15 March 2017

REPORT

RASP MINE, BROKEN HILL, NSW

Design Report for the Blackwood Pit Tailing Storage Facility Extension

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Executive Summary

This report presents Broken Hill Operations Pty Ltd (BHOP) with an extension design for the Blackwood Pit Tailing Storage Facility (TSF) at the Rasp Mine. The Blackwood Pit (the Pit) currently receives tailing from operation of the mine and under the proposed extension additional storage capacity will be provided by construction of embankments around the pit rim. The extension will enable deposition of tailing through to mid-2021 based on ongoing deposition at a rate of approximately 570,000 dry tonnes per year.

The extension design comprises the construction of three embankments along the north western (Embankment 1), northern (Embankment 2) and southern (Embankment 3) rim of the Pit. Embankment 1 will be constructed on *in situ* bedrock with exception of the upstream toe which will be constructed on the tailing beach. Embankment 2 will be constructed on *in situ* bedrock and Embankment 3 will be constructed generally on tailing.

The embankments will be formed with compacted rockfill sourced from mine waste rock excavated during the mining operation. A Filter Sand layer will be formed on the upstream slope of the embankments and will be overlain with a geosynthetic liner to minimise seepage through the embankments. Embankment 1 will be approximately 160 m long, Embankment 2 will be approximately 450 m long and Embankment 3 will be approximately 350 m long. All three embankments include seepage collection pipework and collection sumps. The embankments are designed to conservative parameters recognising the location of the facility relative to the town infrastructure.

Embankment 2 includes a Stormwater Collection Pond for the stormwater runoff, while Embankments 1 and 3 link into the existing site stormwater management system.

Embankment construction will be staged, with Embankment 2 (Stage 1) initially constructed at the northern end of the pit prior to tailing deposition reaching the construction footprint. Embankments 1 and 3 (Stage 2) will be constructed once the tailing beach has developed closer to the rim of the Pit to manage embankment footprint constraints at the rim of the Pit. An emergency spillway will be developed at part of Stage 1 near the north east end of the Pit and will also be used for Stage 2.

The length of the Pit is approximately 700 m along its south-west to north-east alignment. The width varies between 100 m and 200 m. Tailing currently beaches from the south-west end to the north-east end, where a decant pond forms. Excess water is pumped from the pond and reused at the processing plant. A similar tailing deposition and decant pond management strategy will be adopted for the proposed extension, with tailing predominantly deposited from the south-west end and decant water extracted by pumping. An emergency spillway will be developed for the extension, as well as a stormwater collection pond to the north of the TSF. The extension layout is designed to convey water towards a decant pond on the tailing surface and spillway at the north-east end of the pit. As per the current operation, water is expected to intermittently pond at the north-east end of the Pit.

The Blackwood Pit TSF design includes Environmental Containment Freeboard capacity on the tailing beach below the spillway invert sufficient to manage the runoff from a 1 in 10,000 annual exceedance probability (AEP), 72-hour design storm event. The spillway provides capacity to discharge the Probable Maximum Flood (PMF) event. The most conservative values have been selected from the ANCOLD and DSC guidance documents for these design criteria.

Embankment slope stability assessments undertaken for the embankments show appropriate factors of safety under design static and seismic loading for a 1 in 10,000 AEP earthquake event, as required under DSC guidelines.

The current rate of rise for tailing deposition, at a production rate of 570,000 dry tonnes per year, is approximately 4.8 m/year. The rate of rise is expected to reduce to less than 3 m/year, presenting favourable conditions for embankment construction onto tailing at Stage 2.

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1.0 INTRODUCTION

This report presents Broken Hill Operations Pty Ltd (BHOP) with an extension design for the Blackwood Pit Tailing Storage Facility (TSF) at the Rasp Mine (the site). The extension will provide for tailing storage above the rim of the Blackwood Pit (the Pit) by construction of embankments. The report focusses on the civil and geotechnical engineering aspects of the design.

The design is intended to extend deposition of tailing at the Blackwood Pit Tailing Storage Facility (TSF) to mid-2021.

2.0 BACKGROUND

The Rasp Mine is located in Broken Hill, NSW on Consolidated Mine Lease 7 (CML7). A site locality plan and site layout plan is presented on Drawings 1 and 2 (refer APPENDIX A). Production at the mine recommenced in 2012 with commissioning of a new processing plant and utilisation of the Blackwood Pit for tailing storage.

2.1 Site History

The site has been subjected to mining since 1885 and is based on a zinc, lead and silver resource. Ore was recovered from open pit and underground operations by Broken Hill Proprietary Co. Ltd (BHP). Followed by a series of takeovers and lease transfers, mining operations including mining of the Blackwood Pit ceased in 1991 when Normandy Mining Inc. (NMI) purchased the lease. CBH Resources Ltd (CBH) purchased the lease from NMI in 2000 and has re-developed an underground mine.

2.2 Current Operation

The current production phase of the underground operation of the mine commenced in 2012 following completion of the decline. A design for in-pit tailing storage in the Blackwood Pit was completed in 2012 (Golder, 2012). The Blackwood Pit TSF was designed for tailing deposition, at an average gradient of 1.5%, from the south-west end of the pit up to RL 307 m which is below the pit rim at the north-east end. Tailing is currently beaching at approximately 1.5%, as predicted in the design. The TSF was, however, designed on the basis that tailing would be cycloned, with cyclone underflow being reused in the production of backfill for filling underground voids. The operation has progressed without the use of tailing for backfill and all tailing from the processing plant has been deposited in the TSF.

The bottom of the Pit extended into mined out workings over the southern part of the floor and included a number of partially backfilled or soil and rock covered old shafts. Two unoccupied buildings, named British Flats and Old Mine Residence No 27, are located adjacent to and mid-way along the north-west side of the Pit. The British Flats building is heritage listed.

The processing plant, commissioned in April 2012, has generated approximately 1,883,000 dry tonnes of tailing up to April 2016. Tailing has been deposited in the Pit since commissioning, resulting in a tailing elevation of approximately RL 292 m at the north-east end, as at April 2016. Some of the tailing is expected to have filled the old mined out areas, but the volume relative to the total tailing deposited is expected to be very low.

Based on the tailing production rate and the consumed storage of the existing Pit, the estimated achieved average dry density of tailing in the pit is approximately 1.45 t/m^3. During the early stages of operation, lower density tailing was deposited in the TSF, resulting in this relatively low dry density. The surface area of the tailing beach has subsequently increased and the tailings deposition density has increased resulting in higher tailing storage dry density. The tailing deposition conditions will further improve as the beach approaches the pit crest. The tailing beach area will further increase and with a reduction in the rate of rise for tailing deposition. The dry density of the tailings is therefore expected to be higher than the average estimated for the bottom part of the pit. A dry density of 1.55 t/m^3 is adopted for the extension design.

2.3 Remaining Storage

The rim of the Pit has a minimum elevation of approximately RL 306.7 m along the northern perimeter.

The remaining storage capacity in the TSF between the tailing beach surface, surveyed on 25 April 2016, and a projected beach surface 1 m from the lowest point of the pit rim is 1.29 Mm^3. At an expected tailing design dry density of 1.55 t/m^3 this equates to a capacity of approximately 2.0 M dry tonnes, or 3.5 years of tailing production at the indicated 570,000 dry tonnes per year. This indicates that the current capacity of the pit reaches its design limit by approximately end October 2019.

The design presented herein will extend the storage capacity of the Blackwood Pit until mid-2021.

3.0 BASIS OF DESIGN

The basis of design is as follows:

Storage

- Extend the capacity of the Blackwood Pit TSF, adopting a deposition rate of 570,000 dry tonnes per year and a slurry solids concentration of 65% by weight.
- Tailing will continue to be primarily deposited from the south-west end of the Pit, with some adjustments from time to time to manage the decant pond location and to maintain a beach away from Embankment 1 and 3 footprints on tailing.

Embankment construction

- Utilise waste rock generated from the mining operation as the primary embankment fill material, i.e. existing stockpiles on site are not to be used.
- Maintain access along the existing access road along the south east and east of the pit.
- Maintain the footprint of the embankments inside the surface rights boundary of BHOP.

Risk management

- Manage the risk to the local township of Broken Hill.
- Consider long term protection of the buildings adjacent to the rim of the Pit.

4.0 DESIGN OVERVIEW

The proposed design is intended to expand the capacity of the Blackwood Pit TSF by approximately 1.9 Mm^3, relative to the April 2016 tailing beach survey, through the construction of three embankments along the north western (Embankment 1), northern (Embankment 2) and southern (Embankment 3) rim of the Blackwood Pit.

The embankments will be formed with compacted rockfill sourced from mine waste rock excavated during the mining operation. A Filter Sand layer will be formed on the upstream slope of the embankments and will be overlain with a geosynthetic liner to limit seepage through the embankments. Embankment 1 will be approximately 160 m long, Embankment 2 will be approximately 450 m long and Embankment 3 will be approximately 350 m long. All three embankments include seepage collection pipework, directing collected seepage into small lined pits for removal by pumping back onto the tailings surface.

Embankment 2 stormwater runoff will discharge to a new Stormwater Collection Pond, and Embankments 1 and 3 will link into the existing site stormwater management system.

Embankment construction will be staged, with Embankment 2 (Stage 1) initially constructed at the northern end prior to tailing deposition reaching the construction footprint. Embankments 1 and 3 (Stage 2) will then be constructed once the tailing beach has developed closer to the rim of the Pit to manage embankment footprint constraints at the rim of the Pit. An emergency spillway will be constructed during Stage 1 near the north east end of the Pit and will also be used at Stage 2.

The design is presented in APPENDIX Aon the following drawings:

- Drawing No. 1 Cover Sheet
- Drawing No. 2 Existing Site Conditions
- Drawing No. 3 Embankments 1 and 2 Construction Preparation Layout
- Drawing No. 4 Proposed Embankment Layout at Intermediate Tailings Level
- Drawing No. 5 Proposed Embankment 1 Layout Plan
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5.0 SITE CHARACTERISTICS

5.1 Climate

5.1.1 Records

Climatic data for the site was sourced from the Bureau of Meteorology (BOM) website (BOM, 2016). The closest weather station is at Patton Street (station ID 047007), located within a few hundred metres of the mine site. The station is situated at elevation 315 m AHD, consistent with the average surface elevation of the mine site. The BOM website indicates rainfall observations from the Broken Hill Airport are included in the data set. No evaporation data is available for the Patton Street or Broken Hill Airport weather stations. Evaporation data for this study was sourced from the Stephens Creek Reservoir weather station (ID 047031), located approximately 16 km from the mine site. A summary of climatic data from the Patton Street weather station is provided in Table 1.

Table 1: BOM Climatic data for the site

Month	Mean Monthly Rainfall (mm)	Maximum 24 Hour Rainfall		Mean Maximum Temperature (degrees, C)	Mean Monthly Evaporation (mm)
		(mm/24hr)	Date Recorded		
January	25.6	73.6	10/01/1998	32.8	390.6
February	25.8	94.8	21/02/2000	32.2	310.8
March	21.6	139.4	14/03/1989	28.9	269.7
April	17.8	93.5	1/04/1931	23.9	171.0
May	22.4	62.2	26/05/1955	19.2	102.3
June	22.3	58.0	6/06/2008	15.6	72.0
July	18.9	32.8	18/07/1916	15.2	77.5
August	18.7	46.5	23/08/1920	17.4	114.7
September	20.2	91.4	7/09/1978	21.2	177.0
October	23.9	55.1	24/10/1938	25.0	248.0
November	21.3	103.1	29/11/1933	28.7	291.0
December	21.8	87.2	17/12/1992	31.4	356.5
Annual	**259.8**	**139.4**	**14/03/1989**	**24.3**	**2581.1**

The climate of Broken Hill is semi-arid and the site experiences hot summers and cold winters, with mean daily maximum temperature exceeding 32ºC in January and falling to approximately 15ºC in July.

Rainfall is spread throughout the year and there is no notable temporal distribution of average rainfall for Broken Hill, although rainfall is more likely during the cooler months of the year. During the hotter summer months, rainfall is associated with storm activity, whilst during the winter months rainfall is influenced by low pressure systems in the Southern Ocean. The average annual rainfall for Broken Hill is approximately 260 mm.

Mean annual evaporation data for the Stephens Creek Reservoir weather station is approximately 2580 mm. The statistics summarised in Table 1 indicate that mean annual evaporation exceeds precipitation by a factor of approximately 10, although this factor varies from approximately 16 in December and January to approximately 3 in June.

5.1.2 Rainfall

Rainfall intensity-frequency (IFD) data were obtained from the BOM website for the site (BOM, 2016). A summary of the IFD data and corresponding rainfall depth data for the site are presented in Table 2 and Table 3. The rainfall depth data represents the factor of the intensity and the corresponding duration.

Rainfall data for the 1 in 1 Annual Exceedance Probability (AEP) to the 1 in 100 AEP was sourced from the BOM website (BOM, 2016) for the site. Rainfall intensity for all events between the 1 in 100 AEP and probable maximum precipitation (PMP) event were interpolated in accordance with the Australian Rainfall and Runoff guidelines (Nathan & Weinmann, 1998).

Table 2: Summary of rainfall intensity-frequency-duration data

Duration (hours)	Rainfall intensity (mm/hour) for Annual Exceedance Probabilities and the PMP								
	1 in 2 AEP (50%)	1 in 5 AEP (20%)	1 in 10 AEP (10%)	1 in 20 AEP (5%)	1 in 50 AEP (2%)	1 in 100 AEP (1%)	1 in 1,000 AEP (0.1%)	1 in 10,000 AEP (0.01%)	PMP
1	18.8	26.2	30.9	36.9	44.9	51.3	82.1	119.2	270.0
2	11.6	16.2	19.1	22.9	27.9	31.9	51.4	75.4	175.0
3	8.6	12.0	14.2	17.0	20.8	23.8	38.4	56.2	130.0
6	5.1	7.2	8.5	10.2	12.5	14.4	23.8	35.4	85.0
12	3.0	4.3	5.1	6.1	7.5	8.7	13.9	20.0	43.3
24	1.8	2.5	3.0	3.6	4.5	5.2	8.2	11.4	22.1
48	1.0	1.5	1.7	2.1	2.6	3.0	4.7	6.6	13.5
72	0.7	1.0	1.2	1.5	1.8	2.1	3.3	4.6	9.4

Table 3: Summary of rainfall depth data

Duration (hours)	Rainfall depth (mm) for Annual Exceedance Probabilities and the PMP								
	1 in 2 AEP (50%)	1 in 5 AEP (20%)	1 in 10 AEP (10%)	1 in 20 AEP (5%)	1 in 50 AEP (2%)	1 in 100 AEP (1%)	1 in 1,000 AEP (0.1%)	1 in 10,000 AEP (0.1%)	PMP
1	19	26	31	37	45	51	82	119	270
2	23	32	38	46	56	64	103	151	350
3	26	36	43	51	62	71	115	169	390
6	30	43	51	61	75	86	143	213	510
12	36	51	61	73	90	104	167	240	520
24	43	61	72	87	108	124	196	273	530
48	49	70	83	100	124	142	225	317	650
72	51	73	87	105	130	149	237	334	680

The key values for the design are:

- The rainfall intensity for 1 in 10,000 AEP event i.e. 4.6 mm/hour. The intensity over 72 hours results in a rainfall depth of 334 mm. This is considered for the required Environmental Freeboard discussed further in Section 10.9.7.
- The rainfall intensity for the PMP event is used for the spillway design of the TSF in Section 10.9.

5.1.3 Climate Change

Climate change in Australia is subject to ongoing research by BOM and CSIRO. BOM and CSIRO reported in 2016 that Australia's climate has warmed in both mean surface air temperature by approximately 1°C since 1910 with temperatures predicted to continue increasing with more extremely hot days and fewer extremely cool days. Winter and spring rainfall is also projected to decrease across southern continental Australia with more time spent in drought (BOM; CSIRO, 2016).

5.2 Topography and surface conditions

The site has been the subject of extensive mining operations since 1887. As a result, the topography has been extensively altered and little undisturbed ground remains on the site. The original ridge has been mined, and numerous mine pits, waste rock storages and tailing storage sites remain.

The existing topography to the north-east end of the Pit includes a gentle rise to a ridge line between 30 m and 80 m from the Pit rim. The elevation of the ridge is variable but is generally above RL 310 m. An aerial view of the Blackwood Pit and its surrounds as at 25 April 2016 is presented on Drawing No. 2 (refer APPENDIX A).

5.3 Geology

The Blackwood Pit TSF is underlain by weathered Gneiss which is interpreted to be part of the Hores Gneiss unit, a sub-unit of the larger Broken Hill Group (Van der Heyden & Edgecombe, 1990).

6.0 CAPACITY, SCHEDULE AND TAILING CHARACTERISTICS

6.1 Tailing generation and stages of development

BHOP reported approximately 1.9 M dry tonnes of tailing have been deposited in the existing Blackwood Pit TSF between April 2012 and April 2016. A forecast production rate of 570,000 dry tonnes per annum is adopted in the Blackwood Pit TSF extension design.

6.2 Construction and tailing deposition summary

6.2.1 Staging summary

A summary of development stages for the TSF raise is presented in Table 4. The tonnage capacity and filling dates are based on a dry density of 1.55 t/m^3 and 570,000 tailing tonnes per year.

Table 4: Summary of TSF raise stages

Stage	Cumulative Storage volume (million m^3)*	Tailing (million tonnes)	Predicted filling date
1 - Intermediate	1.71	2.6	December 2020
2 – Final	1.92	3.0	July 2021

* based on April 2016 Survey

6.2.2 Construction and tailing deposition sequence

6.2.2.1 Stage 1

The Blackwood Pit extension design includes embankment construction and tailing deposition in two stages: Stage 1 – Interim; and Stage 2 - Final. Tailing will continue to be deposited from the south-west end of the Pit and are expected to continue to beach at an average gradient of 1.5% towards the north-east end. As per the current operation, an intermittent decant pond is expected to form on the surface of the tailing at the north-east end. When water accumulates on the tailing surface, either from excess supernatant water during cooler months or following rainfall events, it will be extracted via pump and directed to the existing water re-use system at the processing plant.

Stage 1 comprises construction of Embankment 2 around the northern extent of the Blackwood Pit TSF and construction of an emergency spillway, as shown in Figure 1 and Figure 2 respectively. Embankment 2 will be founded on *in situ* bedrock.

Flood detention capacity is provided on the surface of the tailing, i.e. between the tailing surface and the spillway invert. Details for flood retention capacity are provided in Section 10.9 of this document.

Figure 1: Stage 1 Embankment 2 and Spillway Construction

Figure 2: Stage 1 Intermediate Tailing Deposition

6.2.2.2 Stage 2

Stage 2 comprises construction of Embankment 1 and Embankment 3 along portions of the north western and south sides of the Pit respectively. The construction of Embankment 1 within the topographic low area will commence before the tailings elevation in Figure 2 is reached to maintain the required tailings freeboard in the TSF. Construction of Embankment 3 will follow Embankment 1. Subsequent tailing deposition will progress against the embankments to form the beach shapes, as shown in Figure 3 and Figure 4 respectively. Embankment 1 includes a small gabion retaining wall within the downstream slope of the embankment, where the embankment is adjacent to an existing building. Embankment 1 is founded on *in situ* bedrock with exception of a portion of the upstream toe which is founded on tailing. Embankment 3 will generally be founded on tailing.

A decant pond will form at the eastern end of the tailing beach and excess water will be extracted by pump and transferred direct to the processing plant. The decant pool may migrate towards the northern end of Embankment 2 as the tailing beach approaches the embankment toe. The decant pump system would be moved as the pond migrates, or its location would be maintained at the east end of Embankment 2 by selective tailing deposition from the northern of the TSF, as indicated by the red arrow in Figure 4. Flood detention capacity is provided on the surface of the tailing, i.e. between the tailing surface and the spillway invert. Details for flood retention capacity and the emergency spillway are provided in the Water Management Design section of this document.

Figure 3: Stage 2 Embankment 1 and Embankment 3 Construction

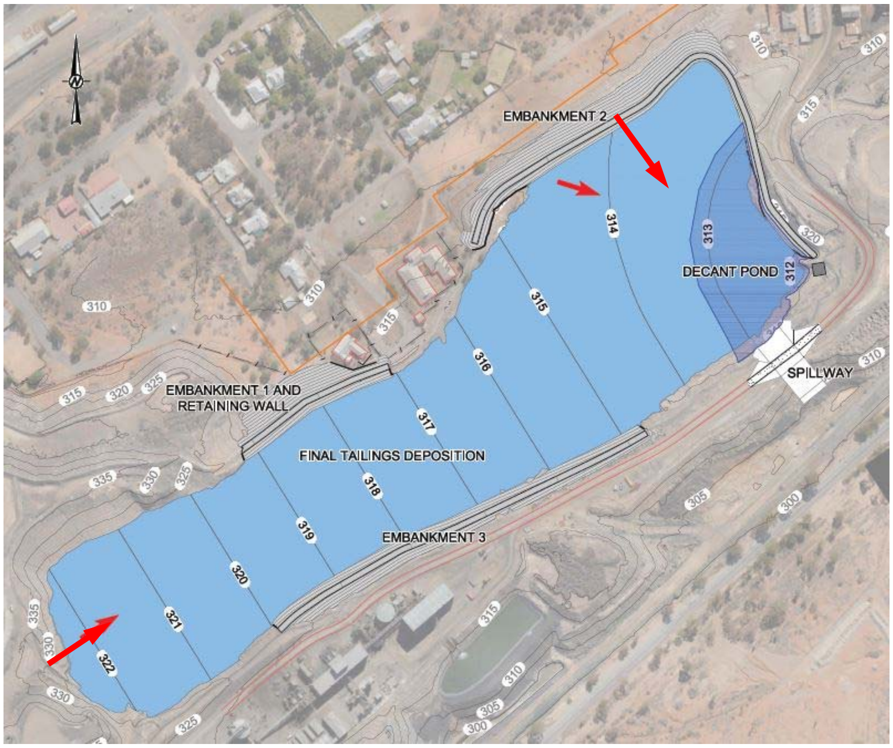

Figure 4: Stage 2 – Final Tailing deposition

6.3 Rate of rise

As the existing tailing deposition operation continues, the tailing beach will progressively increase in area and the rate of rise will decrease. The intermediate tailing elevation at the north-east extent (prior to construction of Embankments 1 and 3) is approximately RL 310 m. The rate of rise will initially be less than 4 m/year reducing to less than 3 m/year as the tailing elevation approaches the final elevation.

6.4 Tailing Properties and Characteristics

6.4.1 Deposition Rate and Slurry Solids Concentration

Deposition of tailing is forecast at an annual rate of approximately 570,000 dry tonnes. The solids concentration of the tailing slurry at discharge is expected to remain at approximately 65% by weight.

6.4.2 Particle Size Distribution

Particle size distribution (PSD) of the tailing was adopted based on testing undertaken in 2015 provided by BHOP. The PSD test results are presented in Figure 5.

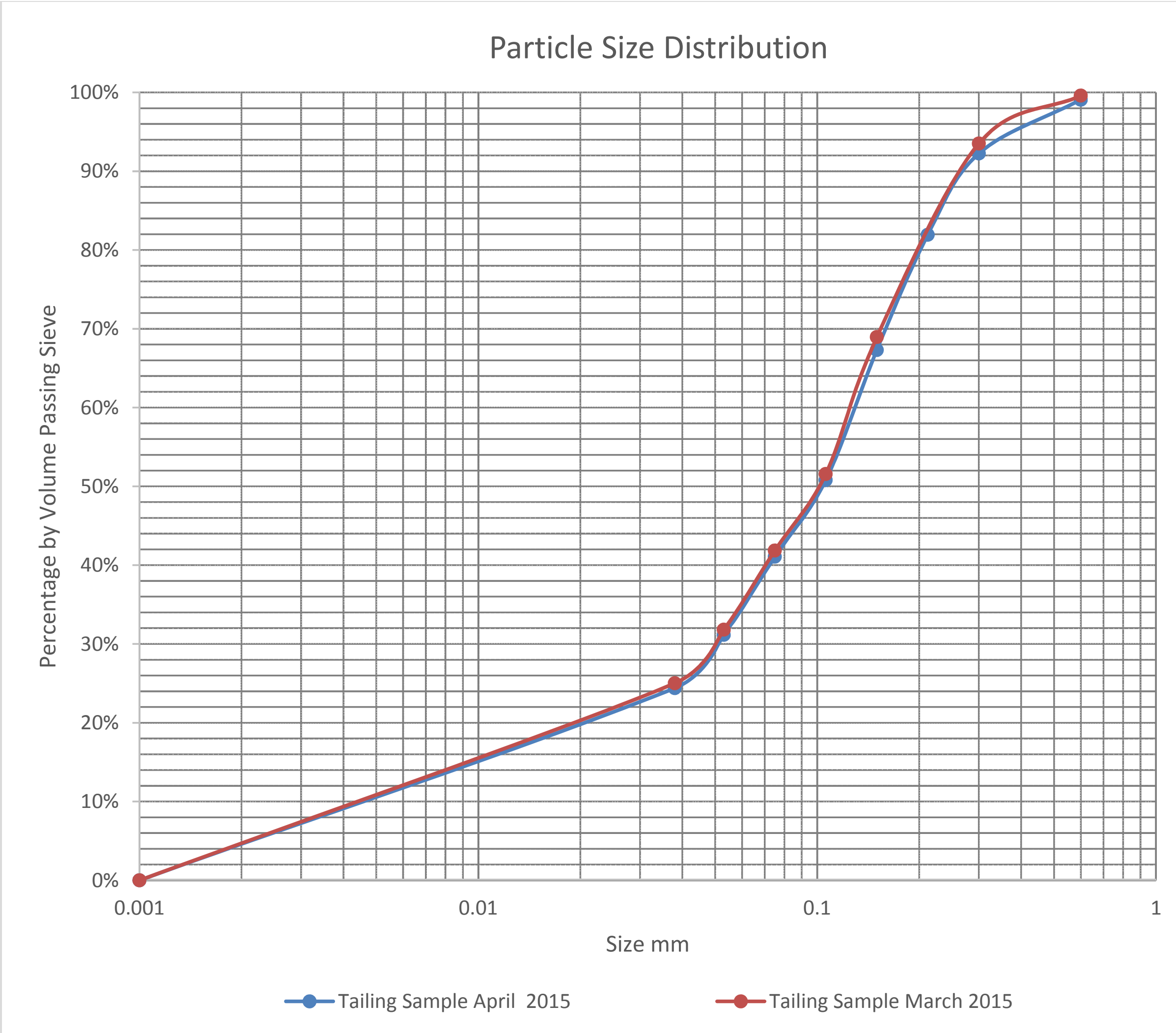

Figure 5: Tailing PSD Results

As indicated by the particle size parameters, the tailing is relatively coarse, with approximately 80% finer than 200 µm and approximately 40% finer 75 µm.

Table 5: Summary of key tailing properties and depositional characteristics

Parameter	Measurement/classification
Particle density (g/cm^3)	3.0
Maximum particle size (µm)	600
P_{80} 80% finer than particle size (µm)	200
Percent fines (passing 75 micron)	40
Clay size fraction: (passing 2 micron)	Less than 5
Unified soil classification	Silty SAND
Average dry density (t/m^3)	1.55
Average beach slope (%)	1.5

6.4.3 Particle Density

Particle density testing was undertaken by BHOP in September 2016 reported a density of 2.97. Previous testing undertaken by Golder in 2011 using the Helium Pycnometry method in accordance with ASTM D854 reported a particle density of 2.96 g/cm^3 and 2.97 g/cm^3 (Golder, 2012).

6.4.4 Tailing Beach

Site observations, as-built information and aerial surveys indicate the current tailing beach slope within the Pit is approximately 1.5%. The current maximum rate of rise of the TSF, based on survey data, is 4.8 m per year. The tailing deposition rate into the TSF is forecast to remain the same for the life of the proposed extension. The increase in tailing surface area as the TSF continues to be filled with tailing will result in a lower rate of rise, reducing to approximately 3 m per year as the south-west end of the tailing (tailing deposition location) reaches RL322 m.

Stormwater and supernatant water periodically ponds on the tailing beach at the north-east end of the tailing beach. Water is removed from this area by pumping.

A tailing beach slope of 1.5% is adopted for the extension design.

7.0 CONSTRUCTION OVERVIEW

7.1 Staging

The Blackwood Pit TSF extension comprises construction of three embankments with an associated water management system. The extension will be constructed in the following stages:

- Stage 1: construction of Embankment 2 with seepage collection pit, the Stormwater Collection Pond and the Spillway.
- Stage 2: construction of Embankments 1 and 3, with seepage collection pits.

7.2 Embankment Design

7.2.1 Embankment Construction

Embankment 1 (refer APPENDIX A - Drawing Nos. 4, 5, 8, 9, 13, 14, and 15) is located along a portion of the north west side of the TSF, southwest of the existing unoccupied Old Mine Residence No. 27. The embankment will be constructed partially on *in situ* weathered bedrock and partially on the tailing beach. The upstream portion of the embankment will be constructed on the future tailing beach. This area of the tailing beach is expected to be relatively dry as it at least 200 m from the decant pond area. Embankment 1 also includes a small gabion wall designed to retain a part of the outer slope of the embankment to maintain separation from the existing unoccupied old mine residence No. 27 building and its existing retaining wall. The maximum height of the gabion wall is 2 m, and reduces to nominal 0.5 m height at either ends of the approximate 35 m wall length.

Embankment 2 (refer APPENDIX A - Drawing Nos. 4, 6, 8, 10, 12, 14, and 15) will be located along a portion of the northern corner of the TSF and will be constructed on weathered bedrock. The works will also incorporate the construction of a pump platform and an extraction pipe to manage the decant pond. A Stormwater Collection Pond (refer Drawing No. 5) will be constructed to the north of the embankment. The Pond will collect stormwater runoff from the outer slopes of Embankment 2. The Stormwater Collection Pond may also be used to harvest this collected water and to transfer water to the processing plant.

Embankment 3 (refer APPENDIX A- Drawing Nos. 4, 7, 8, 11, 12, 13, 14, and 15) will be located along a portion of the southern side of the Pit. Portions of Embankment 3 will be constructed on the tailing with the downstream slope extending on *in situ* weathered bedrock of the edge of the Pit, and the majority of the north eastern length of the embankment will be on weathered bedrock or a thin layer of tailings.

7.2.2 Seepage Management

A geosynthetic liner will be installed on the upstream slope of each embankment to minimise seepage through the embankment. A sand filter zone between the geosynthetic liner and the compacted rockfill of the embankment will be constructed for collection of seepage through potential defects in the geomembrane, and to limit the potential of tailing migration through the embankment. The sand will also form a bedding layer for the geosynthetic liner over the rockfill.

Upstream toe drains will be constructed to collect seepage from the sand filter and convey collected seepage towards the seepage collection pits, located at the downstream toe of the embankments. The upstream toe drains are graded to low spots, from where the collected seepage is directed to the downstream (outer) edge of the embankment via gravity flow, into detention pits. The pipe through the embankment includes a seepage control plug around the pipe annulus. Collected seepage will be pumped back onto the tailings and will be managed by evaporation.

The estimated seepage is reported in Section 10.6.

7.2.3 Embankment Geometry

All three embankment have a minimum crest width of 5 m and have been designed with upstream and downstream slopes of 2.5H:1V. The upstream slope is conservative and may be revised during detailed design subject to geotechnical assessment of the proposed rockfill, construction constraints on the placement of the filter sand material and closure design considerations. The geosynthetic liner on the upstream slope of all embankments will be anchored at the crest, along the toe and the ends of the embankments. A safety bund will also be formed along the upstream and downstream embankment crest edges as shown on the drawings.

Crest elevation details of each embankment are presented in Table 6. Note, due to the gradient of the tailing beach slope and the operational freeboard, the embankment crest elevation varies and will be at least 0.5 m above the projected final beach profile. The crest elevation of Embankment 2 is determined by Section 10.9.

Table 6: Embankments Elevations

Embankment	Crest Elevation
Embankment 1	RL 322.2 m (south western extent) RL 320.1 m (north eastern extent)
Embankment 2	RL 318.3 m (western extent) RL 315.0 m (eastern extent)
Embankment 3	RL 323.0 m (south western extent) RL 318.0 m (north eastern extent)

7.2.4 Upgrade of Safety Bund

The existing safety bund located along the pit rim edge between Embankment 1 and Embankment 2 may need to be re-constructed if required to ensure the 0.5 m freeboard above the tailing surface is maintained, as per DSC requirements. This will be assessed as part of the construction of Stage 2 of the extension.

7.2.5 Spillway Construction and Extraction Pipe

A spillway will be constructed at the eastern corner of the TSF, to the design presented on Drawings No. 5 and 15 (refer APPENDIX A), for emergency release of water in the event of a large storm that exceeds the flood containment capacity. Details of the Spillway design are presented in Section 10.9.7.

A platform and extraction pipe to facilitate the pumping of decant water from the tailing surface will be constructed as part of the Stage 1 works.

8.0 CONSTRUCTION MATERIALS

The Blackwood Pit extension design is proposed to be constructed from the followings materials:

8.1 Rockfill

Mine waste rock from underground operations will be sourced for Rockfill and also to form a pioneering layer of rockfill for raise construction on potentially soft tailing.

The mine waste rock will be generally selected to have particle of less than 200 mm in size. Occasional boulders larger than 200 mm within the placed Rockfill will be selectively moved to the downstream face of the embankment during construction to provide additional armouring of the slope.

The waste rock will also be crushed to produce Select Rockfill. The Select Rockfill will have particles less than 50 mm in size and will be used to form the top 0.8 m thickness of the crests of the embankments and safety bunds. This layer will form the wearing course on the crest of the embankments and facilitate the construction of liner anchor trenches.

8.2 Filter Sand

A layer of Filter Sand will form the filter zone underlying the geomembrane and provide a bedding layer on the upstream slope of the embankments, below the geomembrane liner. The particle size requirements for the filter zone will be specified to filter the tailing to limit the risk of potential migration of tailing through the embankment if a large defect was to occur in the geomembrane liner, and provide a secondary depressurisation function below the geomembrane liner.

The Filter Sand bedding layer over the rockfill will protect the geomembrane liner from potential point loads from the Rockfill. The proposed sand will also be assessed during construction based on PSD testing of the Rockfill to decide whether a filter geotextile is required between the filter sand and Rockfill to reduce the risk of sand migration into the Rockfill.

8.3 Geosynthetic Liner

A 2 mm thick high density polyethylene (HDPE) geomembrane liner will be installed on the upstream slope of Embankment 2 as a barrier to limit seepage through the embankment. HDPE is selected for this embankment as minimal settlement is expected as this embankment is to be founded on rock.

