Design
for a better
future /

Mandalay Resources - Costerfield

Brunswick West Tailings Storage Facility

Groundwater assessment

wsp

ADVERTISED
PLAN

March 2023

Question today
Imagine tomorrow
Create for the future

Brunswick West Tailings Storage Facility
Groundwater assessment

Mandalay Resources - Costerfield

WSP
Level 11, 567 Collins St
Melbourne VIC 3000

Tel: +61 3 9861 1111
Fax: +61 3 9861 1144
wsp.com

ADVERTISED
PLAN

Rev	Date	Details
REVA	29/3/2023	Final

	Name	date	signature
Prepared by:	Tim Smith	20/3/2023	
Reviewed by:	Jason van den Akker	20/3/2023	
Approved by:	Jason van den Akker	20/3/2023	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

wsp

Table of contents

ADVERTISED PLAN

CONTENTS (Continued)

1 Introduction

WSP have been engaged by Mandalay Resources Costerfield Operations (MRCO) to review the proposed Brunswick West Tailings Storage Facility (herein referred to as 'the TSF') location and design with respect to existing and future hydrogeological conditions.

The goal of the assessment is to assess any potential risks to groundwater that may arise during the TSF's construction, operation, and closure phases.

1.1 Scope of Work

The scope of work addressed in this report included the following:

- Provide an overview of the TSF's design, including its layout, excavation depth and seepage control/collection system.
- Provide a description of the site's hydrogeological characteristics and the pre-mining groundwater conditions.
- Outline the current groundwater quality conditions and the environmental value(s), based on existing monitoring data.
- Evaluate the post-mining groundwater conditions, using groundwater modelling results from 2019 that simulated groundwater level recovery and flow paths post-mining.
- Provide a high-level assessment of potential groundwater risks and interactions with groundwater during the TSF's construction, operation, and closure phases.

1.2 Supporting studies

Previous reports relevant to the TSF and to the site hydrogeological conditions, which have been used in preparation of this assessment are listed as follows:

- Golder 2018 Conceptual Groundwater Model Report. This report characterised the groundwater systems beneath the TSF and surrounding mine area.
- Golder 2018 Numerical Groundwater Report. This report presented the outcome of groundwater modelling which was developed in 2018 and simulated current and future mining areas, aquifer recharge and post mining groundwater levels. For this present study, model results were used to assess post mining groundwater recovery and flow direction from the TSF area.
- Golder 2019 Geochemical Modelling of Antimony. This study evaluated the capacity of the Regional Basement Aquifer to attenuate antimony in mine water through aquifer injection. This work is of particular relevance to this study's context, especially with regards to the unforeseen risk of TSF seepage, as the aquifer's ability to attenuate antimony is of particular significance.
- ATC Williams Geotechnical (2022a) Brunswick West Tailings Storage Facility Investigation and Design Geotechnical Investigation and Laboratory Testing. This report characterises the shallow hydro-stratigraphy beneath the TSF area.
- ATC Williams (2022b) Brunswick West Tailings Storage Facility Investigation and Design Detailed Design Report

Figure 1 Site Location Plan

ADVERTISED PLAN

2 TSF Design

The site of the proposed Brunswick West TSF is located approximately 500 m north-west of the Brunswick Processing Plant, located within an adjacent farm paddock. The proposed design layout is presented on Figure 2. The site is roughly triangular in shape, and is confined by Crown Land to the east, MRCO infrastructure and additional farmland to the south, and Bradleys Lane to the west. The following provides an overview of the TSF design during operations, construction and closure taken from the detailed design (ATC Williams, 2022b)

Construction phase

- Foundation preparation involves stripping 0.5m of topsoil, excavating 0.5m of clayey material, and compacting the remaining clay.
- Foundations at farm dams and the ROM pad will be stripped to weathered rock.
- The impoundment will be excavated to an RL of 186 m and graded down to a minimum elevation of RL 180.0 m, providing the bulk of embankment construction material. This is some 50 m to 80 m above current day groundwater levels.
- The base of the facility will be lined with 1.0 m of select compacted clay won from stripping and excavation.
- An underdrainage network at the base of the impoundment, fed into the decant structure, will be constructed to aid in consolidation of the tailings.
- Hydraulic performance of the embankments will be provided by a Bituminous Geomembrane (BGM) liner installed on the embankment upstream face and connected to the base impoundment liner.

Operation phase

- The TSF operational concept involves deposition from a single point at the northernmost point of the facility.
- Occasional deposition from an additional 4-6 spigot points around the facility will help to shape the tailings beach.
- This arrangement will allow the tailings to beach to shape to a low point at the south-western corner of the facility against the embankments.
- An inclined decant filter structure will be constructed in the south-western corner of the facility where surface water will enter.
- The inclined decant structure comprises of three large HDPE pipelines with slots cut into them, wrapped in a UV resistant filter geotextile, and connected to a pre-cast concrete pit at the base of the embankment.
- The geotextile will allow water to migrate into the pipelines and filter down to the base pit, while preventing tailings from entering.
- Water will be pumped out of the pit via a submersible pump and sent to the external RWP (Return Water Pond).
- The external RWP effectively acts as a detention basin for the TSF, allowing for water to be continually removed from the TSF.
- All water collected within the external RWP is conveyed to either the Brunswick Process Plant or Augusta storage dams.

Seepage flux rates

- The Seep/W seepage assessment developed by ATC Williams (ATC Williams 2022b) shows with the BGM liner, the phreatic surface is controlled by the BGM liner. No significant saturation of the embankment section occurs, with the phreatic surface remaining very low, developing at a maximum of 1m above the clay foundations. Seepage from the downstream embankment toe (and reporting to the clean water diversion drains) is expected to be a maximum of 0.015 m^3/day/m length of embankment. Maximum seepage, based on 5.5 HA of total tailings beach is 5 m^3/day.

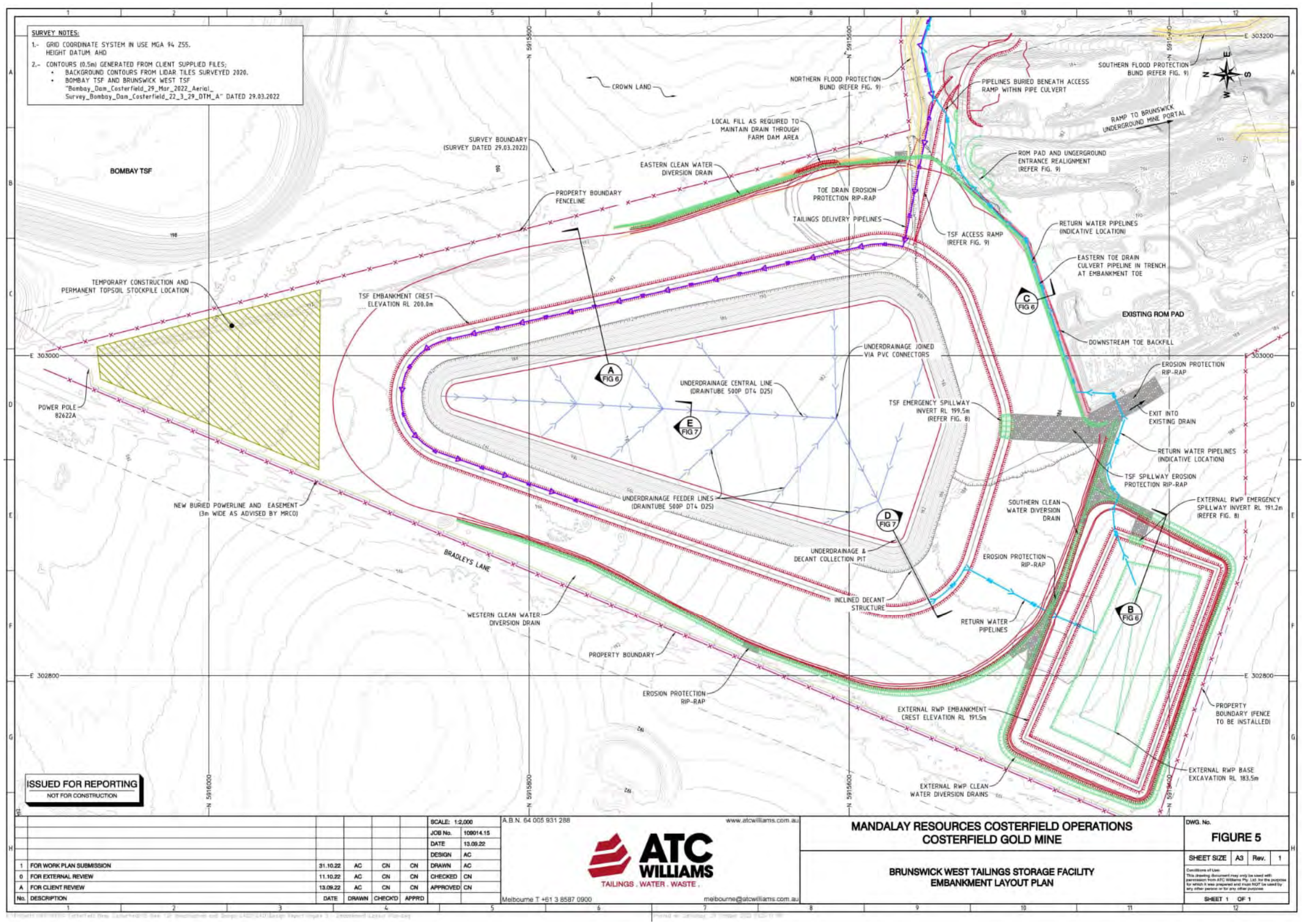
- Seepage losses to the environment are not predicted and modelling shows that TSF underdrainage is providing suitable drainage to prevent the build-up of excess water levels within the TSF tailings.

