality discussions.

Revegetation is more successful when it is viewed as having the level of importance as construction. Reducing the risk of revegetation failure will be achieved via an adaptive management approach, obtaining materials early and spreading their application over time.

Timing is critical. Aligned correctly it will enhance the success of phase 1 revegetation by:

- Using introduced grasses and LNS mix to stabilise the fine topsoil particles
- Control runoff water on batters
- Provide a firm base for future machine seeding of fine seeds
- Enable organic root and foliage cover that will assist and rebuild organic layer and microorganisms in the soil in readiness for machine and hand seeding in the following years.

Revegetation should begin immediately after plans are approved and at the same time the construction activities begin. The guide shown in Table 4 should assist with a smooth revegetation program.

Table 4. Implementation guide

Activity	Start Time	Tips
LNS Seed collection or order from suppliers	As soon as timing of construction activities is known	▪ Seed collection quantities required may take over a year to obtain. ▪ Correct seed storage is important to maintain seed viability
Cover crop seed	As soon as practical after construction sign off	▪ Only use seed guaranteed not to contain contaminants ▪ Species used is designed as a cover crop NOT a permanent sward
Addition of LNS (large seed)	Used with cover crop	▪ Seed used in accordance with this plan ▪ Seed to be treated as described in this plan
Follow-up revegetation	12 months after initial seeding	▪ Mostly fine seeds will be seeded at this time ▪ *Weed control* is paramount at time of seeding ▪ Other seeds added may require treatments
Monitoring vegetation establishment	Throughout the project	▪ Establish photo points at start ▪ 6 weeks after seeding and rainfall should show first results ▪ 12 weeks after seeding ▪ Then every 2 months thereafter for the first 12 months and 6-monthly thereafter

3.7 Revegetation risks

Factors limiting successful revegetation in mine site rehabilitation are generally related to the quality of the soil and seeds. Topsoil, soil placement methods and geochemical properties of the topsoil and subsoils along with collection, storage, contamination and seed viability are key factors. The more disturbed the site, the more likely introduced plants will establish faster than native seeds, which are likely to become lost at depth in the loose soils. Risks and potential mitigation measures for revegetation are described in Table 5. A substantial risk is the lack of available seed especially where projects attempt to establish a diverse range of species and structural elements. Relying entirely on direct seeding may reduce the likelihood of success therefore flexibility is needed in the establishment techniques. Tubestock planting for species where it is difficult to obtain large quantities of seed is advised as a risk mitigation strategy.

Table 5. Revegetation risk assessment

Item	Risk Issue	Mitigation
Site preparation	Sufficient topsoil not available to provide desired depth of cover	▪ Review most important zones requiring stability and apply to these areas first ▪ Use a mulch and or compost to cover sites without topsoil ▪ Modify species seeded at sites with little soil cover ▪ Consider other soil cover treatments
	Site is infested with introduced grasses prior to seeding	▪ Chemically control weeds to enable the seeding of first layer
	Water erosion has occurred prior to seeding	▪ Mechanical replacement of soils required ▪ Cover areas with mulch or jute matting
Seeds	Introduction of weeds	▪ All seeds used must pass the quality tests set out in Section 2.3 of this report
	Not all species are available	▪ Maintain seed review process from the start of the project ▪ Review seed list of species and quantities every 6 months ▪ Purchase seeds from other sources ▪ Reduce risk by engaging more than one seed collection group
	Insufficient quantity available	▪ As above and consider installing tubestock plantings where direct seeding is not viable
	Viability	▪ Review seed storage site so it meets with Australian guidelines ▪ Review seed collection process to meet with Australian guidelines ▪ Ensure experienced seed collectors are engaged ▪ Ensure seed viability testing is undertaken prior to use
Initial soil cover crop	Drought conditions	▪ Consider watering seeded areas once a week until germination occurs ▪ Water impregnate seed prior to application ▪ Only seed most erosive sites ▪ Use a water granule polymer additive at time of seeding
	Seed did not germinate	▪ Native seed germination testing is essential
	Soil erosion potential	▪ Consider adding additional mulches ▪ Use hydro mulch as preferred option for initial success

Item	Risk Issue	Mitigation
Year 2 direct seeding		
Site preparation	High level of grass and weeds on site	▪ Use a low growing persistent / aggressive cover crop species ▪ Spot spray areas 2 weeks prior to seeding by hand ▪ Use strip sprays 1m wide for machine seeding
Seeding	Drought conditions	▪ Cover hand seeded sites with 5mm gravel at time of seeding ▪ Water treat seeds prior to hand seeding ▪ Increase seeding depth of large coated seeds
	Seed did not germinate	▪ Native seed germination testing is essential ▪ Review seed storage processes ▪ Review seed treatment methods ▪ Seed at correct depths ▪ Use equipment designed for native seed establishment ▪ Review controls of weeds prior to seeding ▪ Re seed when conditions are more favourable
	Slow growth of seed	▪ Add additional fertiliser to site ▪ Take soil sample for testing ▪ Review soil tests and apply additional materials

4 Revegetation zones

This revegetation plan identifies four zones, to be treated as a single RE (11.3.25) for revegetation efforts.

The 'Vision' for the revegetation program for the site is: *"To provide, as far as practical, a replication of the native vegetation communities of the area and benchmark conditions for the relevant Regional Ecosystem".*

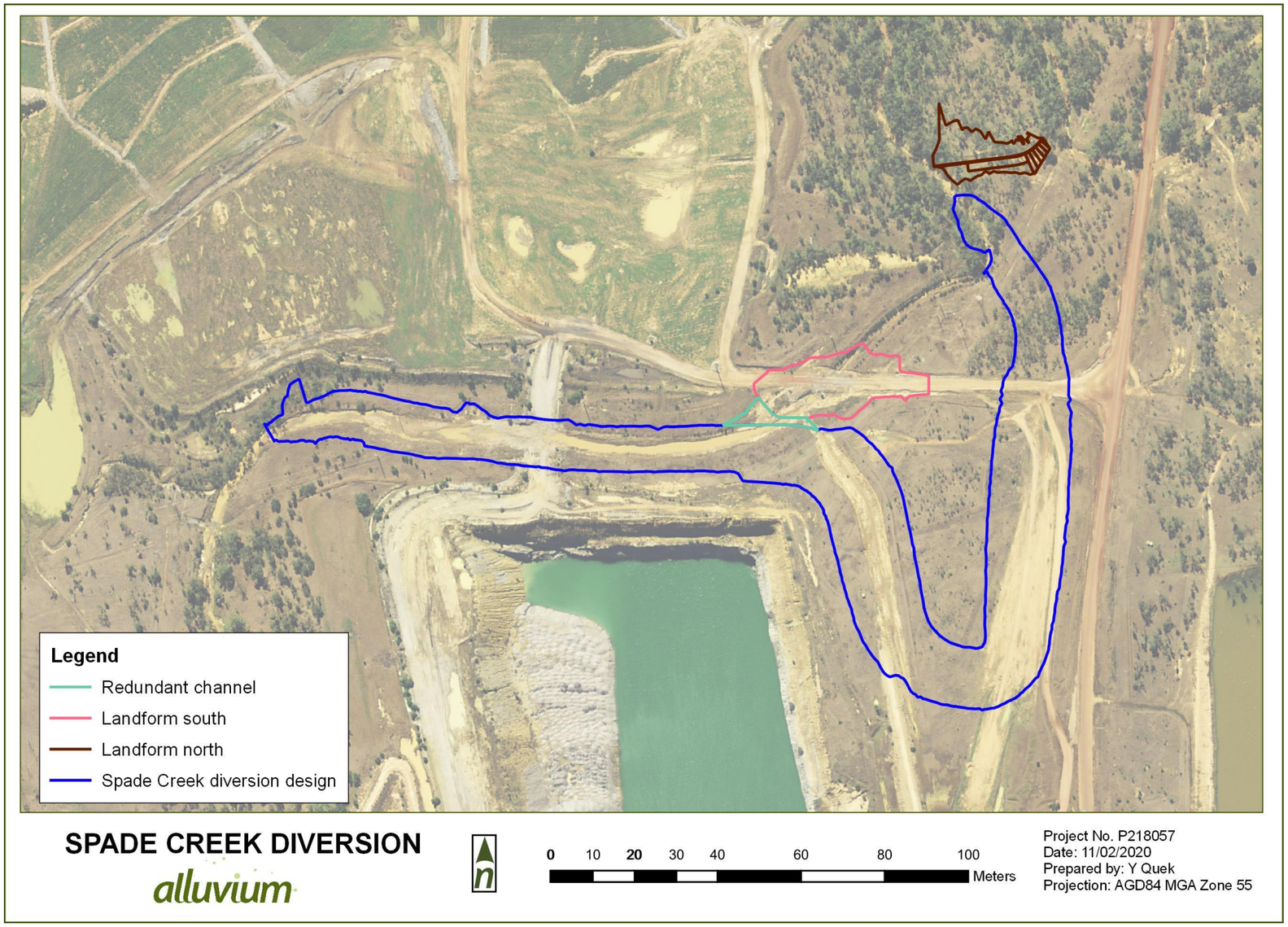

Figure 5. *Revegetation zones proposed for the Spade Creek Diversion*

Table 6. Revegetation zones

Zone	Name	Size (ha)	Key landform characteristics informing revegetation
Zone 1	Landform North	0.62	To be filled and finished with a generally flat topography
Zone 2	Landform South	1.29	Existing track and diversion to be filled and finished with an undulating topography resulting in dry tolerant species required for revegetation
Zone 3	Redundant channel	0.14	Existing diversion to be filled and finished with a generally flat topography
Zone 4	Spade Creek Diversion design	11.46	Large expanse required for revegetation with variable aspect

Application of topsoil to a thickness of 300 mm is ideal for vegetation establishment, but this is unlikely due to limited sources .Priority is to be given to high risk areas at the interface between the existing channel and the newly constructed diversion; that is, both the upstream and downstream ends. Landscaped surfaces should be ripped following application of topsoil to facilitate vegetation growth and water penetration. Topsoil should be a non-dispersive material.

On steep slopes with minimum subsoil, topsoil may be blended with durable material won in excavation of the Diversion to increase growing medium thickness. If a rock rubble layer is to be used it should be placed to at least 400 mm deep prior to applying topsoil to create a suitable growth media.

4.1 Recommended species

The recommended species list reflects species of RE 11.3.25 covering the Spade Creek Diversion and additional species identified during diversion monitoring on site.

Two species mixes are proposed:

- Mix A is comprised of species suited to the conditions which will develop in the new diversion channel and flat filled areas. This mix applies to Zones 1, 3 and 4 (Table 7).
- Mix B is comprised of species suited to drier hillslope conditions and is applied to Zone 2. This mix can also be used as a basis for a substitution list for Mix A in the event that not all species suggested in Mix A are available (Table 8).

Two exotic grasses recommended for establishing initial cover crops are included for both Mix A and Mix B.

Revegetation of the site may not be able to use all the species listed due to seed shortage or where local experience indicates a low success rate with certain species. Revegetation should aim to use at least 80% of the species listed for each of over-storey, mid-storey and ground-storey. Where less than the full species list is used, seed quantities of each species should be adjusted to maintain the total quantity recommended.

Where substitutions are proposed native species are to be substituted only with native species rather than exotic alternatives. Substitutions should as closely as possible match form and function of a species. The alternative proposed species must be suited to the substrate with known examples occurring on the same constituent material.

Not all species need to be established in the same year. Some flexibility is proposed so that an appropriate combination of species reflecting the RE is restored to the site. Where no viable alternative is available in a given year an alteration to the timing of establishment of a species is suggested.

If no seed is available of a desired species for the duration of the project or other project management issues prevent the establishment of the desired species a suitable alternative may be considered. For example, *Terminalia oblongata,* Yellow wood, is a small tree usually attaining 5-10m height. Seed development is dependent on seasonal rainfall, it does not produce a reliable crop every season. A species of similar size and structure such as *Ventilago viminalis,* Supplejack may be an appropriate substitute. It is a structurally important component of the adjoining RE and has ecological amplitude comparable to Terminalia.

Other alternative options include the establishment of tubestock for a select number of species rather than relying upon direct seeding. For example, *Brachychiton rupestris,* Narrow-leaved Bottle Tree, is proposed to be established, however obtaining sufficient seed for direct seeding can be difficult. A substitute species e.g. *Brachychiton australis,* Broad-leaved Bottle Tree, has been proposed. Rather than establishing the substitute by direct seeding the recommended approach is wait and establish Narrow-leaved Bottle Tree via tubestock planting in the second year of the program. Planting tubestock of *Brachychiton rupestris* is likely to be a more reliable approach for establishing this species. If no other option is available planting tubestock of *Brachychiton australis* may be considered in the second or third year of the project.

Table 7. Mix A: Recommended priority species for revegetation and the timing of establishment including species which are character species of the RE applied to zones 1, 3 and 4. Note colour coding is consistent with strategy and timing described in Table 3 of this document. Zone coloration is consistent with Figure 5.

Botanical name	Common name	Zone 1	Zone 3	Zone 4
Over-storey. Trees and large shrubs 8-20m				
Acacia harpophylla ^	Brigalow	Year 1	Year 1	Year 1
Angophora floribunda	Rough-barked apple	Year 2	Year 2	Year 2
Brachychiton rupestris^	Narrow-leaved bottle tree	Tubestock Year 2	Tubestock Year 2	Tubestock Year 2
Casuarina cunninghamiana	River oak	Year 1	Year 1	Year 1
Eucalyptus camaldulensis	River red gum	Year 2	Year 2	Year 2
Eucalyptus coolabah	Coolibah	Year 2	Year 2	Year 2
Eucalyptus tereticornis	Queensland blue gum	Year 2	Year 2	Year 2
Mid-storey. Shrubs 1-8m				
Acacia salicina	Sally wattle	Year 1	Year 1	Year 1
Acacia stenophylla	River cooba	Year 1	Year 1	Year 1
Capparis lasiantha^	Bush caper	Year 1	Year 1	Year 1
Carissa ovata^	Currant bush	Year 1	Year 1	Year 1
Lysiphyllum carronii^	Red Bauhinia	Year 1	Year 1	Year 1
Melaleuca bracteata	Black Tea-tree	Year 2	Year 2	Year 2
Melaleuca viminalis	Weeping Bottlebrush	Year 2	Year 2	Year 2
Terminalia oblongata^	Yellow wood	Year 1	Year 1	Year 1
Ground-storey. Grasses and tussocks 0.2-2.0m				
Bothriochloa bladhii	Forest bluegrass	Year 1	Year 1	Year 1
Bothriochloa ewartiana	Desert bluegrass	Year 1	Year 1	Year 1
Chrysopogon fallax	Golden beard grass	Year 1	Year 1	Year 1
Cyperus dactylotes	Flat-sedge	Year 1	Year 1	Year 1
Cyperus difformis	Variable Flat-sedge	Year 1	Year 1	Year 1
Cyperus exaltatus	Giant sedge	Year 1	Year 1	Year 1
Cyperus gracilis	Slender Flat-sedge	Year 1	Year 1	Year 1
Cyperus iria	Rice Flat-sedge	Year 1	Year 1	Year 1
Cyperus rigidellus	Whisker Flat-sedge	Year 1	Year 1	Year 1
Cyperus victoriensis	Yelka Flat-sedge	Year 1	Year 1	Year 1
Dichanthium sericeum	Queensland bluegrass	Year 1	Year 1	Year 1
Imperata cylindrica	Blady grass	Year 1	Year 1	Year 1
Leptochloa digitata	Whorled Cane Grass	Year 1	Year 1	Year 1
Lomandra longifolia^	Spiny-head Mat-rush	Year 1	Year 1	Year 1
Panicum decompositum	Native Millet	Year 1	Year 1	Year 1
Non-native cover crop species^				
Echinochloa esculenta	Japanese Millet	Year 1	Year 1	Year 1
Lolium multiflorum	Annual Ryegrass	Year 1	Year 1	Year 1

^ NB consider tubestock planting in year 2 if sufficient seed volume can't be obtained.

Table 8. Mix B: Recommended species for Zone 2 which may also be deployed as substitutions if those listed in Mix A Table 7 are not available for the duration of the project. Note colour coding is consistent with strategy and timing described in Table 3 of this document. Zone coloration is consistent with Figure 5.

Over-storey. Trees and large shrubs 8-20m		**Zone 2**
*Acacia harpophylla^*	Brigalow	Year 1
*Brachychiton australis^*	Large-leaved bottle tree	Year 2
Corymbia clarksoniana	Grey bloodwood	Year 1
Corymbia tessellaris	Moreton Bay Ash	Year 1
*Eucalyptus cambageana^*	Dawson River blackbutt	Year 2
*Eucalyptus crebra^*	Narrow-leaved ironbark	Year 2
*Eucalyptus melanophloia^*	Silver-leaved Ironbark	Year 2
*Eucalyptus platyphylla^*	Poplar gum	Year 2
*Eucalyptus populnea^*	Poplar box	Year 2
*Eucalyptus thozetiana^*	Thozets Box	Year 2
*Flindersia dissosperma^*	Scrub Leopardwood	Year 1
Mid-storey. Shrubs 1-8m		
*Capparis lasiantha^*	Bush caper	Year 1
*Carissa ovata^*	Currant bush	Year 1
Croton insularis	Silver croton	Year 1
*Denhamia oleaster^*	Stiff Denhamia	Year 1
Eremophila mitchellii	False sandalwood	Year 1
*Excoecaria dallachyana^*	Brush poison tree	Year 1
*Geijera parviflora^*	Wilga	Year 1
Macropteranthes leichhardtii	Bonewood	Year 1
Melaleuca fluviatilis	Weeping Tea-tree	Year 2
Melaleuca trichostachya	Flaxleaf Paperbark	Year 2
*Notelaea macrocarpa^*	Native olive	Year 1
*Owenia acidula^*	Emu apple	Year 1
*Terminalia oblongata^*	Yellow-wood	Year 1
Ground-storey. Grasses and tussocks 0.2-2.0m		
Aristida caput-medusae	Wiregrass	Year 1
Bothriochloa decipiens	Pitted bluegrass	Year 1
Cyperus polystachyos	Bunchy Flat-sedge	Year 1
Dactyloctenium radulans	Crowfoot grass	Year 1
Eragrostis leptostachya	Paddock Lovegrass	Year 1
Eragrostis megalosperma	Lovegrass	Year 1
Heteropogon contortus	Black speargrass	Year 1
Sorghum nitidum	Sorghum	Year 1
Themeda triandra	Kangaroo grass	Year 1
Non-native cover crop species^		
Echinochloa esculenta	Japanese Millet	Year 1
Lolium multiflorum	Annual Ryegrass	Year 1

^ NB consider tubestock planting in year 2 if sufficient seed volume can't be obtained.

5 Seed requirements

Seed procurement or collection and storage should begin as soon as the project timing is known. Placing a priority on seed obtainment will greatly improve the reliability of supply quantities, reduce the risk of receiving poor quality seed and reduce the need to substitute at the time of seeding.

An estimate of seed quantities for each species per zone is provided in Attachment A. This will need to be checked and if required, revised following completion of earthworks in the event that a greater area of disturbance eventuates.

Seed treatment

Many seeds require treatment prior to use. Advice should be sought from the supplier about appropriate treatments before revegetation works are implemented.

5.1 Seed species per technique

Following construction of the new diversion, the site will be bare of vegetation. The topsoil will be loose and highly erodible requiring rapid cover via a fast germinating cover crop. A longer term LNS seed establishment strategy as a follow-up is required after this stage.

Some species are to be used predominantly in either the first or second year. Exotic grasses are recommended for establishing a cover crop in the first year, LNS with larger seeds e.g. *Acacia, Corymbia, Geijera* etc. are to be sown in the first year. Fine native seeds should be used in in the second year once the site has stabilised. Examples include Eucalypts and Melaleuca, both of which have fine seed which may not find a viable niche for germination if sown into soil which is not stable. The different use of seeds is summarised in **Error! Reference source not found.**. Table 7 and Table 8 identify the appropriate year for establishment of each species.

Table 9. Use of seed and revegetation strategy per zone and over time. Zone coloration is consistent with Figure 5.

	Year 1				Year 2					Year 3			
	Exotic grass cover crop	LNS Large seed	Natural regeneration	Native grasses	Exotic grass cover crop	LNS Fine seed	Natural regeneration	Native grasses	LNS Large seed	Exotic grass cover crop	LNS Fine seed	Natural regeneration	Native grasses
Zone 1	Establish cover crop ensure supplementary moisture is available if requires	Sow appropriate species mix uniformly across zone	Some expected due to proximity to remnant	Sow appropriate species mix uniformly across zone	If seedlings fail and minor areas of erosion observed treat and re-sow to manage erosion	Sow appropriate species mix uniformly across zone	As per year 1	Sow appropriate species mix if seedlings sown in year 1 fail	Sow appropriate species mix if seedlings sown in year 1 fail	Consider site specific sowing if minor areas of erosion observed	Monitor for establishment sow additional if poor establishment density observed	Monitor regeneration note additional diversity as time progresses	Monitor regeneration
Zone 2	Establish cover crop	Ensure species adapted to hillslope conditions are used	Non expected	Ensure species adapted to hillslope conditions are used	As above	Ensure species adapted to hillslope conditions are used	Non expected	As above	As above	As above	As above	Non expected	Monitor regeneration expecting different species mix to that seen in Zone 1, 3 and 4
Zone 3	Establish cover crop	As per zone 1 above	Non expected	As above	As above	As per zone 1 above	Non expected	As above	As above	As above	As above	Non expected	As per zone 1 above
Zone 4	Establish cover crop	As per zone 1 above	Non expected	As above and plant tubestock of species such as *Brachychiton rupestris*	As Above	As above	Possible from upstream seed supply	As above	As above	As above	As above	As per year 2	As per zone 1 above

5.2 Desired seed sowing depth for local native species

Failure of LNS direct seeding can be attributed to inappropriate seed sowing depths. This factor is often overlooked when using a cover crop seed mix with the incorporation of LNS.

If the soil where the seeding is to take place is disturbed or loose it is advisable to seed a cover crop first to control potential soil erosion and later follow-up with the seeding of native species.

If a follow-up seeding is not possible it is advisable to conduct two passes of the site to enable desired seeding depths to be achieved. Advice should be sought from the supplier about preferred seeding depths.

6 Management and maintenance

Management of the revegetation zones will require regular surveillance to avoid or minimise impacts from the most common threats of livestock, weeds, erosion or drought. A monitoring program should form part of the ongoing management to maximise the chances of success. Establishing a good cover crop in the first year will play a major role in subsequent rehabilitation. The cover crop will reduce erosion risk while maintaining soil moisture for slower growing plants to establish.

6.1 Watering

Adequate watering of revegetation works will be crucial to successful establishment. In the event that rainfall alone is insufficient, this requires a regular supplementary watering regime following initial seeding to help establish the cover crop. Where water is likely to be scarce, efforts should focus on high risk areas that are vulnerable to erosion and not subject to regular wetting. It is preferable to rely on rainfall to trigger germination of LNS, however this will likely result in a slower establishment rate. More regular watering will be required where tubestock is used. The amount of watering will need to be carefully considered by Burton Resources and will require some flexibility in response to climatic conditions.

6.2 Livestock management

Livestock can be a valuable asset in controlling weeds and compacting soils post earthworks however grazing should be excluded immediately after seeding has taken place and remain excluded for the following 10 years.

The reasons for this exclusion are:

- Livestock (cattle) are heavy animals whose footprints disturb soil and push seed too deep into the soil thus reducing the opportunity for the seed to germinate.
- Livestock will forage on seedlings; pulling them out or squashing them resulting in high losses.
- Livestock are prone to trample plants or ringbark saplings. They will also forage on seeding species, reducing the opportunity for seed dispersal required over the first 10 years of rehabilitation for improved biodiversity structural outcomes.

6.3 Monitoring program

Regular monitoring will identify any management issues, allowing timely mitigation actions to be implemented. Monitoring should include photo points to track the success of revegetation through time. Vegetation monitoring is recommended to be undertaken for at least five years.

6.4 Maintenance program

The maintenance program is heavily dependent on the success of the direct seeding revegetation of LNS, and their resulting density. The better the initial germination the less impact introduced weeds will have. Maintenance requirements are heavily reliant on the type of grass that is sown or naturally germinates through the restoration process.

If exotic grasses, particularly buffel grass (*Cenchrus ciliaris*), become a problem within the established revegetation zones control with herbicide may be considered. Any herbicide deployed must be applied carefully and accurately so as to minimise impacts to desired native species. Other woody weeds should be spot sprayed or cut and painted on a regular basis.

Any soil rill erosion issues should be mechanically treated, if access by local equipment is possible, followed by hand seeding of a cover crop and LNS.

7 References

AECOM (2017) *Burton ERE Revegetation Management Plan*. Draft report prepared for Peabody Energy Australia.

Alluvium (2019a) *Burton Mine: Spade Creek Diversion Detail Design*. For Peabody Energy, Burton Mine.

Alluvium (2019b) *Burton Mine: Spade Creek Diversion Detail Design – Technical Specifications*. For Peabody Energy, Burton Mine.

Table 10. Seed quantity and approximate cost for each zone Mix A. Note cost is indicative only and is drawn from existing pricing information, this may change due to availability. This estimate is to be used strictly as a guide not for tender. Zone coloration consistent with Figure 5. ^Indicates species that can be may be consider tubestock planting in year 2 if sufficient seed volume can't be obtained. E$ indicates estimated cost based on similar species

Area (ha)	Zone 1	0.62									
	Zone 3	0.14									
	Zone 4	11.46									
Botanical name	Common name	Sow rate kg/ha	Cost $/kg	Volume Zone 1	Cost Zone1	Volume Zone 3	Cost Zone 3	Volume Zone 4	Cost Zone4	Total volume	Estimated Cost
Over-storey. Trees and large shrubs 8-20m											
Acacia harpophylla ^	Brigalow	0.3	520	0.186	96.72	0.042	21.84	3.438	1787.76	3.666	1906.32
Angophora floribunda	Rough-barked apple	0.1	650	0.062	40.3	0.014	9.1	1.146	744.9	1.222	794.3
Brachychiton rupestris^	Narrow-leaved bottle tree	0.1	290	0.062	17.98	0.014	4.06	1.146	332.34	1.222	354.38
Casuarina cunninghamiana	River oak	0.2	400	0.124	49.6	0.028	11.2	2.292	916.8	2.444	977.6
Eucalyptus camaldulensis	River red gum	0.2	300	0.124	37.2	0.028	8.4	2.292	687.6	2.444	733.2
Eucalyptus coolabah	Coolibah	0.2	380	0.124	47.12	0.028	10.64	2.292	870.96	2.444	928.72
Eucalyptus tereticornis	Queensland blue gum	0.3	350	0.186	65.1	0.042	14.7	3.438	1203.3	3.666	1283.1
	TOTAL	**1.4**		**0.868**	**354.02**	**0.196**	**79.94**	**16.044**	**6543.66**	**17.108**	6977.62
Mid-storey. Shrubs 1-8m											
Acacia salicina	Sally wattle	0.2	590	0.124	73.16	0.028	16.52	2.292	1352.28	2.444	1441.96
Acacia stenophylla	River cooba	0.1	380	0.062	23.56	0.014	5.32	1.146	435.48	1.222	464.36
Capparis lasiantha^	Bush caper	0.1	1100	0.062	68.2	0.014	15.4	1.146	1260.6	1.222	1344.2
Carissa ovata^	Currant bush	0.2	600	0.124	74.4	0.028	16.8	2.292	1375.2	2.444	1466.4
Lysiphyllum carronii^	Red Bauhinia	0.1	460	0.062	28.52	0.014	6.44	1.146	527.16	1.222	562.12
Melaleuca bracteata	Black Tea-tree	0.1	520	0.062	32.24	0.014	7.28	1.146	595.92	1.222	635.44
Melaleuca viminalis	Weeping Bottlebrush	0.2	350	0.124	43.4	0.028	9.8	2.292	802.2	2.444	855.4
Terminalia oblongata^	Yellow wood	0.2	580	0.124	71.92	0.028	16.24	2.292	1329.36	2.444	1417.52
	TOTAL	**1.2**		**0.744**	**415.4**	**0.168**	**93.8**	**13.752**	**7678.2**	**14.664**	8187.4
Ground-storey. Grasses and tussocks 0.2-2.0m											
Bothriochloa bladhii	Forest bluegrass	1	55	0.62	34.1	0.14	7.7	11.46	630.3	12.22	672.1
Bothriochloa ewartiana/decipiens	Desert bluegrass	0.5	200	0.31	62	0.07	14	5.73	1146	6.11	1222
Chrysopogon fallax	Golden beard grass	0.5	920	0.31	285.2	0.07	64.4	5.73	5271.6	6.11	5621.2
Cyperus dactylotes	Flat-sedge	0.3	920	0.186	171.12	0.042	38.64	3.438	3162.96	3.666	3372.72
Cyperus difformis	Variable Flat-sedge	0.3	920	0.186	171.12	0.042	38.64	3.438	3162.96	3.666	3372.72
Cyperus exaltatus	Giant sedge	0.4	920	0.248	228.16	0.056	51.52	4.584	4217.28	4.888	4496.96
Cyperus gracilis	Slender Flat-sedge	0.3	920	0.186	171.12	0.042	38.64	3.438	3162.96	3.666	3372.72
Cyperus iria	Rice Flat-sedge	0.3	920	0.186	171.12	0.042	38.64	3.438	3162.96	3.666	3372.72
Cyperus rigidellus	Whisker Flat-sedge	0.3	920	0.186	171.12	0.042	38.64	3.438	3162.96	3.666	3372.72
Cyperus victoriensis	Yelka Flat-sedge	0.2	920	0.124	114.08	0.028	25.76	2.292	2108.64	2.444	2248.48
Dichanthium sericeum	Queensland bluegrass	2	110	1.24	136.4	0.28	30.8	22.92	2521.2	24.44	2688.4
Imperata cylindrica	Blady grass	0.5	500	0.31	155	0.07	35	5.73	2865	6.11	3055
Leptochloa digitata E$	Whorled Cane Grass	0.2	500	0.124	62	0.028	14	2.292	1146	2.444	1222
Lomandra longifolia^	Spiny-head Mat-rush	0.6	160	0.372	59.52	0.084	13.44	6.876	1100.16	7.332	1173.12
Panicum decompositum	Native Millet	0.5	290	0.31	89.9	0.07	20.3	5.73	1661.7	6.11	1771.9
		7.9		**4.898**	**2081.96**	**1.106**	**470.12**	**90.534**	**38482.68**	**96.538**	41034.76
Non-native cover crop species^											
Echinochloa esculenta	Japanese Millet	10	8	6.2	49.6	1.4	11.2	114.6	916.8	122.2	977.6
Lolium multiflorum	Annual Ryegrass	10	15	6.2	93	1.4	21	114.6	1719	122.2	1833
		20		**12.4**	**142.6**	**2.8**	**32.2**	**229.2**	**2635.8**	**244.4**	2810.6
		30.5		**18.91**	**2993.98**	**4.27**	**676.06**	**349.53**	**55340.34**	**372.71**	**59010.38**

Table 11. Seed quantity and approximate cost for Zone 2 Mix B. Note cost is indicative only, drawn from exiting pricing information, this may change due to availability. This estimate is to be used strictly as a guide not for tender. Zone coloration consistent with Figure 5. ^Indicates species that can be may be consider tubestock planting in year 2 if sufficient seed volume can't be obtained. E$ indicates estimated cost based on similar species

Area (ha)	Zone 2	1.29			
Botanical name	Common name	Sow rate kg/ha	Cost $/kg	Volume Zone 2	Cost Zone2
Over-storey. Trees and large shrubs 8-20m					
Acacia harpophylla ^	Brigalow	0.2	520	0.258	134.16
*Brachychiton australis^*	Broad-leaved bottle tree	0.1	290	0.129	37.41
Corymbia clarksoniana	Grey bloodwood	0.1	520	0.129	67.08
Corymbia tessellaris E$	Moreton Bay Ash	0.1	520	0.129	67.08
*Eucalyptus cambageana^*	Dawson River blackbutt	0.2	480	0.258	123.84
*Eucalyptus crebra^*	Narrow-leaved ironbark	0.2	480	0.258	123.84
*Eucalyptus melanophloia^*	Silver-leaved Ironbark	0.2	520	0.258	134.16
*Eucalyptus populnea^*	Poplar box	0.1	650	0.129	83.85
*Eucalyptus thozetiana^*	Thozets Box	0.05	760	0.0645	49.02
*Flindersia dissosperma^*	Scrub Leopardwood E$	0.05	500	0.0645	32.25
	TOTAL	**1.3**		**1.677**	**852.69**
Mid-storey. Shrubs 1-8m					
*Capparis lasiantha^*	Bush caper	0.1	1100	0.129	141.9
*Carissa ovata^*	Currant bush	0.2	600	0.258	154.8
Croton insularis E$	Silver croton	0.1	500	0.129	64.5
Denhamia oleaster^ E$	Stiff Denhamia	0.1	500	0.129	64.5
Eremophila mitchellii	False sandalwood	0.1	470	0.129	60.63
Excoecaria dallachyana^ E$	Brush poison tree	0.1	500	0.129	64.5
*Geijera parviflora^*	Wilga	0.1	480	0.129	61.92
Macropteranthes leichhardtii	Bonewood	0.1	500	0.129	64.5
Melaleuca fluviatilis E$	Weeping Tea-tree	0.1	500	0.129	64.5
Melaleuca trichostachya	Flaxleaf Paperbark	0.1	500	0.129	64.5
*Notelaea macrocarpa^*	Native olive	0.1	420	0.129	54.18
*Owenia acidula^*	Emu apple	0.2	110	0.258	28.38
*Terminalia oblongata^*	Yellow wood	0.2	580	0.258	149.64
	TOTAL	**1.6**		**2.064**	**1038.45**
Ground-storey. Grasses and tussocks 0.2-2.0m					
Aristida caput-medusae	Wiregrass	0.5	200	0.645	129
Bothriochloa decipiens	Pitted bluegrass	0.5	200	0.645	129
Cyperus polystachyos	Bunchy Flat-sedge	0.2	920	0.258	237.36
Dactyloctenium radulans	Crowfoot grass	0.2	750	0.258	193.5
Eragrostis leptostachya	Paddock Lovegrass	0.2	750	0.258	193.5
Eragrostis megalosperma	Lovegrass	0.2	750	0.258	193.5
Heteropogon contortus	Black speargrass	0.8	160	1.032	165.12
Sorghum nitidum	Sorghum	0.8	160	1.032	165.12
Themeda triandra	Kangaroo grass	1	110	1.29	141.9
				5.676	**1548**
Non-native cover crop species^					
Echinochloa esculenta	Japanese Millet	10	8	12.9	103.2
Lolium multiflorum	Annual Ryegrass	10	15	12.9	193.5
		20		**25.8**	**296.7**
		23.7		**30.573**	**3735.84**

Appendix I

Peabody Energy Australia rehabilitation monitoring manual



PEABODY ENERGY AUSTRALIA PTY LTD

PEABODY ENERGY AUSTRALIA REHABILITATION MONITORING MANUAL

Queensland



March 2015

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1. Introduction

Peabody Energy (Peabody) is the world's largest private-sector coal company and a global leader in sustainable mining and clean coal solutions. The company serves metallurgical and thermal coal customers in more than 25 countries on six continents.

Peabody has approximately 9 billion tonnes of proven and probable coal reserves and owns, through its subsidiaries, majority interests in 30 coal operations located throughout all major United States (U.S.) coal-producing regions and in Australia.

Peabody Energy Australia (PEA) operates eight open-cut coal mines throughout Queensland (QLD) and New South Wales (NSW). For the purposes of this rehabilitation monitoring program, only QLD sites will be included, these being: Millennium, Burton, Moorvale and Coppabella in the Bowen Basin, and Wilkie Creek in the Surat Basin. Details of Peabody mining operations are as shown in **Figure 1.**

Peabody's operations produce a broad range of metallurgical and thermal coals for a diverse range of domestic and international customers. Coal produced in the QLD operations is exported through ports in the coastal city of Mackay. The surrounding land use for the majority of the mine sites to be monitored is predominantly cattle grazing.

With a refreshed mission and set of values, Peabody reinforces its commitment to creating superior value for shareholders as the leading global supplier of coal, which enables economic prosperity and a better quality of life. Sustainability is one of the seven core values that ensures Peabody is achieving its' mission. Sustainability to Peabody means that we take responsibility for the environment, benefit our communities and restore the land for generations that follow.

Peabody's rehabilitation program aims to return land to an economic post mine land use, primarily gazing as well as to achieve the rehabilitation goals in the Queensland Department of Environment and Heritage Protection (DEHP) Guideline - Rehabilitation Requirements for Mining Resource Activities (EM1122, Version 2), these being:

- Safe to humans and wildlife;
- Non-polluting;
- Stable; and
- Able to sustain an agreed post mine land-use.



Figure 1 – Map of Mine Site Locations - Queensland.

To achieve this, the rehabilitation strategies typically involve reshaping the spoil piles to designed slopes and the replacement of stockpiled topsoil. On completion of topsoil spreading, deep contour ripping (where appropriate) to a suitable depth is undertaken. Aseed mix of improved pasture and native grasses, legumes, native tree and sometimes shrub species are typically sown into topsoil along with an establishment fertilizer, to recreate a self-sustaining ecosystem, enabling the development of an economic post mine land use. Each site will have specific rehabilitation requirements.

In order to determine the success of the rehabilitation, the following Rehabilitation Monitoring Methodology (RMM) has been developed for Peabody's operations. The RMM has been designed to provide information for:

- Environmental personnel who need to understand how rehabilitation is developing so that feedback can be provided to Peabody and the Regulator;
- Operations personnel who require feedback on the effectiveness of rehabilitation operations;
- Management who require detail on costs and whether commitments are being met;
- Development and continual improvement of success/ completion criteria;
- Peabody to enable communication on relevant information to external stakeholders; and
- Regulatory authorities (and other relevant external stakeholders) who may wish to determine whether they believe rehabilitation is developing toward or has met rehabilitation commitments.

2. Monitoring Aims

The aim of the rehabilitation monitoring program is to collect data on Peabody's rehabilitation, enabling an understanding of the success and development of rehabilitation toward a sustainable ecosystem and agreed final land use following mining and associated impacts.

The rehabilitation assessments will:

a) Provide an understanding of the way in which the rehabilitation develops over time (successional patterns and trends);

b) Provide an understanding of the chemical properties of the reconstructed topsoil profile;

c) Allow for refinement and supplementation of the revegetation process;

d) Allow for refinement of demonstration studies such as grazing;

e) Consider the influence of both internal and external factors on rehabilitation development;

f) Consider the rate at which the rehabilitated landscapes approach the agreed final land use (trends); and

g) Enable Peabody to establish or improve completion criteria for each post-mine landuse.

3. Monitoring Objectives

The rehabilitation monitoring program will enable Peabody to measure and calculate a range of vegetation (pasture), soil and final landform parameters and indices in the developing rehabilitation. The program can be effectively split into two (2) components: 1) vegetation monitoring, with an emphasis on pasture establishment and success, and, 2) final landform monitoring. The objectives of the monitoring program are split out as such:

Vegetation (Pasture) Monitoring

a) To establish and assess practical and applicable reference plots, if not already established.

b) To measure total lowerstorey cover, species density and species richness in the rehabilitation block and determine if the means are significantly different from the mean of the reference plots;

c) To measure pasture yield and determine if the mean is significantly different from the mean of the reference plots;

d) To measure the presence/absence of upperstorey (tree) and midstorey (shrub) species in the rehabilitation block;

e) To measure the presence of declared weeds as per the Land Protection (Pest and Stock Route Management) Act 2002 to enable the weed management issues to be identified;

f) To assess the success of sown species by comparing seeding mixes to monitoring data;

g) To ensure that vegetation monitoring is undertaken on all landform types, including both elevated landforms (i.e. out-of-pit dumps not typical of the surrounding environment) and other lower-lying rehabilitated areas;

h) To assess similarity to reference plots and/or replication across an elevated landform (i.e. upper, middle, lower sections of a rehabilitated out-of-pit dump);

i) To assess parameters that relate to pasture productivity;

   I. Density and richness of pasture lowerstorey;

   II. Pasture yield, to support grazing trials; and

   III. Establishment success and sustainability of sown species;

j) To gather data which can be used to support demonstration studies, such as grazing; and

k) Obtain sufficient relevant data to statistically indicate trends.

Final Landform Monitoring

a) To assess the chemical properties and soil nutrient status of the reconstructed topsoil profile, identifying potential properties that may contribute to any areas of rehabilitation not meeting the desired objectives

b) Record the location of erosion within, or within the vicinity of the plot as per the Australian Soil and Land Survey - Field Handbook. 2nd ed (1990) (i.e. active, stable, depth, type etc). Peabody maintains an Erosion and Sediment Control Plan (ESCP) Guideline which can be accessed on request.

c) To identify and measure landform stability and specifications on the rehabilitated blocks, using LIDAR (as provided by Peabody), with particular attention paid to:

I. determining the post mine landform stability by measuring year on year settlement/ subsidence;

II. determining the post mine landform stability by measuring the extent and year on year progression of erosion features; and

III. determining compliance with the final landform specifications (i.e. slopes, length) detailed within the site Environmental Authority (EA).

4. Method

The rehabilitation monitoring program has been designed so that the measured ecological parameters (e.g. density, pasture yield, richness, cover, soil chemical properties etc.) and erosion and sediment control parameters fulfill a number of criteria including being:

- Measurable;
- Exchangeable;
- Accurate and repeatable;
- Cost effective; and with
- Minimal potential for operator bias (e.g. minimise subjective selection of sampling sites and over/ under estimation of percentage (%) cover).

4.1 Sampling Intensity and Frequency

The sampling intensity proposed for the rehabilitation monitoring program takes into account:

- Practicality and cost-effectiveness of monitoring techniques;
- Separation of pit locations and therefore rehabilitated land which will allow for progressive certification or partial relinquishment opportunities (i.e. mines are not often one extended track of land);
- The need to capture different final landforms (i.e. elevation) and end land uses; and
- The need for broadscale monitoring, ensuring overall site rehabilitation performance is measured.

It is proposed that one (1) rehabilitation monitoring plot will be established per 10 hectares (ha) of each block (i.e. 100 hectare rehabilitation block will result in 10 monitoring plots).

Recognizing that the most rapid vegetation development occurs in the early stages of establishment, slowing as the community matures, rehabilitation will be assessed at 1, 2, 5 and 10 years after establishment. These age defined areas will be referred to as 'blocks' and where necessary, will be divided within the rehabilitation years. Monitoring of the initial establishment (i.e. 1 and 2 years) will allow Peabody to identify early on, areas for improvements as well as prescribe remedial action where required. Monitoring should take place between the months of May - August. This will minimise differences between sites and over time, due to seasonal effects.

4.2 Plot Establishment

Figure 2 outlines the proposed rehabilitation plot design.

4.3 Rehabilitation Plots

Annual rehabilitation will be divided into blocks based on the time at which the rehabilitation (i.e. seeding) was completed. Using a 10 ha grid, each monitoring block will be divided into plots. Within each plot a randomly selected point will be located which will be the start of the cover transect (**Figure 2**).

The cover transect will form the centre of the rehabilitation monitoring plot and will run diagonally across a slope/surface. Running the transect across the slope will avoid coinciding with rehabilitation patterns such as topsoil spreading and seeding directions as well as potential erosion features. Rehabilitation monitoring plots will be established across the rehabilitated block in the upper, middle and lower sections of the rehabilitation.

The start and finish of the cover transect will be permanently marked with steel or wooden pickets and GPS co-ordinates taken. The plot number will be permanently marked on the steel or wooden picket located at the start of the cover transect.

Randomly located plots that fall within 20 metres (m) of the edge of the rehabilitation block or other disturbance features (i.e. infrastructure corridors, tracks etc) will be relocated so as to avoid possible edge effects.

4.4 Pasture Reference Plots

The reference plots are to be located adjacent to the existing mining operations on the mining lease (ML) or Peabody controlled land, but within an area that will not be impacted by future mining activities. The reference plots will be established based on a pasture grass landuse and should consider vegetation and soil attributes similar to those used in the rehabilitation. In addition, past and current grazing pressures must be considered when selecting the pasture reference plot. Multiple reference plots should be established to allow statistical analyses to be undertaken.

4.5 Measurements

For the purposes of ensuring consistency in terminology the following definitions will apply:

- Upperstorey – tree layer, including canopy/ overstorey; 10m – 30m, > 30m.
- Midstorey – shrub layer, including shrubs, low trees, mallee shrubs; 1m to 10m.
- Lowerstorey/ Ground Cover – ground layer, including ground covers such as grasses, forbs, sedges, low shrubs; up to 1m.

(Source: Australian Vegetation Attribute Manual. National Vegetation Information System, Version 6.0. Department of the Environment and Heritage, 2003).

4.6 Upperstorey and Midstorey Presence/Absence

In the event that trees and/or shrubs have established within the monitoring plot, the presence/absence of species will be recorded for 10m either side of the cover transect line. Trees and shrubs will be identified to species level where possible, otherwise identification to genus level is required. Upperstorey and Midstorey species presence/absence will therefore be assessed within an area of 1000m^2.

4.7 Lowerstorey Density and Richness

Lowerstorey species density and richness will be assessed within 2m x 2m quadrats at 5m intervals along the cover transect. Lowerstorey species will be identified to species level where possible, otherwise identification to genus level is required. Lowerstorey species present, but not already encountered in the 2m x 2m quadrats will also be recorded in the upperstorey and midstorey presence/absence monitoring sections allowing a comprehensive species list to be compiled. Thus, lowerstorey species richness and density will be assessed within an area of 10m^2 at each monitoring plot.

4.8 Ground Cover Characteristics

Within the 2m x 2m quadrats, ground cover characteristics including live standing material, dead standing litter, detached or fallen litter and rock will be visually assessed and recorded. Total lowerstorey cover (i.e. ground cover) will be recorded. The contribution of each of the lowerstorey species to the live-standing ground cover assessment will be determined. The proportion of bare ground will be assessed by default. Lowerstorey cover will therefore be assessed for 10m^2 within each monitoring plot. The presence of declared weeds will also be recorded at this time.

4.9 Pasture Yield

Within the 2m x 2m quadrats, pasture yield will be estimated using the GRASS Check photo standards. Results are to be presented in kilograms per hectare (kg/ha). This information is to be used to support any grazing trial that the site may have in progress.

4.10 Erosion

Any signs of erosion within, or within the vicinity of the plot will be recorded and classified as per the Australian Soil and Land Survey - Field Handbook. 2nd ed (1990) (i.e. active, stable, depth, type etc).

4.11 Landform Stability

Use LIDAR imagery (or equivalent) as provided by Peabody to assess landform stability, including the assessment of year on year settlement/ subsidence and progression of erosion features such as gully erosion. In addition, the LIDAR imagery will be used to determine compliance of the 'as built' landform with the specifications (i.e. slopes, length) detailed within the site Environmental Authority (EA). Landform stability will be assessed per rehabilitation block. Refer to Section 4.1 for further information.

4.12 Soil Monitoring

At 5m intervals along the cover transect (i.e. within the 2m x 2m quadrats), a 0-15cm soil sample will be taken and bulked to produce one composite soil sample per transect. The bulked samples will be prepared and analysed for the following:

- Electrical Conductivity (EC);
- pH;
- Total Nitrogen;
- Organic Carbon;
- Available Phosphorus;
- Exchangeable Cations (Ca, Mg, K and Na);
- Chloride;
- Extractable Sulfate;
- Extractable metals (Cu, Fe, Mn, Zn, B and Al);
- Cation Exchange Capacity (CEC) – calculated; and
- Exchangeable Sodium Percentage (ESP) – calculated.

The consultant will be required to assess the reconstructed topsoil profile and identify potential properties that may contribute to the rehabilitation not meeting the desired objectives.

4.13 Supplementary Information

Photographs will be taken at the start and finish of each cover transect as a permanent visual record of the development of the rehabilitation.

A list of all declared weed species with a subjective record of their abundance as sparse, moderately abundant or abundant will be recorded and included in the final Report. Any potential pest species impacts on rehabilitated areas will be noted.

A measurement of the slope, plot landform location (upper, middle, lower slope) and plot aspect will be recorded.

Table 3 provides a summary of the rehabilitation methodology.

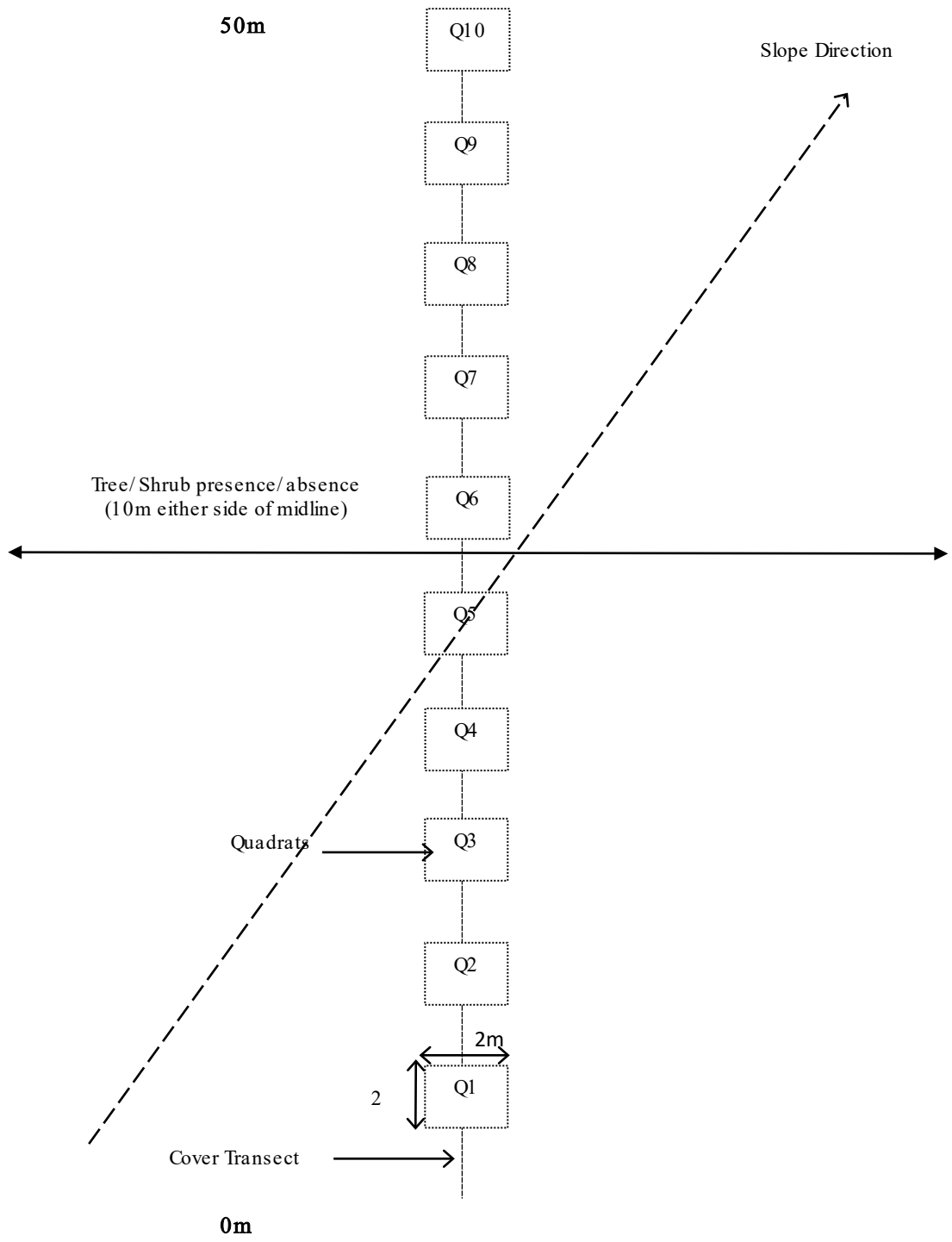

Figure 3: Rehabilitation Plot Design

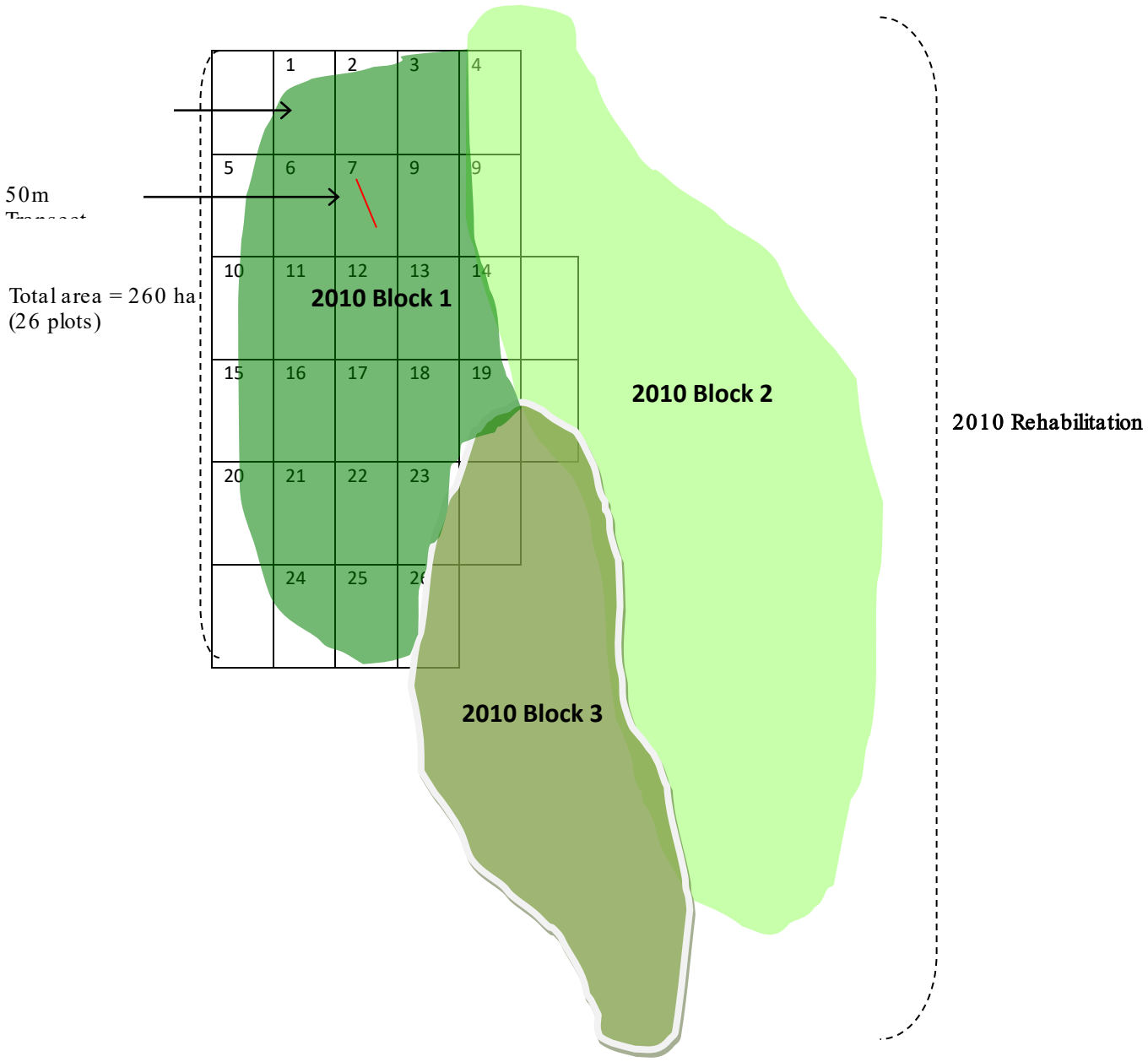

Figure 2: Schematic of Rehabilitation Design and Plot Establishment

Table 3: Summary of Rehabilitation Methodology.

Plot Area	Parameter Measured	Parameter measured
General Description and Supplementary Information	Plot Characteristics	• Record the slope, plot landform location (upper, middle, lower slope) and plot aspect.
	Weed presence/ abundance	• List all declared weed species and subjectively record their abundance as sparse, moderately abundant, or abundant. If the weed outbreak is deemed to be a significant outbreak, record the GPS location for reporting to Peabody.
	Erosion	• Record the location of erosion within, or within the vicinity of the plot as per the Australian Soil and Land Survey - Field Handbook. 2nd ed (1990) (i.e. active, stable, depth, type etc)
	Visual Record	• Take one photograph at the start of the cover transect and a second at the finish, in both cases looking along the transect.
	Climatic Variables	• Recent rainfall events, intensity, duration, measurement in relation to time of seeding. • Potential impacts of other climatic events such as cyclones, droughts, floods.
2m x 2m Quadrats	Lowerstorey Density and Richness	• At 5m intervals along the cover transect record the number of all lowerstorey species in each quadrat to obtain total lowerstorey species density and richness.
	Lowerstorey Cover	• Record total lowerstorey cover (i.e. ground cover). The contribution of each of the lowerstorey species to the live-standing ground cover assessment will be determined. The proportion of bare ground will be assessed by default.
	Pasture Yield	• Estimate pasture yield using GRASS Check photo standards.
	Topsoil Properties	• Take ten 0-15cm soil samples (i.e. one sample taken from each quadrat) and bulk, to produce one composite sample per transect.
10m either side of cover transect	Upperstorey & Midstorey Presence/ Absence	• Record the presence/ absence of tree and shrub species located 10m either side of the cover transect.
	Species Inventory	• Separately record lowerstorey species noted in the vicinity of the plot but not present within the 2m x 2m quadrats enabling a more comprehensive inventory of what species are present.
LIDAR	Landform Stability and Specifications	• Assess landform stability (settlement/ subsidence), progression of erosion features and compliance of the 'as built' landform with the specifications (i.e. slopes, length) detailed within the site Environmental Authority (EA).

5. Annual Report Inclusions

An annual report will be submitted to PEA detailing:

a) Methodology (field sampling and data statistical analysis);

b) Site establishment and descriptions, including photos (reference and rehabilitation plots);

c) Results (displayed graphically) for all assessments detailed in Section 4 of the RMM (i.e. upperstorey (tree) and midstorey (shrub) presence, lowerstorey (i.e. ground cover) density, richness and cover, pasture yield, species list [reference and rehabilitation plots], recalcitrant species, statistical parameter summaries;

d) A comparison of the rehabilitation data (vegetation) with the data obtained from the reference plots (displayed graphically). Statistical analysis should be used to compare results between rehabilitation and reference plots;

e) Assessment and discussion on the soil chemical properties and soil nutrient status of the reconstructed topsoil profile, identifying potential properties that may contribute to any areas of rehabilitation not meeting the desired objectives. A summary of the soil data is to be included within the report with all results included in the appendix.

f) Statistical analysis to determine trends between soil and vegetation measurements (i.e. compare individual soil properties against the vegetation);

g) Establishment success of seeded species;

h) Graphical presentation (i.e. heat mapping) and description of key settlement/subsidence areas and progression of erosion features such as gully erosion and compliance of the 'as built' landform with the specifications detailed within the site Environmental Authority (EA).

i) Detail type and GPS location of erosion identified within, or within the vicinity of, each monitoring plot;

j) Map outlining the blocks and transect locations of rehabilitation and reference plots;

k) Discussion including, but not limited to:

   i. Trends in the vegetation and soil data (i.e. how rehabilitation is developing against expected growth patterns, trends towards reference communities, rehabilitation soil properties); and

   ii. Recommendations for managing erosion and weeds.

Appendix J

Void stability assessment — Bullock and Plumtree voids



Peabody (Burton Coal) Pty Ltd

Stability Assessment of Final Voids - Bullock & Plumtree Voids

May 2015

henderson geotech pty ltd
11 Olive St
Morningside 4170
ph: 07 3399 5020
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CERTIFICATION

Dr Susan Jane Henderson
11Olive Street
Morningside Qld 4170

Statement of Relevant Experience

I hereby state that I am a Registered Professional Engineer of Queensland with demonstrated competence and experience in dam geomechanics, design and safety and that I therefore meet the requirements of the definition of 'suitably qualified and experienced person'.

Statement of Certification

All relevant material relied upon by me is referenced or provided in the attached document *Stability Assessment of Final Voids – Bullock & Plumtree Voids* dated May 2015.

I hereby certify that this assessment of pit wall stability

(a) has been prepared in accordance with good engineering practice and is consistent with the standards required for structures assessed as significant consequence category as set out in the "*Manual for Assessing Consequence Categories and Hydraulic Performance of Dams*" *ESR/2016/1933 Version 5.00* published by the administering authority;

(b) provided the facilities are operated and maintained as assumed in this report the voids are capable of delivering the performance stated in the report, so as to be compliant with relevant conditions of the environmental authority EMPL00879213 effective 10 July 2015.

I, Susan Jane Henderson, declare that the information and opinions provided as part of this certification are true and correct to the best of my knowledge and belief. I acknowledge that it is an offence under section 480 of the *Environmental Protection Act 1994* to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

S. J. Henderson 03-10-16

Dr Susan Jane Henderson, RPEQ 4952

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DEFINITIONS

Crest	the peak or top of the relevant void wall
Dip	the direction and angle of downward slope of the coal seam
Domain	a contiguous area that has a consistent integrated strategy for rehabilitation. For example, a Residual Void domain typically comprises the lowwall, highwall, endwalls, unfilled ramps and the area contained within these.
Endwall	the short exposed width of excavated wall at the end of the pit and roughly perpendicular to the highwall.
Factor of Safety	a common measure of the geomechanical stability of a slope. It is explained in more detail in Section 2.4.
Final void area	the plan area enclosed by the void wall crests. It is the area that is rehabilitated as a final void domain.
Final void capacity	the volume of fluid that could be stored without spilling to surface waters. The spill level could be lowest natural ground elevation around the excavated pit, or the bed level in a nearby watercourse.
Highwall	the excavated pit wall on the down-dip side of the current or final limit of mining.
Lowwall	the wall on the up-dip side of the current pit or final void. Initially it is an excavated slope – the boxcut – and later it comprises spoil that was dumped into the pit behind the current or final mining area.
Stability	the quality of being resistant to change. Note that stability is not the absence of change. Rather, for natural systems it has been described as "*change occurring slowly enough that the system can adapt*".
Strike	the direction 90° from the dip direction and along the plane of the coal seam.
Toe	the bottom of the relevant void wall.

1. INTRODUCTION

The Environmental Authority for Burton Coal Mine requires, as part of the Mine Closure Plan, "a pit wall stability study considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events". The study among others is to be undertaken during the life of the mine and is to include research and modelling.

This report describes the results of the initial pit wall stability study for Bullock and Plumtree Voids, in the context of informing the Mine Closure Plan. It includes a monitoring program for the remaining life-of-mine and may be revised based on results of that monitoring.

1.1 Scope

The study used 2D limit state stability analyses of selected wall sections. The associated geomechanical models were based on profiles interpreted from previous exploration drilling, visual inspection of the current voids and published strength properties for the component materials. Current wall geometry was taken from 2012 aerial survey and overlaid on the design pit shells to estimate any existing slip surfaces.

Hydrological events potentially affecting pit wall stability mainly relate to water levels in the void. Several of the voids will be used for storage of worked water during the remaining life of mine, and a maximum operating level has been specified for each void in the water management procedures. WRM (2012) undertook water balance modelling for the final void to predict maximum and long-term average water levels after the end of mining.

Preliminary allowances for erosion and weathering effects were based on observation of highwalls and lowwalls in the Bowen Basin over more than two decades.

No additional drilling investigation or laboratory testing was undertaken as part of this study, as it would be questionable to extrapolate scale and time effects from small samples logged and tested now to the long-term performance of entire voids. Instead, the current voids have been considered as full scale field trials that allow continued monitoring and revision throughout the remaining life of mine.

2. MECHANISMS GOVERNING PIT WALL STABILITY

2.1 Open–cut Coal Mining and the Resultant Void

As implied by the term "basin", coal seams in central Queensland form massive bowl shapes buried under many metres of later rock and earth. In open-cut mining that rock and earth (overburden) is excavated to expose the coal, which is then mined. Obviously, the lowest cost will be where the coal is shallowest – just below the limit of oxidation (Lox), the depth above which the coal has been weathered due to being close to the surface and no longer has economic fuel value. Most mining then typically starts at the western limit of oxidation and continues down the slope (dip) of the seam's basin until the depth of overburden that needs to be removed makes further open-cut mining uneconomic. Beyond that limit, the coal might be mined using underground methods, where the coal is excavated without removing the overburden.

In typical open-strip mining, an initial strip (boxcut) is excavated down to the shallowest unweathered coal. The excavated overburden (spoil) is dumped out-of-pit directly behind the boxcut. For the next strip, as the overburden is excavated it is spoiled into the void left by the previous strip, the overburden from the third strip is spoiled into the second void, and so on. At any strip in the operation, the highwall is the face of rock not yet excavated and the lowwall is the face of spoil in the previous strip. The endwalls are the short faces of un-excavated rock at each end of the strip.

When the last economic strip has been mined there is no new spoil to dump into it and so a void is left, as illustrated in Figure 2-1. Some key elements of a final void are:

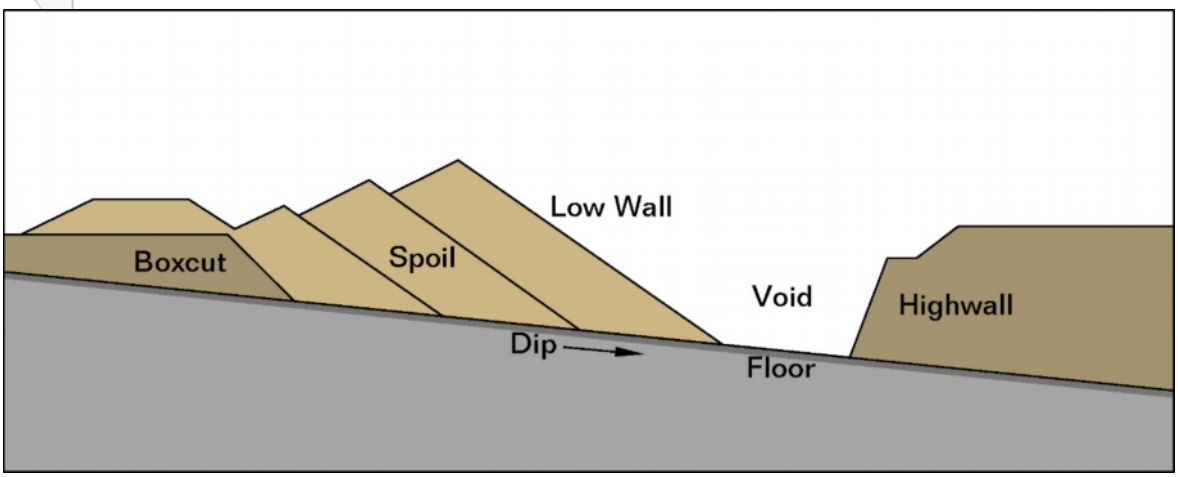
- A highwall of in situ rock that was designed to be stable for the duration of the mining operation. It was not designed specifically to be stable after mining; however features such as benching that were included for operational reasons, incidentally improve long-term stability.

- A lowwall comprising spoil dumped onto the floor of previous strips that dip down toward the final void.

- Because each strip is deeper than the last and because spoil is not as densely packed as the original overburden, normally the spoil does not completely fit into the previous strip but sits higher than the original ground level. Sometimes the excavation sequence requires some of the spoil to be dumped on top of earlier spoil or even in dumps outside the pit shell.

- A ramp, or roadway, that allowed trucks to move the final coal out of the pit and therefore could not be backfilled during mining.

Figure 2-1: Typical section through final void



2.2 Highwalls and Endwalls

A typical highwall in the Bowen Basin comprises soil and (geologically) recent sediments overlying weathered Permian coal measure rocks then fresh coal measure rocks down to the coal seam in the base of the wall.

In general the highly to completely weathered strata behave essentially as soil – the strength is low enough that failures will occur through the material mass, and structures such as joints and faults are rarely significant. Rockmass (or earth-mass) failures tend toward planar slip surfaces for granular soils and circular surfaces for clayey material (Figure 2-2). A common variant of mass failure in clayey overburden occurs when tension or shrinkage cracks open behind the wall face and subsequently fill with rainwater. The water exerts outward pressure that has to be resisted by shear strength; the situation is exacerbated if the water also seeps into the clay and weakens it (Figure 2-3).

By contrast, the rock material within the fresh overburden is generally so strong that instability only occurs along weaker planes (defects) such as joints, faults and bedding. The most common type of failure is when defects intersect to define a wedge that can slide out of the wall (Figure 2-4). Bedding planes normally dip into the highwall (like the coal seams) and so are not prone to instability except where local deformation has reversed the dip.

Another mechanism is toppling failure, where the geometry is such that blocks can simply fall away from the defect rather than sliding along it (Figure 2-5). Obviously it would be difficult to excavate a highwall in the first place if blocks were able to topple; for this mechanism to develop an underlying stratum needs to crush or compress some time after the strip is dug such that the blocks rotate outwards to the point of tipping. There is a final related mechanism, collapse, where bearing failure of a lower stratum (such as due to highwall mining or water-related weakening) initiates a slip encompassing overlying rock (Figure 2-6).

Figure 2-2: Mass instability

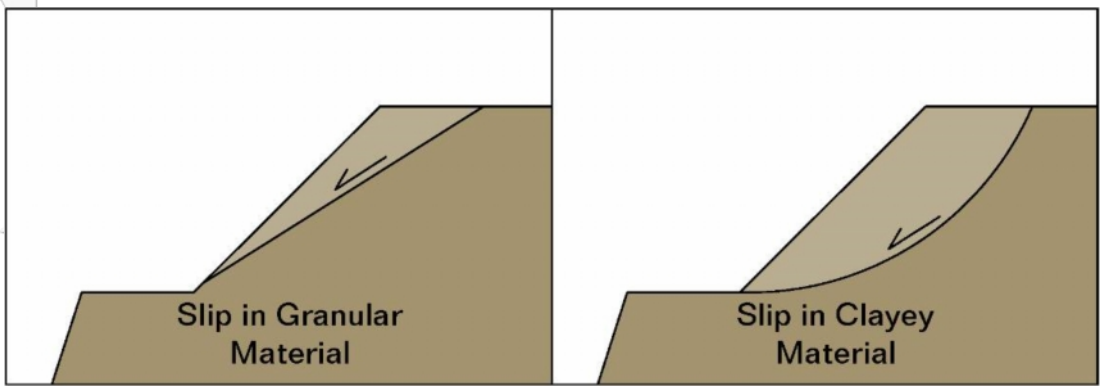


Figure 2-3: Mass instability with water-filled cracks

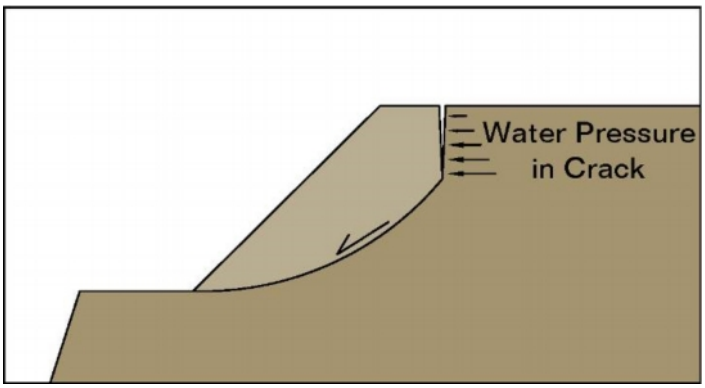


Figure 2-4: Defect controlled instability

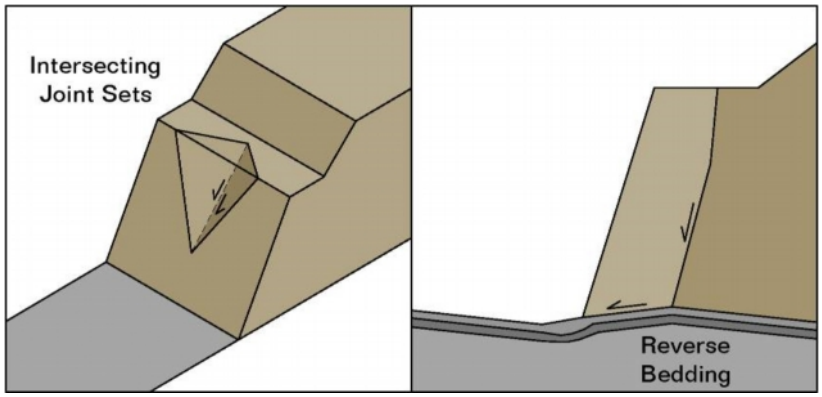


Figure 2-5: Toppling instability

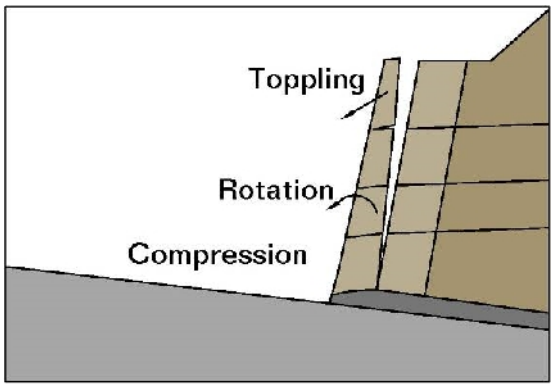
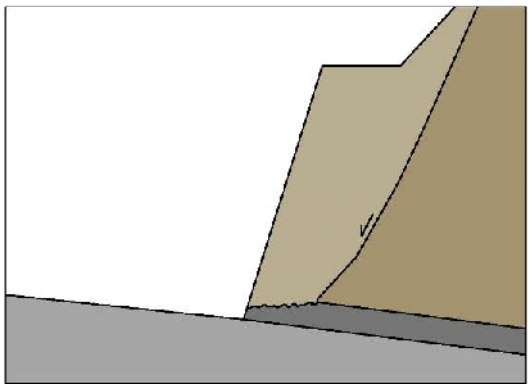


Figure 2-6: Collapse instability



2.3 Lowwalls

Lowwalls in the Bowen Basin consist of spoil overlying the pit floor that was left after removal of the previous strip of coal. Historically, Tertiary and/or weathered overburden – dug first from the next strip – would have formed the lower part of the spoil dump, with fresher Permian spoil above. In recent years however, greater pit depths have involved pre-strip and multiple passes and the excavated weathered overburden has been typically dumped over spoil a few strips behind the current strip or in out-of-pit dumps. Consequently, most lowwalls at final voids will comprise fresh Permian spoil that will be mainly frictional (granular) in character, although there may be a trend to more clayey behaviour in the long term if deterioration of the rock fragments releases clay that was inherent in the mineralogy.

The key determinant in lowwall stability (in dry pits) is actually the floor region – the spoil just above the excavated surface, the spoil/floor interface and the unmined rock in the few metres below the interface. The unmined rock is understandably much less permeable than spoil, so rainfall that infiltrates the spoil percolates down to collect in the layer of spoil just above the floor. This wetting usually causes some degree of slaking and softening; the floor itself would have been disturbed and worked during coal extraction and so generally is also weaker than the equivalent material in the highwall.

In addition, sometimes there are weak layers in the coal measure sequence a short distance below the main coal seams that have the same bedding direction as the coal seam and therefore slope down parallel with the floor toward the void. For example, the Yarrabee Tuff

is a thin layer of soft mudstone occurring widely at the base of the Rangal Coal Measures, which are the measures mined at Burton.

As a consequence of the floor condition, instability in lowwalls frequently presents as bi-planar slip surface with the base along the pit floor and a back-scarp through the spoil mass (Figure 2-7). The simplest mechanism has two wedges, one at the top and rear pushing another out along the floor plane; however structure and non-uniformity caused by the dumping process can produce more complex wedge systems (Figure 2-8).

When a slip occurs, the exposed back-scarp will be steeper than the original lowwall, but as long as the slipped material remains at the toe, the effective slope height will be much less. There may be ongoing smaller slips within the spoil mass but unless movement can continue along the floor the face will eventually self-stabilise (Figure 2-9).

Figure 2-7: Basic spoil failure

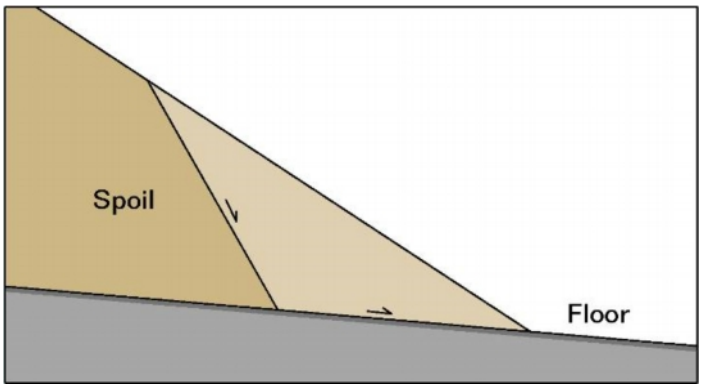


Figure 2-8: Spoil wedge mechanisms

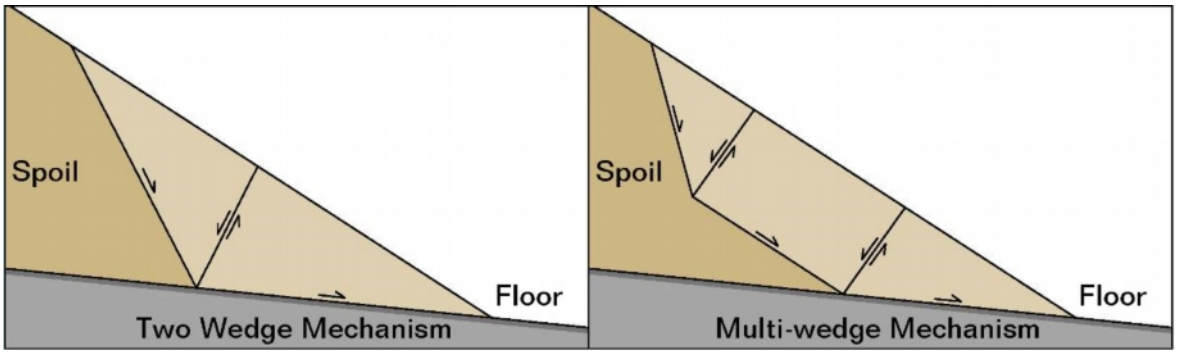
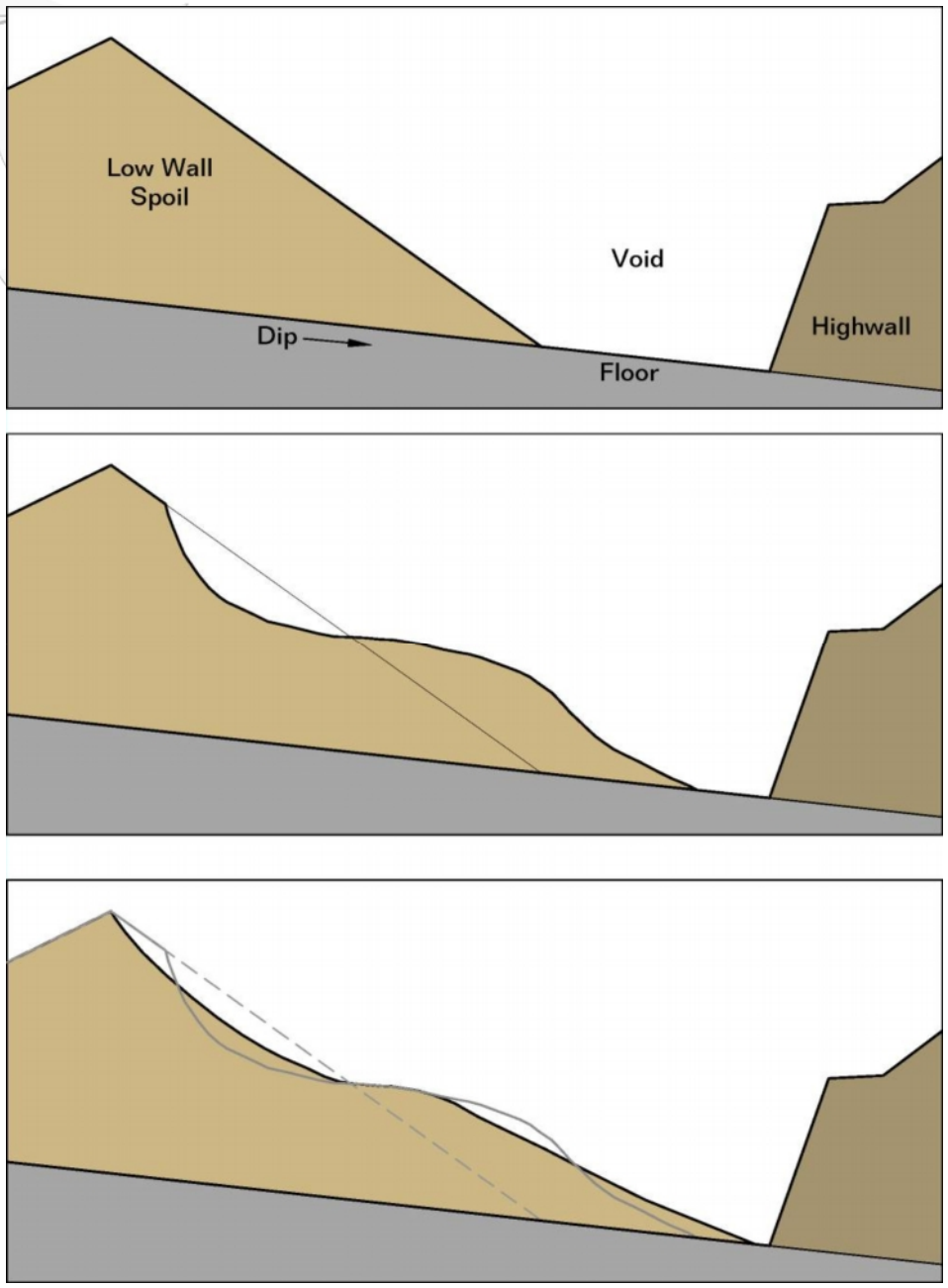


Figure 2-9: Progressive spoil failure and self-stabilisation



2.4 Factor of Safety

Limit equilibrium stability analysis basically compares the sum of forces present working to move the soil/spoil/rock mass with the sum of forces available, as material strength, to hold the mass in place. The result is commonly expressed as the Factor of Safety, which equals the available stabilising force (or moment) divided by the actual destabilising force or moment.

Theoretically, a Factor of Safety greater than 1 means that the stabilising force is greater than the destabilising force and so slip failure should not occur.

In reality, variation and uncertainty regarding the material strengths and the effects of strain movements that occur as limiting equilibrium (FoS = 1) is approached mean that an additional margin is desirable. A Factor of Safety of 1.2 has been found to provide an acceptable level of reliability for mining slopes in the Bowen Basin (GCS 1999).

2.5 Additional Considerations for Residual Voids

If a pit wall is stable at the end of mining, it can only become unstable later if either the applied loads or the strengths change. The applied loads – due to equipment or buildings – will not increase after mine closure. Strengths might change, however, in response to wetting, creep, weathering or erosion.

2.5.1 Wetting

As discussed in Simmons & McManus (2004), when water enters the pore spaces within a spoil mass the contacts point between fragments, and often whole fragments, slake and soften. Once it occurs, the resultant lower “saturated” strength is largely permanent, even if the water subsequently drains out.

In the highwall, weathered overburden is generally susceptible to softening, especially materials containing significant clay. However, with the exception of some claystones/mudstones, water does not penetrate deeply into the unweathered coal measure rocks and so there may be some surface slaking but not wall instability. As discussed in subsequent chapters, at Burton Mine, the completed mining voids are being used for water storage and when the operational water levels are higher than the predicted long term levels, any effects of saturation will have occurred before relinquishment.

There is another mode of instability related to water storage, namely draw-down failure. This can occur when pore water pressures in the lowwall have equilibrated with the standing water level and the water level is then lowered too quickly so that the spoil pore pressures are no longer balanced out. Operational procedures for storage voids are being developed to prevent this condition occurring during the life of Burton Mine; it cannot be an issue after relinquishment because evaporation will not drop water levels quickly enough for the water pressures to get out of balance.

2.5.2 Creep Strain

In this context of this study, creep refers to slow movements behind the highwall and endwalls in response to the stress changes in the rock caused by excavation of the mining pit. Each element of in situ rock is subject to a field of horizontal and vertical stresses related to the original sedimentary deposition and any subsequent folding, faulting and intrusions. When material in front of the highwall is excavated, the restraint on that side is removed and the overburden still in place responds by expanding slightly into the void space. This slow movement can open joints, cause spalling or create shear planes in clayey material, any of which could lead to weakening and eventual instability. Internationally there are examples where this creep has taken several decades to cause slope failure (for example in railway cuttings through the London Clay) but in the sandy clays and jointed sedimentary rocks characteristic of the Bowen Basin, any instability is likely to be apparent with a decade of pit completion, that is, during life of mine and the post-mining monitoring period.

2.5.3 Weathering

There are two phases to weathering, physical degradation and chemical decomposition. Degradation starts almost as soon as the spoil is excavated or the rock face is exposed and is essentially larger fragments or rock breaking down into smaller fragments. This breakdown, or 'slaking', is mainly caused by salt crystals adsorbing moisture and swelling, by clay minerals adsorbing moisture and swelling (although salts are usually involved as well) and less commonly by cementing minerals being dissolved in water. Rainfall and in-pit storage cause immediate slaking in susceptible materials but humidity can produce the same result over a couple of years. Because degradation depends so heavily on water ingress, it is largely restricted to the surface of highwalls and endwalls; obviously water penetrates more freely into lowwall spoil, so much so that in practice the effect of degradation is included in the broader effects of "saturation" described above.

Chemical decomposition involves reactions of the actual rock minerals to form different minerals (ultimately, clay minerals). Because it occurs at the crystalline/molecular level and only where water and other reactants can reach, chemical weathering progresses at an extremely slow rate, even in mined materials. For example, if there was an 'amount' of decomposition that would normally take 100,000 years then if mining increased the exposed surface area a hundredfold and water and reactants were present and could reach all of the surface, it would still take 1,000 years for that decomposition to occur. Therefore, most "weathering" observed after mining (as opposed to overburden that was already weathered) is actually only physical degradation. Considering the definition of stability as "*change occurring slowly enough that the ecosystem (and geosystem) can adapt*", chemical weathering is most unlikely to cause void instability.

2.5.4 Erosion

Erosion is the detachment of solid particles from the soil or rock mass and the subsequent transport of those particles away from their initial location. Most commonly, detachment occurs due to mechanical means – the impact of raindrops and the energy of flowing water – and the transport is also provided by flowing water. In this scenario, the severity of erosion depends on the character of the material – how easily particles are detached – and increases with catchment size and surface slope, both of which increase the volume and velocity of runoff flow.

In the Bowen Basin in particular however, detachment often occurs by chemical means due to the sodic and dispersive nature of some weathered rock (especially Tertiary age sediments). In this case, the bonds and ionic charges within the material are such that clay particles will "disperse" into even still water that is not applying mechanical energy. The loss of clay particles opens the structure of the soil mass so that the next level of particles (silt) can be more easily detached by normal mechanical means. Although clay dispersion can occur in still water, flowing water is still required for the transport phase of erosion. However, in this case the water flow can be over the soil surface or through the soil mass, dispersing more clay to open up flows paths as it seeps. The one thing seepage flow does need is a point of exit from the soil mass, otherwise the clay will eventually re-settle and seal the flow path.

Erosion is characterised as either "sheet erosion" where particles are removed in essentially uniform layers or "rill erosion" where variations in material and ground slope lead to the development of channels, or rills, in the direction of flow. The rills then collect and concentrate the runoff which produces greater flow power and consequent further erosion

within the rills. On opencut mines in the Bowen Basin, rainfall intensity, material properties and ground slopes all contribute to rill erosion dominating, and the rills commonly become large enough that the term gully erosion is used instead.

In the context of mining voids, in fresh rock after initial slaking the solid particles are mainly bound too strongly to be detached by rain or runoff and erosion is characteristically minor.

For pit walls comprising non-dispersive spoil and weathered overburden, the wall slopes encourage high runoff velocities but the catchment – and therefore runoff volume – is often limited to the slope itself. Erosion is expected to be worse at the base of the wall or bench and to reduce up the slope due to the smaller contributing catchment. The batters also tend to self-armour – easily detached and transported particles are removed first, then it needs a more intense runoff event to remove the next level of particles, until it reaches a stage where only a rare and extreme event could erode the particles forming the surface. As a result of these limits to process, mechanical erosion occurs largely within the void and does not extend much outside the initial void footprint; the appearance of erosion behind the wall crest is largely due to the flatter ground cutting the gullies and showing them in cross-section. Individual large washouts are observed but these are due to concentration of runoff behind the wall crest, such as in pre-existing drainage lines. Such washouts become obvious early in the life of the void and can be stabilised by re-directing drainage lines.

Dispersive materials are more problematic because of the potential for 'erosion by infiltration', and the pit slope providing the necessary seepage exit point. Initially tunnels develop close behind the wall crest; these then allow runoff to reach and erode the column of material in front of the tunnel and provide new exits points for the next row of tunnels. In this way the erosion damage can progress some distance behind the wall crest, however it does become limited by successive decrease in the vertical depth of tunnels, once again by the fact that the material left behind is obviously less erodible, and by topsoil and grass cover that prevent free water reaching the dispersive material. While the eroded "badlands" on Bowen Basin mines have a strong visual impact, experience suggests that the distance they extend behind pit wall crests is generally not greater than the depth of dispersive material in the wall face.

As a process at the soil/water interface, erosion rarely causes geomechanical instability. Tunnelling in dispersive materials can work into the soil/rock mass but its effect is essentially that of tension cracking, as discussed in Section 2.5.1. Despite this, erosion can cause significant landform damage in its own right and therefore should be considered as an additional factor overlaid on pit wall stability. Measurement of the extent of erosion damage behind pit walls is required across the region but for the purpose of this study conservative margins will be adopted based on the vertical depth of significant erosion shown on the wall face.

3. STUDY APPROACH

The following methodology was used to assess the long-term stability of pit walls:

1) Inspect the void to identify key characteristics of the wall profiles and any exhibited mechanisms for instability.

2) Prepare a geomechanical model for typical wall sections based on based on pre-mining geological studies, observation made during the site inspection and published typical strength properties for the various strata. Undertake stability analyses for each wall in its current configuration to verify the geomechanical models.

3) Undertake further stability analyses for maximum and long-term average void water levels and associated changes in material strength properties. If the resultant factor of safety is less than 1.2 (suggesting significant risk of further instability) estimate a post-slip geometry and iterate analyses until the minimum factor of safety reaches 1.2 or higher.

4) Overlay the predicted long-term crest position for each wall onto a plan of the current pit to show the final void footprint.

5) Predict the “erosion affected rim” based on the depth and character of erodible material.

6) Identify any assets, including significant environmental values and drainage features, within the void footprint and erosion affected rim to inform decisions regarding any need for mitigative measures.

4. BURTON MINE OVERVIEW

4.1 Geology

The Burton mining leases lie between the Burton Range to the west and the Kerlong Range to the east. The Burton Fault is at the near-side of the Burton Range; this major regional fault caused Permian coal measures to be thrust upward in the mine area so that the coal is at shallower depth than it would otherwise have been.

The coal seams being mined at Burton are in the Permian Rangal Coal Measures, specifically the Leichhardt and Vermont seams, which are called the Burton seam in the areas where they join up. The interburden and direct overburden consists of jointed carbonaceous sandstones, siltstones and mudstones in layers typically about 2m thick.

The Fort Cooper Coal Measures lie below the Rangals. The rock types are similar in character except that the coal seams contain frequent bands of other rock, sometimes including very weak claystone. Consequently the Fort Cooper Coal Measures are a poorer quality resource and mainly not economic to mine at Burton. The Fort Cooper Coal Measures also have poorer geomechanical properties that can affect pit stability when they occur close under the pit floor.

At the eastern side of the leases, the Rangal overburden is covered by Triassic age Rewan Formation sediments. These again comprise sandstones, siltstones and mudstones but with very little carbonaceous matter; the mudstones in particular are often dispersive due to relatively high proportions of sodium ions. Quaternary age alluvium, predominantly poorly consolidated sands and gravel, occur up to about 10m thick but only in the vicinity of creek lines.

The depth of weathering at Burton mine generally averages 20m, except at Wallanbah void (as discussed below).

Key features of the general geologic profile that are relevant to pit wall stability include:

- Steep dips in the mined coal seams (and consequent steep pit floors), typically about 20° but ranging up to 40°.
- Shearing and small scale faults in and around the coal seams, allowing defect surfaces to daylight in the pit floor.
- The Yarrabee Tuff, a thin layer of weak clayey material above the Lower Vermont seam. When the Lower Vermont seam splits away from the Rangal Coal Measures, it and the overlying tuff may be left below the pit floor.
- Various persistent joint sets that may intersect in places to form wedges in the highwalls and endwalls.

Because of the complex geological history, Burton has been mined as a series of discrete areas where the coal depth and quality has made recovery economic. The seven resultant

voids, in four areas, are indicated on Figure 4-1, and specific geological aspects are summarised as follows:

Burton North – *no information available*

Burton Widening – This is the active mining area. Spoil that backfilled the original pit has been excavated to out-of-pit dumps. The Burton Seam dips at 20-22° and there was significant shearing and small-scale faulting in the original Burton Pit floor.

Ellensfield – Rangal Coal Measures overburden extended to ground surface (there were no Rewan Formation rocks present in the mined footprint). The combined Burton Seam was present at the north but spilt into Leichhardt and Vermont seams to the south. Dips ranged from 18° – 29° and shearing was common in the coal seams.

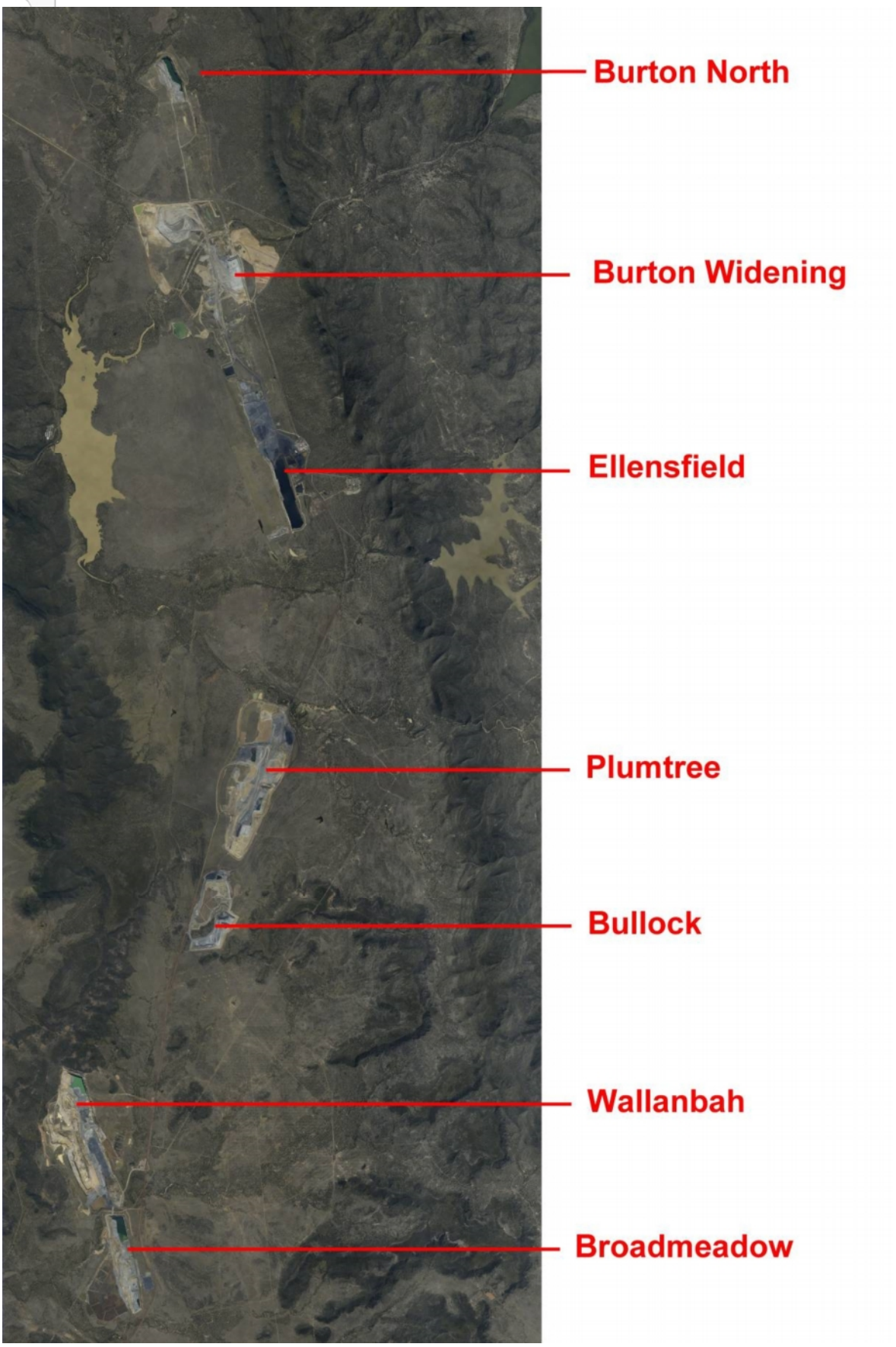
Plumtree – The remaining void is at the southern end of the pit area, the northern part having been backfilled with spoil during mining. Coal was mined as Leichhardt and Vermont seams, with dips steeper than 30° in the remaining void area. Rewan Formation sandstones were present above Rangal Coal Measure overburden.

Bullock – The pit was mined to the Upper Vermont seam, which dipped at 10° – 14°. The Yarrabee Tuff was present but more than 20m below the pit floor and so was not relevant to pit stability. Rewan Formation sandstone was present in the highwall but not along the boxcut.

Wallanbah – The remaining void is at the northern end of the pit, the southern end having been backfilled with spoil during mining. The pit walls are unlike any other at Burton Mine because of the boxcut running along the Burton Range Fault and Tertiary age Suttor Formation overlying the Rewan formation. The Tertiary material comprises poorly consolidated and weathered clay, laterite and quartzose sandstone. The Base of Weathering is much deeper than in other pits, ranging from 16m to 65m with an average of 44m.

Broadmeadow – The void comprises a large volume at the northern end of the pit area and a smaller volume toward the southern end, the middle section having been backfilled with spoil during mining. Up to 10m depth of sand and gravel alluvium overlay the Rewan Formation around the northern end, associated with Spade Creek.

Figure 4-1: Voids at Burton Mine



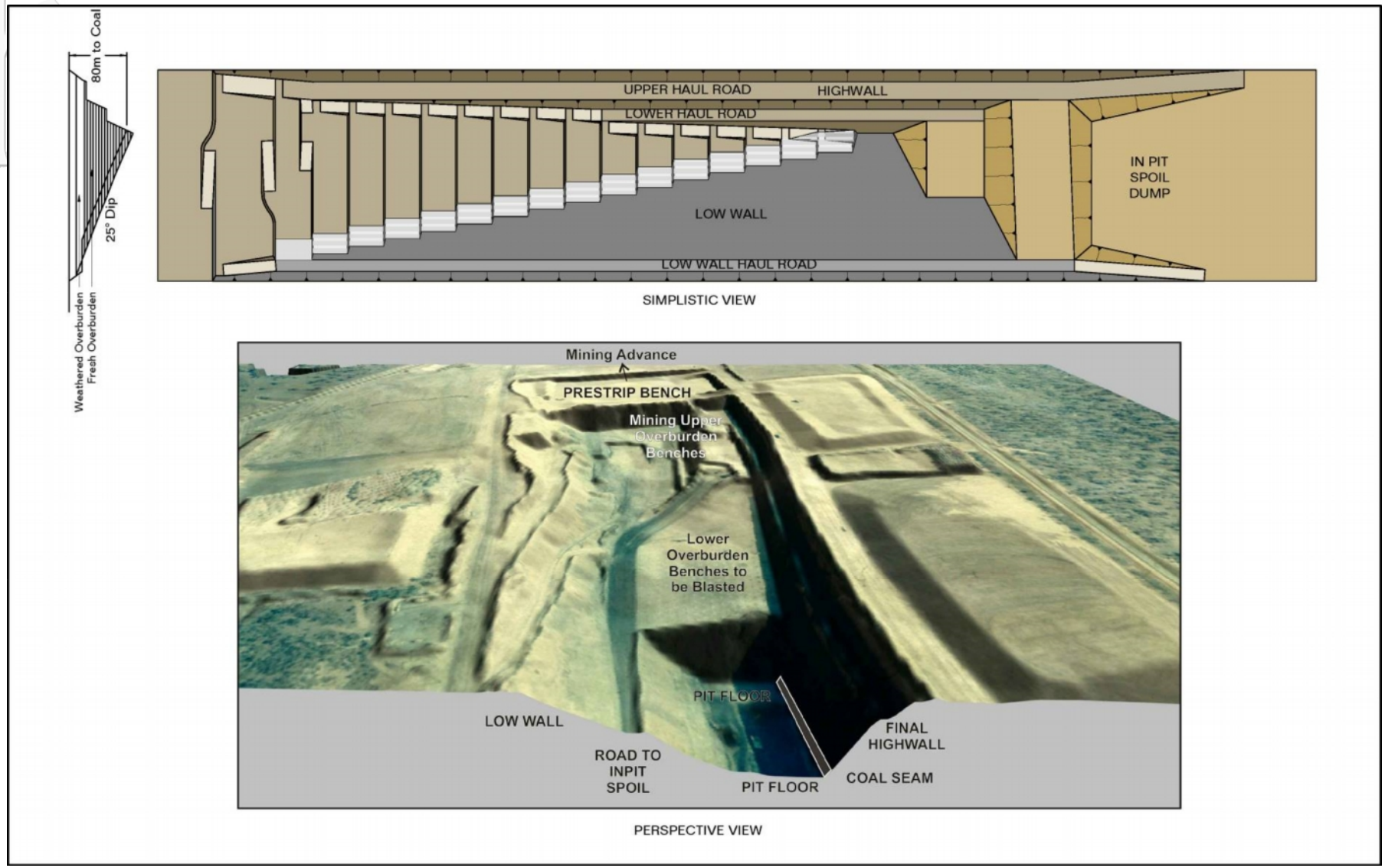
4.2 Mining Methods

The steep seams dips meant that, unlike most Bowen Basin coal mines lowwall stability (or instability) was the driving constraint. The steep dip also meant that the economic mining areas were relatively narrow, as the coal quickly became too deep for economic recovery. As a result, the default mining method has been "truck and shovel terrace mining". This differs from the normal open strip method referred to in Section 2.1, in that instead of excavating the whole length of boxcut, and then the whole next strip, and so on, only a small block of the boxcut is opened at first. When the coal is mined from that block, a block beside it is excavated while the first block is also deepened. When the third block is excavated to the first stage, the first and second blocks are also deepened incrementally, so that when a steady state is reached the pit is a strip of terraces each about 4m lower than the adjacent one. The terrace mining sequence is illustrated in Figure 4-2.

The main advantages of terrace mining at Burton were that only short lengths of coal were exposed at any given time rather than the whole pit length; that the coal was exposed and mined from the side face of each terrace rather than from a steeply dipping floor; and that spoil was not dumped on the floor up-dip (upslope) of the mining area, which reduced the stresses that would otherwise have been loaded onto the floor. While this last aspect was often essential to provide pit stability during mining, it had the disadvantage that, because no spoil could be placed in-pit until the first terrace reached its final depth, large out-of-pit spoil dumps were generally required.

The final highwalls at Bullock and Wallanbah north pits were auger mined. This mining method uses a large auger to "drill" into the coal seam at the base of the highwall and return coal cuttings to the pit from where they are loaded and trucked like other coal. The challenge in auger mining is to leave enough coal as webs between the auger holes to support the overburden so that the highwall either remains intact or subsides slowly without becoming unstable. Auger mining ceased at Bullock when the pit floor was flooded after a severe rainfall event and at Wallanbah when part of the highwall became unstable and collapsed.

Figure 4-2: Terrace Mining



5. BULLOCK VOID

Opencut mining was completed in October 2011 at a maximum pit depth of about 100m. The floor dips at 10-14° toward the highwall at the eastern side. Spoil was dumped against the lowwall at the west, and the ramp entered from the south, along the highwall (Plate 5-1). Bullock Creek was diverted about 50m behind the lowwall but the associated flood protection bund was constructed at the crest of the lowwall. A drain to take runoff from undisturbed land into the creek was constructed close behind the northern endwall. The highwall was auger mined from December 2011 to March 2012 but mining ceased when the pit was inundated following severe rain (a 1:20 AEP 72hr rainfall event).

Plate 5-1: Bullock Void, May 2012



5.1 Current Observations

The void was inspected in December 2012. Since the cessation of auger mining, the void had been used for storage of mine affected water and the water level was noticeably higher than after the inundation event. The highwall was exposed from just above the lower bench and appeared to be generally stable (Plate 5-2).

The northern endwall had suffered major and progressive failure (Plate 5-1, point 3 and Plate 5-3). Ward (2012) identified the mechanism as toppling within the weathered zone and expected it to continue until a slope angle of about 35° is achieved. This would extend into the side of the runoff capture drain behind the endwall; cracking parallel to the wall was already present at the side of the drain.

A slipped area at the northern end of the lowwall showed fresh cracking. Aerial photography suggested that the flood protection bund had breached behind this area, where it crossed a pre-existing drainage gully (Plate 5-1, point 2). The breach probably occurred during the "severe storm" in March 2012 and was the cause of the pit inundation. Another larger and more active slip had occurred over the southern half of the lowwall (Plate 5-4). Ward (2012) considered that the instability had occurred after the void was used for mine water storage and was therefore due to the spoil becoming saturated. This was undoubtedly a contributing factor but the May 2012 aerial photography shows a large arc already reaching back to the flood protection bund after the initial inundation but while the water level was still low (Plate 5-1, point 1).

Plate 5-2: Bullock Void highwall



Plate 5-3: Bullock Void northern endwall



Plate 5-4: Bullock Void lowwall



5.2 Stability Analyses

Three cross-sections through the previous slips were taken for consideration of stability analysis. The designed pit (pit shell) and May 2012 surface topography were overlaid, then nearby drillhole logs were projected onto the sections to produce the geotechnical profiles included in Figure 5-1.

By observation, the spoil comprised predominantly fragments in a fine granular matrix – not clayey but also not blocky. The weathered overburden had the appearance of sandy clay near the surface, grading to weak rock toward the Base of Weathering. The whole weathered zone was conservatively considered as hard residual clay. The Exploration Drilling Geological Report (MBGS 2007) described fresh overburden for both Rewan Formation and Rangal Coal Measures as moderately strong so for the purposes of stability assessment they were considered a single material that was not susceptible to saturation and associated strength loss. Floor material (below the Upper Vermont seam) was described as moderately weak to moderately strong fissile mudstone.

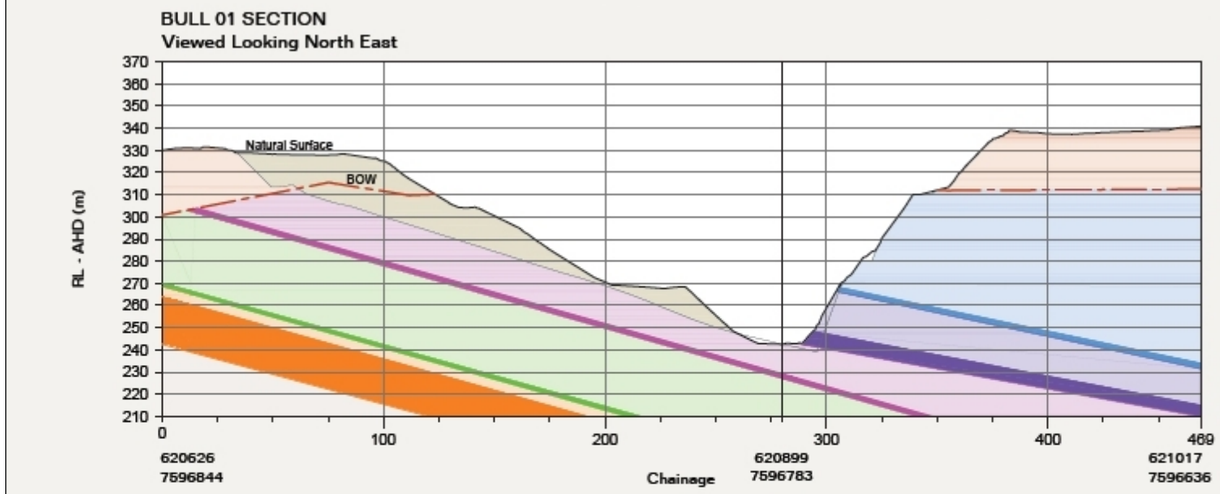
Table 5-1: Bullock Void Adopted Strength Properties

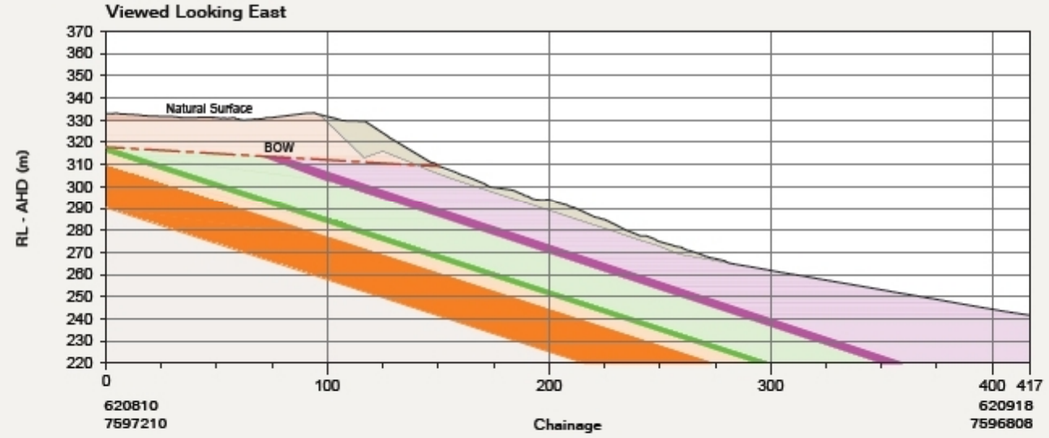
	Initial Condition			After Saturation		
	cohesion c' (kPa)	friction ϕ (°)	weight (kN/m^3)	cohesion c' (kPa)	friction ϕ (°)	weight (kN/m^3)
Sandy spoil (category 2)[1]	30	28	18	15	23	20
Weathered overburden[2]	50	30	20	15	30	20
Fresh overburden[2]	450	42	24	450	42	24
Coal[2]	30	35	15	30	35	15
Weak floor[2]	52	40	24	52	40	24

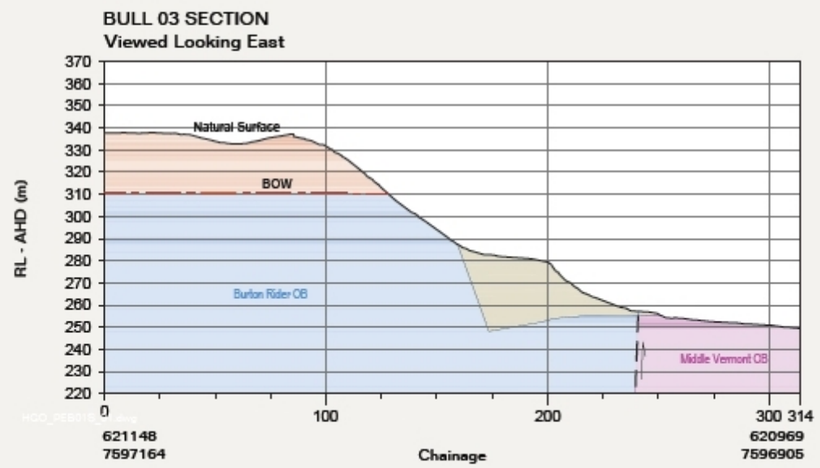
Based on water balance modelling (WRM 2012), the water level in the final void is expected to range between RL 263m and RL 278m. The water level in October 2012 was RL 293m, which means that the pit material has already been saturated higher than the long-term level. It is intended to continue to use the void for water storage during the remaining life of mine and the maximum operating level has been set at RL 315m – 5m below the bed level in nearby Bullock Creek. This then was the critical water level (and saturation level) assumed for pit stability.

[1] Simmons & McManus, 2004
[2] GeoTek Solutions, 2013

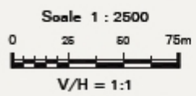
Figure 5-1: Bullock Void Cross Sections













BURTON

henderson geotech

Dsg/Chk:	S. Henderson	15.02.13
Drawn:	RACAD	15.02.13
Cad File:	HGO_PEB018_01.dwg	

Bullock Creek Sections

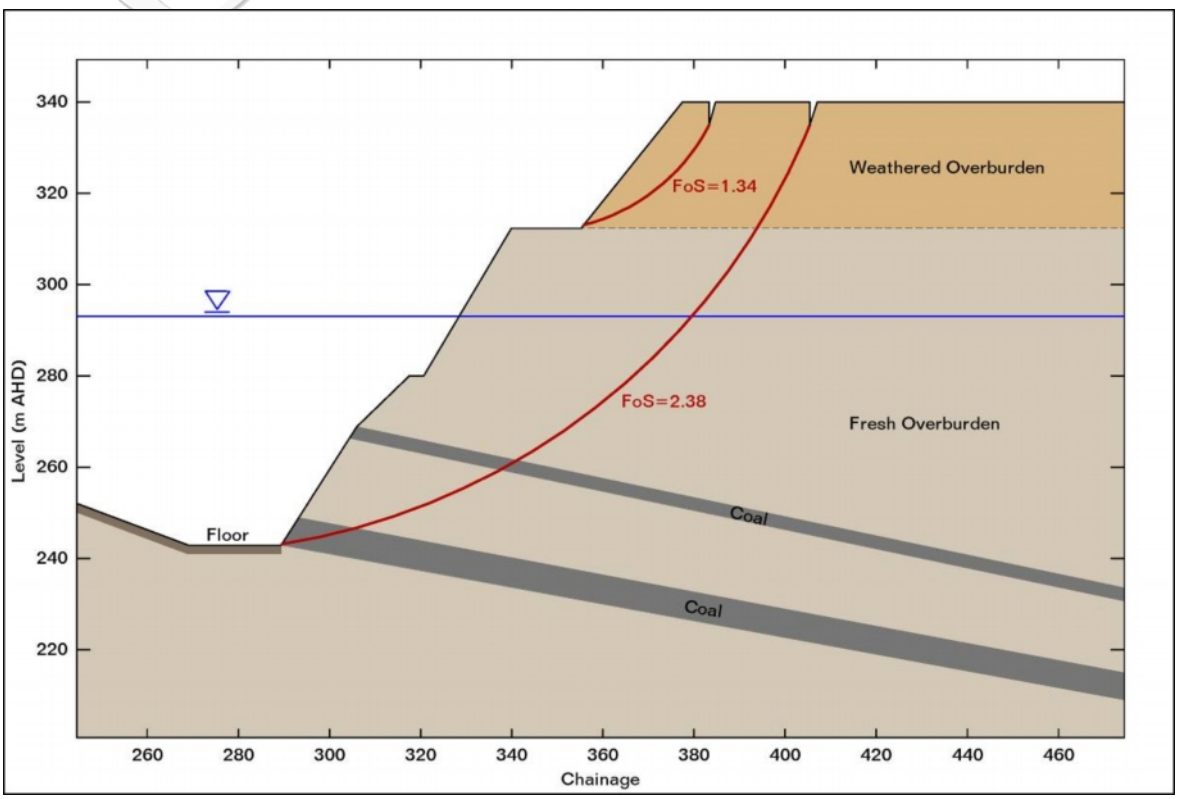
Figure

5.2.1 Highwall

Current stability

Analyses were consistent with the observation of stability under current conditions, with minimum Factors of Safety of 2.38 for slips encompassing the whole wall and 1.34 for slips confined to the upper bench of weathered overburden (refer Figure 5-2).

Figure 5-2: Highwall Stability for Current Conditions

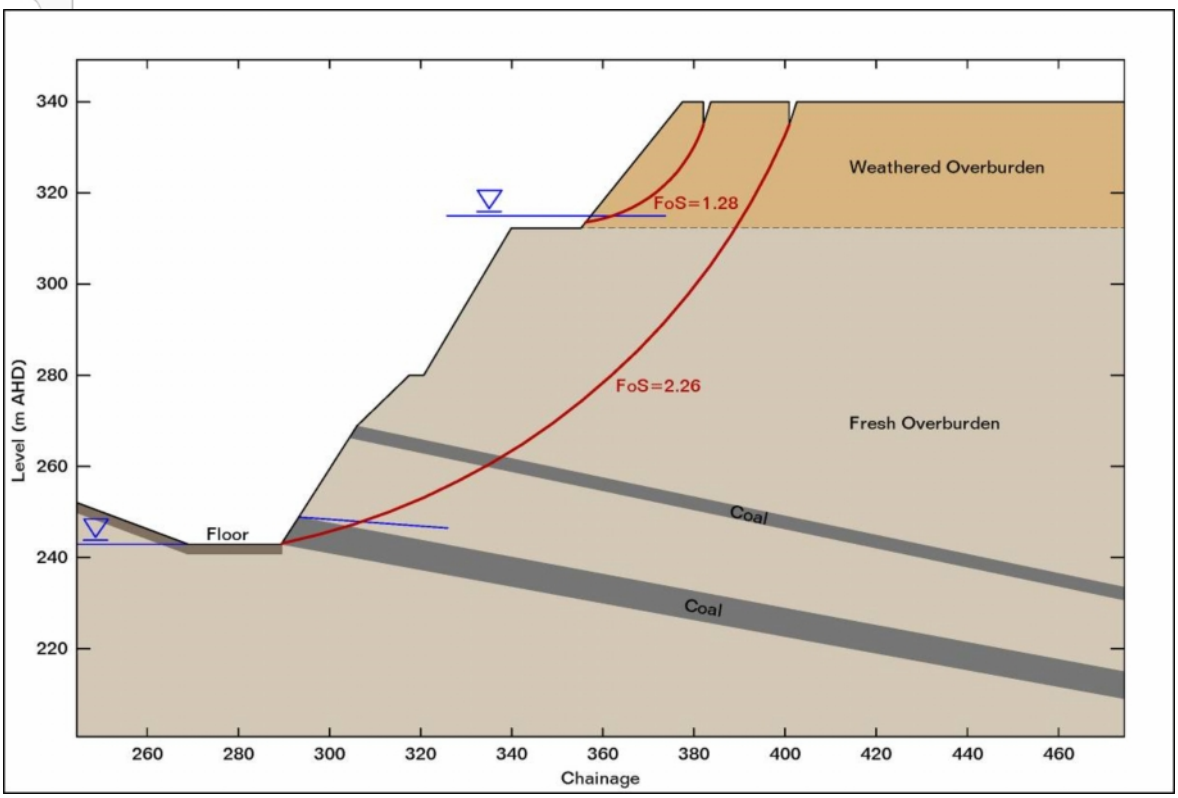


Long term stability

With long term water level ranges included, the least stable condition for whole slope failures was actually with the pit dry, is without any buttressing effect of water (FoS=2.26). For upper bench slips the computed factor of safety occurred at the proposed maximum operational water level, with material at the base of the bench saturated (FoS=1.28). These results are summarised on Figure 5-3.

As factors of safety are higher than the acceptable minimum for current and worst-case conditions, the Bullock Void highwall is assessed as geomechanically stable in the long term.

Figure 5-3: Highwall Stability for Worst-Case Conditions



Erosion Buffer

As apparent on Plate 5-2, erosion on the highwall face is mainly shallow rilling, with deeper gullying restricted to the top 3 – 3.5m (scaled from the depth to the first bench). Apart from a couple of surface drainage lines, aerial photography does not show gullies cutting back behind the crest, and a 2:1 buffer (7m) is considered a conservative forecast of the band that might be significantly erosion-affected post-mining.

5.2.2 Endwall

Current stability

The northern endwall was located so that its toe ran along the coal thrust up by the Bullock Creek Fault. Probably associated with the fault, there were obvious joints and bedding, dipping steeply into the wall and striking roughly parallel to it (marked on Plate 5-3). It is the orientation of these structures sub-parallel to the wall face (parallel to the fault) that has allowed the toppling mechanism to develop in the endwall. By contrast the highwall is nearly perpendicular to these structures and so there is not the mechanism for blocks to topple out.

Observation from a safe set back could not provide sufficient data to warrant a quantitative analysis for toppling stability; however, the failed material has fallen to an angle of repose of about 37°, which is therefore the expected final slope angle, if toppling was the only mechanism causing instability.

Sliding stability was analysed for potential slips encompassing the whole slope, the weathered zone and the spoil dumped in front of the wall. The critical slip circles, indicated on Figure 5-4 produced factors of safety of 2.98, 1.85 and 1.48 respectively for a water table at the current void water level.

It was postulated, however, that the runoff capture drain behind the crest could produce a perched water table in the weathered overburden after prolonged wet weather. Figure 5-5 shows how such a water table would reduce stability in the weathered part of the wall; however, it would not on its own generate wall failures except in abnormally wet conditions. This confirmed that toppling was the driving mechanism for the instability observed to date.

Figure 5-4: Endwall Stability for Current Conditions

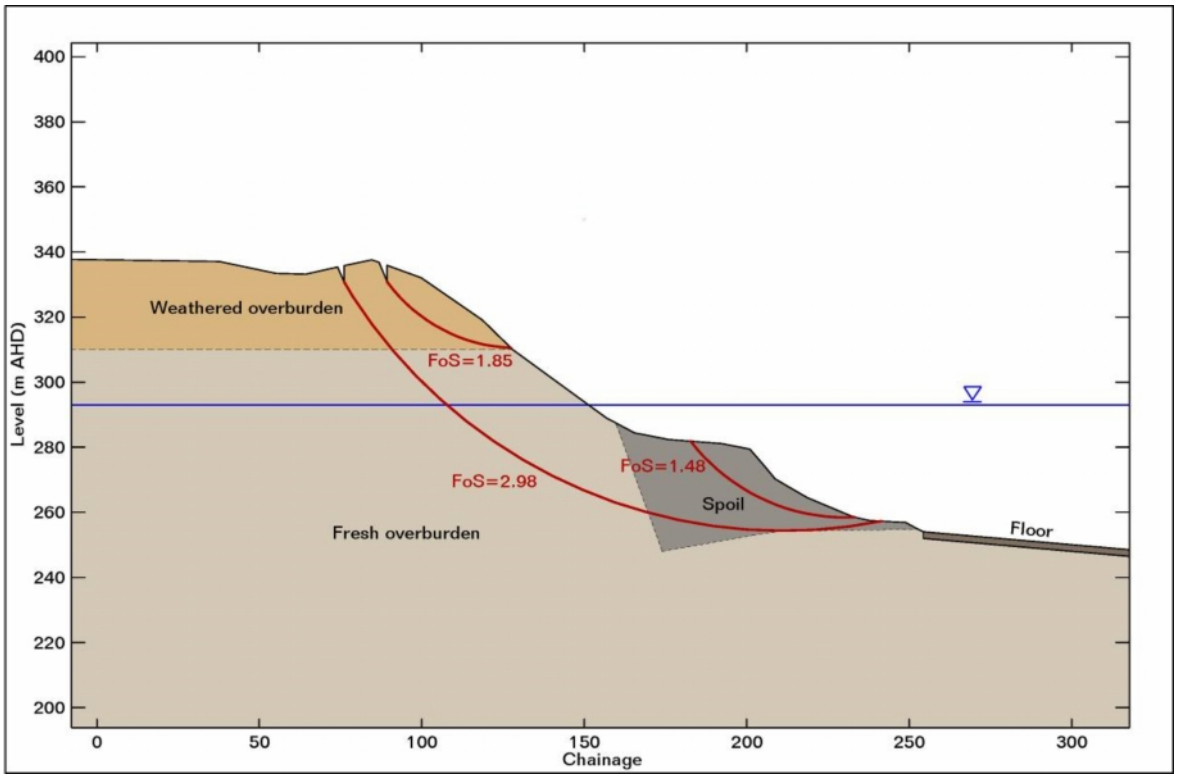
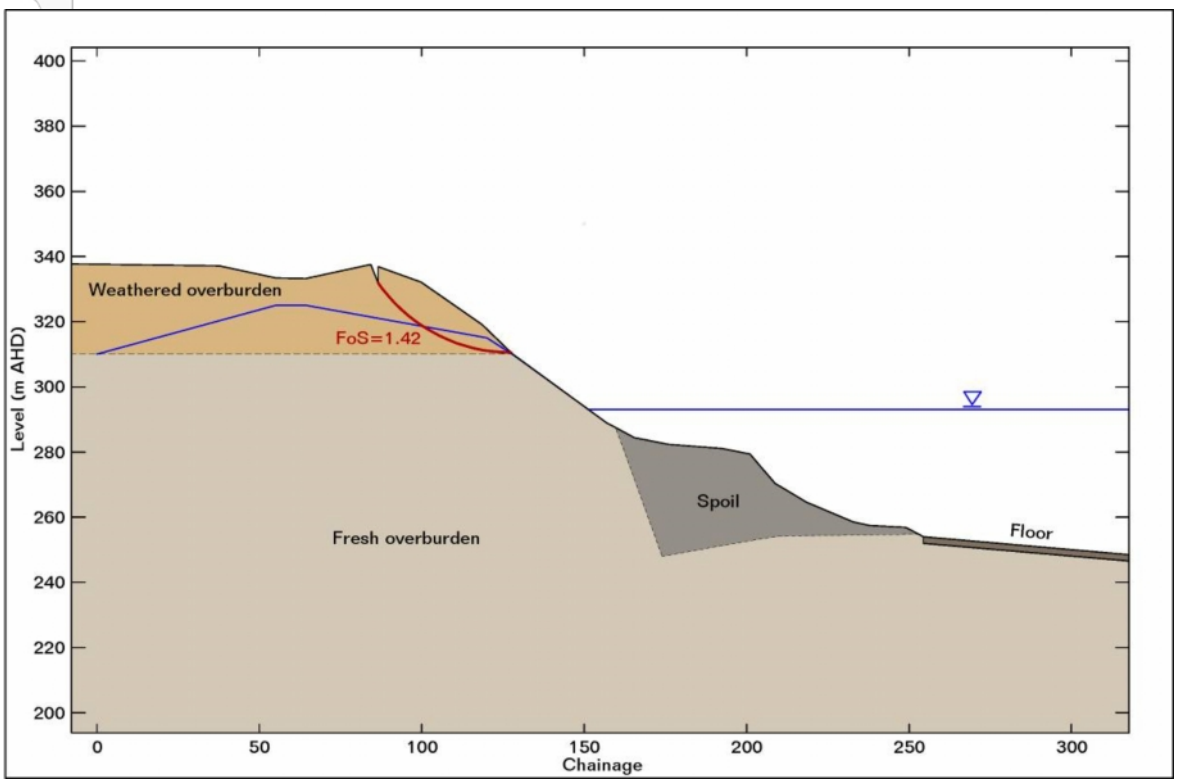


Figure 5-5: Endwall Stability with Perched Water Table



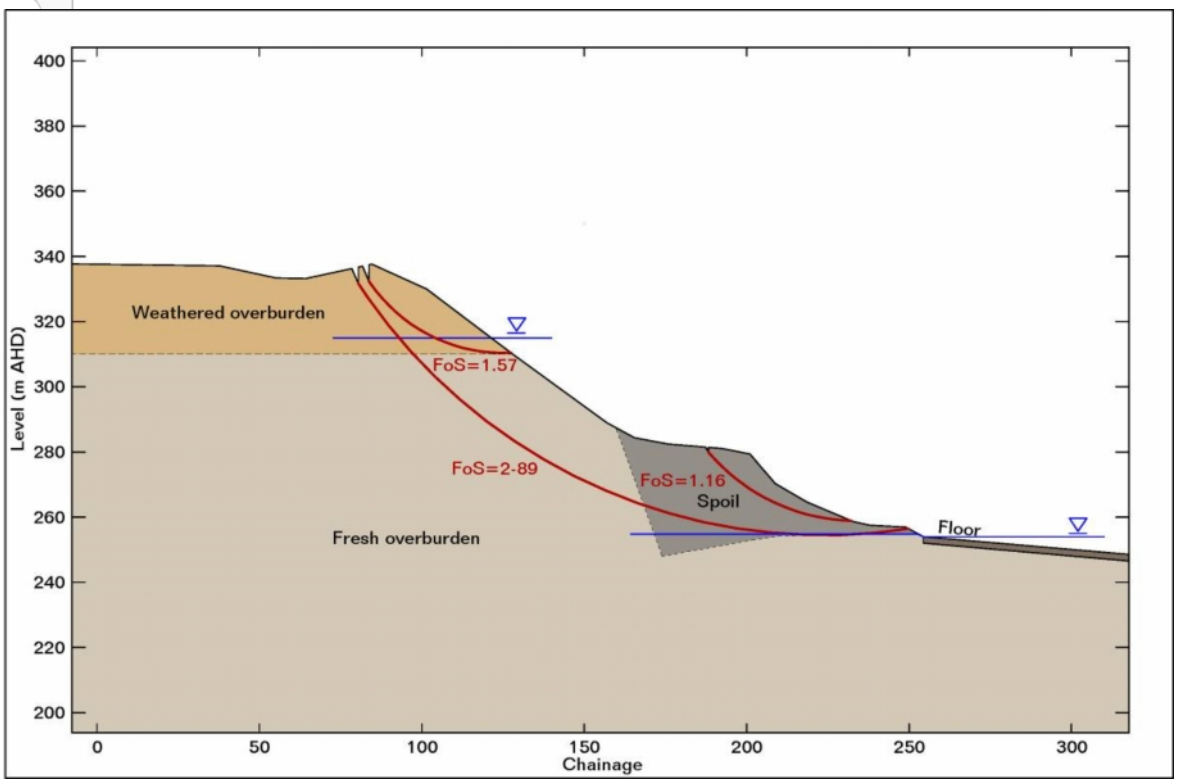
Long term stability

For assessment of long term stability, it was considered that the slope face above Base of Weathering had toppled back to a 37° angle. The two extremes of water condition were then analysed, namely with water stored to maximum life of mine level (RL 315m) and with the void essentially dry.

As discussed in Simmons & McManus 2004, the loss of strength that occurs in spoil when it is saturated is irreversible, that is, once it has been saturated the spoil stays at saturated strength even if it subsequently drains and dries. Therefore, as the void water level is already higher than the spoil, saturated strength properties were used.

As was the case for the highwall, and as summarised on Figure 5-6, the lowest factor of safety for the weathered bench occurred at maximum water level, while the lowest factors of safety for the whole wall and the spoil bench occurred with no water in the pit.

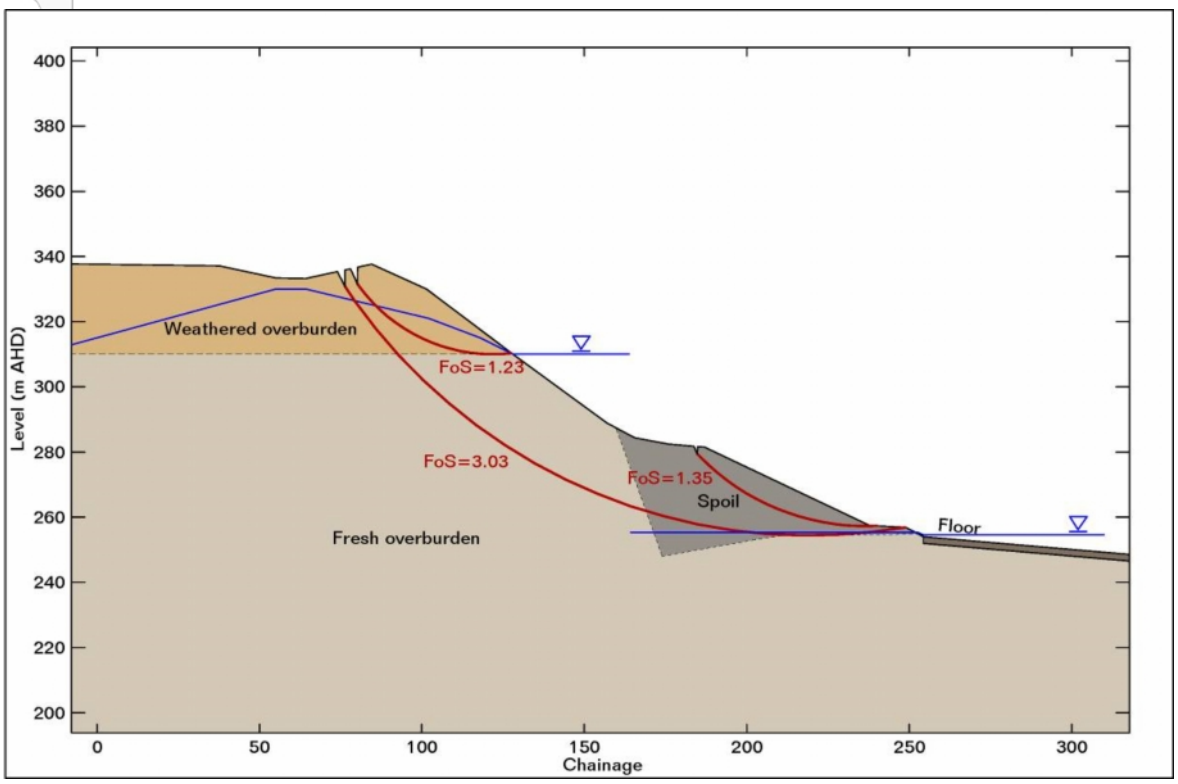
Figure 5-6: Endwall Stability for Worst Case Conditions with Current Geometry



Results for the spoil bench suggested that slip failure was likely for the current geometry; iterations of slope angle found that a batter of about 25° was required to meet the adopted criterion of Factor of Safety >1.2.

The impact of a perched water table in the weathered overburden, fed by flow in the runoff capture drain, was again considered, but for long term conditions the additional water was applied on top of the maximum pit water level. A scenario of 15m extra height of water below the drain would require prolonged severe wet weather but might be feasible, and the resultant analyses suggested likelihood of slip failure. The slope angle was again iterated and found to provide an acceptable outcome at 30°. Assuming that the slipped weathered overburden would fall over the spoil bench, the predicted final stable geometry and associated critical slip circles are shown on Figure 5-7.

Figure 5-7: Endwall Stability for Worst Case Conditions with Final Geometry



Erosion buffer

Because the top of the endwall has been unstable, there was no significant erosion observable on the face. Material in situ on the face appeared blocky (and therefore erosion resistant) from immediately below a shallow soil cover. There was shallow gully erosion behind the crest but this was associated with the runoff capture drain not the endwall. As it has already been considered that the endwall could fall back to 30° due to geomechanical instability, a nominal additional "potential erosion" band of 3m is proposed in this study.

5.2.3 Lowwall

Current stability

Following the Lox line (limit of oxidation) of the Upper Vermont seam, the boxcut was not linear but instead followed a broad arc around the south west, closing into three tight curves at the north-western corner. A bund was constructed along the crest to protect the pit from inflow from Bullock Creek that runs about 50m behind the boxcut.

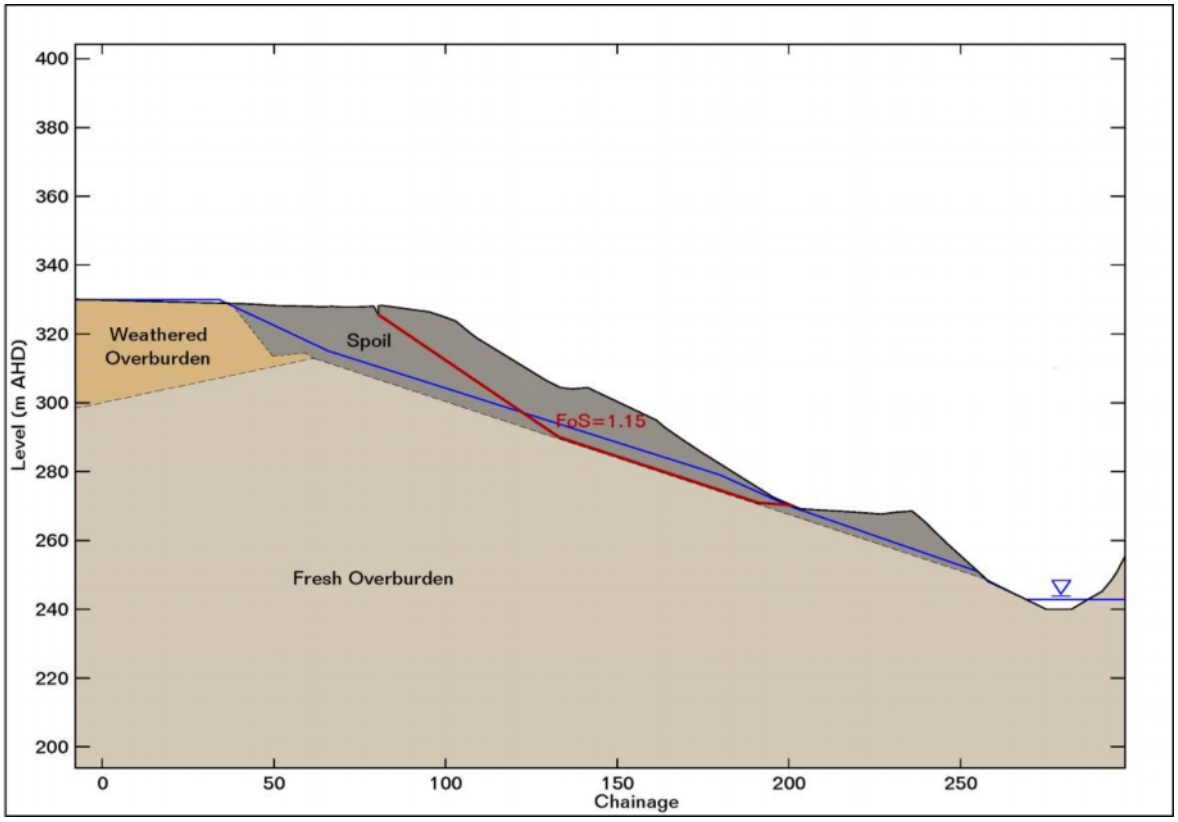
Two large slips have occurred in lowwall spoil in dumped in front of the box cut (points 2 and 3 on Plate 5-1). Both are located around natural surface drainage lines that were cut by the pit. Although the original surface flow was away from the pit, the bund was breached near point 2 (apparently due to overtopping in the large rainfall event in March 2012) and seepage into the pit would also be possible if surface water ponded in the gullies behind the levee.

From observations reported by Ward 2012, it was inferred that the slip at the north-western corner (point 2) was associated with the bund breach and subsequent inflow to the pit. Limited further movement has occurred since then but it is suspected that this is due to settlement in the spoil due to the rising water level in the pit rather than further slip failure.

At the larger slip (point 1) cracking was observed while the highwall was being auger mined, that is, while the pit was dry, but the first slip failure did not occur until the pit floor was inundated. Failure in the spoil continued during 2012 until it reached the excavated boxcut face but there was no obvious further movement from December 2012 to October 2013 despite the water level in the pit rising by more than ten metres.

Aerial survey and photography in May 2012 showed cracking around the main failure but not the large slip movement that subsequently occurred. Consequently, analyses of the cross-section taken from that survey should show it as stable under dry conditions but unstable after wetting. These were the results obtained, with a minimum Factor of Safety of 1.48 for the dry as-dumped spoil, and 1.15 for a scenario with a shallow temporary water table leading from ponding behind the bund, along the mined floor, and into the base of the pit (Figure 5-8).

Figure 5-8: Lowwall Instability Due to March 2012 Rainfall

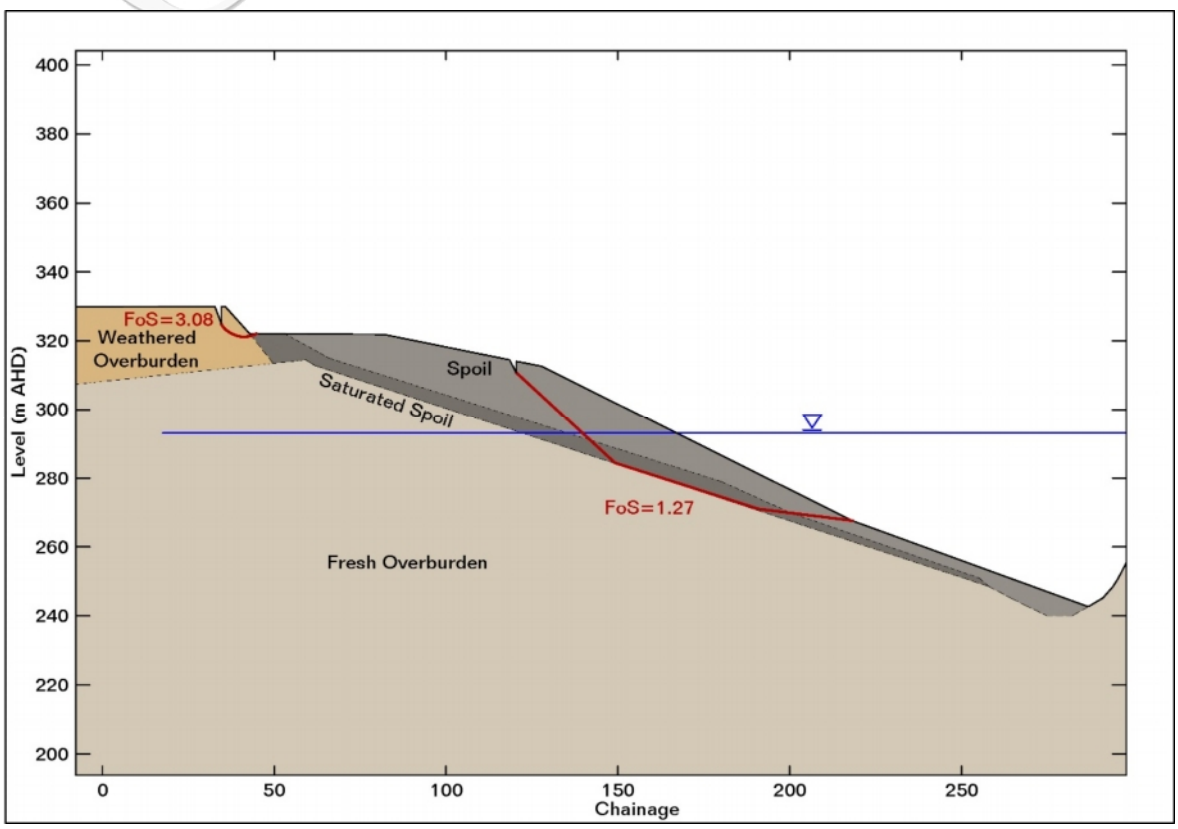


No subsequent survey of the fully-developed failure was available; however by considering rotation and slump about the critical slip surface, likely slip of the lowest spoil bench as the water level rose, and the scarp face apparent in Plate 5-4, a reasonable post-slip geometry was developed. Simmons & McManus (2004) notes that the loss of spoil strength that occurs upon saturation is largely permanent, so that part of the spoil was assigned saturated strength properties for all further analyses.

The consequent analyses for void water levels as at December 2012 and October 2013 showed that the slipped spoil slope had stabilised - Factor of Safety ≥ 1.2 - and that the rising water level had not adversely affected stability (Figure 5-9). This is not to say that there was no movement of the spoil during that ten month period, but that such movement would have been largely due to settlement of the spoil as it became saturated rather than to further geomechanical instability.

The scarp at the back of the slip exposed the excavated boxcut batter (Plate 5-4). Analysis demonstrated that it was geomechanically stable in its current dry condition.

Figure 5-9: Lowwall Stability for Current Geometry



Long term stability

Again stability was analysed for scenarios of maximum and minimum water levels, that is, for water storage at RL 315m and for no water.

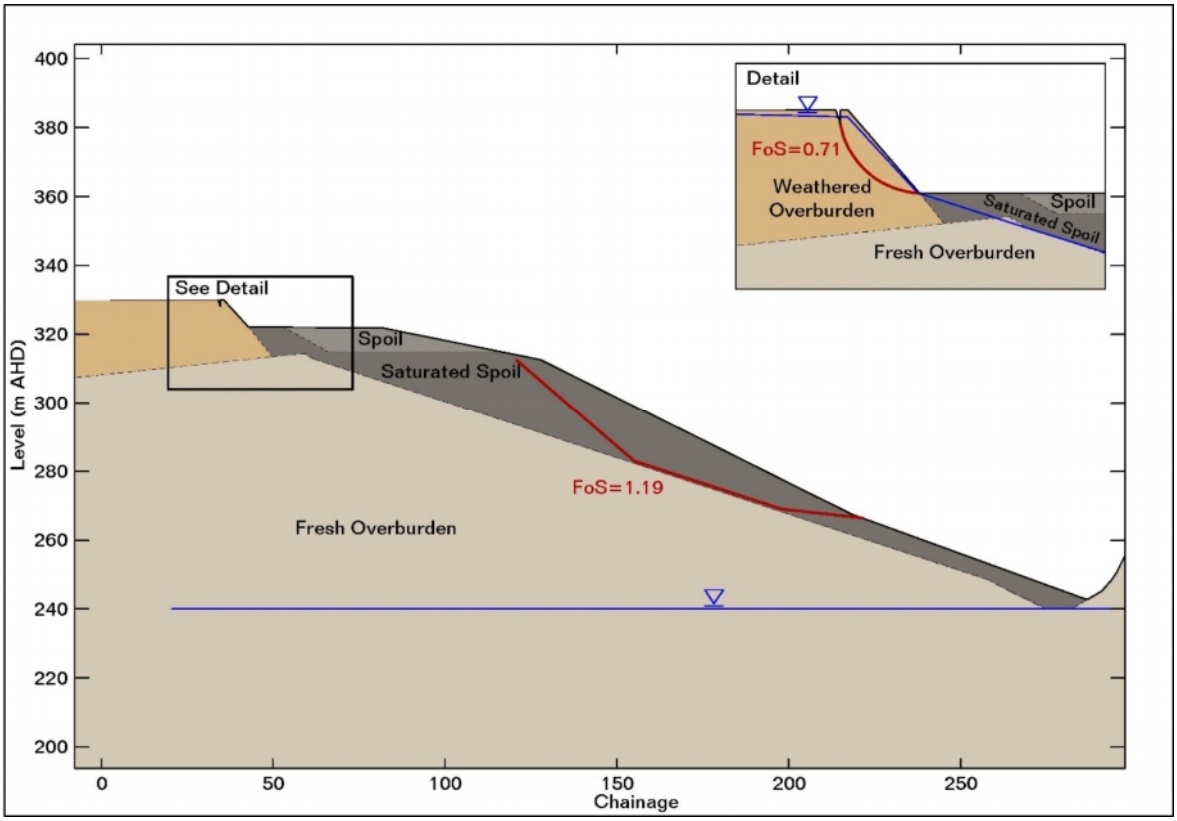
Once again, analyses showed that stability was not significantly impacted by an increased water level – the strength reduction due to saturation was apparently countered by the supporting effect of the weight of water.

Following the assertion in Simmons & McManus (2004), for the "dry" analysis it was assumed that all spoil below the previous maximum water level now had saturated strength. Unsurprisingly, there was a reduction in stability for this scenario, with the minimum Factor of Safety dropping below 1.2 (Figure 5-10). It is noted that this did not represent slope failure due to draw down conditions – it was caused by reduction in spoil strength not by any unequilibrated pore pressure. Two key points implied by the analytical results are that any

slips would tend to stabilise, by falling to a flatter slope angle; and that the slips would be contained well within the spoil and would not produce an increase in the void footprint.

Similar to the highwall and endwall, the worst case scenario for the exposed boxcut face – comprising weathered overburden - was a high water table caused by prolonged heavy rainfall and flooding in Bullock Creek. Under this condition the obtained Factor of Safety was <1.0 indicating that the scarp face would not be stable and slip failure would be likely. Survey was not available to confirm the actual scarp height but a 12m high scarped required a batter angle of 26.5° to meet the standard of FoS >1.2 for the extreme case of a water table at the surface. This is equivalent to a batter angle of 30° up from the base of weathering.

Figure 5-10: Lowwall Stability for Worst Case Conditions



In summary, the lowwall is considered stable under current conditions, largely because the slips that have occurred have resulted in a more stable geometry. Further slips are likely over the long term, caused by extremes of variation in water conditions. Any large slips will be confined to spoil contained within the pit, but there could be local instability in the exposed top of the boxcut.

Erosion buffer

Unlike the endwall, where observable erosion was restricted to the surface soil, in the year between inspections the scarp at the back of the lowwall slip has developed moderate gullying over the top 2-3 metres. That is, the depth of present erosion is similar to the highwall but the predicted long term batter slope is similar to the endwall, and consequently an erosion buffer of 5m – intermediate between the highwall and endwall predictions – is proposed for the lowwall.

5.3 Zone of Impact

Figure 5-12 summarises outcomes of the pit stability analyses, as current and stable long term cross-sections. In the case of Bullock Void the predicted changes are relatively minor because there have already been significant slips that shifted wall material into more stable geometries. The area expected to be affected by erosion is also limited, because the weathered Permian overburden does not appear to be particularly erodible.

Interpreting the results in plan, the change in void footprint from current to long term is shown on Figure 5-12. Both the runoff capture drain, where it passes behind the endwall, and the Bullock Creek bund are within the margin that could be impacted by future pit instability. It should be noted that "long term" includes the remainder of the life-of-mine and that potential changes in water level under the mine water management system produced the critical cases for wall stability analysis. This means that protection of the drain and bund, for example by relocation, needs to be addressed for the operating mine not just as part of mine closure.

Figure 5-11: Comparison of Current and Long Term Wall Profiles

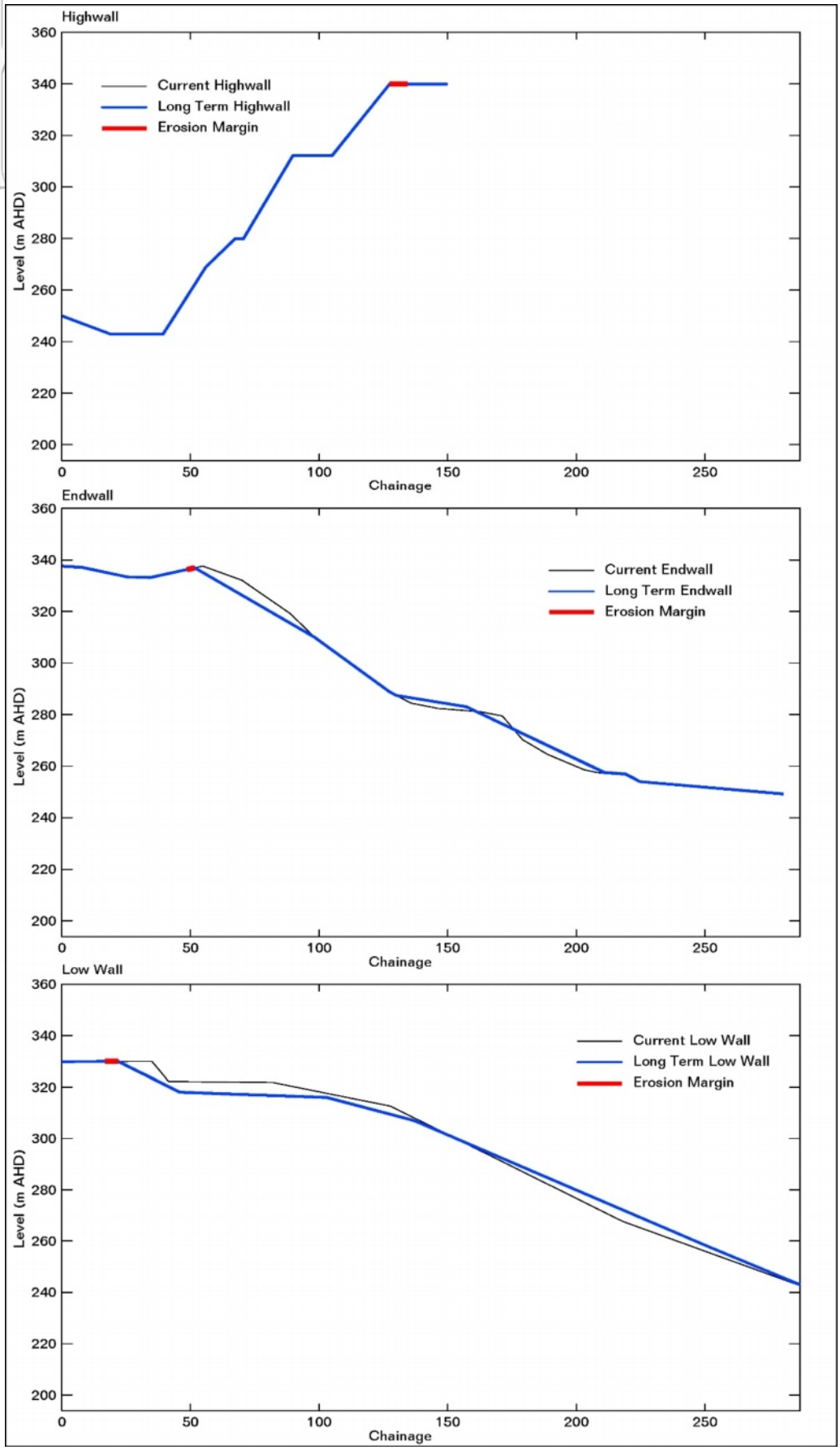


Figure 5-12: Final Void Footprint



6. PLUMTREE VOID

The northern half of the pit was backfilled as mining progressed. At the south, spoil was dumped against the western boxcut but did not reach to the highwall, leaving a 1.5km long void (. Seams dipped at about 18° to the east, resulting in a steep pit floor. After the main mining operation the pit was extended southward past faulting running across the pit; however the area was not mined to completion leaving a section of highwall blasted but not removed. About 2,400ML has been pumped to the void since the end of mining, to a depth of about 35m.

Plate 6-1: Plumtree Void, September 2013



6.1 Current Observations

The void has been inspected annually since 2012. The most notable feature throughout has been large scale instability in the lowwall. A large slip area at the northern end of the remaining void (Plate 6-1, point 1) commenced as mining proceeded through that section. Ward (2012) attributed the instability to undercutting of steep bedding in the pit floor. Initially

failure occurred into the boxcut crest; subsequent spoil dumping in pit buttressed the boxcut somewhat but slips then occurred in the spoil lowwall. Similar instability occurred toward the southern end of the void, again contributed to by the steep floor dip but exacerbated by faulting (Plate 6-1, point 2 and Plate 6-2). No large new slips were noted between 2013 and 2014 but there had been movement on old cracks and scarps. Similar to the situation for Bullock Void, water in the void was not a primary cause of instability but the consequent saturation of in-pit spoil could contribute to later slips.