Embankments 1 and 3 are partially or entirely founded on tailing with an interface with the existing pit rock slopes. Differential settlement is expected in these embankments so a 2 mm thick Linear Low Density Polyethylene (LLDPE) will be installed on the upstream slopes of these embankments. The installation process of these two types of geomembrane is the same, but LLDPE is more appropriate to conditions where deformation is expected.

The geomembrane will be anchored along the crest of each embankment in an anchor trench. At the toe of Embankment 1 and Embankment 3 the geomembrane will be anchored into the tailing. At the toe of Embankment 2 the geomembrane liner will be sealed against the prepared bedrock with a concrete strip over the geomembrane and a bentonite powder layer between the rock surface and the underside of the geomembrane liner.

The geomembrane liner will be sealed against the rock face of the pit at the ends of the embankment, by shaping the embankment slope to form a sloping join surface with the pit rock slope to facilitate the installation of a concrete strip sealing detail, as presented on the drawings. The LLDPE geomembrane will be installed with some slack to accommodate possible deformation and settlement of the embankment slope relative to the pit rock face.

Ballast will be placed over the geomembrane liner on the slopes to manage wind uplift. The ballast may comprise sand bags attached to rope lines anchored at the crest, or alternatively, may comprise geomembrane tubes placed down the slope at selected intervals. The ballast will be progressively buried by the tailing.

8.4 Drainage Pipes

A seepage collection drain (perforated 150 mm diameter PVC or similar material pipe) will be installed at the bottom of the filter sand along the upstream toe of the embankment. The pipe will be embedded in an aggregate layer to minimise migration of sand into the pipe perforations.

The drain will collect water intercepted by the filter layer between the rockfill and the geosynthetic liner and potential seepage flow from the embankment upstream toe foundation area. The collected seepage will be collected in sump pits, from where the collected liquid will be pumped back onto the tailings beach or to the processing plant. The layout of the seepage collection of the embankments is shown in Drawings 5, 6 and 7.

Seepage collection outlet pipes include pits where appropriate to view flow rates from different portions of the embankment lengths.

8.5 Gabion Wall

A Gabion wall up to 2 m high will be constructed as part of Embankment 1 to retain a portion of the outer slope of the embankment to maintain separation from the existing building and its existing retaining wall. The Gabion wall will be constructed from wire mesh baskets filled onsite with rockfill with a nominal particle size of 100 mm. The baskets (usually 0.5 m or 1 m high) are general placed empty and then progressively filled with rock as the wall is built. Each basket has a mesh lid that is wired closed once filled. A cross section of the wall is shown in Detail 5 in Drawing 15.

9.0 DESIGN CRITERIA

9.1 Regulatory Guidelines

A summary of guidelines applicable to the TSF design is provided below:

9.1.1 National Guidelines

- Guidelines on Consequence Categories for Dams, ANCOLD, October 2012 (ANCOLD, 2012)
- Guidelines on Tailings Dams, Planning, Design, Construction, Operations and Closure, ANCOLD, May 2012 (ANCOLD, 2012)
- Guidelines on Dam Safety Management, ANCOLD, August 2003 (ANCOLD, 2003)

9.1.2 NSW Guidelines

- DSC3A Consequence Categories for Dam, November 2015 (DSC, 2015)
- DSC3F Tailings Dams June 2012, June 2012 (DSC, 2012)

9.2 Consequence Category Assessment

9.2.1 Consequence Category

The proposed TSF extension was assessed to be a "High A" hazard category facility based on the DSC 'Guidelines on the Consequence Categories for Dams' dated October 2012 (ANCOLD, 2012), based on the location of the facility. This is consequence category invoked the most conservative design criteria presented in the DSC and ANCOLD design guidance for a TSF, as detailed in Sections 9.3 and 9.4.

9.3 Flood Management

DSC guidelines provide recommended freeboard criteria for tailing and flood containment, and spillway discharge capacity. Tailing and water containment criteria for TSFs are outlined in "DSC3F – Tailing Dams" (DSC, 2012). A summary of the relevant freeboards for a High consequence category facility are presented in Table 7.

Table 7: Summary of freeboard criteria

DSC Criteria	Design event / minimum freeboard	Equivalent ANCOLD criteria
Environmental Containment Freeboard	1 in 10,000 AEP, 72-hour event	Extreme storm storage allowance
Tailing Operational Freeboard	500 mm	n/a
Total Freeboard	1 in 10,000 AEP, critical duration event	Refer Table 8
Pond Recovery Time (7 days)	1 in 100 AEP, 72-hour event	n/a

Table 8: ANCOLD spillway design criteria

	Design Flood AEP	Wave Freeboard Allowance
High	At least 1:100,000, suggested PMF	Wave run-up for 1:10 AEP wind event with 1:100,000 design flood

Note: The spillway design assessment for the TSF considers wind events up to 1:50 AEP in combination with the design flood event.

The Environmental Containment Freeboard (ECF) represents the required flood storage capacity between the tailing beach and the spillway elevation.

The Operational Freeboard represents the vertical distance between the elevation of the tailing beach adjacent to the embankment and the embankment crest elevation. The Operational Freeboard is required to reduce the risk of tailing spillage from the facility.

The Total Freeboard represents the storage capacity between the tailing surface and the crest of the containment embankments, including consideration of the operational water pond. The Total Freeboard is specified to ensure a facility has the capacity to safely manage an extreme storm event by a combination of storage and spillway discharge.

The ANCOLD guidelines on Tailing Dams dated May 2012 (ANCOLD, 2012), state it is good risk management practice to provide an emergency spillway. ANCOLD guidelines suggest a spillway during operation to manage the 1 in 100,000 AEP. The design of the TSF includes a larger spillway to cater for the Probable Maximum Flood (PMF). This larger spillway capacity is conservative for the operational phase of the TSF and meets the ANCOLD guideline for the closure of the TSF.

9.4 Geotechnical Stability

9.4.1 Overview

The following sections address earthquake loading, embankment slope stability and liquefaction risk. A summary of assessments and comments addressing these criteria is presented in Section 10.5.

9.4.2 Earthquake Loading

The ANCOLD "Guidelines on Tailing Dams" (ANCOLD, 2012) present recommended earthquake design criteria for operating and post closure conditions related to the consequence category of a facility. Two levels of earthquake loading are considered for operating conditions – the Operating Basis Earthquake (OBE) and Maximum Design Earthquake (MDE). The Maximum Credible Earthquake (MCE) is considered for post closure.

The MDE represents higher peak ground accelerations (PGA) relative to the OBE, and is typically adopted for tailing dam design. For the MDE, the tailing dam embankments could be extensively damaged with disruption to operations, but the structural integrity is to be maintained, without uncontrolled release of tailing and/or water.

Design PGAs for the OBE and MDE are adopted based on annual exceedance probabilities (AEPs) assigned according to the consequence category. Lower AEPs (and higher PGAs) are assigned as the consequences of failure become greater. Under the ANCOLD guidelines, AEPs of 1 in 1,000 and 1 in 10,000 are assigned for the OBE and MDE events respectively for High consequence category facilities.

The Australian earthquake hazard map published by Geoscience Australia in 2012 (Burbridge, 2012) presents PGA data for the site. The 2012 Australian Earthquake Hazard Map indicates the site peak ground acceleration (PGA) for the 1 in 500 annual exceedance probability (AEP) event to be between 0.01 g and 0.02 g (Burbridge, 2012, p. 60), the 1 in 2,500 AEP event to be between 0.03 g and 0.06 g (Burbridge, 2012, p. 64), the 1 in 10,000 AEP event to be between 0.10 g and 0.20 g (Burbridge, 2012, p. 64).

9.4.3 Embankment slope stability criteria

Table 9 presents recommended minimum Factors of Safety (FoS) for tailing storages based on industry practice and recommendations in the ANCOLD guidelines (ANCOLD, 2012).

Table 9: Adopted target factors of safety

Loading Condition	Recommended Minimum for Tailing Dams	Shear Strength to be adopted for evaluation
Long-term drained	1.5	Effective Strength
Short-term undrained (potential loss of containment)	1.5	Consolidation Undrained Strength
Short term undrained (no potential loss of containment)	1.3	Consolidated Undrained Strength
Post-seismic(Note)	1.0	Post Seismic Shear Strength

Note: ANCOLD does not provide recommended factors of safety for OBE and MDE loading conditions but indicates that embankment displacements should be considered. ANCOLD, however, refers to 'post-seismic' condition, where a factor of safety of between 1.0 and 1.2 may be adopted subject to the confidence in selection of the residual shear strength parameters (ANCOLD, 2012).

9.4.4 Liquefaction Risk

ANCOLD provides an approach for management of risks associated with seismicity and liquefaction (ANCOLD, 2012). The ANCOLD guidelines recommend that design of a tailing dam for earthquake loading should take into consideration the following:

- The level of seismic activity that may occur at the site appropriate for design during operations.
- The level of seismic activity that needs to be considered for closure design.
- The potential for amplification or damping of the base ground acceleration, i.e. the PGA, by foundation and/or embankment materials.
- The ability of the tailing dam to withstand the predicted earthquake loadings.
- The potential for liquefaction of saturated tailing in the storage.
- The potential for liquefaction of embankment and foundation materials.

10.0 DESIGN

10.1 Safety in Design

Safety in design has been considered in the following features:

- At least 5 m crest width for the embankments for safe one-way traffic and 0.5 m high safety bunds at each edge of the embankment crest. On the upstream edge of the embankment the safety bund will be formed over a portion of the geosynthetic liner that extends into the underlying anchor trench.
- A wearing course will be formed on the crest of the embankments to limit damage to vehicle tyres. The thickness of the crest layer course will be 800 mm to facilitate the construction of the liner anchor trenches. A drainage cross fall will be provided on the crest of the limit ponding of stormwater on the surface. Drainage slots will be formed in the safety bund to enable discharge of water.
- Safety barriers around the pump access platform.

10.2 Catchment Area

The catchment area of the TSF is approximately 15.9 ha. The extent of the TSF is approximately 12 ha with the remaining 4 ha of catchment being located south west of the pit. The area south west of the pit contains stockpiles of waste rock.

10.3 Foundation Preparation

The foundation preparation for the embankments includes:

- Removal of loose soil or uncontrolled fill and inspection of the prepared surface by the Dam Engineer.
- Embankment 1 and 3 require deposition of tailing locally within the embankment footprint area prior to commencement of construction to form a well-drained foundation for the embankments, as shown on Drawing No. 3.
- Embankment 1 and 3 require inspection and assessment of the underlying tailing to confirm geotechnical conditions, including vane shear testing.
- Embankment 1 and 3 may also require the construction of a Pioneering Layer comprising compacted rockfill overlying a geotextile. The need for this layer will be assessed shorty prior to start of construction and will depend on the geotechnical condition of the near surface tailing.

10.4 Stormwater Collection Pond

The Stormwater Collection Pond will be excavated into *insitu* soils and possibly some rock to form a 1.5 m deep pond which may be lined if required for seepage control. The pond will have a capacity of at least 500 m^3 for the runoff from Embankment 2 for a 1 in 100 year 72 hour rainfall event, and is intended to be an evaporation pond similar to some of the other stormwater control ponds at the mine. . The pond capacity may be increased if BHOP requires additional surge capacity for its current water harvesting and reuse strategy at the processing plant.

Runoff from Embankment 1 area will flow to the existing drain at the north end of the footprint area. The drain flow the north west and to existing ponds which were sized for catchment which includes Embankment 1 downstream footprint.

Runoff from Embankment 3 downstream slope area will flow to the north east along the existing access road and report back into the pit at the end of Embankment 3, similar the current runoff regime.

10.5 Geotechnical Stability

10.5.1 Embankment Slopes

10.5.1.1 General

An assessment of slope stability for each of the TSF embankments was undertaken using two dimensional limit-equilibrium slope stability software, SLOPE/W (GeoStudio, 2007). Cross sections were taken through the highest sections of the embankments or where thick tailing will be located below the embankments. The cross section locations are shown on Figure 1in APPENDIX B. The geometry and material zones adopted for the TSF are presented in APPENDIX B.

10.5.1.2 Seismic design parameters

Based on the map prepared by Geoscience Australia, the following PGA values were adopted in the assessment of the embankment stability (Burbridge, 2012):

- OBE: 0.12 g.
- MDE/MCE: 0.2 g.

10.5.1.3 Phreatic surface

A phreatic surface was considered in the short term (operational) stability assessments. This assumption is conservative due to the expected performance of the geomembrane liner and the seepage collection system between the compacted rockfill and the geomembrane liner.

10.5.1.4 Liquefaction

Embankments 1 and 2 will be founded on weathered bedrock at the pit rim. A portion of the upstream toe of Embankment 1 will extend onto the tailing beach. Due to their composition and consistency neither the embankment fill or the foundation materials are considered to be potentially liquefiable under seismic loading. Due to land availability constraints Embankment 3 will be constructed on tailing at a location approximately midway along the tailing beach. The tailing surface at Embankment 3 is well drained and not in contact with the extent of a decant pond on the tailing beach. The thickness of tailing below Embankment 3 is expected to vary from less than 3 m to in excess of 17 m.

The average rate of rise of the TSF as it approaches the foundation level of Embankment 1 and 3 is between 3 to 4 m per year which combined with the dry climate at the Broken Hill means that the tailing in the embankment foundation are likely to be partially saturated. The tailing strength of the foundation level of Embankments 1 and 3 will be tested to assess the need for a pioneer layer to support the weight of earthmoving equipment and the embankment rockfill. A minimum undrained shear strength of 35 kPa has been assumed for the tailing in the footprint of embankment construction. At this strength, the void ratio will be sufficiently low that the tailing will not be susceptible to liquefaction. The shear strength will be confirmed prior to construction by vane shear and other geotechnical testing. Based on the PSD, dry climate, location on the tailing beach and future rate of rise of the tailing surface, it is expected that the assumed minimum tailing strength will be achieved. The tailing is classified as a silty sand, with approximately 80% finer than 200 micron and approximately 40% finer than 75 micron. The assumption of undrained strength is therefore likely to be conservative as the relatively coarse tailing will also further consolidate during construction of Embankment 3.

Also, in order to ensure the tailing beach is suitable for construction of Embankments 1 and 3, tailing will be deposited from the pit perimeter for a short period prior to construction to achieve the tailing contour presented on Drawing No.3 and encourage drainage away from the embankment footprint.

10.5.1.5 Loading conditions

Static and seismic loading conditions were considered for the operational embankment slope stability assessment.

The strength parameters adopted for analysis are summarised in Table 10. These are based on our understanding of the site geology and tailing geotechnical testing and are considered to be conservative.

Table 10: Material strength parameters

Material	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Deposited Tailing	16	0	35
Embankment – Compacted Rockfill	18	40	0
Embankment – Filter Sand	19	32	0
Bedrock	Impenetrable		

Also, the Embankment 2 stability is not affected by tailing strength as it will be constructed on *insitu* material along the pit rim. Embankments 1 and 3 will be constructed on unsaturated tailing. At the minimum tailing strength adopted, the void ratio will be sufficiently low that the tailing will not be susceptible to liquefaction. Post-seismic residual strength of the tailing is therefore not considered further due to the adopted minimum strength required for embankment construction and the subsequent further consolidation under embankment loading.

10.5.1.6 Failure surfaces

Stability analyses for Embankments 1 and 2 were prepared for the tailing surface at the full capacity of the Blackwood Pit TSF extension. These embankments are constructed mostly or wholly on weathered *in situ* rock. Cross sections analysed consider the different foundation conditions of the upstream and downstream slopes.

Stability analyses for Embankment 3 consider upstream potential failure surfaces at the completion of construction and downstream slope stability at the completion of tailing deposition.

All assessments considered possible failure surfaces that could potentially release tailing i.e. where the failure surface included the embankment crest. Multiple potential failure surfaces were assessed and the surface with the minimum factor of safety was reported.

Analyses were prepared for one cross section through Embankment 1, and two sections for each of Embankments 2 and 3. The cross sections are presented in APPENDIX B.

10.5.1.7 Analysis Results

Stability analyses were performed for static and seismic loading conditions for the three embankments. A summary of the critical factors of safety for the embankments is presented in Table 11. For Embankments 1 and 2, factors of safety of 1.4 or greater were shown for the MDE seismic loading condition for permanent slopes and higher factors of safety were obtained for the static and OBE loading conditions. Only the MDE results are reported in the table. The slip surfaces for the cases analysed are presented in Attachment B.

Table 11: Stability analysis results

Embankment	Scenario	Critical FoS	Meet minimum target
1 - Section A	Downstream slope under seismic loading with a PGA of 0.2 g.	1.5	Yes
1 - Section A	Upstream slope under seismic loading with a PGA of 0.2 g.	1.4	Yes
2 - Section B	Downstream slope under seismic loading with a PGA of 0.2 g.	1.5	Yes
2 - Section C	Downstream slope under seismic loading with a PGA of 0.2 g.	1.5	Yes
2 - Section C	Upstream slope under seismic loading with a PGA of 0.2 g.	1.5	Yes
3 - Section E	Upstream slope - at completion of construction under seismic loading with a PGA of 0.2 g.	1.3	Yes
3 - Section E	Downstream slope under seismic loading with a PGA of 0.2 g.	1.8	Yes

10.5.1.8 Conclusions and recommendations

The results of the stability analyses indicate the factors of safety for the TSF embankments and for the operating condition satisfy the minimum criteria recommended by the ANCOLD guidelines.

The assumed *in situ* shear strength of the tailing within the embankment foundation footprint will be confirmed by geotechnical investigation prior to embankment construction commencing.

10.6 Seepage Analysis

10.6.1 Model Description

Seepage modelling was conducted along representative cross sections of each embankment to analyse potential seepage from future tailing into the proposed embankment raise and through the existing materials. The sections analysed are presented in APPENDIX C.

The existing TSF is underlain by bedrock of the pit, with a relative shallow layer of weathered or fractured rock due to the original mining works in the pit. The existing tailing were characterised by laboratory testing as silty sand.

The seepage model considers steady state seepage conditions, which may develop at Embankment 2 where return water and runoff may accumulate. The seepage model is conservative and presents the condition that could develop if water was stored on the tailing surface for an extended period, and the tailing in this area remains saturated.

For Embankment 1 and 3 water cannot accumulate against the embankments since tailing will be deposited from the south west of the pit to form a beach sloping to the north east. For these embankments the only source of potential seepage water is interstitial water from tailing consolidation. Seepage analyses were therefore not prepared for these embankments, as there is not enough interstitial water to develop a phreatic surface through the rockfill embankments.

Note these embankments include seepage drains and filter curtains as a backup to the embankment and lining system integrity, in line with best practice for dam embankment construction on foundations subject to potential significant differential settlement.

SEEP/W modelling software (GeoStudio, 2007) was utilised to simulate potential maximum seepage at Embankment 2. SEEP/W is a two dimensional finite element seepage model and is an industry standard for seepage analyses.

10.6.2 Material Zones

The hydraulic conductivity values adopted in the modelling for the *in situ* rock were estimated based on the observed condition of the bedrock and from our experience with similar rock conditions. Parameters for the tailing were obtained from laboratory Rowe cell testing carried out on tailing samples in 2011. The measured permeability varied between 2×10^{-6} m/s with minimal consolidation, to 2×10^{-9} m/s following consolidation at 100 kPa pressure. A conservative estimate of the tailing permeability of 1×10^{-7} m/s was adopted for the seepage modelling, accepting that the seepage rate would reduce by orders of magnitude as the permeability of the consolidated tailing approaches 2×10^{-9} m/s.

Hydraulic conductivities adopted in the models for the various materials are presented in Table 12.

Table 12: Assumed Hydraulic Conductivities for Seepage Analysis

Zone	Model Label	Material Description	Horizontal Hydraulic Conductivity (m/s)	Anisotropy Kv : Kh
1	Embankment Fill	Mine Waste Rock	1×10^{-5}	1.0
2	Tailing	Silty Sand	1×10^{-7}	0.5
3	Weathered Bedrock	Weathered Bedrock	5×10^{-7}	1.0
4	Bedrock	Bedrock	5×10^{-8}	1.0
5	Fabric	Geomembrane*	2×10^{-11}	1.0

*The geomembrane liner was modelled with a conservative permeability which allows for a number of defects.

10.6.3 Boundary Conditions

The following boundary conditions were applied:

- The wet tailing surface was modelled by applying a constant zero water pressure over the tailing surface. This condition models the entire tailing depth being subject to hydrostatic pressure conditions.
- No constraints on volume of available water for seepage.
- Free flow at pipe boundary.

10.6.4 Seepage Results

The steady state models and outputs presenting water pressure contours are presented in APPENDIX C, and shows that any phreatic surface that may build up under conservative assumed conditions results in minor pore pressures in the embankment. The modelled section is at the location in the embankment where the drain is closest to the upstream toe of the embankment, which generally coincide with the outlet pipe location and the highest embankment slope. The model provides a conservative estimate of potential maximum seepage as it assumes the existing and future tailing are saturated with ponded water on the surface. Only Embankment 2 is likely to have water ponded near it on the tailing surface. This estimated maximum seepage rate of 113 L/day/m is used to size seepage collection and discharge pipes, The operational seepage rate from the system is expected to be orders of magnitude lower, due to the low rate of the rise of the tailing beach, the orders of magnitude reduction in permeability of the tailing resulting from its' consolidation and the intended removal of ponded water from the tailing beach for re-use in the processing plant.

Embankments 1 and 3 are not expected to have water ponded near them due to the shape of the tailing beach, so the field seepage rate at these embankments is expected to be negligible.

10.7 Settlement Analysis

Embankment 1 and 3 are partially founded on tailing, while Embankment 2 is founded on bedrock. The embankments are to be formed using compacted rockfill. Embankment 2 is therefore expected to undergo minor settlement only after construction. The embankment may undergo some settlement during extreme earthquake events, with the conventional estimate (Swaisgood Consulting, 2003) being 0.1% of the embankment height. For Embankment 2 the height of the embankment rockfill is generally less than 7 m, so the maximum estimated settlement from extreme earthquake events is 7 mm.

Embankment 1 is also generally founded on bedrock, but the upstream toe extends partially over the future tailing surface. The tailing under the upstream toe is expected to settle as the embankment is formed and subsequently as the tailing is deposited over the embankment slope. Consolidation settlement of the tailing under the upstream toe is expected to continue to occur as the tailing is progressively deposited in the TSF, resulting in differential settlement between the portion of the embankment that is founded on the bedrock and the portion of the embankment that is founded on the tailing.

Consolidation testing conducted on samples of tailing in 2011 returned coefficients of consolidation (C_v) and coefficients of volume change (m_v). Copies of the results are attached in the APPENDIX D of this report, and the salient results are summarised as follows, related to the stress range (less than 100 kPa) expected at the embankments:

- Average C_v = 29 m^2/year
- Average m_v = 2.5 x 10^{-4} m^2/kN

Note the PSD of the 2015 tailing testing indicates that the tailing in the TSF is coarser than the 2011 tailing, so the consolidation rate of the 2015 tailing is expected to be quicker. Also these values are related to tailing not subject to sun drying prior to loading. With sun drying most of the potential consolidation deformation may occur prior to loading due to the suction effect from sun drying on the tailing.

Both Embankment 1 and 3 are designed to receive up to 4 m depth of the tailing over the upstream slope which progressively reduces towards the embankment crest.

Embankment 1 extends over the existing near vertical pit rock face, with up to 7 m thickness of tailing below the toe at the time of construction of the embankment. Most of the embankment toe extends up to 3 m horizontally over the tailing beach at the embankment foundation level. The north east end of the embankment extends approximately 10 m over the pit slope which is approximately at 30 degrees off the vertical.

Based on these results the expected consolidation of the thickness of tailing below the embankment toe, assuming negligible consolidation seepage into the rock face, will occur over less than 2 months. The consolidation settlement of the toe from the embankment load is therefore expected during construction of the embankment. Settlement from subsequent tailing deposition over the embankment slope is expected to be less than 150 mm. This settlement will also be the localised differential settlement between the upstream toe and the remainder of the embankment.

The upstream slope includes a filter curtain and a low stiffness LLDPE geomembrane, which has capacity to stretch to accommodate this differential settlement. Shear deformation is expected to occur near the alignment of the pit edge, which will result in approximately 3 m length of slope liner geomembrane being subject to the differential settlement. The strain induced in the geomembrane by the differential settlement is estimated at 5% which is well within the acceptable range for the material to be specified for the works.

Most of the settlement is expected to occur prior to loading due to the design shape and low rate of rise of the tailing beach, and dry weather at the site. The estimated settlements are therefore conservative. The geomembrane liner is expected to bridge the deformation zone and remain intact, with the conservative estimate of settlements. For additional robustness the slope stability analysis also considered the possibility of a leak in the slope liner resulting from the differential settlement.

The south west length of Embankment 3 extends over a thick layer of future tailing, varying up to 17 m thick. The north east end of the embankment length extends over a thin layer of future tailing with portions to be founded on the weathered bedrock. The existing rock face of the pit below the proposed embankment slopes at approximately 1.5H in 1V, with an existing approximately 10 m wide rock bench (remanent of an old access ramp), ramping down to the south west where the future tailing depth is the greatest. The grade of the existing hard subgrade below the future tailing within the embankment footprint is therefore fairly gentle.

Based on the measured consolidation parameters of the tailing, the estimated time for consolidation to be complete over the thick south west portion of the tailing depth is a number of years, so deformation of the embankment may continue well after the embankment has been constructed and tailing deposition has ceased. The estimated settlement of the embankment will vary from a negligible value at the north east where the embankment base is close to rock, to approximately 400 mm at the south west end. The differential settlement along the embankment will be spread over approximately 150 m due to the old ramp alignment, which is expected to be accommodated by the embankment fill.

The settlement of the upstream slope of the embankment is expected to be higher than the outer downstream toe of the embankment, resulting in a potential inward tilt of the embankment. The maximum inward tilt is expected to be up to 400 mm, related to the same maximum settlement of the thick tailing depth. Depending on the rate of construction some of the settlement will be accommodated during construction and shear deformation may develop in the rockfill following completion of construction near the south west end of the embankment, related to the differential settlement of the upstream slope relative to the rigid pit rim in this area.

Embankment 3 also has a filter curtain and is to be lined with low stiffness LLDPE geomembrane. It is estimated that the differential settlement may occur over a geomembrane liner length of 12 m, which is related to the maximum slope of the existing pit slope. The strain induced in the geomembrane for the differential settlement is estimated to be less than 5%. A small portion of the liner is located over a steep section of the pit batter where the differential settlement is estimated to be 280 mm over a slope length of

5 m, resulting in an induced strain of approximately 6%. These strains are less than the maximum of 10% conventionally adopted for the material to be specified for the works.

Note the embankment end anchor trench locations are designed to be outside the zone of maximum differential settlement related to the settlement of the tailing.

Both Embankment 1 and 3 are located along the edge of the pit, so parts of the embankments are underlain by relatively thin layer of tailings, compared to the deep parts of the pit. The long term settlement of the embankment is therefore expected to minimal, with the deformation settlement outlined above occurring during the operational/filling phase of the TSF.

10.7.1 Freeboard

Embankments 1 and 3 will have no water ponded against them due to the shape of the tailing beach. The embankments are however designed with a nominal 1 m freeboard, to allow for the maximum settlement and to maintain the required 0.5 m operational tailing freeboard, nominated by DSC guidance. The design embankment crest elevation is set by the minimum freeboard required above the final tailings beach elevation. For Embankment 3 this condition will be reached at the end of the operational life of the TSF, so any reduction in crest elevation due to settlement resulting in reduced freeboard can be reinstated by placement of additional embankment fill, if required, during the final stages of operation.

Settlement of the Embankment 1 and 2 embankment crests is expected to be negligible since both crest areas are underlain by bedrock and formed using compacted rockfill. The freeboard required for Embankment 1 is related to the spillway hydraulics as presented in Section 10.9.7.

10.8 Water Management

A Site Water Management Plan (SWMP) was prepared in 2012 (Golder, 2012) and includes measures required at the site to:

- Prevent discharge of potentially contaminated surface waters from active mine areas off-site.
- Limit disruption to the mining activities and provide a safe working environment.
- Identify erosion and sediment control measures from the surface areas of CML7.

These measures presented in the SWMP were adopted by BHOP. The Blackwood Pit TSF extension design has incorporated the SWMP and includes additional measures to collect runoff from the outer slopes of the perimeter embankments. The stormwater management measures are presented on the drawings (refer APPENDIX A) and includes the following:

- Stormwater Collection Pond.
- Stormwater Drainage Ditches.
- Series of Drainage Pipes to convey seepages towards the pits from where it will be pumped back onto the tailing.

Surface water runoff from rainfall and supernatant water from tailing will be directed to the northern end of the TSF by continuing the existing tailing deposition strategy from where it will pool in a decant pond before being pumped to the processing plant for use as process water. Should the ponded water exceed the containment freeboard, the emergency spillway will be activated. The emergency spillway is presented in APPENDIX A(refer Drawings No. 4 and 16).

10.9 TSF Water Management

10.9.1 General

The Blackwood Pit TSF extension has been designed to manage stormwater and includes an emergency spillway designed with the required freeboard in line with DSC guidelines.

10.9.2 Intensity Frequency Duration

The intensity frequency duration (IFD) relationship has been obtained from BOM for events up to the 1 in 100 AEP event (BOM, 2016). Rainfall intensity for all events between the 1 in 100 AEP and PMP event have been interpolated in accordance with the Australian Rainfall and Runoff guidelines (Nathan & Weinmann, 1998).

The complete IFD for Broken Hill, NSW, is provided in Table 2 and Figure 6.

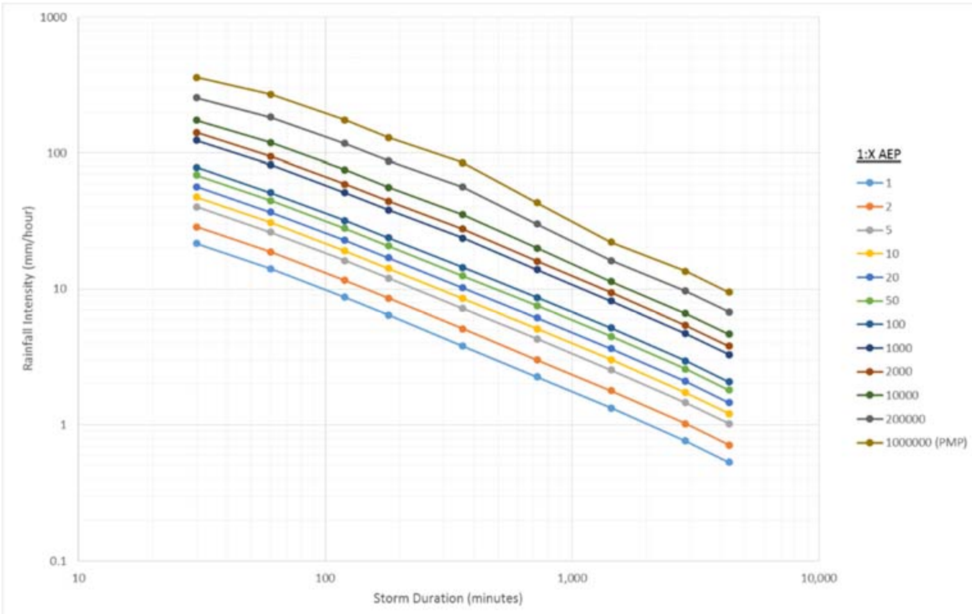

Figure 6: Rainfall Intensity Frequency Duration curve for Broken Hill, NSW

10.9.3 Probable Maximum Precipitation

In order to determine the Probable Maximum Flood, Golder estimated the probable maximum precipitation (PMP). The PMP was estimated in accordance with guidelines published by the Australian Bureau of Meteorology (BoM) using the following methods:

- Generalised Short-Duration Method for storm durations up to 3 hours (BOM, 2003).
- Generalised Southeast Australia Method for storm durations 24 to 96 hours (BOM, 2006).

The PMP is the greatest depth of precipitation for a given duration that is physically possible over a particular catchment and the PMF is the largest flood hydrograph resulting from the PMP and coupled with the worst flood producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

The calculated PMP rainfall is provided in Table 13 for Broken Hill, NSW.

Table 13: Probable Maximum Precipitation for Broken Hill, NSW

Duration (hours)	Rainfall depth (mm)	Average rainfall intensity (mm/hour)
0.5	180	360.0
1	270	270.0
2	350	175.0
3	390	130.0
24	530	22.1
36	600	16.7
48	650	13.5
72	680	9.4
96	690	7.2

10.9.4 Catchment Area

The catchment area of the TSF is estimated to be approximately 15.9 ha. The extent of the catchment is presented in APPENDIX E.

10.9.5 Required Storage below Spillway

The DSC (DSC, 2012) requires the TSF is capable of storing runoff from a design storm on the tailings surface, referred to as the Environment Containment Freeboard (ECF). For the Blackwood TSF extension the design storm is the 1 in 10,000 annual exceedance probability (AEP), 72 hour rainfall event. The ECF is equivalent to ANCOLD Minimum Extreme Storm Storage (ANCOLD, 2012).

Based on the estimated rainfall depth corresponding to the 1 in 10,000 AEP 72 hour event for the pit is 334 mm. The majority of the tailing surface is expected to desiccate and the catchment outside the TSF is relatively permeable being waste rock. Hence based on a conservative runoff coefficient of 90%, the resulting Environment Containment Freeboard required is 48,000 m^3.

The closure design intent of the TSF is to store no water on the final tailing surface, and that the tailing surface be filled to the spillway elevation as part of the closure stage of the TSF. Therefore in the last year of operation of the TSF the Environment containment freeboard will be progressively be reduced.

10.9.6 Water balance and decant pond

During operation, water inflows to the TSF will be limited to tailing slurry water and rainfall. Outflows will be limited to evaporation, seepage losses and excess water extracted for recycle at the processing plant. The remaining water will be retained in the pores of the tailing (referred to as interstitial water). A summary of the inflows and outflows is presented in Table 14.

Table 14: Summary of inflows and outflows to the tailing storage facility

Inflows	Outflows
Tailing slurry water (supernatant)	Evaporation from wet tailing beach
Rainfall runoff onto tailing beach	Evaporation from decant pond
Direct rainfall onto tailing beach and decant pond	Seepage losses
No other mine water inflows	***Return water to processing plant***

As reported above, the tailing beach area (or area to pit rim) is approximately 12 ha, representing approximately 75% of the overall catchment. The large ratio of tailing beach area to total catchment area results in significant evaporation of water that flows into the TSF, either as slurry water or rainfall.

The extent of supernatant water (slurry transport water) will be subject to the tonnage of tailing being delivered to the TSF and the solids concentration of the thickener underflow. For a maximum tailing deposition rate of 570,000 dry tonnes/year and a solids concentration of 65% by weight, this corresponds to approximately 307,000 m^3 of slurry water annually.