Closure phase

- A domed (convex), self-shedding cover with a nominal 5% grade;
- The cover layers will comprise a low permeability earthfill material, overlain by inert (i.e., non-acid generating) earthfill and weathered rockfill, and a final layer of topsoil to support revegetation;
- The low permeability earthfill material will be placed directly over the tailings surface and will be a minimum thickness of 0.5 m at the perimeter embankment, and increase in thickness over the tailing surface to the centre of the TSF to form a minimum 5% grade from the centre of the TSF towards the perimeter embankment;
- The earthfill and weathered rockfill will be placed over the earthfill material to a minimum thickness of 0.5m, and matching the underlying 5% grade of the landform;
- The topsoil material will be placed over the weathered rockfill to a nominal thickness of 300 mm.

ADVERTISED PLAN

Figure 2 TSF Design



3 Existing Groundwater Environment

3.1 Overview

Knowledge of the groundwater systems at the Costerfield Mine Area has been well documented previously and is summarised in the following section. Conceptualisation has been refined with respect to the reduced footprint of the proposed Brunswick West TSF at the mine site.

3.2 Hydro stratigraphy

The hydro-stratigraphic units within the region are:

- Shallow Alluvial Aquifer (SAA); and
- Regional Basement Aquifer (RBA).

The RBA occurs under the entire Study Area and the mining activities have largely been within this aquifer. The SAA is a minor aquifer situated along the confines of the modern-day water course valleys and is mostly dry.

3.2.1 Shallow Alluvial Aquifer

Several creeks and drainage valleys exist within the Study Area, including Wappentake Creek, Wappentake Creek Anabranch, Mountain Creek, Mountain Creek South, Tin Pot Gully Creek and Antimony Creek (Figure 3). Six monitoring wells, GN08, GN11, GN16, GN15, GN19 and GN21, were installed in 2005 to monitor groundwater within the SAA. However, groundwater has only been encountered in GN15 and GN19 (near Wappentake Creek) since groundwater monitoring began in 2005. Historically GN19 has become dry during periods of below average rainfall. However, following recharge events, the wells have recovered with GN15 indicating that the alluvium has experienced a saturated thickness that is greater than pre-mining conditions.

At the TSF site, extensive drilling and test pitting conducted report the SAA as absent (ATC Williams 2022a). It is known to be restricted to the confines of modern-day watercourses, which are located at least 1.25 km from the TSF area (Figure 3).

3.2.2 Regional Basement Aquifer

The RBA is a fractured rock aquifer which comprises Silurian metasediments siltstones and mudstone of the Murrindindi Supergroup and include the Costerfield Siltstone unit.

With respect to the groundwater flow conditions, the RBA is likely to behave as semi-confined fractured rock aquifer system, which can broadly be subdivided into the following sub-zones:

- Upper weathered zone. Approximately 20 m to 30 m thick zone of low hydraulic conductivity. This zone is inferred to be thicker in topographical lows and thinner on the topographical highs. Due to a high degree of weathering, the fractures associated with the main structural features tend to be closed and infilled with product of weathering resulting in a low transmissivity.
- Main fresh rock zone. This is a zone of a subregional groundwater flow system in which groundwater is stored and transmitted through fracture systems beneath the upper weathered profile of lower permeability. Hydraulic conductivity of the rock within this zone has been enhanced by regional faulting and fracturing. The fractures associated with major faults (King Cobra, Adder and Brunswick) tend to be open and clean, providing significant pathways for groundwater movement. Mining activities are generally contained within this zone.

- A deep aquifer zone. A zone of inferred low hydraulic conductivity rock with very long flow paths between areas of recharge and discharge. Although the major structural features extend through this zone, they are expected to become tighter and more closed with depth resulting in reduction of transmissivity with depth.

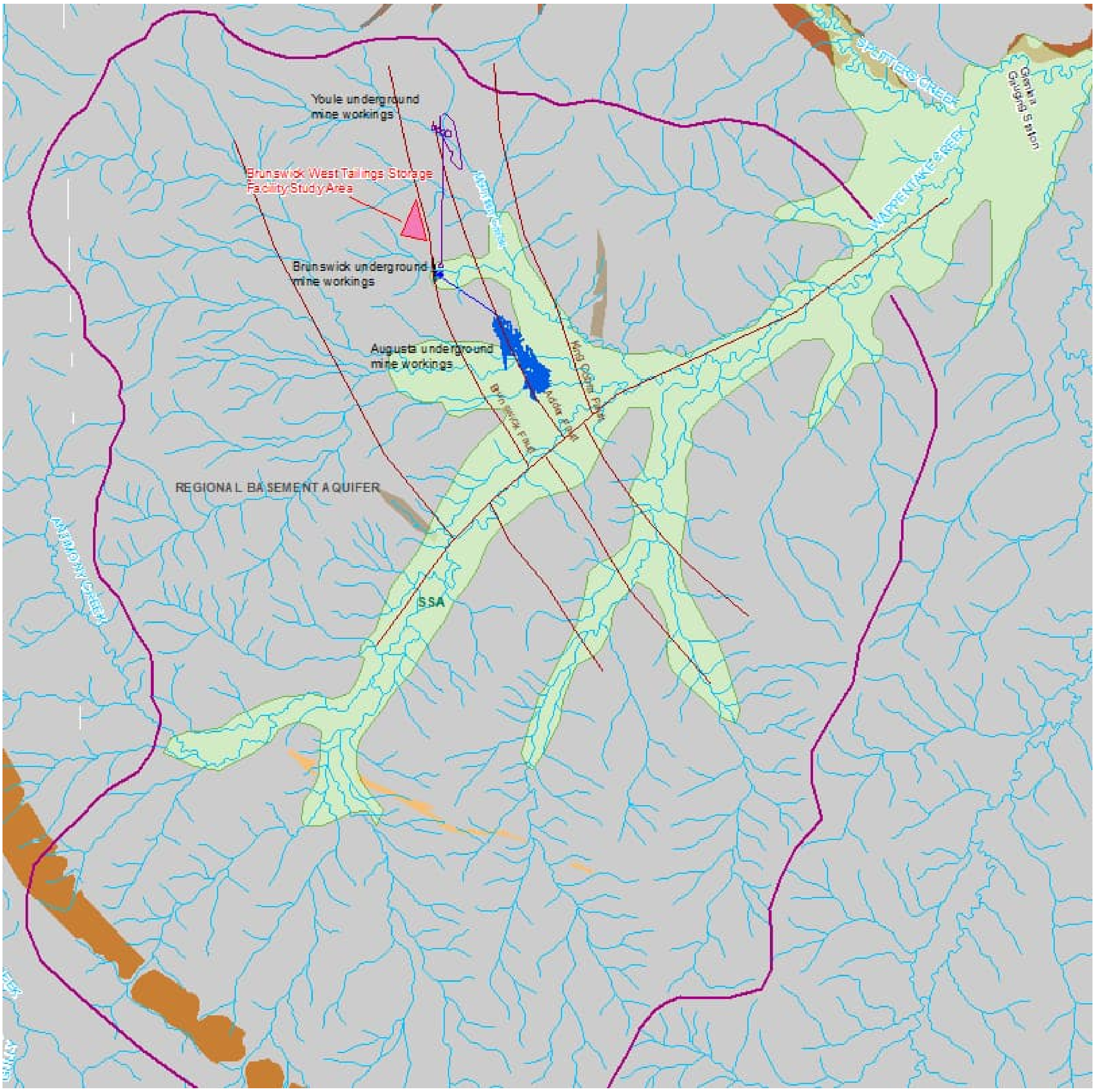


Figure 3 Surface geology and watercourses

ADVERTISED PLAN

3.2.3 Local stratigraphy beneath Brunswick West TSF area

The local stratigraphy has been investigated beneath the TSF footprint via 22 test pits and 12 drillholes within the upper weathered zone and is reported in ATC Williams (2022a). The local stratigraphy can be seen in drill core of borehole 10 (see Figure 4), which was drilled in the centre of the TSF footprint and is representative of the shallow lithology at the proposed impoundment area.

