September 2017

RASP MINE, BROKEN HILL, NSW

Tailings Storage Facility Options Assessment

REPORT

Submitted to:
Broken Hill Operations Pty Ltd

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Distribution:

Broken Hill Operations Pty Ltd
Golder Associates Pty Ltd

Executive Summary

This report presents the assessment of four future tailings storage facility (TSF) options for the Rasp Mine. The TSF options are sized for 10 years of storage capacity from mid-2021, when storage capacity in the Blackwood Pit TSF (following a scheduled raise) is expected to be consumed.

The four options considered are:

- Kintore Pit TSF: In-pit tailings storage following closing of the decline portal by the construction of three plugs in the decline and access ramp tunnels, and construction of an underdrain over the pit floor and below the tailings fill. An embankment would be constructed on the pit crest in the later years of its operation to optimise the tailings storage capacity.
- Site 8 TSF: Located approximately 6.5 km to the east of the mine. The TSF would be formed by construction of a cross-valley embankment and up-valley discharge of tailings from the embankment. The site has a large catchment area that represents approximately 2% of the Stephens Creek Reservoir catchment. A headwater diversion dam and outfall pipe would be constructed to limit stormwater flows into the tailings storage area. Part of the TSF appears to lie within the property of the “Clevedale Station”, located to the east.
- Site 10 TSF: Formed by construction of perimeter embankments and a tailings delivery causeway into the storage area for central discharge of tailings. Supernatant water and rainfall runoff would be managed in Decant Dams located outside of the tailings storage area. The potential requirement for private land acquisition is unknown.
- Site 11 TSF: Located approximately 5 km to the south-east of the mine. The TSF would be formed by construction of a perimeter embankment and a tailings delivery causeway into the storage area for central discharge of tailings. Supernatant water and rainfall runoff would be managed in a decant dam located outside of the tailings storage area. The site is located in area of homesteads and acquisition of land would be required.

A cost summary table for the options assessment is presented over page. The capital costs for each option (inclusive of closure works), are summarised below and show development of the Kintore Pit TSF to be the most favourable, since the cost for development of an off-site TSF is likely to be prohibitively high.

- Kintore Pit TSF: $6.7M
- Site 8 TSF: $71.3M
- Site 10 TSF: $61.0M
- Site 11 TSF: $57.0M

Background to the high costs are provided below:

- Long distances for tailings delivery: This results in additional estimated costs of between $2M and $3.5M for the pumps and the length of the robust pipelines required for the expected conditions.
- Relatively higher embankment fill volumes and long distance for hauling mine waste from the mine to the respective offsite TSF sites for embankment construction. This results in additional estimated costs of between $9M and $18M, relative to the Kintore Pit option. Further work could be undertaken to identify less costly fill material alternatives, however the costs are still likely to be relatively high.
- The potential requirement to install a geosynthetic liner over the tailings storage footprint to manage potential risks associated with seepage. (Sites 8, 10 and 11 lie within the catchment of Stephens Creek Reservoir – the townships water supply). Lining of the impoundment areas results in additional estimated costs of between $22M and $24M for these options, inclusive of associated contingencies.

- Relatively large tailings surface areas for placement of a cover layer at closure and the long distance for hauling waste rock to form the cover layer. On the basis that a 0.5 m thick layer of rockfill may be required at closure to manage the risk of tailings erosion, the additional direct costs are in the order of $11.5M to $13.5M for the offsite TSF options.

Item	***Cost estimate ($Million)***			
	Kintore Pit	***Site 8***	***Site 10***	***Site 11***
Preliminaries	0.3	0.3	0.3	0.3
Closure of mine workings (Kintore Pit only), construction of plugs and seepage management	1.7	0.3	0.5	0.4
Tailings and return water pumps, pipelines and access roads	1.7	6.1	5.4	4.8
TSF perimeter embankments & tailings delivery causeways	0.5	18.6	10.6	9.4
Water management embankments and diversions	0.0	1.6	0.7	0.6
TSF seepage barrier works	0.2	19.8	19.8	19.3
Decant Dam seepage barrier works	0.0	0.0	1.9	1.5
Spillways and gravity decant structures	0.2	0.1	0.4	0.3
Closure works	0.8	14.3	12.9	12.3
Sub-total	**5.3**	**61.0**	**52.3**	**48.8**
Engineering Services	0.5	1.0	0.8	0.8
Contingency	0.9	9.3	8.0	7.4
Total	**6.7**	**71.3**	**61.1**	**57.0**

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1.0 INTRODUCTION

This report presents Broken Hill Operations Pty Ltd (BHOP) with a life of mine (LoM) tailings storage options assessment for the Rasp Mine. It presents four options to provide storage of approximately 7 million dry tonnes (Mdt) of tailings over 10 years. Commencement of deposition in the new TSF will be from about mid-2021, when the Blackwood Pit TSF, with the scheduled raise implemented, is expected to reach its storage capacity.

2.0 OUTLINE OF THIS REPORT

This report is structured as follows:

- Section 3.0 Background – overview of existing TSF, including average tailings dry density
- Section 4.0 Siting assessment – overview of site selection process and basis for shortlisted sites
- Section 5.0 Site characterisation – climate data, topography and subsurface conditions
- Section 6.0 Options assessment criteria – overview of target storage capacity, storage layout types and regulated design criteria
- Section 7.0 Options summary – descriptive summaries of the tailings storage and water management concept design layout for each of the shortlisted options
- Section 8.0 Quantities and cost estimates – summary of key construction quantities and cost estimates for each option
- Section 9.0 Options ranking assessment – comparative ranking of options based capital cost and impact aspects
- Section 10.0 Future work – outline of next stages of work to develop the preferred option to detailed design and construction.

Supporting information is provided in appendices as follows:

- *Appendix A* – Commentary on TSF sites for 30 year storage case
- *Appendix B* – Layouts, site visit observations and technical considerations (letter of 10 August 2017)
- *Appendix B* – Cost estimates – detailed breakdown
- *Appendix C* – Options ranking matrix

3.0 BACKGROUND

3.1 Blackwood Pit TSF

The Rasp Mine commenced operation in 2012 and since this time tailings has been deposited in the Blackwood Pit TSF at a rate of approximately 570,000 dry tonnes per year. Based on the current forecast tailings deposition rate and a scheduled raise, the Blackwood Pit is expected to reach its storage capacity in 2021. The raise design for the Blackwood Pit was completed by Golder Associates Pty Ltd (Golder) in November 2016 (Ref.1654895-009-R-Rev0) and was approved by the NSW Dam Safety Committee (DSC) in January 2017.

Tailings slurry is thickened by a high-rate thickener to an average solids concentration of approximately 65% by weight. The average dry density for tailings deposited in the Blackwood Pit is approximately 1.5 t/m^3, as measured by BHOP based on comparison of topographical surveys and corresponding tailings tonnage for the period between surveys.

3.2 Previous options assessments

A scoping study for tailings storage options within consolidated mine lease 7 (CML 7) was completed by Golder in 2007 (Ref.077611001/031R). The study considered a raise to an old TSF next to Mt Hebbard, in-pit storage in the Blackwood Pit, and in-pit storage in the Old BHP Pit. The Blackwood Pit provided the most efficient storage potential and was subsequently developed to receive tailings.

4.0 SITING ASSESSMENT

Nine potential sites for a new TSF were initially identified within a 10 km radius of the Rasp Mine (and around the periphery of the Broken Hill township). These sites are presented on Figure 1 and were identified based on topographical data and the potential to store up to 21 Mdt of tailings, i.e. for a potential 30 year extension of the mine life.

An option to decommission the Kintore Pit for in-pit storage of tailings was also put forward by BHOP for consideration. An active decline portal is located at the base of the pit and access ramp tunnels underlie the pit floor. A new decline or shaft would be required if the Kintore Pit is to be adopted for tailings storage. A table summarising initial screening commentary on the potential TSF sites and the Kintore Pit is presented in Appendix A. Sites on the western side of the township were ruled out based on the likely prohibitive costs associated with tailings delivery, due to the circuitous and long pipeline distance that would be required. Other sites were ruled out based on recognisable land acquisition constraints due to existing infrastructure.

Based on the siting assessment for the 21 Mdt storage case, it was proposed that the following sites be shortlisted for further consideration:

- Site 7
- Site 8
- Site 9
- Kintore Pit

The Kintore Pit was identified as having capacity for storage of approximately 8 years of tailings production, with a potential 2 year extension by constructing a partial perimeter embankment on the pit rim. Preliminary layouts were prepared for the shortlisted sites and were visited by representatives of BHOP and Golder on 25 July 2017.

On the basis that there may be land acquisition and permitting constraints with accessing some of the proposed new TSF sites and to provide a comparative study of offsite TSFs with the Kintore Pit, the assessment criteria was modified to consider TSFs with capacity for 7 Mdt of tailings, i.e. for approximately 10 years of storage. Additional sites were identified during the site visit that would provide capacity for the smaller tonnage case and which do not have undue land acquisition and permitting constraints. A letter summarising site observations and the additional sites was prepared by Golder in mid-August 2017 and is included as Appendix B. Following discussions with BHOP the following sites were shortlisted for preparation of concept design layouts for tailings storages and costing assessment:

- Site 8
- Site 10
- Site 11
- Kintore Pit

These sites are presented in regional plan on Figure 2. An enlarged plan showing indicative tailings delivery and return water pipeline routes is presented on Figure 3.

5.0 SITE CHARACTERISTICS

5.1 Climate

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 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. This is based on data from the Patton Street weather station (ID 047007), located within a few hundred metres of the mine site.

Mean annual evaporation data for the Stephens Creek Reservoir weather station (ID 047031) is approximately 2580 mm. This station is located approximately 16 km to the north of the mine. Climate statistics for the region 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.

For TSF design, the climate presents optimum conditions for drying and desiccation of tailings, provided that the rate of rise for tailings deposition is relatively low. The rate of rise for each TSF option is addressed in Section 7.4. The combination of low rate of rise and high evaporative conditions provide suitable conditions for upstream raise construction during operation. The high evaporative conditions will also limit the extent of water management during operation.

5.2 Design rainfall data

Rainfall intensity-frequency (IFD) data for the site, obtained from the BOM website[1] is presented in Table 1. Rainfall intensity for probable maximum precipitation (PMP) events were estimated using the Generalised Short Duration Method[2] and rainfall intensity for events between the 1 in 100 annual exceedance probability (AEP) and the PMP were estimated by interpolation.

Table 1: 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

[1] BOM (2016). *Commonwealth Bureau of Meteorology*. Retrieved October 10, 2016, from http://www.bom.gov.au/climate/averages/tables/cw_047007_All.shtml

[2] The Estimation of Probable Maximum Precipitation in Australia, Generalised Short-Duration Method (GSDM). Commonwealth Bureau of Meteorology, June 2003.

The key values for the options assessment are:

- The rainfall intensity for 1 in 100 AEP event i.e. 2.1 mm/hour. The intensity over 72 hours results in a rainfall depth of 151 mm. This parameter is used to assess the Extreme Storm Storage Allowance for decant dam sizing for Sites 10 and 11, as also for sizing the headwater diversion dam for Site 8, discussed further in Sections 6.4.3 and 7.6.
- 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 parameter is used for the Environmental Containment Freeboard for the Kintore Pit raise, discussed further in Sections 6.4.3 and 7.6.

Note, the rainfall intensity for the 1 in 10,000 AEP events and PMP events will be used for future sizing of spillways (outside the scope of this report).

5.3 Regional drainage

The Broken Hill area spans across two large regional catchments: one draining to the north-east towards the Stephens Creek Reservoir which supplies potable water to Broken Hill, and another draining south along Pine Creek. Both catchments are part of the broader Lower Darling Catchment area. The divide between the two catchments, in the area Broken Hill township and the Rasp Mine, follows an approximate north-west to south-east alignment and passes through the Rasp Mine. Sites 8, 10 and 11 fall within the Stephens Creek Reservoir catchment and the Kintore Pit lies approximately on the divide. The Stephens Creek Reservoir catchment[3] has a total area of approximately 51,300 ha. Drainage catchment areas for each TSF site are summarised in Section 7.2.

5.4 Terrain, geology and other conditions

5.4.1 Site 8

Ridges are located along the eastern and western margins of Site 8, with outcrops of metamorphosed igneous rock visible at the western abutment of this site. The outcropping rock is likely to be Thorndale Gneiss based on the observed crystalline texture and reference to a regional geological map for Broken Hill[4].

The Site 8 TSF is located in a valley with an ephemeral watercourse. The gradient of the side slopes ranges between 1% and 10% and the gradient along the watercourse is approximately 0.5% to 1.0% in the tailings storage area. In the area just downstream of the proposed TSF embankment, the watercourse was approximately 25 m wide and 1 m deep and incised into clayey soil. This soil is interpreted to be of alluvial origin, in general agreement with the regional geological map that indicates colluvial and alluvial sediments of Quaternary age.

Photographs for the outcropping rock and the watercourse through Site 8 are included in the letter presented in Appendix B.