Average annual rainfall is approximately 260 mm and rainfall is fairly evenly distributed throughout the year. Conservatively assuming 90% of rainfall reaches the decant pond on the tailing beach, the annual volume of rainfall runoff is approximately 37,500 m^3. Slurry water therefore exceeds rainfall by a factor of approximately 8.2, i.e. 88% slurry water to 12% rainfall runoff. Due to the high rate of evaporation, the average annual rate of excess water for average climatic conditions is approximately 18% of the total water inflows. Based on a monthly water balance assessment and consistent with site observations, excess water is only present between the months of April and September, when the evaporation rate is relatively lower.

The TSF layout provides storage and discharge capacity for the management of large rainfall events, as described in the following sections. During normal operation, excess water will primarily be transferred to the processing plant for recycle.

A Stormwater Collection Pond will be developed to the north of Embankment 2. This pond will provide for collection of stormwater drainage from the downstream toe of the embankment for the 1 in 100 AEP 72 hour rainfall event. The approximate dimensions of the pond are 30 m × 15 m × 1.5 m deep, which provides capacity for approximately 700 m^3 of water.

10.9.7 Spillway Design

10.9.7.1 Freeboard

The freeboard for a dam is a height allowance to contain flood levels and limit the risk of overtopping and potential damage to the embankment and crest that may occur due to wind and wave actions. Total freeboard comprises of a wet and dry freeboard, defined as follows:

- *Wet freeboard*: is the depth available between the maximum water level and flood level.
  - Maximum water level: is taken up to the spillway invert level.
  - Flood level: is the maximum design water level, taken as the maximum level during the design rainfall event.
- *Dry/Wave freeboard (R_C)*: is comprised of the wind setup plus wave run-up height.
  - *Wind setup (S):* Vertical rise above still water level due to wind stresses on the water surface.
  - *Wave run-up (R)*: When a wave strikes an embankment face it runs up the face to a height greater than its open water height. The amount of run-up is dependent on the roughness and slope of the embankment and on the properties of the wave, in particular the ratio of the wave height to wavelength (or wave steepness).

A schematic overview of the components of freeboard within a reservoir is provided in Figure 7

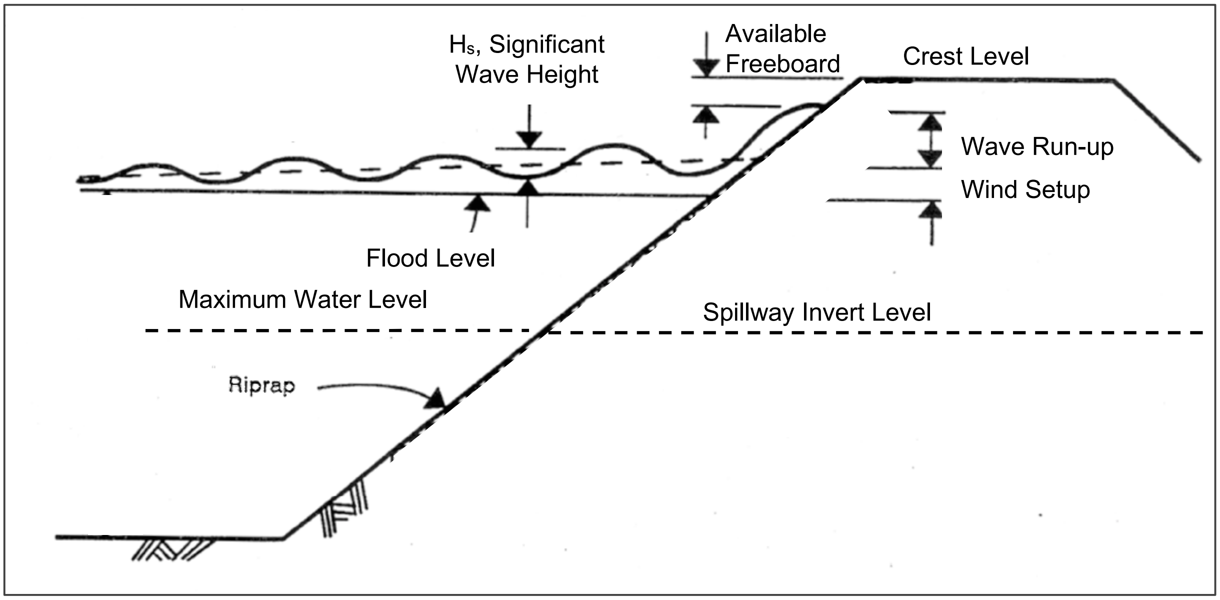

Figure 7: Overview of reservoir freeboard and wind/wave effects (adapted from Washington State Department of Ecology, 1993)

10.9.7.2 Design Criteria

The ANCOLD (ANCOLD, 2012) guidelines recommends the spillway of the dam to be design with a design flood capacity event to pass the probable maximum flood (PMF).

The design wind freeboard allowance is to be determined by a risk assessment (ANCOLD, 2012). Based on the proximity of the pit to populated areas, a minimum wind freeboard allowance relating to the 1 in 50 annual exceedance probability (AEP) has been selected.

10.9.7.3 Environmental containment freeboard

The 'Environmental Containment Freeboard' (ECF) under DSC guidelines represents the required flood storage capacity between the tailing beach and the spillway elevation. The estimated volume of runoff for the 1 in 10,000 AEP, 72-hour duration rainfall event is approximately 48,000 m^3. This estimate conservatively assumes 90% runoff. Note, it is expected that significant losses will occur due to infiltration of water into desiccation in the tailing surface which will be subsequently lost to evaporation. A summary of the available flood storage capacity by stage is presented in Table 15. The estimated capacity at each stage exceeds the flood volume resulting from the design event.

Table 15: Summary of flood storage capacity by stage

Stage	Available capacity (m^3)
1	120,000
2	50,000

10.9.7.4 Hydraulic Modelling

The spillway dimensions were sized by hydraulically assessing the flow of water through the spillway in response to the PMP event. Storm events ranging from 30 minutes to 12 hours were modelled.

The pit was simulated in a 1D hydraulic environment using the XP-RAFTS software package. The assumptions incorporated into the model include:

- Initial water level at the spillway invert level.

- A weir discharge coefficient of 1.6.

A summary of the modelling results for spillway widths ranging from 5 to 30 m is provided in Table 16.

Table 16: Hydraulic modelling results for the PMP event

Spillway Width (m)	Maximum Headwater Level Above Spillway Invert (m)	Peak Flow rate (m^3/s)	Critical duration event (min)
5	1.10	8.9	60
10	0.77	10.7	60
15	0.60	11.2	60
20	0.51	11.5	60
25	0.44	11.5	60
30	0.39	11.6	60

10.9.7.5 Wind Freeboard

10.9.7.5.1 Site wind speed

Wind speeds have been extracted from the Australian Wind Code (Standards Australia, 2011). The site is located in Region A1. Table 17 below shows the factored wind speeds for varying AEPs.

Table 17: Wind speeds (3 second gusts)

Wind AEP (1:X)	Wind Speed (km/hr) (3 Second Gusts)
10	121.2
35	135.4
50	139.0

Factors used for derivation of design site wind from regional wind speed include:

- A terrain category multiplier, $M_{z,cat}$, of 0.99, which relate to structures less than 3 m above surface level and a terrain category for open water bodies (e.g. lakes)
- A wind direction factor of 0.95, corresponding to a south-westerly wind direction.
- A factor of 1.00 for all other wind multipliers.

10.9.7.5.2 Wave run-up and wind setup

The methodology adopted for the estimation of wave run-up and wind setup follows the methodology developed by the U.S. Department of the Interior, Bureau of Reclamation, (USBR) guidelines (2012).

The following components were computed in order to derive the wind setup and wave run-up:

- *Fetch (F):* The fetch is the path over which the wind blows from the up gradient end of the reservoir to the downstream dam wall.
- *Significant wave height (H_S)*: The average vertical distance of between the wave crest and trough of the highest one-third of waves within the wave energy spectrum.
- *Specific wave height (H)*: The design wave height equal to the average vertical distance between the wave crest and trough of the highest 5% of waves (equal to a wave height with a 2% exceedance probability), as recommended by the USBR (2012).

A summary of the freeboard results is provided in Table 18. Detailed calculations are provided in APPENDIX E.

Table 18: Summary of freeboard results

Criteria	1 in 10 AEP Wind Event	1 in 35 AEP Wind Event	1 in 50 AEP Wind Event
Fetch Distance (m)	695	695	695
Average water depth over fetch (m)	1.0	1.0	1.0
Critical Wind Speed (km/hr)	65.2	72.9	74.8
Significant Wave Height (m)	0.26	0.30	0.31
Specific Wave Height (m)	0.37	0.42	0.43
Wave Runup (m)	0.29	0.33	0.34
Wind Setup (m)	0.05	0.06	0.06
Minimum Wind Freeboard (m)	**0.34**	**0.39**	**0.40**

As shown in Table 18, the minimum required wind freeboard ranges from 0.34 m to 0.40 m for wind events ranging from the 1 in 10 to 1 in 50 AEP events. A minimum of 0.40 m has been selected for the spillway design, i.e. the 1 in 50 AEP wind event.

10.9.8 Spillway Design Dimensions

The spillway design dimensions have been designed based on the hydraulic modelling results and guidance from (ANCOLD, 2012).

A summary of the design dimensions are provided in Table 19.

Table 19: Summary of spillway design parameters

Parameter	Design Value
Spillway capacity (AEP)	PMF
Design flow capacity (m^3/s)	11.50
Maximum Headwater Level Above Spillway Invert (m)	0.44
Spillway freeboard based on of wave run-up and wind setup	0.40
Spillway width (m)	25.00
Minimum spillway invert level below embankment crest (m)	0.84
Side slopes (H:1V)	3.00

The side slopes of the spillway are 10H:1V where the access road will cross the spillway. This local flattening of the side slopes will have no meaningful impact on the hydraulics of this spillway.

10.9.9 Spillway Chute Design

The spillway chute on the downstream side of the spillway, to the south east of the access road has been design as a riprap lined chute. A summary of the chute design is provided in Table 20. Detailed calculations are provided in APPENDIX E.

Table 20: Summary of spillway chute design

Parameter	Design Value
Design flow rate (m^3/s)	11.5
Chute face slope (H:1V)	2.5
Median riprap diameter, d_{50} (mm)	370
Maximum riprap diameter, d_{100} (mm)	550
Riprap liner thickness (mm)	550
Apron length at spillway chute toe (m)	5.5

10.9.10 Pond recovery time

The pond recovery time criteria represent the time taken to extract the volume of runoff from the 1 in 100 AEP, 72-hour design storm from the tailing beach. For the Blackwood Pit Extension, the DSC require that the resulting flood water is removed within 7 days. Conservatively assuming 90% runoff, the expected flood volume is 21 500 m^3, i.e. 21.5 ML. The collected volume of runoff will require pumping capacity for approximately 36 L/sec to remove the flood volume within 7 days with 24 hour pumping. The water will be pumped to Horwood Dam, the existing site water management depression to the north of Mt Hebbard (called Mt Hebbard Gully or S22) or to both. Both of these facilities have spare storage capacity to retain additional water after a 1 in 100 AEP rainstorm event.

11.0 RISK MANAGEMENT

11.1 Dam safety

11.1.1 Possible failure modes

A summary of the possible failure modes for the TSF are presented in Table 21. Note that the NSW DSC is satisfied that the design has an appropriate level of robustness that satisfies its guidance for such structures.

11.1.2 Mitigating conditions and design controls

Mitigating site conditions, design controls and operating procedures to manage dam failure risks are summarised in Table 21. The operating procedures will be incorporated into an Operating, Maintenance and Surveillance (OMS) Manual, as discussed in Section 13.0.

Table 21: Potential failure modes, mitigating conditions and design controls

Item No.	Possible failure mode	Description	Comments	Mitigating conditions, design controls and critical operating criteria	Conclusion for TSF design
	Surface water and seepage				
1	Embankment slope failure in the downstream direction due to a high phreatic surface in the tailing and the embankment	A relatively large water pond develops against the embankment. The rate of seepage increases through the embankment, resulting in high pore pressures slope failure and a loss of containment	Only potentially applicable to Embankment 2 when decant pond forms against embankment during winter or following storm event.	Compacted rockfill embankment is robust and has a high shear strength. In addition a geosynthetic liner will be installed on the upstream slope of the embankment with an underlying seepage collection layer (Filter Sand) conveying seepage through defects in the geosynthetic liner to the seepage collection pipe. Refer Section 8.0.	Very low risk
2	Embankment failure due to piping erosion	Seepage through an embankment results in progressive erosion of the embankment creating a “pipe” and inflow of sand/tailing resulting in a loss of containment, if not controlled.	Only applicable to Embankment 2 when decant pond forms against embankment during winter or following storm event.	The embankments will be constructed from non-dispersive material (Rockfill) with a geosynthetic liner installed on the upstream slope of the embankment with an underlying Filter Sand designed to retain the tailing. Refer Section 8.0. TSF Operation manual will include requirement to remove collected water on tailing beach to maximise tailings storage efficiency of TSF.	Very low risk
3	Piping erosion of fill around a buried conduit	Seepage around a buried pipe results in progressive erosion of soil particles, with fine particles flowing through coarser particles and eventually creating a ‘pipe’ in the embankment that can result in a loss of containment, if not controlled.	Applicable for the Toe Drain Outlet pipes through Embankment 2 only.	Toe Drain Outlet pipes include bentonite plugs to limit seepage pathways. Embankment is also constructed from non-dispersive material (i.e. Rockfill) and outlet pipe is a gravity flow pipe with no back pressure to develop high hydraulic gradient. Refer Drawing no. 13.	Very low risk

Item No.	Possible failure mode	Description	Comments	Mitigating conditions, design controls and critical operating criteria	Conclusion for TSF design
4	Embankment failure in the downstream direction due to overtopping by excess water on the tailing beach	A large pond due to excess liquor and/or rainfall overtops the embankment, resulting in erosion of the embankment and a loss of containment.	Applicable to Embankment 2 only when the decant pond will be located adjacent to the embankment.	Compacted rockfill embankment is robust and has a high shear strength. A wide trapezoidal spillway will be excavated into natural ground during the construction of Embankment 2, with additional environmental containment freeboard below spillway level. Spillway is designed to manage the PMF. Refer Section 10.7.1.	Very low risk
5	Embankment 2 upstream slope failure due to rapid drawdown.	A very large pond forms at Embankment 2 and saturates the embankment fill. Sudden drawdown of the pond results in high pore-water pressures remaining in the embankment fill, leading to slope failure	Only applicable to Embankment 2 should a large pond form against the embankment and saturate the embankment fill.	Geosynthetic liner on upstream slope of embankment limits risk of seepage through embankment. Rockfill embankment and filter sand layer are relatively quick draining, so undrained conditions are not likely to occur.	Very low risk
6	Embankment 1 and 3 upstream slope failure due to static liquefaction of tailing foundation.	Static liquefaction occurs where the tailing strength is low and the rate of embankment construction does not sufficiently allow excess pore pressures to dissipate, resulting in a loss of shear strength, embankment failure and a loss of containment.	This mechanism is applicable for Embankments 1 and 3 where the embankment will be constructed onto the tailing beach.	Tailing deposition will occur locally along the footprint of Embankments 1 and 3 prior to Stage 2 construction to create conditions conducive to drying and strength gain of the tailings beach. Tailings are relatively coarse and drainage occurs over few weeks. Also, inspections and testing of the tailing will be undertaken prior to construction to ensure design parameter are achieved.	Very low risk
7	Embankment 1 and 3 upstream slope failure due to liquefaction of tailing.	An earthquake causes cyclic loading of the tailing and induces excess pore pressures, resulting in a loss of shear strength, embankment failure and a loss of containment.	Applicable for Embankments 1 and 3 where the embankment will be upstream-raised onto the tailing beach.	Inspections and testing of the tailing will be undertaken prior to construction to ensure design parameter are achieved. Required tailing strength conditions result in conditions not susceptible to liquefaction.	Very low risk

Item No.	Possible failure mode	Description	Comments	Mitigating conditions, design controls and critical operating criteria	Conclusion for TSF design
8	Embankment failure due to differential settlement.	Tension cracks develop on the crest of the embankment as a result of interface between rigid pit wall/benches and the portion of embankment on tailing. Cracks allow inflow of runoff or wet tailings, resulting in slumping of the embankment slopes and a loss of containment.	Applicable for Embankments 1 and 3 where the embankment will be on the tailing beach.	Estimated differential settlement informed the selection of the deformable geomembrane liner for the upstream slope. Design includes a filter curtain as a backup to damage of the geosynthetic liner Refer Section 10.7. Geomembrane liner includes extra material near pitface interface where maximum differential settlement is expected to increase robustness of the liner design to effects of differential settlement. Rockfill embankment provides a high resistance to internal erosion and remains high strength when wet.	Very low risk
	Other				
9	Embankment failure due to weak foundation conditions	Soft foundations, either naturally occurring or induced by loading and/or seepage from the tailing results in embankment failure and a loss of containment.	Applicable for all of the TSF embankments.	Embankment 2 will be constructed on strong *in situ* material. Embankments 1 and 3 will be constructed on tailing which have been assessed and tested to confirm required strength. All embankments construction required foundation inspection and approval as part of quality assurance during construction.	Very low risk
10	Embankment failure due to earthquake shaking.	An earthquake induces shaking of the embankment, resulting in settlement of the embankment crest and a loss of containment	Applicable for all the TSF embankments.	The seismic risk of the region is low. Embankments formed using high strength rockfill and approved foundation conditions. The stability analyses show high factors of safety for MDE condition.	Very low risk

12.0 CONSTRUCTION METHODOLOGY

The design of the works is based on the following construction methodology:

12.1 Stage 1: Embankment 2 and Spillway

Stage 1 comprises the construction of Embankment 2 with run of mine rockfill placed by articulated dump trucks. The rockfill will be tipped at the embankment and spread by dozer. The material will be sprayed with water for moisture conditioning to facilitate compaction and manage dust. Compaction will be by a large (20 or 25 tonne) smooth drum vibrating roller. The rockfill will be compacted in layers of maximum loose thickness of 400 mm (or thinner depending on roller adopted).

The existing ground within the footprint of the embankment will be stripped and residual soil, where present, will be removed to expose the bedrock. The construction of the embankments will commence from the surface of the bedrock.

The bedrock below the upstream slope may require some treatment to seal defects or significant features or structure in the rock that may potentially be a significant seepage path. The treatment will be carried out over a nominal 5 m width, as indicated on the drawings. The treatment will be carried out only where the geomembrane liner is to be sealed against the bedrock. Treatment may involve removing loose rock blocks and joint gouge, and filling depressions and potential seepage paths with dental concrete or grout.

The upstream face of the embankment slope will be covered with a layer of filter sand. This layer will be commercially sourced as per the particle size distribution presented in Section 8.2 and will be the embankment filter and the bedding layer for the geomembrane liner on the slope. The rockfill of the embankment is expected to be constructed to final elevation, followed by placing the sand layer and geomembrane liner over the upstream face. A seepage collection drain will be formed at the toe of the sand layer, which will include an aggregate layer and perforated pipes, with solid walled outlet pipes extending to the downstream toe of the embankment. The seepage collection outlet pipes discharge to sumps fitted with a pump to return the water to the tailing surface.

The geomembrane liner will be is sealed to the existing bedrock surface. It will be sealed against the bedrock using a concrete strip, with a bentonite powder bedding layer between the bedrock surface and the geomembrane liner. The sealing strip will be located near the centre of the width of seepage control treated bedrock.

The crest of the embankment will be covered by a wearing course constructed from crushed rockfill. The crest anchor trench for the embankment geomembrane will extend into this layer, and be backfilled with cement stabilised sand. A nominal 100 mm thick layer of sand will extend over the upstream crest of the embankment to the edge of the anchor trench to provide a bedding layer over the rockfill for the geomembrane liner.

A surface toe drain will be constructed to collect stormwater runoff from the downstream embankment slope. The drain will discharge to the Stormwater Collection Pond.

The emergency spillway will be constructed during Stage 1. The spillway will be formed by excavation into the existing ground at the east end of the pit. The wide crested spillway will extend across the existing access road. The access road will be re-instated across the spillway, as part of the spillway construction. The spillway will include a concrete apron, which will be the access road surface, plus a concrete sill beam. The sill beam will be excavated into the ground to extend down to intact bedrock to form a seepage cut-off wall at the spillway.

The spillway chute will be lined with cobbles and boulders to provide erosion protection of the subgrade. The end of the chute includes an energy dissipation apron formed with cobbles and boulders.

12.2 Stage 2: Embankments 1 and 3

Stage 2 is to form Embankment 1 and Embankment 3 with construction of Embankment 3 commencing when the tailing have achieved the elevations presented on Drawing 3. Embankment 1 will be constructed across a topographic low before the tailing beach reaches the current pit rim elevation at this location.

These embankments will be constructed in a similar way to Embankment 2. The embankments are partially or wholly supported by the future tailing beach at these locations. The embankments are located well above the potentially inundated portion of the tailing beach, with the lowest crest of the embankments being at least 3 m above the north eastern, low end of the tailing beach.

12.2.1 Embankment 1

The upstream slope of this embankment extends onto the future tailing beach, with the crest of the downstream slope being over bedrock. Similar to Embankment 2, where feasible the embankment will be founded on bedrock after removal of any shallow thickness of existing fill or residual soil.

The undrained shear strength of the upstream tailing beach will be measured using vane shear tests as part of the foundation preparation works. A bridging layer potentially with reinforcement geotextile may be placed over the tailing beach if the strength is low. The tailing strengths will inform the strength requirements of the reinforcement layer, if required.

A geomembrane liner will be constructed over the upstream face with a sand filter curtain below the geomembrane liner. The geomembrane liner will be keyed into the tailing beach at the upstream toe of the slope. The key will be at least 1 m deep and 1 m away from the toe to limit the hydraulic gradient to the filter curtain. No water is expected to pond near the toe of Embankment 1 due to the tailing beach sloping to the north east. Seepage towards the filter curtain is from remnant interstitial water within the tailing that may remain in the tailing following periods of low evaporation from the tailing surface during infrequent wet weather. The tailing is expected to be unsaturated due to the beach slope and high evaporation at the site.

The embankment end anchorage details for the geomembrane liner will be formed on the existing rock face of the pit. The embankment fill will be formed to merge the slope with the rock face of the pit so that the detail indicated in Drawing 14 can be implemented. The detail includes a 250 mm high wrinkle in the geomembrane to provide additional liner material to accommodate potential movement between the geomembrane seal against the rock face and settlement of the upstream slope of the embankment. Where appropriate the pit rock face near the anchorage would be treated to limit preferential seepage paths around the anchorage.

The design also includes a seepage collection system at the toe of the filter curtain to further minimise potential seepage through the embankment. The seepage collection system discharges to a sump. A surface toe drain will be constructed to collect stormwater runoff from the downstream embankment slope. The drain will discharge to the existing stormwater management system.

Embankment 1 also includes a relatively low retaining wall over a short length of the downstream slope. The retaining wall is to restrict the embankment slope for the edge of an existing retaining wall next to a building. The retaining wall is designed as a gravity retaining wall, and includes a layer of reinforcement extending into the embankment fill for additional robustness. The retaining wall is located over the upper part of the embankment height where the existing ground level rises from the topographic low near the middle of the embankment length. The wall is between 0.5 m and 2 m high.

12.2.2 Embankment 3

Most of the southern half of Embankment 3 will be constructed over future tailing beach. The embankment height is generally 5.2 m high above the future tailing elevation. The northern half of the embankment length will generally be founded on the existing pit rim ground surface.

The embankment will be lined with a geomembrane liner similar to the other embankments and will include a sand filter curtain below the geomembrane liner.

Where the embankment is over tailing the geomembrane liner will be keyed into the tailing, as per the detail on Drawing 14. Similarly where the embankment abuts the pit slope the liner will joined to the pit slope with a 250 mm high wrinkle to accommodate the potential differential settlement, as per the detail on Drawing 14. Where the embankment extends over existing ground, the ground conditions will be assessed during construction to decide whether the geomembrane liner is to be sealed against bedrock, as shown on Drawing 14 or whether the geomembrane liner should be anchored in an anchor trench excavated into the existing ground. The thickness of tailing to be stored against the northern length of the embankment is generally less than 2 m with no water ponding due to the tailing beach grading down to the north east. The hydraulic gradient at the geomembrane anchor trench is therefore minor.

The design also includes a seepage collection system at the toe of the filter curtain to further minimise potential seepage through the embankment. The seepage collection system discharges to a storage tank. A surface drain will be constructed to collect stormwater runoff from the downstream embankment slope. The drain will discharge to the existing site stormwater management system.

12.3 Monitoring of Embankment Settlement

The upstream toe of Embankment 1 and a large portion of Embankment 3 will be constructed over tailing. Settlement of the embankments is expected over time, as the tailing consolidates under the embankment load.

Ongoing monitoring will be undertaken during construction to measure the settlement as part of the operations. The embankment settlement will be addressed by periodic review of the magnitude of the settlement. Rectification works, if required, will be undertaken by placement of fill on the crest to re-establish tailing freeboards as appropriate to satisfy NSW DSC requirements.

13.0 OPERATION

13.1 Tailing deposition

The tailing deposition strategy is based on surface deposition from pipe outlets at the southern end of the pit for the majority of the operation. Prior to the construction of Embankments 1 and 3 tailing deposition will be also required from the pit rim at the embankment locations to provide conducive conditions for rapid tailing drying for embankment construction. Also, as the pit is approaching completion, tailing deposition will be required from the Embankment 2 crest to manage the pond location and ensure the freeboard requirements are achieved. The strategy is to direct the tailing beach towards the spillway in the north-east of the TSF. The tailing are predicted to beach at a slope of 1.5%.

Routine operation and inspection of the tailing delivery system will be undertaken on a daily basis, with maintenance occurring on as needs basis.

Flushing of the tailing delivery system will occur from time to time, typically during periods of processing plant shutdown. Flushing of pipes will be undertaken at controlled rates and for controlled periods of time, to limit erosion of the tailing beach and associated sediment load at the decant pond.

Tailing beach slopes and the decant pond location and size will be periodically reviewed by an engineer independent of the operating company, as part of procedures that will developed in the Operating, Maintenance and Surveillance (OMS) Manual. Dam safety inspection and surveillance reviews will identify improvements that can be made to the deposition strategy to achieve the design objectives. Additional discussion on the dam safety inspections and surveillance reviews is provided in Section 13.3.

13.2 Dust Management

The intended dust management plan for the tailing storage is to suppress dust during construction, operation and closure of the facilities.

13.2.1 TSF Construction Dust

During construction of the TSF embankments, the potential exists for minor dust to be generated by some of the construction materials. We note the risk of dust generation will be minimal as the proposed embankment materials predominantly comprise rockfill which will be watered during placement and compaction. Dust modelling has been carried out by others to assess the potential for dust generation. To further reduce the potential for generation of dust during construction, the following measures are proposed.

- Routine water spraying along proposed haulage routes from the waste rock stockpile to the embankment construction site using a water cart and dribble bar.
- Application of water during placement of rockfill layers at the embankments via water cart after spreading and during compaction.

No large scale excavation of the existing tailing is proposed. Excavation of a 1 m deep anchor trench along the toe of two of the embankments is proposed, with a water truck on standby at the location for immediate use when required. Any risk of dust during this short term operation will be controlled by application of water spray from a tanker. Where any excavation is required into tailings, the tailings will be moistened prior to excavation. Any disturbed tailings will be placed back in the anchor trench after the installation of the liner.

A Construction Dust Management Plan will be developed with the construction contractor to implement the above measures. The construction schedule will also include limitations on works permitted during windy days.

13.2.2 TSF Operation Dust

During active tailing deposition, discharge of tailing will occur from the south west end of the TSF. The tailing surface is likely to initially be a slurry, changing slowly over a few days from wet to moist tailings.

The dust suppression strategy plan includes the installation of a spray system around the perimeter and on the tailings beach surface of the TSF. The system comprises application of water through a number of strategically located high capacity sprayers. The spray system also includes the ability to include an additive to the spray water to form a crust over the tailings surface. A similar additive is currently applied over select areas of the mine site where long term dust control is required. APPENDIX F presents details of the spray system.

Over the areas of the TSF where the tailings has dried, current experience on the TSF is that no dust is generated during windy days possibly due to the early formation of a surface crust due to evaporation of tailing liquor from the surface. To increase the robustness of the dust management system and further reduce the likelihood of dust from the tailing surface, a permanent spray system will be constructed, comprising the following components:

- Sprinklers and Reticulation Pipe
- Storage Tank, Backup Water Supply, Pump and Control System
- Crusting agent

The spray system will apply water over the tailing surface from a number of strategically located sprayers. These locations are near the existing perimeter of the pit, along the embankment crests and some will be located on support structures on the tailings beach.

The site currently has a large raw storage tank to the south west of the TSF, called Silver Tank. The capacity of the tank is 7.6 ML. This tank is connected to the raw water supply of the mine, and has an automatic top up from the main water supply pipeline.

It is expected that the majority of sprinkler water application will occur over the south west surface of the TSF, as the north east surface has a flatter gradient which will slow runoff and also be partly covered by runoff and water from the fresh tailing. The sprinkler control system will allow activation of individual or a number of sprinklers, as required.

A surface crusting agent may also be added to the spray water as required. The agent is a polymer modified coating which forms a crust over the tailing, binding the tailing particles and thereby preventing windblown dust. The crusting agent is resistant to wind and water erosion and the durability of the crusting agent is related to the severity of surface disturbance. Prior experience with a crusting agent at this mine site has shown this type of product to be effective.

The spray system will be installed during Stage 1 following completion of Embankment 2 and the spillway. The piping and sprays with the associated control and mixing system could be activated at any time during the operation of the TSF.

The crusting agent would be applied by one sprinkler at a time, and would take a few minutes per sprinkler to apply the recommended rate of crusting agent over the designated spray area. The sprinklers will include a remote activated valves to activate individual sprinklers as required.

The recommended dosing rate for the mixing of the crusting agent, and hence the application rate on the tailing surface, may be varied depending on the weather conditions at the site, with a higher concentration or more frequent application of crusting agent prior to a period of high wind or following intense rainfall events, or if disturbance of the tailing surface has occurred.

The sprinkler system will also apply a moderate volume of water to the surface of the tailings, either as a direct dust control measure or as part of the crusting agent application process. During normal tailing deposition it is proposed that sprayed water is the general dust control method and the application of the crusting agent is an additional measure, if required. Spraying of the crusting agent may be quickly implemented thereby providing an effective management procedure to control dust generation from the tailing surface. The sprinkler system could be activated manually or by an automated system controlled by dust monitoring equipment.

Note as most of the sprinklers are on the pit perimeter any edge areas of the facility that may generate dust can also be included in in the sprinkler spray coverage.

13.2.3 Sprinklers and Reticulation Pipe

Long throw sprinklers are proposed around the perimeter of Blackwood Pit TSF at the locations presented in APPENDIX F. A few sprinklers will be relocated onto the top of the Embankments after construction of the embankments and approximately eight sprinklers will be located on the tailings beach. The proposed sprinklers for the TSF have a maximum throw distance of approximately 60 m, and are sprinklers that are readily available from suppliers. The final selection of the sprinklers type for each location on the TSF will be subject to detailed design of the system related to pipe reticulation system, flow control system and pressure balancing of the reticulation system. The sprinklers will be located around the perimeter and on the beach of the TSF to ensure full coverage of the tailings surface. The operating pressure of the sprinklers units is approximately 7 bar. The sprinkler delivery system will provide equivalent rain application rate of approximately 10 mm/hr.

The typical cycle time of the sprinklers is between 3 minutes to 4 minutes, and reticulation pipe for the operation of the sprinklers will be designed to suit the required pressure head at the sprinkler for its location. Typically one or two sprinklers will be activated at a time to achieve a practical reticulation pipe design. The internal sprinklers on the tailings beach will be located on riser structures within the tailings in order to provide coverage to central area of the tailing beach. The riser structures will be progressively buried by the rising tailing level of the TSF. The riser structures and associated sprinkler will be accessible over the tailing beach for periodic maintenance and repairs, where required. Similarly the sprinklers around the perimeter of the TSF will be accessible via the embankment crests and the edge locations around the pit for periodic maintenance and repairs, where required.

The design is based on the Sime Sprinkler Master, supplied by Wet Earth Mining, Dust and Water Solutions. The proposed sprinkler system is widely used in the mining industry. The design will include an automated control system which will automatically initiate spraying should the perimeter sensors detect dust and wind at or above the trigger level. The detail of the control and activation system of the sprinkler system will be included in the updated air quality management plan.

13.2.4 Crusting Agent

As required, a crusting agent may added to water at an indicative rate of approximately 3% by volume should tailing deposition be delayed for an extended period of time or portions of the tailings beach require more frequent application of water for dust suppression. Supplier information and wind tunnel testing on similar tailing materials has indicated that, for the Blackwood TSF extension site, a mixture of water and crusting agent at a 3% solution applied at a rate of approximately 2 L/m^2 would provide dust control for a number of months. The actual concentration of crusting agent to be adopted for the site will be subject to field trials prior to commencement of operation. Trial criteria will include resistance to wind speeds expected at the site.

The estimated volume of agent required to cover the entire surface of TSF is approximately 7,200 litres, based on an area of 12 ha. Supplier information indicates that the product is supplied in 200 litre drums or 1000 litre bulk containers.

The agent dosage and water requirements for the site will be ascertained during proposed trials prior to commencement of the works.

13.3 Dam safety monitoring

Hand operated vane shear tests will be undertaken in the tailing at Embankment 1 and 3 locations prior to commencement of the upstream raises. The tests measure the undrained shear strength of the tailing. This test work will allow for review of the foundation conditions for the embankment raise stability and allow for adjustments to the design, if required.

Embankment displacement monitoring beacons will also be installed at the crest of each embankment to monitor deformation and settlement.

A surveillance monitoring program for dam safety will be outlined in the OMS Manual. It will include:

- Daily and weekly inspections by TSF operators, with the weekly inspections focussed on embankment integrity.
- Annual dam safety inspection and surveillance reviews by an experienced tailing dam engineer who is independent of the operating company. The inspection will include a walkover of the embankments and water management facilities, with a focus on dam integrity. The review will include:
  - A summary of observations and commentary on the operation with respect to the tailing deposition strategy and decant pond management.
  - Analysis of embankment displacement monitoring data.
  - A review of the flood management system against current industry best practice, i.e. ANCOLD (ANCOLD, 2012).
  - A review of embankment stability against current industry best practice.
  - A review of potential dam safety incidents that may have occurred over the review period.
  - Findings and recommendations for the ongoing safe management of the facility.
- Regular inspections of the downstream face of the embankment during operations. This will be useful in assessment of seepage. The inspections will also focus on where the decant outfall pipe daylights out of the ground, as this is a potential location for piping erosion.