Important conclusions from this work revealed:

- The topsoil material (lost from drill core) at the site is generally classified as a mixture of Sandy Silt and Clayey Silt, generally soft with low strength, dry, and with vegetation. The depth of topsoil varies between 300 mm to 700 mm, with an average depth of 500 mm across the site.
- Extremely Weathered and Highly Weathered Siltstone occurs at shallow depth, with most of the holes encountering Moderately Weathered Siltstone once coring began at depth of ~ 1m below ground surface.
- No alluvium aquifer was encountered within the TSF site footprint.

Figure 4 Drill core – Borehole 10 (Source ATC William 2022a)

3.3 Aquifer Properties (Hydraulic Conductivity)

Based on drilling within the mine area, water bearing zones are typically encountered in the fresh rock at depths of between 50 m below ground level (bgl) to 150 m bgl, however this depth can vary depending on the proximity of the borehole to faults. Due to higher concentration and interconnectivity of fractures, the Brunswick, Adder and King Cobra Faults (Figure 3) exhibit zones of higher hydraulic conductivities and well yields than the surrounding rock mass.

At the TSF site, ATC Williams (2022) conducted falling head permeability tests at 5 borehole locations. Tests targeted the extremely weathered, and slightly weathered siltstone bedrock. Median hydraulic conductivity (K), as reported by ATC Williams 2022 of the in-situ material is reported at 5×10^{-8} m/sec. A summary of hydraulic properties derived from the upper weathered zone beneath TSF site and from a range of hydraulic tests performed on 21 wells targeting the deeper RBA are provided in Table 1.

Table 1 Hydraulic conductivity (m/s)

	Minimum	Maximum	Mean	No of tests
Weathered zone[1]	2×10^{-8}	1.5×10^{-7}	5×10^{-8}	5
Faulted areas (sub regional RBA)[2]	1.4×10^{-6}	1.6×10^{-5}	4.6×10^{-6}	14
Rock mass (sub regional RBA)[2]	3.5×10^{-8}	7.5×10^{-7}	3.5×10^{-7}	7

1. Based on values published in ATC Williams 2022a
2. Based on values published in Golder 2018a

3.4 Pre mining groundwater levels

Prior to the commencement of mining and dewatering in 2006, a total of 14 groundwater monitoring locations were established. However, pre-mining groundwater levels (referred to as potentiometric heads or surface) have been available for 10 locations including:

- two old mine shafts, GN03(Bombay Shaft) and GN02 (Brunswick Entrance);
- one SAA well GN15 (other SSA wells were dry);
- seven RBA wells, GN7, GN9, GN10, GN13, GN14, GN17 and GN18 (depth up to 75 m).

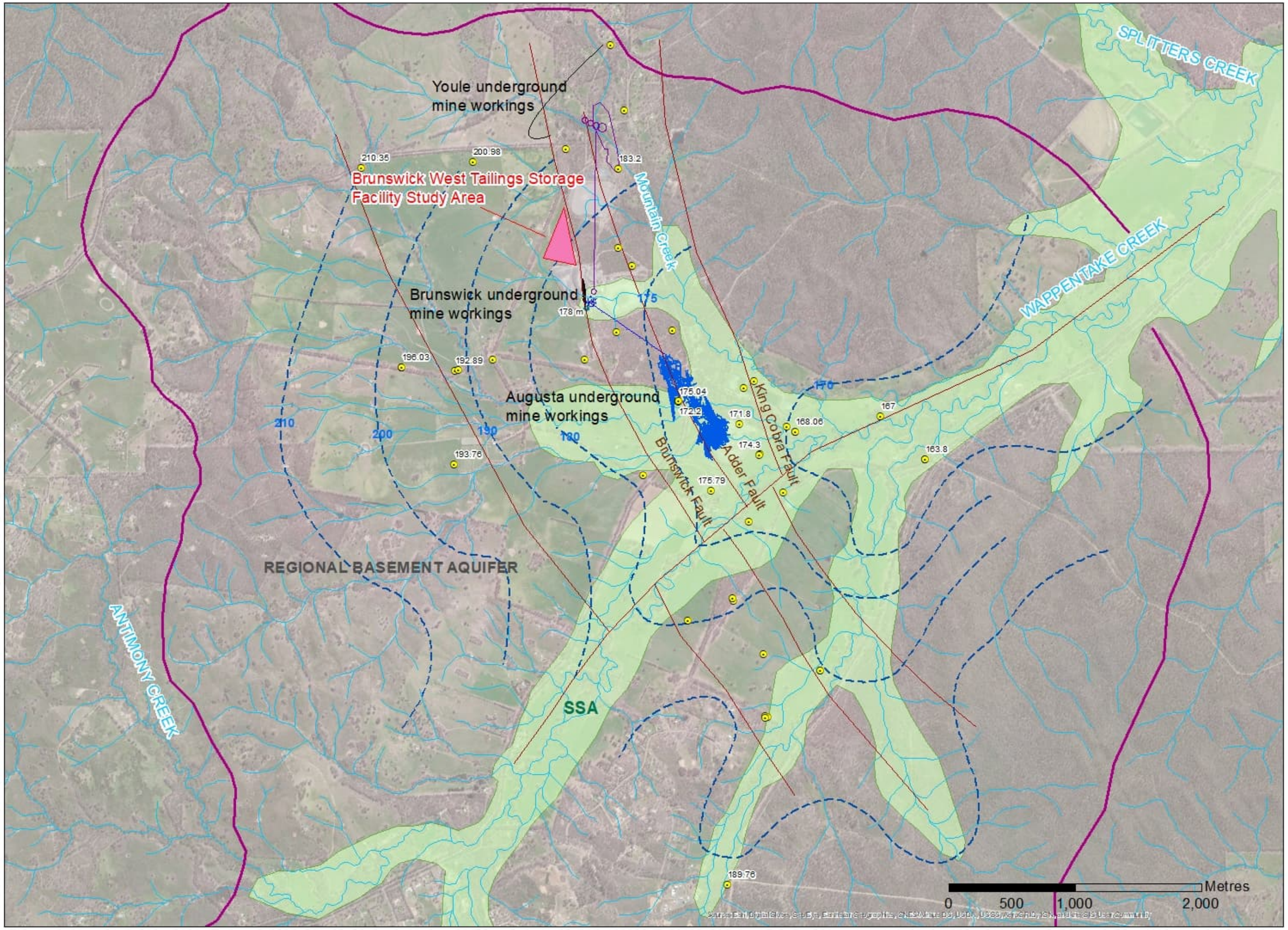
Figure 5 displays pre-mining potentiometric surface (m AHD) developed using this dataset. The Brunswick entrance is the closest site which reported a historic (pre mining) potentiometric head of 178 m AHD.

At the proposed TSF site, the inferred potentiometric head was approximately 180 m AHD. The potentiometric surface conformed to the general topography and flowed in an easterly direction, as indicated by historical measurements taken at various sites in the mine area, including the

- Brunswick Entrance (GN02) at 178 m AHD in 1996,
- Bombay Shaft (GN03) at 183.2 m AHD in 2006, and
- GN14 at 175.04 m AHD in 2006.

It is important to note the above monitoring bores and mine shafts are some 75 m to 330 m deep and therefore their groundwater elevation represents the piezometric pressure of the underlying RBA which is confined by 20 m to 30 m of weathered basement from surface. As outlined under section 3.2.1, shallow water table aquifers are absent from the TSF area.