The exposed highwall was stable over most of its length, except in an area where major faulting intersected the highwall (Plate 6-1, point 3 and Plate 6-3). The main slip occurred before the end of mining; there had been little obvious movement since then, however the back-scarp was steep and might continue to cut back over time. At the southern end of the void part of the highwall had been blasted but not excavated – presumably mining stopped because of the ongoing lowwall instability.

The southern endwall was benched below the base of weathering, and showed the steep dip of the coal measure bedding (Plate 6-4). There was no apparent structural instability but loose material had fallen from the face and this was likely to continue.

Plate 6-2: Plumtree Void lowwall



Plate 6-3: Plumtree Void highwall



Plate 6-4: Plumtree Void southern endwall



6.2 Stability Analyses

Two cross-sections through the previous slips were taken for consideration of stability analysis. The designed pit (pit shell) and May 2012 surface topography were overlaid, then nearby drillhole logs were projected onto the sections to produce preliminary geotechnical profiles. Approximate slip surfaces were interpreted from the back-scarps revealed in the topography and material in front of those was assumed to be effectively spoil. The resultant profiles for stability analyses are show in Figure 6-1.

The southern endwall of Plumtree Void is about 1.2km north of the Bullock Void boxcut. The pits had essentially the same stratigraphy, but vertically offset due to the Bullock Creek Fault lying between. The highwalls are visually similar, supporting use of the same strength properties as adopted for Bullock Void.

However, the exposed boxcut scarp and spoil/slipped material in Plumtree void appeared to be more clayey. The significant proportion of very light material suggested more intensive weathering and leaching, which would be consistent with faulting along the boxcut. Properties conservatively adopted for weathered overburden – equivalent to residual clay – remained appropriate but those for spoil were changed to reflect a more clayey, moisture-sensitive material.

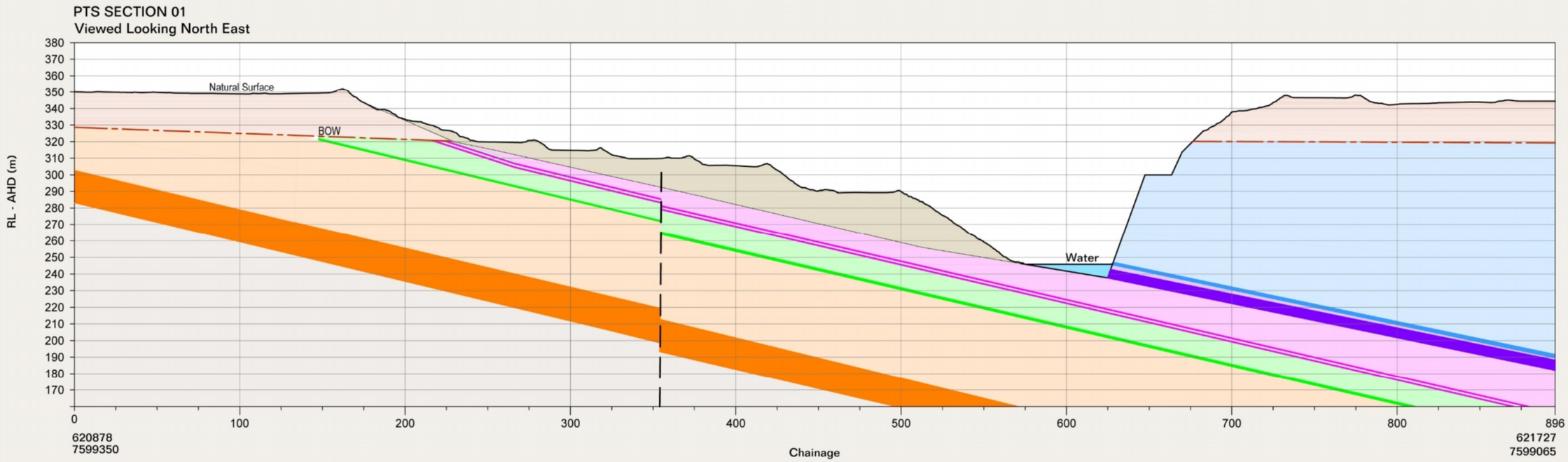
Table 6-1: Plumtree Void Adopted Strength Properties

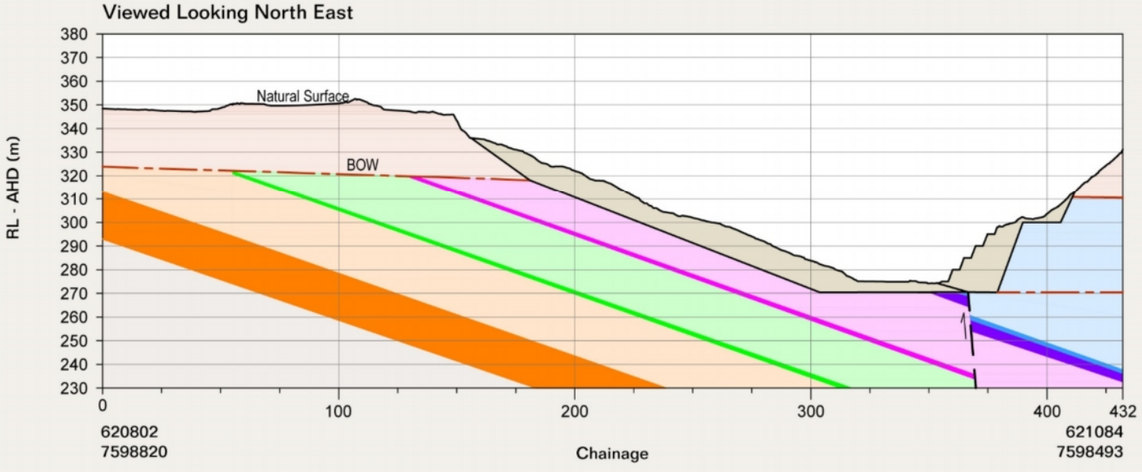
	Initial Condition			After Saturation		
	cohesion c' (kPa)	friction ϕ (°)	weight (kN/m^3)	cohesion c' (kPa)	friction ϕ (°)	weight (kN/m^3)
Clayey spoil (category 1)[3]	20	25	18	0	18	20
Weathered overburden[4]	50	30	20	15	30	20
Fresh overburden[2]	450	42	24	450	42	24
Coal[2]	30	35	15	30	35	15
Fault zone[2]	0	15	20	0	15	20

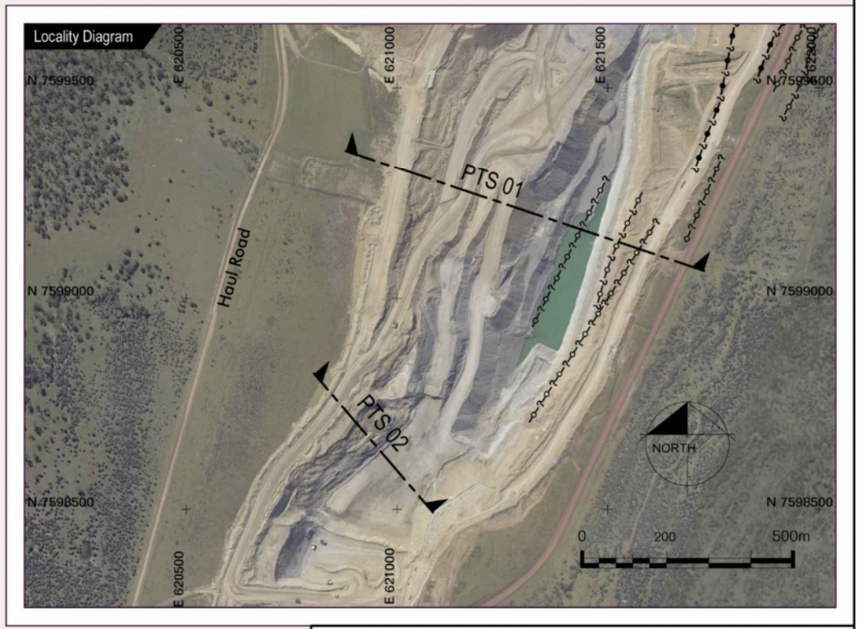
Based on water balance modelling (WRM 2012), the water level in the final void is expected to range between RL 282m and RL 301m. The water level was at RL 249m at the time of the topographical survey (May 2012) and had risen to RL 281m by October 2014. It is intended to continue to use the void for water storage during the remaining life of mine and the maximum operating level has been set at RL 300m – 5m below the bed level in nearby Sandy Creek. The critical water level (and saturation level) assumed for pit stability was therefore RL 301m.

[3] Simmons & McManus, 2004
[4] GeoTek Solutions, 2015

Figure 6-1: Plumtree Void Cross Sections







LEGEND

- Burton Rider
- Upper Vermont
- Middle Vermont
- Lower Vermont
- Girrah
- Fault
- Base of Weathering
- Section Location
- Possible Dyke - approximate position
- Possible Dyke - inferred position

Scale 1 : 2500

0 25 50 75m

V/H = 1:1

BURTON

henderson geotech

Dsg/Chk:	S. Henderson	15.02.13
Drawn:	RACAD	15.02.13
Cad File:	HGO_PEB01S_06.dwg	

Plumtree South Sections

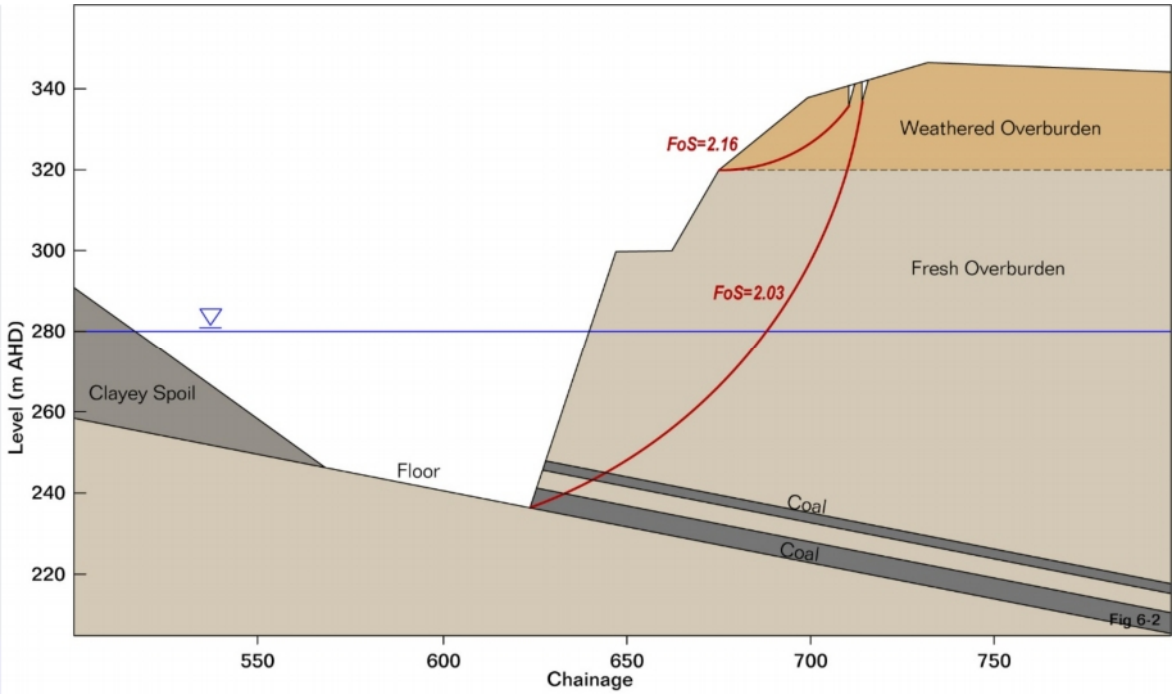
Figure

6.2.1 Highwall

Current stability

Analyses for the normal highwall profile (PTS-01) were consistent with the observation of stability under current conditions, with minimum Factors of Safety of 2.03 for slips encompassing the whole wall and 2.16 for slips confined to the upper bench of weathered overburden (refer Figure 6-2). At the blasted but unmined section (PTS-02) loose fragments are likely to slip into the pit over time but the underlying intact faces would be similarly stable. The faulted section was not separately analysed, but had not moved significantly in the past year.

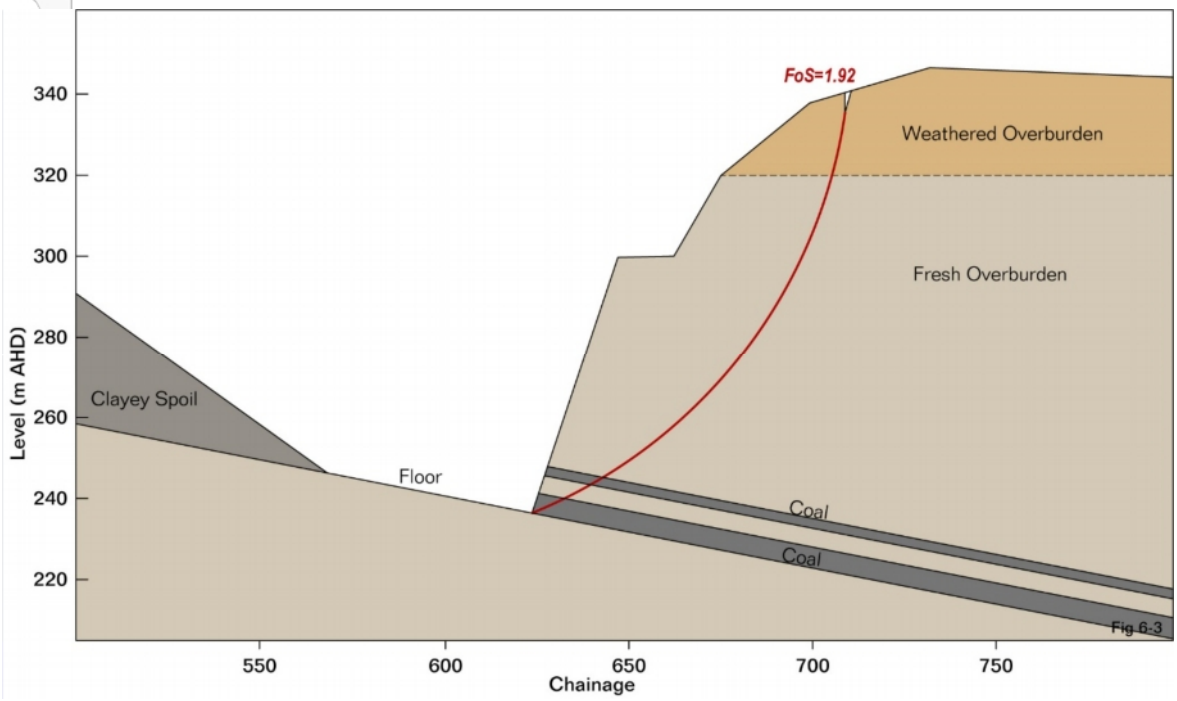
Figure 6-2: Highwall Stability for Current Conditions



Long term stability

Once again for the highwall, the condition with the lowest factor of safety was a dry void (FoS = 1.92, refer Figure 6-3). As the maximum water level was below the Base of Weathering, the minimum factor of safety for the weathered zone was the same as for current conditions. The faulted section was not separately analysed; Ward (2014) suggested that further large slippage was unlikely but that the back-scarp could cut back further. Based on stability analyses for Bullock Creek weathered overburden, a 30° batter projected up from the Base of Weathering would accommodate any such geomechanical degradation. The actual wall crest, behind the slip scarp, is already at that projected stable slope line.

Figure 6-3: Highwall Stability for Worst-Case Conditions



Erosion Buffer

The depth of moderate gullying, estimated by scaling photographs against an average weathering depth of 25m, was about 5m. Aerial photography of the older section of exposed highwall at the northern end of the remaining void showed a couple of significant drainage lines but otherwise just a few gullies extending 5-7m behind the crest. Consequently, a 10m erosion margin is proposed for Plumtree Void highwall. It is noted however that headcuts on drainage lines, at both Bullock and Plumtree Voids, could work back some distance behind the wall crest, highlighting the need to consider highwall catchment management within detailed design for closure.

6.2.2 Endwall

Ward (2012) described the endwall as showing no structural disturbance and not being considered at risk of geotechnical instability. As the rockmass profile and properties are essentially the same as for the highwall, and stability analyses have demonstrated long term stability for the highwall, the endwall was not separately analysed.

Based on 2012 and 2013 aerial photography, erosion behind the endwall crest was less noticeable than that on the highwall. However, the same 10m erosion margin was adopted.

6.2.3 Lowwall

Section 01 current stability

The lowwall at Section 01 was stable under conditions in place when the 2012 topography was surveyed. As shown in Figure 6-4, and as anticipated, the minimum factor of safety occurred at the front of the in-pit spoil. As water in the void was raised toward the current

level, that critical slip surface became unstable. A slipped face profile was estimated and the revised geometry was stable for water up to the current level of RL 281m (refer Figure 6-5).

Figure 6-4: Section 01 Lowwall Instability due to Rising Water Level 2012-14

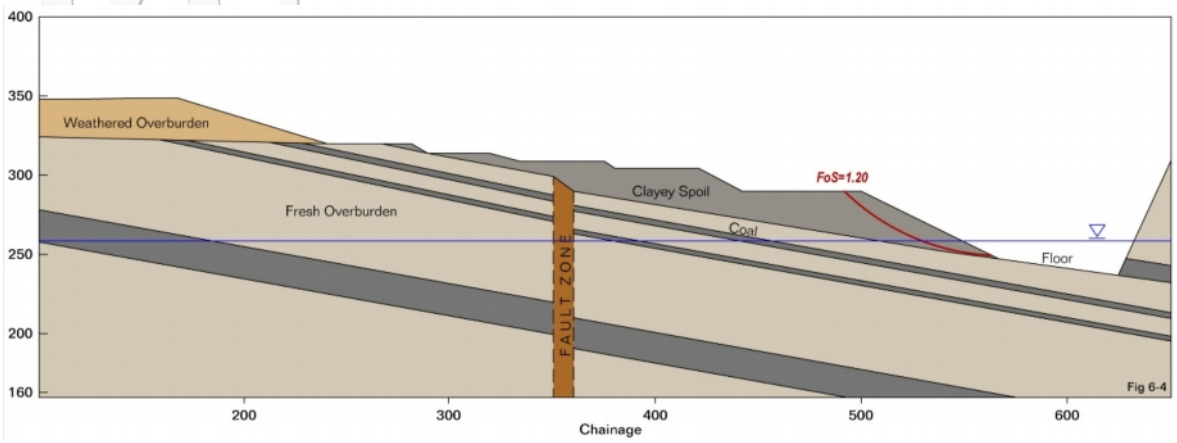
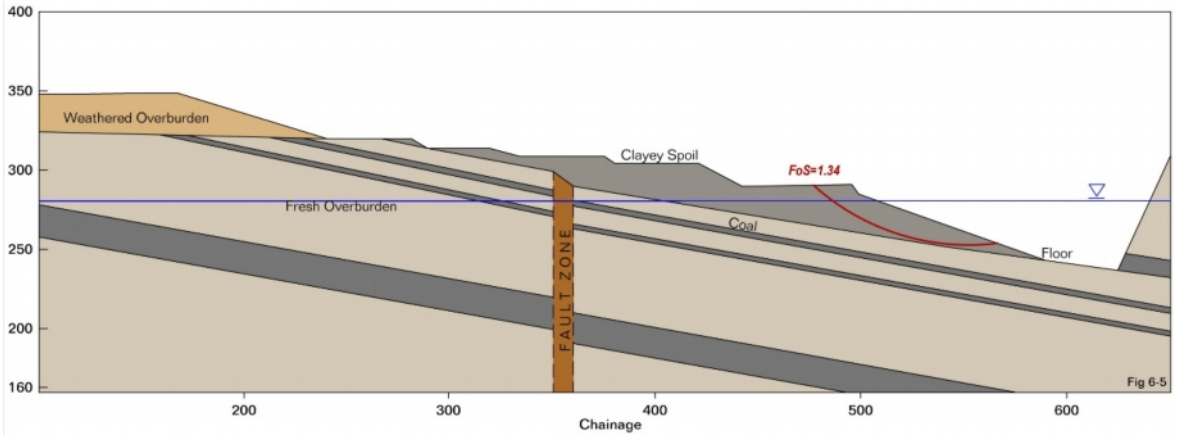


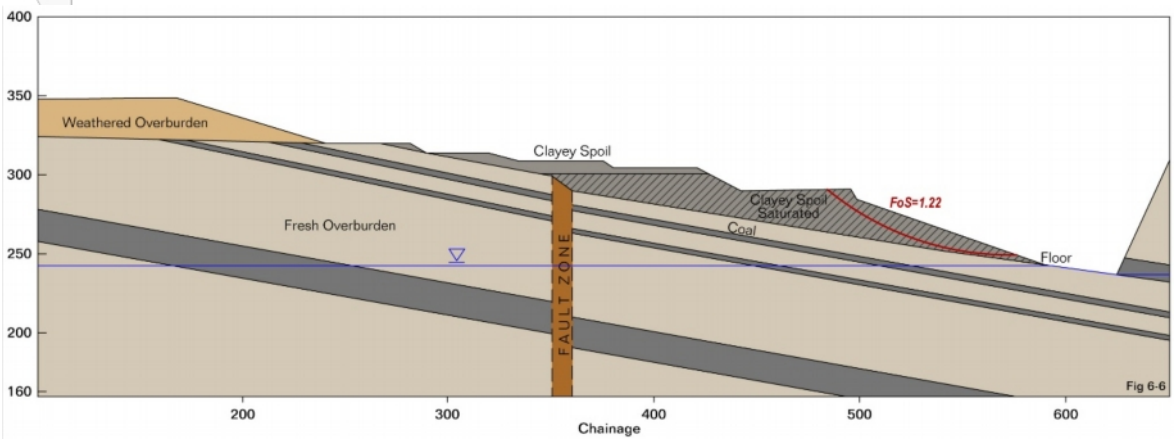
Figure 6-5: Section 01 Lowwall Stability for Current Configuration



Section 01 long term stability

Further analyses showed the lowwall at Section 01 as stable as the water was raised to the predicted operational and long term maximum of RL 301m. As was the case for Bullock Creek Void, the buttressing effect of the water more than countered the strength reduction due to saturation of the spoil. The worst case for stability, but still with an acceptable minimum factor of safety, was again if the void was pumped dry during its operational life as a water storage, leaving spoil up to the previous maximum water level with reduced strength properties (refer Figure 6-6).

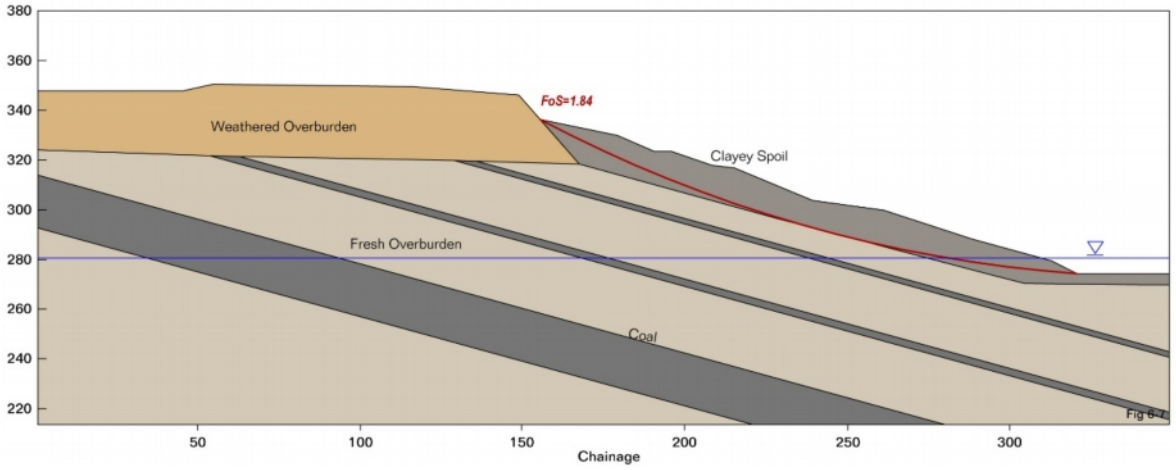
Figure 6-6: Section 01 Lowwall Stability for Worst Case Conditions



Section 02 current stability

Analyses showed the lowwall at Section 02 to be stable with the water level as at the time of the 2012 topographical survey and at the current higher water level (refer Figure 6-7). This is consistent with the observation of no recent new slips; movement along pre-existing surfaces would be related to the settlement that typically occurs when spoil is saturated for the first time.

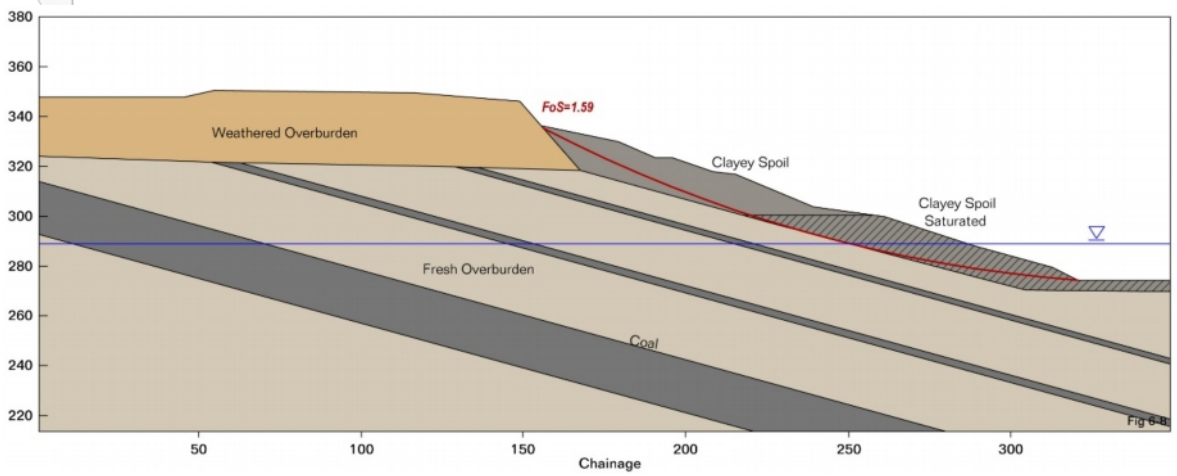
Figure 6-7: Section 02 Lowwall Stability for Current Conditions



Section 2 long term stability

As the void water level was increased to the predicted post-mining maximum, the factor of safety decreased to 1.61. Subsequently lowering the water level only slightly the reduced factor of safety, to a minimum of 1.57 for water levels around RL 290m (refer Figure 6-8). Both wetting to maximum and subsequent dewatering could occur both during the void's use as an operational water storage and as cyclic variation in the long term after mining.

Figure 6-8: Section 02 Lowwall Stability for Worst Case Conditions



To summarise, the lowwall is expected to be essentially stable into the future, because it has already slipped to a more stable geometry. Some further scarping may occur as the rising void water level causes in-pit spoil to saturate and settle but no significant regression of the current wall crest is anticipated.

Erosion buffer

At present, erosion does not extend behind the lowwall crest, mainly because the access road along the crest and its adjacent safety bunds direct rainfall runoff southward along the road rather than eastward over the lowwall. There is erosion at the southern end of the road where it ramps down into the pit but there is no indication or reason for it to work back past the current disturbance footprint, which is marked by the toe of the outer road bund. It is expected that there would be some re-contouring and revegetation of the access road prior to mine closure but as long as this did not greatly change the surface drainage pattern, erosion should continue to be limited to the present cleared area.

6.3 Zone of Impact

Figure 6-9 summarises the stability assessment for Plumtree Void as stable long term cross-sections overlaid on current sections. Similar to Bullock Void, the expected changes are small, partly because previous slips have already created more stable geometry. As the weathered overburden has not shown to be severely erodible, the potentially affected margin is expected to be quite narrow behind the highwall and endwall. As discussed in the previous section, a conservative wider buffer has been allowed along the lowwall covering the area that has already been stripped and disturbed.

Figure 6-10 illustrates the results in plan and shows that there are no assets or areas of significant value within the likely footprint of the post-mining void. Other considerations such as safety and surface drainage may dictate a need for other works or buffers, but from a stability perspective the final void would have minimal additional long term impact.

Figure 6-9: Comparison of Current and Long Term Wall Profiles

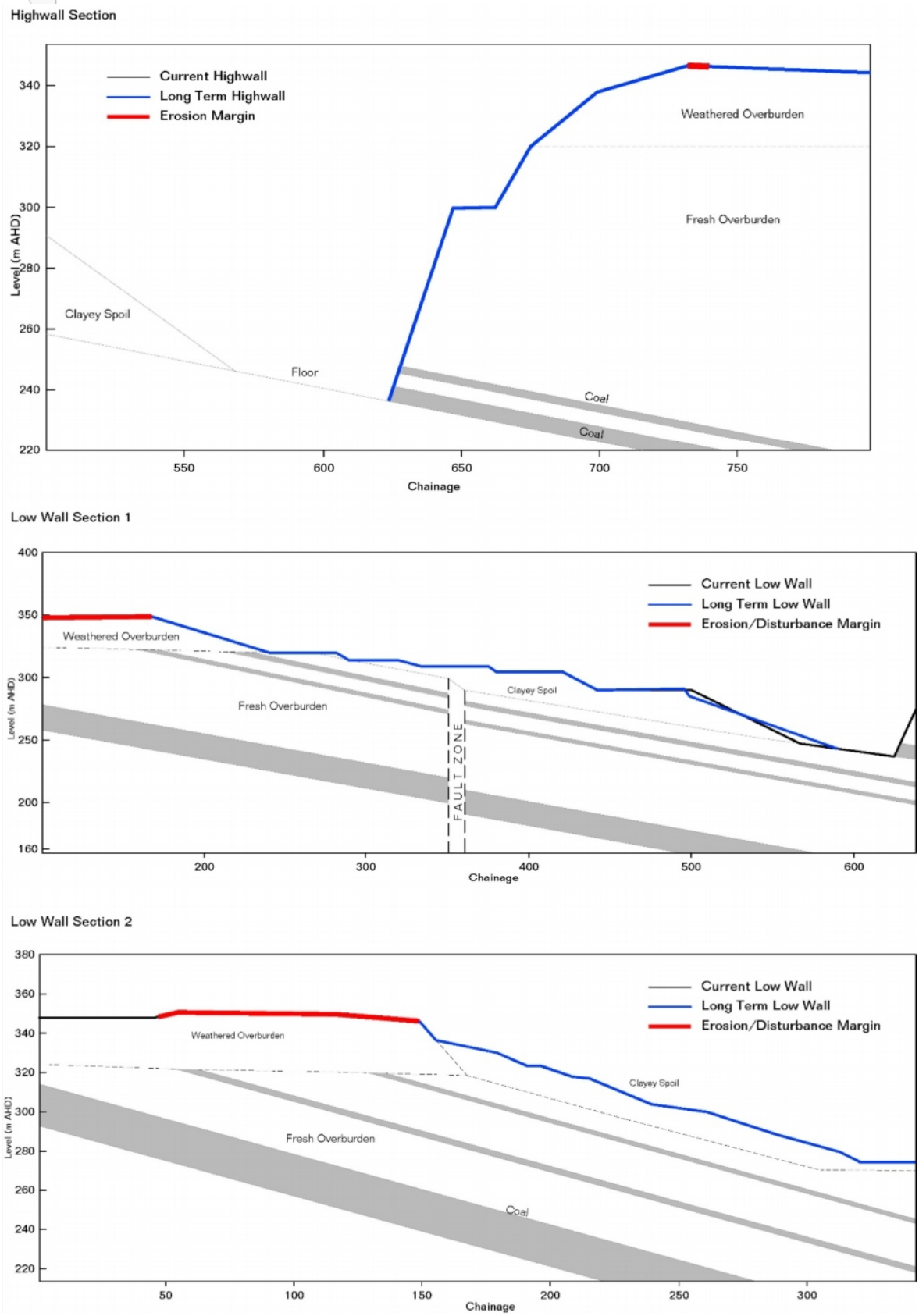
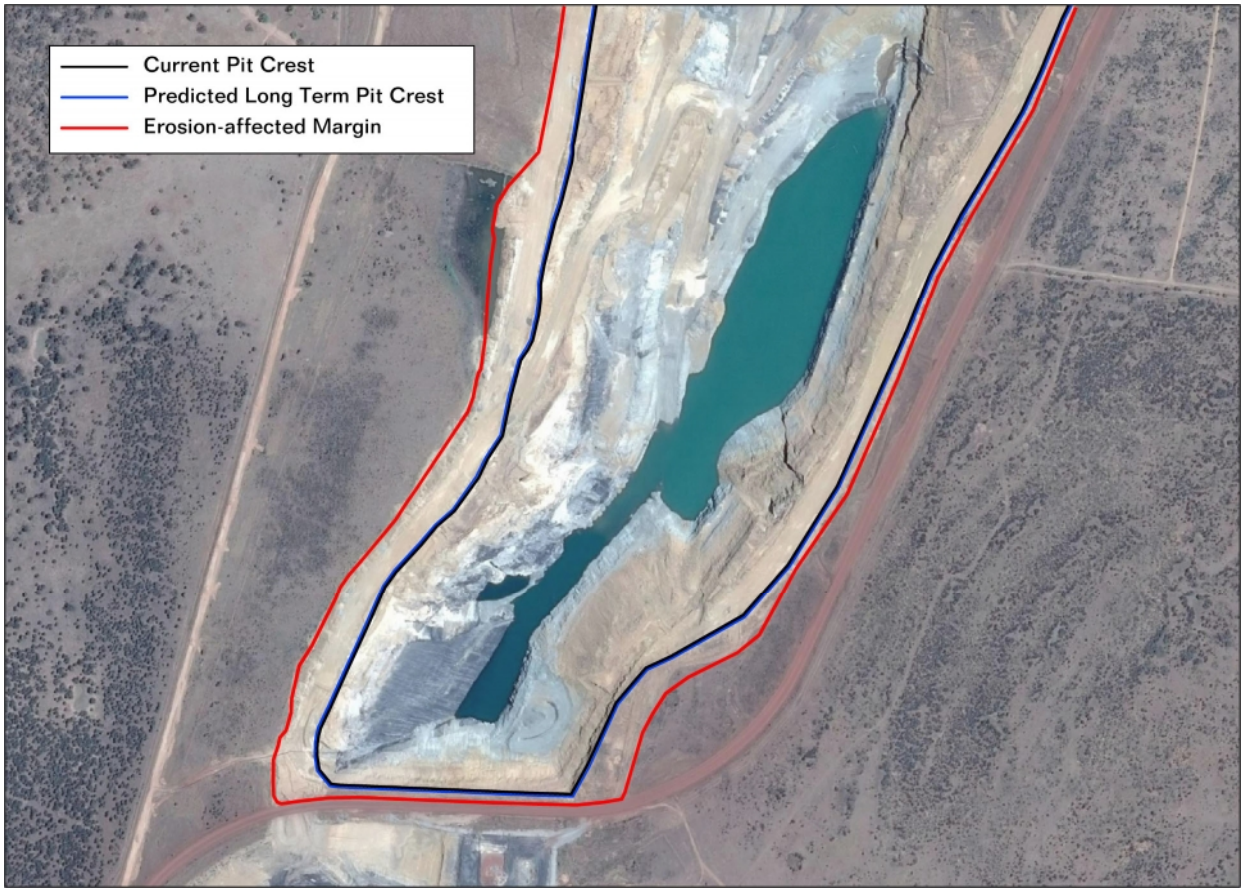


Figure 6-10: Final Void Footprint



7. LIMITATIONS AND FURTHER MONITORING

This study of pit wall stability for Bullock Void was based on geological information from the exploration drilling program. No shear strength and erodibility test results specific to this pit were available and no record of any geological mapping undertaken during mining was provided. The survey data used for wall cross-sections was from a May 2012 flyover but parts of the lowwall and endwall have moved since then.

In this context, the study should be seen as a first assessment, to be revised and refined based on future monitoring. As initial work, a bathymetric survey and a new aerial survey should be undertaken to establish the current topography. Subsequently there should be:

1. Continual water level measurement while the void is being actively used in the water management system and at least monthly measurement if the void becomes simply a passive storage.
2. Annual aerial survey, ideally during the dry season, including interpretation as topographic contours.
3. Annual inspection and photographs, ideally from the same location on the north-western access.
4. Assessment of changes in wall profiles and erosion, over the past year and over the entire monitoring period, and of whether the monitoring interval remains appropriate.

As a regulated structure, the Environmental Authority requires annual "actual observation….of accumulated sediment" to assess adequacy of available storage as for the annual inspection, so there is already a compliance requirement for similar data. The regulated structure's inspection could be expanded to include the foregoing assessment.

However, review of the void stability study in total would be a separate undertaking from any regulated structures' annual inspection and report. It is suggested that this review should be made in five years or at least one year before the planned end of operations (whichever is sooner) and earlier if any more major slip failures occur.

Finally, it should be noted that this study has assumed no intervention to improve pit wall stability, other than any works necessary to prevent future inundation by surface flows (for example, repair or replacement of the breached levee). The mine operator could decide to implement some remedial measures now – most obviously, place additional spoil to cover and buttress the boxcut scarp; in this case this stability study could be revised to provide an amended final void footprint.

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Appendix K

Geotechnical assessment of Bullock Creek pit final void



PEABODY ENERGY AUSTRALIA

GEOTECHNICAL ASSESSMENT OF

BULLOCK CREEK PIT FINAL VOID FOR

REHABILITATION PURPOSES

Report No. gts21324-1
December 2013

GeoTek Solutions Pty Ltd
ABN 84 090 367 409

PEABODY ENERGY AUSTRALIA

GEOTECHNICAL ASSESSMENT OF BULLOCK CREEK PIT FINAL VOID FOR REHABILITATION PURPOSES

GeoTek Solutions Pty Ltd
Report No. gts21324-1
December 2013

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Table 2: Acronyms and Abbreviations.

Code	Description
AS	Australian Standard
BPEM	Best Practice Environmental Management (in Mining)
BOW	Base of weathering
BOM	Bureau of Meteorology
c, ϕ	Mohr-Coulomb shear strength parameters - cohesion and friction
DEHP	Queensland Department of Environment and Heritage Protection
FCCM	Fort Cooper Coal Measures
FOS	Factor of safety
GCS	Geotechnical Consulting Services Pty Ltd (Barry Ward)
GTS	GeoTek Solutions Pty Ltd
HG	Henderson Geotechnics
MBGS	McElroy Bryan Geological Services Pty Ltd
HWM	Highwall mining
RCM	Rangal Coal Measures
UCS	Uniaxial compressive strength
XS	Cross section

BULLOCK CREEK

1 INTRODUCTION

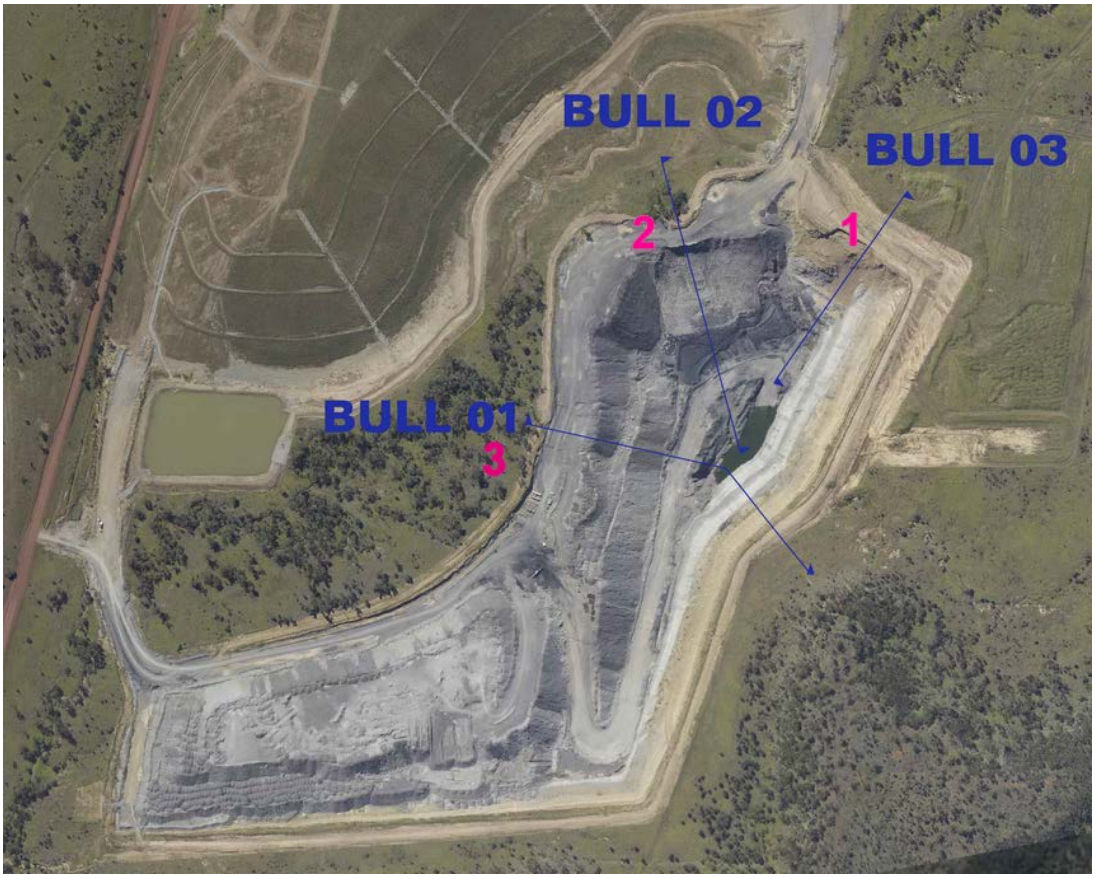
Open cut mining was completed in October 2011 at a maximum pit depth of about 100m. The floor dips at 10-14° toward the eastern highwall. In-pit spoil dumps have completely filled the western limb of the pit and the eastern limb has had spoil placed against the western lowwall. The ramp into the eastern limb entered from the south, along the highwall (Figure 1). Bullock Creek has been diverted about 50 m behind the low wall but the associated flood protection bund was constructed at the crest of the lowwall. A drain to take runoff from undisturbed land into the creek was constructed close behind the northern endwall. The highwall was auger mined from December 2011 to March 2012. Auger mining ceased when the pit was inundated following a severe rainstorm.

There are 3 main areas of geotechnical concern in relation to final void rehabilitation. These are identified in Figure 1 as:

1. Northern endwall failure (Figure 1, Locn 1)
2. Endwall spoil slump (Figure 1, Locn 2)
3. Lowwall failure (Figure 1, Locn 3).

Cross sections have been cut at the locations shown in Figure 1. They have been analysed for stability using 2D limit equilibrium methods in the program Galena (Clover Technology, 2013) and the results are reported and discussed below. The shear strength values used in the analyses are based on extensive prior experience in the Bowen Basin and with reference to Simmons and McManus (2004).

Figure 1: Bullock Creek void, May 2012.



1.1.1 Stability Analysis

Because there is only a very thin veneer of soil, the wall is comprised of intact rock and there are no unfavourably orientated structures, no stability analysis is merited on the basis of the available information.

2 OBSERVATIONS, ANALYSIS AND RECOMMENDATIONS

Barry Ward inspected the void in October 2012 (GCS, 2012) and Sue Henderson inspected it in October 2013 (HG pers. comm., 2012). The purpose of these inspections was to make geotechnical observations and provide preliminary recommendations in relation to final rehabilitation. GCS (2012) reported pit wall angles that were steeper than the original pit shell and this may have resulted in reduced pit wall stability, particularly in the upper, weathered horizons.

The floor of the pit mostly consists of Upper Vermont immediate floor. The Lower Vermont which contains an often puggy, tuffaceous claystone band (Yarrabee Tuff equivalent?) and slickensides in the middle of the plies is many metres below the pit floor (MBGS, 2007) and consequently, has not impacted this pit.

Since the cessation of auger mining, the pit has been used to store water. The current water level is reported to be at approximately RL270 m. This is noticeably higher than immediately after the March inundation event and approximates to the mean design level of water in the final void (Henderson, pers. comm, 2013). Nevertheless, it is possible that the pit will be filled with water to a level of RL315 m when being used as a temporary storage.

Each of the cross sections shown in Figure 1 was analysed to calculate the Factor of Safety (FOS) using mainly the Bishop multiple circle 2D limit equilibrium method as implemented in the program Galena (Clover Technology, 2013).

The shear strength values used in all of the analyses are shown in Table 3. In the absence of any other data, they are the well established values published by Simmons and McManus (2004).

Table 3: Shear strength properties used in stability analyses.

Material	c' (kPa)	φ' (deg)	γ (kN/m^3)
Cat 2U spoil	30	28	18
Cat 2S spoil	15	23	20
Soil U in situ	50	30	20
Soil S in situ	15	30	20
Fr rock	450	42	24
Fr coal	30	35	15
U = unsaturated			
S = saturated			

A unique feature of Galena is that both unsaturated and saturated shear strength values can be specified for an individual material and Galena will assign the appropriate values in an analysis depending on whether a material is above or below the phreatic surface. This capability has been used in the analyses carried out for this report.

Everything above the base of weathering (BOW) has been assigned shear strengths for in situ soil, as shown in Table 3. This is somewhat conservative, but it means that the weathered horizon strength is not overestimated.

2.1 Highwall

The highwall was exposed from just above the lower bench and was generally stable and a view of it is shown in Figure 2. The fresh sedimentary strata showed signs of minor fretting , evidenced by the small cones of scree just above the water line. The weathered strata has similarly fretted and, in addition showed signs of rilling along the crest within the veneer of surficial soil.

Figure 2: Bullock Creek void highwall.



2.1.1 Recommendations

No recommendations are made for the highwall. It is considered to be adequately stable.

2.2 North-Eastern Endwall (Locn 1, XS BULL03)

The north-eastern endwall (Figure 1, Locn 1) has suffered major and progressive failure (Figure 3). GCS (2012) identified the mechanism as toppling within the weathered zone and expected it to continue until a slope angle of about 35° is achieved. This would destroy the clean water drain behind the endwall. In December 2012 cracking, parallel with the wall, was already present at the side of the drain.

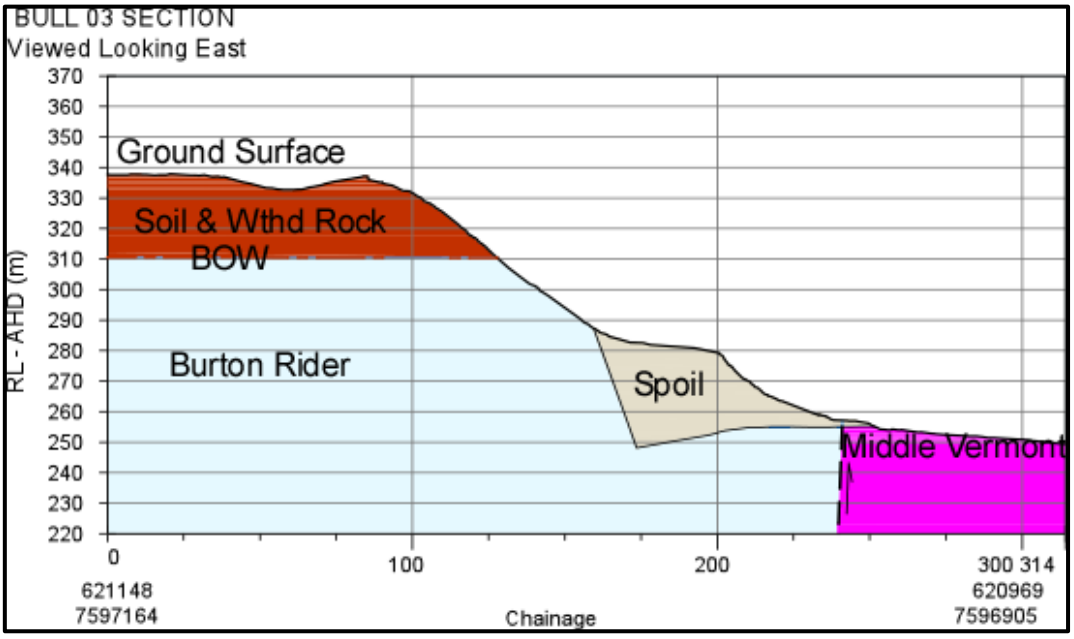
Figure 3: Bullock Creek void north-eastern endwall.



2.2.1 Stability Analysis

HG provided a cross section (XS BULL 03) through the north-eastern endwall, as shown in Figure 4. This section has been used as the basis for a slope stability analysis model. Significantly, the profile of the weathered horizon shows the angle of the wall had already approached a quasi-stable angle of approximately 37°

Figure 4: Cross section BULL03 geometry and geology.



This cross section was digitised and used to create a model in Galena shown in Figure 5 to Figure 10. 6 scenarios were analysed:

- Water level at RL270 m and candidate failure surfaces in the weathered horizon only, through the complete pit wall and in the spoil only.
- Water level at RL315 m and candidate failure surfaces in the weathered horizon only, through the complete pit wall and in the spoil only.

Plots of the results that were obtained are shown in the following figures.

Figure 5: BULL03 GW = RL315, deep path, minimum FOS = 3.33.

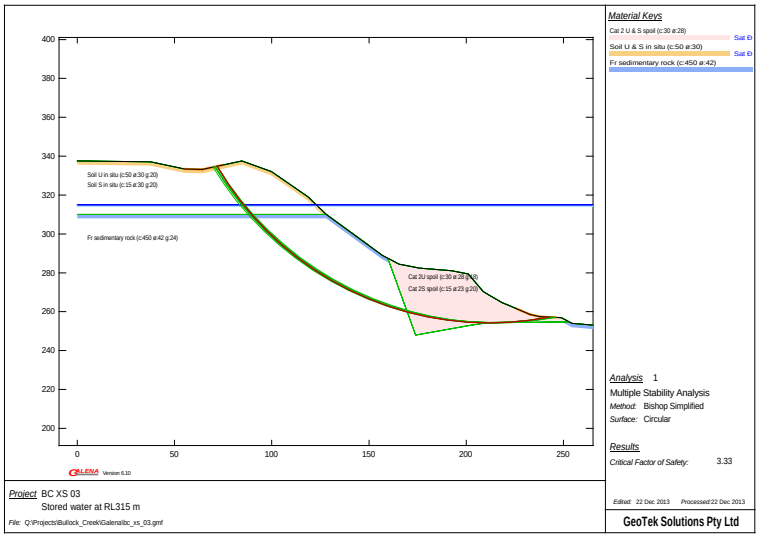


Figure 6: BULL03 GW = RL315, shallow path, minimum FOS = 1.54.

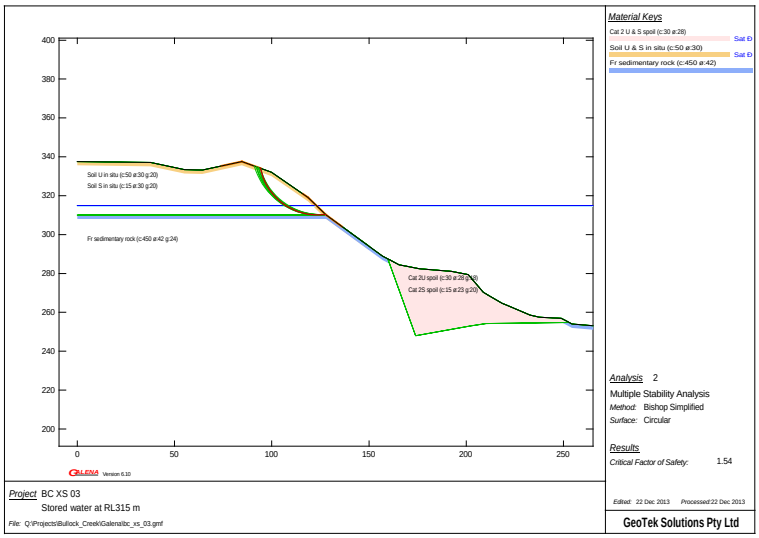


Figure 7: BULL03 GW = RL315, path in spoil, minimum FOS = 1.68.

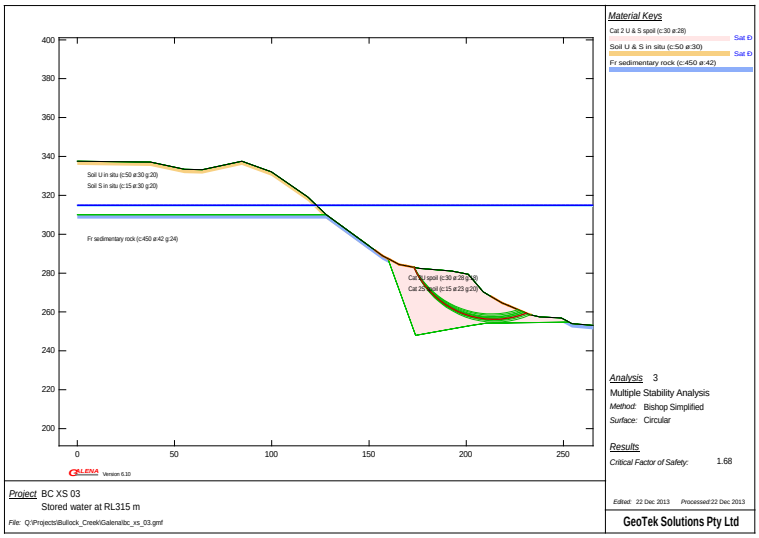


Figure 8: BULL03 GW = RL270m, deep path, minimum FOS = 2.69.

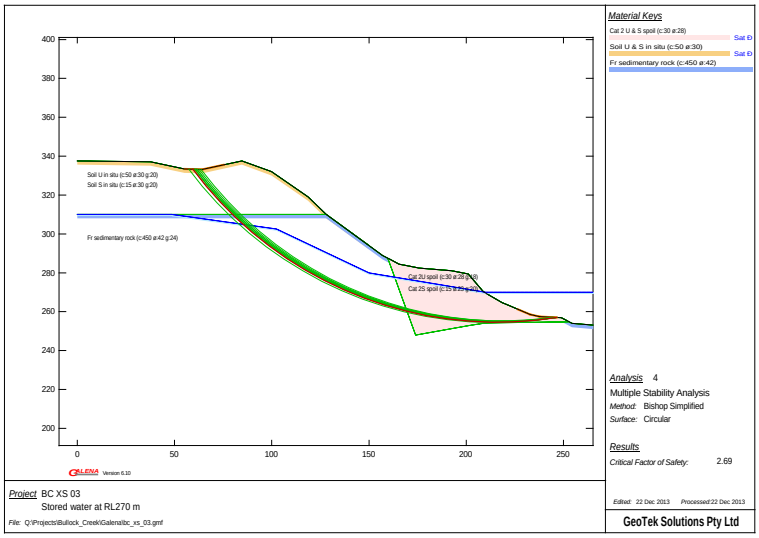


Figure 9: BULL03 GW = RL270m, shallow path, minimum FOS = 1.89.

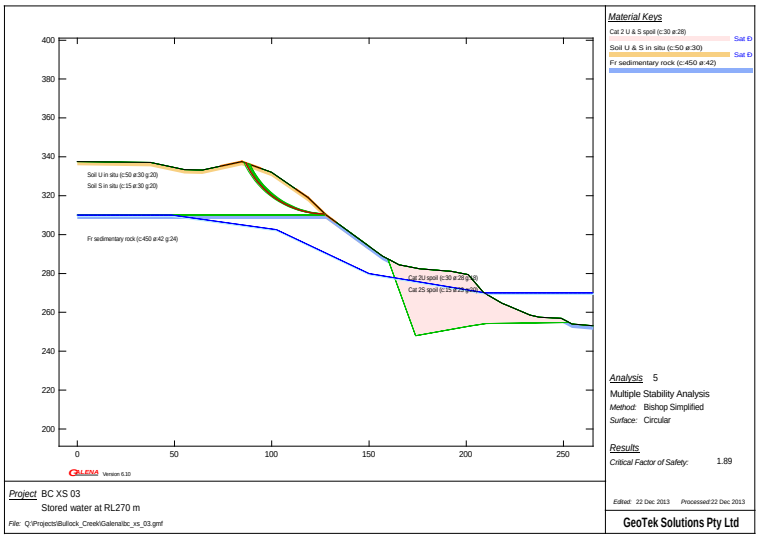
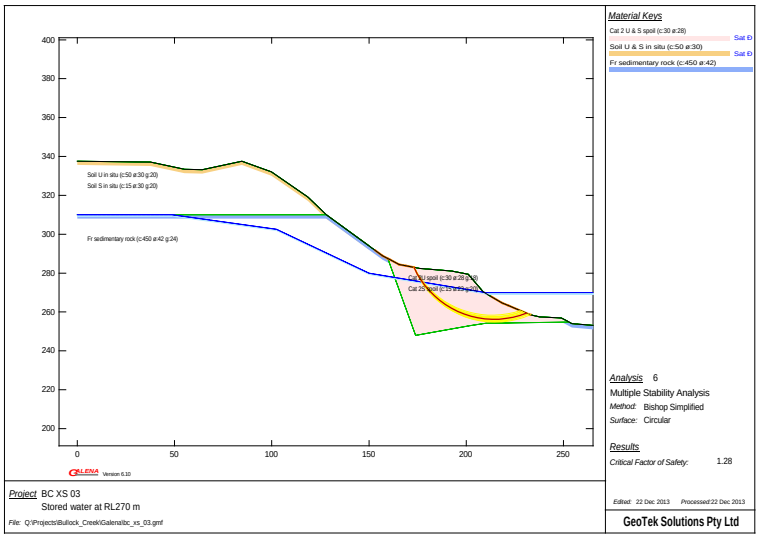


Figure 10: BULL03 GW = RL270m, path in spoil, minimum FOS = 1.28.



The results obtained from the analyses are summarised in Table 4

Table 4: Minimum calculated FOS for Cross Section 03 scenarios.

	Minimum FOS for:		
Water Level	Deep Path	Shallow path in weathered horizon	Shallow path in spoil
RL270 m	1.88	2.69	1.28
RL 310 m	1.88	3.24	1.69

These results show that all of the conditions that were analysed have an adequate FOS for long term stability.

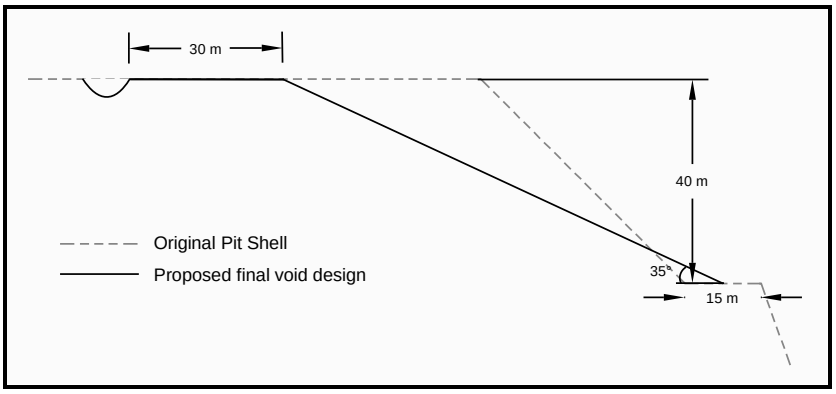
The apparently anomalous result showing a higher FOS for fully inundated spoil versus partially inundated spoil arises from the fact that under conditions of complete inundation, equal and opposite water pressure is acting to both stabilise and destabilise the spoil. When the spoil is only partially submerged, pore pressures within the spoil above the free water level will act to destabilise it.

Although high FOS have been calculated, there are additional factors to consider in relation to long term landform stability (in contrast to geotechnical stability). A bare earth slope at an angle of 35° is very steep and would rarely be found in nature, It would be subject to significant erosion. It is difficult for vegetation to become established on such steep slopes. 20° is the maximum suggested slope angle for rehabilitated ground in Best Practice Environmental Management in Mining - Landform Design for Rehabilitation (Environment Australia, 1998). Thus while a landform may be geotechnically stable, as a landform it will be subject to ongoing slumping, rilling, gullying and other processes all trying to reduce the topographic relief of this slope.

2.2.2 Recommendations

Within the context of landform instability, and consistent with spirit of “Guideline Environmental Protection Act 1994 - EM634 v5 (DEHP, 2013), it is recommended that that the drain be relocated a minimum distance 30 m back from a crest line calculated as being located at an angle of draw of 35° from the middle of the bench at the base of weathering, as shown in Figure 11. In the unlikely event of the pit breaking back a significant distance, the overall slope angle would be 18° before the batter encroached on the drain.

Figure 11: Schematic for relocation of northern endwall drain.



It is also recommended that the failed ground is dozed from the top down to create a smooth ground surface which is then top-soiled and vegetated so that the geotechnical and landform stability is enhanced.

2.3 North-western Lowwall Slip (Locn 2, XS BULL02)

An extensive slip occurred in the lowwall spoil in the north-western corner of the pit, as shown in Figure 1, Locn 2 and Figure 12. A combination of conditions made the likelihood of a slide in this area significantly higher than elsewhere in the pit including:

- The greatest height of unbuttressed spoil in the pit occurs at this location
- The floor dips at angles in the range of 12° to 14° which is moderately steep
- It is possible that the floor is sheared and weak since the pit is situated within a thrust zone although there is no evidence for this
- It is possible that water had been fed into the dump, or along the footwall, via alluvial deposits associated with the diverted creek immediately to the west of the lowwall
- A breach is reported to have occurred in the flood protection bund next to the failed area. It probably happened during a heavy rainfall event during March 2012. Close inspection of Figure 1 shows standing water close to the inferred breach. This may indicate that water management in this area has been an ongoing issue, which may have contributed to excess pore pressures within the lowwall spoil.
- The final factor, as noted by GCS (2012), is that in May 2012 the pit water level started to rise significantly and resulted in inundation and softening of the toe of the dump.

The appearance of the spoil suggests that the toe material flowed out of the waste dumps and stopped when it reached an overall angle of approximately 20°. Based on experience, 20° would be considered a stable angle for this material under dry or inundated conditions. The exposed backscarp follows approximately, the original lowwall excavation. As noted by GCS (2012), the back scarp is too steep for long term stability. It will progressively degrade and encroach on at least part of the current flood protection bund.

Apart from sliding, it is possible that as water entered the spoil, some self-weight settlement took place. Initial void ratios of loose dumped spoil could have been 20 to 30%. If 10% settlement took place over a vertical depth of spoil of 20 m, that would account for 2 m of settlement.

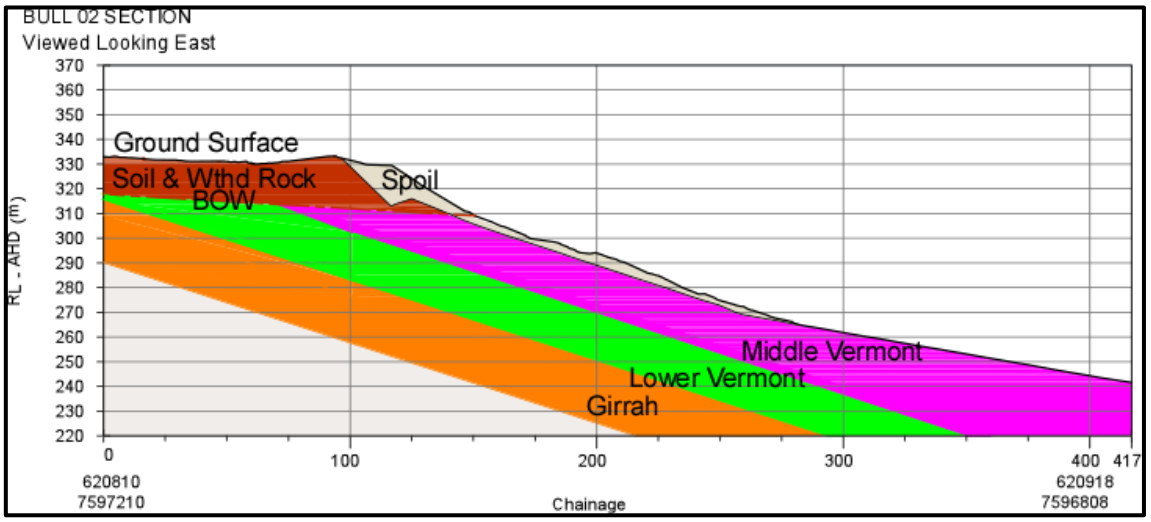
Figure 12: North-western lowwall slip in the foreground.



2.3.1 Stability Analysis

A cross section provided by HG through the north-western endwall is shown in Figure 13. This section was used as the basis for a slope stability analysis model.

Figure 13: Cross section BULL 02 geometry and geology.



A model was set up using Galena as shown in Figure 14 and a number of scenarios were tested. The results show that the spoil only becomes unstable if it is saturated and the water level in the top of the spoil rises to about RL330 m which is significantly above the average ground water surface level of approximately RL300 m. Such a sharp rise in the groundwater level is most likely to occur as a transient response to soaking rain. Under these conditions two modes of failure are possible:

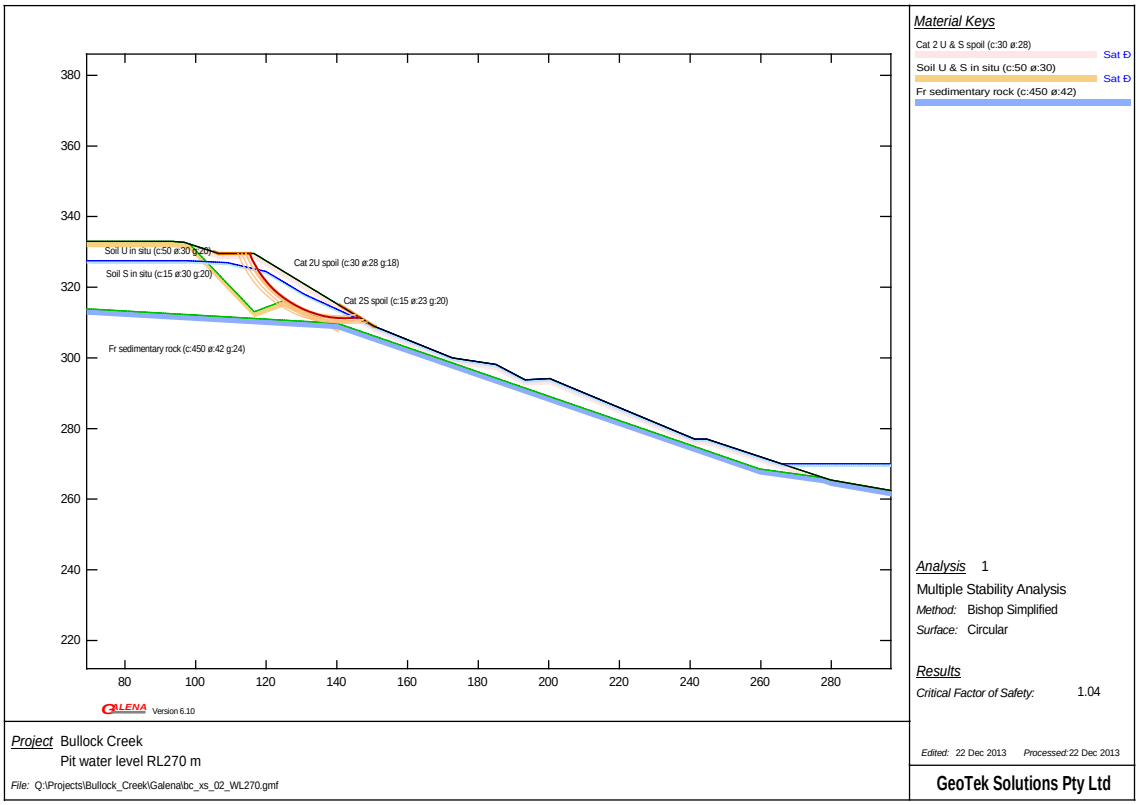
- A relatively shallow circular failure, consistent with the suggestion by GCS (2012) FOS=1.04 and
- A long linear failure surface that extends through the saturated spoil, parallel with the footwall all the way to the floor of the pit FOS = 0.86.

A third possibility is that if the immediate floor is continuously sheared (c'=0 kPa, ϕ' = 15°) then, the failure would occur along the shear plains and, typically, break out in a steep back scarp as has occurred. However, there is no record of continuous floor shears, although it would not be a surprise if they do, in fact exist.

The results of the analysis appear to be consistent with the observation that the failure followed closely to a high rainfall event in March 2012. The BOM rainfall report from Moranbah airport shows there were three, 24 hour, rain events exceeding 40 mm during March. The total monthly rainfall was 206 mm of which 155 mm fell within just 7 days.

The weathered horizon is sufficiently strong that no plausible failure surface could be modelled that went through the weathered horizon, even with an elevated water table. However, in concurrence with GCS (2012), the back scarp that is now exposed will likely erode back to a more stable angle.

Figure 14: Galena output plot for analysis of cross section BULL02, FOS=1.04.



2.3.2 Recommendations

It is recommended to relocate and reconstruct the levee west of its current location. For long term stability purposes, it is recommended that the bund should be located at a minimum setback distance of 40 m. This is based on an angle of draw of 37° (3V in 4H) down to the base of weathering at an averaged depth of 30 m.

Additional slumping of the spoil is possible if ground soaking rain occurs. However, this is will not have any geotechnical impact on the functionality of the final void.

2.4 Western Lowwall Slip (Locn 3, XS BULL01)

Figure 15 shows a view of the slip that has occurred in the spoil on the western lowwall. The failure has created a steep back scarp that is not stable in the long term and which threatens the flood control bund along the edge of the lowwall.

GCS (2012) noted that the whole of the western lowwall has undergone massive failure and suggested that basal slippage down the dipping floor and shearing through to the back of the spoil dump was the mechanism.

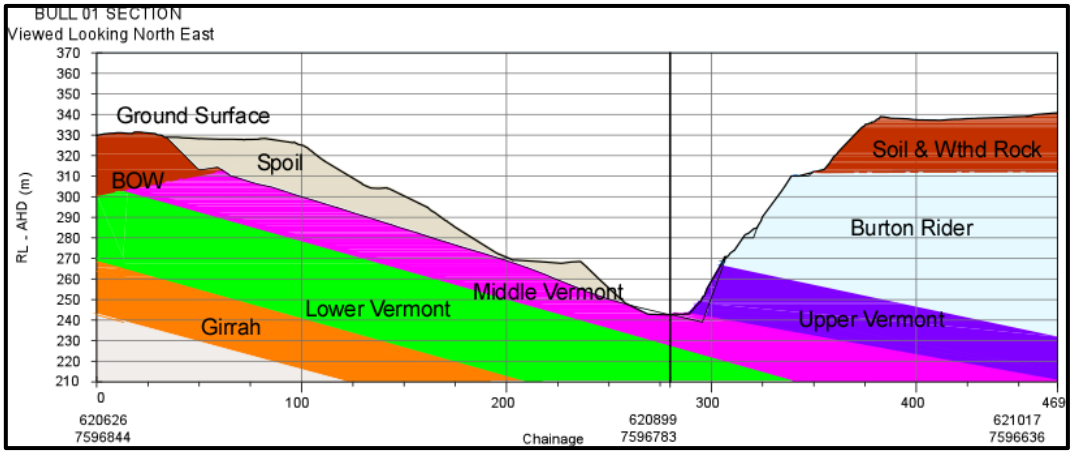
Figure 15: View of the western lowwall slip in spoil.



2.4.1 Stability Analysis

A cross section provided by HG through the western lowwall is shown in Figure 16. This cross section has been used as the basis for a slope stability analysis model.

Figure 16: Cross section BULL 01 geometry and geology.



Models were formulated for pit water levels of RL310 m and RL270 m. As previously, the greatest instability was encountered when the pit water level was at RL270m.

The stability analyses show that while softening of the toe would have contributed to the lowwall failure, an elevated phreatic surface is required in order to achieve a sufficiently low FOS that is consistent with the observed failure. While MBGS (2007) reported an average groundwater level at RL310 m, the phreatic surface required to achieve FOS < 1 is at approximately RL320 m, that is 10 m higher than average groundwater levels. Weather conditions resulting in these sorts of groundwater conditions can be expected to occur from time to time, particularly during the wet season.

Output plots showing the results of analyses under saturated and normal ground conditions are shown in Figure 17 and Figure 18 and demonstrate the requirement for elevated groundwater in order to induce instability in this cross sectional geometry.

Figure 17: Galena plot for BULL 01, saturated conditions, FOS=0.93.

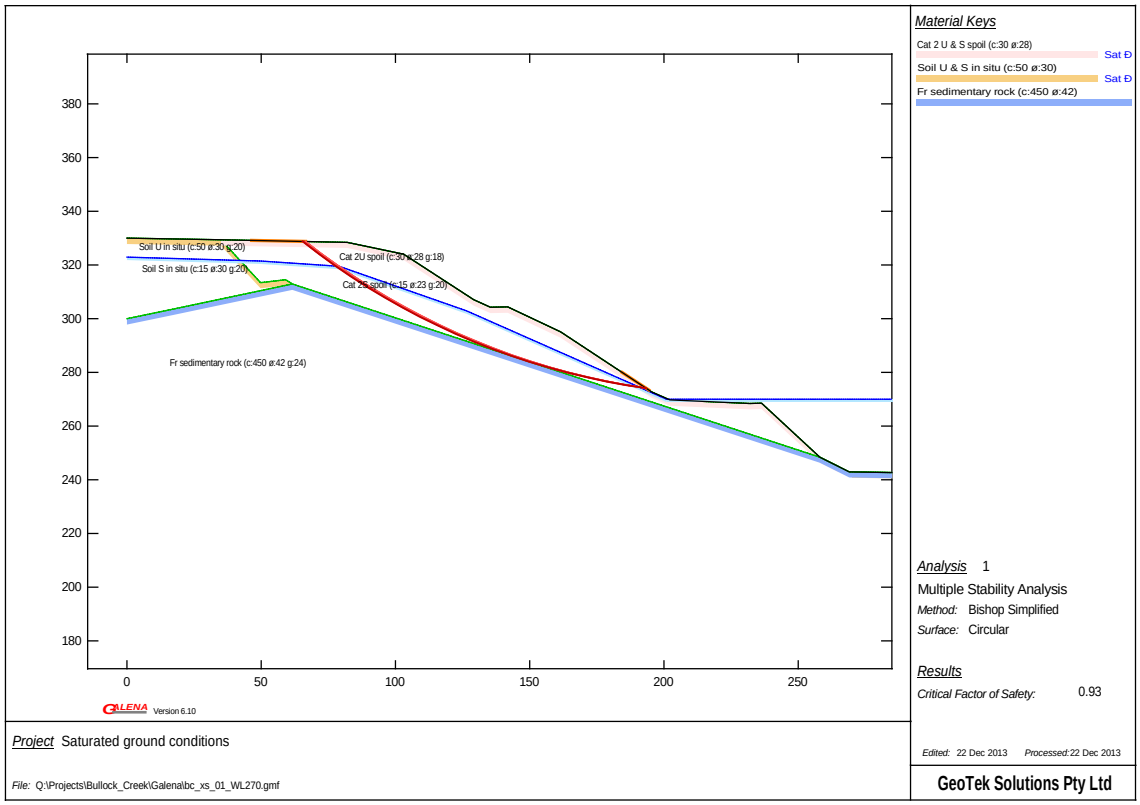
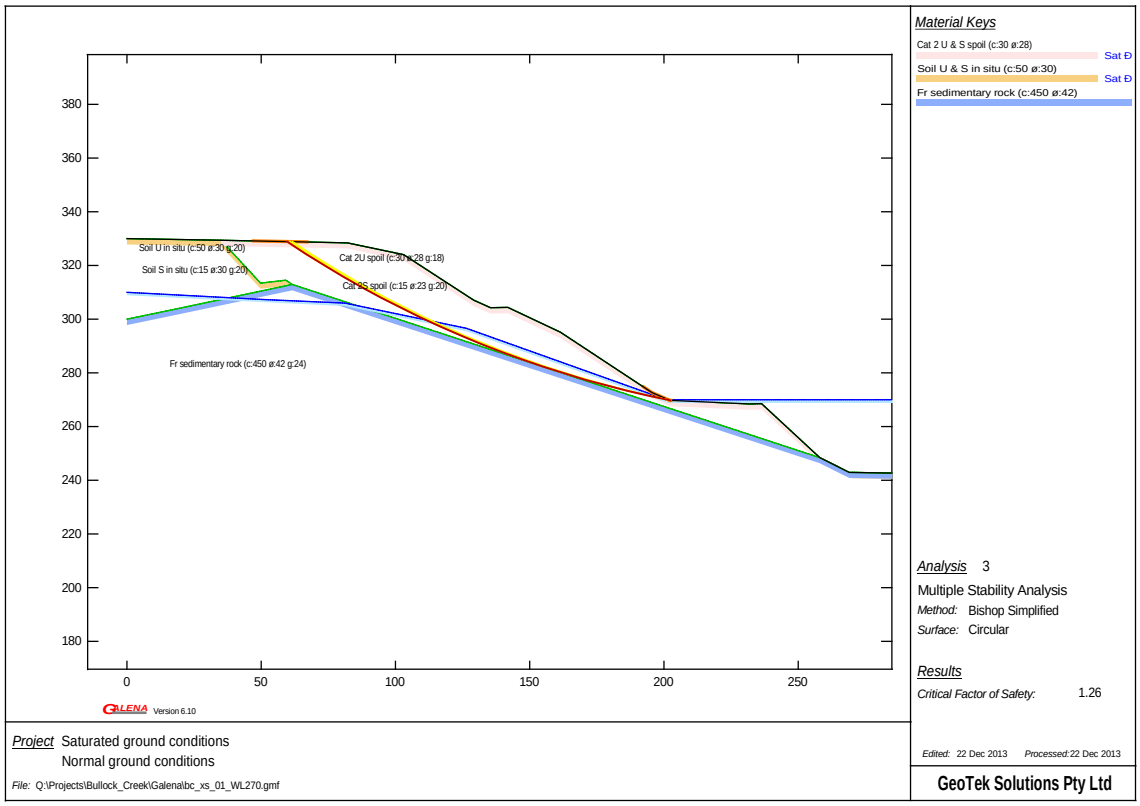


Figure 18: Galena plot for BULL 01, normal conditions FOS=1.26.



2.4.2 Recommendations

It is recommended to relocate and reconstruct the levee west of its current location. For long term stability purposes, it is recommended that the bund should be located at a minimum setback distance of 40 m. This is based on an angle of draw of 37° (3V in 4H) down to the base of weathering at an averaged depth of 30 m.

Additional slumping of the spoil is possible if ground soaking rain occurs. However, this is will not have any geotechnical impact on the functionality of the final void.

3 CURRENT STABILITY

In assessing stability a distinction is made between geotechnical stability and landform stability. Geotechnical stability relates to overall stability controlled primarily by material strength, geological structure and geohydrological conditions. Whereas, landform stability relates to weathering and erosion under normal, natural processes that may include events that are considered to be extreme weather events within a person's lifespan. The results of stability analyses have been presented in the previous section and the following summary synthesises the field observations with the results of the analyses in consideration of geotechnical stability.

The highwall is considered to be stable. No evidence has been observed of any unfavourable structures that may led to premature failure.

Following a series of failures involving the northern endwall and the western lowwall, they are now considered to be geotechnically stable under normal, dry conditions. However, if the site experiences soaking rains which have the effect of raising the phreatic surface to approximately RL310 m, that would be sufficient to induce further movement in the spoil and the toppled endwall material.

Ongoing failures will progressively encroach on the perimeter flood bund and drain. However, instability will not impact on the functionality of the final void as a water storage.

Raising the water level in the pit temporarily to RL310 m or, permanently to RL270 m is unlikely to have any significant geotechnical impacts.

4 LONG-TERM STABILITY

Comments made in the previous section relating to geotechnical and landform stability apply equally to consideration of long-term stability. In this section, long term is considered to be in the range of hundreds to thousands of years. The comments are highly speculative since, since for example, we do not know the extent of climate change within the time span under consideration. It is, for example, only 22,000 years ago that the peak of the last glaciation occurred.

The highwall is considered to be stable. No evidence has been observed of any unfavourable structures that may led to premature failure. Over time the crest will retreat, flatten and round through weathering and erosion.

The unbuttressed spoil will experience episodic conditions that lead to it progressively slide towards the bottom of the pit. In between, it is likely to become vegetated whether by initial

rehabilitation or purely self reporting species and this will assist in stabilising the spoil. The exposed back scarps will erode and flatten to quasi stable slopes on the order of 20°.

The endwall failure is likely to progressively flatten given that it has already failed and is therefore more exposed to weathering and erosion. Again, a long-term stable angle could be on the order of 20°

5 POTENTIAL IMPACTS

The main impact of short term and medium term erosion is to destroy the drainage control structures that are located close to the perimeter of the pit.

A second impact is for potentially hazardous edges to form that could readily crumble under the weight of people.

6 SUMMARY RECOMMENDED ACTIONS

Recommended actions are given in the body of the report. In summary it is recommended to:

- Relocate and reconstruct the drainage control structures away from the geotechnical instability impact zone which is 30 m from the design end wall and 40 m back from the original lowwall crest.
- Seed exposed soil with appropriate species to help stabilise the soil.
- Provide fences and signs to warn people of the presence of potentially hazardous ground conditions.



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7 REFERENCES

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4. Geotechnical Consulting Services, 2012. Burton Mine Rehabilitation - Geotech Inspection. Memo by Barry Ward to John Merritt dated 26 December 2012.
5. McElroy Bryan Geological Services Pty Ltd, 2007. Burton Coal Project Plumtree South and Bullock Creek 2006 Exploration Drilling Geological Report Volume 1.
6. Simmons, J. V. and McManus D.A., 2004. Shear strength framework for design of dumped spoil slopes for open pit coal mines. In: R.J. Jardine; D.M. Potts, and K.G. Higgins, eds. Advances in Geotechnical Engineering: Imperial College, London. Thomas Telford; 2004: 981-991.

Appendix L
Bullock Creek stand-off review



1 Introduction

Burton Mine is undertaking final landform design and remedial works. As part of this, flood modelling identified the need for a levee in the northwestern corner of Bullock Creek pit. However, the proposed position of the levee is within an existing 30 m geotechnical stand-off from the pit crest, as seen in Figure 1. Consequently, the Environmental Department have requested a review of the existing geotechnical stand-off for the Bullock Creek endwall in the vicinity of the proposed levee.

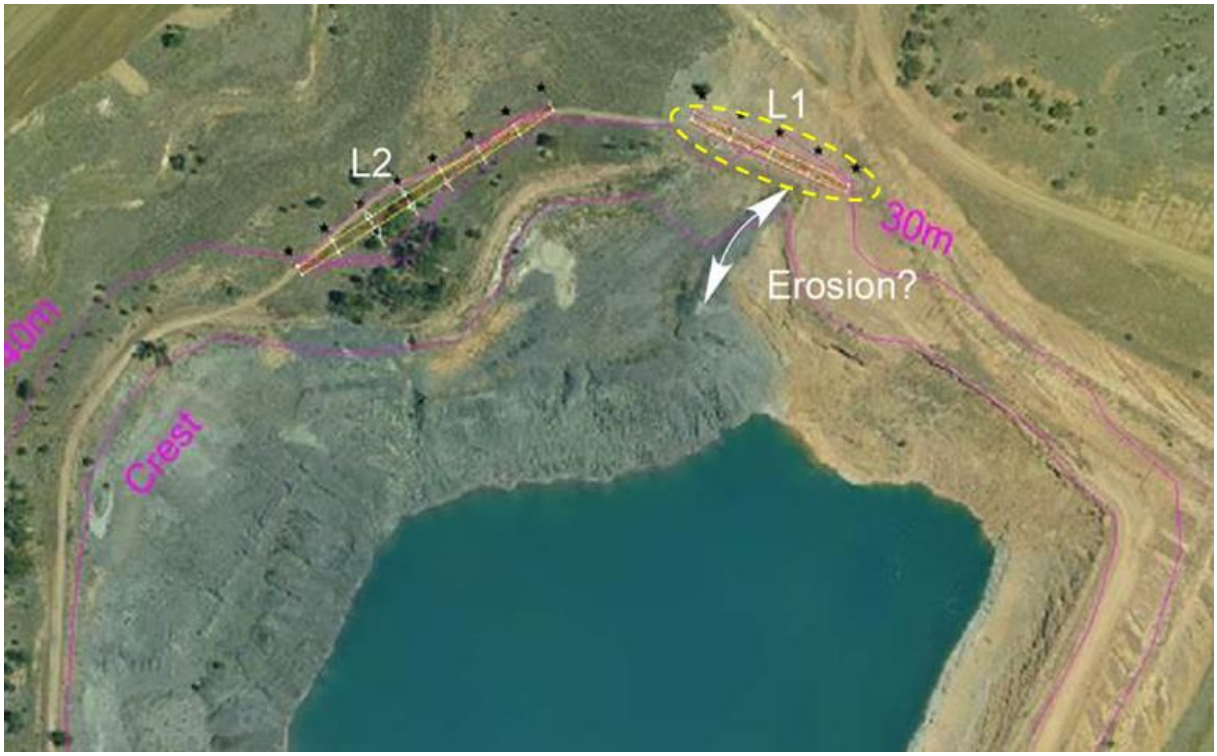

Figure 1 Aerial photograph showing proposed location of levee (yellow dashed oval) within 30 m offset (purple lines)

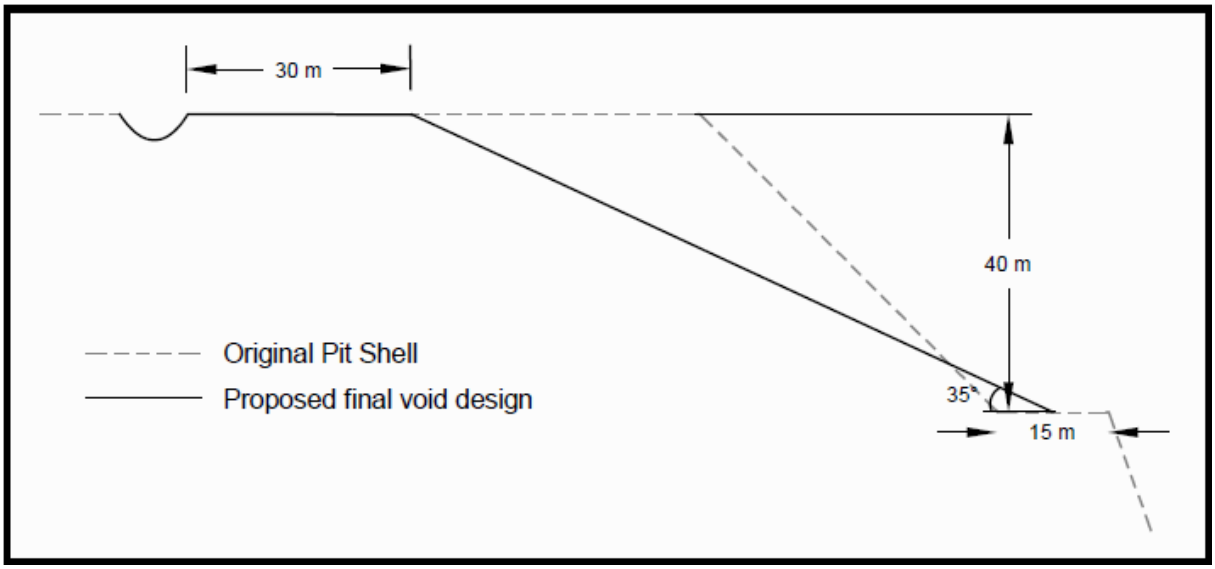

Figure 2 Excerpt of schematic for endwall stand-off from Final Void Geotechnical report

The stand-off was a condition of the final void geotechnical report completed by GeoTek Solutions Pty Ltd. Bullock Creek pit has experienced toppling failure of the northern endwall since 2012 and has been unstable since. Recommendations at the time were that a line be projected at 35° from the toe of the slope and a 30 m stand-off from this projection be implemented, as shown in Figure 2.

1.1 Purpose

The purpose of this letter is to present the results of a review of the geotechnical stand-off at the northern end of Bullock Creek to allow design and construction of the preferred levee position shown in Figure 1.

1.2 Information Used

The following information was used in this study:

- Report by GeoTek Solutions Pty Ltd, 'Geotechnical Assessment of Bullock Creek Pit Final Void for Rehabilitation Purposes', dated December 2013, document reference: gts21324-1;
- Report by Henderson Geotech Pty Ltd, 'Stability Assessment of Mine Voids – Bullock Void', dated January 2014;
- Electronic copy of pit shell: *pit_bc.00t*;
- Electronic copy of topographic surface as point cloud: *Burton_Central-North_LiDAR_20170124_AMG84.xyz*;
- Drone images, received on 17 May, 2018;
- Electronic copy of Leichardt seam: *burpbl_f4.sfg*, from January 2007 model;
- Electronic copy of Leichardt seam: *burpbl_f5.sfg,* from January 2007 model;
- Electronic copy of Vermont seam: *burpbv1_f4.sfg,* from January 2007 model; and,
- Electronic copy of Vermont seam: *burpbv1_f5.sfg,* from January 2007 model;

1.3 Exclusions

The following exclusions are relevant to this report:

- Geotechnical stability of the proposed levee;
- Groundwater conditions that could impact levee performance;
- Suitability of the proposed levee location;
- Subsurface conditions and their suitability for levee construction; and,
- Hydrological assessments and impacts.

2 Endwall History

As noted above the final void geotechnical report (document reference: gts21324-1, dated December 2013) reported that the endwall has experienced major and progressive, multi-bench failure with toppling identified as the failure mechanism, see Figure 3. There has been no further progression of the failure scarp since the initial failure in 2012 but tension cracking and deformation of the crest area behind the scarp is observed, see Figure 4.



Figure 3 Photograph taken from the report gts21324-1 showing multi-bench endwall failure in December 2012



Figure 4 Drone photograph showing disturbed crest area (yellow dashed circle)

3 Geological Structure

A review of the coal model for the area has identified a large thrust fault behind the northern endwall of Bullock Creek. The thrust fault has a vertical throw of approximately 100 m, as shown in Figure 5, and strikes approximately parallel to the endwall. The fault is interpreted to occur below the Vermont seam (i.e. at least 50 m below the pit floor) and dipping towards the south, i.e. into the pit. From this, it is inferred that the fault daylights north of the endwall and is the cause of the existing failure as a result of the disturbed rock mass.

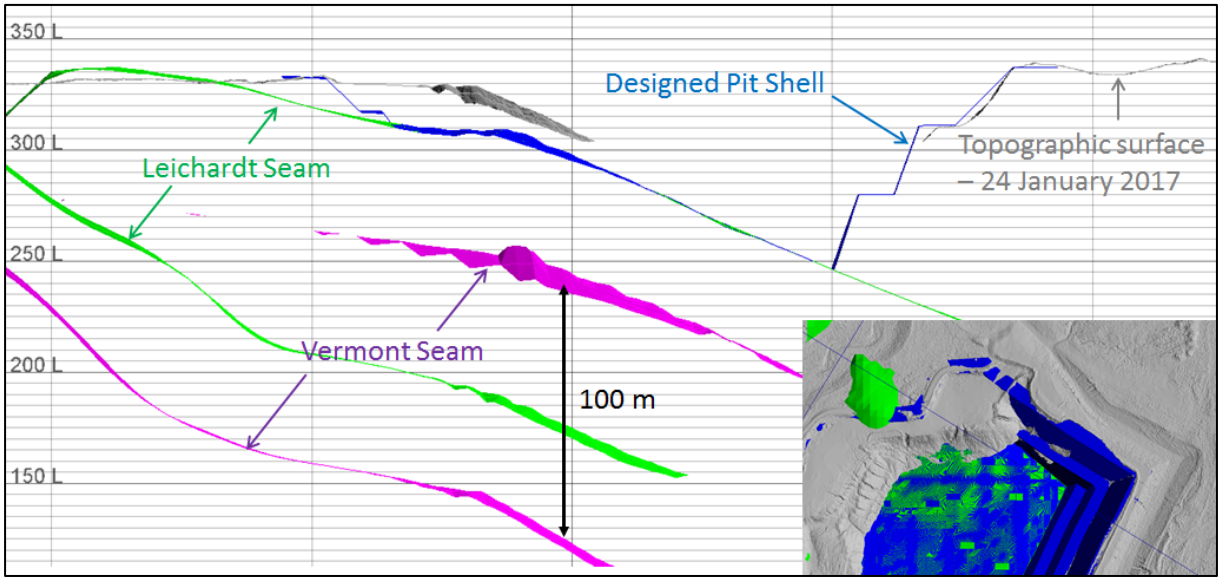

Figure 5 Cross-section showing vertical offset of Coal seams

The highwall exposure shows bedding dipping into the endwall at about 45° (see Figure 4) as a result of fault drag as the southern block is thrust over the northern block. Tensile fracturing associated with the fault drag would be expected on the anticline of the folded bedding and likely contributing, in conjunction with other structures, to the current instability.

4 Discussion

4.1 Endwall Stability

As the fault is below the Vermont seam it is not expected that the wall is at risk of large scale global failure, additionally, the highwall is providing confinement, limiting the failures ability to progress east. Similarly, the failure is unlikely to progress west as the slope height reduces quickly resulting in a reduction in the driving mass contributing to the failure.

The void adjacent the proposed levee position has been backfilled and is thus not susceptible to slope failure. This is supported by limit equilibrium analysis presented in the report gts21324-1 which returned acceptable FOS for all relevant slope geometries within the weathered horizon, lowwall spoil and hydrological (e.g. long term in-pit water levels) conditions analysed in this area of the pit.

Having said this, it is expected that the current scarp will retreat northwards into the adjacent water diversion drain due to progressive slope failure. The area of disturbed ground highlighted in Figure 4 was approximately traced in Vulcan v10.1.3.124 by Maptek Pty Ltd. Offsets from this line were estimated to determine the approximate distance of the levee from the predicted extent of final scarp position, see Figure 6. The currently proposed location of the levee is about 75 m from the edge of the expected scarp position and is thus outside of the currently recommended stand-off of 30 m.

Considering the above discussion, it is recommended that a revised stand-off be adopted as shown in Figure 7.

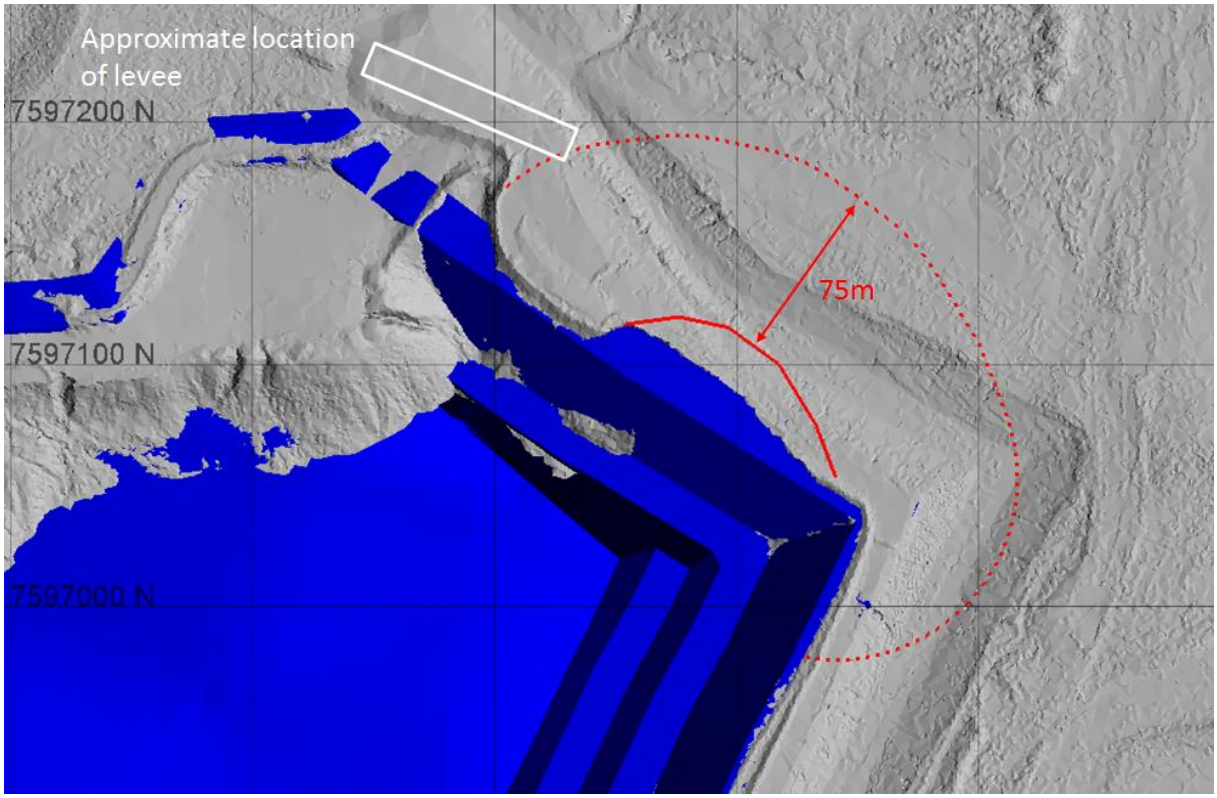

Figure 6 Plan showing outline of predicted failure scarp (solid red line) and 75 m offset (dashed red line)

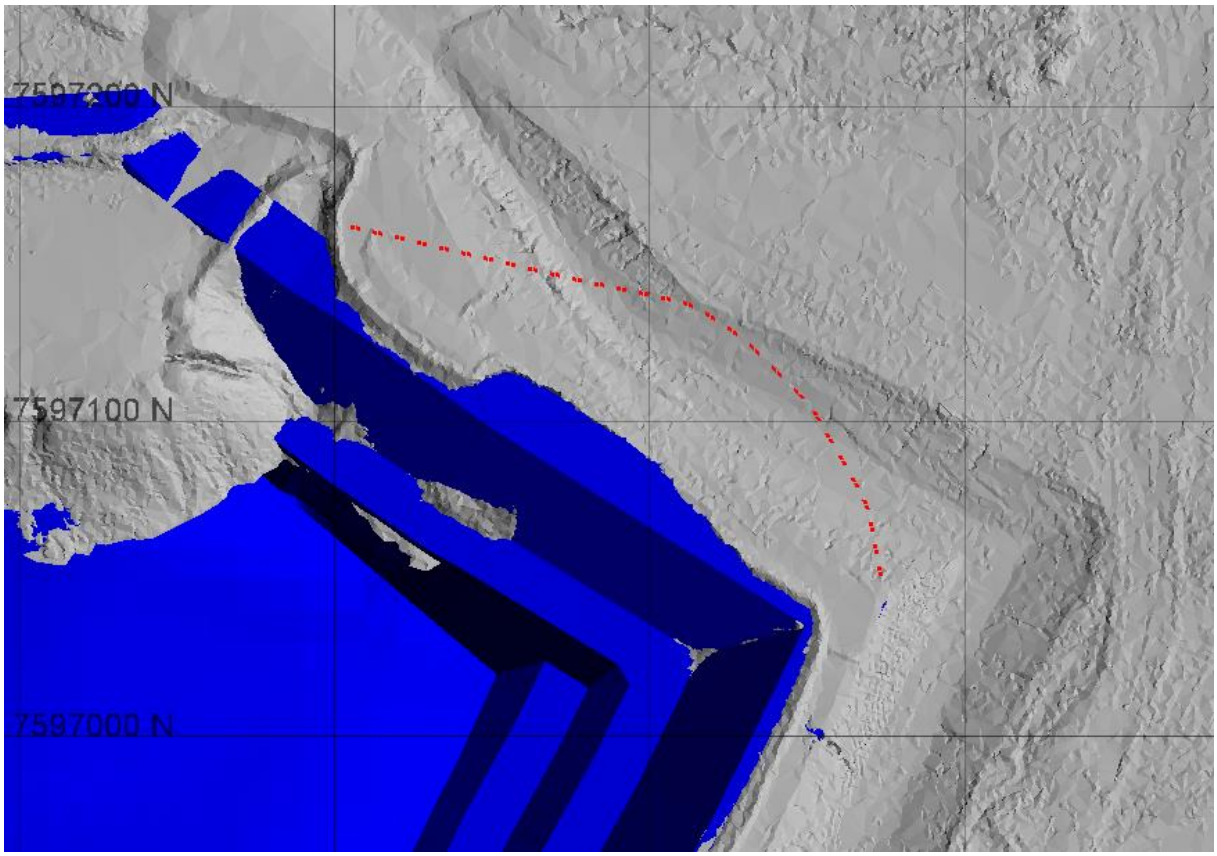

Figure 7 Plan showing revised proposed stand-off (red dashed line) for the northern endwall

4.2 Erosion

Erosion of the endwall due to mechanical and chemical means is likely and could undermine the levee if water flow is not managed well. The report by Henderson Geotech Pty Ltd suggests that a 7 m buffer be left around the edge of the pit as an erosion buffer. It is recommended that appropriate slope contouring and surface water management be implemented in the vicinity of the pit crest as part of the levee design and construction works.

5 Closure

Based on the historical and expected performance of the northern endwall in Bullock Creek pit, it recommended that a revised stand-off shown in Figure 7 from the endwall be adopted. The revised stand-off will allow construction of the provided levee position.

Please contact the undersigned if you have any questions regarding this document.

Regards

Tim Cartledge
Principal Geotechnical Engineer
MAusIMM CP(Geotech) RPEQ

Peer Review The signing of this statement confirms this report has been prepared and checked in accordance with the Peabody Energy Peer Review Process.	
Geotechnical Engineer: Tim Cartledge **RPEQ No: 16952**	**Date: 29 May 2018**
Peer Reviewer: Gavin Lowing **RPEQ No: 10512**	**Date: 29 May 208**

Appendix M
Wallanbah pit void geotechnical study



Peabody Energy Australia Pty Ltd - Wallanbah Pit Void Geotechnical Assessment



July 2018

Blackrock Mining Solutions Pty Ltd Document Control

Document Control – BMS			
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1. INTRODUCTION

A geotechnical assessment was completed by Ty Grantham of Blackrock Mining Solutions Pty Ltd (Blackrock Mining) to assess the stability of the final void at the Wallanbah pit, located within the Burton Mine Complex. A site inspection was undertaken on the 16th November 2017 to observe the geotechnical stability of pit walls and spoil dumps with respect to final void conditions.

The objective of the assessment was to identify areas of concern related to geotechnical stability for excavated and spoil slopes, and to provide recommendations for the long-term stability of slopes in order to meet the residual void design objectives, in accordance with the site's Environmental Authority (EPML00879213).

It is understood this report will be submitted to the Department of Environment, Heritage and Protection (DEHP) as a certified geotechnical report.

2. SCOPE OF WORK

The proposed scope of works was set out as per Blackrock Mining's proposal and comprised:

1. A site visit on the 16th of November for visual inspection of final highwall profiles, in-pit spoil dumps, rehabilitated external dumps and areas of concern;
2. Review of geotechnical data and reports supplied by Peabody, and collation of data procured from site visit;
3. Two-dimensional limit equilibrium analysis using industry accepted methodologies to assess slope configurations against acceptable design criteria, where appropriate. Circular and non-circular slip failure mechanisms would be examined for soft highwall slopes and spoil dumps; and
4. Provision of a report detailing site characteristics and recommendations.

2.1 Previous Work and Client Information

A package data and plans were made available to Blackrock Mining for the purpose of providing information in relation to floor dips, depth of cover thickness and geological structure. This package of work was completed by McElroy Bryan Geological Services Pty Ltd (MBGS).

3. SITE LAYOUT AND FEATURES

The general layout of the Wallanbah pit is shown in Figure 3-1, which shows the section locations generated for slope stability analysis.

The layout shows the majority of the pit is infilled with spoil, leaving a void at the northern end. This area is referred to as 'North Wallanbah' on the plans and is wider than the remainder of the pit to the south.

The infilled section has predominantly been rehabilitated, with an area immediately south of the highwall that had only been re-graded and was awaiting re-vegetation at the time of inspection. Significant degradation of all pit slopes was observed during the site inspection.

A deep drainage channel was constructed behind the endwall to intercept surface water from the adjacent higher topography areas and divert this water away from the crest. This was possibly in response to endwall instability during operations.

The mine is bound to the south by Spade Creek, and is truncated to the north by extensively weathered, remnant basalt flows and undifferentiated Tertiary sediments. Ephemeral drainage channels beyond the eastern and western crests generally flow south towards Spade Creek.

External spoil dumps along the northern highwall adjacent to the void, have been re-graded and contour profiled so the toe line is positioned approximately 20m behind the highwall crest.

Water level measurements recorded on the 2nd of November 2017 showed the pit water level to be at approximately 270 m RL (AHD), and is close to the final void scenario of 272 m RL as modelled by Hatch Pty Ltd.

The maximum depth of the pit is approximately 110m below ground level (approximately 205m RL) and this occurs along the eastern highwall.

The void has been partially backfilled at the southern end with the submerged spoiled material buttressing the eastern highwall at Section 2.

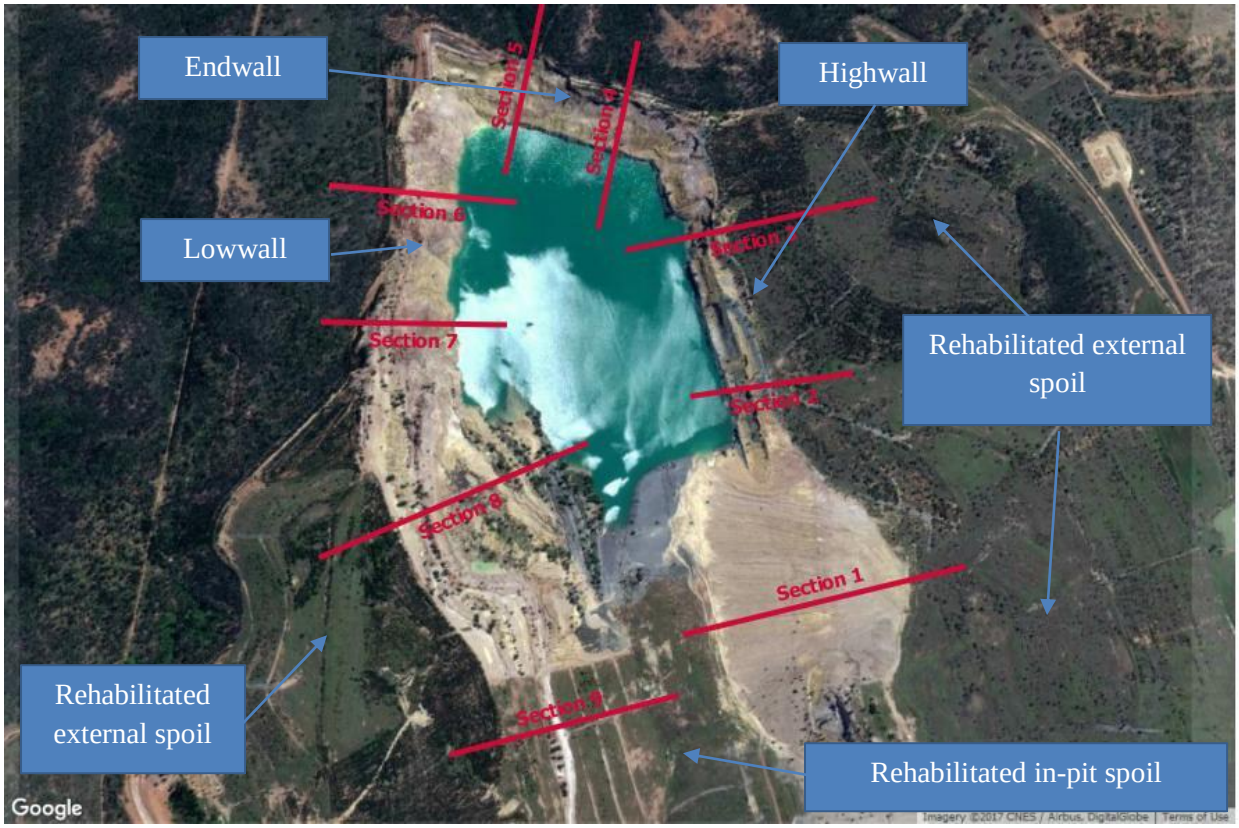

Figure 3-1: Site and Section Layout

4. GEOLOGICAL SETTING

4.1 Site Geology

The main units forming the overburden at the Wallanbah pit are as follows:

- Quaternary alluvium/Tertiary sediments (Suttor Formation) and residual basalt: low to high plasticity, soft to stiff, brown silty to sandy clay. Basalt indurated in areas;
- Weathered Rewan (Triassic): low to moderate strength, brown, interbedded sandstone and siltstone; and
- Unweathered Rewan and Rangal Coal Measures (Permian): moderate to high strength, light grey to grey, interbedded sandstone and siltstone.

The zone of weathering extends to a depth of approximately 30m on the eastern highwall to 55m on the lowwall .

A generalised stratigraphic sequence is shown in Figure 4-1.

Highly weathered, remnant basalt flows are present in the endwall and along the lowwall . This is generally distinguishable by the mottled grey/reddish brown appearance and it is moderately hard in some areas.

The thickness of the Tertiary unit is variable, ranging from 5m - 15m along the eastern highwall to 30m - 40m along the lowwall and endwall, as shown in Figure 4-2.

The base of weathering (BOW) ranges between 260m RL to 285m RL.

The fresh Rewan and Permian coal measure rocks comprise thinly interbedded, light grey, fine to medium grained sandstone and siltstone, with some thicker beds of sandstone. In general, the bottom 45m (approximately) of the rock overburden belongs to the Permian Rangal Coal Measures, with the upper portion being part of the Rewan Sandstone formation (Ref 1). Differentiation between these two units is not visually apparent in the highwall.

At Wallanbah pit, the Vermont Upper and Leichardt Seam coalesce to form the Burton Seam at the southern periphery which is approximately 5m to 7m thick. The Yarrabee Tuff (YT) marks the base of the Rangal Coal Measures and is a regionally extensive and easily recognisable marker band. The underlying Fort Cooper Coal Measures are predominantly sandstones with low quality coal seams, with tuff and stone bands. The Burton Seam and the lower seams are separated by approximately 40m of interburden.

Sectional analysis from the geological model indicated floor dips up to approximately 24° along the eastern highwall in the North Wallanbah void, and 17° along the lowwall in the northern void area. In the central and southern pit areas floor dips between 12° and 19° occur.

The Spade Creek Sill igneous intrusion lies immediately to the south of the pit and constrains the pit in this direction.

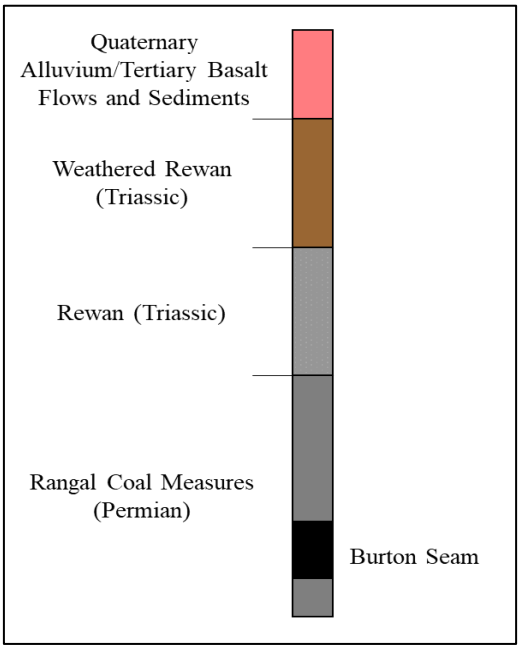

Figure 4-1: Wallanbah Pit – Conceptual Stratigraphic Sequence

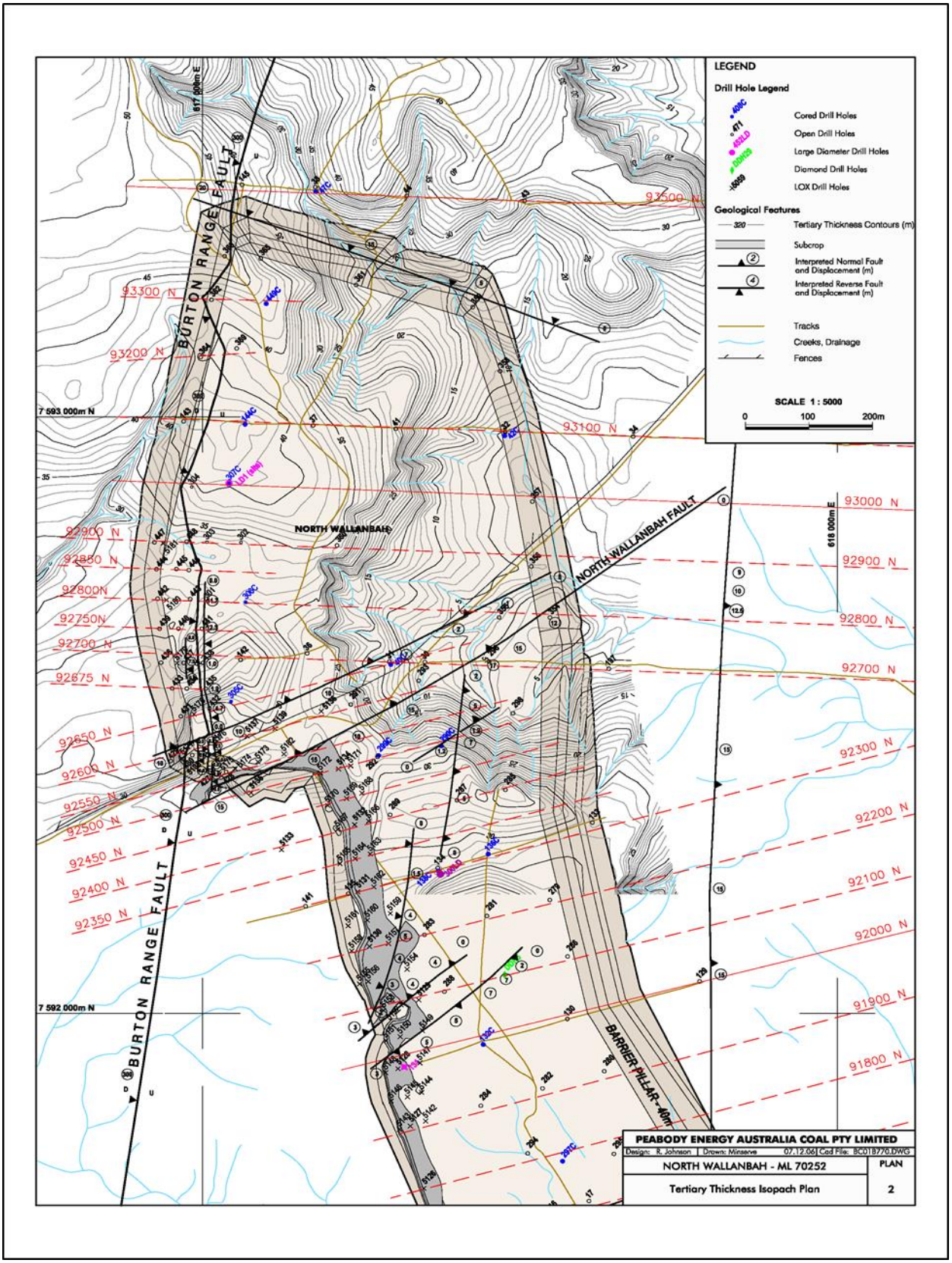

Figure 4-2: Tertiary Thickness Contour Plan – North Wallanbah (MBGS Plan)

4.2 Material Characteristics

It is accepted that Tertiary sediments have low strengths are dispersive in nature and are highly erodible due to their physical and chemical characteristics (Ref 7). The following attributes of Tertiary sediments are given by Ref 7: -

- High exchangeable sodium percentage (ESP) - generally > 15% indicates the material is dispersive and erodible;
- Highly variable pH, mostly alkaline > pH 9, leading to low nutrient availability;
- High salinity - up to 4,000uS/cm which exceeds vegetation tolerance limits and;
- In terms particle size distribution fine sand and silt constitutes > 50% and clay fractions constituting up to 30% of the soilmass. That predisposes the material to strong surface crust development when dry and being highly susceptible to erosion when wet.

Weathered Rewan Formation is generally less susceptible to erosion. The interbedded sandstone layers are generally more slake resistant in comparison to the siltstone layers which tend to degrade rapidly.

4.3 Hydrogeology and Groundwater

No major aquifers have been identified, but the coal seam can constitute a minor aquifer. Fault zones have the potential to form aquifers, which permit the transmission of groundwater through disturbed or broken strata. There was no evidence of seepage from the highwall or endwall slopes during the inspection.

It is possible that the drainage channel behind the lowwall may have incised the sub-crops of both the Rangal and Fort Cooper Coal Measures, and at times of flow, recharge the coal seam aquifer system. These periods of recharge are expected to be short and the volume of water transmitted into the aquifer is expected to be low (Ref 2).

4.4 Geological Structure

The Wallanbah deposit is bound to the south by the Spade Creek Fault, and to the north by Tertiary Volcanics (Suttor Formation).

The north to south striking Burton Range Fault is a regional thrust fault system identified from operational plans. It truncates the western coal resource, as shown in Figure 4-3. Displacements on this system are in the order of 300m, as indicated from the plan. Several subordinate faults were noted along the lowwall with reported displacements up to approximately 10m.

The Wallanbah Fault strike east-northeast and has been mined out across the floor of the North Wallanbah pit area. Another un-named normal fault is indicated to strike parallel to the endwall face; however, this fault appears to have been mined out also.

As outlined in Section 4.1, the multi-bench wedge failure on the highwall is likely to be the interaction of a large east-west striking fault system.

Sections generated from the geological model indicate the seams dipping steeply to the east and west in the North Wallanbah void area.

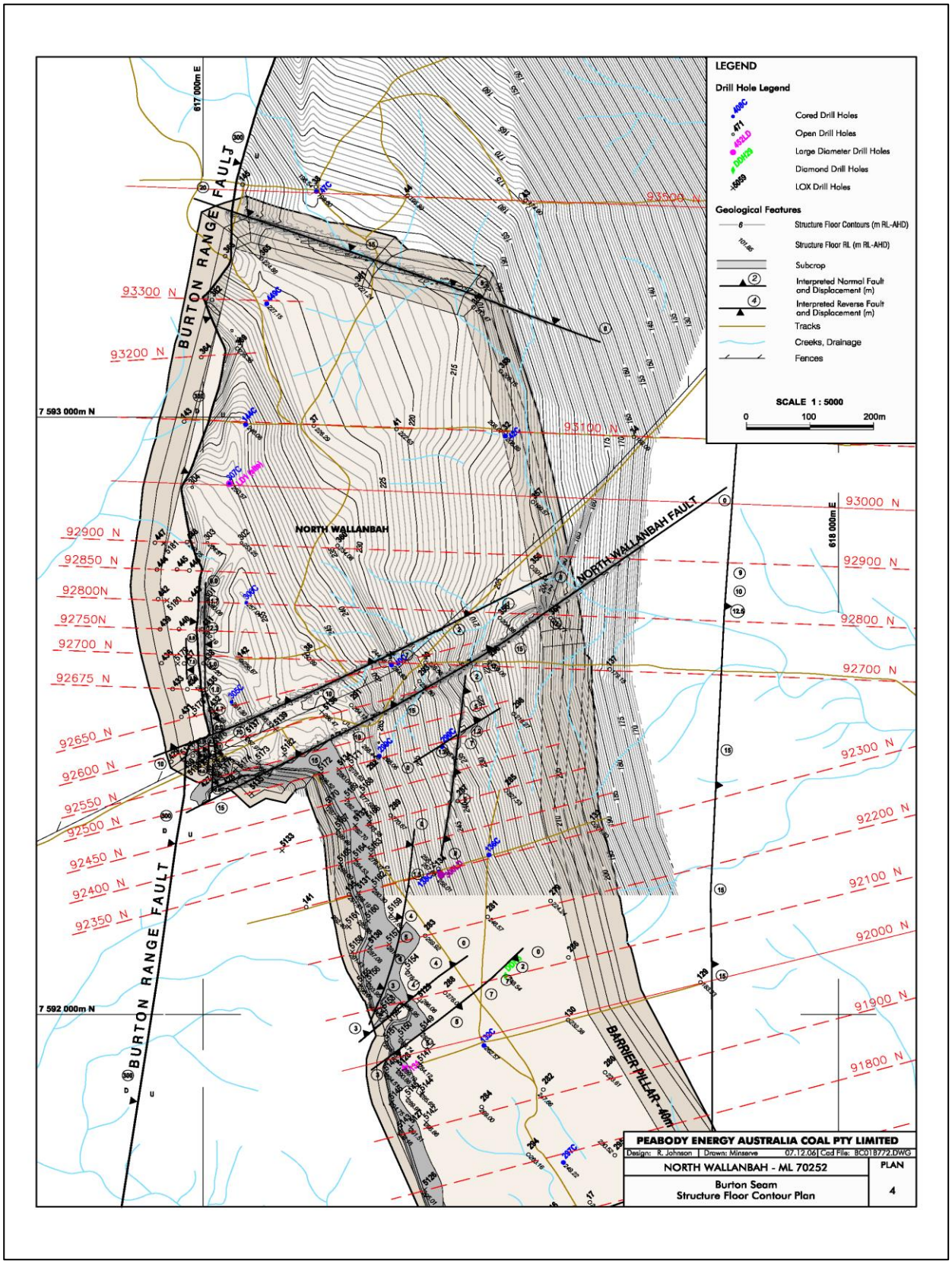

Figure 4-3: Geological Structure Plan – North Wallanbah (MBGS Plan)

5. CURRENT PIT SLOPE CONDITIONS

5.1 Highwall – Current Void Area

There are several locations along the highwall that have been undercut due to localised rotational failures in the Tertiary units. These failures were generally contained by the rockhead berm. The exposed weathered Rewan Formation dips at a moderate angle into the highwall. Figure 5-1 shows the condition of the highwall.

An area of deep rill erosion and over-steepening of the Tertiary and weathered Permian was a prominent feature mid-way along the exposed highwall above the rockhead berm. This area corresponds to a confluence point of two spine drains that direct surface water from the rehabilitated external spoil dumps to the pit, as shown in Figure 5-2.

A large multi-bench wedge failure was observed at the northern end of the highwall, close to the endwall intersection. The intersection of two steeply dipping structures has resulted in a failure intersection approximately 15m back from the crest and is projected to daylight below the rockhead berm (below the current water level – 270m RL), as shown in Figure 5-3. It was indicated that the failure may have been in response to coal recovery using auger techniques.

An inspection of the drainage features behind the failure showed a deeply scoured channel, which will concentrate flow in the direction of the failure zone, as shown in Figure 5-4. In this case, it is possible that periodic surcharging and elevated cleft pressures within the bounding discontinuities due to ponding and seepage of surface water against the crest bund has led to failure.

A 1.5m high bund was constructed along the highwall crest to prevent surface water from flowing into the pit from the external spoil dump. A shallow channel had been incised along the inside toe of the bund which appears to channel surface water to lower elevation discharge points.

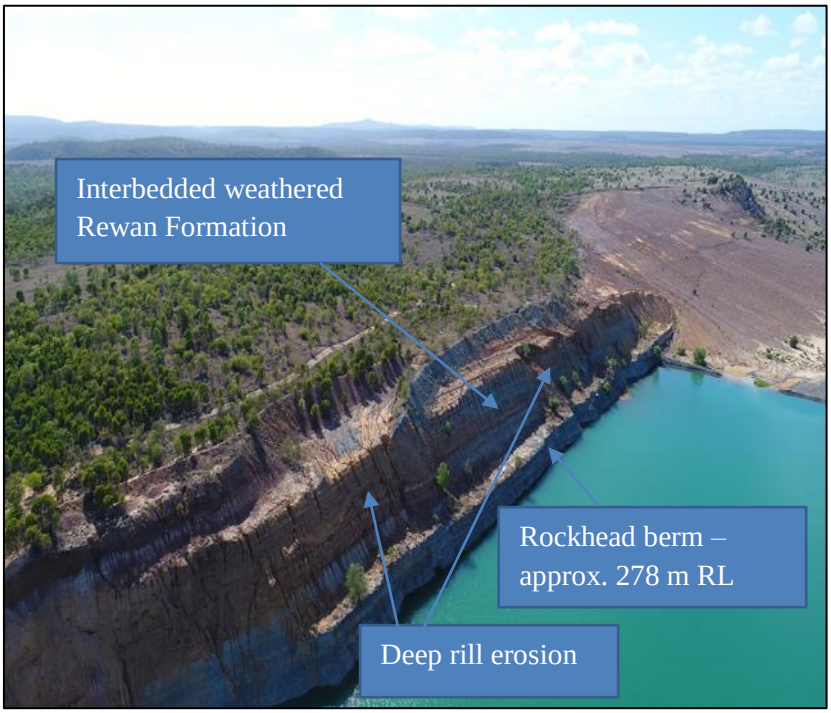

Figure 5-1: Highwall Condition (Looking Southeast)

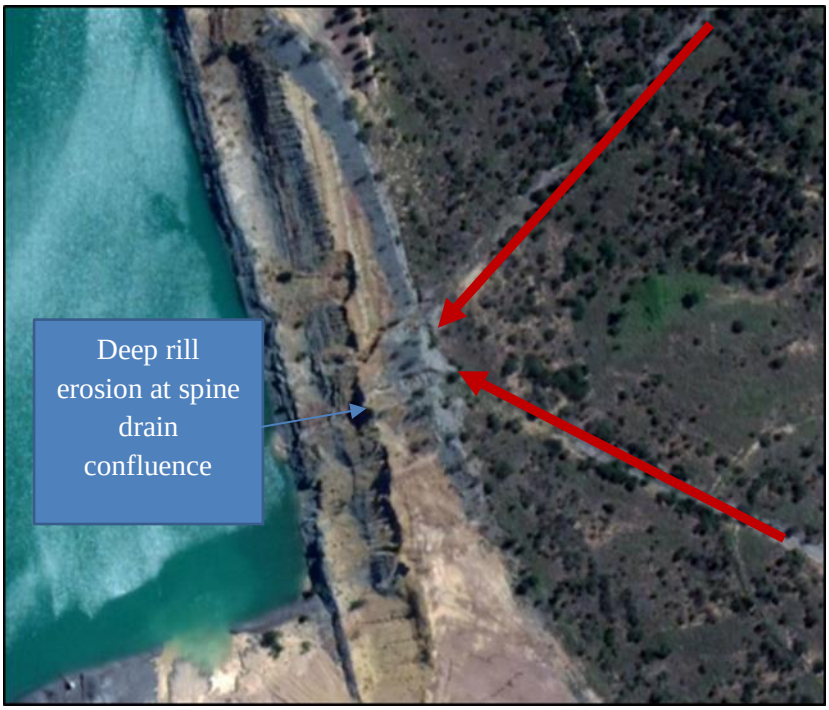

Figure 5-2: Spine Drain Confluence



Figure 5-3: Highwall Condition – Weathering and Structure (Looking East)

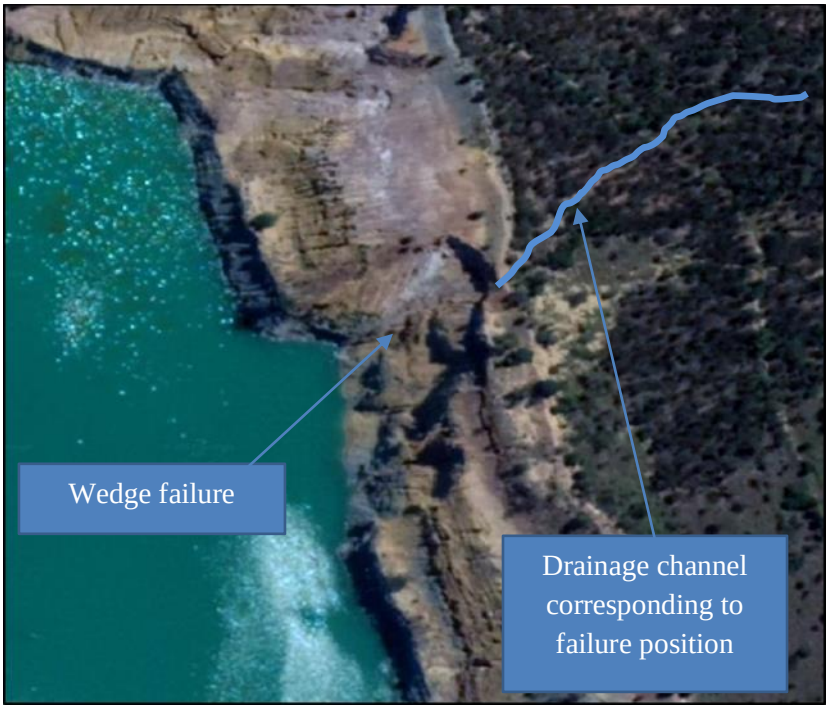

Figure 5-4: Highwall Wedge Failure Location

5.2 Lowwall – Current Void Area

Large slope failures are a prominent feature along the exposed lowwall extending to southern end of the void adjacent to a partially rehabilitated lowwall section refer Figure 5-5 and Figure 5-6. Access to the lowwall was not possible at the time of the inspection, therefore an aerial survey was completed using a drone.

In this case, two modes of failure are possible: Initially, saturation flows/slips in the softened clays, and slumping of the spoil buttress due to rising void water level, which has undercut the harder, weathered basalt cap. The undercutting process has then led to toppling failures of the basalt, creating a receding vertical face (Figure 5-5).

The failure geometry is typical of material that has undergone saturation and increased pore pressure build up within the soil mass.

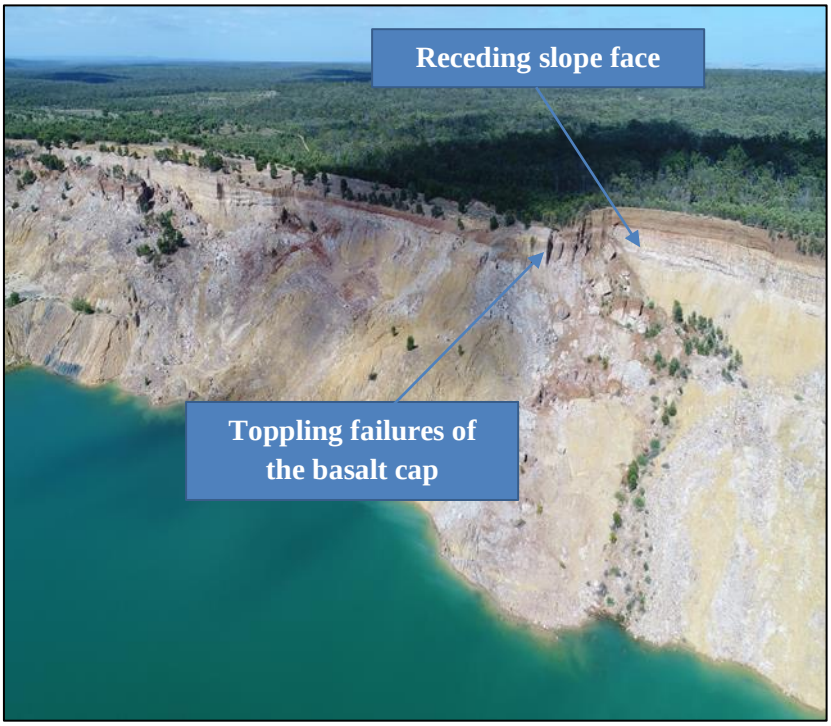

Figure 5-5: Lowwall Failure (Looking Southwest)

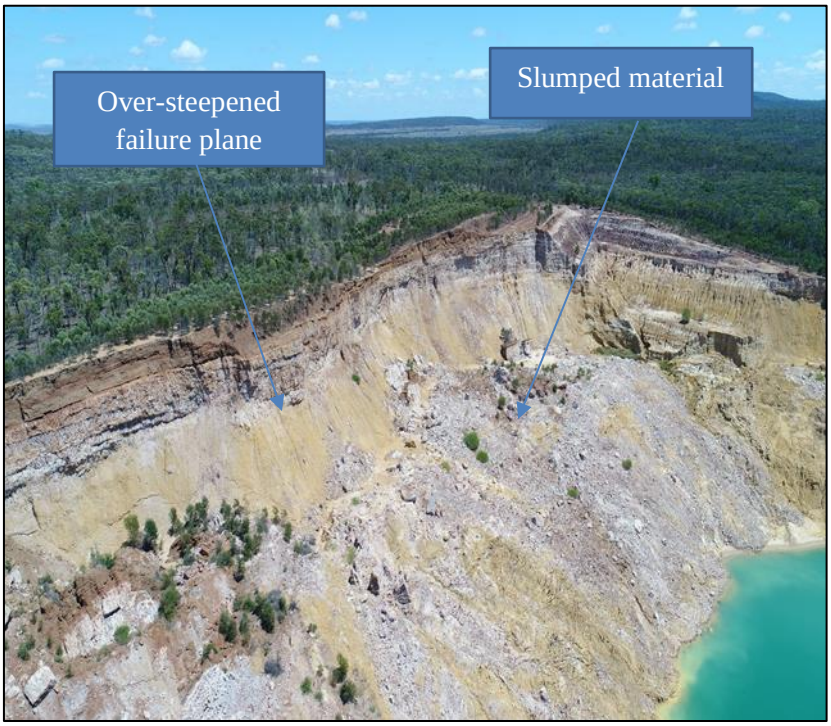

Figure 5-6: Lowwall Failure (Looking Northwest)

5.3 Endwall

A large scale rotational failure was observed along the endwall, as shown in Figure 5-7, resulting in undercutting of the upper bench and also over-steepening of the batter slope. This failure has extended beyond the crest of the endwall.

Several smaller rotational failures were also observed, as shown in Figure 5-8. In this case, most of the failure material were contained by the rock head berm, however this has now resulted in very limited berm capacity to accommodate more material from further failures.

A drainage channel, approximately 4m width x 2.5m depth and 10 -15m behind the crest, had been excavated behind the endwall crest. This channel has been captured by the large rotational failure, as shown in Figure 5-9 and Figure 5-10. The purpose of the channel was to capture overland flows from the higher relief topography north of the endwall crest and divert it to the lowwall.

This channel is now discharging surface run-off directly onto the large failure and rapid degradation of the endwall would ensue.

Minor tensile cracking was observed behind the crest bund at several locations, which was possibly due to undercutting of the batter face immediately below the crest. A wide catchment area exists between the crest bund and drainage channel spoiled material, as shown in Figure 5-11, which may facilitate the ponding of surface water.



Figure 5-7: Large Rotational Slumping in Tertiary Horizon – Endwall

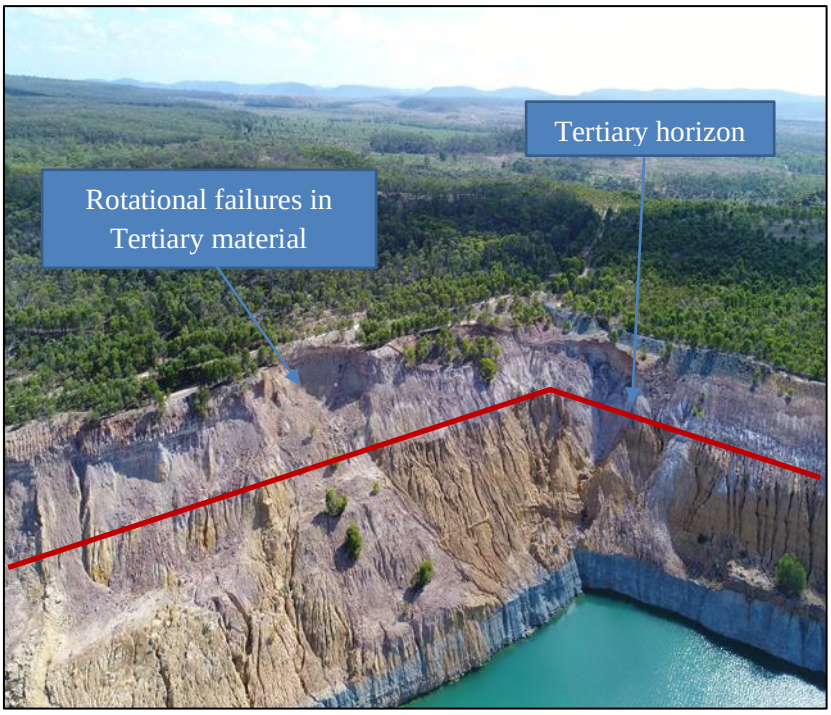

Figure 5-8: Endwall Failures in Tertiary Material



Figure 5-9: Endwall Drainage Channel

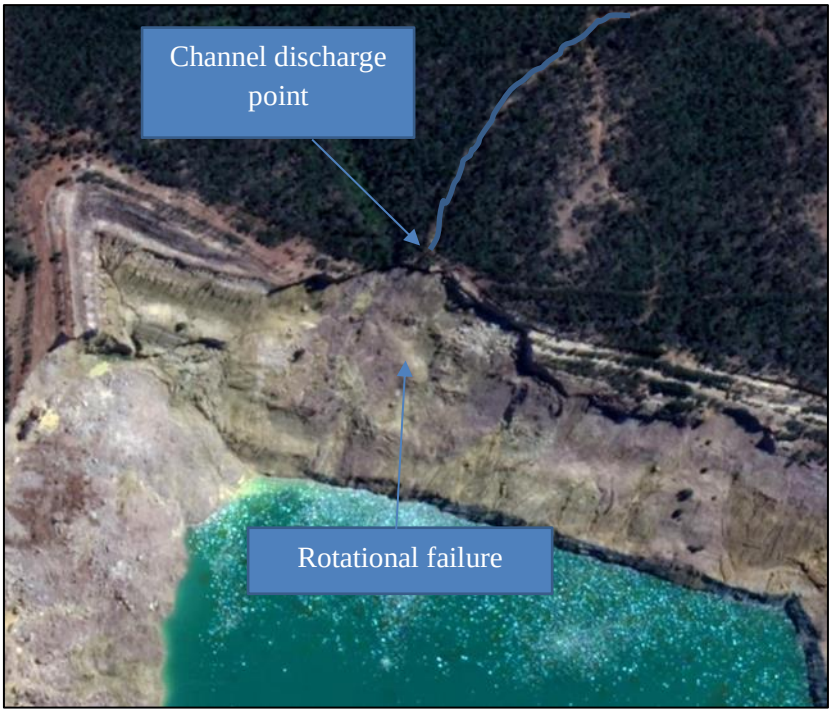

Figure 5-10: Endwall Circular Failure

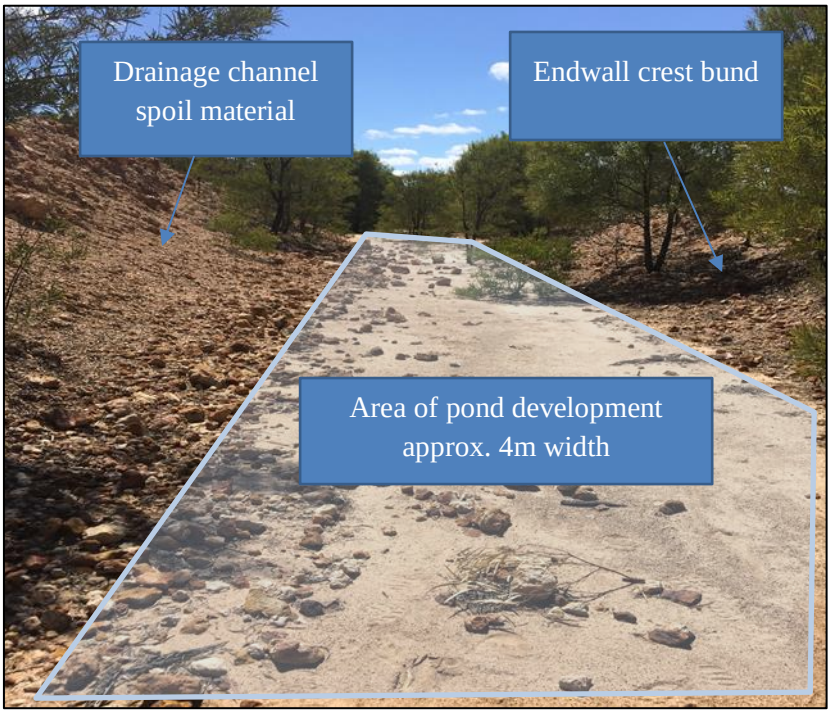

Figure 5-11: Catchment Area – Endwall Crest and Drainage Channel Spoiled Material

5.4 Southern Lowwall and External Spoil Dumps

At the time of inspection, the lowwall section south of the pool had been rehabilitated and it appeared to be in a stable state, refer Figure 5-12. The Tertiary batter above the rehabilitated spoil which is constructed at 40^0 batter slope appeared to be stable.

Hence the two external spoil dumps have been adequately rehabilitated and were in satisfactory condition at the time of inspection with their slopes re-profiled at 1V:6H (9°).



Figure 5-12: Rehabilitated Lowwall

5.5 Re-Graded Highwall

Figure 5-13 and Figure 5-14 shows surface runoff from the exposed face of the re-graded highwall section (south of the current eastern highwall) has resulted in deep gully and piping erosion along most parts of the dump face. These gully features are visible from the aerial photo, as shown in Figure 5-15.

In this case, the length of the slope and wide catchment area formed from the shallow slope are likely to contribute to significant rates of gully erosion. The spoil material is highly dispersive as is evident from accumulation of fine silt and sand factions at the base of the slope (Figure 5-15).

Overall, these features are unlikely to influence slope stability; however, they are likely to present hazards for machinery and personnel when slope is re-profiled for rehabilitation.

A shallow subsidence area and evidence of ponded surface water occur immediately behind the dump crest.



Figure 5-13: Gully Erosion – Re-Graded External Dump Section (Looking West)

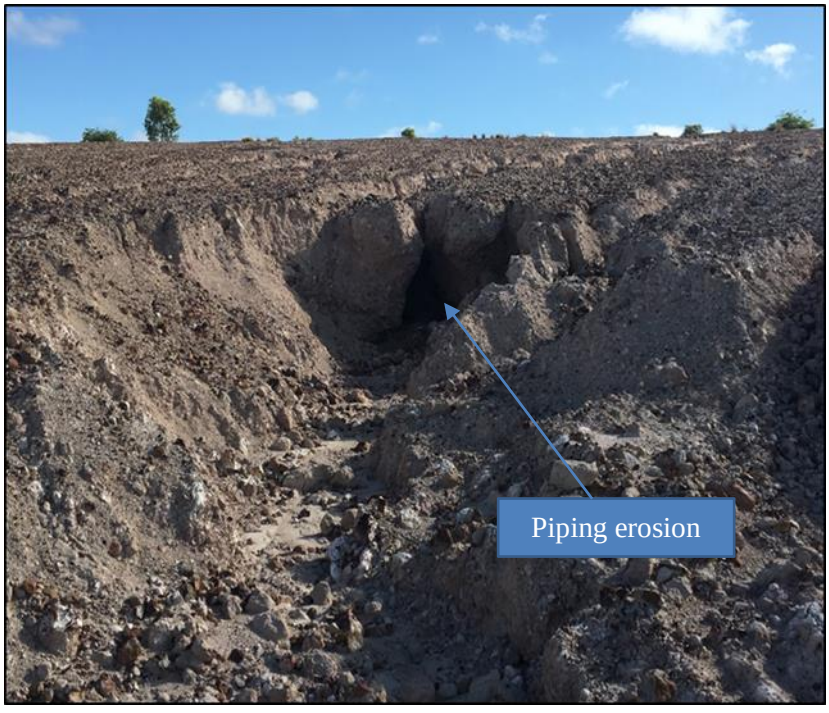

Figure 5-14: Piping Erosion – Re-Graded External Dump Section (Looking West)

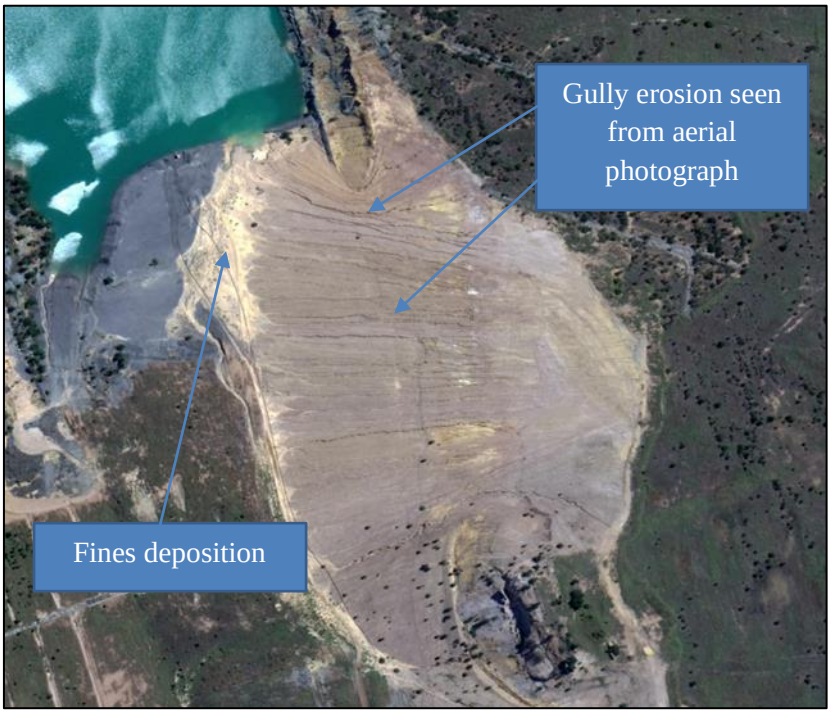

Figure 5-15: Re-Graded Spoil Rill Erosion

6. SLOPE DESIGN

6.1 Highwall and Endwall

The standard slope design criteria for highwalls and endwall in the Rewan Formation and Rangel Coal Measures are summarised as follows:

- Berms are generally designed to RL unless following a coal floor. A rock head berm with a minimum width of 20m is required to control failures from the weathered horizon;
- Batter angle in the Weathered and Tertiary horizon is generally constructed at 45°;
- Rock benches in fresh un-weathered rockmass is generally pre-split blasted and battered at 70° and;
- The maximum bench height in rock is 75m, however this can extend up to 80m.

This design is used for all in-situ pit wall slopes under normal conditions. Modifications are made for local situations where fault zones intersecting the walls could create conditions of instability.

A generalised slope design diagram is illustrated in Figure 6-1, and shows a relatively simple slope geometry. In this case, there is only one fresh rock bench below the weathered bench that extends to the pit floor.

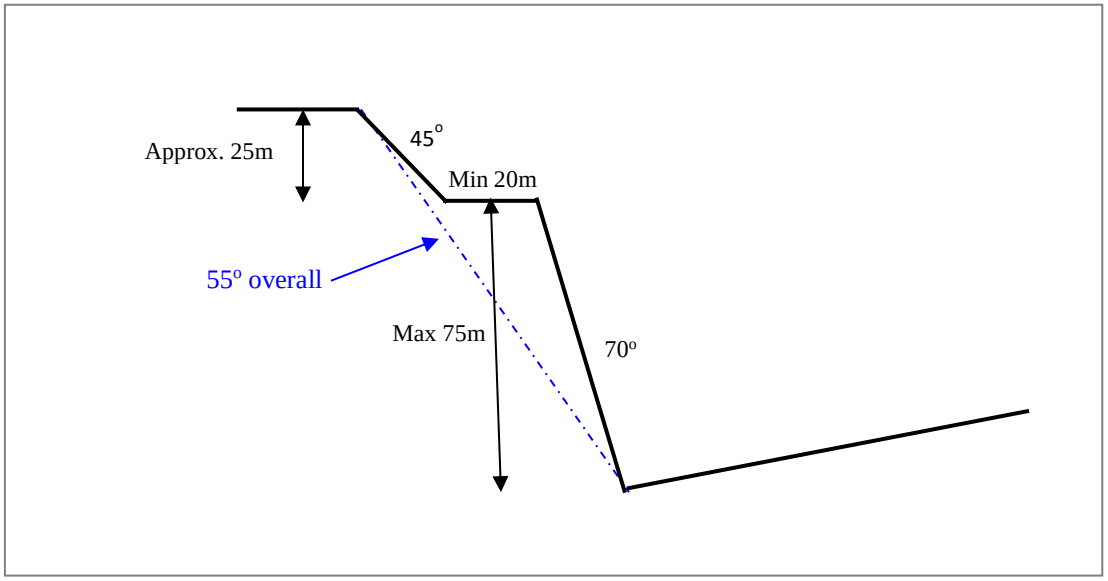

Figure 6-1: Highwall Slope Design

6.2 In-Pit Spoil Dumps

In-pit spoil dumps are generally dumped in at nominated lifts at dump materials angle of repose with berms between lifts to contain material that may come off the dump face. The angle of repose is 35° on average, can be up to 37° for blockier spoil.

The final profile may depend on operational factors, but is usually within the following constraints:

- Maximum dump height - 35m;
- Maximum berm width - 25m; and
- Maximum overall slope angle (toe to toe) not exceeding 25°.

Given the floor dips at Wallanbah pit ranges between 15° – 24° in the north, and 13° - 19° in the south, conventional dip line mining was not a suitable mining method in certain sections of the pit. Terrace mining along strike therefore was used to reduce risks associated with operating on a steep floor gradient.

A generalised design profile is shown in Figure 6-2.

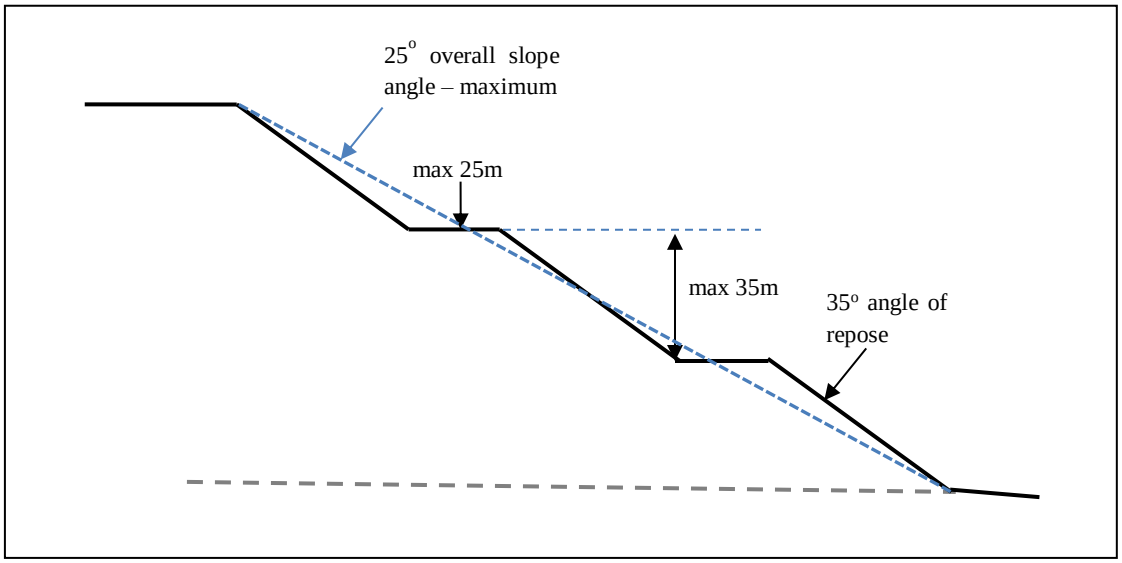

Figure 6-2: In-Pit Spoil Dump Design (Ref 1)

6.2 External Dumps

As a general guide, external dump faces are normally formed to facilitate re-grading to 1V:5H slopes for rehabilitation. The overall guide for external dumps is:

- Maximum dump height is 35m; nominal dump height of 20m;
- Berm width between dump lifts is about 5m and;
- Final re-graded dump slope be battered at 1V:5H (11°).

At the time of the site inspection, external dumps had been regraded to approximately 1V:6H (9°).

A generalised design profile is illustrated in Figure 6-3.

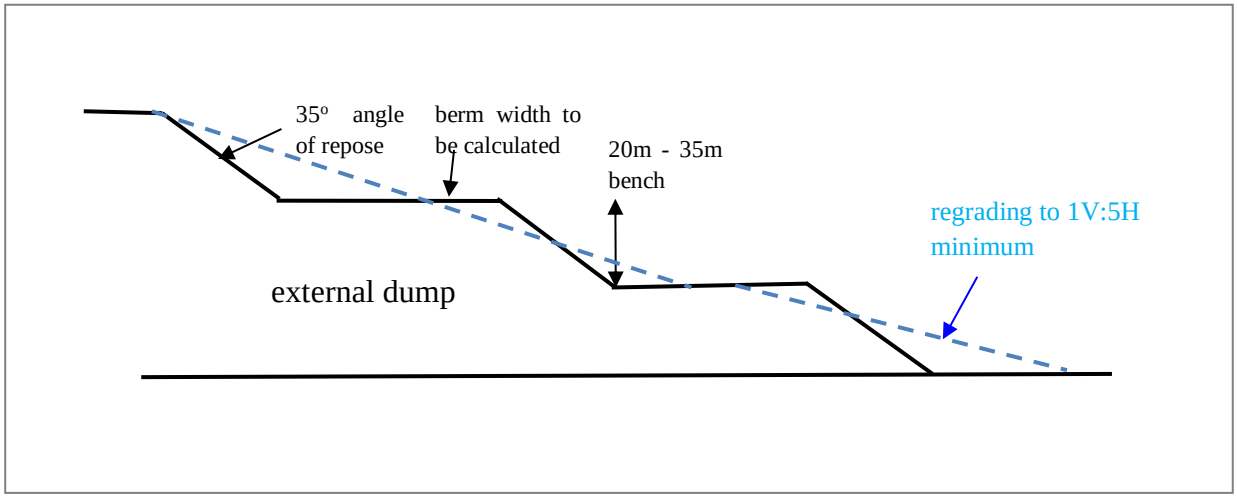

Figure 6-3: External Dump Slope Design – Externally Draining (Ref 1)

6.3 Environmental Authority Compliance – Geotechnical Stability

The Environmental Authority (EA) specifies that highwall slopes in competent rock formations can remain as constructed if they are geotechnically stable, with the EA requirements for pit slopes not being specific in terms of design parameters. In this case, the asbuilt highwall slope profiles are typical of the designs used in the Bowen Basin (Ref 3).

In-pit spoil dumps slopes are generally dumped in at the materials repose angle between 35 - 37^0 with maximum dump lift of 35m on a gently dipping slopes at Wallanbah. It is thus considered that the Wallanbah Inpit Dump is in compliance with industry standard for rockfill dumps on flat or gently dipping ground in accordance with EA requirement for geotechnical stability.

In-pit spoil dumps are generally susceptible to mass failure if the floor is sloping at angles >12.5°, and particularly if the floor is weak or sheared. Floor dips greater than 12.5° are a notable feature of Wallanbah Pit, particularly in the south, and terrace mining methods were employed to account for steep floor gradients.