13.4 Operational monitoring

Monitoring of runoff water quality and quantity will continue to occur in line with the current environmental monitoring program on site. The monitoring program will provide a means of assessing the performance of the TSF and its seepage management design.

In addition the monitoring will include monthly inspection and testing of the dust suppression sprinkler system. This monitoring requirement will be included in the site procedures for the mine.

14.0 REHABILITATION AND CLOSURE

14.1 Principles of closure

The primary objectives of a TSF closure plan are to manage the following:

- ***Safety*** – providing a final surface which does not expose the public to chemical and physical hazards.
- ***Stability*** – ability for the landform to remain stable over an extended period beyond closure, e.g. withstand large earthquakes and flood events, as well as continuous erosion forces from air and water.
- ***Seepage and groundwater*** – managing infiltration such that transportation of contaminants either to groundwater and/or surface water bodies will not impact receptors adversely.
- ***Erosion and sediment load*** – resistance to wind and water energy which may degrade the final surface and result in transportation of sediments to the external environment.
- ***Aesthetics*** – ability to blend into the natural environment and support intended end land uses.

14.2 Closure Plan

Following deposition of the tailing to the Final Tailing Level presented in APPENDIX A, Drawing 8 the Blackwood Pit TSF will be rehabilitated in accordance with the NSW Mine Closure guidelines. Consolidation of the tailing during and following cessation of tailings deposition will result in a mass of relatively low permeability tailing with respect to the surrounding weathered rock. Rainfall onto the surface of the proposed cover layer will mostly run over the surface to any low area, with a low rate of infiltration into the underlying tailing. Minor ponding on the surface of is expected to be evaporated rapidly, given the high evaporation rate at the site. Closure of the TSF will be accomplished in stages as follows:

14.2.1 Preparation of Tailing Surface

In the final stages of tailing deposition the tailing delivery system will be realigned to also discharge tailing from along the crest of Embankment 2. The tailing deposition will result in the tailing surface being shaped to direct runoff towards the spillway. The tailings beach surface near the spillway will be shaped by selective tailing placement from Embankment 2 to fill the environmental containment freeboard to a point that the remaining depression below the spillway level will detain the 1 in 100 year 72 hour rainfall runoff event from the TSF catchment.

Given the projected low rate of rise of the tailing beach as the TSF reaches capacity it is expected that the tailing beach may be accessible for construction works within a few months after final placement of tailing. Ponding water should be evaporated or be recirculated over the dryer part of the beach to remove the water from the tailing beach low areas to promote drying of the tailing prior to placement of cover layer.

14.2.2 Construction of Cover Layer

Following cessation of tailing deposition the tailing surface will dry back, consolidate and gain in strength. Settlement measurements will be made (remotely) onto beacons located on the surface to measure the rate of settlement and construction of the cover layer will commence once the rate of settlement has reduced to a sufficient degree. During this period the tailing surface is likely to be covered with a crusting agent for longer term dust control. The TSF will be covered progressively from the north and finish at the spillway structure. Progressive covering may also commence along Embankment 3 and progress towards the lower part of the beach. Access over the tailing beach will be by end tipping material on previously spread material over the tailing surface, with vehicles travelling on previously placed material only. No vehicles are to travel on the tailing to minimise the risk of disturbing the dust control crust on the tailing surface.

A conceptual design of the cover layer has been prepared and comprises:

- A 200 mm thick capillary break layer formed of screened waste rock placed over the tailings surface.
- A 300 mm thick cover formed of compacted run of mine waste rock. The mine waste rock will contain sufficient fines to create a well graded rockfill after compaction. The rockfill will be watered and compacted using heavy smooth drum compaction equipment. The cover will be robust and resistant to wind and water erosion.

The cover layer will be constructed over the entire tailing surface and be integrated into the *in situ* rock on the pit rim and the embankment rockfill. The surface will be shaped to shed water towards the low area near the spillway, with runoff in excess of 1 in 100 year events discharging through the spillway.

14.2.3 Embankment rehabilitation

The embankments are designed with 2.5H:1V downstream slopes which are appropriate for closure and long term stability of the rockfill embankments, as discussed in Section 9.4. The embankments will be constructed from durable compacted rockfill. Wind and rain erosion of the embankments is expected to be minimal. No further rehabilitation of the downstream embankment slopes is envisaged.

Seepage flow rate from the collection system within the embankments will be monitored periodically. Where the seepage rate has stopped the sumps may be decommissioned and removed. Where minor seepage continues for an extended period the sumps may be modified to discharge to small lined evaporation basins to eliminate the need for ongoing periodic pumping of any seepage. Removed sumps and any other removed materials would be disposed as part of the mine rehabilitation procedure, or disposed to a landfill licensed to receive the waste.

14.2.4 Material sources

Material for closure works will primarily be sourced from waste rock generated during operation, and from remaining stockpiles available on the BHOP site.

14.2.5 Climate Change

Climate change conditions are anticipated to exacerbate the extremes of temperature and reduce rainfall at the site.

15.0 CLOSING

This report presents the conceptual design and the design basis for the Blackwood Pit TSF extension. The reader’s attention is drawn to the Important Information relating to this report (limitations), presented in APPENDIX H.

16.0 REFERENCES

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Report Signature Page

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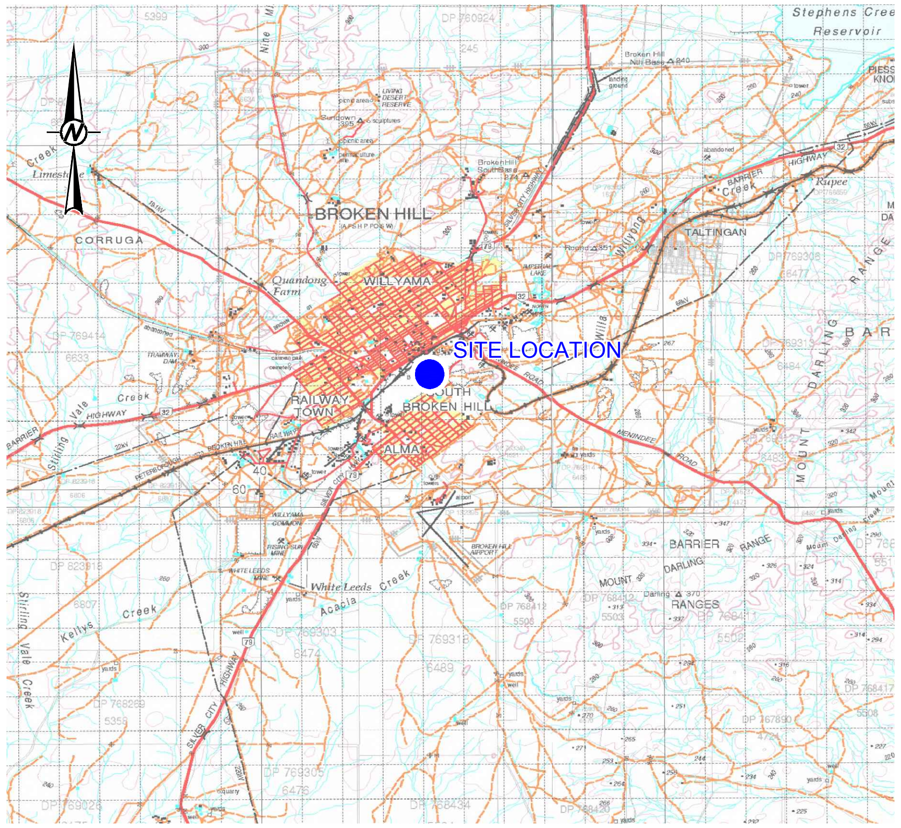
APPENDIX A

Design Drawings

APPENDIX B

Embankment Slope Stability Sections Layout and Analysis Outputs

BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL



SITE LOCATION
NOT TO SCALE

DRAWING LIST

DRAWING No.	TITLE
1	COVER SHEET
2	EXISTING SITE CONDITIONS
3	PROPOSED EMBANKMENTS 1 AND 3 CONSTRUCTION PREPARATION LAYOUT
4	PROPOSED EMBANKMENT LAYOUT AT INTERMEDIATE TAILINGS LEVEL
5	PROPOSED EMBANKMENT 1 LAYOUT PLAN
6	PROPOSED EMBANKMENT 2 LAYOUT PLAN
7	PROPOSED EMBANKMENT 3 LAYOUT PLAN
8	PROPOSED EMBANKMENT LAYOUT AT FINAL TAILINGS LEVEL
9	EMBANKMENT 1 SECTIONS
10	EMBANKMENT 2 LONG SECTION
11	EMBANKMENT 3 LONG SECTION
12	EMBANKMENTS 2 AND 3 SECTIONS
13	TYPICAL SECTIONS AND DETAILS - SHEET 1
14	TYPICAL SECTIONS AND DETAILS - SHEET 2
15	TYPICAL SECTIONS AND DETAILS - SHEET 3
16	SPILLWAY LAYOUT AND SECTIONS

GENERAL NOTE(S)

1. THESE NOTES APPLY TO ALL PROJECT DRAWINGS IN THE SET UNLESS NOTED OTHERWISE AND SHALL BE READ IN CONJUNCTION WITH THE SPECIFICATION.
2. ALL LEVELS ARE IN METRES TO AUSTRALIAN HEIGHT DATUM (m AHD).
3. ALL CO-ORDINATES ARE IN METRES TO MAP GRID AUSTRALIA (MGA 94, ZONE 54).
4. ALL DIMENSIONS ARE IN NETRIC UNITS AS SPECIFIED.
5. DIMENSIONS AND LOCATION OF EXISTING STRUCTURES SHALL BE CONFIRMED ON SITE BY THE CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
6. LOCATION AND DEPTH OF ALL SERVICES TO BE VERIFIED BY THE CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
7. DIMENSIONS SHALL NOT BE SCALED OFF DRAWINGS.
8. DRAWINGS MUST BE PRINTED IN COLOUR TO CORRECTLY IDENTIFY ALL DESIGN FEATURES.

REFERENCE(S)

LOCALITY PLAN SOURCED FROM NSW DEPARTMENT OF LANDS 'TOPOVIEW RASTER 2006' SOFTWARE (LAND AND PROPERTY INFORMATION MAP REF.: 7134 BROKEN HILL)

EXISTING SURVEY SHOWN FROM FILES: 160425 Tailings Dam 1m Contours.dxf AND 160425 RASP Tailings Dam Area.dxf (1 m CONTOURS), RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

AERIAL IMAGE SHOWN FROM FILE: 160425 Rasp Mine MGA54 50cm.ecw, RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

SITE BOUNDARIES SHOWN FROM FILES: mga_cml7_lease_bdy.dwg, surf_leases_mga.dxf, RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

CML SURFACE EXCLUSION BOUNDARY SHOWN FROM FILES: GFH_D2319.DXF AND GFH_M25352.dxf, RECEIVED FROM CBH RESOURCES ON 22 AUGUST 2016.

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PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
COVER SHEET

PROJECT NO.	CONTROL	REV.		DRAWING
1654895	009-R	0	1 of 16	1

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25 mm

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LEGEND

EXISTING CONTOURS AT 1 m INTERVALS

LEASE BOUNDARY EXTENT

SURVEYED CML7 SURFACE EXCLUSION BOUNDARY

NOTE(S)

1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.

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PROJECT
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RASP MINE, BROKEN HILL

TITLE
EXISTING SITE CONDITIONS

PROJECT NO.	CONTROL	REV.	2 of 16	DRAWING
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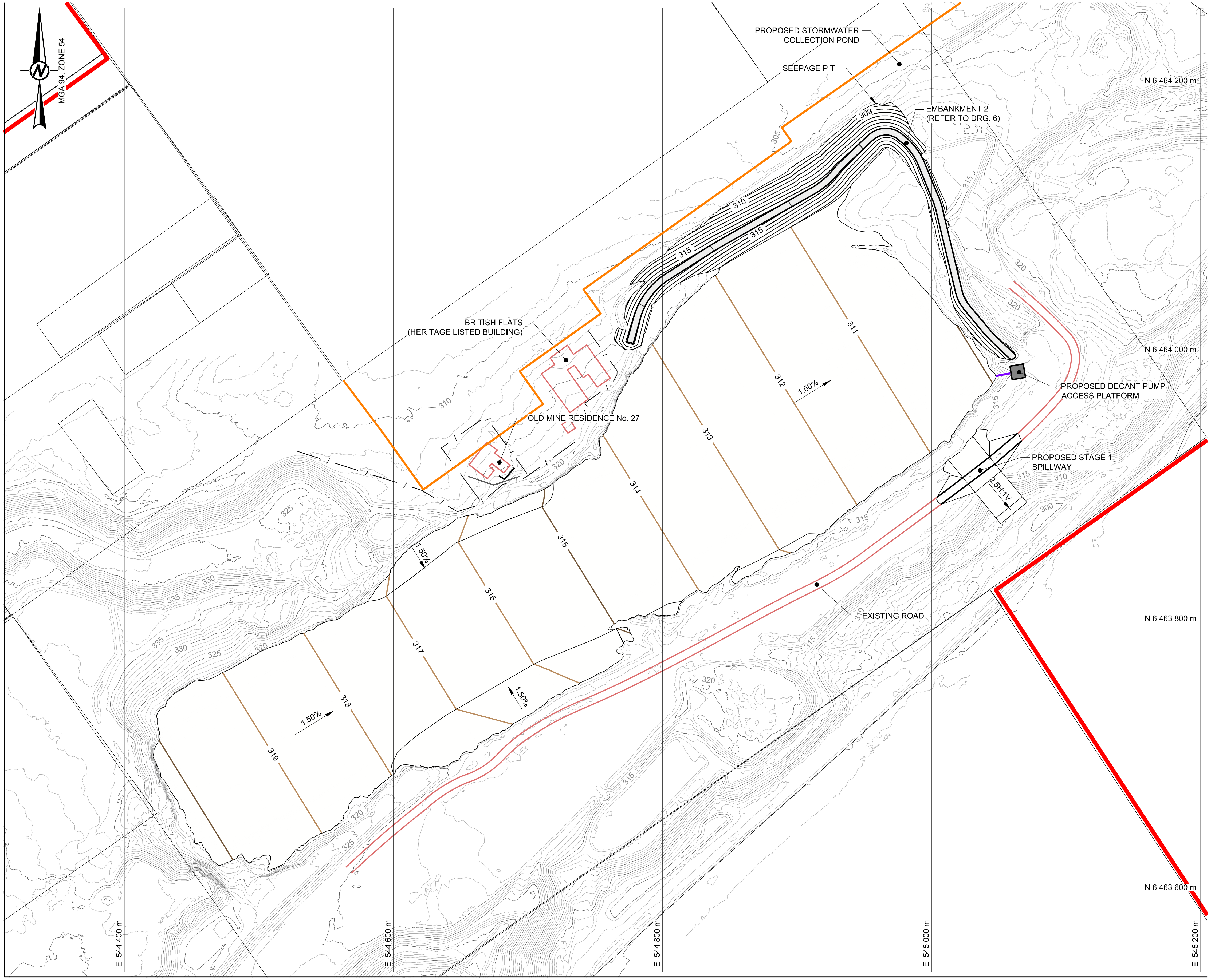

LEGEND

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- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- ANTICIPATED INTERMEDIATE TAILINGS CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY

NOTE(S)

1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. INTERMEDIATE TAILINGS LEVELS REPRESENT THE ANTICIPATED ELEVATION OF TAILINGS SURFACE AT COMMENCEMENT OF EMBANKMENTS 1 AND 3 CONSTRUCTION.

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RASP MINE, BROKEN HILL

TITLE
PROPOSED EMBANKMENTS 1 AND 3 CONSTRUCTION PREPARATION LAYOUT

PROJECT NO.	CONTROL	REV.	3 of 16	DRAWING
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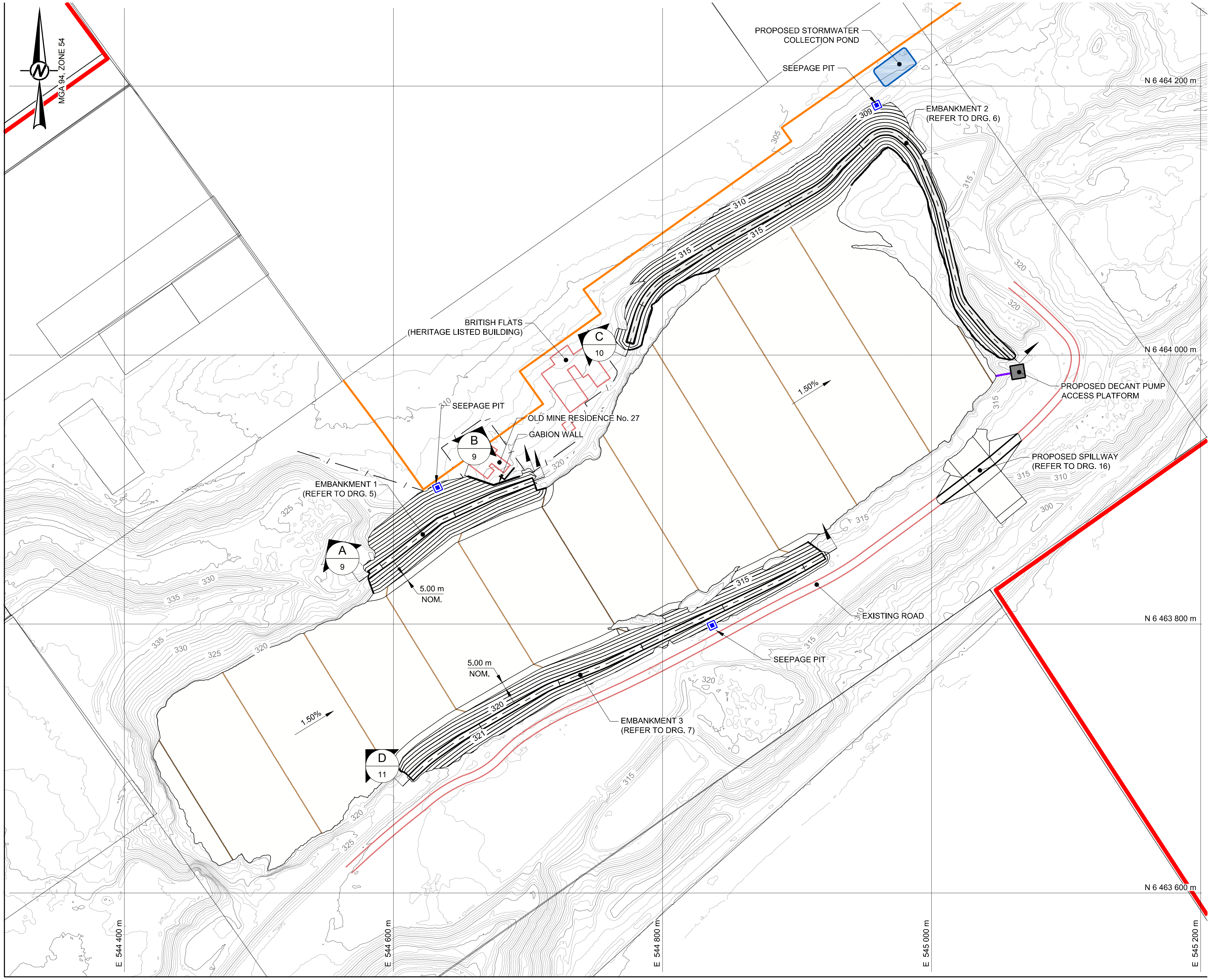

LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- ANTICIPATED INTERMEDIATE TAILINGS CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
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NOTE(S)

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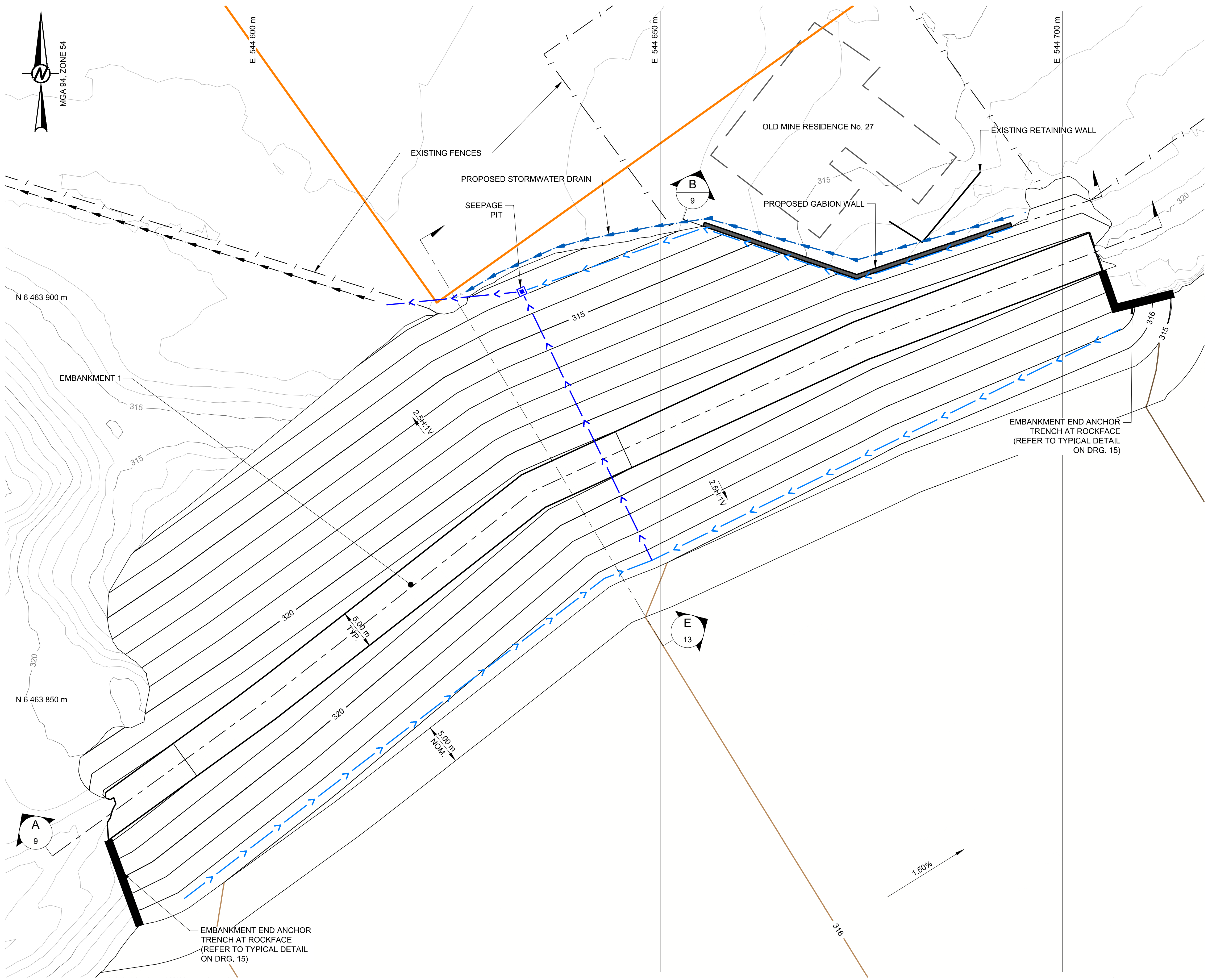
RASP MINE, BROKEN HILL

TITLE
PROPOSED EMBANKMENT LAYOUT AT INTERMEDIATE TAILINGS LEVEL

PROJECT NO.	CONTROL	REV.	4 of 16	DRAWING
1654895	009-R	0		4



LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- PROPOSED INTERMEDIATE TAILINGS CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY
- PROPOSED PERFORATED DRAINAGE PIPE
- PROPOSED SOLID WALL DRAINAGE PIPE
- SEEPAGE PIT
- EXISTING STORMATER DRAIN
- PROPOSED STORMATER DRAIN

NOTE(S)

1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. INTERMEDIATE TAILINGS LEVELS REPRESENT THE ANTICIPATED ELEVATION OF TAILINGS SURFACE AT COMMENCEMENT OF EMBANKMENTS 1 AND 3 CONSTRUCTION.

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APPROVAL

0 10 20
1:500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

CLIENT
BROKEN HILL OPERATIONS PTY LTD

CONSULTANT
Golder Associates

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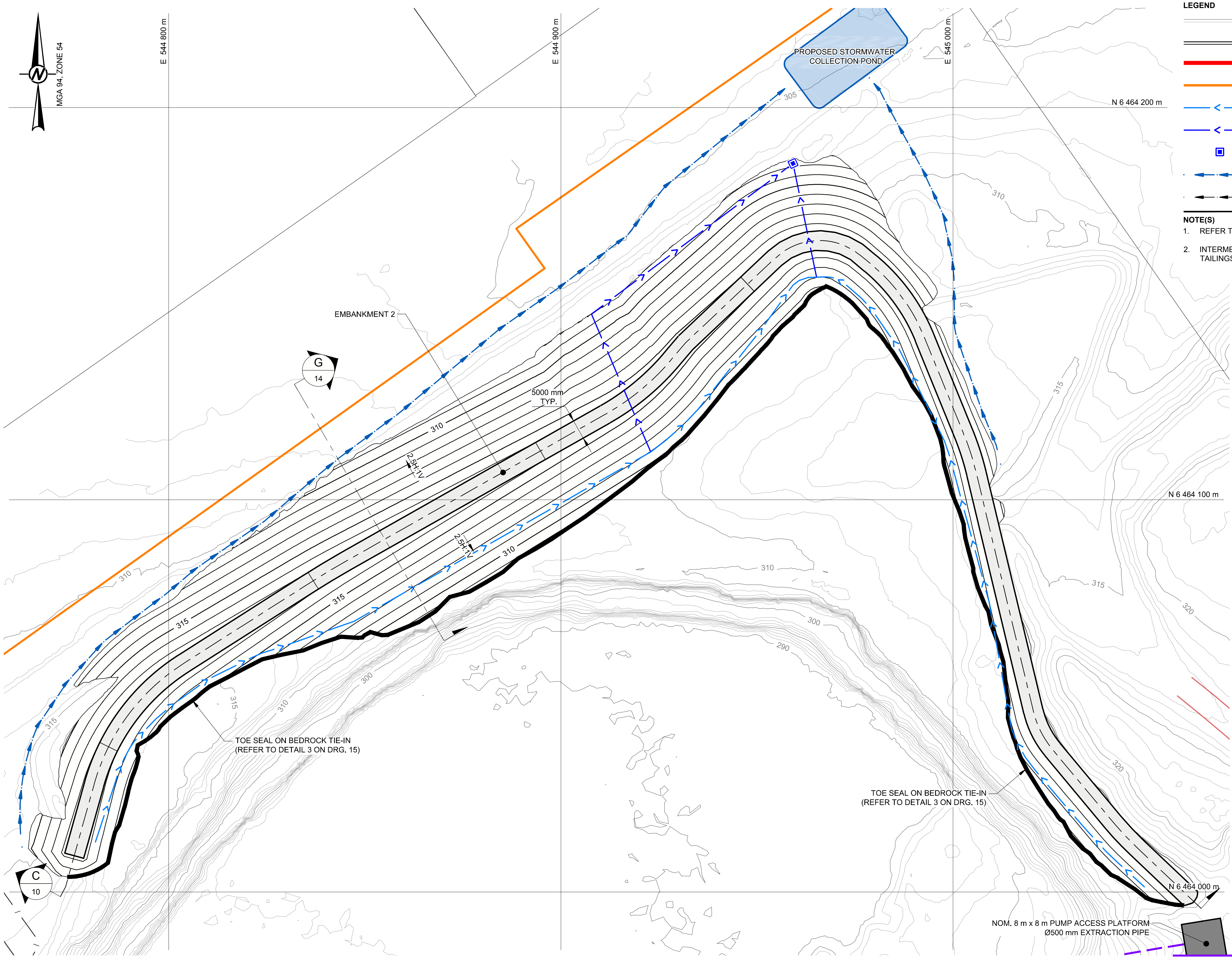
AUSTRALIA
+61 3 8862 3500
www.golder.com

PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
PROPOSED EMBANKMENT 1 LAYOUT PLAN

PROJECT NO.	CONTROL	REV.		DRAWING
1654895	009-R	0	5 of 16	5



LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY
- PROPOSED PERFORATED DRAINAGE PIPE
- PROPOSED SOLID WALL DRAINAGE PIPE
- SEEPAGE PIT
- PROPOSED STORMATER DRAIN
- EXISTING STORMATER DRAIN

NOTE(S)

1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. INTERMEDIATE TAILINGS LEVELS REPRESENT THE ANTICIPATED ELEVATION OF TAILINGS SURFACE AT COMMENCEMENT OF EMBANKMENTS 1 AND 3 CONSTRUCTION.

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0 25 50

1:1,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

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PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
PROPOSED EMBANKMENT 2 LAYOUT PLAN

PROJECT NO.	CONTROL	REV.	6 of 16	DRAWING
1654895	009-R	0		6

Path: \\golder.gds\gap\melbourne\geomatics\CBH\Rasp Mine\99_PROJECTS\1654895_Rasp Blackwood Pit Ext\009 - R (formerly 007)\02_PRODUCTION\DWG\ | File Name: 1654895-009-R-005.dwg

25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

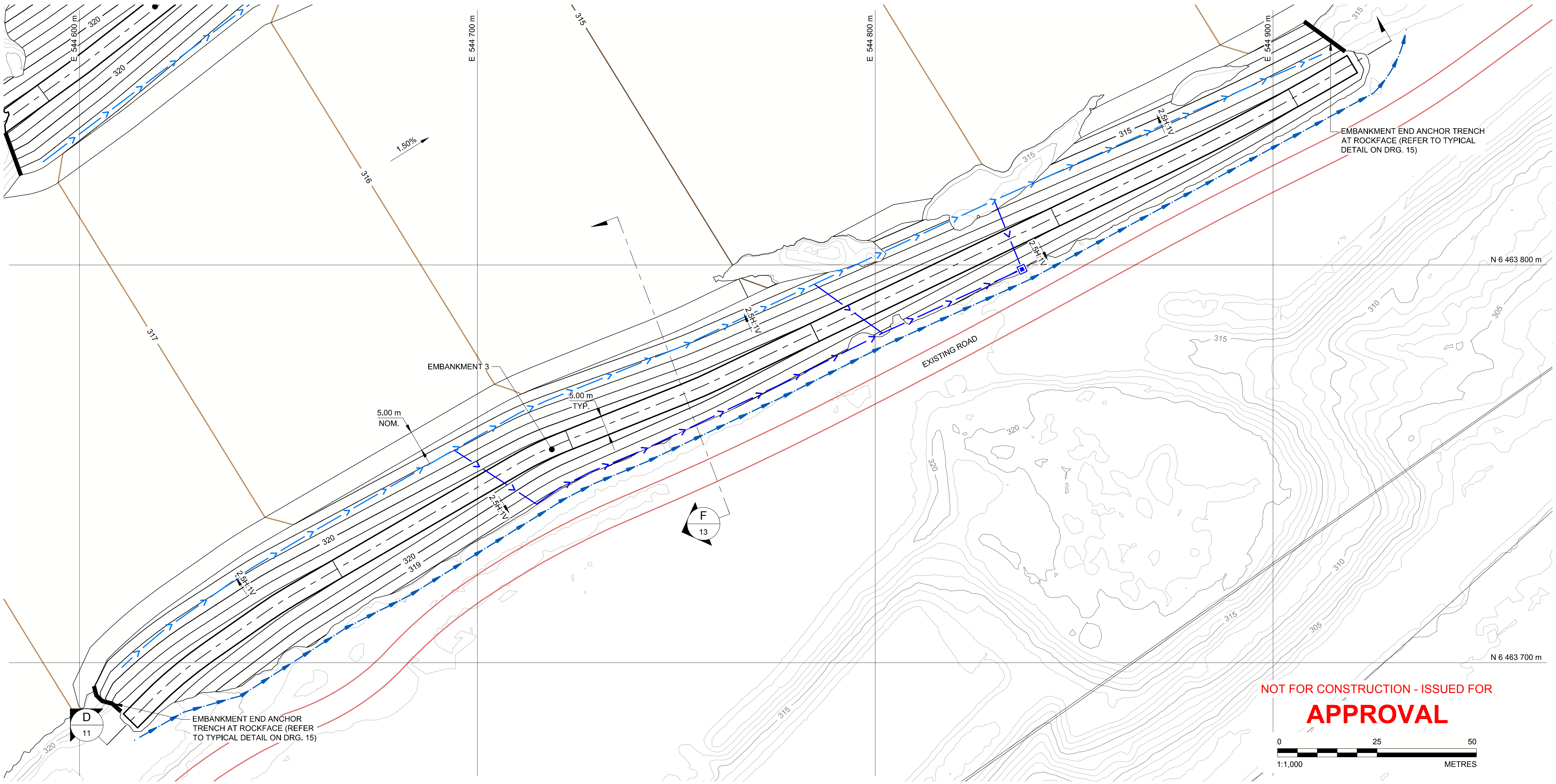
MGA 94, ZONE 54

LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- PROPOSED INTERMEDIATE TAILINGS CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY
- PROPOSED PERFORATED DRAINAGE PIPE
- PROPOSED SOLID WALL DRAINAGE PIPE
- SEEPAGE PIT
- PROPOSED STORMWATER DRAIN
- EXISTING STORMATER DRAIN

NOTE(S)

1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. INTERMEDIATE TAILINGS LEVELS REPRESENT THE ANTICIPATED ELEVATION OF TAILINGS SURFACE AT COMMENCEMENT OF EMBANKMENTS 1 AND 3 CONSTRUCTION.