5.4.2 Site 10

The terrain in the area of the proposed Site 10 TSF gently slopes to the north-west at gradients of between 0.7% and 2%. It is located immediately to the west of Site 8. A railway is located approximately 1 km to the west of the western margin of the proposed TSF perimeter. Embankments for the storage area would abut against the same ridge described above for Site 8. A photograph of the storage area is included in Appendix B.

5.4.3 Site 11

Rock outcrops were not identified within the area of the Site 11 TSF. Regional geological mapping also indicates the presence of Thorndale Gneiss in this area. A general view of the Site 11 TSF area is included in Appendix B.

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[3] Signage at the Stephens Creek Reservoir states a catchment area of 513 km^2 (i.e. 51,300 ha).

[4] Anderson et al. (1970) Broken Hill 1:250,000 Geological Series Sheet SH 54-14, 1st Edition.

5.4.4 Kintore Pit

The Kintore Pit is approximately 210 m deep relative to a minimum rim elevation of RL 310 m on the southern perimeter. A waste rock stockpile has been formed over the southern portion of the pit. The volume of the stockpile based on comparison of topographical surveys before and after placement is approximately 450,000 m^3.

Pit wall excavations have exposed tailings within an old storage in the northern batter, as well as old timber supports from crushed relict mine workings. Adits and shafts to old workings are present in the batters on each side of the pit, including behind the waste rock stockpile.

A wedge failure has occurred in the eastern batter of the pit where the intersection of discontinuity planes in the rock slope have day-lighted in the batter slope. Failure of the wedge occurred in recent years following a period of heavy rainfall.

Access to the current underground workings is provided by a decline and access ramp tunnel system with the decline portal located at the base of the pit and into the toe of the western batter slope. The lower slopes of the western batter above and around the decline portal have been stabilised by cable anchors and shotcrete (and/or fibrecrete). A plan of the decline and access ramps in the Kintore Pit area is presented in Figure 4. This shows the decline branching at about 160 m length with one ramp continuing to the northern mine workings and one turning back under the pit floor and connecting to the southern mine workings.

Mine records provided by BHOP show old mine workings below the pit base, as shown in plan (Figure 4) and cross section (Figure 5). The minimum rock cover thickness to the old workings is approximately 10 m and to the access ramp tunnels is about 15 m.

5.5 Seismicity

The Broken Hill area is a region of low seismicity. The 2012 Australian Earthquake Hazard Map[5] (the Map) shows the site peak ground accelerations (PGAs) for the 1 in 500 annual exceedance probability (AEP) event to be in the range of 0.01g to 0.02g, the 1 in 2 500 AEP event to be in the range of 0.03g to 0.06g, and the 1 in 10 000 AEP event to be in the range of 0.10g to 0.20g.

Note, seismicity is not considered further for the surface TSF options but is considered for the conceptual design of plugs for the access ramps at Kintore Pit. Seismicity will be considered in future preliminary or detailed designs of any surface TSF options. Based on the relatively low seismicity of the region (and semi-arid climate and relatively low rate of rise for the TSF options), upstream raising of embankments is considered feasible for possible TSF at Sites 8, 10 and 11, should any of these sites be taken to a preliminary and/ or detailed design stage.

6.0 OPTIONS ASSESSMENT CRITERIA

6.1 Tailings delivery and storage parameters

The following parameters are adopted for concept design layouts:

- Maximum tailings deposition rate: 700,000 dry tonnes per year
- Average slurry solids concentration: 65%
- Average beach slope (based on Blackwood Pit TSF performance): 1.5%(Note)
- Average dry density (based on Blackwood Pit TSF performance): 1.5 t/m^3

Note, a flat beach slope is adopted for the Kintore Pit for concept design based on the relative small storage area.

[5] Burbidge, D. R. (2012). *The 2012 Australian Earthquake Hazard Map. Record 2012/71.* Canberra: Geoscience Australia.

6.2 Tailings storage layout types

A summary of potential deposition arrangements and commentary on their applicability to the TSF sites is presented in Table 2.

Table 2: Summary of potential tailings deposition arrangements

Tailings discharge arrangement	Comments on applicability
Central discharge	Applicable to the Site 10 and 11 TSFs based on the relatively flat and broad terrain. Not applicable to Site 8 TSF due to the long and irregular shape of the valley, i.e. central discharge would result in multiple surface depressions that would require water management. Not applicable to the Kintore Pit as it is a deep pit, i.e. not practical to establish and raise a central deposition point.
Down-valley discharge	Considered for the Site 8 TSF (a valley site), however, not applicable due to the predicted beach slope and the relatively flat terrain, i.e. it is not possible to beach tailings down the valley, as the beach slope exceeds the valley drainage gradient.
Up-valley discharge	Applicable to the Site 8 TSF only due to the valley shaped terrain. Discharge from the embankment would form a beach slope in an up-valley direction, with a supernatant pond located at the upstream end of the storage area.
Perimeter discharge	Applicable to the Kintore Pit. Not practical at the Site 8 TSF due to similar problems of the down-valley discharge method. Not practical for Sites 10 and 11 TSFs, also due to the gently sloping terrain and inability to beach tailings over the required distance from all side of a perimeter embankment layout. Reduction of the solids concentration could be considered to achieve a flatter beach slope, however, this central discharge method provides a similarly small footprint and a significantly lower embankment fill requirement.
Partial perimeter discharge	Applicable to Kintore Pit, resulting in a pond location at one side of the pit. Similar constraints to perimeter discharge for the other sites.

The following tailings deposition arrangements are adopted for the TSF options:

- Kintore Pit TSF: Perimeter discharge. Flat tailings beach adopted for concept design based on an expected high rate of rise. Note, early stage discharge will be via the pit ramp.
- Site 8 TSF: Up-valley discharge, with a 1.5% average tailings beach slope.
- Site 10: TSF: Central discharge, with a 1.5% average tailings beach slope.
- Site 11: TSF: Central discharge, with a 1.5% average tailings beach slope.

6.3 TSF embankment raise type

The following embankment raise methods can be considered for TSFs:

- Downstream raise construction, where each raise is constructed in a downstream direction, over the initial embankment and onto the ground surface in the downstream area.
- Upstream raise construction – construction onto the tailings surface.
- Centreline raise construction – partial construction onto the tailings surface and onto the ground surface downstream of the initial embankment.

This options assessment does not consider sub-staging of embankment construction, i.e. it conservatively assumes a single tailings storage embankment is constructed for the 10 year storage life. On this basis, the volumes presented in Section 7.4 are representative of the total volume of fill for start-up and downstream raise construction. Sub-staging and the potential for reductions in fill quantities by upstream or centreline raising will be assessed as part of preliminary and/ or detailed design for the preferred option(s).

6.4 Dam safety regulations and guidelines

6.4.1 Overview

Dam safety of tailings dams in NSW is regulated by the NSW Dam Safety Committee (DSC). The DSC provide guidance sheets with design criteria and in general, are based on the Australian National Committee on Large Dams (ANCOLD) tailings dam guidelines of 2012.

6.4.2 Consequence category

The robustness of the design measures, including the extent of seismic load resistance and water management measures are governed by the dam safety consequence category for the facility. The Kintore Pit, once raised is likely to be assigned a 'High' consequence category, similar to that assigned to the Blackwood Pit raise. At the other sites, the consequence category may be lower due to a relatively lower risk to human life. However, for the purpose of concept design criteria for water management, it is assumed all facilities will be classified as 'High'. The consequence category would be reviewed for the preferred site that is adopted for further design work.

6.4.3 Flood management

A summary of the relevant freeboards for a 'High' consequence category facility under DSC guidelines are presented in Table 3.

Table 3: Summary of freeboard criteria for a 'High' consequence category

DSC Criteria	Design event / minimum freeboard
Environmental Containment Freeboard(Note)	1 in 10,000 AEP, 72-hour event
Tailings Operational Freeboard	500 mm
Total Freeboard	1 in 10,000 AEP, critical duration event
Pond Recovery Time (7 days)	1 in 100 AEP, 72-hour event

Note: Adopted for the Site 8 TSF and the Kintore Pit, where flood storage is on the tailings surface.

A summary of relevant freeboards for a 'High' consequence category facility under ANCOLD guidelines are presented in Table 4.

Table 4: ANCOLD flood storage and spillway design criteria for a 'High' consequence category

ANCOLD criteria	Design event	Wave Freeboard Allowance
Extreme Storm Storage Allowance	1 in 100 AEP, 72-hour event	n/a
Spillway capacity	At least 1:100,000 AEP, critical duration, suggested PMF	Wave run-up for 1:10 AEP wind event with 1:100,000 design flood

n/a = not applicable

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 tailings beach and the spillway elevation. This criteria is adopted for the Site 8 TSF and the Kintore Pit. For the central discharge layouts where water storage will be external to the tailings storage area, the Extreme Storm Storage Allowance is adopted.

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

The Total Freeboard represents the storage capacity between the tailings 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 runoff from an extreme storm event by a combination of storage and spillway discharge.

Pond Recovery Time represents the duration in which the design flood storage event is removed from the water storage area, to reinstate flood storage capacity, in readiness for a subsequent event.

For the purpose of concept design layouts for the options, the following criteria area adopted:

- Freeboard of 500 mm at the embankments for the Site 8, 10 and 11 TSFs. This addresses the Operational Freeboard.
- Freeboard of 1.5 m at the embankments for the Kintore Pit, to allow for flood storage on the tailings surface and spillway freeboard.
- Decant Dam storage capacity for the estimated runoff from the 1 in 100 AEP, 72-hour event for the Site 10 and 11 TSFs. This addresses the 'Extreme Storm Storage Allowance and is considered appropriate for the runoff shedding layouts at these sites. The Decant Dams are sized for an operational pond volume of 5000 m^3 plus the estimated runoff for the 1 in 100 AEP, 72-hour event, with 1 m of freeboard to allow for an emergency spillway.
- No Decant dam will be provided for the Site 8 TSF, as the pond will be on the tailings surface, at the upstream end of the storage. A Headwater Diversion Dam and outfall pipe is included to reduce runoff into the storage area. The Headwater Diversion Dam is nominally sized for the 1 in 100 AEP, 72-hour event and 2 m of freeboard to allow for an emergency spillway (for a relatively large catchment area).
- For the Kintore Pit, the Decant Dam that will be constructed for the Blackwood Pit TSF raise will be utilised.

6.5 EMBANKMENT GEOMETRY

The embankment geometry adopted for the concept design layouts at the Site 8, 10 and 11 TSFs is:

- Crest width: 6 m
- Upstream and downstream slopes: 3H:1V(Note)

Note: A batter slope of 3H:1V is conservatively adopted for both upstream (to facilitate safe liner installation) and downstream embankment slopes for stability and ultimate closure profile.

For the Kintore Pit perimeter embankment, the following geometry is adopted:

- Crest width: 6 m
- Upstream and downstream slopes: 2.5H:1V(Note)

Note: 2.5H:1V is adopted for both upstream and downstream slopes based on stability assessments undertaken for the Blackwood Pit embankments, area constraints and due to the works being located within the mine lease area.

The tailings deposition causeway geometry adopted for the Site 10 and 11 TSFs is:

- Crest width: 6 m
- Side slopes: 2H:1V

7.0 CONCEPT DESIGNS FOR TSF OPTIONS

7.1 General

A summary of the proposed tailings storage options are presented in Table 5. The options are presented on layout plans and sections on Figures 4 to 13. Quantities and cost estimates for each option, including embankment fill and potential areas for geosynthetic liners are addressed in Section 7.11. Technical considerations for sourcing of embankment fill materials and the potential requirement for a geosynthetic liner at each of sites are addressed in Section 7.7.