The external dumps have been rehabilitated after the slope was re-graded to less than 11° (1V: 5H) as per the EA requirement (Ref 8).

A summary of the EA specifications is presented in Table 6-1 below.

Table 6-1: Environmental Authority Specifications (Adapted from Ref 8)

Disturbance Type	Design Criteria	Qualifications/Requirements
Highwall/endwall – Competent rock	< 70° slopes	Competency certified by an appropriately qualified professional accredited by a credible third party
Highwall/endwall – Incompetent rock	< 50° slopes	
Lowwall – In-pit	Angle of Repose (approximately 35°)	Drainage, erosion control and seeding works to be conducted as required
External dump (grassland suitable for grazing)	< 20% outer slopes; < 12% on plateau	Currently re-graded to 1V:6H (9°)
External dump (not suitable for grazing)	< 20% outer slopes	

7. LONG TERM STABILITY – FINAL LANDFORM

7.1 Highwall and Endwall Geotechnical Stability

The upper Tertiary horizon along the highwall and endwall are presently in a state of failure. The degradation of the tertiary slope will continue unhindered as drainage pathways at both walls have been captured by slope retreat resulting in surface runoff (from the surrounding country) now being discharge directly into existing slope failures during periods of rainfall. In other area of the slope it is considered that slope failures were initiated by the steep angle (65^{0}) at which slope was constructed refer Ref 1. Failure within the Tertiary Horizon has resulted in the development of a near vertical backscarp which is inherently unstable hence slope instability in this horizon shall continue until the slope reaches a stable configuration at a slope repose angle of between 30 -35^{0}. The typical failure geometry observed in the Tertiary horizon is depicted in Figure 7-1.

It should be noted that the Tertiary sub-vertical slope would remain stable until soilmass is wetted and or pore pressures increases in the material during rainfall events. The process is slow, and a stable slope configuration will be reached over many years.

Geotechnical stability in rock slopes is generally controlled by rock mass strength and presence of geological structure. The rockmass strength is high and will not permit shear failure. Rock mass strength is scale dependent, and if the rock mass has many discontinuities and if the slope is high then, stepped pathways could develop linking the discontinuities which can result is a failure of the slope through the stepped pathway. In such cases the rockmass does not undergo shearing (Ref 2).

Rockmass failures requires the presence of pre-existing discontinuities such as joint sets, faults, adversely dipping bedding planes and shears that are unfavourable orientated with the slope face.

Faults intersections were noted along the NE highwall which had resulted in a multi-bench wedge failure refer Figure 5-3. In this case, the wedge had failed back to the intersecting planes thereby eliminating the risk of further wall failures.

A fault (Endwall Fault) runs subparallel to the endwall. It dips between 65 and 70^0 north i.e. into the endwall. The Endwall Fault will not impact the stability of the endwall refer Table 7-5 below which presents results of stability analysis done on this fault.

Rock mass strength failures are unlikely to occur at slope heights less than 300m under normal slope conditions (Ref 4). The maximum slope height at the Wallanbah Pit is110m of which only between 75 - 80m is constructed in fresh rockmass.

Based on the above the Wallanbah Pit highwall and endwall are stable, they will not be affected by large scale rockmass wall failure, refer stability analysis results presented in Section 7.4 below.

Apart from the above factors and possible built up of cleft pressures during rainfall events that may destabilise a slope, the use of auger coal recovery techniques along the north east segments of the highwall and endwall may have contribute to long term instability of affected wall segments after pit is flooded. The location auger drilling done in 2010 is given in Figure 7-2.

In general, the easterly dipping bedding observed in the highwall reduces the risk of block slippage from the highwall. Along the endwall, bedding dips are orthogonally to the face hence there is a low risk of block sliding occurring.

The designed long-term void water level of 272m RL will not impact on Tertiary and Weathered slopes as the base of weathering is located at 275mRL hence the pit has a 3m high free board.

Residual risk exists for all abandoned pit walls from a stability perspective and the Wallanbah Pit is no exception. For steep rock slopes, rockfall is the most common risk as the faces degrade over time. Blocks will be released and will roll down slope in the graded

slope area or rockfall into the pool is expected from the highwall and endwall.

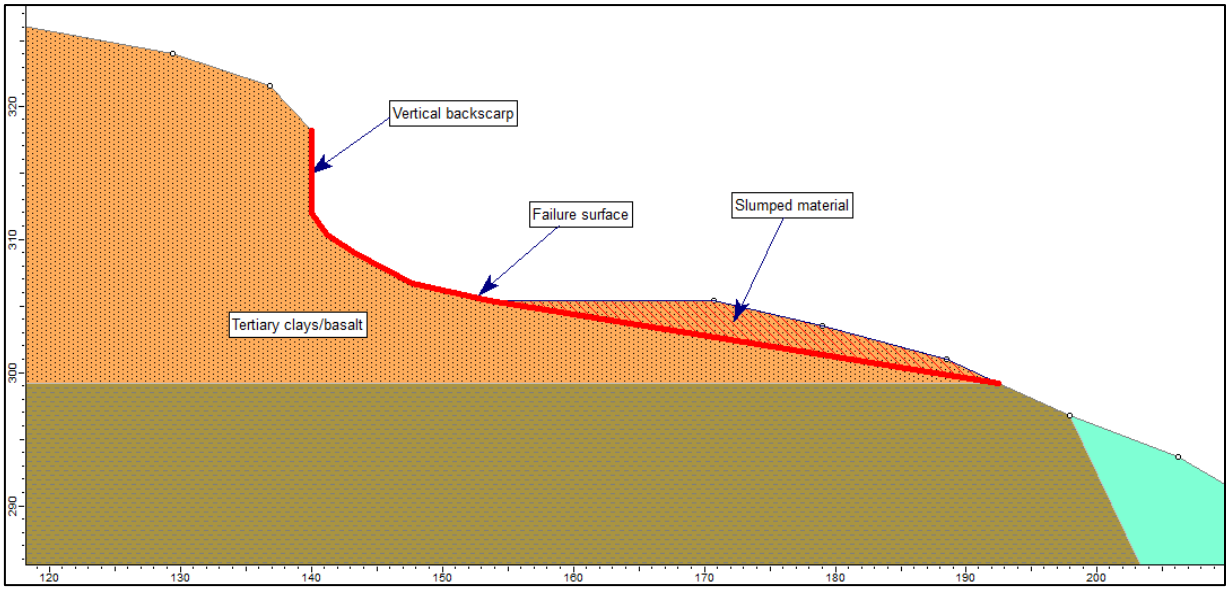

Figure 7-1: Example of Rotational Failure

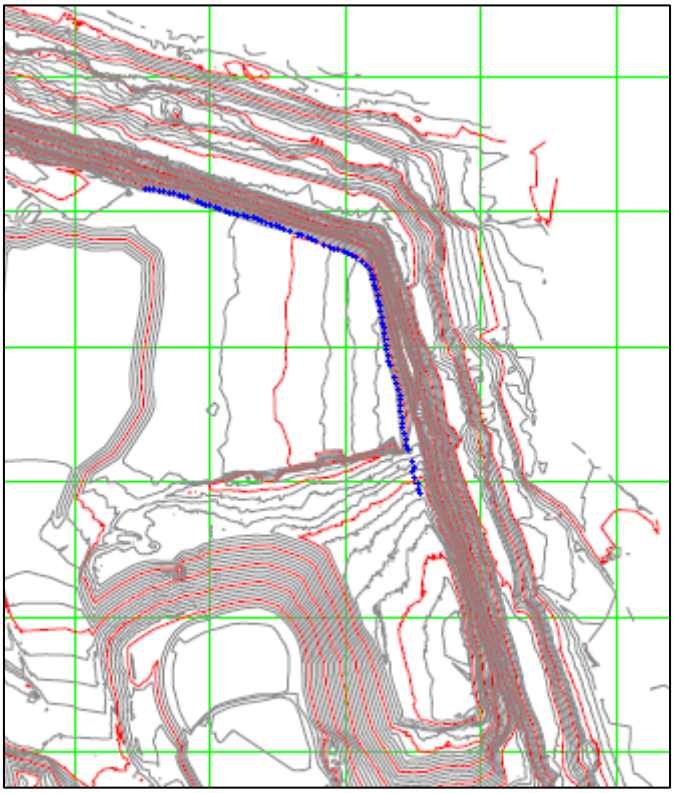

Figure 7-2: Highwall and Endwall Auger Drilling Locations

7.2 Lowwall and Re-Graded Highwall Geotechnical Stability

Historical photographs of the operational lowwall show evidence of instability due to over-steepening of the Tertiary units. In this case, the batter angle was estimated to be approximately 65°, which is too steep for this material type, refer Figure 7-3. Figure 7-4 shows the initiation of a circular failure that has led to the current poor slope conditions due to progression of a series of wall failure after the initial failure.

It is noted that lowwall failures are confined to the Tertiary horizon, it is seen in Figure 7-4 that, the fresh Permo-Triassic rockmass is not affected by instability. This indicates that failures in the Tertiary horizon is largely driven by weak material strengths aggressive batter angle of 65^{0}at which the wall was constructed.

The remnant exposed Tertiary lowwall batter did not show any signs of instability; however, there is a high likelihood of further toppling failures of the basalt cap due to over-steepening and under-cutting because of the previous failures. In this case, it is likely the slope will continue to recede.

The Burton Range Fault (BRF) is located behind the lowwall and it dips between 20 and 25^{0} towards the east (i.e. toward the pit) refer Figure 4-3 and Figure 7-5 below.

The cross section presented in Figure 7-5 indicated the BRF as a discrete line; that is considered to be misleading. The BRF is a 20 - 50m wide zone characterised by sheared soils and fracture pulverised rockmass with associated splay faults and possible drag faulting along the coal refer Ref 10.

Stability analysis on lowwall due to the presence of the BRF suggest that its long-term stability is in question refer §7.6.4 below.

The buttressed lowwall to the south of the North Wallanbah void, has been rehabilitated and no evidence of mass slope instability was observed during the inspection suggesting a low risk of instability over the long-term.

Displaced Tertiary material was observed against the lowwall slope toe possibly failed slope debris or maybe spoil placed to buttress the slope as a risk mitigation strategy.

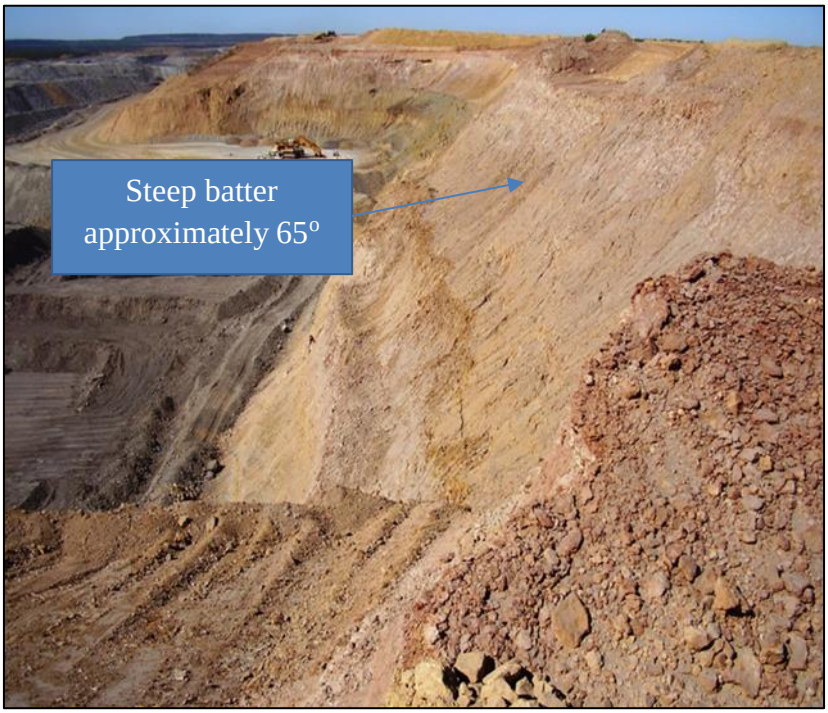

Figure 7-3: Operational Asbuilt Lowwall (NB Steep Batter)



Figure 7-4: Circular Failure in Tertiary Horizon

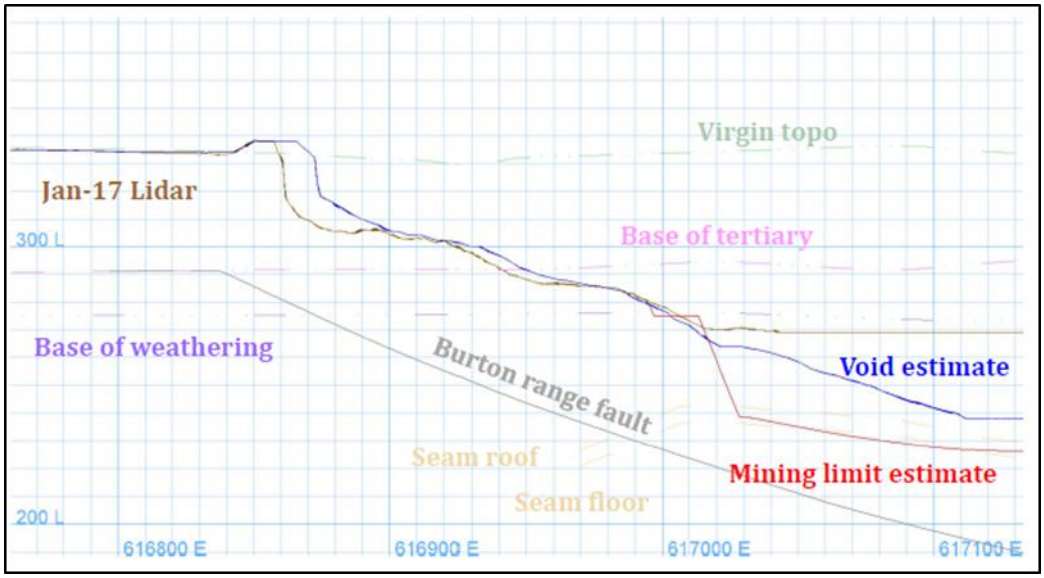

Figure 7-5: Burton Range Fault Location – Lowwall Section

7.3 Re-Graded Highwall Geotechnical Stability

The re-graded section of the highwall has been flatten to approximately 9°. Despite the slope being impacted by erosion, the risk of mass instability is low.

7.4 Environmental Stability - Weathering and Erosion

The Tertiary materials are highly dispersive and susceptible to erosion. Dispersion is a mechanism of chemical detachment requiring minimal physical force and generally occurs where water infiltrates rather than just at the surface (Ref 6). Tertiary clays will continue to degrade over time via these mechanisms if left exposed for extended periods of time.

Sandstone typically is less susceptible to degradation caused by weathering compared to siltstone, mudstone or Tertiary materials. Preferential slaking and erosion of the less competent silts/stone mudstone units underlying competent sandstone units over time will lead to undercutting that can result in development of rockfall hazards within the sandstone horizon.

From visual observations of the highwall it is considered that detached block sizes will be small and inconsequential to slope stability. Rockfall generated off the highwall will fall into the pool of water held in the pit void.

In the long-term, the highwall and endwall faces are expected to erode to some extent due to natural weathering processes; however, the asbuilt profile will be maintain over a long period of time.

It is difficult to set a time frame for weathering; however, studies carried out by the Burton Widening project indicated a degradation rate of 40 - 50mm per year on the highwall; that is equivalent to 1m of weathering after a 20-year period (Ref 1).

The Tertiary cover and weathered horizon forming the upper benches are likely to be susceptible to slaking, and will gradually degrade to a flatter slope angle, as is evident along the endwall and lowwall.

Currently, there is limited space on the rock head berm to accommodate further failures from the upper Tertiary horizon. In this case, mass movement of the failed material into the void will occur as more material is shed from the upper slopes.

Overall, these weathering and erosional processes should not affect the overall stability of the highwall and endwall slopes.

7.5 Limit Equilibrium Analysis Methodology

Stability analyses were carried out to test the long-term stability of the lowwall, endwall and highwall at the designed maximum flooded capacity of 272mRL for the final pit void. Additionally, a series of analyses were also carried out for a minimum pit water level of 246.5 m RL.

Nine representative cross sections were generated and tested, refer to Figure 3-1 which shows where cross sections were taken and are labelled from Section 1 – Section 9.

These sections were tested using 2D limit equilibrium methods in Slide 7.0 for the failure mechanisms listed below: -

- Spenser circular failure method using grid search method for upper Tertiary and weathered horizons. An overall full slope height failure was also tested for the weathered and fresh rock formations;
- Spenser circular failure method using grid search method for the in-pit spoil failures;
- Non-circular failure for full slope height in weathered and fresh rock using the Cuckoo search method and; -
- A Factor of Safety (FoS) of 1.5 was taken as the lower bound to test the long-term slopes or final voids. Any values lower to 1.5 should be taken as unacceptable for the long-term stability of the Wallanbah final pit void.

The shear strength parameters used in the analysis for the different material horizons are summarised in below. They are based on strengths developed by Simmons and McManus (Ref 5) and used as a standard in the coal mining industry. Site specific material strengths were also derived from internal testing carried out by Peabody (Ref 2).

Table 7-1: Adopted Material Shear Strength Parameters (Ref 2)

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu	Ru
Tertiary Clay		20	Mohr-Coulomb	20	25	Water Surface	Custom	1	
Weathered Rewan		22	Mohr-Coulomb	75	30	Water Surface	Custom	1	
Fresh Coal Measures		24	Mohr-Coulomb	450	42	Water Surface	Custom	1	
Coal		15	Mohr-Coulomb	30	35	Water Surface	Custom	1	
Cat 2 U Spoil		18	Mohr-Coulomb	30	28	None			0
Cat 2 S Spoil		20	Mohr-Coulomb	15	23	Water Surface	Custom	1	
Siltstone Floor		20	Mohr-Coulomb	450	42	Water Surface	Custom	1	

U = unsaturated spoil; S = saturated spoil.

7.6 Limit Equilibrium Analysis Results

7.6.1 As-Mined and Re-Graded Highwall

The results of the stability analyses for the as-built and re-graded highwall are summarised in Table 7-2 below.

The stability assessment indicates critical FoS values exceed 1.5 for deep seated circular and non-circular failures in the weathered horizons. It is therefore considered that full slope height failure is unlikely or has a low probability of occurring involving the Tertiary and Weathered horizons, refer Figure 7-6 and Figure 7-7.

The analyses were carried for the maximum and minimum pit water levels showed critical FoS values exceeded 1.5 in both cases, as shown in Figure 7-8 and Figure 7-9.

Results for the other analysis done for the above horizons are including Sections 1 to 3 are presented in Appendix 1 for the interested reader.

Table 7-2 : As-Mined and Re-Graded Highwall Stability Results

Section	Pit Sector	Failure Scenario	Factor of Safety (FoS)
1	Re-graded Highwall	BOW - circular	**4.63**
2	As-mined Highwall	BOW – circular (Fig 7-2)	**2.07**
		BOW – non-circular (Cuckoo)	**3.91**
3	As-mined Highwall	BOW – circular (Fig 7-3)	**1.78**
		Full height - circular	**2.71**
		Full height – non-circular (Cuckoo) - water level max	**2.64**
		Full height – non-circular (Cuckoo) - water level min	**2.08**

FoS ≥ 1.5 highlighted in green

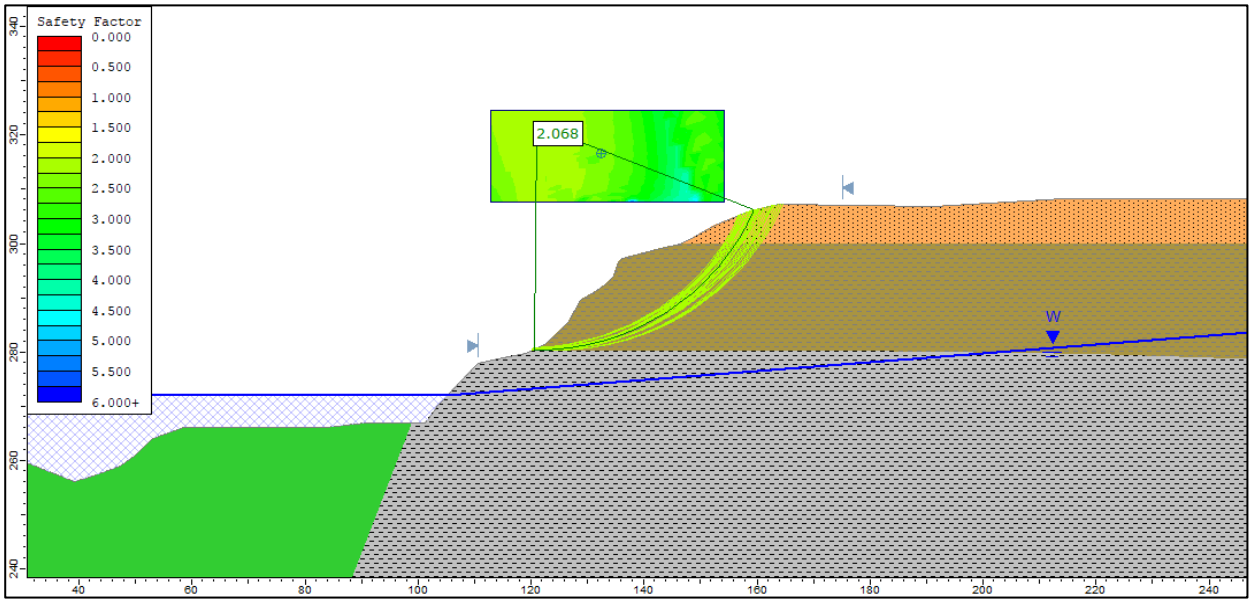

Figure 7-6: Section 2 – Weathered Horizon Circular Failure

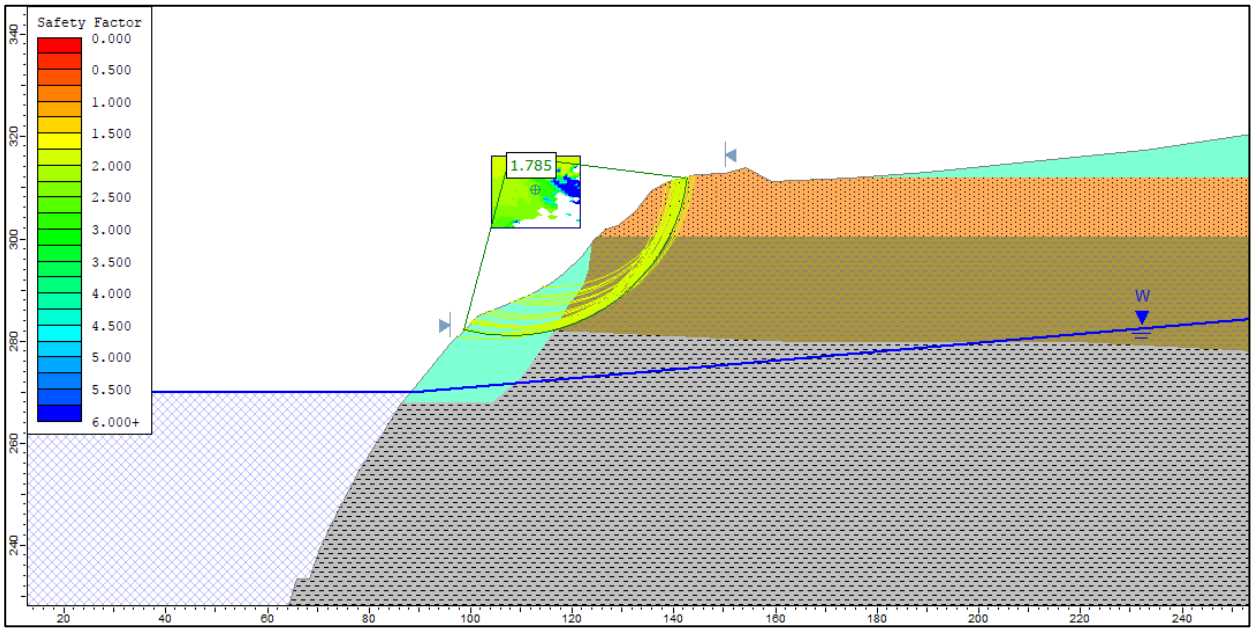

Figure 7-7: Section 3 – Weathered Horizon Circular Failure

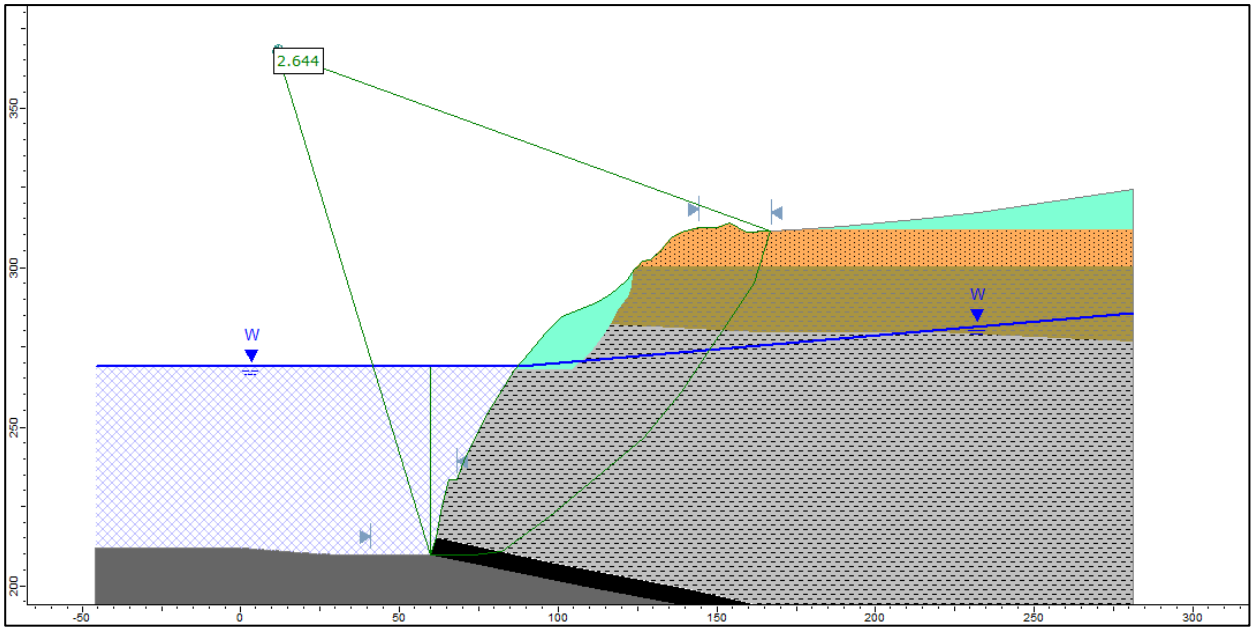

Figure 7-8: Section 3 – Non-Circular Failure Mechanism for Maximum Void Water Level

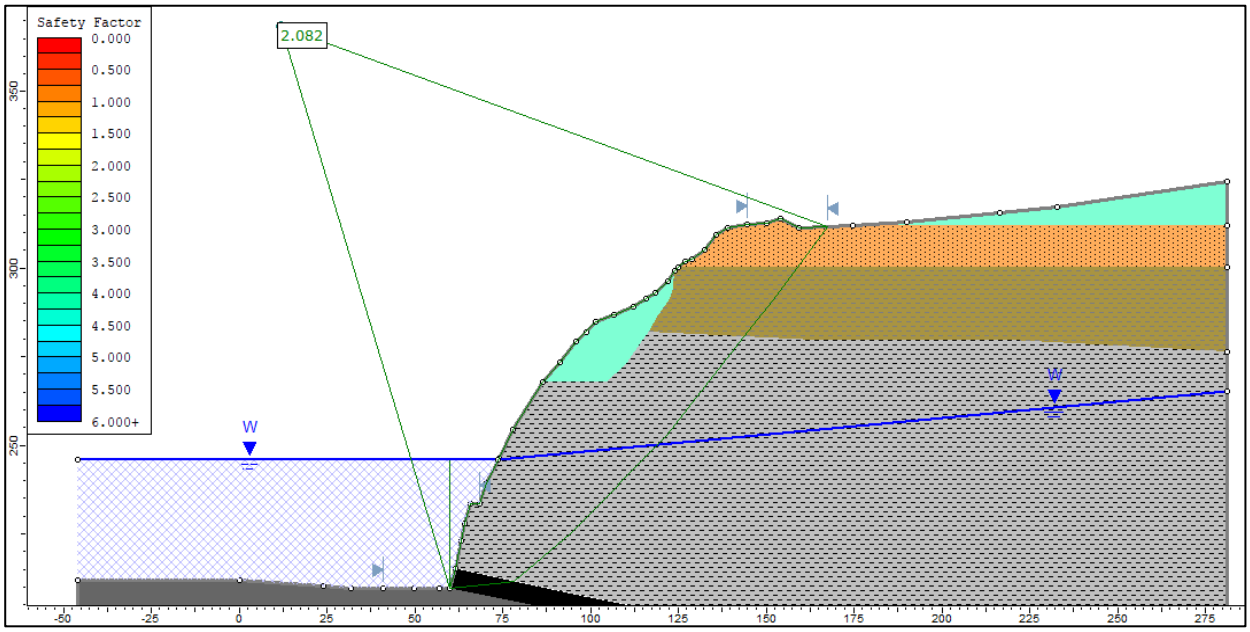

Figure 7-9: Section 3 – Non-Circular Failure Mechanism for Minimum Void Water Level

Table 7-3: Endwall Stability Results

Section	Pit Sector	Failure Scenario	Factor of Safety (FoS)
4	Endwall	Tertiary – circular (shallow failure)	**1.04**
		BOW - circular	**2.34**
		Full height – non-circular (Cuckoo) - water level max	**2.01**
		Full height – non-circular (Cuckoo) - water level min	**1.85**
		* Full height flooded pit non-circular due to fault	**2.03**
5	Endwall	Tertiary – circular (shallow failure)	**0.98**
		Tertiary + weathered - circular	**1.63**
		Flattened Tertiary – circular (shallow failure)	**1.56**
		* Full height flooded non-circular due to fault	**2.53**

FoS ≥ 1.5 highlighted in green; FoS < 1.5 in yellow; FoS <1 in red * Stability Analysis non-circular using GLS / Spencer methods

7.6.2 Endwall

The results of the stability analyses for the endwall are summarised in Table 7- above.

They indicated critical FoS values greater than 1.5 for all analysis on deep seated failures through the weathered profile and full slope height wall failures, refer Figures 7-6 7-13.

Results for circular failure in the over-steepened Tertiary horizon however indicated that a high probability exists for the occurrence of rotational failures in that horizon - FoS values of 1.04 and 0.98 were observed for 2 analyses done for that horizon, refer Figures 7.10 & 7.11.

It is noted that for analysis of the two above cases i.e. Figs 7.10 and 7.11, failure is confined to the over-steepened upper segment of the Tertiary horizon hence it is considered that failure would continue until a stable slope configuration is reached.

It is considered that due to the very low FoS values observed for the over-steepened sections of the Tertiary endwall some remedial works maybe required to increase the stability of the slopes in question.

The maximum effective doze down slope angle for the Tertiary horizon is 28º. Figure 7-12 shows a reprofiled slope where the Tertiary had been graded to 25º at which a critical FoS value of 1.56 was recorded.

Analyses done for the maximum and minimum void water levels showed critical FoS values greater than 1.5 refer Table 7-3. Additional analysis were done to test sections and figures for these are presented in the Appendix 1.

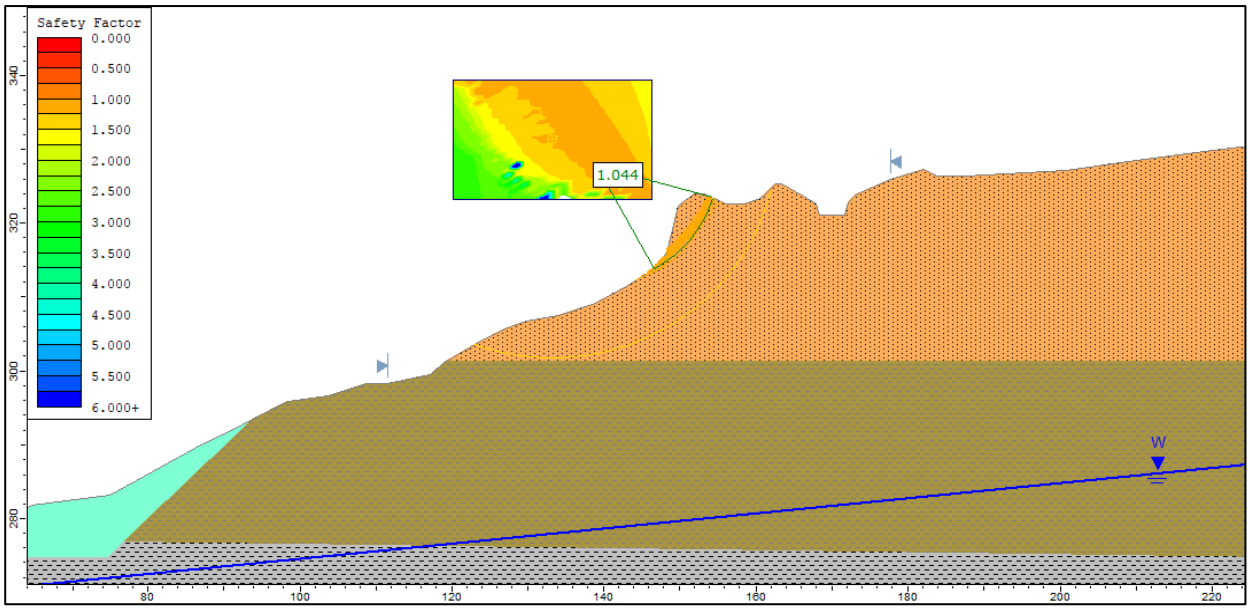

Figure 7-10: Section 4 - Tertiary Horizon Circular Failure

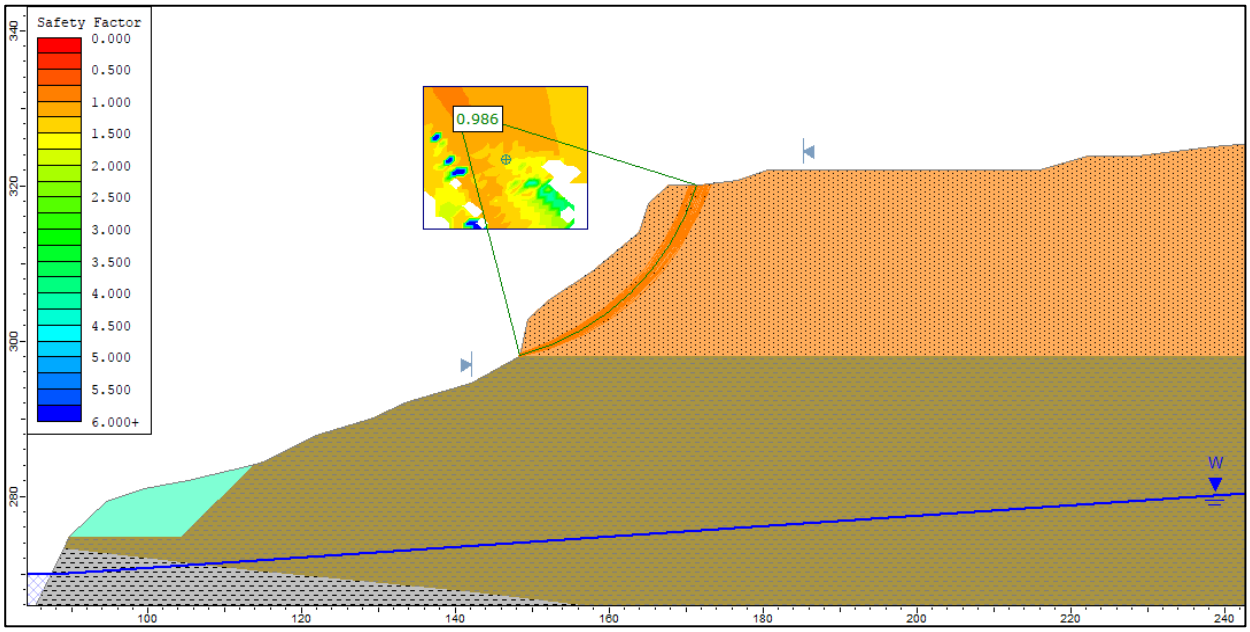

Figure 7-11: Section 5 - Tertiary Horizon Circular Failure

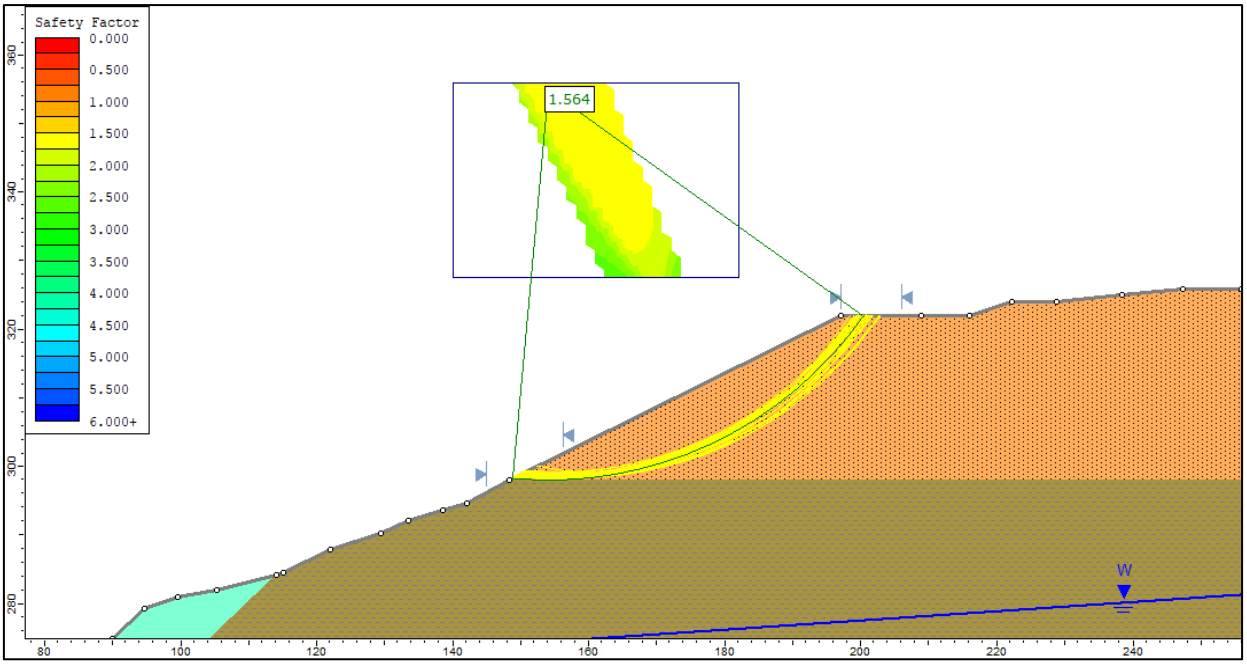

Figure 7-12: Section 5 – Flattened Tertiary Circular Failure

Table 7-4: Lowwall Stability Results

Section	Pit Sector	Failure Scenario	Factor of Safety (FoS)
6	Lowwall	Tertiary – circular (shallow failure)	**0.62**
		Full dry slope non-circular with BRF	**1.49**
		Full wet slope non-circular with BRF	**1.23**
7	Lowwall	Tertiary – circular (shallow failure)	**0.93**
		Historical – Failure initiation	**0.69**
		Full dry slope non-circular with BRF	**1.06**
		Full wet slope non-circular with BRF	**0.92**
8	Lowwall	Tertiary + weathered - circular	**2.01**
		Tertiary – circular (shallow failure)	**1.38**
		Unsaturated spoil - circular	**2.34**
		Full dry slope non-circular with BRF	**1.78**
		Full wet slope non-circular with BRF	**1.57**

7.6.3 Lowwall

The results for stability analyses for the lowwall are summarised in Table 7-4 above.

They showed critical FoS values for the over-steepened upper Tertiary batters of 0.62, 0.93 and 1.38, respectively (refer Figure 7-13 and Figure 7-14). In those cases, failures will continue until the upper slope reaches a stable angle of about 30° or less.

Results for stability analysis done for all other analyses indicate that failures are unlikely with critical FoS values exceeding 1.5.

Back analysis of the initial failure surface (depicted in Figure 7-16) indicated a critical FoS value of 0.69 hence the slope had failed in the past.

It is noted that this slope was constructed at a batter slope angle of 65^{0} which is 2.6 times greater than the internal friction angle of 25^{0} recorded for the Tertiary material refer Table1 above.

Results for additional analysis done to support the above observations results for Sections 6 to 8, are presented in Appendix 1.

Table 7-3 : Lowwall Stability Results

FoS ≥ 1.5 highlighted in green; FoS < 1.5 in yellow; FoS <1 in red

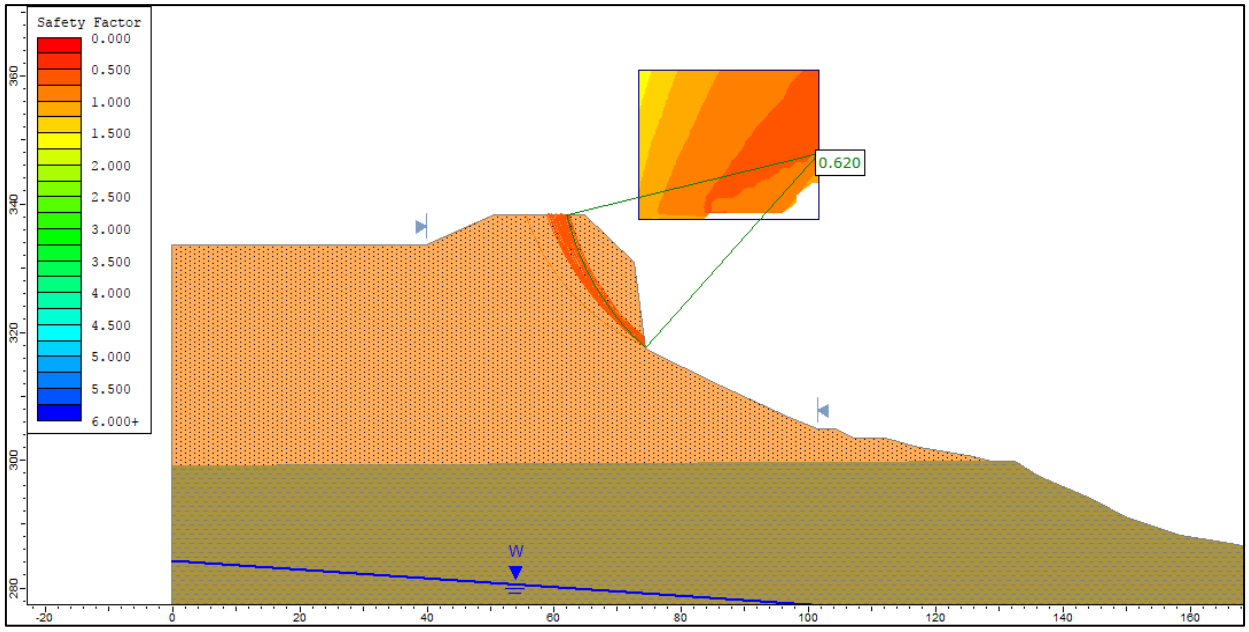

Figure 7-13: Section 6 - Tertiary Horizon Circular Failure

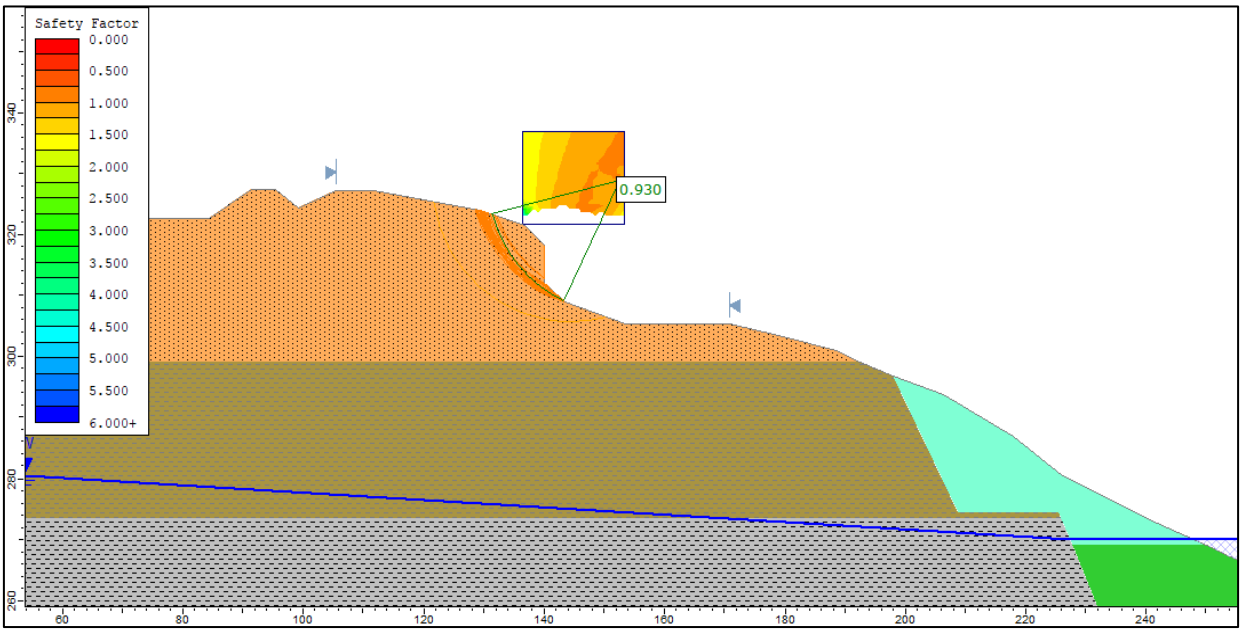

Figure 7-14: Section 7 - Tertiary Horizon Circular Failure

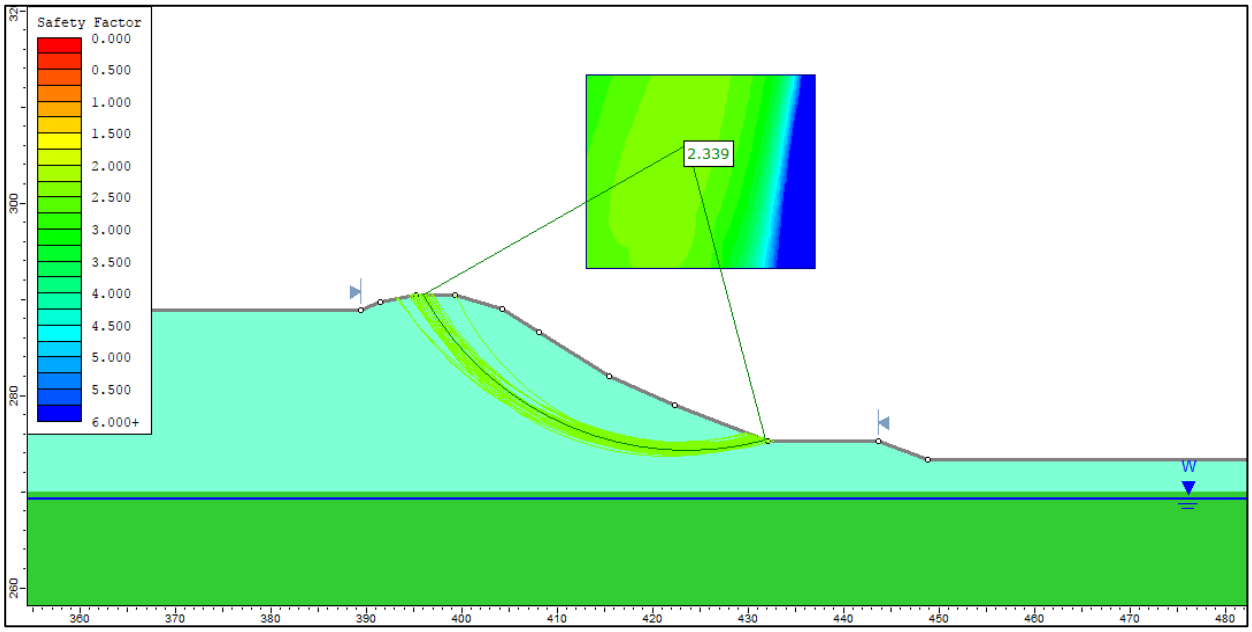

Figure 7-15: Section 8 – In-Pit Spoil Circular Failure

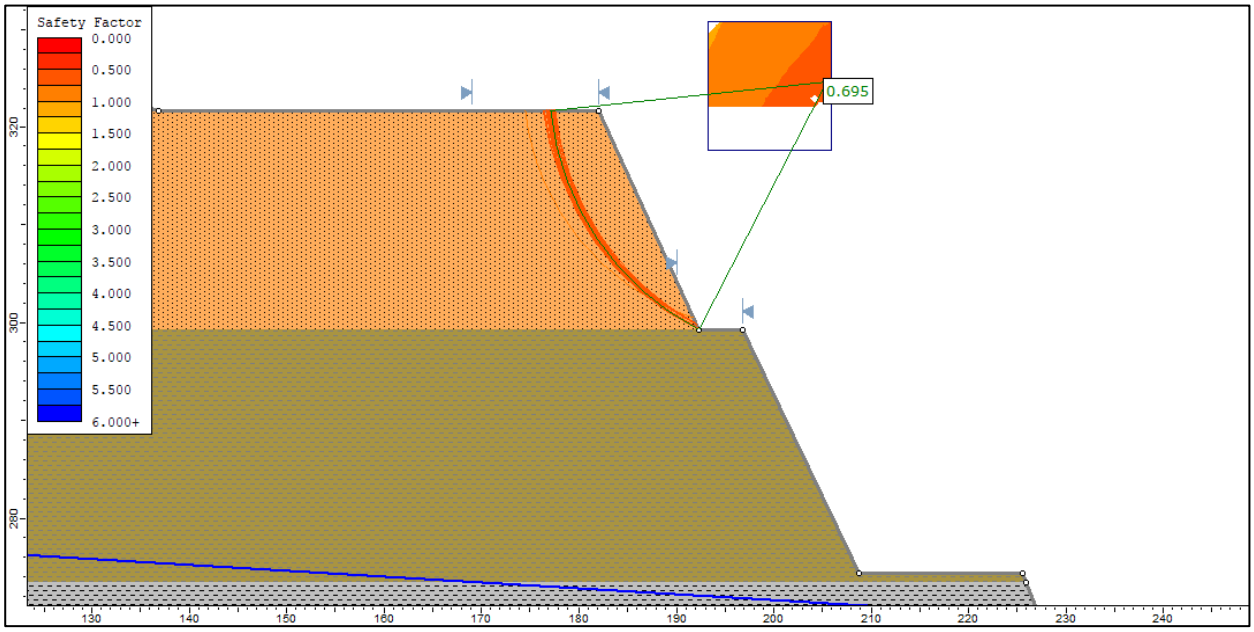

Figure 7-16: Section 7 - Historical Back Analyses Initial Circular Failure

7.6.4 Lowwall Instability due to Burton Range Fault

Ian Kelso (Ref 9) did a series of 2D analysis of the lowwall in 2009 on 4 proposed Lowwall Cut Back Design options to determine best option to optimise coal recovery due to lowwall instability

risks associated with the Burton Range Fault (BRF). In his discussions, Kelso cited that the BRF was a 20 - 50m wide zone of poor rock / soilmass strength, with secondary splay faults and drag faulting of the coal seam.

It is noted also that the BRF is dissected by the North Wallanbah Fault system at the south and the endwall fault refer Figure 4-3 above. Those faults will provide passage for water from the inpit pool to infiltrate and saturate the soil /rockmass in the BRF behind the lowwall.

The long-term stability of the lowwall could be compromised by softening of the material and by pore pressure built up in the BRF behind the lowwall if there is an imbalance in the height of water between the pit and lowwall ground water levels (GWL), a situation where a perched GWL is created.

Such a situation would be created if the water level in the pool is reduced quickly without corresponding drawdowns of the GWL in the lowwall.

A sudden failure of a large segment of the lowwall could generate a tsunami given the depth of water presently held in the Wallanbah Pit void.

The following section of this report is done by John Kawatt (Geotech Engineer – Blackrock Mining Consultants). It will consider the lowwall's long term stability due to the presence of the BRF.

The endwall was also analysed to gauge the effects of the endwall Fault after pit is flooded. The endwall fault which dips at between 60 and 70 degrees north has no bearing on stability the endwall hence it is stable over the long term; it will not be considered further here.

Three cross sections (equivalent to Sections 6,7 and 8 from Figure 3.1 above), were generated and analysed.

Two sets of analysis were each done for Sections 7 and 8 for both dry and wet slope scenarios. A 3rd analysis was also done for section 6; (beside the dry and wet slope scenario ones) to determine reduction in FoS value if a 10m elevation difference was created between the Pit water and lowwall GWLs i.e. a 10m perched water table.

Assumptions used in Lowwall 2D Slope Stability Analysis

- Three representative cross sections were generated, refer Figures A1-9 to A1-13 in Appendix 1;
- The modelled sections included in pit spoil buttress that was dumped in to improve lowwall stability during coal mining operations;
- The dumps in buttress was analysed as using Cat 2 material strengths given that the materials slacking potential;
- The Burton Range Fault (BRF) was assumed to be a 5m wide zone;
- BRF was modelled as dipping east between 20 and 23^0 in the analyses;

- BRF was assigned shear zone strengths properties i.e. unit weight of 24/kN, C= 0 kPa and phi of 15^0;
- A splay of BRF was modelled dipping at 55^0 and tested in section 7 to determine FoS of potential failure paths in the Tertiary horizon;
- Coal was analysed using weathered coal shear strength properties;
- Shear were also modelled for top and bottom of coal;
- Analysis were done for dry pit and flooded pit settings with water level projected at 272mRL for flooded pit and;
- All sections were tested with GLE and Spencer methods as non-circular slip surfaces.

Results of FoS values observed from these analyses are presented in Table 7-5 below, images of Slide Analysis are also presented as Figures A1-9 to A1-13 in Appendix 1 at the end of this report.

Table 7 -5 Stability Analysis Results for Lowwall with respect to BRF

Slope Sector	FoS Observed	Short Term Stability	Long Term Stability	Comments
Cross Section 6				
Dry Slope	1.38	stable	stable	Dry slope stable over short and long term.
Wet Slope	1.35	stable	unstable	Wet slope stable over short term, however fall short of 1.5 FoS for long term stability.
Perch Water Table	1.25	stable	unstable	
Cross Section 7				
Dry Slope	1.03	unstable	unstable	Unstable slope over both short and long term. Could be due to proximity of wall toe to BRF at 35m in model.
Wet Slope	0.84	unstable	unstable	
Dry Slope fail thro BRF Splay at 55^0	1.48	stable	stable	Failure through BRF Splay is stable when dry. When wet FoS = 1.07.
Wet Slope fail thro BRF Splay at 55^0	1.07	unstable	unstable	Near vertical failure paths with FoS values <1.2 refer Fig A1-12 in appendix.
Cross Section 8				
Dry Slope	1.38	stable	unstable	Stable dry slope, however a FoS value of 1.5 required for long term stability. Saturated slope only marginally stable.
Wet Slope	1.10	Stable??	unstable	

Observations

Results presented in Table 7-5 above indicated that the long-term stability of the lowwall is in question. The following observations are made: -

- The northern parts of the lowwall is stable at section 6 - a satisfactory short term FoS values for dry pit was observed at 1.38.
- For the wet pit, the lowwall is stable over short term however the long-term stability is not guaranteed at an observed FoS value of 1.35;
- It is also observed that if a perched water table condition is created then the FoS value would reduce depending on differences in height of water in the pit and GWLs in the lowwall.
- The long-term stability of the slope at Section 6 therefore is not guaranteed however.
- The distance from section 6 face to the 5m wide BRF modelled is about 60m;
- At section 7, the slope has a 50% probability of failure even for a dry pit scenario with an observed FoS value of 1.03. A FoS value of 0.84 was observed for the wet slope face scenario;
- That lowwall slope segment at section 7 has been standing since 2009 and has been in an inundated condition for at least 6 years and can be considered stable however the low FoS values indicate the stability may be marginal, and there would be no leeway to guarantee long term stability.
- With a subvertical BRF splay modelled refer (Fig A1-12) a dry pit FoS of 1.50 makes the slope stable for a dry slope however in a flooded pit model, a FoS value of 1.07 is observed;
- A subvertical failure path with FoS values of 1.08 is also observed refer Figure A1-12;
- The distance between section 7 face and the BRF is about 35m;
- At section 8, a FoS value of 1.38 and 1.10 was observed respectively for the dry and wet slope face. The long- term stability of the slope therefore not assured;
- The distance between section 8 face and BRF was only 38m.

Discussions

Base on the above observations, it is considered that the long-term stability of the lowwall segment extending from northing 92500N – 93500N, (north of the buttressed lowwall section) is not assured. All the results for analysis presented in Table 7-5 above, except result for failure path through a BRF Splay at Section 6, indicate that the long-term stability of the lowwall will be impacted by the BRF after pit void is flooded.

Results presented in Table 7-5 indicate instability of the lowwall at section 7 where FoS values of 1.03 (for dry slope) and 0.84 (for wet slope) were noted. This slope segment is concluded to have marginal level of stability.

It is possible that the failed Tertiary escarpment could indicate the westward extent of the mobile slope segment east of BRF. This theory was tested in one of the analysis done for section 7 where a subvertical splay of the BRF was project at about 55^0, refer Figure A1-12 in the Appendix 1.

The projected failure path returned a FoS value of 1.48 (for a dry slope) and 1.07 (for wet slope).

Interestingly one of the projected failure paths generated had a FoS value of 1.08 had near vertical backscarp through the Tertiary at 82^0. This raises questions as to whether the vertical escarpment extending the entire length of the failing lowwall is due to a subvertical splay of the BRF and whether lowwall failure is confined to the failing segment east of it?

It is also considered that before remediation works can be planned and implemented it would be necessary to establish if the lowwall is stable due to above discussions, using a wall monitoring system. A wall monitoring system consisting of wall prism surveys could be done over a long-term period of say 12 -24 months to establish the current state of equilibrium. Prism survey would enable determination of wall creep behaviour over time which will reveal clearly trends in wall movement and how far any failure induced movement extends back from the face.

Radar monitoring could also be used on short stints (9-month maximum consisting of 3 x 3 months stints on site). That would show any areas on face that are actively moving.

8. SURFACE WATER MANAGEMENT

Run-off over the highwall is likely to have minimal impact on the stability of the rock benches; however, concentrated run-off will erode and gully the upper Tertiary and weathered Triassic horizon. In this case, the large rotational failures along the endwall and lowwall are a function of the nature and thickness of the Tertiary material, and measures designed to encourage the diversion of surface water away from these areas should be given serious consideration.

It is observed that the that segments of excavated drainage channel behind the endwall and the lowwall have been captured by wall failure. Surface discharge from the landscape adjacent to those walls is now being discharged directly onto the failure head scarps. Consequently, the affected slopes will undergo rapid erosion and degradation if no attempts are made to divert water away from the wall failures.

It is observed also that the dumped material from the endwall drainage channel forms a 2m high bund preventing water from the drain flowing towards the crest. There also is a crest bund along the wall. These two bunds now create an area where large pools of water will develop during rainfall events which will result in the saturation of the Tertiary slope adjacent to the crest.

Drainage slots need to be introduced to the outer bund to allow water to drain away from the crest and into the drain meant to channel water away from the crest.

Minor cracking was observed within this catchment area and is likely to be in response to a combination of surface water infiltration and tensile failure initiation in the over-steepened Tertiary material.

The surface water management of the lowwall crest was not assessed at the time of inspection due to access restrictions. It is inferred from drone images that a similar situation to the endwall exists also exists on the lowwall.

9. CREST BUNDING

The following is proposed to improve drainage and to prevent further failure and degradation of the Tertiary horizon on the lowwall and endwall.

- A 2m high bund wall be constructed of Cat 3 material spanning the entire length of lowwall and endwall areas affected by slope instability;
- The bund wall should be constructed at an appropriate distance from the crest to prevent vehicle access onto the area adjacent to the crest and;
- The position of the bund on the lowwall would be determine by wall displacement monitoring so that it is located outside of the area to be impacted by wall instability.

Whilst there are no official guidelines in Queensland pertaining to the appropriate location of exclusion bunds, generic guidelines were developed by Ward, based on unpublished, comprehensive studies of open-cut voids at German Creek and Oaky Creek Mines (Ref 1).

It is not practicable to treat all slopes to eliminate all wall in-stability hazards. The usual approach is to minimize the likelihood of hazards by re-grading slopes which present significant risk, then restrict access to the pit. This is achieved by bunding off the access ramps and placing exclusion bunds along highwalls, lowwall and endwall.

Bund walls (bunds) should have a minimum height of 2m and should be constructed of non-dispersive (Category 3) material type with drainage slots in them to allow passage of water away from slope crest ideally into a diversion drain (Ref 2).

Drainage slots should be cut in the bund at regular intervals and at low points to allow discharge of surface water during rainfall events. Where the diversion drain directs water into the pit then A rubble lined discharge spillways should be installed. The distance between these spillways should be based discharged volumes or at regular intervals along the bund.

Given the high probability of continued failures in the lowwall and endwall Tertiary horizon, the distance at which pit crest bund could be set from the crest shall be determine by wall displacement monitoring.

Options for managing the failing lowwall and endwall are as follows: -

- Do nothing - let the slope continue to fail and recede, place bunds approximately 25m back from the crest and carry out periodic inspections to assess rate of slope loss, slope

retreat towards the bund. Note that the rate of wall degradation could exceed the statutory time limit set for slope rehabilitation.

- Set up wall prism monitoring to determine if lowwall is stable as per discussions held in §7.6.4 above, plan to have monitoring over long term of say 24 months;
- Include also plans to have radar wall monitoring of the lowwall for a period of say 9 months in 3 x 3-month stints as required;
- A two prone approach to stabilise the lowwall should be considered based on the outcome of wall prism monitoring;
- If "doing nothing" isn't the right option, then unstable sections of the endwall and lowwall could be remediated by a wall cutback design using trucks and shovel. This option is preferred for the lowwall as it would unload the vertical loading of the overburden material acting on the BRF which would increase the FoS of that slope;
- The volume of material to be removed and batter slope angles (suitable for the weak Tertiary horizon) should be applied to construct the final slope for that material;
- The slope could then be dozed down to have a grade of 1V:5H as per requirements specified in the EA;
- A simple dozer push operation with intension to doze down slope and push material into pit void is not an option; it is fraud with danger and;
- Alternatively, the wall behind the back scarp on both lowwall and the endwall could be cast blasted to achieve a gentle slope profile which could then be profiled with dozers.

The above lists of options could be detailed in a deferent report in future to design engineers to select best remediation option based on safety and economics of the design. That would be based on the outcome of the wall radar and prism monitoring.

10. CONCLUSIONS

The following conclusions can be drawn from the above geotechnical assessments: -

- The highwalls are stable - no large-scale wall failures are anticipated. There is a low probability that wall instability can occur where geological structures form geometries which daylight on the slope face;
- Large rotational failures observed on the lowwall and endwall are confined to the Tertiary horizons; they are a function of inadequate slope design and poor surface water management.

- Wall instability of the Tertiary will continue along the lowwall and endwall if nothing is done until a stable slope configuration is reached;
- The lowwall is potentially unstable due to the proximity of the BRF; a large deep-seated lowwall failure is feasible for slope segments north of the buttressed lowwall slope.
- Slopes constructed in the fresh rock formations on the highwall and endwall are in compliance with the EA requirements for Asbuilt pit slopes.
- Except for the over-steepened upper Tertiary slope sections along the lowwall and endwall, the Asbuilt slopes in fresh rockmass are generally in compliance with residual void design guidelines set in the EA;
- The Rehabilitated external spoil dumps have been re-graded to have a gradient of 1V:6H. The EA requirement specifies a slope gradient of 1V:5H for such slopes;
- The In-pit lowwall dumps are stable and;
- Any sudden drop in the pit water level would result in a perched water in the formation which will affect the long-term stability of the walls. This is a critical observation for the unstable / marginally stable lowwall.

11. RECOMMENDATIONS

The following recommendations are made regarding the Wallanbah Final Pit Void:

- A wall monitoring program using prisms and radar (refer §7.6.4 above) be implemented on the lowwall ASAP to determine rates and area of lowwall movement beyond the failure escarpment on the lowwall face.
- Include also as part of the slope monitoring program a 9 month radar wall monitoring programs as cited in §7.6.4 above.
- Based on the outcome of the wall monitoring program a lowwall remediation plan be devised and implemented.
- A remediation plan for the endwall could be implemented if that is available as per normal schedule.
- Get Geotechnical inspection of the endwall before implementation begins. Also get a geotechnical review of the endwall design for verification of wall design angles and slope heights.
- In the interim, consideration be given to preventing failures of the Tertiary slopes along the lowwall and endwall, as outlined in §9 above. Two options are hereby proposed: -

a. Do nothing - let the slope recede till a stable slope configuration is achieved. Place isolation bunds at least 25m away from all failing slopes and monitor slope advance towards isolation bunds or;

b. Reprofile slope to a stable slope configuration for the affected material type. Construct bunds 2m back from the crest. Carry out monitoring and periodic inspections. Note that the slope reprofiling option should be decided after the walls stability is determined by monitoring and fail proof zones are identified beyond the failing slopes.

- Surface water management around the pit wall crests be improved so that water is lead away from failing slopes sections.
- Where slope failures on lowwall and endwall have resulted in the capture of diversion drains, the situation be remediated ASAP; flows must be directed away from the affected slope areas. This could involve installation of new drainage channels, as well as re-profiling the surface of the area between the crest and bund to divert surface runoff water away from the crest;
- Backfilling and or re-grading of the erosion gullies over the re-graded highwall and lowwall slopes as much as is practicable to create a levelled slope profile. Introduce drainage galleries over the regraded surface based on projected catchment area and discharge volumes involved. Drainage galleries must be rock lined to prevent erosion and gully formation leading to uncontrolled slope degradation.
- The barren slope areas (between drainage galleries) should be vegetated to prevent soil erosion by surface run-off and;
- The diversion drainage bund at the endwall must have drainage slot built in it and the area between the bund and the walls crest must be re-contoured to encourage surface runoff to flow north into the diversion drain, away from the endwall crest.



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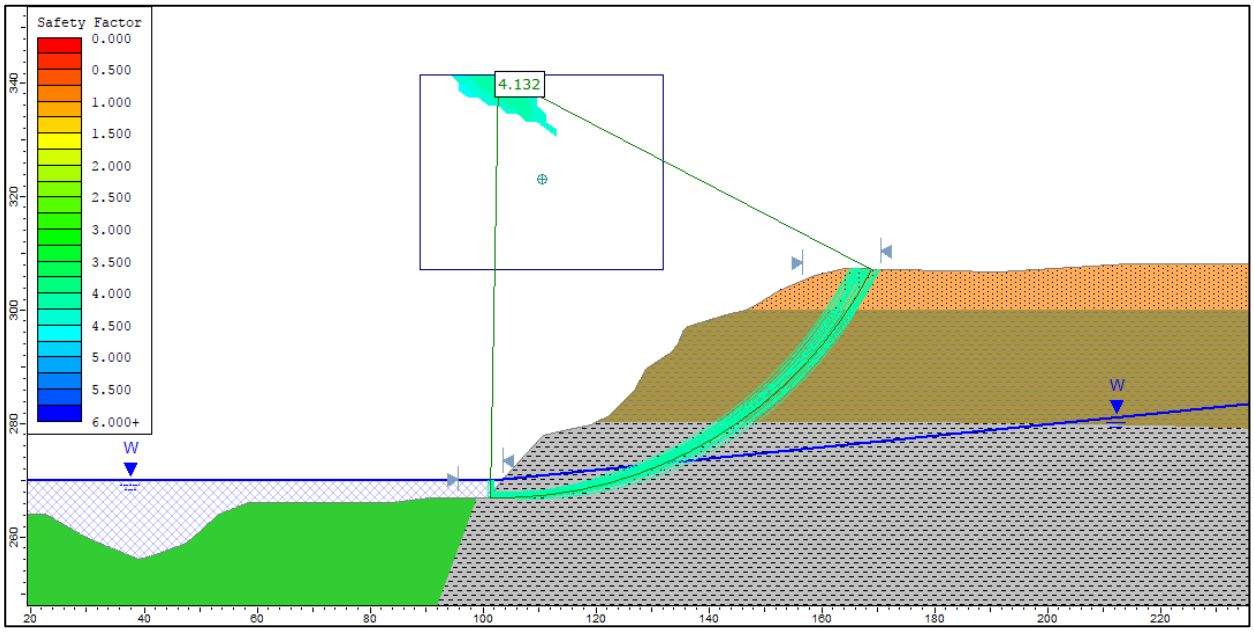
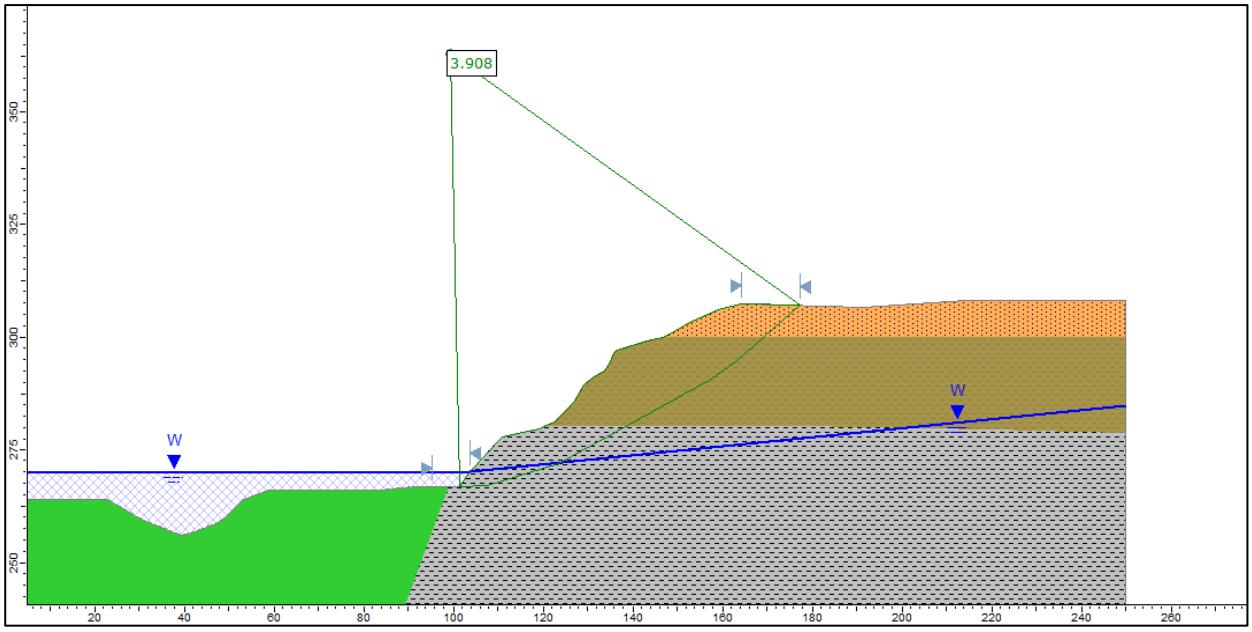
Ref 10: Ian Kelso (April 2009) **Wallanbah Lowwall Cutback Design Geotechnical Review**

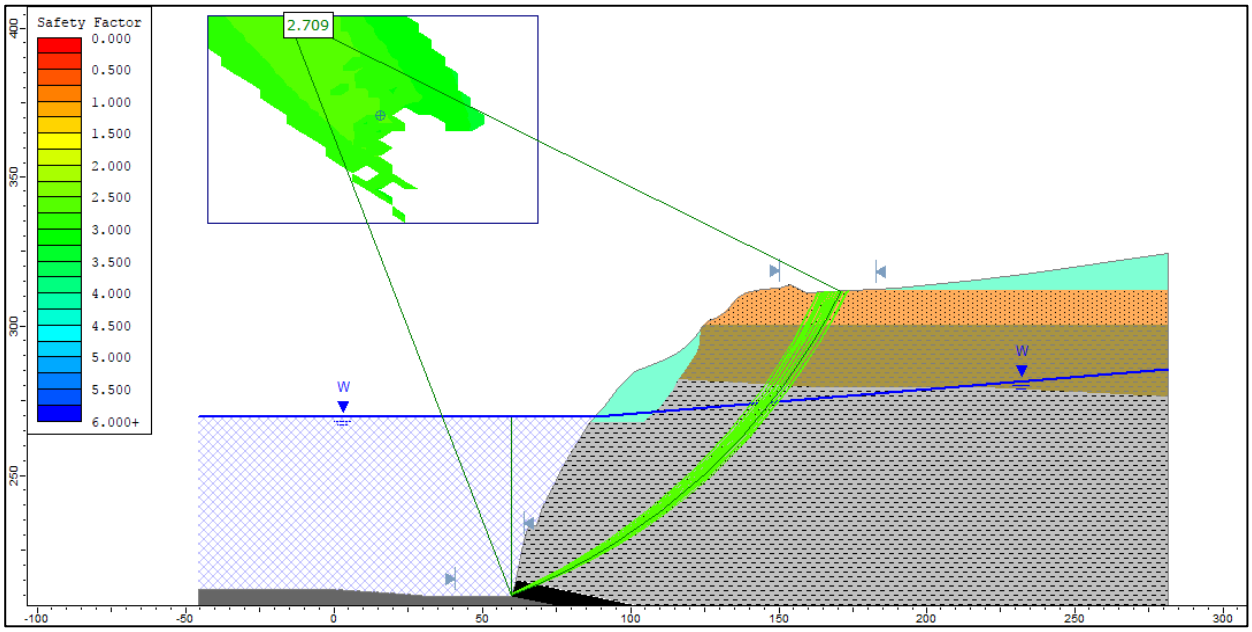
APPENDIX 1 – SLOPE STABILITY ANALYSES OUTPUTS



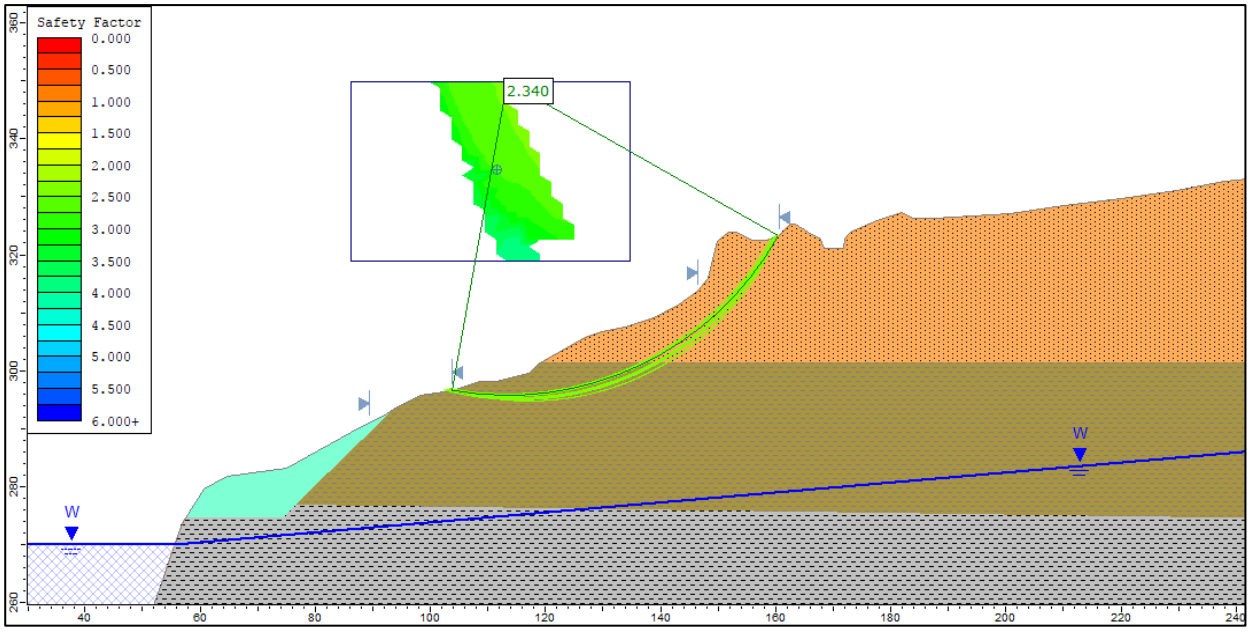
A1-1: Section 2 – Full Slope Failure - Circular



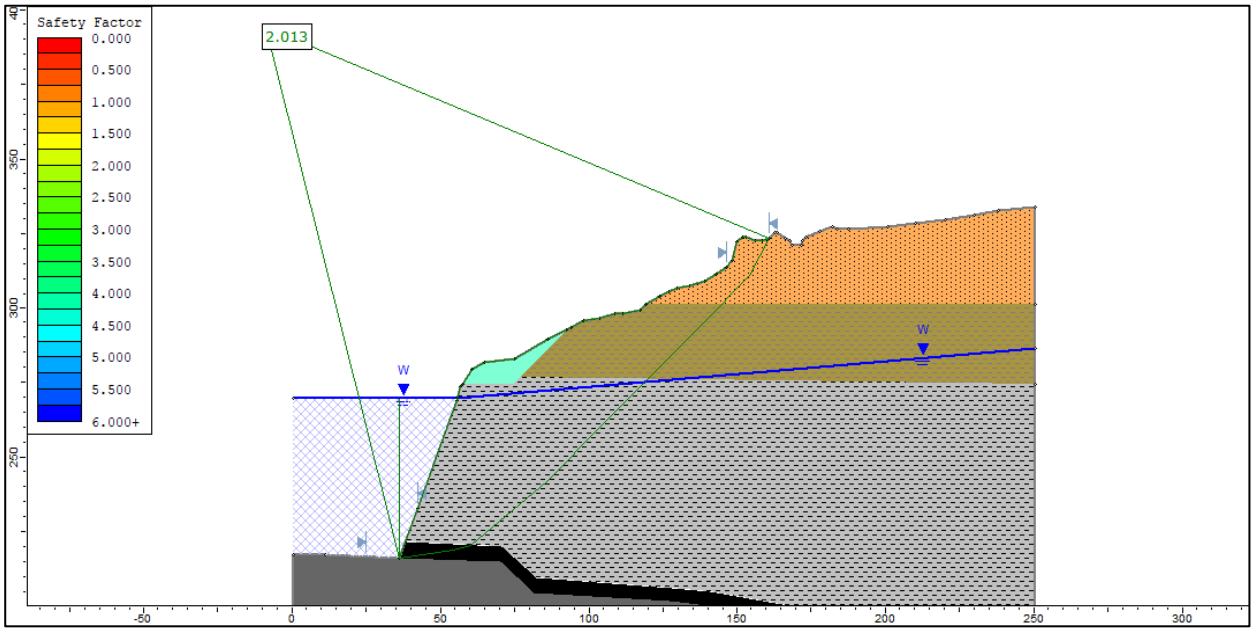
A1-2: Section 2 – Full Slope Failure – Non-circular



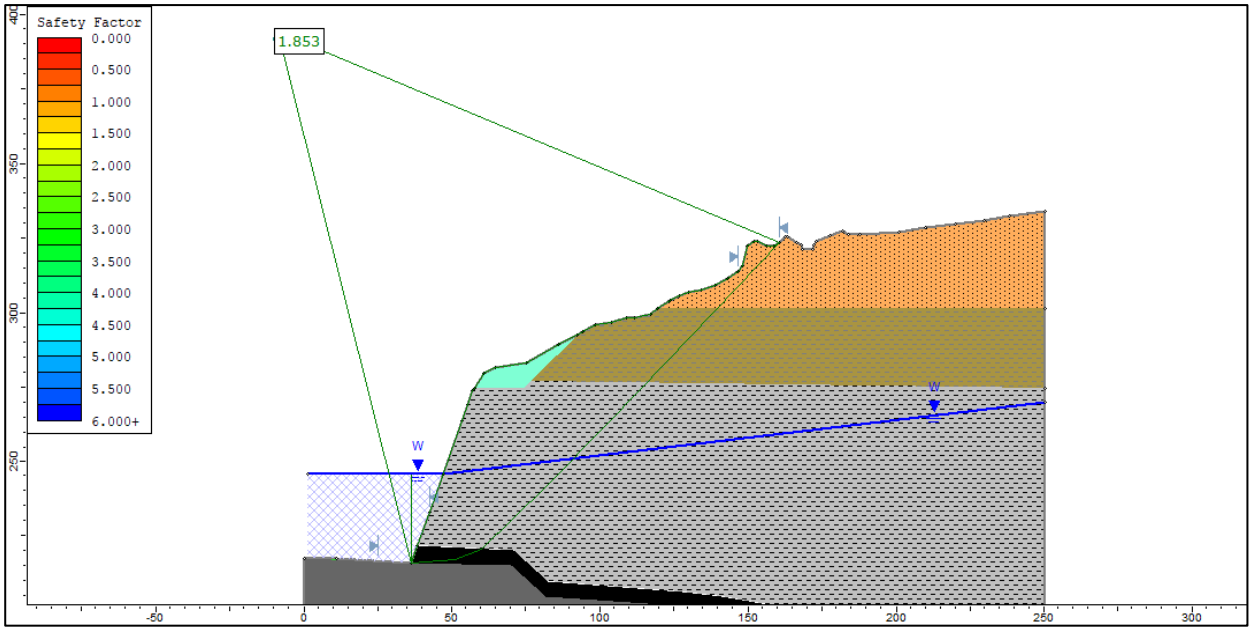
A1-3: Section 3 – Full Slope Failure – Circular



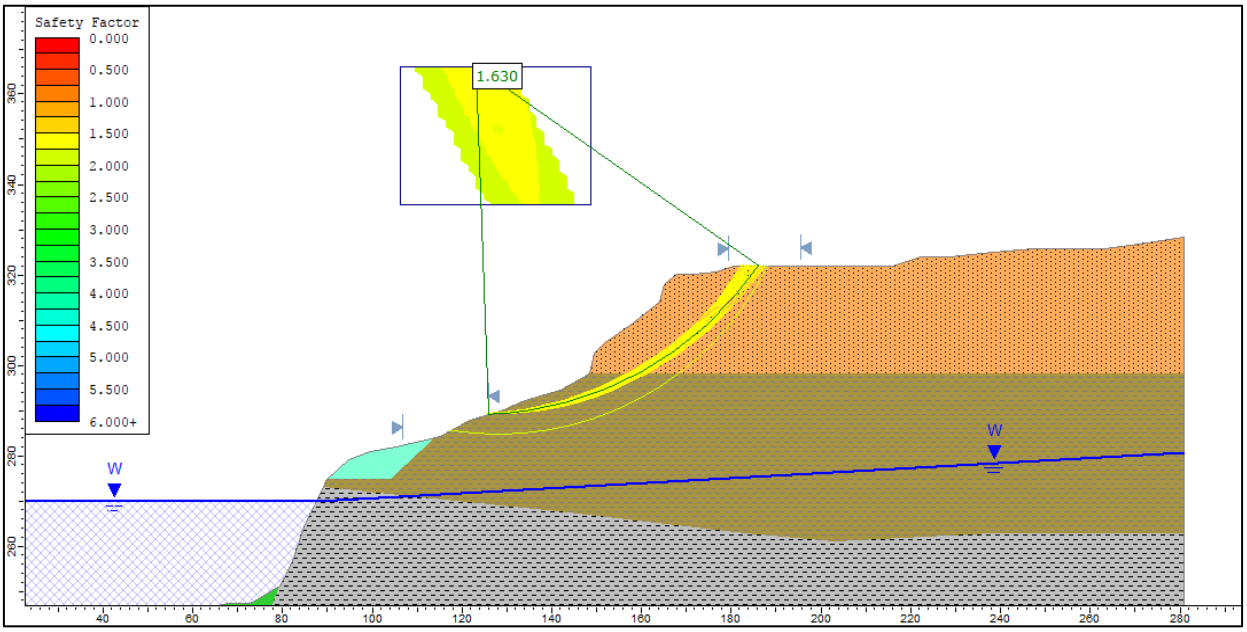
A1-4: Section 4 – Weathered Zone Failure - Circular



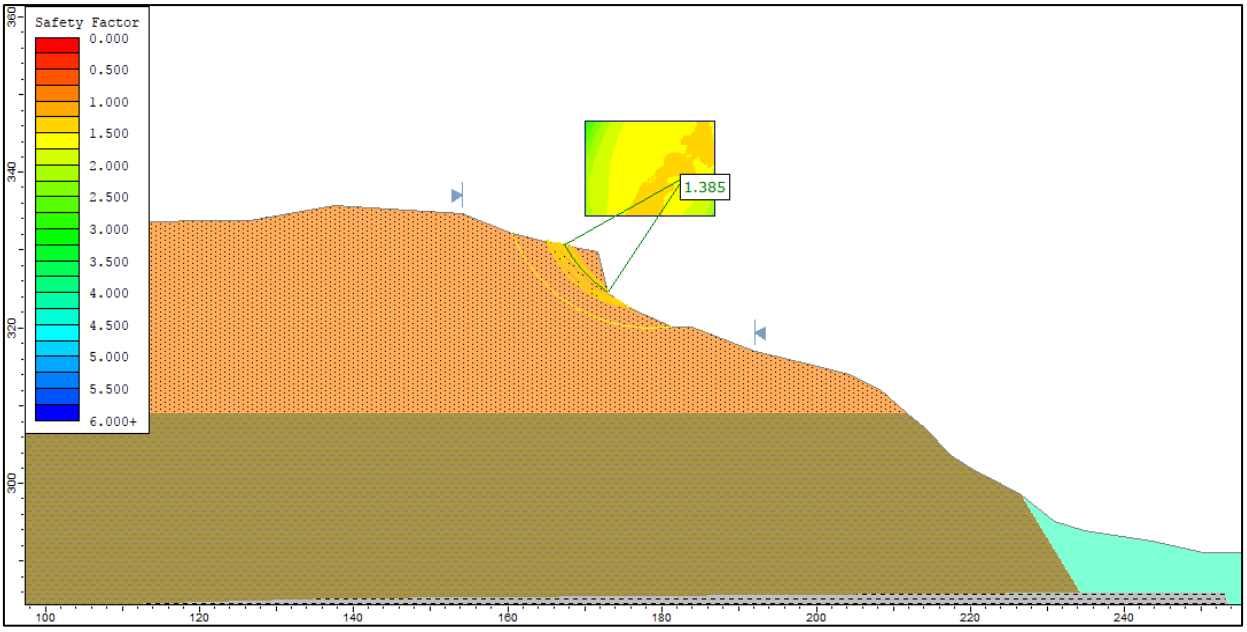
A1-5: Section 4 – Full Slope Failure with Max Water Level – Non-circular



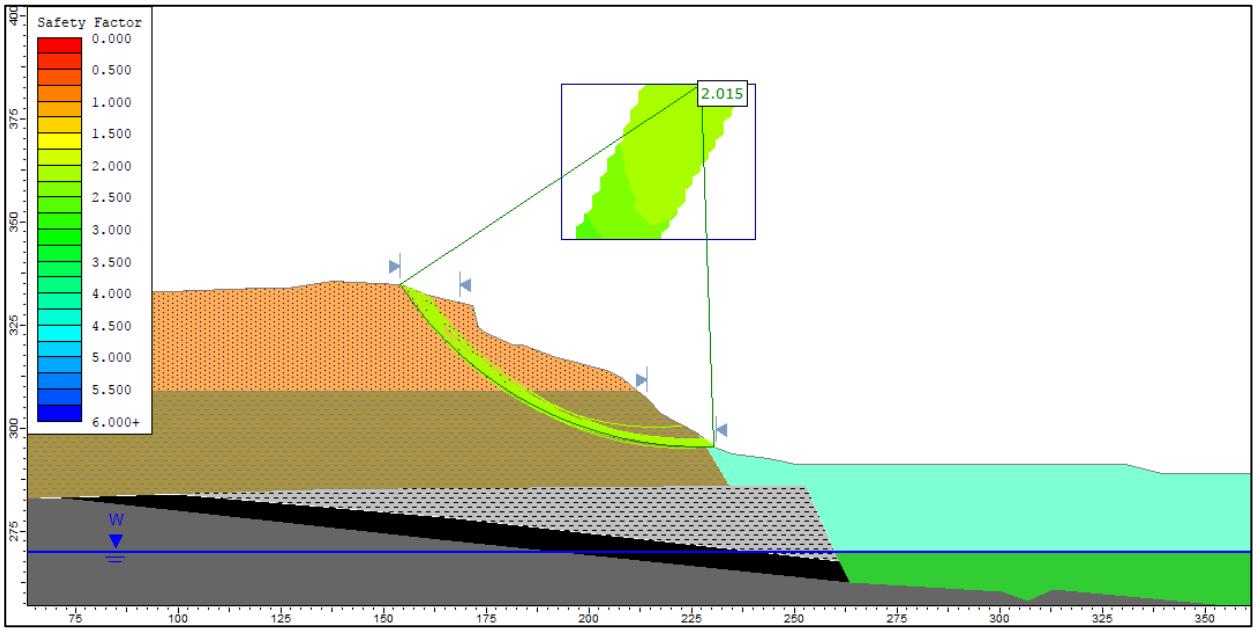
A1-6: Section 4 – Full Slope Failure with Min Water Level – Non-circular



A1-7: Section 5 – Weathered Zone Failure – Circular



A1-8: Section 8 – Tertiary Failure – Circular



A1-9: Section 8 – Weathered Zone Failure – Circular

Fig A – 9 Lowwall Section 6 Dry Pit FoS = 1.38 Section 6 Flooded Pit FoS = 1.35

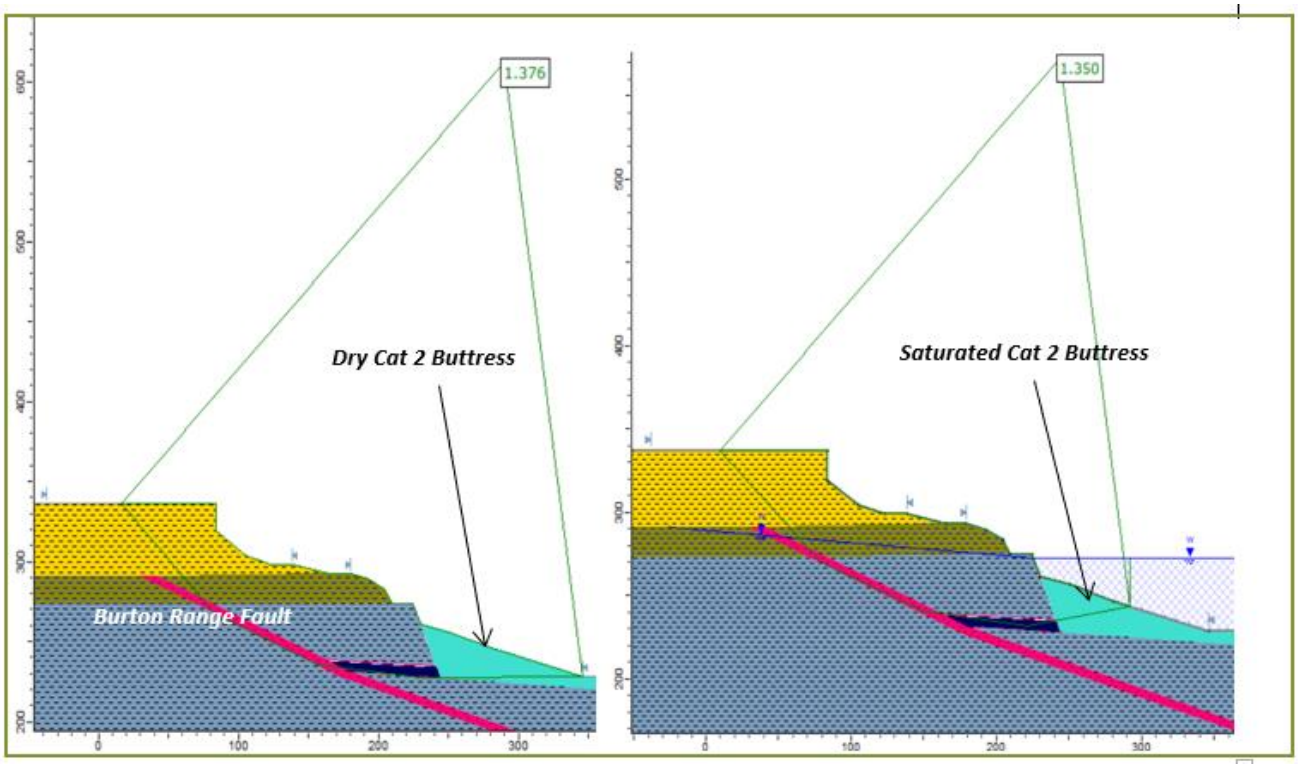


Fig A1-10 Lowwall Section 6 Fos = 1.25 Pit water level – 262mRL & GWL - 272mRL

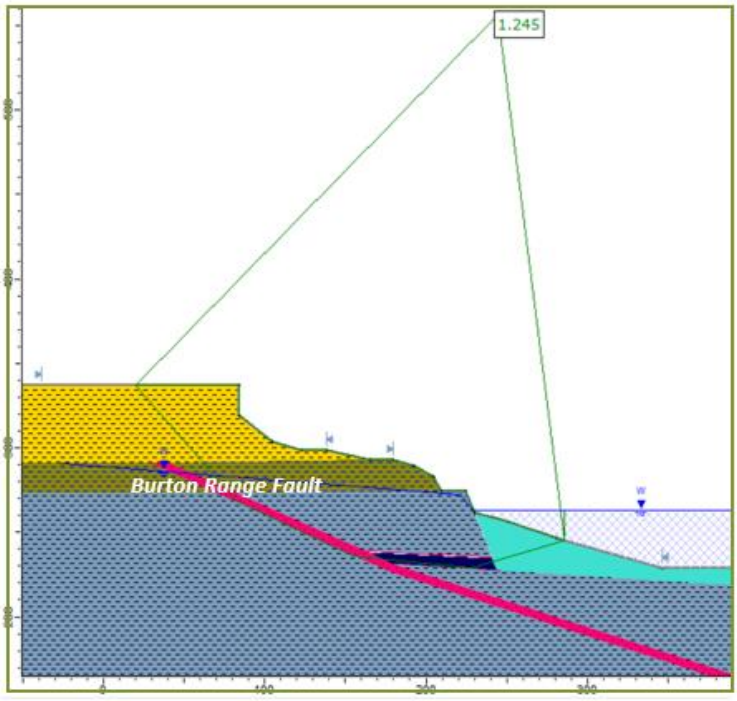


Fig A1-11 Lowwall Section 7 Dry Pit FoS = 1.03 Section 7 Flooded Pit FoS = 0.84

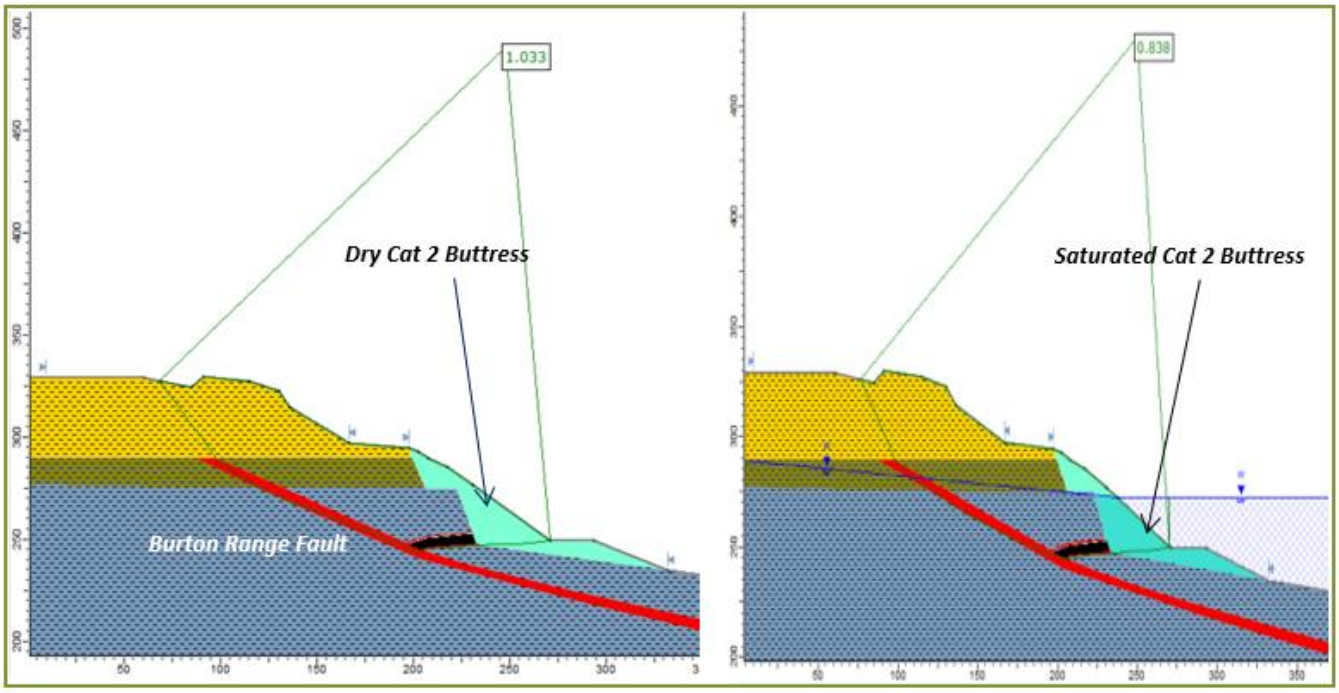
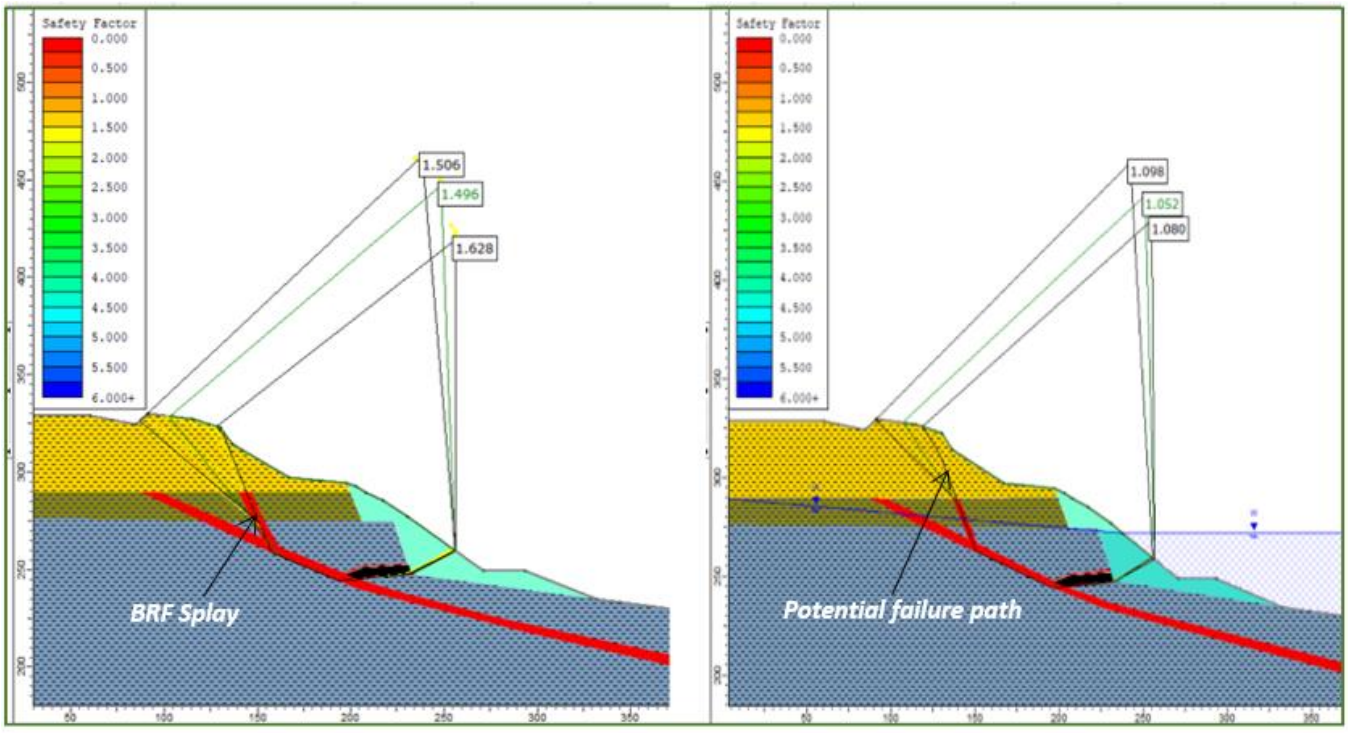
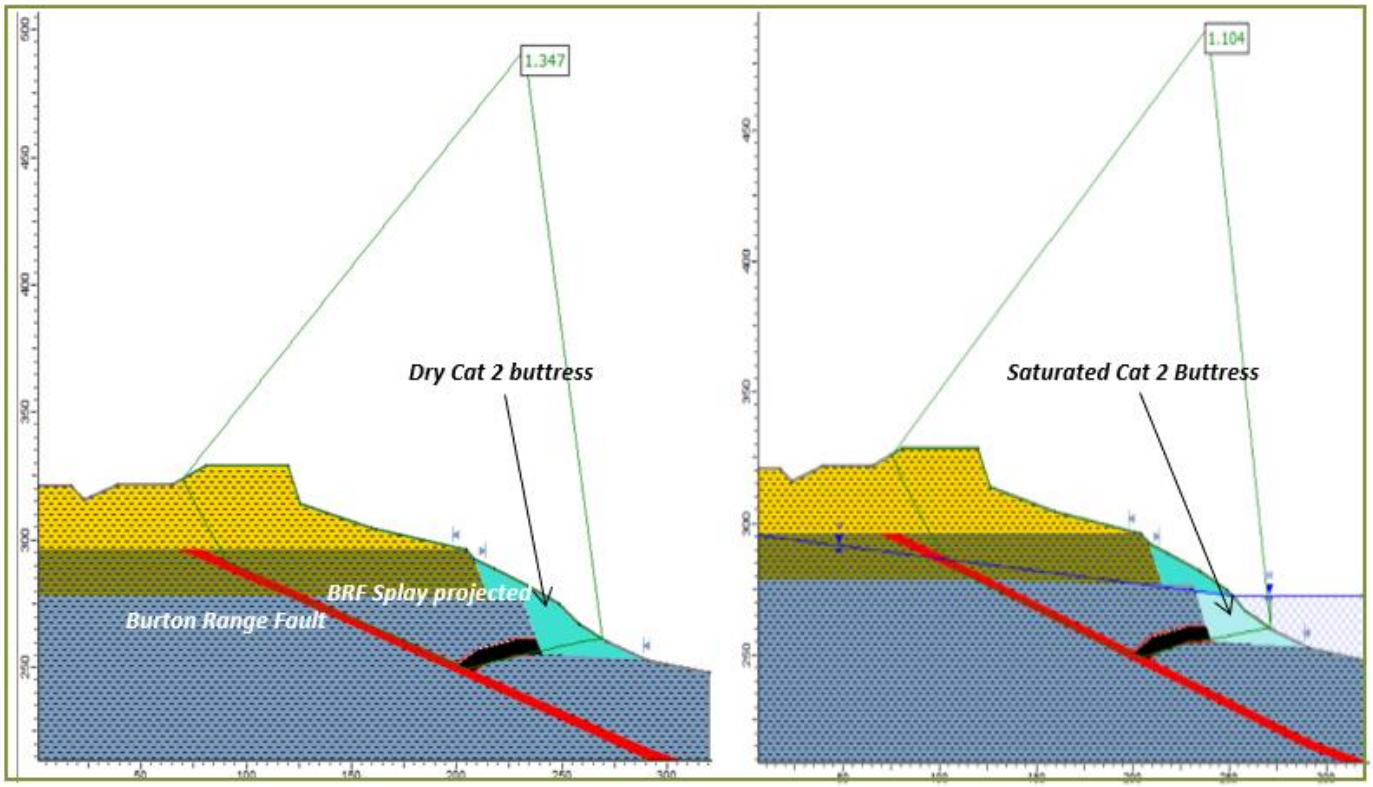


Fig A1-12 Lowwall Section 7 Dry FoS = 1.50 Section 7 Flooded Pit FoS =1.05



Potential sub vertical failure path through BRF splay FoS was reduced from 1.5 (dry pit) to 1.05 for flooded pit.

Fig A1-13 Lowwall Section 8 Dry Pit FoS = 1.35 Section 8 Flood Pit FoS = 1.10



Appendix N
Broadmeadow pit void geotechnical study



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Peabody Energy Australia Pty Ltd - Broadmeadow Pit Final Void Geotechnical Assessment



Blackrock Mining Solutions Pty Ltd Document Control

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1. INTRODUCTION

A geotechnical assessment was completed by Ty Grantham of Blackrock Mining Solutions Pty Ltd (Blackrock Mining) to assess the stability of the final void at the Broadmeadow pit, located within the Burton Mine Complex. A site inspection was undertaken on the 1st September 2017 to observe the geotechnical stability of pit walls and spoil dumps with respect to final void conditions.

The objective of the assessment was to identify areas of concern related to geotechnical stability for excavated and spoil slopes, and to provide recommendations for the long-term stability of slopes to meet the residual void design, in accordance with the site's Environmental Authority. Additionally, appropriate highwall crest standoff distances were recommended for the certified construction of a levee system offset from the corner of the northern endwall and low wall, and the southern endwall. It is understood this report will be submitted to the Department of Environment, Heritage and Protection (DEHP) as a certified geotechnical report.

2. SCOPE OF WORK

The proposed scope of works was set out as per Blackrock Mining's proposal and comprised:

1. Site visit for visual inspection of final highwall profiles, spoil dumps and areas of concern;
2. Review of technical data and reports supplied by Peabody, and collation of data procured from site visit;
3. Two-dimensional limit equilibrium analysis using industry accepted methodologies to assess slope configurations against acceptable design criteria, where appropriate. Circular and non-circular slip failure mechanisms would be examined for soft highwall slopes and spoil dumps; and
4. Provision of a report detailing site characteristics and recommendations.

2.1 Previous Work and Client Information

An internal geotechnical study was completed in 2015 (Ref. 2) that examined the interaction of geological structures on the exposed northern and southern highwall sections, and assessed the potential likelihood of structural failures along the highwall. A review of the 2015 report was completed, with selected data consolidated into this report to confirm and validate the findings.

A package of sections and plans was made available to Blackrock Mining for the purpose of providing information in relation to floor dips, depth of cover thickness and geological

structure. This package of work was completed by McElroy Bryan Geological Services Pty Ltd.

3. SITE LAYOUT

The general layout of the Broadmeadow pit is shown in Figure 3-1, which is based on the most recent aerial survey. This figure also shows the nominated sections that were generated for slope stability analysis, and the proposed levee locations along the northern lowwall/endwall, and southern endwall.

The layout shows the central portion of the pit to be infilled with spoil, leaving voids for the northern and southern portion of the pit. The mine site originally comprised only one pit, bound to the north and west by Spade Creek, and to the south by Hat Creek. Both creeks are ephemeral. An area of rehabilitated spoil exists to the west of the current spoil dumps.

Changes in the water body level within the void were evident from the 2015 and current assessment, likely to be the result of significant rainfall during the most recent wet season. Mining at the Broadmeadow Pit ceased in 2012.

A ROM pad is located approximately 100m to the east of the pit. A surface water body is located approximately 400m to the east of the northern highwall.

The maximum depth of the pit is approximately 105m below ground level (180m RL) and this occur at the northern end.

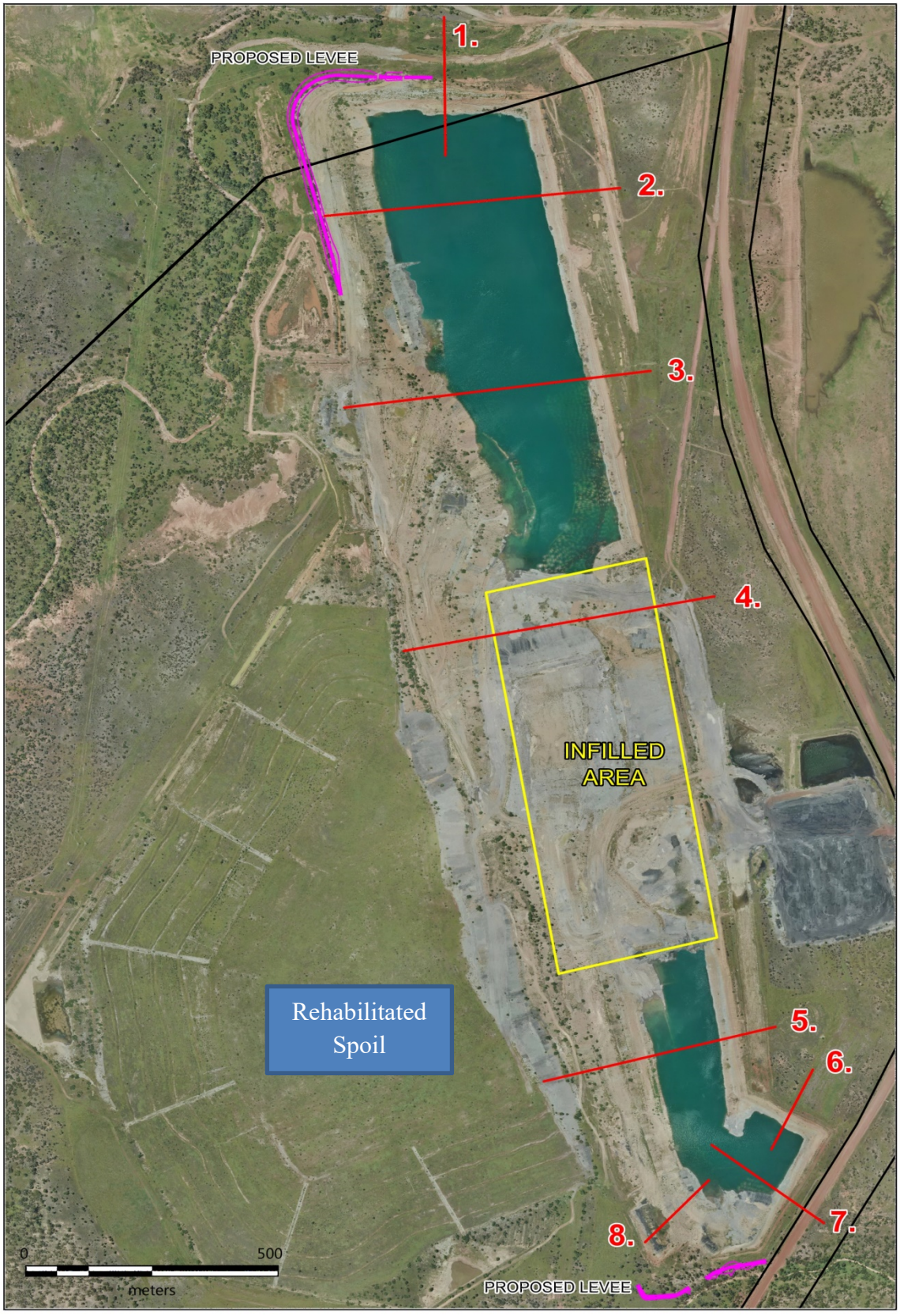

Figure 3-1: Site and Section Layout

4. CURRENT PIT SLOPE CONDITIONS

Along the northern part of the eastern highwall, an outer bund has been constructed approximately 100m back from the highwall crest to divert water towards Spade Creek to the north of the endwall. A low height highwall bund had also been constructed during operations to prevent surface water from flowing over the crest. The area between these bund structures forms a narrow, but relatively large by area, catchment which varies between 50m – 80m in width, as shown in Figure 4-1 and Figure 4-2. It should be noted that these bunds were not designed or constructed to any particular standard. A shallow slide was also observed, as shown in Figure 4-3. At present, these catchment areas do not appear to divert surface water in any particular direction towards a nature drainage channel, but is likely to accumulate against the pit crest bund and within the catchment itself, resulting in a tendency for the water to pond, as shown in Figure 4-4.

Over time, the water accumulating against the crest bund has formed large gully and pipe erosion features, which have penetrated the crest bund, allowing water to flow toward the pit crest. These features were often obscured by the thick grass cover, and in most cases, were only 1m – 2m in wide; however, depths could extend up to 4m – 5m. For the larger gully erosion features, these were several metres wide, and incised down to the weathered rock units (up to 8m depth), as shown in Figure 4-5. Overall, these features do not prejudice the stability of the highwall; however, are more likely to present a safety risk for machinery and personnel during rehabilitation.

In general, the highwall and endwall slopes were observed to be stable. There was no evidence of the adverse interaction of geological structures on the highwall slope, which would indicate the likelihood of large scale failures. Small, bench scale wedge failures were observed on the southern block endwall, which have caused minor, localised undercutting of the batter; however, this is not expected precipitate highwall failure.

In-pit spoil dumps to the north and south of the infilled area appeared to be relatively stable, at the time of inspection, with no evidence of past major instability, other than the usual surficial rill erosion, as shown in Figure 4-6.

The water level in the pit was at approximately 260m RL, which is just below the rock head berm. This level had increased significantly from the 2015 geotechnical study, and is close to the final void scenario of 262.5m RL as modelled by Hatch Pty Ltd.

Seepage was observed to be emanating from the rehabilitated spoil dump and followed a drainage path adjacent to the access track, flowing to the north and then into the pit via an underdrain, as shown in Figure 4-7. White precipitates around the flow channel indicate the seepage to be saline, and this was confirmed by the Environmental Superintendent.

In the southern section of the pit, coal is exposed in the lowwall, which demonstrates the expression of horst block in that part of the pit. A horst block is the raised fault block which is bound on either side by normal faults (extensional), as illustrated in Figure 4-8.

There were some structural features observed along the southern block endwall that have formed bench scale wedge failures. This is not expected to be significant, as the wedge failures are only small, and approximately half of the endwall is buttressed by spoil, as shown in Figure 4-9.

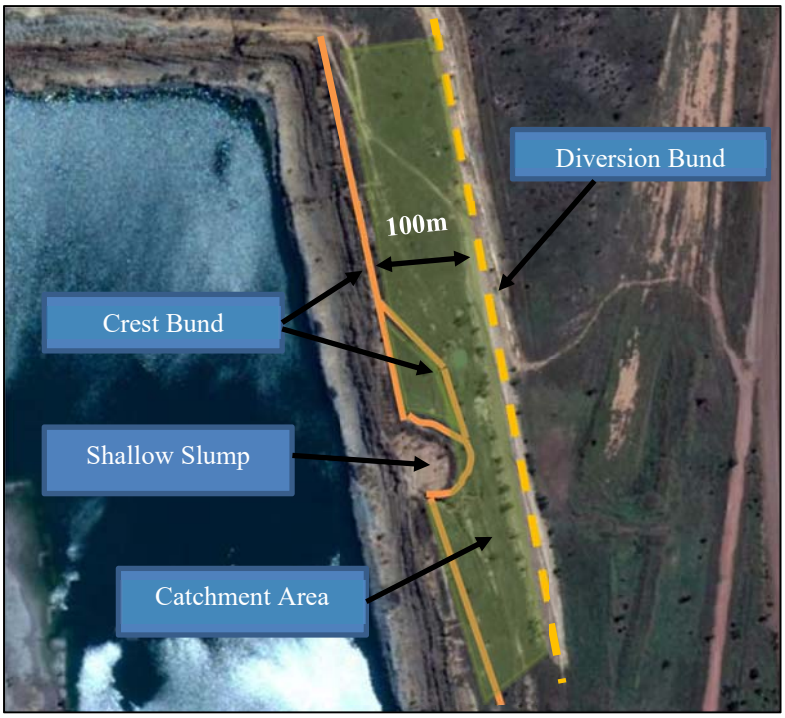

Figure 4-1: Northern Highwall Bund Layout and Catchment Area



Figure 4-2: Diversion Bund and Crest Bund Along Highwall (Looking South)



Figure 4-3: Shallow Slide on Highwall (Looking South)



Figure 4-4: Ponded Water Between Diversion and Crest Bunds (Looking South)



Figure 4-5: Deep Gully Erosion Behind Northern Highwall Crest (Looking East)



Figure 4-6: In-Pit Spoil Conditions – Northern Lowwall (Looking West)



Figure 4-7: Saline Spoil Seepage (Looking Southwest)

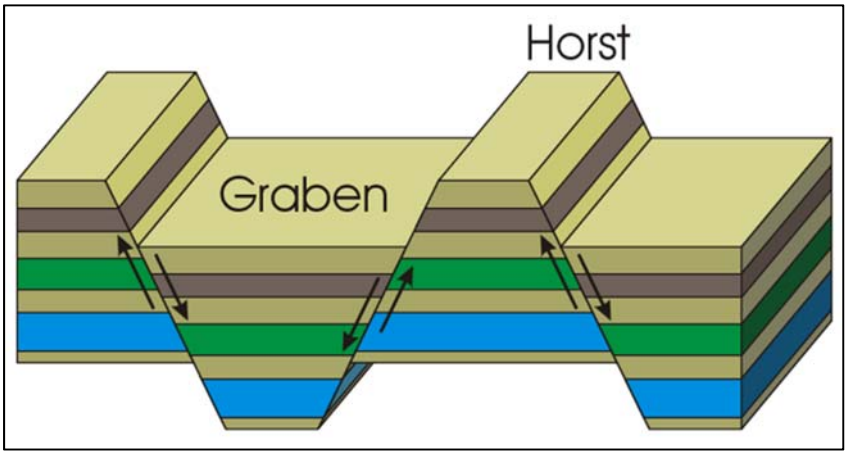

Figure 4-8: Horst Block Illustration

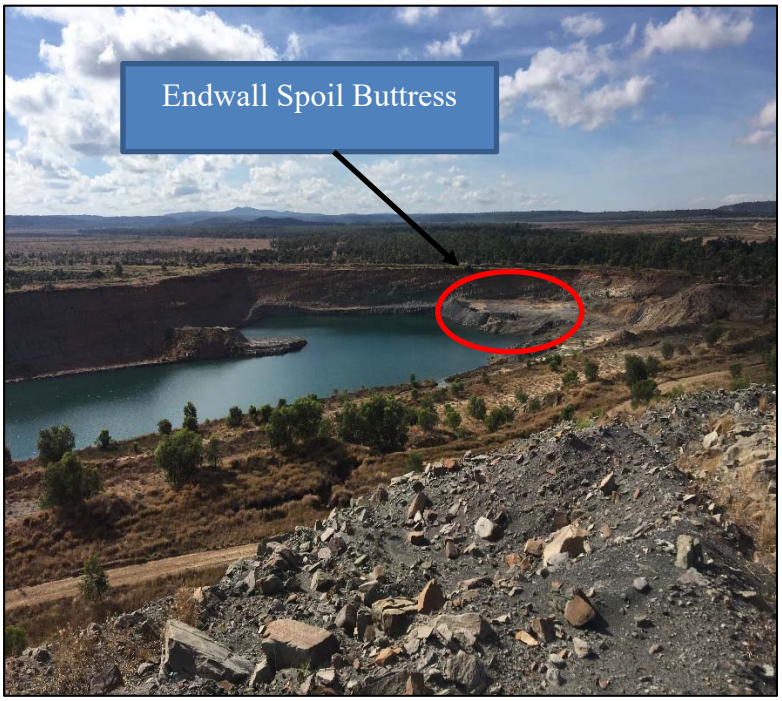

Figure 4-9: Southern Block Endwall Buttress (Looking Southeast)

5. GEOLOGICAL SETTING

5.1 Site Geology

The main units forming the overburden at the Broadmeadow Pit are as follows:

- Quaternary alluvium/Tertiary clays: low to high plasticity, soft to stiff, brown silty to sandy clay;
- Weathered Permian: weak to medium strength, brown, interbedded sandstone and siltstone; and
- Rewan and Permian Coal Measures: moderate to high strength, light grey to grey, interbedded sandstone and siltstone.

There is a layer of superficial deposits, comprising Tertiary clay and loose alluvial soil up to approximately 8m below ground level, below which there is a zone of weathering to a depth of approximately 23m.

The fresh Permian coal measure rocks comprise thinly interbedded, light grey, fine to medium grained sandstone and siltstone, with some thicker beds of sandstone. Technically, the bottom 45m (approximately) of the rock overburden belongs to the Permian Rangal Coal Measures, with the upper portion being part of the Rewan Sandstone formation (Ref 1). This differentiation is not visually apparent in the highwall.

The Burton Seam represents the coalescing of the Vermont and Leichardt Seam, is approximately 11m thick, and is predominantly observed in the north of the pit. In the south of the pit, the seam generally splits into the Vermont and Leichardt Seam's separated by a thin layer interburden.

The Yarrabee Tuff (YT) marks the base of the Vermont Upper (VU) Seam within the Rangal Coal Measures, and is a regionally extensive and easily recognisable marker band. The underlying Fort Cooper Coal Measures are predominantly sandstones with banded coal seams.

A generalised stratigraphic sequence is shown in Figure 5-1

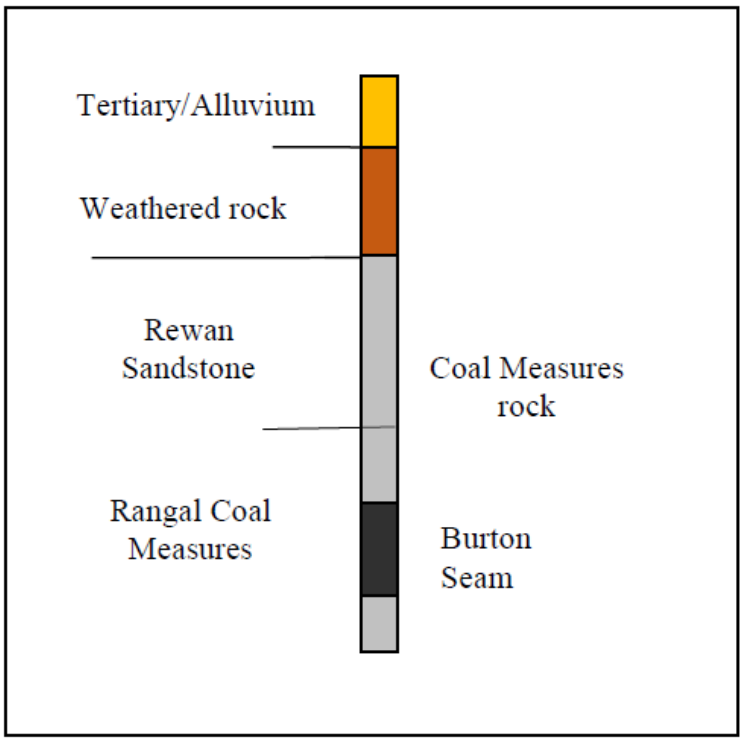

Figure 5-1: Broadmeadow Pit - Stratigraphic Sequence

Sectional analysis showed the strata to dip to the east-northeast at between 13º – 14º north of the infilled area, and between 10º - 12º to the south of this area. Two faults cut across the pit through the highwall that strike in a north-easterly direction, approximately perpendicular to the lowwall. Another mid-pit fault striking approximately north-south had been mined out.

The Spade Creek Sill igneous units lies immediately to the north of the pit, and constrains the pit in this direction.

5.2 Hydrogeology and Groundwater

No major aquifers have been identified, but the coal seam can constitute a minor aquifer. Fault zones can also form aquifers which permit the transmission of groundwater through strata; however, no significant structures have been noted.

As indicated from previous studies, Hat Creek has incised the sub-crops of both the Rangal and Fort Cooper Coal Measures, and at times of flow recharges the coal seam aquifer system. These periods of recharge are expected to be short and the volume of water transmitted into the aquifer is expected to be low as the seams are interpreted to have a relatively low transmissivity (Ref 2).

There was evidence of minor seepage emanating along random bedding surfaces, towards the base of the weathered horizon, at the northern end of the pit. This may be due to hydraulic connection with the dam approximately 400m to the east of the pit, or from minor ponding

of water in the catchment area between the diversion bund and the crest bund. This is unlikely to pose a significant risk to highwall stability.

5.3 Geological Structure

The Broadmeadow deposit is bound to the north by the Spade Creek Fault, and to the south by the Hat Creek Horst, where the bounding fault strike to the northeast. Other north – south striking faults identified from operational plans, were mostly located within the pit and did not have any interaction with the final walls. In most cases, these faults were mined out or dip at a shallow angle into the lowwall. These faults also interact with the western corner of the northern endwall; however, given the faults strike approximately orthogonal to the endwall it is unlikely to result in instability. Additionally, these faults are covered by the in-pit spoil along the lowwall.

The Spade Creek Fault strikes in the same orientation as the northern endwall; however, the plane of the fault appears to be set back at a sufficient distance from the slope so as to not have any influence on stability.

No geological structures were apparent on the highwall north of the infilled area. In this case, it would be reasonable to assume that adverse geological structures behind the highwall are unlikely.

Figure 5-2 presents a plan showing the major geological structures across the Broadmeadow pit.



Figure 5-2: Pit Geological Structure Location

6. SLOPE DESIGN

6.1 Highwalls and Endwalls

The standard slope design criteria for highwalls and endwalls for mining in the Rangal Coal Measures are summarised as follows:

- Berms are designed to RL to ensure consistent drilling horizons, unless following a floor of coal. A rock head berm at a minimum width of 20m to control failures from the weathered horizon;
- Batter angle in the weathered rock/Tertiary horizon – 45º;
- Rock benches are pre-split - 70º; and
- The maximum bench height in rock is 75m, however this can extend up to 80m.

This design is used for all in-situ pit wall slopes under normal conditions. Modifications may be made for local situations where fault zones intersecting the walls could create conditions of instability. This is not expected to occur at the Broadmeadow Pit.

A generalised slope design diagram is illustrated in Figure 6-1, and shows a relatively simple slope geometry. In this case, there is only one fresh rock bench below the weathered bench that extends to the pit floor.

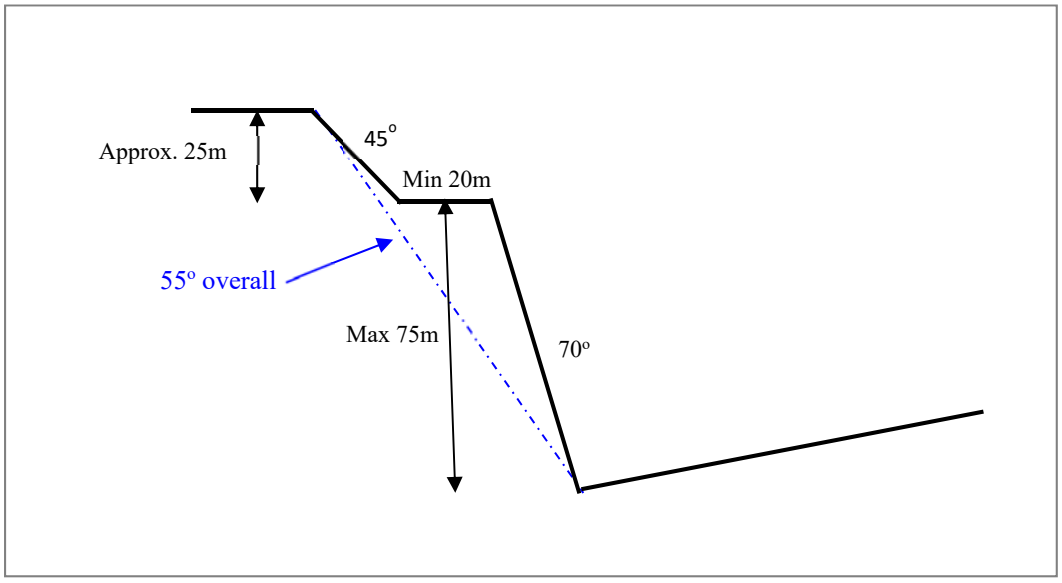

Figure 6-1: Highwall Slope Design

Figure 6-2 and Figure 6-3 below shows the highwall and endwall profile at the northern end of the pit.



Figure 6-2: Highwall Profile – Weathered Horizon (Looking South)



Figure 6-3: Endwall Profile – Weathered Horizon (Looking Northwest)

6.2 In-Pit Spoil Dumps

In-pit spoil dumps are generally built up in lifts at angle of repose batters with berms of sufficient width to control material failures. Angle of repose is 35º on average, up to approximately 37º for blockier spoil. The final profile may depend on operational factors, but is usually within the following constraints:

- Maximum dump bench height - 35m;
- Maximum berm width - 25m; and
- Maximum overall slope angle (toe to toe) not exceeding 25º.

A generalised design profile is shown in Figure 6-4.

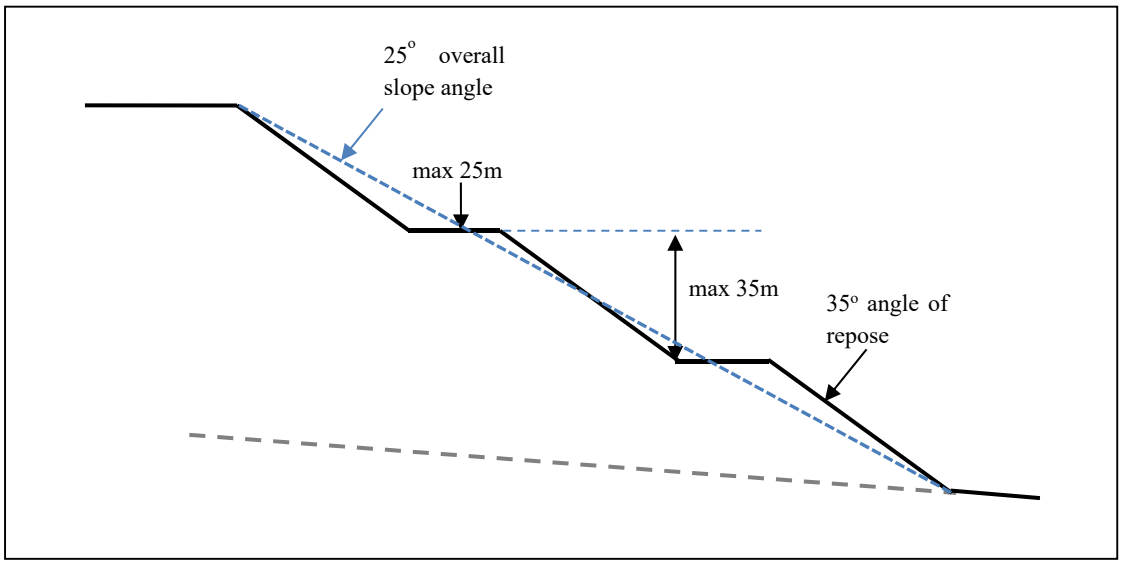

Figure 6-4: In-Pit Spoil Dump Design (Ref 1)

Floor treatment is generally used to disrupt bedding or weak surfaces prior to dumping or casting spoil on steeper floor dips to ensure the in-pit dump remains stable. This is only applicable where the floor dip exceeds 12.5º.

At Broadmeadow pit, floor dips range from approximately 11º in the south to 14º in the north.

6.2 External Dumps

A large proportion of the external dump had been rehabilitated at the time of the site inspection, with only the eastern face requiring contour profiling to tie into the lowwall. The dump had been regraded to a single slope of approximately 1V:5H (11º).

As a general guide, external dump faces are normally formed to facilitate re-grading to 1V:4H slopes for rehabilitation. The overall guide for external dumps is:

- Maximum bench height - 35m; nominal bench height – 20m;
- Residual berm width nominally - 5m; and
- Final re-graded batter of 1V:4H (14º).

A generalised design profile is illustrated in Figure 6-5.

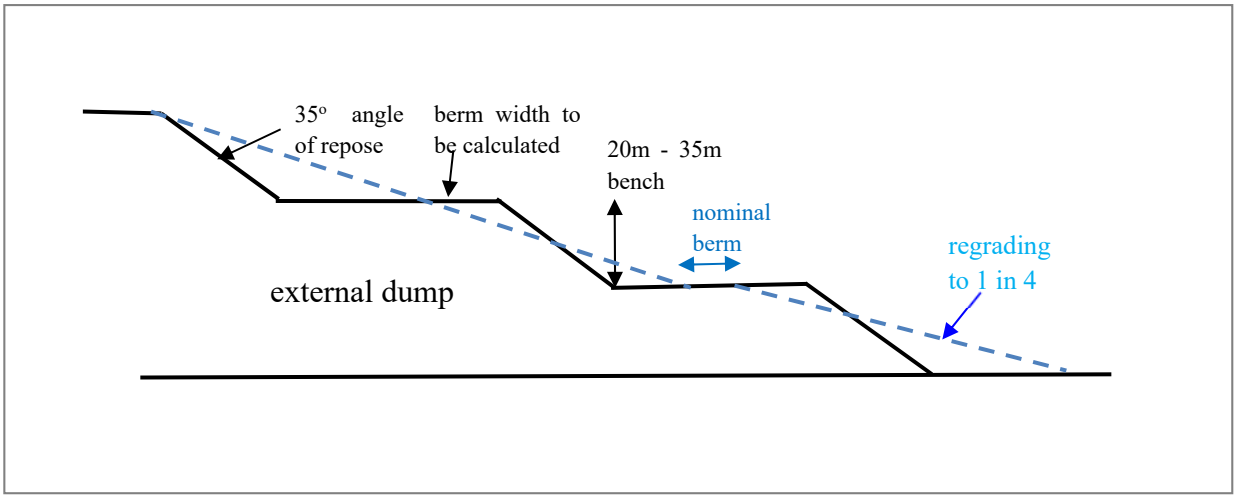

Figure 6-5: External Dump Slope Design – Externally Draining (Ref 1)

6.3 Environmental Authority Compliance – Geotechnical Stability

The Environmental Authority (EA) specifies that highwall slopes in competent rock can remain as constructed if they are geotechnically stable, with the EA requirements for pit slopes not being specific in terms of design parameters. In this case, the as-constructed highwall slope profiles are typical of the designs used in the Bowen Basin (Ref 3).

Low wall dumps are built up in benches at angle of repose to a maximum lift height of 35m between berms, which is a typical industry design for rockfill dumps on flat or gently dipping ground, that meets the current EA requirement for geotechnical stability.

In-pit spoil dumps are generally susceptible to mass failure if the floor is sloping at angles >12.5º, and particularly if the floor is weak or sheared. Floor dips in excess of 12.5º are a notable feature of some parts of Broadmeadow Pit, particularly in the north, but there are design variations which normally involve treating the floor with ripping or shallow blasting, if the floor dip exceeds the threshold value.

At the time of inspection, the external low wall dump had been re-graded to a continuous slope with an overall slope angle of 1V:5H (11°). The internal side facing the pit would require a low wall design to comply with the EA landform requirement.

The external dumps have been rehabilitated with re-grading to a single slope <12° as per the EA requirement.

Factor of Stability (FoS) criteria for long-term slopes or final voids is ≥ 1.5.

Table 6-1: Environmental Authority Specifications (Ref 1)

Slope Type	EA requirement	As constructed
Highwall – Competent rock	Geotechnically stable	70° benches; 15-20m berms
Low wall – In-Pit	Geotechnically stable	Benched, 25° overall slope angle
Landform – External dump	Max 1V:4H	Re-graded to 1V:5H (11°)

7. LONG TERM GEOTECHNICAL STABILITY – FINAL LANDFORM

7.1 Highwalls and Endwalls

The stability in rock slopes is generally controlled by rock mass strength and geological structure, as the rock itself is too strong to permit shear failure. However, the mass strength is scale dependent and if the block size produced by the discontinuities is small enough compared to the slope height, steep slip pathways could be generated in high faces by linking through the discontinuities without shearing the rock itself (Ref 2).

As a general guide, rock mass strength failures are unlikely to occur below slope heights below 300m (Ref 4) in normal conditions, compared to the 105m maximum height at Broadmeadow Pit. Also, inspection of the rock faces indicates typical coal measure jointing producing a block size large enough to preclude contiguous shear development. The highwalls can thus be taken as being inherently stable in the absence of adverse structure.

Mass failure of rock will require the presence of pre-existing discontinuities to create the freedom of movement. Conditions of instability can be generated by the presence of adversely oriented geological structures such as faults, major joints or bedding. Faults are

present in the pit (see Section 5.3) but these tend to intercept the pit walls in a perpendicular direction, which tends to neutralise the potential for mass slippage. No instability was noted in the pit walls at the fault locations.

The bedding dips back into the highwall so that the risk of block slippage can be discounted. In the case of the endwalls, the dip is parallel to the face, giving a horizontal component out of the face, which also would not create any potential for sliding movement.

Sandstone is typically less susceptible to degradation caused by weathering in comparison to siltstone or mudstone. In this case, preferential slaking of the less resistant material below the competent sandstone units is likely to occur over time, which can lead to undercutting of the more durable sandstone beds, increasing the risk of ongoing rockfall. Observations of the highwall and endwall suggest detached block sizes from this type of degradation would be small and inconsequential from an overall stability perspective.

In the long-term, the highwall and endwall faces are expected to erode to some extent due to natural weathering processes; however, these should maintain a similar profile as the stronger sandstone units generally act as reinforcement within the slope.

It is generally difficult to ascribe a time frame for weathering; however, similar studies carried out at the Burton Widening show a possible estimated degradation rate of 40mm to 50mm per year on the highwall, which is equivalent to 1m after 20 years (Ref 1).

The weathered rock, and the thin cover of Tertiary in the upper bench, is likely to be susceptible to slaking, and will gradually degrade to a flatter slope angle. Surficial erosion indicates that clays in the Tertiary units are highly susceptible to erosion and are dispersive. In this case, there is sufficient room on the rock head berm to allow this process without significant displacement of material into the void. Overall, these erosional processes should not prejudice the stability of the slope.

7.2 Lowwall

A portion of the in-pit spoil would be saturated up to the current water level in the pit. As discussed in Simmons & McManus (2004) (Ref 5), once the shear strength properties of spoil have been changed to their lower saturated values, this change is generally permanent, regardless of whether the spoil drains. This situation would be analogous to the pit water level dropping during extended dry periods. Current pit water levels are at 259.5m RL with a maximum pit water level of 262.5m RL.

Fresh rock spoil generally comprises blocky material which is characteristic of Permian strata, but this material is susceptible to rapid slaking, resulting in a significant proportion of fines. Aging spoil dump surfaces will be susceptible to erosion from surface run-off with a possibility of 10% loss of fines. This would apply to untreated low wall dump faces or other in-pit dumps. In these instances, this would result in fines reporting to the enclosed void, which is does not have any effect on stability (Ref 3).

Along the low wall to the north of the infilled area, there is no evidence of instability other than the normal rill erosion. It is possible that the spoil slope is slightly steeper than the angle of repose in the vicinity of the northern endwall intersection. Given the low height of the lowwall and in-pit spoil dumps, floor treatment is likely to have been minimal.

7.3 Geological Structure Analysis – Highwalls and Endwalls

Given that failure of the fresh Permian strata is normally controlled by the interaction of geological structures, a photogrammetry assessment completed in 2015 was reviewed to examine the possibility of adverse geological configurations along the highwall, as shown in Figure 7-1 and Figure 7-2.

The assessment showed the presence of faulting on highwall to the south of the infilled area only. The results are summarised in Table 7-1 to Table 7-3. These structures were analysed in the stereo-net software Dips, to examine the critical intersection of structures on the highwall face. In this case, jointing appears to be more pervasive in the southern block. Faults that bound the horst block strike perpendicular to the lowwall, but are not visible due to being covered by spoil. Geological structures that would have to potential to cause instability were not observed along the highwall to the north of the infilled area.

The stereo-plot analysis in Figure 7-3 to Figure 7-5 does not show a potential for slope instability from combinations of discontinuities and faults analysed. In this case, there were no critical intersections formed, although it is possible for small bench scale configurations to form from randomly oriented discontinuities.

Figure 7-6 shows small wedge failures are in weathered zone, and are likely to be the result of material failure (collapse) along joint-bounded surfaces, possibly from run-off ingress down the face causing saturation and softening. As such, these failures may not necessarily pertain to the un-weathered rock faces, and are not expected to have any influence on the long-term stability of the slope. Any rockfalls that occur from the over-hanging material would fall into the void.

Similarly, given the strata bedding dips into the highwall, block slippage and planar failure mechanisms from daylighting, face parallel structures, are highly unlikely.

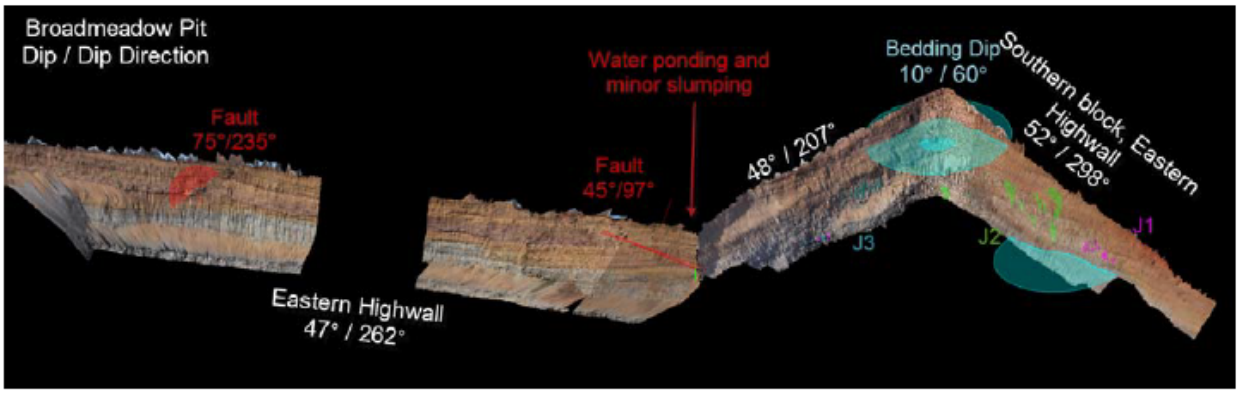

Figure 7-1: Photogrammetry Analysis (Fault Locations in Red) (Ref 2)

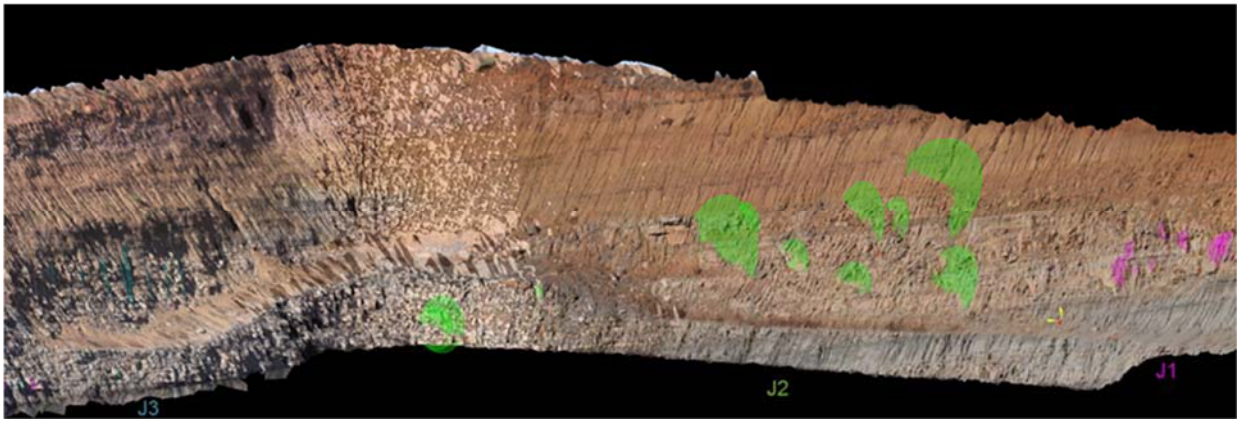

Figure 7-2: Joint Structures in Southern Highwall (Ref 2)

Table 7-1: Structural Measurements (Data from Ref 2)

Feature	Average Dip	Dip Std Dev	Average Dip Dir	DipDir Std Dev
J1	64°	5.3°	245°	8.3°
J2	77°	8.1°	312°	8.4°
J3	77°	4.8°	173°	4.1°
Fault 1	75°	-	235°	-
Fault 2	45°	-	097°	-
Bedding	10°	-	060°	-

Table 7-2: Eastern Highwall (Data from Ref 2)

Feature	Dip	Dip Direction
Fault 1	75°	235°
J2	77°	312°
Bedding	10°	060°
Highwall (West Facing)	47°	262°

Table 7-3: Eastern Highwall and Endwall – Southern Block (Data from Ref 2)

Feature	Dip	Dip Direction
Fault 2	45°	97°
J1	64°	245°
J2	77°	312°
J3	77°	173°
Bedding	10°	060°
Highwall (Nth West Facing)	52°	298°
Highwall (South West Facing)	48°	207°

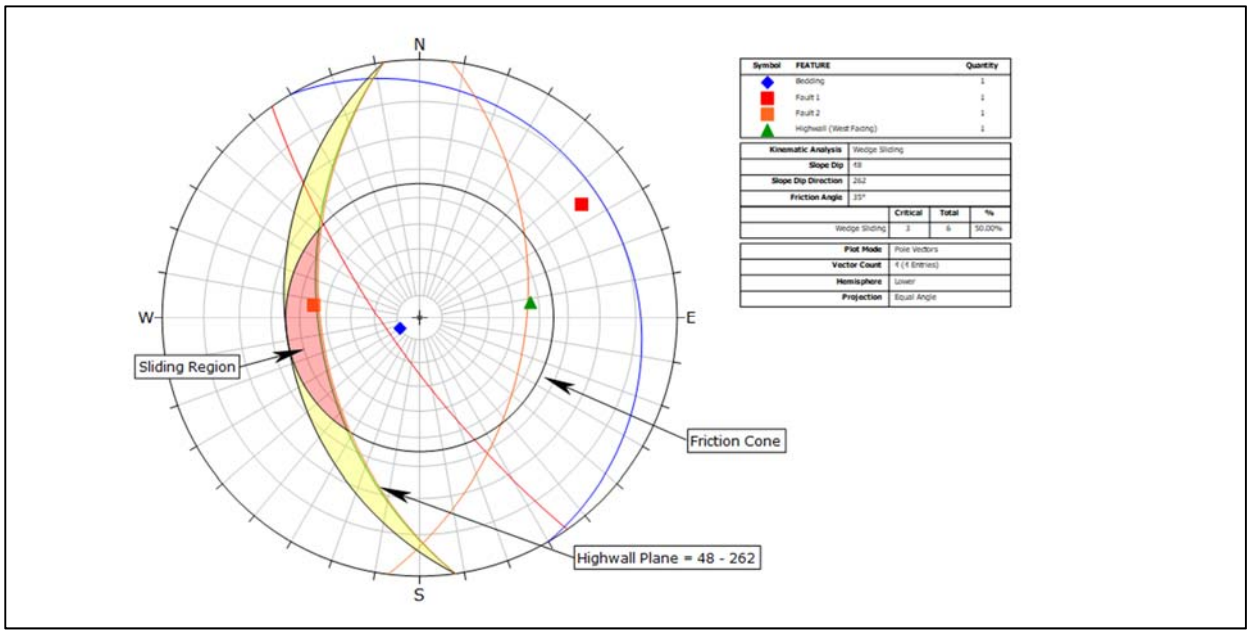

Figure 7-3: West Facing Highwall

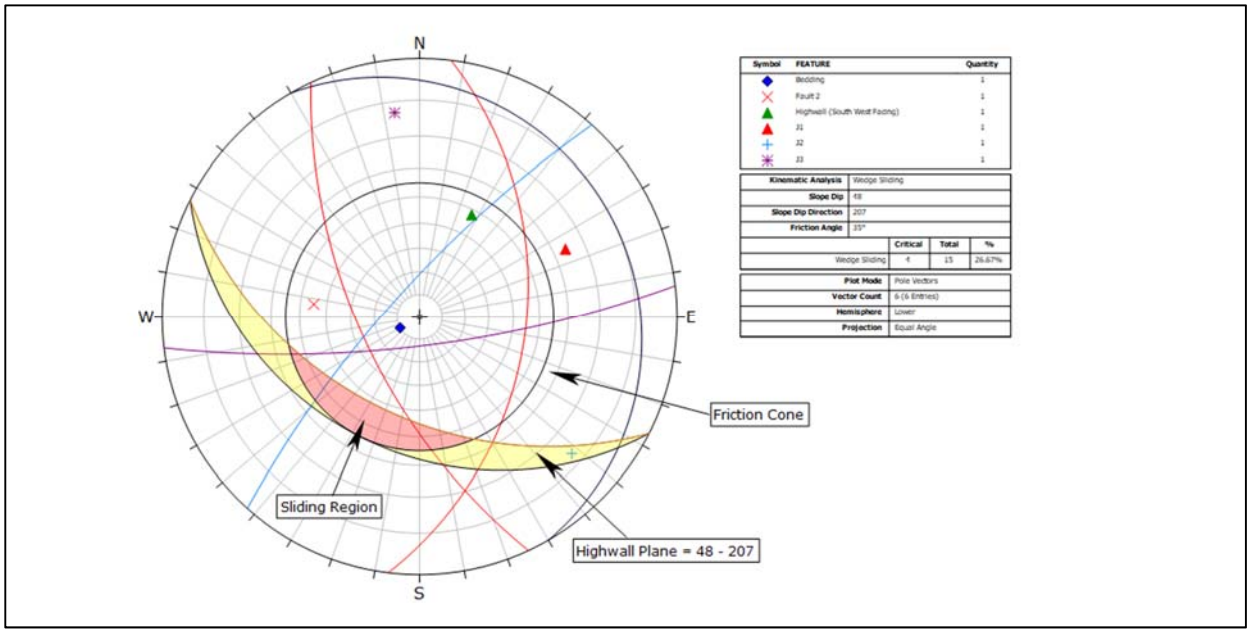

Figure 7-4: Southern Block – Southwest Facing Highwall

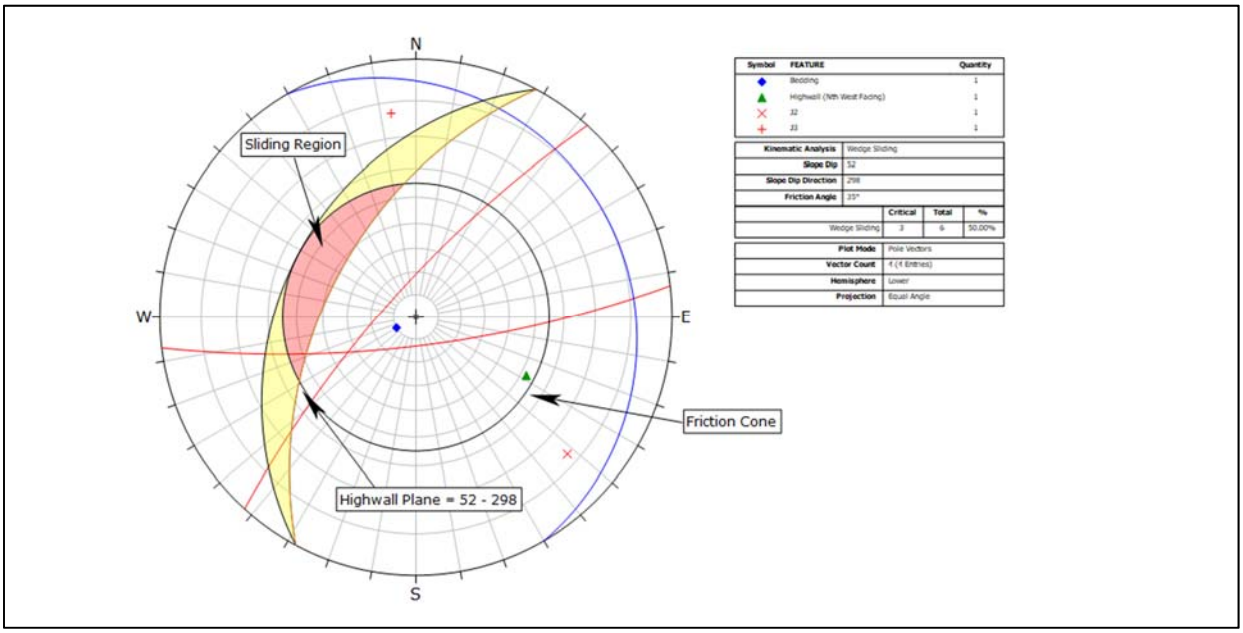

Figure 7-5: Southern Block – Northwest Facing Endwall



Figure 7-6: Bench Scale Wedge Failures – Southern Endwall

7.4 Lowwall Spoil Dumps – Limit Equilibrium Analysis

Stability analysis was carried out for nominated sections through the lowwall spoil during the 2015 geotechnical assessment. This assumed a Category 3 spoil for the analysis in accordance with the coal spoil shear strength framework, developed by Simmons and McManus.

For this assessment, stability analyses were carried out to account for the change in pit water levels to near the long-term water level of 262.5m RL. This has resulted in significantly more of the in-pit spoil being saturated than the 2015 study.

As discussed in Section 7.1, spoil material will continue to degrade, therefore the Category 3 assumption was downgraded to account for the process of weathering. In this case, a Category 2 spoil was considered as a long-term condition. The shear strength parameters for the nominated spoil conditions are outlined in Table 7-4.

Table 7-4: Adopted Shear Strength Parameters for Spoil (Ref 2)

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Cat 2 U		18	Mohr-Coulomb	30	28	None	0
Cat 2 S		20	Mohr-Coulomb	15	23	None	0
Cat 3 U		18	Mohr-Coulomb	50	30	None	0
Cat 3 S		20	Mohr-Coulomb	20	25	None	0
Siltstone Floor		22	Mohr-Coulomb	75	30	None	0

Analyses were made for representative cross-sections of as constructed in-pit spoil dumps for lowwall sections north and south of the infilled area, as shown in Figure 3-1 (Section 3), and was carried out using Slide 7.0 developed by Rocscience.

The following methodology and criteria were used:

- Both circular and non-circular failure analyses using Spencer's and Sarma's method functions, respectively, for inundated conditions which represent the long-term condition; and
- A bi-planar failure mode was analysed, with translational slippage along the floor contact, and a back scarp formed by shearing through to the crest. A back-scarp angle of 63° was assumed, which is common for failures of this type.

The results are summarised in Table 7-5.