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0 25 50

1:1,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

CLIENT
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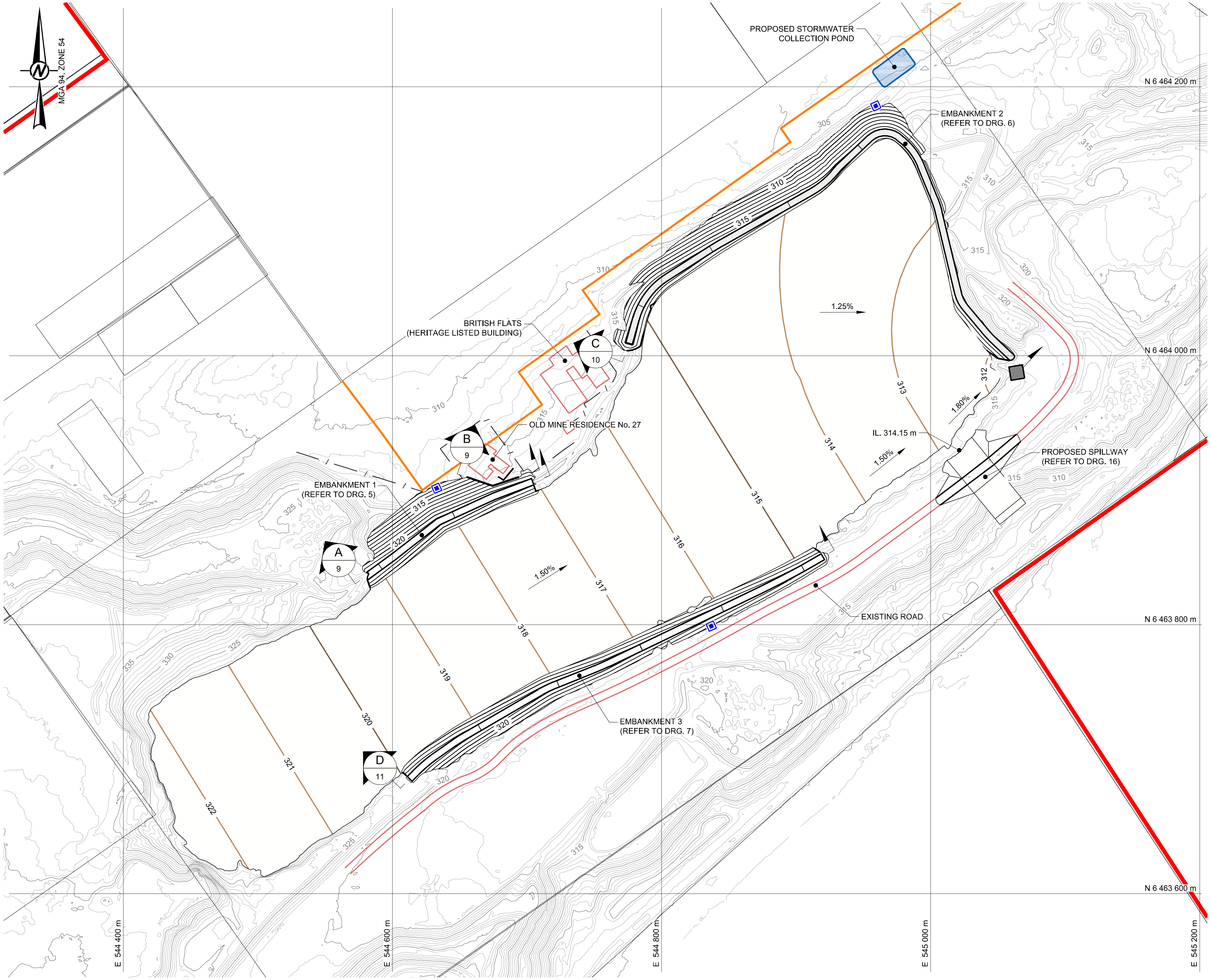
PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
PROPOSED EMBANKMENT 3 LAYOUT PLAN

PROJECT NO.	CONTROL	REV.	7 of 16	DRAWING
1654895	009-R	0		7

Path: \\golder.gds\gap\melbourne\geomatics\CBH\Rasp Mine\99_PROJECTS\1654895_Rasp Blackwood Pit Ext\009 - R (formerly 007)\02_PRODUCTION\DWG\ | File Name: 1654895-009-R-005.dwg



LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- ANTICPATED FINAL TAILINGS LEVEL CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY

NOTE(S)

1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. ANTICIPATED FINAL TAILINGS LEVEL CONTOURS ARE SUBJECT TO CHANGE PENDING ADDITIONAL DETAILED DESIGN ASSESSMENTS.

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0 50 100

1:3,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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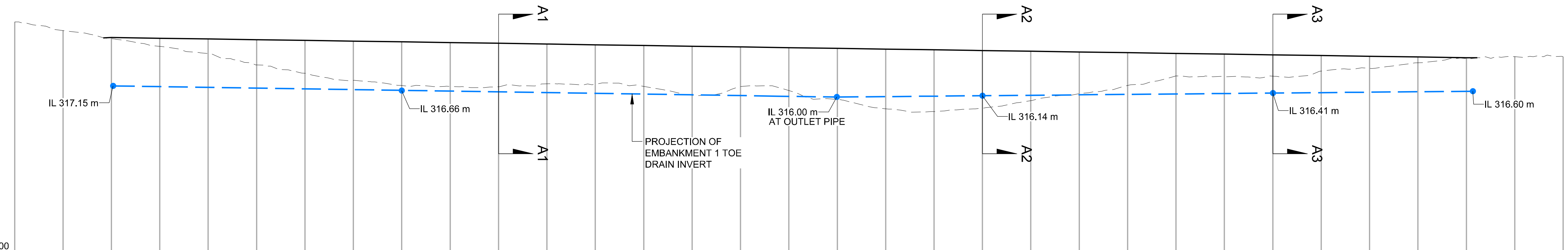
PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

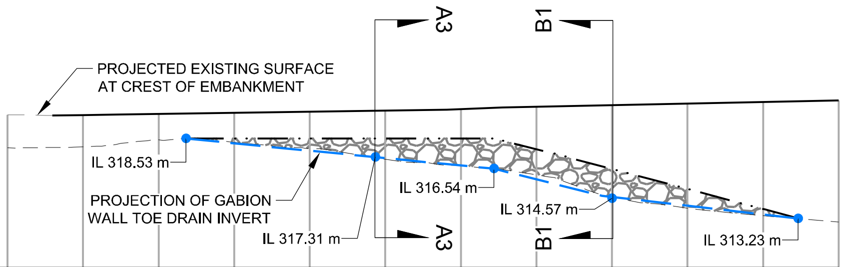
TITLE
PROPOSED EMBANKMENT LAYOUT AT FINAL TAILINGS LEVEL

PROJECT NO.	CONTROL	REV.	8 of 16	DRAWING
1654895	009-R	0		8



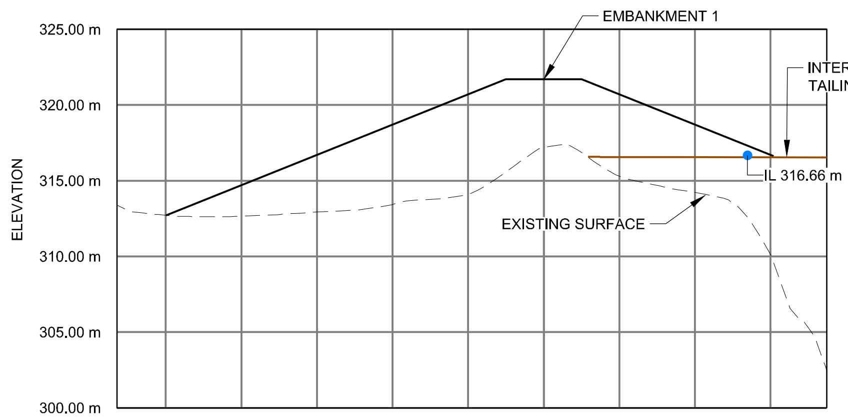
DATUM 300.00																																	
EXISTING GROUND	323.78	322.88	322.03	321.24	320.51	319.33	318.47	317.72	317.19	317.10	317.06	317.37	317.33	317.11	316.18	317.08	316.68	315.75	314.79	314.50	314.84	315.62	316.35	317.20	318.18	318.10	318.16	318.68	318.97	319.54	319.98	320.18	320.18
CUT AND FILL DEPTH (m)			0.13	0.84	1.50	2.60	3.39	4.06	4.52	4.53	4.50	4.11	4.08	4.23	5.08	4.10	4.43	5.29	6.18	6.39	5.97	5.12	4.31	3.39	2.34	2.34	2.21	1.62	1.25	0.60	0.09		
PROPOSED CREST OF EMBANKMENT			322.16	322.08	322.01	321.93	321.86	321.78	321.71	321.63	321.56	321.48	321.41	321.33	321.26	321.19	321.11	321.04	320.96	320.89	320.81	320.74	320.66	320.59	320.52	320.44	320.37	320.30	320.22	320.15	320.07		

SCALE 1:500 A 3 5 8 LONG SECTION THROUGH EMBANKMENT 1 CREST

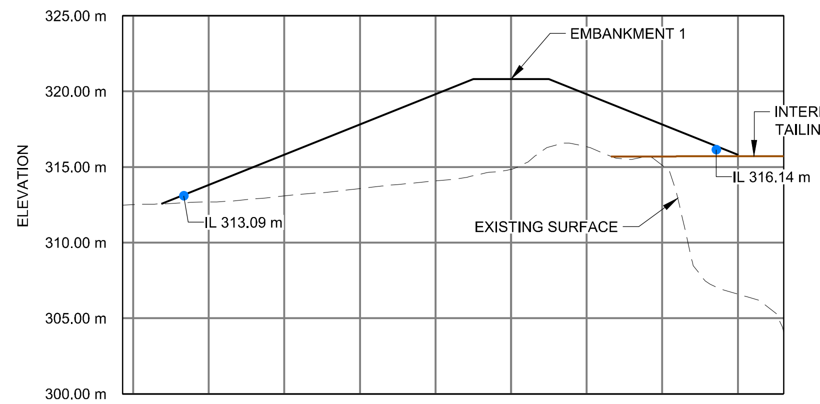


DATUM 310.00												
PROJECTED CREST OF EMBANKMENT		320.09	320.16	320.24	320.31	320.38	320.48	320.64	320.74	320.84	320.94	321.05
PROPOSED TOP OF GABION WALL				318.53	318.53	318.53	318.53	317.83	316.52	315.20	313.87	
CUT AND FILL DEPTH (m)				0.25	0.65	1.36	1.78	1.70	1.86	1.28	0.44	
EXISTING GROUND	317.93	317.99	318.44	318.28	317.88	317.17	316.75	316.13	314.66	313.92	313.43	

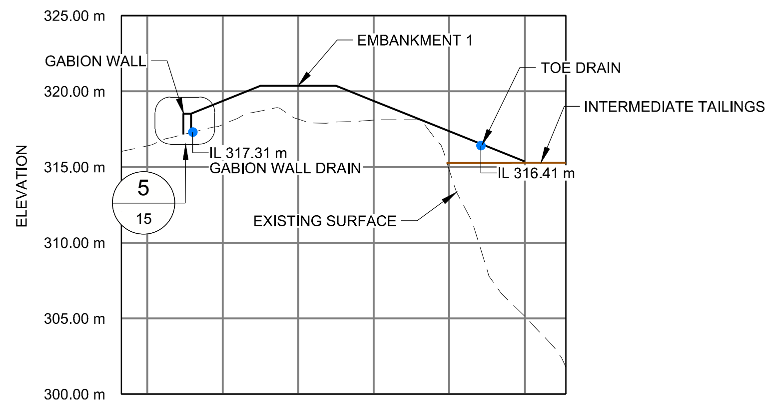
SCALE 1:500 B 3 5 8 LONG SECTION THROUGH GABION WALL



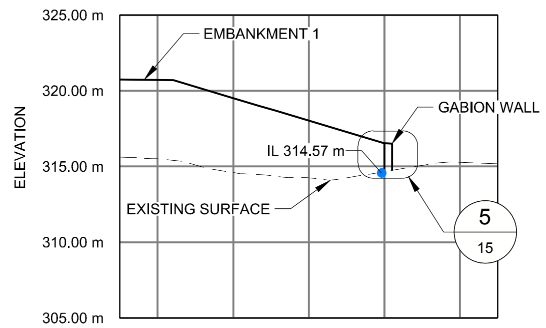
PROFILE SECTION A1
SCALE 1:500



PROFILE SECTION A2
SCALE 1:500



PROFILE SECTION A3
SCALE 1:500



PROFILE SECTION B1
SCALE 1:500

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1:500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

CLIENT
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PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

CONSULTANT

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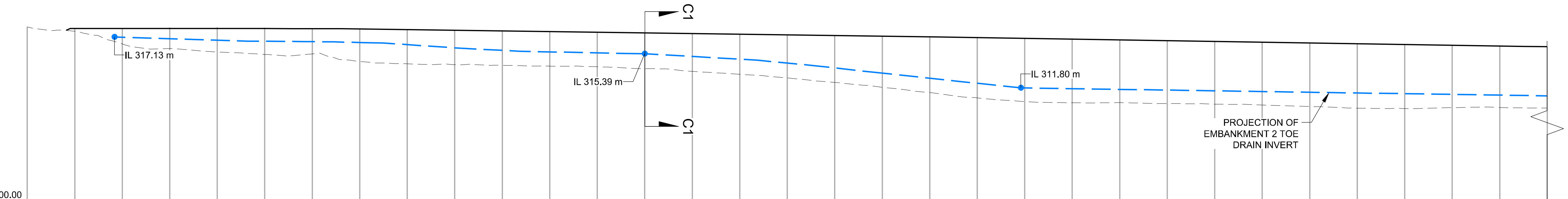
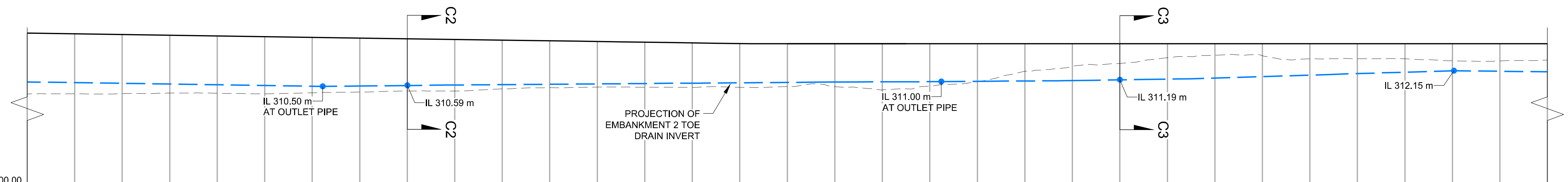
TITLE
EMBANKMENT 1 SECTIONS

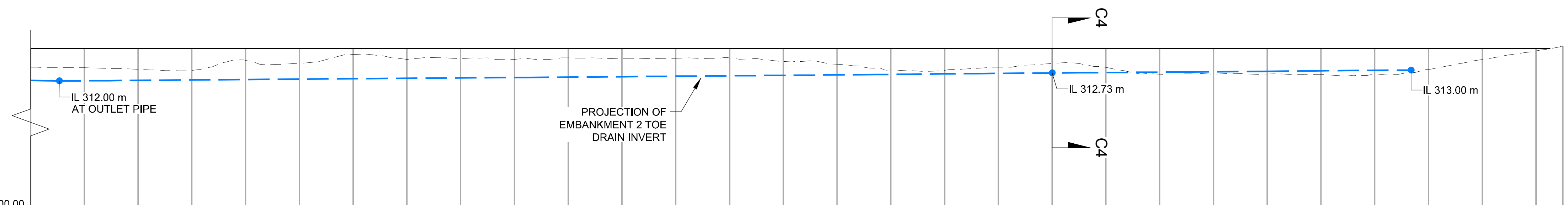
PROJECT NO.	CONTROL	REV.		DRAWING
1654895	009-R	0	9 of 16	9



PROPOSED CREST OF EMBANKMENT		318.02	318.02	318.02	318.02	318.02	318.00	317.98	317.91	317.84	317.77	317.70	317.63	317.56	317.49	317.42	317.35	317.28	317.21	317.14	317.06	316.98	316.90	316.83	316.75	316.67	316.59	316.51	316.43	316.35	316.27	316.19	316.12
CUT AND FILL DEPTH (m)		0.27	1.61	2.09	2.45	2.72	2.64	3.41	3.57	3.60	3.60	3.61	3.62	3.74	3.96	4.19	4.50	4.90	5.35	5.83	6.31	6.61	6.66	6.58	6.59	6.57	6.58	6.66	6.75	6.72	6.55	6.45	6.42
EXISTING GROUND	318.20	317.74	316.40	315.92	315.57	315.31	315.37	314.57	314.33	314.24	314.16	314.08	314.01	313.81	313.53	313.22	312.85	312.38	311.86	311.31	310.75	310.37	310.24	310.25	310.15	310.10	310.01	309.85	309.68	309.63	309.73	309.74	309.70



PROPOSED CREST OF EMBANKMENT	316.12	316.04	315.97	315.89	315.82	315.74	315.67	315.59	315.52	315.45	315.37	315.30	315.23	315.16	315.09	315.02	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00
CUT AND FILL DEPTH (m)	6.42	6.33	6.24	6.10	6.05	6.03	5.85	5.69	5.52	5.44	5.14	4.94	4.80	4.74	4.71	4.62	4.53	4.53	4.88	4.46	4.01	2.91	2.39	2.09	1.48	1.22	1.26	1.59	1.59	1.59	1.81	1.82	1.73
EXISTING GROUND	309.70	309.71	309.73	309.79	309.77	309.71	309.81	309.90	310.00	310.01	310.23	310.36	310.43	310.42	310.38	310.40	310.47	310.47	310.12	310.54	310.99	312.09	312.61	312.91	313.52	313.78	313.74	313.41	313.41	313.41	313.19	313.18	313.27



PROPOSED CREST OF EMBANKMENT	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	315.00	
CUT AND FILL DEPTH (m)	1.73	1.77	1.93	2.02	1.09	1.36	0.55	1.00	0.93	1.00	0.86	0.95	0.89	0.86	1.20	1.45	1.98	2.02	1.74	1.38	1.75	2.38	2.35	2.37	2.40	2.39	1.92	1.02	0.22	
EXISTING GROUND	313.27	313.23	313.07	312.98	313.91	313.64	314.45	314.00	314.07	314.00	314.14	314.05	314.11	314.14	313.80	313.55	313.02	312.98	313.26	313.62	313.25	312.62	312.65	312.63	312.60	312.61	313.08	313.98	314.78	315.22

SCALE 1:500 C LONG SECTION THROUGH EMBANKMENT 2 CREST
3 6 8

NOTE(S)
1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. REFER TO DRAWING 12 FOR EMBANKMENT 2 'C' SERIES PROFILE SECTIONS.
3. INTERMEDIATE TAILINGS LEVELS REPRESENT THE ANTICIPATED ELEVATION OF TAILINGS SURFACE AT COMMENCEMENT OF EMBANKMENTS 1 AND 3 CONSTRUCTION.

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0 10 20
1:500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

CLIENT
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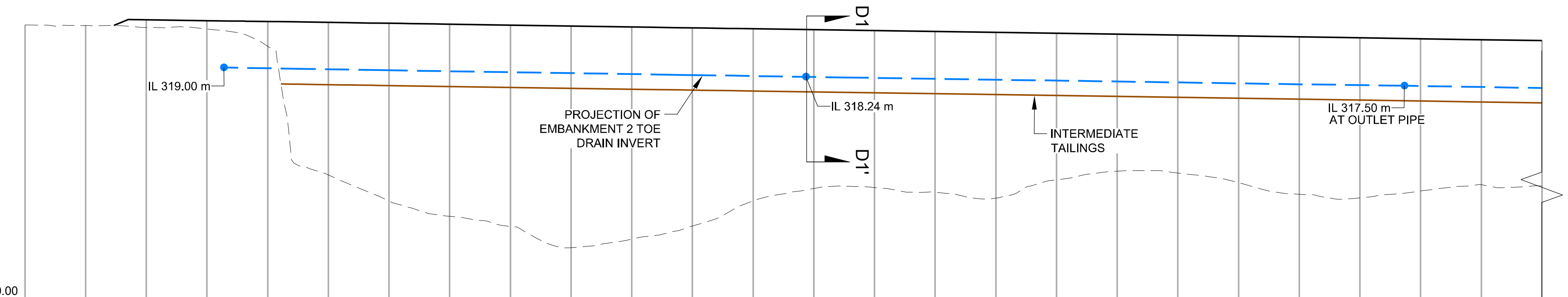
PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
EMBANKMENT 2 LONG SECTION

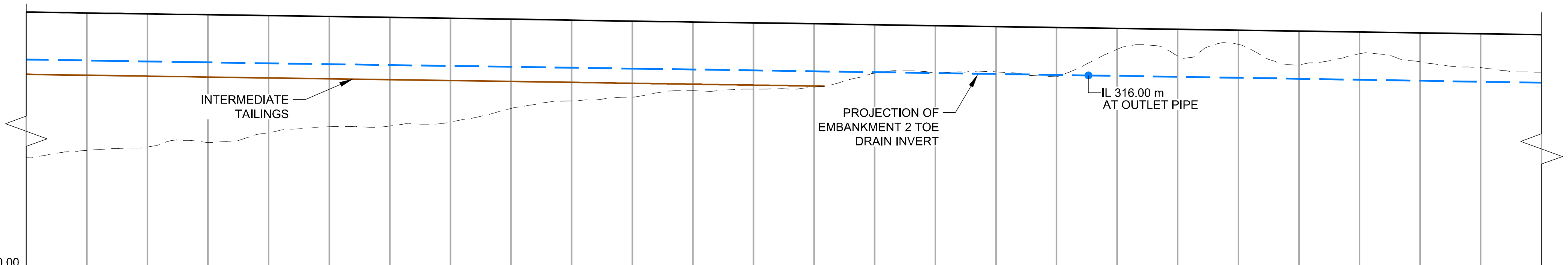
PROJECT NO. 1654895 | CONTROL 009-R | REV. 0 | 10 of 16 | DRAWING 10

NOTE(S)
1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. REFER TO DRAWING 12 FOR EMBANKMENT 3 'D' SERIES PROFILE SECTIONS.
3. INTERMEDIATE TAILINGS LEVELS REPRESENT THE ANTICIPATED ELEVATION OF TAILINGS SURFACE AT COMMENCEMENT OF EMBANKMENTS 1 AND 3 CONSTRUCTION.



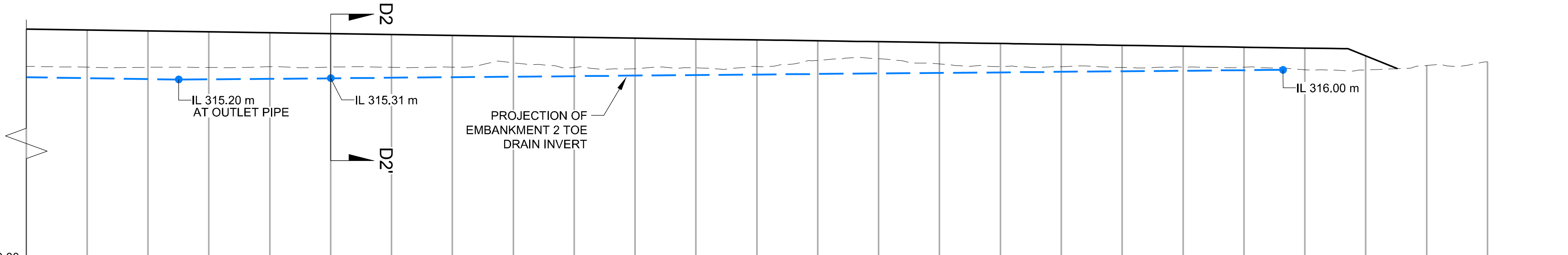
DATUM 300.00

PROPOSED CREST OF EMBANKMENT			322.94	322.87	322.80	322.72	322.65	322.57	322.50	322.42	322.35	322.27	322.20	322.12	322.05	321.97	321.90	321.82	321.75	321.67	321.60	321.52	321.45	321.37	321.30	321.22
CUT AND FILL DEPTH (m)						5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13
INTERMEDIATE TAILINGS LEVEL						317.59	317.52	317.44	317.37	317.29	317.22	317.14	317.07	316.99	316.92	316.84	316.77	316.69	316.62	316.54	316.47	316.39	316.32	316.24	316.17	316.09
EXISTING GROUND	322.52	322.47	322.31	322.18	320.76	310.15	307.98	306.74	305.91	304.15	304.85	305.95	308.01	309.04	309.11	308.73	308.24	309.74	310.46	310.31	309.51	308.56	308.26	308.82	309.34	309.23



DATUM 300.00

PROPOSED CREST OF EMBANKMENT	321.22	321.15	321.08	321.00	320.93	320.85	320.78	320.71	320.63	320.56	320.48	320.41	320.34	320.26	320.19	320.11	320.04	319.96	319.89	319.81	319.74	319.66	319.59	319.51	319.44	319.37
CUT AND FILL DEPTH (m)	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13												
INTERMEDIATE TAILINGS LEVEL	316.09	316.02	315.95	315.87	315.80	315.72	315.65	315.58	315.50	315.43	315.35	315.28	315.21	315.13												
CUT AND FILL DEPTH (m)															4.00	3.89	3.74	4.07	1.73	2.20	1.18	2.80	1.79	2.39	2.79	3.08
EXISTING GROUND	309.23	309.82	310.10	310.48	311.28	311.78	311.83	312.16	313.27	313.90	314.21	314.75	314.88	315.03	316.19	316.22	316.29	315.89	318.15	317.61	318.56	316.86	317.80	317.13	316.65	316.28



DATUM 300.00

PROPOSED CREST OF EMBANKMENT	319.37	319.29	319.22	319.14	319.07	318.99	318.92	318.84	318.77	318.69	318.62	318.54	318.47	318.40	318.32	318.25	318.17	318.10	318.02	317.95	317.87	317.80	317.15		
CUT AND FILL DEPTH (m)	3.08	3.07	3.01	2.94	2.80	2.75	2.70	2.61	2.19	2.50	2.51	2.37	2.19	1.62	1.41	1.76	1.89	1.83	1.82	1.73	1.65	1.79	1.15		
EXISTING GROUND	316.28	316.22	316.21	316.20	316.26	316.24	316.22	316.23	316.58	316.19	316.11	316.17	316.28	316.78	316.91	316.49	316.28	316.27	316.21	316.21	316.23	316.00	316.00	316.37	316.66

SCALE 1:500 D 3 7 8 LONGSECTION THROUGH EMBANKMENT 3 CREST

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APPROVAL

0 10 20
1:500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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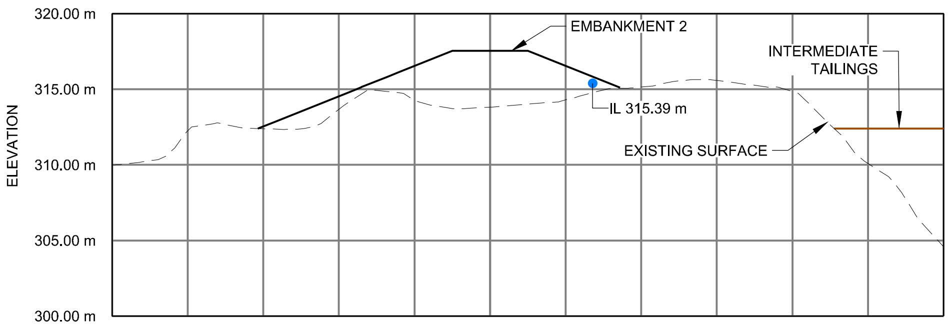
PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

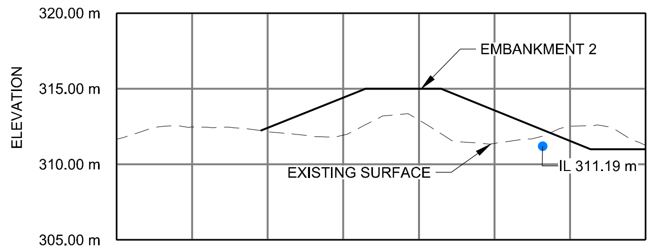
TITLE
EMBANKMENT 3 LONG SECTION

PROJECT NO.	CONTROL	REV.	11 of 16	DRAWING
1654895	009-R	0		11

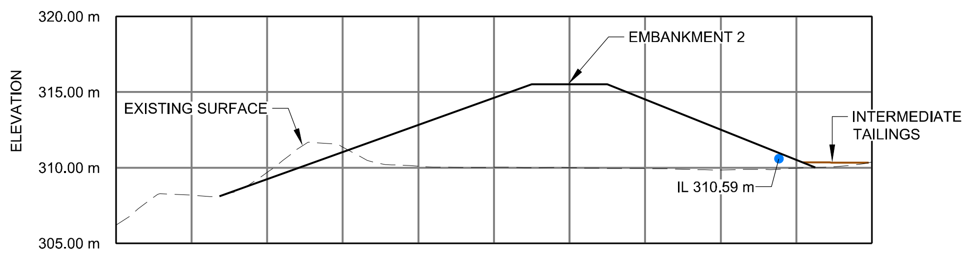
NOTE(S)
1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. REFER TO DRAWING 10 FOR EMBANKMENT 2 'C' SERIES PROFILE LOCATIONS.
3. REFER TO DRAWING 11 FOR EMBANKMENT 3 'D' SERIES PROFILE LOCATIONS.
4. INTERMEDIATE TAILINGS LEVELS REPRESENT THE ANTICIPATED ELEVATION OF TAILINGS SURFACE AT COMMENCEMENT OF EMBANKMENTS 1 AND 3 CONSTRUCTION.



PROFILE SECTION C1
SCALE 1:500



PROFILE SECTION C3
SCALE 1:500



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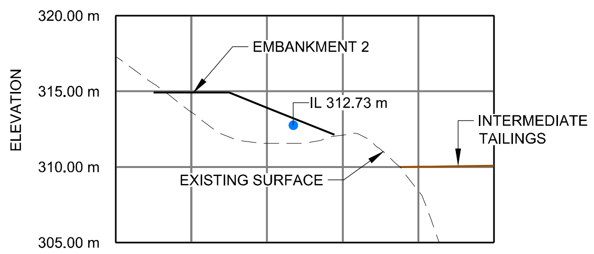

PROFILE SECTION C4
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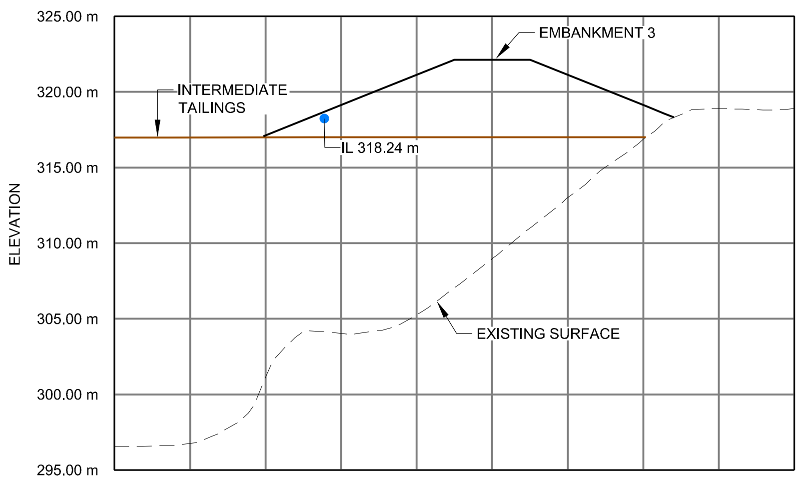
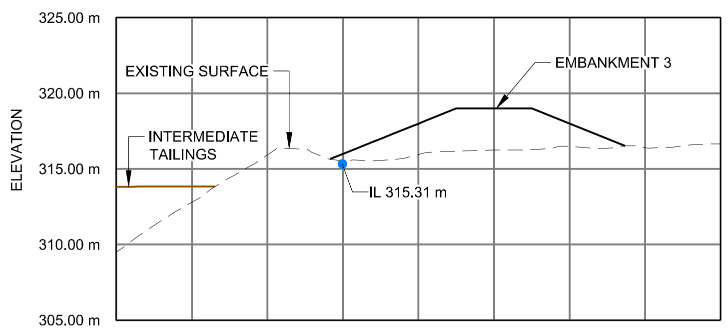


PROFILE SECTION D1
SCALE 1:500



PROFILE SECTION D2
SCALE 1:500

NOT FOR CONSTRUCTION - ISSUED FOR

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0 10 20
1:500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

CLIENT
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CONSULTANT

Golder Associates

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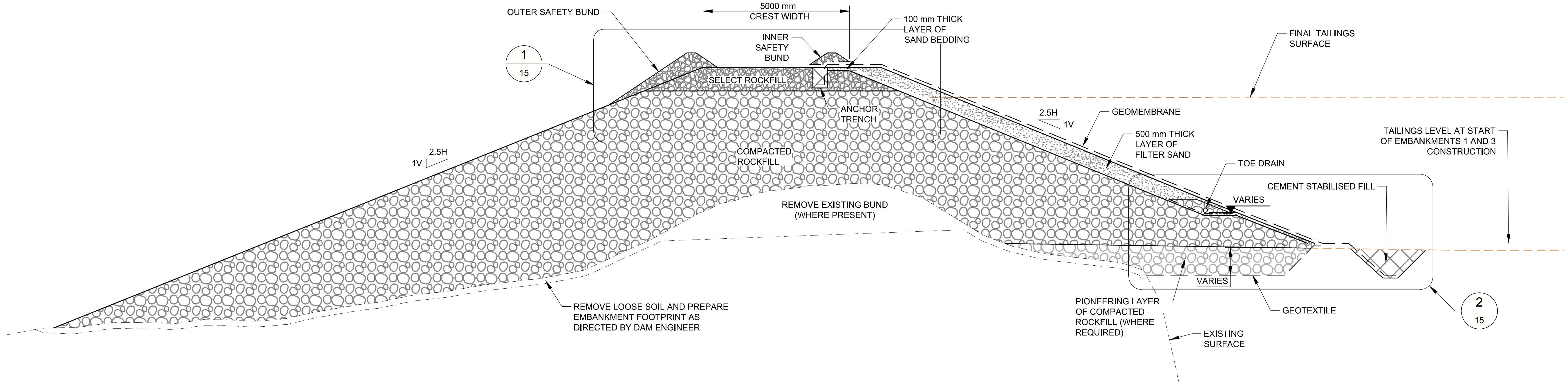
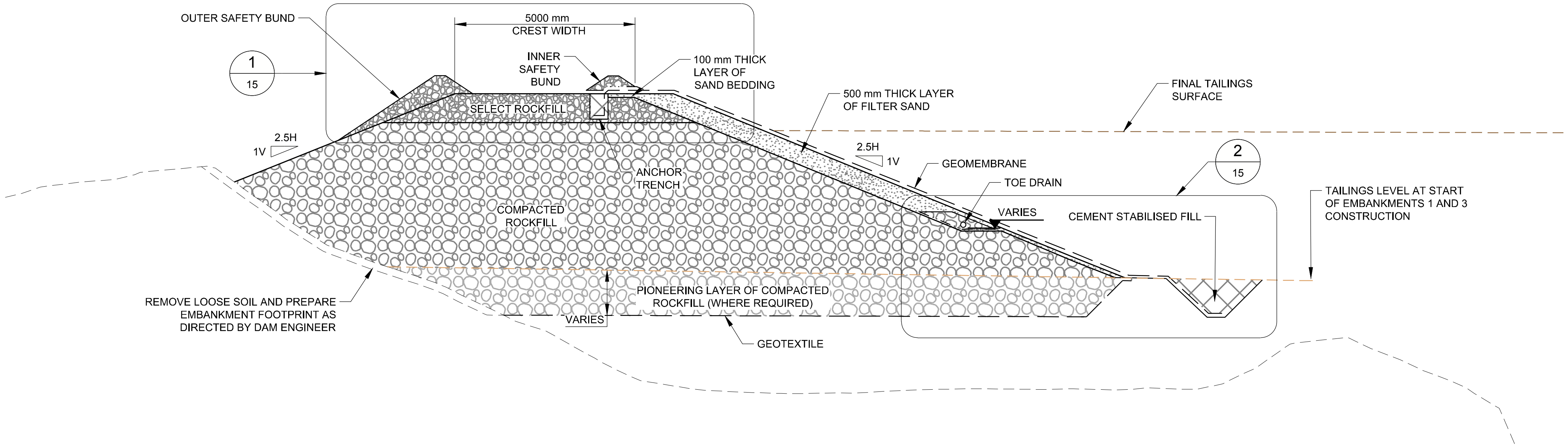
PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
EMBANKMENTS 2 AND 3 SECTIONS