Table 5: Summary of LoM tailings storage options

Option	Description	Figures
Kintore Pit	Decommissioning of the Kintore Pit provides an opportunity for in-pit tailings storage. Tailings deposition would be via a perimeter main and spigots. Partial perimeter discharge would allow for some degree of control on the pond location during the later stages of operation. During early years of operation, the rate of rise would be relatively high and by the end of filling the rate of rise would approach approximately 3.8 m/year. The use of the Kintore Pit as a TSF requires closing the decline portal, managing old workings and recent mine workings southwards beneath the pit. Old workings and the access ramps are within 10 to 15 m of the base of the pit. Based on available information, it may not be possible to safely access the old working and to manage risks associated with collapse into these areas. Unreinforced concrete plugs will be formed at the decline portal and also at two locations in the access ramps to prevent uncontrolled flow of seepage water into the mine workings or access ramps and to contain tailings within the pit footprint. The indicative location and extent of the proposed plugs are shown on Figure 4. Geotechnical investigations will be required to assess rock conditions in the old workings and access ramps beneath the pit to inform the detailed design of the plugs. A risk assessment will also be required for of the plug design and safety of the current workings downstream of the plugs if this option progresses to detailed design. The waste rock stockpile located in the southern area of the pit would be left in place to limit the cost of double handling this material. By approximately Year 7, construction of an embankment at the Pit rim would be required to extend the storage life of the Pit for the required 10 years of storage capacity. A geosynthetic liner would be installed on the upstream slope of the embankment to manage the seepage that would be expected from the tailings and associated surface water. The potential for raises of the storage area by extending and raising the embankment is not considered practical beyond Year 10 due to the relatively small gain in storage volume per unit of embankment fill.	4, 5 & 6

Option	Description	Figures
Site 8 TSF	The TSF basin will be formed by constructing a cross valley embankment and discharging tailings up-valley from the embankment. An ephemeral watercourse drains along the valley floor to the Stephens Creek Reservoir. The embankment has a crest length of approximately 1.7 km for the final layout and the catchment area formed by the embankment, without consideration to diversion drains, is approximately 1024 ha. This represents approximately 2% of the Stephens Creek Reservoir catchment. The site is located approximately 6.5 km to the east of the processing plant and approximately 2 km north of Menindee Road. Tailings delivery and return water pipelines would extend over an approximate distance of 9.5 km from and to the processing plant, requiring crossings at the railway line and Menindee Road. The railway is located downstream of the TSF, at a distance of approximately 4.5 km to the north. Tailings deposition would occur from the upstream crest of the embankment, with beach slopes forming in an upstream direction, resulting in a supernatant pond at the upper area (head) of the valley. The maximum beach length from the embankment crest by the end of filling, is approximately 900 m and the rate of rise approaches 0.6 m/year by the end of filling. Intermittent ponding of supernatant water and rainfall runoff is expected to occur in the depression at the southern end of the storage. A small pump access ramp will be formed along the edge of the watercourse and water would be pumped back to the processing plant for reuse in the mill. To reduce runoff into the tailings storage from the large upstream catchment area, a headwater diversion dam would be constructed upstream of the tailings storage area. This dam closes a catchment area of approximately 642 ha, i.e. approximately 60% of the total TSF catchment area. The dam shown on the layout is sized to store the estimated runoff from a 1 in 100 AEP, 72-hour rainfall event. Water would be released via an outfall pipe located along the watercourse through the tailings impoundment area and below the foundation of the TSF embankment. Due to its location within the Stephens Creek Reservoir, it is likely that a geosynthetic liner would be required over the tailings impoundment area and the upstream slope of the embankment. The requirement for a liner would be subject to groundwater impact assessments and/or minimum regulatory requirements. Based on a fence line through this site, it is likely that the eastern part falls within the Clevedale Station property. Land acquisition may therefore be a constraint with this site.	7, 8 & 9

Option	Description	Figures
Site 10 TSF	A central discharge layout formed by a main embankment around the western side and a small saddle dam on the eastern side. The layout represents a “race-track” shape and deposition would be via a causeway that extends along the main axis, forming a spine in the middle of the storage area for tailings deposition. The site is located approximately 5 km to the east of the processing plant and approximately 2 km to the north of Menindee Road. Tailings delivery and return water pipelines would extend over an approximate distance of 8.5 km from and to the processing plant, requiring crossings at the railway line and Menindee Road. At its nearest, the railway is located 300 m to the north-west. The layout would shed supernatant water and rainfall runoff to the periphery. Further refinement to the layout would allow for drainage to nominated gravity decant structures, where water would be discharged to externally located Decant Dams. Decant Dams are sized for management of the “Extreme Storm Storage Allowance” under ANCOLD guidelines. Due to the siting of the TSF and alignment of the embankments, the drainage catchment is relatively small at approximately 110 ha. This area would be further reduced to approximately 95 ha by construction of a low height bund between the embankments on the southern side. The accumulation of water in the Decant Dams would be intermittent due the relatively high evaporation. Water that does pond in these dams would be pumped back to the processing plant for reuse in the mill. Due to its location within the Stephens Creek Reservoir, it is likely that a geosynthetic liner would be required over the tailings impoundment area, the Decant Dam impoundments and the upstream slope of the respective storage embankments. The requirement for a liner would be subject to groundwater impact assessments and/or minimum regulatory requirements. There are no apparent land acquisition constraints, however, this would be subject to review of title boundaries for the area.	10 & 11

Option	Description	Figures
Site 11 TSF	The TSF basin is formed by a central discharge layout enclosed by a "horse shoe" shaped embankment around the northern side. Similar to the Site 10 TSF, the layout represents a "race-track" shape and deposition would be via a causeway that extends along the main axis, forming a spine in the middle of the storage area for tailings deposition. The site is located approximately 5 km to the south-east of the processing plant and 1 km to the south of Menindee Road. Tailings delivery and return water pipelines would extend over an approximate distance of 7.5 km from and to the processing plant. The TSF is positioned between existing houses and is immediately to the south of a motocross track. The Decant Dam extends over the motocross track area. Acquisition of private property would be required for development of a TSF at this site, including the areas where the houses are situated to provide a suitably safe buffer around the facility. The layout would shed supernatant water and rainfall runoff to the periphery. Further refinement to the layout would allow for drainage to a gravity decant structure, where water would be discharged to an externally located Decant Dam. The Decant Dam is sized for management of the "Extreme Storm Storage Allowance" under ANCOLD guidelines. Due to the siting of the TSF and alignment of the embankments, the drainage catchment is relatively small at approximately 100 ha. A low height bund would be formed at the southern side to further reduce the drainage catchment. The accumulation of water in the Decant Dam would be intermittent due to relatively high evaporation. Water that does pond in the dam would be pumped back to the processing plant for reuse in the mill. Due to its location within the Stephens Creek Reservoir, it is likely that a geosynthetic liner would be required over the tailings impoundment area and the upstream slope of the embankment. The requirement for a liner would be subject to groundwater impact assessments and/or minimum regulatory requirements.	12 & 13

7.2 Drainage catchments

A summary of tailings storage areas and catchment areas for each site is presented in Table 6. Descriptions of the terrain, including watercourses is provided in Section 5.4.

Table 6: Summary of tailings storage and catchment areas

Site	Tailings storage footprint (ha)	Tailings storage catchment area(Note 1) (ha)	Catchment area to tailings storage area ratio	TSF catchment area as a percentage of the Stephens Creek Catchment area
Kintore Pit(Note 2)	12.5	14	1.1	n/a
8(Note 3)	80	1025	12.8	2%
10(Note 4)	82	110	1.3	0.2%
11(Note 5)	79	101	1.3	0.2%

n/a = not applicable

Table 6 Notes:

1. Excluding Decant Dam catchment areas (for Site 10 and 11 TSF) and including Headwater Diversion Dam catchment area (for Site 8).
2. Catchment area mostly defined by the pit rim. Relatively small external catchment area.
3. Site is located over a watercourse that ultimately drains into the Stephens Creek Reservoir. A catchment diversion would be required if this option is to be developed.
4. Relatively small external catchment area due to the site being located off watercourses.
5. Relatively small external catchment area of Site 11 due to it being located at the head of a watercourse.

7.3 Tailings delivery

A review of tailings delivery distance and static head difference between the processing plant and the TSF site locations shows that a pipe with 200 mm internal diameter is sufficient to deliver tailings to the respective sites, under turbulent flow conditions. A summary of pump and pipe requirements for each option is presented in Table 7.

Table 7: Summary of tailings delivery characteristics

Site	Tailings delivery distance (km)	Maximum static head (m)	Internal pipeline diameter	Centrifugal pump pressure (kPa)	Number of 6/4 pumps in stages
Kintore Pit	2.5	13	200	990	1
8	9.5	-35	200	3160	3
10	8.5	-38	200	2615	3
11	7.5	-24	200	2465	3

The cost estimates presented in Section 8.0 allow for:

- One standby pump for each option.
- Ultra-High Molecular Weight Polyethylene (UHMWPE) lined steel pipe. This pipe is consider durable against high temperatures and vandalism.

Each pipeline for the offsite TSF would be installed within a bunded corridor to manage potential leaks. An across road will be developed adjacent to the tailings delivery pipeline corridor.

7.4 Tailings deposition and rate of rise

A summary of the final tailings area and the rate of rise for each option is summarised in Table 8.

Table 8: Tailings storage area and rate of rise

Site	Final storage area (ha)	Rate of rise at end of filling (m/year)
Kintore Pit	12.5	3.7
8	80	0.6
10	82	0.6
11	79	0.6

The rate of rise at the Kintore Pit is relatively high at approximately 3.7 m/year by the end of filling. The potentially much higher rate of rise during early years could be addressed by a period of overlapping operation with the Blackwood Pit TSF.

The rate of rise at Sites 8, 10 and 11 is considered suitable for upstream raise consideration should sub-staging or expansion of these sites be considered. The concept design layouts are based on single stage construction.

7.5 Embankment characteristics

A summary of embankment layout characteristics for the TSF options are presented in Table 9.

Table 9: Summary of embankment characteristics

Site	Embank. Crest elevation (RL m)	Maximum embank. height(Note 1) (m)	Maximum embank. length (km)	Embank. volume (m^3)	Causeway crest (RL m)	Causeway volume (m^3)	Storage ratio(Note 2)
Kintore Pit	322	5	0.7	60,000(Note 3)	n/a	n/a	83
8	287.5	16	1.7	812,000	n/a	n/a	6
10	277(Note 4)	12	3.3	335,000	284.5	145,000	10
11	290(Note 4)	9	2.4	347,000	299	80,000	12

n/a = not applicable

Notes:

1. Measured at the downstream side.
2. Ratio of tailings storage volume to total volume of embankment and causeway fill.
3. Assumes Little Kintore Pit (located on southern side of the Kintore Pit is initially filled with waste rock.
4. Embankment crest elevation would be variable following further design, to achieve drainage to the decant facilities.

7.6 Surface water management layout and characteristics

7.6.1 Overview

Water management requirements vary between the options. An overview of the water management approach for each option is outlined below and key characteristics for embankments are summarised in Table 10.

- Kintore Pit TSF: supernatant water and stormwater that accumulates in the pit would be transferred by pumping to existing water management dams on the mine site.
- Site 8 TSF: supernatant water will be transferred via pumping from a pond that would form against natural ground and the tailings beach at its upstream toe. A small causeway would be used for pump access. To limit the extent of rainfall runoff into the tailings storage area, a Headwater Diversion Dam would be formed upstream of the tailings storage area. An outfall pipe would be installed to allow for the passive release of water to a point downstream of the TSF embankment. Emergency spillways would be provided at both the TSF and Diversion Dam embankments to safely discharge extreme rainfall events.
- Site 10 TSF: Decant Dams would be formed to the west and to the east of the tailings storage area, to collect water that is discharged via gravity decant systems and emergency spillways in the event of large rainfall events. Diversion drains would be formed either side of the Decant Dam impoundment areas, to limit runoff flows into the Decant Dams.
- Site 11 TSF: A Decant Dam would be formed to the north of the tailings storage area, to collect water that is discharged via a gravity decant system and emergency spillway in the event of large rainfall events. Diversion drains would be formed either side of the Decant Dam impoundment, to limit runoff flows into the Decant Dam.

A summary of Decant Dam and Headwater Diversion Dam characteristics for the TSF options are presented in Table 10.

Table 10: Summary of water dam embankment characteristics

Site	Dam type	Embank. Crest elevation (RL m)	Maximum embank. height(Note 1) (m)	Maximum embank. length (m)	Embank. fill quantity (m^3)
Kintore Pit	Not required – assumed use of Decant Dam constructed for the Blackwood Pit TSF raise				
8	Headwater Diversion Dam	281.5	4.0	950	41,400
10	Decant Dam - west	265.0	2.5	520	11,000
	Decant Dam – east	274.5	4.5	470	12,400
11	Decant Dam	281.5	3.0	750	23,000

Return water pumps and pipes are sized based on extraction of flood water. Extraction from the Decant Dam and supernatant pond areas via 280 mm diameter HDPE pipe and two centrifugal pumps. The pump and pipe for each option is sized based on return of up to 60 L/sec. This rate is representative of removal of the Extreme Storm Storage Allowance volume from the Site 10 and 11 Decant Dams, within a 7 day period. The sizing of the Decant Dams is discussed in Section 7.6.2, below.

7.6.2 Flood sizing assessment

Flood storage capacity in the Kintore Pit TSF will be provided over the tailings surface and will be sufficient for the Environmental Containment Freeboard. This design criteria represents a 1 in 10,000 AEP, 72-hour rainfall event, equivalent to a rainfall depth of 334 mm. For an approximate catchment area of approximately 14 ha, the estimated volume of rainfall for is approximately 47,000 m^3. Over a tailings storage of approximately 12.5 ha, this represents a pond depth of approximately 400 mm. The design freeboard of 1.5 m satisfies this storage volume and allows for spillway freeboard.

Flood storage capacity in the Site 8 TSF area is large, exceeding the estimated runoff volume from a 1 in 10,000 AEP 72-hour event.

The Decant Dams for Sites 10 and 11 are sized on the basis of containing the ‘Extreme Storm Storage Allowance’. For a ‘High’ consequence category, this represents a 1 in 100 AEP, 72-hour event. The rainfall depth for this event is approximately 136 mm. For estimated initial losses of 15 mm and 30% runoff of rainfall thereafter, approximately 41 mm depth of rainfall would reach the Decant Dam.

- Site 10 TSF: For the 110 ha catchment area, the combined flood storage capacity for the west and east Decant Dams is estimated to be 35,000 m^3. Allowing for an operational pond volume of 5,000 m^3, the combined storage capacity requirement is approximately 40,000 m^3.
- Site 11 TSF: For the 101 ha catchment area, the flood storage capacity for the Decant Dams is estimated to be 31,000 m^3. Allowing for an operational pond volume of 5,000 m^3, the combined storage capacity requirement is approximately 36,000 m^3.