Table 7-5 : In-Pit Spoil Stability Results – Water Level 259.5m RL

Lowwall Section	Scenario	Floor Dip	Factor of Stability (FoS)
2	Lower bench (non-circular)	14º	**1.40**
	Lower + upper bench (non-circular)		**1.68**
3	Bench (circular)	13º	**1.88**
5	Lower bench (non-circular)	12º	**4.31**
8	Lower bench submerged (non-circular)	11º	**3.42**

FoS ≥ 1.5 highlighted in green

The results show the lower bench scenario for Section 2 recorded a critical FoS of 1.40. Although this is marginally below the specified minimum FoS of 1.5, in the event of block slippage failure, displaced material from the failed slope would be contained within the pit void, therefore unlikely to pose a significant risk.

The remainder of the analyses indicate that in-pit dump failures would be unlikely, as the critical FoS values exceeded the long-term design value for inundated conditions (>1.5). It should be noted that the calculated FoS values for the in-pit spoil dumps south of the infill area are significantly higher, due to the shallower floor dip and the low dump heights.

The outputs from the Slide modelling are presented in Figure 7-7 to Figure 7-11 below.

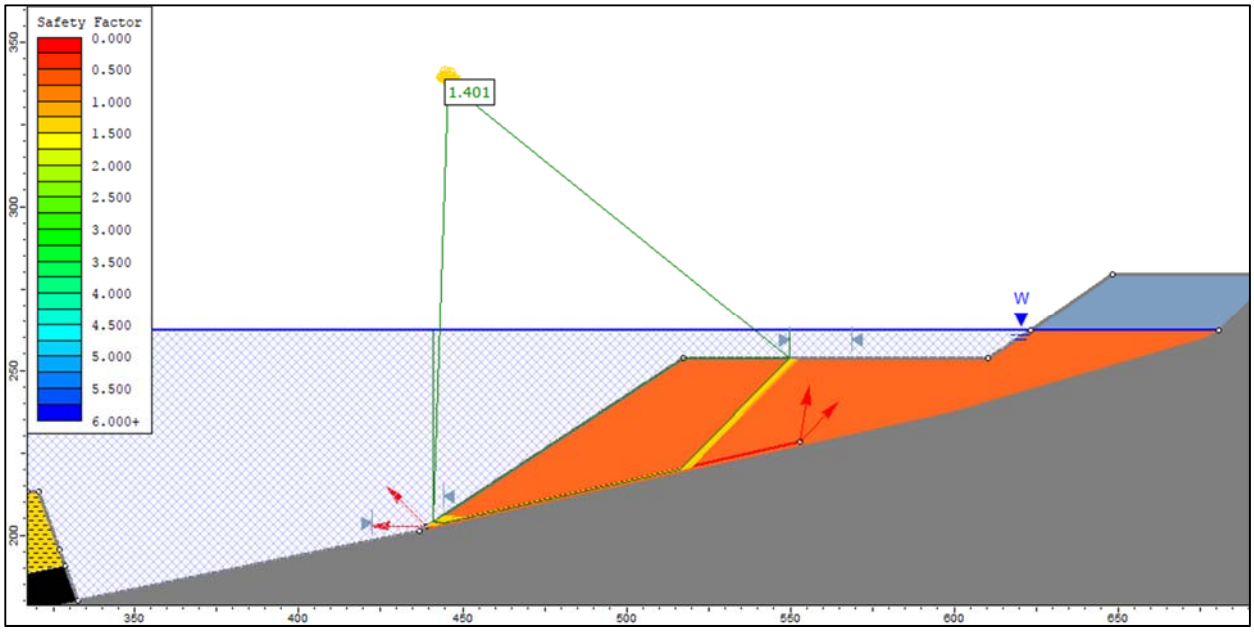

Figure 7-7: Section 2 - In-Pit Spoil Lower Bench - WL 262.5m RL

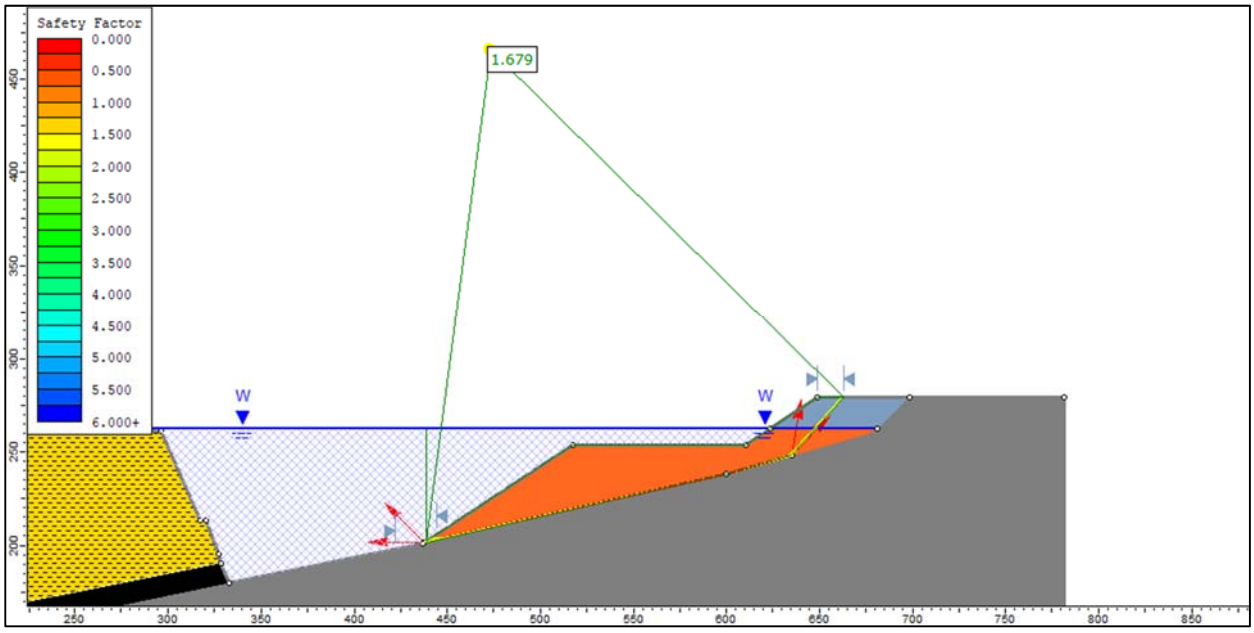

Figure 7-8: Section 2 - In-Pit Spoil Upper + Lower Bench - WL 262.5m RL

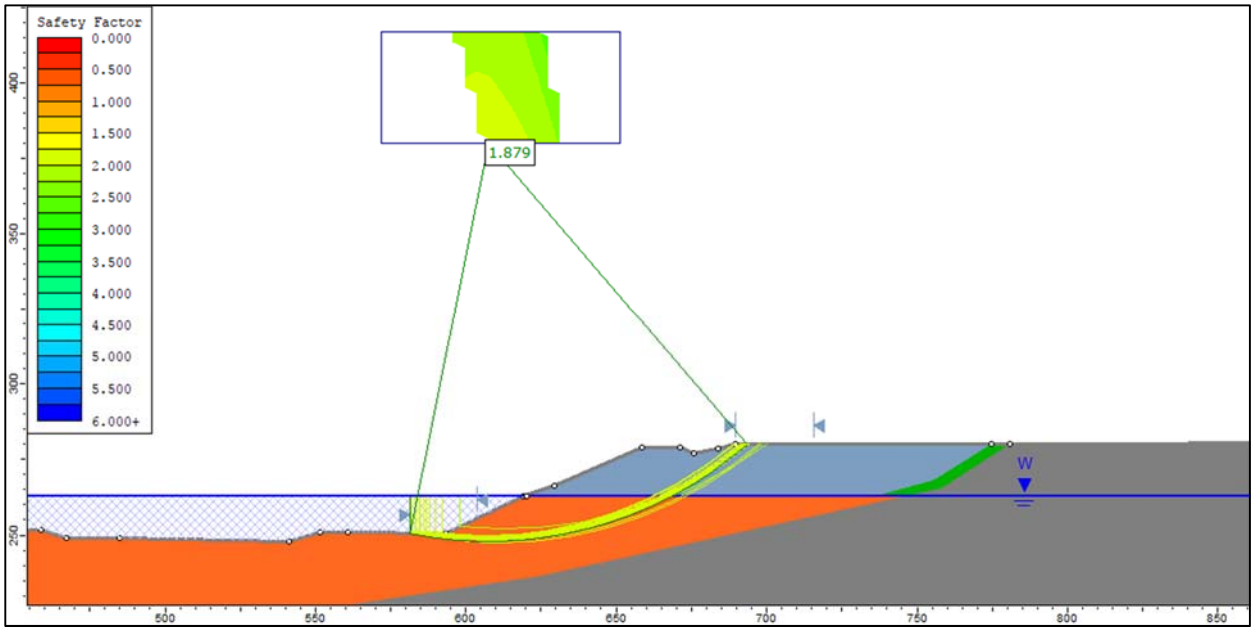

Figure 7-9: Section 3 - In-Pit Spoil - WL 262.5RL

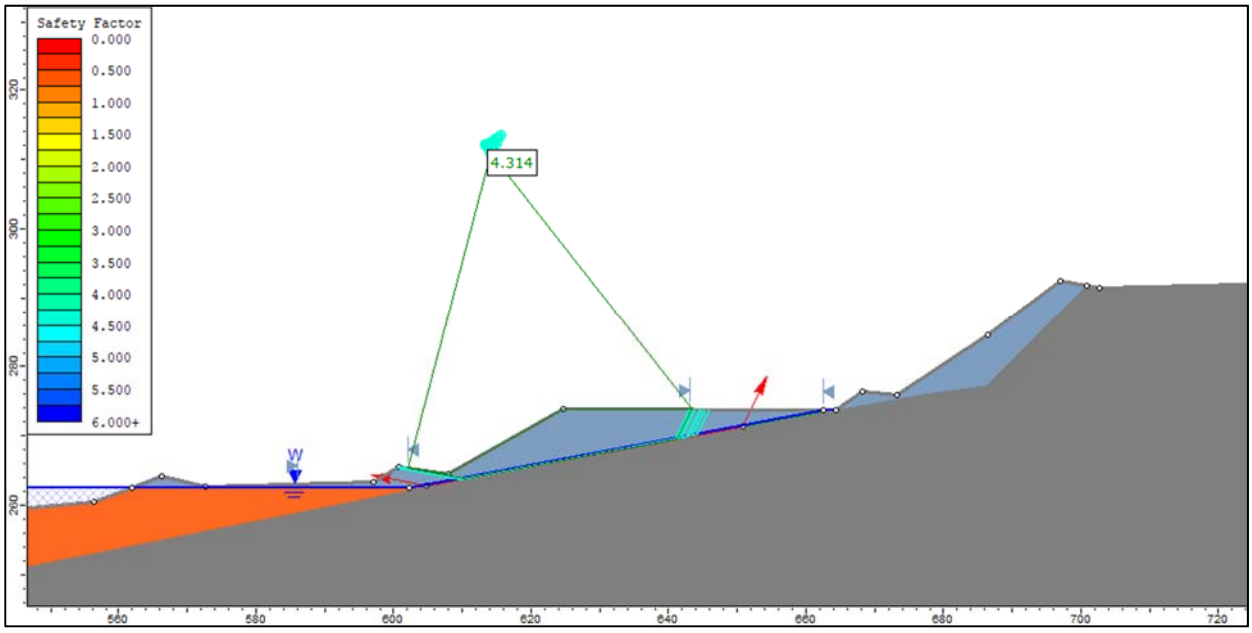

Figure 7-10: Section 5 - In-Pit Spoil Lower Bench – WL 262.5m RL

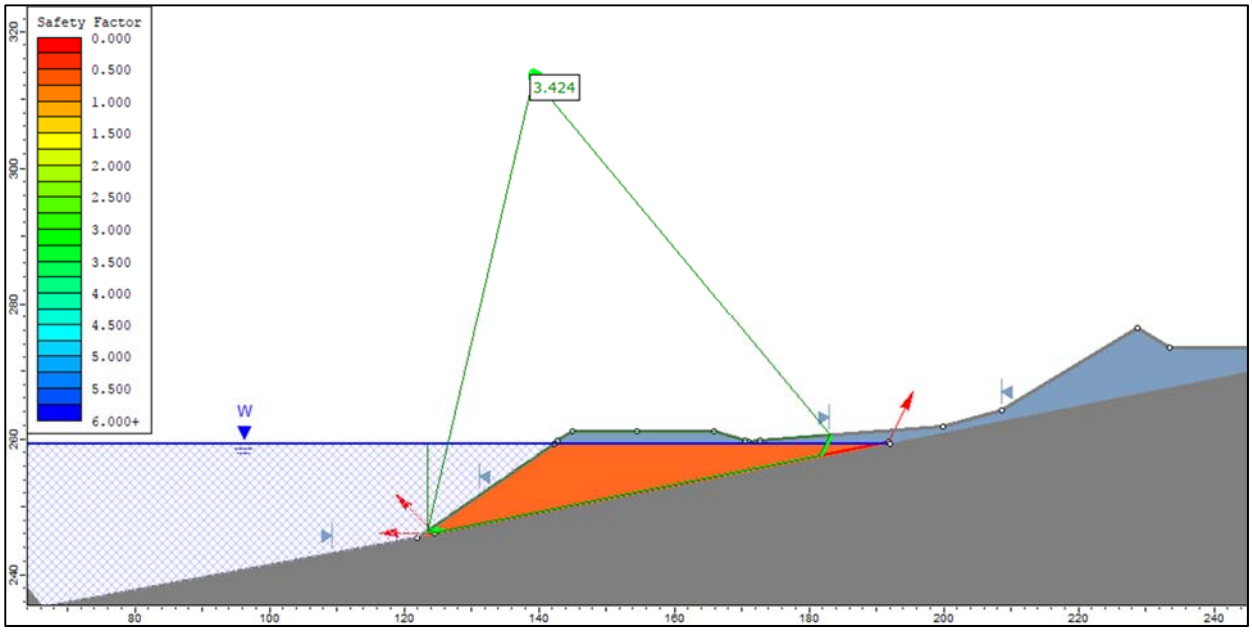

Figure 7-11: Section 8 - In-Pit Spoil Lower Bench – WL 262.5m RL

8. ENVIRONMENTAL STABILITY – WEATHERING AND DEGRADATION

As mentioned in the previous section, the Permian Rangal coal measures are prone to slaking, in particular the siltstone, which slakes and falls as fines continuously from the highwall. This action undercuts the harder more durable sandstone beds, and can lead to ongoing rockfall. To manage the risk of ongoing rockfall hazards, access to the final void should be restricted, and always with a suitable physical barrier and warning signs.

Regardless of the overall stability, there will be a residual effect of slope degradation due to weathering and erosion, referred to as environmental stability. In the long-term, the entire highwall face will erode; however, it should still maintain its profile as the harder lithological units generally act to reinforcethe slope. This process would have no impact on the geotechnical stability of the highwall, and as there is a 20m berm at rock head, there is minimal risk of undercutting the upper weathered benches.

The weathered rock and the thin cover of superficial deposits in the upper benches is likely to be slake susceptible and dispersive, and will gradually degrade to a flatter slope angle. There is sufficient room on the rock head berm to allow this process without significant displacement of material into the void.

9. SURFACE WATER MANAGEMENT

Run-off over the highwall should have no impact on the stability of the rock benches, and there were no areas of potential mass instability identified; however, concentrated run-off will erode and gully the upper Tertiary horizon. This is unlikely to result in failure of the highwall slope.

At present, the area between the diversion bund to the east of the northern highwall, and the current crest bunds, form a catchment that does not adequately drain toward Spade Creek, as intended. Instead, there is likely to be a slight surface gradient in the direction of the highwall crest, which has formed the prominent erosional features. In some areas, there is no drainage, which allows surface water to pond. It was indicated that this area must be filled and re-graded to encourage the flow of surface water away from the crest area. There is a need to minimise the catchment area between the highwall and diversionbank , adjacent to the highwall, as Figure 4-3 clearly demonstrates the impact of erosion due to the size of the catchment area. In this case, an investigation should be carried out to shift the bund closer to the highwall and reduce the catchment area.

A levee system is proposed along both the northern and southern endwall and the lowwall, to mitigate flooding of the void during the 1:1000 - year flood event. Thess structures must be RPEQ certified as required under the sites environmental authority. Given future landholders may not be amenable to maintaining the levee as a certified structure, options for closure may involve negating the need for the levee system by either backfilling the void, or modifying the levee to create a final landform that meets the rehabilitation goals. In this case, the final landform should be higher than the Probable Maximum Flood (PMF) with dimensions that can withstand the effects of weathering and erosion in perpetuity.

Saline seepage from the external dump currently flows behind the northern lowwall and is directed into the pit via an underdrain. As part of long-term water management, a seepage drain should be constructed to confine the seepage to a dedicated drainage channel along the toe of the external dump, in order to minimise the potential for seepage behind the lowwall.

10. LEVEE AND CREST BUND DEMARCATION

A system of levees has been proposed at the southern and northern lowwall/endwall intersections in order to prevent the 1:1000 - year flood waters from entering the void. These levees are to be a certified construction, and such, are required to be placed at an adequate offset from the crest. A perimeter exclusion bund is proposed for installation, and is to be located at an adequate distance from the highwall crest to avoid damage from slope failures or degradation.

Whilst there are no official guidelines in Queensland pertaining to the appropriate location of exclusion bunds, generic guidelines were developed by Ward, based on unpublished, comprehensive studies of open-cut voids at German Creek and Oaky Creek Mines (Ref 1).

Residual risk exists for all abandoned pit walls from a stability perspective. For steep rock slopes, rockfall is the most common risk as the faces physically degrade over time. In this case, structure-bounded blocks can be released, but there is also a risk of larger rock blocks of more competent sandstone on flatter or re-graded slopes which could mobilise due to the preferential weathering of the more slake prone units.

It is not practicable to treat all slopes to entirely eliminate the stability hazards. The usual approach taken is minimize the likelihood of such hazards by re-grading slopes that present a significant risk, and then restrict access to the pit. This is achieved by bunding off the access ramps and placing exclusion bunds along highwalls and lowwalls.

Bund walls for the purpose of restricting access should have a minimum height of 2m, and should be constructed of non-dispersive material, or alternatively by placing hard barriers which would prevent access without constricting run-off if water is being directed into the void (Ref 2).

Given the highwall and endwall slopes are assessed to be geotechnically stable, the inside edge of the levee system and perimeter bunding should be offset at a distance of 15m the crest, as illustrated in Figure 10-1, or 15m offset from the edge of any identified instability, such as the shallow circular failure along the northern highwall.

The same offset could be applied to the lowwall slope. In this case, it should be possible to construct the levee on filled material, given there would have been a significant amount of settlement over time.

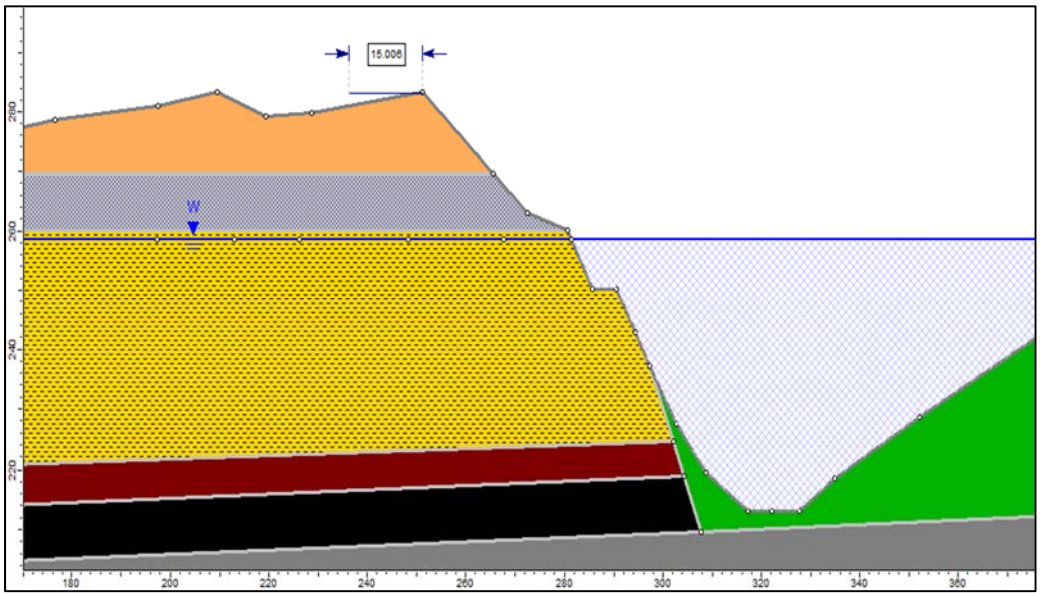

Figure 10-1: Crest Offset Distance

11. CONCLUSIONS

The following conclusions may be drawn from the geotechnical assessment:

- The highwalls are inherently stable against mass failure but local instability can occur where geological structures daylight on the pit face and form geometries that are kinematically unstable. In this case, the bench scale wedge failures in the southern highwall block are unlikely to prejudice the long-term stability of the highwalll; however, these failures may continue to occur as the highwall erodes;
- The standard slope designs meet the EA requirements for as-constructed pit slopes to be geotechnically stable with regard to the ground conditions at the Broadmeadow Pit;
- The as-constructed slopes are in compliance with residual void design, except for lowwall side of the external dump which has yet to be re-graded. This would need to be tied into the lowwall in accordance with the EA requirements;
- In-pit low wall dumps are stable with a more than adequate long-term FoS, including a condition of partial submergence to the predicted 10-year water level;
- There are no issues relating to potential risk of geotechnical instability due to run-off entering the void; and
- Given the highwall and endwall slopes are assessed to be geotechnically stable, the inside edge of the levee system and perimeter bunding should be offset at a distance of 15m from the crest line. The same offset could be applied to lowwall, with the possibility of levee construction on filled material, given amount of settlement that has occurred over time.

12. RECOMMENDATIONS

It is recommended that:

- A program of critical monitoring would need to be undertaken to evaluate the actual performance of the slopes against expected performance. This would be carried out as an annual inspection, and periodic inspections, such as after significant rainfall events;
- Filling and re-contouring/re-grading of the gully erosion and shallow surface water bodies between the diversion and crest bunds be undertaken to encourage the diversion of water away from the pit crest. In this case, water should not be permitted to accumulate around the proposed perimeter bund construction to in order to mitigate the effects of erosion;
- The bunding along the northern highwall be moved closer to the highwall crest to reduce the current catchment size in order to restrict the volume of ponded water within the area. Additionally, bunds should be designed to accommodate the discharge of

surface water during rainfall events to prevent overtopping. In this case, cut-throughs leading to rubble lined discharge spillways should be installed at regular intervals along the bund.

Yours sincerely,



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Ref 1: Ward, B (2016). "**Burton Widening Residual Void Slope Stability Study**". Geotechnical Consulting Services. Report 169.

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Ref 4: Simmons, J (1995). "**Slope Stability for Open Cut Coal Mining**". Sherwood Geotechnical and Research Services Pty Ltd.

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Appendix O
Final void hydrology study



December 21, 2018

Peabody Energy Australia
100 Melbourne Street
South Brisbane, QLD, 4101
Australia

Justin Vohland
Environment Manager / SSE – Burton Mine

Dear Mr. Vohland:

Burton Coal Mine
Final Void Hydrology Study
Final Report

Klohn Crippen Berger (KCB) is pleased to provide Peabody with his final void hydrology study report for the final voids at Burton Coal Mine.

Yours truly,

KLOHN CRIPPEN BERGER LTD.



Kirsty Bethune
Senior Water Resources Engineer

KB:KB

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EXECUTIVE SUMMARY

This report documents a study into the hydrology of the residual or final voids within Broadmeadow, Bullock, Plumtree and Wallanbah Pits which remain as part of the final landform at Burton Coal Mine (BCM).

Investigations have focused on the hydrological characteristics of these four final voids, including long term pit lake water levels, water quality and filling timeframes. Parallel studies have been undertaken to consider the hydrogeological and ecological characteristics of the final voids. Outcomes of both these parallel studies have been taken into account and have also been documented in the accompanying appendices.

Predictive water balance simulation modelling undertaken as part of this study indicates that:

- All voids will maintain a permanent pit lake which will fluctuate around a steady state equilibrium level in response to periods of flood and drought.
- During periods of floods, no final voids are expected to reach levels that would result in overflow to the environment via surface overflow.
- Long term equilibrium conditions will generally be reached over an 80 year period within all four final voids.
- Predicted pit lake water qualities (assessed as electrical conductivity), are expected to support native flora and fauna and not affect fringing vegetation. The permanent pit lakes should provide a permanent aquatic habitat to serve as a wildlife refuge in an otherwise ephemeral system. The aquatic community will be limited in diversity to those species with at least moderate salt tolerance.

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1 INTRODUCTION

BCM is an open cut coal mine located approximately 150 km south west of Mackay in the Bowen Basin region of Central Queensland. Since early 2017, the mine has been operating in care and maintenance phase with rehabilitation and closure activities being undertaken. Peabody is responsible for the rehabilitation and closure planning of the residual or final voids remaining within the following pits:

- Broadmeadow Pit
- Bullock Pit
- Plumtree Pit
- Wallanbah Pit

In accordance with the BCM environment authority (EA), Peabody is required to prepare a management plan for these residual voids (refer to Condition F7) that must, at a minimum, include the following items:

1. A study of options available for minimising residual void area and volume.
2. Develop design criteria for rehabilitation of residual voids.
3. A void hydrology study, addressing the long-term water balance in the voids, connections to groundwater resources and water quality parameters in the long term.
4. A pit wall stability study considering the effects of long term erosion and weathering of the pit wall and the effects of significant hydrological events.
5. A study of void capability to support native flora and fauna.
6. A proposal/s for end of mine void rehabilitation success criteria and residual void areas and volumes.

In response to these requirements, Peabody has engaged Klohn Crippen Berger (KCB) to prepare this report to address items 3 and 5 for the final voids remaining within Broadmeadow, Bullock, Plumtree and Wallanbah Pits. The scope of work is in accordance with KCB proposal PR18D02-65 (dated 13th June 2018) and includes:

- Review of the final landform to define physical characteristics including catchment area and stage storage characteristics for each final void.
- Determine appropriate hydrological inputs to be used for modelling, including rainfall, evaporation, catchment yield and potential impacts of climate change.
- Determine appropriate hydrogeological inputs to be used for modelling, including groundwater interactions, associated groundwater inflow rates and spoil aquifer storage within each final void.

- Development of an OPSIM[1] water balance model (WBM) for the final voids.
- Undertake predictive modelling, for each final void to estimate the following:
  - Time taken to reach equilibrium[2] within each final void.
  - Climate driven pit lake[3] water level variations once equilibrium conditions have been achieved.
  - Likely salinity conditions (i.e. total salt load) when equilibrium is reached[4].
  - Risk of discharging to surface waters either via overtopping the pit crest or seepage to the groundwater system (i.e. via surface alluvial aquifers).
  - How outcomes of the items above may be affected by uncertainty associated with predictive model inputs and/or parameters (e.g. sensitivity analysis).

This final void study has primarily focused on the long term fluctuations of water levels within the pit lakes to understand the likelihood that water will release to the downstream receiving waterways via overtopping. The fluctuation of salinity, assessed as electrical conductivity (EC), has been a secondary study criterion and has focussed on the bulk salt mass when the void reaches equilibrium water levels and the fluctuations of EC as the pit lake volume changes due to climatic cycles.

Key personnel involved with the assessment to date have included:

<u>Peabody</u>

- Justin Vohland, Environment Manager / SSE – Burton Mine

<u>KCB</u>

- Kirsty Bethune, Senior Water Resources Engineer
- Thomas Chung, Senior Hydrogeologist
- Jim Heaslop, Water Engineering Lead / Senior Civil / Water Resources Engineer
- Chris Li, Graduate Engineer

<u>Gauge Industrial and Environment Pty Ltd (Gauge)</u>

- Mike Ferguson, Principal Ecologist

[1] The OPSIM software is a general purpose simulation model for water resource systems. It is industry accepted and primarily used for mine site water management applications throughout Australia.
[2] Equilibrium condition is the term used to describe the conditions in the void when a stable range in the water level is reached. At this time, the water level within the void may fluctuate due to seasonal changes, however, the long term water level trend will not continue to accumulate or deplete over time.
[3] For the purpose of this report, the final void refers to the last remaining pit and associated ramps, while the formation of a water body within the final void is referred to as a pit lake.
[4] This does not include the development of a full lake model with water chemistry and water body saturation.

1.1 Background

A WBM for the care and maintenance operation of the BCM water management system was developed by Hatch Pty Ltd (Hatch) in late 2016. This OPSIM WBM used historical water level and water quality data collected between 2014 to 2016 to define key model parameters (i.e. catchment yield, groundwater, pit evaporation factors and salinity generation rates). This report[5] has been referred to herein as the *2016 care and maintenance WBM* and referenced accordingly.

In late 2017 / early 2018, Hatch undertook preliminary final void modelling for the Broadmeadow, Bullock, Plumtree and Wallanbah Pits at BCM. This preliminary modelling established long term water level fluctuations within each of the four final voids using the current topography as the final landform. No salinity fluctuations were modelled. This report[6] has been referred to herein as the *Q1 2018 Final Void Modelling* and referenced accordingly.

Since then, Peabody have established final landform design for each of the four final voids with this report revising the final void hydrological conditions for these designs and providing assessment of the ecological conditions within the pit lakes.

1.2 Project Data

A summary of relevant project data provided by Peabody and sourced from publicly available sources has been presented in Appendix I.

1.3 Final Void Data Sheets

For ease of interpretation and to ensure consistency with the Q1 2018 Final Void Modelling, a final void data sheet has been developed for each of the four final voids. The following information is presented in each final void data sheet:

- Locality and catchment plan featuring final landform topography, catchment area delineations for surface and baseflow and baseflow only areas, overflow paths, cross section alignment and neighbouring waterways.
- Stage storage curve.
- Indicative cross section through the final void
- Long term water level fluctuations within the final void.
- Long term water level ranges for the sensitivity cases.
- Relevant notes.

The final void data sheets for Broadmeadow, Bullock, Plumtree and Wallanbah Pits have been presented in Appendix II. Key physical components of the final void data sheets have been presented in Section 2.3 of this report with the modelling outcomes presented in Section 3.

[5] *Burton Coal Mine: Care and Maintenance Water Balance Modelling* report by Hatch (H351353-00000-228-230-0001) dated August 2016.
[6] *Burton Coal Mine: Final Void Modelling Q1 2018* report by Hatch (H355622-00000-228-230-0001) dated January 2018.

2 FINAL VOID MODEL

2.1 Conceptual Model

A representation of a conceptual final void water balance has been presented in Figure 2-1.

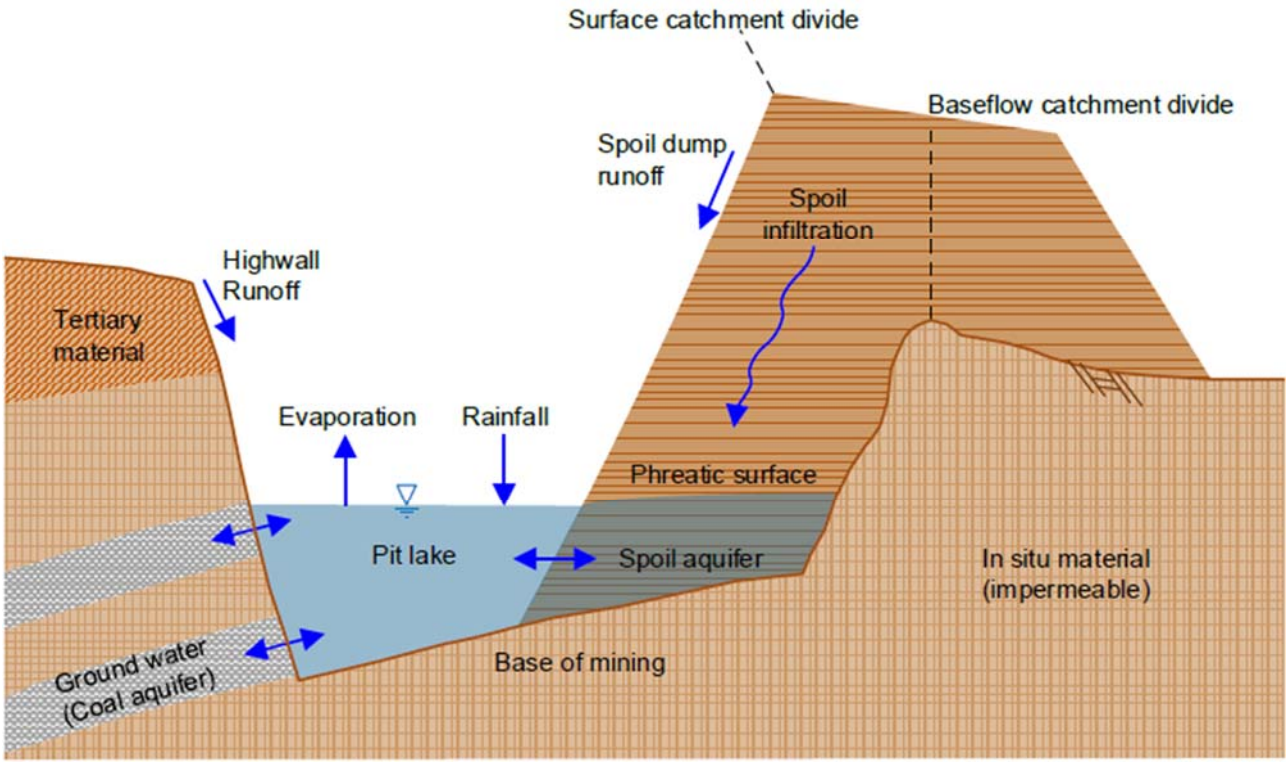

Figure 2-1: Conceptual Final Void Water Balance

Review of Figure 2-1 leads to the following key water inputs and outputs:

- Inputs
  - Rainfall on the pit lake water surface.
  - Rainfall infiltration through the spoil.
  - Runoff from pit faces (i.e. highwall, low wall and spoil dumps) and rehabilitated upstream catchment areas.
  - Groundwater interception.
- Outputs
  - Evaporation from the pit lake surface.
  - Evapotranspiration from the reporting catchments.
  - Seepage outflow through the tertiary or weathered material if the final void water level exceeds the base of the tertiary or weathered layer (i.e. control level).
  - Surface water outflow if the final void water level exceeds the containment of the void.

At BCM, all four final voids already contain water. Over time, water is expected to accumulate and water levels will rise within the final void until a nominal steady state is reached. At this point, the combined inputs of the direct rainfall, catchment runoff and groundwater interception will be balanced by the evaporative losses from the pit lake wetted surface area. When this nominal steady state has been reached, variation above and below the steady state water level will occur during prolonged periods of wet and dry climate bias (i.e. flood and drought).

However, for any voids that are currently filled above their steady state level prior to closure, water levels will reduce due to evaporation until the pit lake wetted surface area contracts to an area at which the evaporative losses balance the inflows.

Dissolved salts enter the final void via groundwater and catchment runoff. In the absence of seepage or surface outflows to the environment, there is generally no removal of salts from the system with salts expected to accumulate over time.

2.2 OPSIM Model

An independent numerical final void WBM has been developed for BCM using the OPSIM software package to simulate the key inputs and outputs, as described in Section 2.1. The final void WBM simulated the generation, movement and loss of water on a daily time-step within each final void over a 1,000 year period. In addition to the water balance within each final void, the bulk volume of salt captured and stored within each void has been tracked.

Key final void WBM input and parameters have been summarised in the following sub-sections of this report as follows:

- Physical characteristics (refer to Section 2.3)
- Hydrological parameters (refer to Section 2.4)
- Hydrogeological parameters (refer to Section 2.5).
- Initial conditions (refer to Section 2.6).
- Sensitivity analysis (refer to Section 4).

2.3 Physical Characteristics

2.3.1 Location

The location of the Broadmeadow, Bullock, Plumtree and Wallanbah Pits and associated final voids have been presented in Figure 2-2.

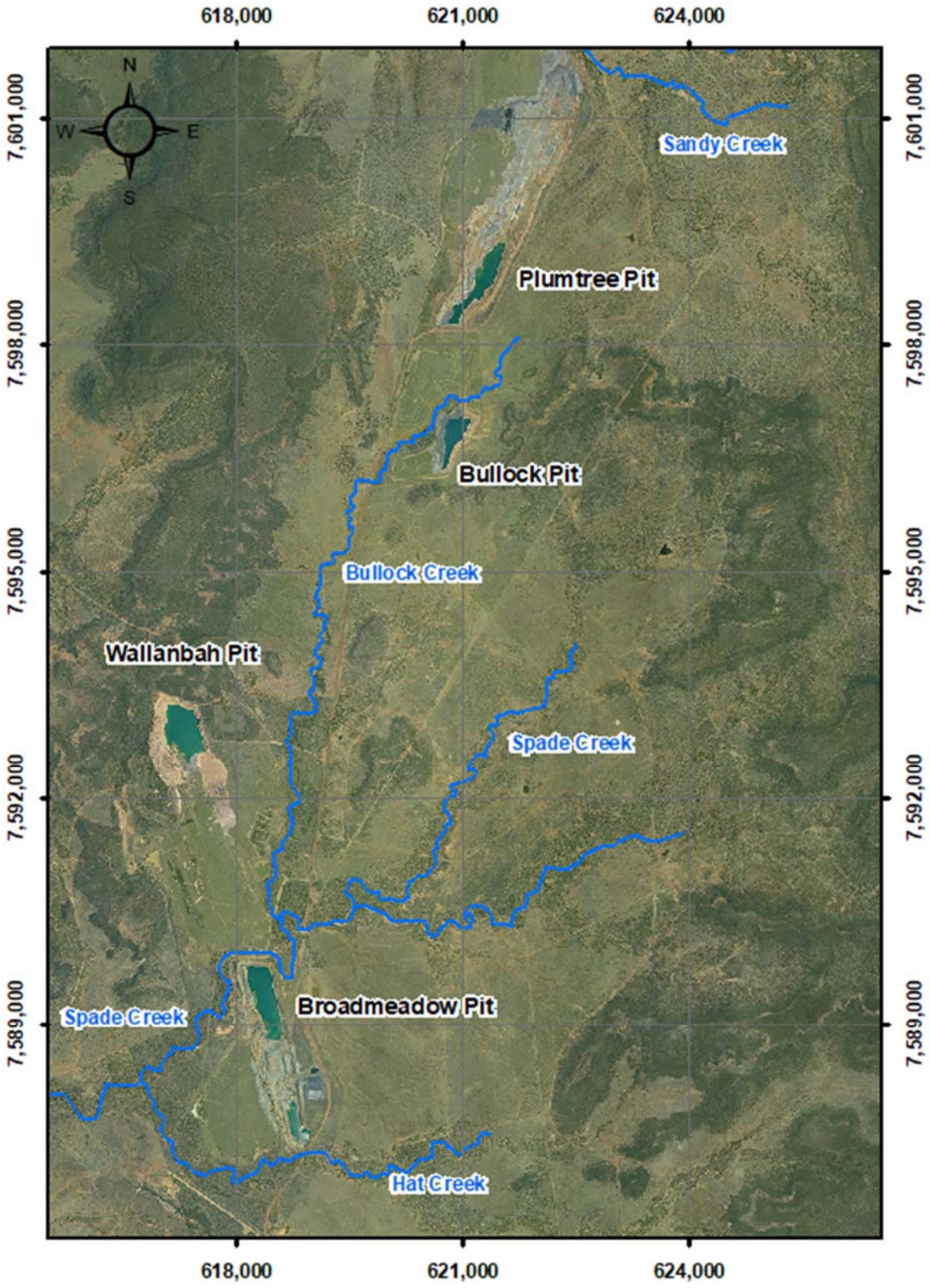

Figure 2-2: Layout Plan – Broadmeadow, Bullock, Plumtree and Wallanbah Pits

Review of Figure 2-2 leads to the following:

- Four separate final voids will remain after rehabilitation and closure.
- All four final voids have been backfilled with large quantities of spoil.
- Two visible pit lakes have formed within the Broadmeadow Pit final void a spoil bridge between the two pit lakes. Historical water level data has indicated that both pit lakes are currently at the same water level. This indicates a strong connection between the two pit lakes through the spoil material. Accordingly, the two pit lakes within Broadmeadow Pit have been modelled to rise and fall together due to the cross connection through the intervening spoil material.

2.3.2 Topography

Final void topographic data has been provided by Peabody as follows:

- Final void landform design
- Deepest mined surface

The final void landform design topography has been presented in the final void data sheets (refer to Appendix II).

As detailed in Section 1.3, a representative cross section through each final void has also been presented in the final void data sheets (refer to Appendix II). The section alignment runs through the deepest region of each final void has been generated using the final landform design and deepest mined topographies. The highwalls of each final void, as presented in the cross sections, are not located on the corresponding section alignments, but would be visible in the direction as detailed in the notes below the cross section.

2.3.3 Level – Surface Area - Volume Relationship

Level – surface area – volume relationships for the free water within each final void have been presented in the final void data sheets (refer to Appendix II). The level – surface area – volume relationships have been derived from computer analysis of the final landform design topography.

Key levels associated with each final void have also been presented on the level - surface area – volume relationships in the final void data sheets. Descriptions of these key level have been summarised in Table 2-1.

Table 2-1: Key Levels

Key Level	Description
Current Water Level	▪ Taken on 7th July 2018.
Design Storm Allowance (DSA)	▪ Water levels within the final voids must be below this target level on 1st November each year to ensure enough storage is available to contain seasonal rainfall to a specified probability.
Mandatory Reporting Level (MRL)	▪ Warning and reporting level determined in accordance with criteria set out in The Manual.
Control Level	▪ Maximum allowable storage level based upon: ◆ Geotechnical advise from Peabody personnel. ◆ Nominal 5 m freeboard below the nearby waterway bed level to account for topographic uncertainty.

Key Level	Description
	◆ Nominal 5 m freeboard below the pit crest level to account for wind/wave action, geotechnical and topographic uncertainty. ▪ Adopted control levels have been taken from the Q1 2018 Final Void Modelling report. ▪ The basis of each control level has been specified on each final void data sheet.
Natural Ground Level	▪ Derived from the deepest mined surface topography.
Spoil Crest Level	▪ Derived from the final landform design topography.

2.3.4 Catchment Areas

Surface runoff catchment areas reporting to the final voids have been provided by Peabody. These catchment delineations have been reviewed by KCB with reference to the final landform design topography. It has been assumed that the surface runoff catchment areas have been delineated based upon suitable flood protection works currently constructed at BCM to prevent ingress of flood water from the adjacent waterways of Sandy, Bullock, Spade and Hat Creeks.

As detailed in Figure 2-1, the final void WBM simulated infiltration of water through the rehabilitated spoil dumps and sub-surface drainage of this water to the downstream pit lake. Baseflow catchment areas reporting to each final void have been determined based on review of the deepest mined topography with any mined area not covered by the surface runoff catchment areas delineated as baseflow ONLY catchments.

Surface runoff and baseflow catchment areas have been summarised in Table 2-2 with delineations presented in the locality and catchment plan in each final void data sheet (refer to Appendix II). For comparison, the catchment areas used on the Q1 2018 final void modelling work have also been presented in Table 2-2 and were based on the current topography as opposed to the final landform design topography.

Table 2-2: Catchment Areas

Final Void	Current Area (ha)		Q1 2018 Area (ha)	
	Surface Runoff	Baseflow ONLY	Surface Runoff	Baseflow ONLY
Broadmeadow Pit	146	3	200	0
Bullock Pit	39	11	41	6
Plumtree Pit	232	45	273	38
Wallanbah Pit	222	43	203	47

Review of Table 2-2 leads to the following:

- Reduction in catchment areas reporting to Broadmeadow and Plumtree Pits.
- Slight increase in catchment area reporting to Wallanbah Pit.
- Minimal change to the catchment area reporting to Bullock Pit.

2.3.5 Land Use Breakdowns

Review of the 2016 care and maintenance WBM identified that the catchments directed to the four final voids consisted of natural, cleared, industrial and roads, mining pit, stockpile dumps, unrehabilitated spoil and rehabilitated spoil land uses.

Over time and due to the progressing rehabilitation of the disturbed catchment areas, the use classification adopted for the final void catchments have been derived based on the following assumptions:

- Cleared land, stockpile dumps, industrial land and roads, unrehabilitated spoil and pit low wall areas will be rehabilitated.
- Rehabilitated land will naturally revert, over time, to natural or pre-mining conditions. This is due to topsoil consolidation and weathering overtime.
- Mining pit highwalls, endwalls and ramps will continue to produce higher runoff than the rehabilitated spoil areas due to the relative differences in slope and cover and will remain as mining pit land use breakdown.
- Mining pit areas will be progressively offset by the wetted surface area in each void (i.e. they will get covered by water as the pit fills).

These assumptions were consistent with the Q1 2018 final void modelling work package.

The long term steady state conditions of the catchments are expected to settle somewhere between the rehabilitated and natural land use classifications. To take this change in catchment land use over time into account, the following two catchment classifications cases have been modelled:

- Rehabilitated case:
  - Cleared land, stockpile dumps, industrial land and roads, pit low walls and unrehabilitated spoil areas have been rehabilitated.
  - Existing natural and mining pit areas remain unchanged.
- Natural case:
  - Cleared land, stockpile dumps, industrial land and roads, pit low walls, unrehabilitated spoil and rehabilitated spoil areas have reverted to a natural land use.
  - Existing natural and mining pit areas remain unchanged.

Land use breakdowns and associated areas have been summarised in Table 2-3.

Table 2-3: Catchment Classification Cases

Final Void	Classification Case	Surface Catchment Area (ha)			
		Natural	Mining Pits	Rehab Spoil	Total
Broadmeadow Pit	Rehabilitated	5	15	126	146
	Natural	131	15	-	146
Bullock Pit	Rehabilitated	2	14	23	39
	Natural	25	14	-	39
Plumtree Pit	Rehabilitated	-	41	191	232
	Natural	191	41	-	232
Wallanbah Pit	Rehabilitated	25	16	181	222
	Natural	206	16	-	222

2.3.6 Volumes and Water Quality

Inventories for Broadmeadow, Bullock, Plumtree and Wallanbah Pits have been established from site measured data from February 2013 to June 2018 and have been presented in Figure 2-3 to Figure 2-6, respectively. These figures also present the available water quality (i.e. EC) along with SILO Data Drill daily rainfall data for the corresponding time frame. Erroneous data has been removed.

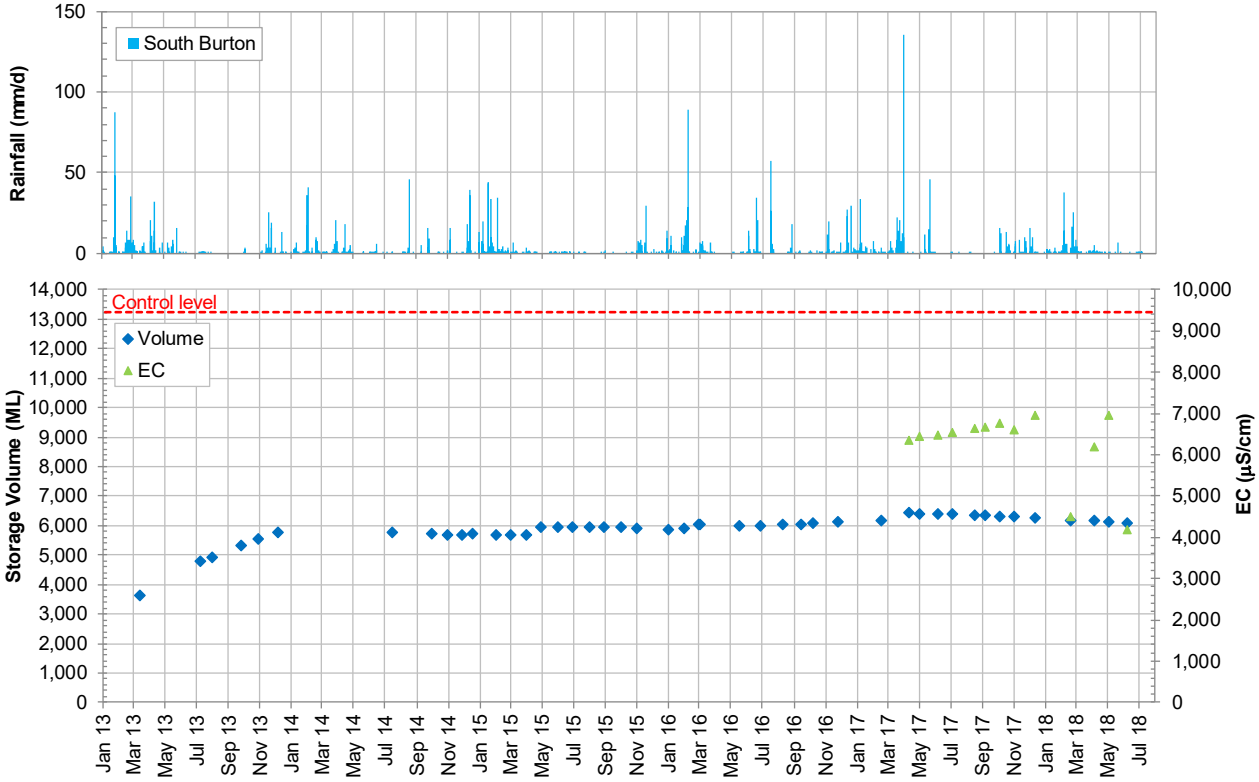

Figure 2-3: Broadmeadow Pit Volume and EC

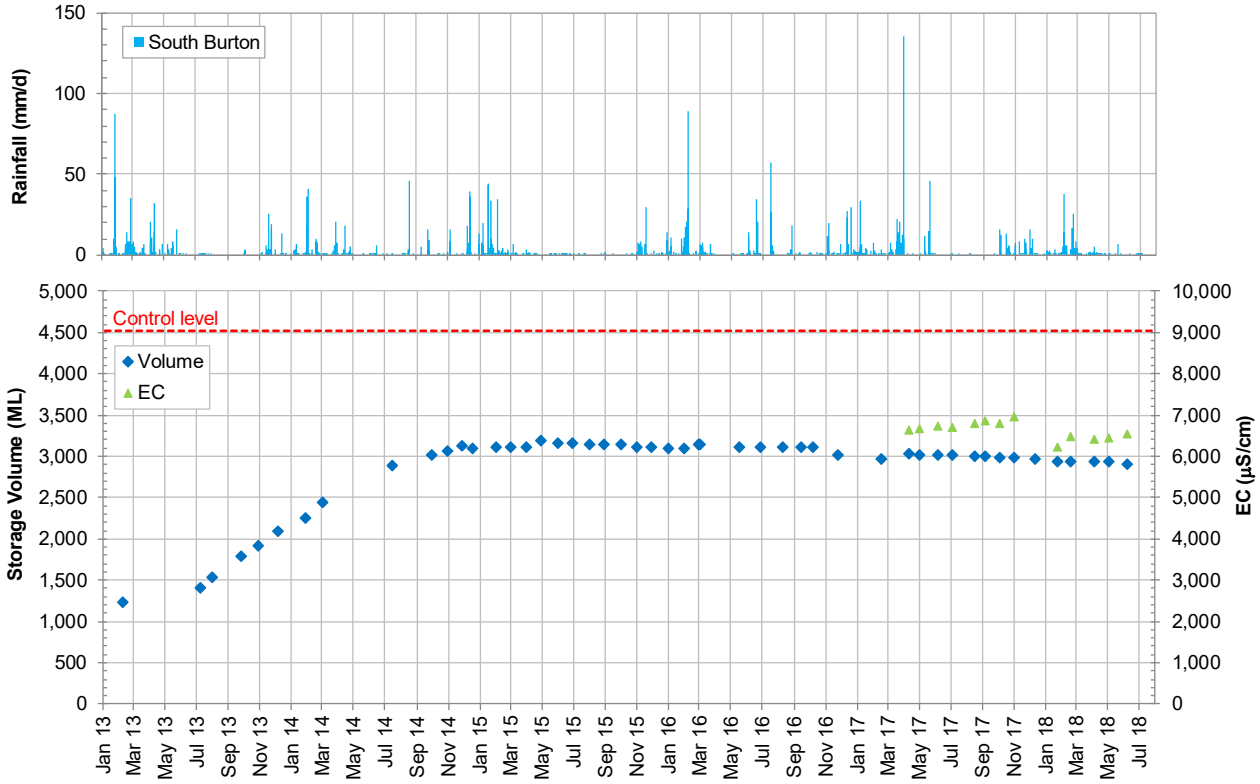

Figure 2-4: Bullock Pit Volume and EC

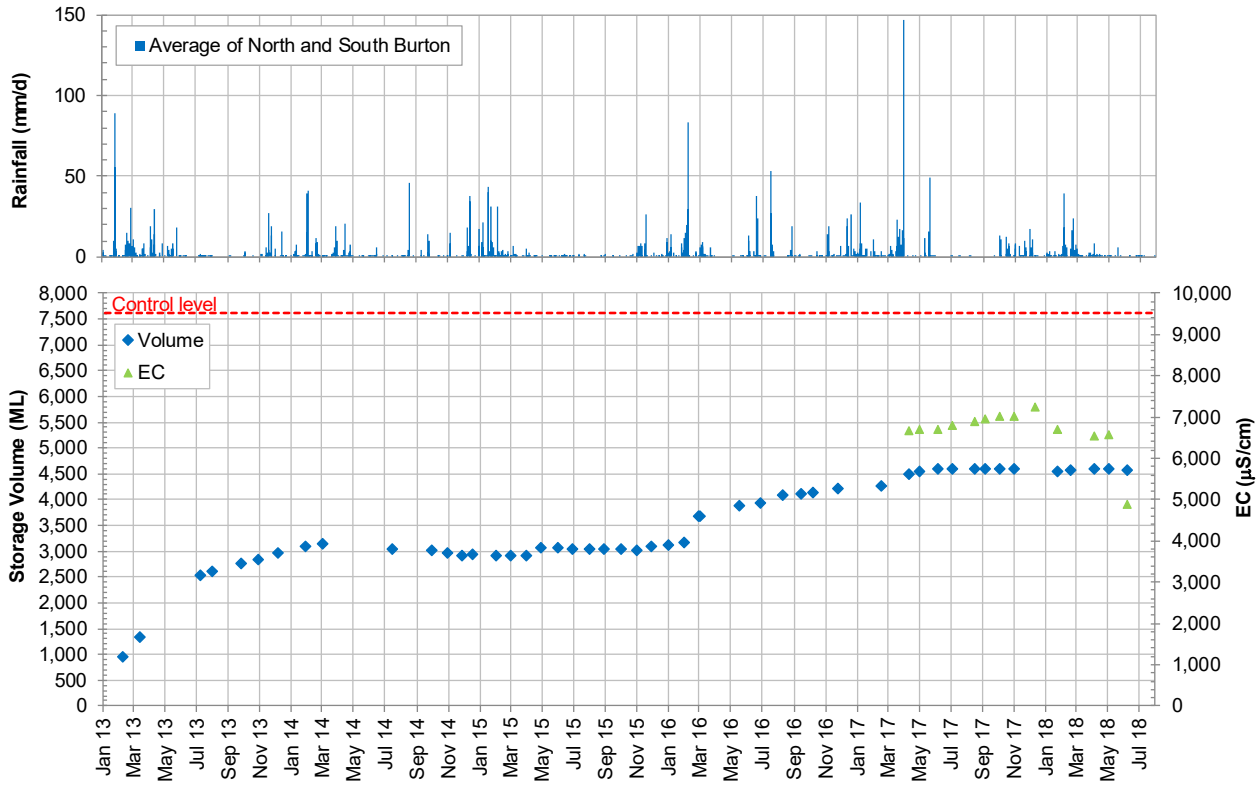

Figure 2-5: Plumtree Pit Volume and EC

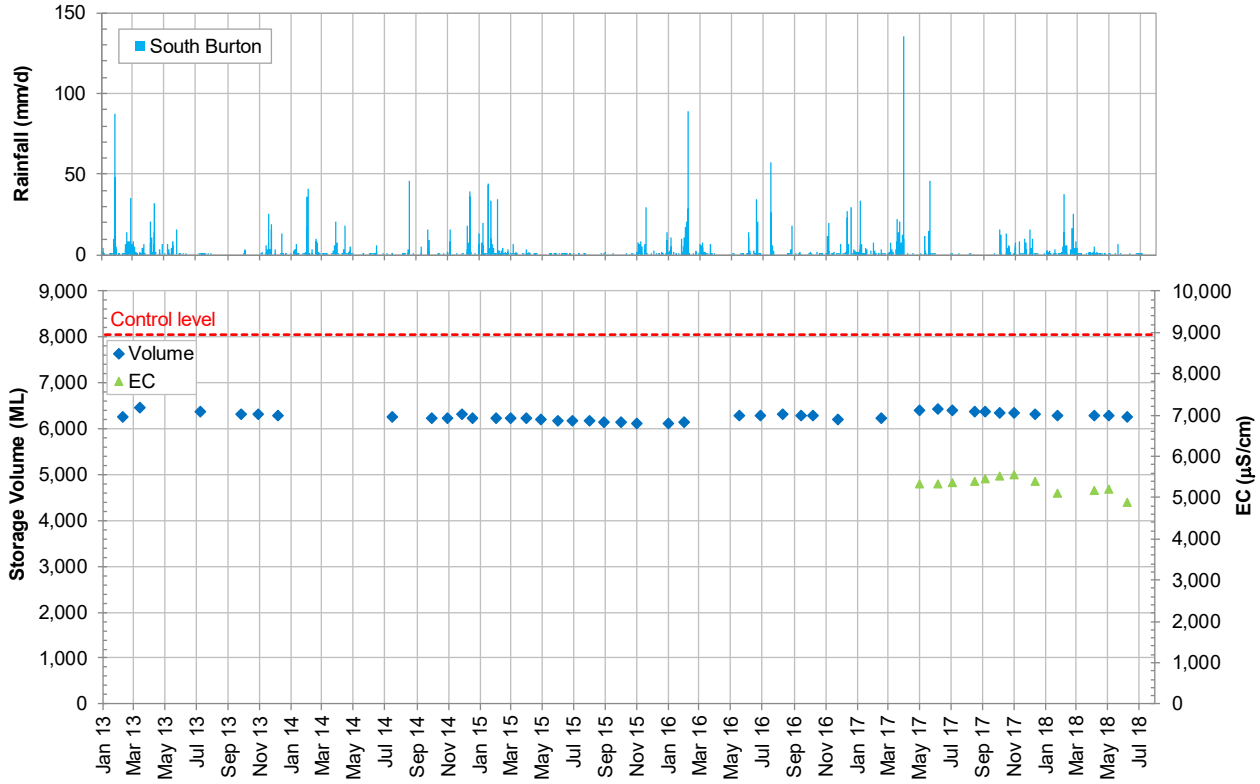

Figure 2-6: Wallanbah Pit Volume and EC

Review of Figure 2-3 to Figure 2-6 leads to the following:

- From January 2013 up until 2016/2017, BCM was operational and Broadmeadow, Bullock, Plumtree and Wallanbah Pits were actively used to store mine water from the northern end operations. As such, inventories for all four final voids have generally increased over this period. From 2016/2017 onwards, when mining ceased and BCM was under care and maintenance operation, no mine water transfers occurred between the four final voids.
- Figure 2-3: Broadmeadow Pit Volume and EC
  - Volume in the pit lake is currently just over 6,000 ML (i.e. 258.3 mRL taken on 7th June 2018).
  - From December 2013, the volume has remained around 6,000 ML with a slight increase annually.
  - EC values generally varied between 6,000 µS/cm to 7,000 µS/cm. However, the latest EC reading taken on 7th June 2018 was of 4,170 µS/cm.
- Figure 2-4: Bullock Pit Volume and EC
  - Volume in the pit lake is currently just below 3,000 ML (i.e. 302.9 mRL) with an EC of 6,550 µS/cm (taken on 7th June 2018).
  - Volume increased by approximately 1,800 ML from February 2013 to November 2014 and gradually decreased by 200 ML from November 2014 to date.
  - EC values generally varied between 6,200 µS/cm to 7,000 µS/cm.

- Figure 2-5: Plumtree Pit Volume and EC
  - Volume in the pit lake is currently just above 4,500 ML (i.e. 291.5 mRL taken on 7th June 2018).
  - Volume increased by approximately 2,100 ML from February 2013 to February 2014 and then remained relatively constant, at around 3,000 ML, from February 2014 to February 2016. Another volume increase was evident from February 2016 to May 2017. From May 2017 to date, the volume has remained relatively constant at just over 4,500 ML.
  - EC values generally varied between 6,500 µS/cm to 7,300 µS/cm expect for the latest reading on 7th June 2018 where the EC decreased to 4,890 µS/cm.
- Figure 2-6: Wallanbah Pit Volume and EC
  - Volume in the pit lake is currently around 6,200 ML (i.e. 269.4 mRL) with an EC of 4,890 □S/cm (taken on 7th June 2018).
  - From February 2013, the volume has remained around 6,000 ML with a slight seasonal variation (i.e. increase during the wet months and decrease during the dry months).
  - EC values generally varied between 4,800 µS/cm to 5,600 µS/cm.

2.4 Hydrological Inputs

2.4.1 Climate Data

As detailed in Figure 2-1, the climatic influences on the final voids include direct rainfall on the pit lake surface, catchment runoff, evaporation from the pit lakes water surfaces and evapotranspiration from their catchments. The final void WBM used long term historical climate data, spanning over 129 years, to model rainfall, evaporation and evapotranspiration within the catchments. These past climatic conditions have been assumed to be indicative of persistent local trends which are likely to be observed in the future. The possible effects of climate change have been taken into consideration and have been discussed in Section 2.4.1.4.

Consistent with the Q1 2018 final void modelling work, 129 years of daily rainfall and evaporation datasets (from January 1889 to August 2018) were obtained from the Data Drill service for the following locations:

- North Burton (21°36’ S and 148°12’E) - North of Plumtree Pit.
- South Burton (21°45’ S and 148°09’E) - South of Plumtree Pit between the Bullock and Wallanbah Pits.

A review of the Data Drill rainfall for the North and South Burton locations against BCM collected rainfall data has been undertaken as part of the 2016 care and maintenance modelling work. The review indicated that the Data Drill daily rainfall sets were consistent with the available site daily rainfall and were deemed to be well suited to modelling applications of this nature.

Through sequential repetition of the 129 year Data Drill climate datasets, long term 1,000 year datasets where established for both the North and South Burton locations. Upon review of the

locations of the sourced Data Drill datasets with respect to the final voids, the following datasets were adopted:

- Plumtree Pit - Average of the North and South Burton datasets.
- Broadmeadow, Bullock and Wallanbah Pits - South Burton dataset.

The Data Drill rainfall and evaporation datasets used for the final void WBM have been processed and summarised in the following sub sections of this report.

2.4.1.1 Rainfall

Historical Data Drill annual rainfall totals have been analysed and presented on a time series and percentile basis in Figure 2-7 and Figure 2-8, respectively.

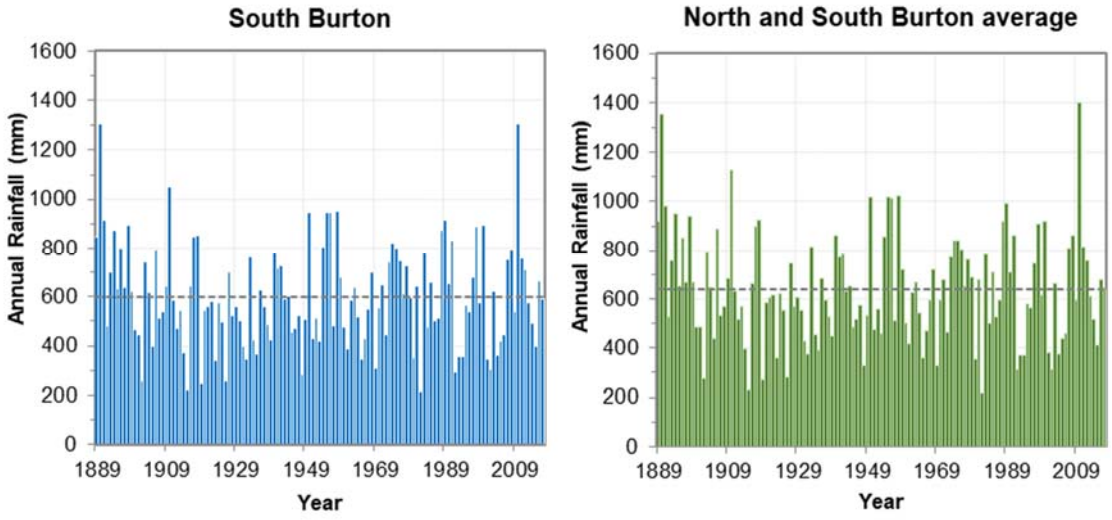

Figure 2-7: Data Drill Annual Rainfall Totals – Time Series

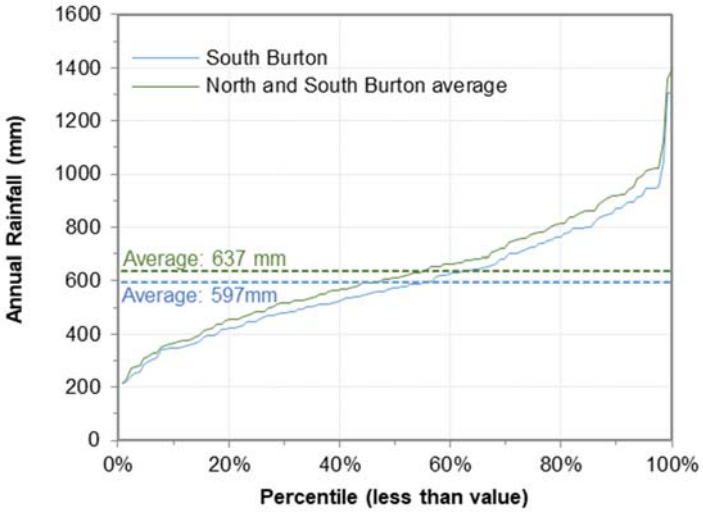

Figure 2-8: Data Drill Annual Rainfall Totals – Percentiles

Key Data Drill annual rainfall statistics have been summarised in Table 2-4.

Table 2-4: Annual Rainfall Data Drill Summary

Data Set	Annual Rainfall (mm)			
	Minimum	Average	Maximum	80% range
Average of North and South Burton	217	637	1,401	± 275 of mean
South Burton	216	597	1,305	± 260 of mean

A rainfall residual mass curve for the South Burton Data Drill dataset has been presented in Figure 2-9. The curve has been derived from the cumulative sum of the difference between each years' annual rainfall from the mean annual rainfall.

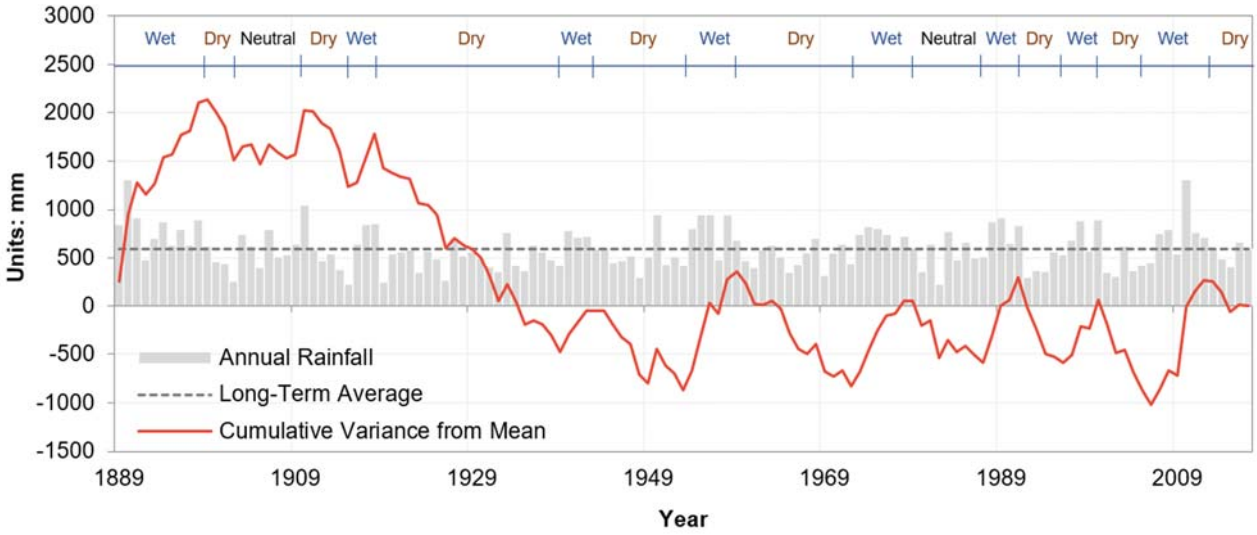

Figure 2-9: Rainfall Residual Mass Curve and Seasonality Analysis

Review of Figure 2-9 leads to the following:

- Downward trends indicated periods of drought and upward trends indicated period of persistent wet-bias (e.g. floods).
- Historical climate sequence from 1889 to 2017 features several periods of persistent flood and drought.

2.4.1.2 Evaporation

Evaporative losses have been calculated within the final void WBM based on the following evaporation data sourced from Data Drill:

- Morton lake (M_{lake}) evaporation – used as the primary data input for the final void WBM to estimate evaporation from the pit lake surface areas.
- Morton wet (M_{wet}) evaporation – used to estimate evapotranspiration losses from catchment areas. Evapotranspiration input for the final void WBM was calculated by factoring M_{lake} daily values by the average ratio of M_{lake} to M_{wet}.

Key Data Drill annual evaporation statistics have been summarised in Table 2-5.

Table 2-5: Annual Evaporation Data Drill Summary

Data Set	Annual M_{lake} Evaporation (mm)			
	Minimum	Average	Maximum	80% range
Average of North and South Burton	1,507	1,795	1,956	± 90 of mean
South Burton	1,523	1,811	1,972	± 90 of mean

Review of the Data Drill rainfall and evaporation datasets indicated that the average annual rainfall has historically been approximately a third of the average annual evaporation.

2.4.1.3 Pit Adjustment Factor

Wind shielding and shading due to the pit walls is expected to result in reduced evaporation from the pit lake surface. To account for this reduction in evaporative losses, an evaporation pit adjustment factor (i.e. pit factor) has been incorporated in the final void WBM.

The base case for the Q1 2108 final void modelling adopted a pit factor of 0.7 which was consistent with past experience with similar water balance studies for open cut coal mines in the Bowen Basin and New South Wales Hunter Valley. However, as the water level within each final void raises, the pit factor is expected to increase due to the reduced shading and wind shielding with the opposite also expected (i.e. decreased pit factor as the water level decreases). To better understand the uncertainty inherent with this parameter, the Q1 2018 final void modelling undertook a sensitivity analysis testing pit factors ± 0.1 (i.e. 0.6 and 0.8). This adopted range was consistent with ACARP Project No C7007[7] where a pit factor of 0.56 for near empty void and 0.78 for a full void where recommended.

Review of the sensitivity outcomes in the Q1 2108 final void modelling, indicated that the long term water level ranges are sensitivity to the pit factor. As such, the final void WBM has also included sensitivity cases testing pit factors of 0.6, 0.7 and 0.8. to account for the uncertainty inherent with this parameter.

2.4.1.4 Climate Change

Variation in the rainfall and evaporation resulting from global climate change are important factors to be considered during the development of final void WBM. Under the expected climate change scenario, the mean temperature of the planet is expected to rise 1.5 to 3.5 during the course of the 21st century (Devin et al. 2009). Climate projection up to 2070 in Central Queensland has been summarised in Table 2-6.

Review of Table 2-6 leads to the following:

- In 2070, the annual volume of rainfall is expected to decrease by 6 to 10 % while average temperature will rise by 1.7 to 3.2°C in Central Queensland.
- As potential evaporation is strongly linked to temperature, evaporation rate is expected to continuously increase in the long run due to the rise in global temperature.

[7] ACARP, 2001. *ACARP Project No. C7007 – Water Quality and Discharge Predictions for Final Void and Spoil Catchments.* Document 86PP081-PR001Bab Rev B (May 2002).

Table 2-6: Summary of climate projections for 2030,2050 and 2070 (CSIRO & BoM 2007)

Variable	(1971–2000)	2030	2050		2070	
		Emissions Scenarios				
	Annual Historical Mean	Medium	Low	High	Low	High
		Projected Changes				
Temperature (°C)	21.6 °C	+1	+1.2	+2	+1.7	+3.2
Rainfall (%)	692 mm	-3	-4	-7	-6	-10
Potential Evaporation (%)	1,997 mm	+3	+4	+7	+5	+10

The decreasing rainfall volume and increasing evaporation rate over time is expected to result in a reduction of the expected water level in each final void. Exclusion of the impact of climate change in the final void WBM is expected to result in a conservative estimate of the final void water level.

2.4.2 Catchment Yield

The final void WBM used the Australian Water Balance Model(ABWM) to model catchment yield. This was consistent with the Q1 2018 final void modelling and this approach is widely accepted and commonly used in Australia[8].

As detailed in Section 2.3.5, mining pit, natural and rehabilitated spoil land use classifications have been modelled as the best long-term representation of the final void catchment conditions. Runoff has been modelled using the AWBM parameter sets as defined in the Q1 2018 final void modelling report and presented in Table 2-7. The long term (LT) average catchment yield for each AWBM parameter set has also been presented in Table 2-7.

Table 2-7: AWBM Catchment Yield Parameters

Parameter Set	Partial Area			Soil Moisture Capacity (mm)			K_s	Baseflow		S_{avg}	LT Yield %
	A_1	A_2	A_3	S_1	S_2	S_3		K_b	BFI		
Mining Pit	0.134	0.433	0.433	5	15	30	0.10	-	0.00	20.2	33.1
Rehabilitated Spoil	0.134	0.433	0.433	5	55	140	0.20	0.85	0.30	85.1	16.5
Natural	0.134	0.433	0.433	20	120	180	0.10	0.70	0.35	132.6	9.7

Review of Table 2-7 confirms the higher LT yield (or runoff) for the mining pit parameter set used to model runoff from the highwalls, endwalls and ramps.

2.4.3 Salinity Generation

The final void WBM tracked the net accumulation of salt mass within each final void. Salt has been modelled as a mass and reported in terms of total dissolved solids (TDS) or EC calculated assuming a conversion factor of 0.67 (EC x 0.67 = TDS).

As detailed in Section 2.1, dissolved salts enter the final void via groundwater and catchment runoff. Salt inflows were calculated by assuming a nominal EC concentration for each inflow stream (i.e. AWBM parameter set). To select of an appropriate range of salt inflows for the

[8] Refer to 'A Hydrograph-based Model for Estimating the Water Yield of Ungauged Catchments' (Boughton, 1993) for further information.

catchment yield from each AWBM parameter set, historical void water quality sampling data, as presented Section 2.3.6, has been reviewed in conjunction with salinity generation rates adopted for the Q1 2018 final void modelling report.

Adopted salinity generation rates for the mining pit, natural and rehabilitated spoil AWBM parameters have been presented in Table 2-8.

Table 2-8: Catchment Runoff Salinity Generation

AWBM Parameter Set	Salinity Generation (µS/cm)
Mining Pit	7,500
Natural	150
Rehabilitated Spoil	300

A salinity generation rate for groundwater has also been established in review of historical bore water quality sampling data. The adopted rates vary between each final void and have been presented in Section 2.5.1 of this report.

2.5 Hydrogeological Inputs

Hydrogeological aspects of the final void WBM have been defined and modelled based on specialist advice provided by KCB senior hydrogeologists. Detailed descriptions, method and basis of the analysis have been documented in the Groundwater Interaction Study presented in Appendix III.

Relevant information, as it pertains to the final void WBM, has been summarised in the following sub sections of this report.

2.5.1 Groundwater Inflows

As detailed above, a groundwater interaction assessment has been undertaken as part of this current final void hydrology study with details presented in Appendix III. A 2D groundwater model has been established for the four final voids based on the following assumptions/parameters:

- Voids have been assumed to act as long term sinks, that is, water accumulating in the voids would not seep to the surrounding strata. This results in conservative estimates of both void water level and salinity as only water losses from evaporation have been considered and there is no means for salt to be removed from the system.
- Site geological data provided by Peabody.
- Material properties for each geological unit have been derived from review of relevant publicly available documentation.
- Highest groundwater level based on Peabody provided historical water level data from the monitoring bores surrounding each final void.

Resulting groundwater inflows have been presented in Table 2-9.

Table 2-9: Groundwater Inflows and Salinities

Final Void	Groundwater Inflows (L/s)		Median EC (µS/cm)	Monitoring Bores
	Min	Max		
Broadmeadow Pit	1.1	8.6	14,180	BDW172(32), BDW172(54), BDW366P, BDW367P*, BDW5C and BDW8C
Bullock Pit	0.7	2.9	16,790	LBP 5 Upper and LBP 5 Seam
Plumtree Pit	0.2	5.7	19,925	BD1252P, BD1253P and BD1254P
Wallanbah Pit	0	4.6	5,445	BDW368P and BDW46*

Note: '* BDW367P and BDW46 are not EA compliance bores and are not currently monitored.

Review of Table 2-9 leads to the following:

- Groundwater inflows have been predicted in all four final voids.
- Minimum predicted groundwater inflow rates ranged from 0 L/s to 1.1 L/s per pit.
- Maximum predicted groundwater inflow rates ranged from 2.9 L/s up to 8.6 L/s per pit.
- Groundwater inflow EC values ranged from 5,445 µS/cm and 19,925 µS/cm and have been based on Peabody provided historical water quality data from the monitoring bores surrounding each final void.

In review of the Q1 2018 final void modelling and the 2016 care and maintenance WBM, groundwater inflows were not modelled and were assumed to be minimal. This was generally consistent with site based knowledge. However, as presented in Table 2-9, the current groundwater interaction assessment was identified potential groundwater inflows. To encompass the possible variability in the groundwater inflow, the final void WBM has included sensitivity cases testing zero and maximum groundwater inflows for all four final voids.

2.5.2 Spoil Aquifer Storage

As detailed in Figure 2-1 along with the cross sections in the final void data sheets (refer to Appendix II), all four final voids have been backfilled with spoil. To estimate spoil volumes within each final void, the deepest mined topography was compared against the final landform design topography to establish a level – volume relationship for the spoil. Water stored within the spoil volume (i.e. spoil aquifers) has been modelled with an assumed 20% spoil porosity.

Final void WBM has included sensitivity cases testing spoil porosities of ±5% (i.e. 25% and 15%).

2.5.3 Hydraulic Connectivity

The final void WBM has not included allowance for any connectivity between the final voids. However, final void water levels estimated as part of this study have been reviewed by KCB to identify areas where potential for such hydraulic connectivity may exist through weathered or tertiary layers. Outcomes of the review have been presented in the Groundwater Interaction Study (refer to Appendix III) and have been summarised in Section 4 of this report.

There are two visible pit lakes within Broadmeadow Pit with spoil material dumped between the two pit lakes. Saturated spoils are assumed to function as a continuous porous median aquifer and water is assumed to equalise between the two pit lakes final voids via spoil aquifer connections. Given the water level within both these pit lakes are currently at similar water levels, modelling has assumed the sub-surface balancing flows between the pit lakes occur at an

unrestricted rate. As such, both pit lakes within Broadmeadow Pit have been modelled to rise and fall together due to the existing cross connection through the intervening spoil material.

2.5.4 Seepage to Environment

The final void WBM has not included allowance for any seepage losses from any of the final voids to the receiving environment. Final void water levels estimated as part of this study have been reviewed by KCB to identify areas where potential for such seepage may exist through weathered or tertiary layers. Outcomes of the review have been presented in the Groundwater Interaction Study (refer to Appendix III) and have been summarised in Section 4 of this report.

2.6 Initial Conditions

The initial conditions adopted for the final void WBM have been presented in Table 2-10 and have been based upon the latest measured water level and EC values as provided by Peabody.

Table 2-10: Adopted Initial Conditions

Final Void	Water Level (mRL)	EC (µS/cm)
Broadmeadow Pit	258.35	4,170
Bullock Pit	302.95	6,550
Plumtree Pit	291.54	4,890
Wallanbah Pit	269.38	4,890

The final void WBM has been configured to simulate water accumulations from the initial or current water levels within each of the four final voids. This initial water level has been assumed to be equal between the pit lake and associated spoil aquifer.

As detailed in Section 2.3.6, water and EC levels have generally remained stable over the past few years in each final void. As such, sensitivity with the initial starting water and EC levels has not been considered as part of the final void WBM. The starting conditions will not have an impact on the long term equilibrium water level ranges. However, filling timeframes will be influenced, as will water quality results to an extent. Sensitivity analysis regarding initial salinities should be undertaken as part of future studies in the final voids where the water quality results are critical.

3 MODELLING OUTCOMES

As detailed in Section 1, the primary focus of this final void study has been the fluctuation of water levels within the pit lakes to determine the potential risk of the voids filling and releasing water. As such, the assessment has been undertaken using a daily time step to estimate the following:

- Time taken to reach equilibrium within the pit lakes.
- Water level within the pit lakes once equilibrium conditions have been reached.

As detailed in Section 2.3.5, to account for the expected change in catchment yield over time, water levels for both the natural and rehabilitated cases have been presented. This has resulted in water level range which has been presented as an envelope encompassing the maximum rehabilitated and minimum natural modelled water levels.

The secondary focus of the final void study has been the fluctuation of salinity, assessed as EC, within the pit lakes. Climate driven fluctuations of salinity of the bulk water volume have been estimated for the period when equilibrium pit lake water levels have been reached. An EC range has been established using the total salt mass in each final void along with the long term maximum and minimum volumes (i.e. envelope extents) in each void.

While an EC range of the water within the pit lakes has been estimated, it is acknowledged and highlighted that estimates do not allow for the following:

- Reduced generation rates over time as salts are leached from the spoil material and the existence of preferential flow paths for infiltration through the spoil material.
- Detailed assessment of the fluctuation of salinity with depth (i.e. stratification, wind mixing, temperature gradients have not been accounted for).
- Any loss of salt mass from the voids via potential seepage into the surrounding aquifers.

This has resulted in an accumulation of salt over time. As such, an indication of the possible EC range has been provided for the period when the equilibrium void water level is reached. EC values should be used as a guide only to indicate the upper limit if EC within the voids.

Currently, levees are in place to provide flood immunity to the final voids and as such, flood ingress from adjacent waterways has not been considered as part of this final void study.

For each final void, modelled final void water level fluctuations and associated envelopes have been summarised in flowing sub-sections of this report and have been presented in the final void data sheets in Appendix II. Key levels such as base of pit, control level and nominal natural ground and/or spoil crest levels have also been presented in the final void data sheets.

For each final void, predicted equilibrium EC ranges have also been summarised in the following sub-sections of this report.

3.1 Broadmeadow Pit

Review of the final void water levels for Broadmeadow Pit (refer to Appendix II) leads to the following:

- Water level within Broadmeadow Pit is expected to decrease for the next 50 years and reaches equilibrium after around 80 years. The reduction in water level is due to the reduced catchment area with the final landform design.
- Once equilibrium conditions are reached:
  - Expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 249 mRL and 228 mRL, respectively.
  - Expected water level fluctuations are below the original natural ground level / nominal spoil crest level and the control level. As such, release of water via surface or sub-surface overflow is not predicted.

Although not shown in the final void data sheet, once equilibrium conditions are reached (i.e. after 80 years), the EC level fluctuates with seasonal variance and ranges from:

- 6,740 µS/cm after prolonged periods of above average wet conditions
- 16,190 µS/cm after prolonged dry periods.

3.2 Bullock Pit

Review of the final void water levels for Bullock Pit (refer to Appendix II) I leads to the following:

- Water level within Bullock Pit is expected to decrease for the next 50 years and reaches equilibrium after around 80 years. The reduction in water level is due to the reduced catchment area with the final landform designed to direct surface runoff of nearby rehabilitated spoil dumps away from the void and no additional mine water being transferred into the pit.
- Once equilibrium conditions are reached:
  - Expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 290 mRL and 271 mRL, respectively.
  - Expected water level fluctuations are below the original natural ground level / nominal spoil crest level and the control level. As such, release of water via surface or sub-surface overflow is not predicted.

Although not shown in the final void data sheet, once equilibrium conditions are reached (i.e. after 80 years), the EC level fluctuates with seasonal variance and ranges from:

- 16,430 µS/cm after prolonged periods of above average wet conditions
- 61,850 µS/cm after prolonged dry periods.

The high EC ranges relate to the lower volume of water expected to be retained within Bullock Pit (i.e. ranging from around 1,600 ML to 500 ML of free water) in comparison with the three other final voids.

3.3 Plumtree Pit

Review of the final void water levels for Plumtree Pit (refer to Appendix II) leads to the following:

- Water level within Plumtree Pit is expected to increase until it reaches equilibrium after around 80 years. The increase in water level is largely due to the geometry of the final landform. As detailed in the final void data sheet, up to a level of around 309 mRL the final void is relatively narrow. From 309 mRL upwards, the surface area increases significantly and allows the balance of inflows and outflows to be achieved.
- Once equilibrium conditions are reached:
  - Expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 306 mRL and 277 mRL, respectively.
  - Expected water level fluctuations are below the original natural ground level and spoil crest level. As such, release of water via surface overflow is not predicted.
  - Expected water level fluctuations are above the control. As such, there is potential for water to seep through the weathered or tertiary layers. This potential seepage is expected to be limited to the northern eastern end of the pit where the Quaternary deposits are evident. This has been discussed further in Appendix III.

Although not shown in the final void data sheet, once equilibrium conditions are reached (i.e. after 80 years), the EC level fluctuates with seasonal variance and ranges from:

- 4,570 µS/cm after prolonged periods of above average wet conditions
- 11,670 µS/cm after prolonged dry periods.

3.4 Wallanbah Pit

Review of final void water levels for Wallanbah Pit (refer to Appendix II) leads to the following:

- Water level within Wallanbah Pit already appears to be very close to reaching equilibrium and is expected to remain relatively stable.
- Once equilibrium conditions are reached:
  - Expected water level will fluctuate with seasonal variance within an envelope defined with maximum and minimum water levels estimated at 274 mRL and 254 mRL, respectively.
  - Expected water level fluctuations are below the original natural ground level / nominal spoil crest level and control level. As such, release of water via surface or sub-surface overflow is not predicted.
  - Expected water level fluctuations are above the base of weathered material in the southern side of the pit. Release of water may occur through the spoil and weathered

rock / Quaternary deposits with flow directed towards the south and Broadmeadow Pit. Further information regarding the base of the alluvial deposits would enable the potential risk to be further evaluated. This has been discussed further in Appendix III.

Although not shown in the final void data sheet, once equilibrium conditions are reached, the EC level fluctuates with seasonal variance. As the point of equilibrium is not as easily defined for Wallanbah Pit, EC ranges have been developed at 30, 50 and 80 years as detailed in Table 3-1.

Table 3-1: EC Range - Wallanbah Pit

Time to Equilibrium (years)	EC (µS/cm)	
	Wet Periods	Dry Periods
30	4,300	10,570
50	4,370	10,730
80	4,590	11,280

3.5 Ecology

From a regional context, BCM is located in a zone of Australia that experiences extended periods of wet and dry, that may last in one cycle for years to decades. The region is characterized by having ephemeral watercourses (i.e. only experience flows for short periods following rainfall) and limited naturally occurring permanent water bodies. In response to these conditions, the ecology of the region has developed the ability to establish opportunistic populations that are salt-tolerant and thrive under a cycle of boom and bust conditions. As such, the pit lakes do represent a novel habitat in an area characterised by ephemeral creek systems and floodplains.

GAUGE has prepared a high level discussion on the capability of the BCM final voids to support flora and fauna. A copy of the discussion has been presented in Appendix IV, with the key outcomes of the discussion presented below:

- The pit lakes are likely to support opportunistic native flora and fauna species that are able to relatively quickly respond to changes in salinity, including fish, invertebrates, macrophytes, algae, amphibians, fringing vegetation and birdlife. The diversity within the aquatic community will be limited to those species with at least moderate salt tolerance.
- The variety of species and the number of individuals present will be cyclical in nature (i.e. species may rapidly colonise during wetter years (fresher waters) but for the most part will eventually perish during drier years in a cycle of boom and bust that is analogous to the surrounding ephemeral systems).
- Inclusions of key features such as significant areas of shallow, littoral zones, a stable and vegetated riparian zone, water plants in the littoral zone, submerged and emergent structures (i.e. logs, mounds, shelves, islands) and access to periodic fresh water inputs (where practical) are expected to enhance the aquatic habitat.

4 SENSITIVITY ANALYSIS

Sensitivity analysis has been undertaken as part of this final void study to better understand the uncertainty of several key final void WBM parameters and inputs and to quantify the impact on the expected water level fluctuations. The sensitivity analysis undertaken have been summarized in Table 4-1.

Table 4-1: Sensitivity Cases

Parameter / Input	Base Case	Sensitivity Case
Catchment Yield	▪ Natural (plus mining pit)	▪ Rehabilitated (plus existing natural and mining pit)
Spoil Porosity	▪ 20%	▪ 15% ▪ 25%
Pit Factor	▪ 0.7	▪ 0.6 ▪ 0.8
Groundwater	▪ 0 L/s	▪ Maximum inflows are detailed in Table 2-9.
Climate Data (Plumtree Pit ONLY)	▪ Average of North and South Burton	▪ South Burton

Review of Table 4-1 leads to the following:

- Base case for each final void has been modelled as a natural catchment yield (except for the mining pit), 20% spoil porosity, 0.7 pit factor and no groundwater inflow.
- Sensitivity to climate data has only been assessed for Plumtree Pit due to its proximity to the South Burton data drill location.

For each final void, modelled final void water level fluctuations have been summarised below and presented in the final void data sheets in Appendix II. For each sensitivity case, the results have been compressed into a single column of data with a range once equilibrium has been reached. This provides a graphical presentation of the uncertainty range associated with each key parameter change.

Review of the sensitivity cases for all four final voids (refer to Appendix II) leads to the following:

- Simulated final void water level ranges are below the maximum capacity of the Broadmeadow, Bullock, Plumtree and Wallanbah Pits final voids (i.e. below the original natural ground level and nominal spoil crest level).
- Simulated final void water level ranges are below the control level for Broadmeadow, Bullock and Wallanbah Pits final voids. However, maximum water levels for Plumtree Pit for the rehabilitated, 0.6 pit factor and maximum groundwater cases were above the control level.
- Simulated final void water level are relatively insensitive to changes in assumed spoil aquifer porosity or volume of water contained within the spoil aquifer.
- Simulated final void water levels are sensitive to changes in:

- Catchment yield with the natural case producing slightly less runoff and as such, lower water levels than the natural case.
- Pit evaporation reduction factor with lowering the pit factor reducing the evaporation and as such, producing higher water levels.
- Groundwater inflows with the higher groundwater inflows producing higher water levels.

- Adopted water level envelopes encompassed the majority of variability with all maximum expected water levels within the envelope except for the groundwater sensitivity case for Broadmeadow, Plumtree and Bullock Pits.

Sensitivity cases have also been modelled to simulate the impact of parameter changes to produce pronounced dry and wet conditions. Under worst case dry conditions, pit lakes were not predicted to completely dry out during drought periods and under worst case wet conditions there were still no predicted instances of voids overflowing.

5 CONCLUSIONS AND DISCUSSIONS

The BCM final void study has been undertaken in accordance with the scope of work outlined in KCB proposal PR18D02-65 (dated 13th June 2018). This report documents aspects of the study relating to surface and groundwater including:

- Review of topographic data to define physical characteristics of the proposed final landform design including topography, drainage, catchment areas and level – surface area – volume characteristics associated with the final voids.
- Definition of hydrological characteristics of the BCM site (i.e. rainfall, evaporation and catchment yield etc.) based on review of available reports and data.
- Definition of hydrogeological characteristics of the BCM site (i.e. groundwater interactions and associated inflow rates and spoil aquifer storages) based on review of available reports and data.
- Development of a final void WBM.
- Predictive modelling to estimate hydrological characteristics of final voids.

Key outcomes of the final void study include:

- Four final voids within Broadmeadow, Bullock, Plumtree and Wallanbah Pits are proposed to remain as part of the final landform and are expected to maintain permanent pit lakes.
- Water levels within the final voids are expected to reach equilibrium in approximately 80 years time. However, equilibrium may be reached sooner in Wallanbah Pit.
- Once equilibrium has been reached, the pit lakes within the final voids are expected to fluctuate around a steady-state equilibrium level in response to periods of flood and drought. No voids are expected to reach levels that would result in overflow into downstream watercourse via surface pathway (i.e. no water levels above the original natural ground level and spoil crest level).
- Equilibrium water levels within Broadmeadow and Bullock Pits are expected to remain below the control level and the base of weathered material. Accordingly, no flow from the final voids is expected via sub-surface pathways. However, equilibrium water levels within Plumtree and Wallanbah Pits have the potential to rise above either the control level and/or the base of weathered material as follows:
  - Plumtree Pit has the potential to rise above the control level 300 mRL which coincides with the base of Quaternary layer in the north eastern end of the pit. If the water level rises above the control level, there is potential for sub-surface flow out of the void to occur. A more detailed understanding of the base of the Quaternary deposits associated with Sandy Creek would enable any seepage potential to be further evaluated.
  - Wallanbah Pit has the potential to rise above the base of weathered material on the southern side of the pit. If water levels rise above the base of weathered material, there is potential for sub-surface flow through the spoil and out of the void to occur. As with Plumtree Pit, a more detailed understanding of the base of weathered material would enable any seepage potential to be further evaluated.

- Fluctuations in the pit lake water quality (i.e. EC levels) will continue to occur and be driven by climatic variability as cycles of above and below average rainfall result in rapid water quality fluctuations (i.e. timeframe of years to tens of years) when compared with long term trends of gradual accumulation metals and metalloids (i.e. timeframes of hundreds of years).
- Sensitivity analysis has been undertaken to determine how final void hydrological characteristics vary in response to changes in model parameters. Changes to parameters in isolation generally produced water level ranges that fell within the range of results predicted by the base case envelope (which was designed to include some variability in selected parameters) and were below the overflow levels.
- Net effects of climate change are expected to increase the annual evaporation and reduce the annual rainfall totals in fewer more intense rainfall events (refer Section 2.4.1.4). As the pit lake assessment is primarily focused on establishing the maximum water level, climate change impacts have not been modelled as part of this final void study. This approach will result in a conservative estimate of the pit lake water levels.
- All the pit lakes within the four final voids are expected to provide a relatively stable habitat in an area characterised by ephemeral creek systems and floodplains. The pit lakes should support opportunistic species that are able to respond relatively quickly to changes in salinity, however these species are likely to exist in a cycle of boom or bust that is analogous to the surrounding ephemeral systems. Key improvements such as significant areas of shallow, littoral zones, a stable and vegetated riparian zone, the presence of water plants in the littoral zone, the presence of diverse aquatic structures and access to periodic fresh water inputs (where practical) are expected to enhance the aquatic habitat.

It is recommended that Peabody personnel thoroughly review the content of this report and seek clarification from KCB as required.

6 CLOSING

This report is an instrument of service of KCB. The report has been prepared for the exclusive use of Peabody for the specific application to the Burton Coal Mine – Final Void Hydrology Study project. The report's contents may not be relied upon by any other party without the express written permission of KCB. In this report, KCB has endeavoured to comply with generally-accepted professional practice common to the local area. KCB makes no warranty, express or implied.

Please contact the undersigned if you have any queries or require further assistance.

Yours truly,

KLOHN CRIPPEN BERGER LTD.



Kirsty Bethune
Senior Water Resources Engineer

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SILO Data Drill service hosted by the State of Queensland (Department of Science, Information Technology and Innovation), https://www.longpaddock.qld.gov.au/silo/datadrill/

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APPENDIX I

Project Data

Type	Item (reference / filename)	Description
Aerial	Burton_Dec2017_1m_20171231_AMG84.ecw	▪ BCM aerial photography. ▪ Projection in file AGD 84 AMG Zone 55. ▪ Assumed current as at December 2017.
Catchment Delineation	20180904 Broadmeadow Catchment.pdf	▪ Derived from final landforms design topography.
	20180904 Bullock Creek Catchment.pdf	
	20180904 Wallanbah Catchment.pdf	
	All Catchments AMG55.dwg	

Climate Data	Data Drill long term climate data	▪ Daily rainfall and evaporation data sourced from the online SILO Data Drill database (Data Drill) for the following locations:
		  ▪ North Burton (21° 36' S; 148° 12' E)
		  ▪ South Burton (21°45' S; 148°09' E)
		▪ Data was downloaded from 1 January 1889 to 29 August 2018.

Geological Data	Bullock Ck soils_2009.doc	▪ Soils and Land Suitability Bullock Creek Area report (2009) by GT Environmental Services.
	Burton Widening Plumtree South 2010_soils_01.doc	▪ Soils and Land Suitability Burton Widening and Plumtree South Developments report (2010) by GT Environmental Services.
	Burton Coal Mine Long Section.pdf	▪ Coal seam schematic.
	Burtons downs land suitability assessmeny.pdf	▪ Burton Downs Land Suitability Assessment report (1993) by Woodward Clyde.
	Burton downs overburden dispersion assessment.pdf	▪ Burton Downs Coal Project Overburden Dispersion Studies (1993) by Woodward Clyde.
	Overburden Characterisation Summary page 1.pdf	▪ Pages from Broadmeadow Geological Information Package.
	Summary of Overburden Characterisation Testing Page 2	
	Summary_of_Drillhole_Data_ 146'1'35 Appendices ii.pdf	▪ Summary of drill hole and seam intersection data.
	plm_section_01_ns, 01_we and 02_ns.jpg	▪ Plumtree Void cross sections.
	wlb_section_01_ns, 01_we, 02_ns, 03_ns and 04_ns.jpg	▪ Wallanbah and Broadmeadow Void cross sections.
	Wallanbah Geotech Sections 171128.pdf	▪ Wallanbah Geotech cross sections.
	Wallanbah Geotech Sections 171212.pdf	
	base_of_tertiary.00t and BASE OF TERTIARY.tif	▪ Base of tertiary layer for Wallanbah Pit.
	base_of_weathering.00t and BASE OF WEATHERING.tif	▪ Base of weathering layer for Wallanbah Pit.
	plumtree_bullock_bow.csv	▪ Base of weathering layer.
	broadmeadow_bow.csv	
	Wallanbah Geotech Sections 180703.pdf	▪ Wallanbah geotechnical cross sections.
	Wallanbah North Sections.pdf	
	Wallanbah North Section Locations.pdf	
Metered Data	Bore Plan Appendix D for BD613, BD1247P - BD1253P, BDW5C, BDW8C, BDW46, BDW366W and BDW368P.	▪ Schematic diagram of piezometric bore.
	Bore_Log_146'1'35 Appendices	▪ Graphic sections of bores.
	Bore_Log_BD1247-BDW368P_146'1'35 Appendices	
Ne	Dam Level.msg	

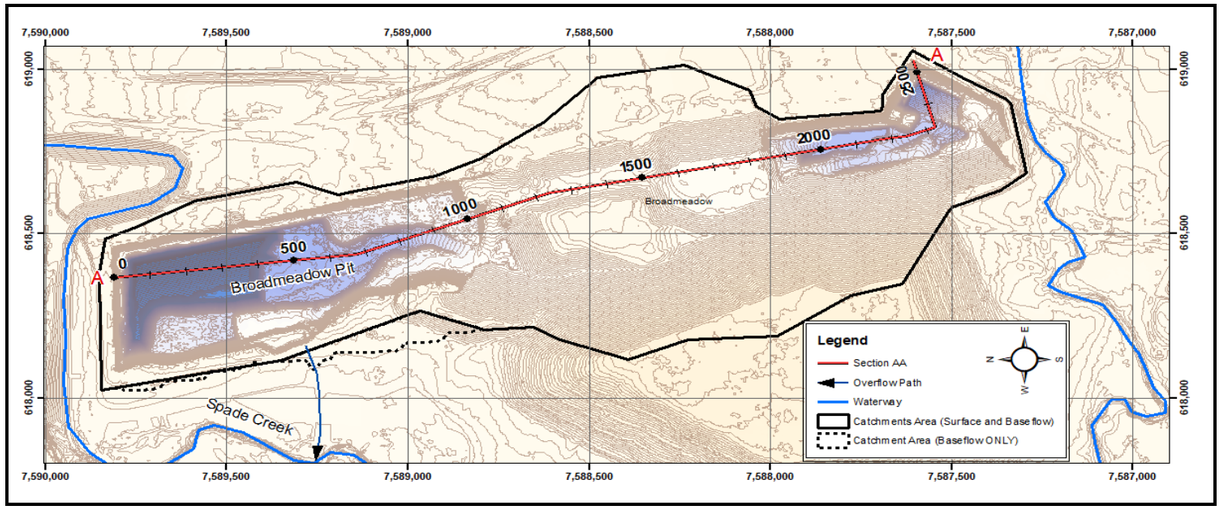
Type	Item (reference / filename)	Description
	170412 to 180712 Water Levels and Sampling_June 2017.xlsx	▪ Pit water levels and water quality data from April 2012 to July 2018.
	Master Bore Data.xlsx	▪ Bore water level and water quality data. ▪ Varied time frames from 2006 up to 2013.
	20160225 to 20180510 Burton G. W monitoring.xlsm	
	G W monitoring Feb 2016.msg	
	140225 to 160225 EDD_in_Situ_Burton_151208.xlsm	
	May 2013 to October 2013 results.xlsx	
	362_Analytical Results (Extra Fields)_201809100003627.xlsx	
Reports	H355622-00000-228-230-0001_0_v2.pdf	▪ Q1 2018 Final Void Modelling report by Hatch.
	REP_BUR_C&M Water Modelling_v2_ENV_HATCH_160829.pdf	▪ 2016 Care and Maintenance Water Balance Modelling report by Hatch.
	JBT01-063-0001-Groundwater Data Assessment.pdf	▪ Review and Assessment of the Groundwater Monitoring Network and Data for Burton Coal Mine report (2016) by JBT.
	Bullock Creek Eastern Highwall - Geotech Summary.pdf	▪ Bullock Pit geotechnical reports.
	Bullock_Ck_Final_Void_Gtch_Rprt_v0.1.pdf	
	Voids Stability Assessment - Bullock Void.pdf	
	Pit Summaries.docx	▪ Timeline of mining within pits.
Topographic Data	Burton_Central-North_LiDAR_2017-124_AMG84.xyz	▪ LiDAR topographic data. ▪ Assumed current as at January 2017.
	Burton_Central-South_LiDAR_20170124_AMG84.xyz	
	170505_plumtree_mined_out_pitshell.dxf	▪ Deepest mined surface data.
	171012_wallanbah_void.dxf	
	Broadmeadow_void.dxf	
	pit_bc.dxf	
	WALLANBAH 4M END OF MINING.xyz	
	WALLANBAH 4M GRADED LOW WALL.xyz	
	WALLANBAH 4M PIT FLOOR MINED.xyz	
	Plumtree and Bullock Creek.tif	▪ Final landform surface data.
	Wallanbah and Broadmeadow.tif	

APPENDIX II

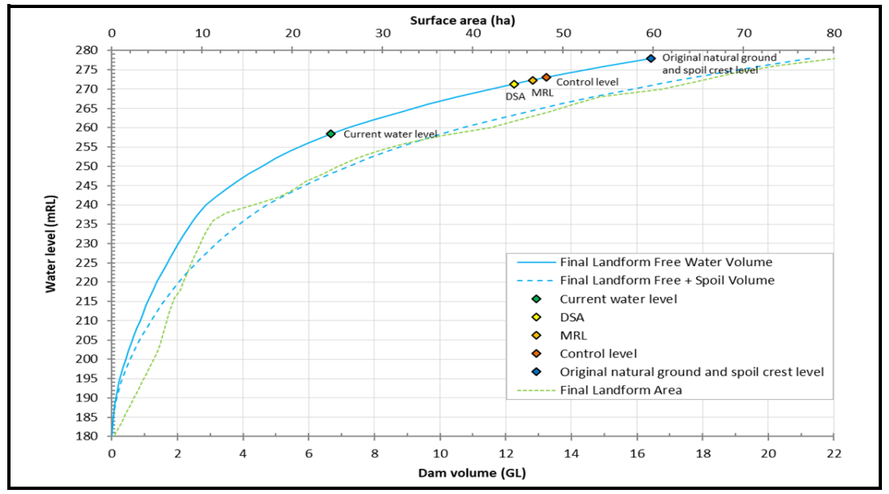
Final Void Data Sheets

Broadmeadow, Bullock, Plumtree and Wallanbah Pits

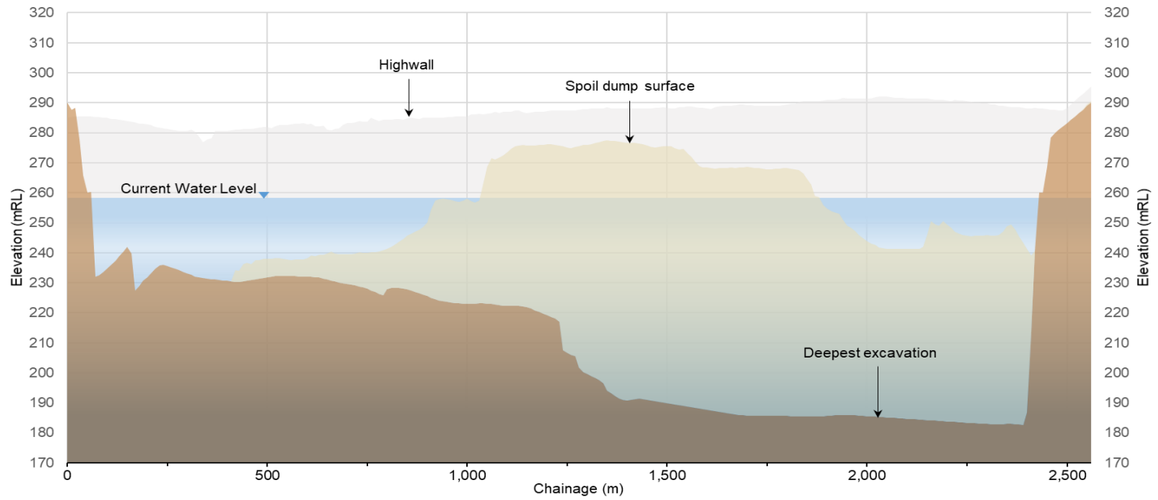
Locality and Catchment Plan



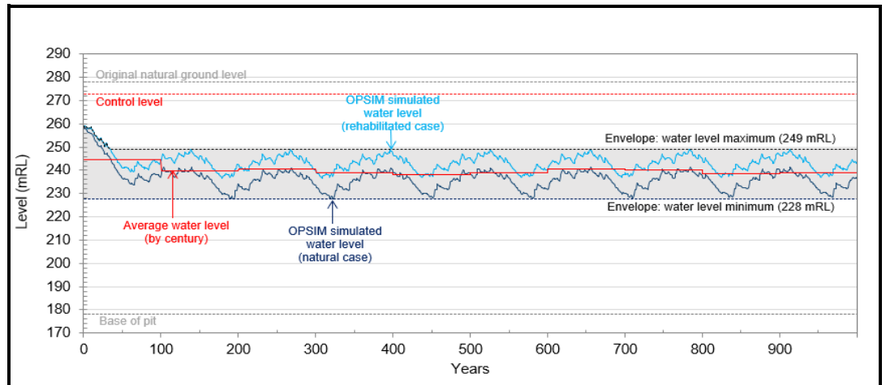
Stage Storage Curve



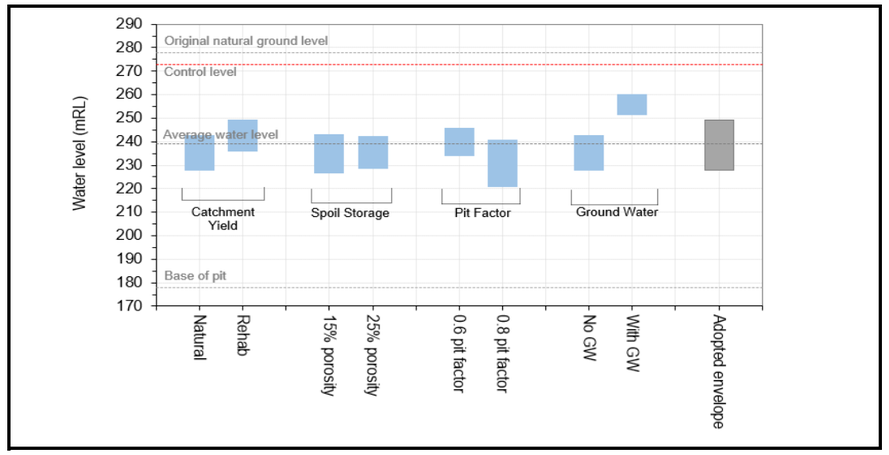
Cross Section AA



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section AA and Stage Storage Curve

Current Broadmeadow Pit final void comprises two visible pit lakes with a spoil dump located between both lakes (i.e. chainage 1,000 to 1,850 m).
The original natural ground level has nominal elevations ranging from 180 to 230 mRL with the spoil crest level raised to an elevation of 280 mRL.
The water surface of the two pit lakes would join above 277 mRL.
Currently, both pit lakes are at the same water level indicating the strong connection between the two pits through the spoil material. As such, the two pit lakes have been configured to rise and fall together due to the cross connection through the intervening spoil material.
The lowest elevation at which surface water would overflow from Broadmeadow Pit void is nominally at 278 mRL (i.e. low wall low point). Flows would drain west towards Spade Creek.
Highwall areas are shown in grey tones are not located on Section AA, but would be visible from Section AA if looking towards the east.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.

Catchment Area (ha)	**146**	(Surface + baseflow)
	3	(Baseflow only)
Base of Mining (mRL)	**178.0**	
Control Level (mRL)	**273.0**	(Nominal 5 m below pit crest level)
Current Water Level (mRL)	**258.35**	(within both pits)

Time to Equilibrium	**80**
Maximum Water Level (mRL)	**249**
Minimum Water Level (mRL)	**228**
Average Water Level (mRL)	**239**

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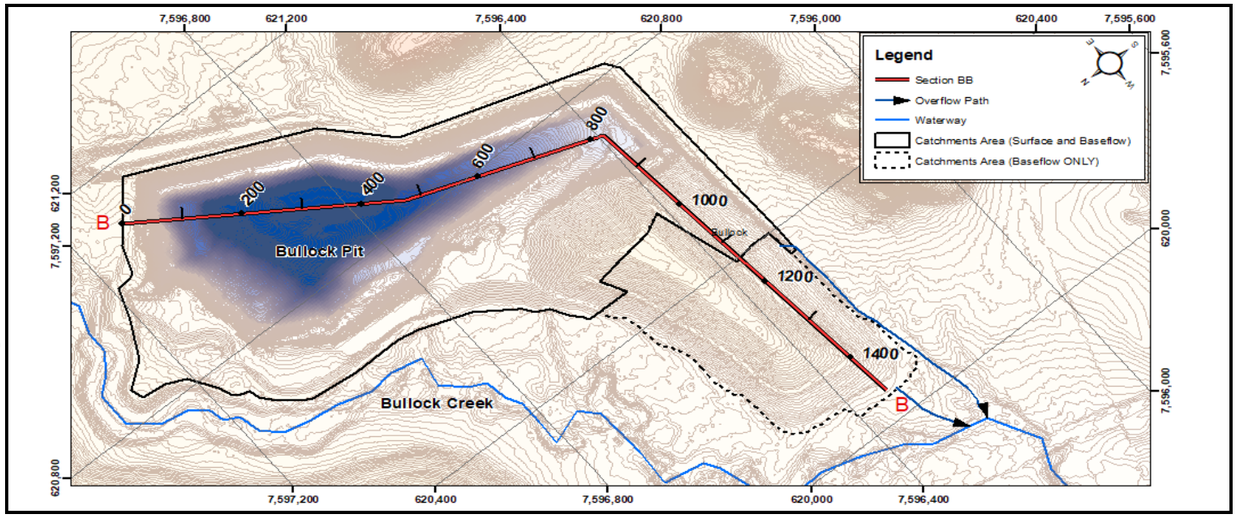
CLIENT: Peabody ENERGY; Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

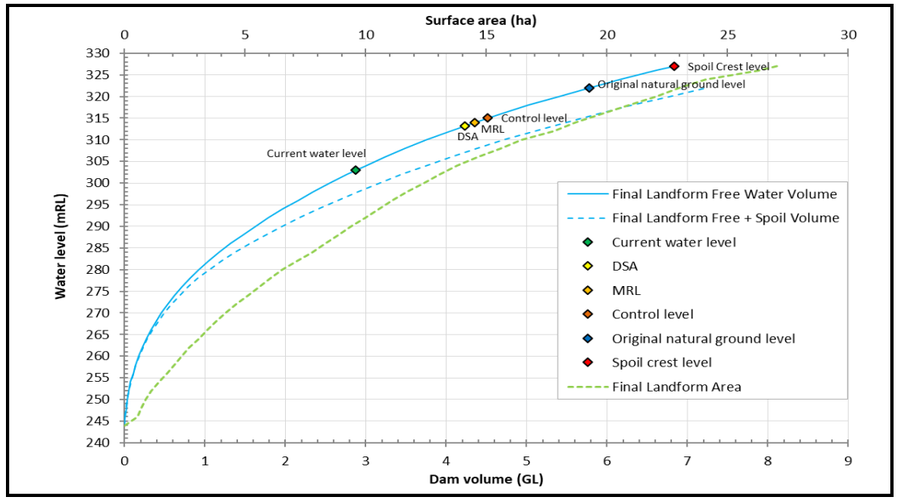
TITLE: FINAL VOID DATA SHEETS
BROADMEADOW PIT

PROJECT No. D10242A01

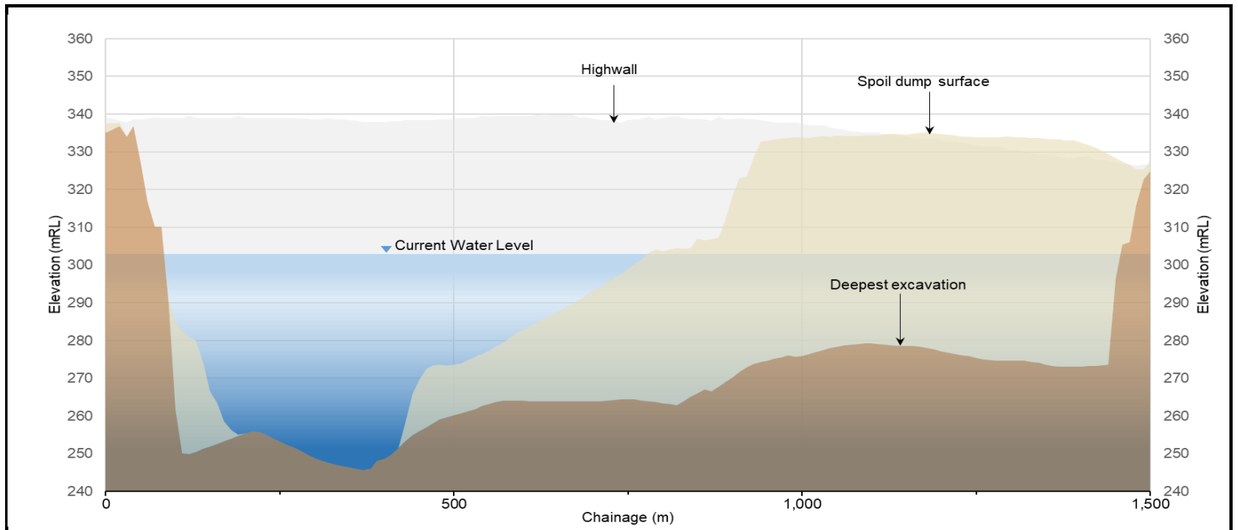
Locality and Catchment Plan



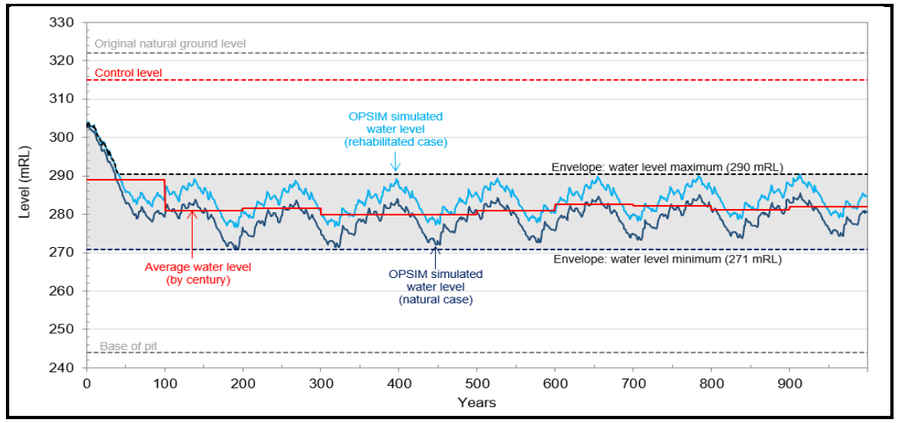
Stage Storage Curve



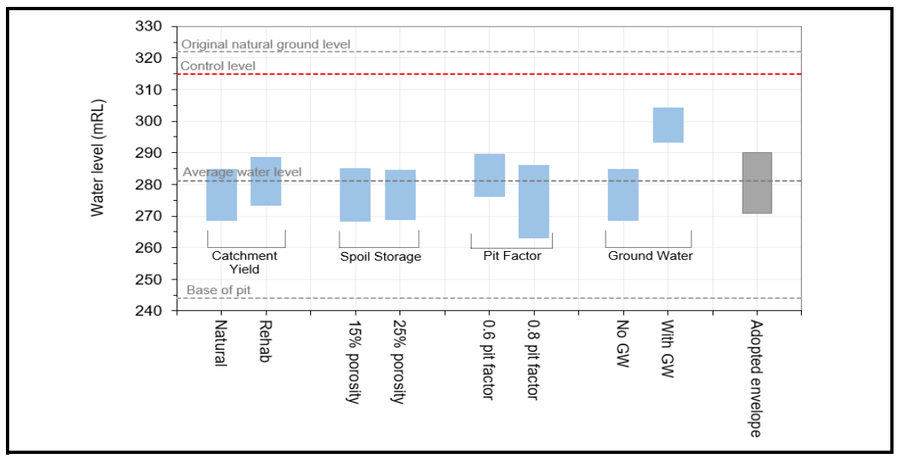
Cross Section BB



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section BB and Stage Storage Curve

Bullock Pit extends in a north-south direction from chainage 0 to 820 m and then extends to the west from chainage 820m to 1485m.
The lowest elevation at which water would overflow from Bullock Pit void is nominally at 322 mRL.
At 322 mRL, water would overflow from two locations towards Bullock Creek.
Highwall areas are shown in grey tones are not located on Section CC. The highwall is visible from Section CC if looking towards the east from chainage 0 m to 820 m and to the south from chainage 820 m to 1485 m.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.

Catchment Area (ha)	**39**	(Surface + baseflow)
	11	(Baseflow only)
Base of Mining (mRL)	**244.0**	
Control Level (mRL)	**315.0**	(Geotechnical advise)
Current Water Level (mRL)	**302.95**	

Time to Equilibrium	**80**
Maximum Water Level (mRL)	**290**
Minimum Water Level (mRL)	**271**
Average Water Level (mRL)	**281**

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CLIENT: Peabody ENERGY

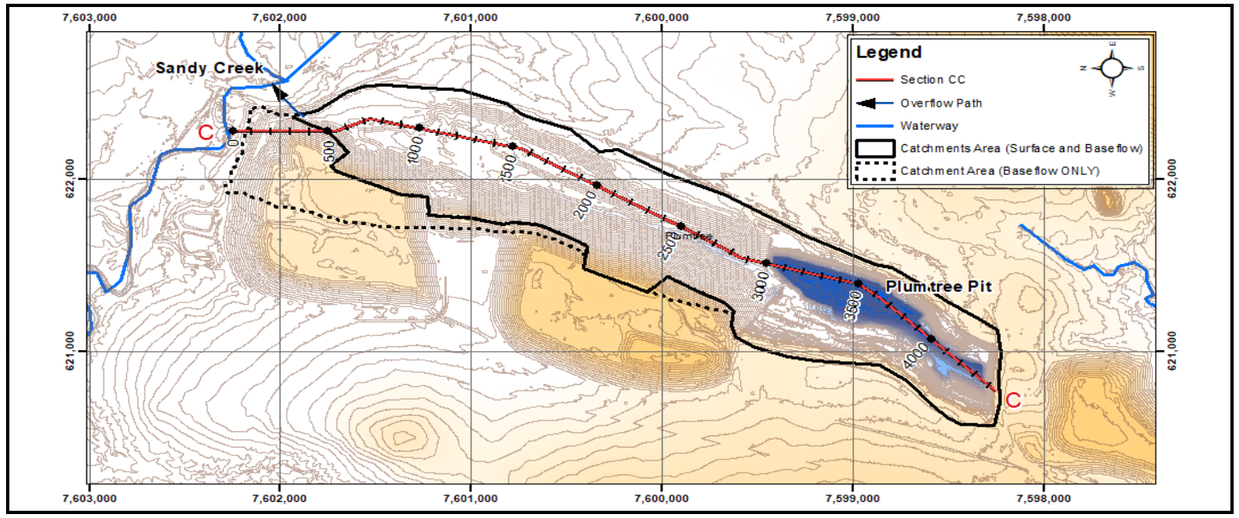
Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

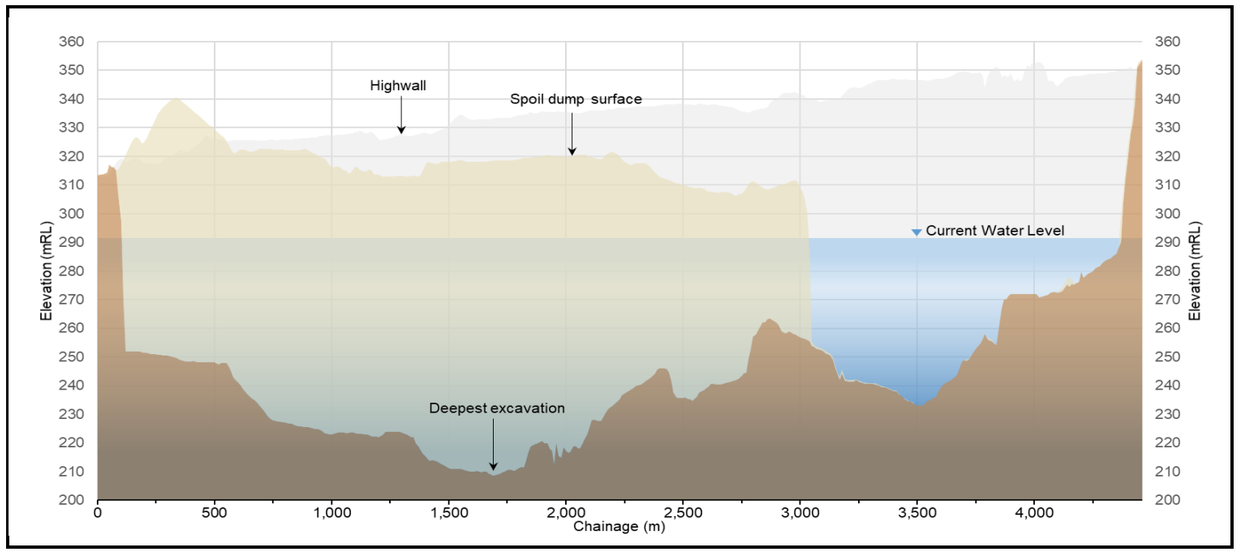
TITLE: FINAL VOID DATA SHEETS
BULLOCK PIT

PROJECT No. D10242A01

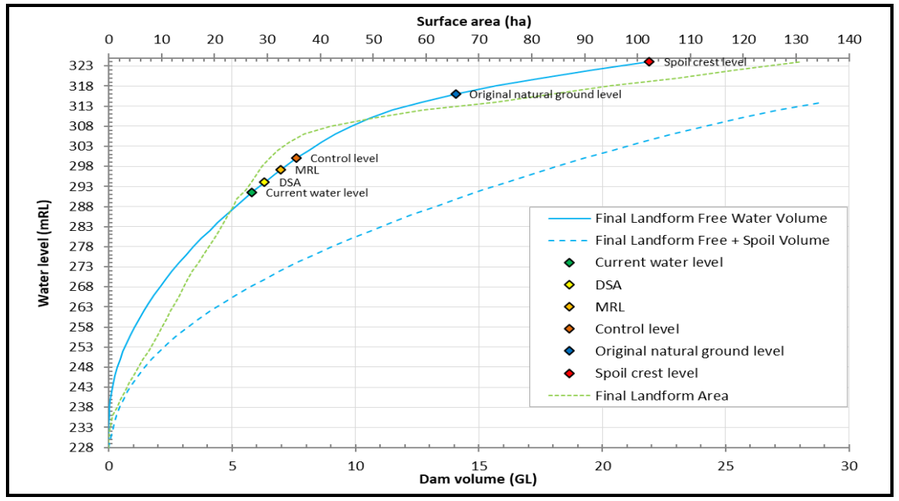
Locality and Catchment Plan



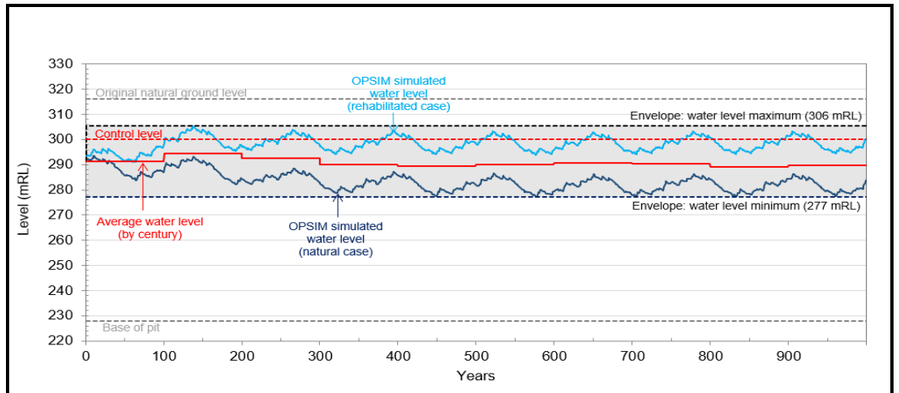
Cross Section CC



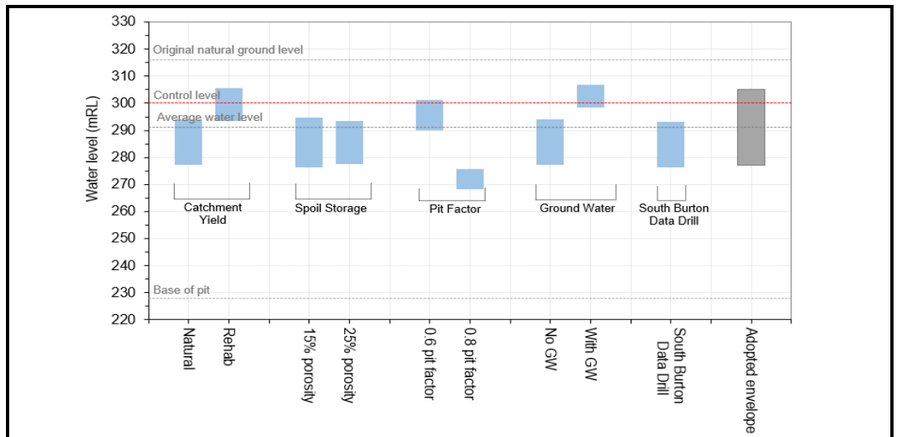
Stage Storage Curve



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section CC and Stage Storage Curve

The pit lake surface area within the void is relatively narrow from the pit floor up to approximately 311 mRL.
The surface area opens up and increases significantly from approximately 311 mRL.
The original natural ground level has a nominal elevation of 316 mRL with the spoil crest level raised to an elevation of 324 mRL.
At 316 mRL, flows would drain west towards Sandy Creek.
Highwall areas are shown in grey tones are not located on Section BB. The highwall is visible from Section BB when looking towards the east.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.
Data Drill location sensitivity cases assumed a natural catchment, a pit factor of 0.7, a spoil porosity of 20% and no ground water inflow.

Catchment Area (ha)	232	(Surface + baseflow)
	45	(Baseflow only)
Base of Mining (mRL)	228.0	
Control Level (mRL)	300.0	(Geotechnical advise)
Current Water Level (mRL)	291.54	

Time to Equilibrium	80
Maximum Water Level (mRL)	306
Minimum Water Level (mRL)	277
Average Water Level (mRL)	291

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CLIENT: Peabody ENERGY

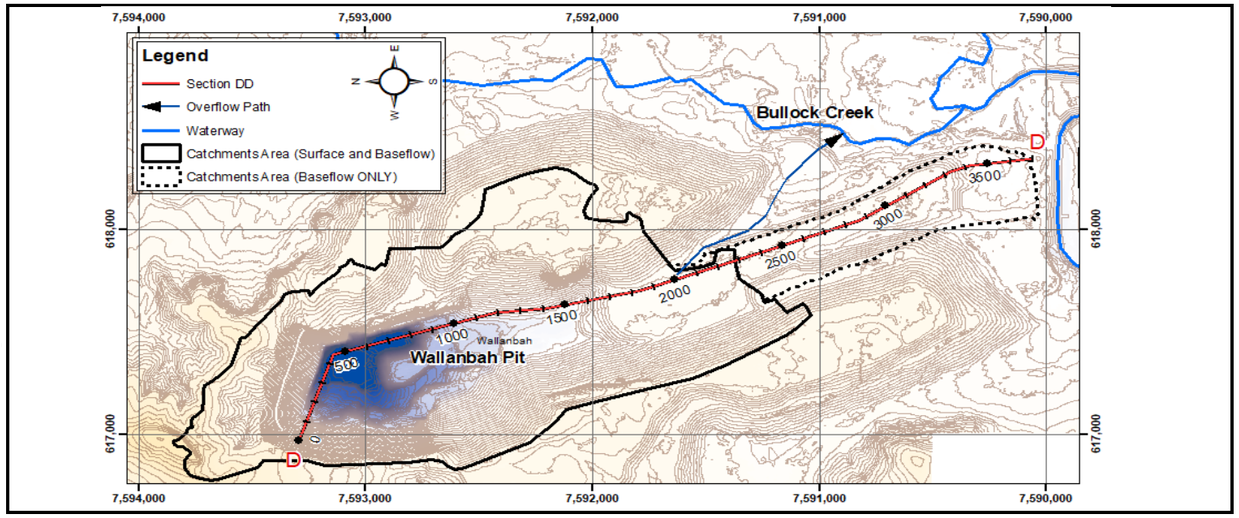
Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

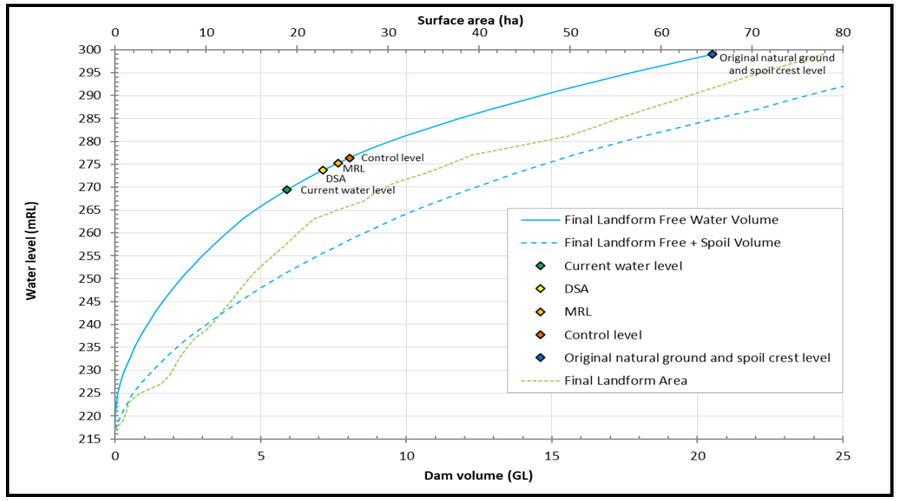
TITLE: FINAL VOID DATA SHEETS
PLUMTREE PIT

PROJECT No. D10242A01

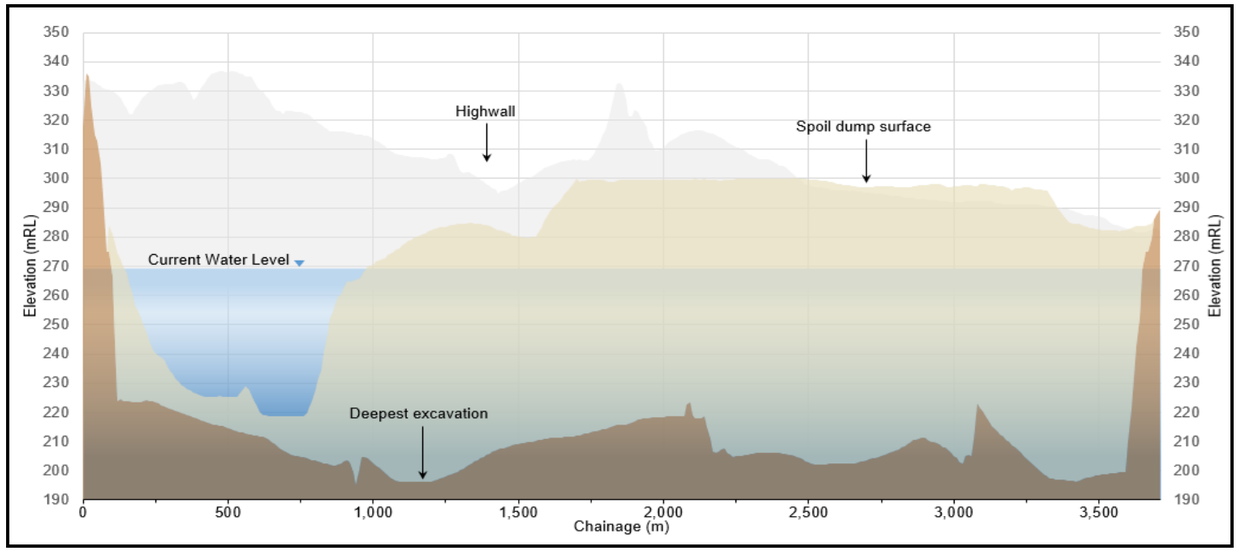
Locality and Catchment Plan



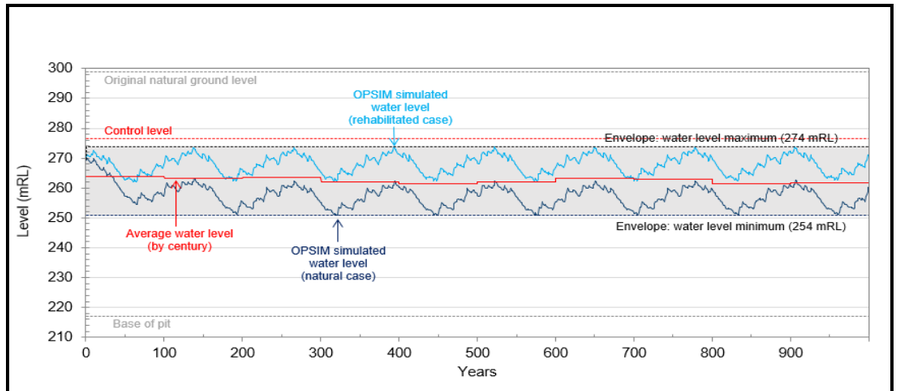
Stage Storage Curve



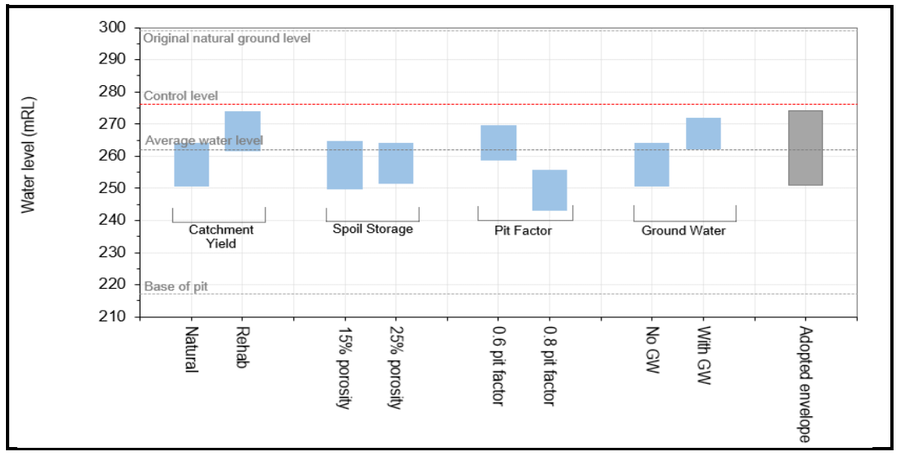
Cross Section DD



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section DD and Stage Storage Curve

The lowest elevation at which surface water would overflow from Wallanbah Pit void is nominally at 299 mRL.
At 299 mRL, water would overflow from two locations towards Bullock Creek.
Highwall areas are shown in grey tones are not located on Section DD, but would be visible from Section DD if looking towards the east.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.

Catchment Area (ha)	222	(Surface + baseflow)
	42	(Baseflow only)
Base of Mining (mRL)	217.0	
Control Level (mRL)	276.4	(Nominal 5 m below Bullock Creek Bed level)
Current Water Level (mRL)	269.38	

Time to Equilibrium	-
Maximum Water Level (mRL)	274
Minimum Water Level (mRL)	254
Average Water Level (mRL)	262

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CLIENT: Peabody ENERGY

Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

TITLE: FINAL VOID DATA SHEETS
WALLANBAH PIT

PROJECT No. D10242A01

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APPENDIX III

Groundwater Interaction Study - Draft

Appendix III
Groundwater Interaction Study

III-1 INTRODUCTION

Peabody Energy Australia appointed KCB (Klohn Crippen Berger Ltd) to undertake a hydrology study for the final voids remaining within Bullock, Broadmeadow, Plumtree and Wallanbah Pits at BCM (Burton Coal Mine). This appendix summarises the groundwater modelling undertaken by KCB to address the impact of the final void design on groundwater resources and water quality parameters in the long term. The general setting for each modelled pit void is presented in Table 1-1.

Table 1-1: General Setting of each pit at the BCM

Pit Void	Deepest Mining Surface Elevation (mRL)[1]	Deepest Final Void Elevation (mRL)[1]	Geology Encountered	Mine Operation Ended In
Plumtree	228	232	Alluvium Rewan Group Rangal Coal Measures Fair Hill Formation	2012
Bullock	244	244	Alluvium Rewan Group Rangal Coal Measures Fair Hill Formation	2011
Wallanbah	217	228	Alluvium Tertiary Basalt Rewan Group Rangal Coal Measures	2009
Broadmeadow	178	230	Alluvium Rewan Group Rangal Coal Measures	2010

Notes: [1] mRL – metres above reference level

III-1.1 Available Data

- Deepest mining and final landform surfaces from Peabody;
- Groundwater quality data and levels from site monitoring bores;
- Site geological data including cross sections and long sections (resource and geotechnical aspects);
- Base of weathering surfaces;
- Base of Tertiary surface (Wallanbah Pit only);
- Hatch (2018) Final void Modelling Report Q1 2018;
- Public online modelling reports; and
- Aerial photo.

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III-1.2 Methodology

Based on available information, the groundwater interaction assessments (2D numerical groundwater modelling of pit inflow and final void water comparison) were carried out as follows:

1. Review of current groundwater and void data (water levels and general chemistry data);
2. Construct 2D cross section and 2D long section SEEP/W models to assess the groundwater inflow into the pits;
3. Pass pit inflow information on to surface water team for their final void water level assessment (OPSIM);
4. Assess the final void water levels with respect to weathering level, locations of alluvium and Tertiary deposits, and any nearby surface water bodies.

III-2 GEOLOGY AND HYDROGEOLOGY

Figure 2.1 shows the published 1: 100,000 geology information. The BCM extracts coal from the coal seams (Burton Rider Seam, Leichhardt Seam and Vermont Seams) of the Rangal Coal Measures. The Rangal Coal Measures generally dip at 15 – 20 degrees to the east and northeast.

III-2.1 Geology

The Rangal Coal Measures are overlain by Rewan Formation and are underlain by Fair Hill Formation (or Fort Cooper Coal Measures). At the Plumtree, Bullock Creek, and Broadmeadow pits, Quaternary deposits (alluvial deposits and residual soils) can be found overlying the weathered bedrock surface. However, at Wallanbah Pit, the Tertiary Suttor Formation overlies the weathered bedrock surface. Lithology descriptions are summarised in Table 6-1.

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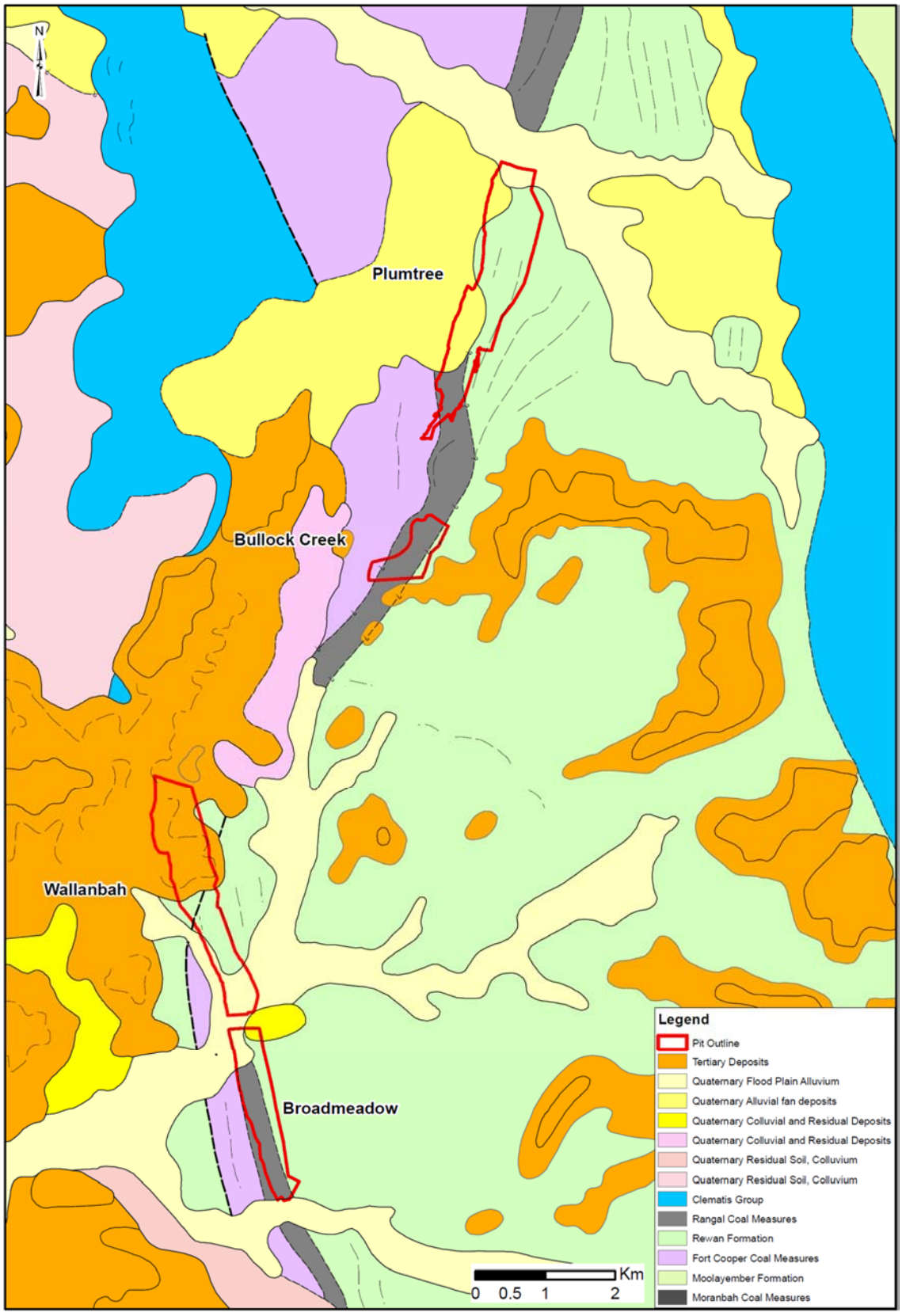

Figure 2.1: 1: 100,000 Scale Detailed Geology Map (Harry Brandt No.8554)

III-2.2 Spoil Material

Spoil materials placed in the final pit voids tend to be heterogeneous and anisotropic with variable hydraulic conductivity due to their composition of coal and interbedded sandstone and mudstone (interburden materials). Based on a study of strip coal mine spoils (Rehm. et. al, 1980), spoil hydraulic conductivity has a range of six orders of magnitude, with a mean value of 8×10^{-7} m/s (i.e. 0.069 m/d). Spoil materials placed in the voids tend to form a storage unit or "spoils aquifer" with an assumed porosity of 20%. Perched water tables can occur on a localised scale within the spoils due to their heterogeneous nature which includes layers of low permeability material. Water stored within, and flowing through the spoil, is subjected to chemical interactions resulting from contact with the spoils.

III-3 GROUNDWATER CONTOURS

Figure 3.1 shows the interpreted groundwater contours of the study area. In general, the groundwater flow direction is towards the south with pits forming localized sinks. Table 3-1 summarises the bore information and water levels around each pit.

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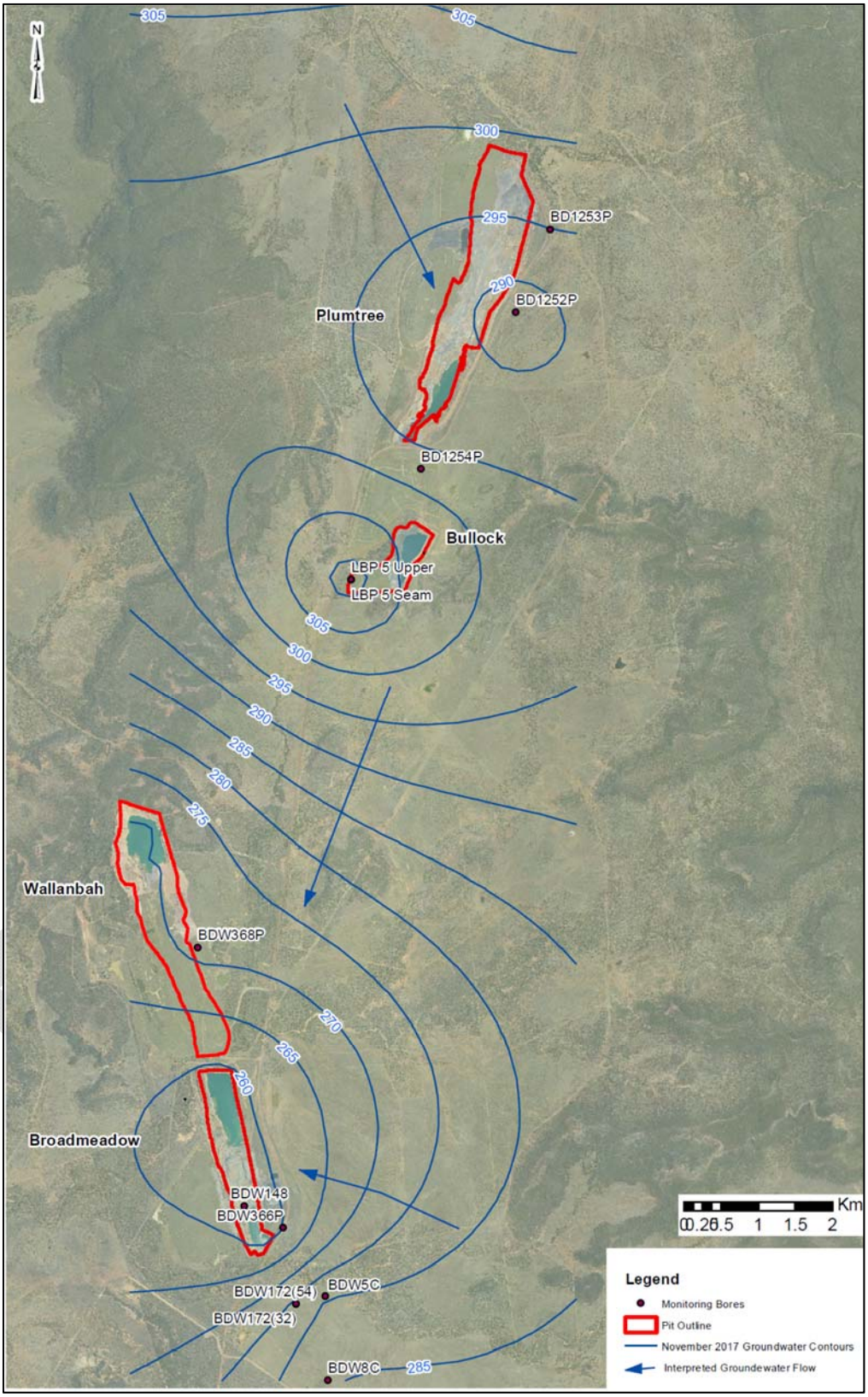

Figure 3.1: Interpreted Groundwater Contours November 2017

Table 3-1: Bore information included in this study

Monitoring Point	Easting (AGD84)	Northing (AGD84)	Total Depth (m)	Casing Stickup (m)	Elevation / Collar RL (mRL)[2]	Ground water Elevation (mRL)[#]	Monitored Formation	Pit
BD1253P[1]	622751	7601157	168.13	0.45	323.63	295.0		Plumtree
BD1252P	622294	7600039	183	0.46	334.55	287.2	Coal seams of Rangal Coal Measures	Plumtree
BD1254P	621022	7597920	264		346.54	297.7	Coal seams of Rangal Coal Measures	Plumtree
BDW148	618642	7587996	54	0.23	338	263.5*	-	Broadmeadow
BDW172(32)	619333	7586689	32	0.35	291	276.1	Interburden of Rangal Coal Measures	Broadmeadow
BDW172(54)	619333	7586689	54	0.35	291.12	274.4*	Coal seams of Rangal Coal Measures	Broadmeadow
BDW366P	619163	7587710	94	0.49	289.94	259.6	Coal seams of Rangal Coal Measures	Broadmeadow
BDW367P	618778	7589869	186	0.45	286.9	254.7*	Coal seams of Rangal Coal Measures	Wallanbah
BDW368P	618017	7591478	131.9	0.19	293.65	271.5	Coal seams of Rangal Coal Measures	Wallanbah
BDW46	617650	7593762	251	-	338.43	280.1*	Coal seams of Rangal Coal Measures	Broadmeadow
BDW5C	619731	7586791	99	0.14	290.58	280.0	Coal seams of Rangal Coal Measures	Broadmeadow
BDW8C	619762	7585670	79	0.15	297.67	284.7	Coal seams of Rangal Coal Measures	Broadmeadow
LBP 5 Upper	620080	7596430	-	-	334	312.7		Bullock Creek
LBP 5 Seam	620080	7596430	-	-	334	312.7	Coal seams of Rangal Coal Measures	Bullock Creek
Plumtree+	-	-	-	-	-	291.6+	Void Water Level	Plumtree
Bullock+	-	-	-	-	-	303.9+	Void Water Level	Bullock Creek
Wallanbah+	-	-	-	-	-	270.0+	Void Water Level	Wallanbah
Broad-meadow+	-	-	-	-	-	259.2+	Void Water Level	Broadmeadow

Notes: [1] BD1253P is not EA Compliance bore
[2] mRL – metres above reference level
[#] Groundwater levels are generally measured in Nov 2017. [+] Void water levels measured in Nov 2017.
*Groundwater levels are not measured in Nov 2017 and not included in the groundwater contouring.

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III-4 WATER LEVELS AND CHEMISTRY

Figure 4.1 to Figure 4.5 are the plots of rainfall data from SILO DataDrill (Burton North and South), void water levels, bore groundwater levels, and bore electrical conductivity (EC) values. Distinct correlations between the SILO Data Drill rainfall data, groundwater levels and void water levels are not evident in the plots. The water level data measured after 2012 shows that the differences between void water levels and the surrounding bore water levels are generally within 10 m except the bores located to the south of Broadmeadow Pit, which are approximately 15-20 m higher than pit water levels. This implies that except for the south side of Broadmeadow Pit, the hydraulic head differences between pit void water level and groundwater level are relatively low and the groundwater inflow into the pit voids is therefore expected to be low under current conditions.

Table 4-1 shows the pH and EC values of the monitoring bores. Apart from BDW8C, most bores have EC values of more than 9,000 uS/cm and mostly within a range of 12,000 to 20,000 uS/cm, which are typical values of coal measures groundwater.

Table 4-1: Summary table of pH and electrical conductivity values

Monitoring Point	pH value	Electrical Conductivity (uS/cm)
BD1253P[1]	7.16 – 7.54	14,520 – 14,800
BD1252P	6.21 – 7.80	12,010 – 16,410
BD1254P	6.79 – 7.84	9,420 – 15,260
BDW148	6.54 – 6.6	19,000 – 19,620
BDW366P	–	18,210 – 20,770
BDW5C	6.23 – 7.93	11,780 – 18,800
BDW8C	7.10 – 8.14	1,800 – 4,560
LBP5 Upper	6.35 – 7.18	12,190 – 22,470
LBP5 Seam	6.72 – 7.66	16,080 – 31,400

Note: [1] BD1253P is not EA Compliance bore

In general, the EC values of void water are below 7,000 uS/cm which is quite different from coal seam groundwater. One exception to this was Plumtree Pit void water, which showed EC values slightly higher than 7,000 uS/cm during October to December 2017 sampling rounds. The EC ranges of each pit are summarised in Table 4-2 below. Notably, the void water EC ranges are significantly lower than the EC values of surrounding groundwater.