PROJECT NO.	CONTROL	REV.		DRAWING
1654895	009-R	0	12 of 16	12



SCALE 1:150 E 5 TYPICAL EMBANKMENT 1 SECTION



SCALE 1:150 F 7 TYPICAL EMBANKMENT 3 SECTION

NOT FOR CONSTRUCTION - ISSUED FOR

APPROVAL

0 2.5 5

1:150 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

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PROJECT
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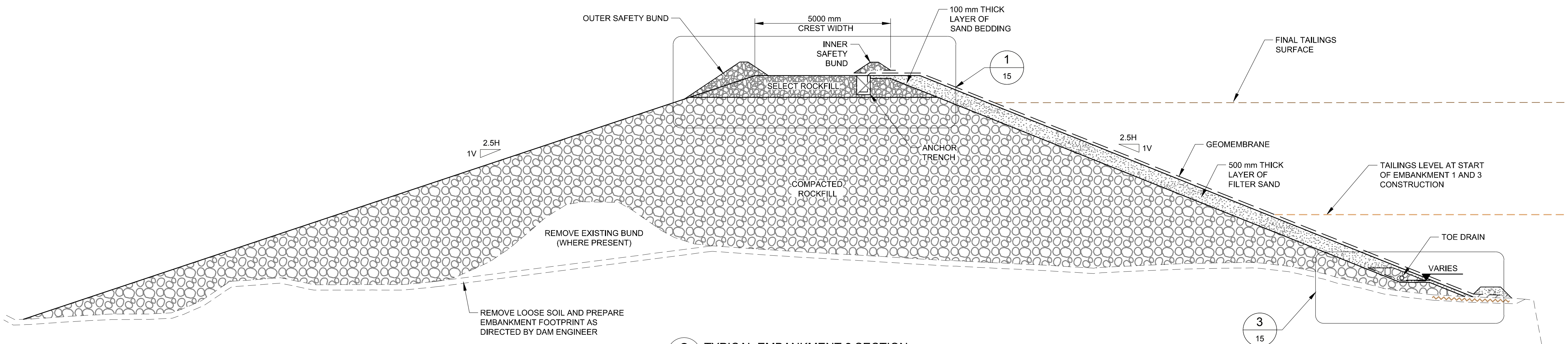
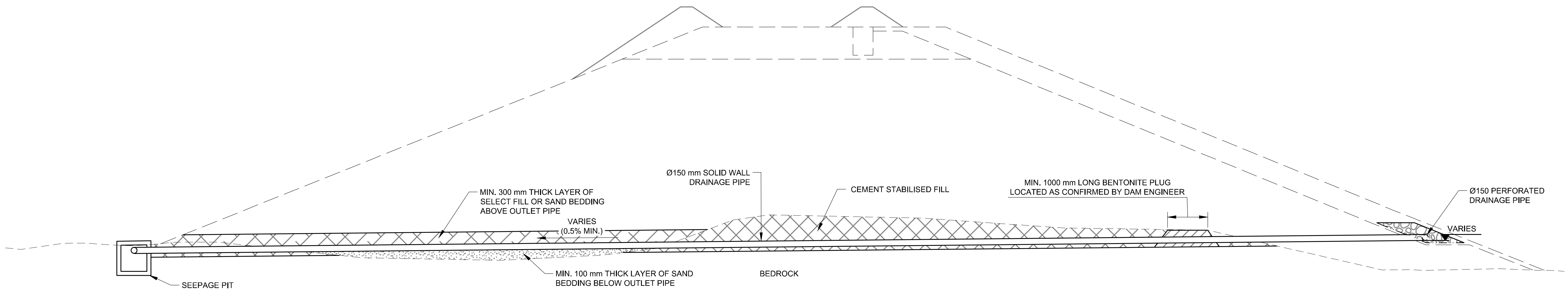
RASP MINE, BROKEN HILL

TITLE
TYPICAL SECTIONS AND DETAILS - SHEET 1

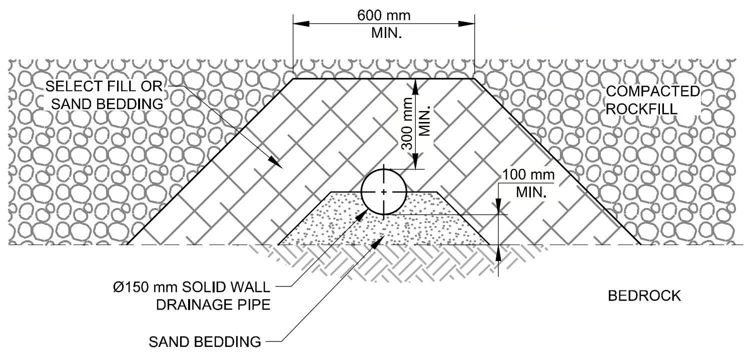
PROJECT NO.	CONTROL	REV.	13 of 16	DRAWING
1654895	009-R	0		13



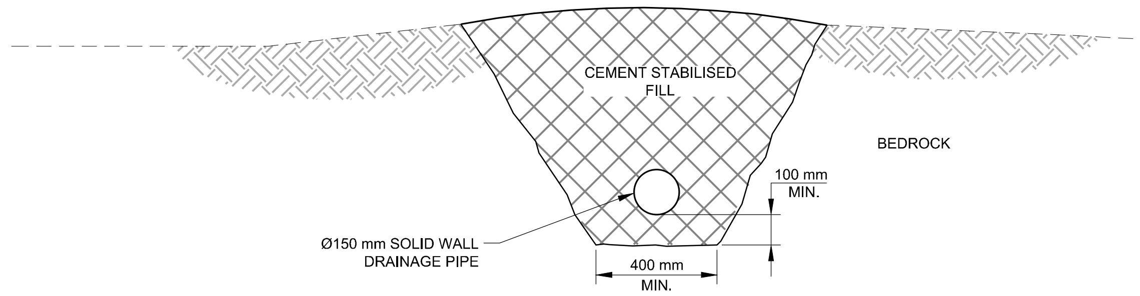
SCALE 1:150 G 6 TYPICAL EMBANKMENT 2 SECTION



TYPICAL TOE DRAIN OUTLET SECTION
SCALE 1:100



TYPICAL TOE DRAIN OUTLET BEDDING DETAIL
SCALE 1:25



TYPICAL TOE DRAIN OUTLET TRENCH DETAIL
SCALE 1:25

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0 0.5 1
1:25 METRES

0 2.5 5
1:100 METRES

0 2.5 5
1:150 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

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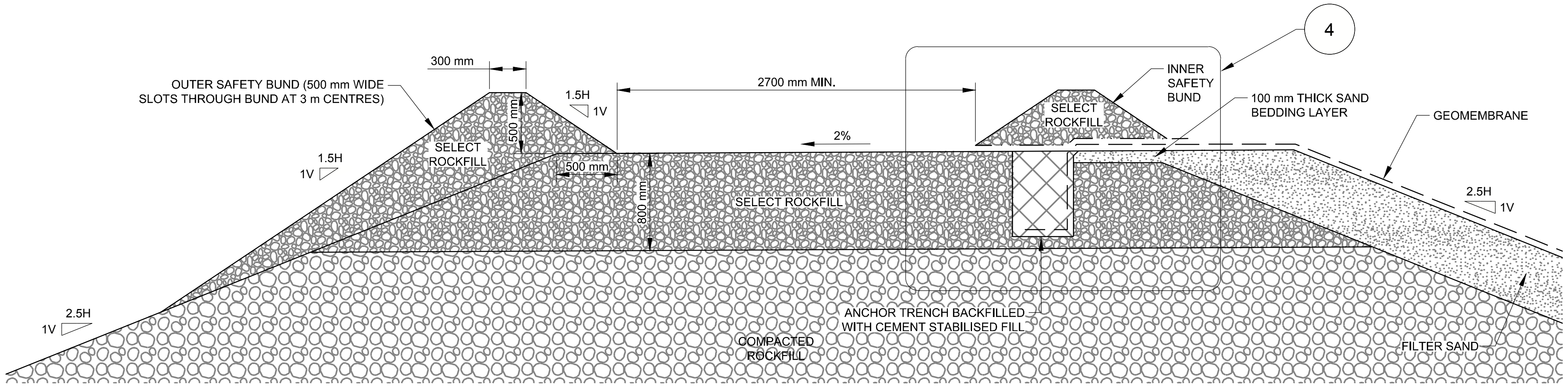
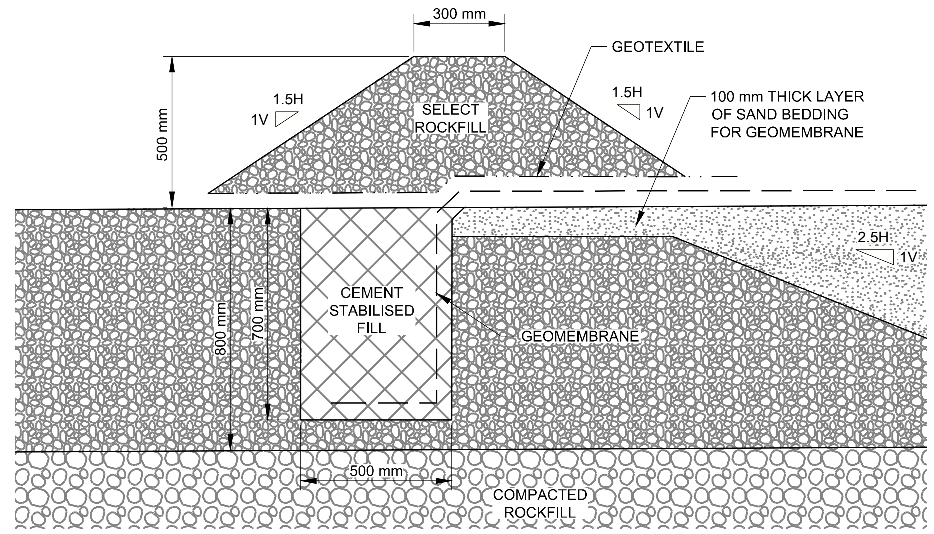
PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
TYPICAL SECTIONS AND DETAILS - SHEET 2

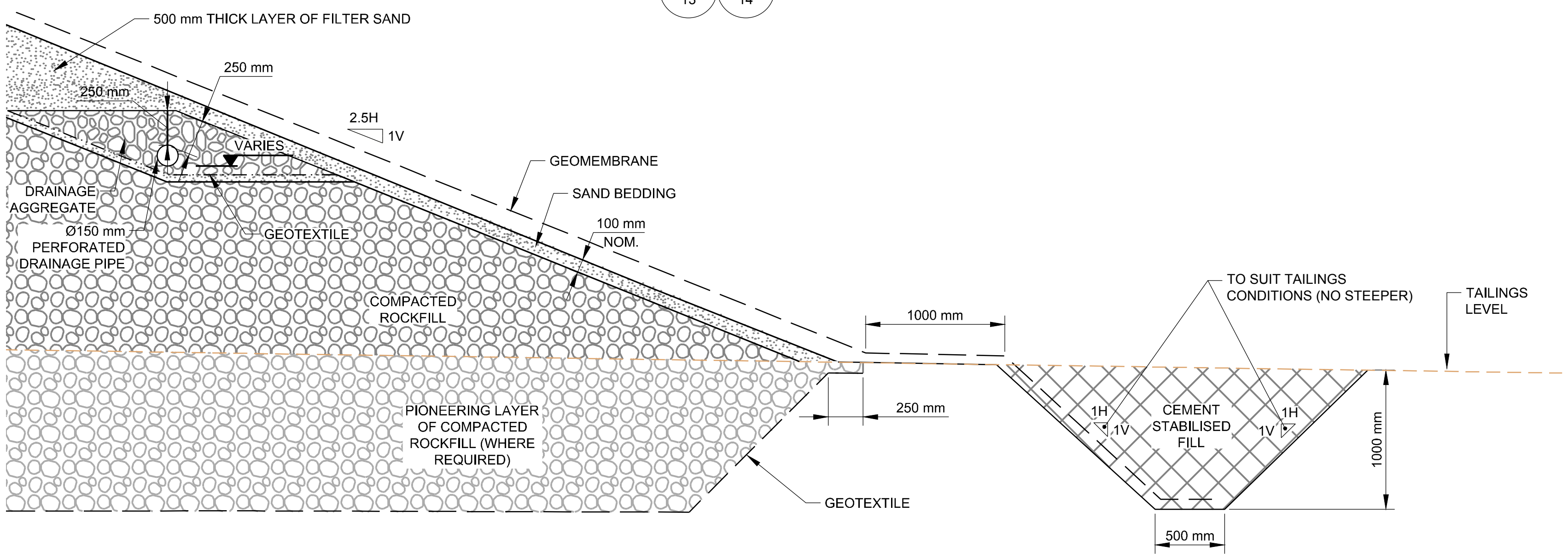
PROJECT NO.	CONTROL	REV.	14 of 16	DRAWING
1654895	009-R	0		14



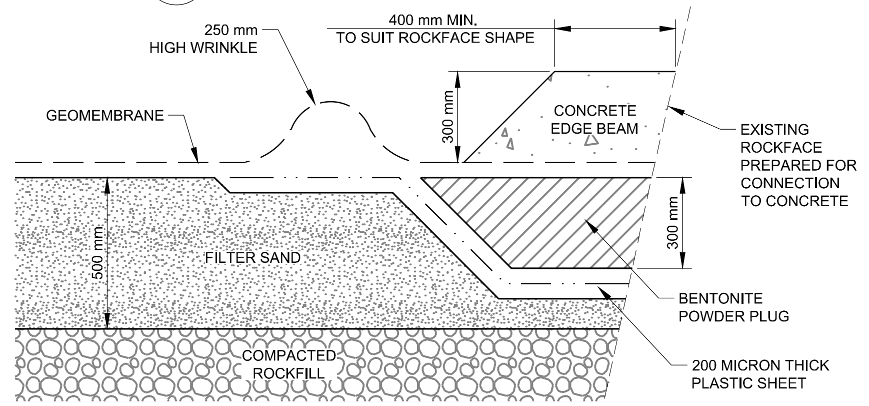
SCALE 1:50 1 TYPICAL CREST OF EMBANKMENT 13 14



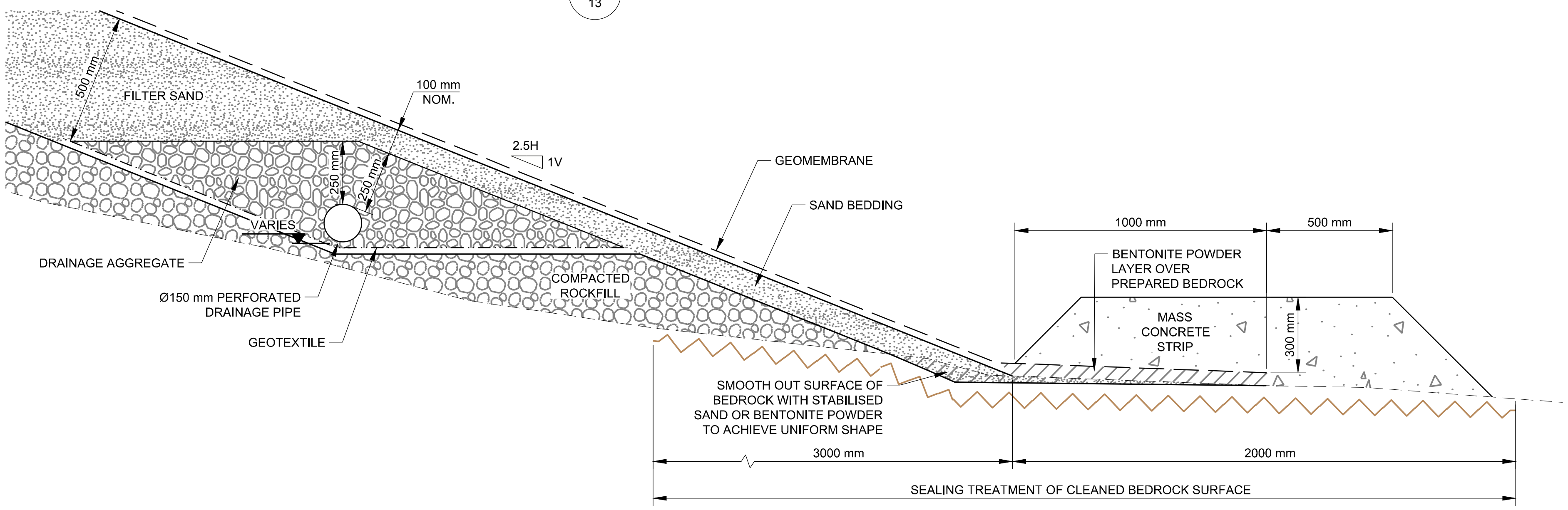
SCALE 1:25 4 TYPICAL EMBANKMENT TRENCH WITH INNER SAFETY BUND



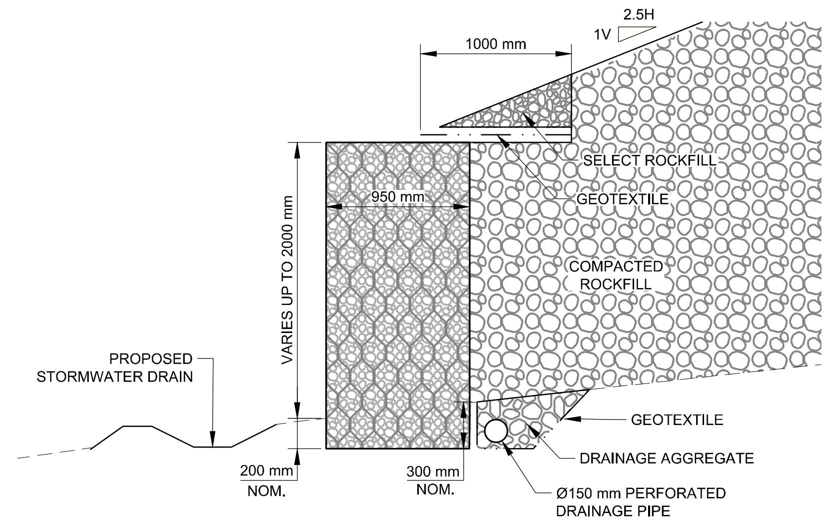
SCALE 1:50 2 TYPICAL TOE SEAL ON TAILINGS SURFACE 13



TYPICAL EMBANKMENT END ANCHOR TRENCH AT ROCKFACE
SCALE 1:25



SCALE 1:25 3 TYPICAL TOE SEAL ON BEDROCK 14



SCALE 1:50 5 TYPICAL GABION WALL 9

0 0.5 1
1:25 METRES

0 1 2
1:50 METRES

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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

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PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

CONSULTANT
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TITLE
TYPICAL SECTIONS AND DETAILS - SHEET 3

PROJECT NO.	CONTROL	REV.	15 of 16	DRAWING
1654895	009-R	0		15

LEGEND

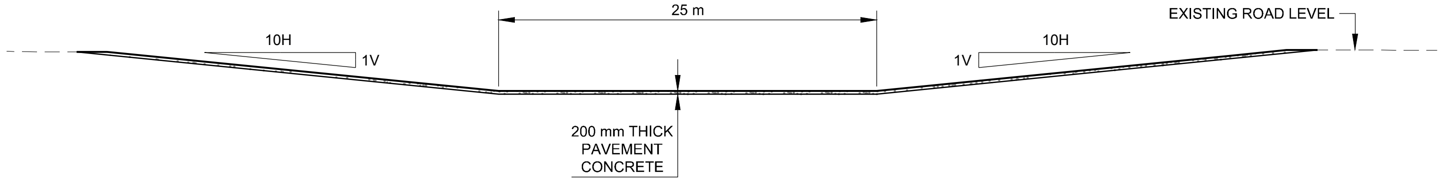
EXISTING CONTOURS AT 1 m INTERVALS

ANTICPATED FINAL TAILINGS LEVEL CONTOURS AT 1 m INTERVALS

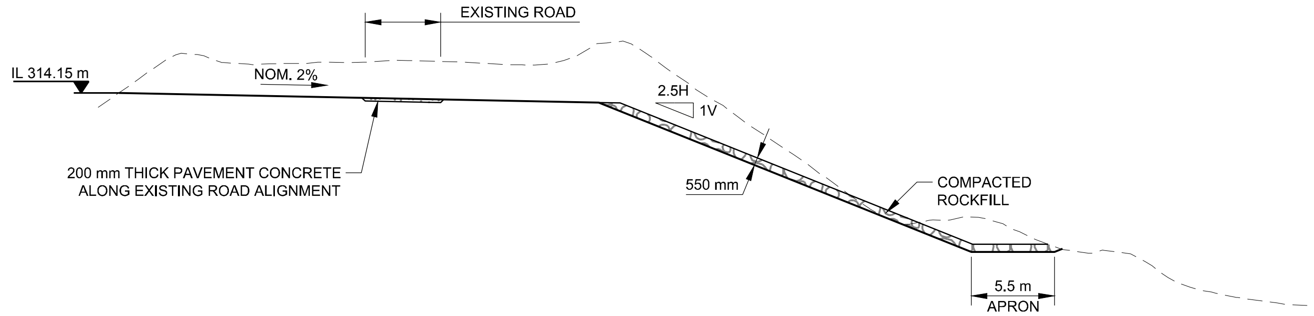
NOTE(S)

1. REFER TO DRAWING 1 - COVER SHEET FOR GENERAL NOTES AND REFERENCES.
2. TYPICAL BATTER SLOPES AT SPILLWAY CREST TO BE NO STEEPER THAN 3H:1V. 10H:1V BATTER APPLIES TO REINSTATEMENT OF EXISTING ROAD ALIGNMENT THROUGH THE PROPOSED SPILLWAY ONLY.

SPILLWAY LAYOUT PLAN
SCALE 1:500



SCALE 1:500 H CROSS SECTION THROUGH CREST OF SPILLWAY



SCALE 1:500 J SPILLWAY LONG SECTION

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APPROVAL

0 10 20
1:500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-03-15	ISSUED FOR APPROVAL	FWG	PDM	GRP	FWG

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PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

TITLE
SPILLWAY LAYOUT AND SECTIONS

PROJECT NO.	CONTROL	REV.	16 of 16	DRAWING
1654895	009-R	0		16

Path: \\golder.gds\gap\melbourne\geomatics\CBH\Rasp Mine\99_PROJECTS\1654895_Rasp Blackwood Pit Ext\009 - R (formerly 007)\02_PRODUCTION\DWG\ | File Name: 1654895-009-R-016.dwg

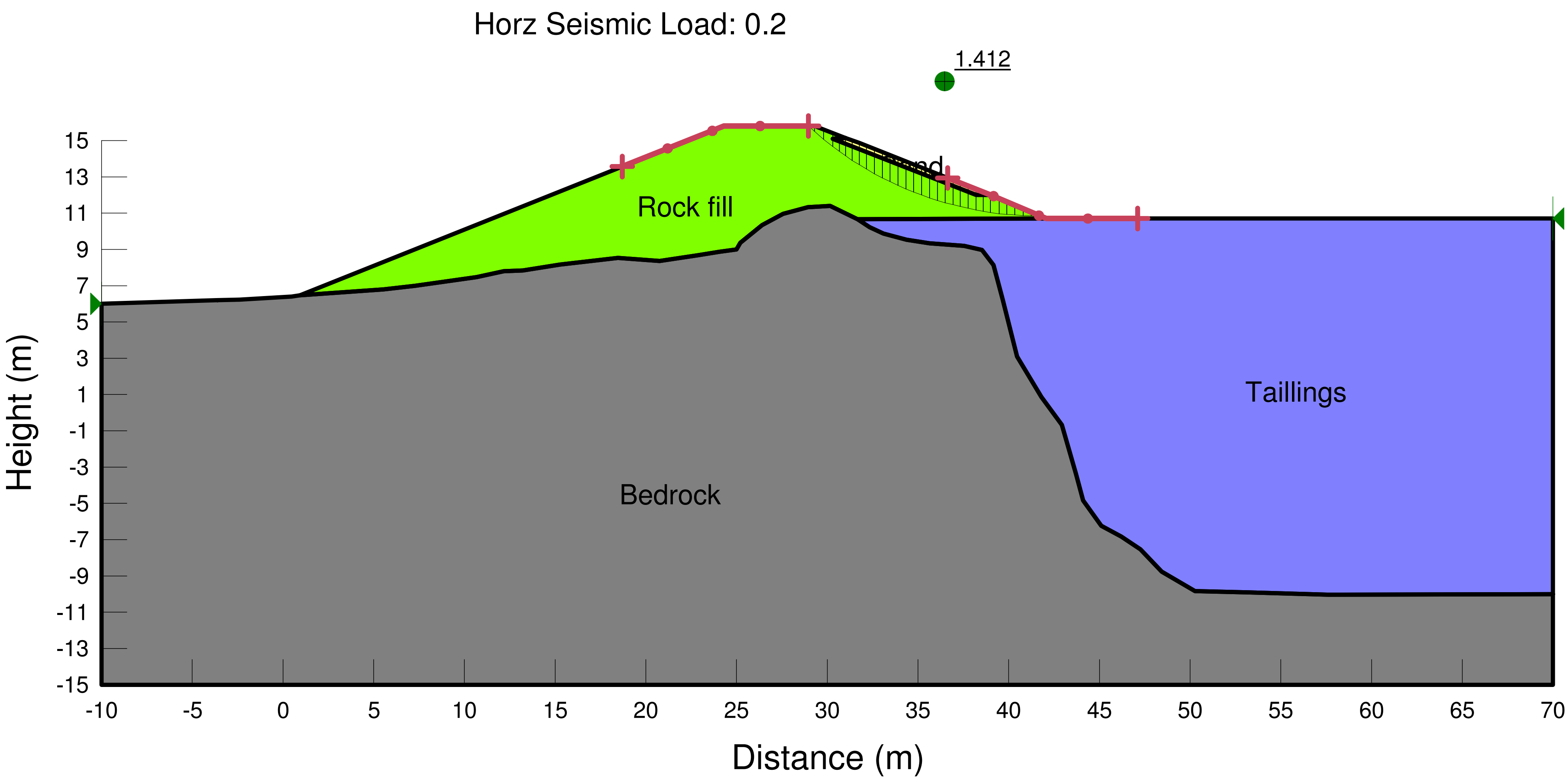
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

25 mm

0

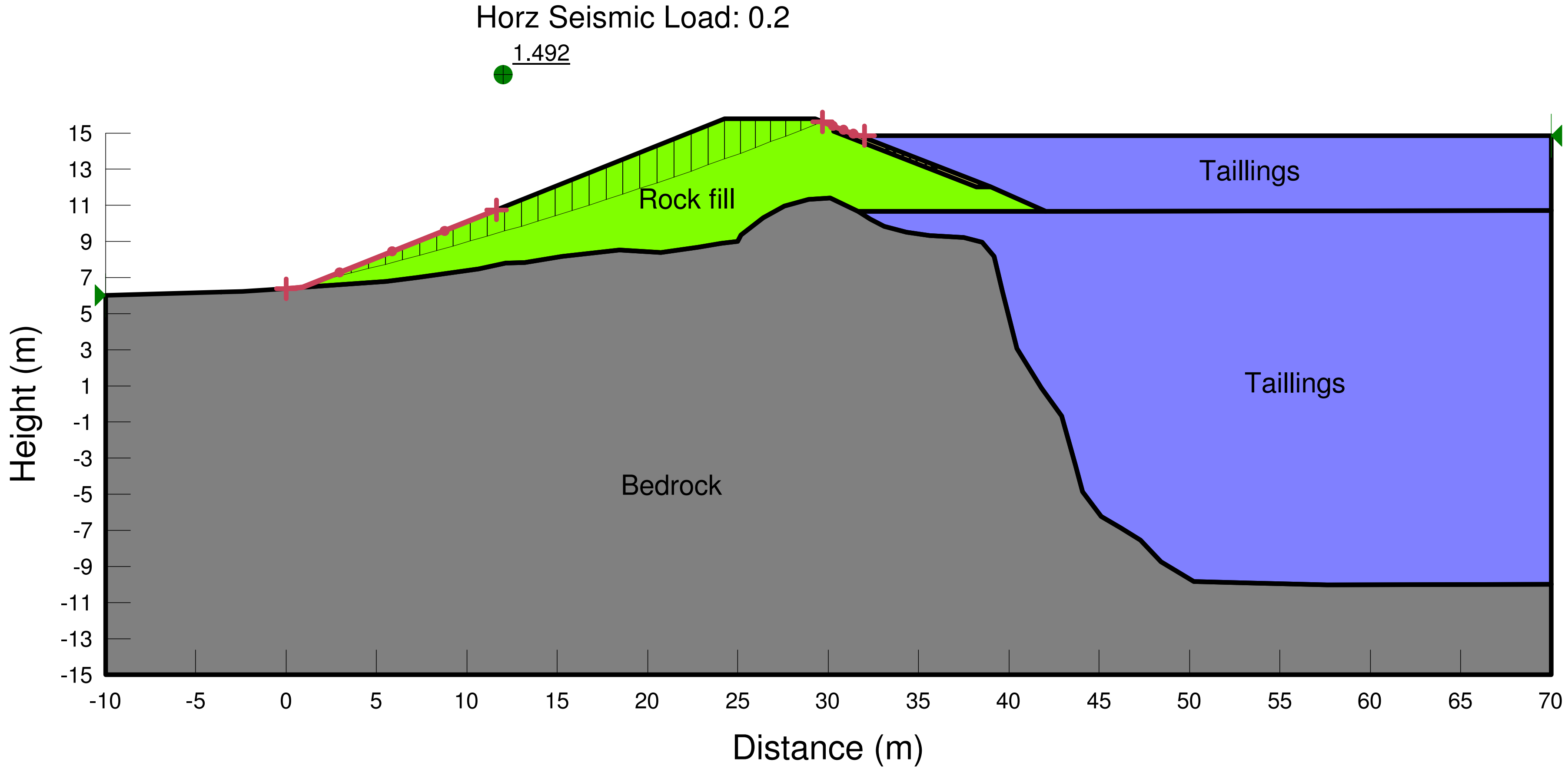
File Name: Emb_1 Section A US.gsz
Name: Slope Stability MDE Earthquake
Method: Morgenstern-Price

Name: Rock fill   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 40 °
Name: Sand   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 32 °
Name: Taillings   Model: S=f(depth)   Unit Weight: 16 kN/m³   C-Top of Layer: 35 kPa   C-Rate of Change: 0.3 kPa/m
Name: Bedrock   Model: Bedrock (Impenetrable)



File Name: Emb_1 Section A.gsz
Name: Slope Stability MDE Earthquake
Method: Morgenstern-Price

Name: Rock fill   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 40 °
Name: Sand   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 32 °
Name: Taillings   Model: S=f(depth)   Unit Weight: 16 kN/m³   C-Top of Layer: 35 kPa   C-Rate of Change: 0.3 kPa/m
Name: Bedrock   Model: Bedrock (Impenetrable)



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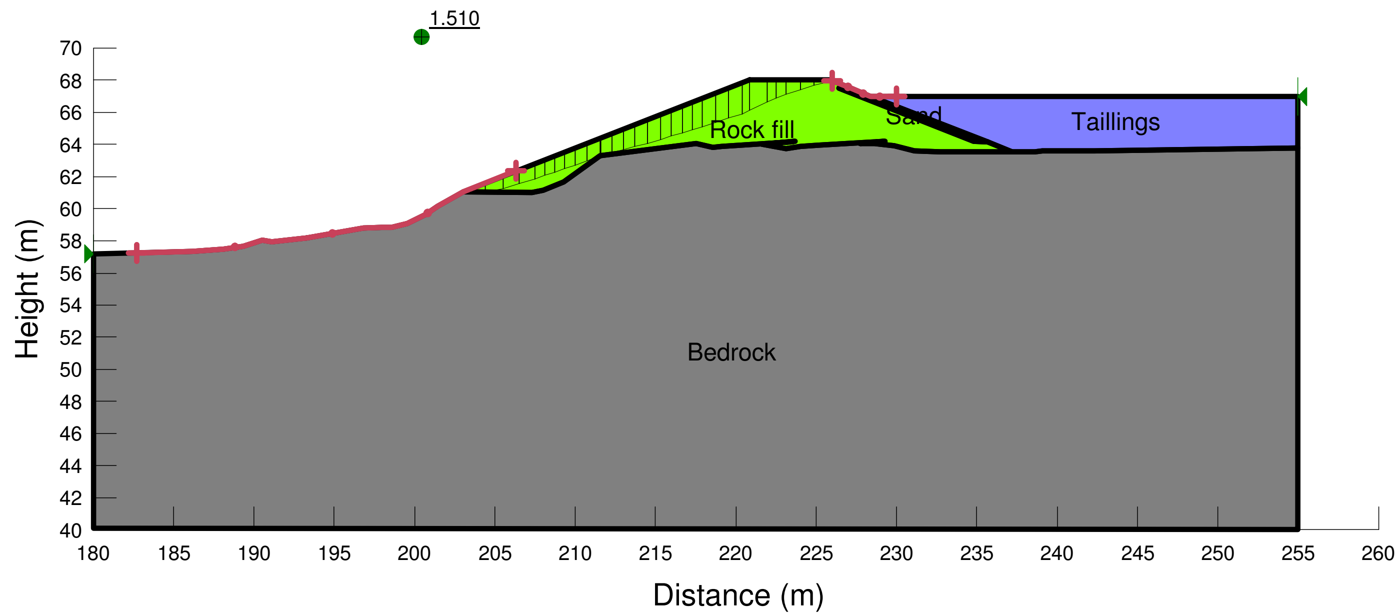
Name: Slope Stability MDE Earthquake
Method: Morgenstern-Price