Emergency spillways have not been sized at this concept design stage. Allowances for spillways are, however, included in the cost estimates presented in Section 8.0.

7.7 Construction

7.7.1 Embankment and causeway materials

The concept designs for each option are based on utilisation of waste rock from stockpiles at the Rasp Mine. In the event that an offsite TSF were considered, further work could be undertaken to identify potentially lower cost sources of materials, i.e. from borrow pits adjacent to or within the TSF locations.

Consideration of a staged construction approach would allow for the potential use of tailings as a low cost embankment construction material.

Based on observation of the outcropping rock along the western margins of the Site 8 TSF (and eastern margin of the Site 10 TSF), sourcing rockfill from quarries is likely to represent a higher cost due to the requirement for drill and blast.

7.7.2 Geosynthetic liner

A robust geomembrane liner would be provided for the TSF options to allow for a potentially rough subgrade and UV exposure until it is ultimately covered by tailings deposition. Cost estimates presented in Section are based on supply and installation of a bituminous geomembrane liner. A LLDPE geomembrane liner is proposed for upstream slope of the embankment for the Kintore Pit TSF, similar to the design for the Blackwood Pit TSF.

7.8 Seepage management

An underdrain is proposed for the Kintore Pit to reduce the pore water pressures in the tailings at the base of the pit. This measure will improve consolidation of the tailings in the early stages of tailings deposition and also reduce possible seepage from the base of the pit into the old workings and the existing decline and access ramp system. The drain will comprise a layer of aggregate placed over the pit floor to collect and drain seepage water towards the decline portal. Some reshaping of the pit floor would initially be required to create a cross fall to the portal area. A seepage outlet pipe would be installed through the concrete plug at the portal entrance and also through the northern ramp plug to facilitate discharge of tailings seepage water into the northern workings where it would be removed by the existing mine dewatering system.

Should BHOP require that the volume of seepage water into the mine workings be reduced the design and installation of a filter press plant may be considered to increase the density of the tailings at the plant (and reduce the volume of seepage water). This approach may be considered as part of future design work. (Refer Section 10.0)

For the Site 8, 10 and 11 TSFs, a seepage collection drain would be installed at the upstream toe of the TSF embankment for collection and discharge of seepage water. Discharge would be via outfall pipes through the foundation of the embankment, or alternatively via extraction pipes installed at the upstream face of the embankment.

7.9 Kintore Pit decline and waste rock

7.9.1 Management of waste rock

Removal of the waste rock stockpile prior to commencement of tailings deposition is not considered practical due to the cost of double handling if relocating it outside of the pit, and the lack of an alternative site within the mine lease area. Future waste rock placement is likely to be in the Old BHP Pit and also the Little Kintore Pit could be used for future waste rock placement. Some of the stockpiled rock may be suitable for use in the underdrain but would need to be screened to achieve the required particle size distribution. Screening and spreading of waste rock is not considered in the cost estimate presented in Section 8.0.

7.9.2 Closing of decline portal

A preliminary design has been prepared to plug the decline and access ramp tunnels. Three unreinforced concrete parallel sided monolithic concrete plugs are proposed, one to close the portal and one each in the access ramps leading to the current northern and southern workings and located under the pit wall slopes.

The rock face at the portal exterior and initial segment of decline is stabilised using cable anchors, mesh and shotcrete. It is assumed that rock excavations in access ramp tunnels are similarly supported.

A plug design guideline[6] was used to assess the minimum length required for plugs based on tailings placed into the pit to a maximum elevation of RL 320 m. The guideline incorporates input from a number of international design guides and published design criteria, including recommended factors of safety. Conceptual designs were prepared considering punching shear failure along the concrete/rock interface contact or through the rock mass, possible deep beam failure, hydraulic jacking of the rock surrounding the plug and hydraulic gradient and leakage of seepage water around the plug. The potential effect of a seismic event with an acceleration of 0.2g was also assessed.

Limited geotechnical information was available for the rock materials in the decline and access ramp tunnels or of significant geological structures within or crossing the pit. Conservative rock properties were therefore used in the analyses which are equivalent to a moderate to weak rock which is moderately jointed and with a Rock Mass Rating of 41.

The decline and access ramp tunnels connect to the current working areas to the north and south of the pit and the plugs must therefore provide protection against hydraulic pressure from seepage water from the tailings and also against a mud flow resulting from liquefaction of the tailings, either by a crown pillar collapse into the old workings and then into the access tunnels, or from the maximum design earthquake.

The analyses indicate a minimum plug length incorporating the recommended factors of safety of 20 m. Since the access ramp tunnels extend under the pit floor it is proposed that northern and southern plugs are located under or beyond the pit crests, where no old workings overlie the plugs. The portal and northern plugs are proposed to be formed by constructing barricades across the tunnel faces and filling with concrete transported through the decline tunnel. The southern plug will be located about 700 m from the decline portal and it is proposed that the plug is formed between barricades in the tunnel with concrete placed through a borehole drilled from surface to intersect the access ramp tunnel. Since the tunnel gradient is shallow the designs include measures for grouting the gap between the top of the concrete fill and the underside of the tunnel roof.

For this conceptual design it is proposed that the portal decline plug should be 20 m long and the northern and southern plugs should be 30 m long.

Additional geotechnical investigations will be required for preparation of preliminary and detailed design of the plugs. Investigations will include collection of RMR data for rock in the decline and ramp tunnels, detailed mapping of rock joints and geological structures at the proposed plug sites, and consideration of the likely condition and stability of old workings in the vicinity of the ramp tunnels and plugs. Depending on the results of these analyses it may be necessary to install additional rock support at the plug sites or to change the plugs to hitched (keyed) or possibly tapered configurations.

[6] Golder Associates Ltd(2006) "Plug Design Guidelines Applied to Mining Closure" The Peru Mineral Resources Reform Project, document 03-111 Plug _Guidelines_ April 18_V3 2006

7.10 Dust management

7.10.1 Overview

Dust management measures are likely to be required for each option due to their proximity to the township, homesteads and livestock stations.

7.10.2 Construction period

The risk of dust generation during construction is expected to 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 for the existing Blackwood Pit TSF to assess the potential for dust generation. To further reduce the potential for generation of dust during construction, the following measures would be adopted.

- 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.

The cost of dust suppression during construction is included in the earthwork rates for embankment fill placement.

7.10.3 Operation period

Following periods of discharge areas of tailings beach will slowly dry, changing from wet to moist conditions. A dust suppression system including reticulated sprinklers and use of a crusting agent, similar to that proposed for the Blackwood Pit TSF, could be considered for each of the offsite TSF options where continued drying of the tailings beach has the potential to result in a dust generating surface. Due to the relatively high rate of rise at the Kintore Pit, dust suppression is not likely to be required at the tailings surface is expected to stay relatively wet.

The cost of dust suppression measures are not included in the cost estimates for the options at this stage. Dust suppression measures are expected to be a relatively low cost item compared and fall well within the cost contingency allowance.

7.11 Closure strategy

Closure of a TSF requires management of the following:

- ***Safety*** – providing a final surface which does not expose the public to chemical and physical hazards.
- ***Stability*** – ability 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*** – limiting rainfall infiltration that may lead to transportation of contaminants either to groundwater and/or surface water bodies.
- ***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.

For concept design, a 500 mm thick cover of rockfill is proposed to limit erosion of the tailings surface at closure. The potential requirement for a low permeability barrier in the cover system would be subject to further work at detailed design based on the geochemical properties of the tailings.

Tailings delivery pipelines, return water pipelines and decant systems would be decommissioned. Additional rockfill would also be placed at the downstream slope of the TSF embankment for reshaping. For concept design, an average 1 m thick layer of waste across the downstream slope of the embankment is adopted.

8.0 QUANTITIES AND COST ESTIMATES

8.1 Quantities

8.2 Items and rates

A summary of items and rates for the TSF works, including closure, is presented in Appendix A. The rates have been established on the basis of recent Golder projects in regional NSW. For waste rock haulage, rates vary according to haulage distance. The following haulage distances have been considered:

- <u>Kintore Pit:</u> 1.5 km
- <u>Site 8:</u> 9 km
- <u>Sites 10 and 11:</u> 7.5 km

8.3 Preliminaries

Preliminaries include the following:

- Site establishment and disestablishment.
- On site and off site overheads.
- Construction management and supervision, including development of:
  - Safe work method statements
  - Construction drainage management plan
  - Other project related documentation.
- Travel, accommodation and meal costs for the contractor, assuming they are mobilised from outside of the Cobar township

The cost of preliminaries is estimated at $250,000 and covers both initial construction and closure works. It assumes mobilisation of a contractor based in Broken Hill.

8.4 Engineering services

Engineering services will be required to prepare and undertake the following:

- Geotechnical investigation
- Detailed design
- Construction tender documents
- Construction Quality Assurance (daily level 1 supervision of geosynthetics installation and periodic inspections and hold point inspections by the Design Engineer)
- Survey (set-out, control and pickup for progress payments and final as-constructed survey)

Engineering services are estimated as follows, based approximately on the extent of embankment fill placement and area for liner installation if required.

- <u>Kintore Pit TSF:</u> $500,000
- <u>Site 8 TSF:</u> $1,000,000
- <u>Sites 10 and 11 TSF:</u> $800,000

8.5 Contingency

A contingency is included in the cost estimates to allow for unforeseen events that may impact on the works for each option. The cost of contingency is estimated at 15% of the direct construction costs for both the TSF development and closure works.

8.6 Exclusions

The following have been excluded from the cost estimate:

- Cost of land acquisition
- Cost of developing a new decline or shafts in the event that the Kintore Pit TSF option is developed
- Cost of dam safety monitoring installation
- TSF operating costs, including tailings delivery and return water pump operation and general TSF management and maintenance costs.
- Post closure monitoring and maintenance
- Net present value and inflation discounting.

8.7 Summary

A summary of the capital cost estimates for the options, inclusive of closure works are presented in Table 11. A summary of the costs excluding geosynthetic liner installation over the impoundment areas of Sites 8, 10 and 11 is presented in Table 12. The costs for Sites 8, 10 and 11 are seven to ten times higher than the estimated cost for the Kintore Pit TSF.

Table 11: Cost estimates for TSF options – capital only

Item	***Cost estimate***			
	Kintore Pit	***Site 8***	***Site 10***	***Site 11***
Preliminaries	$250,000	$250,000	$250,000	$250,000
Closure of mine workings and construction of plugs (Kintore Pit), seepage management	$1,745,000	$255,000	$495,000	$360,000
Tailings and return water pumps, pipelines and access roads	$1,675,000	$6,060,000	$5,375,000	$4,750,000
TSF perimeter embankments & tailings delivery causeways	$500,000	$18,610,000	$10,575,000	$9,395,000
Water management embankments and diversions	$0	$1,625,000	$710,000	$630,000
TSF seepage barrier works	$225,000	$19,820,000	$19,795,000	$19,295,000
Decant Dam seepage barrier works	$0	$0	$1,855,000	$1,530,000
Spillways and gravity decant structures	$150,000	$100,000	$375,000	$250,000
Closure works	$770,000	$14,275,000	$12,875,000	$12,345,000
Sub-total	**$5,315,000**	**$60,995,000**	**$52,305,000**	**$48,805,000**
Engineering Services	$500,000	$1,000,000	$800,000	$800,000
Contingency	$870,000	$9,300,000	$7,965,000	$7,440,000
Total	**$6,685,000**	**$71,295,000**	**$61,070,000**	**$57,045,000**

Table 12: Summary of capital costs, without geosynthetic liner installation over the storage impoundments

Item	***Cost estimate***			
	Kintore Pit	***Site 8***	***Site 10***	***Site 11***
Total direct construction costs (excluding geosynthetic liner over impoundment area)	**$5,315,000**	**$42,630,000**	**$31,675,000**	**$29,145,000**
Engineering Services (approximately 5% of construction costs)	$500,000	$500,000	$500,000	$500,000
Contingency (approximately 15% of construction and engineering costs)	$870,000	$6,470,000	$4,825,000	$4,445,000
Total	**$6,685,000**	**$49,600,000**	**$37,000,000**	**$34,090,000**

9.0 OPTIONS RANKING ASSESSMENT

A ranking matrix was prepared based on a weighted assessment of capital costs and potential impacts, as summarised in Table 13. Relative scores (1 to 5, with 1 being the least favourable) for each aspect were assigned to each option to generate a percentage outcome. The ranking matrix is presented in Appendix D and the results are summarised in Table 14. The results show the Kintore Pit TSF option to be the most favourable, based on both cost and impacts.