Figure 5 Pre mining potentiometric surface (m AHD)



ADVERTISED PLAN

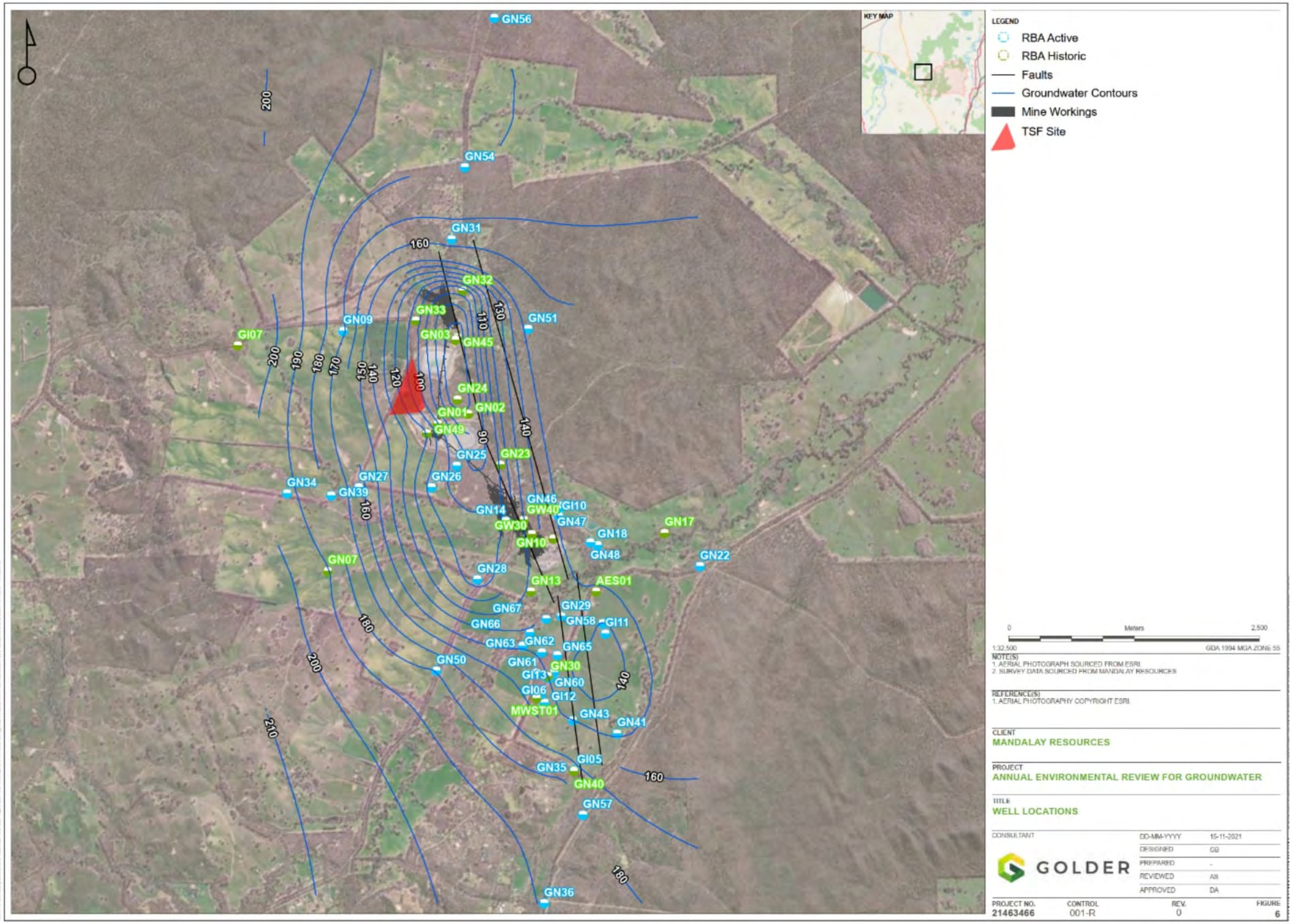
3.5 Current Groundwater Levels

Since 2006, mine dewatering has created a cone of depression, which extends about 2.5 km from the current mine. Current groundwater levels (m AHD) are presented on Figure 6, which shows the TSF site is located near the centre of the cone of drawdown. Consequently, the current groundwater flow direction is radially towards the mine.

The cone of depression is indicated to be elongated in shape reflecting the geometry of the current mine and NW-SE trending faults. The shape and extent of the cone of depression in the north-easterly direction of the mine is shown to be parallel to the King Cobra Fault structure. This suggests a dominant transmissive fracture set on the western side of the fault and potential low transmissivity feature or aquifer zone on the eastern side of the fault. Mandalay Resources has advised that boreholes drilled through the fault zone persistently encounter a low permeability clayey zone at the eastern flank of the King Cobra Fault.

At present, the groundwater elevation beneath the Brunswick West TSF site ranges from 130 m AHD to the west and 100 m AHD to the east. This is some 50 m to 80 m below the proposed excavation levels. The direction of groundwater flow from the Brunswick West TSF precinct area is in the easterly direction towards the mine (centre of the cone of depression).

Figure 6 2022 Potentiometric groundwater elevation contours in m AHD (Golder 2022)



3.6 Assessment of post mining groundwater levels

Predictions of the post mining groundwater elevation (potentiometric head) following the cessation of all mine areas/mine dewatering was previously undertaken via numerical groundwater modelling undertaken in 2018 (Golder 2018). Groundwater level recovery is presented Figure 7 for closest monitoring well GN02 and GN24, located ~300 m distant from the Brunswick West TSF Project area. All plots show that groundwater levels are predicted to recover their pre mining potentiometric elevations within 6 years post mining.

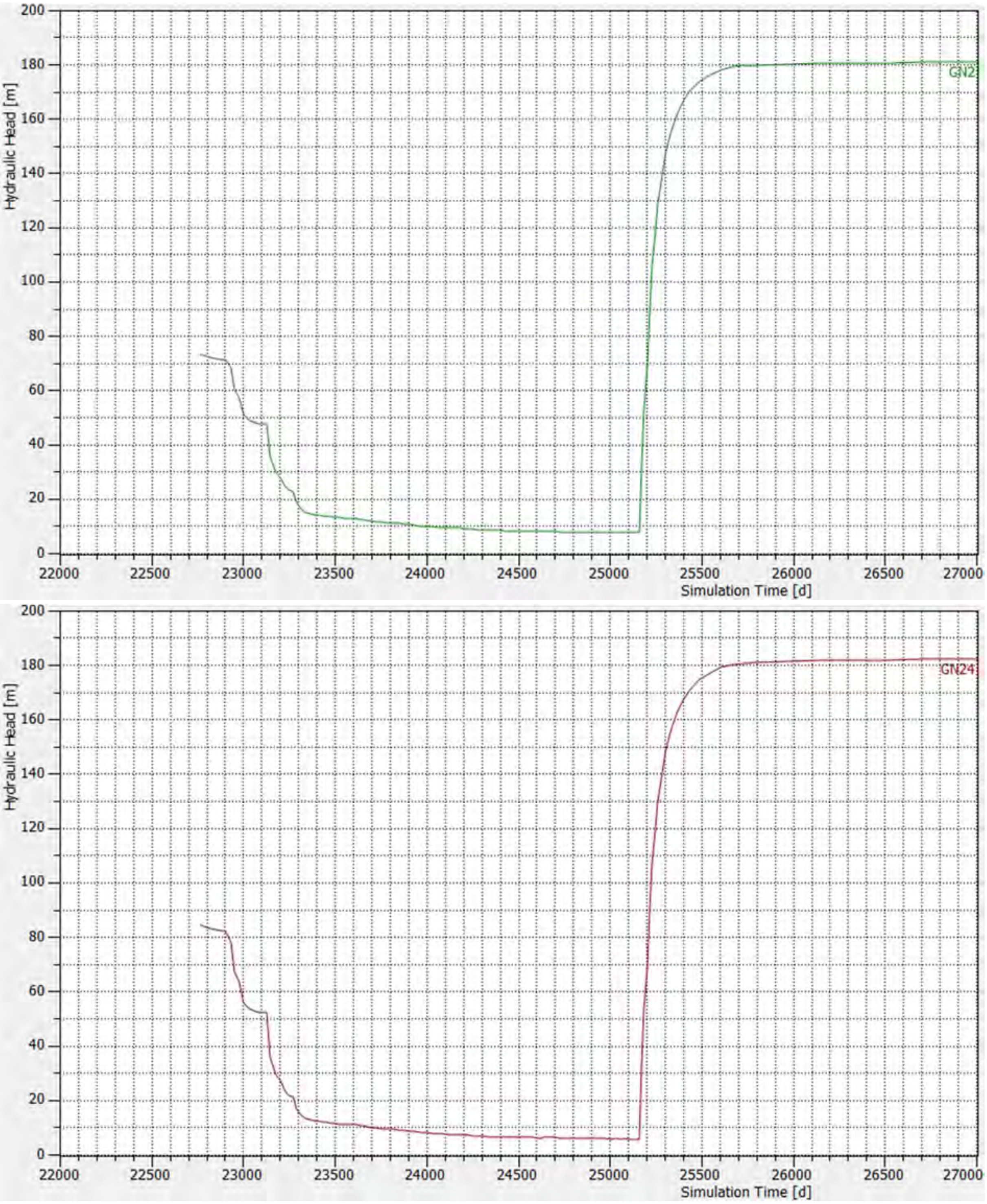


Figure 7 Groundwater level recovery post mining (days)

3.7 Groundwater Recharge

Groundwater recharge rates were estimated by Golder 2018a to range from 0.1 % to 3.1 % of annual rainfall, translating to recharge rates of 0.3 mm/year to 17 mm/year. Recharge is likely to occur at topographical highs, further up catchment where the weathered zone overlying the RBA is thinner.