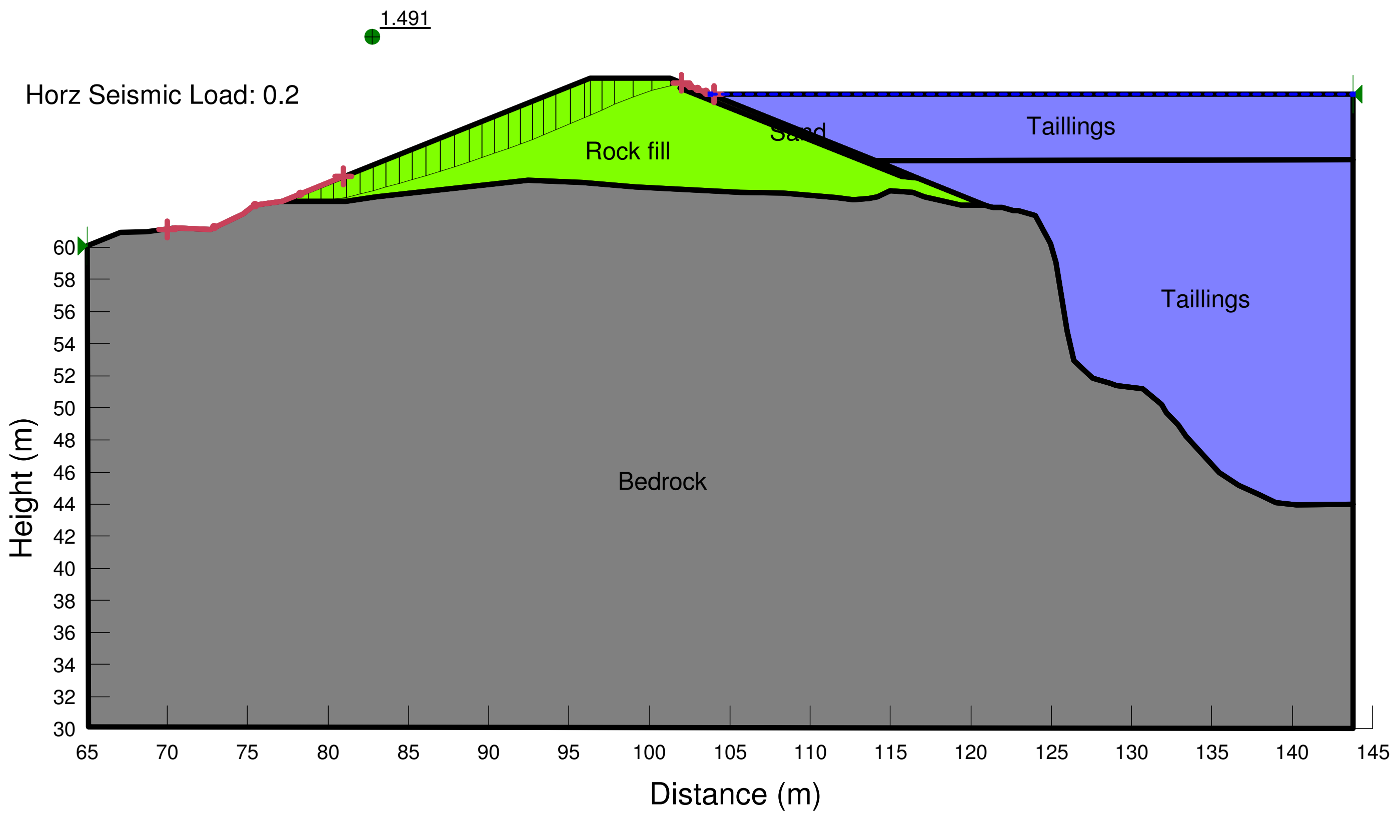
Name: Rock fill   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 40 °
Name: Sand   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 32 °
Name: Taillings   Model: S=f(depth)   Unit Weight: 16 kN/m³   C-Top of Layer: 5 kPa   C-Rate of Change: 0.3 kPa/m
Name: Bedrock   Model: Bedrock (Impenetrable)

Horz Seismic Load: 0.2



File Name: Emb_2 Section C DS.gsz
Name: Slope Stability MDE Earthquake
Method: Morgenstern-Price

Name: Rock fill Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 40 °
Name: Sand Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Taillings Model: S=f(depth) Unit Weight: 16 kN/m³ C-Top of Layer: 5 kPa C-Rate of Change: 0.3 kPa/m
Name: Bedrock Model: Bedrock (Impenetrable)



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Name: Slope Stability MDE Earthquake
Method: Morgenstern-Price

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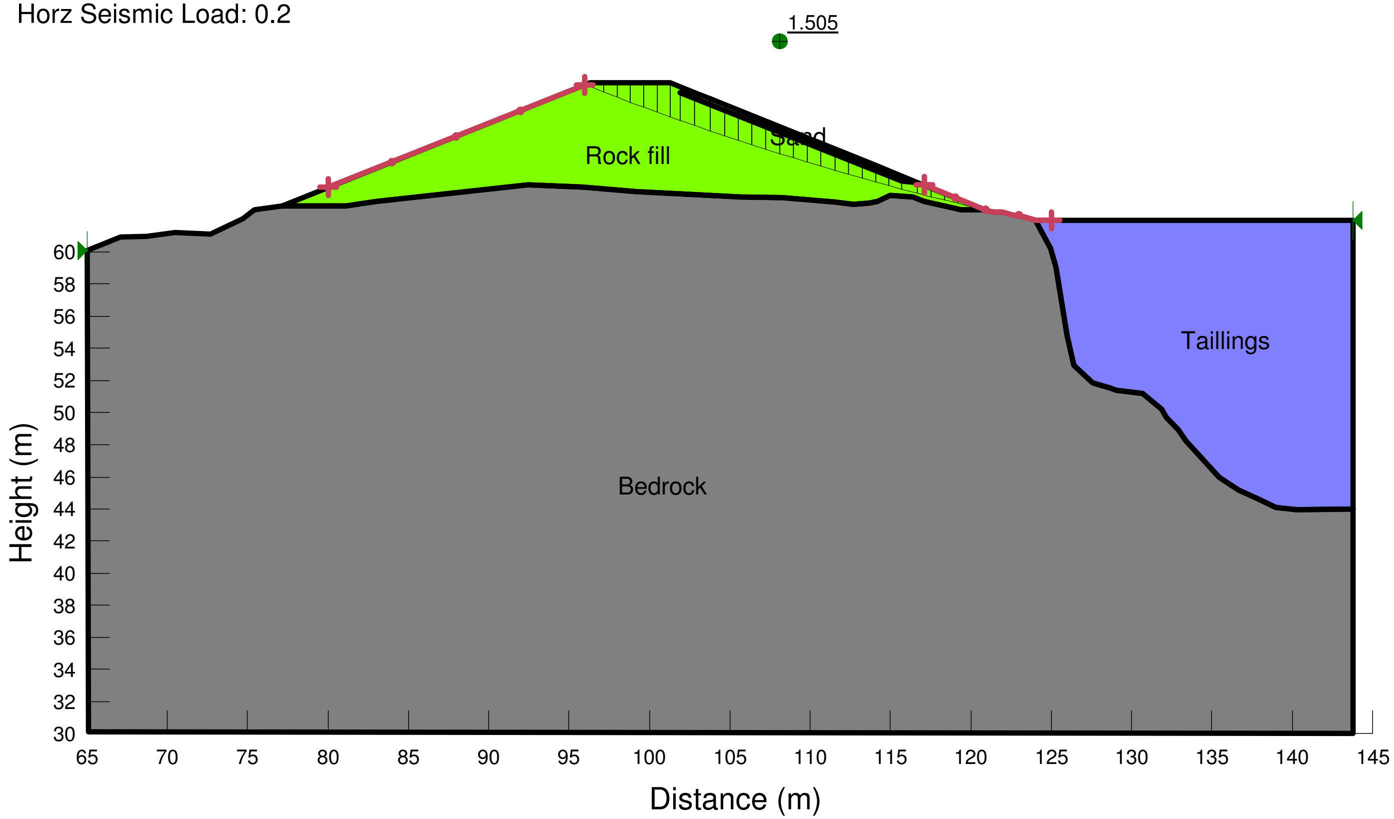
Name: Sand   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 32 °
Name: Taillings   Model: S=f(depth)   Unit Weight: 16 kN/m³   C-Top of Layer: 5 kPa   C-Rate of Change: 0.3 kPa/m
Name: Bedrock   Model: Bedrock (Impenetrable)

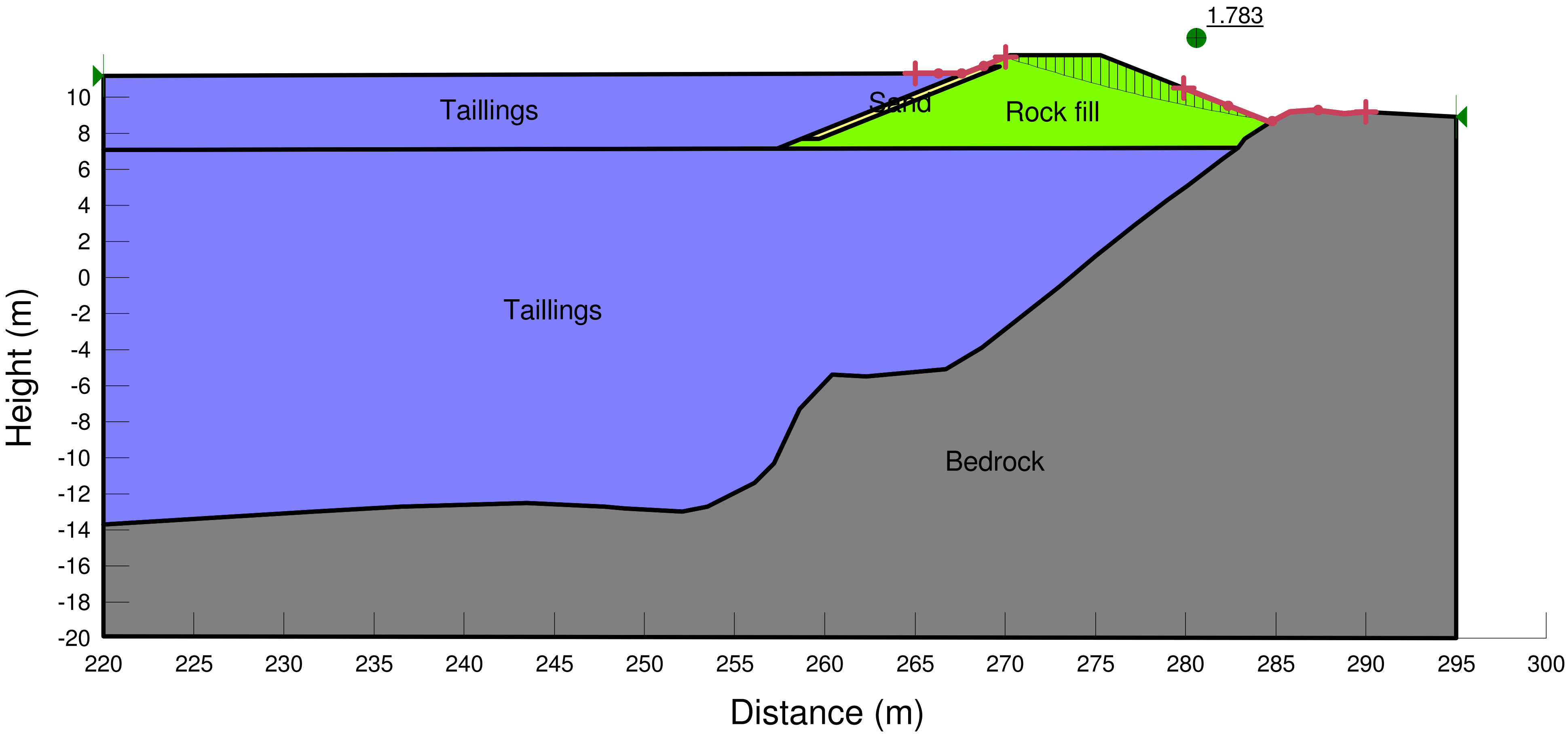
Horz Seismic Load: 0.2



File Name: Emb_3 Section E DS.gsz
Name: Slope Stability MDE Earthquake
Method: Morgenstern-Price

Name: Rock fill Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 40 °
Name: Sand Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Taillings Model: S=f(depth) Unit Weight: 16 kN/m³ C-Top of Layer: 35 kPa C-Rate of Change: 0.3 kPa/m
Name: Bedrock Model: Bedrock (Impenetrable)

Horz Seismic Load: 0.2

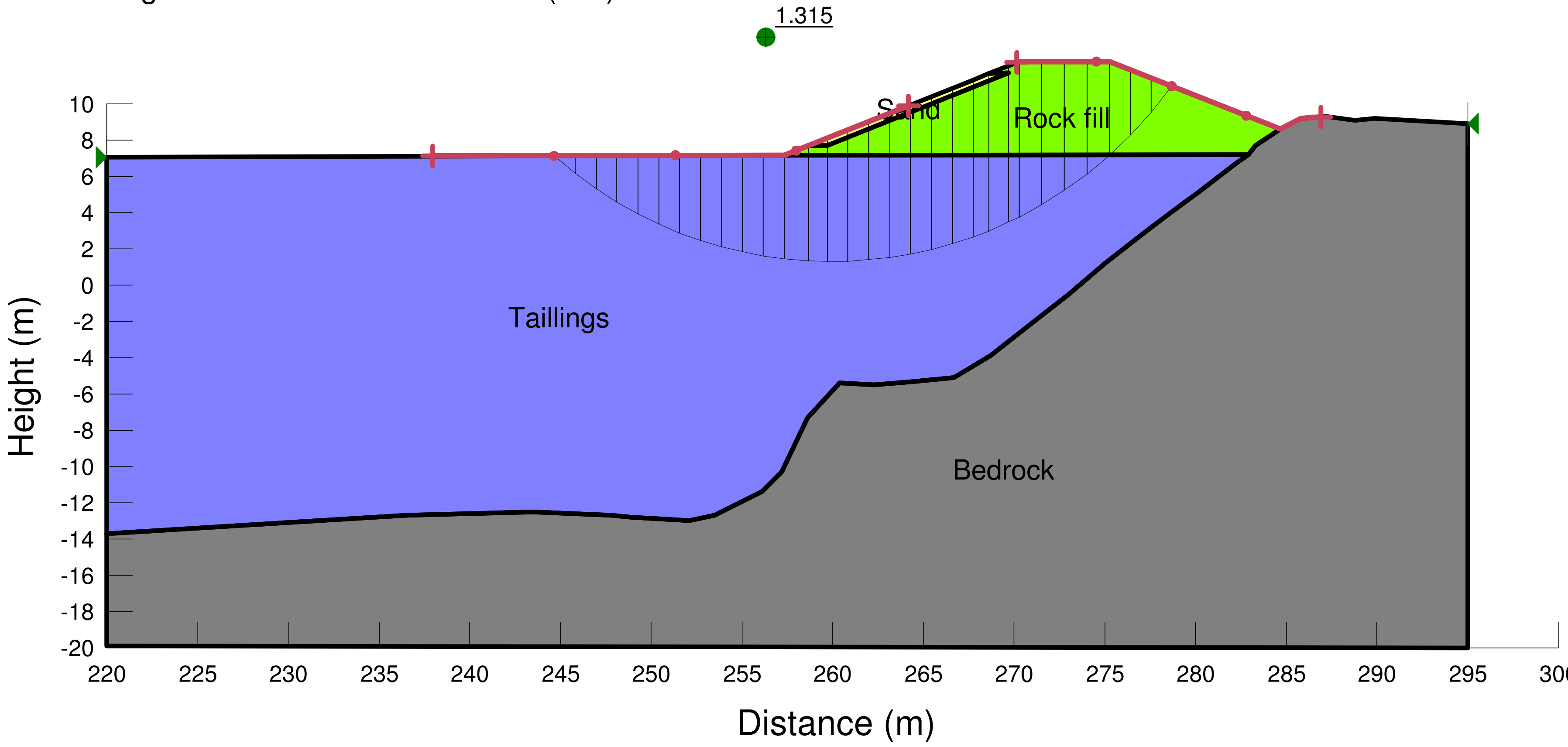


File Name: Emb_3 Section E US MDE_Const_phase 1.gsz
Name: MDE
Method: Morgenstern-Price

Name: Rock fill Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 40 °
Name: Sand Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Taillings Model: Shear/Normal Fn. Unit Weight: 16 kN/m³ Strength Function: Tailling shear force fuction
Name: Bedrock Model: Bedrock (Impenetrable)

Horz Seismic Load: 0.2

Tailing shear force function: 35kPa (min) +0.3*Normal Stress

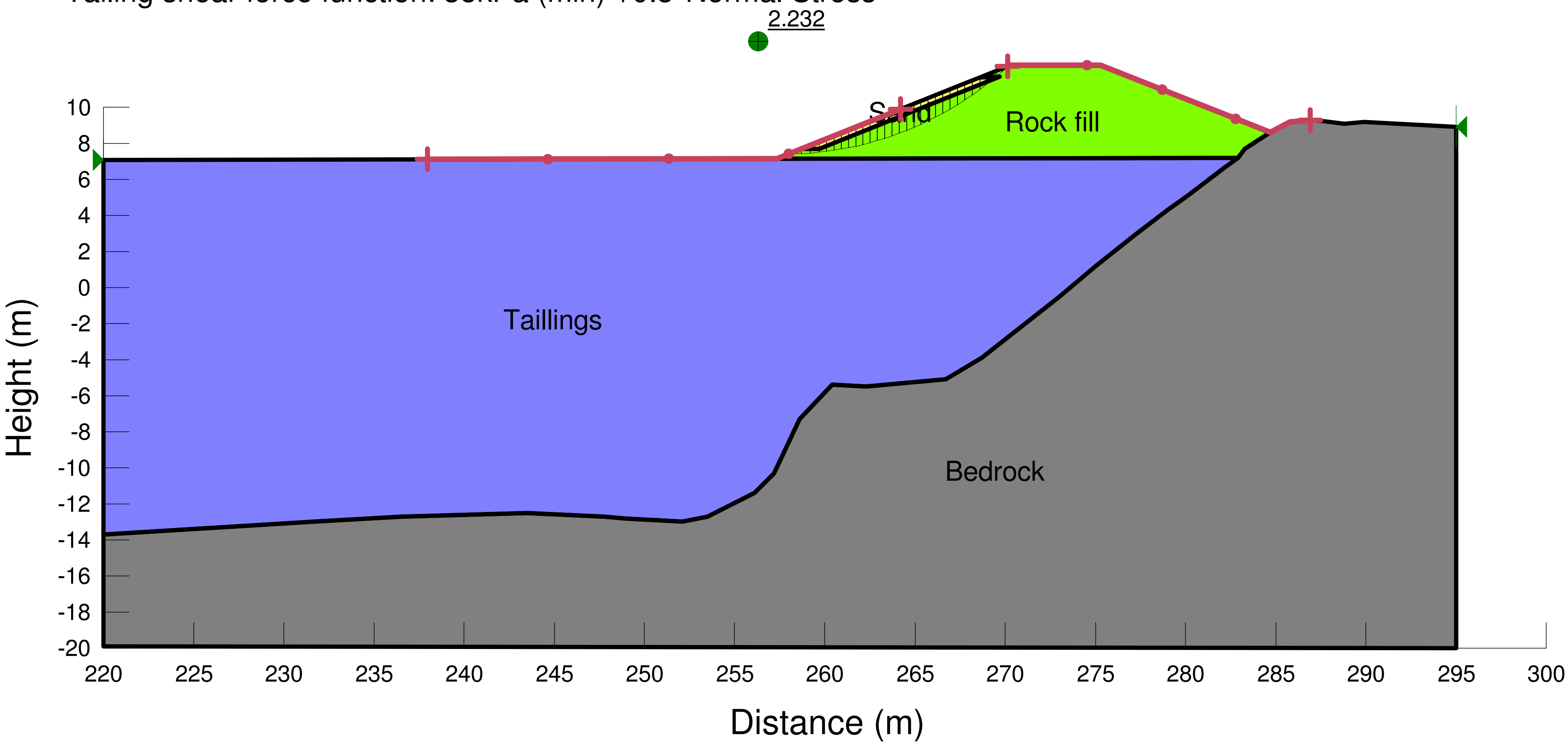


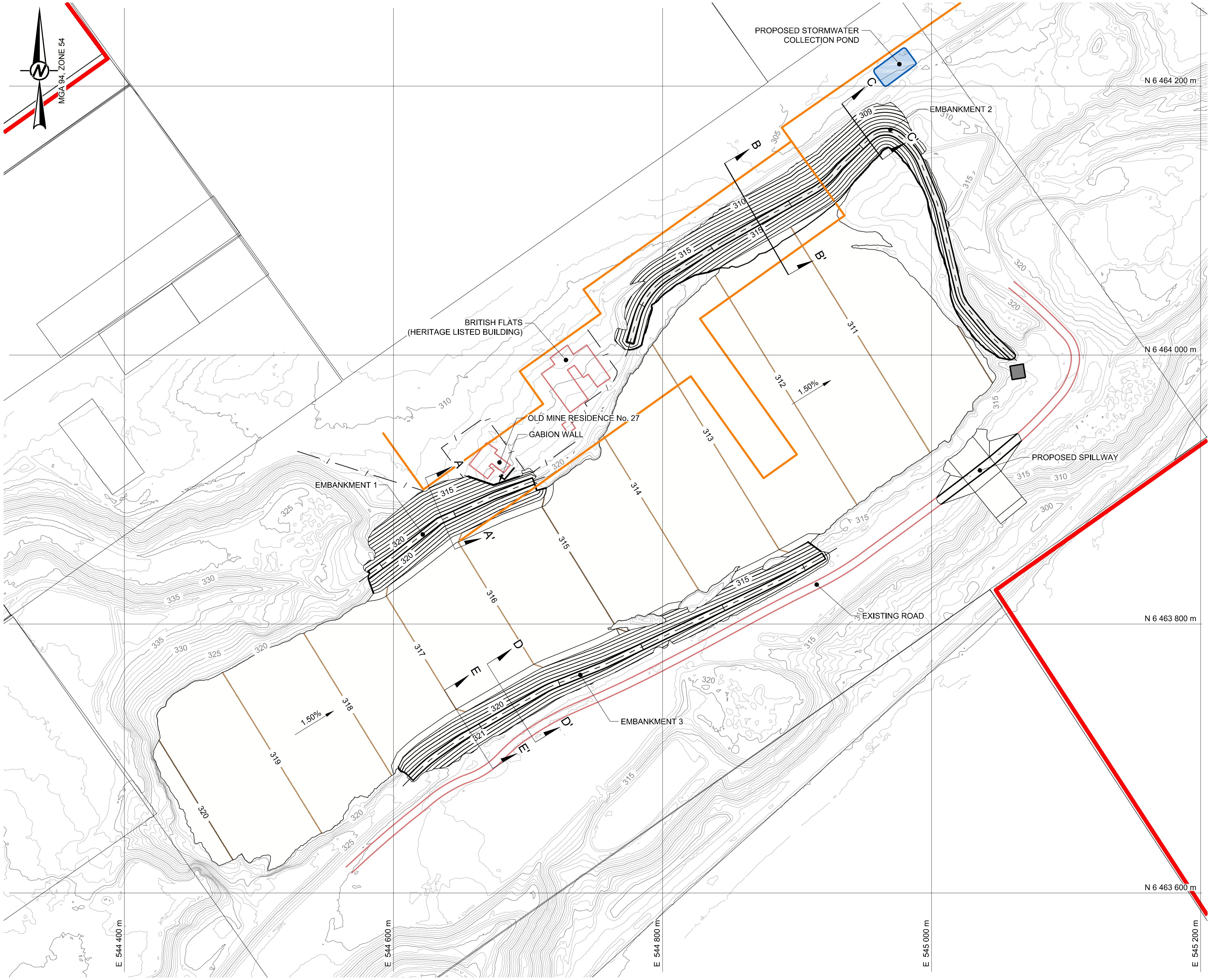
File Name: Emb_3 Section E US Const_phase 1.gsz
Name: MDE
Method: Morgenstern-Price

Name: Rock fill Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 40 °
Name: Sand Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Taillings Model: Shear/Normal Fn. Unit Weight: 16 kN/m³ Strength Function: Tailling shear force fuction
Name: Bedrock Model: Bedrock (Impenetrable)

Horz Seismic Load: 0

Tailing shear force function: 35kPa (min) +0.3*Normal Stress





LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- ANTICIPATED INTERMEDIATE TAILINGS CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY

NOTE(S)

1. REFER TO SECTION 7.2.6 FOR TABLE 5: STABILITY SCENARIOS.
2. LEVELS SHOWN ARE REFERENCED IN METRES TO AUSTRALIAN HEIGHT GRID (m AHD).

REFERENCE(S)

EXISTING SURVEY SHOWN FROM FILES: 160425 Tailings Dam 1m Contours.dxf AND 160425 RASP Tailings Dam Area.dxf (1 m CONTOURS), RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

SITE BOUNDARIES SHOWN FROM FILES: mga_cml7_lease_bdy.dwg, surf_leases_mga.dxf, RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

CML SURFACE EXCLUSION BOUNDARY SHOWN FROM FILES: GFH_D2319.DXF AND GFH_M25352.dxf, RECEIVED FROM CBH RESOURCES ON 22 AUGUST 2016

NOT FOR CONSTRUCTION

0 50 100
1:3,000 METRES

CLIENT
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PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-11-14
DESIGNED	GRP
PREPARED	PDM
REVIEWED	DAA
APPROVED	DAA

TITLE
EMBANKMENTSLOPE STABILITY ASSESSMENT CROSS SECTIONS

PROJECT NO.	CONTROL	REV.	FIGURE
1654895	009-R	0	1

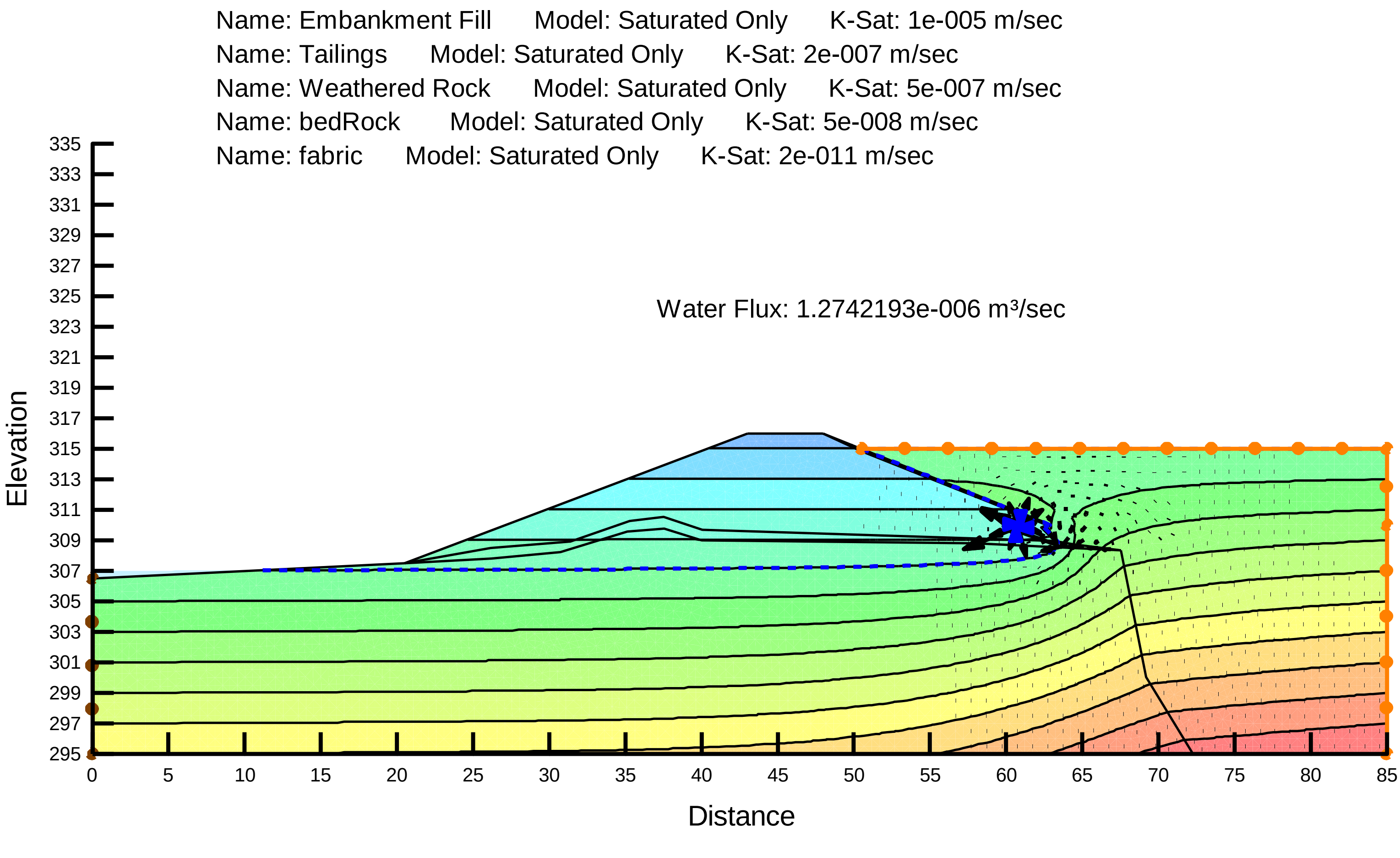
25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

Path: \\golder.gds\gap\Melbourne\Geomatics\CBH\Rasp Mine\99_PROJECTS\1654895_Rasp Blackwood Pit Ext\009 - R (formerly 007)\02_PRODUCTION\DWG\ | File Name: 1654895-009-R-001A.dwg | Last Edited By: pmckeown Date: 2016-11-14 Time:1:44:56 PM | Printed By: DTremelling Date: 2016-11-15 Time:2:17:38 PM

APPENDIX C

Seepage Analysis

File Name: seepage_embank2.gsz



APPENDIX D

Consolidation Results

CONSOLIDATION SUMMARY - ROWE CELL

SAMPLE IDENTIFICATION

Project Number	11-1415-0011	Sample	1

TEST CONDITIONS

Test Type	Rowe Cell
Cell	LFR
Date Started	8/04/2011
Date Completed	9/02/2011

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL (AFTER DRAINAGE)

Sample Height, cm	4.33	Unit Weight, kN/m^3	18.97
Sample Diameter, cm	15.13	Dry Unit Weight, kN/m^3	14.64
Area, cm^2	179.67	Specific Gravity, measured	2.92
Volume, cm^3	777.08	Solids Height, cm	2.211
Water Content, %	29.63	Volume of Solids, cm^3	397.23
Wet Mass, g	1503.54	Volume of Voids, cm^3	379.86
Dry Mass, g	1159.90		

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	4.325	0.956	4.325				
5.00	3.601	0.629	3.963	51	6.53E-02	3.35E-02	2.14E-04
10.00	3.560	0.610	3.581	408	6.66E-03	1.90E-03	1.24E-06
25.00	3.525	0.594	3.543	401	6.63E-03	5.39E-04	3.51E-07
50.00	3.491	0.579	3.508	445	5.86E-03	3.14E-04	1.81E-07
100.00	3.454	0.562	3.473	219	1.17E-02	1.71E-04	1.96E-07
200.00	3.410	0.542	3.432	60	4.16E-02	1.02E-04	4.15E-07
400.00	3.354	0.517	3.382	254	9.55E-03	6.47E-05	6.06E-08
800.00	3.298	0.492	3.326	144	1.63E-02	3.24E-05	5.17E-08
400.00	3.309	0.497	3.304				

Notes:

- Sample placed in cell and allowed to drain until consistency was sufficient for test to be performed
  All calculations based on height after drainage
- Initial sample height = 6.115 cm; initial weight = 1798.54g; volume of water drained = 295cc
- k calculated using cv based on t_{90} values

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	3.31	Unit Weight, kN/m^3	21.79
Sample Diameter, cm	15.13	Dry Unit Weight, kN/m^3	19.13
Area, cm^2	179.67	Specific Gravity, measured	2.92
Volume, cm^3	594.53	Solids Height, cm	2.211
Water Content, %	13.89	Volume of Solids, cm^3	397.23
Wet Mass, g	1320.99	Volume of Voids, cm^3	197.31
Dry Mass, g	1159.90		

CONSOLIDATION SUMMARY - ROWE CELL

SAMPLE IDENTIFICATION

Project Number	11-1415-0011	Sample	2

TEST CONDITIONS

Test Type	Rowe Cell
Cell	GA
Date Started	8/15/2011
Date Completed	9/03/2011

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL (AFTER DRAINAGE)

Sample Height, cm	3.73	Unit Weight, kN/m^3	19.42
Sample Diameter, cm	15.11	Dry Unit Weight, kN/m^3	15.25
Area, cm^2	179.32	Specific Gravity, measured	2.96
Volume, cm^3	669.30	Solids Height, cm	1.961
Water Content, %	27.36	Volume of Solids, cm^3	351.66
Wet Mass, g	1325.67	Volume of Voids, cm^3	317.64
Dry Mass, g	1040.90		

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	3.733	0.903	3.733				
5.00	3.601	0.836	3.667	834	3.42E-03	7.04E-03	2.36E-06
25.00	3.548	0.809	3.574	254	1.07E-02	7.18E-04	7.50E-07
50.00	3.499	0.784	3.523	122	2.16E-02	5.26E-04	1.11E-06
100.00	3.461	0.765	3.480	104	2.47E-02	2.01E-04	4.87E-07
200.00	3.414	0.741	3.437	297	8.43E-03	1.27E-04	1.05E-07
400.00	3.363	0.715	3.388	254	9.58E-03	6.82E-05	6.40E-08
800.00	3.303	0.684	3.333	187	1.26E-02	3.98E-05	4.91E-08

Notes:
- Sample placed in cell and allowed to drain until consistency was sufficient for test to be performed
  All calculations based on height after drainage
- Initial sample height = 5.76 cm; initial weight = 1,682.67g; volume of water drained = 357cc
- k calculated using cv based on t_{90} values

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	3.30	Unit Weight, kN/m^3	20.67
Sample Diameter, cm	15.11	Dry Unit Weight, kN/m^3	17.23
Area, cm^2	179.32	Specific Gravity, measured	2.96
Volume, cm^3	592.33	Solids Height, cm	1.961
Water Content, %	19.95	Volume of Solids, cm^3	351.66
Wet Mass, g	1248.56	Volume of Voids, cm^3	240.68
Dry Mass, g	1040.90		

APPENDIX E

Spillway Design Details

Rock Lining for Open Channels

Method: FHWA. 2005. HEC No. 15, Third Edition. Design of Roadside Channels with Flexible Linings.