Table 13: Ranking aspects and importance weightings

Aspect	Description	Applied weighting
Capital Costs Overall Importance Ranking = 50%	■ Land Acquisition *Cost of acquiring land that would be developed for tailings and associated water management.*	*15%*
	■ Tailings Delivery and Return Water, Access Roads *Cost of additional tailings delivery pipeline installation and associated pumping costs.*	*15%*
	■ Embankment Construction *Costs associated with material borrow, foundation preparation, and construction.*	*30%*
	■ Liner Installation *Costs associated with supply and installation of a geosynthetic liner over the TSF and Decant Dam impoundment areas.*	*40%*
	Total	*100%*
Impacts Overall Importance Ranking = 50%	■ Social Perceptions / Constraints *This aspect considers the potential issues associated with local land holders surrounding the proposed TSF and permitting constraints that may be imposed.*	*20%*
	■ Dam Break Risk *This aspect considers the people, infrastructure and environment effected in the unlikely event of a dam failure.*	*35%*
	■ Environmental - dust *This aspect considers the potential for dust generation during construction and operation.*	*20%*
	■ Environmental – groundwater and surface water *This aspect considers the potential impact on groundwater and surface water, particularly with respect to potential impact on the Stephens Creek Reservoir – Broken Hill’s water supply*	*25%*
	Total	*100%*

Table 14: Options Ranking

Option	**Relative total (%)**	**Overall ranking**
Kintore Pit TSF	73	1
Site 8 TSF	45	4
Site 10 TSF	56	2
Site 11 TSF	50	3

10.0 FUTURE WORK

10.1 Kintore Pit

10.1.1 Risk assessment

A risk assessment should be undertaken for the Kintore Pit TSF, if this option is progressed. The assessment should include a review of recent and old workings through and adjacent to the Pit to identify appropriate design controls.

10.1.2 Filter tailings assessment

Installation of a filter plant to further dewater the tailings would provide benefits associated with less supernatant water and associated seepage risks as well as a higher average dry density and higher storage potential. Consideration should be given to assessing the feasibility of a filter press plant, if the Kintore Pit option is progressed. Note, filter tailings is not considered viable for the offsite TSFs based on the long haulage distance.

10.2 Property titles and land acquisition

A review of property titles and the cost of land acquisition should be undertaken, if any of the offsite TSFs are to be considered further.

10.3 Geotechnical investigation

If any of the offsite TSFs are to be considered further, a geotechnical investigation may identify areas of clay soil, suitable for borrow pit development to win embankment fill. The investigation would also focus on the foundation areas of the proposed embankments. It would include excavation of test pits for borrow pit and foundation investigation and drilling of boreholes for deeper foundation and hydrogeological assessment.

If the Kintore Pit TSF option is to be considered further additional geotechnical investigations are required to provide parameters for design of the decline and access ramp plugs. These investigations should include *in situ* mapping of exposed rock surfaces in the decline and access ramps at the plug locations, measurement of the unconfined compressive strength of the rock, mapping of joint orientations and roughness, and assessment of Rock Mass Rating and mass permeability. Structural geological assessments will include review of faulting and geological structures (including old workings) in the pit and in the rock above and around the plugs and assessment of crown pillar stability in areas where old workings are in close proximity to the plugs.

10.4 Preliminary and Detailed designs

If required by BHOP a preliminary design of one or two preferred options may be prepared, for selection of the final option. This would have the advantage of refining the designs of a surface TSF and of the Kintore pit option (if it is to be considered further) and allowing time for discussions of plugs and associated risks with the regulator, without delaying the preparation of an alternative TSF design. Alternatively BHOP may decide to proceed to directly to a detailed design of the preferred option to optimise the proposed design measures and associated costs. The design report would be submitted to the DSC, the mines department as well as the State environmental regulators for approval. For the Kintore Pit, the design report for the DSC may be delayed for some years into operation, until such a time that the embankment construction is required.

10.5 Construction documentation

Design drawings, technical specification, schedule of quantities and construction quality assurance plan would be prepared following completion of the design to facilitate the tender process.

11.0 CLOSING

This report presents concept level designs and cost estimates for TSF options for a 10 year extension to the Rasp Mine operation beyond mid-2021. The reader's attention is drawn to the Important Information presented in Appendix E.

Report Signature Page

GOLDER ASSOCIATES PTY LTD

David Accadia
Associate

Brian Wrench
Principal

DAA/BPW

A.B.N. 64 006 107 857

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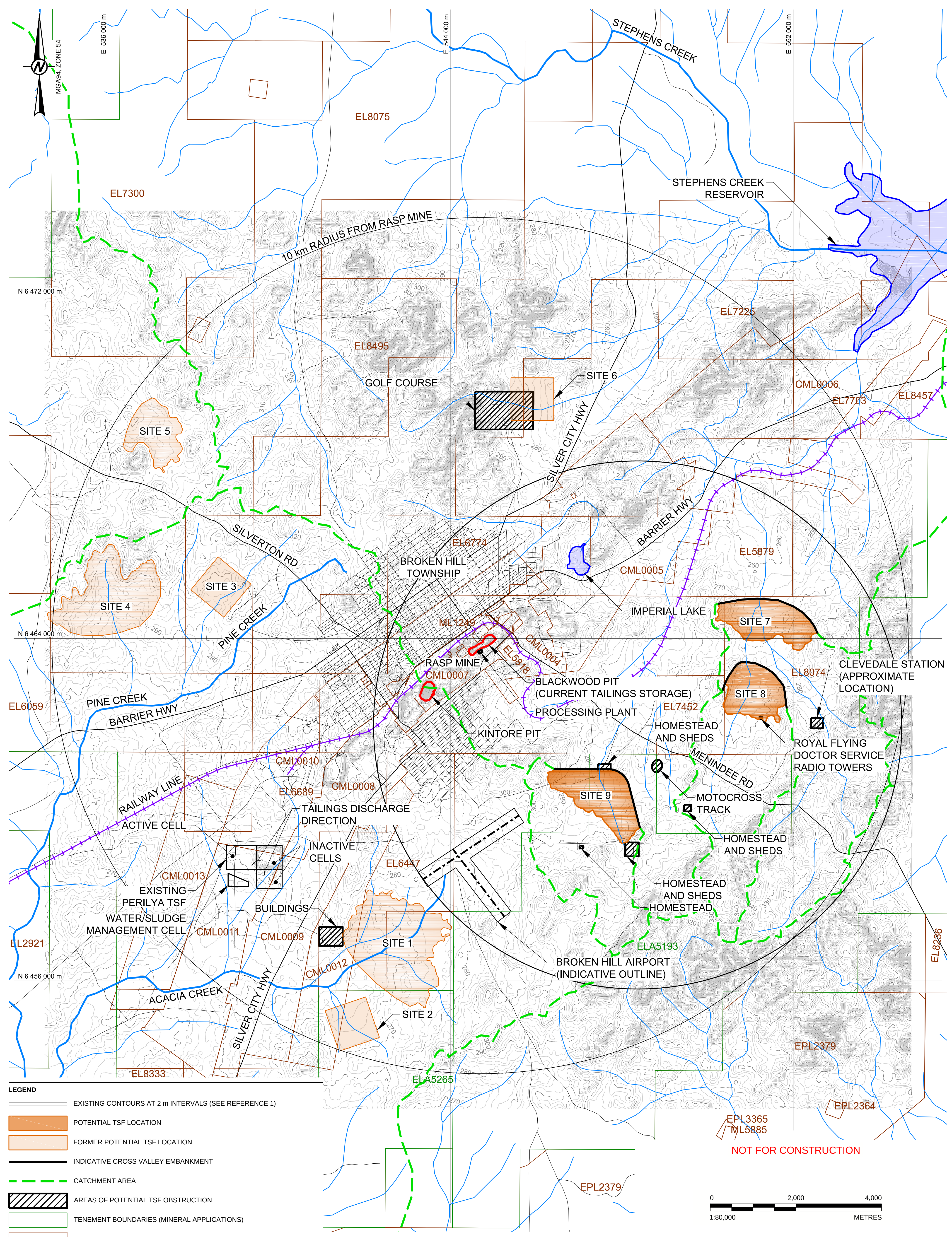

LEGEND

- EXISTING CONTOURS AT 2 m INTERVALS (SEE REFERENCE 1)
- POTENTIAL TSF LOCATION
- FORMER POTENTIAL TSF LOCATION
- INDICATIVE CROSS VALLEY EMBANKMENT
- CATCHMENT AREA
- AREAS OF POTENTIAL TSF OBSTRUCTION
- TENEMENT BOUNDARIES (MINERAL APPLICATIONS)
- TENEMENT BOUNDARIES (MINERAL TITLES)
- ROAD AND CITY PROPERTY LINE
- CREEK/DRAINAGE LOCATION

REFERENCES

1. GROUND SURVEY CREATED USING .ASCI FILES TAKEN FROM STRM DIGITAL ELEVATION MODEL, THROUGH GEOSCIENCE AUSTRALIA.
2. BASE DATA TAKEN FROM NSW GOVERNMENT WEBSITE, "nswtitles.minerals.nsw.gov.au/nswtitles/".
3. CREEK DATA TAKEN FROM AUSTRALIAN HYDROLOGICAL GEOSPATIAL FABRIC (GEOFABRIC) DATA PRODUCT SPECIFICATION, VERSION 2.1, DATED NOVEMBER, 2012.

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CONSULTANT
Golder Associates

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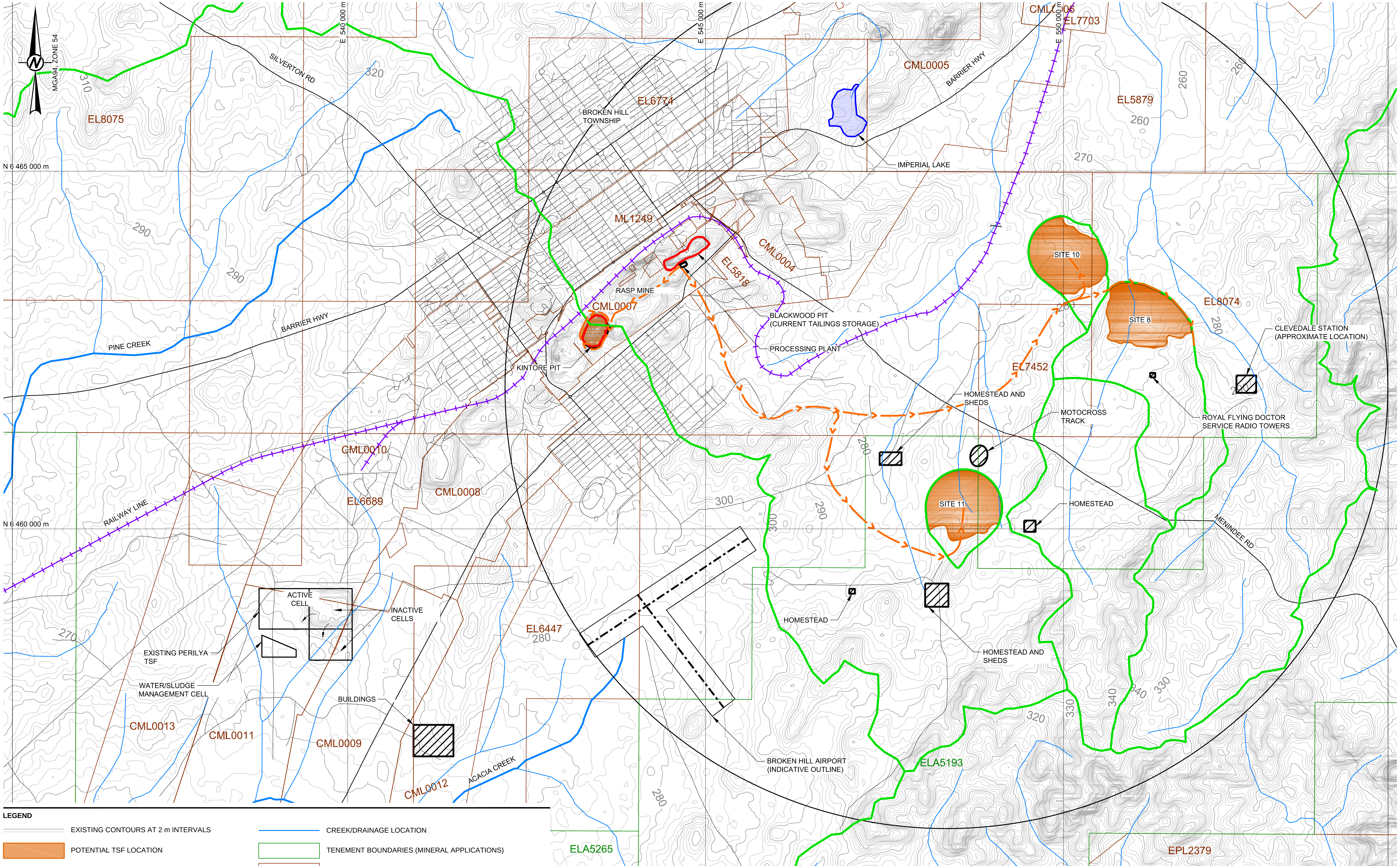
DESIGNED	DAA
PREPARED	DAT
REVIEWED	BRW
APPROVED	BRW

PROJECT
TSF SITING ASSESSMENT
RASP MINE, BROKEN HILL

TITLE
TSF SITING ASSESSMENT PLAN
INITIALS 30 YEAR STORAGE OPTIONS

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	1



LEGEND

- EXISTING CONTOURS AT 2 m INTERVALS
- POTENTIAL TSF LOCATION
- INDICATIVE CROSS VALLEY EMBANKMENT
- AREAS OF POTENTIAL TSF OBSTRUCTION
- CATCHMENT AREA
- ROAD AND CITY PROPERTY LINE
- CREEK/DRAINAGE LOCATION
- TENEMENT BOUNDARIES (MINERAL APPLICATIONS)
- TENEMENT BOUNDARIES (MINERAL TITLES)
- PROPOSED TAILINGS DELIVERY PIPELINE ROUTE