3.8 Groundwater Discharge

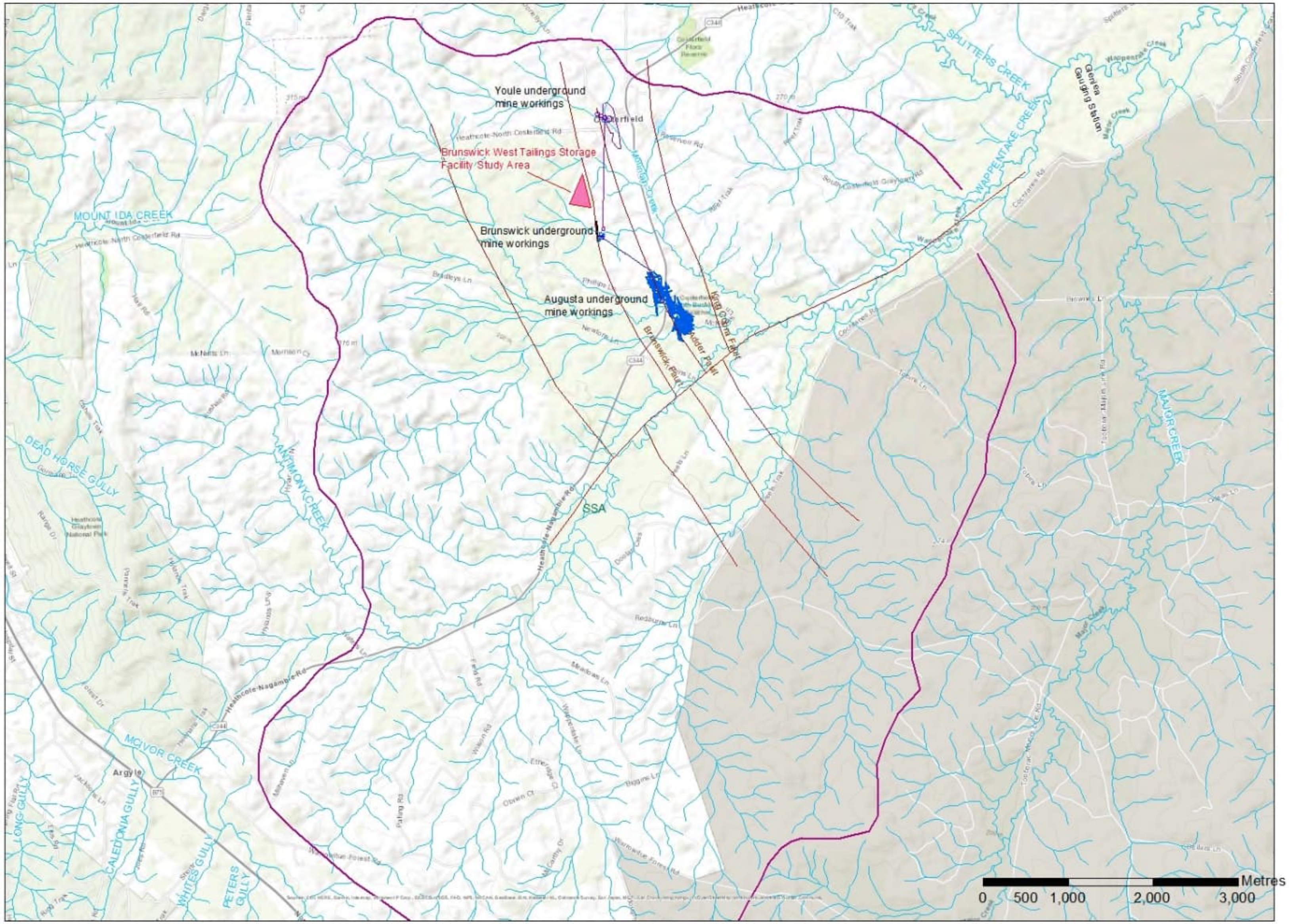
The catchment, within the mine site, is drained by two small tributaries to Wappentake Creek, which is situated about 2 km to the south of the TSF site. Water in Wappentake Creek flows from the area of the site for 4.5 km before merging with Major Creek. The closest surface water gauging station is Glenlea Station located in Major Creek, about 4.5 km to the northeast of the mine (Figure 8).

During the previous study, URS 2012 identified a small reach of the Wapentake Creek where groundwater could contribute to flows in the creek upstream of the Glenlea gauging station, during winter when groundwater in the alluvium or RBA is higher. The study suggested that groundwater, whether the source is the SAA or the RBA, does not make any significant contribution to the flow of water in the creeks within the Wappentake Creek Catchment upstream of the Glenlea gauging station.

Based on the above, there is unlikely to be an groundwater dependent ecosystems within 4.5 km of the proposed TSF site.

ADVERTISED PLAN

Figure 8 Surface water catchment



3.9 Groundwater Quality

The background water quality at the Brunswick West TSF site has been assessed by review of existing groundwater monitoring data. Given the absence of the SAA, the review covers only the RBA in proximity to the TSF site. The mine monitoring bore network includes historical and current bores within the immediate area of the TSF site and also down-gradient of the intended site.

Mandalay have and routinely undertake groundwater quality monitoring across there mineral tenement and nearby area. For the purpose of this assessment, Mandalay provided their water quality database for review. Not all groundwater monitoring data has been included. A select subset of the groundwater data for the following bores (in near proximity to the proposed site) has been reviewed:

- Active groundwater monitoring bores: GN25, GN26, GN27.
- Historical groundwater monitoring locations: GN02, GN03, GN24, GN33, GN45 and GN49.

Bores GN03 (the Bombay Shaft) and GN09 report salinity concentrations consistently below 800 mg/L, which is inconsistent with all other bores and not considered reflective of ambient groundwater (i.e. these bore or site may have localised influences). Data from these locations has been excluded. Monitoring at GN02 (the Brunswick Entrance) is also considered to be influenced by being open to the atmosphere and has been excluded from the assessment.

The resulting data set contains 328 data points, collected between January 2006 and January 2023, noting that not all monitored dates contain relevant water quality information. For the purpose of understanding the baseline (pre TSF construction water quality), the maximum, minimum, 25th, 50th and 75th percentiles are described.

3.9.1 Environmental Reference Standard

The EPA Victoria (2022a) Environment Reference Standard (ERS) is a tool that identifies environmental values (EVs) and provides a way to assess environmental values across Victoria. An environmental value (EV) is defined as:

"an aspect of the environment and how we use it that is important to us."

The ERS includes surface and groundwater reference standards and generally lists indicators and objectives to measure and assess the reference standards. At the time of authoring this report, the most recent version of the ERS is: *No. S245 Gazette 26 May 2021, as amended by Environment Reference Standard No. S158 Gazette 29 March 2022.*

The ERS defines groundwater by its salinity and allocates a resource into seven water quality segments that are presented in Table 3.2.

Table 3.2: EPA Victoria ERS Groundwater Segments (after EPA, 2022)

Segment	A1	A2	B	C	D	E	F
TDS range (mg/L)	0-600	601-1,200	1,201-3,100	3,101-5,400	5,401-7,100	7,101-10,000	>10,000

3.9.2 Environmental values of groundwater

The ERS also defines the Environmental Values of waters to be considered and which apply to the individual groundwater segments (listed in Table 3.3).

Environmental values may be determined not to apply to groundwater where:

- There is insufficient yield;
- The background level of a water quality indicator other than TDS precludes a beneficial use;
- The soil characteristics preclude a beneficial use, or

– A groundwater quality restricted use zone has been declared.

Table 3.3 Groundwater segments and corresponding Environmental Values to be considered.