Table 4-2: Electrical Conductivity (uS/cm) of Pit Void Water

Pit	Electrical Conductivity (uS/cm)
Plumtree	4,890 to 7,250
Bullock Creek	6,210 to 6,950
Wallanbah	4,890 to 5,560
Broadmeadow	4,170 to 6,960

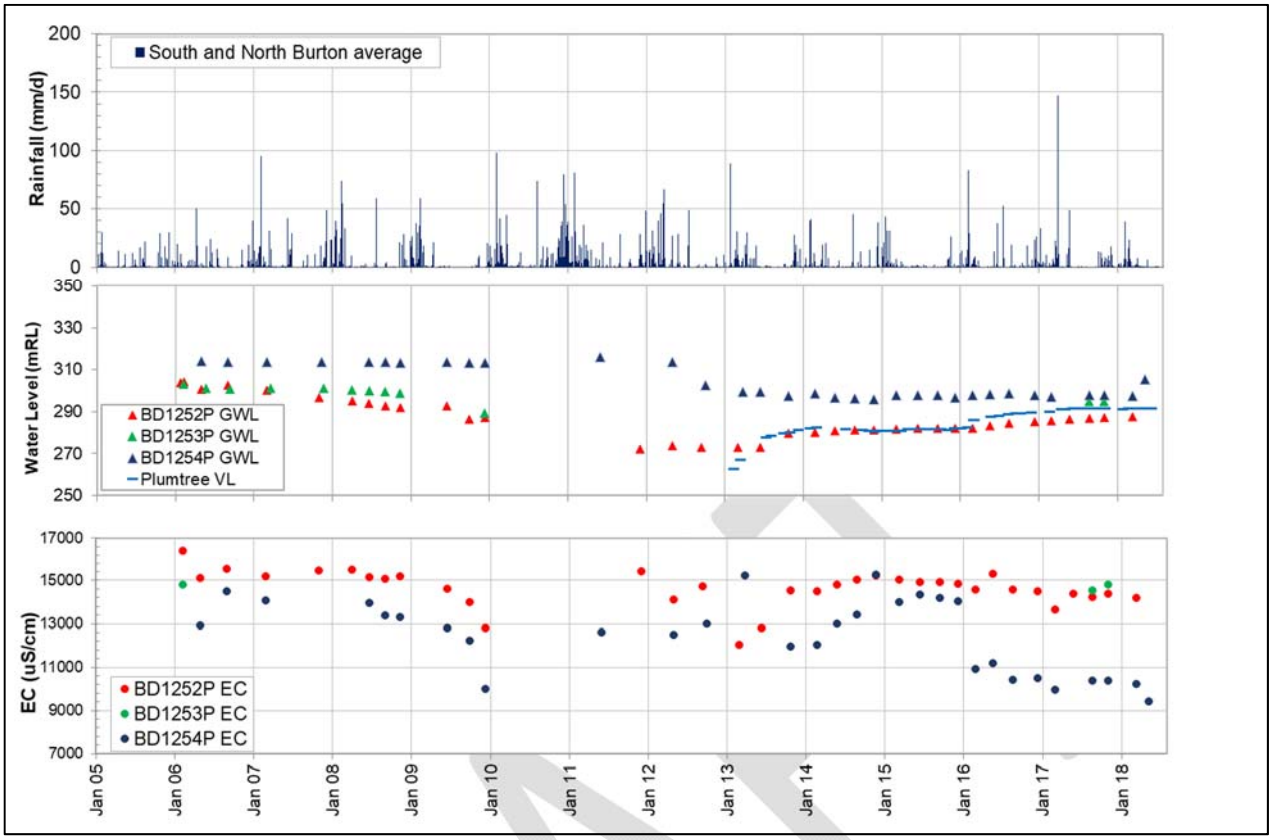

Figure 4.1: Plumtree Pit

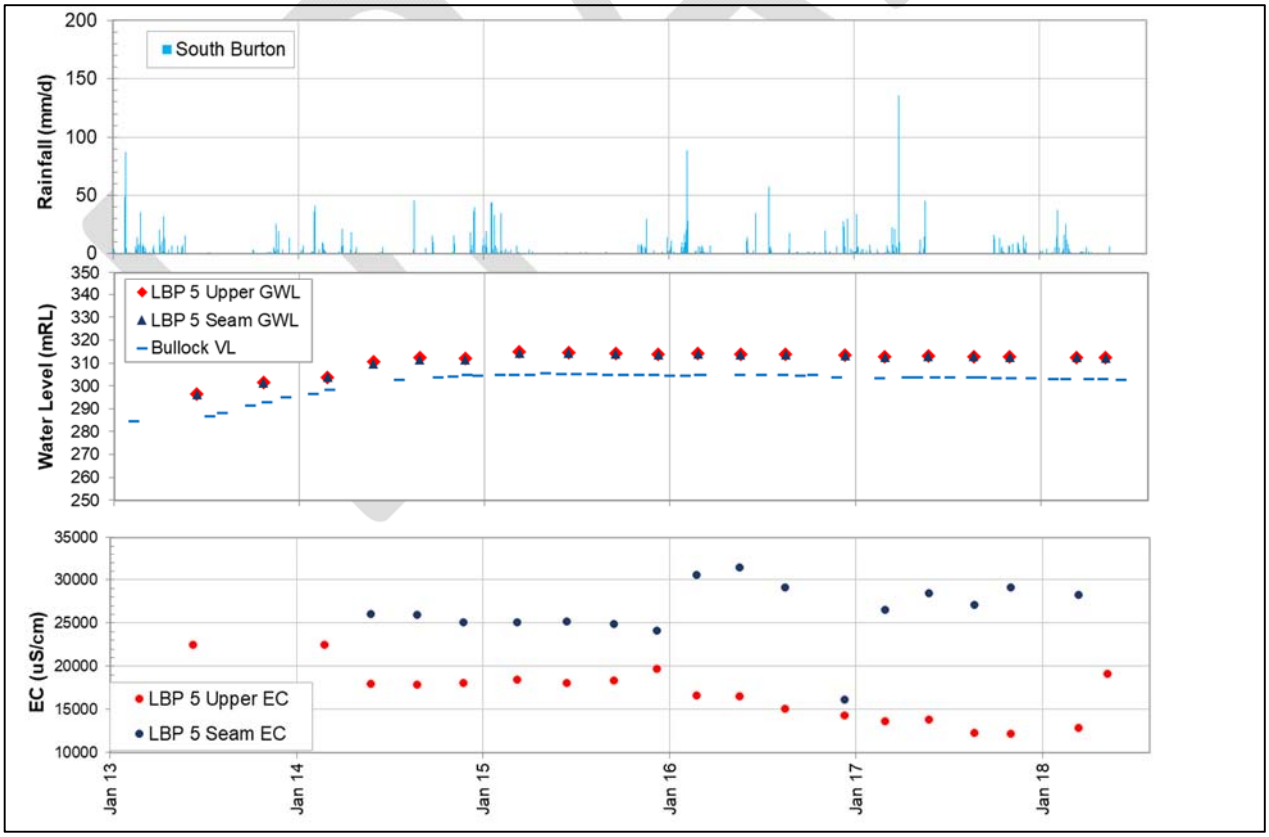

Figure 4.2: Bullock Pit

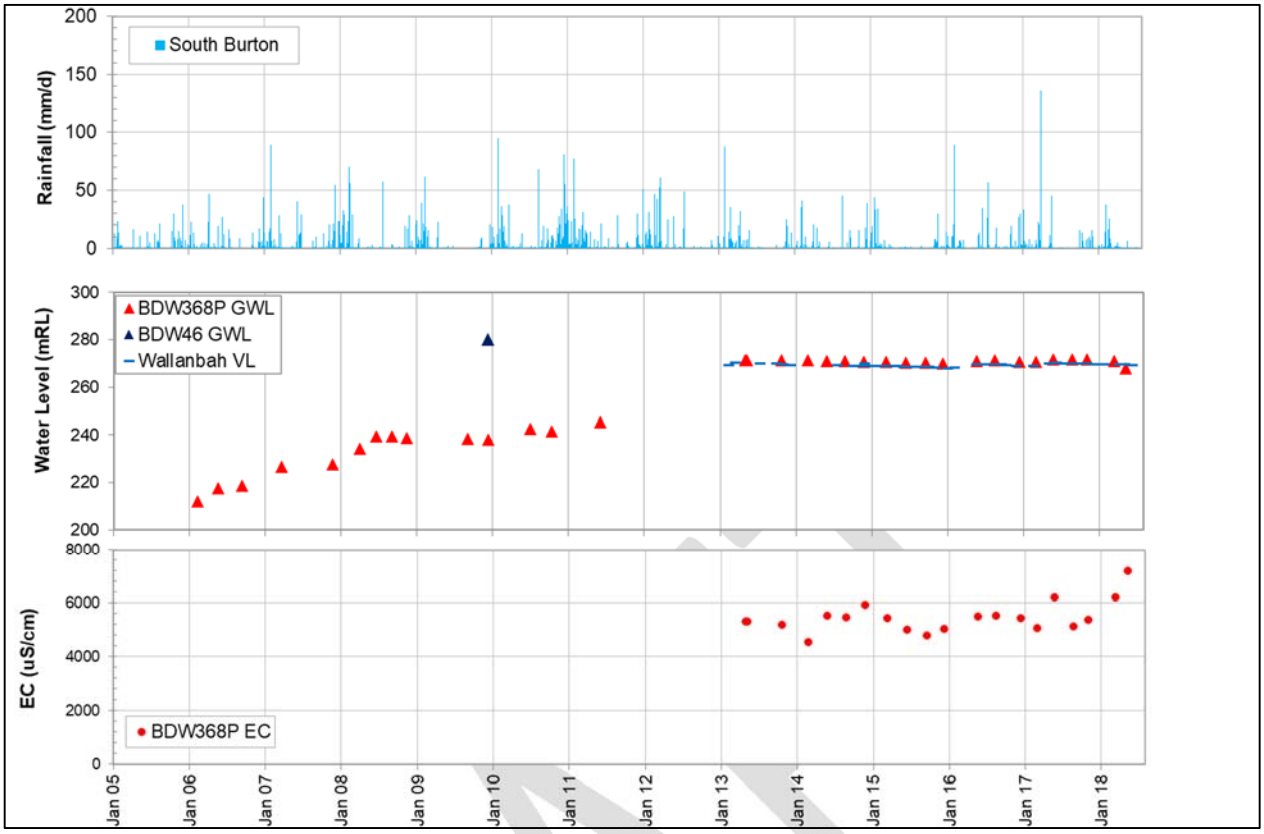

Figure 4.3: Wallanbah Pit

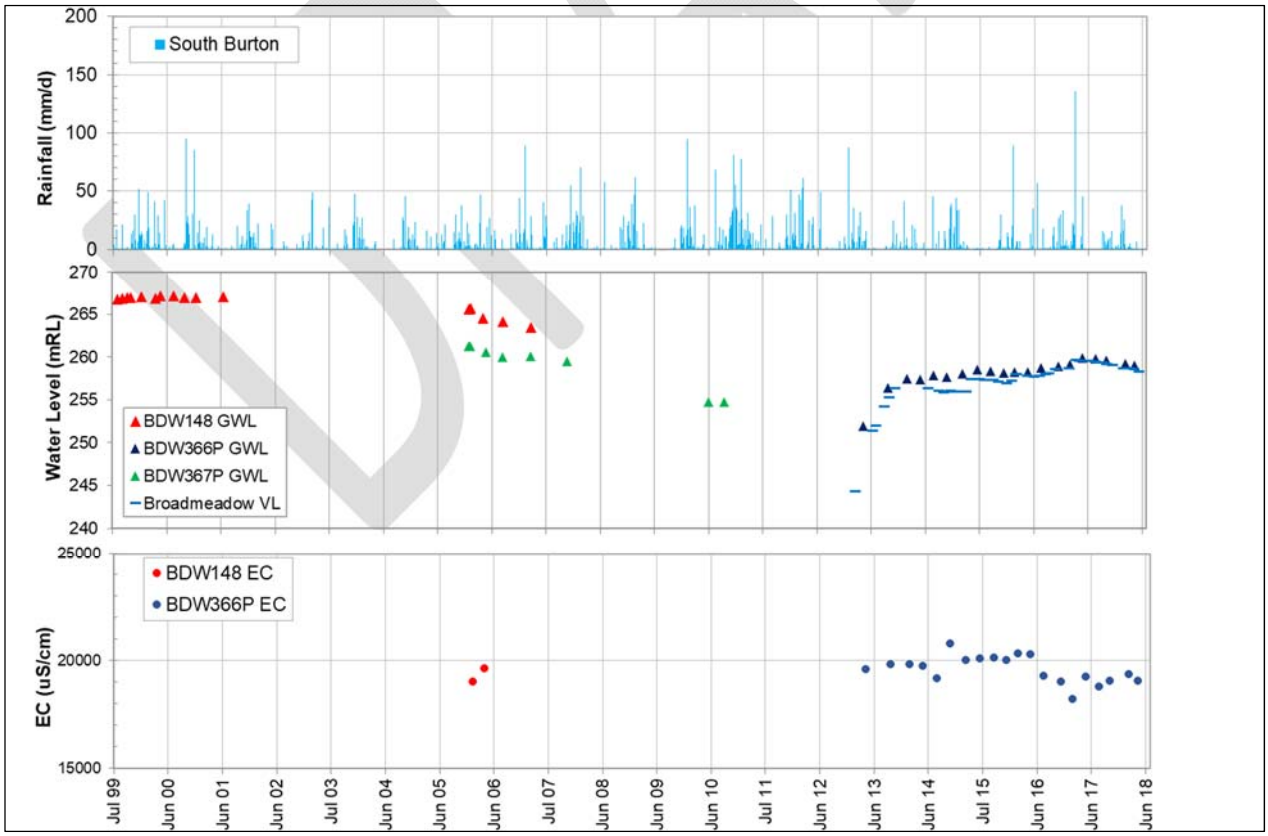

Figure 4.4: Broadmeadow (North)

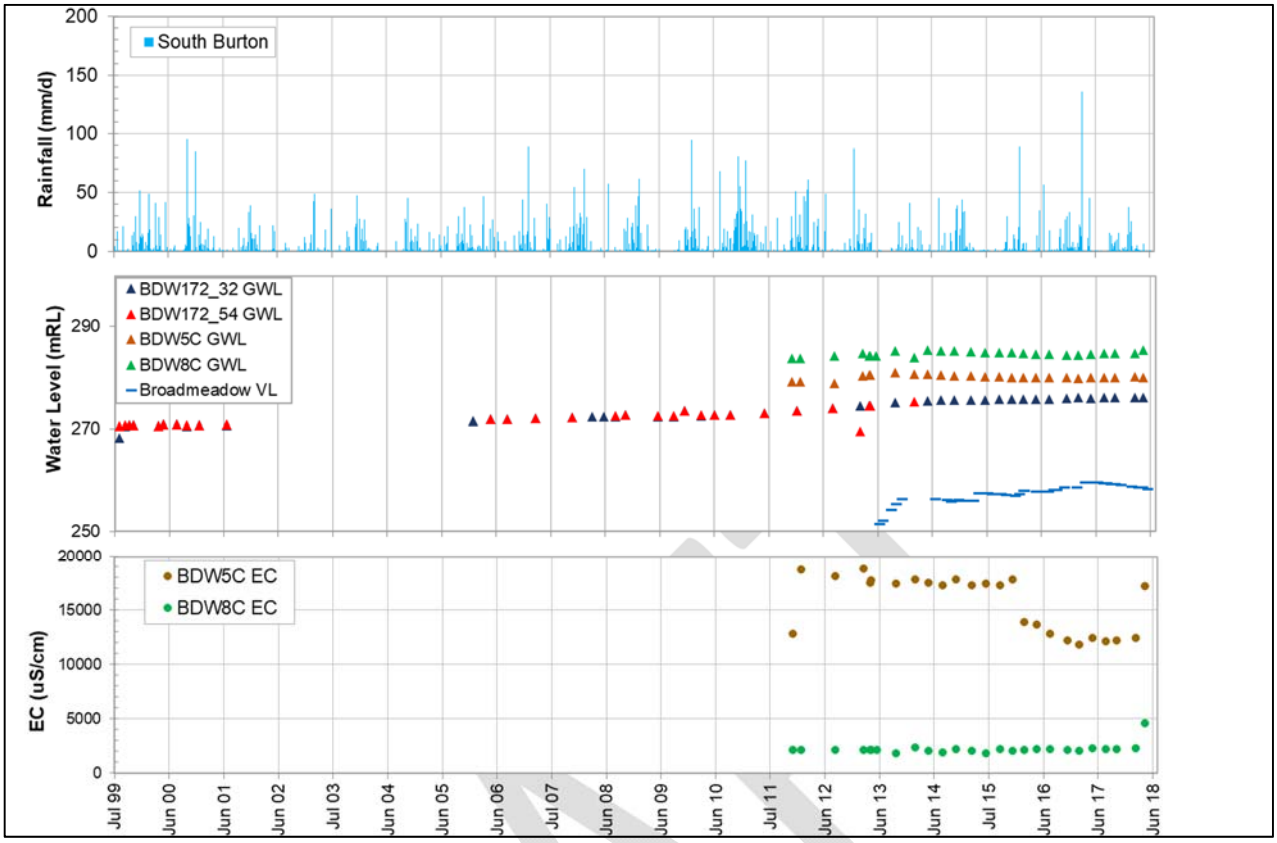

Figure 4.5: Broadmeadow (South)

III-5 CONCEPTUAL GROUNDWATER MODEL

Figure 5.1 is a schematic diagram representing the inflow and outflow dynamics of the final pit void. The void water outflow from the pit and the groundwater inflow into the pit are governed by the magnitude and direction of hydraulic gradients between the surrounding groundwater levels and void water levels.

Figure 5.1 shows that if the void water level is below the surrounding groundwater, groundwater inflow to the void will occur. If the void water level is higher than the surrounding groundwater, there will be outflow from the void to the surrounding aquifer units. The magnitude of inflow/outflow depends on the permeability of the surrounding lithologic units and the hydraulic gradients.

III-5.1 Impact Assessment Approach

Based on the chemistry data, the void water samples have EC values lower than most of the groundwater samples, thus the potential is low for void water to have a negative impact on surrounding groundwater quality under void outflow conditions. However, the results of mixing of inflow groundwater with the void water and/or the potential interaction of spoil materials and void water, could increase the salinity concentrations of the void water. With the potential for this resultant void water mix to reach the base of Tertiary/Quaternary deposits, elevated risk of water quality impacts to the near surface deposits exists.

Groundwater inflow (into pit void) is one of the factors contributing the rise of void water levels. As a result, the first part of the groundwater assessment is focused on quantifying groundwater inflow from the surrounding geologic units to the pit. These results represent one of the inputs for the void water balance modelling.

Subsequently, the water balance modelling enabled the final void water levels to be computed and those levels were then compared against the available base of weathering and base of Tertiary deposits (Wallanbah only) to assess the risk of void water egress to these units.

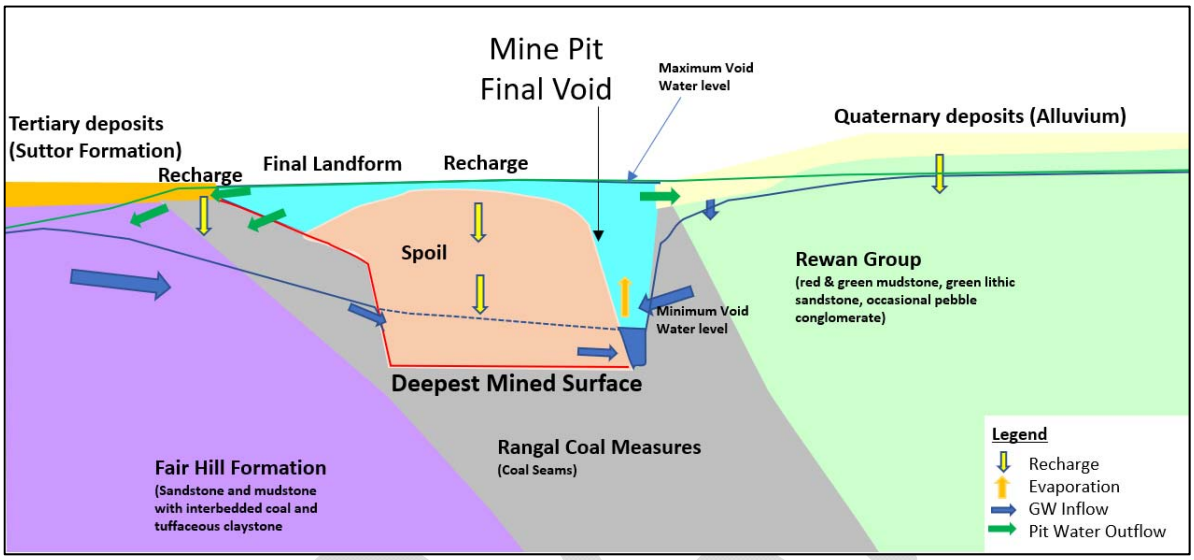

Figure 5.1: Conceptual Groundwater Model

III-6 2D NUMERICAL GROUNDWATER MODELS

2D SEEP/W models were set up to assess the possible ranges of groundwater inflow into the pit voids using a combination of minimum and maximum of groundwater levels and void water levels. Figure 6.1 shows the locations of the four modelling cross-sections and the two modelling long-sections.

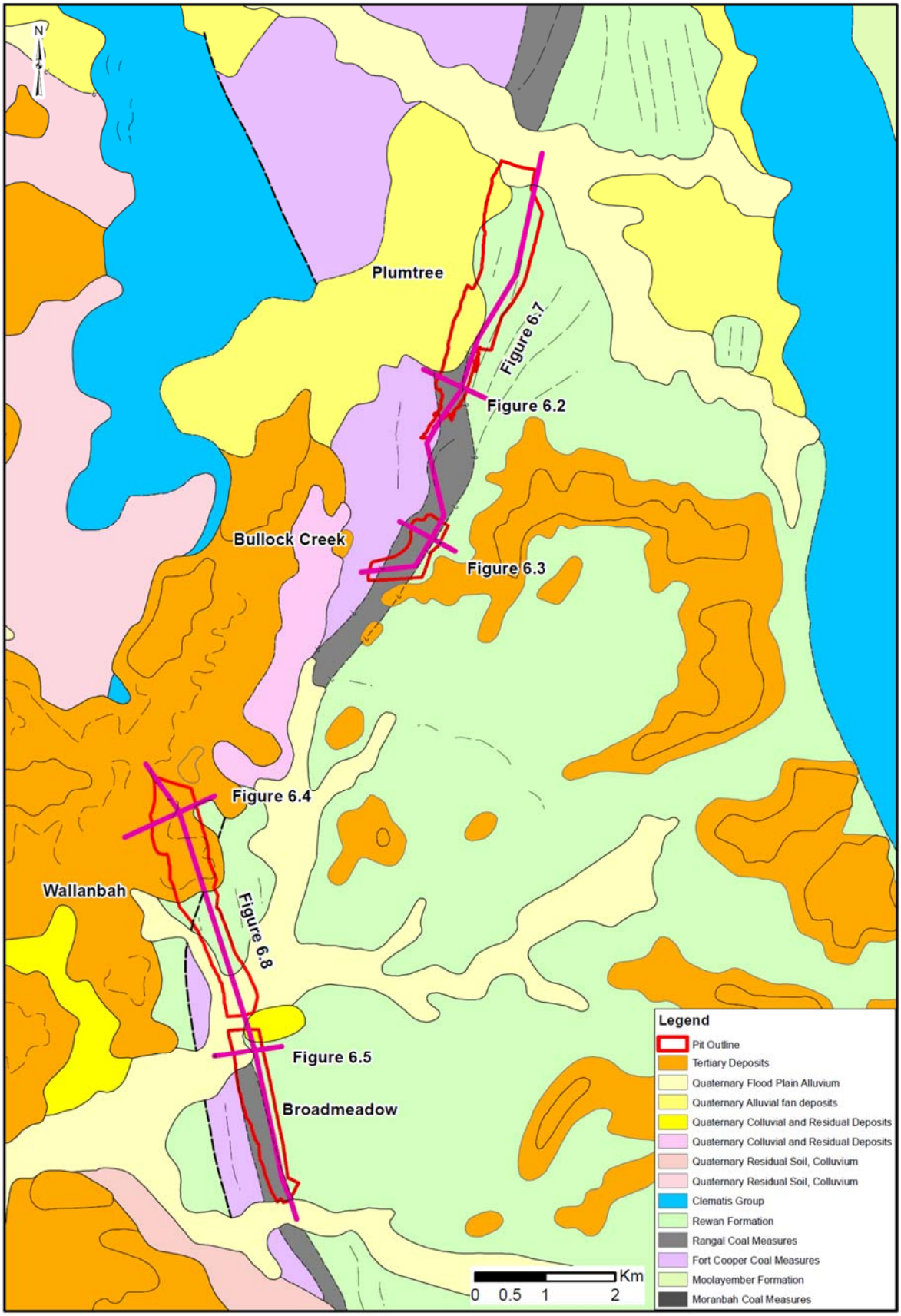

Figure 6.1: Location map of SEEP/W Sections

III-6.1 SEEP/W Model Setup

Four cross-section models across the final pit voids (Figures 6.2 to 6.5) and two long-section models (Figures 6.6 and 6.7) through the pits (Plumtree/Bullock and Wallanbah/ Broadmeadow) were constructed based on available geology, final void pit shells, and final landform information.

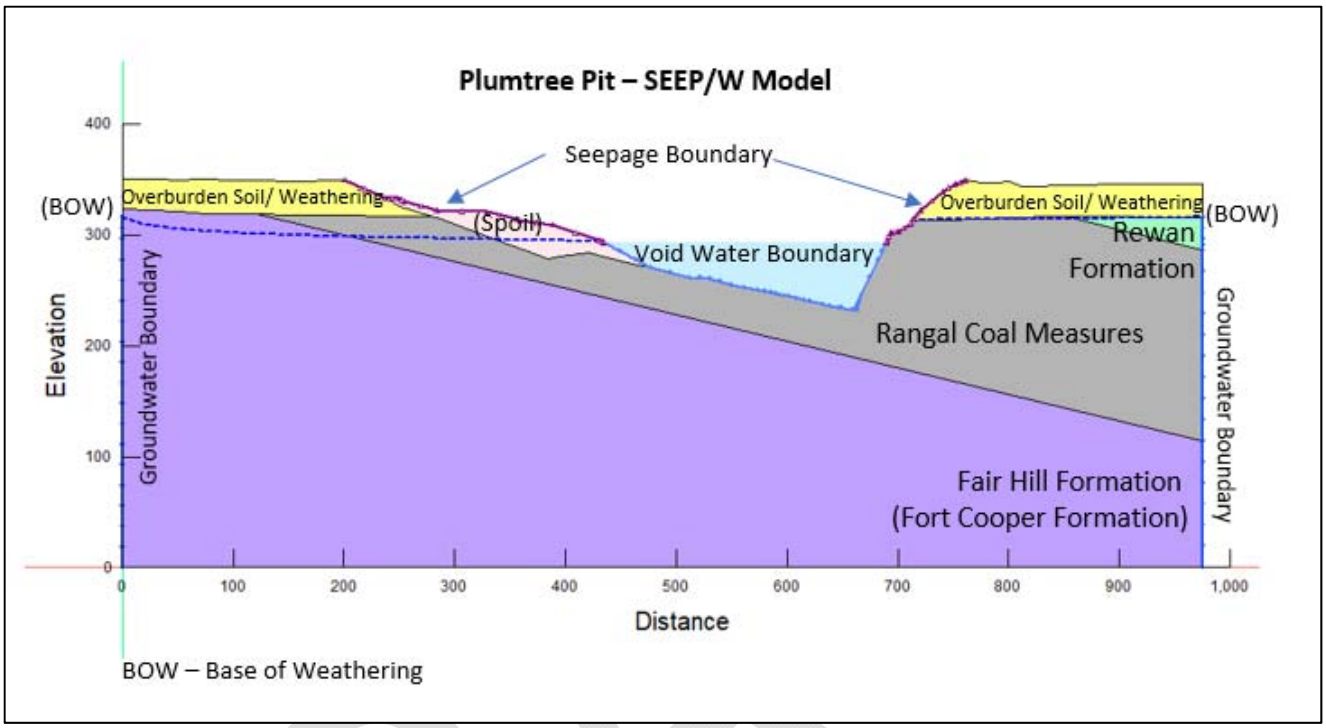

Figure 6.2: Plumtree Pit SEEP/W Cross Section

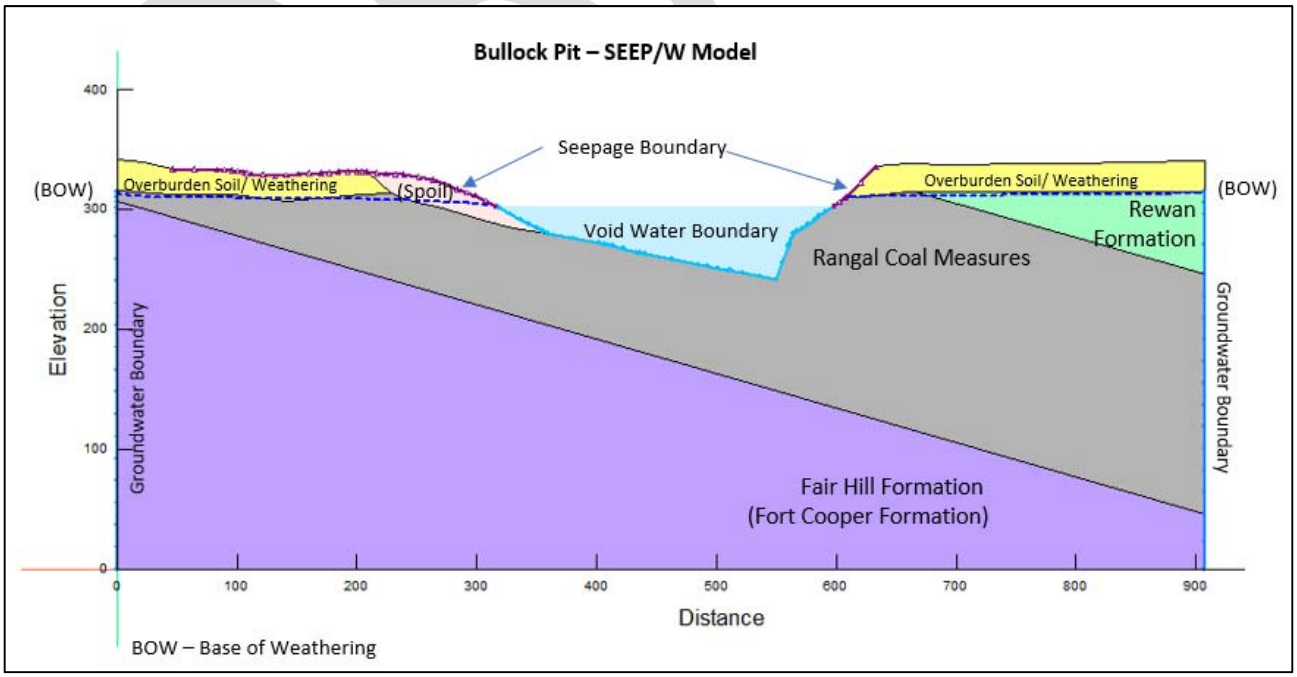

Figure 6.3: Bullock Pit SEEP/W Cross Section

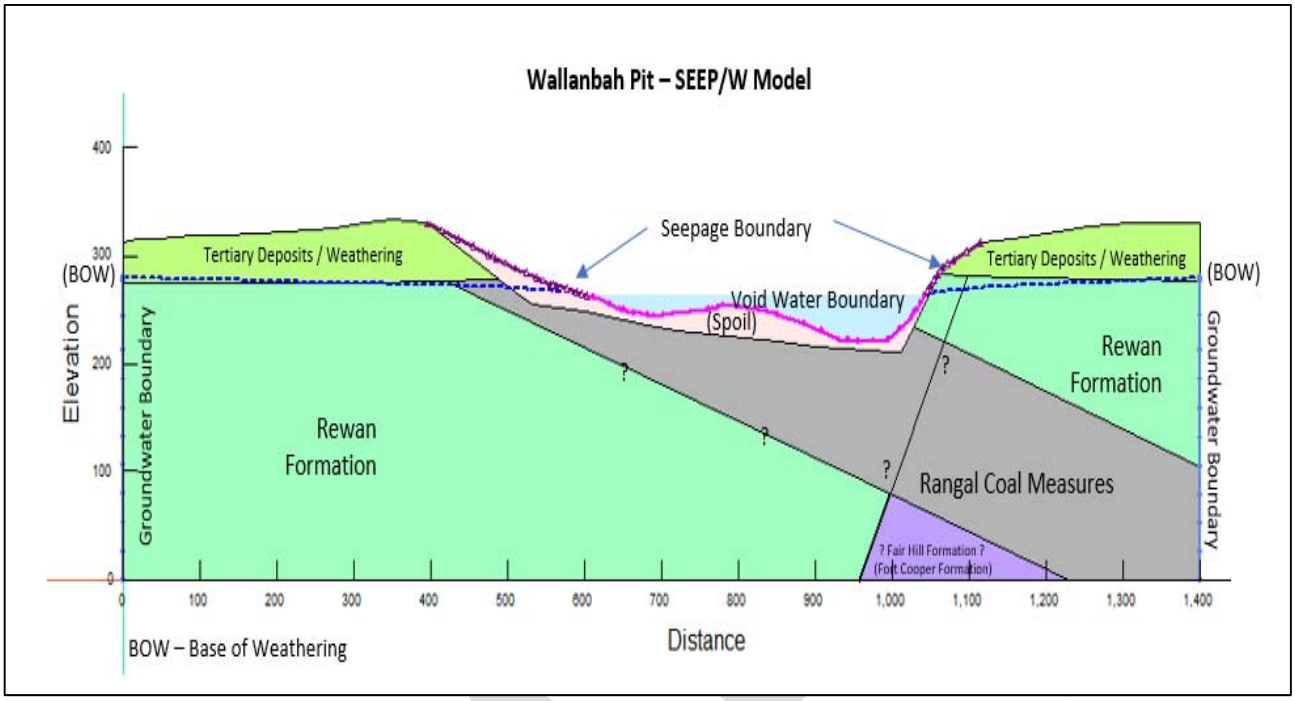

Figure 6.4: Wallanbah Pit SEEP/W Cross Section

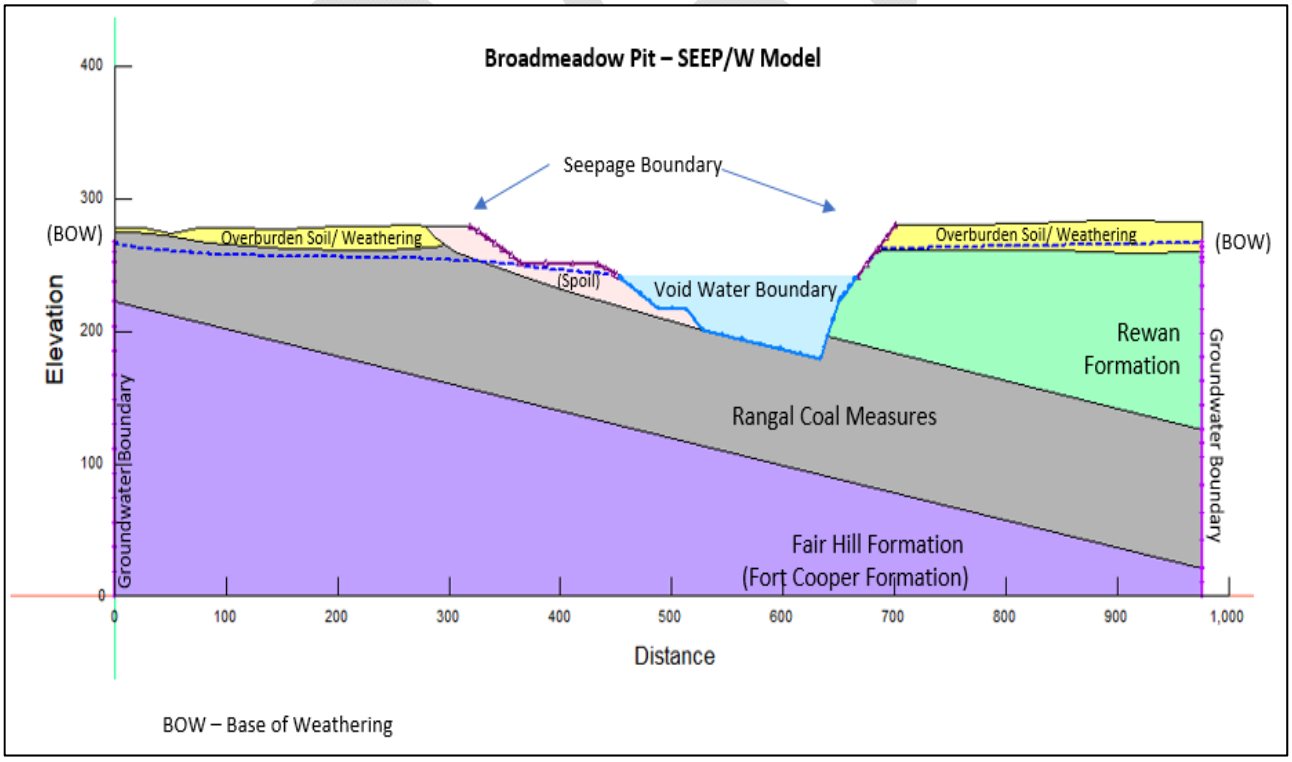

Figure 6.5: Broadmeadow SEEP/W Cross Section

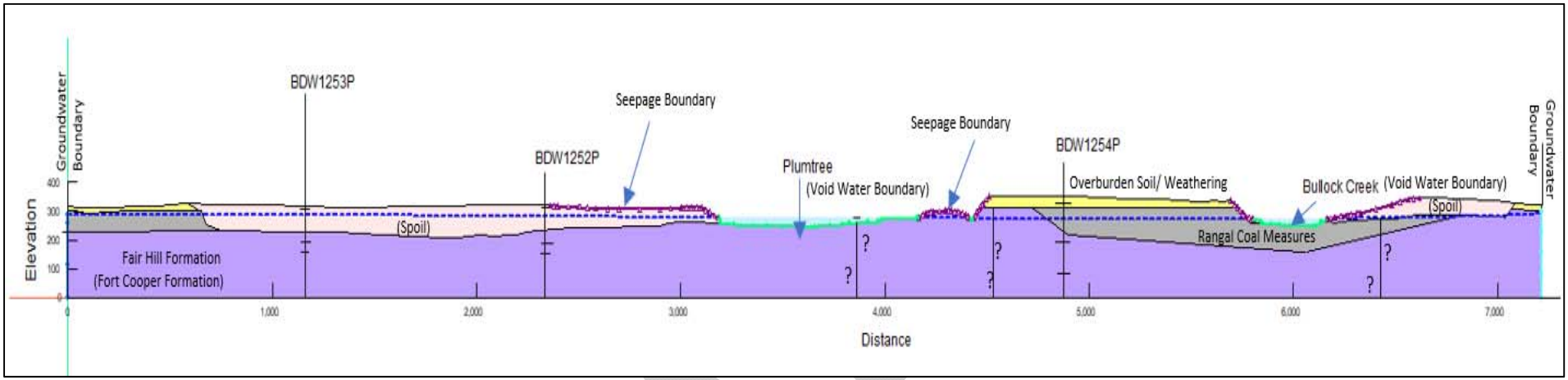

Figure 6.6: Plumtree and Bullock Pits SEE/W Long Section

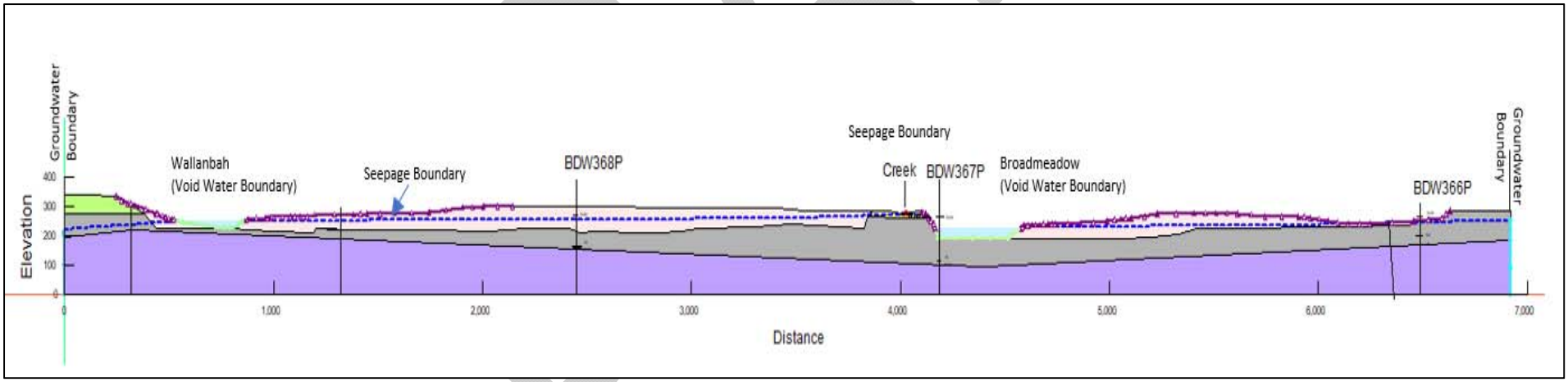

Figure 6.7: Wallanbah and Broadmeadow Pits SEEP/W Long Section

III-6.2 Material Properties

The material properties are mainly referenced to the public/ open source modelling reports (KCB, 2018 and URS, 2012) of Bowen Valley Area.

Table 6-1: Material Properties Summary Table

Materials	Lithology Descriptions	Kxy (m/d)	Kz (m/d)	Beta (1/kPa)	Sy	Porosity
Quaternary Alluvium	Soil, clay, silt, sand and gravel	1	0.1	$1x10^{-5}$	0.1	0.1
Tertiary Sediments	Suttor Formation (where no alluvium is present) Quartz sandstone, clayey sandstone, mudstone and conglomerate; fluvial and lacustrine sediments; minor interbedded basalt.	0.1	0.02	$1x10^{-5}$	0.01	0.01
Triassic Rewan Formation	Red and green mudstone, green lithic sandstone, occasional pebble conglomerate	0.005	0.0001	$5x10^{-6}$	0.01	0.01
Rangal Coal Measures	Coal seams, carbonaceous mudstone, siltstone and sandstone. Coal seams included: Burton Seam, splitting in some mining areas to the Leichhardt Seam and the underlying Vermont Seam and Girrah Seam (not mined in BCM).	0.005	0.0005	$5x10^{-7}$	0.001	0.001
Fair Hill Formation	Sandstone and mudstone with interbedded coal and tuffaceous claystone	0.005	0.0005	$1x10^{-7}$	0.002	0.002
Spoils	Heterogeneous materials	0.069	0.069	$1x10^{-6}$	0.01	0.01

III-6.3 Assumptions

1. Steady state mode and saturated permeability were adopted and are considered a conservative approach for this assessment.
2. Limited geology information is available for faulting and weathered materials. Faults are assumed to be similar permeability to the host formation and weathered materials are assumed to have similar hydraulic properties to the overburden materials (Tertiary deposits and Quaternary alluvium).
3. Groundwater boundaries are set approximately 200 m to 300 m from the pit.
4. Recharge (incident precipitation) or runoff contribution to the voids is not included in the groundwater modelling. This is considered conservative with respect to groundwater inflow potential. Direct recharge to voids and runoff inflows are more likely to contribute

the rise of void water levels and induce outflow to the surrounding environment. Surface water modelling (OPSIM) included these components in the final void water assessment.

III-6.4 Model Cases

Each SEEP/W model was run with four cases of groundwater and void water levels as shown in Table 6-2.

Table 6-2: SEEP/W Modelling Cases

SEEP/W	Maximum Groundwater Level	Minimum Groundwater Level
Maximum Void Water Level	Case 1	Case 2
Minimum Void Water Level	Case 3	Case 4

The hydraulic head boundary values (groundwater and void water) are summarized in Table 6-3.

Table 6-3: SEEP/W Head Boundaries

SEEP/W	Groundwater Boundary (mRL)[1]	Void Water Boundary (mRL)[1]
Plumtree Pit		
Maximum	316.2	293
Minimum	295.9	277
Bullock Creek		
Maximum	314.8	285
Minimum	296.4	271
Wallanbah		
Maximum	280.1	263
Minimum	211.9	251
Broadmeadow		
Maximum	267.1	241
Minimum	252.0	228

Note: [1] mRL – metres above reference level

Sensitivity scenarios were run to include higher hydraulic conductivity values for the Rewan Formation and Rangal Coal Measures. Table 6-4 is a summary of parameters used for the sensitivity runs.

Table 6-4: Maximum hydraulic conductivity of Rewan Formation and Rangal Coal Measures

Materials	Kxy (m/d)	Kz (m/d)
Triassic Rewan Formation	0.05	0.005
Rangal Coal Measures	0.043	0.004

III-6.5 Results

To obtain representative estimates of inflow/outflow for the final voids of the respective pits, the 2D-SEEP/W inflow/outflow results (l/s/m) were factored using the widths and lengths of each pit void. Figure 6.8 shows the dimensions used to factor the Seep/W unit flows for each void. The long-axis lines shown for each pit were used

to factor the cross-section model results, while the lines shown crossing the pits (approximately E-W) were used to factor the results for the long-section models. For each void the three respective factored flows were added together to get the total flows per void, which are presented in Table 6-5 and

Table 6-6. The results presented cover the various combinations of water levels and sensitivity parameters simulated.

Inflow values represent groundwater flowing from the surrounding area into the pit voids, whereas outflow values represent groundwater flowing from the pit voids out to the surrounding groundwater system.

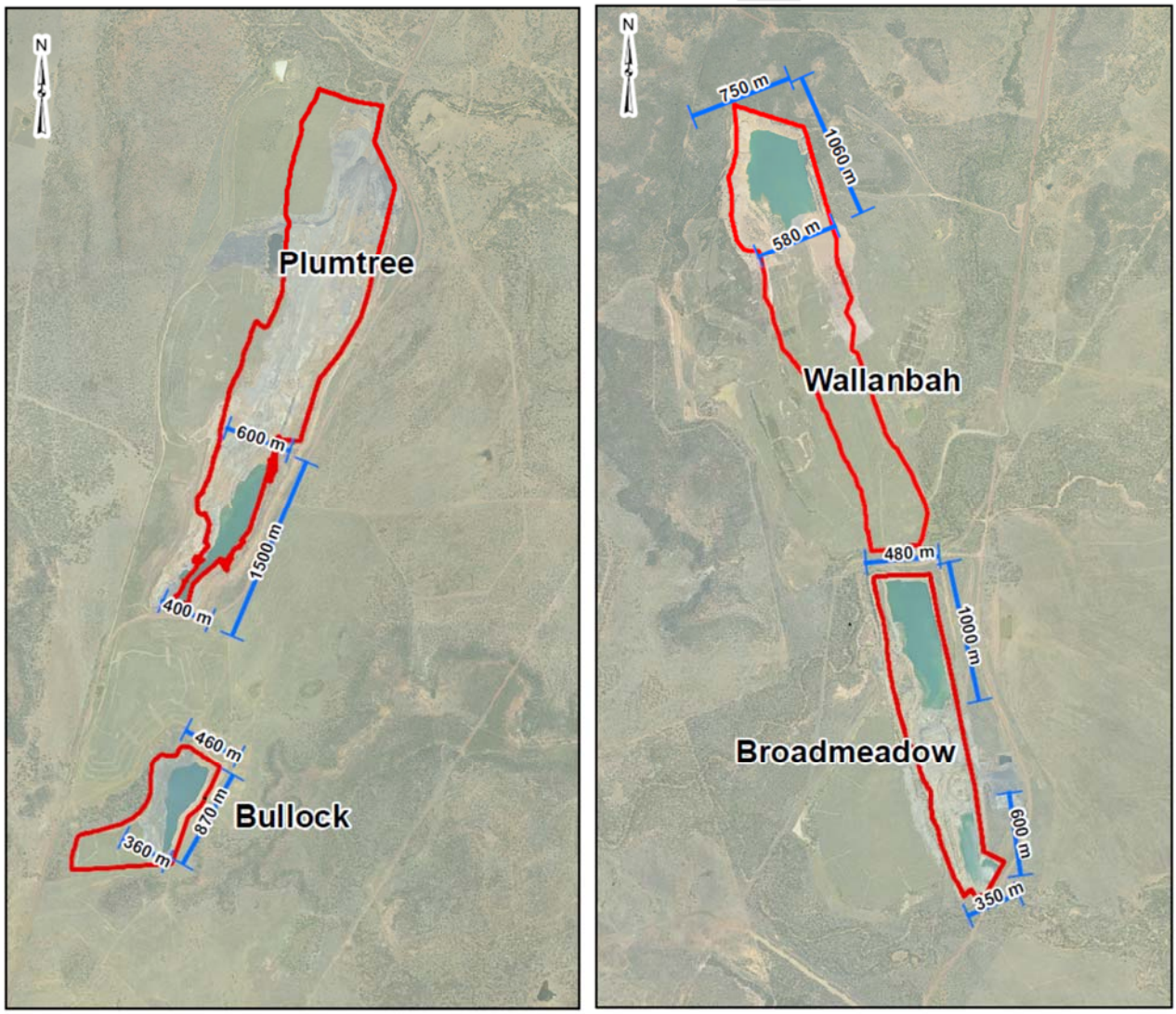

Figure 6.8: Void Dimensions used to scale Seep/W Unit flow rates

Table 6-5: Base Case Total Flow Results

Void Water Level	Maximum Groundwater Level	Minimum Groundwater Level
Plumtree Pit (Flow L/s)		

Void Water Level	Maximum Groundwater Level	Minimum Groundwater Level
Maximum Void Level	Inflow: 4.3	Inflow: 0.2
Minimum Void Level	Inflow: 5.7	Inflow: 1.6
Bullock Creek (Flow L/s)		
Maximum Void Level	Inflow: 2.6	Inflow: 0.7
Minimum Void Level	Inflow: 2.9	Inflow: 1.1
Wallanbah (Flow L/s)		
Maximum Void Level	Inflow: 3.1	Outflow: 3.3
Minimum Void Level	Inflow: 4.6	Outflow: 2.5
Broadmeadow (Flow L/s)		
Maximum Void Level	Inflow: 7.6	Inflow: 1.1
Minimum Void Level	Inflow: 8.6	Inflow: 2.1

Table 6-6: Sensitivity Case Flow Results with Higher Hydraulic Conductivities

Void Water Level	Maximum Groundwater Level	Minimum Groundwater Level
Plumtree Pit (Flow L/s)		
Maximum Void Level	Inflow: 10.6	Inflow: 1.1
Minimum Void Level	Inflow: 16.2	Inflow: 7.0
Bullock Creek (Flow L/s)		
Maximum Void Level	Inflow: 10.3	Inflow: 2.9
Minimum Void Level	Inflow: 12.5	Inflow: 5.5
Wallanbah (Flow L/s)		
Maximum Void Level	Inflow: 9.4	Outflow: 23.7
Minimum Void Level	Inflow: 14.2	Outflow: 16.7
Broadmeadow (Flow L/s)		
Maximum Void Level	Inflow: 20.7	Inflow: 7.5
Minimum Void Level	Inflow: 26.5	Inflow: 14.2

III-7 COMPARISON OF FINAL VOID WATER LEVEL AND GEOLOGY

The maximum final void water levels were modelled with OPSIM software by the surface water team. The resulting simulated maximum final void water levels are summarized in Table 7-1.

Table 7-1: Maximum Simulated Void Water Level

Pit	Maximum Pit Void Water Level (mRL)[1]
Plumtree	306.6
Bullock Creek	304.3
Wallanbah	273.8
Broadmeadow	260.1

Note: [1] mRL – metres above reference level

Figure 7.1 shows the comparison of the base of weathering and the maximum void water level in each pit. For Bullock Pit and Broadmeadow Pit, maximum final void water levels are generally below the base of weathering. The geology map indicates that the areas where the maximum void water levels are above the base of weathering, are not overlain by Tertiary or Quaternary deposits.

The Plumtree Pit results indicate that the maximum void water level can rise above the base of weathering at the north and northeast sides of the pit. In these areas there is a potential risk that the void water can reach the base level of Quaternary alluvial deposits and escape to Sandy Creek (surface water drainage).

Wallanbah Pit simulations showed that the void water level can rise above the base of weathering at the north side and the south side of the pit. Based on available Tertiary deposit information for the north side of the pit, the void water levels appear to be below the base of Tertiary deposits. The potential risk of the void water escaping the pit through Tertiary deposits is therefore low at the north side. Without available Quaternary deposit information, the potential risk that void water can reach the Quaternary deposits and escape through alluvial deposits to Spade Creek at the south side of the pit cannot be excluded.

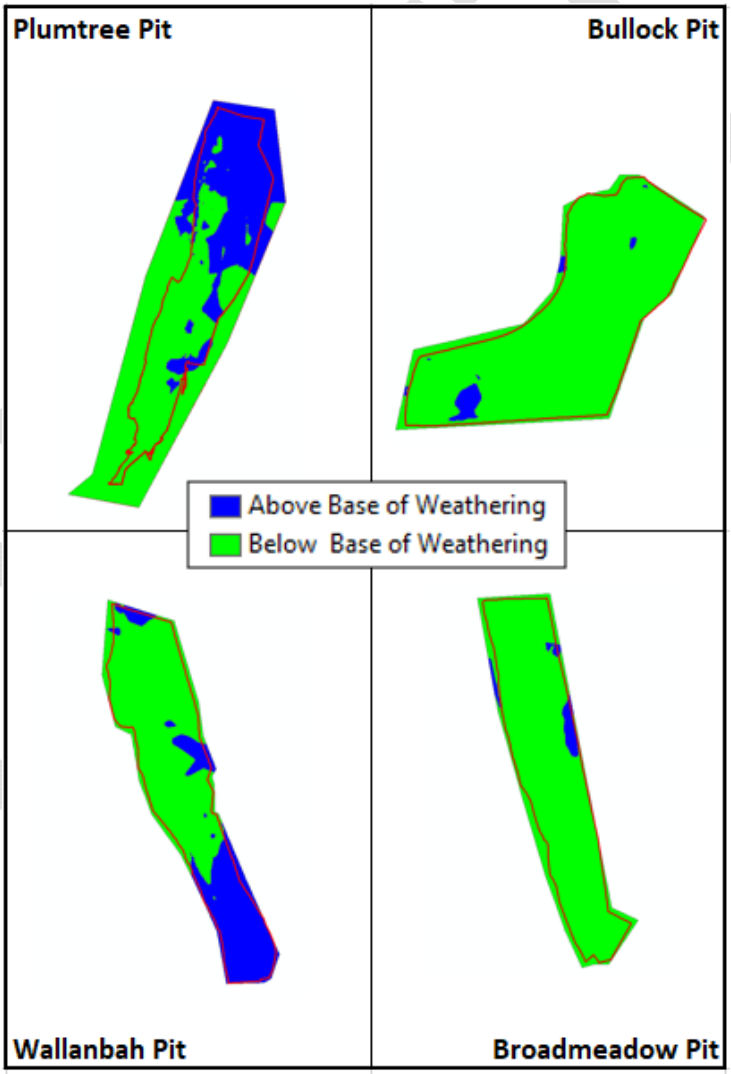

Figure 7.1: Comparison of Base of Weathering and Maximum Void Water Levels

III-8 CONCLUSIONS

Based on the 2D groundwater modelling exercise and the results of final void water level simulations, the following conclusions are made.

1. Most of the pits showed a strong correlation between void water levels and the groundwater levels in close proximity to the pits, with less than 10 m difference between void water levels and surrounding bore water levels. This implies relatively low hydraulic gradients between the void water levels and the surrounding groundwater system and therefore low groundwater inflow rates should be expected under current conditions.

2. A slight increasing trend was observed in void water levels and some bore water levels after 2012 which indicates a slow rebound of groundwater levels after cessation of mining activities.

3. Based on the EC values of surrounding bores ranging from 9,420 to 31,400 uS/cm, groundwater quality is considered poor, and not suitable for livestock watering.

4. 2D numerical groundwater model simulations, using various combinations of groundwater levels and void water levels, confirmed that in general, low inflow rates (0.2 L/s to 8.6 L/s) are likely under existing aquifer and void conditions. Only two cases for the Wallanbah pit precited outflow may occur (2.5 L/s to 3.3 L/s).

5. As expected, sensitivity simulations using higher permeability values for the Rangal Coal Measures and Triassic Rewan Formation resulted in increases flow rates being predicted. Inflow rates increased to between 1.1 L/s and 26.5 L/s and predicted outflow rates increased to 16.7 L/s to 23.7 L/s.

6. Groundwater modelling inflow results were reported to the surface water team to model the final void water levels under various hydrologic conditions. The maximum final void water levels were simulated to vary from 260 mRL to 307 mRL.

7. Based on the maximum void water levels and the available geology information, Plumtree pit, where the simulated void maximum water levels (maximum catchment yield case – 307 mRL) showed potential risk for void water escaping to the surrounding formation at the north and northeast sides of Plumtree Pit. At the northeast corner, the topographic elevation is around 310 mRL, which implies a resulting void water level of 3m below surface and likely reaching the base of Quaternary deposits. Also, a 1: 100,000 scale geology map indicate Quaternary deposits associated with Sandy Creek. More detailed information regarding the base of the alluvial deposits would enable the potential risk to be further evaluated.

8. The maximum final void water level (304 mRL) of the Bullock pit simulated under maximum groundwater inflow case is generally below the base of weathering and therefore not a risk.

9. The maximum final void water level of the Wallanbah Pit was simulated below 274 mRL and therefore below the base of Tertiary deposits (>287 mRL). The potential risk of void water escaping from the Wallanbah Pit was evaluated as low in the final void area. The potential risk that void water escaping from the south side through the spoils to the

weathered rock / Quaternary deposits is considered as high. The modelled void water level (274 mRL) is about 10 m above the base of weathering (around 263mRL to 265mRL) at the south side of the Wallanbah pit. Further information regarding the base of the alluvial deposits would enable the potential risk to be further evaluated.

10. There is also a potential of pit water flowing from the south side of Wallanbah Pit to the north of Broadmeadow Pit through spoils and the Coal Measures.
11. The final void water levels of Broadmeadow pit were simulated generally below the base of weathering and therefore outflow risk is low.

III-9 CLOSING

This is a draft report only and we solicit your review and comments within 4 weeks of submission. Upon issue of the final report, we request that all draft reports be destroyed or returned to Klohn Crippen Berger Ltd. This draft report should not be relied upon as a final document for design and/or construction.

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DRAFT

APPENDIX IV

Ecology Report

Assessment of Residual Void Water Capability to Support Native Flora and Fauna

Burton Coal Mine

November 2018

Prepared for:
Klohn Crippen Berger

Version 1.0 FINAL

Prepared by:

GAUGE Industrial & Environmental Pty Ltd
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Executive Summary

This report assessed the capability of residual voids at Burton Coal Mine to support native flora and fauna, and suggests potential structural improvements to enhance the aquatic ecosystem.

Modelling of four mine voids predicted at equilibrium they will have a minimum salinity of EC 4,570 – 6,740 (µS/cm), and concentrate to maximum EC 11,280 – 16,190, with the exception of the more saline Bullock Pit which will range from EC 16,430 – 61,850.

The modelled salinity is expected to support native flora and fauna, including fish, invertebrates, macrophytes, algae, amphibians, and birdlife, and not affect fringing vegetation. The voids will provide a permanent aquatic habitat to serve as a wildlife refuge in an otherwise highly ephemeral system. The aquatic community will be limited in diversity to those species with at least moderate salt tolerance. Bullock Pit is likely to support only highly to extremely salt tolerant taxa particularly at the middle to upper predicted range.

The variety of species and the number of individuals present will be cyclical in nature. More diverse communities recruited during low salinity periods are expected to diminish to a less diverse, salt

tolerant community as salinity increases, and with seasonal changes in salinity stratification. This assessment was limited to salinity influences on flora and fauna, as other water quality parameters were not included in the modelled conditions.

The aquatic habitat can be enhanced by considering structural features of the voids that provide a more suitable and diverse physico-chemical and physical habitat. The key features for improvement are the inclusion of:

(1) significant areas of shallow, littoral (near shore) zones,

(2) a stable and vegetated riparian zone,

(3) water plants in the littoral zone,

(4) diverse aquatic structures, and

(5) access to periodic fresh water inputs, preferably with connection to local waterways (if practical/safe).

1. Scope

Gauge Industrial and Environmental Pty Ltd was engaged by Klohn Crippen Berger (KCB) to assess the capability of Burton Coal Mine's residual voids to support native flora and fauna, based on projected salinity levels, and to consider opportunities to structurally improve voids for flora and fauna.

2. Modelled Void Water Quality

Burton Coal Mine (BCM), a coal mining operation in the Central Queensland, in currently under care and maintenance. The mine has four (4) residual voids containing water after mining, located in the southern extent of the mine:

- Broadmeadow Pit
- Bullock Pit
- Plumtree Pit
- Wallanbah Pit

The location, final landforms and estimated volumes for each void (KCB, 2018) are shown in Appendix A.

The void water will contain analytes associated with coal mining, particularly salts from the Permian and Tertiary age strata and ongoing groundwater inflows. In November 2018, KCB (2018) modelled these voids to predict their salinity once hydraulic equilibrium is reached (Table 1). For all voids except Bullock Pit, salinity is expected to be at least EC 4,570 – 6,740 (µS/cm) and up to a maximum

EC 11,280 – 16,190. Bullock Pit is expected to be considerably more saline ranging from EC 16,430 – 61,850.

Table 1 – Void Estimate Volumes and Predicted Salinity

	Volume Range (GL)[1]			Modelled Salinity (µS/cm [1]EC)	
Void	**2018 Level**	**Control Level**	**Crest Level**	**Minimum**	**Maximum**
Broadmeadow Pit	6.7	13.0	16.4	6,740	16,190
Bullock Pit	2.9	4.5	6.8	16,430	61,850
Plumtree Pit	5.8	7.6	21.9	4,570	11,670
Wallanbah Pit	5.9	8.0	20.5	4,590	11,280

*Source: KCB (2018). [1]EC = Electrical Conductivity.

In addition to long term accumulative changes, seasonal variation in salinity will arise from brief rainfall inputs providing fresher water followed by evaporation during mainly dry periods.

Salinity is also expected to stratify in the significant void depths, and seasonal temperature fluctuations may cause some inversion mixing of salinity within a void.

Other water quality parameters, such as pH and heavy metals, were not modelled, and this assessment is limited to salinity measured as Electrical Conductivity (EC), and does not include chemical interactions or variations in ionic composition.

3. Capability to Support Flora and Fauna

3.1 General

Some species have a capacity to tolerate saline conditions, although increased salinity is generally associated with lower aquatic biodiversity (Dunlop, et al., 2005). Ecotoxicology studies found salinity levels up to EC 2,000-2,500 (as µS/cm) provide 95% protection for aquatic species in the Fitzroy Basin (Prasad, et al., 2012). Above these salinities, mildly to highly salt tolerant flora and fauna tend to dominate.

Variations in salinity caused by seasonal changes and droughts may have short to median term impacts on flora and fauna individuals and populations.

The streams near the mine are highly ephemeral with species present before mining limited to those adapted to the seasonal and drought cycles whereby the available aquatic habitat is minimal and short-lived. The residual voids are a permanent aquatic habitat which can potentially support native species in all seasons and during drought, and serve as a wildlife refuge that would otherwise not be available in the area. Although the voids are usually hydrologically isolated from local waterways, recruitment of native species can occur via stocking, water birds and aerial invertebrates.

3.2 Fish

Most native freshwater fish are derived from recent marine ancestors and are tolerant of salinities up to EC 14,000 – 19,000 or greater, although adverse effects on eggs can occur at EC 3,000-6,600 (Hart et al, 1991; Bacher and Garnham, 1992; Dunlop, et al, 2005; Nielsen, et al, 2003). Optimal juvenile fish growth, survivorship and sperm motility occurs between EC 6,600-7,300 (Dunlop, et al, 2005). Native fish common to the area (DERM, 2010) include species tolerant of salinities greater than EC 15,000 and up to EC 40,000 (Pusey, et al, 2004).

The less saline voids (Broadmeadow, Plumtree and Wallanbah pits) are expected to support breeding native fish when salinity is in the mid-low range (EC 4,570-6,740), and support the growth of established or recruited individuals when salinities are at a maximum (up to EC 16,190). After prolonged dry periods, as salinities reach the maximum, diminished fish breeding may reduce numbers, however the voids are expected to support a variety of native fish species. The higher salinity in Bullock Pit will support saline tolerant native species recruited to the void, however fish breeding is expected to be limited.

3.3 Invertebrates

Elevated salinities can be lethal to small, multicellular organisms (e.g. flatworms) and macroinvertebrates without impermeable exoskeletons (e.g. gastropods). A general threshold of EC 3,000 produces lethal effects in microinvertebrates, and adverse effects on macroinvertebrates, particularly those without impermeable exoskeletons (Dunlop, et al., 2005). However, many native macroinvertebrate species are of marine ancestry, and relatively tolerant of elevated salinity (Dunlop, et al., 2005). Marshall and Bailey (2004) challenged numerous taxa in lowland streams to increased salt concentrations between approximately EC 1,500 and EC 5,000. They found most taxa (88%) were unaffected by salinity, and a minority (12%) were significantly reduced in numbers at EC 2,200. Although diversity decreases rapidly as salinity approaches EC 15,000, the rate of decrease slows above this level (Nielsen, et al, 2003).

A study of eleven mine pit lakes in the Collie Basin (Western Australia) found they were inhabited by a low to moderate diversity of macroinvertebrates, especially those with a winged adult stage, even within a year or two of mine closure (Zhao, 2011).

The modelled salinities in the voids are expected to affect sensitive invertebrates, particularly microinvertebrates. As salinity increases to maximum concentrations (EC 11,280-16,190), a shift to moderately to highly salt tolerant communities is likely, with a subsequent reduction in species diversity. As invertebrates have short lifecycles, and many macroinvertebrates are aerially mobile, a more diverse macroinvertebrate community is expected to re-establish following fresh water inputs. Bullock Pit will support the moderately to highly tolerant species, and be limited to extremely tolerant invertebrates when salt levels are in the upper range (up to EC 61, 850).

3.4 Macrophytes and Algae

Freshwater algae are sensitive to increasing salinity although some have adopted life stages and undergo morphological and physiological changes to survive a broad range of salinities (Nielsen, et al, 2003). The majority of algae do not tolerate salinities above EC 15,000 (Bailey and James, 2000).

Aquatic macrophytes (water plants) are susceptible to raised salinity, with sub-lethal effects (lethal to some species) occurring at salinities above EC 1,500-3,000; and the upper limit for most freshwater macrophytes being EC 6,000 (Nielsen, et al, 2003; Dunlop, et al, 2005). Salt tolerant native species such as *Ruppia* spp and *Lepilaena* spp species tend to dominate above EC 6,000 (Nielsen, et al, 2003).

The voids are expected to support some salt tolerant algae, and if macrophytes are present, salt tolerant species will dominate.

3.5 Amphibians

Amphibians are particularly sensitive to salt, although the limited tolerance data available (for *Rana esculenta* and *Rana temporaria*) suggests salinities above EC 10,000 are tolerable (Dunlop, et al., 2005).

3.6 Fringing Vegetation

The Hart, et al (1991) review of salinity effects on riparian trees (limited to Eucalyptus, Melaleuca and Casuarina species) indicates salt-sensitivity starts around EC 3,000, and with the majority of species (including *Eucalyptus tereticornis*) sensitive at approximately EC 9,000, and some species tolerating EC >22,000. A south-east Queensland study found many native trees were moderately to highly salt resistant, requiring root zone salinities of ECse[1] 6,000-14,000 to inhibit growth by 25% (Dunn, et al., 1994). *Eucalyptus tereticornis* and *Casuarina cunninghamiana* are considered tolerant of soil salinities up to EC 8,000-12,000 (QDPI, 1998; FAO, 2002; Anderson, 2003). Riparian species such as *Eucalyptus camaldulensis* and *Melaleuca halmaturorum*, with extensive root systems in contact with several sources of subterranean water of varying salt concentrations, have been observed to utilise the less saline microhabitats (James, et al., 2003).

The modelled void salinities are expected to provide a source of water tolerable to support salt tolerant fringing riparian vegetation with root systems deep enough to access the void. As salinities increase toward the maximum, the void water may become too saline for all but the most salt tolerant species.

The Brigalow (*Acacia harpophylla*) vegetation common to the area have relatively shallow, spreading roots (up to 4 metres) (CSIRO, 2003) and are unlikely to access the voids except possibly in low wall areas, and are therefore unlikely to be affected.

[1] ECse is the electrical conductivity of a saturated soil extract. Using irrigation water conversions provided in ANZECC (2000 p 4.2-6), average root zone salinities (loam soil) of ECse 1,360 equate to EC1,000 in water.

3.7 Birds

The voids are expected to support native bird life as a source of food (e.g. fish, algae and crustaceans), and if necessary, their mobility allows them to use alternative, fresher water sources for drinking.

4. Structural Improvements for Flora and Fauna

The ecological requirements of biota in mining voids for food and habitat are rarely studied and poorly understand, although they are likely to be very similar to those of natural systems (McCullough and Van Etten, 2011). A sustainable aquatic habitat relies not only on the provision of tolerable salinity and broader water quality, but also adequate air, sunlight, nutrients, temperature regulation, shelter and substrate. The structure of a voids' final landform can greatly improve their ecological value by providing these essential elements. A functioning ecosystem may also improve the water quality over time, for example by countering the negative effects of sulfates and metals (McCullough and Van Etten, 2011).

In reviewing mining voids world-wide, Blanchette and Lund (2016) concluded steep, highly mobile banks and the absence of fringing/riparian vegetation create an aquatic "desert", starving the void of nutrients and habitat complexity.

They suggest that pits should be sculpted, as with terrestrial spoil piles, to match the critical components of a natural lake, namely the formation of littoral (close to shore) areas and extending the landscape contouring beyond the void shoreline to an integrated catchment to facilitate passive input of clean water and allochthonous carbon (e.g. leaf litter). Adding organic material and promoting sustained aquatic biomass growth allows for pit lakes to act as sinks for atmospheric carbon dioxide and further promote aquatic growth.

The Burton Mine's final voids are steep sided, deep excavations at 50-100 metres at their deepest point, depending on the water level (KCB, 2018, see Appendix A). The voids are unlike natural lakes which have a lower depth to surface & catchment area ratios (Zhao, et al., 2009) and receive significant input from waterways. Broadmeadow Pit has a shallower section up to 30 metres, and at current water levels, Plumtree Pit contains a shallower bench of up to 20 metres deep, and if water levels rise another 20 metres, it will inundate a 2,000-metre low gradient bench on the spoil dump surface.

Deep water limits light penetration and the growth of algae and aquatic macrophytes (water plants). Salinity, oxygen and temperature stratification occur in deep water bodies, particularly in summer when the upper layer is warmer and more oxygen enriched by air/wind, and the lower layer contains significantly higher salinity and lower dissolved oxygen (Zhao, et al., 2009). In winter this stratification can reverse with colder surface water sinking and forcing a turnover in water from the bottom.

Voids with steep sides and bases, and lacking in shallow, littoral zones, limit the opportunity for the establishment of aquatic and fringing vegetation which would otherwise provide a significant source of food and shelter. Graduated shallow zones facilitate a variety of temperatures and sunlight levels, and provide a structure and substrate to harness nutrients to establish an ecosystem.

The key structural improvements that can enhance aquatic environment of the voids include the following (Gammons, et al, 2009; McCullough and Schulte, 2015; Zhao, et al., 2009; Blanchette and Lund, 2016):

1. Shallow, littoral areas – provides habitat, sunlight, substrate, structure, oxygen transport, temperature range, critical zone for juveniles and invertebrates. Providing zones and maintaining water at levels where large areas of shallow, littoral habitat are inundated, will greatly enhance the aquatic environment.
2. Stabilised banks and riparian vegetation – provide shade, nutrients, detritus, structures (logs, branches, leaves), food source, and substrate for burrowing fauna. Contour and secure banks with nutritious substrate/top soil for sustainable growth of native riparian flora.
3. Water plants (emergent, submerged, floating) – provides a food source, structure, shelter, nutrients, detritus and oxygen. Introduce, or allow for the establishment of, native water plants where there is sufficient light and substrate.
4. Submerged and emergent structures (logs, rocks, mounds, shelves, islands, etc) – provide shelter and surface area for the growth of algae/plants and attachment of eggs, etc. Establish these structures to give variety if the benthic profile is bare.
5. Fresh water inflows from a vegetated catchment area – improves water quality, introduces nutrients and recruits new species (if connected to a waterway). Consider if possible, practical and environmentally safe.

5. Conclusion

The predicted salinity of the residual voids is expected to support native flora and fauna, including fish, invertebrates, macrophytes, algae, amphibians and birdlife, and not affect fringing vegetation. The voids will provide a permanent aquatic habitat to serve as a wildlife refuge in an otherwise highly ephemeral system.

The aquatic community will be limited in diversity to those species with at least moderate salt tolerance. The more saline Bullock Pit will primarily support highly salt tolerant species and likely to have very low diversity. The variety of species and the number of individuals present will be cyclical in nature, with more diverse taxa recruited when salinities are lowest, and transitioning to a less diverse, salt tolerant community during extended dry periods when salinities increase to maximum concentrations and with seasonal changes from salinity stratification.

Structural features of the voids enhance the aquatic habitat by providing a more suitable and diverse physico-chemical and physical habitat. The key features for improvement are the inclusion of (1) significant areas of shallow, littoral zones, (2) a stable and vegetated riparian zone, (3) the presence of water plants in the littoral zone, (4) the presence of diverse aquatic structures, and (5) access to periodic fresh water inputs, preferably with connection to local waterways (if practical/safe).

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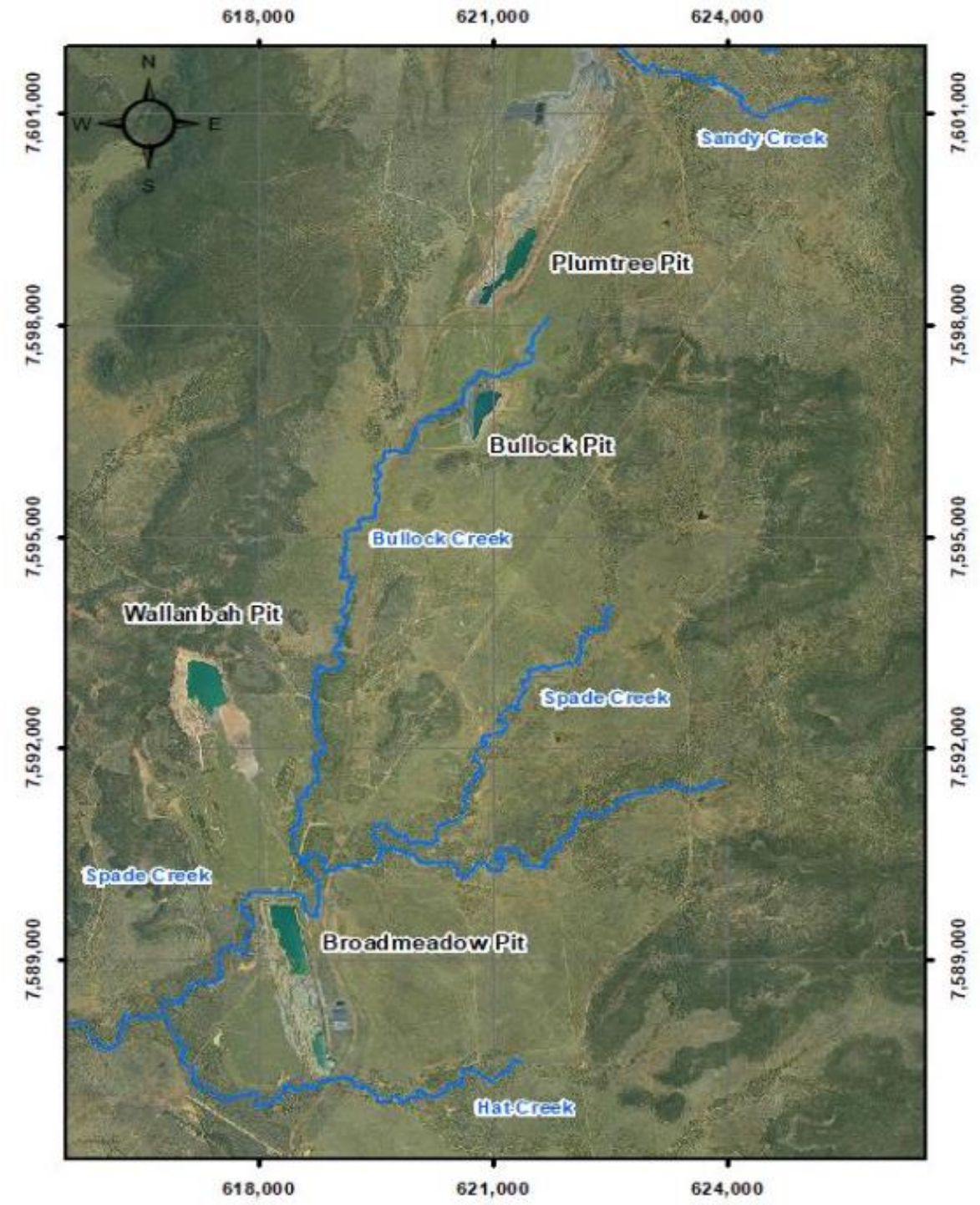
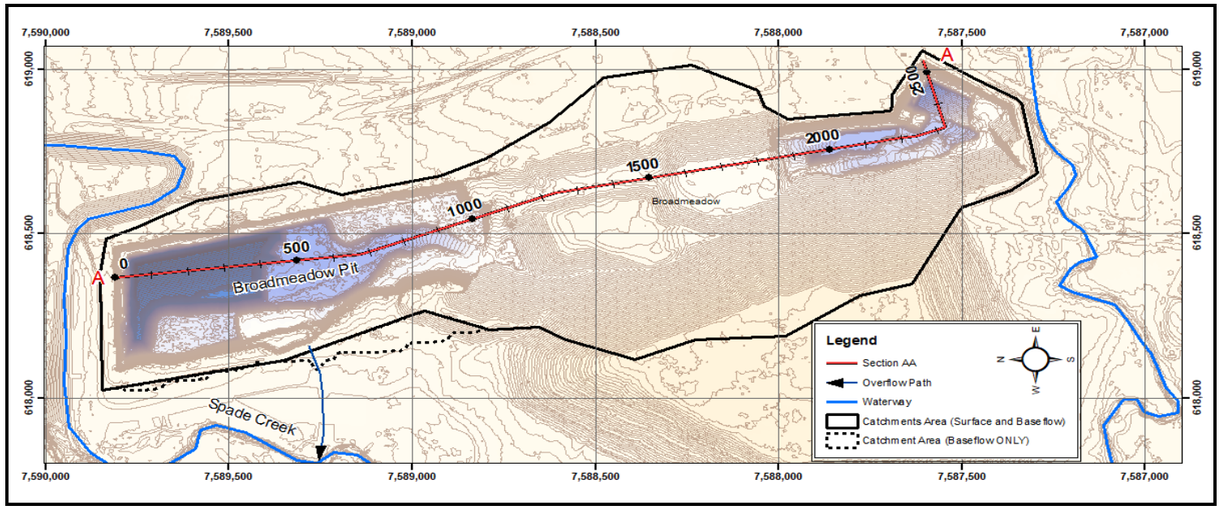
Appendix A – Void Location, Volume and Final Landform

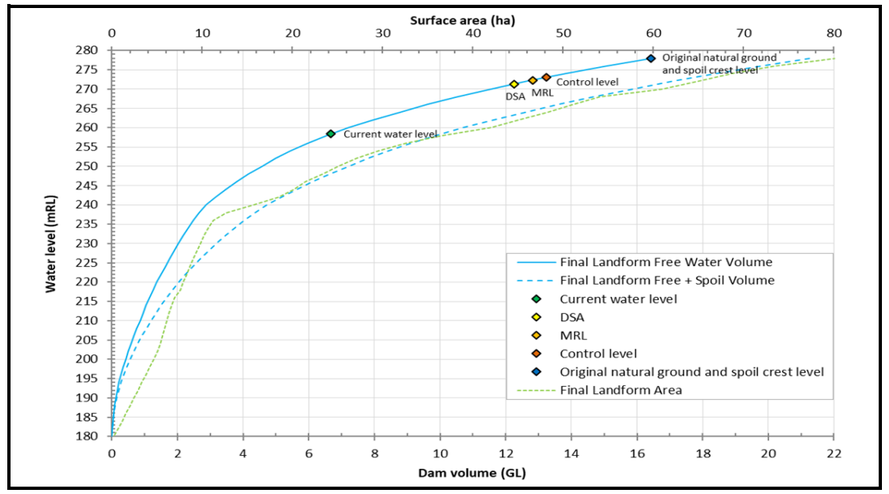
Source: KCB (2018)



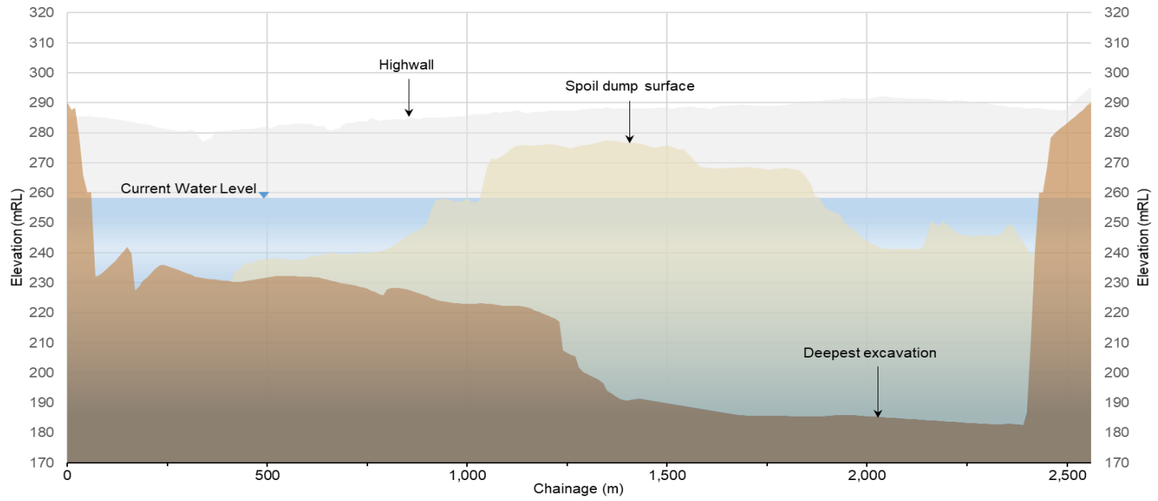
Locality and Catchment Plan



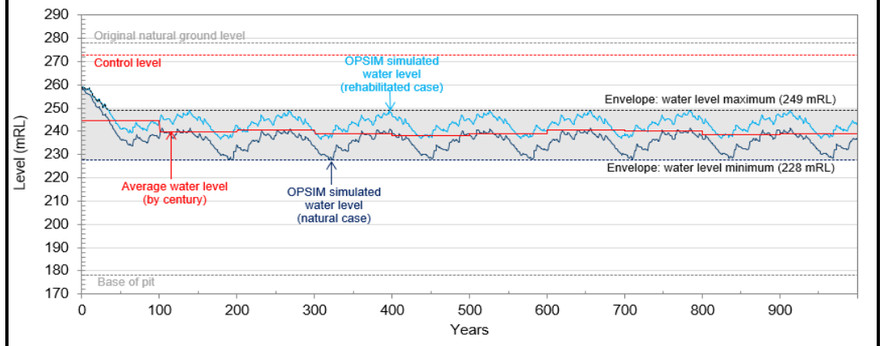
Stage Storage Curve



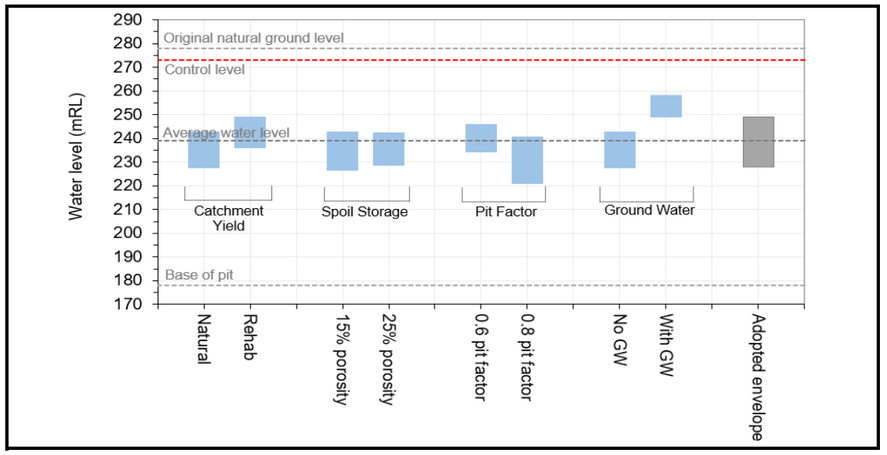
Cross Section AA



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section AA and Stage Storage Curve

Current Broadmeadow Pit final void comprises two visible pit lakes with a spoil dump located between both lakes (i.e. chainage 1,000 to 1,850 m).
The original natural ground level has nominal elevations ranging from 180 to 230 mRL with the spoil crest level raised to an elevation of 280 mRL.
The water surface of the two pit lakes would join above 277 mRL.
Currently, both pit lakes are at the same water level indicating the strong connection between the two pits through the spoil material. As such, the two pit lakes have been configured to rise and fall together due to the cross connection through the intervening spoil material.
The lowest elevation at which surface water would overflow from Broadmeadow Pit void is nominally at 278 mRL (i.e. low wall low point). Flows would drain west towards Spade Creek.
Highwall areas are shown in grey tones are not located on Section AA, but would be visible from Section AA if looking towards the east.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.

Catchment Area (ha)	**146**	(Surface + baseflow)
	3	(Baseflow only)
Base of Mining (mRL)	**178.0**	
Control Level (mRL)	**273.0**	(Nominal 5 m below pit crest level)
Current Water Level (mRL)	**258.35**	(within both pits)

Time to Equilibrium	**100**
Maximum Water Level (mRL)	**249**
Minimum Water Level (mRL)	**228**
Average Water Level (mRL)	**239**

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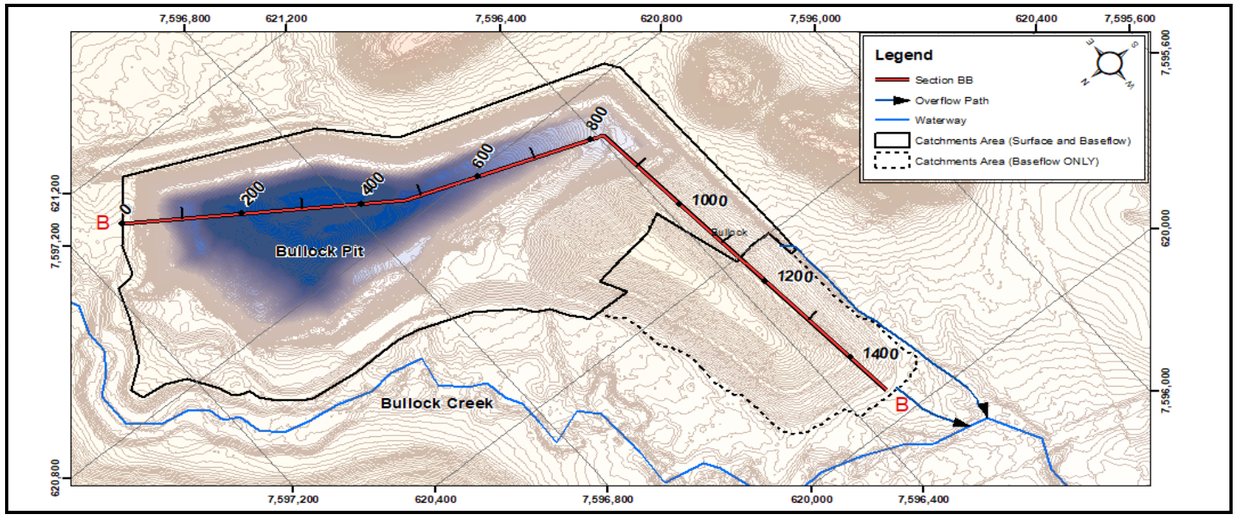
CLIENT: Peabody ENERGY; Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

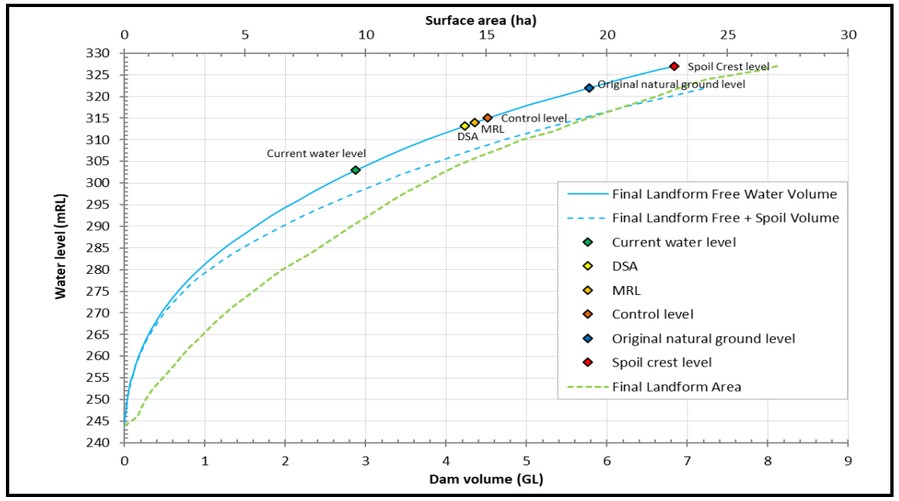
TITLE: FINAL VOID DATA SHEETS
BROADMEADOW PIT

PROJECT No. D10242A01

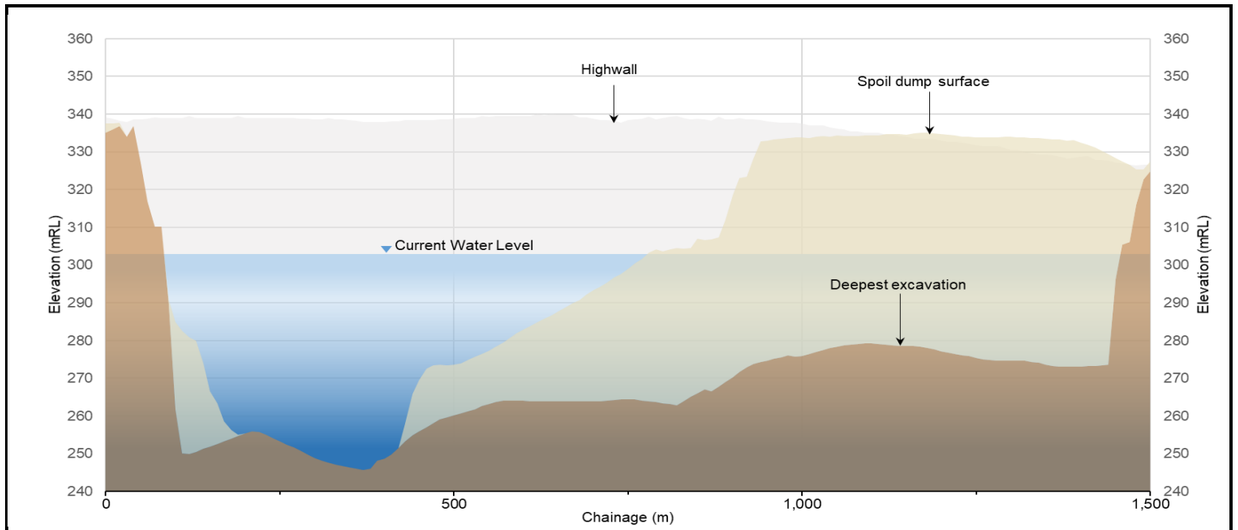
Locality and Catchment Plan



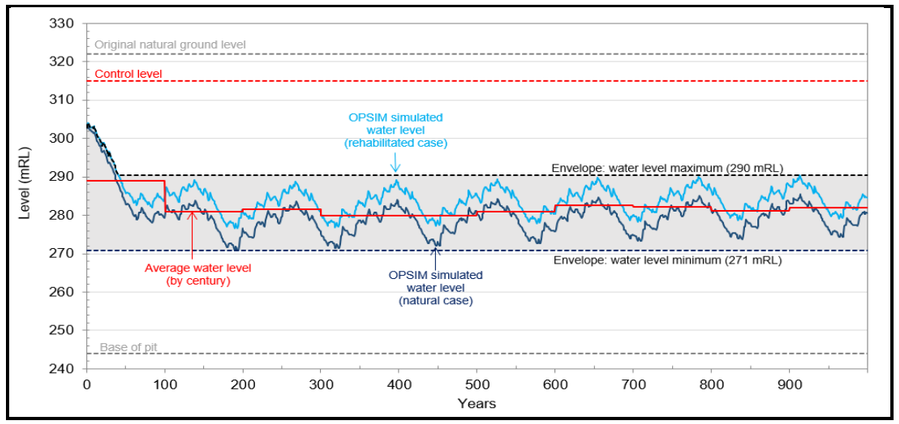
Stage Storage Curve



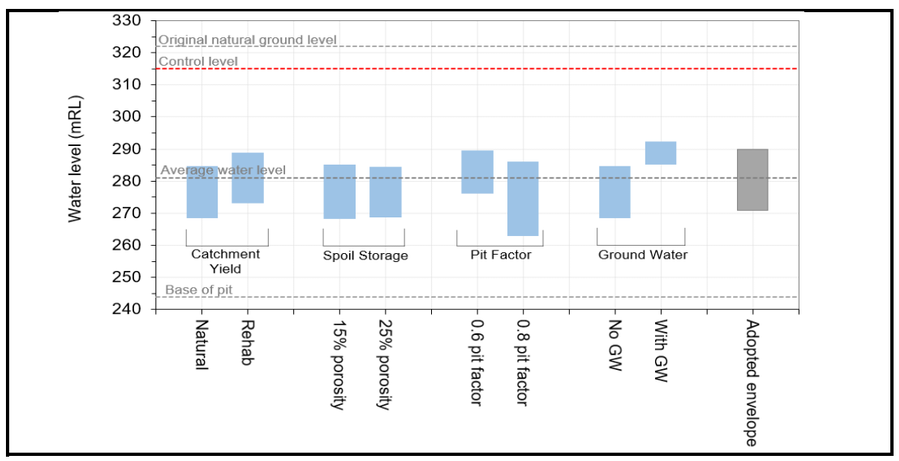
Cross Section AA



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section BB and Stage Storage Curve

Bullock Pit extends in a north-south direction from chainage 0 to 820 m and then extends to the west from chainage 820m to 1485m.
The lowest elevation at which water would overflow from Bullock Pit void is nominally at 322 mRL.
At 322 mRL, water would overflow from two locations towards Bullock Creek.
Highwall areas are shown in grey tones are not located on Section CC. The highwall is visible from Section CC if looking towards the east from chainage 0 m to 820 m and to the south from chainage 820 m to 1485 m.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.

Catchment Area (ha)	39	(Surface + baseflow)
	11	(Baseflow only)
Base of Mining (mRL)	244.0	
Control Level (mRL)	315.0	(Geotechnical advise)
Current Water Level (mRL)	302.95	

Time to Equilibrium	100
Maximum Water Level (mRL)	290
Minimum Water Level (mRL)	271
Average Water Level (mRL)	281

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CLIENT: Peabody ENERGY

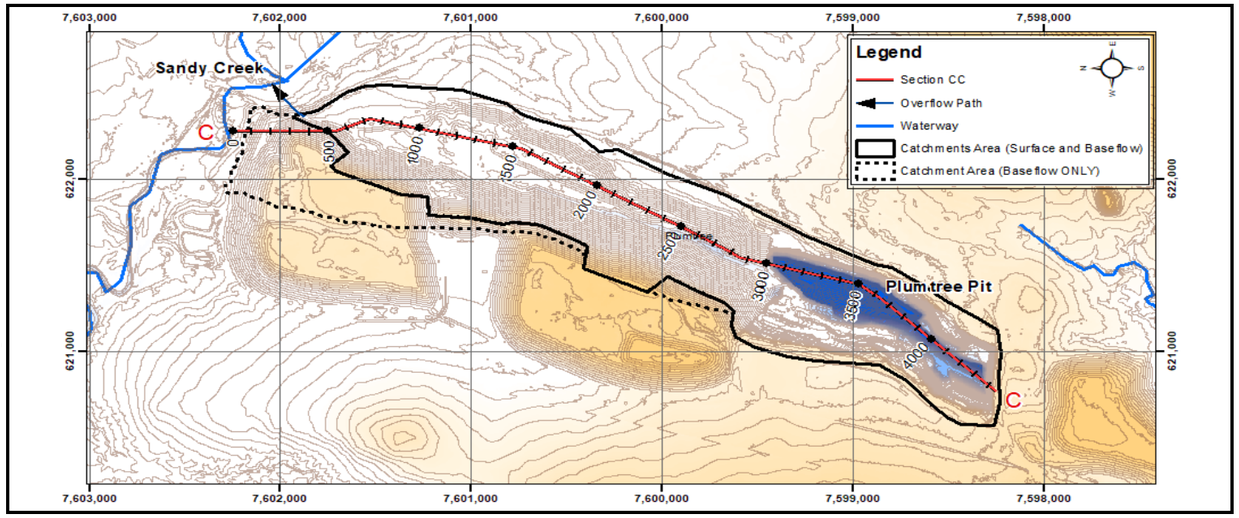
Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

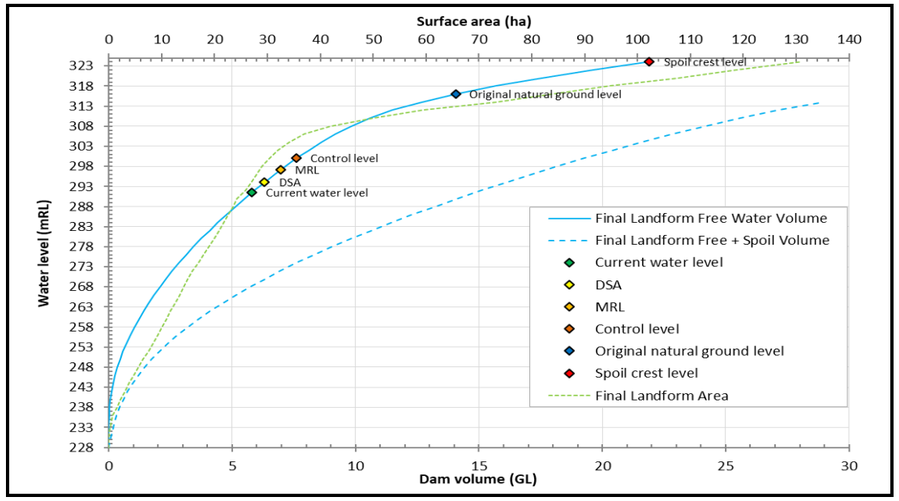
TITLE: FINAL VOID DATA SHEETS
BULLOCK PIT

PROJECT No. D10242A01

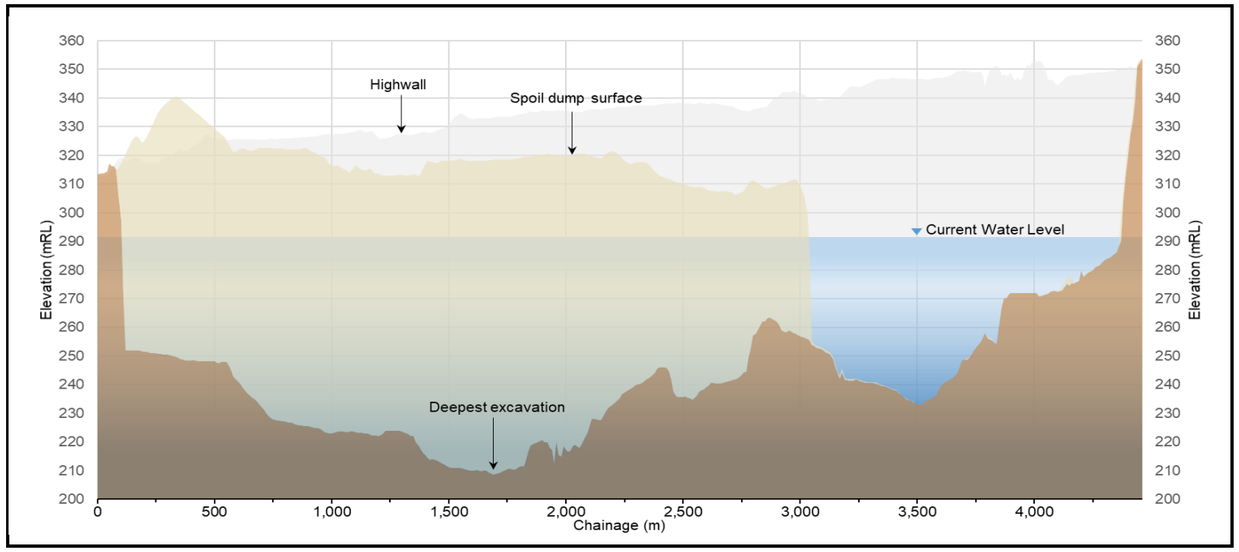
Locality and Catchment Plan



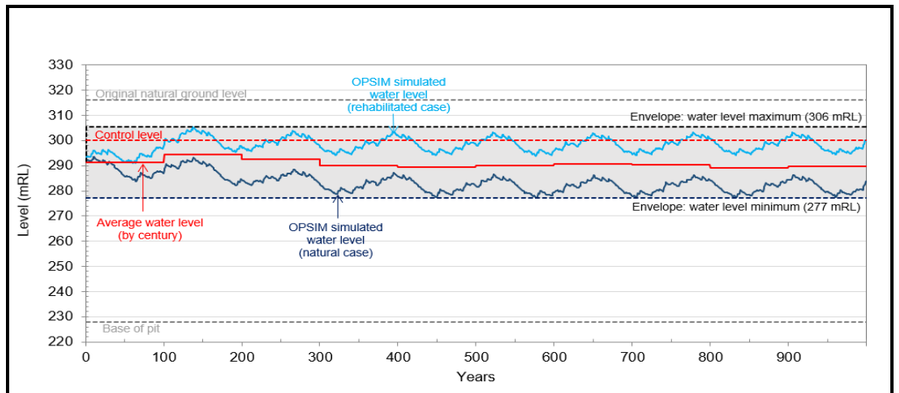
Stage Storage Curve



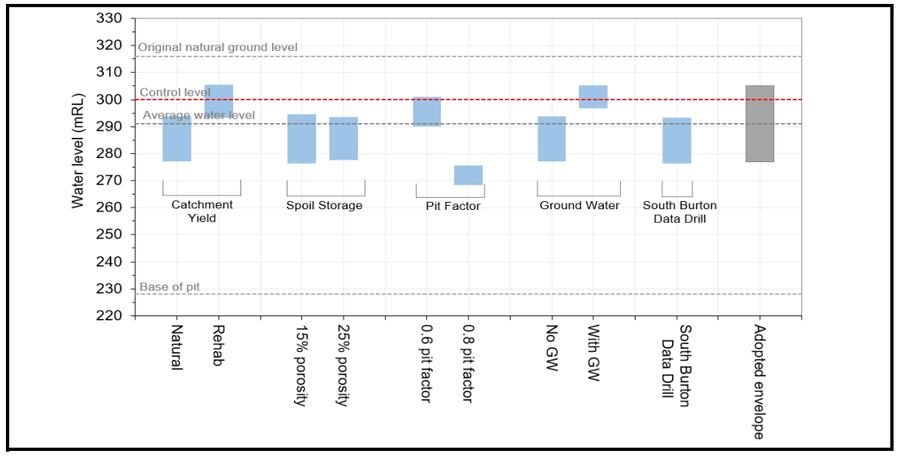
Cross Section AA



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section CC and Stage Storage Curve

The pit lake surface area within the void is relatively narrow from the pit floor up to approximately 311 mRL.
The surface area opens up and increases significantly from approximately 311 mRL.
The original natural ground level has a nominal elevation of 316 mRL with the spoil crest level raised to an elevation of 324 mRL.
At 316 mRL, flows would drain west towards Sandy Creek.
Highwall areas are shown in grey tones are not located on Section BB. The highwall is visible from Section BB when looking towards the east.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.
Data Drill location sensitivity cases assumed a natural catchment, a pit factor of 0.7, a spoil porosity of 20% and no ground water inflow.

Catchment Area (ha)	232	(Surface + baseflow)	Time to Equilibrium	-
	45	(Baseflow only)	Maximum Water Level (mRL)	306
Base of Mining (mRL)	228.0		Minimum Water Level (mRL)	277
Control Level (mRL)	300.0	(Geotechnical advise)	Average Water Level (mRL)	291
Current Water Level (mRL)	291.54			

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CLIENT: Peabody ENERGY

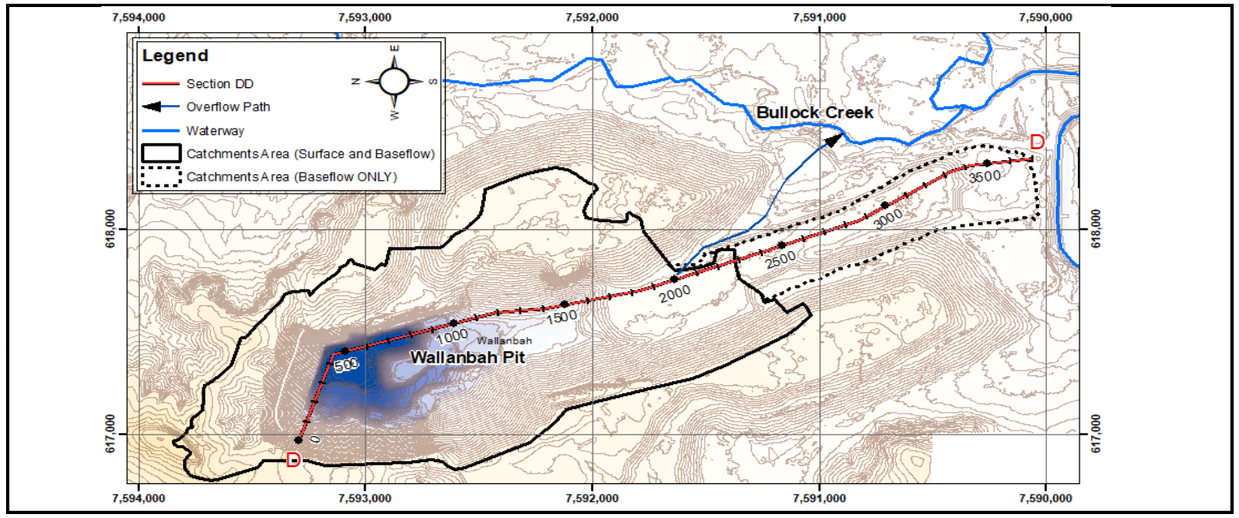
Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

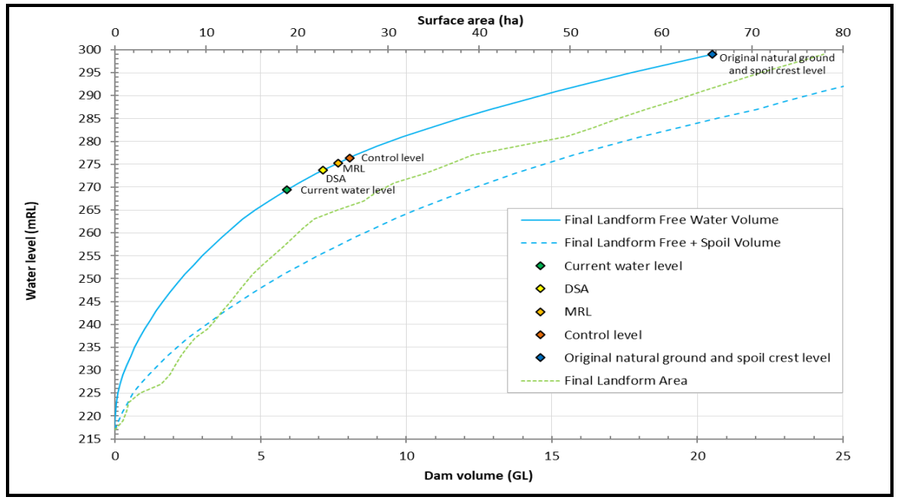
TITLE: FINAL VOID DATA SHEETS
PLUMTREE PIT

PROJECT No. D10242A01

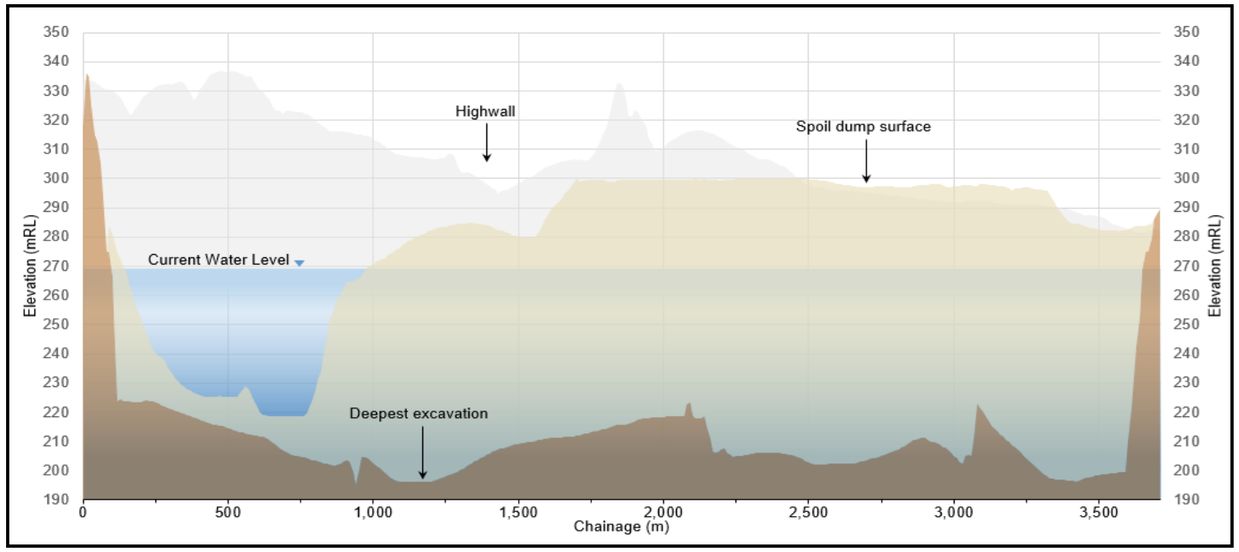
Locality and Catchment Plan



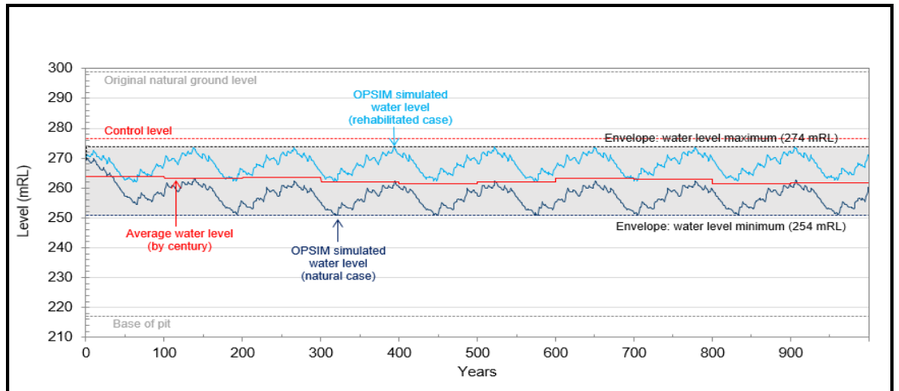
Stage Storage Curve



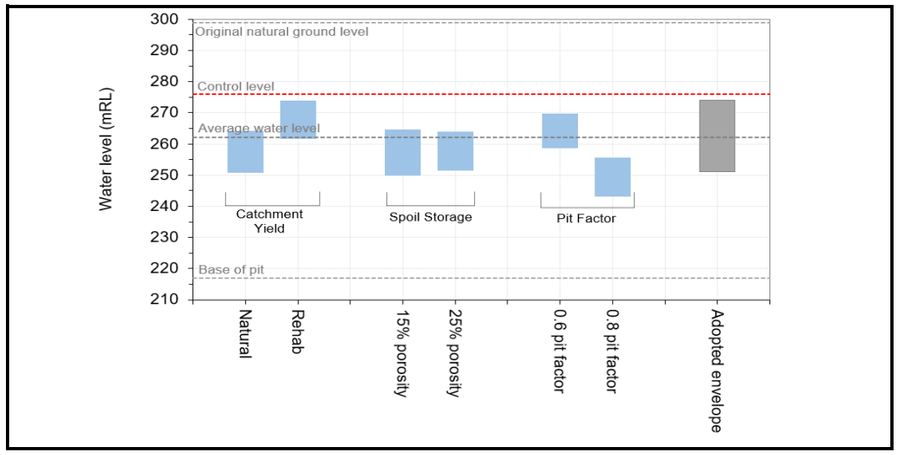
Cross Section AA



Final Void Water Levels



Sensitivity Cases



Notes:

Locality and Catchment Plan, Cross Section DD and Stage Storage Curve

The lowest elevation at which surface water would overflow from Wallanbah Pit void is nominally at 299 mRL.
At 299 mRL, water would overflow from two locations towards Bullock Creek.
Highwall areas are shown in grey tones are not located on Section DD, but would be visible from Section DD if looking towards the east.

Sensitivity Cases

Catchment yield sensitivity cases assumed 20% porosity, a 0.7 pit factor and no ground water inflow.
Spoil storage sensitivity cases assumed a natural catchment, a pit factor of 0.7 and no ground water inflow.
Pit factor sensitivity cases assumed a natural catchment, a spoil porosity of 20% and no ground water inflow.
Ground water sensitivity cases assumed a natural catchment,a pit factor of 0.7 and a spoil porosity of 20%.

Catchment Area (ha)	222	(Surface + baseflow)
	42	(Baseflow only)
Base of Mining (mRL)	217.0	
Control Level (mRL)	276.4	(Nominal 5 m below Bullock Creek Bed level)
Current Water Level (mRL)	269.38	

Time to Equilibrium	-
Maximum Water Level (mRL)	274
Minimum Water Level (mRL)	254
Average Water Level (mRL)	262

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CLIENT: Peabody ENERGY; Klohn Crippen Berger

PROJECT: BURTON COAL MINE - FINAL VOID HYDROLOGY STUDY

TITLE: FINAL VOID DATA SHEETS
WALLANBAH PIT

PROJECT No. D10242A01

Appendix P

Pit evaporation factor investigation



Klohn Crippen Berger

27 August 2020

Peabody Energy Australia
Burton Coal Mine
Sutor Development Road
Burton, Queensland
4743

Justin Vohland
Environment Manager / SSE – Burton Mines

Dear Mr. Vohland:

Burton Coal Mine
Pit Evaporation Factor Investigation

1 INTRODUCTION

Burton Coal Mine (BCM) is an open cut coal mine in Queensland's Bowen Basin which is owned and managed by Peabody Energy Australia (Peabody). Since early 2017, the mine has been in care and maintenance with rehabilitation and closure activities being undertaken. Peabody is responsible for the rehabilitation and closure planning of the residual or final voids remaining within the Plumtree, Bullock, Wallanbah and Broadmeadow Pits.

In accordance with the BCM environmental authority (EA), Peabody has prepared a management plan for these residual voids which included a final void hydrology study undertaken by KCB Australia Pty Ltd (KCB) in December 2018. This final void hydrology study established long-term fluctuations of water levels within the pit lakes[1] to understand the likelihood that water will be released to the downstream receiving waterways via overtopping of the pit crest or seepage to the groundwater system (i.e. via shallow alluvial aquifers).

The final void hydrology study included:

- Development of an OPSIM[2] water balance model (WBM) for the final voids (referred in herein as the final void WBM);
- Predictive modelling for each final void to estimate:
  - Time taken to reach equilibrium[3];
  - Climate driven pit lake water level variations once equilibrium conditions have been achieved;

[1] For the purpose of this letter, the final void refers to the last remaining pit and associated ramps, while the formation of a water body within the final void is referred to as a pit lake.
[2] The OPSIM software is a general-purpose simulation model for water resource systems. It is industry accepted and primarily used for mine site water management applications through Australia.
[3] Equilibrium condition is the term used to describe the conditions in the void when a stable range in the water level is reached. At this time, the water level within the void may fluctuate due to seasonal changes, however, the long-term water level trend will not continue to accumulate or deplete over time.

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- How outcomes of the items above may be affected by uncertainty associated with predictive model inputs and/or parameters (e.g. sensitivity analysis); and
- Reporting of outcomes in a final void hydrology study report (referred to herein as the final void report).

As part of the final void hydrology study (KCB 2018), the sensitivity of the long-term fluctuations of water levels within each pit lake was assessed for pit evaporation factors ranging from 0.6 up to 0.8 based on available research.

Since the completion of the final void hydrology study, recent local research has further highlighted the uncertainty in pit evaporation factors and suggested that ranges up to 1 may be applicable to final voids remaining after open cut strip mining.

As a result of this recent research, Peabody have engaged KCB to undertake this pit evaporation factor investigation to build upon the initial final void sensitivity modelling and further investigate the long-term fluctuations of water levels for pit evaporation factors ranging from 0.6 up to 1.0.

2 PIT EVAPORATION FACTOR RESEARCH

The remaining final voids at BCM are typical of most open cut coal mines in the Bowen Basin resulting from strip mining. The final voids and remaining pit lakes are typically long and rectangular-box-shaped voids. Due to the geometry and depth to the water surface below the original-natural-ground level, pit lakes are unique environments when compared to typical lakes and reservoirs.

For the final void WBM, the primary data input to estimate evaporation from the pit-lake-surface area is Morton's lake (M_{lake}) evaporation. However, wind shielding and shading due to the pit walls was expected to result in reduced evaporation from the pit lake surface. To account for this expected reduction in evaporative losses, a pit evaporation factor is applied.

The base case for the final void WBM adopted a pit evaporation factor of 0.7 which was consistent with past experience of similar water balance studies for open cut coal mines in the Bowen Basin and New South Wales Hunter Valley at the time. As the water level within each final void raises, the pit factor is expected to increase due to the reduced shading and wind shielding with the opposite also expected (i.e. decreased pit evaporation factor as the water level decreases).

To better understand the uncertainty inherent with this parameter, KCB undertook a sensitivity analysis testing pit evaporation factor ± 0.1 (i.e. 0.6 and 0.8) for the final void WBM (KCB 2018). This adopted range is consistent with ACARP Project No C70077 where a pit factor of 0.56 for near empty void and 0.78 for a full void where recommended.

Review of the sensitivity outcomes in the final void report, indicated that the long-term water level fluctuations were sensitive to changes in the pit evaporation factor ranging from 0.6 and 0.8.

Since the completion of the final void hydrology study, research work has been undertaken by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in conjunction with BHP[4]

[4] McJannet, D, Hawden, A, Baker, B, Ahwang, K, Gallant, J, Henderson, S and Hocking, A. 2019. *Evaporation from coal mine pit lakes: measurement and modelling*. Mine Closure 2019, Perth, Australia.

which measured actual evaporation rates at the water surface of a coal-mine pit at Norwich Park Mine (NPM) over a six-month period. NPM is an open cut coal mine also located in the Bowen Basin with similar final void and pit lake geometry to the final voids at BCM.

CSIRO observations from NPM showed that wind speeds at the pit lake levels were greater than those at land levels possibly because of the long-narrow shape of the coal pits funnelling the wind into the pit, resulting in an acceleration of airflow. Accordingly, actual evaporation rates were found to be substantially higher when compared to modelled rates, derived through the application of measured pan evaporation rates at the nearest Bureau of Meteorology (BOM) site and a pan evaporation coefficient of 0.7.

This research has further highlighted the uncertainty of the pit evaporation factor and suggested that the pit evaporation factors may range up to 1.

To further understand the uncertainty that the pit-evaporation factor has on the fluctuation of the long-term-equilibrium-water levels within the final voids, pit evaporation factors of 0.6, 0.7, 0.8, 0.9 and 1.0 have been applied to modelling for the current investigation.

3 WATER BALANCE MODELLING

As detailed in Section 1, an OPSIM final void WBM was established part of the final void hydrology study which simulated the generation, movement and loss of water on a daily time-step within each final void over a 1,000 year period. This final void WBM has been used for the current pit evaporation-factor investigation with further details relating to the final void WBM key physical characteristics, hydrological parameters and hydrogeological parameters detailed in the final void report[5].

3.1 Scenarios

Adopted modelling scenarios are presented in Table 3.2 and include sensitivity of pit-evaporation factor along with groundwater inflow.

As part of the final void hydrology study, a groundwater interaction assessment was undertaken which identified potential groundwater inflows into the four final voids. The potential groundwater inflows estimated from this assessment are presented in Table 3.1. To encompass the possible variability in groundwater inflows, zero and maximum groundwater inflows are modelled in the current pit evaporation investigation.

[5] KCB, 2018. *Burton Coal Mine – Final Void Hydrology Study*. 181221R BCM Final Void Hydrology Study.

Table 3.1 Groundwater inflows

Void	Groundwater inflows (L/s)	
	Minimum	Maximum
Plumtree Pit	0.2	5.7
Bullock Pit	0.7	2.9
Wallanbah Pit	0.0	4.6
Broadmeadow Pit	1.1	8.6

Table 3.2 Adopted modelling scenarios

Scenario	Pit evaporation factor					Groundwater inflow	
	0.6	0.7	0.8	0.9	1.0	Zero	Max
1	✓					✓	
2		✓				✓	
3			✓			✓	
4				✓		✓	
5					✓	✓	
6	✓						✓
7		✓					✓
8			✓				✓
9				✓			✓
10					✓		✓

To maintain consistency with the final void WBM and report, each scenario in the current pit evaporation investigation assumes the following:

- Natural catchment yield (except for mining pit areas);
- Spoil porosity of 20%; and
- Initial or current water levels (on 9th January 2020) as presented in Table 3.3.

3.2 Outcomes

For each scenario, the final void WBM has been run over a 1,000-year period to obtain long-term water level fluctuations within each final void. For ease of interpretation and for comparison purposes, the results for each scenario have been compressed into a single column of data representing the climate driven water level range within each pit lakes once equilibrium has been reached.

This graphical presentation of the uncertainty range associated with changes in the pit evaporation factor and groundwater inflows are presented as follows:

- Figure 3.1 Plumtree Pit long-term water levels;
- Figure 3.2 Bullock Pit long-term water levels;
- Figure 3.3 Wallanbah Pit long-term water level; and
- Figure 3.4 Broadmeadow Pit long-term water levels.

Key final void levels such as base of pit, current level, control level and original natural ground are also presented in the figures and in Table 3.3. Key voids levels, except for the current level, remain consistent with the final void report, with descriptions summarised as follows:

- Base of pit: derived from the deepest mined surface topography surface level
- Current level: water level within each void as of 9 January 2020
- Control level: maximum operational level within each void; above this level seepage may occur to the environment. It is based on:
  - Geotechnical advice from Peabody personnel (i.e. Bullock and Plumtree Pits);
  - Nominal 5 m freeboard below the nearby waterway bed level to account for topographic uncertainty (i.e. Wallanbah Pit); and
  - Nominal 5 m freeboard below the crest level to account for wind/wave action, geotechnical and topographic uncertainty (i.e. Broadmeadow Pit).
- Original natural ground level: derived from the deepest mined surface topography and above this level overflow may occur to the environment.

Table 3.3 Key void levels

Final void	Base of pit (mRL)	Current level (mRL)	Control level (mRL)	Original natural ground level (mRL)
Plumtree Pit	228	290.47	300	314
Bullock Pit	244	301.13	315	322
Wallanbah Pit	217	267.95	276	299
Broadmeadow Pit	178	256.35	273	278

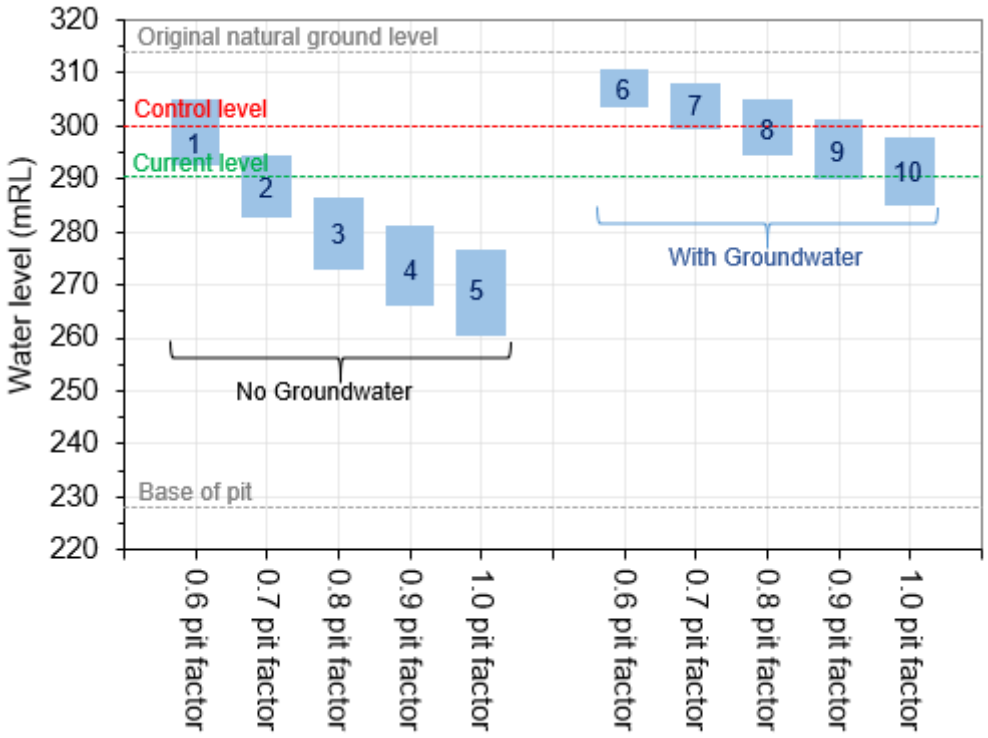

Figure 3.1 Plumtree Pit long-term water levels

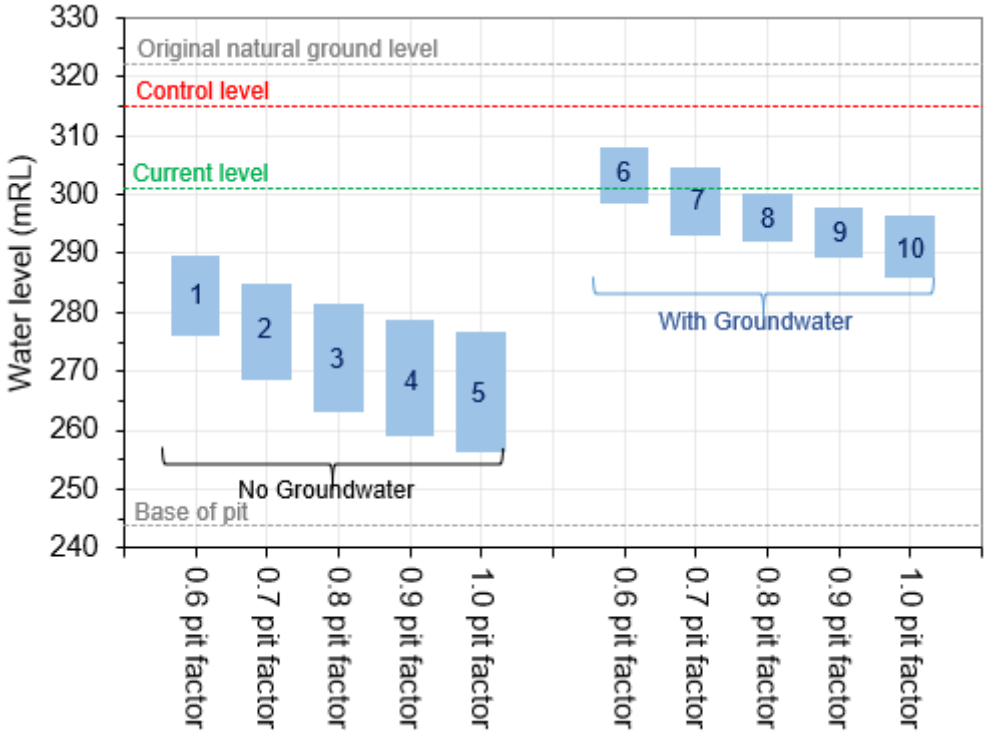

Figure 3.2 Bullock Pit long-term water levels

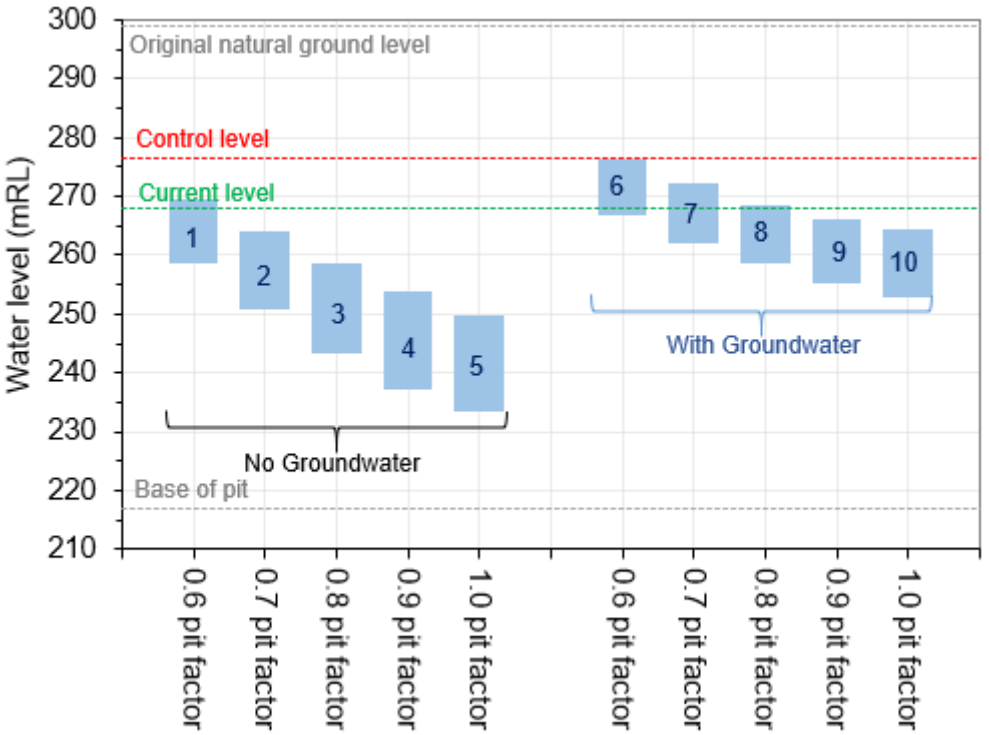

Figure 3.3 Wallanbah Pit long-term water levels

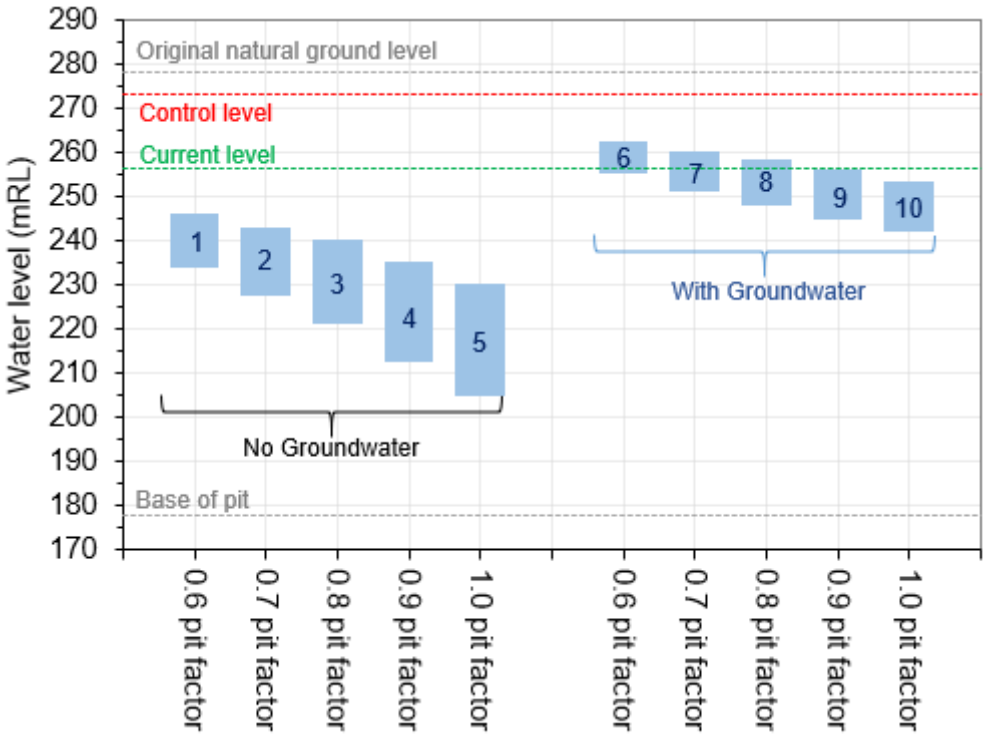

Figure 3.4 Broadmeadow Pit long-term water levels

In review of Figure 3.1 to Figure 3.4, simulated final void water levels are sensitive to changes in:

- Pit evaporation factor
  - Lower pit evaporation factors reduce the evaporation producing higher water levels; and
  - Variance in maximum long-term water levels due to lowering pit factors is significant with up to 28 m difference in Plumtree Pit when comparing scenarios 1 to 5 (i.e. with no groundwater).
- Groundwater inflows
  - Higher groundwater inflows producing higher water levels; and
  - Variance in long-term water levels due to change in pit evaporation factors is less pronounced with groundwater inflows when compared to no groundwater inflow.

Simulated long-term equilibrium water level fluctuations are expected to:

- Remain below the original natural ground level with no overflow to the receiving environment expected for the four final voids;
- Remain below the control level with no seepage to the receiving environment expected from Bullock, Wallanbah and Broadmeadow Pits for any scenario and Plumtree Pit for scenarios 2, 3, 4, 5 (i.e. no groundwater and 0.7 to 1.0 pit factors) and 10 (i.e. with groundwater and 1.0 pit factor); and
- Reach above the control level within Plumtree Pit for scenarios 1 (i.e. no groundwater and 0.6 pit factor), 6, 7, 8 and 9 (i.e. with groundwater and 0.6 to 0.9 pit factors) with seepage possibly occurring to the receiving environment via shallow alluvial aquifers.

4 CONCLUSIONS

KCB has extended the long-term final void water level assessment to include a wider range of pit evaporation factors to estimate the impacts on the final void water levels. Pit evaporation factors ranging from 0.6 up to 1.0 have been adopted, in line with the recent evaporation monitoring studies.

KCB has confirmed that simulated long-term water levels are sensitive to changes in pit evaporation factor, with lower pit evaporation factors reducing the evaporation and producing higher water levels. Maximum long-term water variance due to changing pit factors is expected to be significant, with up to 28 m difference in Plumtree Pit, with the variance decreasing with the introduction of groundwater.

For the final voids of Bullock, Wallanbah and Broadmeadow Pits, the simulated variance in long-term water levels due to changing pit evaporation factor are not expected to result in any overflow or seepage to the environment (i.e. above original natural ground or control levels). Within Plumtree Pit, no overflow to the receiving environment is expected, however, the simulated long-term water levels may reach above the control level for lower pit evaporation factors of 0.6 and 0.7 with no groundwater and 0.6 to 0.9 with groundwater. Above the control level seepage to the receiving environment may occur via shallow alluvial aquifers.

As part of ongoing closure planning, it is recommended that BCM:

- Keep up to date with any continuing research in the Bowen Basin regarding pit lake surface evaporation;
- Investigate opportunities to monitor the wind at the pit lake and ground levels to understand whether funneling or shielding is occurring (particularly at Plumtree Pit);
- Continue regularly monitoring of water levels within the pit lakes to assist with continued modelling work; and
- Further refine the final void WBM if any changes occur or further information is provided regarding model assumptions or parameters (i.e. pit evaporation factors, final landforms, control levels, groundwater inflows).

KCB recommends that outcomes of this pit evaporation investigation be used as a guide only to help support ongoing closure planning at BCM.

5 CLOSING

This letter is an instrument of service of KCB. The letter has been prepared for the exclusive use of Peabody for the specific application to the BCM for the pit evaporation factor investigation. The letter's contents may not be relied upon by any other party without KCB's written consent.

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Please contact the undersigned if you have any queries or require further assistance.

Yours truly,

KCB AUSTRALIA PTY LTD.



Kirsty Bethune
Senior Water Resources Engineer

KB:KB:JH

Appendix Q

Preliminary site investigation — phase 1



Peabody Energy Australia Coal Pty Limited

Preliminary Site Investigation Burton Coal Mine
Phase 1- Selected Infrastructure Areas

November 2017

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Appendices

Appendix A – Site Information Desktop Review

Appendix B – Peabody supplied figures and plans

Appendix C – Environmental Authority and Licences

Appendix D – Environment management register (EMR) searches

Appendix E – Risk Assessment

Appendix F – Site Functional Areas SAPs

List of abbreviations

General terms	
AHD	Australian Height Datum
ALS	Australian Laboratory Services
ANFO	Ammonium Nitrate/Fuel Oil (ammonium nitrate/fuel oil mix used as an explosive)
AST	Aboveground Storage Tank
BGL	Below ground level
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
BTEXN	Benzene, Toluene, Ethylbenzene, Xylenes and Naphthalene
CHPP	Coal Handling and Preparation Plant
CLR	Contaminated Land Register
CSM	Conceptual Site Model
DQI	Data Quality Indicators
EHP	Department of Environment and Heritage Protection (formerly EPA)
EMR	Environmental Management Register
Go-line	Either a v-drain in the ground or a raised hump where dump trucks and other machines park up for breaks or at end of shift.
HIL	Health Investigation Levels
HSE	Health, Safety and Environment
HSL	Health Screening Levels
LOR	Limit of Reporting
MAH	Monocyclic Aromatic Hydrocarbons
NATA	National Association of Testing Authorities
MPU	Mobile Processing Unit (purpose-built vehicles that are used in mining operations to manufacture or blend Class 1 bulk explosives at the location of blasting).
NDD	Non Destructive Digging
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
PAH	Polycyclic Aromatic Hydrocarbon
PCoC	Potential Contaminants of Concern
Peabody	Peabody Energy Australia
PID	Photo Ionising Detector
PSI	Preliminary Site Investigation
Prill	Prilled ammonium nitrate (made into "prills" or small beads).
QA	Quality Assurance
QC	Quality Control
QLD	Queensland
ROM	Run Of Mine (refers to ore/coal in its natural, unprocessed state just as it is when blasted or excavated, usually stockpiled in an area for later processing)
RP	Remediation Plan
SAP	Sampling and Analysis Plan
STP	Sewage Treatment Plant
TRH	Total Recoverable Hydrocarbons
WTP	Water Treatment Plant

Units	
ha	Hectares
km	Kilometre
m	Metre
mg/L	milligrams per litre
mbgl	metres below ground level
mg/kg	milligrams per kilogram
ppm	Parts Per Million
µg/L	micrograms per litre

1. Introduction

Peabody Energy Australia (Peabody) engaged GHD Pty Ltd (GHD) to conduct a Preliminary Site Investigation (PSI) of a number of selected key infrastructure areas present at the Burton Coal Mine, located off Suttor Development Road, Burton, Queensland (herein referred to as the site). The assessment is being undertaken at the site to inform Peabody of potential environmental liabilities, including future remediation and/or management requirements.

1.1 Background

The Burton mine was developed in the mid-1990s with the original coal mining pit being exhausted in 2005, followed by a number of other pits (satellite pits) that were progressed during the mines operations. Thiess started operations at Burton in 1996 (life-of-mine contract) from various pits within the 45-kilometre project site, managing all aspects of the Burton Coal Mine operations, including statutory mine management, engineering and design, drill and blast, overburden removal and rehabilitation. This includes operating a coal handling and production plant, as well as, train load-out facilities. They were also responsible for the construction and operation of water containment at the site.

Associated with the future winding down of operations and the Mine going on care and maintenance, Thiess will be demobilising from the site.

This PSI is focusing on a number of functional areas that contain key infrastructure to identify potential environmental issues and liabilities, management planning and remedial activities that may be required prior to Thiess demobilisation. The following areas and activities are included:

a. BLAST magazine (Wallanbah) – ANFO storage

b. Ex-Orica reload facility – blasting reload facility and diesel storage

c. Burton Widening Reload facility - blasting reload facility, diesel storage

d. Plumtree excavator laydown (north-pit demob pad) – old laydown area and possible minor maintenance

e. Demobilisation pad/compound – machinery storage and decommissioning, potential impact from hydrocarbons

f. Wallanbah hardstand – machinery storage and possible maintenance

g. Workshop area – current workshop servicing, hydrocarbon and waste oil storage, wash down bays, bulk diesel, oil and lube storage, former Orica magazine area

h. Workshop fuel farm – as above, current workshop bulk diesel storage and refuelling activities

i. Mallawa train load-out – bulk diesel storage, refuelling facility and train coal load-out facilities

j. Bullock Creek former workshop site – former laydown area, small mobile workshop area, minor servicing

k. Burton Widening North demob pad – machinery storage and decommissioning, possible hydrocarbon impact

l. BIS workshop – bulk hydrocarbon storage, Heavy Vehicle (HV) workshop and servicing for road trains and other equipment

m. Sewage treatment plant – sewage treatment and effluent disposal

n. CHPP – (Coal Handling and Production Plant) former hydrocarbon storage and CHPP activities.

o. Water Treatment plant (chemical storage and sludge management)

p. Kerlong Accommodation Village (backup generators, fuel storage, waste management and maintenance facilities)

Current land use at the site is to remain and some infrastructure may be likely be permanently decommissioned.

1.2 Objectives

The objectives of this PSI are to:

- Undertake a desktop study to evaluate historical site information pertaining to potential for, or presence of, contamination related to the identified functional areas at Burton Mine Site
- Undertake a site inspection and conduct interviews with individuals who have intimate knowledge of the site and activities undertaken (either past or current knowledge)
- Develop a preliminary Conceptual Site Model (CSM) to identify potential source-pathway-receptor (SPR) linkages that may indicate risks to human health and/or the environment, and
- Prepare a PSI report detailing the outcomes of the desktop assessment, site inspection and interviews undertaken, present the CSM model produced and provide an assessment as to the potential for contamination to be present at the site along with recommendations on further assessment, remediation and/or management works which may be required.
- Development of a soil Sampling and Analysis Plan (SAP) following the completion of the DSI, prioritising the Areas of Environmental Concern (AECs) identified at each functional area.

Note: The whole Burton mine is not being assessed and a full site history is not being completed as part of this study.

1.3 Scope

The PSI is being undertaken in general accordance with:

- Department of Environment and Heritage Protection (EHP),2015: Assessing a Suitably Qualified Persons According to Sections 381, 395 and 410 of the Environmental Protection Act 1994, 2015.
- Department of Environment and Heritage Protection (EHP), 2014. Guideline for Contaminated Land Assessment, July 2014
- Department of Environment and Heritage Protection (EHP) 2014 Guideline for Managing Contaminated Land under the Sustainable Planning Act 2009, July 2014
- Department of Environmental and Heritage Protection (EHP), 2014, *Environmental Protection Regulation 2008,* Section 115C pp-99
- NEPC 2013. National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended by the National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1), National Environment Protection Council, May 2013
- Australian Standard AS 4482.1–2005. Guide to the investigation and sampling of sites with potentially contaminated soil - Part 1: Non-volatile and semi-volatile compounds.

- Australian Standard AS 4482.1–1999. Guide to the sampling and investigation of potentially contaminated soil - Part 2: Volatile substances.

The scope of work for the PSI included:

- Review of readily available historical aerial photographs either provided by Peabody, or through google earth map, if available, to gain an understanding of site and functional areas development over time
- Documenting of current certificates of title, lessees and Environmental Authorities, to identify site activities that may be associated with functional areas
- Review of published data on geology, hydrology and hydrogeology to gain an understanding of general site conditions and identify sensitive receptors
- Search of the groundwater bore database to understand beneficial uses for groundwater in the area and a brief review of the Burton Mine groundwater monitoring that may be undertaken, where relevant to potential contamination
- Review of historical reports and records provided by Peabody and Thiess to provide some background to previous investigations and site conditions
- A detailed site inspection of the functional areas to gain an understanding of site condition and inspect areas where there is potential Areas of Environmental Concern (AECs)
- Interviews with personnel who have an understanding of current and historical activities to identify areas AECs at the functional areas
- Development of a Conceptual Site Model (CSM) and potential source, pathway, receptor linkages
- Development of a risk assessment using Peabody's risk matrix to assessment to allow a revised focus to be on the sites of highest relative risk to drive future completion of site specific intrusive site works
- Conclusions and recommendations

2. Site information

2.1 Site location

The Burton Mine is an open-cut mine located off Suttor Development Road, approximately 35 km north east of Moranbah. The mine produces hard and semi-hard coking and thermal coals and uses truck and shovel operation and the terrace mining method for extracting steep seams.

Since the mine was opened in 1996 it has produced 60 million tonnes of coal. The Burton coal mining operation produces thermal and hard coking coal that is purchased by customers in South America, India, Europe and Asia.

The Burton coal mine, was originally owned by Portman Mining Limited, before being sold to RAG Australia, is now majority owned by Peabody Energy Australia, who have contracted out the mining operation to Thiess.

Thiess has operated the life-of-mine contract at Burton Coal Mine since January 1996, managing all aspects of the Burton Coal Mine operations, including statutory mine management, engineering and design, drill and blast, overburden removal and rehabilitation. They also operate and maintain a coal handling and production plant (CHPP) and train load-out facilities, and construct and operate water containment.

The original mining pit was exhausted in June 2005, followed by Broadmeadow and Wallanba satellite pits in 2009 which are being progressively rehabilitated, being overseen by Peabody who is engaging a multitude of rehabilitation contractors and specialists to undertake the works.

Two more open pits, Plumtree South and Bullock Creek, began production in 2010, have also finished being mined with the Burton Widening still operational. The open pits at the Burton Mine are mined as satellite operations from the central mine processing plant to which the coal is transported by road.

Peabody are currently reducing production levels and following through on placing the Burton Mine in care and maintenance.

Associated with the Burton coal mine a number of key facilities present include:

- coal processing plant
- workshops and fuel storage
- blasting magazine and reload facilities
- rail loading facility at Mallawa
- railway loop
- Water supply dam and distribution system
- accommodation village
- water (potable) and sewage treatment plant
- stormwater/runoff dams and pumping infrastructure
- mine office
- coal haulage roads and light vehicle roads
- mine access

And the associated activities within the Burton Coal Mine may include:

- Controlled clearing of vegetation;

- Removal of topsoil and stockpiling;
- Drilling and blasting to facilitate open cut mining;
- Storage of explosives
- Exploration
- Removal of overburden and construction of waste rock dumps
- Coal extraction, highwall mining and haulage from the open cut
- Maintenance of equipment
- Construction / maintenance of infrastructure including:
  - Site roads and tracks
  - Power lines and associated infrastructure
  - Clean water dams, process water dams, and sediment traps
- Co-disposal area and associated drainage
- Installation of minor infrastructure such as fire breaks, road access, pipelines and pumps
- stations
- Open cut pit dewatering
- Site rehabilitation
- Water management
- Coal processing and handling
- Bulk storage of hydrocarbon products
- Product coal haulage, stockpiling and rail load out.

2.2 Brief site history

The original Burton open pit was increased in 1998 from its original 80 metres to 110 metres. At the same time extra infrastructure was constructed to cater for the increase. This included an expansion of the accommodation village, the creation of a truck receiver and skyline stockpiling facility at Mallawa, a second 400 tonnes an hour coal processing module and other mine site facilities. The open pits at the Burton Mine are not continuous in their operational capabilities additional pits are added as they become necessary. The expansion that took place in 1998 lifted production from two million tonnes to four million tonnes a year.

Additional pits that have been added over time, from north to south include Burton North (original pit), Burton (now called Burton Widening), Ellensfield, Plumtree, Bullock Creek, Wallanbah and Broadmeadows.

The mined coal that is removed from the operational pits at the Burton Mine are taken to the central coal processing plant where it is blended and washed at a current feed rate of 5.5 million tonnes a year. Peabody acquired 95 percent of Burton in April 2004.

2.3 Environmental Authority

The Burton Coal Mine open cut operations and associated activities on site are covered by Environmental Authority EPML00879213 (16 July 2013), the EA holder is Peabody (Burton Coal) Pty Ltd. In accordance to the 2016 Plan of Operations (POO)

2.4 Property information

GHD has been provided with the tenure information relating to Burton Coal Mine, as summarised in Table 2-1.

Table 2-1 Tenures for Burton Coal Mine

Tenure Type	Tenure Number	Lease Name
Mining Lease (ML)	70109	Burton/Ellensfield
ML	70260	Plumtree North East
ML	70258	Plumtree West
ML	70259	Plumtree East
ML	70252	Wallanbah
ML	70257	Broadmeadow East
ML	70256	Broadmeadow West
Mining Development License (MDL)	315	Kerlong
MDL	349	-
MDL	308	-
Exploration Permit for Coal (EPC)	857	Baldwin

The Burton Coal Mine site is comprised of the whole of portion of the following land parcels:

Table 2-2 Properties within the Burton Coal Mine

Lot and Plan numbers	
Lot 1 SP159745	Lot E SP184908
Lot 18 SP104452	Lot B GV151
Lot 9 RP903903	Lot C GV278
Lot 5311 PH1655	Lot D SP184906
Lot F SP184907	Lot 2 SP1229980
Lot 4 RP852463	Lot 4 CP903281
Lot 13 SP178466	Lot P SCP216411
Lot A GV150	Lot 41 CP903280
Lot 3 GV54	Lot A GV106
Lot A GV149	Lot 42 CP903280

2.5 Functional Areas Assessment

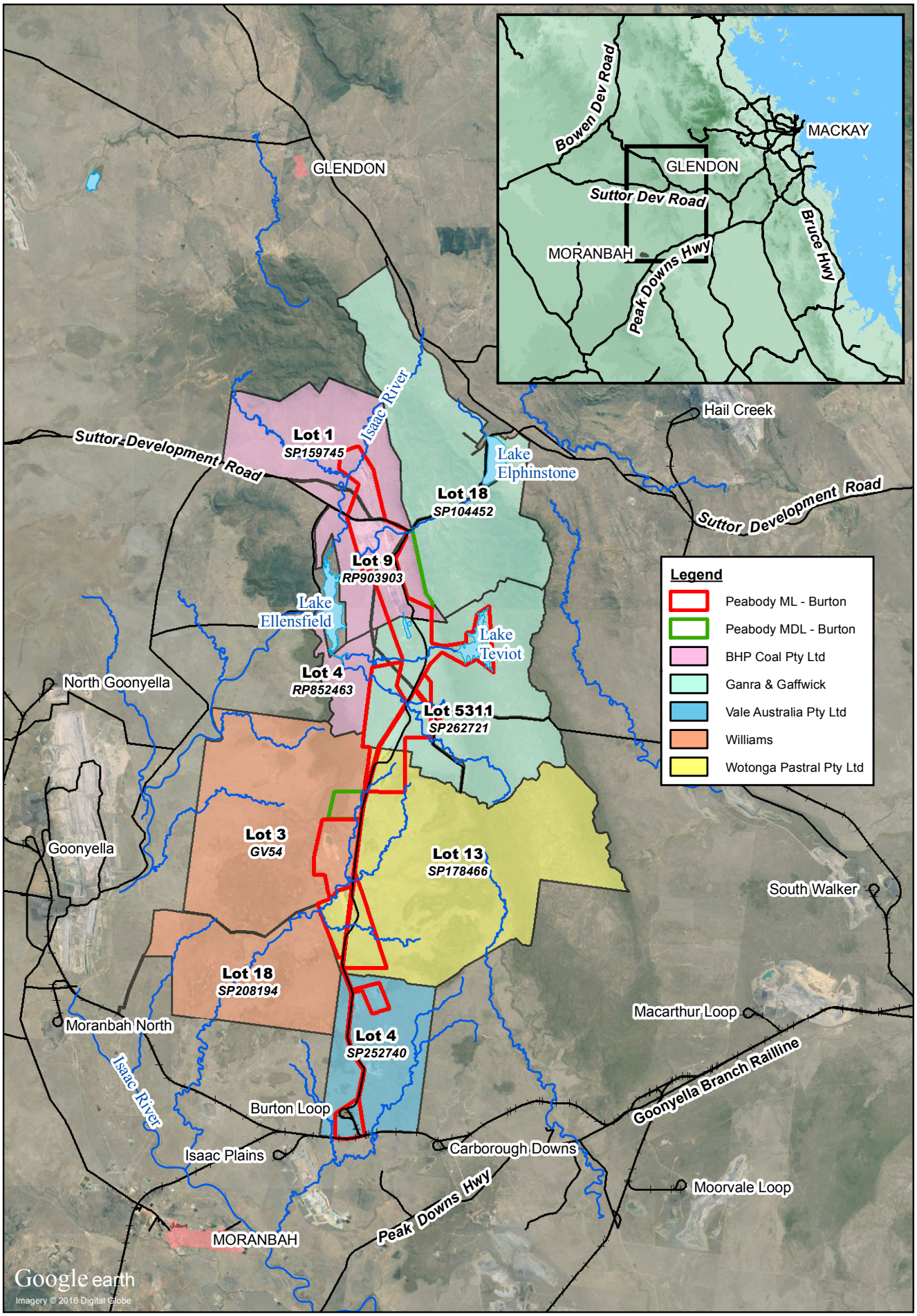
Outlined below is a list of the Functional Areas that are being assessed which have been given a unique letter identifier, along with a brief description of the activities undertaken, remediation and management goals that are proposed.

Table 2-3 Functional areas and description

ID	Functional Area Name	Activity	Current plan	Goal
A	Blast Magazine (Wallanbah)	ANFO storage	Tanks and infrastructure will be removed	Full clean up
B	Ex-Orica Reload Facility	Blasting reload area, diesel storage	Tanks and infrastructure will be removed	Full clean up
C	Burton Widening Reload Facility	Blasting reload area, diesel storage	ANFO products removed	Delineate and manage

ID	Functional Area Name	Activity	Current plan	Goal
D	Plumtree excavator laydown	Old laydown area - possible minor servicing	Area cleared of all infrastructure	Validate
E	Demob pad/compound	Machinery storage and decommissioning - possible hydrocarbon contamination	Area to be cleared in following 12 months	Full clean up
F	Wallanbah hardstand	Machinery storage- possible hydrocarbon contamination	Area cleared of all infrastructure	Full clean up
G	Workshop area	Current workshop - servicing, hydrocarbon storage, waste oil storage, previous Orica magazine area according to mapping	Majority of infrastructure to remain.	Partial remediation
H	Workshop fuel farm	Current workshop bulk diesel storage	Tanks to be removed	Full clean up
I	Mallawa train loadout	Bulk diesel storage and coal load out facilities	Diesel tanks to remain	Delineate and manage
J	Bullock Creek former workshop site	Old laydown area - possible minor servicing	Area cleared of all infrastructure	Validate
K	Burton Widening north demob pad	Machinery storage and decommissioning - possible hydrocarbon contamination	Area to be cleared in following 12 months	Full clean up
L	BIS workshop	BIS workshop - hydrocarbon storage, servicing	Some infrastructure to go - bulk diesel tank to remain and be in use	Partial remediation
M	Sewage treatment plant	Sewage water treatment	Plant to be removed from site	Full clean up
N	CHPP	Previous hydrocarbon storage and CHPP activities	Area to be effectively mothballed	Delineate and manage
O	Water Treatment plant	Water treatment for potable use, floculation, screening, chlorination, chemicfal storage and sludge management	Area cleared of all infrastructure	Validate
P	Kerlong Accommodation Village	Worker accommodation village with backup generators, fuel storage, waste management and maintenance facilities	Area cleared of all infrastructure	Validate

The desktop review, including site history and site inspections for each of the Functional Areas are presented separately in Sections 5 to 20.