NOTE(S)
1. REFER TO FIGURE 1 FOR REFERNCES

0 1,000 2,000
1:50,000 METRES

NOT FOR CONSTRUCTION

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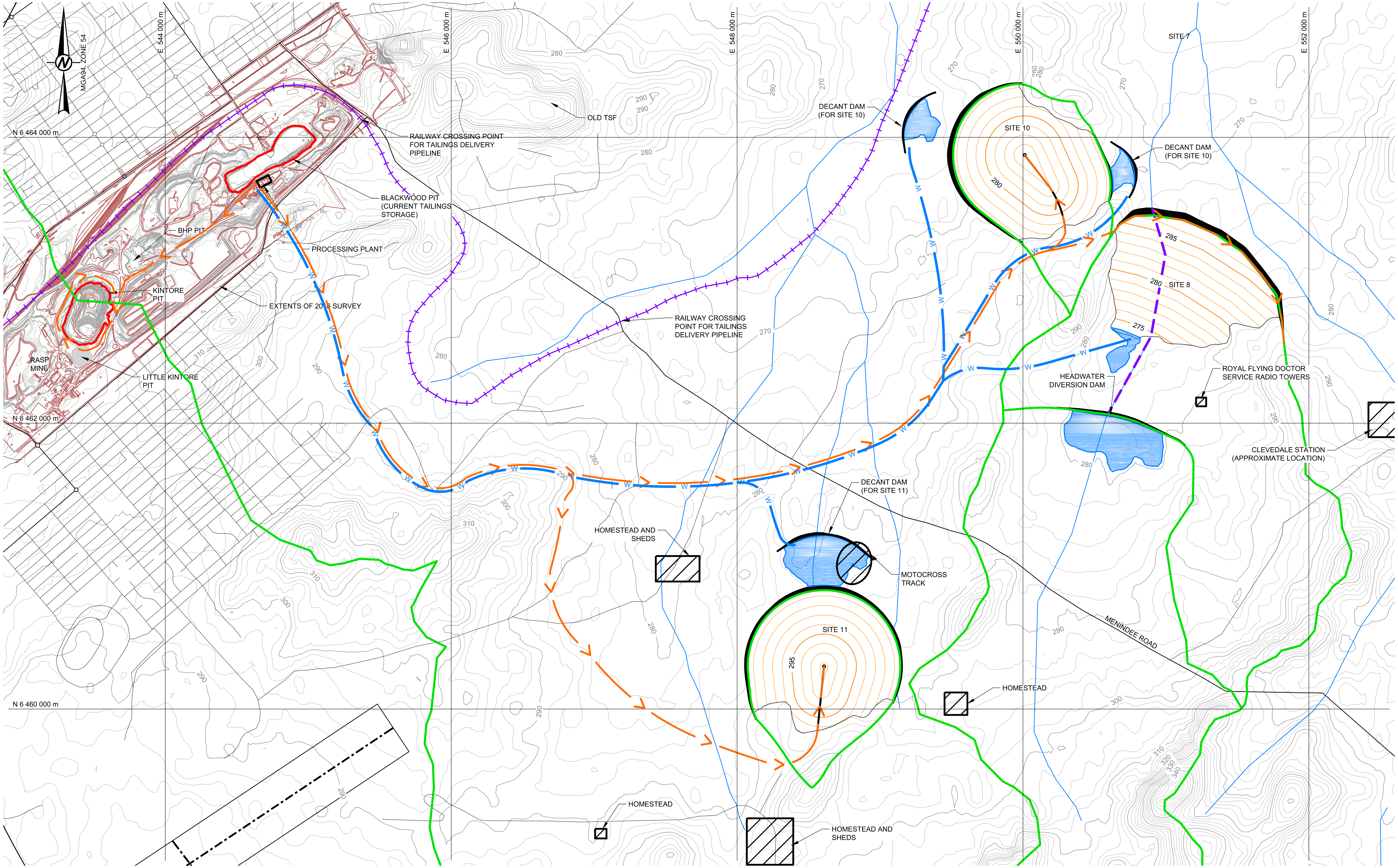
APPROVED	BRW

TITLE
AVAILABLE TSF SITE OPTIONS FOR FURTHER ASSESSMENT
10 YEAR STORAGE LAYOUTS (SITES 8 TO 11)

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	2



LEGEND

EXISTING CONTOURS AT 2 m INTERVALS

POTENTIAL SITING CONTOURS AT 1 m INTERVALS

PIT LOCATION

ROAD AND CITY PROPERTY LINE

CREEK/DRAINAGE LOCATION

PROPOSED TAILINGS DELIVERY PIPELINE ROUTE

PROPOSED RETURN WATER PIPELINE ROUTE

NOTE(S)

1. REFER TO FIGURE 1 FOR REFERENCES

NOT FOR CONSTRUCTION

0 500 1,000

1:25,000 METRES

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PROJECT
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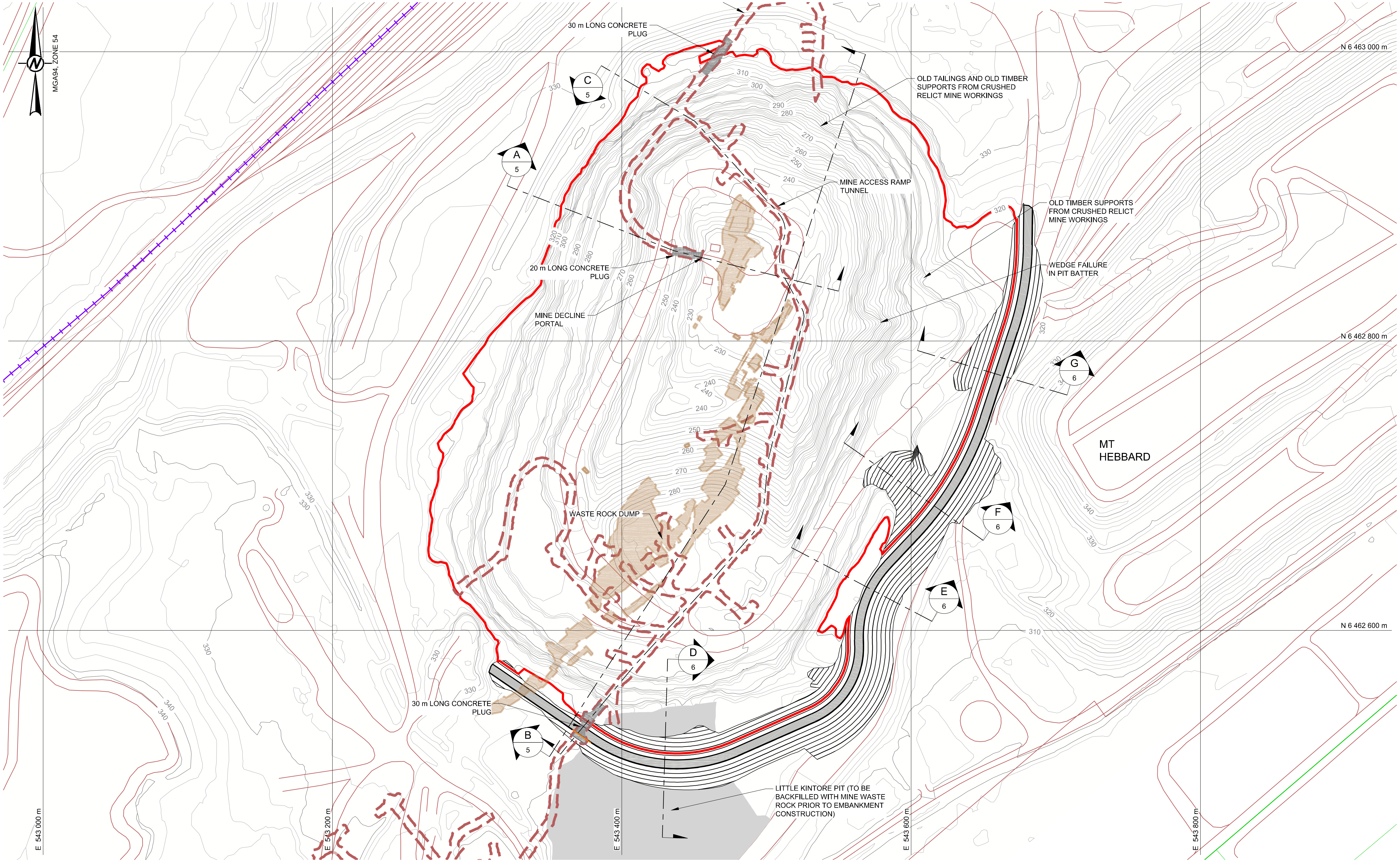
TITLE
TAILINGS STORAGE FACILITY OPTIONS

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	3

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



LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- KINTORE PIT EMBANKMENT CONTOURS AT 1 m INTERVALS
- KINTORE PIT EXTENTS
- WORKINGS TUNNEL PROVIDED BY CBH RECEIVED 31 AUGUST 2017 FROM FILE rasp_workings_kintore_mga.DXF
- OLD WORKINGS TUNNEL PROVIDED BY CBH RECEIVED 31 AUGUST 2017 FROM FILE old_workings_b10b7_mga.DXF

NOTE(S)

1. REFER TO FIGURE 1 FOR REFERENCES

NOT FOR CONSTRUCTION

0 50 100
1:2,500 METRES

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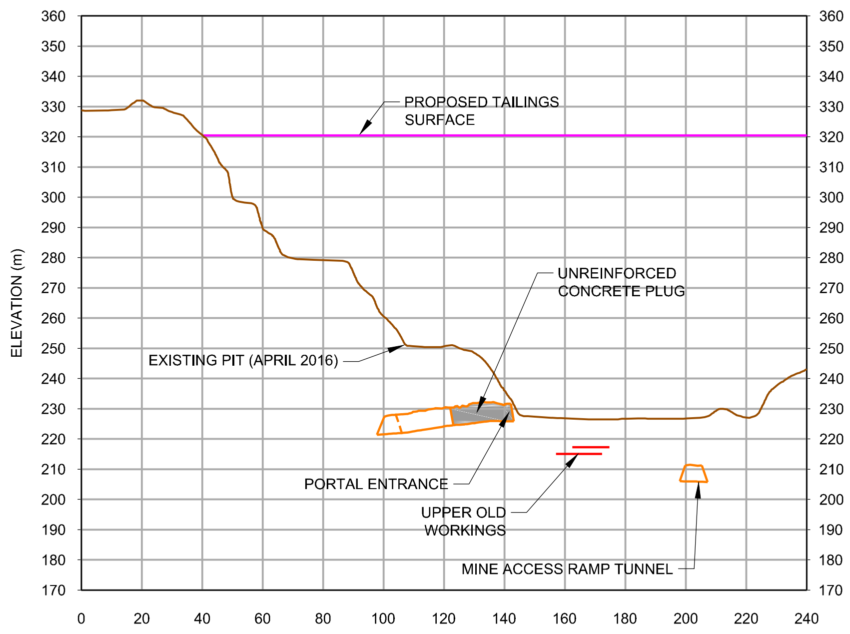
TITLE
KINTORE PIT - IN-PIT TAILINGS STORAGE GENERAL LAYOUT