Environmental Value	Segment (TDS mg/l)						
	A1 (0-600)	A2 (601-1,200)	B (1,201-3,100)	C (3,101-5,400)	D (5,401-7,100)	E (7,101-10,000)	F (>10,000)
Water dependent ecosystems and species	✓	✓	✓	✓	✓	✓	✓
Potable water supply (desirable)	✓						
Potable water supply (acceptable)		✓					
Potable mineral water supply	✓	✓	✓	✓			
Agriculture and irrigation (irrigation)	✓	✓	✓				
Agriculture and irrigation (stock watering)	✓	✓	✓	✓	✓	✓	
Industrial and commercial use	✓	✓	✓	✓	✓		
Water-based recreation (primary contact recreation)	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values	✓	✓	✓	✓	✓	✓	✓
Buildings and structures	✓	✓	✓	✓	✓	✓	✓
Geothermal properties	✓	✓	✓	✓	✓	✓	✓

3.9.3 Salinity

Salinity data (as Total Dissolved Solids) is measured in the field (converted from Electrical Conductivity) and reported by laboratory analysis. Salinity is variable across the monitoring bores in proximity to the TSF site, with site specific measurements across the historical monitored period ranging from 2,000 mg/L to >9,000 mg/L. Results from the field and laboratory measurements show consistency in the simple statistics (refer Table 3.4).

Sample locations from the water quality database with reduced salinity are known to be influenced by mining related activities (open shafts subject to precipitation). These data are excluded.

Table 3.4 Salinity (as TDS) statistics for field and laboratory measurements

Item	Field TDS	Laboratory TDS
Number of Samples available	219	55
Minimum Value	2,000	2,090
Maximum Value	9,991	8,220
Median (50^{th} percentile)	4,807	5,110
25^{th} Percentile	2,952	2,640
75^{th} Percentile	6,360	6,020

3.9.3.1 Adopted Groundwater Segment

Based on the TDS results, the 25th, 50th and 75th salinity statistical values for field and laboratory TDS as described in Section 3.9.3, Groundwater at the TSF site is allocated to ERS Segments B through D. Baseline groundwater quality is considered with respect to the applicable EVs and their literature adopted guideline criteria, as listed in Table 3.5.

Table 3.5 EPA Victoria ERS Groundwater Segment B applicable environmental values

Environmental Value	Adopted Guideline
Water dependent ecosystems and species (slightly to moderately modified)	ANZG (2018) – Australian and New Zealand Guidelines for Fresh and Marine Waters (Default Guideline Values for Aquatic (freshwater) Ecosystems – 95% species protection
Irrigation	ANZG (2018) defaults to the ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Waters (Primary Industries) – Water quality for irrigation and general water use
Stock watering	ANZEG (2018) Australian and New Zealand Guidelines for Fresh and Marine Waters (Primary Industries) - Livestock drinking water guidance
Water-based recreation (primary contact)	NHMRC (2008) Management Risks in Recreational Water
Traditional Owner cultural values	
Buildings and structures	Standards Australia AS2159 (2009) – Buildings and Structures
Geothermal properties	NHMRC (2008) Management Risks in Recreational Water

3.9.4 pH

pH data is reported from collection in the field and also by laboratory analysis in the database. The 25th, 50th and 75th percentile results for both field and laboratory pH indicate a mostly near neutral groundwater system.

Table 3.6 Field and Laboratory pH measurements

Item	Field pH	Laboratory pH
Number of Samples available	147	94
Minimum Value	6.38	6.96
Maximum Value	10.22	8.54
Median (50th percentile)	7.08	7.55
25th Percentile	6.81	7.33
75th Percentile	7.56	7.75

3.9.5 Nutrients

Water samples have been analysed for the following nutrients over the historical period:

- Ammonia (as N)
- Nitrate (as N)
- Total Kjeldahl Nitrogen (as N)
- Total Nitrogen (as N)
- Total Phosphorus (as N)

ADVERTISED PLAN

Key observations of the nutrient results, with respect to the applicable environmental values are:

- For ammonia, two sample results exceed the adopted guideline criteria value for 95% ecosystem protection (0.9 mg/L). The 75th percentile value (0.595 mg/L) is below the guideline.
- For Nitrate, five sample results exceed the guideline criteria value for 95% ecosystem protection (2.4 mg/L). The 75th percentile value (0.53 mg/L) is below the guideline.
- Two Total Nitrogen samples exceed the guideline criteria value for long term irrigation water (5 mg/L). The 75th percentile value (2.0 mg/L) indicates most sample results are well below the guideline value.
- For Total Phosphorus, 30 of 45 samples exceed the long-term irrigation water guideline (0.05 mg/L). The 75th percentile is 3 times greater than the guideline value at 0.15 mg/L.

Table 3.7 Nitrogen and Phosphorus water quality statistical summary

Item	Ammonia as N mg/L	Nitrite as N mg/L	Nitrate as N mg/L	Total Kjeldahl Nitrogen as N mg/L	Total Nitrogen as N mg/L	Total Phosphorous as P mg/L
Number of Samples available	45	45	45	45	45	45
Number of samples above laboratory detection (LOR value)	43 (>0.01)	18 (>0.01)	37 (>0.1)	40 (>0.01)	40 (>0.1)	41 (>0.01)
Minimum Value	0.01	0.01	0.01	0.1	0.1	0.01
Maximum Value	1.29	0.13	4.26	26.4	26.4	2.51
Median (50th percentile)	0.200	0.010	0.080	0.300	0.700	0.080
25th Percentile	0.045	0.010	0.015	0.100	0.300	0.035
75th Percentile	0.595	0.015	0.530	0.950	2.000	0.150
Applied EV guideline value	0.9[4]	9.1[3]	2.4[4]	-	5[2]	0.05[2]

1. ANZECC 2000 Short term irrigation; 2. ANZECC 2000 Long term irrigation; 3. ANZECC 2000 Livestock Drinking Water; 4. ANZG (2018) Freshwater 95%

3.9.6 Metals and metalloids

Water samples have been analysis for the following metals and metalloids over the historical period:

- Antimony
- Arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Nickel
- Zinc
- Iron

Key observations of the nutrient results, with respect to the applicable environmental values are:

- Antimony is known to be naturally present within the groundwater catchment (Golder, 2019). The only EV with a guideline value is aquatic ecosystems (0.009 mg/L), the 75th percentile for samples at the project site (0.204 mg/L) is around two orders of magnitude greater than the guideline value.
- Arsenic is known to be naturally elevated within the groundwater catchment (Golder, 2019). The median sample set statistic (0.006 mg/L) remains below the recreational health value (0.007 mg/L). The 75th percentile statistic (0.024 mg/L) is one order of magnitude below the long-term irrigation concentration and livestock drinking guideline values however exceeds the 95% freshwater ecosystem health guideline.
- One out of 56 cadmium samples were above laboratory detection.
- 20% of chromium samples were above laboratory detection. Of the sample data set above detection, the 75th percentile is 0.004 mg/L and below the recreational health guideline value (0.05 mg/L).
- 41% of copper samples were above laboratory detection. Of the sample data set above detection, the 75th percentile (0.004 mg/L) which is slightly elevated with respect to the 95% ecosystem health protection EV (0.0014 mg/L).
- 9% of lead samples were above laboratory detection. The 75th percentile (0.002 mg/L) is below the 95% ecosystem health protection EV (0.0034 mg/L).
- 84% of nickel samples were above laboratory detection. The 75th percentile (0.031 mg/L) is elevated with respect to the 95% ecosystem health protection EV (0.011 mg/L) and recreational health (0.01 mg/L) guideline values.
- 95% of zinc samples were above laboratory detection. The 75th percentile for zinc (0.082 mg/L) exceeds the 95% ecosystem health protection EV (0.008 mg/L) but is well below irrigation and livestock values.
- 29% of iron samples were above laboratory detection. The 75% percentile for iron (0.958 mg/L) exceeds the long-term irrigation value (0.2 mg/L).