Input

Q, discharge, m3/s	11.50
S_0, average channel gradient, m/m	0.40
Z, channel side slope, ZH:1V	3
B, bottom width, m	25.0
φ, angle of repose, degrees	42.0
γ_s, specfic weight stone, N/m3	26000
γ, specific weight of water, N/m3	9810
SG, specific gravity of stone	2.65
v, kinematic viscosity, m^2/s	1.13E-06
α, angle of channel bottom, radians	0.381
θ, angle of side slope, radians	0.322
φ, angle of repose, radians	0.733
n, Manning's roughness (iterative solution, match n below)	0.061
D_{50}, median rock size (iterate solution, match D50 below), m	0.37

Depth Calculation

d, depth of flow (calculated using Manning's Eq.), m	0.154
A, cross-section area of flow (based on above geometry and depth), m2	3.92
V, Velocity, V=Q/A, m/s	2.94
T, Top Width (based on above geometry and depth), m	25.92

Manning's n Calcultion

n, Manning's roughness (calc'd based on *Design of Rock Chutes* , n = 0.0292 $(D_{50,mm} \times S_o)^{0.147}$	0.061

Solution for D_{50}

eq. 6.8 $D_{50} \geq \frac{SF\, d\, S_o}{F_*(SG-1)}$ — D_{50}, m: 0.37

eq. 6.9 $R_e = \frac{V.D_{50}}{\nu}$ — Reynolds number, Re: 2.52E+05

Table 6.1 values		
Re	*F**	*SF*
4.00E+04	0.047	1
2.00E+05	0.15	1.5

shields factor (see Table 6.1), F*	0.150
safety factor (see Table 6.1), SF	1.50

eq. 3.1 $\tau_d = \gamma d S_o$ — T_d, shear stress in channel, N/m2: 603.62

eq. 3.2 $\tau_s = K_1 \tau_d$ — T_s, shear stress on sides, N/m2: 523.94

eq. 3.4
$$K_1 = 0.77 \quad Z \leq 1.5$$
$$K_1 = 0.066Z + 0.67 \quad 1.5 < Z < 5$$
$$K_1 = 1.0 \quad 5 \leq Z$$
K_1, shear ratio: 0.868

D_{50} on sideslope (only increased when gradient is less than 5%)

eq. 6.15 $D_{50,s} = \frac{K_1}{K_2} D_{50,b}$ — D_{50} on sideslopes (only for gradients < 5%), m: 0.37

eq. 6.16 $K_2 = \sqrt{1-\left(\frac{\sin\theta}{\sin\phi}\right)^2}$ — K_2, tractive force ratio: 0.881

Rock Lining for Open Channels

Method: FHWA. 2005. HEC No. 15, Third Edition. Design of Roadside Channels with Flexible Linings.

Rock Gradation

D_{50}, based side slope if gradient < 5%, m	**0.37**
D_{100}, (D_{100} = 1.5* D_{50}), m	**0.55**
D_{15}, (D_{15} = 0.6 * D_{50}), m	**0.22**
Liner thickness (same as D_{100}), m	**0.55**

Apron length at toe of spillway

min. length of apron, 15*D50, m	**5.51**

WAVE RUNUP AND WIND SETUP

This calculation document follows the methodology outlined in Chapter 6: Freeboard in Design Standards No. 13 (2012), published by the U.S. Department of the Interior Bureau of Reclamation. Wind speed gust factors calculated as outlined in Guidelines for converting between various wind averaging periods in tropical cyclone conditions (2008), published by the World Meteorological Organisation.

Author:	MP	**Date:**	29/09/2016
Review:	RDM	**Date:**	30/09/2016
File name:	RockLining_FHWA15_new_n_calc_r3.xlsx		
Sheet:	1	**Status:**	For Use

1.0 General Details

- Structure name: Blackwood Pit
- Design ARI (yrs): 10
- Water Level: Maximum
- Water Level (m RL): 315.00
- F_E, Effective Fetch Length (km): 0.70
- F_E, Effective Fetch Length (miles): 0.43
- Client: CBH Resources
- Project Name: RASP Mine
- Job Number: 1654895
- Embankment Slope (1V:xH): 3.00
- d, Average water depth (m): 1.00
- d, Average water depth (ft): 3.28

2.0 Wind Data

2.1 Site Wind Speed

Wind data obtained from:
Australian Standard 1170.2.2002 Part 2 Table 3.1

ARI (yrs)	3 sec gust (m/s)
1	30
5	32
10	34
20	37
25	37
35	38
50	39
100	41
200	43
500	45
1,000	46
2,000	48
2,500	48
5,000	50

$$V_{sit,\beta} = V_R M_d (M_{z,cat} M_s M_t)$$

- Wind Region: A
- V_R (m/s): 34.00
- Region Factor: 1.00
- M_d: 0.95
- $M_{z,cat}$: 0.99
- M_s: 1.00
- M_t: 1.00
- $V_{sit,\beta}$ (m/s): 33.66
- $V_{sit,\beta}$ (mph): 75.29

121.18

2.2 Critical Wind Speed

- R_L, Ratio of wind speed over water/land: 0.90
- Class: In-Land
- Class Description: *Roughly open terrain*

Duration		Gust Factor	Maximum Wind Speed (mph)	
sec	min		Over-land	Over-water
3	0.05	1.00	75.29	67.76
60	1	1.49	50.53	45.48
120	2	1.55	48.58	43.72
180	3	1.58	47.65	42.89
600	10	1.66	45.36	40.82
3600	60	1.75	43.03	38.72

- Critical Wind Duration (min): 18.16
- Critical Wind Speed (mph) *(based on site)*: 40.48
- Critical Wind Speed (mph) *(based on fetch)*: 40.48
- Site and fetch based speed difference (mph): 0.00
- Adopted Critical Wind Speed (mph): 40.48
- Adopted Critical Wind Speed (m/s): 18.10

3.0 Wave Runup and Wind Setup

3.1 Wind Setup

- F_S, Setup Fetch (km): 0.70
- S, Wind setup (ft): 0.15
- S, Wind setup (m): 0.05
- SWL, Still water level (m RL): 315.05

3.2 Wave Runup

Wave Height

- H_S, Significant wave height (ft): 0.86
- H_S, Significant wave height (m): 0.26
- β, Angle of incidence of fetch (°): 0.00
- R_H, Angle reduction factor: 1.00
- P_V, Probability of Exceedance (%): 2.00
- Highest X% of waves to average (%): 5.00
- Ratio of specific/significant: 1.40
- H, Specific wave height (ft): 1.20
- H, Specific wave height (m): 0.37

Wave Period and Length

- T, Wave period (sec): 1.32
- L, Wave length (ft): 8.92
- L, Wave length (m): 2.72

Wave Classification

- Ratio of depth to wave length, d/L: 0.37
- Wave Classification: Transitional

Wave Runup Reduction (1)

• θ, Angle u/s face with horizontal (°)	18.43
• s_p, Steepness of peak waves	0.13
• ξ_p, Surf similarity factor	0.91
• Slope surface:	1 rock layer, dia. D, (Hs/D=1.5 - 3.0)
• Slope of vertical wave wall (1V:xH)	N/A
• α_{wall}, Slope of vertical wave wall (°)	N/A

Wave Runup Reduction (2)

• B, Berm width (m)	0.00
• Berm level (m RL)	0.00
• Slope below berm level (1V:xH)	0.00
• α_1, Slope below berm level (°)	0.00
• α_{eq}, Equivalent slope (°)	33.69
• α, Average slope (°)	18.43
• d_B, Depth between SWL & berm (m)	315.05

• Reduction Factors:

A	C	γ_r	γ_β	γ_b	γ_h
1.60	0.00	0.55	1.00	1.00	1.00

Wave Runup

• R, Wave Run-up (ft)	0.96
• R, Wave Run-up (m)	0.29

3.3 Wave Runup

• Total Freeboard (ft)	1.11
• Total Freeboard (m)	0.34

WAVE RUNUP AND WIND SETUP

This calculation document follows the methodology outlined in Chapter 6: Freeboard in Design Standards No. 13 (2012), published by the U.S. Department of the Interior Bureau of Reclamation. Wind speed gust factors calculated as outlined in Guidelines for converting between various wind averaging periods in tropical cyclone conditions (2008), published by the World Meteorological Organisation.

Author:	MP	**Date:**	29/09/2016
Review:	RDM	**Date:**	30/09/2016
File name:	RockLining_FHWA15_new_n_calc_r3.xlsx		
Sheet:	2	**Status:**	For Use

1.0 General Details

- Structure name: Blackwood Pit
- Design ARI (yrs): 35
- Water Level: Maximum
- Water Level (m RL): 315.00
- F_E, Effective Fetch Length (km): 0.70
- F_E, Effective Fetch Length (miles): 0.43

- Client: CBH Resources
- Project Name: RASP Mine
- Job Number: 1654895
- Embankment Slope (1V:xH): 3.00
- d, Average water depth (m): 1.00
- d, Average water depth (ft): 3.28

2.0 Wind Data

2.1 Site Wind Speed

Wind data obtained from:
Australian Standard 1170.2.2002 Part 2 Table 3.1

ARI (yrs)	3 sec gust (m/s)
1	30
5	32
10	34
20	37
25	37
35	38
50	39
100	41
200	43
500	45
1,000	46
2,000	48
2,500	48
5,000	50

$$V_{sit,\beta} = V_R M_d (M_{z,cat} M_s M_t)$$

- Wind Region: A
- V_R (m/s): 38.00
- Region Factor: 1.00
- M_d: 0.95
- $M_{z,cat}$: 0.99
- M_s: 1.00
- M_t: 1.00
- $V_{sit,\beta}$ (m/s): 37.62
- $V_{sit,\beta}$ (mph): 84.15

72.862

2.2 Critical Wind Speed

- R_L, Ratio of wind speed over water/land: 0.90
- Class: In-Land
- Class Description: *Roughly open terrain*

Duration		Gust Factor	Maximum Wind Speed (mph)	
sec	min		Over-land	Over-water
3	0.05	1.00	84.15	75.74
60	1	1.49	56.48	50.83
120	2	1.55	54.29	48.86
180	3	1.58	53.26	47.93
600	10	1.66	50.69	45.62
3600	60	1.75	48.09	43.28

- Critical Wind Duration (min): 17.49
- Critical Wind Speed (mph) *(based on site)*: 45.27
- Critical Wind Speed (mph) *(based on fetch)*: 45.27
- Site and fetch based speed difference (mph): 0.00
- Adopted Critical Wind Speed (mph): 45.27
- Adopted Critical Wind Speed (m/s): 20.24

3.0 Wave Runup and Wind Setup

3.1 Wind Setup

- F_S, Setup Fetch (km): 0.70
- S, Wind setup (ft): 0.19
- S, Wind setup (m): 0.06
- SWL, Still water level (m RL): 315.06

3.2 Wave Runup

Wave Height

- H_S, Significant wave height (ft): 0.98
- H_S, Significant wave height (m): 0.30
- β, Angle of incidence of fetch (°): 0.00
- R_H, Angle reduction factor: 1.00
- P_V, Probability of Exceedance (%): 2.00
- Highest X% of waves to average (%): 5.00
- Ratio of specific/significant: 1.40
- H, Specific wave height (ft): 1.37
- H, Specific wave height (m): 0.42

Wave Period and Length

- T, Wave period (sec): 1.38
- L, Wave length (ft): 9.74
- L, Wave length (m): 2.97

Wave Classification

- Ratio of depth to wave length, d/L: 0.34
- Wave Classification: Transitional

Wave Runup Reduction (1)

• θ, Angle u/s face with horizontal (°)	18.43
• s_p, Steepness of peak waves	0.14
• ξ_p, Surf similarity factor	0.89
• Slope surface:	1 rock layer, dia. D, (Hs/D=1.5 - 3.0)
• Slope of vertical wave wall (1V:xH)	N/A
• α_{wall}, Slope of vertical wave wall (°)	N/A

Wave Runup Reduction (2)

• B, Berm width (m)	0.00
• Berm level (m RL)	0.00
• Slope below berm level (1V:xH)	0.00
• α_1, Slope below berm level (°)	0.00
• α_{eq}, Equivalent slope (°)	33.69
• α, Average slope (°)	18.43
• d_B, Depth between SWL & berm (m)	315.06

• Reduction Factors:

A	C	γ_r	γ_β	γ_b	γ_h
1.60	0.00	0.55	1.00	1.00	1.00

Wave Runup

• R, Wave Run-up (ft)	1.07
• R, Wave Run-up (m)	0.33

3.3 Wave Runup

• Total Freeboard (ft)	1.26
• Total Freeboard (m)	0.39

WAVE RUNUP AND WIND SETUP

This calculation document follows the methodology outlined in Chapter 6: Freeboard in Design Standards No. 13 (2012), published by the U.S. Department of the Interior Bureau of Reclamation. Wind speed gust factors calculated as outlined in Guidelines for converting between various wind averaging periods in tropical cyclone conditions (2008), published by the World Meteorological Organisation.

Author:	MP	**Date:**	29/09/2016
Review:	RDM	**Date:**	30/09/2016
File name:	RockLining_FHWA15_new_n_calc_r3.xlsx		
Sheet:	3	**Status:**	For Use

1.0 General Details

• Structure name:	Blackwood Pit	• Client:	CBH Resources
		• Project Name:	RASP Mine
• Design ARI (yrs):	50	• Job Number:	1654895
• Water Level:	Maximum		
• Water Level (m RL):	315.00	• Embankment Slope (1V:xH):	3.00
• F_E, Effective Fetch Length (km):	0.70	• d, Average water depth (m):	1.00
• F_E, Effective Fetch Length (miles):	0.43	• d, Average water depth (ft):	3.28

2.0 Wind Data

2.1 Site Wind Speed

Wind data obtained from:
Australian Standard 1170.2.2002 Part 2 Table 3.1

ARI (yrs)	3 sec gust (m/s)
1	30
5	32
10	34
20	37
25	37
35	38
50	39
100	41
200	43
500	45
1,000	46
2,000	48
2,500	48
5,000	50

$$V_{sit,\beta} = V_R M_d (M_{z,cat} M_s M_t)$$

• Wind Region	A
• V_R (m/s)	39.00
• Region Factor	1.00
• M_d	0.95
• $M_{z,cat}$	0.99
• M_s	1.00
• M_t	1.00
• $V_{sit,\beta}$ (m/s)	38.61
• $V_{sit,\beta}$ (mph)	86.37

74.791

2.2 Critical Wind Speed

• R_L, Ratio of wind speed over water/land:	0.90
• Class:	In-Land
• Class Description:	*Roughly open terrain*

Duration		Gust Factor	Maximum Wind Speed (mph)	
sec	min		Over-land	Over-water
3	0.05	1.00	86.37	77.73
60	1	1.49	57.96	52.17
120	2	1.55	55.72	50.15
180	3	1.58	54.66	49.20
600	10	1.66	52.03	46.83
3600	60	1.75	49.35	44.42

• Critical Wind Duration (min)	17.33
• Critical Wind Speed (mph) *(based on site)*	46.47
• Critical Wind Speed (mph) *(based on fetch)*	46.47
• Site and fetch based speed difference (mph)	0.00
• Adopted Critical Wind Speed (mph)	46.47
• Adopted Critical Wind Speed (m/s)	20.78

3.0 Wave Runup and Wind Setup

3.1 Wind Setup

• F_S, Setup Fetch (km):	0.70
• S, Wind setup (ft):	0.20
• S, Wind setup (m):	0.06
• SWL, Still water level (m RL)	315.06

3.2 Wave Runup

Wave Height

• H_S, Significant wave height (ft)	1.01
• H_S, Significant wave height (m)	0.31
• β, Angle of incidence of fetch (°)	0.00
• R_H, Angle reduction factor	1.00
• P_V, Probability of Exceedance (%)	2.00
• Highest X% of waves to average (%)	5.00
• Ratio of specific/significant	1.40
• H, Specific wave height (ft)	1.42
• H, Specific wave height (m)	0.43

Wave Period and Length

• T, Wave period (sec)	1.39
• L, Wave length (ft)	9.95
• L, Wave length (m)	3.03

Wave Classification

• Ratio of depth to wave length, d/L	0.33
• Wave Classification	Transitional

Wave Runup Reduction (1)

• θ, Angle u/s face with horizontal (°)	18.43
• s_p, Steepness of peak waves	0.14
• ξ_p, Surf similarity factor	0.88
• Slope surface:	1 rock layer, dia. D, (Hs/D=1.5 - 3.0)
• Slope of vertical wave wall (1V:xH)	N/A
• α_{wall}, Slope of vertical wave wall (°)	N/A

Wave Runup Reduction (2)

• B, Berm width (m)	0.00
• Berm level (m RL)	0.00
• Slope below berm level (1V:xH)	0.00
• α_1, Slope below berm level (°)	0.00
• α_{eq}, Equivalent slope (°)	33.69
• α, Average slope (°)	18.43
• d_B, Depth between SWL & berm (m)	315.06

• Reduction Factors:

A	C	γ_r	γ_β	γ_b	γ_h
1.60	0.00	0.55	1.00	1.00	1.00

Wave Runup

• R, Wave Run-up (ft)	1.10
• R, Wave Run-up (m)	0.34

3.3 Wave Runup

• Total Freeboard (ft)	1.30
• Total Freeboard (m)	0.40

RASP MINE, BROKEN HILL, NSW
TAILINGS STORAGE FACILITY

SPILLWAY DESIGN
SITE LAYOUT

LEGEND

Blackwood Pit Boundary

Catchment Boundary

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NOTES

SOURCE FILES: AERIAL IMAGE PROVIDED BY CBH RESOURCES AS AT 25 APRIL 2016 (FILENAME: "160425 Rasp Mine MGA54 10cm.ecw")

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INSET MAP SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, INCREMENT P CORP, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI (THAILAND), MAPMYINDIA, OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

BASE IMAGE SOURCE: NSW GOVERNMENT, LAND AND PROPERTY INFORMATION 2015

0 50 100 200 metres

SCALE (at A3) 1:5,000

DATUM MGA 94, PROJECTION MGA Zone 54

PROJECT: **1654895**
DATE: **04 OCT 2016**
DRAWN: **MP**
CHECKED: **RDM**

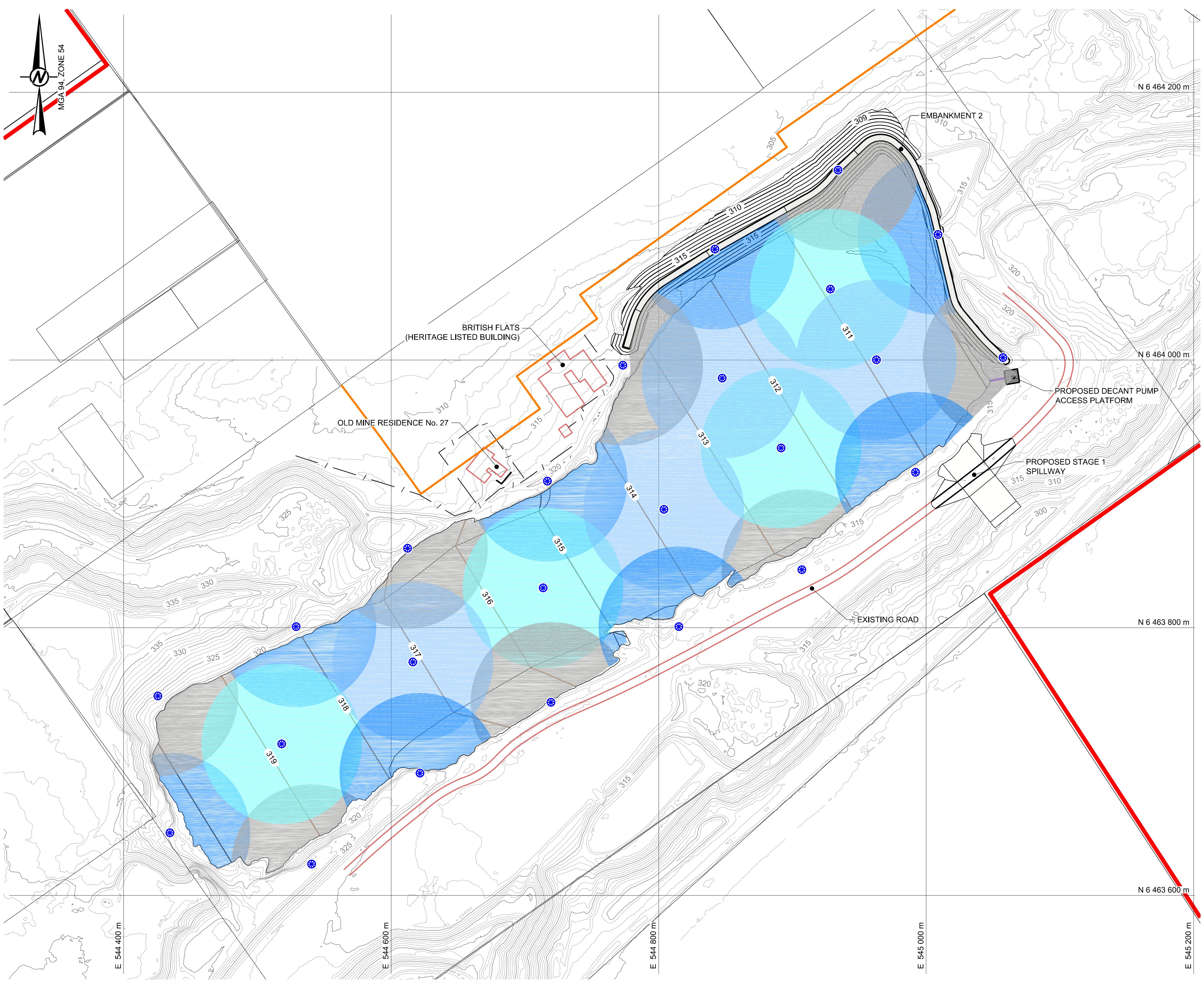
FIGURE 02

Golder Associates

File Location: J:\Hyd\2016\Melbourne\1654895 - Rasp Mine Broken Hill\Figures Drawings\1654895-008-R-F001-RevA.mxd

APPENDIX F

Dust Suppression Sprinkler Layout



LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- ANTICIPATED INTERMEDIATE TAILINGS CONTOURS AT 1 m INTERVALS
- DUST SUPPRESSION SPRINKLER LOCATION
- THROW RADIUS (TYP. 60 m) WITH OVERLAP
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY

NOTE(S)

1. ALL LEVELS ARE REFERENCED IN METRES TO AUSTRALIAN HEIGHT DATUM (m AHD).

REFERENCE(S)

EXISTING SURVEY SHOWN FROM FILES: 160425 Tailings Dam 1m Contours.dxf AND 160425 RASP Tailings Dam Area.dxf (1 m CONTOURS), RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

SITE BOUNDARIES SHOWN FROM FILES: mga_cml7_lease_bdy.dwg, surf_leases_mga.dxf, RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

CML SURFACE EXCLUSION BOUNDARY SHOWN FROM FILES: GFH_D2319.DXF AND GFH_M25352.dxf, RECEIVED FROM CBH RESOURCES ON 22 AUGUST 2016.

NOT FOR CONSTRUCTION

0 50 100

1:3,000 METRES

CLIENT

BROKEN HILL OPERATIONS PTY LTD

PROJECT

BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

CONSULTANT

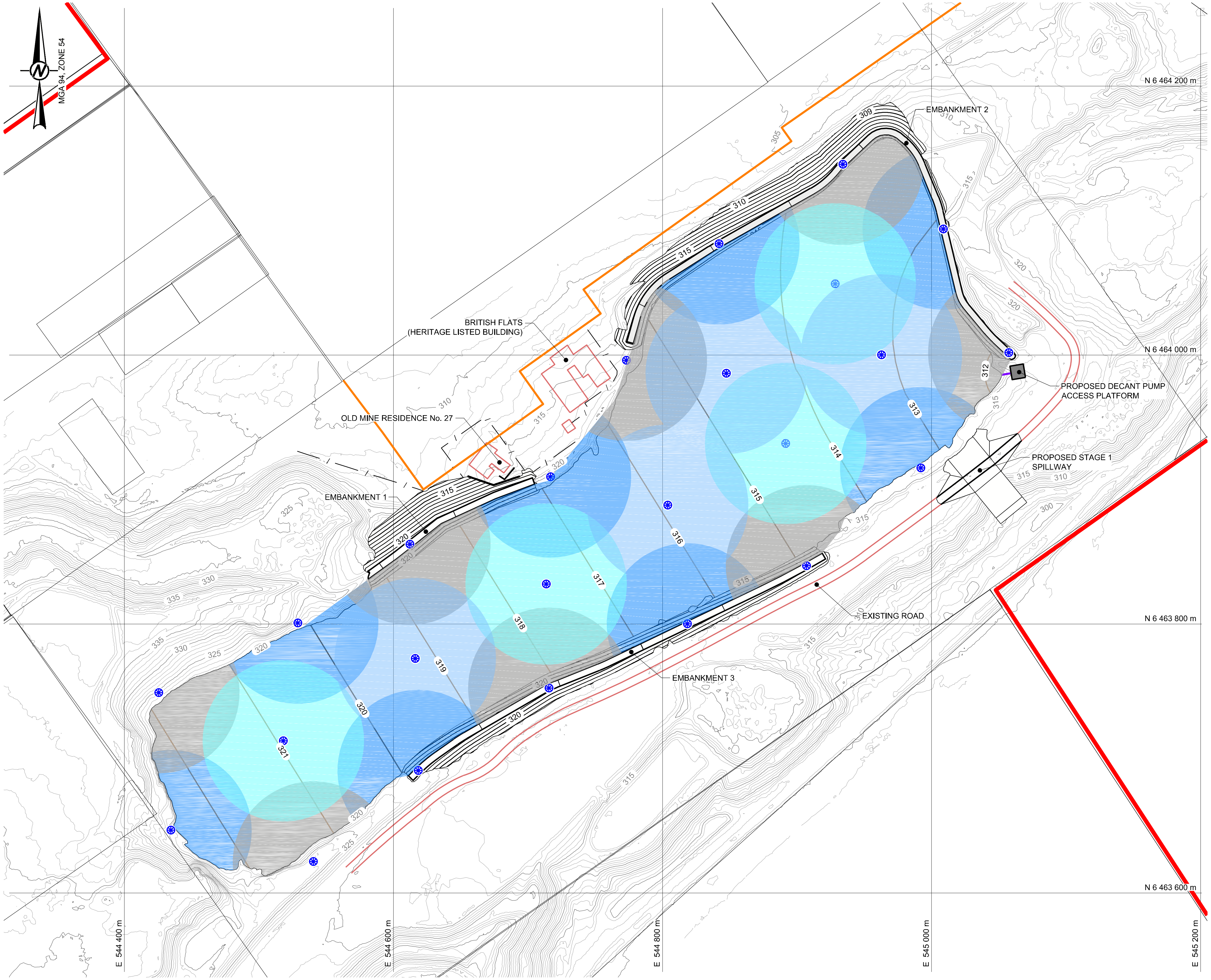
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	GRP
PREPARED	PDM
REVIEWED	FWG
APPROVED	FWG

TITLE

PROPOSED DUST SUPPRESSION SYSTEM AT STAGE 1

PROJECT NO.	CONTROL	REV.	FIGURE
1654895	011-L	1	1



LEGEND

EXISTING CONTOURS AT 1 m INTERVALS

PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS

ANTICIPATED FINAL TAILINGS CONTOURS AT 1 m INTERVALS

DUST SUPPRESSION SPRINKLER LOCATION

THROW RADIUS (TYP. 60 m) WITH OVERLAP

LEASE BOUNDARY EXTENT

SURVEYED CML7 SURFACE EXCLUSION BOUNDARY

NOTE(S)

1. ALL LEVELS ARE REFERENCED IN METRES TO AUSTRALIAN HEIGHT DATUM (m AHD).

REFERENCE(S)

EXISTING SURVEY SHOWN FROM FILES: 160425 Tailings Dam 1m Contours.dxf AND 160425 RASP Tailings Dam Area.dxf (1 m CONTOURS), RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

SITE BOUNDARIES SHOWN FROM FILES: mga_cml7_lease_bdy.dwg, surf_leases_mga.dxf, RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

CML SURFACE EXCLUSION BOUNDARY SHOWN FROM FILES: GFH_D2319.DXF AND GFH_M25352.dxf, RECEIVED FROM CBH RESOURCES ON 22 AUGUST 2016.

NOT FOR CONSTRUCTION

0 50 100

1:3,000 METRES

CLIENT
BROKEN HILL OPERATIONS PTY LTD

PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

CONSULTANT

Golder Associates

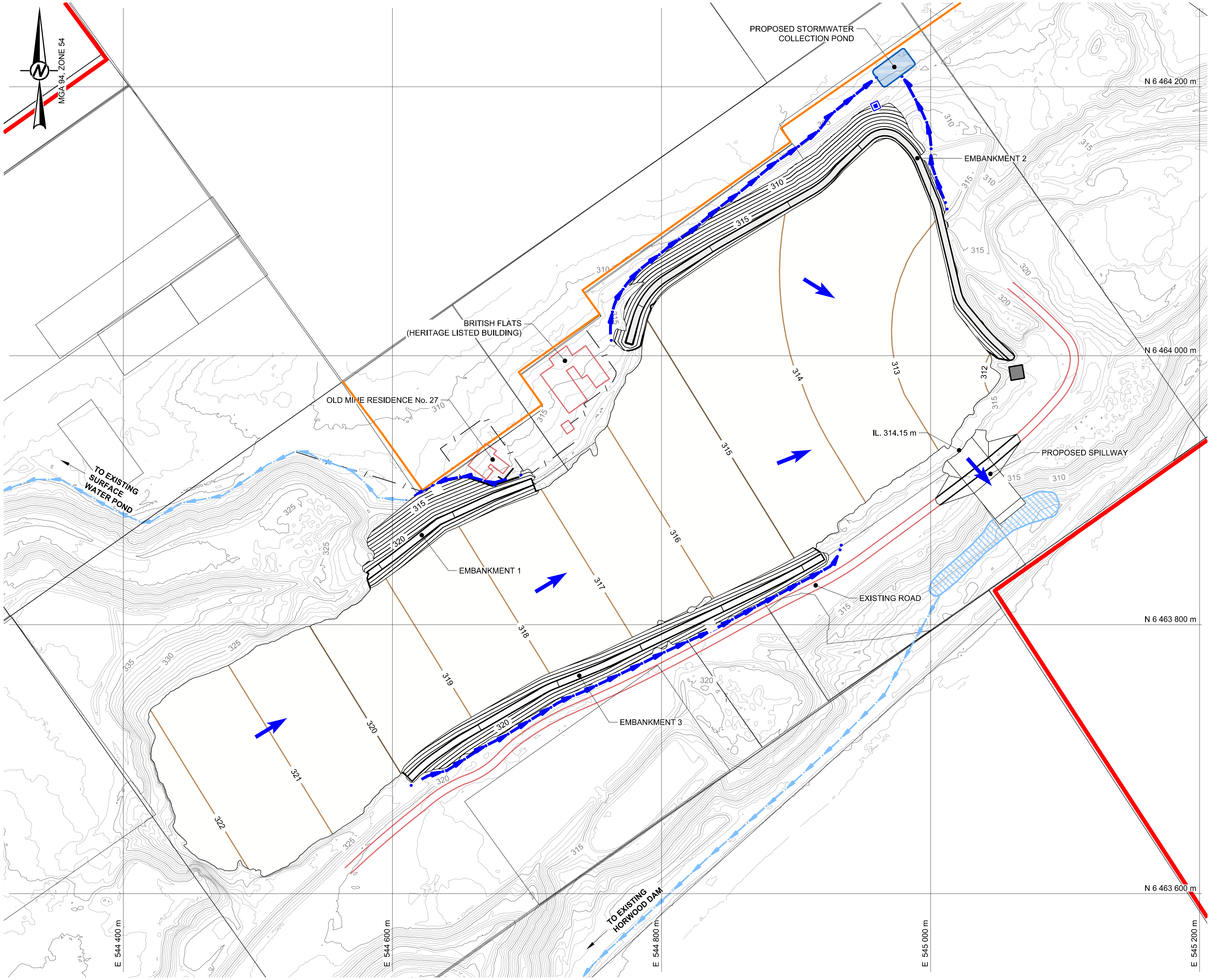
YYYY-MM-DD	2017-03-15
DESIGNED	GRP
PREPARED	PDM
REVIEWED	FWG
APPROVED	FWG

TITLE
PROPOSED DUST SUPPRESSION SYSTEM AT STAGE 2

PROJECT NO.	CONTROL	REV.	FIGURE
1654895	011-L	1	2

APPENDIX G

Concept Stormwater Management Plan at Closure



LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED EMBANKMENT CONTOURS AT 1 m INTERVALS
- INDICATIVE TAILINGS CONTOURS AT 1 m INTERVALS
- LEASE BOUNDARY EXTENT
- SURVEYED CML7 SURFACE EXCLUSION BOUNDARY
- PROPOSED SURFACE WATER DRAIN
- TSF STORMWATER RUN OFF
- EXISTING SURFACE WATER POND
- EXISTING SURFACE WATER DRAIN

NOTE(S)

1. ALL LEVELS ARE REFERENCED IN METRES TO AUSTRALIAN HEIGHT DATUM (m AHD).

REFERENCE(S)

EXISTING SURVEY SHOWN FROM FILES: 160425 Tailings Dam 1m Contours.dxf AND 160425 RASP Tailings Dam Area.dxf (1 m CONTOURS), RECEIVED FROM CBH RESOURCES ON 11 MAY 2016.

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CML SURFACE EXCLUSION BOUNDARY SHOWN FROM FILES: GFH_D2319.DXF AND GFH_M25352.dxf, RECEIVED FROM CBH RESOURCES ON 22 AUGUST 2016.

NOT FOR CONSTRUCTION

0 50 100
1:3,000 METRES

CLIENT
BROKEN HILL OPERATIONS PTY LTD

PROJECT
BLACKWOOD PIT TAILINGS STORAGE FACILITY
RASP MINE, BROKEN HILL

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	GRP
PREPARED	PDM
REVIEWED	FWG
APPROVED	FWG

TITLE
TSF STORMWATER MANAGEMENT PLAN

PROJECT NO.	CONTROL	REV.	FIGURE
1654895	011-L	0	3

APPENDIX H

Important Information Relating to this Report

IMPORTANT INFORMATION RELATING TO THIS REPORT

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

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This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

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