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	4



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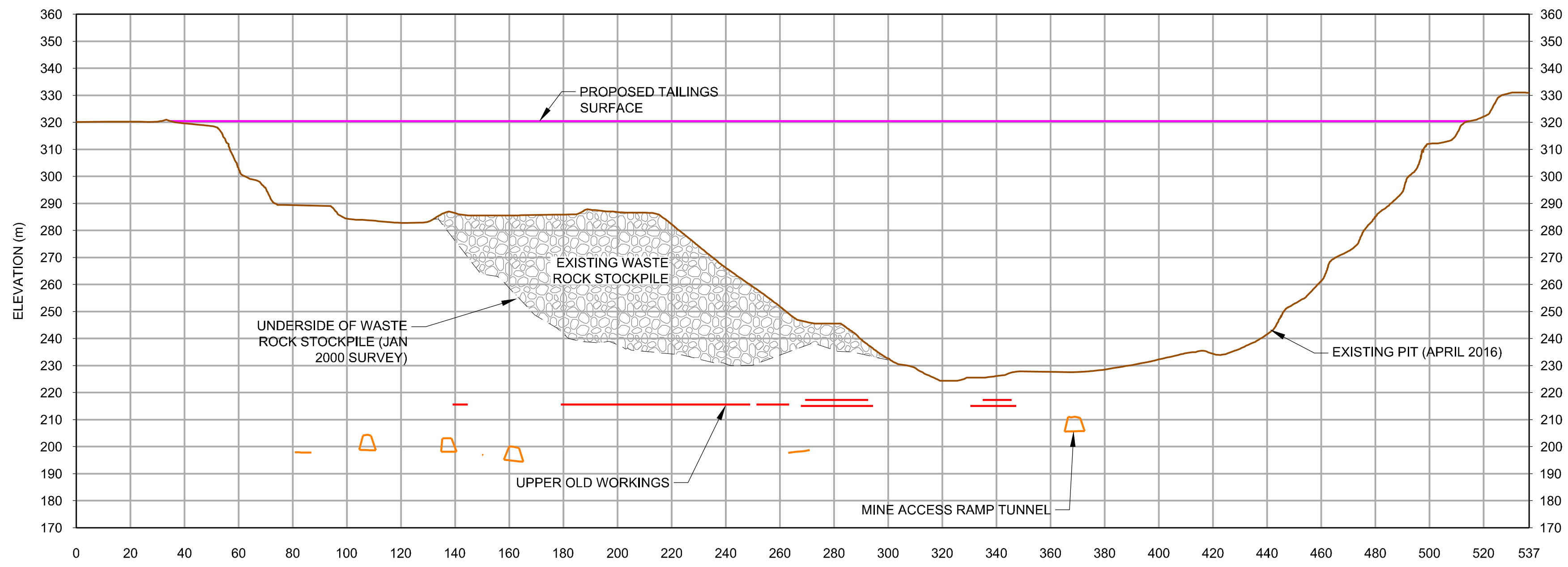
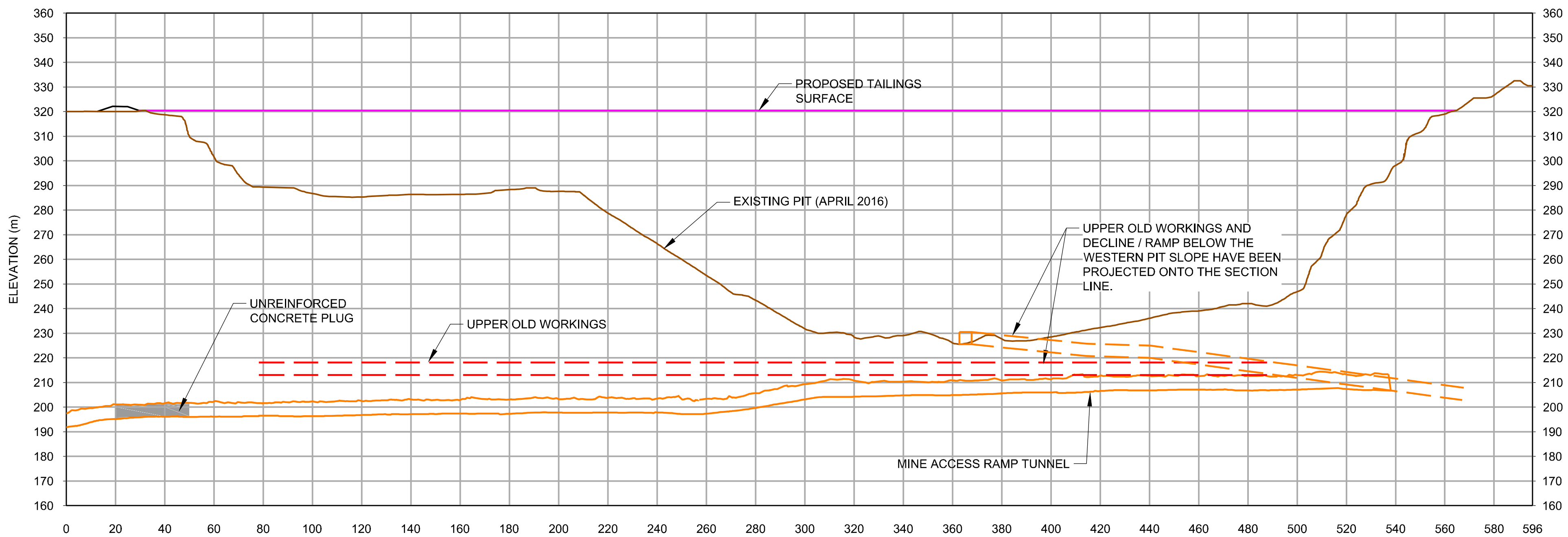


SCALE 1:2,500 B 4 SECTION THROUGH KINTORE PIT NORTH-SOUTH

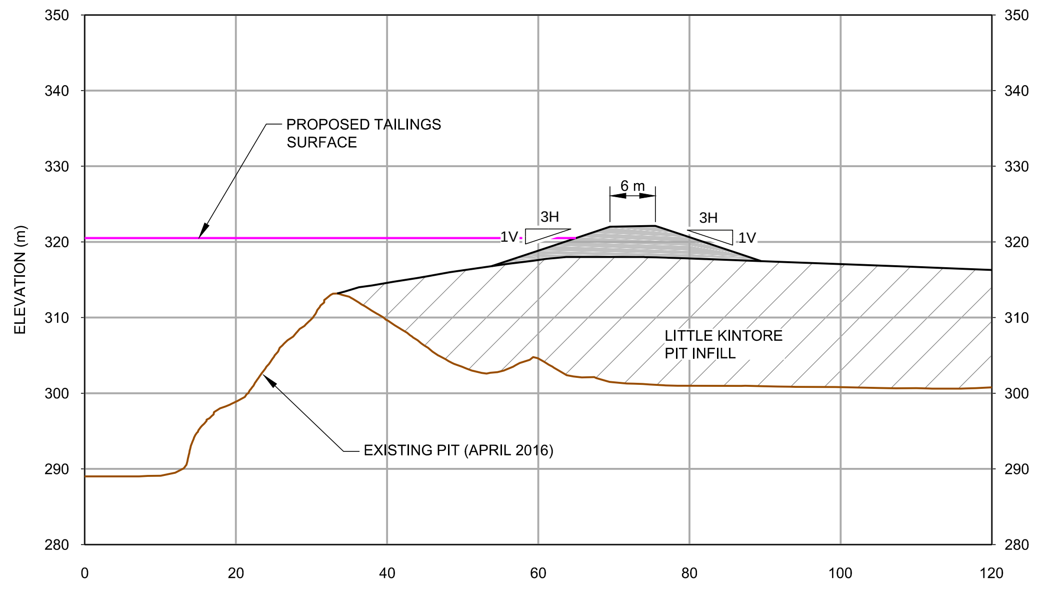


SCALE 1:2,500 C 4 LONG SECTION OF WORKING DECLINE TUNNEL

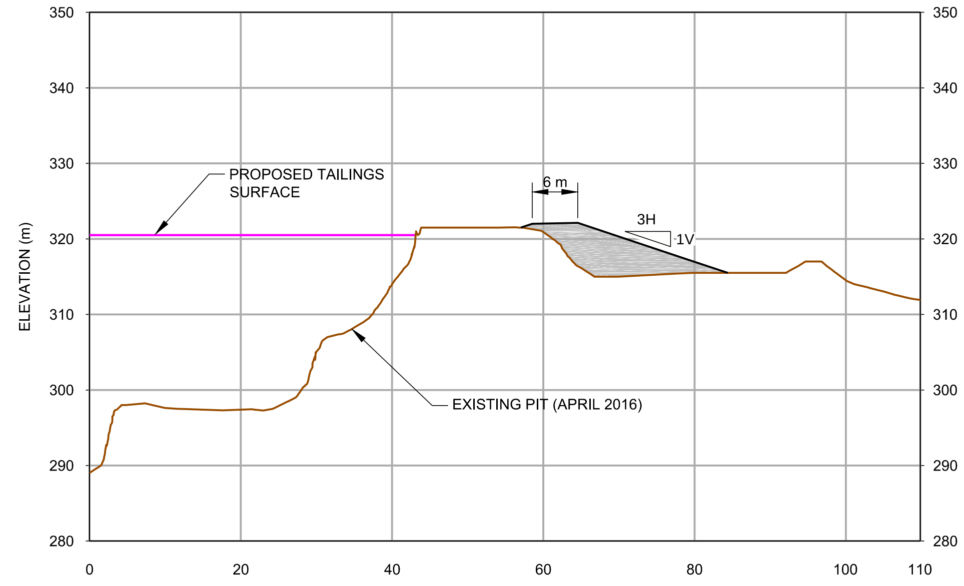
NOT FOR CONSTRUCTION

0 50 100
1:2,500 METRES

CLIENT BROKEN HILL OPERATIONS PTY LTD		PROJECT TSF SITING ASSESSMENT RASP MINE, BROKEN HILL	
CONSULTANT	YYYY-MM-DD: 2017-09-15	TITLE **KINTORE PIT - IN-PIT TAILINGS STORAGE SECTIONS SHEET 1**	
Golder Associates	DESIGNED: DAA		
	PREPARED: DAT		
	REVIEWED: BRW	PROJECT NO. 1776899	CONTROL 005-R
	APPROVED: BRW	REV. 0	FIGURE 5



SCALE 1:1,000 D 4 SECTION



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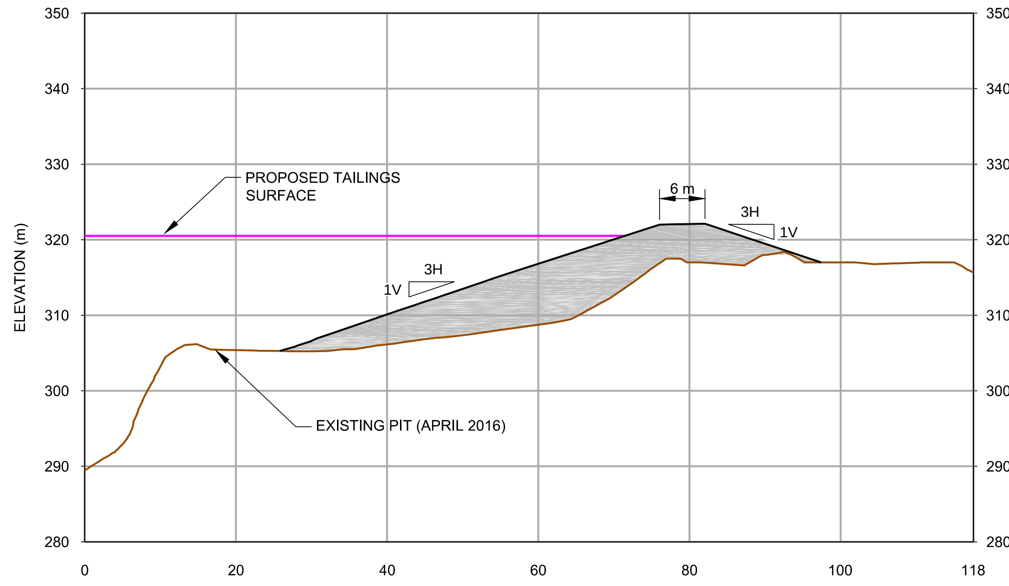

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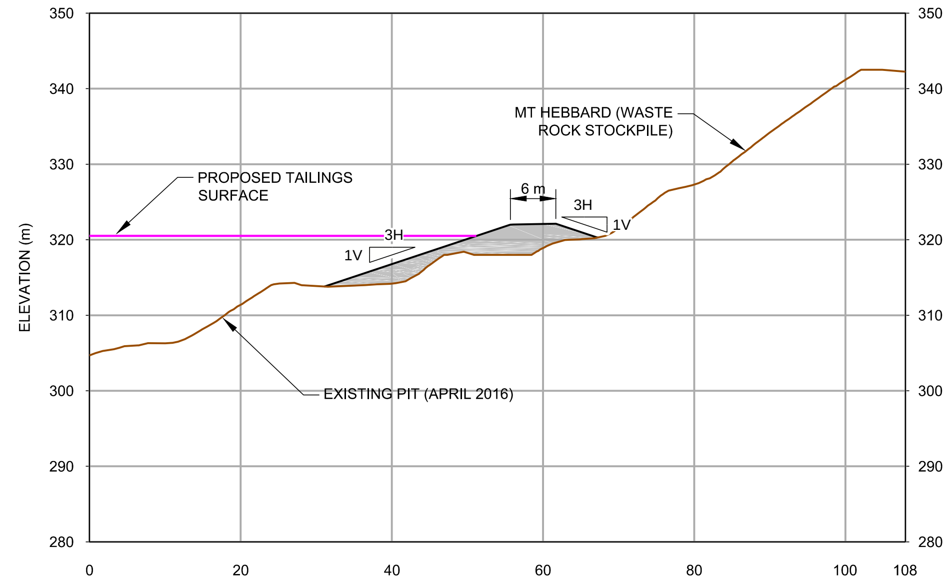