Table 3.8 Metals and metalloids water quality statistical summary

Item	Antimony mg/L	Arsenic mg/L	Cadmium mg/L	Chromium mg/L	Copper mg/L	Lead mg/L	Nickel mg/L	Zinc mg/L	Iron mg/L
Number of Samples available	56	56	56	56	56	56	56	56	56
Number of samples above laboratory detection (LOR value)	56 (<0.001)	46 (<0.001)	1 (<0.0001)	11 (<0.001)	23 (<0.001)	5 (<0.001)	47 (<0.001)	53 (<0.005)	16 (<0.05)
Minimum Value	0.001	<0.001	0.0001	<0.001	<0.001	<0.001	<0.001	0.005	<0.05
Maximum Value	5.060	0.143	0.0001	0.296	0.011	0.002	0.097	3.43	2.54
Median (50th percentile)	0.078	0.006	0.0001	0.002	0.002	0.001	0.011	0.034	0.725
25th Percentile	0.008	0.002	NA	0.001	0.001	0.001	0.004	0.015	0.305
75th Percentile	0.204	0.024	NA	0.004	0.004	0.002	0.031	0.082	0.948
Applied EV guideline value/s	0.009[4]	0.013[4] / 0.1[5] 0.5[3] / 2[1]	0.0002[4] / 0.002[5] / 0.01[2,3] / 0.05[1]	0.05[5] / 1[1,3]	0.0014[4] / 0.22 / 0.4[3] / 2[5] / 5[1]	0.0034[4] / 0.01[5] / 0.1[3] / 2[2] / 5[1]	0.011[4] / 0.01[5] / 0.05[2,3] / 0.05[1]	0.008[4] / 2[2] / 5[1] / 20[3]	0.2[2] / 10[1]

1. ANZECC 2000 Short term irrigation; 2. ANZECC 2000 Long term irrigation; 3. ANZECC 2000 Livestock Drinking Water; 4. ANZG (2018) Freshwater 95%; 5. NHMRC (2008) Recreational Health

3.9.7 Perched water systems

Investigation boreholes and constructed monitoring bores drilled within the TSF footprint and excavation depth did not encounter groundwater.

3.9.8 Existing TSF Decant Water Quality

The decant water quality of Bombay and Brunswick TSFs provides an insight to potential water quality of Brunswick West TSF seepage quality (refer Table 3.9). The results are summarised:

- Salinity concentrations are greater than 10,000 mg/L and are elevated with respect to the baseline RBA salinity data.
- Antimony in the decant water is elevated with respect to the groundwater and its EVs. Results from the decant are one order of magnitude greater than the maximum background concentration, and two orders of magnitude greater than the 75th percentile value for background results, in the TSF area.
- Arsenic in the decant water is elevated with respect to the groundwater and some EVs. Results are comparable to the maximum concentrations observed in the background data and about one order of magnitude greater than the 75th percentile.
- Nickel and Zinc concentrations in the decant water quality are comparable to maximum and 75th percentile concentrations in background RBA water quality.
- Cadmium, Copper, Lead and Iron concentrations are non-detect which is similar to background RBA water quality.
- Nutrient results were not available for TSF decant water.

In summary, it is primarily the Antimony concentrations which are elevated with respect to background RBA water quality and EVs. The capacity of the RBA to attenuate arsenic was assessed previously for aquifer recharge studies through a literature review and geochemical modelling (Golder 2018a). Attenuation is the reduction in hazard concentration by natural processes in the aquifer which has a known attenuation capacity. This study and injection trials showed that some of the antimony that is injected (average = 24 mg/L maximum = 40 mg/L) sorbs to amorphous iron hydroxide (ferrihydrite) surfaces. Using best estimates for input parameters, the model predicted that antimony concentration in groundwater would be 4.6 times higher than the concertation sorbed to rock. This would result in 57% of the antimony mass in the rock water system being sorbed to ferrihydrite surfaces.

This assessment is of particular relevance to this study's context, especially in regard to the unforeseen risk of TSF seepage, which is also elevated with respect to antimony, thus the aquifer's ability to attenuate antimony and further reduce risk to surrounding groundwater is of particular relevance.

Table 3.9 Decant water quality in existing Brunswick and Bombay TSFs.

Bore ID	pH (pH units)	Salinity (as TDS) mg/L)	Antimony (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Iron (mg/L)
Brunswick Decant	7.46	11500	30.5	0.132	<0.0001	<0.001	0.004	<0.001	0.115	0.042	<0.05
Bombay Decant	7.47	13600	46.7	0.114	<0.0001	<0.001	<0.001	<0.001	0.077	0.009	<0.05

ADVERTISED PLAN

4 Summary of the Conceptual Hydrogeological System

The proposed Brunswick West TSF site is located west of Mandalay's existing TSF structures (to the east). The land is currently cleared for pastoral use and the natural ground surface topographic elevation ranges from 190 to 194 m AHD.

Ground investigations identify a thin topsoil veneer present and supporting vegetation cover. Beneath the surface, an extremely to moderately weathered siltstone bedrock profile is encountered across the site. The encountered siltstones are part of a complex of Silurian aged metasediments, siltstones and mudstones, which are host to the Regional Bedrock (fractured rock) Aquifer. The upper weathered portion of these rocks are known to be low in transmissivity which has been confirmed on site with falling head tests reporting K values in the order of 10^{-8} m/s.

At the TSF site, extensive drilling and test pitting conducted report the there are no water table aquifers. These are known to be restricted to the confines of modern-day watercourses, which are located at least 1.25 km from the TSF area.

The site is underlain by the regional basement aquifer which is confined by 20 m – 30 m of weathered basement. Historically the pre mining potentiometric heads of the underlying RBA are in the order of 180 m AHD (10 to 20 metres below ground surface). It is noted that pre-mining potentiometric heads are below the proposed base of the TSF. Pre mining groundwater flow direction was west to east and reflected the topographic grade.

At present, due to the location of the proposed TSF site within the mine dewatering cone of depression, groundwater levels are well below their pre-mining baseline (100 – 130 m AHD) and groundwater flow direction is toward the cone of depression centre (deepest area of mine dewatering). Groundwater flow remains eastward, however at a significantly steeper gradient.

Recharge to the site is very low and expected to occur via precipitation and groundwater through-flow due to the observed flow gradients. Current discharge will be via mine-dewatering activities. Post closure, recharge mechanisms are not expected to change. Groundwater flow beneath the site will continue to be towards the mine workings. Discharge will occur significantly further down gradient east of the catchment area.

Groundwater quality monitoring in proximity to the site reports a salinity range from brackish to saline. An assessment of the salinity with respect to EPA Victoria Environment Reference Standard suggest it should be classified as Segments B through D, however not all EVs are realised as background concentrations for some metals and nutrient exceed guideline levels.

The regional / background groundwater system is known to be elevated in heavy metals. 75^{th} percentile of background values for Antimony, Arsenic, Lead, Nickel, Zinc are elevated with respect to literature guideline criteria for ecosystem health protection.

For nutrients, total phosphorus 75^{th} percentile statistic is also observed at concentrations three times greater than the long-term irrigation acceptable guideline criteria.

5 Assessment of risks to groundwater

This section addresses risks that the proposed Brunswick TSF may pose to sensitive receptors such as the groundwater environment, receiving surface water environments and to groundwater users (public). Assessment of the risks is with respect to the identified relevant environmental values outlined in Section 3.9.

Outcome of the assessment is provided in Table 5.1. The assessment provided is semi-quantitative in the approach. Actual data informing the risk assessment include measurement of water levels and quality, modelling of groundwater recovery and geochemistry. Some of the data informing the assessment has been completed previously, for various other mine related aspects and activities.

The previous sections have attempted to collate all the relevant information which inform the assessment of groundwater risk.

Table 5.1 Preliminary Assessment of Risks to Groundwater

Hazard	Risk Event	Description of potential impact Risk Event	Phase	Receptors	Justification (controls)	Residual Risks		
						Likelihood	Consequence	Rating
Excavation	Interception of perched groundwater system	Expose aquifer material to atmosphere Localised drainage of perched water during construction activities	Construction	Surface water bodies (point of discharge for groundwater flow system\s)	— Perched aquifers are encountered within alluvial materials associated with surface water drainage features. Investigation drillholes at the TSF site indicate no presence of alluvium at the site. — Investigation boreholes and constructed monitoring bores drilled within the TSF footprint and excavation depth did not encounter groundwater. — Interception of temporary perched groundwater in the siltstone will only require limited management (e.g. small sump extraction) during construction.	Possible	Insignificant	Low
Excavation	Interception of regional aquifer system	Expose aquifer material to atmosphere Localised dewatering required during construction activities	Construction	Regional aquifer system	— Due to current operations of the Costerfield Mine, the regional water table beneath the site is currently dewatered well below the base of TSF excavation. — Interception of the regional groundwater system for temporary construction is not possible. — Management of surface water within excavation will capture poor quality water from flowing into the aquifer system.	Rare	Insignificant	Low
Excavation	Construction stormwater migrates outward into aquifer	Poor quality water accumulating with the construction footprint seeps outward into the regional aquifer system	Construction	Regional aquifer system Groundwater Users	— The location of the TSF is within the current mine cone of depression. Any unforeseen seepage emanating from the TSF footprint during construction will be directed towards the mine workings and dewatered. — The siltstone bedrock, which is host to the regional aquifer system is also understood to have a strong attenuation capacity for elevated metals (antimony and arsenic).	Rare	Insignificant	Low
Seepage	Surface expression of seepage water	Mounding of seepage beneath the TSF increases hydraulic head pressures to a level that induces surface seepage at the TSF toe or at some point down gradient of TSF	Operations Closure	Regional groundwater system Groundwater users	— TSF design includes 1.0 m of select compacted clay, BGM liner and a seepage drain collection system to maintain reduced saturated head pressure within the TSF. — At closure, the TSF will be capped and rehabilitated to reduce mounding recharge. — TSF is located within the mine area footprint, any seepage impact will likely be localised and minor. — Any observable impact is expected to be rehabilitated / cleaned to the extent practicable at closure	Rare	Minor	Low