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Kilometers

Map Projection: Universal Transverse Mercator
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Peabody Energy Australia
Coal Pty Limited, Burton Coal Mine
Preliminary Site Investigation

Job Number	41-30188
Revision	A
Date	29 Sep 2016

Property Details and Locality Figure 2.1

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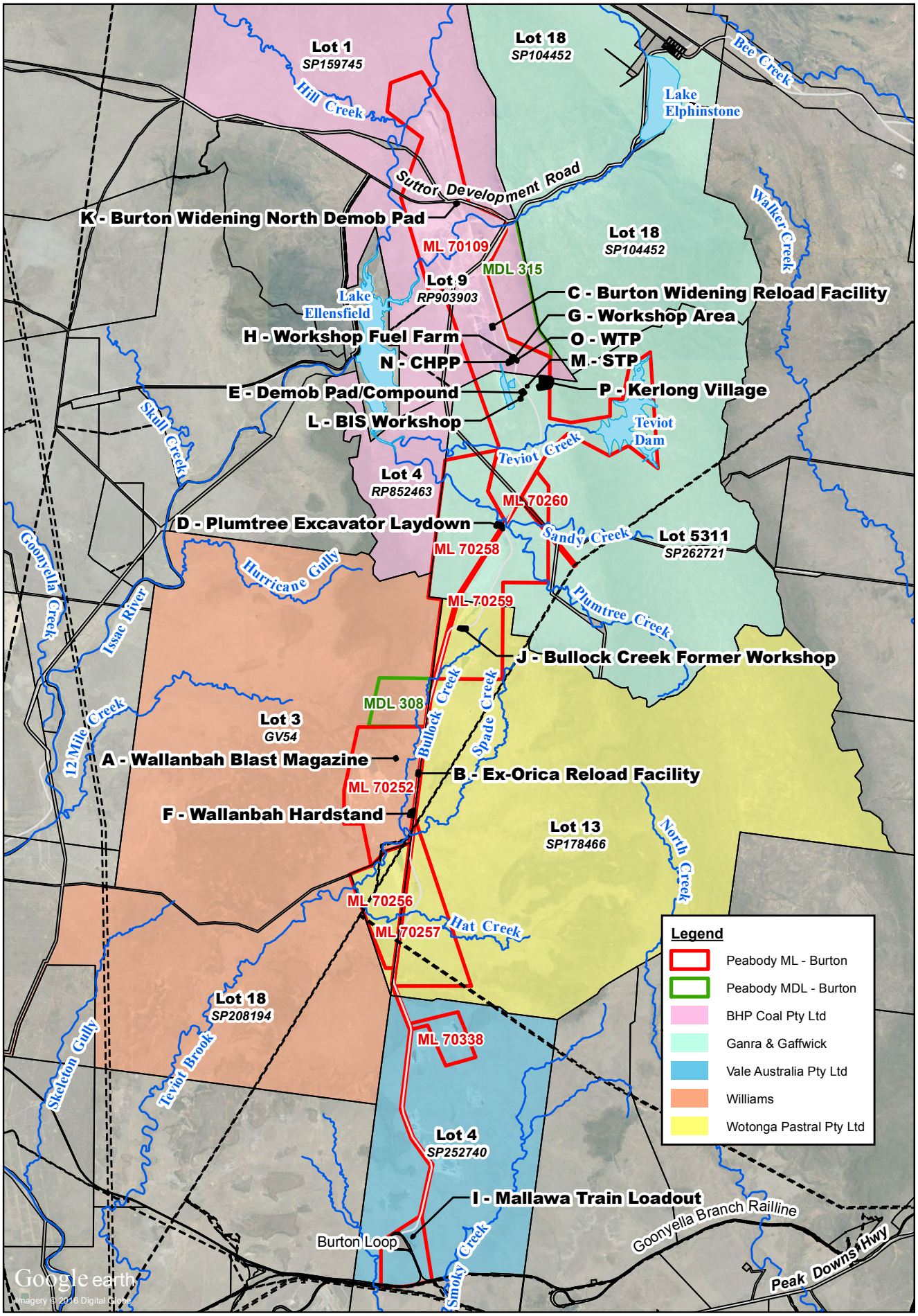

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Kilometers

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Functional Areas

Figure 2.2

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3. General Site conditions

Outlined below are general details pertaining to the whole Burton Coal Mine.

3.1 Surrounding land uses

The surrounding land of the Burton Coal Mine were predominantly grazing pastures, mine sites and pockets of coal seam gas production wells scattered around the general area. More detail on the immediate surrounding land uses of the functional areas will be provided in the Sections 5 to 20.

3.2 Topography

The site elevation ranged between 300 and 350 metres Australian Height Datum (mAHD)[1].The regional topography appears to be sloping down towards south with steep slope upwards to the ranges at both east (Kerlong Range) and west (Burton Range) side of the mine site.

3.3 Geology

The surface geology of the Burton Coal Mine is presented in Figure 2 in Appendix A, and the geology of the functional areas are summarised below:

Table 3-1 Geology

Functional Areas	Geology units
A - Wallanbah Blast Magazine	Triassic aged Rewan Formation: Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate (at base).
C – Burton Widening Reload Facility	
E – Demob Pad/Compound	
G – Workshop Area	
H – Workshop Fuel Farm	
N – CHPP	
L – BIS Workshop	
K – Burton Widening North Demob Pad	
B – Ex-Orica Reload Facility	Tertiary to Quaternary aged locally mottled, poorly consolidated sand, silt, clay, minor gravel, high-level alluvial deposits, generally dissected, and related to present stream valleys.
D – Plumtree Excavator Laydown	
F – Wallanbah Hardstand	
J – Bullock Creek Former Workshop	Permian aged Fort Cooper Coal Measures: Lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, cherty mudstone
I – Mallawa Train Load Out	

Source: Department of Natural Resources and Mines (DNRM) Geology 1:100K scale mapping

[1] Elevation information obtained from Queensland Globe (Contour layer), assessed on 21 September 2016.

3.4 Regional Hydrology

There are several creeks that runs across or adjacent to the Burton Coal Mine, including the following:

- Anna Creek, which diversion creek runs through north of Burton Widening pits area and continue towards south-west into Lake Ellensfield
- Isaac River, located 2.3 km west from the Burton Widening operation site and run towards south-west
- Teviot Creek, runs from southern end of Teviot Dam
- Sandy Creek, runs across the northern end of Plumtree Mining operation site towards north-west into Lake Ellensfield
- Bullock Creek, which diversion creek runs around northern end of Bullock Creek Pit and towards south-west direction
- Spade Creek
- Hat Creek

Surface water bodies located adjacent to the mine site includes:

- Teviot Dam, located 3 km east from the Burton Widening operation site (main water supply for the mine site)
- Lake Elphinstone, located 6.5 km north-east from the Burton Widening operation site

Apart from the natural water bodies, there are also several constructed dams and pits on site that have been and continue to be used for storages of various source of water.

Standard practice at the site includes establishing a system of berms, drains and dams to intercept and divert water, including using pipelines and pumping, where required,

Rainfall runoff from the surrounding catchment is diverted around the disturbed areas with no direct impact on the water quality from the mining operations. The runoff from “out of pit” spoil dumps, surface drainage water captured in regulated dams from catchment and areas containing hazardous materials (e.g. workshop area and coal stockpile areas) are treated as separate catchments and contained/managed on site.

The mine site water management system involves the management of different types of

water, including:

- Raw water (or external) supply, sourced external to the mine operations from
- Teviot Dam that can be treated to a potable standard
- Worked Water, being water that is retained on site, is available for site utilisation reuse at the site (including “mine affected” water) and is managed accordingly depending on its quality and any EA conditions. Worked water may include dam water, groundwater inflow and rainfall runoff removed from mine workings, CHPP process water including recycled water from the Co-disposal area (CDA).

Further site specific hydrology will be discussed in the relevant functional areas sections.

3.5 Regional Hydrogeology

Information sourced from the *Groundwater Resource Map of Queensland* (QLD Government, 1987) shows the groundwater reserves of the Mine Site is located within the Bowen Basin, which is classified as low bore yield, with a medium range salinity of 1500-5000 milligrams per litre Total Dissolved Solids (mg/L TDS), which is suitable for most stocks, with some domestic irrigation. The lithology of the site is described as sedimentary strata, which comprised of sandstone and shales conglomerate. The site is located within the Isaac Connors Groundwater Management Areas.

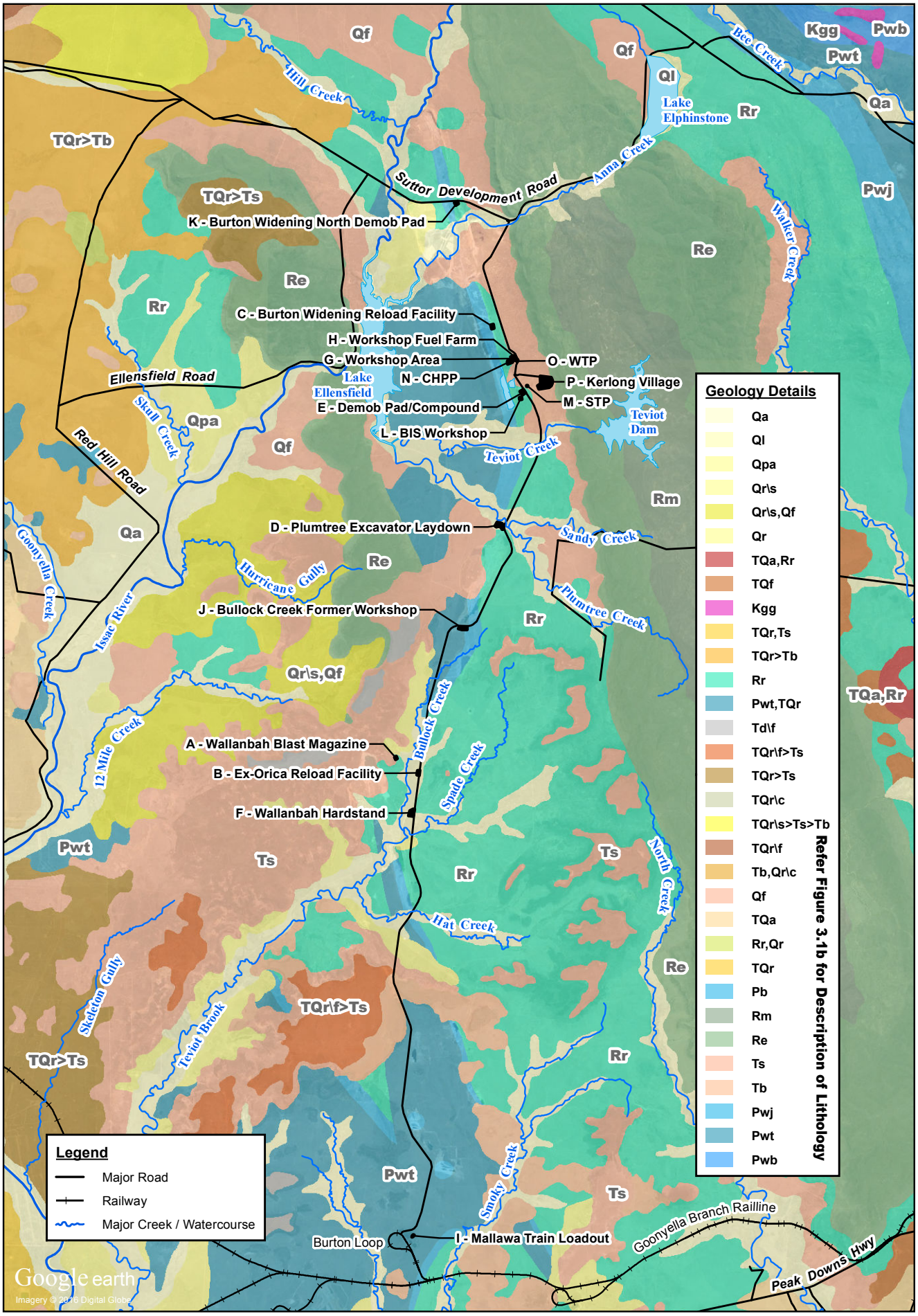
Based on the bore data provided by Peabody, there are groundwater monitoring bores located across the Burton Coal Mine that were monitored quarterly, however, only a portion of which were monitored for water quality parameters, the remaining were monitored only for standing water level (SWL). There is one registered bore (RN162255) located 0.8 km south-east from the functional area. The bore was registered as sub-artesian facility for monitoring purposes. The SWL of the groundwater was recorded at 4.24 mbTOC. No groundwater quality available. Based on the Queensland Groundwater Database, registered bores for monitoring, water supply purposes were noted outside of the Burton mine site. However, as the purpose of the PSI is focused only on the selected functional areas, site specific hydrogeology will be discussed in the relevant functional areas Sections 5 to 20. The bore report for RN162255 is provided in Appendix A.

3.6 Environmentally Sensitive Areas

A search of the Department of Environment and Heritage Protection (EHP) Environmentally Sensitive Areas mapping tool for Category A and B environmentally sensitive areas, as described in the Environmental Protection Regulation 2008, identified the following:

- Category A - Endangered regional ecosystem (Biodiversity status)

Environmental mapping search results are included in Appendix B.



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Kilometers

Map Projection: Universal Transverse Mercator
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Peabody Energy Australia
Coal Pty Limited, Burton Coal Mine
Preliminary Site Investigation

Job Number	41-30188
Revision	A
Date	29 Sep 2016

Geology Mapping

Figure 3.1a

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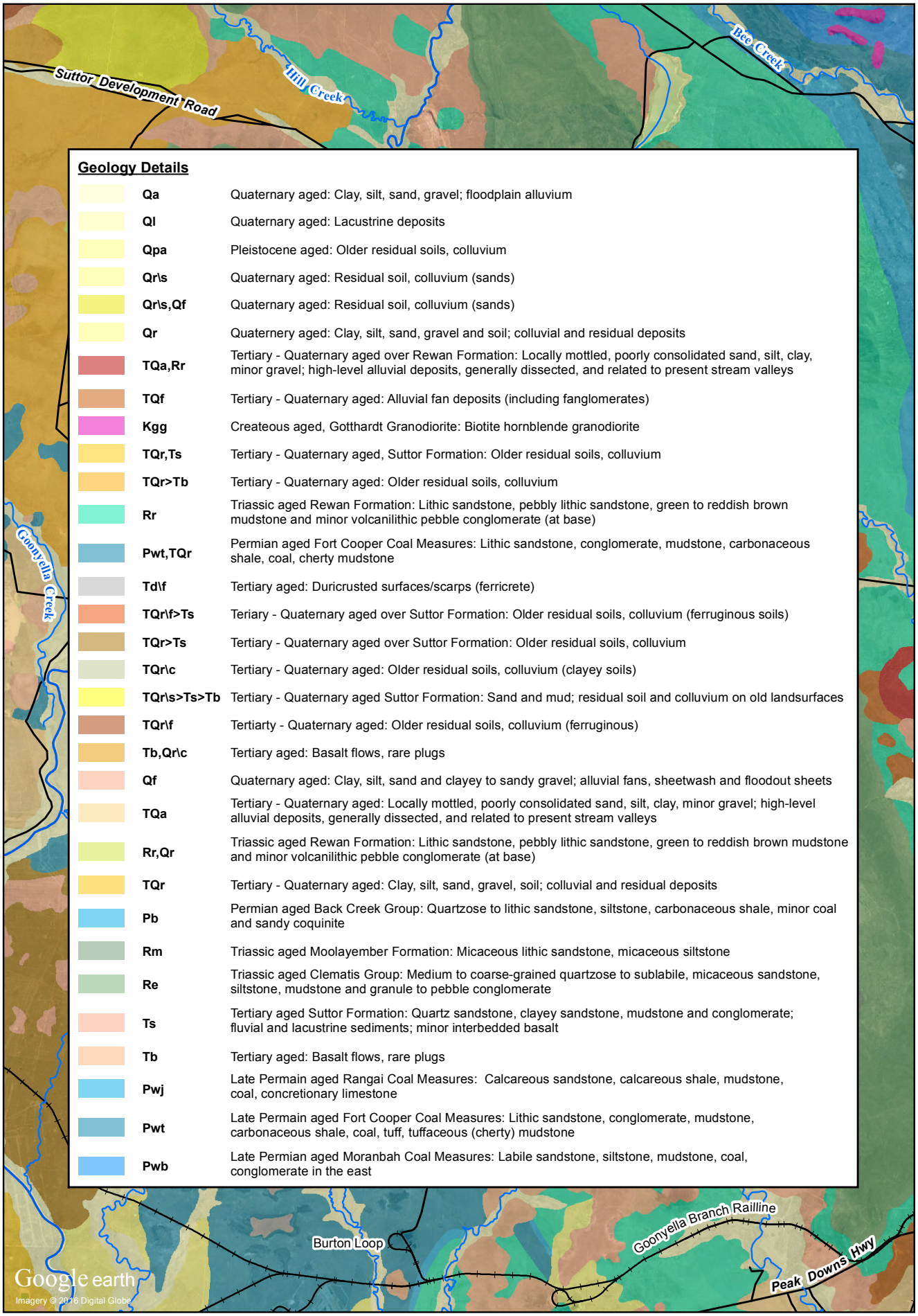

Geology Details

	Qa	Quaternary aged: Clay, silt, sand, gravel; floodplain alluvium
	Ql	Quaternary aged: Lacustrine deposits
	Qpa	Pleistocene aged: Older residual soils, colluvium
	Qr\s	Quaternary aged: Residual soil, colluvium (sands)
	Qr\s,Qf	Quaternary aged: Residual soil, colluvium (sands)
	Qr	Quaternery aged: Clay, silt, sand, gravel and soil; colluvial and residual deposits
	TQa,Rr	Tertiary - Quaternary aged over Rewan Formation: Locally mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits, generally dissected, and related to present stream valleys
	TQf	Tertiary - Quaternary aged: Alluvial fan deposits (including fanglomerates)
	Kgg	Createous aged, Gotthardt Granodiorite: Biotite hornblende granodiorite
	TQr,Ts	Tertiary - Quaternary aged, Suttor Formation: Older residual soils, colluvium
	TQr>Tb	Tertiary - Quaternary aged: Older residual soils, colluvium
	Rr	Triassic aged Rewan Formation: Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate (at base)
	Pwt,TQr	Permian aged Fort Cooper Coal Measures: Lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, cherty mudstone
	Td\f	Tertiary aged: Duricrusted surfaces/scarps (ferricrete)
	TQr\f>Ts	Teriary - Quaternary aged over Suttor Formation: Older residual soils, colluvium (ferruginous soils)
	TQr>Ts	Tertiary - Quaternary aged over Suttor Formation: Older residual soils, colluvium
	TQr\c	Tertiary - Quaternary aged: Older residual soils, colluvium (clayey soils)
	TQr\s>Ts>Tb	Tertiary - Quaternary aged Suttor Formation: Sand and mud; residual soil and colluvium on old landsurfaces
	TQr\f	Tertiarty - Quaternary aged: Older residual soils, colluvium (ferruginous)
	Tb,Qr\c	Tertiary aged: Basalt flows, rare plugs
	Qf	Quaternary aged: Clay, silt, sand and clayey to sandy gravel; alluvial fans, sheetwash and floodout sheets
	TQa	Tertiary - Quaternary aged: Locally mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits, generally dissected, and related to present stream valleys
	Rr,Qr	Triassic aged Rewan Formation: Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate (at base)
	TQr	Tertiary - Quaternary aged: Clay, silt, sand, gravel, soil; colluvial and residual deposits
	Pb	Permian aged Back Creek Group: Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite
	Rm	Triassic aged Moolayember Formation: Micaceous lithic sandstone, micaceous siltstone
	Re	Triassic aged Clematis Group: Medium to coarse-grained quartzose to sublabile, micaceous sandstone, siltstone, mudstone and granule to pebble conglomerate
	Ts	Tertiary aged Suttor Formation: Quartz sandstone, clayey sandstone, mudstone and conglomerate; fluvial and lacustrine sediments; minor interbedded basalt
	Tb	Tertiary aged: Basalt flows, rare plugs
	Pwj	Late Permain aged Rangai Coal Measures: Calcareous sandstone, calcareous shale, mudstone, coal, concretionary limestone
	Pwt	Late Permain aged Fort Cooper Coal Measures: Lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff, tuffaceous (cherty) mudstone
	Pwb	Late Permian aged Moranbah Coal Measures: Labile sandstone, siltstone, mudstone, coal, conglomerate in the east

1:200,000 (at A4)

0 2 4 6 8

Kilometers

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
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Peabody Energy Australia
Coal Pty Limited, Burton Coal Mine
Preliminary Site Investigation

Job Number 41-30188
Revision A
Date 29 Sep 2016

Geology Mapping Details

Figure 3.1b

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4. Functional Area review

4.1 Desktop Information

Findings of the preliminary desktop study of the individual functional areas are discussed individually in Sections 5 to 20. For each functional area, the following desktop information were reviewed and summarised:

- Site setting (topography, hydrology, hydrogeology, sensitive receptors, aerial imagery [2]etc.)
- All relevant reports/information provided by Peabody, including Environmental Authority (EA), Plan of Operations (POOs), Hazardous Substance Register, Spill Incident Register, previous Audit reports etc.

4.2 Interviews

Site interviews and information was provided principally from the following key personnel during the site inspections conducted between the 19 -23 September 2016.

- Justin Vohland – Environmental Superintendent– Peabody
- Daniel Sawtell – Technical Services Superintendent, Thiess, Burton Coal Project
- Terry Stanger - Dragline Supervisor/Planner & Workshop Superintendent, Thiess, Burton Coal Project
- Matt Harrison – CHPP Manager, Thiess, Burton Coal Project
- Name unknown – BIS Workshop manger
- John - STP and WTP Operator, Site Plumber, Thiess, Burton Coal Project
- Quin – Maintenance Personnel, Thiess, Burton Coal Project

4.3 Site Inspections

Site inspections were undertaken by an environmental engineer from GHD and the environmental superintendent from Burton Mine. Key Peabody staff with associated to the functional area also undertook the site inspection where available, principally associated with the workshop, treatment plants, reload facilities and accommodation camp. Full detailed inspections of all areas was not part of this scope.

The objective of the site inspection was to identify possible areas of contamination not recorded in the site history and to provide an indication as to suitable locations for soil sampling.

The site inspections concentrated on the identification of evidence that may be indicative of contaminated land, including:

- disturbed discoloured or stained soil;
- bare soil patches;
- disturbed or distressed vegetation;
- presence of chemicals containers, holding tanks, etc;
- chemical odour;
- quality of surface water;

[2] No complete review of historical aerial photographs (back to pre-mining) has been undertaken as it is not part of the scope. Aerial photographs were reviewed on web-based information such as Google Earth Pro.

- condition of buildings, concrete and bitumen floors and roads, etc;
- presence and condition of potentially contaminative plant and equipment; and
- presence of fill.

4.4 Conceptual Site Model[3]

Based on the understanding of the contamination issues and site setting, a conceptual site model (CSM) is then being generated for each functional area as a basis for assessing the risk posed by any potential *source -> pathway -> receptor* linkages (or pollutant linkages). The consideration of the CSM is as followed:

4.4.1 Sources and receptors

Based on the findings obtained through desktop study and site observation, the following information were summarised for each functional area:

- Areas of environmental concern (AEC)
- Potential contaminants of concern (PCoC)
- Potential Sensitive Receptors (Human and Ecological)

Note that on-site groundwater consumer is not considered likely as a potable water source at Burton Mine Site, with it being sourced from the Teviot Dam. Based on the significant distance from potential contamination sources being assessed as part of this study from adjoining rural properties, there is unlikely a direct connection geologically with water supply bores in the area. Also as a high level of attenuation may also be occuring, there is considered to be no direct connectivity present; hence fore, off-site groundwater user is not considered in this case.

4.4.2 Transport Pathway

Based on the contaminant sources and potential sensitive receptors identified, possible transport mechanisms for contaminant movement and the associated exposure pathways at the functional areas are considered to include:

- Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater during subsurface work on and in the vicinity of the site
- Inhalation of hydrocarbon vapour from subsurface impacted soil or shallow/perched groundwater
- Lateral migration of contamination through surface water runoff

Offsite migration of contamination through groundwater flow is not considered in the CSM, as the detailed hydrogeology information of each functional area is not available for the consideration. It is recommended that this potential pathway be included in the future assessment should intrusive site investigationbeundertaken.

It should also be noted that the site is an operational mine and potential exposure to hydrocarbons may occur during normal site operations (i.e. oil and fuel dispensing, maintenance work. The potential exposure from normal operating activities at the mine is considered to be voluntary exposure and is addressed under the relevant occupational health and safety legislation for this industry.

[3] Based on the current understanding of possible contaminant sources the CSM is general in nature and there is considered to be limited value in individual CSMs for each possible source. It should be noted that the CSM considers the functional areas to remain as industrial land use.

Followed the identification of potential contamination sources, potential sensitive receptors and possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for each functional area.

In the case where no AEC and PCoC was identified, no CSM will be developed.

4.5 Data Limitations

With the site and a number of the functional areas, due to the varying periods of operation and that many have been decommissioned or modified as the mine plan of operations changed over time, limited site specific information was available for perusal. Also, with a large number of contractors, personnel and companies having operated on site during the mines operation, continuity of knowledge has also been found to be limited, including provision of anecdotal information over the period of the mines and functional areas operation.

5. Functional Area A – Blast Magazine (Wallanbah)

5.1 Site Description

The blast magazine, associated with the Wallanbah and Broadmeadow Pits is located off the Mallawa Haul Road via an access road entry located adjacent to the Ex-Orica Reload Facility (Functional Area B). It is a rectangular cleared area containing man proof perimeter fencing and opposing entry and exit roadways, sited at an appropriate distance from the Wallanbah reloading facility for safety reasons.

The location of the functional area, in the context of the Burton Coal Mine is presented in Figure 2-2 with the area and site details shown in Figure A, included in Appendix A, which also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 1.

Table 1 Site Details Summary

Site Details	Description
Location	South of Broadmeadow Pit, North of Wallanbah Hardstand site, West of the major haul road and directly East of a small dam.
Area (ha)	0.5
Lot/Plan	Lot 3 GV54
EMR/CLR	Not listed on EMR/CLR.
Current land owner	Allan Gordon Homer Williams
Mining lease	ML 70252
Current use/activity	Explosives and detonator storage
Former use/activity	Unknown, but considered to be undeveloped grazing land
Current infrastructure	Three storage containers
Former infrastructure	Unknown
Topography and drainage	Regional topography slopes gently towards south-east towards Bullock Creek.
Hydrology	The closest creek is Bullock Creek, located 0.4 km east of the blast magazine site. To the north eastern is a brown water dam located 0.65 km south from the functional area A.
Hydrogeology	There is one groundwater monitoring bore (BDW46) located 0.8 km north-west from the functional area. No water quality information from the bore, except the SWL was recorded at 57.89 mbTOC in December 2009. This bore is considered to be associated with mine groundwater level monitoring.

Site Details	Description
Surrounding land use	North: Vegetated bushland and pasture, a farm dam is located 0.3 km north. South: Magazine access road, vegetated pasture and north eastern brown water dam located 0.65 km south East: Vegetated pasture, then Bullock Creek and Mallawa haul road located 1km east West: Topsoil stockpiles, established and rehabilitated pit then Wallanbah North pit.
Proposed strategy	Storage containers and infrastructure will be removed

5.2 Site history

The Wallanbah blast magazine is a purpose built facility for storing detonators and explosives for use in initiating bulk explosives in the mine pits. The magazine has been present since the early 2000 and has had up to 3 magazine containers present on site . Currently the magazines are used for storage of detonators in one container and dynamite in the other. It was indicated that, regulatory requirements and procedures are in place for the facility to minimise risks during operation, including access, storage and handling with all materials required to be in sound condition and free from exposure to contamination, that may include iron, steel, dirt, grit, trace of explosive, or other dangerous or objectionable substance. This would guarantee that no spills or releases of any explosive contents would have occurred.

Explosives and initiating explosives must be stored and managed to ensure compliance with Statutory regulations including Queensland Government Explosives Act 1999 (Explosives Regulation 1955), Mining and Quarrying Safety and Health Act 1999 and the Coal Mining Safety and Health Act 1999. Other key considerations include minimising the risk of accidental explosions, deterioration and maximise shelf life and maintain appropriate security measures including preventing unauthorised access and theft. Blast magazines are usually established near mine areas where blasting occurs to facilitate easy and safe access and often use special containers (constructed to AS2187.1-1998) to allow the magazine to be portable and allow re-establishment elsewhere as required.

Magazines and magazine compounds must be correctly established and licenced by the relevant statutory authority of the state in which they are located and are regularly audited along with the management and operation of all explosive facilities and their use.

5.2.1 Chemical Register

The following hazardous materials were identified to have been used or stored at the magazine facility:

- BESTDETS non-electric detonators
- BST Boosters
- Digi Shot Electronic Detonators
- Powermite Pro

5.2.2 Spill Incidents

No records of spill incidents or environment hazards were reported at the Wallanbah Blast Magazine.

5.2.3 Aerial photographs

Based on the available information and documents provided by Peabody, the following relevant site history were summarised:

Table 2 Aerial Image Review

Year	Comment
2009	The site is a rectangular cleared area, with perimeter fencing and a main access road from the southeast and another smaller track located in the northern corner, travelling northeast. A haul road or light vehicle road, is also present, 30 m to the west of the compound, parallel to the access track. Three mounds (blast protection) within the compound are present, appearing as large trapezoidal stockpiles, one at each end of a line of three shipping containers, stacked parallel to each other and located approximately 15 m apart. Another large stockpile is present along the whole eastern side of the compound extending past the containers and both stockpiles located at the ends. A small rectangular pad or building is also present outside the cleared area, to the east and another dirt roadway is located to the north, approximately 60 m away. The immediate surrounds appear to be vegetated with grass and trees with open grazing areas also present.
2015	Based on review of the aerial image from November 2015, no changes have been observed at the Wallanbah Blast Magazine site.

5.3 Site inspection

The site inspection was undertaken outside the fenced area due to regulation requirements. The magazine compound was located in a cleared area and had a secure perimeter fence with warning signage and two locked gates at each associated with access and egress roads. No vegetation was apparent in proximity or within the facility and it was clean and tidy with no debris or equipment except for two shipping containers located off centre with compacted and formed earthen bunds at each end and along the eastern side, approximately 2 m high. The bunds were observed to act as blast protection mounds.

5.4 Conceptual site model

5.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the information obtained, no areas of environmental concern (AECs) and potential contaminants of concern (PCoC) have been identified and therefore no qualitative risk assessment or conceptual site model is considered required to be undertaken.

5.5 Summary

Although there was limited history information, based on the regulatory requirements for these facilities, the area is considered to pose a low risk to the environment, based on the storage and handling of materials within the magazines. It is also noted that these materials will be removed upon decommissioning of the facility.

6. Functional Area B – Ex-Orica Reload Facility

6.1 Site Description

The reload facility, is located directly off and parallel to the Mallawa Haul Road. It is a rectangular cleared area containing a man proof perimeter fencing and opposing entry and exit roadways, currently having all internal infrastructure removed.

Reload facilities are compounds where bulk explosive components are stored, weighed and loaded for use. Consistent with magazine and explosives storage and use, reload facilities require bulk explosive components to be stored, managed and handled to ensure compliance with Statutory Regulations, Codes of Practice and guidance documents. These facilities and compounds must be correctly established and licenced by the relevant statutory authority. The site access to the reload facility is managed under stringent requirements and supervision.

Security sensitive ammonium nitrate (SSAN), is administered under the Explosives Act 1999 and is authorised administratively as an explosive under the Act. SSAN retains its dangerous goods classification and is referred to as an explosive of class 5.1, class 9 or a non-dangerous good in the case of calcium ammonium nitrate. Safety distances and storage of SSAN must also meet safety requirements as outlined in the Dangerous Goods Safety Management Act 2001 and, if on a mine site, the applicable mining legislation, plus any particular requirements outlined in the manufacturer's Material Safety Data Sheet.

All SSAN is to be accounted for as an explained loss and spills are to be cleaned up and disposed of in accordance with AS 4326. The amount disposed of is to be recorded and written off by a person who is authorised to do so in the security plan with spills and explained losses formally recorded.

Location of the functional area is presented in Figure 2-2, and the site features are showed in Figure 6-1. Details of the site are summarised in Table 1.

Table 1 Site Details Summary

Site Details	Description
Location	Located 1.5 km east of the Wallanbah North Pit and next to the Mallawa Haul Road
Area (ha)	1.8
Lot/Plan	Lot 3 GV54
EMR/CLR	Not listed on EMR/CLR.
Current land owner	Allan Gordon Homer Williams
Mining lease	ML 70252
Current use/activity	Decommissioned and unused.
Former	Storage of blasting material/chemical, including diesel and AN storage,

Site Details	Description
use/activity	reload area,
Current infrastructure	Perimeter fencing, with a small dam located near the south-west corner, outside the fence.
Former infrastructure	• Aboveground storage tanks (ASTs) for diesel fuel, AN Gel (emulsion) or prill on a concrete pad. • Shipping containers for storing equipment • Portable water tank • Amenities, demountable buildings • Equipment and containers for handling and loading the ANFO chemicals • Mobile Processing Unit (MPU) used for mixing materials
Topography and drainage	Generally flat, regional topography slopes very gently towards west.
Hydrology	Bullock Creek is located 0.4 km west from the functional area.
Hydrogeology	There is one groundwater monitoring bore (BDW46) located 1.8 km north-west from the functional area. No water quality information from the bore, except the SWL was recorded at 57.89 mbTOC in December 2009.
Surrounding land use	North: Vegetated pasture land and a farm dam located at north-east across the Mallawa Haul Road South: Vegetated pasture East: Mallawa Haul Road running towards south. West: Bullock Creek and blast magazine (functional area A) located 0.9 km north-west.
Proposed strategy	Tanks and infrastructure will be removed. The area will be remediated as required, with respect to contamination only.

6.2 Site history

The Ex-Orica reload facility was associated with the Wallanbah and Broadmeadow Pits and was indicated to have operated from approximately 2004 till being demobilised around 2013.

The reload facility and the Burton Mine use ANFO (for ammonium nitrate/fuel oil) which is a widely used bulk industrial explosive mixture consisting of approximately 94% porous prilled ammonium nitrate (NH4NO3) (AN) that acts as the oxidizing agent and absorbent for the fuel and 6% of a fuel oil (FO) such as diesel. Its cost, performance and ease of use make it a common explosive for mining industry use.

Other explosives based on the ANFO chemistry are emulsions (gels) which are also used, having water resistance, higher bulk density and that the slurry material can simply be poured into the casing (blast hole). The AN, as a prill (porous pellets) and gel are delivered in bulk form, where they can be stored on site along with the FO. A gassing solution is also used to promote oxidisation of the explosion and is stored in IBCs within the compound.

Prior to use, specially designed trucks or trailers called Mobile Processing Units (MPUs), combine the ingredients and pump or auger them into the borehole at the proposed blast location. The authorised shot firer undertakes the measuring of the ingredients, including weighing the materials at the reload facility to confirm ratios, prior to the mixing being undertaken and the explosive placed in the borehole.

Recently, in August, the remaining concrete slabs were broken up and removed, for appropriate disposal, with the demountable building and water tank being removed also. Staff indicated that no odours or staining was apparent during the slab removal in the location of the fuel and AN storage.

6.2.1 Chemical registers

In accordance to the Thiess Burton Hazardous substance register, the chemicals stored or used on the reload facility included the following:

- ANE Series Ammonium Nitrate Emulsion
- Spray Paints
- Anglomoil Trans 90GL-1 (Gear Oil)
- Aqueous Sensitiser (gassing solution)
- BESTCORD detonating cord
- CRC 3013 soft seal (aerosol)
- L4 Gassing solution
- Molybon Opal Hi-Load Grease
- Porous Prill Ammonium Nitrate (AN)
- Pumpable Emulsion Series (S100 and S300)
- Heavy ANFO Series (S100 and S300)
- Silastic 732 (R) RTV Adhesive Sealant
- Surface bulk emulsion
- Koolkap Gas Bags
- Blast Bag Zero

6.2.2 Spill incidents

There were four spill incidents recorded on the Peabody Spill Registers, as summarised below:

- 22 January 2004: Approximately 80 kg of explosives products (have not specified which ingredient) spilled onto ground from the transfer hose when transferring explosives product from the storage container. No corrective actions recorded. The weather was recorded to be fine and dry when incident occurred.
- 24 May 2004: Explosives products (have not specified which ingredient) overflowed onto the roof of the storage tank during pumping, however, the spill was not cleaned up as it was not accessible to the roof of the tank.
- 30 October 2004: Approximately 5 tonnes of explosives products (have not specified which ingredient) was spilled onto the ground overnight, the weather was recorded to be raining and muddy. No corrective actions recorded.

- 3 May 2012: Approximately 800 L of the gassing solution chemical was spilled onto the ground from a punctured bulk chemical bin. The spilled area was contained, and contaminated soil was removed from site by contractor (JJ Richards) for treatment.

6.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed and is discussed in Table 2. Aerial images perused included 2010 - 2015.

Table 2 Historical aerial photograph summary

Date	Description
2010	The site appears as a fenced rectangular area with entry and exit roads in the north and south from a haul road that runs parallel to the site. Another roadway, is also present, from the southern access point that travels to the west (towards the magazine site). Near the centre of the site are two white rectangular structures, assumed to be the diesel and AN gel tanks/hoppers, with another structure located adjacent, being possibly the AN prill hopper. Some smaller objects are coated in the south-western corner, possibly mobile ANFO mix modules and trucks. Outside the fenced compound, a rectangular area to the south contains two structures, considered to be the demountable office building and amenities, with another structure between the two buildings that may be the water tank. Located to the northwest of the office building are possibly shipping containers. To the south west of the fenced compound, the small dam is visible, with a drainage line catching runoff from the compound. The immediate surrounds appear to be well vegetated with grass and trees present.
2015	In this photo, it is seen that all infrastructure within the fenced area is removed with some slabs remaining in the centre. To the south outside the compound is two small structures, being the water tank and a demountable building with the small dam located further west. The surrounding land appears similar to the earlier photo.

6.3 Site inspection

The former reload facility perimeter fence remained with no infrastructure being present inside the compound at the time of site inspection. A depression approximately 0.5 m deep was noted in the centre of the compound where the former concrete slabs were located. The remnants of a reinforced footing still remained in one location but no other debris was noted in the area.

Outside the fenced area, to the south, a pad was observed where the former water tank was located with no evidence of the former demountable location being present.

The small dam contained some water, was earthen, shallow and had no indicators of any contamination. A sign was also present on the ground adjacent.



Photo 1 View of the adjacent dam.

There was no indication of any staining, odours or indicators of contamination noted within and outside the fenced area.



Photo 2 Looking through the access gate to the location of the former concrete slab.

6.4 Conceptual site model

Based on our understanding of the contamination issues and site setting a conceptual site model (CSM) has been generated as a basis for assessing the risk posed by any potential *source -> pathway -> receptor* linkages (or pollutant linkages). Based on the current understanding of possible contaminant sources the CSM is general in nature and there is considered to be limited value in individual CSMs for each possible source.

The CSM assumes a commercial industrial land use scenario consistent with the sites current use as coal processing facility.

6.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the document review provided by Peabody, the following areas of environmental concerns (AECs) and potential contaminants of concern (PCoC) were identified.

Table 3 Summary of AECs and PCoCs

AEC	Contamination Sources	Associated PCoC
Former ASTs/IBCs	Leaks from storage system & accidental spills that cause hydrocarbon impacts in soils and within shallow perched water underneath ASTs	Diesel (TRH and BTEXN) Ammonium nitrate
General Areas	Trucks and equipment, potential localised soil contamination from leaks and spills	TRH and BTEXN Ammonia nitrate

6.4.2 Potential sensitive receptors

Based on site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- Current workers at the site including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench

Potential Sensitive ecological receptors

- The closest ecological receptor is Bullock Creek located approximately 0.4 km west from the functional area, that runs toward south-west.
- Stock grazing on adjacent pasture

6.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 4), showing no potential source-pathway-receptor (S-P-R) linkages.

Table 4 CSM -Potential source-pathway-receptor linkage

AECs	Former ASTs/bulk containers	General Areas
Source	Spills and leaks of explosives ingredients or fuel causing contamination to surface soil and shallow groundwater	Storage, loading and dispensing equipment, where potential localised soil contamination from leaks and spills occurr
PCoC	TRH, BTEXN Ammonium Nitrate	

AECs	Former ASTs/bulk containers		General Areas
Pathway	Direct Contact/ Ingestion of impacted soil/perched groundwater Inhalation of hydrocarbon vapour		Lateral migration of contaminants surface water through runoff
Receptor	Workers on site	Workers on site	Bullock Creek Stock of adjacent grazing pasture
S-P-R Linkages	Unlikely (see note 1)	Unlikely (see note 2)	Unlikely (see note 3)

1. Infrastructure and chemical storages have been removed from the site, and no gross contamination observed during the site inspection. Although a few spill incidents have occurred previously, none of the spills were related to hydrocarbon fuel spills, and the explosive ingredient spills were most likely cleaned up immediately due to the regulation and safety requirements on site.
2. Local groundwater gradients are considered to have been influenced within the mine site operational areas including the pits, dewatering, water storage and backfilling. Based on the significant distance from potential contamination sources to adjoining rural properties, that there is unlikely a direct connection geologically with water supply bores in the area and that a high level of attenuation may be occur, there is considered to be no direct connectivity present. Vertical migration is also thought to be limited, considering the relatively shallow bedrock onsite and observed lo permeability soils.
3. Creeks that flow through the mine site are required to be isolated from receiving any potential contaminated runoff which is captured and managed on site. As part of the mine licence, licenced release points are required to meet specific discharge criteria also, including further approval prior to any release occurring. Potentially dirty and clean runoff is managed and separated within the whole mine site with sediment and process dams, diversion structures and water pumping systems being employed at the mine site, for use and also recycling.

6.5 Summary

The site historical review and inspection indicated that diesel and AN was stored on site and dispensed into the mobile ANFO mix modules, prior to them going to the blast location for transferring the ANFO to the borehole. Based on the stringent requirements for cleanliness, immediate clean-up of any spills and no recorded incidences noted, the absence of chemical storage on site, the ex-orica reload facility is considered to pose a limited risk for contamination.

7. Functional Area C – Widening Reload Facility

7.1 Site Description

The Burton Widening reload facility is similar to the former operational Functional Area B facility where bulk explosive components are stored, weighed and loaded for use, that must comply with Statutory Regulations, Codes of Practice and guidance documents. This facility is still currently operational and licenced by the relevant statutory authority.

The locality of the functional area is shown in Figure 2-2, and Figure C, included in Appendix A illustrates current infrastructure and areas.

Details of the site are summarised in Table 1 and discussed further below.

Table 1 Site Details Summary

Site Details	Description
Location	Located at the North-Eastern Boundary of the Burton Pit.
Area (ha)	1.65
Lot/Plan	Lot 9 RP903903
EMR/CLR	Listed on EMR for the following Notifiable Activities: • Chemical Storage • Petroleum Product or Oil Storage • Waste Storage, Treatment or Disposal • Mine Wastes • Livestock Dip or Spray Race (associated to farming activities) Not listed on CLR.
Current land owner	BHP Coal Pty Ltd, UMAL Consolidated Pty Ltd, BHP Queensland Coal Investments Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investment Pty Ltd, QCT Mining Pty Ltd and QCT Resources Pty Ltd.
Mining lease	ML 70109
Current use/activity	Blast/Explosive Chemical Storage and reloading
Former use/activity	Unknown (possibly grazing land)
Current infrastructure	• ASTs for diesel fuel, AN Gel (emulsion) or prill on a concrete pad. • IBC containing gassing solution • Loading equipment (loader, scales) • Generator
Former	There was a former site building located at the south-eastern corner of the

Site Details	Description
infrastructure	site.
Topography and drainage	Based on review of Google Earth and QLD global imagery from 2010, it appears that drainage from the site is likely to run towards the north. The C1 drain is present to north adjacent to the Mine access road, that flows to Anna Creek, approximately 4.6 km away.
Hydrology	Small dam approximately 400 m North East of site.
Hydrogeology	The closest groundwater bores are BD1249P (1.2 km north-west, next to a dam) and DDH55 (1.2 km south-west). The historical monitoring results indicated: • SWL of BD1249P was 4.70 mbTOC as recorded in May 2012, the shallow SWL is most likely influenced by the presence of water dam adjacent • pH of groundwater at BD1249P was neutral pH 7.27 while EC was highly saline (13,100 µS/cm) • SWL of DDH55 was 47.31 mbTOC recorded in October 2012 • No water quality information available at DDH55.
Surrounding land use	North: Cleared land and a light vehicle road that goes to the pit South: Vegetated vacant land, Go-Line and crib hut, then further south the ROM and workshop East: Light vehicle road, grassed area (rehab), C1 drain, site access road. West: Burton Coal Mine pit (backfilled with CHPP waste) then landfill spoil
Proposed strategy	Currently in use and will remain post Thiess demobilisation, however ANFO products will be removed.

7.2 Site history

The Burton Widening reload facility is currently associated with the Burton Pit widening operations and was indicated to have commenced operated from approximately 2011 and has had a number of changes over time. The facility is similar in infrastructure to what was present at the Functional Area B, former reload facility.

Bulk diesel fuel in an Above Ground Tank (AST) located on a concrete pad, an AST (approx. 40,000 L) containing AN gel (emulsion) and shipping container with stores is currently present. The facility uses heavy ANFO, being a blend of ANFO and emulsion (gel), which is made to increase the bulk density of normal ANFO, with the ability to be loaded into partial wet holes. A gasifier (exciter) solution stored in IBCs, is also used as an additive to promote oxidation, and is stored within IBCs within the compound. It was indicated that the gel tank is orientated at an angle to aid in the draining of the liquid but the tank usually has a quantity of get remaining always in the tank that partially solidifies. When required, gel is ordered and arrives in a truck at an elevated temperature that flows better as a liquid when it is added to the AST. There is no prill storage on site and this is ordered and delivered where it discharges to the hopper elevator to load the Mobile Processing Unit (MPU) directly. Sometimes product may also be bagged on

site, when the truck has some remaining or when it requires its contents to be emptied out for things like servicing.

A diesel generator is used to power a pump for emulsion and a potable water tank s also present on site. Scales are present along with measuring hoppers that are used to check the density and mixing quantities for the ANFO, which is loaded into a specialised bulk truck (MPU vehicle) used for the loading of heavy ANFO, which mixing of components prior to loading the shot hole. The NPU has three chambers, diesel process fuel, AN (prill) and emulsion with both an auger mix and a mono pumping system that pumps out through a flexible hose. A container on site is used to store spares, bags, shovels, absorbent for spills and other equipment for use on site. Depending on the blasting requirements, the type and amount of equipment may have varied over time.

The spillage of any materials were indicated to be immediately cleaned up, including using a sucker truck, or manually shovelling up spills along with any soils for appropriate disposal.

7.2.1 Chemical registers

In accordance to the Thiess Burton Hazardous substance register, the chemicals stored or used on the reload facility includes the following:

- ANE Series Ammonium Nitrate Emulsion
- Spray Paints
- Anglomoil Trans 90GL-1 (Gear Oil)
- Aqueous Sensitiser (gassing solution)
- BESTCORD detonating cord
- CRC 3013 soft seal (aerosol)
- L4 Gassing solution
- Molybon Opal Hi-Load Grease
- Porous Prill Ammonium Nitrate (AN)
- Pumpable Emulsion Series (S100 and S300)
- Heavy ANFO Series (S100 and S300)
- Silastic 732 (R) RTV Adhesive Sealant
- Surface bulk emulsion
- Koolkap Gas Bags
- Blast Bag Zero

7.2.2 Spill Incidents

There is one spill incident recorded at the Burton Widening Reload Facility on the Peabody Spill Incident Register:

- 13 August 2012: A diesel spill that occurred while filling or operating a pump was identified during an inspection.

7.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed and is discussed in Table 2. Aerial images perused included 2010 - 2015.

Table 2 Historical aerial photograph summary

Date	Description
2009	Based on review of imagery from 2009 provided by Peabody, it appears that the Burton Widening Reload Facility did not exist at this point in time.
2012	Based on review of aerial photo from 2012, the functional area appeared to been cleared of vegetation and covered with hardstand or concrete and have commenced utilized as reload facility. The boundaries of the site can be seen, isolated byan earth bund, and the tanks and shipping containers/silo tanks can also be seen on site. There was also a small demountable building at the south-eastern corner.
2016	There are no available aerial imagery after 2012, however, the current site features will be further discussed in Section 7.3.

7.3 Site inspection

The site differs considerably regarding infrastructure compared to the aerial photo and no site hut was present outside the fence also.

The reload facility is operational and surrounded by a man proof perimeter fence. In the centre of the compound is a self bunded AST diesel tank with a cylindrical AST set at an angle directly opposing. In the centre is a pump and diesel generator with a HDPE pellet bund containing the fill nozzle to contain any spills. A poly tank also present adjacent for water.



Photo 1 The compound with the diesel AST to the left, the generator, pump and water tank in the centre and the gel (emulsion) AST to the right.

Parked adjacent is an auger elevator loader and against the southern fence line is an IBC containing exciter liquid in a frame that is roofed and able to be lifted by a forklift, along with some empty IBCs.

Directly north of the gel AST is a set of scales with some bags present on a pellet adjacent and a shipping container located near the northern fence. Another two containers are also located outside the fence line to the west.



Photo 2 The gel (emulsion) AST tank, with the scales in the centre and the container of equipment to the left and north.

Other isolated pieces of equipment include a small front end loader bucket and two hoppers used for weighing products. There was no indication of any staining, odours or indicators of contamination noted within and outside the fenced area, although a full inspection inside was not possible as the site was secure.



Photo 3 Specialised Mobile Processing Unit (MPU vehicle) vehicle with its three chambers, diesel process fuel, AN (prill) and emulsion along with its auger and mono pump mix and delivery systems.

7.4 Conceptual site model

7.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the document review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 3 Summary of AECs and PCoCs

AEC	Contamination Sources	Associated PCoC
ASTs/IBCs	Leaks from storage system & accidental spills that cause hydrocarbon impacts to soil and shallow perched water underneath ASTs	Diesel (TRH and BTEXN) Ammonium nitrate
General Areas	Trucks and equipment and potential localised soil contamination from leaks and spills	Diesel (TRH and BTEXN) Ammonium nitrate

7.4.2 Potential sensitive receptors

Based on site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- Current workers at the site, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- No sensitive ecological receptors were identified in the vicinity of the area.

7.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table Table 4), showing no potential source-pathway-receptor (S-P-R) linkages.

Table 4 CSM -Potential source-pathway-receptor linkage

AECs	ASTs/bulk containers	General Areas
Source	Spills and leaks of explosives ingredient or fuel causing contamination to surface soil and shallow groundwater	Trucks and machineries working where potential localised soil contamination from leaks and spills
PCoC	TRH, BTEXN, Ammonium Nitrate	
Pathway	Direct Contact/ Ingestion of impacted soil/perched groundwater	

AECs	ASTs/bulk containers	General Areas
	Inhalation of hydrocarbon vapour	
Receptor	Current workers at the site, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.	
S-P-R Linkages	Unlikely (see note 1)	

1. Although a few spill incidents have occurred previously, none of the spills were related to hydrocarbon fuel spills, and the explosive ingredient spills were most likely cleaned up immediately due to the regulation and safety requirements on site. Therefore, the migration of contamination either lateral or vertical is limited. The C1 drain is located to the north approximately 350 m with Anna Creek, being a sensitive receptor, 4.5 km away

7.5 Summary

The site historical review and inspection indicated that diesel and AN was and is still stored on site and dispensed into the mobile ANFO mix modules, prior to them going to the blast location for transferring the ANFO to the borehole. Based on the stringent requirements for cleanliness, immediate clean-up of any spills and no recorded incidences noted, the Burton Widening reload facility is considered to pose a limited risk for contamination.

8. Functional Area D – Plumtree Excavator Laydown

8.1 Site Description

The Plumtree excavator laydown area is located directly off the Mallawa Haul Road, adjacent to the east and sits at the toe of the batter of the Plumtree north spoil stockpile which is north of the Plumtree void. Sandy creek is present to the north and east and to the west and southwest the stockpile area has been rehabilitated. The facility is an oval shape with a heavy vehicle and separate light vehicle access and has been closed for a number of years.

The location is presented in Figure 2-2 with the area and site details shown in Figure D, included in Appendix A that also illustrates current infrastructure and activity areas, where present.

Details of the site are summarised in Table 1.

Table 1 Site Details Summary

Site Details	Description
Location	Located at the Northern end of the Plumtree pit
Area (ha)	4.0
Lot/Plan	Lot 5311 SP262721
EMR/CLR	Not listed on EMR/CLR
Current land owner	Queensland State Government. The land is leased (expiring on 7 November 2043) to Ganra Pty Ltd Gaffwick Pty Ltd
Mining lease	ML 70258
Current use/activity	Not used, redundant.
Former use/activity	Excavator laydown, Go-line and light vehicle parking. Crib facilities, demobilisation laydown area.
Current infrastructure	No infrastructure remaining except for earth windrows and bunds, access roadways
Former infrastructure	Hardstand, windrows and bunded areas, sediment basin, Demountable crib hut, access roads.
Topography and drainage	Topography at the functional areas is likely to slope towards the pit and north towards Sandy Creek. Generally, runoff previously drained to a sediment basin and then the pit, with some flows also possible outside operational areas towards Sandy creek.
Hydrology	Sandy Creek is located 0.1 km north from the site. A surface water

Site Details	Description
	release point (R12) is also located close to the site along Sandy Creek.
Hydrogeology	There is no registered groundwater bore identified in the vicinity of the site.
Surrounding land use	North: Road, bushland, Sandy Creek with further bushland. South: Plumtree North void East: Road, Haul road and creek, cleared grazing land West: Cleared area and rehabilitation hill
Proposed strategy	The area to be progressively rehabilitated with a levee bank to be constructed to divert flows from entering the Plumtree pit.

8.2 Site history

The Plumtree laydown area was associated with the Plumtree pit and was indicated to have operated from approximately early 2000 till being demobilised around 2013 with the Go-line operating the last 3 years of operation.

An excavator laydown and heavy vehicle go line was located on the site with a circular turn and park and an entry and exit roads. Minor maintenance and provisioning may have occurred at the site and no hardstand, servicing or permanent fuel/oil storage occurred. A crib hut and light vehicle parking area also was present in the northern portion with a tank for sewage that was emptied by vacuum truck for appropriate disposal.

8.2.1 Chemical Registers

No records of hazardous material stored at the functional area.

8.2.2 Spill Incident

No records of spill incident occurred at the functional area.

8.2.3 Aerial photographs

Based on the available information and documents provided by Peabody, the following relevant site history were summarised:

Table 2 Historical aerial photograph summary

Date	Description
2010	Based on review of aerial imagery from July 2010 it appears that the site held vehicles as well as a shed. The site is present at the northern end of a large stockpile with access from the east along two roadways. In the west, there appears to be two large pieces of equipment parked, possibly excavators with a circular turning area and Go-line to the south and east, surrounded by perimeter bunds. In the centre portion of the site is a structure which may be the crib building and some vehicles parked, To the north is a sediment basin containing water with stockpiles of soil adjacent. Further north is a roadway, some grassland and then Sandy Creek with riparian vegetation along tits length. To the east is the haul road and grazing land and Sandy Creek with an adjacent farm dam. A large stockpile is present directly south of the site with a haul road

Date	Description
	on its crest and a ROM pad adjacent. A revegetated hill is to the west of the site.
2013	Based on review of aerial photo from September 2013, it appears that the vehicles had been removed from the site, however the crib hut remained.
2015	Based on review of aerial photo from November 2015, it appears that there is no infrastructure on site. There is a pool of water at the South-Western section of the site. There are two main accesses to the site, one at the South-Eastern end of the site, and the other at the Northern end of the site.

8.3 Site inspection

The former facility had no infrastructure present with some remnant bunds identifying the former parking areas. In the west a number of stockpiles were observed, not fully contoured and a number of small riles and berms were noted in the area. No remnants of buildings were apparent and the former sediment basin area was not present.



Photo 1 View of the excavator laydown area.

A small depression collecting site runoff contained water and no films, staining or evidence of any contamination was observed and there was no indication of any other staining, odours or indicators of contamination noted within the area.

8.4 Conceptual site model

8.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the document review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 3 Summary of AECs and PCoCs

AEC	Contamination Sources	Associated PCoC

AEC	Contamination Sources	Associated PCoC
Laydown and Go-line areas	Possible minor leaks and spills from vehicles and machinery	TRH and BTEXN

8.4.2 Potential sensitive receptors

Based on site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

- Current workers at the site, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench

Potential Sensitive ecological receptors

- Sandy Creek is located 0.1 km north from the site.

8.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 4), showing no potential source-pathway-receptor (S-P-R) linkages.

Table 4 CSM -Potential source-pathway-receptor linkage

AEC	Laydown and Go-line areas	
Source	Possible minor leaks and spills from vehicles and machinery	
PCoC	TRH and BTEXN	
Pathway	Direct Contact/ Ingestion of impacted soil/perched groundwater Inhalation of hydrocarbon vapour	Lateral migration through surface water runoff
Receptor	Current workers at the site, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.	Sandy Creek
S-P-R Linkage	Unlikely[1]	Unlikely

1. The site has only been used as laydown and demobilising, no spills and former chemical storage identified in site history assessment. No gross contamination observed during the site inspection. Any potential residual risk can be managed by normal site operation Occupational Health and Safety (OH&S).
2. As only minor spills were expected, it is more likely to be contained on site. Historical during operation, flows would have gone to sediment basin and the pit.

8.5 Summary

Based on the site history review and CSM, the Plumtree Excavator laydown area is considered to pose limited human health and environmental risk.

9. Functional Area E – Demob Pad/Compound

9.1 Site Description

The demobilisation pad is a current fenced laydown area that is located directly north of the BIS workshop, where equipment has and is now being stored prior to being demobilised from the mine site.

The location is presented in Figure 2-1 with the area and site details shown in Figure E, that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 1 and discussed further below:

Table 1 Site Details Summary

Site Details	Description
Location	The demobilisation compound is located directly off and parallel to the Mallawa Haul Road and north of the BIS workshop.
Area (ha)	2.44
Lot/Plan	Lot 5311 SP262721
EMR/CLR	Not listed on EMR/CLR
Current land owner	Queensland State Government. The land is leased (expiring on 7 November 2043) to • Ganra Pty Ltd • Gaffwick Pty Ltd
Mining lease	ML70109
Current use/activity	Laydown area and demobilisation pad for Thiess equipment
Former use/activity	Laydown area.
Current infrastructure	Perimeter fence and hardstand area, waste and recycling bins
Topography and drainage	Site grades towards a surface water dam located directly to the west and drains via overland flow. Surface water dam (enviro dam) , overflowing to the Ellensfield Co-Disposal void dam. Minor flows may also travel south-west towards the Dirty Water Dams., open vegetated area.
Hydrology	Closest creek is Teviot Creek located 2 km south-east from the site.
Hydrogeology	The closest monitoring bore is BD1250P located 0.8 km north-west from the compound. Latest groundwater monitoring result available dated June 2011 indicated:

Site Details	Description
	• Standing water level was 13.08 m below top of casing (bTOC) • Neutral pH 7.46 and high salinity 10,800 µS/cm • Heavy metal concentrations were either non-detectable of at very low levels Hydrocarbon analytical results level were reported non-detectable.
Surrounding land use	North: Pump Fitters workshop South: Truck GO-line and BIS workshop, then grassed and tree vegetated area East: Sewage Treatment Plant and irrigation area, grassed and tree vegetated area, Kerlong accommodation village West: Surface water dam, then co-disposal pit void dam
Proposed strategy	Remain as a hardstand area and in possession of Thiess as Site Senior Executive) for a year until handed back to Peabody. Any rubbish and debris will be cleaned up by Thiess and the area will be remediated as required, with respect to contamination only.

9.2 Site history

The site has been used as a mobilisation/demobilisation compound and a storage area for equipment since early 2000. Vehicles, equipment, pipes, containers, machinery and parts have been stored there but it has not been used for permanent fuel/oil storage or as a maintenance area. Recycled steel has also been stored there along with some minor inert waste prior to being disposed of.

Currently, Thiess is parking its equipment within the yard prior to taking to the north demobilisation yard for dismantling, or dismantling on site, for removal. Dump trucks and machinery will be routinely started up and run for a period as part of maintaining the equipment in running order and to minimise degradation over time. It is unlikely that refuelling will occur as the run time will be limited but other provisioning, checking oils and fluids, pumping up tyres and routine maintenance will occur on an as need basis.

On occasion, self-contained and bunded fuel tanks may be stored onsite awaiting removal, with no bulk fuel or oil dispensing being undertaken on site. When this is required, it will be done by service trucks.

9.2.1 Chemical Registers

No records of hazardous material stored at the functional area.

9.2.2 Spill Incident

No records of spill incident occurred at the functional area.

9.2.3 Aerial photographs

Based on the available information and documents provided by Peabody, the following relevant site history were summarised:

Table 2 Historical aerial photograph summary

Date	Description

Date	Description
2010	The site appears as a fenced rectangular area with entry and exit roads in the north and south from a haul road that runs parallel to the site and the access road to the BIS workshop. Various equipment is present throughout the compound, including what appears to be shipping containers, dump trucks, bins and equipment of various sizes, with a concentration of these in the northeast corner. The surrounding area includes the haul road, STP and village to the east, trailer storage and a dam to the west, the pump fitters shed to the immediate north and the BIS workshop to the south.

There is no aerial imagery available post 2010 at the time of this PSI.

9.3 Site inspection

The facility perimeter fence is secure and the area appears to have been recently cleaned up prior to large equipment being placed in rows across the site. Two stockpiles (at eastern gate and northern fence line) of soil scrapings with minor debris and a pile of steel, pipe, wood and polyvinyl chloride (PVC) material are present, approximating 100 m^3 in total. Industrial bins are also present with recycling being undertaken. It was indicated that the rubbish will be removed and appropriately disposed of.



Photo 1 Stockpiled soil scrapings debris present near the northern fence line awaiting removal.

Across the site, machinery including loaders, dump trucks, bulldozers, water trucks and other mine vehicles are present.



Photo 2 Machinery present at the functional area.

Associated with the equipment storage, isolated staining from leaks of oil was evident beneath some machinery, but was of low volume and generally not extensive.

There was no other indication of any indicators of contamination noted within and outside the fenced area.

9.4 Conceptual site model

9.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the document review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated PCoC
Discrete areas of staining	Minor drips and leaks from machinery and residues from equipment stored	TRH and BTEXN
Stockpiled debris and scrap material on site	Material is not removed and remains	TRH and BTEXN, heavy metals Inert waste, litter

9.4.2 Potential sensitive receptors

Based on information contained in past reports, review of aerial imagery, observations made during the site inspection, and the site remained as commercial industrial land use, with no redevelopment or upgrade work proposed, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- Current workers at the site including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench

Potential Sensitive ecological receptors

As there are no natural surface water bodies adjacent to the functional area E, and the onsite surface water runoff is likely to end up in the surface water dam located west and eventually into the Ellensfield Co-Disposal Pit, it is therefore considered that no potential ecological receptors is likely to be affected by the activities on functional area E.

9.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 4 CSM -Potential source-pathway-receptor linkage

AECs	Discrete areas of staining and minor debris within the compound	Stockpiled debris and scrap material on site
Source	Minor drips and leaks from machinery and residues from equipment stored	Material is not removed and remains
PCoC	TRH and BTEXN	TRH and BTEXN, heavy metals Inert waste, litter
Pathway	Direct Contact/ Ingestion of impacted soil/perched groundwater Inhalation of hydrocarbon vapour	
Receptor	Current workers at the site, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.	
S-P-R Linkages	Unlikely[1]	Unlikely[2]

Note:

1. The site has only been used as laydown and demobilising, no spills and former chemical storage identified in site history assessment. No gross contamination observed during the site inspection. Any potential residual risk can be managed by normal site operation Occupational Health and Safety (OH&S).
2. The inert waste is not likely to cause human health or environmental harm, however, it is recommended that the stockpiled soil and debris on site be appropriately disposed of and documented, including where significant leaks/staining is present.

9.5 Summary

It is concluded based on the preliminary assessment undertaken, the demobilisation pad is considered to pose a limited risk for onsite contamination and potential migration.

Based on no major incidences occurring on site with respect to contamination and that any significant spills are remediated, it is considered that no further assessment, including quantitative investigation, be required and that the site is suitable for its continued use as planned.

If during future rehabilitation operation and earthworks, if any visual indications or olfactory of contamination are identified, work should be halted and further assessment undertaken with subsequent remediation as required.

10. Functional Area F – Wallanbah Hardstand Area

10.1 Site Description

The Wallanbah hardstand was a former maintenance and machinery storage area in the early part of the mines operation associated with the satellite pits Wallanbah and Broadmeadow.

The locality of the functional areas is showed on Figure 2-2, and the site features are presented in Figure F. Details of the site are summarised in Table 1 and discussed further below.

Table 1 Site Details Summary

Site Details	Description
Location	East of the Wallanbah pit
Area (ha)	5.2
Lot/Plan	Lot 3 GV54
EMR/CLR	Not listed on EMR/CLR
Current land owner	Allan Gordon Homer Williams
Mining lease	ML 70252
Current use/activity	None, remains unused
Former use/activity	Machinery and equipment storage, workshop and maintenance, washbay, Go-line, fuel storage – Redundant-l equipment has also been stored here.
Current infrastructure	No buildings, remnant earth bunds, open drains, hardstand areas and dam at North Western edge of site. Minor concrete foundations and pit/pipes in ground.
Former infrastructure	Hardstand areas, demountable office buildings, workshop using two shipping containers and frame roof, bunded AST diesel storage, possible washbay. .
Topography	Likely to slope gently towards west and dam, via overland flow and open drains.
Hydrology	Bullock Creek is located 0.2 km west from the functional area, running towards south. Spade Creek is located 0.7 km south and runs into Bullock Creek. A dam (South Eastern Dirty Water Dam) is located immediately west to the hardstand (which likely to collect runoff from the hardstand and functional area).
Hydrogeology	There is one registered bore (RN162255) located 0.8 km south-east from the functional area. The bore was registered as sub-artesian facility for monitoring purposes. The SWL of the groundwater was recorded at

Site Details	Description
	4.24 mbTOC. No groundwater quality available.
Surrounding land use	North: Grazing, outer pit dump (stockpile) and vegetated area South: Pit Access Road and then vegetated area, Spade Creek East: Mallawa Haul Road and grassed area West: Dirty water dam then Bullock Creek. Further West is the Eastern Dirty Water Dam.
Proposed strategy	Cleared of all infrastructure and equipment, possible use as a hardstand area

10.2 Site history

The facility was associated with the Wallanbah and Broadmeadow Pits and was indicated to have operated from early 2000 till around 2011 as a site that provided remote refuelling, minor workshop activities such as provisioning (lubrication) and possibly operated a wash bay. Later it was used intermittently as a hardstand area for storage of equipment.

Bulk diesel fuel in two Above Ground Tanks (ASTs, approximately 50,000 L each) were indicated to be located within a concrete bunded area near the mid-northern portion of the functional area with a concrete refuelling pad located adjacent to the south. The Burton mine uses Wiggins pressurised auto shut of nozzles which are locked onto the tank fill point and limit the potential for overfilling/spills occurring when refuelling larger equipment. Light vehicles filling nozzles are a conventional type within the mine site though and can backflow and spill on overfilling.

The temporary workshop was constructed on a concrete pad using two shipping containers and an igloo suspended canvas roof, where minor maintenance occurred such as lube and minor fitting. Most of the maintenance was undertaken at the main workshop where parts, cranes and better equipment was available to undertake the work.

An office and crib hut was located onsite with amenities having a collection tank that was regularly pumped out by a sucker truck. Potable water was also supplied by a tanker to an onsite tank.

Limited information was available about any wash bay, but the dam was named Wallanbah Wash Bay Dam and there was a drainage line from the facility where runoff would likely flow. In the absence of major maintenance on site, wash bay activities would likely be limited to washing coal dust and dirt from equipment rather than degreasing and chemical wash. In the event of an overflow, the dam would flow into a larger dam located to the west adjacent to the pit.

10.2.1 Chemical Registers

No records of hazardous material stored at the functional area.

10.2.2 Spill Incident

There is one spill incident recorded at the Wallanbah Hardstand area on the Peabody Spill Incident Register:

- 11 April 2008: During refuelling of a dump truck, the fuel shot off system malfunctioned. When the tank was full, approximately 100 L of fuel spilled out of the breather and into the Wallanbah Go-Line area. No clean-up reported.

10.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2010 and 2015.

Table 2 Historical aerial photograph summary

Date	Description
2006 (Google maps)	The site is located on the corner of the haul road and an access road to the pits on the east and south respectively. The site is triangular, to the west is an earthen dam within a depression and a square hardstand area directly to its south. A rectangular hardstand area makes up the eastern potion that has a number of compounds and earth bunded areas with no equipment or vehicles visible. In the centre are two structures that appear to be fuel tanks within a concrete area and directly north a rectangular building (workshop). Adjacent and to the northeast is a bunded area containing ponded water, possibly a washbay. Further north is another rectangular building, possibly offices. A number of GO lines are present, including one parallel to the haul road. It appears that the site drains via overland flow and a channel to the adjacent dam, which appears partially full of water. The southern roadway appears bunded and any runoff would be expected to flow towards the dam. Associated with the mine pit to the south, a number of dams are present to the west and northwest, possibly for sediment control associated with rehabilitation that is occurring.
2010	In the 2010 aerial imagery, the northern portion of the functional area can be seen cleared and there are concrete slabs, containers in the centre of the site. No ASTs were noted from the imagery. Some equipment is present in the south-western hardstand area and stockpiles of soil are located directly south of the former fuel bund location, but otherwise no vehicles or other equipment is present. Some of the bunded areas, are removed but the outer bunds, the dam and drainage channel still remain, with the dam having more water storage than in the previous photo. To the west, the adjacent mine area appears to have further rehabilitation completed but activity still occurring within the pit. Up at the northern area of the functional area, a rectangle container is also noted.
2015	In this photo, no infrastructure remains except for some concrete slabs, earth bunding and what appears to be a container in the north. Some equipment is present in the south western laydown area and the adjacent dam appeared dry. To the west, further significant rehabilitation and backfilling of the Wallanbah pit has occurred.

10.3 Site inspection

The site inspection indicated the site was devoid of any infrastructure but a number of earthen bunds, roadways and hardstand areas remained.

In the location of the south western hardstand, minor debris as steel swarf, trace surface oil staining (5 m^2 in total) and trace bolts and inert waste was present in discrete locations.

In the location of the former AST bund, no concrete remained but a section of partially exposed reinforced concrete pipe (RCP) remained with a small sump being apparent at one end containing a small amount of oily liquid. The depth of the sump is unclear. No staining or odours were apparent in the area and also where the former workshop and other building were present, with trace fragments of concrete the only indication of the former buildings locations.

The drainage line to the west and the dam, appeared overgrown with some internal erosion and collapse but no films, odours or staining of the area or the water surface of the dam was noted in close proximity to the facility.

Within the remainder of the site, isolated pieces of material such as star pickets, a HDPE liner and trace isolated material was observed, but not considered to pose any risk of contamination.

No other issues were noted at the site during the inspection, although not all other non-infrastructure areas were inspected at the time.



Photo 1 View of the location of the former AST bund (identified by the bedding sand present in the centre)

10.4 Conceptual site model

Based on our understanding of the contamination issues and site setting a conceptual site model (CSM) has been generated as a basis for assessing the risk posed by any potential *source -> pathway -> receptor* linkages (or pollutant linkages). Based on the current understanding of possible contaminant sources the CSM is general in nature and there is considered to be limited value in individual CSMs for each possible source.

The CSM assumes a commercial industrial land use scenario consistent with the sites current use as coal processing facility.

10.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

As discussed in previous sections of this report, the findings from this investigation did not identify any quantitative information on the presence of soil or groundwater contamination at the functional area F location.

Based on the site history and information obtained through the document review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated CoPC
Former AST tank bund	Bulk storage and dispensing	TRH and BTEXN
Former workshop	Oil/lubricant storage and minor maintenance associated with provisioning	TRH and BTEXN
Former wash bay drainage lines and separator/ sump/dirty water dam	Fuel/oil contamination impacting soil, shallow groundwater and possible downgradient dam	TRH and BTEXN

10.4.2 Potential sensitive receptors

Based on information contained in past reports, review of aerial imagery, observations made during the site inspection, and that the site is to remain as commercial industrial land use, with no redevelopment or upgrade work proposed, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- Current workers at the site.
- On-site maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- Bullock Creek is located 0.2 km west from the functional area.

10.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 4 CSM-Potential source-pathway-receptor linkage

AECs	Former AST tank bund	Former workshop	Former wash bay drainage lines and separator/sump/dirty water dam
Source	Fuel spill/leakage at the ASTs	Oil/lubricant storage and maintenance	Fuel/oil contamination impacting soil, shallow groundwater and possible downgradient dam, and then thecreek
PCoC	TRH and BTEXN		

AECs	Former AST tank bund	Former workshop	Former wash bay drainage lines and separator/sump/dirty water dam	
Pathway	Direct Contact/ingestion of impacted soil/perched groundwater Inhalation of hydrocarbon vapour Lateral migration through surface water runoff			
Receptor	Current workers at the site, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.			Bullock Creek
S-P-R Linkages	Possible[1]	Unlikely[2]	Possible[3]	Possible[4]

Note:

1. Former ASTs were thought to be located within concreted bunds, therefore, in the event of a spills, it will more likely to be contained within the bunds or overflow towards the wash bay sump/dirty water dam. Minor spills/leaks may have occurred during the dispensing/refilling activities at the ASTs area over a long period which may migrate into subsurface soil environment, as a result, it is recommended that further assessment (test pitting) around the former ASTs and workshop area be carried out to confirm presence of contamination.
2. The former workshop was built on concreted slab. Based on the site history, no spill incident was recorded related to the functional area, and no gross contamination indicator was noted at the former ASTs and workshop area. It is likely that any potential contamination related to the former ASTs and workshop is limited or localised, and unlikely to cause human health risk for the onsite workers.
3. As there were former sumps and wash bay that captured the dirty water when washing down equipment/machineries, hydrocarbon contamination might migrate into the groundwater environment through the sumps. A nearby registered bore (0.8 km up gradient) shows that groundwater is shallow (4.24 mbTOC) around the area. However, it is likely that most captured water runs into the adjacent Dirty Water Dam. It is recommended that further assessment (test pitting) around the sump and pipework that was observed during the site inspection area be carried out, to remove redundant infrastructure and to confirm presence of any contamination.
4. As Bullock Creek is located very close to the site (200 m), overflows of potentially contaminated water captured in the Dirty Water Dam may overflow into Bullock Creek.

10.5 Summary

The site historical review and inspection indicated that there were diesel ASTs, workshop, wash bay previously at the functional area. Based on the conceptual site model, there were three plausible S-P-R linkages for this functional area. It is recommended that qualitative assessment be conducted to confirm the presence of soil/groundwater contamination at these AECs to further refine the risk assessment for this functional area. Also, redundant pipework and a sump along with surface debris should be removed and appropriately disposed of.

11. Functional Area G – Workshop Area

11.1 Site Description

The workshop area is the mine sites main facility for maintenance and lubrication work, parts storage, fitting and provisioning and has operated at the same location since commencement with a number of upgrades over time.

The location is presented in Figure 2-2 with the area and site details shown in Figure G that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 1.

Table 1 Site Details Summary

Site Details	Description
Location	Directly east of the CHPP area at the Ellensfield Operation Site.
Area (ha)	1.8
Lot/Plan	Lot 9 RP903903
EMR/CLR	Listed on EMR for the following Notifiable Activities: • Chemical Storage • Petroleum Product or Oil Storage • Waste Storage, Treatment or Disposal • Mine Wastes • Livestock Dip or Spray Race (associated to farming activities) Not listed on CLR.
Current Land Owner	BHP Coal Pty Ltd, UMAL Consolidated Pty Ltd, BHP Queensland Coal Investments Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investment Pty Ltd, QCT Mining Pty Ltd, QCT Resources Pty Ltd
Mining lease	ML 70109
Current use/activity	Workshop area for repairs and maintenance
Current infrastructure	• Workshop shed with parts storage and adjacent new workshop building (capacity for larger vehicles) • Fitting Shed for minor fabrication, wielding and body repairs • Service/lubrication bay, original building and adjacent new lube shed • Store • Tyre bay • Office demountable buildings and amenities • Waste coolant and lubricant storage bund • Bunded area for waste oil and ICBs

Site Details	Description
	• Bunded area for waste oil • Bunded area for used battery storage and spend products • Vehicle and large equipment wash bay, interceptor, pump house and washbay dam • Igloo roofed storage area (using shipping containers) • Parts and equipment laydown areas
Topography and drainage	Site runoff flows principally to the west towards the wash bay dam, which flows into the Process Dam, that overflows to Process Dam Overflow and eventually into Ellensfield Co-Disposal pit to the west. Upstream flows from the ephemeral creek from the east are captured in the site boundary stormwater drain (C1) located adjacent to the access road that flows towards north and eventually enter Anna Creek approximately 8 km away. Internal drainage from workshops and lube bays is captured in waste (dirty) water drainage system and flows with bund released water (controlled by valves) to the wash bay treatment system, where is pumped to the Process Dam and also recycled
Hydrology	Apart from the ephemeral creek (originally a tributary to Teviot Creek) at the east, there are several surface water/dirty water dams around the functional areas, including the following: • Water treatment storage dam directly South • Wash Bay Dam located directly North • Process Dam is located 0.3 km south-west • Ellensfield Co-Disposal Pit is located 0.5 km west
Hydrogeology	No monitoring bore within functional area, nearest monitoring bore BH1250P is located approximately 0.77 km south-west from workshop (next to Ellensfield Co-Disposal Pit). Latest groundwater monitoring result available dated June 2011 indicated: • Standing water level was 13.08 m below top of casing (bTOC) • Neutral pH 7.46 and high salinity 10,800 µS/cm • Heavy metal concentrations were either non-detectable of at very low levels Hydrocarbon analytical results level were reported non-detectable.
Surrounding land use	North: Fuel farm site, wash bay area, former Orica offices, and grassed pasture. South: Water treatment plant for portable water supply, raw water dam, then Mallawa Haul Road, vegetated pasture and STP (approximately 1.2 km South) East: Laydown areas, Mine amenities/office buildings, stormwater drain (C1) then Ellensfield Road, followed by vegetated pasture.

Site Details	Description
	West: CHPP functional area, ROM stockpile area then Ellensfield Co-Disposal pit.
Proposed strategy	Tanks, wash bay, bunded areas, temporary buildings and stores will be removed The area will be remediated as required, with respect to contamination only. The workshop buildings and the service bays will remain, emptied of equipment.

11.2 Site history

The workshop buildings and facilities were part of the original construction at the mine from start up, where fitting, assembly and servicing has occurred for all mine vehicles and equipment.

Specialist work such as engine rebuilding do not occur with equipment going of site and being delivered for installation but changeovers of components such as differential heads, gearboxes, bearings, pups, parts replacement and repairs occur at the facility.

Servicing of mobile and stationary equipment, including oil and grease, transmission, and all fluid replacement is undertaken, as well as tyre fitting and some fabrication, fitting, fixing of pumps and other equipment that can be brought to the site. There is some maintenance and repairs that do occur around the mine site, particularly for stationary equipment such as pumps and/or where there is a breakdown.

Workshop

The original workshop facilities consisted of a service bay and a workshop building and stores building that was later augmented in mid-2000 with mine expansion and also when a larger dump trucks (CAT 793) required bigger facilities to fit into. Subsequently, a second larger workshop and service bay building were constructed adjacent and west of the original ones. Additional fuel storage facilities were also completed, and are discussed in the fuel farm functional area section of the report.

The main workshop sheds are open on two sides and have gantry cranes for lifting and fitting equipment, with a number of bays with aisles containing tools and repair equipment. At the end of the concrete slabs, the southern side has a spoon drain that flows to a collection manhole pit, with the eastern side having a strip drain that also flows to the wash bay interceptor system.

Any oil or fluids are drained from the machinery using direct coupling systems and vacuum evacuation, so no sump plugs or bungs require removal and thus minor spills and handling of oils and liquids are limited. The waste oils, via an above ground piping system, flow to a waste oil tank located within a bunded area. Waste coolant is also collected into containers for disposal by a waste management company.

Located at the eastern end is a parts annex containing consumable parts and spares in shelves and on pellets. Further parts storage occurs in a store building to the east and a temporary store building constructed with shipping containers and a canvas roof located near the mine offices. Further equipment and parts that can be exposed to the weather are in outside storage areas surrounding the workshop with shipping containers also used and placed in the yard.

Located at the end of the workshop buildings are compressors in lean too areas along with hardstand areas used for temporary storage of Intermediate Bulk Containers (IBCs), gas bottles, ladders and work platforms, equipment jacks and stands, jigs and trays.

A bunded area containing a waste oil AST, approximately 20,000L is present at the eastern end of the workshop, which is fitted with a sump but not connected to any external drainage or release. It was indicated that the workshop area is elevated and does not flood, but some localised ponding does and has occurred after heavy rainfall. Runoff travels towards the wash bay dam, the CHPP waste water (process water dam) and ultimately to the former mine pit, now the co-disposal area, where CHPP tailings are placed. However, it was mentioned in the Burton Mine 2011 Environmental Audit Report that runoff and wash down from the south-west corner of the workshop appears to drain directly onto the ground.

Fitting Shed

A large shed to the south of the workshop buildings is used for general fitting, minor fabrication, wielding, grinding and body repairs. Minor repainting of repairs is also undertaken within the concrete floored building and only limited quantities of hydrocarbons are kept in flammable cabinets.

Lubrication Bays

Two service bays/lubrication sheds are present to the north of the workshops, the original building in the east and adjacent slightly larger new lube shed to the west. The square high roofed, concrete floored buildings are open at the southern and northern end and are separated by an area containing a lean too and a shipping container for spares storage. Servicing of vehicles and machinery is undertaken in the lubrication bays, including oil, filter changes and provisioning. Oil is removed from equipment using coupling and vacuum hoses and waste oil is pumped via overhead lines, to two waste oil ASTs, each located within the two main mine fuel storage bunds. A stormwater collection system is also associated with the lubrication bays concrete area that drains to the wash bay treatment plant.

To the east of the lubrication bay sheds is a concrete waste coolant, oil and drum storage area, that is graded to a sump and two bund walls, allowing forklifts to aces the area from the south. IBCs, small drums and other containers are also decanted here into larger containers. This bund drains to a sump and gate valve, that flows to the wash bay interceptor system. A smaller isolated bunded area is located adjacent containing a poly tank for radiator coolant. Another small bunded area contains racks used for waste battery storage.

Often, when busy, sometimes IBCs and drums are also stored outside the bunded area along with industrial bins, recycle bins, filter bins and containers for radiator water, which are collected for disposal off site.

Tyre bay

The tyre bay is an open area of hardstand with an L shaped earth bund where tyres are stored and fitted. New and waste tyres are also stored in other areas of the hardstand, north of the workshops. Waste tyres are allowed to be disposed on site in designated areas.

Office demountable buildings and amenities

To the east and adjacent to the workshop are demountable buildings containing crib rooms and amenities.

Wash Bay

North of the lube sheds is the concrete floored wash bay facility, that has a light vehicle bay in the north and a heavy vehicle bay adjacent to the south, using water supplied from the raw dam to the south, which is initially supplied from Teviot dam. A wash water collection system and pump house is present in the centre along with a bunded area containing truck wash (low foam detergent). The wash water treatment system consists of a sediment bay, that can be accessed

by a bobcat, a trash rack, an oil trap and under over weir where the decant then flows to an in-ground wash bay dam located adjacent, which is recycled. The wash bay dam water is pumped to the process water dam where it is used in the coal washing process. Sediment removed from the pit is stockpiled on a drying pad (draining to the dam), then removed for disposal in the co disposal dam with oil trapped in the sump being removed by sucker truck and offsite disposal by a waste contractor.

The wash bay dam was mentioned in the Burton Mine 2011 Environmental Audit report, where oily water from all workshop activities appears to drain directly to the wash pad dam (Wash Bay Dam) with minimal treatment. In the Audit Report, this dam was noted to have a considerable oil slick and was overflowing via a culvert outlet. However, during the site inspection, this was not the case (refer to Section 11.3).

Parts and equipment laydown areas

In the northern portion, hardstand laydown areas are used for equipment storage and laydown areas, with these also having been used for contractor laydown also, including container storage.

Abrasive blasting areas

A contractor conducts the sand blasting on site very intermittently, when needed, using GMA Garnet for the media, which has always been used on site. The areas in which the blasting is conducted is to the north of the workshop near the tyre lay down, and the other area is the demob pad at the white gates (Functional Area E). The area is cleaned when finished and product placed in old 1000 L pods, before being disposed of in regulated waste bins.

11.2.1 Chemical Registers

The following hazardous substances were recorded in the Thiess Burton Hazardous substance registers that were stored at the workshop area:

- Solvent Degreaser
- Bakers No.47 Fluid (Soldering fluid)
- Lectra Shield (anti-corrosive spray)
- Transmission and drive Oil
- Lubricant oil

11.2.2 Spill Incidents

There are several spill incidents recorded at the workshop area on the Peabody Spill Incident Register:

- 15 May 2008: Approximately 300 L of oil spilled from oil IBC when demobilising an excavator, a waste oil trailer was used to suck up most of oil, but there were approximately 100 L left on the ground.
- 16 June 2009: Approximately 200 L of oil spilled when assembling a rear dump truck. The spill occurred within a controlled area at the workshop, and was contained and cleaned up immediately.
- 17 May 2011: Approximately 100 L of oil was leaked from the steer hose of a dump truck at the workshop area, the spill was contained and cleaned up immediately.
- 21 June 2013: Approximately 500 L of hydraulic oil spill when transferring oil IBC, the spill was contained and cleaned up before reaching any drains.

- 29 November 2013: Approximately 150 L of hydraulic oil leaked from the vacuum pump hose.

11.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2010 and 2015.

Table 2 Historical aerial photograph summary

Date	Description
2010	In the 2010 aerial imagery, the site approximating a rectangular area appears as a series of buildings in the southern portion with hardstand and laydown to the north and the wash bay dam located in the northwest corner. Directly east is the C1 drain, flowing to the north and the access road, and open grazing land. Separated by a haul road is the CHPP and ROM pad is to the west, and then the former pit, now used for co disposal. Directly south two small dams and a larger dam is visible, being the water treatment plant (WTP) sludge dams and the raw water dam, being green in colour. The photo shows the current building layout with the original workshop and lube shed and the new additions to these, with the fitters shed, store buildings and the mine offices further east. The fuel farm contains two separate bunded areas with four large ASTs in the northern bund and approximately 8 small and 4 large ASTs in the southern adjacent bund. A service truck also appears to be filling up on the southern side. Surrounding the workshops are a number of large mine haul trucks and smaller vehicles are parked in carpark compounds in the east. The tyre bay area contains a small number of tyres with larger stacks being located to the north in rows and also orientated to form bays. A number of containers and temporary buildings (igloo structure) are also present with equipment stored in piles within the laydown area. The wash bay is visible with the dam adjacent, containing brown water, with what appears to be stockpiled sediment located at the end of the wash bay.

No aerial imagery available post 2010 at the time of this PSI.

11.3 Site inspection

Workshop

The workshop sheds appeared clean and tidy with no extensive staining, oil spills or indication of any major surface contamination within and adjacent to the entry and exit points. Some minor localised stains were present on the concrete hardstand within the building along with small hairline cracks. Tools were located in the centre of the isles in boxes along with some stands and service equipment. Parts were stored in the eastern end on shelves and bins, which was clean and tidy with no observed potential contamination sources present.



Photo 1 View of the original workshop building with the two service bays located in the background. Note the spoon drain along the edge of the concrete and absence of staining and rubbish.

An IBC with hose real used to connect to vehicles for oil transfer was also present at the end of the bay with a vacuum system and above ground pipework seen to travel up and along the roof line to the go to the waste oil ASTs.



Photo 2 View to the west with the newer and larger workshop shed in the background and then the CHPP

The catch drain and strip drain at the workshop concrete apron extents was observed to flow to collection points and was not observed to contain oils or recent spills. No inspection of any degreasing equipment was undertaken or observed, but it is considered that the workshops are routinely hosed out, based on wet areas being observed on the floor.



Photo 3 Located outside the workshop building to the north was a lean tool with a compressor, some stands, gas bottles, IBCs, mobile oil tank and reel and frames with only trace staining in isolated areas.

Industrial bins were noted in the general area along with recycling bins, spent radiator coolant bins, used filter bins and equipment.

A bunded area containing a waste oil AST approximately 20,000 L is present at the eastern end of the workshop, which is fitted with a sump but not connected to any external drainage. The bund contained oil residues at the base along with some sediment and a vacuum diaphragm pump was present, to evacuate the bund when required, into IBCs for disposal by the waste management company. All pipework was observed to be above ground.



Photo 4 Waste oil AST and bund located at the eastern end of the workshop building, with a temporary parts shed to the rear.

Stores

Stores located at the end of the workshop and within an igloo were observed not to have any potential contamination issues.



Photo 5 Workshop stores area

Other stores as parts were located in the open area generally on pellets, including in the northern laydown area.

Fitting Shed

The fitting shed had a haul truck being worked on and some minor equipment located in the vicinity including a diesel electric wielder, bins and frames. This facility, due to limited use and handling of oils and fuels, and absence of associated infrastructure, is considered to pose a limited risk from hydrocarbon impact.



Photo 6 View of the fitting shed with a haul truck parked for repairs.

Lubrication Bays

The two lubrication bays, both the original building and adjacent new lubrication shed were seen to have some isolated stains and spills within and in the surrounding area but no observed gross potential contamination was noted.



Photo 7 View to the south and the original lube bay with minor staining present in discrete locations.

Located to the east, the bunded area at the end of lubrication bay for exposed product contained drums, IBCs, portable vacuum pumps and containers with significant oil staining noted on the concrete surface. In the corner, a sump was present with the valve closed, which flowed to the wash bay treatment system. Another adjacent bund contained a poly tank, of approximately 10,000 L for spent radiator coolant.



Photo 8 Bunded area at end of lubrication bay for exposed product.

Located adjacent to the fuel farm, was another bund for drums and battery storage, but due to the rack being broken, a pellet with batteries was located on the ground adjacent. The bund contained waste oil drums.



Photo 9 Battery storage and waste oil drum

In the immediate area near the empty drum bund, a number of IBCs were present along with industrial bins, pellets, waste filter bins and scrap bins with minor staining in localised discrete areas including at the bund discharge valve.

Wash bay

The wash bay contained two areas, with the light vehicle area having a concrete hardstand and also a ramp to enable washing under vehicles and a large wash bay for heavy vehicles that also had a gantry walkway for washing at height. There was no indication of significant hydrocarbon impact in the area. Adjacent was a detergent tank in a bunded area and a pump shed with electric pumps.



Photo 10 Light vehicle wash bay with tank for detergent and the pump shed to the left and the larger heavy vehicle wash bay adjacent.

The wash water treatment system had a primary sediment tank that had only minor oil films present with the oil trap having heavy oil as a floating product, with the adjacent secondary

chamber after the under and overflow weir, not exhibiting any oil films. The facility appeared to be well maintained.



Photo 11 Wash bay wash water treatment with oil trap and weir

To the rear of the wash bay was stockpiled sediment that had been removed from the sediment trap for drying, prior to disposal. It appeared to be a mix of both fine and coarse grained material (silts and sands), contained coal fines and did not exhibit a hydrocarbon odour or have visible films present, including along its drainage lines towards the wash bay.



Photo 12 Wash bay dam and pump.

The wash bay dam contained reasonably clear water with no scum or observed films and emergent macrophyte vegetation within the dam, and the edges were well vegetated with the earth banks not showing evidence of staining. A diesel pump was located to one side and a windrow of sediment was also present long the edge of the wash bay entrance to act as a bund.

Tyre bay

The tyre bay was observed as an open area containing some equipment and tyres, with no evidence of any significant contamination or issues.

Abrasive blasting areas

Sand blasting activities were indicated by Peabody staff to occurred at the northern portion of the site (refer to Figure G).

General Areas

The office demountable buildings, amenities and general hardstand area were not observed to pose a contamination risk with only trace staining on the open hardstand in isolated areas. A variety of general equipment and parts, along with tyres were stored in the area.

11.4 Conceptual site model

Based on our understanding of the contamination issues and site setting a conceptual site model (CSM) has been generated as a basis for assessing the risk posed by any potential *source -> pathway -> receptor* linkages (or pollutant linkages). Based on the current understanding of possible contaminant sources the CSM is general in nature and there is considered to be limited value in individual CSMs for each possible source.

The CSM assumes a commercial industrial land use scenario consistent with the sites current use as coal processing facility.

11.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

As discussed in previous sections of this report, the findings from this investigation did not identify any quantitative information on the presence of soil or groundwater contamination at the functional area G location.

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated PCoCs
Above ground storage tank (waste oil)	Potential leakage from ASTs and bunds	TRH and BTEXN , PAHs
Chemical Storage (IBCs, bins and drums) in bunded areas	Storage, filling and dispensing	TRH and BTEXN, heavy metals
Chemical Storage (IBCs, bins and drums) in open hardstand areas in proximity to buildings (exposed product, battery)	Storage, filling and dispensing	TRH and BTEXN, heavy metals
Workshop areas	Spills and leaks, fabrication residues (grinding, wielding)	TRH and BTEXN, heavy metals
Lubrication bays	Spills and leaks	TRH and BTEXN, heavy metals

AEC	Primary Contamination Sources	Associated PCoCs
Waste (Dirty) water drainage system	Possible spills at entry pits and failure of integrity of system from workshop/lubrication shed	TRH and BTEXN, heavy metals
Wash bay and wash water treatment system	Possible spills and releases outside structures, failure of integrity of system and/or wash water treatment system Impacted from location or cross contamination in wash bay system	TRH and BTEXN, heavy metals
Wash bay dam including the stockpiled sediments	Receiving contaminated water and sediment from runoff and wash bay discharge Impacted sediment stockpiled along the wash bay dam	TRH and BTEXN, heavy metals
General Area	Leaks and spills from equipment and storage	TRH and BTEXN, heavy metals

11.4.2 Potential sensitive receptors

Based on information contained in past reports, review of aerial imagery, observations made during the site inspection, and the site remained as commercial industrial land use, with no redevelopment or upgrade work proposed, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- On-site workers including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

On-site groundwater consumer is not considered likely as portable water at Burton Mine Site is sourced from the Teviot Dam. Based on the significant distance from potential contamination sources to adjoining rural properties, that there is unlikely a direct connection geologically with water supply bores in the area and that a high level of attenuation may be occur, there is considered to be no direct connectivity present; hence fore, off-site groundwater user is not considered in this case.

Potential Sensitive ecological receptors

The closest creek is located upstream to the functional area and is diverted towards the site boundary drainage (C1), and based on the site topography and drainage system, the onsite surface water runoff is likely to end up in the wash bay dam or process water dam nearby, it is therefore considered that no potential ecological receptors is likely to be affected by the activities on workshop area.

11.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 7-4), showing the potential source-pathway-receptor (S-P-R) linkages.

12. Functional Area H – Workshop Fuel Farm

12.1 Site Description

The workshop fuel farm consists of two facilities, including:

- Fuel bund 1 - the original bunded structure containing 4 diesel ASTs (T1 –T4 @ 109,000 L), a number of oil ASTs up to 19,000 L, and grease IBCs; and;
- Fuel bund 2 - a more recent standalone bunded structure containing diesel ASTs (T5-1 –T7 @ 140,000 L), and a waste oil AST of 52,500 L, with an area for storing oil IBCs and drums at the western end.

The fuel farms are rectangular structures and are separated by a grassed strip approximately 4 m wide. All delivery pipework is above ground and the tanker revival loading area is present directly adjacent to Fuel bund 1 on the eastern wall, within its own nib bunded enclosure, containing an electric pump and filter, supplying both fuel bunds. The revival bund has a valve that appears to allows controlled release to the dirty water drain and the wash bay treatment system. Any spilled diesel would not be properly treated if released to the wash bay system, and would result in dissolved phase hydrocarbons being allowed to enter the wash water dam.

The filling point for the diesel is located adjacent to the southern bund wall in the centre where two high flow nozzles are located and also a low flow for light vehicles. An earthen bund surrounds the filling area grading to a grate that drains into the Fuel bund 1 main bunded structure.

The Burton mine uses Wiggins pressurised auto shut of nozzles which are locked onto the tank fill point and limit the potential for overfilling/spills occurring when refuelling larger equipment. The light vehicles filling nozzle are a conventional type and can backflow and spill on overfilling.

Fuel bund 1 also contains oil ASTs that are dispensed via hoses and pumps adjacent to the bund along the southern side, near the diesel refuelling area. The receival area is not bunded and any spills go to ground. Grease IBCs are also located within the bund and this and oil is loaded into service trucks for dispensing around the mine site.

The Fuel bund 2 is supplied from and delivers to the Fuel farm 1 system via above ground pipework. The waste oil AST is collected by tanker from a waste management recycling firm, being fed from the lube sheds via vacuum pump and then gravity to the AST. IBCs stored within the bund are moved into and out of storage by forklift.

The location is presented in Figure 2-2 with the area and site details shown in Figure H that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 1.

Table 1 Site Details Summary

Site Details	Description
Location	The fuel farm facility is located directly east and off the mine access road and is located adjacent and east of the lube sheds.
Area (ha)	0.13
Lot/Plan	Lot 9 RP903903

Site Details	Description
EMR/CLR	Listed on EMR for the following Notifiable Activities: • Chemical Storage • Petroleum Product or Oil Storage • Waste Storage, Treatment or Disposal • Mine Wastes • Livestock Dip or Spray Race (associated to farming activities) Not listed on CLR.
Current Land Owner	BHP Coal Pty Ltd, UMAL Consolidated Pty Ltd, BHP Queensland Coal Investments Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investment Pty Ltd, QCT Mining Pty Ltd, QCT Resources Pty Ltd
Mining lease	ML 70109
Current use/activity	Bulk diesel storage
Current infrastructure	Tanks for diesel storage
Topography and drainage	Site runoff flows principally to the west towards the wash bay dam, which flows into the Process Dam, and overflows to Process Dam Overflow and eventually into Ellensfield Co-Disposal pit to the west. Upstream flows from the ephemeral creek from the east are captured in the site boundary stormwater drain (C1) located adjacent to the access road that flows towards north and eventually enter Anna Creek approximately 8 km away. Internal drainage from workshops and lube bays is captured in drains and flows with bund released water (controlled by valves) to the wash bay treatment system, where is pumped to the Process Dam and also recycled
Hydrology	Apart from the ephemeral creek (originally a tributary to Teviot Creek) at the east, there are several surface water/dirty water dams around the functional areas, including the following: • Water treatment storage dam directly South • Wash Bay Dam located directly North • Process Dam is located 0.3 km south-west Ellensfield Co-Disposal Pit is located 0.5 km west
Hydrogeology	No monitoring bore within functional area, nearest monitoring bore BH1250P is located approximately 1 km south-west from the fuel farm (next to Ellensfield Co-Disposal Pit). Latest groundwater monitoring result available dated June 2011 indicated: • Standing water level was 13.08 m below top of casing (bTOC) • Neutral pH 7.46 and high salinity 10,800 µS/cm

Site Details	Description
	• Heavy metal concentrations were either non-detectable of at very low levels Hydrocarbon analytical results level were reported non-detectable.
Surrounding land use	North: laydown area, former Orica offices open grassed and tree vegetated areas South: Mine offices, Water treatment plant (potable), raw water storage dam, mine access road, open grassed and treed areas, approximately 1 km away the STP, with Kerlong accommodation village adjacent East: Hardstand, the C1 stormwater drain (flows to north) and the Ellensfield Road, then open grass and tree vegetation West: Lubrication shed, coal stockpiles and ROM pad, and co disposal area
Proposed strategy	Tanks and associated infrastructure will be removed. The area will be remediated as required, with respect to contamination only.

12.2 Site history

The fuel farm bund 1 area is the original facility constructed in the early part of the mines operation storing bulk diesel fuel, oil and grease for dispensing primarily into service trucks that deliver to equipment present in various areas of the mine site. Filling of heavy vehicles and the service truck has always been done using high flow nozzles with backflow shutoff and overfilling spills would be unlikely to occur. Light vehicles use a conventional low flow nozzle and minor spills have been noted to occur, but the filling is undertaken in a bund that drains to the main bund and is captured.

The facility was upgraded in mid-2000 with another tank farm being built that was connected to the original one. This provided further diesel storage along with waste oil and an IBC storage area. The tankers that deliver to the site, connect to a fill point within a bunded area and there is also limited potential to spill outside the area.

Historically, there have been incidents anecdotally, where tanks have been overfilled by tankers, resulting in spills to the internal bund, that required pumping out and recovery with disposal offsite by a waste contractor. Recently a new electronic tank level monitoring system was installed with high level alarms, that minimise the potential for overfilling to occur.

When the bunds collect rainwater, generally it is allowed to evaporate unless there is a substantial amount and if it is not highly contaminated, it is sometimes released into the wash bay treatment system, and when contaminated with fuel, it is removed by a waste contractor. Procedures were indicated to be in place for these operations.

12.2.1 Chemical Registers

No records of hazardous material stored at the functional area.

12.2.2 Spill Incidents

There are several spill incidents recorded at the workshop fuel farm area on the Peabody Spill Incident Register:

- 23 February 2007: Approximately 200 L of diesel spilled inside the bund during re-fuelling. The diesel spilled was contained and removed to the waste oil tank.
- 28 February 2007: Approximately 200 L of diesel spilled inside the bund during re-fuelling of tanks. The spill was contained and removed to the waste oil tank.
- 17 August 2007: Oil stains found where fluids had seeped through the besser block wall surrounding the fuel farm area
- 16 November 2011: Approximately 80-100 L diesel spilled while carrying out refuelling of Bulk Fuel Tanks. Spilled fuel was contained.
- 16 November 2011: Approximately 40-50 L of diesel spilt into the Bulk Fuel Farm Bunded Area during refuelling of a Thiess Service Truck due to a fuel hose failure. Bulk Fuel Pump was isolated and tagged out of service.
- 15 January 2013: Approximately 200 L spilled when the automatic shutoff system on the service truck failed to turn off during refuelling of a service truck. The spill was contained in the bunded area and cleaned up and disposed of in the correct waste bin.
- 11 October 2013: Approximately 200 L of Diesel spilled onto the ground while unloading fuel into Tank 5. No record of clean up
- 2 September 2014: Approximately 60 L spilled while fuelling VT1208 when valve did not shut off. No record of clean up.
- 9 March 2015: Approximately 100 L of fuel spilled into the bunded area while refuelling. The spill was contained.

12.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2010.

Table 2 Historical aerial photograph summary

Date	Description
2010	The site appears as two bunded rectangular areas containing white ASTs with vehicles present at the refuelling area. The southern bund has 4 large tanks and up to 7 smaller tanks with the northern bund having 3 large and one smaller tank visible. The photo resolution does not allow detailed identification of features.

No aerial imagery available post 2010 at the time of this PSI.

12.3 Site inspection

The fuel farm contains two separate bunded areas that contain ASTs storing diesel and oil.



Photo 1 The fuel farm, consisting of two bunded areas, with the newer structure to the left and the adjacent lube bay.

The original fuel farm to the south contains 4 ASTs of 109,000L capacity, a waste oil AST and approximately 6 smaller ASTs containing oils ASTs of various sizes including 19,000 L and 9,500 L, dispensed through flexible hose reels. The newer, bund No. 2 fuel farm contains three 140,000 L diesel ASTs and a smaller waste oil AST of approximately 52,000 L with an area at the western end where approximately 11 IBCs and drums are stored on pellets and racks.

Located between the bunds is a grassed area containing manholes associated with the waste (dirty) water drainage system directed to the wash bay. In this area the vegetation appearing healthy with no evidence of any staining or impact. Above ground pipework was evident in the area and no buried fuel pipes were observed.



Photo 2 Original fuel farm bunded area. To the front are the grease bins and the smaller oil tanks and fill points with the yellow pole indicating the diesel refuelling area for service trucks and light vehicles. Note minor staining from oil and fuel dispensing

The diesel dispensing area is located within an earth bund, that drains to a grate and this then flows into the bund. Some localised staining in the area of the delivery hoses was noted and further staining was observed by the oil refilling hoses near refill points, which was located outside the fuel delivery capture bund area.

The bund No. 1 contained some hydrocarbon residues, particularly where opposite the diesel bunded refuelling area and entry grate, with staining also observed within the bund near the oil ASTs. A pile of grease was also present below the storage units within the bund.



Photo 3 View of diesel refuelling area and the Wiggins pressurised auto shut of nozzles. Some limited localised staining is present outside the bund with the inside showing some more extensive staining of the slab.

Within the Bund No. 1, a grate was present that appeared to be connected to and flow to the wash water drainage system, being controlled by a valve.



Photo 4 Fuel farm (new bunded area 2, with the waste oil tank and IBC storage being undertaken to the west of the diesel ASTs within the bund.

Within the bund No. 2, there was trace areas of staining and no films including where IBCs were located at the rear.



Photo 5 Fuel receivable bund that supplies both facilities via above ground pipes.

Within the fuel receiving and pump bund, some staining was present below the coupling and a valve was noted to allow release of the bund water if required. A new electronic tank metering and high level alarm system was located to the rear that had digital display of volumes.

In the surrounding area, except for the staining along the southern wall of the bund, no observed impacts were noted in the vicinity of the fuel farm.

12.4 Conceptual site model

12.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated PCoCs
ASTs (Fuel Farm)	Potential leakage from ASTs	TRH and BTEXNPAHs
Refuelling and oil dispensing area	Storage, filling and dispensing	TRH and BTEXN
Washbay stormwater drainage system	Contaminated water leakage from drainage network	TRH and BTEXNheavy metals

12.4.2 Potential sensitive receptors

Based on information obtained through site settings and observations made during the site inspection, and the site remained as commercial industrial land use, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

- On-site workers including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

The closest creek is located upstream to the functional area and is diverted towards the site boundary drainage (C1), and based on the site topography and drainage system, the onsite surface water runoff is likely to end up in the wash bay dam or process water dam nearby, it is therefore considered that no potential ecological receptors is likely to be affected by the activities on workshop area.

12.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 4 CSM - Potential source-pathway-receptor linkage

AECs	ASTs	Refuelling and oil dispensing area	Washbay stormwater drainage system
Source	Potential leakage from ASTs	Storage, filling and dispensing	Contaminated water leakage from drainage network
PCoC	TRH and BTEXN Heavy Metals		
Pathway	Direct contact (including accidental ingestion) with petroleum hydrocarbon impacted soil or shallow/perched groundwater Inhalation of hydrocarbon vapour emitted from impacted subsurface soil and perched groundwater.		
Receptor	On-site workers including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.		
S-P-R Linkage	Unlikely but require assessment[1]	Unlikely but require assessment[1]	Unlikely but require assessment[2]

Note:

1. During the site inspection, some grease and staining were noted within the concrete bunds of the AST, and at the dispensing area. Minor spills/leaks may have occurred during the dispensing/refilling activities at the ASTs area over a long period which may migrate into subsurface soil environment, and into shallow perched groundwater. However, as no petrol fuel (volatile) was stored on site, petroleum hydrocarbon vapour impact is not considered likely to pose human health risk. It is recommended that a site intrusive assessment be

carried out around the dispensing refilling area and adjacent to AST to confirm the contamination status.

2. Oil staining or minor contamination may be trapped within the waste (dirty) water collection drainage system at the lubrication shed in the event of spill, however, it is considered to be unlikely to cause human health risk to workers on site as most of the contamination will have been washed off into the wash water treatment system. There may be a potential for localised soil impact where possible fuel product/degreasers were directly released into the drainage system,

12.5 Summary

The site historical review and inspection indicated that there were several AECs including the ASTs fuel farm, adjacent refuelling and dispensing areas and underground waste water/stormwater collection drainage system (flow into washbay treatment system). Although the S-P-R linkage is considered to be unlikely, it is recommended that qualitative assessment be conducted to confirm the presence of soil/groundwater contamination at the identified AECs to further refine the risk assessment for this functional area.

13. Functional Area I – Mallawa Train Load Out

13.1 Site Description

The Mallawa train load out consists of the processed coal stockpiling and train wagon loading with the functional area and site principally associated with the support facilities for bulldozers that work the stockpiles, including bulk diesel storage and refuelling facility. The remainder of the load out infrastructure, including the rail loop, coal stockpile and conveyor is not included in this assessment.

The location is presented in Figure 2-1 with the area and site details shown in Figure 13-6, that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 13-1 and discussed further below

Table 13-1 Site Details Summary

Site Details	Description
Location	South of the Burton Mine and next to Burton Mine rail branch, located North off of the Goonyella Branch.
Area (ha)	0.4
Lot/Plan	Lot 4 SP252740
EMR/CLR	Listed on EMR due to the following Notifiable Activities: • Mine wastes • Petroleum product or oil storage • Waste storage, treatment or disposal Not listed on CLR.
Current Land Owner	Vale Australia Pty Ltd
Current use/activity	Diesel storage and refuelling, oil provisioning, crib facilities and minor stores
Current infrastructure	Bunded area containing diesel AST (55,000 L) and minor oils, storage and refuelling, provisioning, crib facilities and minor stores
Topography and drainage	There are two sub catchments in the coal stockpile area, with the refuelling area located on the southern side of the conveyor which receives runoff from the southern portion of the coal stockpile and the north eastern grassed corner via an open drain that travels around the truck unloading loop, under the conveyor and down a constructed channel to a sediment runoff dam located to the south. A second clean water dam is located further south, separated from the sediment dam catchment. Any potential refuelling spills and leaks would enter the drain and flow towards the sediment dam.
Hydrology	There are two main creeks in the vicinity of the functional area:

Site Details	Description
	• Smoky Creek, located 1.7 km south-east • Unnamed tributary creek runs south into Smoky Creek, located 0.75 km north-west
Hydrogeology	No registered bores or monitoring bores in the vicinity of the functional area.
Surrounding land use	North: Coal conveyor belt and coal stockpiles then Mallawa Haul Road South: Sediment runoff dam then clean water (runoff) dam then open grassed pasture East: open grassed pasture then an access road West: Vegetated enclosed area within the rail line loop then grassed area.
Proposed strategy	Diesel tank to be emptied, with oils removed and the bunded facility will be under care and maintenance in the short term. The coal handling equipment remain on site, with the coal stockpile being loaded out and remaining residual coal trucked back to the CHPP for reprocessing.

13.2 Site history

The train load out facility has been associated with the life of mine and was indicated to have commenced operation from the mid-1990s, to present.

No servicing is done on site but the service truck does undertake some minor activities and provisioning at the plants location.

There is a crib hut located adjacent to the access road, supplied by a potable water tank that is routinely filled up by tanker and amenities have a sewage storage tank that is emptied by sucker truck. Some minor equipment and spares are also kept in a storage shed, made up of two shipping containers with a skillion roof in-between.

13.2.1 Chemical Registers

- Applied 3152C Duct Membrane Technology Part C (used for dust suppression of coal)

13.2.2 Spill Incident

No record of spill incident occurred at the Mallawa Train Load Out area.

13.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2010.

Table 13-2 Historical aerial photograph summary

Date	Description
2010	The coal load out area is dominated by a large coal stockpile with a conveyor along its centre, the railhead loop to the west and the truck unloading road loop to the east. A sediment dam is located north of the coal stockpile with another present to the south and a clean water dam further south and adjacent.

Date	Description
	The site refuelling facilities are present as a rectangular structure located adjacent and southwest of the truck road loop, with two buildings located on the side of an access road with vehicles also present. Two yellow objects appear to be bulldozers parked near the refuelling area. A drainage line is seen to be present to the west of the refuelling area receiving up gradient contributions from the coal stockpile and a grassed area to the north of the truck road loop. This drain is seen to travel to the dam located in the south. The wider area is grazing land with a creek present to the north and east and another creek located to the southeast, possibly located in another catchment.

No aerial imagery post 2010 was available at the time of this PSI.

13.3 Site inspection

Bulk diesel fuel in an Above Ground Tank (AST) of 55,000 L capacity located within a concrete bunded facility is stored along with drums of engine oil, hydraulic oil and grease fitted with hose reel dispenser's. Radiator fluid is also stored in an IBC. Refilling of diesel into bulldozers is undertaken on one side (southwest) of the bund, where the plant is parked adjacent and a flexible hose fitted with a Wiggins nozzle is used to connect to the fuel tank. It was indicated that the nozzle has an auto stop when the tank is full, minimising he potential for overfilling of equipment. A conventional nozzle is available for light vehicles and it was indicated there have been some small dispensing spills over time. Grease and top up oil is also added via flexible hoses from the bund bay. A compressor for process air and a water supply fed from the adjacent dam is used to rinse of coal dust from the machines, including from windscreens, grills and air conditioning units.



Figure 13-1 The Diesel AST bund with a dozer being filled.

A cabinet with hose reels and dispensers for oil and grease and fuel delivery hoses is present on the western side with Wiggins nozzle fitted to the high flow dozer hose and a conventional one on the light vehicle nozzle. Staining was apparent on the external walls and on the immediate ground surface that was covered in coal with coal dust covering a lot of the equipment and area.



Figure 13-2 View of the refuelling bay to the rear of the bund and oil/grease hose reels in the centre

At the time of the inspection, a dozer was being filled and greased and was parked adjacent with a dozer Go-line located immediately to the west. Within the bund, some minor films were present on the floor.



Figure 13-3 View of a bulldozer being refilled adjacent to the Go-Line

At the southern end was the tanker unloading area and inlet pipe that extended outside the bund but no staining in the vicinity or below it was apparent. A compressor was present for air supply and a large diameter pipe supplied water for washing which was pressurised by a pump. An excavator was also parked to the rear.



Figure 13-4 Open stormwater drain flowing to the sediment dam.

In front of the Go-line was an open drain fil of coal residues that had a culvert crossing to allow upgradient flows to enter the drain, which flowed southwest towards a sediment dam.



Figure 13-5 Demountable buildings and amenities

Located behind the Go-line and across a roadway were demountable buildings as office and amenities with shipping containers located further, used for stores.

There was no indication of any staining, odours or indicators of contamination noted outside the immediate bund location. The dam was not inspected at the time but no extensive oily films were noted at the time.

13.4 Conceptual site model

13.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 13-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated CoPC
AST and bunded areas	Fuel spill/leakage at the ASTs	TRH and BTEXN
Refuelling area	Fuel spill/leakage during dispensing/refilling	TRH and BTEXN

13.4.2 Potential sensitive receptors

Based on site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

- Current workers on site, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- Smoky Creek that is located 1.7 km east from the functional area.
- Clean water dam (assume no beneficial uses including irrigation on pasture or stock watering)
- Stock grazing on adjacent pasture

13.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 13-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 13-4 CSM-Potential source-pathway-receptor linkage

AEC	AST and bunded areas	Refuelling area
Source	Fuel spill/leakage at the ASTs	Fuel spill/leakage during dispensing/refilling
PCoC	TRH and BTEXN	

AEC	AST and bunded areas		Refuelling area	
Pathway	Direct contact (including accidental ingestion) with petroleum hydrocarbon impacted soil or shallow/perched groundwater Inhalation of hydrocarbon vapour emitted from impacted subsurface soil and perched groundwater.	Lateral migration of contamination through surface runoff	Direct contact (including accidental ingestion) with petroleum hydrocarbon impacted soil or shallow/perched groundwater Inhalation of hydrocarbon vapour emitted from impacted subsurface soil and perched groundwater.	Lateral migration of contamination through surface runoff
Receptor	Onsite Workers	Smoky Creek Clean water dam Stock grazing on adjacent pasture	Onsite Workers	Smoky Creek Clean water dam Stock grazing on adjacent pasture
S-P-R Linkages	Unlikely[1]	Unlikely[2]	Unlikely[1]	Unlikely[2]

Note:

1. The ASTs are located within concreted bunds, therefore, in the event of a spills, it will more likely to be contained within the bund. Minor spills/leaks may have occurred during the dispensing/refilling activities at the ASTs area over a long period which may migrate into subsurface soil environment, and into shallow perched groundwater. However, as no petrol fuel (volatile) was stored on site, petroleum hydrocarbon vapour impact is not likely to present. It is recommended that a site intrusive assessment be carried out around the dispensing refilling area and adjacent to AST to confirm the contamination status.
2. Potential surface water runoff from the area is likely to be captured in the sediment dam located south of the functional area instead of overflowing over to adjacent paddock unless flooding and overtopping occurred. The cleanwater dam located south of the sediment dam was noted to have high earthen bund surrounding it, which also helps prevent any ingress of water and potential cross contamination from the sediment dam. As the land parcel is currently owned by Vale Australia Pty Ltd, it is considered that access for stock grazing within the area is restricted.

13.5 Summary

There was evidence of minor spills within and around the fuel storage bund but any potential impact is considered to be localised in the area.

It is recommended that the area and bund be cleaned up and the tank emptied along with the lubricant and other storage. To provide a quantitative assessment of potential contamination, test piting and sampling should be undertaken in the refuelling area to evaluate if any remediation and/or management is required, including along the adjacent drainage line.

Figure 13-6 Functional Area I – Mallawa Train Load-Out

14. Functional Area J – Bullock Creek Former Workshop

14.1 Site Description

The former site was associated with the Plum Tree Pit, located north of the void. It operated as a laydown area and Go-line for trucks and had a small mobile workshop area where minor servicing was undertaken.

The location is presented in Figure 2-1 with the area and site details shown in Figure 14-3 that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 14-1 and discussed further below:

Table 14-1 Site Detail Summary

Site Details	Description
Location	The Bullock Creek facility is located in-between the Plumtree pit and the Plumtree south pit and is directly south of the haul road. It is approximately rectangular in shape and is located adjacent and north of the former ROM pad and sediment dam with Bullock Creek to the south.
Area (ha)	3.0
Lot/Plan	Lot 13 SP178466
EMR/CLR	Listed on EMR for the following Notifiable Activity: • Petroleum Product or oil storage Not listed on CLR.
Current land Owner	Queensland State Government leased to Peabody (Burton Coal) Pty Ltd
Mining lease	ML70259
Current use/activity	None
Former use/activity	Workshop area for minor maintenance and laydown area for storage of gear
Current infrastructures	No infrastructure on site.
Former infrastructure	• Workshop • ASTs • GO line • Former office building/amenities
Topography and drainage	Site topography is likely to slope towards the south.
Hydrology	There are no natural surface water bodies in the vicinity of the site. There were several depressions and pits noted around, including the partially excavated mine pit immediately west of the functional area and further south-west, is the ROM sediment dump which overflows into the Bullock Creek outer pit dam located 2 km south.
Hydrogeology	The nearest monitoring bore is BD1254P which is located 0.3 km south away. Previous groundwater monitoring results indicated: • SWL at the bore was recorded at 47 mbTOC in March 2013. • Water quality is neutral (pH 7.77) and saline (EC 15,200 µS/cm) in March 2013 • Heavy metal results were reported at low or undetectable levels.
Surrounding	North: Mallawa Haul Road, then Plumtree Southern Out of Pit Dump

Site Details	Description
land use	South: Rehabilitated Bullock Creek pit East: Grassed area West: Former excavation pit
Proposed strategy	Infrastructure has been removed from functional area, to be rehabilitated.

14.2 Site history

The Bullock Creek facility was indicated to have been associated with the Bullock pit and operated principally from 2010 to 2011 for approximately 18 months. A ROM pad was also located to the southwest along with its associated runoff dam. A Go-line and laydown area was present with infrastructure including a hardstand and igloo structure for minor workshop servicing and provisioning with oil and a temporary bunded diesel AST present equipped with a quick fill, auto cut off. No wash bays were present and much of the infrastructure except slabs was removed by 2013. Crib huts and amenities were also present at the site during its operation as a Go-line.

Associated with a proposal to undertake excavation of a satellite pit as a small extension of Plumtree that was later scraped, a void at the western end was created and remains on site, grading from the surface at the western end to a maximum of approximately 15 m deep.

Recently, in August 2016, the remaining concrete slabs were broken up and pushed into the void to the west onto a benched area and covered with scrapings from the laydown area.

Associated with the removal works, Peabody staff undertook inspections and did not identify any evidence of any potential contamination. Concrete waste from the Wallanbah hardstand (reload area) were also buried prior to capping with excavated material. The Peabody waste disposal procedure was used also to document the works.

It was indicated that stormwater would tend to flow towards a sediment dam located at the south of Bullock Creek outer pit dump, 2 km away, via an existing drain.

14.2.1 Chemical register

No specific chemical register available for the Bullock Creek Former Workshop.

14.2.2 Spill Incidents

No record of spill incident occurred at the Bullock Creek Former Workshop area.

14.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2010 and 2015.

Table 14-2 Historical aerial photograph summary

Date	Description
2010	The site is present at the northern end of a spoil area with a large ROM pad present to the west, extending over the entrance to the current void. A triangular ROM sediment dam is adjacent and in the centre of the current Bullock pit is a small unknown rectangular structure. To the east is a hardstand area with a rectangular building present (possible temporary workshop) with two square buildings located further east, side by side (possible crib). What appears to be light vehicles are parked adjacent and a small cylindrical object, possibly an AST

Date	Description
	is present directly south of the larger building in a triangular bund.
2015	In this photo, it is seen that all infrastructure is removed with some slabs and what looks like stockpiled rubble remaining in the hardstand area and former building locations. Two triangular bunded areas also visible next to the hardstand area that is distinguished by red coloured soil. Directly west is the satellite pit that contains water, with the ROM sediment dam, also containing water. The adjacent ROM pad, has no stockpiled coal but residues are apparent with some large soil stockpiles and possible rehabilitation being undertaken adjacent to the haul road in the west and to the east of the laydown area also. The surrounding land appears similar to the earlier photo.

14.3 Site inspection

The Bullock Creek site did not contain any infrastructure and a large level area appeared recently ripped and poorly graded. In the approximate location of the former possible workshop building, red soil/rock was evident that was associated with the previous hardstand. View of the former hardstand area and building site, identified by the red soil. The former ROM sediment dam is to the rear.



Figure 14-1 View of the hardstand area where two buildings were located.

In the location of the possible crib buildings, different coloured weathered rock/soil was present and trace pieces of concrete rubble. Some small soil stockpiles were also present but there was no evidence observed of any possible AST location or former bunds. There was no indication of any gross staining, odours or indicators of contamination noted within the area.



Figure 14-2 Looking west towards the satellite pit that was not completed. The recently piled up material at the edge of the pit indicates where concrete rubble was buried and capped with material.

The pit did contain some water, at shallow depth, that was turbid but did not have any films or staining present within. Local stormwater would appear to flow towards the void or the former ROM sediment dam.

14.4 Conceptual site model

14.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 14-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated CoPC
Temporary fuel storage in ASTs	Minor storage and dispensing	TRH and BTEXN
Waste and debris	Waste and damaged/redundant materials and consumables	General inert wastes

14.4.2 Potential sensitive receptors

Based on site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

- On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

Based on the site topography and drainage system, the onsite surface water runoff is likely to end up in the sediment dam nearby, it is therefore considered that no potential ecological receptor is likely to be affected by the activities on workshop area.

14.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 14-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 14-4 CSM-Potential source-pathway-receptor linkage

AECs	Temporary fuel storage in ASTs	Waste and debris
Source	Minor storage and dispensing	Waste and damaged/redundant materials and consumables
PCoC	TRH and BTEXN	General inert waste
Pathway	Direct contact (including accidental ingestion) with petroleum hydrocarbon impacted soil or shallow/perched groundwater Inhalation of hydrocarbon vapour emitted from impacted subsurface soil and perched groundwater.	No identified pathway
Receptor	On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.	
S-P-R Linkages	Unlikely[1]	No pathway identified between the source of contamination and receptor

Note:

1. The ASTs were apparently located within concreted bunds temporarily on site, minor spills/leaks may have occurred during the dispensing/refilling activities at the ASTs area, however is expected to be localised and of small volume. No visual impact was noted, including by Peabody staff during infrastructure removal. However, as no petrol fuel (volatile) was stored on site, petroleum hydrocarbon vapour impact is not likely to present. It is recommended that a site intrusive assessment be carried out around the dispensing refilling area and adjacent to AST to confirm the contamination status.

14.5 Summary

There is some potential for contamination to be present at the site, based on its previous activities such as a minor workshop, provisioning and infrastructure that was present, including temporarily, an AST. Limited plans and anecdotal information was available to confirm if there were any major issues at the site, during its operation, but it is expected that gross contamination or spills would have been recorded in the incident register, and cleaned up as required.

The former above ground infrastructure has been removed over 3 years ago and the recent slab removal and ripping did not identify any gross contamination by Peabody or Thiess personnel.

The concrete rubble has been buried and is capped at least 2 m below ground level, and with subsequent rehabilitation of the area, it is considered that it would pose a limited risk with respect to contamination.

For further quantitative assessment and confirmation of the contamination status at the site, test pitting, should be undertaken at the former infrastructure locations, along transects, followed by sampling and analysis if potential contaminant indicators are identified.

Figure 14-3 Functional Area J – Bullock Creek Former Workshop

15. Functional Area K – Burton Widening North Demobilising Pad

15.1 Site Description

The Burton Widening North demobilisation pad is to be used for the storage, dismantling and loading of Thiess machinery for removal from the site.

The location is presented in Figure 2-1 with the area and site details shown in Figure 15-3, that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 15-1 and discussed further below

Table 15-1 Site Details Summary

Site Details	Description
Location	Located adjacent to the Suttor Development Road and provides an access to the road crossing for transport off the mine site.
Area (ha)	1.2
Lot/Plan	Lot 9 on RP903903
EMR/CLR	Listed on EMR for the following Notifiable Activities: • Chemical Storage • Petroleum Product or Oil Storage • Waste Storage, Treatment or Disposal • Mine Wastes • Livestock Dip or Spray Race (associated to farming activities) Not listed on CLR.
Current site owner	BHP Coal Pty Ltd, UMAL Consolidated Pty Ltd, BHP Queensland Coal Investments Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investment Pty Ltd, QCT Mining Pty Ltd, QCT Resources Pty Ltd
Mining lease	ML70109
Current use/activity	The Burton Widening North demobilisation pad is to be used for the storage, dismantling and loading of Thiess machinery for removal from the site.
Former use/activity	Former coal mining pit
Current infrastructure	Crib hut, hardstand area, diversion bunds and crane
Former infrastructure	Unknown
Topography and	Site drains to bund in south of hardstand pad that directs flow to large

Site Details	Description
drainage	depression in former pit.
Hydrology	The closest surface water body is the Anna Creek, which is located 0.5 km south-east away. A small tributary is present to the east of the pad, traveling through a culvert under the Suttor Development Road to Anna Creek.
Hydrogeology	No registered bores or monitoring wells in the vicinity of the functional area.
Surrounding land use	North: Suttor Developmental Road then former Burton coal mine pit (rehabilitated) South: Refilled area of the former void East: Grassed pasture West: North Western Operation Pit (rehabilitated)
Proposed strategy	The area will be remediated as required, with respect to contamination only and remain as a demobilisation and remobilisation pad.

15.2 Site history

The facility was constructed in late 2015 to provide an area for dismantling equipment and load onto trucks for transport off site. The area was constructed to grade to a diversion bund that directs runoff to a low point to the south towards a depression associated with a former void. Anna Creek is present to the south, approximately 500 m away and runs east west from Lake Elphinstone through a Creek diversion over the former pit backfilled area.

Thiess propose to operate from the area, with fitters using compressors and light plant and cranes to disassemble gear. Some minor servicing of equipment and mobile refuelling may also be undertaken and be ongoing. A crib hut and amenities will also be used for staff but no permanent infrastructure will be present. ON site sewage will be collected as required and wastes will be managed by contractors who will remove material as required.

Historically the area was a Go-line pad compacted and used as a park up area adjacent to the gate crossing and traffic lights to the west, present on the Suttor Development Road. The former Burton void, now backfilled, was located in the vicinity of the traffic lights and west of the pad

Sandblasting area

A contractor conducts the sand blasting on site very intermittently, when needed, using GMA Garnet for the media, which has always been used on site. The areas in which the blasting is conducted is in the demob pad at the white gates (Functional Area K). The area is cleaned when finished and product placed in old 1000 L pods, before being disposed of in regulated waste bins.

15.3 Chemical Registers

No records of hazardous material stored at the functional area.

15.4 Spill Incidents

No record of spill incident occurred at the Burton Widening North Demobilisation area.

15.4.1 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2010 and 2015.

Table 15-2 Historical aerial photograph summary

Date	Description
2011	The site appears as a grassed area with a road running parallel towards the road crossing and lights, the Suttor Development Road directly north and then the backfilled and rehabilitated original mine pit. A range is present to the northeast and further east. To the west is a void containing water and a large spoil stockpiled area being established. To the south is Anna Creek diversion and the mine pit with undeveloped grazing and vegetated land surrounding the general area.
2015	In this photo, the site is it is seen as a rectangular pad with a bund located along its border to the south that directs flow to a large depression containing water. Further west is a partly rehabilitated spoil pile with Anna Creek to the south and then another rehabilitated backfilled pit. The east is grazing land and the range. One small structure is present on the site along the western side. The surrounding land appears similar to the earlier photo.

15.5 Site inspection

The North demob pit is a hardstand area with perimeter bunding and a southern diversion drain directing flows to a pit. A rectangular crib building is located along one side equipped with a generator and water tank.



Figure 15-1 The crib hut located along the western border of the northern demob pad, with recycling and industrial bins, and an IBC located adjacent.



Figure 15-2 A crane on the demob pad loading a truck body.

A large crane is present for assisting with the dismantling of equipment and loading onto vehicles also. positioned in the centre.

15.6 Conceptual site model

15.6.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 15-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated CoPC
Discrete areas of staining	Minor drips and leaks from machinery and residues from equipment stored	TRH and BTEXN

15.6.2 Potential sensitive receptors

Based on site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

- On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- Tributary creek located 0.2 km east that runs into Anna Creek.

15.6.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 15-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 15-4 CSM-Potential source-pathway-receptor linkage

AECs	Discrete areas of staining	
Source	Minor drips and leaks from machinery and residues from equipment stored	
PCoC	TRH and BTEXN	
Pathway	Direct contact (including accidental ingestion) with petroleum hydrocarbon impacted soil or shallow/perched groundwater Inhalation of hydrocarbon vapour emitted from impacted subsurface soil and perched groundwater.	Lateral migration through surface water runoff
Receptor	On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.	Tributary located 0.2 km east that runs into Anna Creek.
S-P-R Linkages	Unlikely[1]	Unlikely[2]

Note:

1. The functional area was only constructed and commenced use recently and no bulk fuel storage is currently at the compound. Vurrently,no spill incident has been recorded and no gross contamination indicators were noted during site inspection. It is likely that any potential contamination is or will be during the use of the facility, limited or localised, and unlikely to cause human health risk for the onsite workers.
2. Based on the site topography, the surface runoff from the functional area is directed towards the pit of the former void located south-west, which has a large capacity and limited catchment. It is unlikely that it would overflow and enter the adjacent creek . Therefore, it is considered unlikely to pose any ecological risk to Anna Creek.

15.7 Summary

As the facility is recently constructed, it is considered to pose a limited potential for contamination, with runoff also being directed to a contained area.

Prior to the area being vacated, a site history study and inspection should be undertaken to identify any potential risks and the need for any clean-up and validation and that may be required.

Figure 15-3 Functional Area K – Burton Widening North Demobilising Pad

16. Functional Area L – BIS Workshop

16.1 Site Description

The BIS workshop is associated with a haulage operations company at the mine site and includes repair and provisioning services for the fleet of trucks and side tipper trailers hauling coal to the rail head.

The location is presented in Figure 2-1 with the area and site details shown in Figure 16-7, that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 16-1 and discussed further below:

Table 16-1 Site Details Summary

Site Details	Description
Location	The reload facility, is located directly off and parallel to the Mallawa Haul Road. It is a rectangular cleared area containing a man proof perimeter fencing and opposing entry and exit roadways, currently having all internal infrastructure removed.
Area (ha)	1.60
Lot/Plan	Lot 5311 SP262721
EMR/CLR	Not listed on EMR/CLR
Current land owner	Queensland State Government. The land is leased (expiring on 7 November 2043) to • Ganra Pty Ltd Gaffwick Pty Ltd
Mining lease	ML70109
Current use/activity	Service and maintenance for machinery and coal haulage vehicles on site,
Former use/activity	NA
Current infrastructure	Workshop, provisioning shed, oil and fuel storage, tyre and equipment/parts storage. Washbay and associated treatment system (including dams), onsite sewage treatment plant, Go-line, office buildings and shipping containers storing spares.
Former infrastructure	NA (considered to have been grazing land)
Topography and drainage	Area has moderate grade towards the west, drains via overland flow to surface water dam, then south of Ellensfield Co-Disposal pit, via a drain and overland flow to the Dirty Water Dam No. 1.
Hydrology	Closest creek is Teviot Creek located 1.4 km south-east from the site.
Hydrogeology	The closest monitoring bore is BD1250P located 0.8 km north-west from

Site Details	Description
	the compound. Latest groundwater monitoring result available dated June 2011 indicated: • Standing water level was 13.08 m below top of casing (bTOC) • Neutral pH 7.46 and high salinity 10,800 µS/cm • Heavy metal concentrations were either non-detectable of at very low levels Hydrocarbon analytical results level were reported non-detectable.
Surrounding land use	North: Trailer lay down area then surface water dam South: Open grassed area East: Go-line, then Mallawa Haul Road and grassed area, accommodation village sewage treatment plant West: Topsoil stockpile area then Ellensfield Co-Disposal pit.
Proposed strategy	Some infrastructure to be removed - bulk diesel tank and sheds to remain and kept operational for Peabody care and maintenance activities.

16.2 Site history

The BIS workshop and associated infrastructure include the following:

- a workshop and servicing building incorporating a washbay
- offices and a STP for onsite sewage
- fuel (diesel ASTs at 53,800 and 51800 L capacity)) and oil storage, washwater treatment system and two associated dams
- back up generator
- Go-line, trailer laydown area, tyre storage and parts laydown in open areas and
- Access roads and parking areas.

A surface water dam is also located to the north that is used for a water supply and dust suppression.

The facility operates a Heavy Vehicle (HV) workshop and servicing for road trains and other equipment and is self-contained, undertaking coal haulage using 3-5 semi-trailer combinations , road maintenance and dust suppression. Quarry rock from Burton Red Hill Quarry is used for road base and the haul road is regularly graded. The facility has been present since the early stages of the mines operation, having some upgrades over time associated with mine expansion. Originally Brambles logistics company operated the facility under contract, with BIS having more recently provided the haulage services since around 2013.

The workshop building has two bays, the western one being a provisioning area (daily bay) for fuel, oil and water as well as having a washbay at the southern end, with the eastern section having the workshop maintenance area. In the workshop, fitting, gearbox and differential head changes, brakes, bearings, oil changes, hydraulics repairs, wielding and minor fabrications undertaken. Oil changes use a direct coupling and vacuum system to a tank for recovery and recycling, located within a bund, that drains to the washwater treatment system via a gate valve. Parts and new oil is stored in an annex, within drums, IBCs, and within containers. A bin is used for waste filters and recycling and general waste industrial bins are also present.

The fuel is stored in ASTs within a bunded area with fuel pumps and two dispensers for trucks (fitted with Wiggins nozzle) and light vehicles respectively located in an adjacent second bund on the western side adjacent to the workshop. No significant spills were indicated to have occurred

A third bund is present next to the bowser area which contains truck wash within a fibreglass tank (Caltex super wash) and a pressure cleaner. A washwater treatment system abutts to the south with a sediment pit, interceptor weir and decant chamber, that drains to an underground poly tank. A coalescing plate separator interceptor pumps up washwater for treatment, and then discharges the treated water to a small dam (10 m diameter), located to the west, which incorporates an overflow dam of the same size adjacent. The interceptor oil chamber was indicated to be emptied periodically by a waste management company but little was known about the coalescing plant separator unit or if any servicing is done to the unit, but it is often heard running. It was indicated that the washwater treatment receival dam, is used for haul road dust suppression, with a pump located adjacent used to fill the water truck.

In the hardstand areas, earth bunding is present around many of the laydown areas with a parts laydown, tyre storage and a trailer laydown area, used to store broken trailers prior to scraping and recycling.

The office building has amenities and a backup generator that is run monthly as part of maintenance, by Thiess. An inground septic tank and wastewater treatment pump in another tank is located adjacent and south to the offices but it was not known if any servicing of the unit was done or where the wastewater is pumped to or if there were any evaporation trenches present.

16.3 Chemical Register

No records of hazardous material stored at the functional area.

16.4 Spill Incidents

There is one spill incident recorded at the BIS Workshop Facility on the Peabody Spill Incident Register:

- 13 April 2008: Approximately 150 L fuel spilled during refuelling due to the ‘Quick-fill’ gun failing to shut off. The spill happened in a bunded area and the fuel was washed into a sump. Contaminated water was sucked up with a vacuum truck.

16.4.1 Aerial photographs

A review of historical aerial photographs and summary of the key findings is outlined in Table 3.

Table 16-2 Historical aerial photograph summary

Date	Description
2010	Based on reviewed of aerial imagery from July 2010, it appears that several buildings are on site for the purposes of maintenance work for train or truck carriages. The main buildings consisted of three rectangular structures abutting each other (Day bay, workshop and offices) with auxillary structures including shipping containers, lean toos and awnings present adjacent to the northwest, south and east. A truck with trailers is present in the workshop extending into the yard with some smaller vehicles also parked to the north in a bunded area. The diesel ASTs can be seen on the western side of the building with the

Date	Description
	washwater dam and overflow dam located further west next to a turning circle roadway. To the north of the dams is a laydown area with small objects stored within and further north, two other laydown areas contains trailers. In the northwest, in a low lying area is a surface water dam, that contains water, accumulated next to a bund wall, which appears to overflow along this wall to the south along a drainage channel. Tor the north of the BIS workshop is a large fenced compound which is the demob area (functional Area E) with a smaller compound further north with some buildings (pump maintenance area).

There is aerial photography post 2010 available at the time of this PSI. However, based on the site inspection (refer to Section 16.5), the site features were found to be similar to 2010 aerial imagery.

16.5 Site inspection

The BIS workshop buildings were in a fair condition as also the other infrastructure present, considering its age. The day bay had the fuel and pump bund on the western side and parts, tyres and other equipment located on the side of the building.



Figure 16-1 Inside the workshop shed.

The Daily bay (provisioning shed) had the washbay area at one end with a spoon drain in the concrete, draining to a wash water treatment pit. Generally, the area was tidy with no indication of any oil spills on the ground.

Within the treatment pit, the oily waste chamber was heavily loaded with oil and also had some absorbent socks present. The adjacent sediment chamber also was turbid but only had trace films on the water surface and the trash rack was reasonably clear.



Figure 16-2 View of the treatment pit



Figure 16-3 Washwater detergent tank and pressure water bund located adjacent to the fuel dispensing bund.

In the adjacent bund, a detergent tank and pump was present with some sediment within. A crack in the bund, may have allowed leaks to flow into the wash water pit. It was also noted that a break had been made in the fuel pump bund that allowed its contents to flow into the pressure cleaner bund. Further, the large diesel AST bund also had a pipe connecting it to the fuel bump bund, so a large spill in this structure could run out into the fuel bund then to the pressure cleaner bund, ultimately flowing into the washbay treatment plant system and inside the workshop.



Figure 16-4 View of the ASTs in the fuel tank bund with the fuel pump and dispensing bund located in front.

To the west of the wash water pit was a container containing oils in drums, with no spills noted and on the other side of the ASTs were another two shipping containers storing parts. Further containers were present separated by a roof, containing parts, with a stockpile of wheels, tyres and the waste oil bay, with a steel tank and also IBCs stacked on racks along with the waste filter bin.

The coalescing plate separator unit located next to an in ground poly tank, on inspection was full of oil and not working properly with the sludge IBC adjacent being half full and near capacity also. To the west, the treated waste water dam was present, being an excavated earthen dam, exhibiting some staining on its banks and trace oily films on the water surface. A diesel powered pump was located on the bank for filling the water truck to undertake dust suppression.

Another overflow dam adjacent appeared in a cleaner condition with no films or staining noted.



Figure 16-5 Wash water treated water dam showing evidence of possible oil carry over from the wash bay.

The workshop bay contained a truck having its brakes and bearings serviced and trace stains were noted on the concrete but no significant spills were noted, including outside the concreted area. At the southern end of the building was racks and two shipping container with fitting gear and parts, a wielder and some flammable good cupboards.

The eastern buildings included, demountable office blocks were separated by a skillion roof and to the rear were two in ground tanks for sewage, with a pump fitted to one. It appeared that this was a package treatment plant but no site operators have any knowledge of any discharge or irrigated area for the treated effluent.



Photo 16-1 Package treatment plant

To the north of the offices, a backup generator was present, but no indication of any contamination was noted in the surrounding area. Located parallel to the buildings was the Go-line, being a wide section of roadway for trucks to park up. Although a full inspection was not undertaken, no evidence of gross impact was noted in the area.

Northwest of the buildings the laydown area contained parts, axles, steel, pipe, stands, empty IBCs, frames and other equipment but no potentially contaminating sources were noted or any extensive staining observed. Further north within an earth bunded area, a number of trailer bodies were located, ready for scrapping and recycling.



Figure 16-6 View of the general laydown area

Generally, except for the wash bay treatment system and dams, there was no indication of any significant staining, odours or indicators of contamination noted within the buildings and outside the fenced area.

An inspection of the surface water dam present in the northwest was not undertaken.

16.6 Conceptual site model

16.6.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 16-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated CoPC
ASTs, fuel pump and dispensing bund	Spills and leaks from bulk storage and dispensing	TRH, BTEXN
Washbay treatment system and dam	Visible oil in pits, poorly maintained, carry over into dams. Possible releases from fuel bunds into system	TRH and BTEXN
Oils/Waste oil storage in IBCs and containers and dispensing bunds	Spills and leaks from bulk storage and dispensing	TRH, BTEXN, PAH

AEC	Primary Contamination Sources	Associated CoPC
Laydown areas and adjacent to the workshop building	Minor spills and leaks from machinery or vehicle	TRH and BTEXN
STP and irrigation area	Spills and leaks, ineffective treatment and disposal	Nutrients Microbiological (Faecal Coliforms, *Escherichia Coli*)

16.6.2 Potential sensitive receptors

Based on the site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

- On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- Teviot Creek located 1.4 km south-east away from the site. As the surface water run-off flows towards west into the wash bay dams then Ellensfield Co-Disposal pit, it is therefore considered unlikely to pose any ecological risk to Teviot Creek.

16.6.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 16-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 16-4 CSM-Potential source-pathway-receptor linkage

AECs	ASTs and associated bunds, fuel pump and dispensing bund	Washbay treatment system and dam	Oils storage in IBCs and containers	Laydown areas and adjacent to the workshop building	STP and irrigation area
Source	Spills and leaks from bulk storage and dispensing	Visible oil in pits, poorly maintained, carry over into dams. Possible releases from fuel bunds into system	Spills and leaks from bulk storage and dispensing	Minor spills and leaks from machinery or vehicle	Spills and leaks, ineffective treatment and disposal
PCoC	TRH and BTEXN		TRH, BTEXN, PAH	TRH and BTEXN	Nutrients Microbiological (Faecal Coliforms, *Escherichia Coli*)
Pathway	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater Inhalation of hydrocarbon vapour emitted from impacted subsurface soil and perched groundwater. Lateral migration through surface water runoff.				Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater
Receptor	On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.				
S-P-R Linkages	Potential[1]	Potential[2]	Unlikely[3]	Unlikely[3]	Unlikely but requires further assessment[4]

Note:

1. The ASTs were apparently located within concreted bunds and there had been one spill incident occurred at the ASTs area. Crack was noted on the concrete bunds which suggest integrity failure of the bunds for the ASTs. However, as no petrol fuel (volatile) was stored on site, petroleum hydrocarbon vapour impact is not likely to present. It is recommended that a site intrusive assessment be carried out around the dispensing refilling area and adjacent to AST during decommissioning to confirm the contamination status.
2. The washbay treatment system is not functioning properly (treatment pit was loaded with oil) and the treated water dam was noted to be oily on the surface. It is potential for localised contamination within the washbay treatment system, and eventually leaked subsurface soil and shallow groundwater. However, the contamination is likely to contained within the workshop area and it is not considered to pose human health risk as the exposure will be managed through OH&S procedures (i.e PPE).
3. Minor spills and leaks are likely to be localised and not considered to pose human health risk.
4. The discharge effluent of the package treatment plant was unknown at this stage, although unlikely to pose human health risk due to OH&S procedures, it is recommended that further assessment be undertaken to confirm the effluent discharge location.

16.7 Summary

The facility and general yard area was in fair condition and appeared to not pose a risk of serious contamination except for the following areas, based on visual inspection and their use:

- The AST bund, fuel pump bund and dispensing areas, including any in ground pipework
- The wash bay water treatment interceptor, sumps and the discharge dams

Figure 16-7 Functional Area L – BIS Workshop

17. Functional Area M – Sewage Treatment Plant (STP)

17.1 Site Description

A sewage treatment plant (STP) was constructed and operated from the establishment of the mine in mid 1990s, treating the domestic wastewater from the accommodation camp and the mine offices. Treatment and effluent disposal occur on site.

The location is presented in Figure 2-1 with the area and site details shown in Figure 17-7, that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in and discussed further below in Table 17-1.

Table 17-1 Site Details Summary

Site Details	Description
Location	Located 0.5 km west from the Kerlong Village
Area (ha)	0.57
Lot/Plan	Lot 5311 SP262721
EMR/CLR	Not listed on EMR/CLR
Current land owner	Queensland State Government. The land is leased (expiring on 7 November 2043) to • Ganra Pty Ltd Gaffwick Pty Ltd
Mining lease	ML 70109
Current use/activity	Sewage generated at the CHPP, admin and workshop buildings and Kerlong village is treated using an Acron Noble Aerobic Wastewater Treatment System. The effluent is not used for dust suppression, but was irrigated within designated areas, that are not in the vicinity of a watercourse or drainage line.
Former use/activity	NA
Current infrastructure	Sewage treatment processing plant, STP ponds
Topography and drainage	Generally flat with very gentle slope towards south-west
Hydrology	Teviot Creek located 1.7 km south-east from the STP
Hydrogeology	No monitoring bore within site, nearest monitoring bore BH1250P is located approximately 0.9 km north-west from STP. Latest groundwater monitoring result available dated June 2011 indicated: • Standing water level was 13.08 m below top of casing (bTOC) • Neutral pH 7.46 and high salinity 10,800 µS/cm • Heavy metal concentrations were either non-detectable of at very low levels • Hydrocarbon analytical results level were reported non-detectable.

Site Details	Description
Surrounding land use	North: Grassed vegetated vacant land, access road towards the Kerlong Village South: Grassed pasture and access/haul roads, the demob pad/compound is located 0.1 km south-west from the STP East: Grassed vegetated pasture and Kerlong Village located 0.5 km away West: Mallawa Haul Road, and process overflow dam and Ellensfield Pit located 0.5 km away from the site.
Proposed strategy	Plant to be removed from site.

17.2 Site history

The STP treats the accommodation camp and the administration buildings, being fed by pump and gravity from the camp, to a wet well and pump lift system that is still operating. Previously septic tanks around the site were pumped out and went to be disposed at Glendon, but recently the septage is being pumped into the STP on site.

The original plant, shut down in December 2010, was an activated sludge unit and had two parallel systems working in tandem. The former plant had four inground concrete tanks, approximately 70,000 L capacity that were divided into internal chambers with settlement, aeration and clarification followed by UV disinfection. Sludge was wasted into two former sludge lagoons with another larger lagoon to the north possibly used for treated effluent storage. It was discussed that further lagoons may have been added over time associated with increase in capacity.

The new STP was constructed in 2010 and has 500 Equivalent Persons (EP) capacity, and currently treats about 250 EP. At the height of operations up to 550 EP were on site. The new plant is located in two shipping container sized modules, located side by side, with bar screens, activated sludge one module with flow balance and an anoxic stage. The second module undertakes equalisation, aeration, settlement and clarification with a chlorine contact tank at the end. A back up pad mounted generator is also present for emergencies. Treated effluent is discharged to a large lagoon based on a BOD of below 20 mg/L and is authorised by Thiess internally. Also a smaller overflow lagoon is connected in the south-eastern corner. Effluent is pumped to spray irrigators installed in an irrigation area east of the plant, approximately 20 m x 100 m in size. The effluent lagoon previously had seepage issues with liquid being emergency pumped to Ellensfield pit (with EHP approval) and the embankment repaired and the lagoon dug out 2 years ago. Currently sludge is transferred to an onsite digester and later disposed in the former effluent lagoon adjacent and north of the STP. None of the dams have spillways or designated overflows. The irrigators currently run alternating days for a month, until laboratory results verify that irrigation can again recommence from the lagoon. Any spills were indicated to be cleaned up immediately being dosed with potassium permanganate and there is an earth bund around the plant.

The irrigation area is a grassed strip that is regularly mowed and earth bunds are located upgradient near the camp and downgradient to divert runoff to and from the area.

There is also some redundant pumping that appears to go to somewhere near the camp, but it is not known if any other areas were irrigated.

Grit and screenings are not buried on site but disposed as waste collected from site. It is not known if this was done previously with the older plant.

The catchment is primarily domestic and there was indicated to be limited potential for contaminants to enter the system.

17.2.1 Chemical Register

There is one hazardous substance registered at the STP, which is Norchlor - liquid pool chlorine.

17.2.2 Spill Incidents

There were three spill incidents recorded on the Peabody Spill Registers, as summarised below:

- 10 December 2014: 1000 to 2000 L of sewage was spilled on the surrounding land due to an electrical fault on the wet well pump. The spill was contained by the speed bump on the track.
- 20 May 2014: Approximately 2000 L of sewage spilled onto the surrounding land due to faulty pump at the wet well. The spill was then contained to the land adjacent to the STP. Spill bunds were then constructed around STP.
- 29 March 2014: Approximately 50,000 L of treated effluent from the STP pond overflowed to the surrounding land as the water level breached the low point of the dam and the recent heavy rain received at that time. To reduce the water level in the dam, the water was used for irrigation at that time (not compliant with EA).

17.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2009 and 2010.

Table 17-2 Historical aerial photograph summary

Date	Description
2009	In the 2009 aerial imagery, the STP and the pond can be seen. The STP is located north of the pond. Surrounding area appeared vegetated and the access roads to/from the STP were unsealed.
2010	In the 2010 aerial imagery, the site setting appeared similar to the 2009 aerial imagery, except the STP building has been upgraded since the 2009 aerial imagery.

There is no post 2010 aerial photography available at the time of this PSI.

17.3 Site inspection

The STP plant appears new and are steel containers with internal chambers and a top gantry for access. Some 20 L chlorine containers were coated in the vicinity on pellets and a shipping container was present for spares and equipment. The inlet works are a wet well fitted with macerator pumps and a rising main to the plant, with the backup generator adjacent appearing in good condition, all present in a hardstand area.



Figure 17-1 New STP with inlet works and pump station to the right and the backup generator.

Located adjacent is the former STP with four large concrete in ground tanks with manholes and some remnant equipment from the UV disinfection plant. A switchboard in the centre is still operational.



Figure 17-2 Former STP and the underground treatment tanks.

Within a treed area to the east are two depressions as former sludge dams, one with 1 m embankments and 15 m dia and the other approximately 18 m dia at 1.5 m deep. They both contained leaves, one had green grass and the other juvenile trees growing within.



Figure 17-3 A former sludge dam associated with the former STP located to the left of the plant

A larger lagoon in the north, being rectangular at 40 m x 30 m, and 0.8 m deep with one corner having a green lush area where sludge is currently disposed at present, the remainder, dry with some trees within.



Figure 17-4 Former effluent lagoon now used for current sludge disposal.

The treated effluent lagoon, approximates 50 m x 30 m is excavated and embankment filled, being around 2 m deep with a freeboard of 1 m, where it overflows to a smaller dam in the corner. No trees were present on the embankments, it was well grassed and no seepage was noted. A pump was present on the embankment for supplying the irrigators and a large pipe was on the other side, that may have been for pumping to the mine pit.



Figure 17-5 Treated effluent lagoon with the overflow lagoon present in the left corner.

At the irrigation area, healthy grass in a mowed strip was observed, with no ponded areas or indication of runoff visible.



Figure 17-6 Looking along the effluent irrigation area with the sprinklers present in the centre.

There was no indication of any staining, odours or indicators of contamination noted around the STP and irrigation area.

17.4 Conceptual site model

17.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 17-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated CoPC
STPs, former and current and surrounds	Sewage treatment plant effluent and wastes	Biological, nutrients, metals
Effluent lagoons, sludge dams	Sewage treatment plant wastes, sludge and effluent	Biological, nutrients, metals, salts
Irrigation area	Sewage treatment plant effluent	Biological, nutrients, salts

17.4.2 Potential sensitive receptors

Based on the site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- On-site worker, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- No sensitive ecological receptors were identified in the vicinity of the site.

17.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 17-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 17-4 CSM-Potential source-pathway-receptor linkage

AECs	STPs, former and current and surrounds	Effluent lagoons, sludge dams	Irrigation area
Source	Sewage treatment plant effluent and wastes	Sewage treatment plant wastes, sludge and effluent	Sewage treatment plant effluent
PCoC	Biological, nutrients, metals	Biological, nutrients, metals, salts	Biological, nutrients, salts

AECs	STPs, former and current and surrounds	Effluent lagoons, sludge dams		Irrigation area
Pathway	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater	Lateral migration through surface water	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater
Receptor	On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.			
S-P-R Linkages	Unlikely[1]	Unlikely[1]	Unlikely[1]	Unlikely[2]

Note:

1. Although dermal contact with raw sewage or treated effluent may cause microbial infection, human exposure on STP is managed by standard OH&S requirements (i.e. Personal Protective Equipment (PPE)), therefore it is not considered likely to pose human health risk on the on-site workers.
2. Irrigated effluent will need to be treated to meet EA criteria before it can be released at designated irrigation area, and sewage treatment plant only receive domestic waste (low potential for industrial waste/contamination).