SCALE 1:1,000 G 4 SECTION

NOT FOR CONSTRUCTION

0 25 50
1:1,000 METRES

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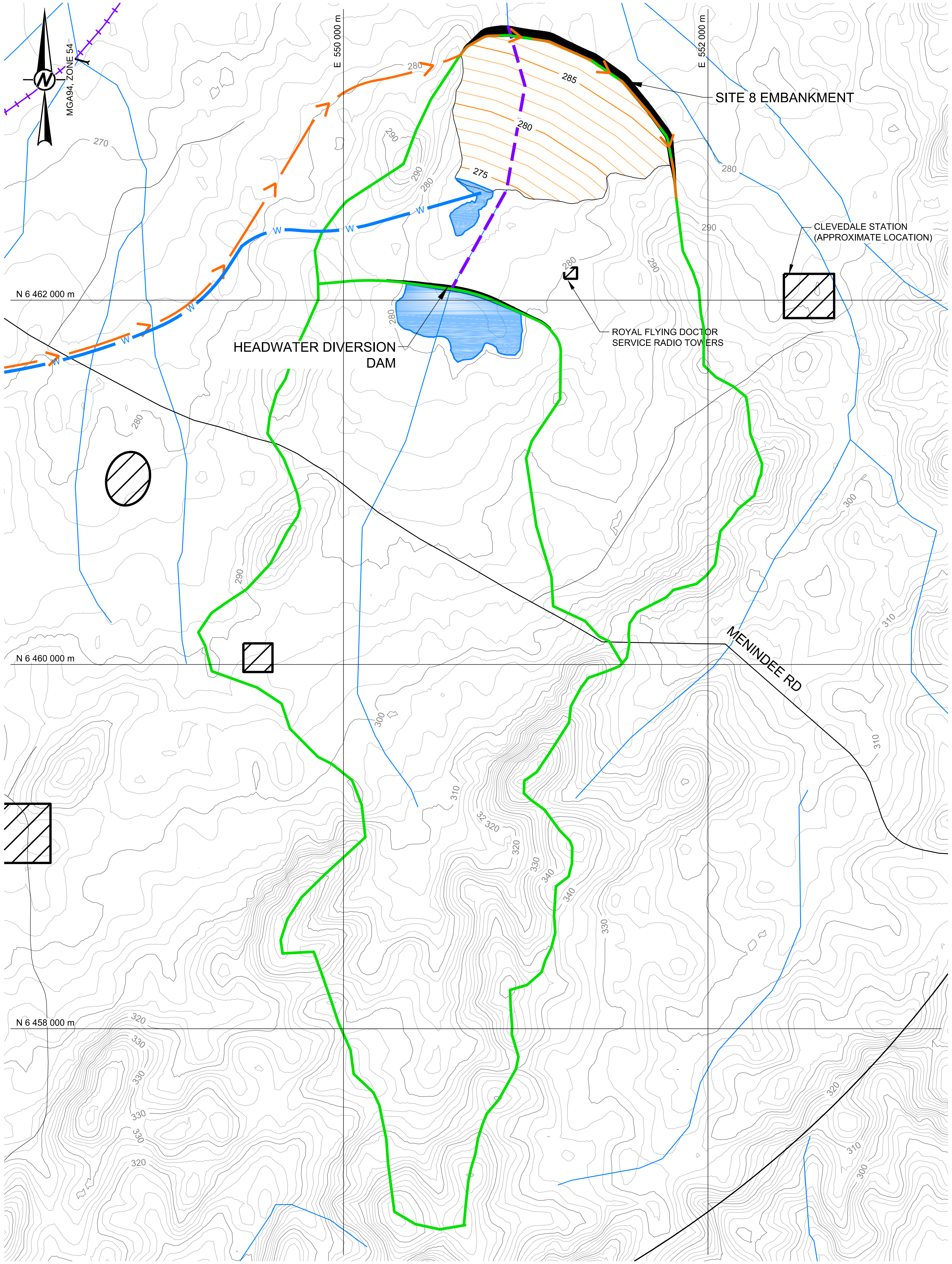
APPROVED	BRW

TITLE
KINTORE PIT - IN-PIT TAILINGS STORAGE SECTIONS SHEET 2

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	6



LEGEND

- EXISTING CONTOURS AT 2 m INTERVALS
- PROPOSED TSF EMBANKMENT DESIGN CONTOURS AT 1 m INTERVAL
- PROPOSED TAILINGS BEACH DESIGN CONTOURS AT 1 m INTERVAL
- AREAS OF POTENTIAL TSF OBSTRUCTION
- CATCHMENT AREA
- ROAD AND CITY PROPERTY LINE
- CREEK/DRAINAGE LOCATION
- PROPOSED TAILINGS DELIVERY PIPELINE ROUTE
- PROPOSED RETURN WATER PIPELINE ROUTE
- HEADWATER DIVERSION OUTFALL PIPE

NOTE(S)

1. REFER TO FIGURE 1 FOR REFERENCES

NOT FOR CONSTRUCTION

0 500 1,000

1:25,000 METRES

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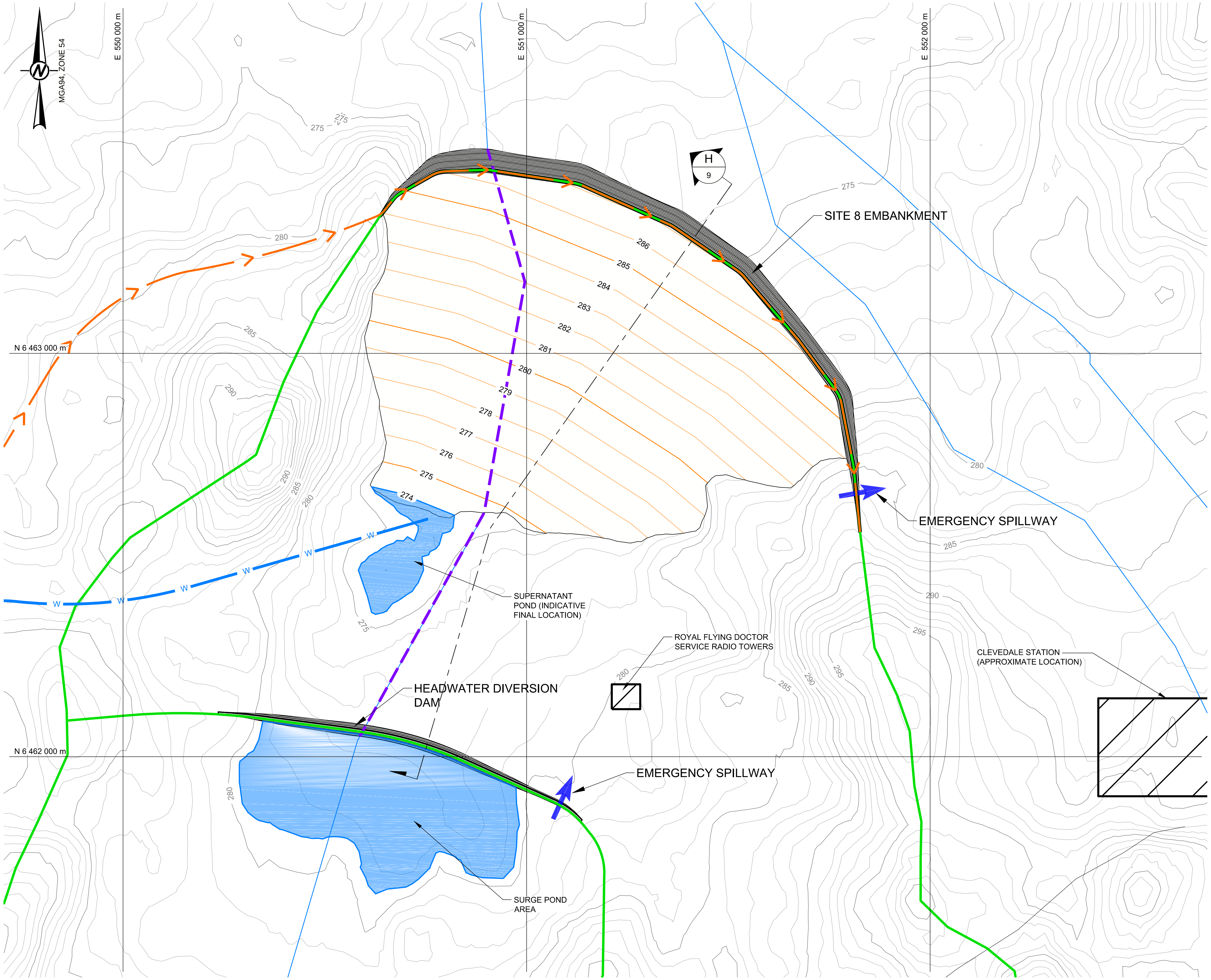
TITLE
SITE 8 - TAILINGS STORAGE FACILITY CATCHMENT PLAN

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	7



LEGEND

- EXISTING CONTOURS AT 1 m INTERVALS
- PROPOSED TSF EMBANKMENT DESIGN CONTOURS AT 1 m INTERVAL
- PROPOSED TAILINGS BEACH DESIGN CONTOURS AT 1 m INTERVAL
- AREAS OF POTENTIAL TSF OBSTRUCTION
- CATCHMENT AREA
- ROAD AND CITY PROPERTY LINE
- CREEK/DRAINAGE LOCATION
- PROPOSED TAILINGS DELIVERY PIPELINE ROUTE
- PROPOSED RETURN WATER PIPELINE ROUTE
- HEADWATER DIVERSION OUTFALL PIPE

NOTE(S)

1. REFER TO FIGURE 1 FOR REFERENCES

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0 250 500
1:10,000 METRES

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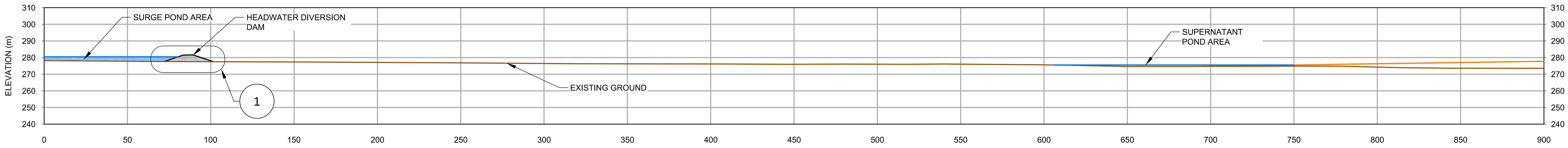
TITLE
SITE 8 - TAILINGS STORAGE FACILITY GENERAL LAYOUT

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	8



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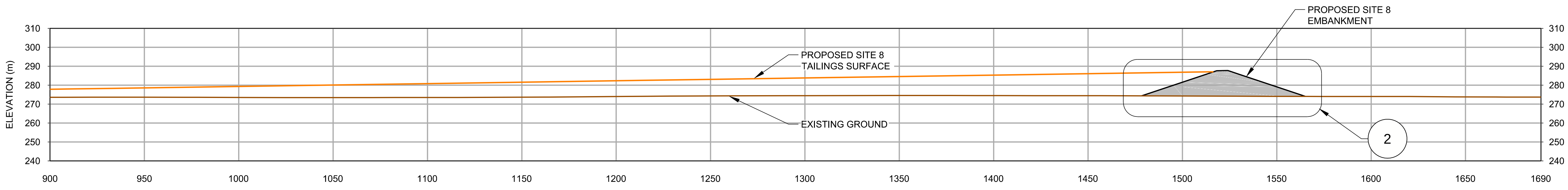

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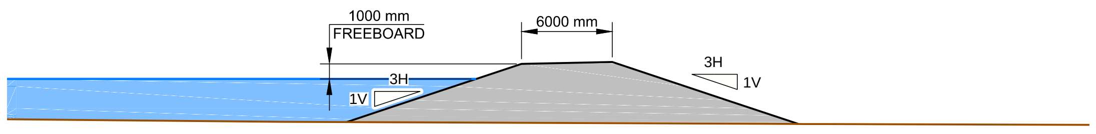

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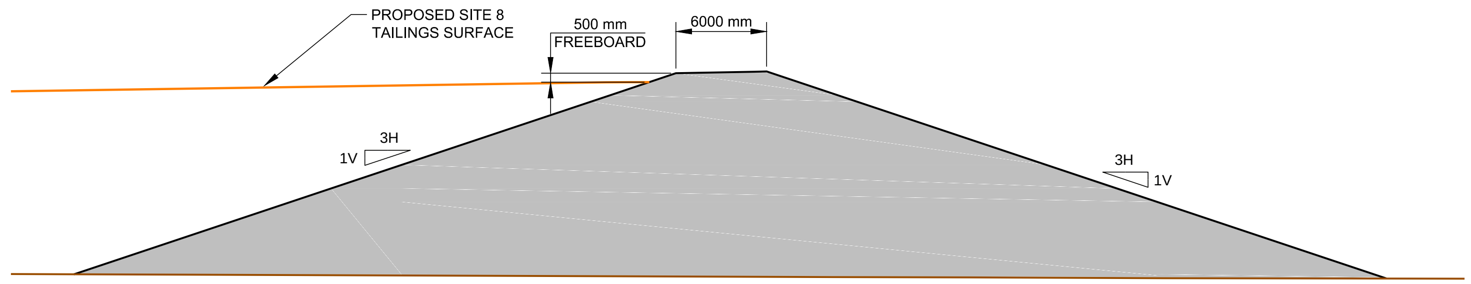

SCALE 1:500 2 TYPICAL EMBANKMENT DETAIL

NOT FOR CONSTRUCTION

0 10 20
1:500 METRES

0 50 100
1:2,500 METRES

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TITLE
SITE 8 - TAILINGS STORAGE FACILITY SECTIONS

PROJECT NO.	CONTROL	REV.	FIGURE
1776899	005-R	0	9