Hazard	Risk Event	Description of potential impact Risk Event	Phase	Receptors	Justification (controls)	Residual Risks		
						Likelihood	Consequence	Rating
Seepage	TSF seepage migrates outward into aquifer	Seepage beneath TSF drives outward groundwater flow of poor water quality Seepage enters groundwater intermediate and regional flow paths	Operations Closure	Regional groundwater system Groundwater users	— TSF design includes 1.0 m of select compacted clay, BGM liner and a seepage drain collection system to maintain reduced saturated head pressure within the TSF. — At closure, the TSF will be capped and rehabilitated to reduce mounding recharge. — The location of the TSF is within the current mine cone of depression. Any seepage emanating from the TSF will be directed towards the mine workings and dewatered. — TSF decant contaminants of concern (antimony and arsenic) are known to naturally occur at elevation concentrations, with respect to environmental values, within the regional groundwater system. — The siltstone bedrock, which is host to the regional aquifer system is also understood to have a strong attenuation capacity for elevated metals (antimony and arsenic). — Surface water – groundwater interactions in the region indicate no foreseeable connection to watercourses. The regional aquifer system point of discharge is likely to be further down basin. It would be expected that the contaminant loads entering the system from the TSF would be attenuated over the course of the groundwater flow path, before discharge. — Post mining recovery of regional water levels is predicted below the base of the TSF. Regional aquifer system is unlikely to provide recharge to TSF or TSF mound.	Possible	Insignificant	Low

6 Conclusions and Recommendations

The proposed TSF site is situated within an area already utilised for tailings storage. The risks to groundwater are expected to be low due to the following key hydrogeological attributes:

- Disconnect between base of TSF excavation and pre and post mining groundwater levels.
- Investigations indicate the perched alluvial aquifer systems are absent at the site.
- The TSF site is underlain by a low permeability weathered siltstone bedrock, with a horizonal hydraulic conductivity of 10^{-8} m/s. Vertical hydraulic conductivity is assumed to be lower than the horizontal estimates.
- Geochemical modelling predicts the siltstone strata has a high capacity for attenuation of the elevated Antimony (main contaminant constituent in decant water).
- During operations, all (if any) seepage from the TSF will be captured within the mine dewatering cone of depression.
- The TSF design includes a seepage collection system (i.e. underdrainage system) which will be maintained and operated to a point that the tailings has sufficiently consolidated to permit closure.
- At closure, the TSF will be rehabilitated to significantly reduce recharge and prevent the further restrict seepage.
- Post closure, seepage (if any) emanating from the proposed TSF will be directed along the predicted groundwater flow path in the direction of the mine workings. Groundwater users will not be intersected within this flow path.
- Elevated heavy metals are naturally occurring in the background water quality of the RBA, and already exceed guideline criteria for Environmental Values relevant to the adopted ERS segments.

Based on the above, the proposed TSF is considered to be a low risk to the present groundwater environments.

6.1 Recommendations

Installation of a seepage monitoring network prior to TSF operations is recommended. The current design includes a series of nested monitoring bores. The shallow holes are target embankment fill or near-surface foundation seepage, whilst the deeper holes target deeper seepage through the impoundment excavation walls.

Due to the significant depth of current RBA groundwater levels beneath the TSF site, monitoring of the RBA is not considered practical for the purpose of early detection of seepage.

Routine monitoring of water levels and chemistry (field and laboratory) are recommended at frequencies consistent with monitoring plans for existing Bombay and Brunswick TSFs.

7 Limitations

This Report is provided by WSP Australia Pty Limited (*WSP*) for Mandalay Resources Costerfield Operations Pty Limited (*Client*) in response to specific instructions from the Client and in accordance with WSP's proposal dated 13 February 2023 and agreement with the Client dated 15 February 2023 (*Agreement*).

7.1 permitted purpose

This Report is provided by WSP for the purpose described in the Agreement and no responsibility is accepted by WSP for the use of the Report in whole or in part, for any other purpose (*Permitted Purpose*).

7.2 qualifications and assumptions

The services undertaken by WSP in preparing this Report were limited to those specifically detailed in the Report and are subject to the scope, qualifications, assumptions and limitations set out in the Report or otherwise communicated to the Client.

Except as otherwise stated in the Report and to the extent that statements, opinions, facts, conclusion and / or recommendations in the Report (*Conclusions*) are based in whole or in part on information provided by the Client and other parties identified in the report (*Information)*, those Conclusions are based on assumptions by WSP of the reliability, adequacy, accuracy and completeness of the Information and have not been verified. WSP accepts no responsibility for the Information.

WSP has prepared the Report without regard to any special interest of any person other than the Client when undertaking the services described in the Agreement or in preparing the Report.

7.3 use and reliance

This Report should be read in its entirety and must not be copied, distributed or referred to in part only. The Report must not be reproduced without the written approval of WSP. WSP will not be responsible for interpretations or conclusions drawn by the reader. This Report (or sections of the Report) should not be used as part of a specification for a project or for incorporation into any other document without the prior agreement of WSP.

WSP is not (and will not be) obliged to provide an update of this Report to include any event, circumstance, revised Information or any matter coming to WSP's attention after the date of this Report. Data reported and Conclusions drawn are based solely on information made available to WSP at the time of preparing the Report. The passage of time; unexpected variations in ground conditions; manifestations of latent conditions; or the impact of future events (including (without limitation) changes in policy, legislation, guidelines, scientific knowledge; and changes in interpretation of policy by statutory authorities); may require further investigation or subsequent re-evaluation of the Conclusions.

This Report can only be relied upon for the Permitted Purpose and may not be relied upon for any other purpose. The Report does not purport to recommend or induce a decision to make (or not make) any purchase, disposal, investment, divestment, financial commitment or otherwise. It is the responsibility of the Client to accept (if the Client so chooses) any Conclusions contained within the Report and implement them in an appropriate, suitable and timely manner.

In the absence of express written consent of WSP, no responsibility is accepted by WSP for the use of the Report in whole or in part by any party other than the Client for any purpose whatsoever. Without the express written consent of WSP, any use which a third party makes of this Report or any reliance on (or decisions to be made) based on this Report is at the sole risk of those third parties without recourse to WSP. Third parties should make their own enquiries and obtain independent advice in relation to any matter dealt with or Conclusions expressed in the Report.

7.4 disclaimer

No warranty, undertaking or guarantee whether expressed or implied, is made with respect to the data reported or the Conclusions drawn. To the fullest extent permitted at law, WSP, its related bodies corporate and its officers, employees and agents assumes no responsibility and will not be liable to any third party for, or in relation to any losses, damages or expenses (including any indirect, consequential or punitive losses or damages or any amounts for loss of profit, loss of revenue, loss of opportunity to earn profit, loss of production, loss of contract, increased operational costs, loss of business opportunity, site depredation costs, business interruption or economic loss) of any kind whatsoever, suffered on incurred by a third party.

References

- Golder (2018) Conceptual Groundwater Model and Numerical Groundwater Model Setup, Costerfield Mine Area. Reference No. 1778741-014-L-RevA
- Golder, (2019) Mandalay Resources Costerfield Mine – Geochemical Modelling of Antimony. Technical Memorandum 1778741-016-Rev0
- EPA, 2022a. *Environment Reference Standard*. No. S245 Gazette 26 May 2021, as amended by Environment Reference Standard No. S158 Gazette 29 March 2022. Victorian Government.
- EPA, 2022b. *Background levels: Identifying naturally occurring chemical substances.* Publication 2033, authorized and published by Environment Protection Authority Victoria, Victorian Government, August 2022.
- URS, 2012. *Hydrogeological Assessment – Application for groundwater (Take and Use) Licence Increase*.