17.5 Summary

Based on the findings, the STP is considered to pose very limited risk, however, as sewage treatment is listed as an Environmentally Relevant Activities (ERA), it might stipulate a more formal documentation of closure, including validation. Therefore it is recommended that:

- Maintain infrastructure in good condition for future use if required.
- When the site is decommissioned, clean and remove residual waste prior to demolition.
- Sewage sludge dams and disposal area will require residues to be removed and disposed of appropriately.
- Validation should be undertaken at all infrastructures locations (including irrigation area) to demonstrate there is no residual contamination on site.
- Implementation a site management plan to allow attenuation of any potential biological risk on site.

Figure 17-7 Functional area M – Sewage Treatment Plant (STP)

18. Functional Area N - CHPP

18.1 Site Description

The Coal handling and Production Plant (CHPP) process coal from the ROM pad (pre crushed), washes coal of soil and rock, crushes it into graded sized chunks (sorting), prior to it being stockpiles/loaded out by rucks for transport to the railhead.

The location is presented in Figure 2-1 with the area and site details shown in Figure 18-1 that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in Table 18-1 and discussed further below:

Table 18-1 Site details summary

Site Details	Description
Location	Located east of the Ellensfield Pit.
Area (ha)	Approximately 2.63
Lot/Plan	Lot 9 on RP903903
EMR/CLR	Listed on EMR for the following Notifiable Activities: • Chemical Storage • Petroleum Product or Oil Storage • Waste Storage, Treatment or Disposal • Mine Wastes • Livestock Dip or Spray Race (associated to farming activities) Not listed on CLR.
Current site owner	BHP Coal Pty Ltd, UMAL Consolidated Pty Ltd, BHP Queensland Coal Investments Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investment Pty Ltd, QCT Mining Pty Ltd, QCT Resources Pty Ltd
Mining lease	ML 70109
Current use/activity	Coal handling and production, used water extracted from the Ellensfield Co-disposal pit. There are four pipelines that run from the CHPP to the northern end of the Ellensfield Co-disposal pit, two of the pipelines transfer co-disposal material while the other two contains tailings.
Current infrastructure	• Processing plant structure (coal fines clarifiers) • Above ground storage tanks (ASTs) for diesel and surfactants for coal processing • Above ground pipelines and conveyor belts
Topography and drainage	Runoff travels towards the CHPP waste water (process water dam) and this overflows to the southern Process Dam 2 (overflow) and ultimately to the former mine pit, now the co-disposal area, where CHPP tailings are placed. As mentioned previously, the CHPP tailings has water recovery to the south (Ellensfield pit) in the active co disposal area, where water is

Site Details	Description
	recycled back to the CHPP for reuse.
Hydrology	The closest creek is Teviot Creek which located 3.3 km south-east. The process dam and Ellensfield Co-Disposal Pit are located south-west from CHPP.
Hydrogeology	No monitoring bore within site, nearest monitoring bore BH1250P is located approximately 0.6 km south-west from CHPP (next to Ellensfield Co-Disposal Pit). Latest groundwater monitoring result available dated June 2011 indicated: • Standing water level was 13.08 m below top of casing (bTOC) • Neutral pH 7.46 and high salinity 10,800 µS/cm • Heavy metal concentrations were either non-detectable of at very low levels • Hydrocarbon analytical results level were reported non-detectable.
Surrounding land use	North: ROM stockpile area at north-west and wash bay dam at further north-east South: Coal stockpiles East: Workshop area and fuel farm further north-east West: Process dam and Ellensfield Co-Disposal pit
Proposed strategy	Site will be under maintenance and care. ASTs will be emptied.

18.2 Site history

The CHPP, currently a 5.7 Mtpa capacity coal handling and production plant was established in the early part of the mine development and due to increasing production in 1998 was expanded and now operates two modules. The CHPP generally runs continuously, except for when maintenance, shut down or production requirements dictate otherwise.

Screening, gravity separation with cycloning, and floatation occur as part of the process with the addition of additives, monitored and controlled to aid in the production process. Magnetite is added for controlling density, and later recovered using magnetic separators, with up to 40 Tonnes of rejects per month.

A flocculant (suppressant and catonic) as a powder is mixed in a mixing tank to a day tank of 5000L where it is added to the thickeners to supress fines with decant going to reuse tank. Other additives used in trace amounts include diesel and Nalflote® coal collector (formerly methyl isobutyl carbinol (MIBC) pre 2005) is also added as a frothing agent to aid floatation. The dosage of reagents is 180 ml/min for diesel and 120 ml/min for Nalflote, fed through dosing pumps, being heavily diluted with water through the process.

Fines go to rejects with coarse rejects and tailings combined in a sump at the wash plant and pumped directly to the Ellensfield co-disposal emplacement area. Water is pumped back to the plant from the decant dam and reused in the plant's process water circuits, thereby minimising raw water use and preventing the release of processed water from the system.

The reagent storage area, in the eastern section of the plant is original and feeds both modules, having a bunded area with a AST storing Nalflote® frothing reagent, that previously stored diesel, another AST also storing Nalflote® frothing reagent and a flocculant storage tank. Currently diesel in IBCs are stored directly south of the AST (temporary for two months), as one of the ASTs will be switched back to diesel storage and the IBCs will be removed.

It was indicated any spills are retrieved by a sucker truck including the bunds collected water and disposed by the waste management company.

Generally, a lot of water is released from the plant as leaks and spills and which suggests that there may subsequently be a layer of perched water below the plant from its years of operation.

A small workshop building is located to the south of the CHPP building and processed coal conveyor north of the stockpile, where fitters work and minor stores are kept. Usually parts and motors are reconditioned offsite and delivered for fitting, but some minor repair work is undertaken, with breakdowns and shutdowns, maintenance is usually completed at the location within the CHPP building. A front end loader operates in the coal stockpile area, moving product and also loading coal into trailers when require. It is serviced in the workshop facility and refuelled on site by the service truck.

18.2.1 Chemical Register

The following hazardous materials were recorded at the CHPP facilities:

- Alvania RL3 Grease
- Burndy Penetrox A
- Castrol Clearedge EP690
- Corena Oil AS68
- CRC Battery Terminal Protector
- DSF910
- Enerpac HF Hydraulic Oil
- Gadius S3 V22OC2
- Galmet Industrial corrosive Primer
- Glamet rust paint expoxy finish
- Hyperia S220
- Hyrperia S320
- Interfine 629 Part A
- Interfine 629 Part B
- Loctite Freeze and Release
- MIBC – Methyl Lsobutyl Carbinol
- Omala Oil 150 – Gear Oil
- Omala Oil HD 220
- Omalla 220 S2G
- Omalla 320 S2 G
- Ridgid Thread Cutting Oil
- Septone Dry Up

- Snow White Petroleum Jelly
- Stamina RL2 Grease
- Sullube Compressor Fluid
- Ultra Sound Coupling Gel
- Windex Glass Cleaner
- Polyfroth H15
- Polyfroth H30
- Hydrated lime (Calcium Hydroxide)

The following hazardous materials were recorded at the CHPP Bulk Storage facility:

- Diesel Fuel
- Hydrasperse SO300 – Scale Inhibitor
- Nalco Nalflote 9840
- SNF Floquat FL 4440 – Liquid Coagulant

The following hazardous materials were recorded at the CHPP Hazardous Substances Container facility:

- Albida EP2 – Grease (Red). Cartridge
- Albida EP2 – Grease (Red). Drum
- APS Silica Gel Blue Bead 5-10 Mesh
- Ardrox 800/3 Black Magnetic Ink
- Ardrox 9DIB Aerosol
- BP Enersyn RC-S68 Compressor Oil
- Caltex Kopr Kote – Anti Seize
- Candan Inox – Anti Corrosion Penetrating Oil
- Chefs Pro Release
- Chesterton ARC BX1 (Part A)
- Chesterton ARC BX1 (Part B)
- Chesterton ARC BX2 (Part A)
- Chesterton ARC BX2 (Part B)
- Contitech Conti Secur BFA
- CRC 5.56 Multi-Purpose (Aerosol)
- CRC Belt Grip
- CRC CO Contact Cleaner (Aerosol)
- Devcon Flexane 80 Putty Curing Agent
- Devcon Flexane 80 Putty Resin
- Devcon Wear Resist Putty WR2 Hardener
- Devcon Wear Resist Putty WR2 Resin
- Eli Flex FR909N 60 Paste – Resin & Hardener

- Enerpac Highway Patch – Rapid Set Mortar
- Fosroc Conbextra EP 10 – Hardener
  Gadius Grease
- Galmet Fast Dry High Gloss (Aerosol)
- Gasket Eliminator 515 – Flange Sealant
- Grena S4 R-68 Oil
- Hi Glow Superglow Multi-Purpose Thinner
- Intergard 251 Epoxy Primer Part (A)
- Intergard 251 Part (B) – Curing Agent
- International Thinner GTA 007
- International Thinner GTA 220
- International Thinner GTA 713
- Interplus 1180 (Part B)
- Interplus 1180 Base Light (Part A)
- Interprime 198 – Grey Primer
- Interthane 990 – Part B
- Interthane 990 – Part A
- Interzone 954 – Black Part A
- Interzone 954 – Part B
- Interzone 954 Base Light Part A
- ITW Rocol RTD – Metal Cutting Compound
- Jasol Multikleen – Cleaner Degreaser
- Lanotec Heavy Duty Liquid Lanolin (aerosol)
- Loctite 243 – Threadlocker
- Loctite 567 – Thread Sealant
- Loctite 577 – High Pressure Pipe Sealant
- Loctite 587 – Flange Sealant
- Maxwell Combowaer FC – Hardener
- Maxwell Combowear FC – Resin
- Megadure Ceramic Part (A)
- Megadure Ceramic Part (B). Standard
- Megaproxy PM Part (A)
- Megapoxy PM Part (B)
- Methyl Isobutyl Carbinol (Redundant product)
- Omala Oil 100
- Omala Oil HD 320
- Omala Oil HD 460 – Gear Oil

- Pedoz – Anti Fungal Powder
- Penetrene (Bulk)
- Perma Lube – Futura
- Perma Lube – Star
- Polyester Gelcoat / Flowcoat – Resin Solution
- Powers Fasteners Powerfoam
- PPG Rustfighter 215 – Zinc Cromate Free
- Ramset – Chemset Injection 801
- Ramset Chemset 101 Anchoring Adhesive
- Rimula R3 15W 40
- Rydlyme
- Selleys Gel Grip Contact Adhesive
- Selleys Kwik Grip
- Septone – Diatomite
- Shell Degreasing Fluid
- Sikaflex 11FC
- Silastic 732 – Clear
- Silastic Gel 8-19 Mesh
- Silber Zinc – Cold Galvanising
- Solufix MP 2100 – Metal Primer for Cold Bonding
- Solufix 14BV – Cold Bonding Adhesive
- Solufix 14T – Cold Bonding Adhesive
- Spirax A 85W-140
- Spirax A LS 90
- Tectyl 506 – Heavy Rust Preventative
- Tellus Oil 46 – Hydraulic Oil
- Tellus Oil M68
- Tellus Oil S2M 100
- Toluene
- Turco Dy Chek Developer

The following hazardous materials were recorded at the CHPP Laboratory facility:

- Sodium Hydroxide Pellets

The following hazardous materials were recorded at the CHPP Workshop facility:

- Acetylene (Cylinder) (Size G)
- Aerogard – Personnel Insect Repellent
- Ardrox 800/3 Black Magnetic Ink

- Ardrox 8901W – White Background Lacquer
- Argoshield 52. (Size G)
- Autocraft MNMO, CRMO1 and NICRMO Low Alloy Steel Wires
- Battery Fluid – Sulfuric Acid
- Candan Inox – Anti Corrosion Penetrating Oil
- Cigweld Anti-Spatter
- Cigweld Weldall – Welding Rods
- Ferrocraft 61 – Welding Rods
- Galmet Fast Dry High Gloss (Aerosol)
- ITW Rocol RTD – Metal Cutting Compound
- Liquid Petroleum Gas (LPG)
- Loctite Silver grade Anti – Seize Lubricant
- Ludowici Wear Resist – Trowelable (Part A)
- Ludowici Wear Resist- Trowelable (Part B)
- Nitrogen (Cylinder)
- Oxygen – Industrial (Cylinder). (Size G)
- Premium Air Toll Oil
- Rocol UltraCut Premium
- Satincrome 309 – Mo17 – Welding Rods
- Tremco Metal Armour
- Ultracolor Spray Paint – EZY
- Unleaded Petrol
- Weldall Arc Torch Carbon Rods
- WIA Austarc 16TC – Welding Rod

The following hazardous materials were recorded at the CHPP Magnetite Pit facility:

- Magnetite

It should be noted that although a wide range of hazardous material were recorded at the CHPP functional area, most of them were of small volume and were stored within workshop, laboratory or containers.

18.2.2 Spill Incidents

There was one spill incident recorded on the Peabody Spill Registers, as summarised below:

- 14 June 2012: BIS 5 Trailer Coal Hauler was hauling Raw Coal to CHPP ROM and has run over a rock which has then hit the fitting causing the fitting to break. Approximately 250 L of Diesel Fuel has been discharged out of the fuel tank onto the ground beside the Raw Coal Stockpile. The spill was contained and dealt with by taking the stock pile to an area for future remediation.

18.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed and is discussed below. Aerial image perused includes 2009 - 2012.

Table 18-2 Historical aerial photograph summary

Date	Description
2009	In the 2009 aerial imagery, the large processing plant structure can be seen located in the middle, and conveyor belts for coal transporting is seen running towards south (truck load out area) and north-west (ROM stockpile area). A big stockpile of coal can be seen at the north of the processing plant. Small structures can be seen scattered around the area.
2010	In the 2010 aerial imagery (July 2010), the site appeared similar to the 2009 aerial imagery. In addition, there are two large cylinders (coal fine clarifiers) and ASTs were noted east to the processing plant, vehicles or machinery and pipelines were also noted at the site.
2012	CHPP in the 2012 aerial imagery (provided by Peabody) appeared similar to 2010 aerial imagery.

There is no 2016 aerial photography available at the time of this PSI. However, based on the site inspection (refer to Section 18.3), the site features were found to be similar to 2012 aerial imagery.

18.3 Site inspection



Photo 18-1 View of the CHPP facility

The site inspection focused principally on the reagent area where the ASTs are present. A concrete bunded AST, containing Nalflote® frothing reagent was present at the southern end and contained some product within the bund, from possible leaks/spills.



Photo 18-2 The reagents area with the Nalflote® ASTs and the flocculants day tank on the left.

An adjacent bund also contained an AST, with the same product. Both bund drain valves were closed and locked. A flocculant AST was present next to a mixing tub that uses powdered product, which is added and mixed before being placed into the day tank. An oil dispensing bay was also observed within a bunded area with no staining outside the facility and a shipping container was adjacent containing drums of oil and some 200 L drums on pellets.



Photo 18-3 Oil dispensing bay adjacent to the AST

Two ICBs were also located next to the bund containing diesel as a temporary storage measure at the time. A concreted sediment pit was also observed receiving runoff and coal spills from

the plant, with a lot of water noted to be falling from the plant for collection. The sediment pit had floating and settled material.



Photo 18-4 Sediment pit receiving floor runoff from the CHPP

The fitter's sheds contained wielders, fitting benches, tools and spares and minor flammables in purpose cupboards. There did not appear to be any potential contamination issues observed in this area.

A full inspection of the CHPP, the stockpiles or the dams was not undertaken as part of this assessment.

18.4 Conceptual site model

18.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 18-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated PCoC
ASTs for reagents and fuel and mixing tank	Bulk storage and supply to CHPP	TRH, BTEXN, MIBC, alcohol (frothing agent), heavy metal (magnetite)
Minor storage areas, IBCs, drums and containers	Minor storage and dispensing	TRH, BTEXN, MIBC, alcohols (frothing agent)
Sediment pit	Collecting all runoff from the CHPP	TRH, BTEXN, MIBC, alcohols (frothing agent), heavy metal (magnetite)
General Area	Incidental spills or leaks from moving vehicles or machinery	TRH, BTEXN, Heavy Metal

18.4.2 Potential sensitive receptors

Based on the site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- On-site worker, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- No ecological receptors were identified within the vicinity of CHPP.

18.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 18-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 18-4 CSM-Potential source-pathway-receptor linkage

AECs	ASTs for reagents and fuel and mixing tank	Minor storage areas, IBCs, drums and containers	Sediment Pit	General Area
Source	Reagent storage and supply to CHPP	Minor storage and dispensing	Collecting all runoff from the CHPP	Incidental spills or leaks from moving vehicles or machinery
PCoC	TRH, BTEXN, MIBC, alcohol (frothing agent), heavy metal (magnetite)	TRH, BTEXN, MIBC, alcohols (frothing agent)	TRH, BTEXN, MIBC, alcohols (frothing agent), heavy metal (magnetite)	TRH, BTEXN
Pathway	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater. Lateral migration through surface runoff	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater Lateral migration through surface runoff	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater. Lateral migration through surface runoff
Receptor	Onsite Workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.			

AECs	ASTs for reagents and fuel and mixing tank	Minor storage areas, IBCs, drums and containers	Sediment Pit	General Area
S-P-R Linkages	Unlikely[1]	Unlikely[1]	Unlikely[1]	Unlikely[1]

Note:

1. Reagent storage and fuel ASTs are mostly located within concreted bunds or on concreted pads, therefore, in the event of a spills, it will more likely to be contained within the bunds or localised. However, it is possible for contamination to occur in the shallow perched groundwater underneath the CHPP due to long term of water spills from the plant facility. Although it is not considered to pose human health or environmental risk, it is recommended that exploratory test pitting be conducted when the plan or tanks are decommissioned.

18.5 Summary

Based on the findings, the CHPP is considered to pose low risk, however, the following is recommended:

- Remove any spills that are contained within the bunded area
- Remove all chemical reagents stored at the CHPP and properly empty the ASTs
- Clean the sediment pit and associated pipework to ensure no residual chemicals/fuel left on site
- Maintain infrastructures in good condition for future use if required.

If the CHPP facility and ASTs are to be decommissioned and removed, undertake intrusive site investigation, and, remediation and validation as required.

Figure 18-1 Functional Area N – CHPP

19. Functional Area O – Water Treatment Plant

19.1 Site Description

A Water Treatment Plant operates at the mine, providing piped potable water supply to the camp and offices and also supplies remote facilities with water, which is usually held in storage tanks and replenished as required.

The location is presented in Figure 2-1 with the area and site details shown in Figure 19-1, that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in and discussed further below in Table 19-1.

Table 19-1 Site Details Summary

Site Details	Description
Location	The WTP is located directly behind the administration offices car park with the raw water dam to the west and the mine access road bordering to the east.
Area (ha)	1.84
Lot/Plan	Lot 9 RP903903
EMR/CLR	Listed on EMR for the following Notifiable Activities: • Chemical Storage • Petroleum Product or Oil Storage • Waste Storage, Treatment or Disposal • Mine Wastes • Livestock Dip or Spray Race (associated to farming activities) Not listed on CLR.
Current Land Owner	BHP Coal Pty Ltd, UMAL Consolidated Pty Ltd, BHP Queensland Coal Investments Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investment Pty Ltd, QCT Mining Pty Ltd, QCT Resources Pty Ltd
Mining lease	ML70109
Current use/activity	Water treatment plant that process raw water from Teviot Dam.
Current infrastructure	Water treatment processing plant, raw water dam and sludge lagoons.
Topography and drainage	Site is generally flat and most run-off will probably flows into the sludge lagoons located north of the WTP.
Hydrology	The closest creek is an ephemeral creek (originally a tributary to Teviot Creek) at the north-east (0.2 km). Upstream flows from the ephemeral creek from the east are captured in the site boundary stormwater drain (C1) located adjacent to the access road that flows towards north and eventually enter Anna Creek approximately 8 km away.
Hydrogeology	No monitoring bore within functional area, nearest monitoring bore BH1250P is located approximately 0.77 km south-west from WTP (next to Ellensfield Co-Disposal Pit). Latest groundwater monitoring result available dated June 2011 indicated: • Standing water level was 13.08 m below top of casing (bTOC)

Site Details	Description
	• Neutral pH 7.46 and high salinity 10,800 µS/cm • Heavy metal concentrations were either non-detectable of at very low levels • Hydrocarbon analytical results level were reported non-detectable.
Surrounding land use	North: Workshop area and CHPP located north-west South: Ellensfield road and grassed pasture. East: Ellensfield road and grassed pasture and Kerlong Village located 0.5 km away West: CHPP conveyor belt and coal stockpiles, then process dam 1 and followed by Ellensfield Co-disposal pit.
Proposed strategy	Plant and infrastructures to be removed from site.

19.2 Site history

The WTP has operated at the mine since the start up, with the original plant still present and operating, but augmented by a new unit that was installed to provide increased capacity.

The original unit has a capacity of 150,000 L/day and has alum, polyelectrolyte, soda ash and chlorine dosing for disinfectant and was recently fitted with GAC (carbon) filters. It receives its water from the raw water dam adjacent, that is supplied by Teviot Dam.

The new WTP (Akwa Worx), uses DAF (dissolved air flotation) and also uses alum for flocculation, filtration, soda ash for pH adjustment and chlorination for disinfection. This plant is supplied by the raw water dam and treats water on demand with a potable water holding tank located adjacent. The WTPs discharge their alum sludge to two circulars in ground sludge lagoons located directly north that are separated by a small earth wall, which are de sludged yearly and the sludge taken away by contractors. A back up pad mounted generator is located north west of the sludge lagoons also.

Staff indicated that there have been no known incidences at the plant.

19.2.1 Chemical Register

The following hazardous materials were recorded at the Water Treatment Plant facility:

- ACM Toro UPVC Pipe Cement (Type P) Green
- AFM Advanced Filtration Media
- All Clear 325
- ALS Standard Buffer Solution Ph 10
- ALS Standard Buffer Solution Ph 7
- Bostik Clear Priming Fluid
- Caustic Soda (Sodium Hydroxide)
- Cement - GP
- Chlorine (Sodium Hypochlorite)
- Norchlor - Liquid Pool Chlorine
- Potassium Permanganate
- SNF Floquat FL 4440 - Liquid Coagulant
- Soda Ash Solution

19.2.2 Spill Incidents

There is no recorded spill incident at the Water Treatment Plant on the Peabody Spill Incident Register.

19.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2009 and 2010.

Table 19-2 Historical aerial photograph summary

Date	Description
2010	The site appears as a fenced triangular area with the raw water dam to the west and near the access road, the two WTP buildings with the sludge lagoons directly north. Two cylindrical tanks are visible also in the yard. North of the sludge lagoon is a rectangular structure, being the generator.
2016	There is no 2016 aerial photography available at the time of this PSI. However, based on the site inspection (refer to Section 19.3), the site features were found to be similar to 2010 aerial imagery.

19.3 Site inspection

The site had a hardstand area with the WTP buildings, access road and tanks and the surrounding area was covered in long grass.



Photo 19-1 View of the WTP buildings with the new facility to the left.

The new WTP is in a shipping container, fitted with dosing and filtration equipment with the adjacent DAF tank located externally. Some storage of 20 L containers of chemical on pellets are present outside the structures.



Photo 19-2 View of the inside of the new WTP.

Some minor corrosion of the steel was noted in some areas.

The original STP is located within a rectangular building with a water tank at one end and a lean too with carbon filters present against one wall. Inside the building, settlement tanks and dosing equipment is present with a small water laboratory testing area at one end.



Photo 19-3 The original WTP with the carbon filters at the end.

The sludge lagoons both contained water that appeared to be clear with no scums and the perimeter was surrounded by macrophytes and grasses, all appearing healthy.



Photo 19-4 WTP sludge lagoons

There was no indication of any staining, odours or indicators of contamination noted within the area. There was also no staining in the vicinity of the generator.

19.4 Conceptual site model

19.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 19-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated PCoC
Chemical storage areas and tanks	Minor storage and dosing	Soda ash, hydrated potassium aluminium sulfate (alum), chlorine, sodium hydroxide
Sludge lagoons	Alum sludge is disposed here	potassium aluminium sulfate (alum)
Diesel generator	Leaks and spills	TRH and BTEXN

19.4.2 Potential sensitive receptors

Based on the site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- On-site worker, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.

Potential Sensitive ecological receptors

- No sensitive ecological receptors were identified in the vicinity of the site.

19.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 19-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 19-4 CSM-Potential source-pathway-receptor linkage

AECs	Chemical storage areas and tanks		Sludge lagoons		Diesel generator	
Source	Minor storage and dosing		Alum sludge is disposed here		Leaks and spills	
PCoC	Soda ash, hydrated potassium aluminium sulfate (alum), chlorine, sodium hydroxide		potassium aluminium sulfate (alum)		TRH and BTEXN	
Pathway	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater	Lateral migration through surface water (raw water dam)	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater	Lateral migration through surface water (raw water dam)	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater	Lateral migration through surface water (raw water dam)
Receptor	On-site workers, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.					
S-P-R Linkages	Unlikely[1]	Unlikely[2]	Unlikely[1]	Unlikely[2]	Unlikely[3]	Unlikely[2]

Note:

1. Although direct contact with chemicals stored at the WTP is consider hazardous, human exposure on WTP is managed by standard OH&S requirements (i.e. Personal Protective Equipment (PPE)), therefore it is not considered likely to pose human health risk on the on-site workers.
2. Raw water stored in the dam will need to be treated prior supplied as portable water, and the chemicals stored and used on site were part of the water treatment process, therefore it is considered unlikely to pose human health risk on the onsite workers.
3. As the generator is pad mounted, any potential leaks is likely to be localised around the concrete pad due to small volume. In the absence of surface staining in the vicinity of the

generator (during site inspection) and previous spill incidents, it is considered unlikely to pose human health risk on the onsite workers.

19.5 Summary

Based on the findings, the WTP is considered to pose very limited risk, it is recommended that:

- Remove all chemical stored on site and remove generator from site
- When the site is decommissioned, clean and remove sludge from the sludge lagoons and backfill to surface layer
- Validation should be undertaken at all infrastructures locations (including sludge lagoons and generator) to demonstrate there is no residual contamination on site.

Figure 19-1 Functional Area O – Water Treatment Plant

20. Functional Area P – Kerlong Village

20.1 Site Description

The Kerlong Village is located south-east of the Burton Widening operation area, which served as the accommodation camp for the mine site workers. This section only discusses the areas where generators are stored and maintenance shed at the village.

The location is presented in Table 2-1 with the area and site details shown in that also illustrates current and former infrastructure and activity areas, where present.

Details of the site are summarised in and discussed further below in Table 17-1.

Table 20-1 Site Details Summary

Site Details	Description
Location	Located 0.5 km east from the STP
Area (ha)	14.27 (whole village)
Lot/Plan	Lot 5311 SP262721
EMR/CLR	Not listed on EMR/CLR
Current land owner	Queensland State Government. The land is leased (expiring on 7 November 2043) to • Ganra Pty Ltd Gaffwick Pty Ltd
Mining lease	ML70109
Current use/activity	Workers accommodation and amenities.
Current infrastructure	Accommodation buildings, maintenance shed, power generator and backup generators, transformer, fuel storage
Topography and drainage	Generally flat with very gentle slope towards south
Hydrology	There is a drainage line located 0.3 km south from the village that runs south-west into Teviot Creek located 1.5 km south and Teviot Dam is located 2.5 km south-east away.
Hydrogeology	No monitoring bore within or in the vicinity of the site.
Surrounding land use	North: Grassed vegetated vacant land, Ellensfield road towards the Kerlong Village South: Grassed pasture and drainage line that flows south into Teviot Creek. East: Grassed vegetated area and Kerlong range 0.5 km east West: Grassed areas, access road between mine site and village, STP then mine site
Proposed strategy	Infrastructures to be removed from site.

20.2 Site history

- There are currently three generators on site, including the main generator, West Kerlong generator and the Olympic generator.
- There is a small diesel AST located adjacent to the main generator.
- The backup generators are run once per month for test/inspection.
- No flood occurred at the camp previously.
- All waste (municipal waste) are removed offsite by waste contractor (JJ Richards).

- No known spill incidents occurred at the Kerlong Village by the interviewees.

20.2.1 Chemical Register

The following hazardous materials were recorded at the camp maintenance shed:

- Bunnings Ant Kill RTU
- Cherry Air Spray
- ClenAir Citrus Spray
- Unleaded Petrol (20 L)
- Viper Coil Degreaser
- Yates Blitzem Indoor/ Outdoor Barrier Spray
- Rational Special Descaler

20.2.2 Spill Incidents

There is no recorded spill incident at the Water Treatment Plant on the Peabody Spill Incident Register.

20.2.3 Aerial photographs

A review of historical aerial photographs provided by Peabody and sourced from Google Earth was completed. Available aerial image only includes year 2009 and 2010.

Table 20-2 Historical aerial photograph summary

Date	Description
2010	The site appears as a fenced triangular area with the raw water dam to the west and near the access road, the two WTP buildings with the sludge lagoons directly north. Two cylindrical tanks are visible also in the yard. North of the sludge lagoon is a rectangular structure, being the generator.
2016	There is no 2016 aerial photography available at the time of this PSI. However, based on the site inspection (refer to Section 19.3), the site features were found to be similar to 2010 aerial imagery.

20.3 Site inspection

The generators were all pad mounted and observed to be in good conditions, except some minor surface staining within the AST fuel bund (adjacent to main generator), which is likely resulted from filling.



Photo 20-1 Pad mounted generator with adjacent transformer and switchboard



Photo 20-2 Diesel fuel in an Above Ground Tank (AST) located in a concrete bund adjacent to main generator

The maintenance shed is consists of cupboards (contained flammable liquids), storage racks, mower, a maintenance buggy.



Photo 20-3 View of maintenance shed

There was no indication of any staining, odours or indicators of contamination noted within and outside the area inspected.

20.4 Conceptual site model

20.4.1 Areas of Environmental Concerns (AECs) and Potential Contaminants of Concern (PCoC)

Based on the site history and information obtained through the documents review provided by Peabody, the following area of environmental concerns (AECs) and potential contaminants of concern (PCoC).

Table 20-3 Summary of AECs and PCoCs

AEC	Primary Contamination Sources	Associated PCoC
AST, generators	Leaks and Spills	TRH, BTEX and PAH
Pad mounted transformers	Leaks and Spills	TRH, BTEX and PAH

20.4.2 Potential sensitive receptors

Based on site setting, the following potentially sensitive receptors have been identified:

Potential Sensitive human receptors

The primary *human receptors* are considered to include:

- On-site worker, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench.
- Residents at the Kerlong Village

Potential Sensitive ecological receptors

- No ecological receptors are noted in the vicinity of the generators and fuel storage areas.

20.4.3 Conceptual site model

Based on the potential contamination sources, the potential sensitive receptors and the possible transport mechanisms and exposure pathways identified, a tabulated conceptual site model (CSM) has been developed for the site (Table 20-4), showing the potential source-pathway-receptor (S-P-R) linkages.

Table 20-4 CSM-Potential source-pathway-receptor linkage

AECs	AST, generators	Pad mounted transformers
Source	Leaks and Spills	
PCoC	TRH, BTEX and PAH OC/OP pesticides	
Pathway	Direct contact (including accidental ingestion) with impacted soil or shallow/perched groundwater	
Receptor	• On-site worker, including maintenance workers engaged in subsurface earthworks to shallow depths (<1 m) or access of shallow pits/ trench. • Residents at the Kerlong Village	
S-P-R Linkages	Unlikely[1]	Unlikely[1]

Note:

1. The fuel AST and transformer is located within concreted bunds/pads, therefore, in the event of a leaks or spills, it will more likely to be contained within the bunds or on the concrete pad. Minor contamination may occur during the dispensing/refilling activities at the ASTs area, however, due to the low volume and, it is considered to be low human health risk.

20.5 Summary

Based on the findings, the Kerlong Village is considered to pose very limited risk, it is recommended that:

- On decommissioning of site (fuel ASTs, generators and maintenance shed), undertake visual assessment and document for future references.
- If subsurface contamination is identified, remediation and validation to be undertaken. All actions should be documented.

Figure 20-1 Functional Area P – Kerlong Village

21. Risk Assessment

This section discusses the risks associated with each functional area based on the PSI findings and conceptual site models.

The risk assessment was developed based on the Peabody risk matrix (provided in Appendix E). Aligned with the risk matrix we have considered the following risk categories human health, environmental, financial and compliance regulatory; impact on reputation and strategic risk are not included as they are not considered part of the scope.:

- Harm to people
- Environmental
- Finance
- Impact on reputation
- Law/Compliance/Regulatory
- Strategic Risk

For the purpose of this PSI, impact on reputation and strategic risk were not included in this risk assessment, as they are outside the scope.

In accordance to the site setting, interviews/inspection observations and conceptual site model, most of the functional areas were considered to pose low risks to the risk categories. However, the following listed functional areas were rated as minor to moderate risk due to potential contamination noted on site or regulatory requirements that were associated with the onsite infrastructures or activities:

- Wallanbah Handstand (Environmental, Law/Compliance/Regulatory and Financial Risk)
- Workshop Area (Environmental, Law/Compliance/Regulatory and Financial Risk)
- Workshop Fuel Farm (Environmental, Law/Compliance/Regulatory and Financial Risk)
- BIS workshop (Environmental, Law/Compliance/Regulatory and Financial Risk)
- Sewage Treatment Plant (Law/Compliance/Regulatory Risk)

GHD has prepared Sampling Analysis Plans (SAP) to be implemented for these functional areas to better quantify the extent of contamination and reassess the risk assessment once more information is confirmed. The SAPs are provided in Appendix F.

The risk assessment for the functional areas is presented in Appendix E.

22. Conclusion and Recommendations

22.1 Conclusion

Based on the review of available site history information, site inspection and site interviews, the potential contamination sources and potential sensitive receptors have been identified for the various functional areas assessed. Most of the functional areas were considered to pose low risk to human health and environment, except for the five functional areas that requires assessment and validation or remediation if contamination is confirmed.

These include:

- Wallanbah Hardstand
- Workshop
- Workshop fuel farm
- BIS workshop
- Sewage Treatment Plant

In order to further assess the identified potential sources of contamination, GHD has prepared five SAPs (provided in Appendix F) for sampling program for the assessment and validation works at identified AECs, and to be implemented during demobilisation works from these functional areas.

22.2 Recommendations

Recommended actions includes the following:

- A Sampling and Analysis Plan (SAP) that includes validation should be prepared for the fuel tanks decommissioning and undertaken during its removal. Where identified, contamination should also be remediated via excavation and appropriate disposal of material undertaken.
- Pipework, tanks and drainage systems that have a potential for or can come in contact with contaminated substances or material, are to be cleaned and flushed prior to dismantling or removal.
- Existing services and plans should be reviewed and prior to any decommissioning, with redundant services, including wash water treatment system drainage infrastructure, should be isolated and removed, while ensuring any remaining infrastructure is not compromised or subject to potential contamination or migration.
- Pipework, tanks and drainage systems that have a potential for or do come in contact with contaminated substances or material, to be cleaned and flushed prior to dismantling or removal.
- Where possible, any identified or visual indications of contamination should be excavated until visual and/or olfactory indicators are not present, including prior to infrastructure removal, to minimise cross contamination and potential migration of contamination
- All remediation works to be documented, include waste tracking and disposal information, quantities and for higher risk AECs and where identified contamination is removed, undertake validation sampling and reporting.

- A SQP and/or a Peabody representative is required to undertake inspections of areas prior to, during and after infrastructure removal of AEC infrastructure and document, including photos. When competed and satisfactory, sign of and retain records.
- Any excavated and contaminated material needs to be appropriately handled and disposed of.

23. References

- Airports Act 1996.
- Airports (Environment Protection) Regulations 1997.
- Australian Standard AS 4482.1:2005: Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil.
- AS/NZS ISO 31000:2009: Risk management - Principles and guidelines.
- Australian Commonwealth Work Health and Safety Act 2011.
- Commonwealth Work Health and Safety Regulations 2011.
- Department of Environment and Energy, Protected Matters Search.
- Department of Infrastructure and Regional Development (DoIRD, 2015): GEM 002 - PFC Management Actions Advice.
- GHD, 2015, Airservices Interim Contamination Management Strategy and Decision Framework for PFC contamination, June 2015 (the 'Interim Framework').
- GHD, 2016: Airservices Australia – Gold Coast Airport Sampling and Analysis Quality Plan.
- Environment Protection Act 1970.
- NEPC, 2013: National Environment Protection (Assessment of Site Contamination) Measure 1999 as amended 2013 (the ASC NEPM).
- Sinclair Knight Mertz, *Preliminary Site Investigation, ARFF Area, Sunshine Coast Airport, Maroochydore, Qld*, 6 March 2009
- Sinclair Knight Mertz, Limited Site Contamination Assessment Letter Report, *ARFF Pre-Lease Area, Sunshine Coast Airport, Maroochydore, Queensland*, 3 June 2009
- US EPA US EPA 2014, *Emerging Contaminants – Ferfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)*, Emerging Contaminants Fact Sheet – PFOS and PFOA, http://www2.epa.gov/sites/production/files/2014-04/documents/factsheet_contaminant_pfos_pfoa_march2014.pdf, viewed 28 April 2015.

24. Limitations

This report: has been prepared by GHD for Peabody Energy Australia Coal Pty Limited and *may only be used and relied on by Peabody Energy Australia Coal Pty Limited for the purpose agreed between GHD and the Peabody Energy Australia Coal Pty Limited as set out in section … of this report.*

GHD otherwise disclaims responsibility to any person other than Peabody Energy Australia Coal Pty Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Peabody Energy Australia Coal Pty Limited and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

Appendices

Appendix A – Site Information Desktop Review

o eo o
Re iste e P s
it es

GROUNDWATER DATABASE

BORE REPORT

REG NUMBER 162255

REGISTRATION DETAILS

		BASIN	1304	**LATITUDE**	21-47-11	**MAP-SCALE**	
OFFICE	Mackay	**SUB-AREA**		**LONGITUDE**	148-09-14	**MAP-SERIES**	
DATE LOG RECD		**SHIRE**	3980-ISAAC REGIONAL	**EASTING**	619280	**MAP-NO**	
D/O FILE NO.		**LOT**	13	**NORTHING**	7590379	**MAP NAME**	
R/O FILE NO.		**PLAN**	SP178466	**ZONE**	55	**PROG SECTION**	
H/O FILE NO.		**ORIGINAL DESCRIPTION**		**ACCURACY**		**PRES EQUIPMENT**	
				GPS ACC			
GIS LAT	-21.7863094	**PARISH NAME**	4866-WALLANBAH			**ORIGINAL BORE NO**	EFGW1S
GIS LNG	148.1538058	**COUNTY**	GROSVENOR			**BORE LINE**	-
CHECKED	Y						
						POLYGON	
						RN OF BORE REPLACED	
FACILITY TYPE	Sub-Artesian Facility	**DATE DRILLED**	06/06/2008			**DATA OWNER**	
STATUS	Existing	**DRILLERS NAME**	KEVIN HILL				
ROLES	MM	**DRILL COMPANY**	BELLDALE DRILLING				
		METHOD OF CONST.	ROTARY AIR				

CASING DETAILS

PIPE	DATE	RECORD NUMBER	MATERIAL DESCRIPTION	MAT SIZE (mm)	SIZE DESC	OUTSIDE DIAM (mm)	TOP (m)	BOTTOM (m)
A	06/06/2008	4	Polyvinyl Chloride				0.00	8.72
A	06/06/2008	5	Perforated or Slotted Casing				8.72	11.72
X	06/06/2008	1	Grout				0.00	6.00
X	06/06/2008	2	Bentonite Seal				6.00	7.00
X	06/06/2008	3	Gravel Pack				7.00	11.72

STRATA LOG DETAILS

RECORD NUMBER	STRATA TOP (m)	STRATA BOT (m)	STRATA DESCRIPTION
1	0.00	2.00	SOIL: MEDIUM BUFFISH BORWN, PARTIALLY SANDY
2	2.00	3.00	SAND: MEDIUM ORANGY BORWN, FINE GRAINED, DAMP
3	3.00	10.00	SAND: MEDIUM BROWN, VERY COARSE GRAINED, COMMON PEBBLES THROUGHOUT, WET AT 5M
4	10.00	10.50	CLAYSTONE: DULL YELLOWISH BUFF

BORE REPORT

REG NUMBER 162255

RECORD NUMBER	STRATA TOP (m)	STRATA BOT (m)	STRATA DESCRIPTION
5	10.50	12.00	MUDSTONE: DARK BROWNISH RED

STRATIGRAPHY DETAILS

****** NO RECORDS FOUND ******

AQUIFER DETAILS

REC	TOP BED(M)	BOTTOM BED(M)	BED LITHOLOGY	DATE	SWL (m)	FLOW	QUALITY	YIELD (l/s)	CTR	CONDIT	FORMATION NAME
1	8.72	10.00	SAND	09/07/2008	-4.24	N			Y	UC	TERTIARY - UNDEFINED
2	10.00	10.50	CLAY	09/07/2008	-4.24	N			Y	UC	TERTIARY - UNDEFINED
3	10.50	12.00	MDST	09/07/2008	-4.24	N			Y	PS	REWAN FORMATION

PUMP TEST DETAILS PART 1

****** NO RECORDS FOUND ******

PUMP TEST DETAILS PART 2

****** NO RECORDS FOUND ******

BORE CONDITION

****** NO RECORDS FOUND ******

ELEVATION DETAILS

PIPE	DATE	ELEVATION	PRECISION	DATUM	MEASUREMENT POINT	SURVEY SOURCE
A	06/06/2008	288.39	SVY	AHD	R	EIS
X	06/06/2008	288.00	SVY	AHD	N	EIS

WATER ANALYSIS PART1

****** NO RECORDS FOUND ******

WATER ANALYSIS PART 2

****** NO RECORDS FOUND ******

BORE REPORT

REG NUMBER 162255

WATER LEVEL DETAILS

PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE	PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE	PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE
A	09/07/2008	-4.24	R		NR												

WIRE LINE LOG DETAILS

****** NO RECORDS FOUND ******

FIELD MEASUREMENTS

****** NO RECORDS FOUND ******

SPECIAL WATER ANALYSIS

****** NO RECORDS FOUND ******

BORE REPORT

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**** End of Report. Produced:** 25/09/2016 05:21:57 PM ******

LAND TITLE ACT 1994

SURVEY PLAN

FORM 21 VERSION 1

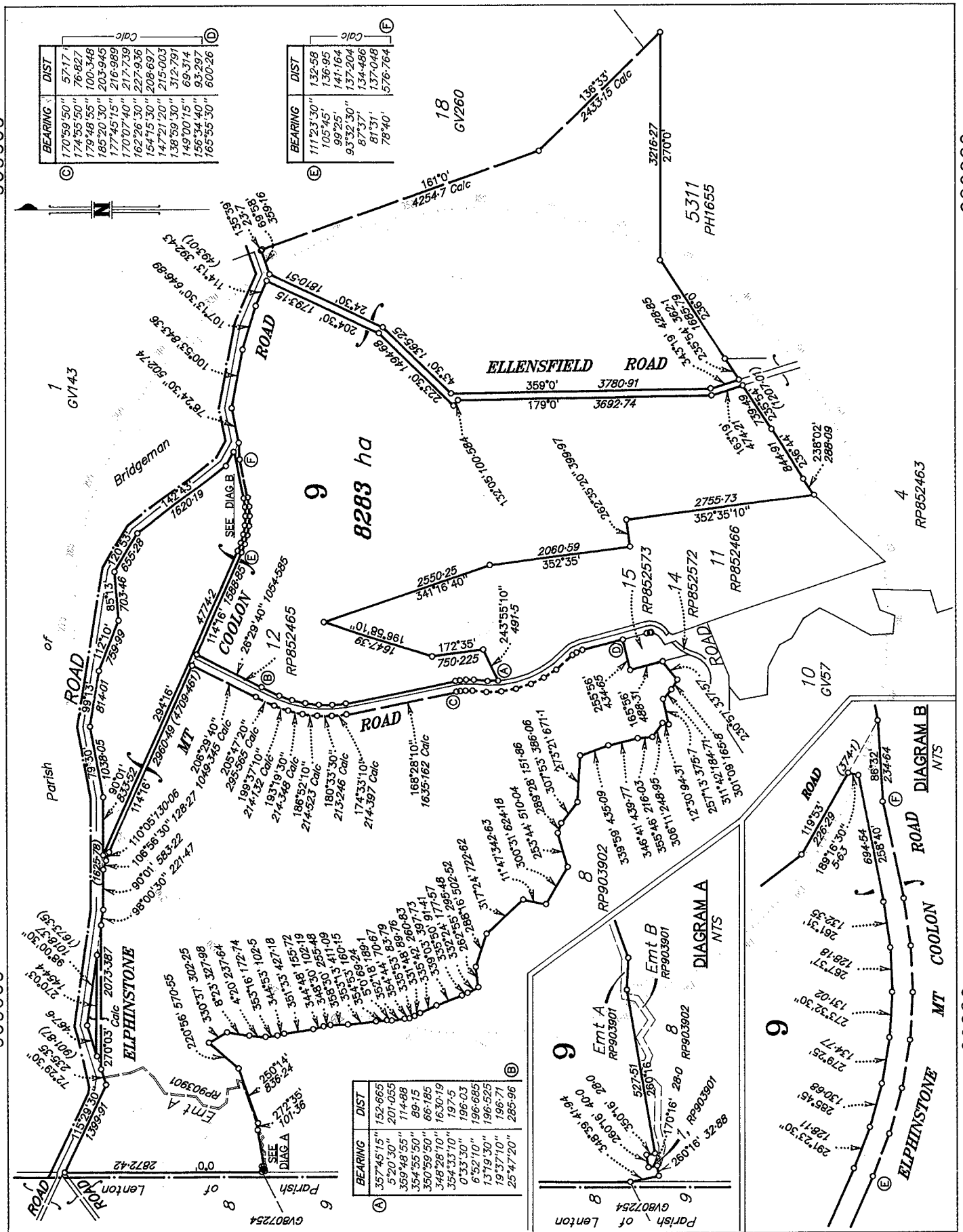
903903

PLAN MUST BE DRAWN WITHIN BLACK LINES

903903

WARNING - PLAN MAY BE ROLLED - A FOLDED OR MUTILATED PLAN WILL NOT BE ACCEPTED

903903



Calc ©	
BEARING	DIST
170°59'50"	57·17
174°55'50"	76·827
179°48'55"	100·348
185°20'30"	203·945
177°45'15"	216·989
170°07'40"	217·739
162°26'30"	227·936
154°15'30"	208·697
147°21'20"	215·003
138°59'30"	312·791
149°00'15"	69·314
156°34'40"	93·297
165°55'30"	600·26

Calc (F)	
BEARING	DIST
111°23'30"	132·58
105°45'	136·95
99°25'	141·164
93°32'30"	137·204
87°37'	134·486
81°31'	137·048
78°40'	576·764

(B)	
BEARING	DIST
357°45'15"	152·665
5°20'30"	201·055
359°48'55"	114·88
354°55'50"	89·15
350°59'50"	66·185
348°28'10"	1630·19
354°33'10"	197·5
0°33'30"	196·03
6°52'10"	196·685
13°19'30"	196·525
19°37'10"	196·71
25°47'20"	285·96

I, Trevor David Johnston hereby certify that I have made this plan pursuant to Section 25 of the Surveyors Regulation 1992, and that the plan is accurate and compiled from GV145, GV339, RP852583 and RP903901 in the Department of Natural Resources.

Trevor D Johnston — Licensed Surveyor — 18/7/96 — Date

PLAN OF *Lot 9*

Cancelling balance of Lot 9 on RP852583

ORIGINAL Lot 9 on CP852460 — NO SURVEY RECORDS DEPOSITED

MERIDIAN	MAP REF	SCALE	ENDORSED	ARCHIVED
Add 7°25' for AMG Vide RP852465	8554	1:50,000	RGV 19/8/96	Central

PARISH BURTON
COUNTY Grosvenor
~~TOWN~~/LOCALITY BURTON DOWNS
LOCAL GOVERNMENT NEBO S.C.
LANDS REGION MACKAY
MINING DISTRICT

REGISTERED PLAN 903903

0 10 20 30 40 50 60 70 80 90 100mm

CROWN COPYRIGHT RESERVED

CISP

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WARNING - PLAN MAY BE ROLLED - A FOLDED OR MUTILATED PLAN WILL NOT BE ACCEPTED

702389185
$250.00
$250.00
11/12/1997 09:22
BE 400 PLAN OF SURV ORIG

W/DARE FORMERLY 7023F2958.

CISP

Lodged by QETC
PO BOX 1193
VIRGINIA Q 4014
3860 2149
(Include address, phone number and reference)

75.

Particulars entered in the Register on the Titles listed below,

REGISTERED
11 DEC 1997
EXAMINER

Title Reference	Description	New Lots
30652239	Lot 9 on RP852583	9

I/We CLARENCE GILBERT SHAW and GEOFFREY CHARLES SHAW

(Names in full)

* As Registered Owner of this land * As Lessee/s of Miners Homestead agree to this Plan, # and dedicate the Public Use Land as shown hereon in accordance with Section 50 of the Land Title Act 1994.

C G Shaw Geoff C Shaw.
Signature of * Owner/s * Lessee/s

FOUR

* Rule out whichever is inapplicable
# NOTE: A Lessee of a Miners Homestead is unable to dedicate Public Use Land.

* NERIS SHIRE COUNCIL
certifies that all the requirements of this Council, the Local Government Act 1993, the Local Government (Planning and Enviroment) Act 1990 and all Local Laws, ~~# and the City of Brisbane Act 1924 and all Ordinances thereunder~~, have been complied with and approves this plan of Subdivision, SUBJECT TO

Dated this 27th day of OCTOBER 1997

Mayor
Appointed Officer

Chief Executive Officer

* Insert the n... ...ent
# Delete for Lo... ...han the City of Brisbane

For Additional Plan & Document Notings Refer to CISP

SURVEY EXAMINATION	ORIGINAL GRANT	CHARTING	LODGEMENT FEES	REFERENCES
Exam. Fee $ NO FEE		Charted	Survey Exam $	Lands File 903901
Receipt No.			Lodg, Exam & Ass $	Local Government Reference
Date			New Titles $	Surveyors Reference
Deposited 18/7/96 RGV			Photocopy $	
Examined 5/8/96 RGV			Postage $	REGISTERED PLAN 903903
Passed 5/8/96 RGV			TOTAL $	

903903

903903

CISP

111900–1/KWL/Mackay

Land Title Act 1994; Land Act 1994
Form 21 Version 2

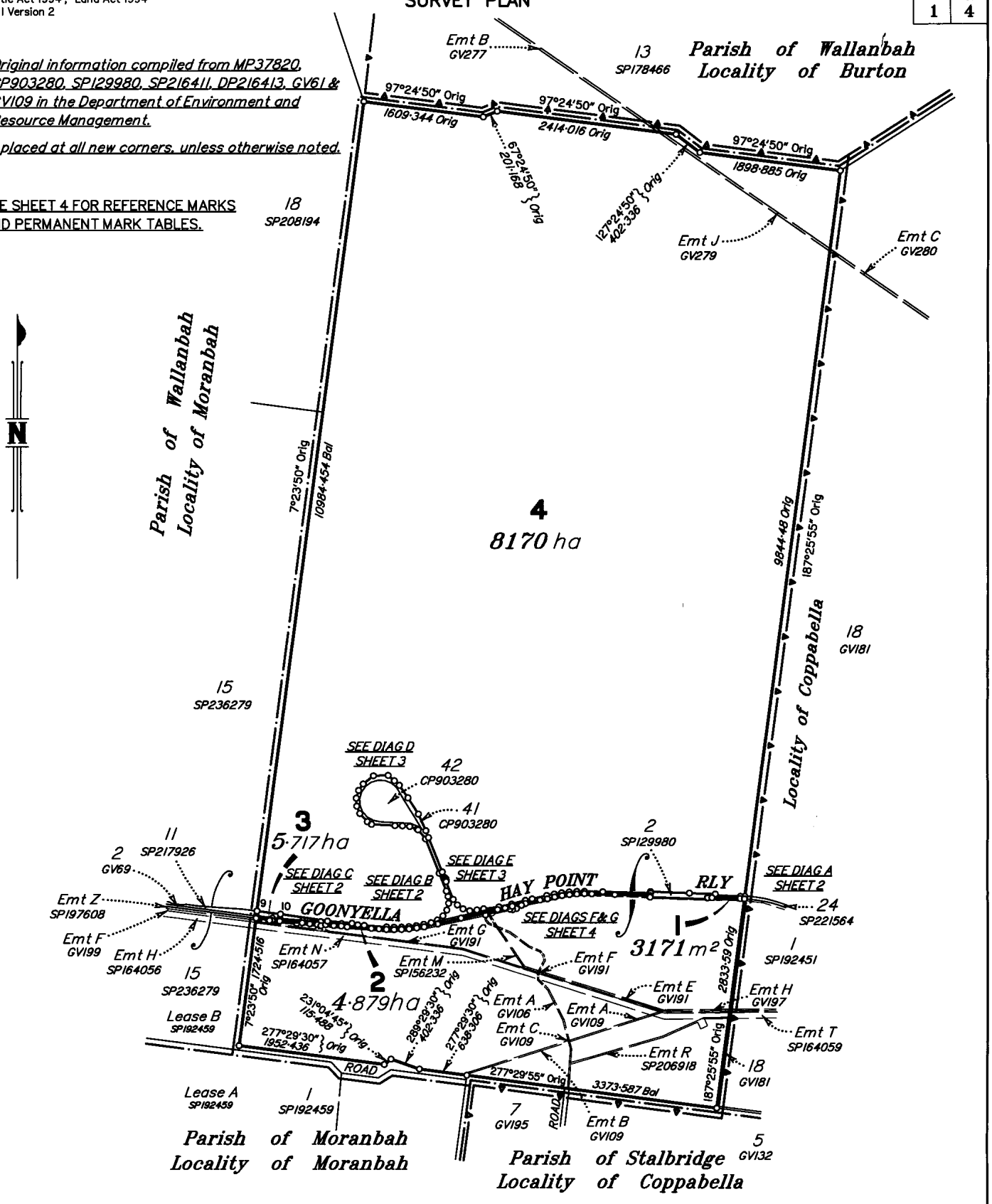
SURVEY PLAN

Sheet 1 of 4

Original information compiled from MP37820, CP903280, SP129980, SP216411, DP216413, GV61 & GV109 in the Department of Environment and Resource Management.

Peg placed at all new corners, unless otherwise noted.

SEE SHEET 4 FOR REFERENCE MARKS AND PERMANENT MARK TABLES.



Scale 1: 50000 – Lengths are in Metres.

500 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000

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RPS Australia East Pty Ltd (ACN 140 292 762) hereby certify that the land comprised in this plan was surveyed by the corporation, by Richard Lloyd DUMMETT, cadastral surveyor, for whose work the corporation accepts responsibility, and that the plan is accurate, that the said survey was performed in accordance with the Survey and Mapping Infrastructure Act 2003 and Surveyors Act 2003 and associated Regulations and Standards and that the said survey was completed on 17.02.2012.

Authorised Delegate

Date 19/07/2012

Plan of Lots 1–4

Cancelling Lot 4 on CP903281

PARISH: INGSDON COUNTY: Grosvenor

Meridian: MGA Zone 55 Vide DP216413

F/N's: No

Scale: 1:50000

Format: STANDARD

SP252740

Plan Status:

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714824147

$623.50
06/12/2012 09:57

BE 400 NT

Registered

5. Lodged by
QR National 2238
GPO Box 456, Brisbane 4001
Ph: 3019 2735
Ref: Enterprise Real Estate
(Include address, phone number, reference, and Lodger Code)

1. Certificate of Registered Owners or Lessees.

I/We ~~Guilherme Bregs and Stephanus Badenhorst~~ ~~Directors of~~ VALE AUSTRALIA PTY LTD A.C.N. 062 536 270

(Names in full)

*as Registered Owners of this land agree to this plan and dedicate the Public Use Land as shown hereon in accordance with Section 50 of the Land Title Act 1994.

VALE AUSTRALIA PTY LTD
*~~as Lessees of this land agree to this plan~~
A.C.N. 062 536 270

Stephanus Badenhorst
Director

Signature of *Registered Owners *Lessees

DIRECTOR

* Rule out whichever is inapplicable

2. Local Government Approval.

*

hereby approves this plan in accordance with the :

%

This plan for reconfiguring a lot does not require local government approval under schedule 19 of the Sustainable Planning Regulation 2009 because it is not a "subdivision plan" for the purpose of the Sustainable Planning Regulation 2009: see schedule 26 of the Sustainable Planning Regulation 2009, definition of "subdivision plan", items 3 (b)(i),(ii) or (iii).

Dated this 21 SEP 2012

The chief executive for the Department of Transport and Main Roads for and on behalf of the State of Queensland

the Delegate of the chief executive for the Department of Transport and Main Roads

#

* Insert the name of the Local Government. % Insert Integrated Planning Act 1997 or Local Government (Planning & Environment) Act 1990
# Insert designation of signatory or delegation

3. Plans with Community Management Statement :
CMS Number :
Name :

4. References :
Dept File :
Local Govt :
Surveyor : 111900-1

6.

Existing		Created				
Title Reference	Description	New Lots	Road	Emts	Cov.	Profit a prendre
50875480	Lot 4 on CP903281	1 – 4	——	——	——	——

MORTGAGE ALLOCATIONS

Mortgage	Lots Fully Encumbered	Lots Partially Encumbered
714334689	1 – 4	——

EXISTING ADMINISTRATIVE ADVICE ALLOCATIONS

Administrative Advice	Lots to be Encumbered
709445249	1 – 4
712980663	1 – 4

ENCUMBRANCE EASEMENT ALLOCATIONS

Easement	Lots to be Encumbered
602803066 (Emt A on GV106)	2, 4
602803067 (Emts A, B & C on GV109)	4
602803068 (Emts E, F & G on GV191, & Emt H on GV197)	4
602803069 (Emt J on GV279)	4
703015328 (Emt K on SP106036)	2
703015328 (Emt L on SP106036)	4
706947253 (Emt M on SP156232)	2, 4
707148824 (Emt M on SP156232)	2, 4
707716772 (Emt N on SP164057)	4
711958203 (Emt P on SP216411)	1, 2, 4
712728009 (Emt R on SP206918)	4

1 – 4	Lot 4 on CP903281
Lots	Orig

7. Portion Allocation :

8. Map Reference :
8554-32

9. Locality :
MORANBAH

10. Local Government :
ISAAC REGIONAL COUNCIL

11. Passed & Endorsed :
By : RPS Australia East Pty Ltd ACN 140 292 762
Date : 19/07/2012
Signed :
Designation : Cadastral Surveyor

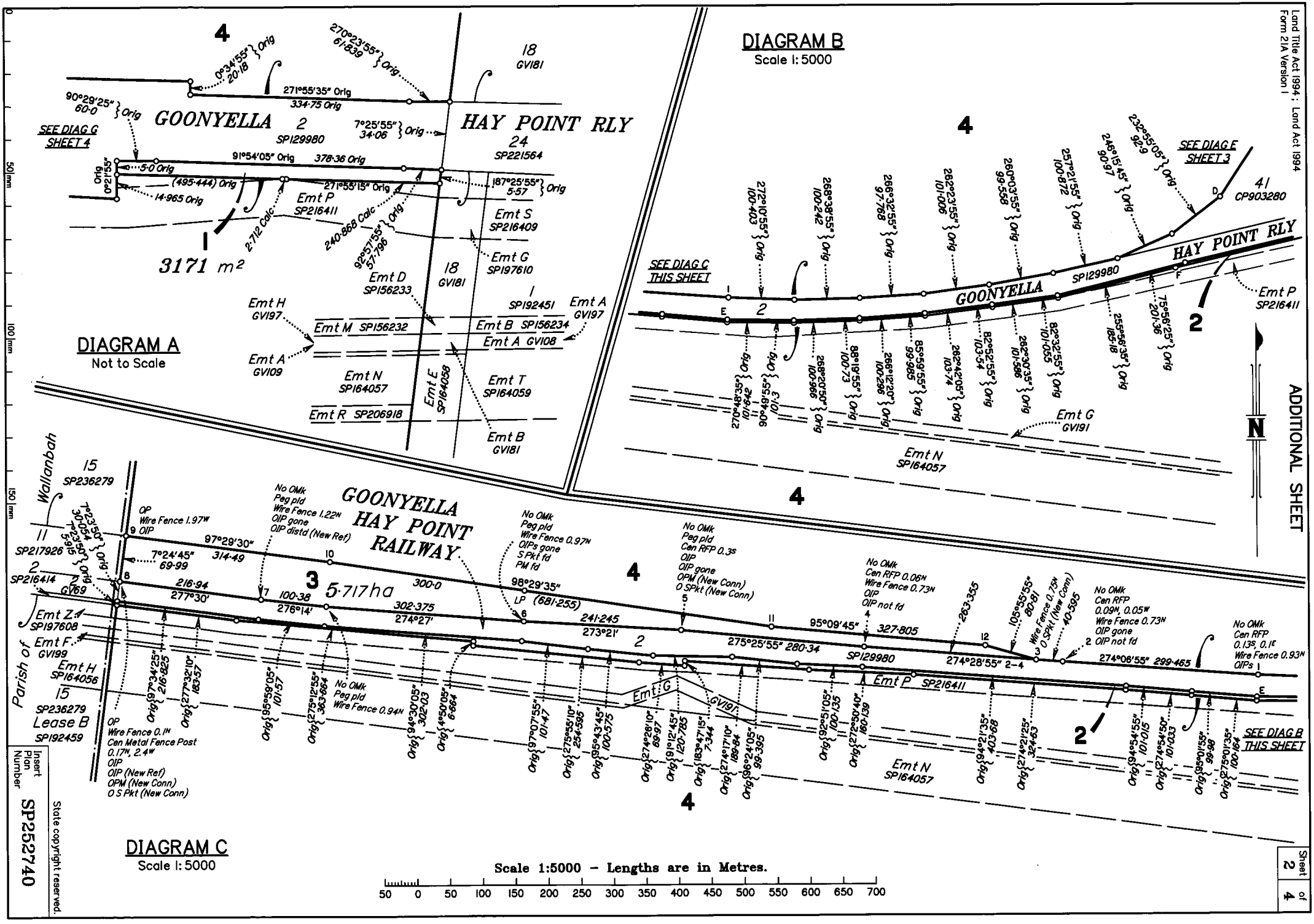
12. Building Format Plans only.
I certify that :
* As far as it is practical to determine, no part of the building shown on this plan encroaches onto adjoining lots or road,
* Part of the building shown on this plan encroaches onto adjoining * lots and road

Authorised Delegate * Date
*delete words not required

13. Lodgement Fees :

Survey Deposit	$
Lodgement	$
New Titles	$
Photocopy	$
Postage	$
TOTAL	$

14. Insert Plan Number **SP252740**



Land Title Act 1994; Land Act 1994
Form 21A Version 1

Insert Plan Number SP252740

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Sheet 2 of 4

Land Title Act 1994 ; Land Act 1994
Form 21A Version 1

ADDITIONAL SHEET

Sheet 3 of 4

DIAGRAM D
Scale 1:5000

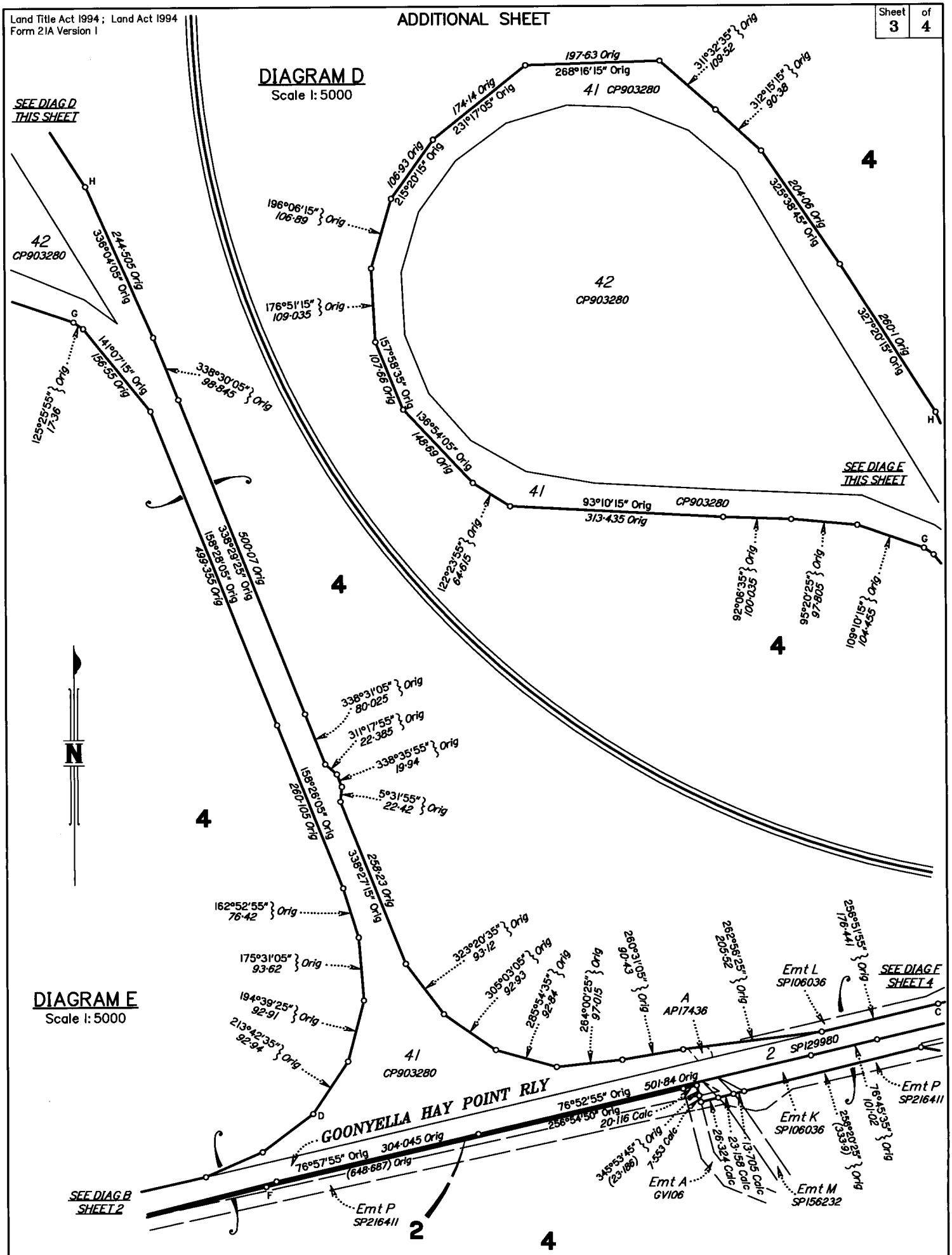

DIAGRAM E
Scale 1:5000

Scale 1:5000 – Lengths are in Metres.

50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700

0 50 mm 100 mm 150 mm

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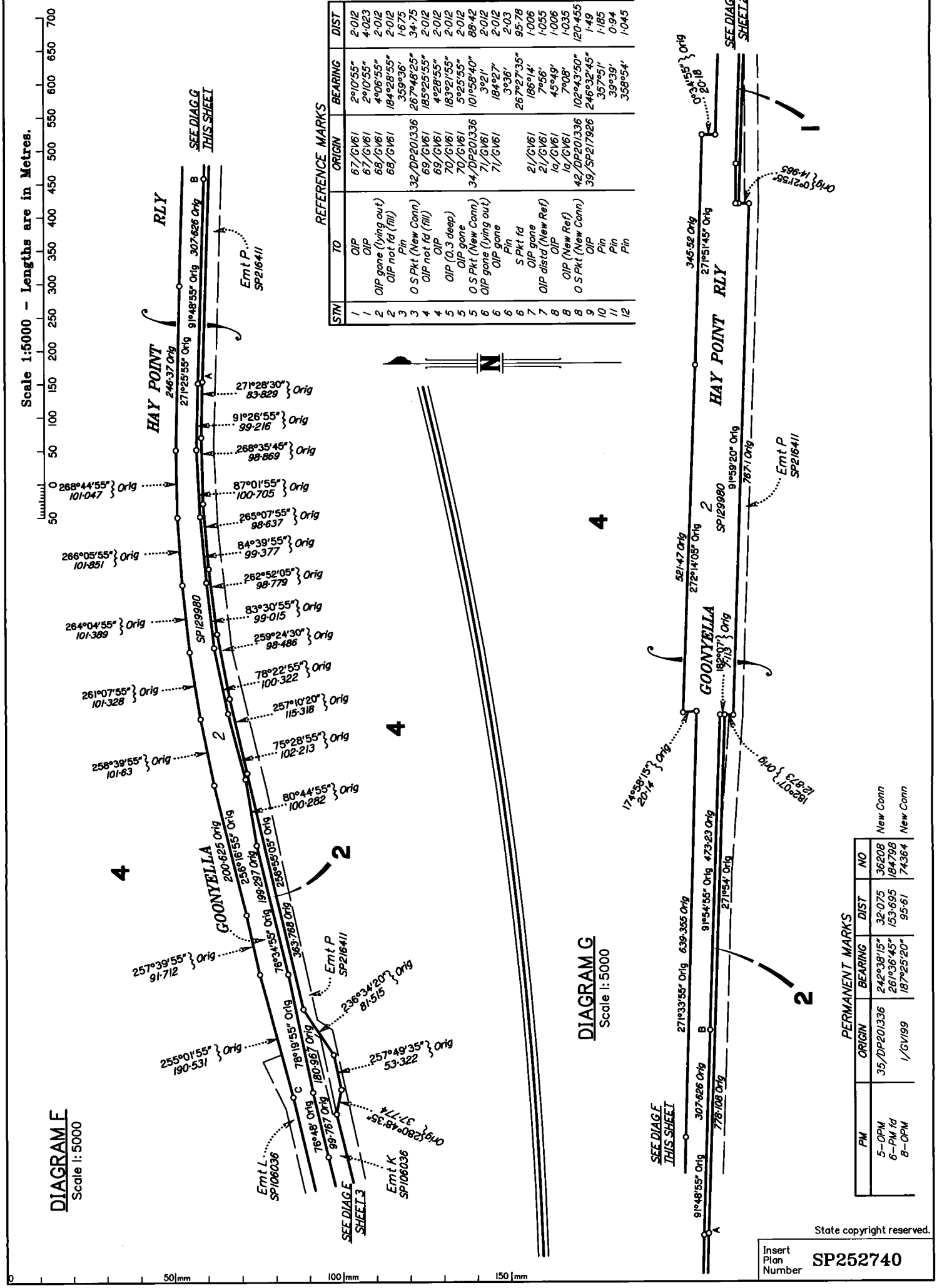
Insert Plan Number **SP252740**

Land Title Act 1994 ; Land Act 1994
Form 21A Version 1

ADDITIONAL SHEET

Sheet 4 of 4



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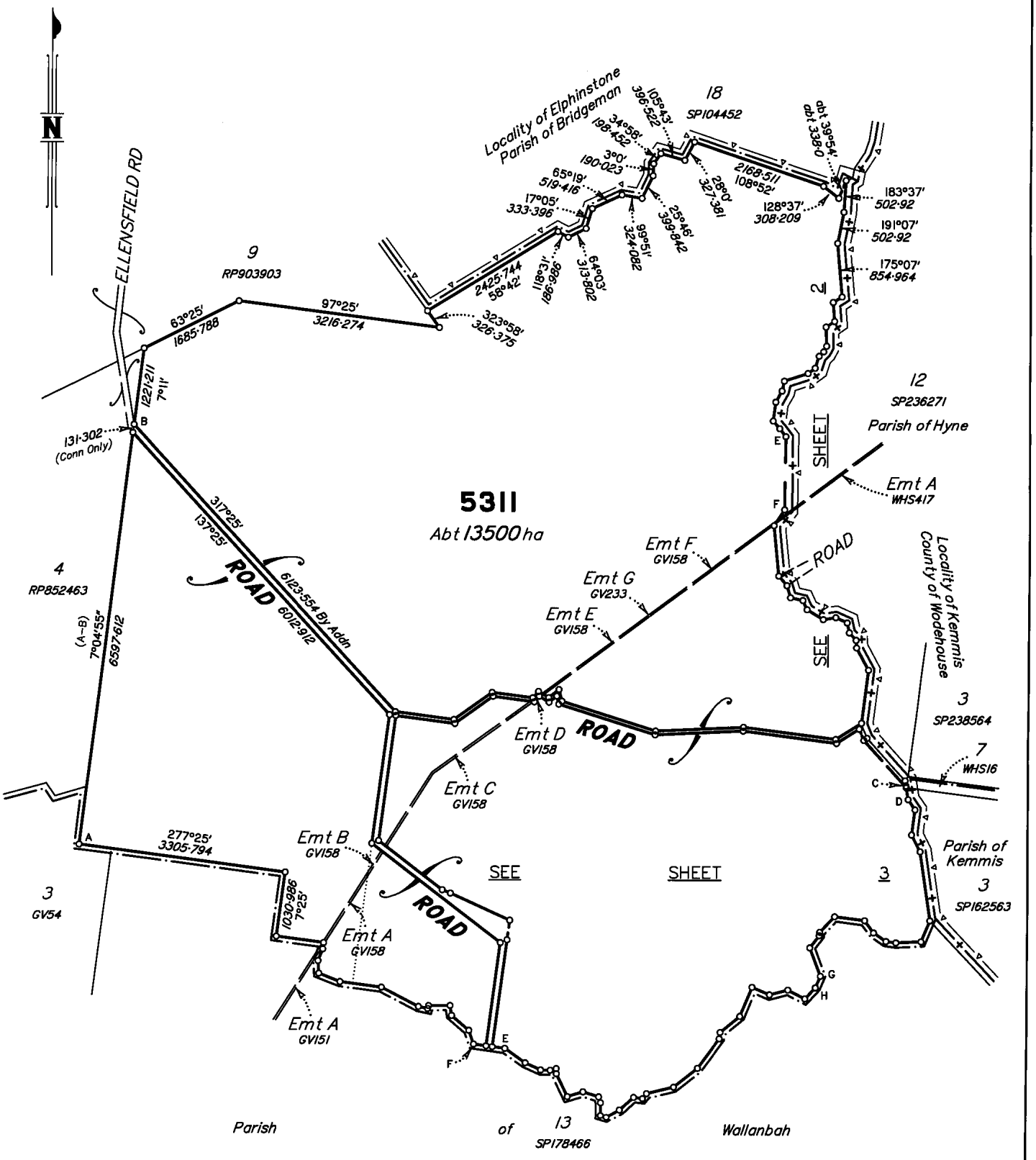
Insert Plan Number **SP252740**

Land Title Act 1994; Land Act 1994
Form 21 Version 3

SURVEY PLAN

Sheet 1 of 4

BD13375



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MACKAY SURVEYS PTY LTD (ACN 113 769 994) hereby certify that the corporation, by Derek Anthony WOODS, Cadastral Surveyor, for whose work the corporation accepts responsibility, has made this plan under Section 17 of the Survey and Mapping Infrastructure Regulation 2004 and pursuant to the Survey and Mapping Infrastructure Act 2003 and Surveyors Act 2003 and associated Regulations and Standards and that the plan is accurate, and complied from SP147333, SP162563, SP104452, MP41207, GV2, GV10, GV26, WHS16 and RA2[illegible]

Common Seal
Director

Date 30/10/2013

13147

PLAN OF

Lot 5311

Cancelling Lot 5311 on PH1655

LOCAL GOVERNMENT: ISAAC R.C. LOCALITY: BURTON

Meridian: MGA Zone 55 Vide SP147333

Survey Records: NO

Scale: 1:60000

Format: STANDARD

SP262721

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715631462

NO FEE
03/03/2014 16:00

MY 495

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Plans may be rolled.
Information may not be placed in the outer margins.**

5. Lodged by ~~SB Wright Wright & Co. dlc~~
~~PO Box 38~~
~~Mackay Q 4740~~
~~4957 2363~~
781.
Diana Muscat, LAO.
Dept of Natural Resources Mines
PO Box 63, MACKAY. Q4740
Ph. 49496875 case ID 2011/2793
E: SLAM-Mackay@dnrm.qld.gov.au.

(Include address, phone number, reference, and Lodger Code)

1. Certificate of Registered Owners or Lessees.

I/We GEOFFREY CHARLES SHAW
DALRAE MARGOT SHAW
SCOTT ANTHONY SHAW

(Names in full)

~~* as Registered Owners of this land agree to this plan and dedicate the Public Use Land as shown hereon in accordance with Section 50 of the Land Title Act 1994.~~

* as Lessees of this land agree to this plan.

Geoff C Shaw, D Shaw

Signature of ~~*Registered Owners~~ *Lessees

* Rule out whichever is inapplicable

6. Existing		Created		
Title Reference	Description	New Lots	Road	Secondary Interests
17668044	Lot 5311 on PH1655	5311	–	–

ENCUMBRANCE EASEMENT ALLOCATIONS

Easement	Lots to be Encumbered
602806112 (Emts A to F on GV158 & Emt G on GV233)	5311

EXISTING LEASE ALLOCATIONS

Lease	Lots to be Encumbered
713573084	5311

EXISTING ADMINISTRATIVE ADVICE ALLOCATIONS

Administrative Advice	Lots to be Encumbered
715002794 (Strategic Land)	5311
715165569 (Vegetation Notice)	5311

2. Planning Body Approval.

*

hereby approves this plan in accordance with the :

%

Dated this ..... day of .....

..... #

..... #

* Insert the name of the Planning Body.
# Insert designation of signatory or delegation
% Insert applicable approving legislation.

Lots	Orig

7. Orig Grant Allocation :

8. Map Reference :
8554–42124

9. Parish :
BURTON

10. County :
GROSVENOR

11. Passed & Endorsed :
By : MACKAY SURVEYS P/L
ACN 113 769 994
Date : 30/10/2013
Signed :
Designation : LIAISON OFFICER

12. Building Format Plans only.
I certify that :
* As far as it is practical to determine, no part of the building shown on this plan encroaches onto adjoining lots or road;
* Part of the building shown on this plan encroaches onto adjoining * lots and road

....
Cadastral Surveyor/Director* Date
*delete words not required

13. Lodgement Fees : LAIS RECEIPT #2015395

Survey Deposit	$333.00
Lodgement	$
New Titles	$
Photocopy	$
Postage	$
TOTAL	$333.00

14. Insert Plan Number SP262721

3. Plans with Community Management Statement :
CMS Number :
Name :

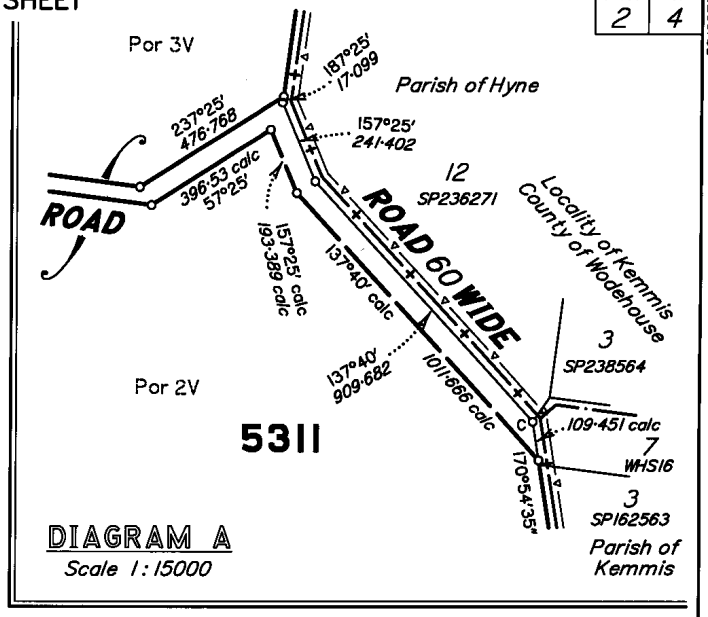
4. References :
Dept File : 2011/002793
Local Govt :
Surveyor : 13147

Land Title Act 1994; Land Act 1994
Form 21A Version 1

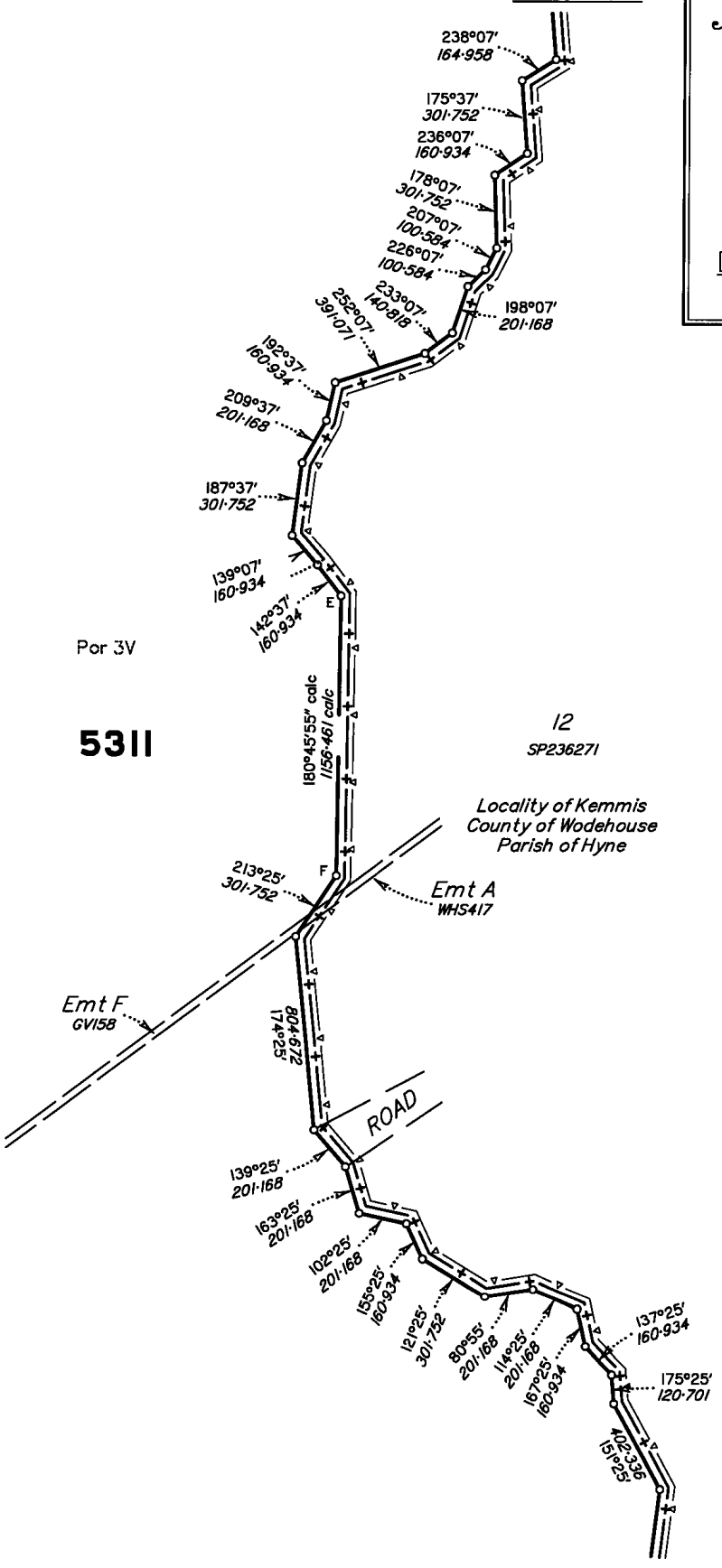
ADDITIONAL SHEET

Sheet 2 of 4

BD13375



SEE SHEET 1



SEE SHEET 3

N

Scale 1:20000

Metres 0 1000m 50 mm 2000m 100 mm 3000m 150 mm

State copyright reserved.

Insert Plan Number SP262721

13147

Land Title Act 1994; Land Act 1994
Form 21A Version 1

ADDITIONAL SHEET

Sheet 3 of 4

BDI3375

Locality of Kemmis
County of Wodehouse

Parish of Hyme — 3 SP238564 — 7 WHS16 — Parish of Kemmis — 3 SP162563

Parish — 12 SP236271

SEE DIAG A SHEET 2

SEE SHEET 2

ROAD 60 WIDE

ROAD 60·35 WIDE

ROAD

5311

Por 3V — Por 2V — Por IV — 13 SP178466 — Wallanbah — Parish

Emt A GV158 — Emt B GV158 — Emt C GV158 — Emt D GV158 — Emt E GV158 — Emt A GV151

SEE SHEET 1

1106·424 171°25'
202°25' 362·102
267°25' 402·336
277°25' 160·934
304°25' 241·402
323°25' 241·402
277°25' 482·803
223°25' 341·986
187°25' 56·327
217°25' 241·402
482·803 159°25'
203°25' 261·518
222°55' 241·402
297°25' 301·752
255°25' 301·752
293°25' 301·752
202°25' 502·92
187°25' 100·584
230°25' 402·336
218°25' 583·387
231°25' 482·803
256°25' 442·57
218°25' 100·584
228°25' 301·752
277°25' 140·818
240°25' 241·402
341°25' 100·584
287°25' 261·518
287°25' 96·561
201·168
252°55' 261·518
255°25' 100·584
357°25' 80·467
333°55' 402·336
271°25' 150·876
294°25' 271·577
304°55' 397·307
201·168
100·584 (Conn Only)
1767·864 70°25'
1709·928 187°25'
277°25' (E–F)
201·168
340°55' 231·343
350°25' 160·934
310°25' 362·102
269°25' 341·986
196°25' 50·292
282°25' 150·678
297°25' 663·854
277°25' 663·854
291°25' 362·102
356°25' 201·168
277°25' 764·438
7°25' 100·584
21°25' 201·168
6°32' calc 308·841 calc
291°25' 140·818
307°25' 1278·624
127°25'
1005·84 294°25'
2552·42
2005·645 70°25'
2063·984 by Addn 187°25'
277°25' 939·455
947·501 97°25'
744·322 234°25'
277°25' 653·796
662·044 97°25'
118°25' 41·488
221°25' 136·794
300°59' 190·707
120°59' 182·258
165°25' 132·167
51°25' 156·509
345°25' 189·701
230°25' 205·594
287°25' 1565·288
107°25' 1609·344
267°25' 1402·744
87°25' 1408·176
277°25' 1592·647
97°25' 1609·344
237°25' 476·168
187°25' 847·923

Scale 1:30000

Metres 0 — 1500m (50 mm) — 3000m (100 mm) — 4500m (150 mm)

State copyright reserved.

Insert Plan Number SP262721

13147

Report on compilation

The compilation of this plan has been from numerous plans as noted on sheet 1 of 4.

The meridian of MGA Zone 55 has been derived from SP147333 which states a meridian of CAM Add 7°25' for MGA Zone 55. This is the CAM to MGA Zone 55 correction at the County Initial Point.
There are numerous preceeding registered plans which state MGA Zone 55 Meridian but there are ambiguities between these plans. Therefore the option was to go back to the Original surveys of GV2, GV10 and GV26 which are on CAM and a correction of Add 7°25' for MGA Zone 55 from the County Initial Point. Also WHS 16 which is on CAM and a correction of Add 7°37' for MGA Zone 55 from the County Initial Point.
Additional information used in the compilation has been from actual surveyed boundaries of more recent plans which state MGA Zone 55 generally by RTK GPS.

There are some major miscloses in GV2 which surveys a majority of the land of Lot 5311 on PH1655 and without further field investigation these errors cannot be eliminated.

There is one Boundary Line with About dimensions. A couple of boundary Lines have been calculated due to a Road Closure and Opening on RA2699. The North Eastern corner of Lot 5311 (Carborough Range) has been surveyed by Compass and therefore it has been impossible to obtain a close within prescribed limits. The Area of Lot 5311 has been shown as About 13500 Ha which is the stated area on PH1655.

The Boundary Line E–F along the Carborough Range has been shown as Abt on previous plans, but more accurate dimensions have been able to be calculated from GV2 & GV26. This boundary is shown as too steep to survey and therefore must have been inaccessible.

The line G–H has been compiled on numerous previous plans as 203°25' for 201·168 but on closer inspection of GV2 the length of this line should be 261·518.

State copyright reserved.

FOR OPENING NOTIFICATIONS SEE BACK

POR. No	ARM No
3	~~G.F. 3877~~ Amd. 73.628

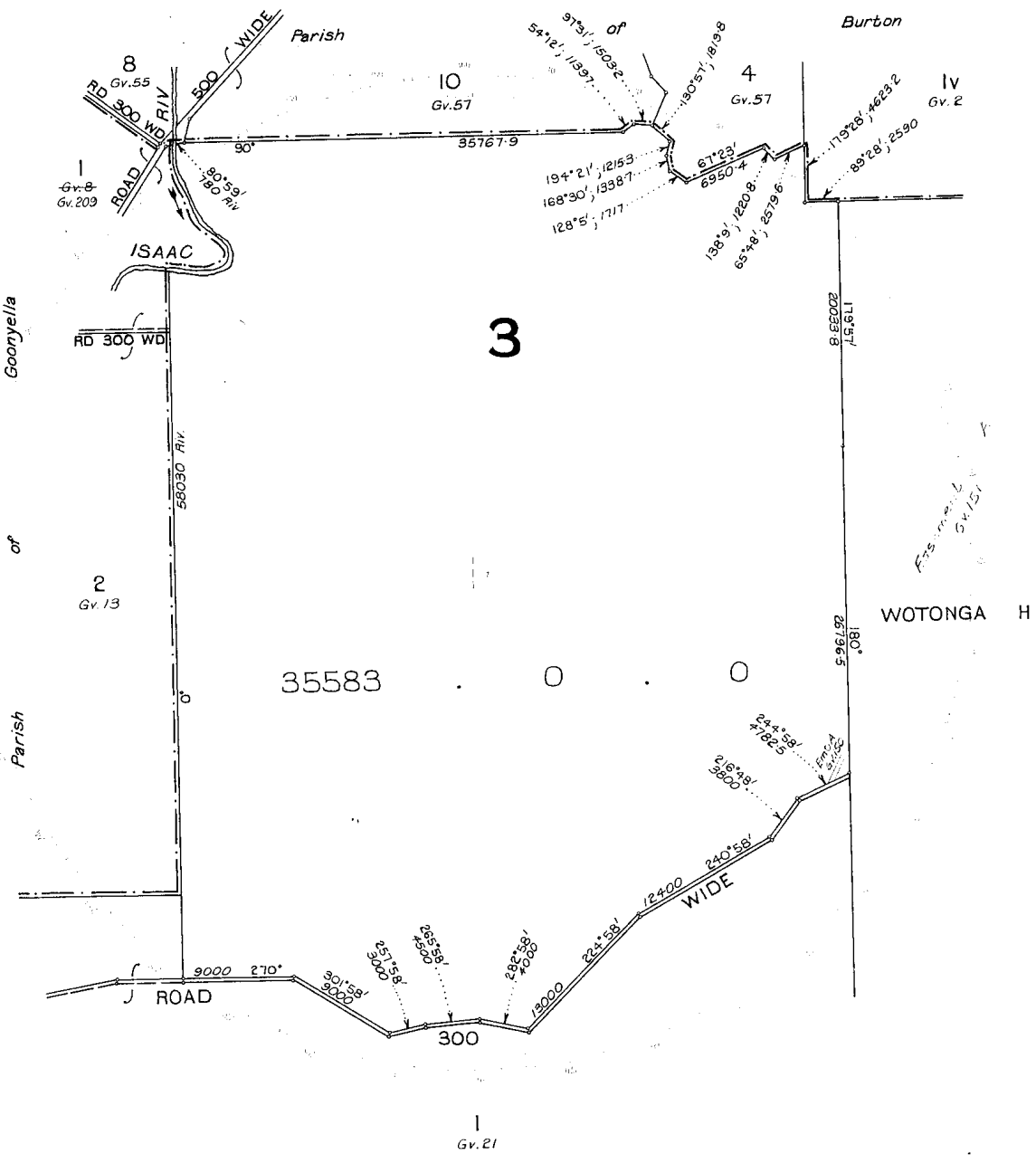
3(14399929 ha) G.H.F.L. 3877 L

TRAVERSES ETC.

LINE	BEARING	DIST.

REFERENCE TO CORNERS

COR.	BEARING	FROM	DIST.	MARKS



Compiled from Gv. 21 & 57

For Additional Plan & Document Dealings Refer to CISP

AUTHORITY	INSTRUCTIONS	DRAWN	EXAMINED	CHECKED	PASSED	CHARTED

ADJUSTMENTS

AUTHORITY	POR.	PREV. AREA	DRAWN	EXAMINED	CHECKED	PASSED	CHARTED
GF. 3877 Mackay	3	36313.0.	C.A.P 28.4.71	M.C 19.8.71	T.P 20.8.71	[signature] 7-3-73	[signature] 7.3.73

MERIDIAN OBSERVATIONS

STN.	VARIATION OBS.	VARIATION C.A.M.
Vide	C.A.M Gv.57	

COMPILED PLAN

SCALE 80 CHAINS TO AN INCH

SURVEYED BY	DATE	~~FIELD NOTES~~
		71/4847SG

Portion 3

PARISH OF WALLANBAH

County of GROSVENOR

L.A. District of MACKAY

Gv .54

CROWN COPYRIGHT RESERVED

2m. 278 & 280

DRAWING OF PLAN MUST BE RESTRICTED TO THE SPACE INSIDE THE BLUE LINES

DRAWING OF PLAN MUST BE RESTRICTED TO THE SPACE INSIDE THE BLUE LINES

Copyright protects the plan/s being ordered by you. Unauthorised reproduction or amendments are not permitted.

CURRENT TITLE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331786
Search Date: 25/09/2016 11:48 **Title Reference: 50368034**
Date Created: 08/10/2001

Previous Title: 40030413

REGISTERED OWNER

Dealing No: 705097474 08/10/2001

ALLAN GORDON HOMER WILLIAMS

ESTATE AND LAND

Estate in Fee Simple

LOT 3 CROWN PLAN GV54
Local Government: ISAAC

EASEMENTS, ENCUMBRANCES AND INTERESTS

1. Rights and interests reserved to the Crown by
   Deed of Grant No. 40030413 (Lot 3 on CP GV54)

2. MORTGAGE No 602799752 (M140545) 18/12/1963
   AUSTRALIA AND NEW ZEALAND BANK LIMITED

3. EASEMENT No 602799753 (A1250) 05/06/1979
   burdening the land to
   QUEENSLAND ELECTRICITY COMMISSION
   OVER EASEMENT A ON CP GV150

4. TRANSFER No 706303072 24/01/2003 at 11:36
   EASEMENT: 602799753 (A1250)
   QUEENSLAND ELECTRICITY TRANSMISSION CORPORATION LIMITED
   A.C.N. 078 849 233

5. SEC 174 NOTATION No 705097193 08/10/2001 at 10:51
   The provisions of Section 174(1), Land Act 1994 apply to a
   Transfer of the whole or part of the land

6. EASEMENT IN GROSS No 711278411 17/12/2007 at 11:18
   burdening the land
   QUEENSLAND ELECTRICITY TRANSMISSION CORPORATION LIMITED
   A.C.N. 078 849 233
   over
   EASEMENT F ON SP184907

ADMINISTRATIVE ADVICES - NIL
UNREGISTERED DEALINGS - NIL

CERTIFICATE OF TITLE ISSUED - No

CURRENT TITLE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331786
Search Date: 25/09/2016 11:48 **Title Reference: 50368034**
Date Created: 08/10/2001

Caution - Charges do not necessarily appear in order of priority

** End of Current Title Search **

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Requested By: D-ENQ CITEC CONFIRM

CURRENT TITLE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331787
Search Date: 25/09/2016 11:48 **Title Reference: 50900010**
Date Created: 07/12/2012

Previous Title: 50875480

REGISTERED OWNER

Dealing No: 714824147 06/12/2012

VALE AUSTRALIA PTY LTD A.C.N. 062 536 270

ESTATE AND LAND

Estate in Fee Simple

LOT 4 SURVEY PLAN 252740
Local Government: ISAAC

EASEMENTS, ENCUMBRANCES AND INTERESTS

1. Rights and interests reserved to the Crown by
   Deed of Grant No. 40063955 (Lot 4 on CP 903281)

2. RESUMPTION EASEMENT No 602803066 (R1163) 26/02/1974
   Burdening
   THE LAND
   TO THE COMMISSIONER FOR RAILWAYS
   OVER EASEMENT A ON GV106

3. RESUMPTION EASEMENT No 602803067 (R1164) 26/02/1974
   Burdening
   THE LAND
   TO THE COMMISSIONER FOR RAILWAYS
   OVER EASEMENT A, B AND C ON GV109

4. EASEMENT No 602803068 (A1709) 08/08/1983
   burdening the land to
   TO THIESS DAMPIER MITSUI COAL PTY LTD
   OVER EASEMENT E, F AND G ON GV191
   AND EASEMENT H ON GV197

5. RESUMPTION EASEMENT No 602803069 (R1165) 01/06/1987
   Burdening
   THE LAND
   THE QUEENSLAND ELECTRICITY COMMISSION
   OVER EASEMENT J ON GV279

6. TRANSFER No 703437140 07/07/1999 at 08:20
   RESUMPTION EASEMENT: 602803069 (R1165)
   QUEENSLAND ELECTRICITY TRANSMISSION CORPORATION LIMITED
   A.C.N. 078 849 233

EASEMENTS, ENCUMBRANCES AND INTERESTS

7. RESUMPTION EASEMENT No 703015328 18/11/1998 at 12:13
   burdening the land
   THE STATE OF QUEENSLAND
   over
   EASEMENT L ON SP106036

8. EASEMENT No 706947253 02/09/2003 at 15:15
   burdening the land to
   LOT 1 ON SP107309
   OVER EASEMENT M ON SP156232

9. EASEMENT No 707148824 31/10/2003 at 15:36
   burdening the land to
   LOT 1 ON SP158697
   OVER EASEMENT M ON SP156232

10. EASEMENT IN GROSS No 707716772 13/05/2004 at 10:53
    burdening the land
    ERGON ENERGY CORPORATION LIMITED
    over
    EASEMENT N ON SP164057

11. EASEMENT IN GROSS No 711958203 01/10/2008 at 15:28
    burdening the land
    EUNGELLA WATER PIPELINE PTY LTD A.C.N. 070 999 236
    over
    EASEMENT P ON SP216411

12. EASEMENT No 712728009 14/09/2009 at 15:13
    burdening the land to
    LOT 18 ON CP GV181
    OVER EASEMENT R ON SP206918

13. EASEMENT IN GROSS No 717489805 05/09/2016 at 09:27
    burdening the land
    QUEENSLAND ELECTRICITY TRANSMISSION CORPORATION LIMITED
    A.C.N. 078 849 233
    over
    EASEMENT V ON SP281894

ADMINISTRATIVE ADVICES

Dealing	Type	Lodgement Date	Status
709445249	VEG NOTICE VEGETATION MANAGEMENT ACT 1999	17/03/2006 09:39	CURRENT
712980663	VEG NOTICE VEGETATION MANAGEMENT ACT 1999	08/01/2010 10:25	CURRENT

UNREGISTERED DEALINGS - NIL

CURRENT TITLE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331787
Search Date: 25/09/2016 11:48 **Title Reference: 50900010**
Date Created: 07/12/2012

CERTIFICATE OF TITLE ISSUED - No

Caution - Charges do not necessarily appear in order of priority

** End of Current Title Search **

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Requested By: D-ENQ CITEC CONFIRM

CURRENT STATE TENURE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331784
Search Date: 25/09/2016 11:48 **Title Reference: 40067982**
Date Created: 26/03/2014

Previous Title: 17668044

DESCRIPTION OF LAND

Tenure Reference: TL 0/237488

Lease Type: ROLLING TERM LEASE

LOT 5311 SURVEY PLAN 262721
Local Government: ISAAC

Area: 13500.000000 Ha. (ABOUT)

No Land Description

No Forestry Entitlement Area

Purpose for which granted:
PASTORAL

TERM OF LEASE

Term and day of beginning of lease

Term: 30 years commencing on 08/11/2013

Expiring on 07/11/2043

REGISTERED LESSEE Interest

Dealing No: 715806671 02/06/2014

GANRA PTY LTD A.C.N. 002 944 489 1/2
GAFFWICK PTY LTD A.C.N. 010 584 522 1/2

AS TENANTS IN COMMON

CONDITIONS

CONDITIONS

A78 (1) The lessee must use the leased land for pastoral purposes only.

(2) This lease may be forfeited if not used for the purpose stated above.

(3) The annual rent must be paid in accordance with the Land Act 1994.

(4) The Parties acknowledge that GST may be payable in respect of a supply made under this lease. Where GST becomes payable in respect of a supply made under this lease, the State (lessor) may recover the GST from the lessee by increasing the consideration payable by the lessee to the State by an amount equal to that which the State is obliged to remit to the Commonwealth as GST on the supply and that amount may be recovered from the lessee as part of the money payable to the State under this lease. The State will upon request by the lessee, issue to the lessee a valid GST tax invoice in respect of any taxable supply made under this lease. (NOTE: For the purposes of this condition "GST" means the goods and services tax which results from the enactment of A New Tax System (Goods and Services Tax) Act 1999 and the related Acts which constitute the Commonwealth taxation reform (as amended from time to time)).

(5) The lessee must pay the cost of any required survey or re-survey of the leased land.

(6) The lessee must control pest plants and animals, on the leased land, in accordance with the Land Protection (Pest and Stock Route Management) Act 2002 and the Local Laws and requirements of the Isaac Regional Council.

(7) The lessee has the responsibility for a duty of care, to take all reasonable and practicable measures to sustainably manage the leased land by conserving the physical, biological, productive and cultural values, either on the leased land or in areas affected by the management of the leased land.

(8) The lessee must ensure that the use and development of the leased land conforms to the Planning Scheme, Local Laws and requirements of the Isaac Regional Council, binding on the lessee.

(9) The lessee must give the Minister administering the Land Act 1994, information about the lease, when requested.

(10) The lessee must not clear any vegetation on the leased land, unless in accordance with the Sustainable Planning Act 2009.

(11) No compensation for improvements or developmental work is payable by the State at the forfeiture, surrender or expiry of the lease, but the lessee has the right to remove the lessees moveable improvements within a period of three (3) months from the forfeiture, surrender or expiry of the lease, provided all money due by the lessee to the State on any account whatsoever has been paid, or be required to remove those improvements as specified in any further condition of lease.

CONDITIONS

(12) This lease is subject to the Land Act 1994 and all other relevant State and Commonwealth Acts.

A89 (1) The lessee must allow any person authorised under the Forestry Act 1959 access to the leased land for the purpose of cutting and removing timber or removing other forest products, or quarry material, or other material from the leased land.

(2) Except as hereinafter provided the lessee must not interfere with any forest products or remove any quarry material (including any stone, gravel, sand, earth, soil, rock, guano or clay which is not a mineral within the meaning of the Mineral Resources Act 1989) or other material upon the leased land without the permission of the Minister administering the Land Act 1994 except under the authority of and in compliance in every respect with the requirements or a permit, licence, agreement or contract granted or made under the Forestry Act 1959.

A90 Further to Condition A78(11), the lessee must remove moveable improvements and rehabilitate the area to the satisfaction of the Minister administering the Land Act 1994 within three (3) months from the date of forfeiture, surrender or expiry of the lease.

A91 If the lessee fails to remove the improvements and rehabilitate the area as detailed in Condition A90 above, the Minister administering the Land Act 1994 , can remove the improvements and rehabilitate the area and is hereby authorised to do whatever is necessary to effect the said removal and rehabilitation. The said Minister may recover from the lessee the total cost incurred in the said removal and rehabilitation.

C342 The lessee must comply with any lawful requirements of the Minister administering the Land Act 1994 and the Isaac Regional Council.

C391 Upon forfeiture, surrender or expiry of the lease, the lessee must remove from the leased land all cattle owned by the lessee. Any cattle not removed from the leased land within three (3) months from the date of forfeiture, surrender or expiry of the lease, will become the property of the State and maybe disposed of or otherwise dealt with as the Minister administering the Land Act 1994 may determine. The lessee has no right to compensation or any claim against the State in respect of the loss of ownership of any cattle.

CONDITIONS

F46 The lessee must from commencement of the lease and to the satisfaction of the Minister administering the Land Act 1994, fence the leased land, with a good and substantial stock proof fence and must thereafter maintain the fence in a good and substantial state of repair.

H127 The lessee must, at all times during the currency of the lease, allow officers of the Departments administering the Forestry Act 1959 and administering the Land Act 1994, their employees and their servants, free and unrestricted access to, from and across the leased land.

I66 The lessee indemnifies and agrees to keep indemnified the Minister administering the Land Act 1994, and the State of Queensland, Crown Instrumentalities, local governments and other Statutory bodies (the "Indemnified parties") against all actions, suits, proceedings, claims, demands, costs, losses, damages and expenses ("Claim") arising out of or in any way connected to or resulting from the granting of this lease to the lessee or which is connected to or resulting from the lessees' use and occupation of the leased land (all of which are referred to as "the indemnified acts or omissions") save to the extent that the Claim arises as a result of any negligent act or omission of the Indemnified parties, however, any negligent act or omission of one of the Indemnified parties does not negate the indemnity to any of the other Indemnified party/ies. The lessee hereby releases and discharges the Indemnified parties from any Claim relating to the indemnified acts or omissions which may be made against the Indemnified parties.

L110 The lessee must from commencement of the lease, to the satisfaction of the Minister administering the Land Act 1994, maintain improvements on the leased land in a good and substantial state of repair.

ENCUMBRANCES AND INTERESTS

1. Rights and interests reserved to the Crown by
   Lease No. 40067982

CURRENT STATE TENURE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331784
Search Date: 25/09/2016 11:48 **Title Reference: 40067982**
Date Created: 26/03/2014

ENCUMBRANCES AND INTERESTS

2. RESUMPTION EASEMENT No 602806112 (R1035) 07/04/1986
   EASEMENT PURSUANT TO PROCLAMATION DATED 16TH JANUARY, 1986 UNDER SECTION 306 OF THE LAND ACT 1962-1985 OVER AN AREA OF 2299 SQUARE METRES AS SHOWN AS EASEMENT G ON PLAN GV233 AND OVER AREAS OF 4.356 HECTARES, 1.427 HECTARES, 10.905 HECTARES, 799 SQUARE METRES, 6.811 HECTARES AND 8.365 HECTARES AS SHOWN AS EASEMENTS A,B,C,D,E AND F RESPECTIVELY ON PLAN GV158 DEPOSITED IN THE DEPARTMENT OF MAPPING AND SURVEYING FOR THE PURPOSE OF ELECTRICAL WORKS (TRANSMISSION LINE) IS HEREBY RESUMED AND SHALL VEST IN THE QUEENSLAND ELECTRICITY COMMISSION
   AS FROM 18TH JANUARY, 1986.

3. TRANSFER No 703437134 07/07/1999 at 08:08
   RESUMPTION EASEMENT: 602806112 (R1035)
   QUEENSLAND ELECTRICITY TRANSMISSION CORPORATION LIMITED A.C.N. 078 849 233

4. LAND MANAGEMENT AGREEMENT No 715676314 26/03/2014 at 10:48
   In accordance with the Land Act 1994

ADMINISTRATIVE ADVICES

Dealing	Type	Lodgement Date	Status
715002794	STRTGIC LAND STRATEGIC CROPPING LAND ACT 2011	26/03/2013 14:52	CURRENT
715165569	VEG NOTICE VEGETATION MANAGEMENT ACT 1999	26/06/2013 11:19	CURRENT

UNREGISTERED DEALINGS - NIL

Caution - Charges do not necessarily appear in order of priority

** End of Current State Tenure Search **

Information provided under section 34 Land Title Act(1994) or section 281 Land Act(1994)

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Requested By: D-ENQ CITEC CONFIRM

CURRENT TITLE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331785
Search Date: 25/09/2016 11:48 **Title Reference: 50199169**
Date Created: 11/12/1997

Previous Title: 30652239

REGISTERED OWNER	Interest
Dealing No: 714234008 22/12/2011	
BHP COAL PTY LTD A.B.N. 83 010 595 721	163/400
UMAL CONSOLIDATED PTY LTD A.B.N. 29 000 767 386	3/400
BHP QUEENSLAND COAL INVESTMENTS PTY LTD A.B.N. 56 098 876 825	17/200
MITSUBISHI DEVELOPMENT PTY LTD A.B.N. 17 009 779 873	1553/10000
QCT INVESTMENT PTY LTD A.B.N. 45 010 487 831	3/25
QCT MINING PTY LTD A.B.N. 47 010 487 840	789/5000
QCT RESOURCES PTY LTD A.B.N. 74 010 808 705	669/10000

AS TENANTS IN COMMON

ESTATE AND LAND

Estate in Fee Simple

LOT 9 REGISTERED PLAN 903903
Local Government: ISAAC

EASEMENTS, ENCUMBRANCES AND INTERESTS

1. Rights and interests reserved to the Crown by
   Deed of Grant No. 30647029 (Lot 9 on CP 852460)

2. SEC 147A NOTATION No 601083730 (147A) 31/12/1984
   THE PROVISIONS OF SECTION 147A OF THE LAND ACT 1962-1990
   REFER TO SECTION 174 OF THE LAND ACT 1994
   APPLY TO A TRANSFER OF THE WHOLE OR PART OF THE LAND

3. EASEMENT No 702389180 11/12/1997 at 09:21
   burdening the land to
   LOT 1 ON RP903901 OVER EASEMENT A ON RP903901

4. EASEMENT No 711774584 07/07/2008 at 10:12
   burdening the land to
   LOT 11 ON SP852466 OVER EASEMENTS B, C AND E ON SP178467

ADMINISTRATIVE ADVICES - NIL
UNREGISTERED DEALINGS - NIL

CERTIFICATE OF TITLE ISSUED - No

CURRENT TITLE SEARCH

DEPT OF NATURAL RESOURCES AND MINES, QUEENSLAND

Request No: 24331785
Search Date: 25/09/2016 11:48 **Title Reference: 50199169**
Date Created: 11/12/1997

Caution - Charges do not necessarily appear in order of priority

** End of Current Title Search **

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Requested By: D-ENQ CITEC CONFIRM

Appendix B – Peabody supplied figures and plans

Document Name	Title	Date of Document
Audit findings (3)_2011 audit	2011 Audit Findings	2011
120815 Workshop Audit signed	2015 Audit Report	Aug-15
PLN_BUR_Plan of Operations 2014 Amendment_V2_ENV_SP_20140501	Amended Plan of Operations 2014	Jan - Dec 2014
Burton Mine Audit Report_150711	Audit Report - Burton Mine	2011
20120831 Burton Mine Plan of Operations Blomfield Env Rev 3	Burton Coal Mine Plan of Operations	1 Sep 2012 - 31 Dec 2012
Risk Register	Burton Coal Mine Risk Register	Apr-06
Burton compliance report and audit report 1997	Burton Coal Project Compliance Report and A	Feb-97
AM-BT-ENV-FO-0400 Environmental risk register 2014	Burton Environmental Risk Register	2014
AM-BT-ENV-FO-0400 Environemntal risk register 2015	Burton Environmental Risk Register	2015
AM-BT-ENV-RE-001-01 Environmental Risk Register	Burton Environmental Risk Register	Oct-08
AM-BT-ENV-RE-001-02 Environmental Risk Register	Burton Environmental Risk Register	Jul-09
AM-BT-ENV-RE-001-03 Environmental Risk Register	Burton Environmental Risk Register	Sep-09
AM-BT-ENV-RE-001-04 Environmental Risk Register revised 110323	Burton Environmental Risk Register	Aug-11
AM-BT-ENV-RE-001-04 Environmental Risk Register	Burton Environmental Risk Register	Feb-10
AM-BT-ENV-RE-001-05 Environmental Risk Register April 2011	Burton Environmental Risk Register	Apr-11
AM-BT-ENV-RE-001-05 Environmental Risk Register	Burton Environmental Risk Register	Mar-11
BU Operational Plan August 2011_110727-BCK-POO-1866--RO	Burton Pit Operational Plan - Burton Widening	Aug-11
BU-ENV-MNP-Waste Management Plan-E101	Burton Waste Management Plan	Unknown
AM-ENV-LIB-1000 Emergency response - Hydrocarbon and chemical spills	Emergency Response - Hydrocarbon and Cher	May-14
LIC_BUR_Environmental Authority_v2_DEHP_SP_20150722	Environmental Authority Permit	Jul-15
Enviro Hazards Project to Date	Environmental Hazards to Date	Unknown
AM-BT-ENV-PR-014-01 Environmental Incident Reporting	Environmental Incident Reporting Work Proce	Unknown
080916_Environmental Risk Assessments	Environmental Risk Assessments	Unknown
2013 Risk Register Environment	Environmental Risk Register	2013
111005 Pipelines in clean water catchments risk assessment	Environmental Risk Register - Pipelines crossi	Unknown
Sediment and erosion risk assessment BW	Erosion and Sediment Control Plan Burton Wi	2011
DAT_BUR_Groundwater Monitoring Locations_v1_ENV_SP_160223	Groundwater Monitoring Locations	unknown
Hazardous Substances	Hazardous Substances	May-13
AM-BT-ENV-PR-009-00 Haz Substances Spill Prevention Control	Hazardous Substances Spill Prevention and Co	Unknown
Burton Coal Mine_Licence to Store 1400140	Licence to Store Explosives 2015 - 2016	25 Mar 2015 - 24 Mar 2016
Burton Coal Mine_Licence to Sotre 1400140_EXP Date 24th March 2017	Licence to Store Explosives 2016 - 2017	25 Mar 2016 - 24 Mar 2017
Master Bore Data	Master Bore Data	Unknown
090831_Revised Ellensfield Operational Plan_Rev_3_T	Operations Plan for Codisposal into Ellensfield	Aug-09
Burtonb PoO 99	Plan of Operations 1999	Dec-99
PoO 03_2003	Plan of Operations 2003	Apr-03
Burton PoO 05	Plan of Operations 2005	Feb-05
BurtonProject_PlanOps_Sep06	Plan of Operations 2006	1 Sep 06 - 31 Aug 2007
FINAL_Burton_Project_PlanOps_2007-2008	Plan of Operations 2007-2008	1 September 2007 - 31st August 2008
FINAL_Burton_Plan of Operations_2008-2009 Rev 2 EA Ammend_110209	Plan of Operations 2008-2009	1 Sep 2008 - 31 Aug 2009
2009 Plan Ops	Plan of Operations 2009	1 Sep 2009 -31 Aug 2010
Burton_Plan of Operations_2010_020610	Plan of Operations 2010	1 Sep 2009 - 31 Aug 2010
Burton_Plan of Operations_2011_010911	Plan of Operations 2011	1st September 2011
20121213 Plan of Operations_costings removed	Plan of Operations 2013 (Costings removed)	1 Jan 2013 - 31 Dec 2013
PLN_BUR_Plan of Operations 2016_V1.3_ENV_SP_160114	Plan of Operations 2014	Jan - Dec 2016
PLN_BUR_Plan of Operations 2015_V1_ENV_SP_20141119	Plan of Operations 2015	Jan - Dec 2015
NWC-Burton-Rehabilitation 2015 - Risk Assessment - REVC	Risk Assessment Worksheet	8th May 2015
AM-BT-ENV-PR-1804 Sewage Treatment Plant	Sewage Treatment Plant Work Procedure	Apr-14
BW_WOOP_Rehab_Project Risk Assessment_Signed	Signed Risk Assessment	March 2016 - April 2016
Spill Incidents Project to Date	Spill Incidents to Date	Unknown
AM-BT-ENV-MP-1800 Waste management plan	Waste Management Plan	May-14
amg55_burton_mine_rgb_1302_025_2013	Burton Mine Aerial Image 2013	2013
amg55_bw_rgb_1209_025_2012	Burton Mine Aerial Image 2012	2012
Burton_Area1_100_2009	Burton Mine Aerial Image 2009	2009
Burton_Area2_100_2009	Burton Mine Aerial Image 2009	2009
Burton_Area3_100_2009	Burton Mine Aerial Image 2009	2009
Burton_Area4_100_2009	Burton Mine Aerial Image 2009	2009

Appendix C – Environmental Authority and Licences

Permit[1]

Environmental Protection Act 1994

Environmental authority EPML00879213 – Burton Coal Mine

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Permit[1] number: EPML00879213

Environmental authority takes effect: **10 July 2015**

The anniversary day of the environmental authority is **3 January**

Environmental authority holder(s)

Name	Registered address
Peabody (Burton Coal) Pty Ltd	Bank of Qld Building Level 13 259 Queen Street BRISBANE CITY QLD 4000

Environmentally relevant activity and location details

Environmentally relevant activities (ERAs)	Location(s)
Environmental Protection Regulation 2008 – Schedule 2 ERA 31(2)(b) Mineral processing - processing, in a year, the following quantities of mineral products, other than coke - more than 100,000t. ERA 56 Regulated waste storage – receiving and storing regulated waste. ERA 60(2)(a) Waste disposal - operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(b) – 50t to 2,000t. ERA 63(1)(b)(i) Sewage treatment - operating sewage treatment works, other than no-release works, with a total daily peak design capacity of more than 100 but not more than 1500 EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme. **Environmental Protection Regulation 2008 – Schedule 2A** ERA 9 Drilling, costeaning, pitting or carrying out geological surveys causing significant disturbance. ERA 13 Mining black coal.	MDL308 MDL315 MDL349 EPC857 ML70109 ML70252 ML70256 ML70257 ML70258 ML70259 ML70260

[1] Permit includes licences, approvals, permits, authorisations, certificates, sanctions or equivalent/similar as required by legislation

Additional information for applicants

Environmentally relevant activities

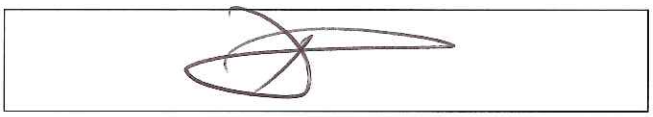
The description of any environmentally relevant activity (ERA) for which an environmental authority is issued is a restatement of the ERA as defined by legislation at the time the approval is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an environmental authority as to the scale, intensity or manner of carrying out an ERA, then the conditions prevail to the extent of the inconsistency.

An environmental authority authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the authority specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that if an owner or occupier of land becomes aware a notifiable activity (as defined in Schedule 3 and Schedule 4) is being carried out on the land, or that the land has been, or is being, contaminated by a hazardous contaminant, the owner or occupier must, within 22 business days after becoming so aware, give written notice to the chief executive.



Signature

10 July 2015

Date

Tristan Roberts
Department of Environment and Heritage Protection
Delegate of the administering authority
Environmental Protection Act 1994

Enquiries:
Business Centre (Coal)
Department of Environment and Heritage Protection
Po Box 3028
EMERALD QLD 4720
Phone: (07) 4987 9320
Email: CRMining@ehp.qld.gov.au

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- General environmental duty (section 319);
- Duty to notify environmental harm (section 320-320G);
- Offence of causing serious or material environmental harm (sections 437-439);
- Offence of causing environmental nuisance (section 440);
- Offence of depositing prescribed water contaminants in waters and related matters (section 440ZG); and
- Offence to place contaminant where environmental harm or nuisance may be caused (section 443).

Conditions of environmental authority

The environmentally relevant activities conducted at the location as described above must be conducted in accordance with the following site specific conditions of approval:

Agency interest: General	
Condition number	**Condition**
A1	**Financial assurance** Provide a financial assurance in the amount and form required by the administering authority prior to the commencement of activities proposed under this environmental authority. ***NOTE**: The calculation of financial assurance for condition A1 must be in accordance with the administering authority's Guideline – Financial Assurance under the* Environmental Protection Act 1994 *(EM1010), and may include a performance discount. The amount is defined as the maximum total rehabilitation cost for complete rehabilitation of all disturbed areas, which may vary on an annual basis due to progressive rehabilitation. The amount required for the financial assurance must be the highest total rehabilitation cost calculated for any year of the Plan of Operations and calculated using the formula: (Financial Assurance = Highest total annual rehabilitation cost x Percentage required).*
A2	The financial assurance is to remain in force until the administering authority is satisfied that no claim on the assurance is likely. ***NOTE:** Where progressive rehabilitation is completed and acceptable to the administering authority, progressive reductions to the amount of financial assurance will be applicable where rehabilitation has been completed in accordance with the acceptance criteria defined within this environmental authority.*
A3	**Maintenance of measures, plant and equipment** The environmental authority holder must ensure: (a) that all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority are installed; (b) that such measures, plant and equipment are maintained in a proper condition; and (c) that such measures, plant and equipment are operated in a proper manner.

A4	**Storage and handling of flammable and combustible liquids** Spillage of all flammable and combustible liquids must be contained within an on-site containment system and controlled in a manner that prevents environmental harm (other than trivial harm) and maintained in accordance with Section 5.8 of *AS 1940 - Storage and Handling of Flammable and Combustible Liquids of 2004*.
A5	**Monitoring and records** Record, compile and keep for a minimum of **five (5) years** all monitoring results required by this environmental authority and make available for inspection all or any of these records upon request by the administering authority.
A6	Where monitoring is a requirement of this environmental authority, ensure that a competent person(s) conducts all monitoring.
A7	**Notification of emergencies, incidents and exceptions** All reasonable actions are to be taken to minimise environmental harm, or potential environmental harm, resulting from any emergency, incident or circumstances not in accordance with the conditions of this environmental authority.
A8	As soon as practicable after becoming aware of any emergency, incident or information about circumstances which results or may result in environmental harm not in accordance with the conditions of this environmental authority, the administering authority must be notified by telephone and in writing.
A9	The notification of emergencies or incidents as required by **Condition A8** of this environmental authority must include but not be limited to the following: (a) the holder of the environmental authority; (b) the location of the emergency or incident; (c) the number of the environmental authority; (d) the name and telephone number of the designated contact person; (e) the time of the release; (f) the time the holder of the environmental authority became aware of the release; (g) the suspected cause of the release; (h) the environmental harm caused, threatened, or suspected to be caused by the release; and (i) actions taken to prevent any further release and mitigate any environmental harm caused by the release.
A10	Not more than ten business days following the initial notification of an emergency, incident or information about circumstances, which result or may result in environmental harm, written advice must be provided to the administering authority in relation to: (a) proposed actions to prevent a recurrence of the emergency or incident; (b) the outcomes of actions taken at the time to prevent or minimise environmental harm; and (c) proposed actions to respond to the information about circumstances which result or may result in environmental harm.

A11	As soon as practicable, but not more than **six (6) weeks** following the conduct of any environmental monitoring performed in relation to the emergency or incident, which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with the conditions of this environmental authority, written advice must be provided of the results of any such monitoring performed to the administering authority.
A12	**Exploration activities** Exploration activities must be undertaken in accordance with the conditions contained in the *Code of Environmental Compliance for Exploration and Mineral Development Projects* (EM586).
A13	**Definitions** Words and phrases used throughout this environmental authority are defined in the **Definitions** sections at the end of this document. Where a definition for a term used in this environmental authority is sought and the term is not defined within this environmental authority, the definitions in the *Environmental Protection Act 1994*, its Regulations and Environmental Protection Policies must be used.

Agency interest: Air	
Condition number	**Condition**
B1	**Dust nuisance** Subject to **Conditions B2** and **B3** of this environmental authority, the release of dust or particulate matter or both resulting from the mining activity must not cause an environmental nuisance at any sensitive or commercial place.
B2	When requested by the administering authority, dust and particulate monitoring must be undertaken within a reasonable and practicable timeframe nominated by the administering authority to investigate any complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer) of environmental nuisance at any sensitive or commercial place, and the results must be notified within fourteen days to the administering authority following completion of monitoring.

B3	If the environmental authority holder can provide evidence through monitoring that the following limits are not being exceeded then the holder is not in breach of **Condition B1**: (a) dust deposition of 120 milligrams per square metre per day, averaged over one month, when monitored in accordance with AS 3580.10.1 *Methods for sampling and analysis of ambient air - Determination of particulates - Deposited matter - Gravimetric method* of 1991 (or more recent editions); or (b) a concentration of particulate matter with an aerodynamic diameter of less than 10 micrometre (µm) (PM10) suspended in the atmosphere of 50 micrograms per cubic metre over a 24 hour averaging time, at a sensitive or commercial place downwind of the operational land, when monitored in accordance with: (i) particulate matter - Determination of suspended particulate PM10 high-volume sampler with size-selective inlet - Gravimetric method, when monitored in accordance with AS 3580.9.6 *Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM (sub) 10 high volume sampler with size-selective inlet - Gravimetric method* of 1990 (or more recent editions); and (ii) any alternative method of sampling PM10, which may be permitted by the *Air Quality Sampling Manual* as published from time to time by the administering authority.
B4	If monitoring indicates exceedance of the relevant limits in **Condition B3** of this environmental authority, then the environmental authority holder must: (a) Address the complaint including the use of appropriate dispute resolution if required; and (b) Immediately implement dust abatement measures so that emissions of dust from the activity do not result in further environmental nuisance.

Agency interest: Water	
Condition number	**Condition**
C1	**Contaminant Release** Contaminants that will or have the potential to cause environmental harm must not be released directly or indirectly to any waters as a result of the authorised mining activities, except as permitted under the conditions of this environmental authority.
C2	Unless otherwise permitted under the conditions of this environmental authority, the release of mine affected water to waters must only occur from the release points specified in **Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)** and depicted in **Figures 1, 2 and 3** attached to this environmental authority.

Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)

Release Point (RP)	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)	Mine Affected Water Source and Location[1]	Monitoring Point	Receiving waters description
RP 3	21.77967	148.145287	Wallanbah Eastern Dirty Water Dam	Spillway or End of Pipe	Spade Creek via Bullock Creek (480 metres)
RP 6	21.595611	148.15697	B2W (formerly Western Lease Dam)	Spillway or End of Pipe	Anna Creek (Burton Gorge Dam)
RP 7	21.58841	148.158429	Tank B2N Mine Affected Water – Pit distribution Network[2] (Burton Widening / Burton North Void)	End of Pipe	Lower Anna Ck
RP 9	21.57388	148.16943	Mine Affected Water – Pit distribution Network[2] (Burton Widening Sump)	End of Pipe	Anna Creek
RP 10	21.537101	148.15161	Burton North Void	End of Pipe	Isaac River
RP 11	21.573591	148.169379	Burton North Void Mine Affected Water – Pit distribution Network[2]	End of Pipe	Anna Creek
RP 12	21.679175	148.184726	Mine Affected Water – Pit distribution Network[2]	End of Pipe	Sandy Creek
RP 13	21.644339	148.202723	Mine Affected Water – Pit distribution Network[2]	End of Pipe	Teviot Creek
RP 14	21.789179	148.14575	Mine Affected Water – Pit distribution Network[2]	End of Pipe	Spade Creek
RP 15	21.622801	148.128228	Mine Affected Water – Pit distribution Network[2]	End of Pipe	Isaac River

NOTE:

1. *Contaminant Source and Location describes the final holding dam before the potential release of water. The water may be mine affected water pumped from other locations: e.g. mixed rainfall accumulations, fish bowls and sumps.*
2. *The source of the water may be from a specific pit or combination of mixed pit waters. Prior to release the water will be assessed for release suitability (**Table C2** and **C4**).*

C3	The release of mine affected water to internal water management infrastructure that is installed and operated in accordance with a water management plan that complies with **Conditions C31** to **C36** inclusive is permitted.
C4	The release of mine affected water to waters in accordance with **Condition C2** must not exceed the release limits stated in **Table C2 (Contaminant Release Limits)** when measured at the monitoring points specified in **Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)** for each quality characteristic.

Table C2 (Contaminant Release Limits)

Quality Characteristic	Release Limits	Monitoring frequency	Comments
Electrical conductivity (uS/cm)	Release limits specified in Table 4 for variable flow criteria	Daily during release (the first sample must be taken within 2 hours of commencement of release)	
pH (pH Unit)	6.5 (minimum) 9.0 (maximum)	Daily during release (the first sample must be taken within 2 hours of commencement of release)	
Turbidity (NTU)	No Limit	Daily during release (the first sample must be taken within 2 hours of commencement of release)	Turbidity is required to assess ecosystems impacts and can provide instantaneous results.
Suspended Solids (mg/L)	1000	At commencement and prior to cessation of release (at a minimum) and weekly during a release [1]	Suspended solids are required to measure the performance of sediment and erosion control measures.
Sulphate (SO_4^{2-}) (mg/L)	Release limits specified in Table 4 for variable flow criteria	At commencement and prior to cessation of release (at a minimum) and weekly during a release [1]	

NOTE: *[1]The determination of suitability for release of water should be informed by monitoring undertaken prior to release.*

C5	The release of mine affected water to waters from the release points must be monitored at the locations specified in **Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)** or each quality characteristic and at the frequency specified in **Table C2 (Contaminant Release Limits)** and **Table C3 (Release Contaminant Trigger Investigation Levels – Potential Contaminants)**. ***NOTE:*** *The administering authority will take into consideration any extenuating circumstances prior to determining an appropriate enforcement response in the event* ***Condition C5*** *is contravened due to a temporary lack of safe or practical access. The administering authority expects the environmental authority holder to take all reasonable and practicable measures to maintain safe and practical access to designated monitoring locations.*

Table C3 (Release Contaminant Trigger Investigation Levels – Potential Contaminants)

Quality Characteristic	Trigger Levels (µg/L)	Comment on Trigger Level	Monitoring Frequency
Chromium	1	*Based on background data*	Commencement of release and thereafter weekly during release.
Copper	2	*Based on background data*	
Zinc	8	*For aquatic ecosystem protection, based on SMD guideline*	
Selenium	10	*For aquatic ecosystem protection, based on LOR for ICPMS*	
Uranium	1	*For aquatic ecosystem protection, based on LOR for ICPMS*	
Nitrate	1,100	*For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (2006) for TN*	
Petroleum hydrocarbons (C6-C9)	20		
Petroleum hydrocarbons (C10-C36)	100		
Sodium (mg/L)	180	*Australian Drinking Water Guidelines. Trigger may require amendment if future advice from Queensland Health becomes available.*	
Barium	2000	*Trigger from Australian Drinking Water Guidelines.*	

NOTE:

1. All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/metalloids apply if dissolved results exceed trigger.

*2. The quality characteristics required to be monitored as per **Table C3** can be reviewed once the results of two years monitoring data is available, or if sufficient data is available to adequately demonstrate negligible environmental risk, and it may be determined that a reduced monitoring frequency is appropriate or that certain quality characteristics can be removed from **Table C3** by amendment.*

3. SMD – slightly moderately disturbed level of protection, guideline refers ANZECC & ARMCANZ (2000).

4. LOR – typical reporting for method stated. ICPMS/CV FIMS – analytical method required to achieve LOR.

C6	If quality characteristics of the release exceed any of the trigger levels specified in **Table C3 (Release Contaminant Trigger Investigation Levels – Potential Contaminants)** during a release event, the environmental authority holder must compare the downstream results in the receiving waters to the trigger values specified in **Table C3 (Release Contaminant Trigger Investigation Levels – Potential Contaminants)** and: (a) where the trigger values are not exceeded then no action is to be taken; or (b) where the downstream results exceed the trigger values specified **Table C3 (Release Contaminant Trigger Investigation Levels – Potential Contaminants)** for any quality characteristic, compare the results of the downstream site to the data from background monitoring sites and; (i) if the result is less than the background monitoring site data, then no action is to be taken; or (ii) if the result is greater than the background monitoring site data, complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining: (1) details of the investigations carried out; and (2) actions taken to prevent environmental harm. ***NOTE:*** *Where an exceedance of a trigger level has occurred and is being investigated, in accordance with* ***Condition C6 2(b)*** *of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.*
C7	If an exceedance in accordance with **Condition C6-(b)(ii)** is identified, the holder of the authority must notify the administering authority within **fourteen (14) days** of receiving the result.
C8	**Mine affected water release events** The holder must ensure a stream flow gauging station/s is installed, operated and maintained to determine and record stream flows at the locations and flow recording frequency specified in **Table C4 (Mine Affected Water Release During Flow Events)**.
C9	Notwithstanding any other condition of this environmental authority, the release of mine affected water to waters in accordance with **Condition C2** of this environmental authority must only take place during periods of natural flow events in accordance with the receiving water flow criteria for discharge specified in **Table C4 (Mine Affected Water Release during Flow Events)** for the release point(s) specified in **Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)**.
C10	The release of mine affected water to waters in accordance with **Condition C2** of this environmental authority must not exceed the Electrical Conductivity release limits, Sulphate release limits or the Maximum Release Rate (for all combined release point flows) for each receiving water flow criteria for discharge specified in **Table C4 (Mine Affected Water Release During Flow Events)** when measured at the monitoring points specified in **Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)**.

Table C4 (Mine Affected Water Release During Flow Events)

Receiving waters/ stream	Release Point (RP)	Gauging station	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)	Receiving Water Flow Recording Frequency	Receiving Water Flow Criteria for discharge (m^3/sec) #	Maximum release rate (m^3/sec) (for all combined RP flows)[3]	Electrical Conductivity ^ (µS/cm)	Sulphate (SO_4^{2-}) (mg/L)
Anna Creek	RP6 RP7	GST 4	21.578053	148.161795	Continuous (minimum daily)	**No/Low Flow** <1.0 m^3/sec for a period of 28 days after natural flow events that exceed 1.0 m^3/sec	0.5*	<500	250
						Medium Flow >1.0 m^3/sec	0.12*	<1500	500
	RP9 RP11	GST 4	21.578053	148.161795	Continuous (minimum daily)	**No/Low Flow** <1.0 m^3/sec for a period of 28 days after natural flow events that exceed 1.0 m^3/sec	0.5*	<500	250
						Medium Flow >1.0 m^3/sec	0.34* 0.23* 0.17* 0.14* 0.11* 0.082*	<1500 <2000 <2500 <3000 <3500 <4500	300 500 1000 1000 1000 1000
						High Flow	0.45*	<3500	1000

Receiving waters/ stream	Release Point (RP)	Gauging station	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)	Receiving Water Flow Recording Frequency	Receiving Water Flow Criteria for discharge (m^3/sec) #	Maximum release rate (m^3/sec) (for all combined RP flows)[3]	Electrical Conductivity ^ (µS/cm)	Sulphate (SO_4^{2-}) (mg/L)
						>4.0 m^3/sec	0.34*	<4500	1000
							0.27*	<5500	1000
							0.23*	<6500	1000
							0.19*	<7500	1000
							0.17*	<8500	1000
						Very High Flow >20 m^3/sec	0.85*	<8500	1000
Isaac River	RP10	GST 5	21.537001	148.151725	Continuous (minimum daily)	**High Flow** >5.32 m^3/sec	0.60	<3500	1000
							0.45	<4500	1000
							0.36	<5500	1000
							0.30	<6500	1000
							0.26	<7500	1000
							0.23	<8500	1000
						Very High Flow >26 m^3/sec	1.11	<8500	1000
Sandy Creek	RP12	GST 1	21.670569	148.175378	Continuous (minimum daily)	**High Flow** >1.5 m^3/sec	0.17	<3500	1000
							0.13	<4500	1000
							0.10	<5500	1000
							0.09	<6500	1000
							0.07	<7500	1000
							0.06	<8500	1000

Receiving waters/ stream	Release Point (RP)	Gauging station	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)	Receiving Water Flow Recording Frequency	Receiving Water Flow Criteria for discharge (m^3/sec) #	Maximum release rate (m^3/sec) (for all combined RP flows)[3]	Electrical Conductivity ^ (µS/cm)	Sulphate (SO_4^{2-}) (mg/L)
						Very High Flow >8 m^3/sec	0.34	<8500	1000
Teviot Creek	RP13	GST 6	21.670569	148.175378	Continuous (minimum daily)	**High Flow** >0.62 m^3/sec	0.07	<3500	1000
							0.05	<4500	1000
							0.04	<5500	1000
							0.04	<6500	1000
							0.03	<7500	1000
							0.03	<8500	1000
						Very High Flow >3.1 m^3/sec	0.21	<5500	1000
Spade Creek	RP3 RP14	GST 7	21.650606	148.19804	Continuous (minimum daily)	**Medium Flow** >0.50 m^3/sec	1.18	<1000	300
							0.40	<1500	500
							0.24	<2000	1000
							0.17	<2500	1000
							0.13	<3000	1000
							0.11	<3500	1000
						High Flow >1.70 m^3/sec	0.27	<4500	1000
							0.21	<5500	1000
							0.17	<6500	1000
							0.15	<7500	1000
							0.13	<8500	1000

Receiving waters/ stream	Release Point (RP)	Gauging station	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)	Receiving Water Flow Recording Frequency	Receiving Water Flow Criteria for discharge (m^3/sec) #	Maximum release rate (m^3/sec) (for all combined RP flows)[3]	Electrical Conductivity ^ (µS/cm)	Sulphate (SO_4^{2-}) (mg/L)
						Very High Flow >8.5 m^3/sec	1.06 0.65	<5500 <8500	<5500 <8500
Burton Gorge Dam	RP15	BGD GST	21.622801	148.128228	Continuous (minimum daily)	**High Flow** >1.0m^3/sec	0.12	<6000	1000

 # Flow triggers should be compared to natural flow only (except for Teviot Creek gauging station , where upstream Teviot Dam influences local flow conditions). As stream flow measurements are downstream of the discharges for many of Burton Coal Mines release points, the discharge rates should be subtracted from the stream flow measurements before comparing to the stream flow trigger.

^ Prior to release commencement, an assessment of the water quality of the relevant mine affected water source must be undertaken and the Electrical Conductivity release limit and maximum release rate determined. This determined release limit and maximum release rate applies for the duration of the release.

** Discharges from RP6/RP7 cannot occur concurrently with discharges from RP9/RP10.*

*Note: The minimum flow triggers listed in **Table C4** may be reviewed once the results and interpretation of two years continuous natural flow monitoring and electrical conductivity data is available from gauging stations and application for amendment is made to the administering authority.*

C11	The daily quantity of mine affected water released from each release point must be measured and recorded at the monitoring points in **Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)**.
C12	Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build-up of sediment in such waters.
C13	**Notification of Release Event** The environmental authority holder must notify the administering authority as soon as practicable and no later than **twenty-four (24) hours** after commencing to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information: (a) release commencement date/time; (b) expected release cessation date/time; (c) release point/s; (d) release volume (estimated); (e) receiving water/s including the natural flow rate; (f) determined maximum release rate and EC limit (in accordance with condition **C10**); and (g) any details (including available data) regarding likely impacts on the receiving water(s). ***NOTE:*** *Notification to the administering authority must be addressed to the Manager and Project Manager of the local Administering Authority via email or facsimile.*
C14	The environmental authority holder must notify the administering authority as soon as practicable (nominally within **twenty-four (24) hours** after cessation of a release event) of the cessation of a release notified under **Condition C13** and within **twenty-eight (28) days** provide the following information in writing: (a) release cessation date/time; (b) natural flow volume in receiving water; (c) volume of water released; (d) details regarding the compliance of the release with the conditions of Department Interest: Water of this environmental authority (i.e. release limits, natural flow, discharge volume); (e) all in-situ water quality monitoring results; and (f) any other matters pertinent to the water release event. ***NOTE:*** *Successive or intermittent releases occurring within twenty-four (24) hours of the cessation of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with* ***Conditions C13*** *and* ***C14****, provided the relevant details of the release are included within the notification provided in accordance with* ***Conditions C13*** *and* ***C14****.*
C15	**Notification of Release Event Exceedance** If the release limits defined in **Table C1 (Contaminant Release Limits)** are exceeded, the holder of the environmental authority must notify the administering authority within **twenty-four (24) hours** of receiving the results.

C16	The authority holder must, within **twenty-eight (28) days** of a release that exceeds the conditions of this authority, provide a report to the administering authority detailing: (a) the reason for the release; (b) the location of the release; (c) all water quality monitoring results; (d) any general observations; (e) all calculations; and (f) any other matters pertinent to the water release event.
C17	**Water Storage access by Livestock** Where practicable, the holder of the environmental authority must implement measures to prevent access by livestock to water storages which are associated with the release points listed in **Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)**.
C18	**Receiving Environment Monitoring and Contaminant Trigger Levels** The quality of the receiving waters must be monitored at the locations specified in **Table C5 (Receiving Water Upstream Background Sites and Downstream Monitoring Points)** for each quality characteristic and at the monitoring frequency stated in **Table C6 (Receiving Waters Contaminant Trigger Levels)**.
C19	If quality characteristics of the receiving water at the downstream monitoring points exceed any of the trigger levels specified in **Table C7 (Stock Water Release Limits)** during a release event the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and: (a) where the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action is to be taken; or (b) where the downstream results exceed the upstream results, complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining: (i) details of the investigations carried out; and (ii) actions taken to prevent environmental harm. ***NOTE:*** *Where an exceedance of a trigger level has occurred and is being investigated, in accordance with* ***Condition C19(b)*** *of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.*

Table C5 (Receiving Water Upstream Background Sites and Downstream Monitoring Points)

Monitoring Points	Receiving Waters Location Description	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)
Upstream Background Monitoring Points			
UBMP 1	Sandy Creek 60 metres upstream of RP 12	7602294	623234
UBMP 3	Spade Creek 1500 metres upstream of RP 14, 620 metres upstream of RP 3	7590458	619050
UBMP 4	Anna Creek 2100 metres upstream of RP 9 and RP 11. 4400 metres upstream of RP 7. 6100 metres upstream of RP 6.	7613732	622706
UBMP 5	Isaac River 100 metres upstream of RP 10.	7618028	619293
UBMP 6	Teviot Creek 150 metres upstream of RP 13	7606129	624528
Downstream Monitoring Points			
DMP 7	Spade Creek via Bullock Creek, 650 metres downstream of confluence	21.788163	148.147705
DMP 8	Lower Anna Creek (Burton Gorge Dam)	To be provided	To be provided
DMP 4	Anna Creek 4400 metres downstream of RP 9 & 11	21.587677	148.157409
DMP 5	Isaac River 4500 metres downstream of RP 10	21.562708	148.141682
DMP 1	Sandy Creek 2500 metres downstream of RP 12	21.672291	148.174706
DMP 6	Teviot Creek 1200 metres downstream of RP 13	21.650606	148.19804
DMP 3	Spade Creek 4000 metres downstream of RP 14	21.804535	148.128847

NOTE: *The data from background monitoring points must not be used where they are affected by releases from other mines.*

Table C6 (Receiving Waters Contaminant Trigger Levels)

Quality Characteristic	Trigger Level	Monitoring Frequency
pH	6.5 – 8.5	Daily during the release
Electrical Conductivity (µS/cm)	1000 *(NOTE: For protection against toxicity this may need to be reduced in some circumstances e.g. where in close proximity upstream of a drinking water dam or regional waterway.)*	
Suspended solids (mg/L)	To Be Determined. *(NOTE: Turbidity may be required to assess ecosystems impacts and can provide instantaneous results.)*	At commencement and prior to cessation of release (at a minimum) and weekly during a release
Sulphate (SO_4^{2-}) (mg/L)	250 *(NOTE: Protection of drinking water Environmental Value.)*	
Sodium (mg/L)	180	

Table C7 Stock Water Release Limits)

Quality characteristic	Units	Minimum	Maximum
pH	pH units	6.5	8.5
Electrical Conductivity	µS/cm	N/A	5000

C20	**Receiving Environment Monitoring Program (REMP)** The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site. For the purposes of the REMP, the receiving environment is the waters of the Burton Gorge Dam and connected or surrounding waterways, including Isaac River, Anna Creek, Teviot Creek, Bullock Creek, Spade Creek and Sandy Creek, within 20km downstream of the release. The REMP should encompass any sensitive receiving waters or environmental values downstream of the authorised mining activity that will potentially be directly affected by an authorised release of mine affected water.

C21	The REMP must: (a) Assess the condition or state of receiving waters, including upstream conditions, spatially within the REMP area, considering background water quality characteristics based on accurate and reliable monitoring data that takes into consideration temporal variation (e.g. seasonality); and (b) Be designed to facilitate assessment against water quality objectives for the relevant environmental values that need to be protected; and (c) Include monitoring from background reference sites (e.g. upstream or background) and downstream sites from the release (as a minimum, the locations specified in **Table C5 (Receiving Water Upstream Background Sites and Downstream Monitoring Points)**); and (d) Specify the frequency and timing of sampling required in order to reliably assess ambient conditions and to provide sufficient data to derive site specific background reference values in accordance with the *Queensland Water Quality Guidelines 2006*. This should include monitoring during periods of natural flow irrespective of mine or other discharges; and (e) Include monitoring and assessment of dissolved oxygen saturation, temperature and all water quality parameters listed in **Table C2 (Contaminant Release Limits)** and **Table C3 (Release Contaminant Trigger Investigation Levels – Potential Contaminants)**; and (f) Include, where appropriate, monitoring of metals/metalloids in sediments (in accordance with ANZECC & ARMCANZ 2000, BATLEY and/or the most recent version of *AS5667.1 Guidance on Sampling of Bottom Sediments*); and (g) Include, where appropriate, monitoring of macroinvertebrates in accordance with the AusRivas methodology, and (h) Apply procedures and/or guidelines from ANZECC & ARMCANZ 2000 and other relevant guideline documents; and (i) Describe sampling and analysis methods and quality assurance and control; and (j) Incorporate stream flow and hydrological information in the interpretations of water quality and biological data.
C22	An REMP Design Document that addresses each criterion presented in **Conditions C20** and **C21** of this environmental authority must be maintained and submitted to the administering on request. Due consideration must be given to any comments made by the administering authority on the REMP Design Document and subsequent implementation of the program.
C23	A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with **Conditions C20** and **C21** of this environmental authority must be prepared annually and made available on request to the administrating authority. This must include an assessment of background reference water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current discharge limits to protect downstream environmental values.

C24	Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party for the purpose of: (a) Supplying stock water subject to compliance with the quality release limits specified in **Table C7 (Stock Water Release Limits)**; or (b) Supplying irrigation water subject to compliance with quality release limits in **Table C8 (Irrigation Water Release Limits)**; or (c) Supplying water for construction and/or road maintenance in accordance with the conditions of this environmental authority.

Table C8 (Irrigation Water Release Limits)

Quality characteristic	Units	Minimum	Maximum
pH	pH units	6.5	8.5
Electrical Conductivity	µS/cm	N/A	Site specific value to be determined in accordance with ANZECC & ARMCANZ (2000) Irrigation Guidelines

C25	If the responsibility for mine affected water is given or transferred to another person in accordance with **Condition C24** of this environmental authority: (a) The responsibility for the mine affected water must only be given or transferred in accordance with a written agreement (the third party agreement); and (b) The third party agreement must include a commitment from the person utilising the mine affected water to use it in such a way as to prevent environmental harm or public health incidents and specifically make the persons aware of the General Environmental Duty (GED) under section 319 of the *Environmental Protection Act 1994,* environmental sustainability of the water disposal and protection of environmental values of waters; and (c) The third party agreement must be signed by both parties to the agreement.

C26	**Water general** All determinations of water quality and biological monitoring must be: (a) performed by a person or body possessing appropriate experience and qualifications to perform the required measurements; (b) made in accordance with methods prescribed in the latest edition of the Department of Environment and Resource Management's Monitoring and Sampling Manual; (c) collected from the monitoring locations identified within this environmental authority, within **ten (10) hours** of each other where possible; (d) carried out on representative samples; and (e) analysed at a laboratory accredited (e.g. NATA) for the method of analysis being used. ***NOTE: Condition C26** requires the Monitoring and Sampling Manual to be followed and where it is not followed because of exceptional circumstances this should be explained and reported with the results.*
C27	The release of any contaminants as permitted by this environmental authority, directly or indirectly to waters, other than internal water management infrastructure that is installed and operated in accordance with a water management plan that complies with **Conditions C31** to **C36** inclusive: (a) must not produce any visible discolouration of receiving waters; and (b) must not produce any slick or other visible or odorous evidence of oil, grease or petrochemicals nor contain visible floating oil, grease, scum, litter or other objectionable matter.
C28	**Annual water monitoring reporting** The following information must be recorded in relation to all water monitoring required under the conditions of this environmental authority and submitted to the administering authority in the specified format with each annual return: (a) the date on which the sample was taken; (b) the time at which the sample was taken; (c) the monitoring point at which the sample was taken; (d) the measured or estimated daily quantity of mine affected water released from all release points; (e) the release flow rate at the time of sampling for each release point; and (f) the results of all monitoring and details of any exceedances of the conditions of this environmental authority.
C29	Water quality monitoring data must be provided to the administering authority in the specified electronic format upon request.
C30	**Temporary interference with waterways** Temporarily destroying native vegetation, excavating, or placing fill in a watercourse, lake or spring necessary for and associated with mining operations must be undertaken in accordance with Department of Environment and Resource Management *Guideline - Activities in a Watercourse, Lake or Spring associated with Mining Activities.*

C31	**Water management plan** A Water Management Plan must be developed by an appropriately qualified person and implemented by **26 February 2010**.
C32	The Water Management Plan must: (a) Provide for effective management of actual and potential environmental impacts resulting from water management associated with the mining activity carried out under this environmental authority; and (b) Be developed in accordance with Department of Environment and Resource Management guideline *Preparation of water management plans for mining activities* and include: (i) a study of the source of contaminants; (ii) a water balance model for the site; (iii) a water management system for the site; (iv) measures to manage and prevent saline drainage; (v) measures to manage and prevent acid rock drainage; (vi) contingency procedures for emergencies; and (vii) a program for monitoring and review of the effectiveness of the water management plan.
C33	The Water Management Plan must be reviewed each calendar year and a report prepared by an appropriately qualified person. The report must: (a) assess the plan against the requirements under **Condition C32** of this environmental authority; (b) include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; and (c) identify any amendments made to the water management plan following the review.
C34	The holder of this environmental authority must attach to the review report required by **Condition C33** of this environmental authority, a written response to the report and recommended actions, detailing the actions taken or to be taken by the environmental authority holder on stated dates: (a) to ensure compliance with this environmental authority; and (b) to prevent a recurrence of any non-compliance issues identified.
C35	The review report required by **Condition C33** of this environmental authority and the written response to the review report required by **Condition C34** must be submitted to the administering authority with the subsequent annual return under the signature of the appointed signatory for the annual return.
C36	A copy of the Water Management Plan must be provided to the administering authority on request.
C37	**Saline drainage** The holder of this environmental authority must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of saline drainage.

C38	**Acid rock drainage** The holder of this environmental authority must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of acid rock drainage.
C39	**Stormwater and water sediment controls** An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the mining activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater.
C40	Stormwater, other than mine affected water, is permitted to be released to waters from: (a) erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by **Condition C39** of this environmental authority; and (b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with **Conditions C31** to **C36** inclusive, for the purpose of ensuring water does not become mine affected water.
C41	The maintenance and cleaning of any vehicles, plant or equipment must not be carried out in areas from which contaminants can be released into any receiving waters.
C42	Any spillage of wastes, contaminants or other materials must be cleaned up as quickly as practicable to minimise the release of wastes, contaminants or materials to any stormwater drainage system or receiving waters.
C43	**Sewage effluent** All effluent released from the treatment plant must be monitored at the frequency and for the parameters specified in **Table C9 (Sewage effluent quality targets for dust suppression and irrigation)**.
C44	Sewage effluent used for dust suppression or irrigation must not exceed sewage effluent release limits defined in **Table C9 (Sewage effluent quality targets for dust suppression and irrigation)**.

Table C9 (Sewage effluent quality targets for dust suppression and irrigation)

Quality characteristics	Release limit	Units	Limit type	Monitoring frequency
5-day Biochemical Oxygen Demand (uninhibited)	20	mg/l	max	Monthly
pH	6.5-8.5		range	Monthly
Free Chlorine Residual	140	mg/l	max	Monthly
Faecal Coliforms, based on the average of a minimum of five samples collected	1 000	Colonies per 100 millilitres	max	Monthly

C45	Sewage effluent used for dust suppression or irrigation must not cause spray drift or over spray to any sensitive or commercial place.
C46	Subject to **Conditions C43** to **C45** inclusive, sewage effluent from sewage treatment facilities must be reused or evaporated and must not be directly released from the sewage treatment plant to any water way or drainage.
C47	**Groundwater** Groundwater affected by the mining activities must be monitored for pH, Electrical Conductivity and water levels at frequencies and locations defined in **Table C10 (Groundwater monitoring locations and frequency)**.
C48	Groundwater levels must be monitored and groundwater draw down fluctuations in excess of two metres per year, not resulting from the pumping of licensed bores, must be notified within **fourteen (14) days** to the administering authority following completion of monitoring.
C49	Groundwater standing water level and quality must be monitored during exploration activities ahead of mining. This data may be used by the administering authority as grounds for amendment of groundwater monitoring and/or management requirements of this environmental authority.
C50	The method of water sampling required by this environmental authority must comply with that set out in the latest edition of the administering authority's *Water Quality Sampling Manual.*

Table C10 (Groundwater monitoring locations and frequency)

Monitoring point	Easting	Northing	Monitoring frequency
BD1247P	620264	7616055	Quarterly – water levels only
BD1248P	622890	7606690	Quarterly – water levels only
BD1249P	620770	7610360	Quarterly
BD1250P	622560	7607860	Quarterly
BD1252P	622294	7600039	Quarterly
BD1254P	621022	7597920	Reinstated post mining
BD613C	623101	7605268	Quarterly
BDW148	618642	7587996	Quarterly[1]
BDW172	619333	7586689	Quarterly – water levels only
BDW366P	619163	7587710	Quarterly
BDW367P	618778	7589869	Quarterly – water levels only
BDW368P	618017	7591478	Quarterly – water levels only
BDW46	617650	7593762	Quarterly
BDW5C	619731	7586791	Quarterly
BDW8C	619762	7585670	Quarterly
DDH55	621775	7608775	Quarterly
DDH6	619304	7618185	Quarterly
LBP 5 Seam	620080	7596430	Quarterly
LBP 5 Upper	620080	7596430	Quarterly

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Agency interest: Noise and Vibration	
Condition number	**Condition**
D1	**Noise nuisance** Subject to **Conditions D2** and **D3** of this environmental authority noise from the mining activity must not cause an environmental nuisance, at any sensitive or commercial place.
D2	When requested by the administering authority, noise monitoring must be undertaken within a reasonable and practicable timeframe nominated by the administering authority to investigate any complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer) of environmental nuisance at any sensitive or commercial place, and the results must be notified within **fourteen (14) days** to the administering authority following completion of monitoring.
D3	If the environmental authority holder can provide evidence through monitoring that the limits defined in **Table D11 (Noise Limits)** and **Table D12 (Airblast overpressure level)**, are not being exceeded then the holder is not in breach of **Condition D1** of this environmental authority. Monitoring must include: (a) $L_{A,\ max\ adj,\ T}$; (b) relevant background sound level; (c) the level and frequency of occurrence of impulsive or tonal noise; (d) atmospheric conditions including wind speed and direction; and (e) location, date and time of recording.
D4	If monitoring indicates exceedance of the limits in **Table D11 (Noise Limits)** and **Table D12 (Airblast overpressure level)**, then the environmental authority holder must: (a) address the complaint including the use of appropriate dispute resolution if required; and (b) immediately implement noise abatement measures so that emissions of noise from the activity do not result in further environmental nuisance.

Table D11 (Noise limits)

Noise level dB(A)	**Monday to Sunday (including public holidays)**		
	7am - 6pm	**6pm - 10pm**	**10pm - 7am**
	Noise measured at a 'sensitive or commercial place'		
$L_{A10,\ adj,\ 10\ mins}$	B/g + 5	B/g + 5	B/g + 3
$L_{A1,\ adj,\ 10\ mins}$	B/g + 10	B/g + 10	B/g + 5

NOTE: *Where "Background" means background sound pressure level measured in accordance with the latest edition of the administering authority's Noise Measurement Manual.* ***Table D11*** *does not purport to set operating hours for the mining activities.*

Table D12 (Airblast overpressure level*)

Parameter	Airblast overpressure measured at a sensitive or commercial place	
	Monday to Sunday 9am - 7pm	**Other times and public holidays**
Air blast overpressure level (dB [Lin] Peak)	Maximum 115 dB for 4 out of 5 consecutive blasts	No blasting to occur
Air blast overpressure level (dB [Lin] Peak)	120 dB maximum	No blasting to occur

***NOTE: Table D12** does not purport to set limits applicable to any particular explosive blast, rather sets design criteria for every explosive blast.*

D6	The method of measurement and reporting of noise levels must comply with the latest edition of the administering authority's *Noise Measurement Manual*.
D5	**Vibration nuisance** Subject **to Conditions D7** and **D8** of this environmental authority vibration from the mining activity must not cause an environmental nuisance, at any sensitive place.
D7	When requested by the administering authority, vibration monitoring must be undertaken within a reasonable and practicable timeframe nominated by the administering authority to investigate any complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer) of environmental nuisance at any sensitive or commercial place, and the results must be notified within **fourteen (14) days** to the administering authority following completion of monitoring.
D8	If the environmental authority holder can provide evidence through monitoring that the limits defined in **Table D13 (Vibration Limits)**, are not being exceeded then the holder is not in breach of **Condition D6** of this environmental authority. Monitoring must include: (a) peak particle velocity (mm/s); (b) air blast overpressure level (dB linear peak); (c) location of the blast/s within the mining area (including which bench level); (d) atmospheric conditions including temperature, relative humidity and wind speed and direction; and (e) location, date and time of recording.
D9	For the purposes of **Condition D6** of this environmental authority the mining activities will not cause environmental nuisance where noise from the mining activities does not exceed the criteria specified in **Table D13 (Vibration Limits)**.
D10	If monitoring indicates exceedance of the limits in **Table D13 (Vibration Limits)**, then the environmental authority holder must: (a) address the complaint including the use of appropriate dispute resolution if required; and (b) immediately implement noise abatement measures so that emissions of noise from the activity do not result in further environmental nuisance.

Table D13 (Vibration limits)

Vibration parameter	Vibration measured at a sensitive place	
	Monday to Sunday 9am - 7pm	**Other times and public holidays**
Peak particle velocity (mm/s)	Maximum 5 mm/s for 4 out of 5 consecutive blasts	No blasting to occur
Peak particle velocity (mm/s)	10 mm/s maximum	No blasting to occur

D11	Every explosive blast for the mining activity shall be designed by a competent person to achieve the criteria specified in **Table D12 (Airblast overpressure level)** and **Table D13 (Vibration Limits)**.
D12	All relevant information pertaining to the design of every explosive blast for the mining activity in relation to the criteria specified in **Table D12 (Airblast overpressure level)** and **Table D13 (Vibration Limits)** shall be kept in written and diagrammatic form.

Agency interest: Waste	
Condition number	**Condition**
E1	**Waste management** A waste management program must be developed and submitted to the administering authority for approval. The waste management program must at a minimum include the following: (a) types and amounts of regulated waste generated; (b) description of how the types of regulated waste are generated and will be dealt with under the waste management hierarchy; (c) procedures for identifying and implementing opportunities to minimise the amount of regulated waste generated and improve practices employed; (d) procedures for dealing with accidents, spills and incidents that may impact on waste management; (e) location of disposal of regulated waste; (f) staff training on matters relevant to regulated waste management; and (g) mechanisms and dates for review of the waste management program.
E2	Waste must not be burnt or allowed to burn on the site unless permitted by the administering authority.
E3	A designated area must be set aside for the segregation of economically viable recycling solid or liquid waste.
E4	Site contamination will be assessed at relinquishment of the mining tenure according to the *Environmental Protection Act 1994*, with results and any required remediation actions detailed in the Final Rehabilitation Report.

E5	Records of trade waste or material leaving the Mining Lease for recycling or disposal, including the final destination and method of treatment, in accordance with the *Environmental Protection Act 1994*, will be maintained and be made available for inspection by an authorised person or the administering authority.
E6	Regulated waste disposal areas on the mining lease will be capped with one metre of inert material and revegetated in accordance with available and recognised best practice following the cessation of their use as disposal areas in a manner that will encourage run-off.
E7	**Storage of tyres** Scrap tyres stored awaiting disposal or transport for take-back and recycling, or waste-to-energy options must be stored in stable stacks and at least ten (10) metres from any other scrap tyre storage area, or combustible or flammable material, including vegetation.
E8	All reasonable and practicable fire prevention measures must be implemented, including removal of grass and other materials within a ten (10) metre radius of the scrap tyre storage area.
E9	Where no feasible recycling or waste to energy options are available, disposing of scrap tyres resulting from the mining activities in spoil emplacements is acceptable, provided tyres are placed as deep in the spoil as reasonably practicable.
E10	Scrap tyres resulting from the mining activities disposed within the operational land must not impede saturated aquifers or compromise the stability of the consolidated landform.

Agency interest: Land	
Condition number	**Condition**
F1	**Rehabilitation and final landform design** All areas significantly disturbed by mining activities must be rehabilitated to a stable landform with a self-sustaining vegetation cover in accordance with **Table F14 (Final land use rehabilitation approval schedule), Table F15 (Final land use rehabilitation approval schedule – Bullock Creek site)** and **Table F16 (Landform design)**.
F2	Progressive rehabilitation must commence within **twelve (12) months** of the area becoming available within the operational land.
F3	For Bullock Creek site, vegetation communities established along the Bullock Creek diversions must be able to establish a self-sustaining vegetation cover to minimise erosion from the banks of the diversions.

F4	The holder of the environmental authority must: (a) Notify the administering authority of approval for the diversions of Bullock Creek. (b) Make available, **twenty-eight (28) days** prior to construction, the following: (i) creek diversion approval documentation; (ii) hydrological assessment; (iii) diversion specifications; (iv) harm reduction methods to be implemented; (v) a detailed map of the proposed diversion; (vi) vegetation types to be established within the diversion; and (vii) monitoring and maintenance program.

Table F14 (Final land use and rehabilitation approval schedule)

Disturbance Type		Class *		Rehabilitation Methods	Proposed Land Use
		Capability	*Suitability*		
Overburden		VI - VII	3 - 4	Generally less than 5% gradient on plateau and up to 20% on outer margins. Includes selective topsoil placement concentrated in more erosion potential areas such as margins. Includes areas of bushland habitat and grasslands with potential for grazing (to be verified through grazing trials).	Potential for grazing on some areas
Ramps		VIII	^ 5	Ramps not in-filled with tailings, reject or pre-strip spoil will be basically treated as part of the final void and left at angle of repose. Limited benching, battering or drainage control works may occur along adjoining spoil to control erosion.	Not suitable for grazing
Final Voids		VIII	^ 5	Those not utilised for rejects, tailings or pre-strip placement will remain as water storage bodies. Exposed coal seams may be sealed in areas not permanently or seasonally inundated to prevent spontaneous combustion. Its potential use will be dependant on the final water quality.	Not suitable for grazing
High walls		VIII	^ 5	Highwalls will be assessed on an individual basis. Some will be backfilled and others associated with final voids left at 65 degrees in competent rock or blasted to <17 degrees in non-competent rock.	Not suitable for grazing
Infrastructure	Buildings, Roads, ROM, Camp Laydown	VI - VII	3 -4	Facilities to be either left for future users or sold for removal with the site rehabilitated to grassland or bushland, dependant on original use. Contaminated areas to be remediated in consultation with the Administering Authority. Contaminated areas have been identified and will be rehabilitated on a case-by-case basis from a Stage 2 Contaminated Land Survey.	Suitable for grazing
Tailings	In dams	VIII	5	Two options will be considered: 1. Decommissioned well before cessation of mining to dewater then capped with 1m with spoil and topsoil designed to drain water off the structure. Seeded to trees and shrubs (bushland). 2. Reprocessed with waste placed in spoil.	Not suitable for grazing
	In pits	VII - VIII	4 - 5	Capped with adjoining spoil so that the area is freely drained, topsoiled and seeded to trees, shrubs and grasses (bushland).	Not suitable for grazing
Rejects	Designated dumps	VIII	5	Re-graded to less than 15%, capped with 1m of spoil (minimum) and seeded to grasses, trees and shrubs (bushland)	Not suitable for grazing
	In pits / Spoil	VII - VIII	4 - 5	Capped to a minimum of 1 m with spoil and topsoiled. Seeded to trees and shrubs (bushland).	Not suitable for grazing
Co-disposal	In pits / Spoil	VII - VIII	4 - 5	Capped with adjoining spoil so that the area is freely drained, topsoiled and seeded to trees, shrubs and grasses (bushland).	Not suitable for grazing

** DME (1995) Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland. "Land Suitability Assessment Techniques".*
^ 5 – The class could be graded higher if the voids are backfilled

Table F15 (Final land use and rehabilitation approval schedule – Bullock Creek site)

	Disturbance type						
	Tenure ID	**Projective surface area (ha)**	**Map reference**	**Post mine land use**	**Post mine land capability classification**	**Post mine land suitability classification**	**Rehabilitation methods**
Bullock Creek Diversion (Endangered Regional Ecosystems)	Burton Coal Mine Project – Bullock Creek Pit.	7Ha	Figure 1 – Bullock Creek Disturbance areas	Self sustaining native vegetation	VI - VII	3 -4	Offset plant greater then area of ERE cleared. Topsoil from ERE area recovered in separate stockpile and utilized in ERE offset planning locations. A mixture seed and tubestock native tree, grass and shrub species which must include *Eucalyptus cambageana, Acacia harpophylla, Flindersia dissospera, Ereophila, Carissa ovata, Alectryon diversifolius, Capparis lasiantha, Eucalyptus populnea, Eromophila mitchelli* and *Sorghum nitidum* to reproduce as close as practical the Brigalow – Dawson Gum woodland community (Endangered Regional Ecosystem 11.9.1). The rehabilitated area and remaining ERE shall be fenced.
Final Void(s)		42.1		Not suitable for grazing	VIII*	^ 5	Those not utilized for rejects, tailings or pre-strip placement will remain as water storage bodies. Exposed coal seams may be sealed in areas not permanently or seasonally inundated to prevent spontaneous combustion. Its potential use will be dependent on the final water quality.
High walls		10.0		Not suitable for grazing	VIII*	^ 5	Highwalls will be assessed on an individual basis. Some will be backfilled and others associated with final voids left at 65 degrees in competent rock or blasted to <17 degrees in non-competent rock.
Ramps		2.4		Not suitable for grazing	VIII*	^ 5	Ramps not in-filled with tailings, reject or pre-strip spoil will be basically treated as part of the final void and left at angle of repose. Limited benching, battering or drainage control works may occur along adjoining spoil to control erosion.
Overburden Rejects		102.1		Not suitable and suitable for grazing	VI - VII	3 - 4	Generally less than 5% gradient on plateau and up to 20% on outer margins. Includes selective topsoil placement concentrated in more erosion potential areas such as margins. Includes areas of bushland habitat and grasslands with potential for grazing (to be verified through grazing trials).
Road(s) and track(s)		20.7		Suitable for grazing	VI - VII	3 - 4	Facilities to be either left for future users or sold for removal with the site rehabilitated to grassland or bushland, dependant on original use. Contaminated areas to be remediated in consultation with the Administering Authority. Contaminated areas have been identified and will be rehabilitated on a case-by-case basis from a Stage 2 Contaminated Land Survey.

Table F16 (Landform design)

Disturbance type	Design Criteria	Qualifications
Final Highwalls and Ramps: *competent material * incompetent material	<70° slope <50° slope	Competency certified by an appropriately qualified professional accredited by a credible third party
Lowwalls	Left at angle of repose	Drainage, erosion control and seeding works is to be conducted as required.
Spoil emplacement areas – grassland suitable for grazing	Slope angle <12% Plateau <20% outer batters	
Spoil emplacement areas – not suitable for grazing	Slope angle <20%	
Subsidence	Risk based treatment of subsided areas.	Monitoring and evaluation of risk will be used to determine appropriate treatment.
Coal washery waste disposal areas	Average slope angle for outer batters <20%. Minimum 1m of inert spoil cover.	Externally draining or in pit. No acidic leachate. Capping must be sufficient to break capillary rise of solutes.
Industrial areas	<12% slope	
Water storages	Drained and walls breached unless otherwise agreed with landholder.	

F5	Vegetation and creek morphology will be restored on the affected portions of Bullock Creek. Rehabilitation of Bullock Creek diversions will be assessed against analogue site(s) to be agreed upon with the administering authority, and must include *Eucalyptus cambageana, Acacia harpophylla, Flindersia dissospera, Carissa ovata, Alectryon diversifolius, Capparis lasiantha, Eucalyptus populnea, Eromophila mitchelli* and *Sorghum nitidum.*
F6	Residual voids must comply with the following outcomes; (a) residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority; (b) be left as stable structures with the competency certified by an appropriately qualified third party (e.g. an engineer listed on the National Professional Engineers Register; and (c) be fenced or bunded appropriately to restrict human, stock and other fauna in areas representing a potential hazard.

F7	Complete and submit a Mine Closure Plan to the administering authority for acceptance for the Burton Coal Mine by **30 July 2012**. A component of the Mine Closure Plan must include an investigation into residual voids and propose acceptance criteria to meet the outcomes in condition F3 and landform design criteria in **Table F15 (Final land use rehabilitation approval schedule – Bullock Creek site)** and **Table F16 (Landform design)**. The investigation must at a minimum include the following: a) a study of options available for minimising final void area and volume; b) develop design criteria for rehabilitation of final voids; c) a void hydrology study, addressing the long-term water balance in the voids, connections to groundwater resources and water quality parameters in the long term; d) a pit wall stability study, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events; e) a study of void capability to support native flora and fauna; and f) a proposal/s for end of mine void rehabilitation success criteria and final void areas and volumes. These studies will be undertaken during the life of the mine, and will include detailed research and modelling.
F8	Areas which are to be progressively rehabilitated to land suitable for grazing must demonstrate achieving the specified land suitability and ensure: (a) success criteria defined in the document entitled "*Burton Coal Mine Environmental Management Plan*" dated May 2010, Appendix 3 - Proposed rehabilitation success criteria - Grassland suitable for grazing, are met; and (b) all areas disturbed by mining activities must be rehabilitated to a stable landform and comply with the design criteria defined in Attachment 1 - Table 18 (Final land use rehabilitation approval schedule – Bullock Creek site) and Table 19 (Landform design).
F9	Areas which are to be progressively rehabilitated to land not suitable for grazing must demonstrate achieving the specified land suitability and ensure: (a) achieve a self-sustaining native ecosystem; (b) success criteria defined in the document entitled "*Burton Coal Mine Environmental Management Plan*" dated May 2010, Appendix 3 - Proposed rehabilitation success criteria - Bushland, are met; (c) all areas disturbed by mining activities must be rehabilitated to a stable landform and comply with the design criteria defined in Attachment 1 - Table 15 and Table 16.
F10	Subsidence management procedures must be developed and implemented during the continuation of this environmental authority. The subsidence management strategies must be detailed in the relevant Plan of Operations and must at a minimum include: (a) subsidence modelling (predictions) ahead of mining; (b) rehabilitation methods; and (c) land management practices pre and post mine area.

F11	All infrastructure, constructed by or for the environmental authority holder during the mining activities including water storage structures, must be removed from the site prior to mining lease surrender, except where agreed in writing by the post mining land owner / holder. ***NOTE:*** *This is not applicable where the landowner / holder is also the environmental authority holder.*
F12	Topsoil resources that are suitable for use in rehabilitation must be salvaged ahead of mining disturbance for strategic use in rehabilitation of the mine area.
F13	The characteristics of overburden must be determined prior to disturbance by mining to a standard sufficient to enable selective handling of materials required.
F14	Cleared vegetation from the site must be managed in accordance with the following hierarchy: (a) reuse, e.g. use of logs and tree stumps as shelter for fauna in rehabilitated areas; (b) recycle, e.g. mulching of vegetation and use in rehabilitation on the site; and (c) other alternative management options implemented in a way that causes the least amount of environmental harm.
F15	The environmental authority holder must provide the administering authority a map that shows the aerial extent and topography of final landforms including final voids. If amendments to the map are required then the environmental authority holder must provide the administering authority with the amended map.

Agency interest: Dams and Levees	
Condition number	**Condition**
G1	The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* at the following times: (a) prior to the design and construction of the structure, if it is not an existing structure; or (b) prior to any change in its purpose or the nature of its stored contents.
G2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.
G3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).*
G4	**Design and construction of a regulated structure** **Conditions G5** to **G9** inclusive do not apply to existing structures.
G5	All regulated structures must be designed by, and constructed under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).*

G6	Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this authority.
G7	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*, and must be recorded in the Regulated Dams/Levees register.
G8	Regulated structures must: (a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);* (b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: (i) floodwaters from entering the regulated dam from any watercourse or drainage line; and (ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line. (c) have the floor and sides of any dam regulated for "failure to contain – seepage" designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam.
G9	Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that: (a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; (b) construction of the regulated structure is in accordance with the design plan.
G10	**Operation of a regulated structure** Operation of a regulated structure, except for an existing structure, is prohibited unless the holder has submitted to the administering authority: (a) one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with **Condition G6**, and (b) a set of 'as constructed' drawings and specifications, and (c) certification of those 'as constructed drawings and specifications' in accordance with **Condition G9**, and (d) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan. (e) the requirements of this authority relating to the construction of the regulated structure have been met; (f) The holder has entered the details required under this authority, into a Register of Regulated Dams; and (g) There is a current operational plan for the regulated structures.

G11	For existing structures that are regulated structures: (a)where the existing structure that is a regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, the holder must submit to the administering authority within **12 months** of the commencement of this condition a copy of the certified system design plan including that structure; and (b)there must be a current operational plan for the existing structures.
G12	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.
G13	**Mandatory reporting level** **Conditions G14** to **G17** inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain – overtopping'.
G14	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.
G15	The holder must, as soon as practical and within **forty-eight (48) hours** of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.
G16	The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.
G17	The holder must record any changes to the MRL in the Register of Regulated Structures.
G18	**Design storage allowance** The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to **1 July** of each year.
G19	By **1 November** of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems).
G20	The holder must, as soon as possible and within forty-eight (48) hours of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, notify the administering authority.
G21	The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.
G22	**Annual inspection report** Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.

G23	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure.
G24	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.
G25	The holder must: (a) within 20 business days of receipt of the annual inspection report, provide to the administering authority: (i) the recommendations section of the annual inspection report; and (ii) if applicable, any actions being taken in response to those recommendations; and (b) if, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within **10 business days** of receipt of the request.
G26	**Transfer arrangements** The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.
G27	**Decommissioning and rehabilitation** Dams must not be abandoned but be either: (a) decommissioned and rehabilitated to achieve compliance with **Condition G28**; or (b) be left in-situ for a beneficial use(s) provided that: (i) it no longer contains contaminants that will migrate into the environment; and (ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and (iii) the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).

G28	After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria: (a) the landform is safe for humans and fauna; (b) the landform is stable with no subsidence or erosion gullies for at least three (3) years; (c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated; (d) not allowing for acid mine drainage; or (e) there is no ongoing contamination to waters (including groundwater); (f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the *Instructions for the treatment and management of acid sulfate soils* (2001); (g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class; (h) for land that is not being cultivated by the landholder: (i) groundcover, that is not a declared pest species is established and self-sustaining; (ii) vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and (iii) the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies). (i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of petroleum activities being completed.
G29	**Register of Regulated Rams** A Register of Regulated Dams must be established and maintained by the holder for each regulated dam.
G30	The holder must provisionally enter the required information in the Register of Regulated Dams when a design plan for a regulated dam is submitted to the administering authority.
G31	The holder must make a final entry of the required information in the Register of Regulated Dams once compliance with **Condition G10** and **G11** has been achieved.
G32	The holder must ensure that the information contained in the Register of Regulated Dams is current and complete on any given day.
G33	All entries in the Register of Regulated Dams must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct.
G34	The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Dams, in the electronic format required by the administering authority.
G35	**Transitional arrangements** All existing structures that have not been assessed in accordance with either the Manual or the *former Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* must be assessed and certified in accordance with the Manual within 6 months of amendment of the authority adopting this schedule.

G36	All existing structures must subsequently comply with the timetable for any further assessments in accordance with the Manual specified in **Table G17 (Transitional hydraulic performance requirements for existing structures)**, depending on the consequence category for each existing structure assessed in the most recent previous certification for that structure.
G37	**Table G17 (Transitional hydraulic performance requirements for existing structures)** ceases to apply for a structure once any of the following events has occurred: (a) It has been brought into compliance with the hydraulic performance criteria applicable to the structure under the Manual; or (b) It has been decommissioned; or (c) It has been certified as no longer being assessed as a regulated structure.
G38	Certification of the transitional assessment required by **Conditions G35** and **G36** (as applicable) must be provided to the administering authority within 6 months of amendment of the authority adopting this schedule.

Table G17 (Transitional hydraulic performance requirements for existing structures)

Transition period required for existing structures to achieve the requirements of the Manual for Assessing Consequence Categories and Hydraulic Performance of Dams			
Compliance with criteria	**High**	**Significant**	**Low**
>90% and a history of good compliance performance in last 5 years	No transition required	No transition required	No transitional conditions apply. Review consequence assessment every 7 years.
>70%-≤90%	Within 7 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Within 10 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	No transitional conditions apply. Review consequence assessment every 7 years.
>50-≤70%	Within 5 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Within 7 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Review consequence assessment every 7 years.
≤50%	Within 5 years or as per compliance requirements (e.g. TEP timing)	Within 5 years or as per compliance requirements (e.g. TEP timing)	Review consequence assessment every 5 years.

Agency interest: Community	
Condition number	**Condition**
H1	**Complaint response** All complaints received must be recorded including details of complainant, reasons for the complaint, investigations undertaken, conclusions formed and actions taken. This information must be made available for inspection by the administering authority on request.

Definitions

Key terms and/or phrases used in this document are defined in this section. Applicants should note that where a term is not defined, the definition in the *Environmental Protection Act 1994*, its regulations or environmental protection policies must be used. If a word remains undefined it has its ordinary meaning.

"acceptance criteria" means the measures by which actions implemented are deemed to be complete. The acceptance criteria indicate the success of the decommissioning and rehabilitation outcomes or remediation of areas which have been significantly been disturbed by the mining activities. Acceptance criteria may include information regarding:

(a) stability of final land forms in terms of settlement, erosion, weathering, pondage and drainage;
(b) control of geochemical and contaminant transport processes;
(c) quality of runoff waters and potential impact on receiving environment;
(d) vegetation establishment, survival and succession;
(e) vegetation productivity, sustained growth and structure development;
(f) fauna colonisation and habitat development;
(g) ecosystem processes such as soil development and nutrient cycling, and the recolonisation of specific fauna groups such as collembola, mites and termites which are involved in these processes;
(h) microbiological studies including recolonisation by mycorrhizal fungi, microbial biomass and respiration;
(i) effects of various establishment treatments such as deep ripping, topsoil handling, seeding and fertiliser application on vegetation growth and development;
(j) resilience of vegetation to disease, insect attack, drought and fire;
(k) vegetation water use and effects on ground water levels and catchment yields.

"acid rock drainage" means any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions, when geological strata is disturbed and exposed to oxygen and moisture as a result of mining activity.

"administering authority" means the Department of Environment and Heritage Protection or its successor.

"AEP" means the Annual Exceedance Probability, which is the probability that at least one event in excess of a particular magnitude will occur in any given year.

"affected person" is someone whose drinking water can potentially be impacted as a result of discharges from a dam or their life can be put at risk due to dwellings or workplaces being in the path of a dam break flood.

"air blast overpressure" means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dB).

"annual inspection report" means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan);

(a) against recommendations contained in previous annual inspections reports;
(b) against recognised dam safety deficiency indicators;
(c) for changes in circumstances potentially leading to a change in consequence category;
(d) for conformance with the conditions of this authority;
(e) for conformance with the 'as constructed' drawings;
(f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated

sediment, state of the containment barrier and the level of liquids in the **dam** (or network of linked containment systems);

(g) for evidence of conformance with the current operational plan.

"annual exceedance probability or AEP" the probability that at least one event in excess of a particular magnitude will occur in any given year.

"assessed or **assessment"** by a suitably qualified and experienced person in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

(a) exactly what has been assessed and the precise nature of that determination;
(b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;
(c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and
(d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

"associated works" in relation to a dam, means:

(a) operations of any kind and all things constructed, erected or installed for that dam; and

(b) any land used for those operations.

"appropriately qualified person" means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods or literature.

"authority" means environmental authority (mining activities) under the *Environmental Protection Act 1994*.

"blasting" means the use of explosive materials to fracture-

(a) rock, coal and other minerals for later recovery; or
(b) structural components or other items to facilitate removal from a site or for reuse.

"certification" means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by this Manual, including design plans, 'as constructed' drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID: 1.4 (2A)).

"certifying, certify or certified" have a corresponding meaning as 'certification'.

"coal seam gas water" means groundwater that is necessarily or unavoidably brought to the surface in the process of coal seam gas exploration or production.

"coal seam gas water concentrate" means the concentrated saline water waste stream from a water treatment process that does not exceed a total dissolved solid concentration of 40 000 mg/L.

"coal seam gas evaporation dam" is defined as a impoundment, enclosure or structure that is designed to be used to hold coal seam gas water for evaporation.

"consequence" in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

"consequence category" means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).*

"competent person" means a person with the demonstrated skill and knowledge required to carry out the task to a standard necessary for the reliance upon collected data or protection of the environment.

"construction" includes building a new dam and modifying or lifting an existing dam.

"contaminated" means the substance has come into contact with a contaminant.

"contaminant" A contaminant can be –

(a) a gas, liquid or solid; or
(b) an odour; or
(c) an organism (whether alive or dead), including a virus; or
(d) energy, including noise, heat, radioactivity and electromagnetic radiation; or
(e) a combination of contaminants.

"commercial place" means a work place used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees accommodation or public roads.

"control measure" means any action or activity that can be used to prevent or eliminate a hazard or reduce it to an acceptable level.

"dam" means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and **associated works**.

"dam crest volume" means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

"design plan" is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

"design storage allowance" or **"DSA"** means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an **annual exceedance probability** (AEP) specified in that Manual.

"designer" for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam.

"development approval" means a development approval under the *Integrated Planning Act 1997* or the *Sustainable Planning Act 2009* in relation to a matter that involves an environmentally relevant activity under the *Environmental Protection Act 1994*.

"emergency action plan" means documentation forming part of the operational plan held by the holder or a nominated responsible officer, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the dam owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact.

"**existing structure"** means a structure that was in existence prior to the adoption of this schedule of conditions under the authority.

"environmental authority" means an environmental authority granted in relation to an environmentally relevant activity under the *Environmental Protection Act 1994.*

"environmental authority holder" means the holder of this environmental authority.

"**Extreme Storm Storage"** – means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

"flare pit" means containment area where any hydrocarbon that is discovered in an over-pressured reservoir during a drilling operation is diverted to, and combusted, The flare pit is only used during the drilling and work over process on a petroleum well.

"**flowable substance"** means matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.

"hazard" in relation to a dam as defined in this environmental authority, means the potential for environmental harm resulting from the collapse, or failure of the dam to perform its primary purpose of containing, diverting or controlling flowable substances.

"hazard category" means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the Site Water Management Technical Guideline for Environmental Management of Exploration and Mining in Queensland (DME 1995).

"holder" means:

(a) where this document is an environmental authority, any person who is the holder of, or is acting under, that environmental authority; or
(b) where this document is a development approval, any person who is the registered operator for that development approval.

"hydraulic performance" means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).*

"infrastructure" means water storage dams, roads and tracks, buildings and other structures built for the purpose of mining activities but does not include facilities required for the long terms management of mining impacts or the protection of potential resources. Such facilities include dams containing hazardous waste, waste rock dumps, voids, or ore stockpiles and buildings or other structures whose ownership can be transferred and which have a residual beneficial use for the next owner of the operational land or the background land owner.

"$L_{A\ 10,\ adj,\ 10\ mins}$" means the A-weighted sound pressure level, *(adjusted for tonal character and impulsiveness of the sound)* exceeded for 10% of any 10-minute measurement period, using Fast response.

"$L_{A\ 1,\ adj,\ 10\ mins}$" means the A-weighted sound pressure level, *(adjusted for tonal character and impulsiveness of the sound)* exceeded for 1% of any 10-minute measurement period, using Fast response

"$L_{A,\ max\ adj,\ T}$" means the average maximum A-weighted sound pressure level, adjusted for noise character and measured over any 10 minute period, using Fast response.

"land" in the "land schedule" of this document means land excluding waters and the atmosphere.

"land capability" as defined in the DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland.

"land suitability" as defined in the DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland.

"land use" term to describe the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

"levee" means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of **water** or **flowable substances** at any other times.

"low consequence dam" means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).*

"mandatory reporting level" means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

"manual" means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

"mine affected water" means the following types of water:

(a) pit water, tailings dam water, processing plant water;
(b) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the *Environmental Protection Regulation 2008* if it had not formed part of the mining activity;
(c) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage runoff containing sediment only, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;
(d) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated;
(e) groundwater from the mine's dewatering activities;
(f) a mix of mine affected water (under any of paragraphs i)-v)) and other water.

"mg/L" means milligrams per litre.

"natural flow" means the flow of water through waters caused by nature.

"noxious" means harmful or injurious to health or physical well-being, other than trivial harm.

"offensive" means causing reasonable offence or displeasure; is disagreeable to the sense; disgusting, nauseous or repulsive, other than trivial harm.

"operational land" means the land associated with the project for which this environmental authority has been issued.

"operational plan" includes:

(a) normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance);

(b) contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

"peak particle velocity (ppv)" means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mms^{-1}).

"progressive rehabilitation" means rehabilitation (defined below) undertaken progressively or a staged approach to rehabilitation as mining operations are ongoing.

"receiving environment" means all groundwater, surface water, land, and sediments that are not disturbed areas authorised by this environmental authority.

"receiving waters" means all groundwater and surface water that are not disturbed areas authorised by this environmental authority.

"reference site" (or analogue site) may reflect the original location, adjacent area or another area where rehabilitation success has been completed for a similar biodiversity. Details of the reference site may be as photographs, computer generated images and vegetation models etc.

"rehabilitation" the process of reshaping and revegetating land to restore it to a stable landform and in accordance with the acceptance criteria set out in this environmental authority and, where relevant, includes remediation of contaminated land.

"Register of Regulated Dams" includes:

(a) Date of entry in the register;
(b) Name of the dam, its purpose and intended/actual contents;
(c) The consequence category of the dam as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635);
(d) Dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;
(e) Name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;
(f) For the regulated dam, other than in relation to any levees –
    (i) The dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;
    (ii) Coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area
    (iii) Dam crest volume (megalitres);
    (iv) Spillway crest level (metres AHD).
    (v) Maximum operating level (metres AHD);
    (vi) Storage rating table of stored volume versus level (metres AHD);
    (vii) Design storage allowance (megalitres) and associated level of the dam (metres AHD);
    (viii) Mandatory reporting level (metres AHD);
(g) The design plan title and reference relevant to the dam;
(h) The date construction was certified as compliant with the design plan;
(i) The name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;
(j) Details of the composition and construction of any liner;
(k) The system for the detection of any leakage through the floor and sides of the dam;

(l) Dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;
(m) Dates when recommendations and actions arising from the annual inspection were provided to the administering authority;
(n) Dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

"regulated dam' means any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

"regulated structure" includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity.

"representative" means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

"residual drilling material" means waste drilling materials including muds and cuttings or cement returns from well holes and which have been left behind after the drilling fluids are pumped out.

"residual void" means an open pit resulting from the removal of ore and/or waste rock which will remain following the cessation of all mining activities and completion of rehabilitation processes.

"saline drainage" is the movement of waters, contaminated with salt(s), as a result of the mining activity.

"self sustaining" means an area of land which has been rehabilitated and has maintained the required acceptance criteria without human intervention for a period nominated by the administering authority.

"sensitive place" means;

(a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or
(b) a motel, hotel or hostel; or
(c) an educational institution; or
(d) a medical centre or hospital; or
(e) a protected area under the *Nature Conservation Act 1992*, the *Marine Parks Act 2004* or a World Heritage Area; or
(f) a public park or gardens.

"spillway" means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges form the dam, normally under flood conditions or in anticipation of flood conditions.

"stable" means land form dimensions are or will be stable within tolerable limits now and in the foreseeable future. Stability includes consideration of geotechnical stability, settlement and consolidation allowances, bearing capacity (trafficability), erosion resistance and geochemical stability with respect to seepage, leachate and related contaminant generation.

"stormwater" means all surface water runoff from rainfall.

"suitably qualified and experienced person" in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

(a) for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.

(b) for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

"system design plan" means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

"trivial harm" means environmental harm which is not material or serious environmental harm and will not cause actual or potential loss or damage to property of an amount of, or amounts totalling more than $5,000.

"void" means any man-made, open excavation in the ground.

"waste" as defined in section 13 of the Environmental Protection Act 1994.

"waste management hierarchy" has the meaning given by the *Waste Reduction and Recycling Act 2011*.

"waste water" means used water from the activity, process water or contaminated storm water.

"water quality" means the chemical, physical and biological condition of water.

"waters" includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

"water year" means the 12-month period from 1 July to 30 June. "**watercourse"** - means a river, creek or stream in which water flows permanently or intermittently in a visibly defined channel (natural, artificial or artificially improved) with:

(a) continuous bed and banks;
(b) an extended period of flow for some months after rain ceases, and
(c) an adequacy of flow that sustains basic ecological processes and maintains biodiversity.

"wet season" means the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive.

END OF DEFINITIONS

Figure 1: Burton Mine Monitoring and Release Points – Burton (RP's 6, 7, 9, 10 & 11)



Figure 2: Burton Mine Monitoring and Release Points – Plumtree (RP's 12 & 13)

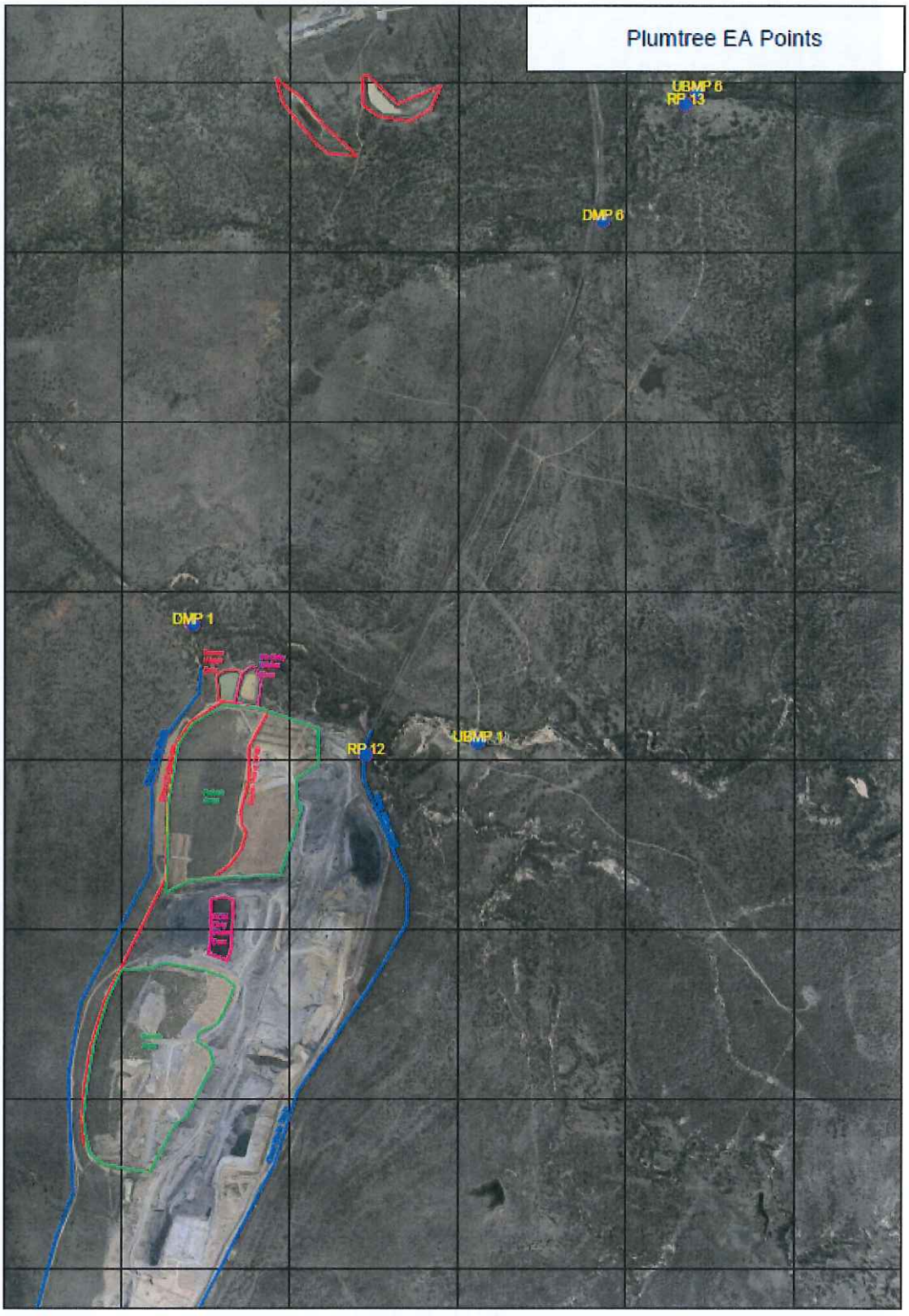
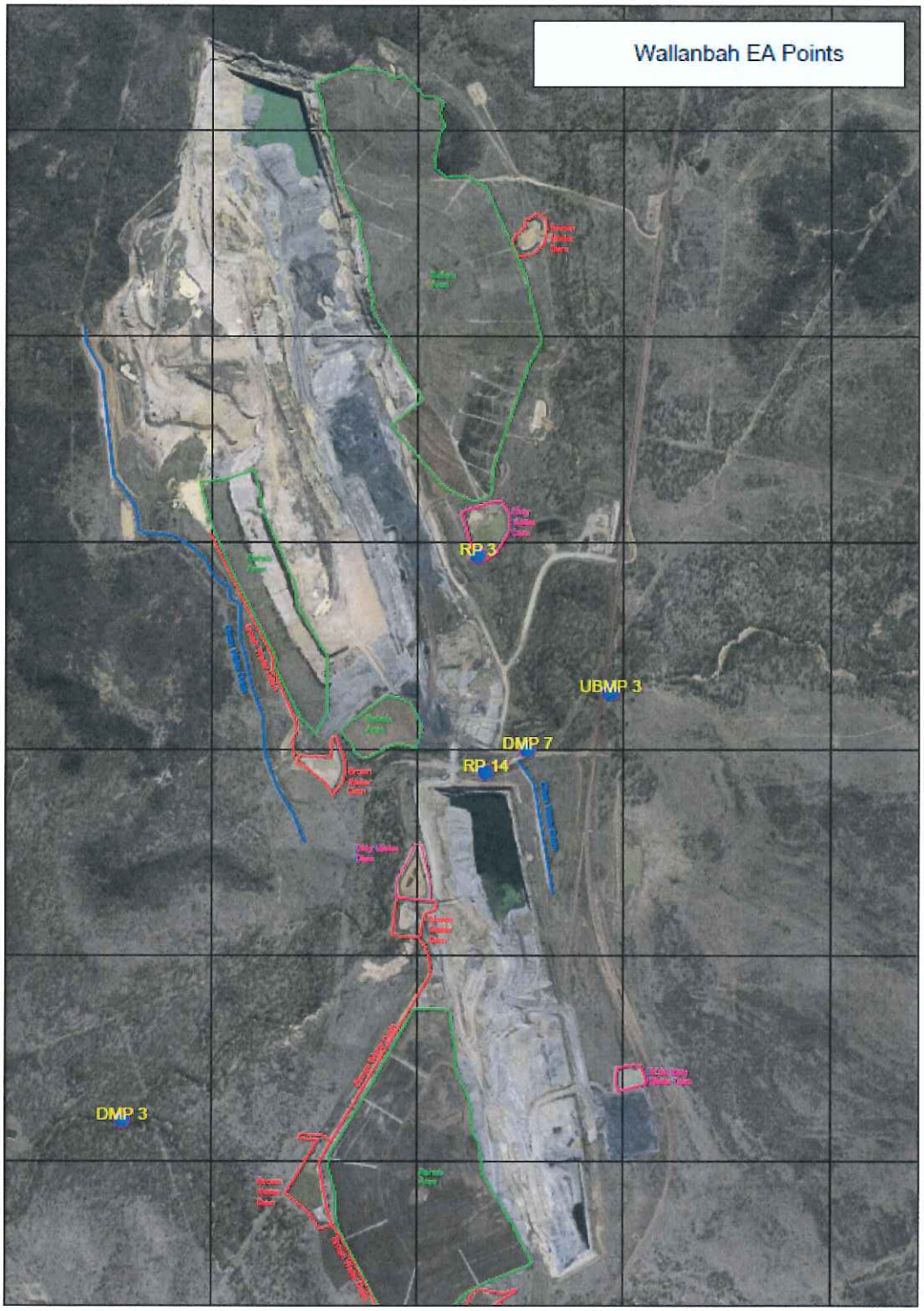


Figure 3: Burton Mine Monitoring and Release Points – Wallanbah (RP's 3 & 14)



END OF PERMIT

Appendix D – Environment management register (EMR) searches

Department of Environment and Heritage Protection (EHP)
ABN 46 640 294 485
400 George St Brisbane, Queensland 4000
GPO Box 2454 Brisbane QLD 4001 AUSTRALIA
www.ehp.qld.gov.au

SEARCH RESPONSE
ENVIRONMENTAL MANAGEMENT REGISTER (EMR)
CONTAMINATED LAND REGISTER (CLR)

Transaction ID: 50152976 EMR Site Id: 06 February 2015
This response relates to a search request received for the site:
Lot: 3 Plan: GV54

EMR RESULT

The above site is NOT included on the Environmental Management Register.

CLR RESULT

The above site is NOT included on the Contaminated Land Register.

ADDITIONAL ADVICE

If you have any queries in relation to this search please phone 13QGOV (13 74 68)

Registrar
Administering Authority

Department of Environment and Heritage Protection (EHP)
ABN 46 640 294 485
400 George St Brisbane, Queensland 4000
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www.ehp.qld.gov.au

SEARCH RESPONSE
ENVIRONMENTAL MANAGEMENT REGISTER (EMR)
CONTAMINATED LAND REGISTER (CLR)

Transaction ID: 50324120 EMR Site Id: 102531 30 September 2016

This response relates to a search request received for the site:

Lot: 4 Plan: SP252740

EMR RESULT

The above site IS included on the Environmental Management Register.

The site you have searched has been subdivided from the following site, which IS included on the EMR or the CLR.

Lot: 4 Plan: CP903281
Address: VIA PEAK DOWNS HIGHWAY
MORANBAH QLD 4744

The site has been subject to the following Notifiable Activity or Hazardous Contaminant.

MINE WASTES -
(a) storing hazardous mine or exploration wastes, including, for example, tailings dams, overburden or waste rock dumps containing hazardous contaminants; or
(b) exploring for, or mining or processing, minerals in a way that exposes faces, or releases groundwater, containing hazardous contaminants.

While sites are listed on the EMR using the lot and plan description, a mining lease may affect only a limited area of the lot. In many instances with rural properties, only a small area may be potentially affected by the mining activities and the ongoing landuse is unaffected. More detailed information relating to the location of the mining activities may be held by the Department of Environment and Heritage Protection or the Department of Natural Resources and Mines.

PETROLEUM PRODUCT OR OIL STORAGE - storing petroleum products or oil -
(a) in underground tanks with more than 200L capacity; or
(b) in above ground tanks with -
(i) for petroleum products or oil in class 3 in packaging groups 1 and 2 of the dangerous goods code - more than 2, 500L capacity; or
(ii) for petroleum products or oil in class 3 in packaging groups 3 of the dangerous goods code - more than 5, 000L capacity; or
(iii) for petroleum products that are combustible liquids in class C1 or C2 in Australian Standard AS1940, 'The storage and handling of flammable and combustible liquids' published by Standards Australia - more than 25, 000L capacity.

WASTE STORAGE, TREATMENT OR DISPOSAL - storing, treating, reprocessing or disposing of regulated waste (other than at the place it is generated), including operating a nightsoil disposal site or sewage treatment plant where the site or plant has a design capacity that is more than the equivalent of 50, 000 persons having sludge drying beds or on-site disposal facilities.

CLR RESULT

The above site is NOT included on the Contaminated Land Register.

ADDITIONAL ADVICE

All search responses include particulars of land listed in the EMR/CLR when the search was generated.
The EMR/CLR does NOT include:-

1. land which is contaminated land (or a complete list of contamination) if EHP has not been notified
2. land on which a notifiable activity is being or has been undertaken (or a complete list of activities) if EHP has not been notified

If you have any queries in relation to this search please phone 13QGOV (13 74 68)

Administering Authority

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SEARCH RESPONSE
ENVIRONMENTAL MANAGEMENT REGISTER (EMR)
CONTAMINATED LAND REGISTER (CLR)

Transaction ID: 50321986 EMR Site Id: 31060 22 September 2016
This response relates to a search request received for the site:
Lot: 9 Plan: RP903903

EMR RESULT

The above site IS included on the Environmental Management Register.
Lot: 9 Plan: RP903903
Address: SUTTOR DEVELOPMENT ROAD
VIA GLENDON 4743

The site has been subject to the following Notifiable Activity or Hazardous Contaminant.
CHEMICAL STORAGE - (other than petroleum products or oil under item 29) - storing more than 10 t of chemicals (other than compressed or liquefied gases) that are dangerous goods under the dangerous goods code.
PETROLEUM PRODUCT OR OIL STORAGE - storing petroleum products or oil -
(a) in underground tanks with more than 200L capacity; or
(b) in above ground tanks with -
(i) for petroleum products or oil in class 3 in packaging groups 1 and 2 of the dangerous goods code - more than 2, 500L capacity; or
(ii) for petroleum products or oil in class 3 in packaging groups 3 of the dangerous goods code - more than 5, 000L capacity; or
(iii) for petroleum products that are combustible liquids in class C1 or C2 in Australian Standard AS1940, 'The storage and handling of flammable and combustible liquids' published by Standards Australia - more than 25, 000L capacity.
WASTE STORAGE, TREATMENT OR DISPOSAL - storing, treating, reprocessing or disposing of regulated waste (other than at the place it is generated), including operating a nightsoil disposal site or sewage treatment plant where the site or plant has a design capacity that is more than the equivalent of 50, 000 persons having sludge drying beds or on-site disposal facilities.
MINE WASTES -
(a) storing hazardous mine or exploration wastes, including, for example, tailings dams, overburden or waste rock dumps containing hazardous contaminants; or
(b) exploring for, or mining or processing, minerals in a way that exposes faces, or releases groundwater, containing hazardous contaminants.

While sites are listed on the EMR using the lot and plan description, a mining lease may affect only a limited area of the lot. In many instances with rural properties, only a small area may be potentially affected by the mining activities and the ongoing landuse is unaffected. More detailed information relating to the location of the mining activities may be held by the Department of Environment and Heritage Protection or the Department of Natural Resources and Mines.

LIVESTOCK DIP OR SPRAY RACE - operating a livestock dip or spray race facility.

For the majority of rural properties only a small area may be affected by the chemicals used in livestock dips and spray races. The Department of Environment and Heritage Protection may hold further

information relating to the location of the dip site within this property.

CLR RESULT

The above site is NOT included on the Contaminated Land Register.

ADDITIONAL ADVICE

All search responses include particulars of land listed in the EMR/CLR when the search was generated.
The EMR/CLR does NOT include:-

1. land which is contaminated land (or a complete list of contamination) if EHP has not been notified
2. land on which a notifiable activity is being or has been undertaken (or a complete list of activities) if EHP has not been notified

If you have any queries in relation to this search please phone 13QGOV (13 74 68)

Administering Authority

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SEARCH RESPONSE
ENVIRONMENTAL MANAGEMENT REGISTER (EMR)
CONTAMINATED LAND REGISTER (CLR)

Transaction ID: 50324165 EMR Site Id: 78772 30 September 2016
This response relates to a search request received for the site:
Lot: 13 Plan: SP178466

EMR RESULT

The above site IS included on the Environmental Management Register.

The site you have searched has been subdivided from the following site, which IS included on the EMR or the CLR.

Lot: 1 Plan: CP907954
Address: BROADMEADOWS ROAD
BELYANDO 4721

The site has been subject to the following Notifiable Activity or Hazardous Contaminant.
PETROLEUM PRODUCT OR OIL STORAGE - storing petroleum products or oil -
(a) in underground tanks with more than 200L capacity; or
(b) in above ground tanks with -
(i) for petroleum products or oil in class 3 in packaging groups 1 and 2 of the dangerous goods code - more than 2, 500L capacity; or
(ii) for petroleum products or oil in class 3 in packaging groups 3 of the dangerous goods code - more than 5, 000L capacity; or
(iii) for petroleum products that are combustible liquids in class C1 or C2 in Australian Standard AS1940, 'The storage and handling of flammable and combustible liquids' published by Standards Australia - more than 25, 000L capacity.

CLR RESULT

The above site is NOT included on the Contaminated Land Register.

ADDITIONAL ADVICE

All search responses include particulars of land listed in the EMR/CLR when the search was generated.
The EMR/CLR does NOT include:-

1. land which is contaminated land (or a complete list of contamination) if EHP has not been notified
2. land on which a notifiable activity is being or has been undertaken (or a complete list of activities) if EHP has not been notified

If you have any queries in relation to this search please phone 13QGOV (13 74 68)

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SEARCH RESPONSE
ENVIRONMENTAL MANAGEMENT REGISTER (EMR)
CONTAMINATED LAND REGISTER (CLR)

Transaction ID: 50321990 EMR Site Id: 22 September 2016
This response relates to a search request received for the site:
Lot: 5311 Plan: SP262721

EMR RESULT

The above site is NOT included on the Environmental Management Register.

CLR RESULT

The above site is NOT included on the Contaminated Land Register.

ADDITIONAL ADVICE

All search responses include particulars of land listed in the EMR/CLR when the search was generated.
The EMR/CLR does NOT include:-

1. land which is contaminated land (or a complete list of contamination) if EHP has not been notified
2. land on which a notifiable activity is being or has been undertaken (or a complete list of activities) if EHP has not been notified

If you have any queries in relation to this search please phone 13QGOV (13 74 68)

Administering Authority

Department of Environment and Heritage Protection (EHP)
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400 George St Brisbane, Queensland 4000
GPO Box 2454 Brisbane QLD 4001 AUSTRALIA
www.ehp.qld.gov.au

SEARCH RESPONSE
ENVIRONMENTAL MANAGEMENT REGISTER (EMR)
CONTAMINATED LAND REGISTER (CLR)

Transaction ID: 50322356 EMR Site Id: 25 September 2016
This response relates to a search request received for the site:
Lot: 3 Plan: GV54

EMR RESULT

The above site is NOT included on the Environmental Management Register.

CLR RESULT

The above site is NOT included on the Contaminated Land Register.

ADDITIONAL ADVICE

All search responses include particulars of land listed in the EMR/CLR when the search was generated.
The EMR/CLR does NOT include:-

1. land which is contaminated land (or a complete list of contamination) if EHP has not been notified
2. land on which a notifiable activity is being or has been undertaken (or a complete list of activities) if EHP has not been notified

If you have any queries in relation to this search please phone 13QGOV (13 74 68)

Administering Authority

Department of Environment and Heritage Protection (EHP)
ABN 46 640 294 485
400 George St Brisbane, Queensland 4000
GPO Box 2454 Brisbane QLD 4001 AUSTRALIA
www.ehp.qld.gov.au

SEARCH RESPONSE
ENVIRONMENTAL MANAGEMENT REGISTER (EMR)
CONTAMINATED LAND REGISTER (CLR)

Transaction ID: 49690670 EMR Site Id: 80582 09 April 2014
This response relates to a search request received for the site:
Lot: 18 Plan: SP208194

This response relates to a search request received for the site:
The site you have searched has been subdivided from the following site, which is included on the EMR. Subdivided new parcels will remain on the EMR unless it can be shown that they are not located near the contaminating activity.

Lot: 1 Plan: CP907954
Address: BROADMEADOWS ROAD
BELYANDO 4721

The site has been subject to the following Notifiable Activity pursuant to section 374 of the *Environmental Protection Act 1994.*
PETROLEUM PRODUCT OR OIL STORAGE - storing petroleum products or oil -
(a) in underground tanks with more than 200L capacity; or
(b) in above ground tanks with -
(i) for petroleum products or oil in class 3 in packaging groups 1 and 2 of the dangerous goods code - more than 2, 500L capacity; or
(ii) for petroleum products or oil in class 3 in packaging groups 3 of the dangerous goods code - more than 5, 000L capacity; or
(iii) for petroleum products that are combustible liquids in class C1 or C2 in Australian Standard AS1940, 'The storage and handling of flammable and combustible liquids' published by Standards Australia - more than 25, 000L capacity.

CLR RESULT

The above site is NOT included on the Contaminated Land Register.

ADDITIONAL ADVICE

If you have any queries in relation to this search please phone 13QGOV (13 74 68)

Registrar
Administering Authority

Appendix E – Risk Assessment

Area of Environmental Interest (AEC)	Site Name	Proposed plan	Human Health Risk (HR)	Environmental Risk (ER)	Regulatory/Law Risk (RR)	Financial Risk (FR)	Justification	Action Required
F	Wallanbah hardstand Figure 10.1	Area cleared of all infrastructure	Low (2) Unlikely	Minor (6) Possible	Moderate (15) Possible	Minor (6) Possible	**HR**: Historically there was fuel farm and workshop, but no reported spills. Residual risk can be managed via implementation of appropriate OH&S measures. **ER**: Bulk fuel storage, wash bay dam, and waste (dirty) water dam may pose contamination risk, and Bullock Creek is located adjacent to the site. Potential S-P-R identified in CSM. Consider quantitative assessment to confirm risk rating (and possibly reduce it). **RR**: EA stipulates that formal documentation of the closure methodology / execution including validation sampling (to provide quantitative evidence) and reporting be undertaken. If action is taken risk score may be reduced to MINOR. **FR**: Intrusive investigation and minor clean-up/reporting may be required.	- Prepare SAP for intrusive investigation and validation at identified AEC, especially in areas of in-ground wash bay sump, wash bay infrastructures and former AST/workshop locations. - Remediation and validation (documented) will be required if contamination is identified.
G	Workshop area Figure 11.1	Majority of infrastructure to remain	Low (3) Possible	Minor (6) Possible	Moderate (15) Possible	Moderate (15) Possible	**HR:** Historically through out its operation there has been minor spills, chemical solvent/oil storage on site. Most contamination will end up in the wash bay dam. But dermal risk can be managed via implementation of appropriate OH&S measures. **ER**: Potential integrity failure of waste (dirty) water drainage collection system, waste oil/exposed products/bateries stored outside of bunded area, historical minor spills were reported. potential cumulative impacts (hydrocarbon and heavy metal) especially in the wash bay infrastructure. No sensitive ecological receptors identified in CSM (assumed deep GW aquifer not impacted) so limited or no S-P-R linkage. **RR**: EA require a more formal documentated closure including validation. If action is taken, risk score may be reduced to MINOR. **FR**: May require clean-up and validation following intrusive investigation which may exceed $100k (conservative estimate).	- Prepare SAP and undertake intrusive site investigation for AEC identified - Remediation and validation will be required for identified contamination (if any).
H	Workshop fuel farm Figure 12.1	Tanks to be removed	Low (3) Possible	Minor (6) Possible	Moderate (15) Possible	Moderate (15) Possible	**HR**: Historically through out its operation there has been minor spills (dispensing/refilling activities), oil storage on site but dermal risk be managed by imlpementation of appropriate OH&S measures. **ER**: Potential integrity failure of waste (dirty) water drainage collection system (and preferential pathway for contamination migration), historical minor spills with documented closure. Cumulative impacts especially in the wash bay infrastructure. However no sensitive receptors were identified in CSM. **RR**: EA stipulates that formal documentation of the closure methodology / execution including validation sampling (to provide quantitative evidence) and reporting be undertaken. If action is taken risk score may be reduced to MINOR. **FR**: May require clean-up and validation following intrusive investigation which may exceed $100k (conservative estimate).	- As part of decomissioning, vessels and pipelines and associated infrastrucutres should be evacuated and flushed to an appropriate receiving container. - With any redundant infrastructures (i.e. waste water drainage) to be isolated from operational system. - Prepare SAP and undertake intrusive site investigation for AEC identified - Remediation and validation will be required for idenfied contamination (if any).
L	BIS workshop Figure 16.1	Some infrastructure to be removed. Bulk diesel tank to remain and in operation	Low (3) Possible	Minor (6) Possible	Moderate (15) Possible	Moderate (15) Possible	**HR**: Historically through out its operation there has been minor spills, chemical solvent/oil storage on site. Packaged sewage treatment plant is not listed on EA, but effluent discharge location is unclear. Dermal risk be managed by implementation of appropriate OH&S measures. **ER**: Fuel oil storage and dispensing and minor localised spills (some potentially captured by the wash bay sump). Waste (dirty) water drainage collection system not functioning properly, potential for localised contamination impact wash bay infrastructure and collection system (i.e. water dams). Condition of the wash water treatment system was noted to be poor. Possible S-P-R likages identified but likely to be contained on site and adjacent mine infrastructure. **RR**: EA stipulates that formal documentation of the closure methodology / execution including validation sampling (to provide quantitative evidence) and reporting be undertaken. If action is taken risk score may be reduced to MINOR. **FR**:May require clean-up and validation following intrusive investigation which may exceed $100k (conservative estimate).	- If the fuel storage system is to be retained, install gate valves and repair penetration on bunds. All visual contamination should be removed. If the fuel storage is to be removed, prepare a SAP for intrusive site investigation, and remediation and validation will be required as the facility is a major fuel storage. - It is recommended that the wash bay colllection and treatment system to be retained, as it helps collects dispensing fuel spill on site. The system should be serviced and visual contamination should be removed. On decomissioning, undertake remediation and validation as required if extensive subsurface contamination been identified.
M	Sewage treatment plant Figure 17.1	Plant to be removed from site	Low (2) Unlikely	Low (2) Unlikely	Moderate (15) Possible	Low (2) Unlikely	**HR**: Microbial contamination, but managed by implementation of appropriate OH&S measures. Primary contact with effluent/sludges is not likely. (No S-P-R linkage identified). **ER**: Discharge of effluent is managed under the EA criteria and sewage treatment plant only receive domestic waste (low potential for industrial waste/contamination). No clear S-P-R linkage identified. **RR**: EA stipulates that formal documentation of the closure methodology / execution including validation sampling (to provide quantitative evidence) and reporting be undertaken. If action is taken risk score may be reduced to MINOR. **FR**: Low expectation of extensive contamination.	- Maintain infrastructure in good condition for future use if required. - When the site is decommissioned, clean and remove residual waste prior to demolition. - Sewage sludge dams and disposal area will require residues to be removed and disposed of appropriately. - Validation should be underataken at all infrastructures locations (including irrigation area) to demonstrate there is no residual contamination on site. - Implementation a site management plan to allow attenuation of any potential biological risk on site.
A	Blast Magazine (Wallanbah) Figure 5.1	Tanks and infrastructure will be removed	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR**: Potential dermal exposure managed by implementation of appropriate OH&S measures. **ER**: High / stringent level of management of PCoC (Explosive products). No historical spills recorded. No sign of contamination based on site inspection. **RR**: Documentation of decommisioning may be required under*Explosives Act* and *Coal Mining Safety and Health Act* . **FR**: Low expectation of contamination	- Ensure removal of magazines in accordance to the relevant legislation and license requirements and document all actions taken. - Site to be rehabilitated to surrounding landform when required.
B	Ex-Orica Reload Facility Figure 6.1	Tanks and infrastructure will be removed	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR**: Dermal exposure managed by implementation of appropriate OH&S measures. PCoC includes diesel and AN. Minor historical spills recorded on site. CSM S-P-R linkage not likely. **ER:** High / stringent level of management of PCoC. Discrete materials and low volume. Not all clean up actions closed off but assumed all spills were remediated due to safety requirements. No visual indication of gross contamination based on site inspection. CSM S-P-R linkage considered not likely. **RR**: Not considered to be non-compliance of regulatory/legislations. Limited potential for environmental harm to have occured is expected. **FR**: Low expectation of contamination and hence potential clean-up costs are*Low* .	- To provide further contamination that no potential contamination underlies former ASTs, exploratory test pitting to be undertaken. - If gross contamination is identified, sampling analysis, remediation and validation and document all actions undertaken. All actions should be documented.
C	Burton Widening Reload Facility Figure 7.1	ANFO products removed	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR**: Dermal exposure managed by implementation of appropriate OH&S measures. PCoC includes diesel and AN. No historical spills recorded on site. CSM S-P-R linkage not likely. **ER**: High / stringent level of management of PCoC. Discrete materials and low volume. Assumed all spills are remediated due to safety requirements. CSM S-P-R linkage not likely. **RR:** Not considered to be non-compliance of regulatory/legislations. Limited potential for environmental harm to have occured is expected. **FR**: Low expectation of contamination.	- On decommissioning of site, undertake visual assessment and exploratory test pitting to further confirm non -contamination status of the area. - If gross contamination is identified, sampling analysis, remediation and validation and document all actions undertaken. All actions should be documented.

Area of Environmental Interest (AEC)	Site Name	Proposed plan	Human Health Risk (HR)	Environmental Risk (ER)	Regulatory/Law Risk (RR)	Financial Risk (FR)	Justification	Action Required
D	Plumtree excavator laydown Figure 8.1	Area cleared of all infrastructure	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR**: No historical spills recorded. Dermal exposure managed by implementation of appropriate OH&S measures. No S-P-R linkage identified in CSM. **ER**: No permanent facilities noted. A creek located north, but all minor spills will be attenuated. No S-P-R linkage identified in CSM (no source). **RR**: Operational site due diligence demonstrated by spill register and environmental responses. **FR**: Low expectation of contamination.	- Site to be rehabilitated to surrounding landform as scheduled. - If contamination was identified in future rehabilitation, assessment and remediation may be required.
E	Demob pad/compound Figure 9.1	Area to be cleared in following 12 months	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR:** No historical spills recorded, but small discrete localised staining on surface ground during site inspection. No clear S-P-R linkages identified. **ER:** No historical spills recorded, but small discrete localised staining on surface ground during site inspection. No clear S-P-R linkages identified **RR:** Due-Dilligence demonstrated by spill register and environmental responses. Possible EA (sand blasting undertaken on site) required documentation of closure and validation. **FR:** Low expectation of contamination.	- All debris and scraps on site is properly disposed of off site, including any areas of significant staining and to be appropriately disposed of. - If subsurface contamination is identified, remediation and validation to be undertaken. All actions should be documented.
I	Mallawa train loadout Figure 13.1	Diesel tanks be degassed but remain onsite	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR:** No S-P-R likages identified in CSM, dermal risk managed through implementation of appropriate OH&S measures. **ER:** Primary dispensing spills at the facility and transport to sediment dam located south of the facility, assuming no beneficial use (irrigation and stock watering). **RR:** Minor storage of fuel, site is managed through due-dilligence and Peabody procedures. **FR:** Low expectation of extensive contamination.	- On decommissioning of site, undertake visual assessment and exploratory test pitting to further confirm non -contamination status of the area. - If subsurface contamination is identified, remediation and validation to be undertaken. All actions should be documented.
J	Bullock Creek former workshop site Figure 14.1	Area cleared of all infrastructure	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR**: Absence of infrastructures, any residual risk managed by implementation of appropriate OH&S measures. **ER**: Assuming low quantity of fuel storage (no mention of EA in any POO), however no documentation/information on fuel storage and workshop available. Assume there could be some minor contamination remaining onsite, and demolished slabs had been encapsulated on site. No clear S-P-R likages identified in CSM. **RR**: Minor storage of fuel, site is managed through due-dilligence and Peabody procedures. **FR**: Low expectation of gross wide-spread contamination.	- In the absence of historical information, undertake exploratory intrusive investigation to confirm the non-contamination status at the former locations of ASTs and workshop. - If subsurface contamination is identified, remediation and validation to be undertaken. All actions should be documented.
K	Burton Widening north demob pad Figure 15.1	Area to be cleared of vehicles and equipments in following 12 months	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR**: Potential minor and isolated contamination may occur on site, managed by implementation of appropriate OH&S measures. No S-P-R likage indentified. **ER**: Functional area was only built recently, no permanent fuel infrastructures on site. Only fitting/dismantling vehicles and load out. Run-off will end up in the adjacent pit, no S-P-R linkage identified in CSM. **RR:** Site is managed through due-dilligence and Peabody procedures. **FR:** Low expectation of extensive contamination.	- Any debris or waste on site is properly disposed of off site, including any areas of significant staining and to be appropriately disposed of. - If subsurface contamination is identified, remediation and validation to be undertaken. All actions should be documented.
N	CHPP Figure 18.1	Tanks be degassed but structure remain onsite	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR:** The reagent storage area managed by implementation of appropriate OH&S measures. **ER:** Reagent storage area contains ASTs, have been previously documented in POOs including MIBC. Any potential contamination (surface runoff and shallow perched water) are likely to be localised, no S-P-R linkage identified for sensitive receptors. **RR:** Managed and maintained under Peabody procedures. **FR:** Low expectation of contamination and associated clean up cost at this stage.	- For the reagent storage system to be retained, all visual contamination should be removed (including temporary IBCs storage area). - If the reagent ASTs to be removed in the future, undertake intrusive site investigation, and, remediation and validation as required.
O	Water Treatment Plant Figure 19.1	Area cleared of all infrastructure	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR:** Not likely to cause human health risk from undertaking water treatement on site, chemical storage and use is managed through implementation of appropriate OH&S measures. **ER:** Chemical storage and sludge management (storing on site) and back-up generator. But no S-P-R linkage identified in CSM. **RR:** Managed and maintained under Peabody procedures. **FR:** Low expectation of contamination.	- Appropriate decommisioning and removal of chemicals and equipment. - Undertake cleaning of dams and appropriate disposal of sludge. - Validation report/documentation of the decommissioning.
P	Kerlong Accomodation Village - Generators, AST and maintenance sheds Figure 20.1	Area cleared of all infrastructure	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	Low (2) Unlikely	**HR:** Human health risk managed by implementation of appropriate OH&S measures. **ER:** Leaks from generators/AST, minor spills of from maintenance/dispensing, likely to small volume and localised, and likely to be cleaned-up immediately. **RR:** Managed and maintained under Peabody procedures. **FR:** Low expectation of extensive contamination.	- On decommissioning of site, undertake visual assessment and document. - If subsurface contamination is identified, remediation and validation to be undertaken. All actions should be documented.

Table Notes

S-P-R	Source-pathway-receptor
SAP	Sampling Analysis Plan
AEC	Areas of Environmental Concern
PCoC	Potential Contaminants of Concern
CSM	Conceptual Site Model
EA	Environmental Authority
POO	Plan of Operation

EA conditions related to Site Contamination

E4	Site Contamination will be assessed at relinquishment of the mining tenure according to the Environmental Protection Act 1994, with results and any required remediation actions detailed in the Final Rehabilitation Report.
E6	Regulated waste disposal areas on the mining lease will be capped with one metre of inert material and revegetated in accordance with available and recognised best practice following the cessation of their use as disposal areas in a manner that will encourage run-off.
F1	All areas significantly disturbed by mining activities must be rehabitated to a stable landform with a self-sustaining vegetation cover in accordance with Table F14

Buildings, Road, ROM, Camp, Laydown - Facilities to be either left for future users or sold for removal with the site rehabilitated to grassland or bushland, dependant on original use. Contaminated areas to be remediated in consultation with the Administering Authority. Contaminated Areas have been identified and will be rehabilitated on a case by case basis from a stage 2 Contaminated Land Survey.

General recommendations:

If gross contamination is discovered in sub-surface during intrusive site investigation, or infrastructure deconstruction, it is recommended that groundwater investigation bores be installed to assess the groundwater impact. Followed by remediation and validation if required.
This risk assessment has been prepared on the basis that the site will go into care and maintenance. If full closure of the AEC is required, it is recommended that intrusive investigation with sampling analysis to be undertaken.
During care and maintenance phase, it is recommended that potential contamination sources (fuel, chemicals) be removed from the AEC.
If ASTs remain on site an exploratory test pit should be taken next to the facility to assess the contamination status.
All actions including intrusive site investigation, decommissioining, test pitting should be documented / recorded appropriately so it can be used for future planning. If the documents will be used in future mine closure assessment, these should be signed off by a suitably qualified person (SQP).

			Consequence					
Likelihood	***Likelihood description***	***Probability***	**Low (1)**	**Minor (2)**	**Moderate (5)**	**Significant (10)**	**Major (25)**	**Catastrophic (50)**
5 - Very Likely	Likely to occur repeatedly – Expected in the work team	**10% - 100%**	**5**	**10**	**25**	**50**	**125**	**250**
4 - Likely	Probably will occur several times - Expected at this location	**1% - 10%**	**4**	**8**	**20**	**40**	**100**	**200**
3 - Possible	Could occur intermittently - Expected within Peabody	**0.1% - 1%**	**3**	**6**	**15**	**30**	**75**	**150**
2 - Unlikely	Could occur but hardly ever - Expected within the mining industry	**0.01% - 0.1%**	**2**	**4**	**10**	**20**	**50**	**100**
1 - Rare	Improbable or unrealistic - Not expected in the mining industry but seen in other industries	**< 0.01%**	**1**	**2**	**5**	**10**	**25**	**50**

			Consequence descriptions					
	Consequence Category		**Low**	**Minor**	**Moderate**	**Significant**	**Major**	**Catastrophic**
	Harm to People	**P**	Near miss, near hit, no medical treatment, report only (RO)	Slightly injured, first aid treatment (FAI)	Medical treatment (MTI), disabling reversible impairment, restricted work (RWI) or lost time (LTI)	Serious bodily injury or disabling irreversible impairment, permanent partial disability (PPD)	Single fatality incident. Total and permanent disability (TPD). Major irreversible health effects	Multiple fatality incident. Major injury / disease among multiple employees
	Environmental	**E**	Negligible or reversible environmental impact Nil to minor remediation (typically a shift) No breach of regulations or requirement to report to regulators	Minor reversible environmental impact, minor remediation (typically < 5 days) Non-compliances and breaches of regulation that may result in a citation (NOV) May require reporting to the regulators	Incident resulting in moderate reversible onsite and/or off-site impact causing short term effect. Moderate remediation required (typically a month) Non-compliances and breaches of regulation that may result in prosecution or citation or punitive fine. Requirement or obligation to report to the regulators	Incident resulting in significant onsite or off-site environmental impact causing medium to long term environmental harm Significant remediation required (typically less than 12 months) Significant legal issues, non-compliances and breaches of regulation that results in a prosecution or citation or fine Moderate litigation issues involving many weeks of senior management time	A major incident resulting in regional environmental impact causing long term environmental harm Major long term remediation required (greater than 12 months) Major litigation or prosecution resulting in long term interruption to operations or loss of licence at a site	Incident resulting in catastrophic widespread regional environmental harm causing disastrous effect Major long term remediation required (over multiple years) Major litigation or prosecution , Loss of License to operate at Multiple sites
	Finance (higher of cost or NPV)	**F**	<$10,000	$10,000 - $100,000	$100,000 - $1 mil	$1 mil - $20 mil	$ 20 mil-$100 mil	>$100 mil
	Impact on reputation	**R**	Minor impact, no public concern; Market cap impact < $20 M (< $0.07 per share)	Local media or public concern; Market cap impact $20 M - $30 M ($0.07 - $0.12 per share)	Regional media or public concern. Local criticism; Market cap impact $30 M - $100 M ($0.12 - $0.40 per share)	National adverse media or public criticism; Market cap impact $100 M - $250 M ($0.40 - $1.00 per share)	International adverse media or public criticism. International public concern; Market cap impact $250 M - $500 M ($1.00 - $1.85 per share)	Significant international public or media criticism or condemnation; Market cap impact > $500 M (> $1.85 per share)
	Law / Compliance / regulatory	**C**	Minor, one-off violations of law, regulation, permit or policy; minimal fines, penalties or costs	Recurring or systemic minor violations of law, regulation, permit or policy	Violations of law, regulation, permit or policy with moderate fines or penalties, Moderate Litigation, MSHA imminent danger order or similar	Significant violation of law or permit with material fines, penalties or costs. Serious dispute with strategic customer. Major Litigation	Material Litigation. Serious investigation by SEC, DOJ or foreign equivalent. Code of Conduct violations	Criminal investigation or proceedings involving officers or directors. Litigation with allegations of executive fraud or misappropriation
	Strategic risk	**SR**	Event does not have a meaningful impact to Strategic Outlook	Event does not have meaningful impact to Strategic Outlook, but may require further monitoring	Event may have a material impact on near-term outlook for a region or mine	Event has a material impact on strategic outlook for a region or basin that may require a change to operations to mitigate risk	Event causes mines in a region or basin to cease current operations	Event or threat such that BTU would cease to exist as an ongoing concern in coal operations

Risk Score	**Notification**	**Level**	**Action (H&S)**
0	Crew / team	Same level	Develop a plan (formal or informal) with crew or continue with and established plan (SOP etc.) that ensures the task can be completed safely. Team should remain aware for changing conditions.
11	Supervisor	.+1	Develop a formal safe action plan with supervisor and others within the crew (SOP) that identifies all known hazards and details what controls need to be place and how the task should be performed to ensure it can be completed safely.
31	Area manager or site GM	.+2	Conduct a formalized risk review of existing work process and controls. Explore additional control options that eliminate, substitute or reduce the risk. Monitor controls for effectiveness during the task.
51	BU Mgt	.+3	Controls should be reviewed to ensure risk is as low as reasonably practicable (ALARP), critical controls must be identified and monitored for effectiveness. If risk is not at ALARP, additional controls must be identified and a plan developed for implementation.
101	ELT	.+4	Controls should be added / improved and an additional risk assessment completed for activity to proceed.
200	CEO	.+5	Controls should be added / improved and an additional risk assessment completed for activity to proceed.

Appendix F – Site Functional Areas SAPs

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		Name	Signature	Name	Signature	Date
0	Steve Lawrence	B Ng				
1	B Ng	N Stemmett		N Stemmett	On File	7/04/2017

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Appendix R
ERE revegetation plan



AECOM Imagine it. Delivered.

Regional Ecosystem Revegetation Management Plan
Peabody Energy Australia
31-Jan-2018
Doc No. 60548018

Burton ERE Revegetation Management Plan



Burton ERE Revegetation Management Plan

Client: Peabody Energy Australia

ABN: 63077679515

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Quality Information

Document Burton ERE Revegetation Management Plan

Ref 60548018

Date 31-Jan-2018

Prepared by Mallory Barnes

Reviewed by Dee Murdoch

Revision History

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			Name/Position	Signature
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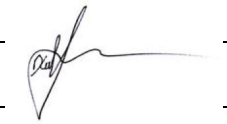
0	31-Jan-2018	Final Issue	David Gatfield Project Manager	

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Parthenium Weed Fact Sheet A

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1.0 Introduction and Management Objectives

1.1 Background

Peabody Australia's (PA) Burton Coal Mine is subject to the Environmental Authority EPML00879213 (11 October 2016) (herein EA) under Queensland's *Environmental Protection Act 1994*. Condition F1, Table F15 (page 32) in the EA details the final land use and approval schedule for the 7 hectare (ha) Bullock Creek Diversion. The EA stipulates this area is to: "…*reproduce as close as practical the Brigalow – Dawson Gum woodland community (Endangered Regional Ecosystem 11.9.1)..."* The condition also lists a number of flora species that the rehabilitated area must comprise and dictates that the rehabilitated area and adjacent endangered regional ecosystem (ERE) area must be fenced (see Table 1 for an extract of condition F1). AECOM Australia Pty Ltd (AECOM) notes that a number of the recommended species listed in the EA are incorrectly spelt, and have included the correct spelling below as intended.

The purpose of this Revegetation Management Plan is to describe the methodology proposed to meet the EA conditions in Table 1 and re-establish a Brigalow - Dawson gum woodland in the Bullock Creek Diversion Area. In developing this methodology, AECOM undertook a literature review and field assessment, as well as consulting Dr. John Dwyer of the University of Queensland. Many of the methods have arisen out of the key findings from the Burton ERE Revegetation Management Plan Technical Report (AECOM, 2017).

Table 1 Extract of EA EPML00879213 Condition F1, Table F15 - Bullock Creek Diversion

Disturbance Area	Projective Surface Area (ha)	Post Mine Land Use	Post Mine Land Capability Classification	Post Mine Land Suitability Classification
Bullock Creek Diversion (Endangered Regional Ecosystems)	7 ha	Self-sustaining native vegetation	VI-VII	3-4
	Rehabilitation Methods			
	Offset plant greater than area of ERE cleared. Topsoil from ERE area recovered in separate stockpile and utilized in ERE offset planning locations. A mixture of seed and tubestock native tree, grass and shrub species which must include *Eucalyptus cambageana, Acacia harpophylla, Flindersia dissosperma, Eremophila, Carissa ovata, Alectryon diversifolius, Capparis lasiantha, Eucalyptus populnea, Eremophila mitchelli* and *Sorghum nitidum* to reproduce as close as practical the Brigalow – Dawson gum woodland community (Endangered Regional Ecosystem 11.9.1). The rehabilitated area and remaining ERE shall be fenced.			

1.2 Site Description of the Bullock Creek Diversion

The Bullock Creek Diversion is located within the Peabody-controlled Burton Coal Mine. Burton Coal Mine is situated within the northern Brigalow Belt, approximately 140 kilometres (km) south-west of Mackay and 12 km north-west of Moranbah. The Bullock Creek Diversion is located approximately 20 km from the Burton Coal Mine's entrance off Suttor Development Road. Bullock Creek Diversion and the proposed revegetation area are depicted in Figure 1. Currently, the Bullock Creek Diversion is a modified landscape, dominated by exotic grasses, including *Cenchrus ciliaris* (Buffel grass). It is understood that in addition to the originally proposed 7 ha area (8.6 ha Figure 1), PA may also be interested in increasing the footprint of the ERE revegetation to include:

- **Option A -** The narrow strip between the toe of dump and the woodland running from the south-eastern corner of the Creek Diversion Area (an additional 1.2 hectares and 945.7 metres (m))
- **Option B -** The narrow strip between the toe of dump and the woodland running from the south-eastern corner of the Creek Diversion Area as well as the infilled dam area (an additional 1.7 ha and 1698.6 m).



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AGD 1984 AMG Zone 55

0 50 100 200
metres

1:7,500 (when printed at A4)

LEGEND

- Site location
- Pipeline
- Mining lease
- ERE revegetation perimeter fence line
- 20m x 20m islands of tube stock and coarse woody debris
- 2m slashing zone
- Additional Revegetation Area - Option A
- Additional Revegetation Area - Option B
- Course woody debris
- Ripping zone along contours

Data sources:
© The State of Qld (Dept of Natural Resources and Mines) 2012 Imagery; 2017

Burton ERE Revegetation Plan

RECOMMENDED TREATMENT

PROJECT ID	60548018
CREATED BY	XL
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Figure 1

Filename: P:\60SX\60548018\4. Tech Work Area\4.99 GIS\02_MXDs\02 Recommended Treatment\P60548018_RecTreatment_Location_v2_20170922.mxd

A4 size

1.3 Brigalow Ecosystem Features and ERE Description

Brigalow is the common name applied to *Acacia harpophylla* and to the woodlands in which this species dominates or co-dominates. Brigalow occurs predominantly in Central Queensland in what is known as the Brigalow Belt. Brigalow is a leguminous, nitrogen-fixing tree species that forms open forests in association with other species, such as *Eucalyptus cambageana* (Dawson gum), in the semi-arid tropical and sub-tropical regions of eastern Australia (Isbell, 1962). A total of 18 Brigalow regional ecosystems (REs) are listed as Endangered under the Queensland *Vegetation Management Act 1999* (Butler , 2008), whilst the Brigalow community also forms an Endangered Threatened Ecological Community (TEC) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

The following features characterise RE 11.9.1 and have informed the development of this management plan (Queensland Government , 2017):

- Slopes and crests of undulating plains and low ridges and escarpments formed from Cainozoic to Proterozoic consolidated, fine-grained sediments;
- Open forest to woodland structure comprised of predominantly *Eucalyptus cambageana* (Dawson gum) or *Eucalyptus thozetiana* (Thozet's box) and *Acacia harpophylla* (Brigalow);
- *Eucalyptus cambageana* (Dawson gum) is often co-dominant with *Acacia harpophylla* (Brigalow) in open forest, or *Acacia harpophylla* (Brigalow) may be dominant with scattered emergent *Eucalyptus cambageana* (Dawson gum) or *Eucalyptus thozetiana* (Thozet's box) trees;
- *Acacia harpophylla* (Brigalow) trees range in height from 12 m to 14 m, while the eucalypts range between 15 m – 18 m high;
- There is a moderately dense to dense lower tree/tall shrub layer which is dominated by *Eremophila mitchellii* (False sandalwood), *Carissa ovata* (Currant bush),*Geijera parviflora* (Wilga), and *Terminalia oblongata* (Yellow-wood);
- The ground layer is typically sparse and dominated by leaf litter; and,
- Texture contrast soils predominate, often with surface stone or gravel in sub-surface horizons, but other soils such as clays, sandy clay loams and cracking clays may also be present.

1.4 Aims and Objectives

The aim of this Revegetation Management Plan is to:

- Develop the key performance criteria and indicators that could be used to ascertain the status of the revegetation of the Brigalow – Dawson gum woodland community (ERE 11.9.1) using the key results from AECOM's Technical Report (AECOM, 2017);
- Develop a methodology to re-establish a safe, stable and self-sustaining Brigalow – Dawson gum community; and,
- Outline the ongoing monitoring and management requirements.

Because there are no documented cases of successful re-establishment of Brigalow woodlands from seed, an additional aim of this Revegetation Management Plan is to develop a framework for communicating the findings from the monitoring regime to the wider scientific community. This may have the added benefit of contributing to the requirements of the EA in the event that the revegetation is unsuccessful. AECOM propose that this component of the Plan would be driven by Dr. John Dwyer, Lecturer at the University of Queensland's School of Biological Sciences, and may also involve the use of students from the University of Queensland. However, agreement with mine site personnel would be required prior to this being undertaken.

2.0 Risks to the Revegetation Management Plan

Risks and issues that may potentially impact on the ability to successfully implement the Revegetation Management Plan include:

- Insufficient resourcing to implement the defined works;
- Unauthorised clearing;
- Lack of availability of locally occurring species to be either seeded or planted in rehabilitation or regeneration areas;
- Weed infestation;
- Feral animal species;
- Grazing of livestock within prohibited areas;
- Erosion and sedimentation;
- Poor seed quality; and,
- Unauthorised access.

These risks are mitigated by the implementation of the measures aligned to the performance indicators and criteria as defined in Section 7.0.

3.0 Site Preparation

3.1 Fencing and Signage

The entire Bullock Creek Diversion area must be enclosed with cattle fencing to ensure that crash grazing with livestock can be used as a weed management strategy prior to direct seeding. Fencing should also ensure that cattle are excluded from the site during the critical stages of the revegetation program. Livestock tend to preferentially feed on *Acacia harpophylla* (Brigalow) shoots, so exclusion of cattle is essential to ensure the longevity of the Brigalow – Dawson gum community.

The fence line should have at least one vehicle/livestock access point. The top wire should be plain wire which has been shown to limit the damage to native fauna which may, in time, move across the site. Both the inside and outside perimeter of the fence should be subject to a slashing program (approximately 2 m distance from the fence) to create an area of reduced fuel load. This area can also be used as an access corridor for the purpose of site maintenance.

The length of the fenced area in Figure 1 is 1,363.3 m.

All access gates are to include signage defining the Project Area and contact information.

3.2 Sodicity and pH

Ameliorants for sodicity and alkalinity are not recommended. No correction for sodic soil conditions is recommended because:

- Only two samples returned sodic readings, while the remaining readings displayed very low Exchangeable Sodium Percentage (ESP);
- The sodic readings were only marginally above the recommended ESP of <6% (Hazelton & Murphy , 2007) and were below 12%, above which surface soil is considered to be moderately sodic (Grains Research & Development Corporation , 2017);
- Sodic soils are not unusual in the Brigalow Belt and elevated ESP has been observed in previous studies (Silburn , et al., 2009; Grains Research & Development Corporation , 2017);
- The risk of erosion from dispersive sodic soils should be mitigated by rapidly establishing vegetative cover crop, establishing high woody biomass per hectare and placing course woody debris across the site, focusing on drainage lines; and,
- Reducing ESP to 6% from current levels (7.9% -11.6%) should require between 60 to 290 kilograms (kg) of gypsum per hectare; however further soil tests are required to determine the application rate with greater accuracy. It may then take several months for the gypsum to incorporate into the topsoil and take effect. This is not compatible with site timeframes for revegetating the Bullock Creek Diversion as outlined by site personnel.

In addition, AECOM does not recommend applying a pH treatment to the Bullock Creek Diversion despite the observation of moderate alkalinity and despite the lower pH levels observed at reference sites because:

- Intense cattle grazing may increase the organic matter content of the soil due to the cattle excrement, thereby reducing the pH level;
- Brigalow soils often have the unique characteristic of strongly alkaline surface soils that grade to strongly acidic in deep subsoil layers. For this reason, it is unclear if the alkalinity of the Bullock Creek Diversion would act as a critical barrier to seedling establishment; and,
- Reducing pH to neutral from the current moderately alkaline levels (8.5 – 9) should require between 21.32 to 32.69 kg of sulphur per hectare; however further soil tests are required to determine the application rate with greater accuracy. It may then take several months for the sulphur to incorporate into the topsoil and take effect. This is not compatible with site timeframes for revegetating the Bullock Creek Diversion.

3.3 Crash Grazing

'Crash grazing' of the Bullock Creek Diversion area is recommended for a short period of time prior to the subsequent phases of the vegetation plan with the aim of substantially reducing the biomass of exotic grasses. Crash grazing is defined as very high density grazing over a very short period of time with the intention of reducing the competitive effects of the dominant perennial grasses (Dorrough, et al., 2004). It involves grazing at three to four times the regular grazing pressure and has lead 20% reduction in survival of weed species (Shea , et al., 2010). The grazing regime (stocking rate and period) should be dependent on a pasture productivity stock rate carrying assessment, to be determined by the site environmental personnel. Site personnel may refer to the Cattle Grazing Establishment and Monitoring Manual (AECOM, 2017) for further guidance about determining the most appropriate stocking rate.

In the event that standard stocking rate calculation methods are not used, the stocking rates in studies of crash grazing should be used as guidance when establishing the stocking rate and time period for the Bullock Creek Diversion. For example, one study stocked experimental plots at 32.7 Dry Sheep Equivalent (DSE) per hectare for a total of 24 days and livestock preferentially grazed plants at the early vegetative to flowering stage (Kirkegaard, et al., 2008). Following crash grazing, crop growth rate was rapid. Other studies have applied an elevated stocking rate of 200 DSE per hectare to reduce weed biomass (Huwer, et al., 2002). The crash grazing period could be shortened by dramatically increasing the stocking rate per hectare (e.g. > 100 per ha).

The crash grazing regime should ideally be timed to occur before the largest annual flowering event of *Cenchrus ciliaris* (Buffel grass), to reduce the risk of seed introduction via cattle manure from cattle entering the site and also removing the flower and resultant seed from the annual reproductive cycle. In Central Australia, growth and reproduction of *Cenchrus ciliaris* (Buffel grass) correlates strongly with the highly variable rainfall events (Department of Environment and Natural Resources , 2005). Although *Cenchrus ciliaris* (Buffel grass) has the ability to flower and set seed all year round, the largest flowering event of this species is most likely once temperatures increase and following the first rainfall event. Local weather conditions should be reviewed to ensure optimal reduction in flower and vegetative material.

Any cattle that are to be used for the purpose of crash grazing are to be rested in yards for 1-2 days prior to entry to the site to mitigate the risk of weed seed via their manure. While the duration of the stocking period can be calculated from the carrying capacity, it should be important to regularly monitor any reduction in weed load to ensure that livestock are not left enclosed for an extended period without sufficient feed.

Crash grazing has been recommended because it is important that biomass is removed and converted into biological waste. Slashing is not a suitable substitute because biomass remains *in situ* and is not broken down. However, crash grazing alone is not sufficient to reduce weed biomass and must be applied with herbicide to achieve effective, long-term weed control (Huwer, et al., 2002). It is commonly accepted that combining several weed control approaches into an integrated weed management strategy is the most effective way to suppress weeds over the longer term. In particular, the combination of herbicide spraying and grazing is very effective.

3.4 Herbicide Application

As soon as fresh shoots of the *Cenchrus ciliaris* (Buffel grass) emerge following the crash grazing regime, a registered monocot-specific herbicide should be applied across the entire Bullock Creek Diversion area. Seedlings are susceptible to the grass-selective herbicide, fluazifop-p-butyl (Fusilade®), as well as dicamba, 2,4-D, triclopyr, tebuthiuron, and hexazinone (Anon., n.d.).

The Weed of National Significance and Queensland listed species, *Parthenium hysterophorus* (Parthenium), was observed in isolated locations within the Bullock Creek Diversion area. It should be controlled according to the use of registered herbicides. Further details on the control of Parthenium Weed are provided in Appendix A.

It is important that PA consult the label of any herbicide used and all work should be undertaken by trained, qualified and competent operators. By law, herbicides may only be used in accordance with

the label. The Australian Pesticides and Veterinary Medicines Authority (APVMA) keep a record of all registered herbicides and pesticides and their approved uses.

Records must be maintained relating to all weed control work that is undertaken. Crash grazing and herbicide application may be highly effective when used in concert because the crash grazing treatment can alleviate the residual impact of herbicides on desirable native species (Huwer, et al., 2002).

3.5 Slashing

As described in Section 3.1, a buffer zone on the inside and outside perimeter of the fence line should be maintained. The area within 2 m of the fence line should be periodically slashed to assist in maintaining a *Cenchrus ciliaris* (Buffel grass) free zone in the Bullock Creek Diversion area. However, if grazing is a more feasible practice, this should achieve a similar, if not better, outcome as the aim is to keep this zone free of weed reproductive material. This should, at the very least, slow the rate of re-invasion of the Bullock Creek Diversion Area with *Cenchrus ciliaris* (Buffel grass) and enable Brigalow species to establish.

The buffer should create a perimeter of approximately 0.3 ha, shown in Figure 1. Slashing should be frequent enough to ensure that grass in this area does not flower and set seed. Therefore, the frequency of slashing should be determined by temperature and precipitation, as *Cenchrus ciliaris* (Buffel grass) tends to flower and set seed most prolifically in warm conditions after a rainfall event (Department of Environment and Natural Resources , 2005). However, regular monitoring of the buffer zone should occur as *Cenchrus ciliaris* (Buffel grass) is capable of flowering and setting seed all year round.

Fuel loads in the areas slashed along fence line should be assessed during the fire season, with subsequent slashing works undertaken as required.

No revegetation works should be undertaken within the buffer zone.

3.6 Ripping

Topsoil should be lightly ripped to a maximum depth of 50 millimetres (mm), to firstly open the soil surface and in doing so optimise rainfall infiltration, and secondly aid in seed contact with soil. Ripping should not occur within the creek bed and should conform to the natural contours of the landscape. Deep ripping must be avoided.

3.7 Habitat Augmentation

To maximise the habitat value of the site for a wide variety of fauna, the Bullock Creek Diversion area should be managed to maintain or enhance the diversity of its structure and species composition. The area has the potential to provide shelter for small animals in the form of grass tussocks and inter tussock spaces; soil cracks and holes; rocks; shrubs; trees and their bark; and fallen timber and litter, all of which provide shelter from weather, predators and fire. Accordingly, the more niches there are and the more species of fauna present, the greater the abundance and variety of food for other species of fauna.

The following actions are to be implemented to enhance structural diversity and shelter:

- Allow for a diversity of vegetation types, form and structure;
- Leave fallen large woody debris in situ;
- Leave rock material in situ;
- Utilise woody debris, mulch and rock material harvested from the adjoining mining operations for optimal placement associated with the patch plantings;
- Minimise site access during the warmer months where ever possible, as this is the time when small fauna are most active;

- Optimise the number of shallow depressions which assist in water movement and retention across the site;
- Use plant species that provide a diversity of flowering and seeding times, the availability of flaky bark and woody debris; and,
- Promote habitat niches that may encourage fauna connectivity between the Bullock Creek Diversion area and the nearby RE 11.9.1 woodland to the south.

3.8 Woody Debris

Woody debris from other areas of the Burton Coal Mine should be placed within the Bullock Creek Diversion area. Ideally, woody debris should be sourced from the topsoil stockpile to the east of the Bullock Creek Diversion area as site investigations revealed that these stockpiles contained a large amount of woody material, most likely from the pre-existing Brigalow woodland. Woody debris should have the combined effect of reducing surface flows and therefore erosion, as well as creating habitat values commensurate with RE 11.9.1.

Coarse woody debris should be placed in ten scattered 'island' formations across the Bullock Creek Diversion area. These islands should be approximately 20 m x 20 m (400 square metres (m^2)) in size. The density of coarse woody debris should reflect that observed in the Brigalow – Dawson gum woodland to the south of the Bullock Creek Diversion area which had 428 m of coarse woody debris per hectare equating to17.12 m of coarse woody debris in a 20 m x 20 m area. This might be the equivalent of three large branches per island. The density of coarse woody debris should aim to not exceed the benchmark value for RE 11.9.1 of 565 m per hectare or 22.6 m in a 20 m x 20 m area.

Access tracks to these islands should be maintained for future maintenance.

Where there is additional coarse woody debris, this should be placed within the creek line to reduce flow velocity during and post large rainfall events, but not on the embankments leading into the creek bed.

Long term, course woody debris should be established all over the Bullock Creek Diversion Area by over seeding and selective thinning, leaving woody debris in situ.

3.9 Direct Seeding

The selected seed mix from Section 4.1 could be direct seeded using one of the following tractor mounted options, depending on the availability of the machinery:

- a V blade seeder which clears weeds and dead Buffel grass tussocks and creates a wide scalp;
- a disc seeder may be used to create a shallow groove that collects water; or
- an air seeder and trailing press wheel that is mounted behind the rippers and the work undertaken concurrently with the secondary ripping.

It is recommended that seed is not mixed with topsoil any deeper than twice the depth of the seed's diameter (Anon., 1993); therefore care should be taken not to compact soil after direct seeding. It is also important that there is sufficient time between application of herbicides and direct seeding to ensure that residual herbicides potentially stored in the soil do not impact seedling growth. The label of the selected herbicide should be referred to, to determine the soil latency period. Seeding should be timed to coincide with the highest likelihood of rainfall (See 4.1.2).

Bulking agent for the seed may include inert materials such as vermiculite or damp sand. To assist in limiting the risk of increased exotic grass growth, fertilisers should not be used.

3.10 Tube Stock

Tube stock of the two co-dominant species, *Acacia harpophylla* (Brigalow) and *Eucalyptus cambageana* (Dawson gum), should be planted manually within the ten islands of course woody debris. Planting should occur at density of approximately 125 stems per 400 m^2 (approximately 63 of each species). Although this equates to 3,125 stems per hectare it factors in approximately 20%

mortality to give a final density of 2,500 stems per hectare. This is more than double the observed maximum stem density of 900 stems per hectare in the remnant Brigalow - Dawson gum woodland to the south of the Bullock Creek Diversion area; however it is similar to densities observed in undisturbed Brigalow recorded in scientific literature. This high density should also help to achieve canopy closure in isolated locations and assist in mitigating the risk of exotic grass invasion. The added benefit of using combination of tube stock and direct seeding should create heterogeneity in age class.

All tube stock must be watered immediately after planting and on an ongoing basis to avoid mass mortality. Watering regimes are discussed in Section 5.1. The tube stock are to be delineated, for instance, by the use of tree guards, which may also assist in restricting predation by herbivores and offer protection from strong winds. Tree guards also allow for easy identification of plants for watering and maintenance purposes.

Island locations in Figure 1 are indicative only and may be changed by site personnel. Figure 1 aims to demonstrate that island locations should be relatively evenly spaced. For maintenance and monitoring purposes, it is also important that access tracks to each island are maintained.

3.11 Fertiliser

The low macronutrient levels (phosphorus, nitrogen and organic carbon) are suited to the development of a Brigalow plant community. Fertiliser should not be applied during or following seeding because:

- It may promote weed species' growth and recruitment. Although the nutrient profile of the Bullock Creek Diversion area is low, even by the standards of Brigalow topsoil, fertiliser application should likely increase the competitiveness of invasive grasses. Evidence from other Australian woodland systems suggests that fertilizer addition in combination with soil disturbance can enhance the growth of introduced species more than native species (Hobbs & Atkins, 1988);
- There is a high probability of nutrient leaching. The low Cation Exchange Capacity of the soil at the Bullock Creek Diversion area suggests that there is minimal capacity to retain and exchange essential nutrients (Hazelton & Murphy , 2007). Therefore it is likely that the any nutrient additions would leach shortly after the first rainfall or irrigation event;
- Brigalow is adapted to reasonably low phosphorus soils (Russell, et al., 1967) and previous studies have attributed higher concentrations of other topsoil macronutrients, such as organic carbon and nitrogen, to the greater concentrations of roots in this soil horizon. Therefore, it is plausible that the low nutrient profile of the Bullock Creek Diversion area would recover following re-establishment of woody canopy and associated nutrient cycling from canopy-leaf fall (Dowling , et al., 1986);
- *Acacia harpophylla* (Brigalow) is a nitrogen-fixing species and is expected to increase plant-available nitrogen.

4.0 Revegetation Methodology

4.1 Direct Seeding

4.1.1 Target Flora Species and Density

The seed mix and seeding rate of the larger tree species in Table 2 is based on observations of remnant Brigalow woodlands on-site, as well as observations in scientific literature (Dwyer & Mason 2017). The densities for small trees and shrubs is based on maximum densities across the remnant RE 11.9.1 observed at Burton Coal Mine. Many of the species listed in the EA condition were not observed on-site and are therefore not considered to be of primary importance in revegetation efforts, as the aim is to recreate remnant RE 11.9.1 that mimics, where possible, site conditions. The shrub and small tree density observations upon which Table 2 is based are found in AECOM's Technical Report (AECOM, 2017).

Table 2 Recommended seeding rates

Species name	Common name	Classification [10]	Long-term target density [5]	5-year target density [6]	5% multiplier seed number (seeds per ha) [7]	Average seed mass [8]	Approx. viable seeds per kg [9]	Sowing rate (kg/ha)	Cost ($/kg)
Species observed in the RE 11.9.1 woodland on site									
LARGE TREES									
Acacia harpophylla	Brigalow	N	750	1500	30000	0.0504	14881	2.016	450
Eucalyptus cambageana	Dawson gum	N	150	300	6000	0.0014	535714	0.011	395
Lysiphyllum carronii	Red bauhinia	N	200	400	8000	0.4762	1575	5.079	295
Terminalia oblongata[4]	Yellow-wood	N	400	800	16000	NA	NA	1	375
SHRUBS & SMALL TREES									
Acacia salicina	Sally wattle	D	160	320	6400	0.0478	15690	0.408	365
Acalypha eremorum[3]	Soft acalypha	D	20	40	800	0.0005	1500000	0.001	N/A
Alectryon diversifolius	Scrub boonaree	D	40	80	1600	0.0508	14764	0.108	N/A
Diospyros humilis[3]	Queensland ebony	D	60	120	2400	0.126	5952	0.403	N/A
Ehretia membranifolia[3]	Peach bush	D	60	120	2400	0.013	57692	0.042	N/A

Species name	Common name	Classification [10]	Long-term target density [5]	5-year target density [6]	5% multiplier seed number (seeds per ha) [7]	Average seed mass [8]	Approx. viable seeds per kg [9]	Sowing rate (kg/ha)	Cost ($/kg)
Eremophila mitchellii	False sandalwood	N	20	40	800	0.0015	500000	0.002	295
Pittosporum spinescens	Orange thorn	D	40	80	1600	0.012	62500	0.026	N/A
Psydrax odorata	Canthium	D	20	40	800	0.05	15000	0.053	N/A
Species not observed on site but stipulated in Burton Coal Mine EA									
Geijera parviflora	Wilga	D	50	100	2000	0.0201	37313	0.054	410
Flindersia dissosperma	Leopardwood	D	50	100	2000	0.01	75000	0.027	750
Carissa ovata	Conkerberry	N	50	100	2000	0.0749	10013	0.2	475
Capparis lasiantha	Bush Caper	D	50	100	2000	0.023	32609	0.061	475
Eucalyptus populnea	Poplar box	D	50	100	2000	0.0004	1875000	0.001	490
Sorghum nitidum [3]	NA	S	50	100	2000	0.0078	96154	0.021	N/A
Cover crop species									
Echinochloa esculenta	Japanese millet	N	NA	NA	NA	NA	NA	5	4

1 Estimated seed multiplier to allow for sub-optimal germination and some seedling mortality, while ensuring high enough densities of saplings to achieve site capture and minimise weed growth. We recommend a lower multiplier for some species given their high germination rates and large seed sizes (seedlings of larger-seeded species tend to have greater survival rates).

2 Based on values from Royal Botanic Gardens Kew (2015) *Seed Information Database (SID). Version 7.1*. Available from: http://data.kew.org/sid/ and Gunn, B. (2001) *Australian Tree Seed Centre: Operations Manual*. CSIRO, Canberra.

3 Where data was not available on the exact species, a similar species has been used as a proxy. In the case of *Acalypha eremorum*, the seed weight of *Acalypha lanceolate* was used. In the case of *Diospyros humilis*, the seed weight of *Diospyros fasciculosa* was used. In the case of *Ehretia membranifolia*, the seed weight of *Ehretia acuminata* was used. In the case of *Sorghum nitidum*, the seed weight of *Sorghum arundinaceum* (Desv.) Stapf was used. In the case of *Ehretia membranifolia*, the seed weight of *Ehretia acuminata* was used.

4 The optimal sowing rate for this species was estimated as there was no suitable substitute species upon which to base calculations.

5 Based on field observations and scientific literature

6 Twice the long-term target

7 Assumes that only 5% of sown seeds will germinate and survive to 5 years

8 Estimates only

9 Assumes 75% of each kg is viable

10 N – non-negotiable; D – desirable; S – supplementary

The total final tree density in is **1,550 stems per hectare**. This includes both species observed on-site and those recommended in the EA condition. The relative composition of different species is based on a combination of the species compositions detected in remnant Brigalow – Dawson gum woodlands on-site, observations of similar woodlands in scientific literature and the EA conditions. Species from the EA have been recommended despite most of them not being observed on-site. This is to ensure maximum diversity is achieved and accounts for variable establishment success among species. AECOM has recommended a higher stem density than what was observed on-site with the aim of achieving full canopy closure and therefore groundcover weed suppression. The application rate estimates that, on average, only 75% of each kg of seed should be viable. Where possible, this information should be validated from the seed supply merchant prior to the purchase of the seed and Table 2 should be updated accordingly.

The seeding rate should lead to a target tree density of 1,550 stems per hectare, which matches reported densities in other remnant Brigalow communities (Dwyer & Mason 2017) and is consistent with AECOM's recommended density of >900 stems per hectare in AECOM's Technical Report (AECOM, 2017). Based on discussions with Dr. John Dwyer, this tree density is the minimum required to achieve the foliage projected cover of >50% per hectare and biomass of >95 tonnes per hectare in the final plant community.

The target density of shrub and small tree species is **670 stems per hectare**. Again, this includes both species observed on-site and those recommended in the EA condition. This layer should form the understory and is consistent with site observations made in AECOM's Technical Report (AECOM, 2017). Thus, the target final stem density (both trees, small trees and shrubs) in is **2,220 stems per hectare.**

The five year target density is twice the long term density for each species. For instance, the five year tree density in Table 2 is 3,100 stems per hectare. This is higher than the upper target in Table 6 of 2,500 stems per hectare to account for a range of factors which may reduce stem count over time, such as:

- High seedling mortality;
- Low seed viability;
- Suboptimal climatic conditions at the time of seeding and establishment;
- A large non-seed fraction in the initial seed mix; and,
- Poor storage resulting practices resulting in low germination percentage.

Thus, the initial seeding rate has been designed to lead to a higher final stem density than is recommended in Table 6. Where this is the case, selective thinning should occur after five years to achieve a target final stem density (both trees, small trees and shrubs) of **2,220 stems per hectare** as outlined in Table 2. All removed biomass from any thinning operations should be left in situ as it should contribute significantly to the density of coarse woody debris and leaf litter which are key features of Brigalow - Dawson gum woodland and should create habitat refuges for wildlife. This should promote coarse woody debris across the entire site, rather than just in isolated patches.

Enquiries should be made with seed suppliers about germination rates and any dormancy mechanisms or necessary seed treatments. This information should be used to update Table 2 . Local provenance seed should be used where available. If seed is not available in the initial seeding year but becomes available in subsequent years, efforts should be made to re-seed with these species at the desired density.

The estimated cost of the implementation of the direct seeding regime is between $3,370.83 and $3,697.4 per hectare. The cost of absolutely necessary species as indicated in Table 2 is $3,096 per hectare. The cost of each tube stock island is $432.82 each. Some of the assumptions that fed into the lower and upper cost estimate include:

- Prices are based on seed available from Global Hardwood supplies.
- Stock must be contract grown as AECOM could not find any *Acacia harpophylla* (Brigalow) or *Eucalyptus cambageana* (Dawson gum) in stock.

- Contract grown tube stock cost $1.90 per tube stock with a 25% deposit (Yuruga Nursery). This does not include the price of seed.
- It will take Yuruga Nursery anywhere between 2 and 4 months to grow the stock.
- Approximately 1 gram (g) of *Acacia harpophylla* (Brigalow) and less than 1 g of *Eucalyptus cambageana* (Dawson gum) is required for contract growing one island (125 plants).
- Mallee bioguards to protect tube stock cost $0.85 per item (450 mm x 160 mm).
- Bamboo canes cost approximately $0.32 each. Two are required per tree guard.
- Labour associated with preparing the site, delivering the seed and planting tube stock is not included.
- Seed with no available price information in Table 2 was given a lower estimate of $250 per kg and an upper estimate of $750 per hectare. This is information is to be updated upon receipt of more accurate information from suppliers.

AECOM has requested a quote for the supply of seed from the Australian Seed Federation which has a network of over 300 seed suppliers nationwide, and is awaiting the outcome of this request. Quotes are expected no later than 6 October 2017.

To sow the additional rehabilitation areas with a native grass mix of *Themeda triandra* (Kangaroo grass) and *Cymbopogon refractus* (Barbed wire grass) at 2 kg per ha, it is expected to cost between $530 and $2,950 per ha.

4.1.2 Timing of Seeding

Direct seeding should be timed to occur immediately prior with the wettest months based on long term annual average rainfall conditions. This timing enables machinery to access the site prior to the creation of soggy and wet soil conditions and ensure that the seed is in the soil prior to the onset of rain. Figure 2 shows the actual rainfall for the 12 months prior to AECOM's field survey in June 2017, as well as the long term average. While there can be unseasonal winter rain, as occurred in 2016, the months of December, January and February tend to receive the highest rainfall. Therefore, seeding should be timed for late November through to December to maximise the likelihood that seedlings should benefit from rainfall. National seasonal forecasting tools may be used closer to the seeding event to predict optimal timing such as POAMA.[1] However, the timing of seeding should be less critical if an irrigation system is installed.

[1] The Australian Bureau of Meteorology's (BOM) POAMA-2 Experimental can be used to predict rainfall with greater accuracy than traditional forecasting tools - http://poama.bom.gov.au/. Temperature and rainfall maps can be accessed with the username and password demo/access. Maps include customised start date, lead time and variable. Alternatively, national, seasonal climate outlooks maps with temperature and rainfall predictions can be accessed through the BOM's website at: www.bom.gov.au/climate/outlooks/#/overview/summary/.

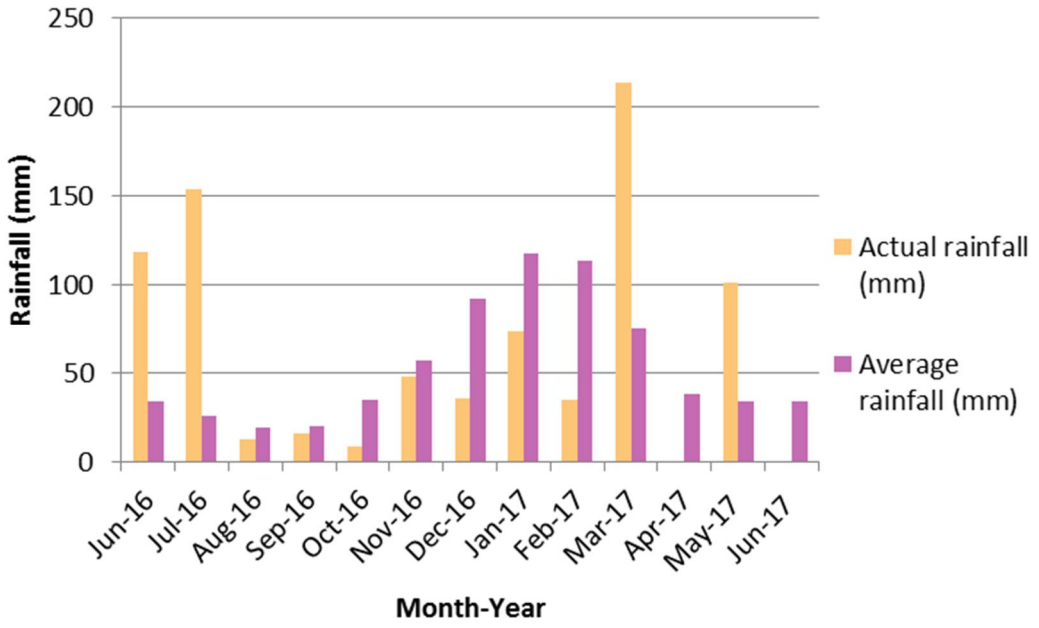

Figure 2 Monthly rainfall compared to the annual mean in the months during and prior to the field assessment (Moranbah Treatment Plant Weather Station, Bureau of Meteorology)

4.2 Tubestock

In addition to seed, a total of 500 tube stock of *Acacia harpophylla* (Brigalow) and 500 *Eucalyptus cambageana* (Dawson gum) should be required for the ten 'islands'. Each island should have 125 tubestock, equating to approximately 63 of each species (See Section 3.10).

4.3 Ecotones

There should be no compositional transition toward more riparian species near the creek line due to:

- The low likelihood and frequency of flooding;
- The lack of any observed riparian community in remnant Brigalow - Dawson gum woodlands on site; and
- The ability for the co-dominant species to persist in alluvial conditions.

5.0 Maintenance Works

5.1 Irrigation

Irrigation after seeding is critical in a semi-arid, water-limited environment to ensure maximum seed germination and seedling survival (Arnold, et al., 2014). Maintaining sufficient soil water conditions has been identified as the critical determinant of revegetation success in post-mining areas when direct seeding is the primary method of plant re-establishment.

Ideally, soil water potential should be kept as close as possible to saturated conditions (0 megapascals (MPa)) immediately after seeding and not lower than -0.75 MPa. Below -0.75 MPa the germination rate (percentage of germinated seeds relative to the entire seed lot) of *Acacia harpophylla* (Brigalow) decreases markedly and decreases the mean germination time (Arnold, et al., 2014). Soil moisture conditions should remain within this water potential range for seven days following seeding.

There is less scientific evidence surrounding the water requirements for the seedling establishment phase for Brigalow species. As a minimum, soil water potential should not drop any lower than -1.5 MPa during the seedling establishment period as this is considered the permanent wilting point beyond which the physiological function of many plant species ceases (Bell, 1999). Visual signs of plant performance (e.g. wilting or leaf discolouration) should be used as a guide when adapting the irrigation regime.

In order to maintain soil moisture conditions above the permanent wilting point for the period of seedling establishment, AECOM recommends setting up an irrigation system. This might resemble a dust suppression sprinkler system that could be set up around the perimeter of the fence line or throughout the Bullock Creek Diversion area, and could be fed off a water truck to ensure an accurate understanding of how much water is being delivered to the area. This system enables an adaptive irrigation regime.

Alternative methods might include:

1. **Boom irrigation system –** a mobile, boom irrigation system could be hired from nearby agricultural supply stores and used to maintain soil water potential above -0.75 MPa for the first seven days and not less than -1 MPa for the next three months thereafter (13 week irrigation regime). This system should utilise freshwater from the Teviot pipeline.
2. **Hand watering vegetation islands –** Hand water tubestock using a mobile water tank or water truck should be undertaken with 5 – 10 litres of water applied per plant, amounting to 500 to 10,000 litres per vegetation island. This should occur immediately after planting and then as per details provided in Table 3. Vegetation should be monitored at least weekly and if signs of drought induced mortality are detected (e.g. wilting or leaf discolouration), the watering frequency or volume should be increased.

It is important that the watering regime is continued beyond the germination and emergence stage to optimise establishment rates. This equates to at least the first three months of growth; however visual signs of plant distress should be used as an indicator of performance and the duration/volume of the irrigation regime adjusted accordingly. It is estimated that the ideal irrigation regime should continue for the first 12 months. It is also very important that robust weed management efforts are undertaken as invasive species such as *Cenchrus ciliaris* (Buffel grass) respond extremely well to elevated moisture conditions.

5.2 Weed Management

Exotic grass competition has been identified as one of the key threats to Brigalow establishment. The site should be monitored regularly for the reinfestation of *Cenchrus ciliaris* (Buffel grass) and other exotic pasture species. Spraying should occur on an as-need basis or monthly for 12 months, whichever is more frequent. After 12 months, spraying should occur on an as-need basis. Care should be taken to use a herbicide that does not impact those species recommended in the seed mix.

The declared weed species *Parthenium hysterophorus* (Parthenium) was detected during the field survey. Under the *Biosecurity Act 2014* (Qld), Parthenium is considered a restricted invasive plant and land holders have a general biosecurity obligation to take reasonable and practical steps to minimise

the risk associated with the invasive plant. The control strategies for the management of Parthenium in the Bullock Creek Diversion area should include:

- Periodic inspections of the project area;
- Control measures as defined in the literature provided in Appendix A;
- Repeated spraying may be required;
- Control efforts should be timed to occur prior to setting seed. Control efforts should occur at least twice a year as Parthenium can flower and set seed all year round. Germination normally occurs in spring and early summer (Environment, Commonwealth Department of the, 2003) so one of the spraying efforts should occur in this period. As germination of Parthenium often occurs shortly after rain and it can set seed within four weeks of germination, concerted spraying efforts should also occur within one month after a significant rain event with the aim of preventing seed set.
- Any contractors used for maintenance actives must maintain equipment in a clean state prior to commencement of work at the Bullock Creek Diversion area and upon leaving the area. This includes washing machinery down with water in a restricted area;
- Any contractors used for weed management should have relevant licenses and permits; and
- Contractors used in weed management should have all relevant license and permits.

5.3 Fire Management

Mature, undisturbed stands of *Acacia harpophylla* (Brigalow) possess a structure that excludes fire (Johnson , 1997). However, invasion by exotic grasses makes fire more likely. *Cenchrus ciliaris* (Buffel grass) is extremely fire-adapted and its invasion into Brigalow - Dawson gum woodlands can create unnaturally high fuel loads that encourages more frequent and sever fires that increases *Acacia harpophylla* (Brigalow) mortality and leads to the gradual decline of Brigalow woodland (Butler & Fairfax, 2003). Achieving rapid canopy closure should decrease the likelihood of fire as it should reduce the light interception of understory grasses that promote fire.

However, effort must be made to decrease the biomass of exotic grasses, not only during the establishment and germination phase, but also while the juvenile stand is developing towards full canopy closure. These efforts should include:

- Slashing along the perimeter of the fence line, as described in Section 3.5;
- Ongoing weed management using herbicides, as described in Section 5.2.

5.4 Re-seeding and Revegetation

A reassessment of the stem density and composition should occur as part of the monitoring regime until the desired stem density of each species outlined in Section 4.1 has been achieved. Where monitoring events reveal a lower stem density than that stipulated in Section 4.1, either re-seeding or revegetation through tube stock planting should take place. Re-seeding or revegetation efforts should follow the methods outlined in Section 3.9 (noting that ripping within woodland is not practicable) or Section 4.2.

6.0 Implementation Timeframes

Proposed implementation timeframes are provided in Table 3. The schedule is indicative only and may change depending on the availability of such resources as seed, tube stock, irrigation equipment and livestock.

Table 3 Indicative revegetation works schedule

Action	Timing	Comments
Fencing	October 2017	
Establish irrigation system	October 2017	
Crash graze	Mid October 2017	
Regrowth of exotic grass species	Late October 2017	Assumes early rainfall.
Application of selective herbicide for optimal kill rate of Buffel grass	Early November 2017	
Weed control targeting Parthenium	Early to mid-November 2017	
Death of above ground parts of Buffel grass	Late November 2017	
Ripping and delineation of access corridors for the tubestock islands	Late November 2017	Particularly important if tube stock planting is occurring after direct seeding.
Slashing along fence lines targeting removal of flowering parts of Buffel grass and to reduce fuel load	Late November and throughout the fire season	
Direct seeding	Late November - early December 2017	Time frame for seeding may be partially relaxed due to the establishment of an irrigation system. If seeding is delayed, weed suppression is very important.
Watering of seed	Continue for at least the first three months after direct seeding	Adjust watering regime according to visual signs from plants (e.g. discolouration or wilting).
Placement of large woody debris	Late November 2017	Ensure that ground is dry before using heavy machinery. Use access corridors to tube stock islands to minimise seedling death.
Tubestock planting	February 2018	Contingent on speed of growth.
Watering of tubestock	At least weekly for first 6 weeks and then fortnightly during dry season for 12 months	Not required when rainfall > 20 mm has occurred in the previous week.
Maintenance weed control – *Cenchrus ciliaris* (buffel grass) and *Parthenium hysterophorus*	Ongoing – targeting early flower	
Maintenance of fences / gates	As required and as per the Annual walk over	
Monitoring	Refer Section 7.0	

7.0 Monitoring

All rehabilitated areas should be inspected by site environment staff (or specialist consultants) to note any problem areas (such as bare patches, failed revegetation, drainage structure failure, significant erosion or significant weed infestation) requiring maintenance or further treatment. Remedial works should then be scheduled to address these areas. The assessment program is designed to collect sufficient data to compare the results of rehabilitation against the agreed completion criteria. The assessment program consists of three components:

- Annual maintenance inspections;
- Scheduled rehabilitation monitoring; and
- Review of inspection/measurement data over time to assess rehabilitation performance.

In the event that the inspection finds there are issues with the rehabilitation, further investigations should be undertaken to determine the possible causes and identify an appropriate remediation strategy. Factors to consider include:

- Nutrient levels;
- Soil limitations such as depth, pH, salinity;
- Insect attack, weeds or other pests;
- Species mix in revegetation programs;
- Drought or storm damage; and
- Grazing resulting from unplanned access by cattle or native fauna.

Where appropriate, the rehabilitation procedures should be amended to improve the standard of rehabilitation.

7.1.1 Sites

The monitoring sites should be permanently marked using steel pickets or a similar marking item. Representative monitoring sites should be established at locations across the project area at an average of one site per hectare, with monitoring plots being based on a 100 m transect, positioned along the contour of the slope. Each site should be monitored as per Table 4. Transects should be established using the Biocondition assessment methodology (Eyre , et al., 2015). Monitoring should follow the Biocondition field assessment methodology with a small number of modifications outlined in Table 4. This should provide a robust set of monitoring data in the first ten years following rehabilitation works. Monitoring should continue until performance criteria in Table 6 have been achieved.

7.1.2 Attributes

The attributes listed in Table 4 are to be collected as part of the site based monitoring program. The frequency of the monitoring assumes site conditions are suitable for the development of the desired plant community and recognises that changes may be required in situations of extended drought or other mitigating circumstances. Monitoring should occur annually in line with the rehabilitation monitoring schedule.

Table 4 Monitoring parameters and methods.

Parameter	Assessment Area	Method	Frequency
Floristics: Shrubs, grasses and forb species	50m x 10m plot	· A full floristics survey of the plot should be undertaken. All groundcover, understory and over vascular species should be identified and recorded, and consistent with the Biocondition methodology (Eyre , et al., 2015).	Annually in line with rehabilitation monitoring schedule

Parameter	Assessment Area	Method	Frequency
Floristics: tree species	100 m x 50 m	· Undertake a full survey of total native species richness consistent with the Biocondition methodology (Eyre , et al., 2015). · Undertake a stem density and biomass assessment consistent with Section 7.1.3.	Annually in line with rehabilitation monitoring schedule
Foliage Projected Cover	100 m transect	· The canopy intercept of both over-storey and mid-storey vegetation (i.e. trees and shrubs) directly above a 50 m tape should be recorded. The percent cover should be calculated consistent with the methodology in the Biocondition methodology (Eyre , et al., 2015). The overall FPC score for the site should be obtained by averaging the score at the ten assessment points.	Annually in line with rehabilitation monitoring schedule
Ground Cover	1 m x 1 m transects	· Groundcover assessments are to be undertaken in five 1 m x 1 m plots consistent with the Biocondition methodology (Eyre , et al., 2015). The type and percentage of ground cover should be recorded as either: native grass, native forbs and other non-grass species, native shrubs (<1 m in height), non-native grass, non-native grass and forbs, litter, rock, bare ground, cryptograms. · The overall ground cover performance for the site should be derived by averaging the relative composition of each type of cover as a percentage.	Annually in line with rehabilitation monitoring schedule
Habitat Potential	20m x 50 m plot	· The total length of fallen logs >10 cm in diameter and with >80 in contact with the ground should be measured and recorded consistent with the Biocondition method (Eyre , et al., 2015). Only measure parts of the logs in contact with the ground. · The total number of hollows in tree which trunk is within the plot boundaries should be recorded. · The total number of stags (standing dead trees) in the plot should be recorded. · The number of large rock tumbles should be recorded (i.e. rock piles or rocks large enough to provide potential habitat).	Annually in line with rehabilitation monitoring schedule
Vegetation health	20m x 50 m plot	· A total of up to 20 shrubs/trees (where present) representative of the dominant species should be randomly selected within the plot and tagged (for future monitoring). Their health condition should be assessed using the following ranking system: - Dead: individual is dead. - Very sick: no new growth, several limbs showing dieback symptoms, severe leaf discoloration, necrosis or insect attack symptoms. - Sick: little new growth, branch dieback and some limbs, obvious leaf discoloration, necrosis or insect attack symptoms. - Healthy: active new growth, no or negligible tip dieback, no or negligible leaf discoloration, necrosis or insect attack symptoms.	Annually in line with rehabilitation monitoring schedule

Parameter	Assessment Area	Method	Frequency
Regeneration	20m x 50 m plot	· The number of species with second generation seedlings (i.e. <2m) within the plot and the number of species bearing reproductive material (i.e. flowers/fruits) should be recorded. Regeneration should be assessed as follows: - Active: second generation seedlings present. - Potential: no seedlings but reproductive material present. - Absent: no seedlings or reproductive material present.	Annually in line with rehabilitation monitoring schedule
Soil Profile	50 m transect	· Take soil samples at 10 m intervals along a 50 m transect. The methodology is outlined in Section 7.1.4.	Annually in line with rehabilitation monitoring schedule
Slope	50 m transect line	· The slope gradient at the transect line should be measured in % using a digital clinometer for accurate results.	Annually in line with rehabilitation monitoring schedule
Erosion	20m x 50 m plot	· Erosion should be estimated along each transect, with ratings 1 (no erosion), 2 sheet erosion, 3 rill erosion (<0.2m deep), 4 gully erosion (>0.2m<1m deep), 5 gully erosion (>1 m deep) or tunnel erosion. · Where rills or gully features are present, their location, depth and width should be recorded as they intercept the transect line.	Annually in line with rehabilitation monitoring schedule

7.1.3 Stem Density and Biomass

Stem density should be measured from all tree species and above-ground biomass should be estimated using the allometric equations from academic literature found in Table 5. All woody species ≥ 2 m in height that are within the 10 m by 50 m transect should be measured. Stem densities within the transect area should then be extrapolated to stems per hectare, by multiplying the recorded density by a factor of 20.

To calculate biomass, the diameter at 30 centimetres (cm) above ground level of all woody species ≥ 2 m in height should be recorded using a diameter tape. Published allometric equations for similar woody species should be used to estimate biomass from diameter measurements (See Table 5) in a manner consistent with the method used by (Dwyer , et al., 2010). For trees or shrubs that are < 2 m, biomass is to be extrapolated from the same published allometric equations using height instead of diameter. Biomass should be represented in kilograms per hectare.

Table 5 Published allometric equations to estimate biomass for each specific species.

Species	Allometric species	Reference
Acacia harpophylla	*Acacia harpophylla*	(Scanlan, 1991)
Acacia salicina	*Acacia harpophylla*	
Lysiphyllum carronii	*Acacia harpophylla*	
Terminalia oblongata	*Acacia harpophylla*	
Acalypha eremorum	*Eremophila mitchellii*	(Harrington, 1979)

Species	Allometric species	Reference
Alectryon diversifolius	*Eremophila mitchellii*	
Capparis mitchellii	*Eremophila mitchellii*	
Citrus glauca	*Eremophila mitchellii*	
Diospyros humilis	*Eremophila mitchellii*	
Ehretia membranifolia	*Eremophila mitchellii*	
Eremophila deserti	*Eremophila mitchellii*	
Eremophila mitchellii	*Eremophila mitchellii*	
Pittosporum spinescens	*Eremophila mitchellii*	
Psydrax odorata	*Eremophila mitchellii*	
Eucalyptus cambageana	*Eucalyptus spp.*	(Burrows, et al., 2000)
Eucalyptus populnea	*Eucalyptus spp.*	

7.1.4 Soil Sampling and Laboratory Analysis

Soil samples should be collected at all monitoring site locations. At each monitoring site, five grab samples should be taken along a 50 m transect at 10 m intervals. The samples should be taken from the top 0 - 10 cm of soil to ensure that they are representative of the topsoil profile. Care should be taken to ensure leaf litter and woody debris is not included. The five grab samples should be mixed into one composite sample. Approximately 500 g of material should be placed inside a zip lock bag. Samples should be double bagged to prevent cross contamination and stored on ice until they are sent for analysis at ALS laboratories (National Association of Testing Authorities accredited). Analysis of the following chemical and physical properties should be undertaken:

- pH;
- Electrical Conductivity (µS/cm);
- Exchangeable Sodium Percent (%);
- Particle Size (Sand, Silt, Clay, Gravel and Cobbles);
- Soil Particle Density (g/cm^3);
- Cation Exchange Capacity (CEC) (meq/100 g);
- Sulphate (mg/kg);
- Chloride (mg/kg);
- Boron (mg/kg);
- Total metals (mg/kg);
- Nitrite and Nitrate (mg/kg);
- Total Nitrogen (mg/kg);
- Total Phosphorus (mg/kg);
- Extractable Phosphorus (mg/kg);
- Total Organic Carbon (%); and
- Particle size distribution (sand, silt and clay content).

7.1.5 Photographic Monitoring

Photographic monitoring is a simple and useful tool that allows for direct visual comparison of a specific site between monitoring events. Digital photographs are to be taken at fixed reference points during each monitoring event. This way, a visual record can be created and maintained of the evolution of vegetation establishment in rehabilitation areas over time, and the record consulted to check what a specific site 'looked like' at a certain point in time since the start of the monitoring program. The following photographic monitoring should be undertaken:

- At each rehabilitation monitoring site, a photograph should be taken from:
  - The start location of the 100 m transect with the end of transect in the centre background;
  - The end of the transect looking in; and,
  - The centre looking north, south, east and west.
- Opportunistic photographs should also be taken to capture:
  - Active disturbance processes impacting the monitoring site area e.g. active erosion, weed infestation, evidence of recent fire, excavations, damage form vertebrate pests.
  - Evidence of rehabilitation success indicators e.g. flowering or fruiting trees.

7.1.6 Field Assessment – Walkover

A field assessment should consist of a rapid style walkover of the project area and should be undertaken at 6-8 weeks post the revegetation works (direct seeding and tubestock planting). The field assessment should assess the site health and should be undertaken concurrently with the other monitoring program. A methodical approach should be used whereby a grid pattern should be overlaid onto the rehabilitation polygons to be assessed, and the area walked in lines approximately 75-100 m apart across the contour to ensure suitable coverage of the areas.

While covering the project area on foot, opportunistic sightings and assessments should be made identifying the following, where relevant:

- Presence and severity of active erosion areas (e.g. rill, gully and tunnel erosion);
- Stability of slopes and landforms;
- Function and condition of existing erosion and sediment control structures and landform features, including water management structures (e.g. spine drains), water ponding areas, etc. (where applicable);
- Visual assessment of ground protection and vegetation cover, vegetation health and growth rates (high level assessment);
- Areas of significant weed incursion;
- Evidence of presence/impact of vertebrate pests; and
- Any other disturbance factors or features which may impact on site safety, such as presence of mine waste (e.g. signage, tyres, pipes, drums, etc.), track disturbance, damaged fences etc.

GPS points (2- 4 m accuracy) and geo-referenced photographs should be taken of all observations made during the assessment. By collecting geo-located photos, areas can be re-visited in the future and photo-monitoring continued to demonstrate the evolution of the site condition over time.

7.1.7 Honours Student Research Opportunities

Given the pioneering nature of this Revegetation Management Plan, there is an excellent opportunity to undertake more detailed monitoring of the crucial initial periods of germination and seedling establishment. Such detailed monitoring over the first six months is likely beyond the resources and time available to most environment teams, but is well suited to university Honours research. Dr. John Dwyer from the University of Queensland is prepared to try and secure an Honours student for this purpose. Dr. Dwyer would design an appropriate monitoring approach and analyses to estimate germination and initial survival rates for all sown species. Regardless of the results, this small research project would provide much-needed information about how to re-establish Brigalow

communities from direct seeding and tube stock plantings on cleared or reclaimed land. However, student availability for this kind of project would not occur until February 2018.

Monitoring would involve 20 to 30 transects, each 30 m in length covering the environmental variation across the site. Transect length would depend on the density of seedling emergence. The number of seedling of each species would be recorded along each transect. Ideally this would be done soon after germination (between 2 and 4 weeks) to capture peak germination (when most seeds have germinated and seedlings are still alive). After this, monitoring would ideally occur monthly for the first six months and at the six-month mark, and the heights of the remaining seedlings would be measured (noting their species identity). Such a monitoring regime would provide invaluable information about germination, survival and growth.

Monitoring would take approximately 1.5 days each survey and 2 days for the final survey. A participating University of Queensland student cannot be guaranteed at this stage and would not be available until late February. Monitoring would have to occur during this period if seeding occurs in late November. Equipment required would be star pickets for each transect, a star picket driver and an HOBO temperature and moisture probe for each transect.

8.0 Performance Indicators and Criteria

The performance indicators and criteria have been defined to underpin the implementation of the Revegetation Management Plan, inclusive of the monitoring program. This includes the following:

- Identification of **performance indicators** of the biophysical environment that can be measured reliably over time using accepted scientific techniques and standards; and
- Establishment of the **performance/completion criteria** for each indicator which quantitatively demonstrates rehabilitation.

The objectives, performance indicators, and criteria in this Plan are designed to form the basis of the performance measure and provide the ability to track the development of sustainable ecosystems through a series of conceptual stages. This information is provided in Table 6 with the methodology as discussed in Section 7.0.

Table 6 Performance Indicators and criteria

Objective	Performance indicators	Performance Criteria
The Bullock Creek revegetation area should: · Reflect the composition of RE 11.9.1 as observed on site · Be safe, stable and non-polluting; and, · Require minimal ongoing management inputs.	Groundcover distribution	· Majority leaf litter; and, · Grass tussocks dispersed but not forming a dense sward.
	Species diversity	· Minimum of four tree species and eight shrub and small tree species. Total of 12 Brigalow-Dawson gum woodland species. · The abovementioned species should occur in similar proportions to that outlined in Section 4.1.1; · Exotic species such as *Cenchrus ciliaris* may be present but must be sparse and not form dense swards.
	Woodland composition	· Average stem density >900 stems/ha <2500 stems per hectare; · Woody biomass between 95 tonnes/ha and 160 tonnes/ha; · Foliage Projected Cover > 50%; · Biocondition score in the range of 0.56;
	Woody debris	· Coarse woody debris present and ideally between 428 m/ha and 565 m/ha.
	Presence/absence of biosecurity threat	· No significant infestations of Weeds of National Significance, i.e. > 15% of total area; · Weeds do not dominate rehabilitated lands after disturbance or rain; · Weeds and feral pest animal species are controlled in accordance with relevant legislation; · Weed control is undertaken prior to seed set of noxious species. · Weed species diversity and abundance should not increase throughout the course of the study.

Objective	Performance indicators	Performance Criteria
The Bullock Creek revegetation area should: · Have the same or improved soil conditions from the baseline conditions in AECOM's Technical Report (AECOM, 2017), commensurate with typical soil conditions of a Brigalow woodland. · Be safe, stable and non-polluting; and, · Require minimal ongoing management inputs.	Soil physicochemical properties	If the following soil criteria are met, it should represent an improvement from starting conditions and suggest that there has been a reinstatement of natural nutrient cycling processes: · pH >6 < 9; · EC <300 µS/cm; · ESP <12%; · Nitrate > 0.3 mg/kg; · Total Nitrogen >520 mg/kg; · Colwell Phosphorus >15 mg/kg; · Total Phosphorus >262 mg/kg; and, · Total Organic Carbon >0.66 mg/kg.
The Bullock Creek revegetation area should be geomorphically stable	Erosion	· Subsoil not present during walkover assessment · Number of erosion features (width and depth of gullies and rills), erosion dimensions and erosion category (rill, gully, sheet, tunnel) distribution remains stable throughout study period;
The Bullock Creek revegetation area should have a low fire risk	Presence/absence of fire	· No visible signs of fire scarring on trees; and, · Low biomass of vegetative groundcovers such as *Cenchrus ciliaris* (buffel grass).

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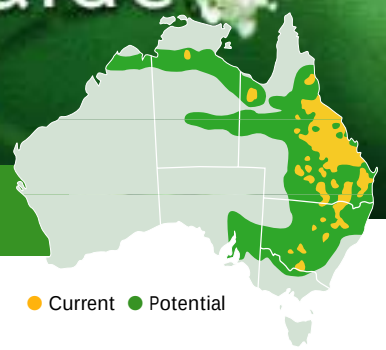
Appendix A

Parthenium Weed Fact Sheet

Weed Management Guide

Parthenium weed –
Parthenium hysterophorus



Parthenium weed (*Parthenium hysterophorus*)

The problem

Parthenium weed is a *Weed of National Significance*. It is regarded as one of the worst weeds in Australia because of its invasiveness, potential for spread, and economic and environmental impacts.

Parthenium weed is a major problem in rangelands and summer cropping areas of Queensland. It has a serious impact on the pastoral industry, costing farmers and graziers in Queensland over $22 million a year in reduced production and increased management costs. Some people suffer severe allergic reactions to the plant or its pollen; it can cause dermatitis, hay fever and asthma. Parthenium weed is toxic to cattle, and meat from livestock that eat the weed can be tainted. It also threatens biodiversity in the Einasleigh Uplands bioregion and native grasslands in the central highlands of Queensland.

The weed

Parthenium weed is native to the subtropics of North and South America. It is a fast-maturing annual (or, under certain conditions, a short-lived perennial) with a deep tap root and an erect stem that becomes woody with age. It may eventually reach a height of 2 m. Its leaves are pale green, branched and covered with soft fine hairs. The small white flowers (4 mm across) have five distinct corners and grow on the stem tips. Each flower produces four or five black wedge-shaped seeds that are 2 mm long with thin white scales.

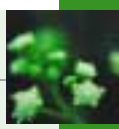
Its large and persistent soil seedbank, fast germination rate and ability to undergo dormancy make it well adapted to semi-arid environments. It also releases chemicals that inhibit the germination and growth of pasture grasses and other plants.



Parthenium weed matures quickly and produces large quantities of seed (up to 100,000 seeds per plant).
Photo: Larry K. Allain

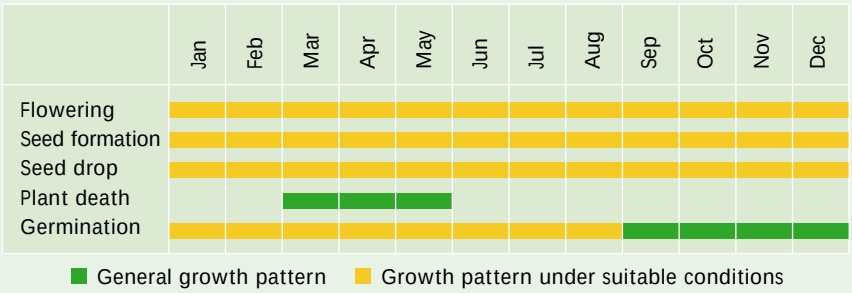
Key points

- Parthenium weed can germinate, grow, mature and set seed in four weeks.
- Parthenium weed is toxic to stock and contact with parthenium weed, particularly its pollen, can cause allergic reactions such as dermatitis, hay fever and asthma in people.
- The best way to prevent an allergic reaction to parthenium weed is to avoid contact with it, especially breathing pollen from flowering plants.
- Pay close attention to property hygiene. Weed seeds are spread very easily by vehicles, machinery, stock, grain and fodder.
- Use mechanical, chemical and biological control and grazing to manage parthenium weed.

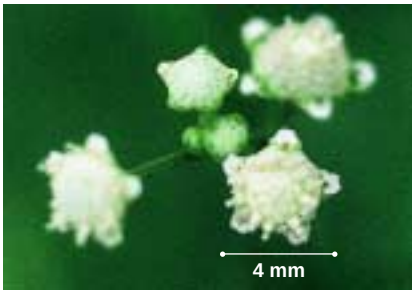


Natural Heritage Trust
Helping Communities Helping Australia
An Australian Government Initiative

Growth calendar



Parthenium weed normally germinates in spring and early summer, produces flowers and seed throughout its short life and dies in late autumn. However, with the right conditions (rain, available moisture, mild soil and air temperatures), parthenium weed can grow and produce flowers at any time of the year. In a good season, four or five generations may emerge. In summer, if plants are stressed (eg due to lack of water), parthenium weed can complete its life cycle in four weeks. Buried seeds have been found to last much longer than seed on the soil surface, and a significant proportion can still germinate after eight to ten years.



Parthenium weed can flower year round.
Photo: Colin G. Wilson

Potential distribution

Parthenium weed is best suited to areas with an annual summer rainfall greater than 500 mm. Based on climate suitability, it could potentially grow in all mainland states and territories.

How it spreads

Parthenium weed can produce large quantities of seed, up to 100,000 per plant. More than 340 million parthenium weed seeds per hectare can be present in the surface soil, compared to 120,000 native grass seeds.

The seed is easily spread by vehicles, machinery and animals, and in pasture seed, stock feed and water. Most long distance spread is in produce, vehicles and farm machinery. It can also be spread by flooding and by animals.

Parthenium weed was first discovered in Queensland in 1955. In a short time it spread from isolated outbreaks to establish core infestations across the Central Highlands of Queensland and into New South Wales and the Northern Territory.

Where it grows

Parthenium weed infests more than eight million hectares of central Queensland with serious outbreaks in the south and north of the state. Outbreaks, many of which have been controlled, have been found throughout New South Wales as far south as the Victorian border.

In Queensland it grows best on alkaline, clay-loam to heavy black clay soils but tolerates a wide variety of soil types. It aggressively colonises areas with poor groundcover and exposed soil such as wastelands, roadsides and overgrazed pastures. It does not usually become established in undisturbed vegetation or vigorous pastures. Drought, and subsequent reduced pasture cover, create the ideal opportunity for parthenium weed to establish. Flooded country is also very prone to parthenium weed distribution and flooded pastures may need to be spelled from grazing to gain their competitive edge.

What to do about it

Preventing spread into new areas

Preventing the spread of parthenium weed is the most cost-effective management strategy.

There is a high risk of spreading parthenium weed by the movement of vehicles, machinery, livestock, grain and other produce. Queensland has a number of washdown facilities and contractors are required to clean harvesters and other equipment before leaving the state. All harvesters are inspected as they cross the Queensland – New South Wales border.



Parthenium weed can germinate, grow, mature and set seed in four weeks.
Photo: Sheldon Navie

Property hygiene is also important. Double-check machinery (including the interior of the vehicle) moving onto your property and drive visitors around in your own vehicle. Always wash down vehicles and machinery in the same area to allow easy follow-up control of any seeds that may germinate. Ensure that service provider vehicles (eg telephone, electricity, gas) are free of parthenium weed seed.

Avoid moving cattle in wet weather as they readily transport seed in muddy soil. When new stock arrive on a property, hold them in yards or small paddocks to let seed drop from their coats and tails before releasing them into large paddocks. Always feed stock in the same area to contain weeds imported in contaminated fodder.

When you are buying hay or seed, be aware of what you are buying. In Queensland landowners are required to supply a vendor declaration to state whether their produce is free of parthenium.

Recent experience with parthenium weed

The Queensland Department of Natural Resources and Mines and the Parthenium Action Group have developed management and control techniques for parthenium weed, which include a combination of biological control agents, pasture management, cultivation and herbicides. Small infestations can be eradicated by early detection and monitoring. An ongoing commitment is needed to remove any seedlings and ensure new infestations do not establish. The extent of parthenium weed in New South Wales has been significantly reduced in recent years; all known roadside infestations have been suppressed and all known infestations on private land are under active control. In the Northern Territory, parthenium weed has been eradicated from previous infestations on the Roper River, at Katherine and in the Gulf of Carpentaria. However, although the area infested with parthenium weed is being reduced, the number of new infestations is increasing.



Large parthenium weed infestation in central Qld. Photo: Qld DNRM



Parthenium weed's large and persistent soil seedbank and fast germination rate make it well adapted to semi-arid environments. Photo: Colin G. Wilson

Control of new outbreaks

Once parthenium weed has been positively identified, treat isolated patches immediately with herbicides recommended by the local council weeds officer. Watch the area closely for at least seven years as repeated spraying may be necessary to kill new germinations. Don't pull up plants by hand, particularly if they have already set seed. There is a danger that mature seeds will drop off the plant and increase the area of infestation.

Control in pasture...

Control in pasture requires timely herbicide application and pasture management. Conservative stocking to keep a good pasture cover is the best way of controlling large-scale parthenium weed infestations and preventing new infestations in clean areas. Areas where stock congregate, such as watering points, often have low groundcover and are highly susceptible to parthenium infestation. To overcome this problem, establish several stock water points per paddock and rotate stock between them.

Breaking up large paddocks by fencing into single units of similar land type can even out grazing and thus avoid bare patches where weeds can invade. It also allows more flexible management strategies, such as spelling pasture and applying herbicide.

...and control in crops

Parthenium weed is becoming a significant problem in crops due to the threat to exports from contaminated grain or other produce. Once in a crop it is very difficult to eradicate, so try to keep crops clean by spraying selective, pre-emergent herbicides where possible and cleaning equipment and machinery such as harvesters. Do not purchase seed that does not comply with the relevant seed Acts. For further information on parthenium weed control in crops, consult your local crop agronomist.

Herbicides

Timing of chemical control is critical. Parthenium weed should be treated when plants are small and have not produced seed, and when grasses are actively growing to recolonise the infested area (eg early summer). Maintaining competition is important for control of parthenium weed, so spraying with a selective herbicide that will not kill other species is recommended. Keep a close watch on treated areas for at least seven years and spot spray isolated outbreaks. A number of herbicides are recommended for parthenium weed control. Contact your local authority for details.

Weed control contacts

State / Territory	Department	Phone	Email	Website
ACT	Environment ACT	(02) 6207 9777	EnvironmentACT@act.gov.au	www.environment.act.gov.au
NSW	NSW Agriculture	1800 680 244	weeds@agric.nsw.gov.au	www.agric.nsw.gov.au
NT	Dept of Infrastructure, Planning and Environment	(08) 8999 5511	weedinfo.ipe@nt.gov.au	www.nt.gov.au
Qld	Dept of Natural Resources and Mines	(07) 3896 3111	enquiries@nrm.qld.gov.au	www.nrm.qld.gov.au
SA	Dept of Water, Land and Biodiversity Conservation	(08) 8303 9500	apc@saugov.sa.gov.au	www.dwlbc.sa.gov.au
Vic	Dept of Primary Industries/Dept of Sustainability and Environment	136 186	customer.service@dpi.vic.gov.au	www.dpi.vic.gov.au www.dse.vic.gov.au
WA	Dept of Agriculture	(08) 9368 3333	enquiries@agric.wa.gov.au	www.agric.wa.gov.au
Australia wide	Australian Pesticides and Veterinary Medicines Authority	(02) 6272 5852	contact@apvma.gov.au	www.apvma.gov.au

For up-to-date information on which herbicides are registered to control parthenium weed and the best application methods and dosages, contact your state or territory weed management agency or local council. This information varies from state to state and from time to time. Contact details are listed above, including contacts for the Australian Pesticides and Veterinary Medicines Authority, which hosts the PUBCRIS database. This database contains information on all herbicides that are registered for use on weeds in each Australian state and territory.

When using herbicides always read the label and follow instructions carefully. Particular care should be taken when using herbicides near waterways because rainfall running off the land into waterways can carry herbicides with it. Permits from state or territory Environment Protection Authorities may be required if herbicides are to be sprayed on riverbanks.

Mechanical removal

Ploughing the weed in before plants reach flowering stage and then establishing pasture may be effective. Before crops are planted, parthenium weed is normally ploughed in, or pre-emergent herbicides can be used.

Biological control

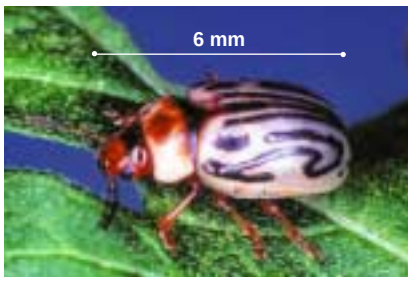
Biological control of parthenium weed has been investigated in Australia for more than 20 years. Nine insect species and two rusts have been released. Most insects and both rusts have established.

Biological control is one tool that forms part of an integrated management program for large-scale scattered and dense infestations. However, biological control on its own will not eradicate parthenium weed infestations.

The leaf beetle *Zygogramma bicolorata* and the stem moth *Epiblema strenuana* cause the most damage. The beetle emerges in late spring and is active until autumn. The moth is established in all parthenium weed areas. Its larvae (grubs) feed inside the stem, stunting the plant's growth and reducing its competitiveness and seed production. Other species are: a stem boring weevil from Argentina, *Listronotus setosipennis*, which is having limited success; a seed-feeding weevil, *Smicronyx lutulentus*, which lays eggs in the flower buds, leaving the newly hatched grubs to feed on the seed heads; a leaf mining moth, *Bucculatrix parthenica*, from Mexico, whose grubs feed on the leaves of parthenium weed; a stem-galling weevil, *Conotrachelus albocinereus*, from Argentina, which is still becoming established; and *Carmentia ithacae*, a stem boring moth from Mexico released from quarantine in 1999 and still becoming established in the Central Highlands.

Seasonal conditions and the need for green plants for insect survival play a major role in the effectiveness and abundance of biological control agents. This is highlighted during long dry periods when insect populations are reduced and need time to recover.

Puccinia abrupta, a winter rust from Mexico, infects and damages leaves and stems. It is established over a wide area in Queensland, south from Clermont. The release program for a second rust, *Puccinia melampodii*, a summer rust, began in 1999 and is continuing. Its establishment has been hindered by drought but further releases have been made in some areas following better rainfall. Its impact is expected to improve if rainfall increases



The leaf beetle *Zygogramma bicolorata* emerges in late spring and is active until autumn.
Photo: Rachel McFadyen



The leaf beetle *Zygogramma bicolorata* can remove virtually all of parthenium weed's foliage.
Photo: Rachel McFadyen

in the areas infested with parthenium weed. The rust weakens the plant by damaging the leaves over the summer growing season.

Field collection and distribution of biological control agents will help reduce local parthenium weed infestations. For best results a nursery site to raise biological control agents should be developed. Good nursery sites can be as simple as a leaking pipe or tank. Other ideal sites are infested black soil creek flats, gullies or swampy areas. At the same time, ensure that your nursery site does not become a source for further parthenium weed infestations. Contact your state/territory weed management agency or local council for assistance in collecting and rearing biological control agents for parthenium weed.



The distinctive branched leaves are covered with soft, fine hairs.
Photo: Sheldon Navie

Burning

Burning is not a useful control strategy for parthenium. However, research suggests that burning for other purposes (eg woody weed control) will not result in an increased infestation of parthenium so long as the pasture is allowed to recover before stock are introduced. Stocking of recently burnt areas known or suspected to contain parthenium weed decreases competition, ultimately creating a more serious infestation. Permits may be required to burn, so check with your state/territory weed management agency or local council.

Legislation

Parthenium weed is declared a noxious weed in all mainland states and territories, and landowners are required to control it. Its introduction into Australia is prohibited. Legislation introduced into Queensland recently makes it a legal requirement for suppliers of stock, machinery, soil, water or other products likely to transport weed seeds to complete a declaration stating whether or not the material is clean of parthenium weed. In New South Wales landowners must report the presence of parthenium weed to the local control authority within three days. This agency will then advise the necessary action to be taken to eradicate the infestation.

Acknowledgments

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Maps: Australian Weeds Committee.

...case study

Management of parthenium weed at Mt Panorama



While parthenium weed is certainly something landholders should try and prevent invading their properties, it can be managed. This is the message from Gail Godwin Smith, project officer with the Parthenium Action Group. Gail and her husband Howard Smith are farmers and graziers at Rolleston in central Queensland.

In 1988, when Howard and his family bought 'Mt Panorama', it was infested with parthenium weed. Today, they regard the weed as an indicator species which appears if pasture is being overgrazed.

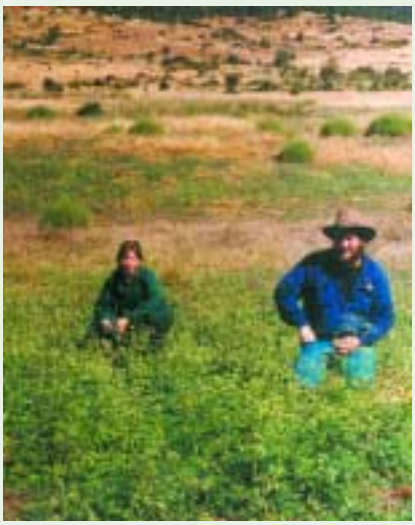
'Mt Panorama' has been a trial property for the release of biological control agents, two of which (the *Zygogramma* beetle and summer rust) have had a big impact on the weed.

However, changing management practices has been the major factor in controlling parthenium, says Gail. The main infestations on the property now occur along waterways. Many of these waterways have been fenced off to allow native vegetation to compete with parthenium and they are grazed seasonally to reduce any fire risk.

Favourable seasonal conditions allow spelling of paddocks and rotation of cattle so that healthy pasture is maintained and no one paddock gets eaten out.

Parthenium weed is no longer a problem on the cultivated country either, where minimum tillage is used and pre-emergent herbicide sprayed for other weeds.

The Smith family recognise that they are unlikely to totally eradicate parthenium weed, and so they must live with it and manage it appropriately.



Changing management practices has been the major factor in controlling parthenium weed on 'Mt Panorama'.
Photo: Qld DNRM

How to control parthenium weed

Quick reference guide

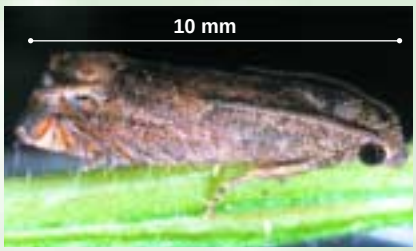
Parthenium weed – *Parthenium hysterophorus*

Prevention

Maintaining good hygiene on your property can prevent the spread of parthenium weed seed – check vehicles and machinery moving onto the property, drive visitors around in your own vehicle and always wash down vehicles and machinery in the same place. Always feed stock in the same area to contain weeds carried in contaminated fodder and place new stock into a small holding paddock until seed has dropped from their coats and tails.

New outbreaks

Treat immediately with a herbicide recommended by the local council weeds officer. Apply herbicides when plants are actively growing and before they set seed; keep a close watch on treated areas for at least seven years. Spot spray one to two weeks after rain, when plants are large enough to see but before they produce seed.



The stem moth, *Epiblema strenuana*, is established in all parthenium weed areas. Photo: Rachel McFadyen

In pasture

Stock conservatively to keep a good pasture cover, which will help prevent invasions of parthenium weed. Some strategies to improve pasture competition are to: spell pastures in the growing season, use rotational grazing, and spray herbicide to encourage grass seed production and reseeding.

To overcome high grazing pressure points, establish several stock water points per paddock and rotate stock between them.

Fencing different land types enables better grazing management.

In crops

Keep crops free of parthenium weed by spraying selective, pre-emergent herbicides where possible and cleaning equipment and machinery such as harvesters.

Biological control

Researchers in Queensland have located and tested a number of biological control agents against parthenium weed. Landowners can collect and distribute biological control agents to help reduce local infestations.

Control options

Type of infestation	Chemical	Biological	Physical	Pasture management	Mechanical
Light – few plants, over a small area	Spot spray before seeds set.	Not suitable.	Hand pulling is not recommended because of the health risks associated with parthenium weed. Use strategic fencing to separate different land types and improve grazing management.	Maintain good pasture cover by not overgrazing.	Some landholders have achieved success by ploughing in parthenium weed in the rosette stage before it seeds, but this must be followed up by sowing a crop or direct seeding perennial pasture.
Medium – plants over a medium area	Spray before seeds set.	Release biological control agents.			
Heavy – large number of plants	Spray before seeds set.	Establish a nursery site for biological control agents if possible.			

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CRC Weed management

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